

# A PRACTICAL TREATISE

ON

## THE MANUFACTURE OF VINEGAR AND ACETATES, CIDER, AND FRUIT-WINES;

PRESERVATION OF FRUITS AND VEGETABLES BY  
CANNING AND EVAPORATION;

PREPARATION OF FRUIT-BUTTERS, JELLIES, MARMALADES,  
CATCHUPS, PICKLES, MUSTARDS, ETC.

EDITED FROM VARIOUS SOURCES,

BY

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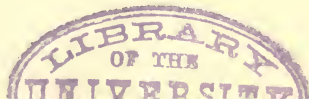
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## PREFACE.

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IT is quite unnecessary here to enlarge upon the prominence and the commercial value of the products of the various branches of industry treated of in this volume, since they are indispensable requisites as well in domestic economy as in the arts. But notwithstanding the great importance of these subjects, little reliable information in regard to them is found in our technical literature, and that little is so widely scattered as to make it almost inaccessible to most manufacturers.

Of all the branches of industry based upon chemical processes, the manufacture of vinegar has made the least progress, and consequently disturbances and large losses of material are here of much more frequent occurrence than in other fermenting industries which are carried on in accordance with established rules, whose correctness has been ascertained by many experiments.

With few exceptions there are no works in the English language in which an attempt has been made to establish the manufacture of vinegar upon a rational basis, and in accordance with the laws of nature as regards the chemical as well as the physical processes. To attain this object as nearly as possible has been the aim in the preparation of the portion of this volume relating to vinegar. Since the physical processes, especially the exact maintenance of determined temperatures and the production

of a change of air corresponding to the chemical processes, play an important role in the manufacture of vinegar, the section relating to this subject has been very fully treated.

To the manufacture of wine-vinegar a space corresponding to the importance of the subject has been devoted. Wine-vinegar is undoubtedly the most valuable product of the vinegar industry, and its fabrication might be made specially advantageous in this country, since in California and other States a vast amount of material could thus be profitably utilized, which otherwise would go to waste. On account of its great interest considerable space has been devoted to the manufacture of acetic acid from wood, and of acetates, especially those which are used for technical purposes.

As regards the manufacture of cider and fruit-wines, the preservation of fruit, etc., much time and care have been devoted to the gathering of information from all available and widely-scattered sources in order to do justice to the great and constantly growing fruit industry of this country. Special attention has been paid to evaporation, since this process is likely to supersede all other modes of drying fruit.

The volume is divided into three parts, upon each of which a few observations are offered.

Part I. treats of the Manufacture of Vinegar. It is chiefly based upon the German works, *Die Schnell-Essig Fabrikation und die Fabrikation von Weinessig*, by Dr. Josef Bersch, and *Lehrbuch der Essigfabrikation*, by Dr. Paul Bronner. Both are works of acknowledged authority, in which the authors have brought together the results of their experience of many years.

Part II. contains the Manufacture of Cider and Fruit-wines, and Part III. Canning and Evaporating of Fruit, etc. For information on these subjects we are indebted to the French work, *Culture du Pommier à Cidre, Fabrication du Cidre, etc.*, by Jules Nanot, and to the German works, *Die Hebung der Obstverwerthung und des Obstbaues*, by Heinrich Semler, and *Die Obstweinkunde*, by Dr. N. Graeger. Wherever required, the information derived from the above works has been supplemented by American processes.

The editor also acknowledges his indebtedness to numerous American and English authors for valuable information, due credit for which has been given whenever possible.

A copious table of contents as well as a very full index will render reference to any subject in the book prompt and easy, and the whole treatise is submitted to the public with a feeling of confidence as to its value and usefulness.

WILLIAM T. BRANNT.

PHILADELPHIA, Sept. 26, 1889.





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# A PRACTICAL TREATISE

ON

## THE MANUFACTURE OF VINEGAR, CIDER, AND FRUIT-WINES;

THE PRESERVATION OF FRUITS AND VEGETABLES BY  
CANNING AND EVAPORATION, ETC.

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### PART I.

#### THE MANUFACTURE OF VINEGAR.

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#### CHAPTER I.

##### INTRODUCTION.

ORDINARY vinegar is dilute acetic acid, contaminated with various vegetable impurities. In this form it has been known from the earliest times, and its discovery must have immediately followed that of wine, because it is evident that at the temperature of the Eastern countries, where the first experiments on the juice of the grape were made, fermentation must have set in rapidly, and the wine been quickly transformed into an acid compound. Moses mentions it and Hippocrates made use of it as a medicine. Its property of dissolving calcareous earth under the development of effervescence was known in the earliest times, and there can be no doubt that its action upon metal, etc., had been investigated at a very remote period. Pliny relates how Cleopatra, by dissolving large pearls in vinegar and drinking the resulting liquid, won her wager of being able to consume the value of one million sesterces at one meal; and Livy and

Plutarch state that Hannibal dissolved the rocks impeding his march across the Alps by ordering his soldiers to pour vinegar upon them.

Although there can be no doubt that vinegar was in very general use at an early period, there was until very recently no definite knowledge as to the cause of its production and the mode of its formation. The alchemist Gerber, who lived in the eighth century, was the first to make known the process of increasing the strength of wine-vinegar by distillation, and Albucases (about 1100) stated the fact that vinegar to be colorless has to be distilled over a moderate fire. Basilus Valentinus, a monk and celebrated alchemist of the 15th century, knew that by the slow distillation of vinegar, first a weak product, and then a stronger one is obtained, and he was probably also acquainted with the process of obtaining strong acetic acid by distilling copper acetate (*verdigris*). In fact for a long time this was the only mode of preparing acetic acid, the product of the further rectification of the liquid being termed *radical vinegar*, *spiritus Veneris*, *Venus's vinegar*, *spiritus aeruginis*, etc.

Stahl and Westendorf were the first to prepare the acid in a pure state, and Lauranguais, in 1759, discovered the property of very strong acetic acid to crystallize at a low temperature. Loewitz, however, in 1793, was the first to obtain it as a pure hydrate (glacial acetic acid).

The formation of an acid body in the dry distillation of wood was already known in the 17th century. However, it was for a long time not recognized as acetic acid, but considered as a special acid (pyroligneous acid). Foureroy and Vauquelin, in 1800, were the first to recognize this acid as acetic acid, and Thénard, in 1802, demonstrated the presence of acetic acid among the products formed in the dry distillation of animal substances.

Berzelius, in 1814, determined the exact chemical constitution of acetic acid, and Saussure, in the same year, that of alcohol. Dr. J. Davy observed that spongy platinum, in contact with vapor of alcohol, became incandescent and generated acetic acid. Döbereiner further studied the nature of the acid, and proved that the alcohol was oxidized at the expense of the atmospheric air, producing acetic acid and water, and that no carbonic acid

was formed—thus pointing out the fallacy of the opinion held by the chemists of his time that carbonic acid was one of the products of acetous fermentation.

Schützenbach, in 1823, one year after the establishment by Döbereiner of the now generally accepted theory of the formation of acetic acid from alcohol, introduced the quick process of manufacturing vinegar.

Without detracting from the credit due to Schützenbach for the introduction of his method and the improvement in the process of the manufacture of vinegar, it may be mentioned that as early as 1732, nearly a century before, the celebrated Dutch chemist and physician Boerhaave made known a method for the fabrication of vinegar from wine, which contained the principles of the quick process.

Although it is now more than sixty years since the introduction of Schützenbach's process into the practice, the manufacture of vinegar from alcohol remains nearly the same. While no change can be made as regards the theoretical part of the process, it being erected upon a foundation clearly indicated by a knowledge of natural laws, many important improvements may surely be introduced in the manufacture of vinegar on a large scale, this being especially the case where it is uninterruptedly carried on with the use of suitable apparatus. Many manufacturers still work according to Schützenbach's original plan, *i. e.*, they use an immense amount of labor for a performance which can be attained in a much simpler manner.

Progress is necessary in every business, but for several reasons it is especially necessary for the manufacturer engaged in the fabrication of vinegar by the quick process. Alcohol in every form (whiskey, beer, wine) is everywhere subjected to a high tax, and the constantly increasing taxation of this fundamental material for the fabrication of vinegar, of course increases the price the manufacturer has to pay for it. Another reason why the manufacture of vinegar from alcohol becomes constantly more difficult is found in the great competition arising from the continued improvements in the manufacture of pure acetic acid from wood. Not many years ago it was considered impossible to obtain entirely pure acetic acid from wood when manufacturing on

a large scale, but the article produced at the present time may be almost designated as "chemically pure" in the true sense of the word, it containing, besides acetic acid, only water, and the most accurate analysis cannot detect a trace of the products of tar, which render unpurified wood vinegar unfit for use.

For consumption on a large scale, especially where only a body of an acid taste is required, the use of so-called "vinegar essence" (*i. e.*, pure 80 to 90 per cent. acetic acid) prepared from wood, and which, when properly diluted, furnishes ordinary vinegar, will undoubtedly gradually supersede vinegar prepared from alcohol, it being considerably cheaper. And notwithstanding that the price of vinegar essence is decreasing every year, in regions where wood is plentiful and cheap, its manufacture is a well-paying industry on account of the many valuable by-products (tar, wood-spirit, charcoal) obtained besides acetic acid. Even at the present time for all industrial purposes where acetic acid is required, as, for instance, in the manufacture of tar colors, that obtained from wood is used, and the quantities consumed in the fabrication of table vinegar become larger every year.

But the manufacture of vinegar from alcohol and alcoholic fluids will nevertheless continue to flourish because the product obtained from them actually possesses different properties from the pure acetic acid prepared from wood. Vinegar obtained from pure alcohol, and, still more so, that from fermented fruit juices, as wine, cider, skins of pressed grapes, or from malt, contain, besides acetic acid and water, small quantities of bodies, which on account of their being analogous to those occurring in wine, may be designated as "bouquet-bodies," and which give to the vinegar an agreeable smell and taste entirely wanting in acetic acid prepared from wood. These properties are so characteristic that any one gifted with a sensitive and practised sense of smell can at once distinguish pure acetic acid vinegar from that prepared from wine, cider, beer, etc.

By the addition of volatile oils or compound ethers an agreeable odor can, of course, be imparted to vinegar obtained by diluting pure wood acetic acid with water, but it is impossible to produce the harmonious bouquet peculiar to vinegar prepared from alcohol or fruit juices, a similar relation existing here as



between wine and so-called artificial wine. The latter can be made so as nearly to approach, as regards taste and smell, genuine wine, but a connoisseur will at once detect the difference.

The principal defects of the process of manufacturing vinegar by the quick process in general use are not in the method itself, for that, as already indicated, corresponds entirely to the theoretical conditions, and yields as good a product as can be obtained from the raw material used. The weak point of the process is found in the practical execution of it: the losses of material are much more considerable and greater than are absolutely necessary, the consumption of labor is very large, and, as every manufacturer knows from experience, interruptions in the regular process of working are of too frequent occurrence.

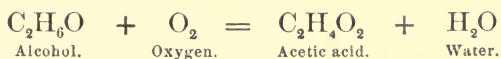
All these disadvantages can be reduced to a minimum, if not absolutely overcome, and it is hoped sufficient hints how this can be done will be found in the following chapters.

## CHAPTER II.

### THEORY OF THE FORMATION OF VINEGAR.

INDEPENDENTLY of the formation of acetic acid by the so-called dry distillation, the chemical processes by which acetic acid in larger quantities is formed are at present quite well understood, and will be briefly explained as follows:—

As previously mentioned, Döbereiner, in 1822, established the theory of the formation of acetic acid from alcohol, and the processes taking place thereby may be expressed by the following formula:—



According to the above formula, acetic acid and water are formed by the action of oxygen upon alcohol, and hence the formation of acetic acid takes place by a partial combustion or oxidation of the latter. Alcohol and acetic acid are, however, only two members of the process, and that, besides the latter,

other bodies are formed from the alcohol can be readily detected in a vinegar manufactory by the sense of smell.

By treating alcohol with pyrolusite and sulphuric acid—hence by the action of oxygen at the moment of its liberation from a combination (in its nascent state)—Döbereiner obtained a body which he called “light oxygenated ether” (leichter Sauerstoffäther). Liebig, later on, studied the nature of this combination more accurately, and found that, as regards its composition, it differed from that of alcohol only by containing two atoms less of hydrogen. He applied to it the term “aldehyde.”

Aldehyde is composed of  $C_2H_4O$ , and its formation is represented by the formula—



In the examination of the properties of aldehyde it was shown that it is readily converted into acetic acid by the absorption of oxygen, and, based upon these facts, Liebig established a theory of the formation of vinegar which was for many years considered correct.

Essentially Liebig's theory is as follows :—

By the exposure, under suitable conditions, of alcohol to the action of the atmospheric oxygen, one-third of the entire quantity of hydrogen contained in it is withdrawn, and aldehyde is formed. The latter, however, immediately further combines with oxygen, and is converted into acetic acid; the formation of vinegar from alcohol being, therefore, a partial process of combustion.

From the present stand-point of our knowledge as regards the formation of acetic acid from alcohol, the correctness of this theory is about parallel with that according to which alcohol and carbonic acid are formed by the alcoholic fermentation of sugar. This latter process can also be illustrated by an equation in as simple a manner as the conversion of alcohol into acetic acid by aldehyde. At the present time the processes taking place in the formation of acetic acid from alcohol must, however, be considered as far more complicated than supposed by Liebig. According to the latter, a simple oxidation, *i. e.*, a simple chemical process, takes place; but, according to the now universally accepted view, the formation of vinegar is due to a chemico-physiological pro-



cess with the coöperation of a living organism. Alcohol and oxygen alone do not suffice for this purpose, the presence of nitrogenous bodies and salts, besides that of an organism, being absolutely necessary.

The French chemist, Pasteur, was the first to establish the formation of vinegar as a peculiar process of fermentation, and he maintains that a certain organism, the "vinegar ferment" or "vinegar yeast," consumes the alcohol, nitrogenous substances and salts, and separates acetic acid, aldehyde, etc., as products of the change of matter taking place in the living organism. On the other hand, the German chemist, Nægeli, is of the opinion that the role of the organism is to bring the particles of the substance to be fermented (in this case, alcohol) lying next to it, into such vibrations as to decompose them into more simple combinations—in this case, acetic acid, aldehyde, etc.

The scientific dispute over these two different views is not yet settled, though the majority of chemists are inclined to accept Pasteur's theory. For the practical man it is of no consequence which of these views will be finally accepted as the correct one; the fact that the process of the formation of vinegar is connected with the living process of an organism is alone of importance to him.

As is well known, organisms producing fermentation are named after certain products which they form in larger quantities, the organism forming alcohol from sugar being, for instance, briefly termed "alcoholic ferment." In this sense we may also speak of a vinegar or acetous ferment, since a definite organism causing the formation of larger quantities of acetic acid from alcohol is known, and the cultivation of this ferment is one of the principal tasks of the manufacturer of vinegar.

Numerous observations have established the fact that the properties of forming large quantities of acetic acid are inherent only in this ferment. Small quantities of acetic acid are, however, also constantly formed by other ferments, so that in examining products due to the process of decomposition induced by organisms, acetic acid will be generally found among them. In the alcoholic fermentation, at least in that of wine and bread-dough, acetic acid is always found. It originates in the germination of

many seeds, and generally appears in the putrefaction of substances rich in nitrogen, such as albumen, glue, etc. It appears also in the so-called lactic fermentation, the lactic acid formed by the specific ferment of this species of fermentation being by further processes of fermentation decomposed into butyric and acetic acids.

Acetic acid, belonging to those bodies which may be considered as quite far advanced products of oxidation of higher compound combinations, its occurrence in living organisms is not remarkable. It is found in many fluids of animal origin, for instance, in meat-juice, milk, sweat, and urine. It also occurs constantly in the fresh fruit of the tamarind. What processes take place in its formation in these cases are not known, though it is very likely directly formed from certain varieties of sugar. Just as little do we know about the origin of the acetic acid found in the mineral water of Brückenau.<sup>1</sup>

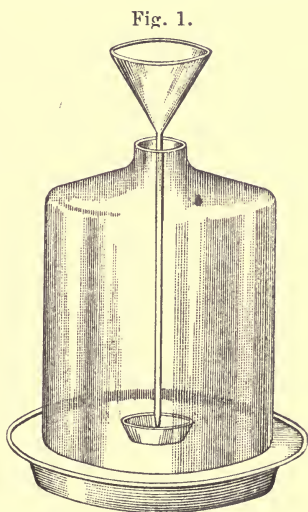
There is quite a large series of chemical processes in which certain quantities of acetic acid are always formed. Sugar, starch, woody fibre, and, in general, all compounds known as carbohydrates, when fused with caustic alkalies, always yield certain quantities of acetic acid, as also by themselves when subjected to destructive distillation.

Among the processes by which acetic acid is produced in a purely chemical manner, *i. e.*, without the coöperation of organisms, the most interesting is that by which its formation is effected by the action of very finely divided platinum (the so-called platinum black) upon alcohol. Platinum black is easily prepared by boiling a solution of platinic chloride with an addition of an excess of sodium carbonate and a quantity of sugar until the precipitate, formed after a little time, becomes perfectly black and the supernatant liquor colorless. The black powder is collected on a filter, washed and dried by gentle heat. From its minute state of division this substance condenses within it several hundred times its volume of oxygen; consequently, when the vapor of alcohol comes in contact with it, a supply of oxygen in a concentrated state is presented to it, and the platinum, without

<sup>1</sup> Free acetic acid is also claimed to occur in the water of a river of Brazil.

losing any of its inherent properties, effects chemical combination, the alcohol undergoing slow combustion, and being converted into acetic acid. In order that the reaction may continue, it is, of course, necessary to present fresh oxygen to the platinum to replace that which is withdrawn. The two actions then go on side by side.

This can be illustrated by an apparatus similar to Fig. 1. It consists of a bell glass through the mouth of which a long funnel passes; the lower end of this funnel terminates in a fine point, so that the alcohol poured in may percolate very slowly. The vessel is placed upon supports within a dish in which is a saucer or small flat basin containing the platinum black. The interstice between the bottom of the dish and the bell serves for the circulation of air in the jar. On pouring the alcohol through the funnel, in the course of a short time the odor of acetic acid is perceived at the mouth from the acetic acid vapors, which are generated. These condense on the sides of the jar and trickle to the bottom, where they collect in the vessel in the dish. It is advantageous for the success of the experiment to have the alcohol heated to about  $90^{\circ}$  F. when it is poured in. By washing and glowing the platinum used for the oxidation of alcohol, it can be again employed for the same purpose.



Independently of the purely chemical methods which, with the exception of that by which acetic acid is produced by the dry distillation of wood, are of no practical importance, the formation of vinegar, no matter what method may be adopted, can only be effected in the presence of certain organisms. It has long been known that organisms to which the term *mother of vinegar* has been applied; develop upon fluids containing, besides alcohol, certain other substances, for instance upon weak wine and beer,

and this mother of vinegar has also been used for the fabrication of vinegar on a large scale. To Pasteur, however, belongs the incontestable merit of having more accurately examined the relations of these organisms to the formation of vinegar. These examinations gave rise to his experiments on the diseased alteration of wine, which were later on succeeded by his researches on the formation of wine vinegar.

Pasteur found that upon the surface of every fluid capable by reason of its composition of being converted into vinegar, organisms develop immediately after the commencement of the formation of vinegar. He recognized these organisms as fungoid plants of a low order and called them *Mycoderma aceti*. More recent researches on the botanical nature of these plants show them to belong to the group of lowest fungoid organisms to which the term *bacteria* or *schizomyces* has been applied.

These plants consist of a single, generally globular or filiform cell, their special characteristic being their mode of propagation, which is effected by the division of the cell into two and then a separation or splitting of both.

The exceedingly minute size of the schizomyces and their great resemblance to each other make their accurate determination very difficult, and, hence, it is customary to name the better known species in accordance with the chemical products they form or in accordance with the phenomena they produce. Among the first kind may be classed those which effect the formation of acetic, lactic, butyric acids; other very little known bacteria must be considered as the cause of the so-called nitric acid fermentation, and again others appear in putrid fermentation. A special group of bacteria reaches development in animal organisms and give rise to terrible diseases, some causing rinderpest, others tuberculosis, and various other maladies. Cholera and other epidemics have also recently been found to be due to certain bacteria.

The bacteria causing disease are of course very interesting to the physician; but to the manufacturer of vinegar a thorough knowledge of the conditions of life governing the vinegar bacteria is of the utmost importance, in order to conduct the fabrication in such a manner that disturbances shall rarely occur, and, should they happen, that he may be able readily to remove them. It may,

therefore, be said that the entire art of the manufacture of vinegar consists in an accurate knowledge of the conditions of life of the vinegar bacteria and in the induction of these conditions of life. As long as the latter are maintained, the process of the formation of vinegar will go on without disturbance and the origination of new generations of vinegar ferment be connected with the conversion of certain quantities of alcohol into vinegar.

### CHAPTER III.

#### THE VINEGAR FERMENT AND ITS CONDITIONS OF LIFE.

##### A. *The Vinegar Ferment.*

NOTHING is as yet known about the origin of the vinegar bacteria, but experiments have shown these organisms to be everywhere distributed throughout the air and to multiply at an enormous rate when fluids of a composition suitable for their nourishment are presented to them. A fluid especially adapted for this purpose is, for instance, thoroughly fermented, ripe wine, its exposure in a flat vessel and at the ordinary temperature of a room being sufficient to induce the augmentation of the vinegar bacteria reaching it from the air.

This experiment is, however, only a certain success when executed with *ripe* wine, by which is meant wine which shows but little turbidity when strongly shaken in contact with air and exposed in a half-filled bottle to the air. Young wine contains a large quantity of albuminous substances in solution, and is especially adapted for the nourishment of an organism (*saccharomyces mesembryanthemum*) belonging to the *saccharomycetes*. It develops upon the surface of such wine as a thick white skin which later on becomes wrinkled and prevents the growth of the vinegar ferment. A fluid well adapted for the nourishment of the vinegar ferment, and which may be used as a substitute for wine for its cultivation, is obtained by adding 5 to 6 per cent. of alcohol and about  $\frac{1}{2}$  per cent. of malt extract to water.



By exposing ripe wine or the last-mentioned fluid at the ordinary temperature of a room, and best in a plate covered by a glass plate resting upon small wooden blocks to prevent the access of dust, the formation of a thin veil-like coating upon the surface, which shortly covers the entire surface, will, in a few days, be observed. The wine soon shows the characteristic odor and taste of acetic acid, and in a few days assumes a somewhat darker color and deposits a slight, brownish sediment consisting of decayed vinegar ferment. In 14 to 21 days the fluid is entirely converted into vinegar, *i. e.*, it contains no more alcohol, but instead the corresponding quantity of acetic acid.

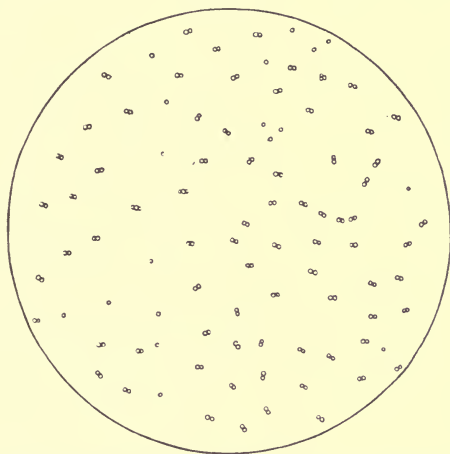
By exposing the vinegar thus obtained for a longer time to the air, a thick white skin of mold may happen to form on the surface, and, on chemically examining the fluid, the content of acetic acid will be found steadily to decrease, the mold which is able to convert the alcohol into water and carbonic acid possessing also the power of forming the same products from acetic acid.

The above-described process of the destruction of the wine and its conversion into vinegar by a veil-like coating of the vinegar ferment occurs most frequently; a thick spume, the so-called *mother of vinegar*, may, however, also happen to form upon the surface, a phenomenon to which we will refer later on.

On examining under the microscope a drop taken from the surface of the wine when the veil of vinegar ferment commences to form, a picture like that shown in Fig. 2 presents itself. In a somewhat more advanced stage the formations resembling chains and strings of beads appear more frequently, and when finally the development of the ferment is in full progress, it appears as an aggregation of numerous single cells mixed with double cells and many other cells strung together like beads. The field of vision of the microscope is then completely filled with a large number of colorless globules, which are present either singly or in combination of twos, the formations resembling chains or strings of beads occurring but seldom. In many of the separately-occurring formations oval forms generally slightly contracted in the centre are observed; this contraction indicates the place where the splitting of one cell into two new cells takes place. By strongly shaking the fluid before viewing

it under the microscope, very few of the above-mentioned bead-like formations will be found, but more frequently the contracted ones. By observing for hours a drop of the fluid containing the ferment in an advanced state of development, the globules strung together will be noticed to fall apart when at rest. Hence it may be supposed that in the augmentation of cells by splitting, the newly formed cells adhere together up to a certain stage, and later on separate in the fluid when in a quiescent state. Like

Fig. 2.



Development of the Vinegar Ferment. The ferment is young but in full activity.  
 $\times 500$ .

every other organism the vinegar ferment only lives for a certain time, and after dying, sinks below the fluid and forms upon the bottom of the vessel the above-mentioned sediment. The latter appears under the microscope in the same form as the living ferment, but differs from it in being less transparent and of a brownish color. The augmentation of the vinegar ferment takes place very rapidly, and it will be found in a few hours after the commencement of its development in all stages of life upon the surface of the fluid, it being possible to distinguish cells of from 1.5 to 3.5 micromillimetres in size.<sup>1</sup>

The vinegar ferment requiring *free oxygen* for its augmentation

<sup>1</sup> One micromillimetre =  $\frac{1}{1000}$  millimetre.



can exuberantly grow only upon the surface of the nourishing fluids. By filling a bottle about four-fifths with wine, and after allowing the vinegar ferment to develop, closing the mouth of the bottle with the hand and submerging the neck of the bottle in water, the fluid will be seen to rise for some time in the bottle and then remain stationary. A determination of the content of acetic acid immediately before the commencement of this experiment, and a few days after, shows but a slight increase of acetic acid, because after the ferment has consumed the free oxygen present in the bottle, the essential condition for its further development is wanting, and it must cease its activity without, however, perishing. It may here be remarked that the vinegar ferment, like the majority of bacteria, possesses an extraordinary vitality; under unfavorable conditions it passes into a kind of quiescent state, during which no perceptible increase of cells takes place. It may remain in this state for a long time without suffering destruction, and recommences augmentation and propagation in a normal manner as soon as the conditions required for its nourishment are again presented.

The great rapidity of the augmentation of the vinegar bacteria can be shown by an experiment of some importance to the practice. Pour into a shallow vat of about three feet in diameter a fluid suitable for the nourishment of bacteria, and divide upon the surface by means of a thin glass rod small drops of wine, upon which the frequently mentioned veil has been formed. In a few hours the entire surface of the fluid in the vat will be covered with vinegar bacteria, spreading concentrically from the points where the drops of wine have been distributed. From this it will be seen that the cultivation of the ferment for the purpose of manufacturing vinegar offers no difficulties, provided all conditions required for the propagation of this organism be observed.

### *B. Nourishing conditions of the vinegar ferment.*

Through many observations and experiments made in practice the conditions most favorable for the development of the vinegar ferment, and for converting in the shortest time the largest quantity of alcohol into acetic acid have been determined. These con-

ditions will first be briefly enumerated and then the separate points more fully discussed.

For the vinegar bacteria to settle upon a fluid, and for their vigorous augmentation the following factors are required :—

1. A fluid, which, besides alcohol and water, contains nitrogenous bodies and alkaline salts. The quantities of these bodies must, however, not exceed a certain limit.
2. The fluid must be in immediate contact with oxygen (atmospheric air).
3. The temperature of the fluid and the air surrounding it must be within certain limits.

As regards the composition of the nourishing fluid itself, it must contain all the bodies required for the nourishment of a plant of a low order. Such substances are carbohydrates, albuminates, and salts. Alcohol must be named as a specific nourishment of the vinegar ferment, provided the supposition that the latter consumes the alcohol and separates in its place acetic acid is correct. The quantity of alcohol in the fluid intended for the fabrication of vinegar must, however, not exceed a certain limit, a content of 15 per cent. appearing to be the maximum at which acetous fermentation can be induced. But even a content of 12 to 13 per cent. of alcohol is not very conducive to the vegetation of the vinegar ferment, and every manufacturer knows the difficulty of preparing vinegar from such a fluid. Like a high content of alcohol, a large quantity of acetic acid in the nourishing fluid exerts also an injurious influence upon the vinegar ferment. Upon a fluid containing 12 to 13 per cent. of acetic acid, and 1 to 2 per cent. of alcohol, the ferment vegetates only in a sluggish manner, and considerable time is required to convert this small quantity of alcohol into acetic acid.

That the vinegar ferment cannot live in dilute alcohol alone may be shown by a simple experiment. By placing fully developed ferment upon a fluid consisting of only water and alcohol, a very small quantity of acetic acid is formed, but the ferment perishes in a short time—it starves to death. A fluid suitable for the nourishment of the ferment must therefore contain the above-mentioned nourishing substances, sugar, dextrine, or similar combinations occurring in wine, malt extract, beer, being generally

employed as carbohydrates. These fluids further contain nitrogenous combinations which may serve as nutriment for the ferment, and also considerable quantities of phosphates. Hence by an addition of wine (or must), malt extract, beer, or any fruit wine (apple or pear cider) to a mixture of alcohol and water, a fluid can be prepared, which contains all the substances essential to the nourishment of the ferment.

The quantity of these nourishing substances, as compared with that of alcohol, is very small, the quantity by weight of vinegar ferment required for the conversion of a very large amount of alcohol into vinegar being only a few fractions of one per cent. of weight of alcohol used. Hence the manufacturer may be very economical with the addition of nourishing substances to the fluid to be converted into vinegar without having to fear that the ferment will be stunted.

The vinegar ferment is very sensitive to sudden changes in the composition of the fluids upon which it lives and suffers injury by such changes which is recognized by diminished propagation and decreased conversion of alcohol into acetic acid.

By bringing, for instance, vinegar ferment which vegetated in an entirely normal manner upon a fluid containing only 4 to 5 per cent. of alcohol, upon one with a content of 10 to 11 per cent., its augmentation, as well as fermenting energy, decreases rapidly and remains sluggish until a few new generations of cells have been formed which are better accustomed to the changed conditions. By bringing, on the other hand, a ferment from a fluid rich in alcohol upon one containing a smaller percentage the disturbances in the conditions of the ferment can also be observed, but they exert a less injurious influence upon the process of the formation of vinegar than in the former instance.

The process of nourishment of the vinegar ferment must, however, not be understood to consist simply in the consumption of sugar, albuminates, and salts. It differs according to the composition of the nourishing fluid, and is so complicated as to require a very thorough study for its explanation. If, for instance, wine is converted into vinegar, and the composition of the latter compared with that of the original wine, it will be found that not only the alcohol has been converted into acetic acid and the fluid

has suffered a small diminution of extractive substances and salts, which might be set down to the account of the nourishment of the ferment, but that the quantity of tartaric, malic, and succinic acids has also decreased as well as that of glycerine, and of the latter even nothing may be present. Hence it must be supposed that the vinegar ferment also derives nourishment from these substances, or that its fermenting activity acts upon them as well as upon the alcohol. There is finally the very important fact for the practice, which has not yet been sufficiently explained, that the vinegar ferment develops more rapidly upon a fluid which, besides the requisite nourishing substances, contains a certain quantity of acetic acid, than upon a fluid entirely destitute of it. Regarding the supply of air, it may be said that, while for mere existence the vinegar ferment requires comparatively little air, large quantities of it are necessary for its vigorous augmentation and fermenting activity. In the practice it is aimed to accomplish this by exposing the fluid in which the ferment lives in thin layers to the action of the air, and, in fact, upon this the entire process of the quick method of fabrication is based.

Besides the above-mentioned factors the temperature to which the ferment is exposed takes an important part as regards its development. The limits at which the augmentation of the ferment and its vinegar-forming activity are greatest, lie between  $68^{\circ}$  and  $95^{\circ}$  F. Above this limit the formation of vinegar decreases rapidly and ceases entirely at  $104^{\circ}$  F. By again reducing the temperature to  $86^{\circ}$  F. the ferment reassumes its activity. At a temperature exceeding  $104^{\circ}$  F. the ferment suffers perceptible injury; heated to  $103^{\circ}$  F. it becomes sensibly weaker, and at first augments very slowly, regaining its original vigorous development only after several generations. By raising the temperature of the fluid to  $122^{\circ}$  F. the ferment perishes.

To low temperatures the ferment seems to be less sensitive. By lowering the temperature of a fluid showing an exuberant growth of ferment to  $50^{\circ}$  F. or less, the formation of vinegar continues, though at a very much reduced rate. Experiments especially made for the purpose have shown that by exposing wine with a growth of ferment to a temperature of  $14^{\circ}$  F. so that it was converted into ice, the ferment recommenced to grow

and to form acetic acid after melting and heating the fluid to 59° F. It should, however, be expressly stated that while vinegar ferment in a state of development keeps up a slow growth when the fluid is reduced to a low temperature, it is very difficult to rear it upon a cold fluid. This is very likely the reason why acetous degeneration is not known in cold wine cellars, while in those having a temperature of over 59° F. this dreaded process can only be guarded against by the greatest care. .

Since the augmentation of the ferment and its fermenting activity increase with a higher temperature, it would appear most suitable to keep the temperature of the fluid to be converted into vinegar as near the uppermost limit of 95° F. as possible. Experience, however, has shown that at this temperature disturbances are of frequent occurrence in the generators, and for this reason one of 86° to 89° F. is generally preferred. The process of the formation of vinegar itself explains why disturbances may easily occur at a high temperature. It is a chemical (oxidizing) process in which a certain quantity of heat depending on the quantity of alcohol to be oxidized within a certain time is always liberated. If now by the use of a temperature close to 95° F. the activity of the ferment is strained to the utmost, a large quantity of alcohol is in a short time converted into acetic acid, and consequently so much heat is liberated that the temperature in the generator rises above the permissible maximum and the ferment immediately ceases its activity. Thus it may happen that in a generator which has satisfactorily worked for some time, the formation of vinegar ceases all at once, and on examining the thermometer placed on the apparatus the cause will be generally found to be due to too high a temperature.

### *Mother of Vinegar.*

In connection with the description of the conditions of life of the vinegar bacteria, a peculiar formation, playing in many cases a role in the practice of the fabrication of vinegar, has to be mentioned. This is the so-called mother of vinegar, the term having very likely been applied to it on account of its causing



acidification when brought into a fluid suitable for the formation of acetic acid.

The mother of vinegar occurs generally only in fluids which, besides alcohol, contain large quantities of extractive substances, for instance, wine or beer. After the ordinary vinegar ferment has for some time grown upon the surface of these fluids a coating is formed which acquires a thickness of up to  $\frac{3}{4}$  inch, and such consistency, that with some care, it can be lifted as a coherent mass from the fluid. The mother of vinegar then represents a very elastic transparent mass of a yellowish-white color and closely resembles an animal hide swelled to a high degree by treatment with water.

Upon the side of the skin exposed to the air numerous molds frequently settle and form complete sods of the well-known gray green or yellow color. This is, however, only a secondary phenomenon, the mother of vinegar being especially adapted as a basis for the development of molds. By exposure to the air, best upon a porous support (a plate of brick or gypsum), the mother of vinegar quickly decreases in bulk and finally dries to a very thin layer resembling paper. Viewed under the microscope the mother of vinegar appears as a mass entirely devoid of structure in which numerous individuals of the vinegar ferment are imbedded.

Several opinions have been expressed as to the nature of the mother of vinegar, and among others that it is a special variety of vinegar ferment, which, however, cannot be accepted as correct, it being far more probable that its formation depends on the nature of the fluid upon which ordinary vinegar ferment grows. As previously mentioned, the mother of vinegar reaches development upon young wine and beer, and these fluids always contain certain quantities of albuminous substances in solution. Now it is very probable that the mother of vinegar consists of peculiarly changed albuminous substances—eventually also of carbohydrates—and that innumerable organisms of the vinegar ferment are distributed throughout the mass which cause the acidification of fluids to which it is transferred. This view is supported by its composition, with regard to its organic substance, as determined by Mulder.

Composition of the mother of vinegar, according to Mulder :—

Carbon	.	.	.	.	.	.	46.8
Hydrogen	.	.	.	.	.	.	6.4
Nitrogen	.	.	.	.	.	.	3.9
Oxygen	.	.	.	.	.	.	42.7

According to R. D. Thomson, who also examined the mother of vinegar, its composition is :—

Organic substance	{ cellulose albuminous substance }	about 5 per cent.
Salts	{ potash, lime phosphoric acid }	“ $\frac{1}{3}$ “
Water	.	more than 94 “

These analyses justify the opinion that albuminous substances as well as carbohydrates participate in the formation of the mother of vinegar. (In beer carbohydrates are always present, while in wine extractive substances occur which, at least, are closely allied to the carbohydrates.) An experiment especially made for the purpose conclusively proves that the formation of the mother of vinegar depends on the presence of the above-mentioned substances in the fluid upon which it grows.

A thick cover of mother of vinegar had formed upon young wine; this being removed it was in a few days replaced by a new growth, which, however, was not quite so thick. This cover being also removed a third but very slight one was formed until finally a cover of mother of vinegar was no longer developed upon the fluid, but only normal vinegar ferment. The explanation of this phenomenon is that with the decrease of nitrogenous substances in the wine, the conditions for the development of mother of vinegar became constantly more unfavorable until finally nothing but vinegar ferment could form. By transferring a piece of mother of vinegar to a fluid composed of alcohol, water, and some old wine (hence such as contained only very small quantities of nitrogenous substances) the slimy mass remained floating in the fluid without increasing or undergoing alteration, while the surface became covered with ordinary vinegar ferment and acidification proceeded in a normal manner.

The formation of mother of vinegar can always be successfully attained by exposing young wine to the air until the commence-



ment of the formation of mold is indicated by the appearance of white dots and then transferring the wine to a room having a temperature of 86° F. At this temperature the development of the vinegar ferment proceeds so vigorously that it suppresses the mold ferment, and the peculiar mass constituting the mother of vinegar soon forms upon the surface.

Mother of vinegar occurs so generally in young wine (which is chiefly used for the preparation of wine vinegar) that its formation was considered as inseparably connected with that of acetic acid from alcohol, while actually it is only due to the peculiar constitution of the fluid to be converted into vinegar. In many places this opinion is still entertained, and especially where, as is generally the case, the manufacture of vinegar from wine is yet carried on in the primitive way of centuries ago. In speaking of the preparation of vinegar from wine, it will be shown that the conversion can be effected by means of the ordinary vinegar ferment without the appearance of mother of vinegar.

### *Summary.*

Briefly stated the points of the theoretical conditions of the formation of vinegar of importance to the manufacturer are:—

1. Acetic acid is formed during many chemical conversions ; for the manufacture of acetic acid, and consequently of vinegar on a large scale, only two methods are available, viz., the preparation of vinegar from alcohol by fermentation, or the obtaining of acetic acid by dry distillation of wood.
2. All alcoholic fluids formed by vinous fermentation of sacchariferous plant juices or fermented malt extracts are suitable for the preparation of vinegar by fermentation. Specially prepared mixtures of water, alcohol, and vinegar may also be used for the purpose, provided they contain small quantities of certain organic substances and salts, and not over 14 per cent. of alcohol.
3. The acetous fermentation is induced by a microscopic organism belonging to the bacteria, and the conversion of the alcohol into acetic acid is in a certain ratio to the augmentation of this organism.

4. Besides the substances mentioned in 2, the vinegar ferment requires for its vigorous development free oxygen and a temperature lying between  $68^{\circ}$  and  $95^{\circ}$  F.
  5. In the acetous fermentation the greater portion of the alcohol is converted into acetic acid and water ; besides these small quantities of other products are formed which are partially, not yet thoroughly, known. In the conversion of wine, beer, etc., other combinations contained in the fluids, besides alcohol, are also essentially changed.
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## CHAPTER IV.

### PRODUCTS OF ACETOUS FERMENTATION.

THE formation of vinegar by fermentation being a chemico-physiological process, many and complicated chemical processes must take place in the fluid to be converted into vinegar in order to produce all the combinations required for the augmentation of the ferment. Attention cannot be too frequently called to the fact that from the standpoint of the manufacturer, the regular augmentation of the ferment is the main point of the entire fabrication, the quick conversion of the alcohol contained in the fluid being a necessary consequence of it.

The body of the ferment, however, contains cellulose, albuminous substances, very likely fat and other combinations not yet known, all of which must be formed from the nourishing substances (sugar, dextrine, albuminous substances, etc.), present. It being very probable that a portion of the alcohol contained in the fluid is consumed for this purpose, a small but nevertheless perceptible loss of alcohol will occur in the fabrication. It would be erroneous to suppose that the conversion of alcohol into acetic acid and water is effected according to the formula given on p. 21 ; a certain portion of it is always converted into other combinations, the nature and formation of which can only be, to a certain extent, explained.

In the vinous fermentation, which of all fermenting processes

has been most thoroughly studied, we find that besides alcohol and carbonic acid large quantities of glycerin and succinic acid and probably other bodies are formed from the sugar, which must undoubtedly be classed among the products of vinous fermentation. Similar processes, no doubt, take place in the acetous fermentation, and besides acetic acid and water other little known products of fermentation are regularly formed.

According to the nature of the sacchariferous fluids subjected to vinous fermentation small quantities of certain bodies called fusel oils are formed which are decidedly products of fermentation. They impart to the fermented fluid, as well as to the alcohol distilled from it, such characteristic properties that from the odor of the alcohol a correct judgment can be formed as to the material employed in its preparation.

In the conversion of such a fluid, or of alcohol prepared from it, into vinegar, the fusel oils are also changed—very likely oxidized—and with some experience the material (wine, beer, malt, etc.), from which the vinegar has been made can be determined by the sense of smell. The quantities of aromatic substances which reach the vinegar in this manner are, of course, very small, but they must nevertheless be classed among the most important products of acetous fermentation, they being very characteristic as regards the nature of the vinegar. Of the products of acetous fermentation, besides acetic acid, aldehyde and acetal are best known, these combinations appearing always, even if only in small quantities, in the fabrication of vinegar according to the methods customary at the present time.

#### *Acetic Aldehyde or Acetaldehyde.*

Acetic aldehyde, commonly called simply aldehyde (from *alcohol dehydrogenatum*), is obtained by oxidizing spirits of wine by means of manganese dioxide (pyrolusite) and sulphuric acid, chromic acid, or platinum black, in the presence of air, or if alcohol or ether is burning without a sufficient supply of air. It is also formed by heating a mixture of acetate and formate of calcium. It is contained in considerable quantities in the first runnings obtained in the manufacture of spirit of wine.

To prepare pure aldehyde 3 parts of potassium dichromate in small pieces are placed in a flask surrounded by a freezing mixture and a well-cooled mixture of 2 parts of spirit of wine, 4 of sulphuric acid, and 4 of water added. After connecting the flask with a condenser the freezing mixture is removed; a violent reaction soon sets in and the liquid begins to boil. The vapors have first to pass through an ascending tube surrounded by warm water at about  $122^{\circ}$  F. Alcohol and different products are condensed and flow back while the vapor of the aldehyde, after having passed through a descending condenser, is absorbed in anhydrous ether.

Pure aldehyde thus obtained is a colorless liquid of the composition  $C_2H_4O$ . Its specific gravity is 0.800, and it boils at about  $71.5^{\circ}$  F. It has a pungent and suffocating smell and is readily soluble in water, alcohol, and acetic acid. Like all the aldehydes it is very easily oxidized and acts, therefore, as a powerful reducing agent. Thus, on heating it with a little ammonia and nitrate of silver, metallic silver separates out, coating the sides of the vessel with a bright mirror. It combines with ammonia and forms a crystalline compound which has a peculiar smell of mice.

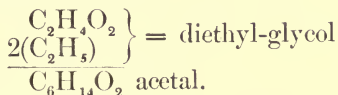
Though it is likely that in the fabrication of vinegar by the quick process, besides aldehyde, acetic and formic ethers are formed, they are of comparatively little importance for our purposes. Of more importance, however, is acetal, the formation of this combination affording an interesting insight into the complicated processes accompanying the conversion of alcohol into acetic acid.

#### *Acetal.*

This combination is best prepared by distributing pieces of pumice, previously moistened with 25 per cent. alcohol over a large glass plate, placing watch crystals containing platinum black upon the pieces of pumice and covering the whole with a large bell-glass. The alcohol absorbed by the pumice being converted into acetic acid, 60 per cent. alcohol is poured upon the plate and the air in the bell-glass from time to time renewed. In a few

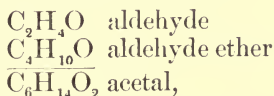
weeks a quite thick fluid of an agreeable odor has collected upon the glass plate. This is collected and distilled, the portion passing over at 219° F., being collected by itself.

Pure acetal is composed of  $C_6H_{14}O_2$ . It is a colorless liquid, has a specific gravity of 0.821, and boils at 219.2° F. It has a refreshing odor, calling to mind that of fruit ethers. By oxidizing agents it is quickly converted into acetic acid. Nitrate of silver in the presence of ammonia is, however, not reduced by it, and it remains unchanged on boiling with potash lye. From its composition acetal may be considered from several points of view. It may be regarded as an ethyl alcohol (glycol)  $C_2H_6O_2$ , in which two atoms of hydrogen have been replaced by two molecules of the radical ethyl  $C_2H_5$ , hence thus

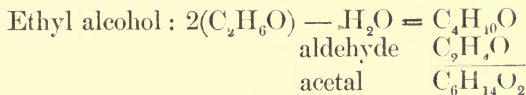


This view of the composition of acetal is supported by the fact that methyl or amyl can be substituted for either one or both molecules of ethyl in the combination.

According to other opinions, acetal may be considered as a combination of aldehyde and aldehyde ether:—



or as a combination of aldehyde with ethyl alcohol, one molecule of water in the latter having been replaced by the aldehyde:—



By keeping in view the fact that the process of the formation of vinegar is an oxidation of the alcohol which does not proceed with equal energy in all parts of the apparatus, it will be understood that during this process aldehyde, acetal, and acetic ether can be formed which, if the operation be correctly conducted, will be finally converted into acetic acid, though small quantities of them will be found in the vinegar when just finished and exert an influence upon its constitution.

*Acetic Acid.*

Pure acetic acid,  $C_2H_4O_{21}$ , cannot be directly obtained from vinegar, but only from acetates by methods which will be described later on. The strongest acetic acid which can be prepared is known as *glacial acetic acid*, from its crystallizing in icy leaflets at about  $40^\circ$  F. Above a temperature of about  $60^\circ$  F. the crystals fuse to a thin, colorless liquid of an exceedingly pungent and well-known odor. When diluted it has a pleasant acid taste and agreeable odor. Pure acetic acid is a powerful restorative when applied to the nostrils in impending fainting. It is the strongest of the organic acids and nearly as acrimonious as sulphuric acid. When dropped on the skin it acts as an escharotic, speedily raising a blister and producing much heat and rapid inflammation; when taken into the mouth or applied to any mucous membrane it blackens like sulphuric acid. Highly concentrated acetic acid is a solvent of many volatile oils, resins, albuminates, and glue; the ability to dissolve lemon oil is used in the practice as a test for the high concentration of acetic acid, since in the presence of only 2 per cent. of water in the acid lemon oil is no longer dissolved by it.

The specific gravity of pure acetic acid is at  $59^\circ$  F.:—

According to Oudemans	.	.	.	.	.	.	1.0553
“ Roscoe	.	.	.	.	.	.	1.0564
“ Kopp	.	.	.	.	.	.	1.0590
“ Mendelejeff	.	.	.	.	.	.	1.0607
“ Mohr	.	.	.	.	.	.	1.0600

According to Mohr's determinations, the specific gravity of pure acetic acid varies much at different temperatures, it being

1.0630	at	$54.5^\circ$ F.
1.0600	“	$59.0^\circ$ “
1.0555	“	$68.0^\circ$ “
1.0498	“	$77.0^\circ$ “
1.0480	“	$79.0^\circ$ “

Mixtures of acetic acid and water show a peculiar behavior in regard to their specific gravity; the latter rises steadily until the content of water amounts to from 20 to 23 per cent.; the density of the liquid then diminishes so that a mixture containing 46

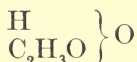


per cent. of water shows the same specific gravity as the anhydrous acid. From this point on, the specific gravities of the mixtures decrease with the increase in the content of water.

This peculiar behavior of the mixtures renders the accurate determination of the content of acid in a concentrated mixture by means of the aerometer impossible. There are a number of determinations of specific gravities of acetic acid with varying contents of water (by Mohr, von der Toorn, Oudemans, etc.), but they differ considerably from each other, like the tables at the end of this volume, so that, while the specific gravity test answers very well for the determination of the amount of anhydrous acid in dilute solutions, it is very fallacious when the acid increases in strength, and an accurate determination can only be effected by chemical methods.

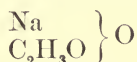
Highly concentrated acetic acid has recently found considerable application in photography and surgery, and frequently occurs in commerce in the form of so-called vinegar essence. The acetic acid occurring under this name is generally prepared from wood vinegar and is only fit for the preparation of table vinegar when a chemical examination shows no trace of tar products, which are formed in abundance, besides acetic acid, in the dry distillation of wood.

In regard to the composition of acetic acid, it may be mentioned that one atom of hydrogen can be readily replaced by univalent metals or univalent compound radicals which may be expressed by



whereby the acetic acid is considered as water  $\left. \begin{array}{c} \text{H} \\ \text{H} \end{array} \right\} \text{O}$  in which one atom of hydrogen is replaced by the compound radical  $\text{C}_2\text{H}_3\text{O} = \text{acetyl}$ .

If the one atom of hydrogen standing by itself be replaced by a univalent metal a neutral acetate is formed, for instance:—

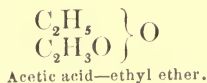
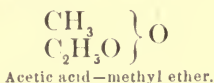


or sodium acetate.

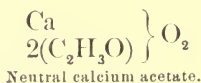
If this atom of hydrogen is replaced by a univalent compound



radical, for instance by methyl  $\text{CH}_3$  or ethyl  $\text{C}_2\text{H}_5$ , the so-called compound ethers are formed.



If a bivalent metal or compound radical yields a neutral combination with acetic acid, the substituted hydrogen in two molecules of acetic acid must evidently be replaced by this bivalent metal, for instance :—



### *Theoretical Yields of Acetic Acid.*

In industries based upon chemical processes a distinction is made between the *theoretical* and *practical* yields.

By *theoretical* yield is understood the quantity of the body to be manufactured which would result if no losses of substance were connected with the chemical process; the *practical* yield, on the other hand, is that in which such losses are taken into account, the average being ascertained by long-continued comparison of daily yields. The closer the practical yield approaches the theoretical, the more suitable the method pursued in the fabrication evidently is, and thus the manufacturer, who has a clear idea of the theoretical yield, can readily judge of the value of his method by comparing it with the practical yield attained.

Now suppose no loss of substance (by evaporation or formation of other combinations) occurs in the conversion of alcohol into acetic acid, it can be readily calculated from the composition of the two bodies how many parts by weight of acetic acid can be formed from a determined number of parts by weight of alcohol.

Alcohol has the composition  $\text{C}_2\text{H}_6\text{O}$ , or an atomic weight of 46, because :—

$\text{C}_2 =$	.	.	.	.	.	24
$\text{H}_6 =$	.	.	.	.	.	6
$\text{O} =$	.	.	.	.	.	16
						—
Makes	.	.				46

The composition of acetic acid is  $C_2H_4O_2$  and its molecular weight 60, because :—

$$\begin{array}{rcl} C_2 & = & . \ . \ . \ . \ . \ 24 \\ H_4 & = & . \ . \ . \ . \ . \ 4 \\ O_2 & = & . \ . \ . \ . \ . \ 32 \end{array}$$

$$\text{Makes} \quad . \ . \ 60$$

Hence from 46 parts by weight of alcohol 60 parts by weight of acetic acid may be formed, or by reducing the ratio to 100 parts of alcohol it follows that 100 parts by weight of alcohol must yield 130.43478 parts by weight of acetic acid. (The increase in weight has to be attributed to the absorption of one atom of oxygen, atomic weight 16, against the loss of two atoms of hydrogen, atomic weight 2.) Since these two atoms of hydrogen are themselves oxidized to water by the absorption of oxygen, the total yield from 100 parts by weight of alcohol would be :—

Acetic acid . . . . . 130.43478 parts by weight.

Water . . . . . 39.13043 “ “ “

Total . . . . . 169.56521 parts by weight.

The quantity of oxygen required to form acetic acid and water from 46 parts by weight of alcohol, amounts to 32 parts by weight, hence for 100 to 69.562 parts by weight. The oxygen is conducted to the alcohol in the form of air, and it can be readily calculated how much of the latter is required to convert a given quantity of alcohol, for instance 100 grammes, into acetic acid. In round numbers the air contains in 100 parts by weight 23 parts by weight of oxygen. Since 1 liter of air of  $68^\circ F.$ , *i. e.*, of that temperature which should at the least always prevail in the vinegar generators, weighs 1.283 grammes, the oxygen contained in it weighs 0.29509 grammes. Since, as above stated, 69.562 parts by weight are necessary for the conversion of 100 parts by weight of alcohol into acetic acid, it follows that 235.70 liters of air are required for the same purpose.

Examinations as to the content of oxygen in the air escaping from well-conducted vinegar generators have shown that on an average only one-quarter of the entire content of oxygen is consumed in the formation of vinegar; hence four times the theoretic-

cally calculated quantity of air must pass through the apparatus to completely convert the alcohol into acetic acid. Hence 100 grammes of alcohol require at least 942.92 liters of air for their conversion into acetic acid, and, without being far wrong, it may be assumed that in a vinegar factory, in round numbers, 1000 liters or one cubic metre of air are required for every 100 grammes of alcohol to be converted into acetic acid.

A vinegar generator can, on an average, convert daily 3 liters of alcohol into acetic acid; 3 liters of absolute alcohol (specific gravity 0.794) weigh 2382 grammes. Now, if, as stated above, 1 cubic metre of air is required for every 100 grammes of alcohol, it follows that 23.82 cubic metres, or 23,820 liters of air must pass daily through each vinegar generator in operation.\*

Calculated to 16 working hours a day, somewhat more than 0.4 liters (more accurately 0.413 liters) must pass every second through the generator in order to supply the quantity of oxygen required for the conversion of alcohol into acetic acid.

Since the formation of vinegar has theoretically to be considered as a process of combustion, in which of 46 parts by weight of alcohol 2 parts by weight of hydrogen, or of 100 parts by weight of alcohol 4.34782 parts by weight of hydrogen, are consumed, the quantity of heat liberated by the conversion of 100 parts by weight of alcohol into acetic acid can also be calculated. By combustion 1 gramme of hydrogen yields 34.126 units of heat, and hence 4.34782 grammes of hydrogen 148.373 units of heat, *i. e.*, in the conversion of 100 grammes of alcohol into acetic acid sufficient heat is liberated to heat 148.373 kilogrammes of water from 0° C. to 1° C., or 1.48 kilogrammes from 0° C. to boiling, and thus a considerable development of heat is caused by the rise of temperature in the apparatus in which a vigorous formation of vinegar takes place.

In answer to the question, what can the practical manufacturer of vinegar learn from these theoretical explanations, it may be said there are many points of great importance for the execution of the work. The calculation of air shows that the alcohol

\* It is always supposed that the manufacture of vinegar is effected in generators used in the quick process.

requires a large supply, but the generators in general use in the quick process are by no means so arranged as to be adequate to the theoretical demands. In fact it may be said that most of them allow only a limited change of air and consequently work slower than they actually could. That the generators now in use are deficient is conclusively proved by the numerous constructions which have been proposed, especially in modern times, whose chief aim is to afford a free passage to the air.

The fact that considerable heat is developed in the interior of the generator deserves consideration in connection with the heating of the manufactory. If the temperature of the latter is so high as nearly to approach the *optimum*, i. e., the temperature most favorable for the formation of vinegar, it may easily happen that, in consequence of the vigorous oxidation of the alcohol, the temperature in the interior of the generators is increased to such an extent as to exceed this optimum, and the activity of the vinegar ferment would immediately diminish and even cease altogether.

If, on the other hand, the temperature of the workroom is kept too low, the generators act sluggishly and do not produce as much as when the correct conditions are observed. But as by raising the temperature of the workroom the activity of the generators is increased, too low a temperature is less injurious to the regular course of the process than too high a one.

The optimum of the formation of vinegar is at about 86° F., and hence the aim should be to maintain this temperature as nearly as possible in the *interior* of the generator. The temperature of the *workroom* must, however, be kept sufficiently low, so that the optimum in the interior of the generator cannot be exceeded.

Another factor may here be mentioned. The closer the temperature in the interior of the generator approaches the optimum and the quicker the supply of air, the more alcohol and acetic acid are lost by evaporation, or, in other words, the smaller the yield of acetic acid. By the skillful utilization of conditions the manufacturer must aim to reduce this loss to a minimum, and this can be best effected by a suitable arrangement of the workroom. By regulating the change of air so that it is not greater than absolutely necessary, the air will soon become so saturated

with vapors of alcohol and acetic acid that no further loss will take place until the renewing of the air in the workroom appears necessary. In which manner the manufacturer is to work in order to carry on the business most advantageously depends on the conditions of trade. If large orders have to be filled, he will endeavor to increase the capacity of the generators to the utmost by maintaining the optimum of temperature and a vigorous change of air in them, and in this case must submit to the increased losses inseparably connected with this high performance. If, on the other hand, he works for stock, he will not force the capacity of the generators to the utmost, but in order to work as cheaply as possible direct his attention to reduce the losses to a minimum.

*Yields of Acetic Acid obtained in the Practice.*

By keeping for some time an accurate account of the actual yields and comparing them with those theoretically obtainable, the former will be found to fall more or less short of the latter, and the difference will be the smaller the better the method of fabrication in use.

In a vinegar factory occur many unavoidable losses, the sources of which have been indicated in the preceding explanations; alcohol and acetic acid evaporate, and besides a portion of them is entirely destroyed by too much oxidation. Now a loss by evaporation, etc., of ten per cent. of the quantity of alcohol originally used must no doubt be considered a large one, but from numerous observations it may be asserted that even with the greatest care in working the loss in vinegar factories is not less than from 15 to 20 per cent., and may even be as much as 30 per cent.

These enormous losses of substance conclusively prove the defectiveness of the processes in general use and the urgent necessity for reformation. The experiments made for this purpose, and which have been especially directed towards a remodelling of the apparatus used, cannot be considered entirely satisfactory, though they were partially instituted by practical manufacturers, who, however, lacked the necessary theoretical education.

The principal requirement in our opinion is to provide the generator with a suitable ventilator, which will allow of the passage through the generator of exactly the quantity of air required for the conversion of the alcohol into acetic acid, and is so constructed that the vapors of alcohol and acetic acid (or at least the larger portion) carried away by the current of air are condensed and thus regained.

A vinegar generator has frequently been compared to a furnace, and in continuation of this comparison it may be said, that the construction generally used is a furnace lacking every arrangement for the regulation of combustion. In such a furnace as much fuel is burned as corresponds to the quantity of oxygen entering, while in a furnace of suitable construction the combustion of fuel can be accurately regulated by increasing or decreasing at will the supply of air by means of a simple contrivance.

A vinegar generator of suitable construction should be provided with a similar arrangement. If the thermometer on the apparatus shows too low a temperature—hence too slow a process of oxidation—the course of the operation can in a short time be accelerated by the production of a stronger current of air and the temperature correspondingly increased. If, on the other hand, oxidation proceeds too rapidly, which on account of the high temperature then prevailing in the apparatus is accompanied by considerable loss of substance, it can be quickly reduced to within the correct limits by decreasing the current of air. An apparatus unprovided with a ventilator is left more or less to itself, while one provided with such an arrangement is under the entire control of the manufacturer.



## CHAPTER V.

## METHODS OF FABRICATION OF VINEGAR.

THE fabrication of vinegar from wine is undoubtedly the oldest and most simple method known, since it is only necessary to leave the wine to itself at a sufficiently high temperature to find it within a certain time converted into vinegar. A similar process takes place in all fermented fruit juices resembling wine.

It would, therefore, seem proper to commence the description of the various methods of fabrication of vinegar with this simple process, but for reasons of an entirely practical nature it has been concluded not to do so.

Since alcoholic fluids directly formed by the vinous fermentation of sacchariferous plant juices possess the property of changing under circumstances favorable to acetous fermentation into vinegar, it is evident that the latter can be prepared from them, and, in fact, it is possible to prepare it from all sweet fruits and parts of plants, such as cherries, strawberries, figs, bananas, etc., as well as from the juice of the sugar-cane, beet, chicory root, etc.

Honey, which represents a concentrated solution of fermentable sugar, as well as crystallized cane sugar, can likewise be indirectly used for the preparation of vinegar, since solutions of either can be brought into vinous fermentation and the resulting alcohol converted into acetic acid.

By malting grain a peculiar body called *diastase* is formed, which possesses the property of converting starch into fermentable sugar, and upon this fact is based the manufacture of beer and alcohol. In an indirect manner (the starch having to be converted first into sugar, and the latter into alcohol) it is, therefore, possible to prepare vinegar from every substance containing starch, and for this reason we can speak of grain and malt vinegars. The beer prepared from the malt containing already



a certain quantity of alcohol can thus be *directly* converted into vinegar.

Alcohol furnishing ultimately the material for the fabrication of vinegar, the direct use of dilute alcohol or spirit of wine for the manufacture of vinegar became obvious. By the employment of a suitable process, *i. e.*, one corresponding to the laws of acetous fermentation, it was found that the conversion of dilute alcohol into acetic acid could be effected in a much shorter time than by the old method, and upon this process is based the quick method of fabrication now in general use. A distinction may, therefore, be made between two principal methods of fabrication, *viz.*, the older or slow process, which requires more time, and the more modern or quick process.

In the old process many modifications are found, which are partially based upon old usage and partially upon the difference in the chemical composition of the raw material used. Beer, for instance, which contains only about 4 per cent. of alcohol and a large quantity of extractive substances (sugar, dextrin, salts, etc.), requires a different treatment from wine, which contains on an average 10 per cent. of alcohol, but scarcely 2 per cent. of extractive substances. Fruit-wines (cider, etc.), with only 5 to 6 per cent. of alcohol but a large quantity of extractive substances, again require different treatment from grape wine, etc., so that, in a certain sense, it may be said there are as many different methods of fabricating vinegar as there are fundamental materials, and by taking into consideration the difference in the chemical composition of the latter, it is evident that there must be just as many varieties of vinegar. Besides acetic acid and a certain amount of water, every vinegar contains other substances, which, though frequently only present in very minute quantities, nevertheless exert considerable influence upon its properties.

Even vinegar obtained from dilute alcohol shows differences in odor, which depend on the material used in the preparation of the specific alcohol. Potato alcohol always contains traces of potato fusel oil (amyl alcohol), while certain fusel oils are found in alcohol prepared from grain or molasses. In the oxidation of the alcohol by the vinegar ferment these fusel oils are also oxi-

dized and converted into combinations distinguished by their peculiar and very strong odor.

Though these bodies occur in the vinegar in such minute quantities that they can scarcely be determined by chemical analysis, an expert can detect them by the sense of smell, and from the specific odor of the vinegar form a conclusive judgment as to the material used in its preparation.

The differences in vinegar from wine, fruit, beer, and malt are still more prominent, and extend not only to the odor but also to the taste. Besides a specific odoriferous principle every wine contains ænanthic ether, tartar, tartaric and succinic acids, glycerin, and a series of extractive substances not thoroughly known. The odoriferous substances and the ænanthic ether also undergo alteration in the oxidation of alcohol, and are converted into other odoriferous combinations, with such a characteristic odor that wine vinegar can at once be recognized as such by it. On account of the presence of so many substances possessing a specific taste, that of the wine vinegar must, of course, differ from that of pure dilute acetic acid.

Similar conditions prevail in fruit-wine, beer, malt-extract, etc., and hence vinegar prepared from these fluids must possess definite properties.

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## CHAPTER VI.

### QUICK PROCESS OF FABRICATION OF VINEGAR.

IN 1823 Schützenbach conceived the idea that by greatly enlarging the relative surfaces of contact of the alcoholic solution and air containing oxygen, the process of acetification would be greatly facilitated. His experiments proved successful, and soon after the quick vinegar process was generally adopted. Analogous processes were nearly at the same time invented, in Germany by Wagmann, and in England by Ham.

The principle involved of course depends on an extreme division of the liquid being effected. This is very skilfully con-

trived. By making the alcoholic solution percolate slowly through and diffuse over a mass of shavings, wooden blocks, pieces of coal or cork, etc., it forms a very thin layer, the surface of which is very extensive, and is therefore better adapted for the chemical appropriation of the oxygen in the current of air which is transmitted over it. The mass of shavings, etc., serves not only for the division of the liquid into fine drops but also as a carrier of the vinegar ferment.

It will be readily understood that this arrangement presents in a high degree all the conditions required for the formation of vinegar: the vinegar ferment upon the shavings acquires from the liquid all the substances required for its maintenance and augmentation, and by the current of air passing through between the shavings is enabled to oxidize the alcohol to acetic acid. This process taking place simultaneously on thousands of points in a normally working generator explains why a large quantity of alcohol can in a comparatively short time be converted into acetic acid. The term quick process is hence very appropriate for this method, it differing from the older slow process only in less time being required for its execution; the chemical processes are the same in both cases.

It will be seen that the generator, technically called "graduator," used in the quick process may be compared to a furnace in which the fuel (in this case the alcoholic fluid) is introduced from above and the air from below. The spaces between the shavings, etc., may be compared to the interstices of a grate; combustion takes place on the points of contact of the alcoholic fluid, vinegar ferment, and air. The product of (partial) combustion—the vinegar—collects in a reservoir in the lower part of the generator.

Each generator, as previously stated, requires about 0.4 liter of air per second, which must ascend uniformly from below through the mass of shavings, etc. At the first glance this would seem very simple, but its practical execution is accompanied by many difficulties, and hence a large number of various constructions of generators have been proposed by which this object is claimed to be best attained.

*Arrangement of the Generators.*

A generator consists of a large vessel divided into three spaces above one another, the uppermost serving for the division of the alcoholic liquid into many small drops; in the centre one, which forms the largest part of the apparatus, the alcoholic liquid is converted into vinegar, while the lower one serves for the collection of the vinegar.

The best form of the generator is that of a truncated cone. This form offers to the alcoholic liquid in its passage from the upper part of the generator the opportunity of spreading over a constantly increasing surface, and by thus coming in contact with the fresh air entering the lower part of the apparatus its oxidation must evidently be promoted. The current of air in passing from below to above yields a certain portion of its oxygen in the lower part of the apparatus, and if it were allowed to ascend in a vessel of a purely cylindrical shape, the alcoholic fluid running down would come in contact with air quite poor in oxygen. Hence this evil must be sought to be overcome by the acceleration of the motion of the air upwards, which is accomplished by giving the vessel the form of a slightly truncated cone.

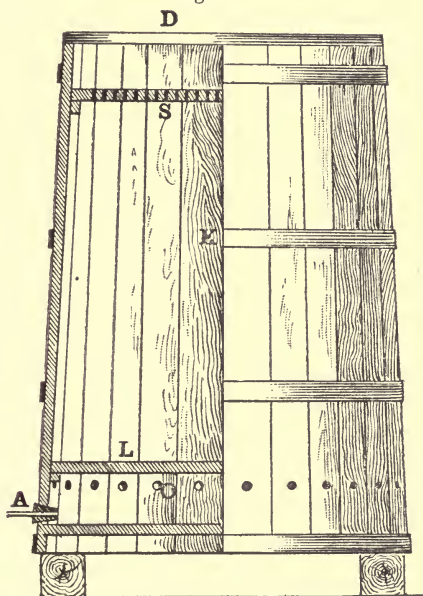
The generator, Fig. 3, consists of the vat *K* of larch, fir, or other durable wood. The use of oak cannot be recommended, partially because of its being too expensive, and further on account of being so rich in extractive substances that a generator constructed of it has to be several times lixiviated with water before use, as otherwise the vinegar prepared in it would for a long time acquire a disagreeable tang and dark color. In the upper portion of the vat is a perforated wooden disk *S*, and in the lower a false bottom of laths, the so-called lath-bottom *L*. The aperture *A* serves for the discharge of the fluid collecting underneath the lath-bottom. The cover *D*, the arrangement of which will be described later on, serves for regulating the draught of air in the generator.

The hoops of the generators, as well as all other metallic parts in the factory, should be coated with good linseed-oil varnish or asphaltum lacquer, and care should be had immediately to repair any injury to this coating, as otherwise strong rusting is caused

by the vapors of acetic acid contained in the air of the work-room.

In the lower portion of the generator, holes, *O*, are bored. These holes are intended for the entrance of air, and in number

Fig. 3.



General Form of a Generator.

may be as many as desired, since the regulation of the current of air is not to be effected on the lower portion of the apparatus, but on the cover.

There is considerable variation in the dimensions of the generators, some having only a height of 5 feet, with a lower diameter of 3 feet 3 inches, and others again a height of 20 feet or more, with a diameter of up to  $6\frac{1}{2}$  feet. The small generators have the disadvantage of rapidly yielding heat to the exterior, and hence a correspondingly high temperature must be maintained in the workroom in order to keep up the proper degree of heat in their interior. On the other hand, generators of considerable height have the disadvantage of the shavings, etc., with which the centre space is filled, becoming strongly compressed by their



own weight, thus obstructing the proper passage of the air. It has been sought to overcome this evil by placing several false lath-bottoms in the generator, in order to divide the weight of the filling into as many smaller weights as there are lath-bottoms. But this arrangement is also attended with inconveniences, it being difficult to maintain a sufficiently strong draught of air in generators of such height.

Some manufacturers hold that the production of very strong vinegar containing 11 to 12 per cent. of acetic acid is only possible in very tall generators. This opinion is, however, unfounded, the manufacture of very strong vinegar being just as well or rather better effected in small generators than in those 20 feet or more high, which besides are very expensive.

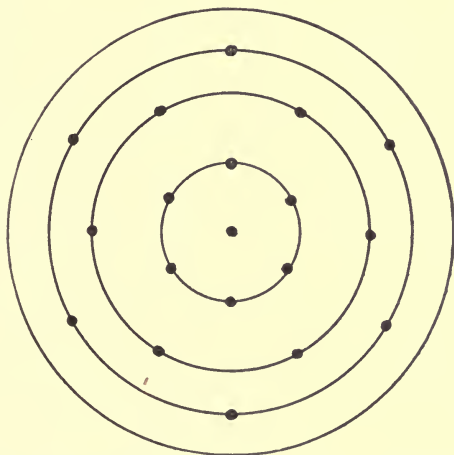
The manufacture of vinegar should be carried on in a room with a low ceiling, since even with the best heating arrangement the temperature near the ceiling is always much higher than on the floor. However, with the use of generators 20 feet high the ceiling of the workroom must be at least 26 feet high, which makes it impossible to maintain a uniform temperature, as the difference between the upper and lower parts would frequently amount to more than 25°.

The most suitable generators are very likely those with a height not exceeding 10 feet, and a lower diameter of about 45 inches and an upper one of about 35 inches. A large diameter, to be sure, contributes towards the maintenance of a uniform temperature in the generator, but it has the disadvantage of making it difficult for the air to ascend uniformly through all parts of the filling. This evil is sought to be overcome by placing in the centre of the generator a tube open above and below and provided on the sides with holes. Such tube, however, does not produce the intended favorable effect upon the draught of air in the parts of the filling surrounding it, experience having shown that the greater portion of the warm current of air ascending in the interior takes the nearest road to the top, *i. e.*, through the tube, without passing sideways into the filling. Every generator of suitable construction should be provided with a well-fitting cover. In this cover, Fig. 4, are bored in concentric circles holes which are intended for draught apertures. If the draught of air



in the interior is too great, it can be at once diminished by closing a number of these holes, it being even possible to direct it towards a certain portion of the filling. This arrangement is, however, only available when the false bottom to be described

Fig. 4.



Cover of a Generator provided with Draught Apertures.

later on is either not used or provided with a number of short vertical tubes which permit the passage of the air.

Many generators are provided with a number of obliquely bored apertures below the false bottom through which the air can escape. This is, however, attended with the disadvantage that a regular draught of air only takes place in the outer layers of filling next to the walls, while it is not sufficiently strong in the centre of the apparatus. It is also incorrect to have but one air aperture in the cover, which can be enlarged or diminished by means of a slide. In a generator thus arranged the current of air entering below will naturally pass chiefly through the conical portion of the filling, the basis of which is formed by the lower lath-bottom and the apex by the draught aperture in the cover. The lower portion of the filling, which embraces this cone, remains without sufficient ventilation and is ineffective as regards the oxidation of alcohol.

In Figs. 5 and 6 the hatched surfaces terminated by the dotted

lines illustrate the portions of the generator in which, with the use of many apertures below the false bottom and a single one in the centre of the cover, the regular current of air from below to

Fig. 5.

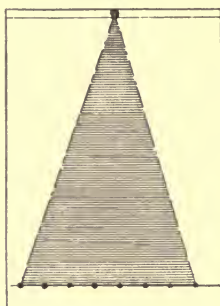
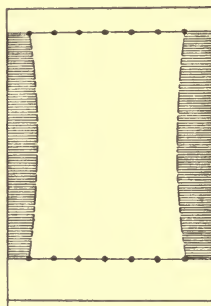


Fig. 6.

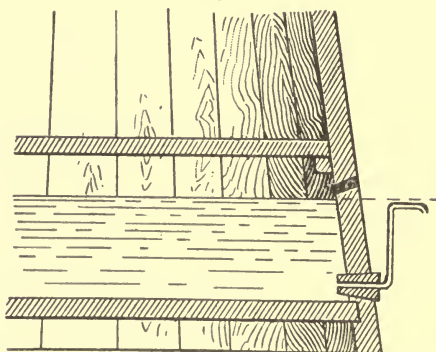


Scheme of the Incorrect Conduction of Air in Vinegar Generators.

above passes ; though a current of air takes place outside of these lines, it is in most cases too weak, and consequently the entire available space of the generator is not sufficiently utilized.

The generators may also be entirely open below and stand in a shallow tub, which serves for the collection of the vinegar ; generally, however, the lower portion of the generator itself is used for this purpose, and is provided with an arrangement for the

Fig. 7.



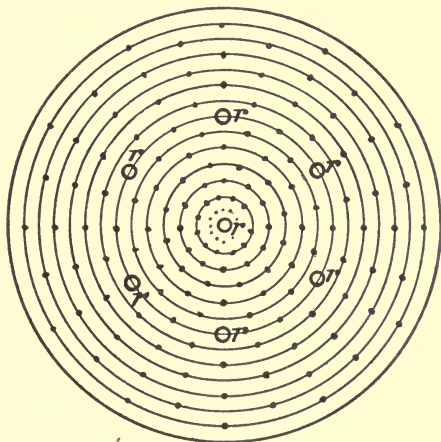
Self-acting Discharge Arrangement on the lower part of the Generator.

occasional discharge of the collected fluid. This can be effected either by a spigot fixed immediately above the bottom, or, as in

Fig. 7, by a glass tube, which bends upwards nearly as high as the air-holes and then curves downward so as to discharge the liquid, when it rises as high as the shelf in the interior of the apparatus, into an appropriate vessel placed to receive it. Simple as this arrangement is, it is scarcely suitable in the practice on account of its being too liable to breakage, and hence it is better to provide the generator with an ordinary spigot, and prevent the vinegar from rising too high, by boring about  $\frac{1}{2}$  inch below the draught apertures a hole in which is fitted a pipe leading to a tub. The vinegar rising to the height of this pipe will commence to run off, and thus give warning to empty the generator by opening the spigot.

In generators of older construction a strong hoop is fixed about one foot from the top, on which is placed a perforated disk which serves for distributing the alcoholic fluid as uniformly as possible over the entire filling. The disk, Fig. 8, is perforated with numerous holes (about 400 with a disk diameter of 3 feet)

Fig. 8.

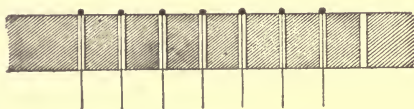


Disk of a Generator.

arranged in concentric circles. These holes are loosely filled with cotton wick or packthread, a knot being made at the top end to keep them from falling through. The threads pass down to the shavings, and serve the double purpose of conducting the liquid

equally through the body of the generator and also of stopping it from passing too rapidly through it (see Fig. 9). It is important to pack the disk so tightly against the walls of the generator that none of the liquid can percolate, which is best effected by a packing of tow and coating this with a mixture of equal parts of wax and colophony. The dripping of the alcoholic fluid through the disk taking place uniformly only when the latter lies perfectly horizontal, great care must be exercised in placing the generator. To prevent warping several strong cross pieces are inserted in the lower side of the disk.

Fig. 9.



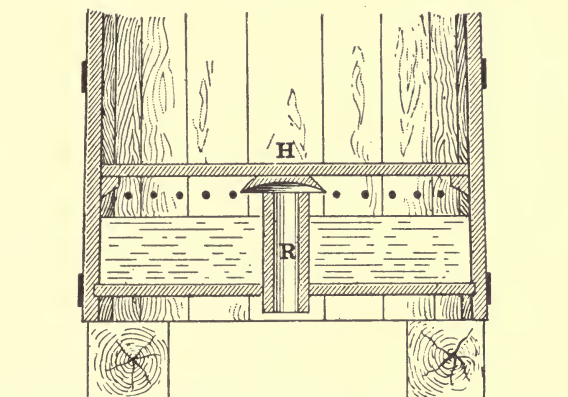
Cross Section of the Disk.

As previously mentioned the current of air must pass through all portions of the filling, and for this purpose seven short glass tubes, *r* (Fig. 8), about  $\frac{3}{4}$  inch in diameter, are inserted in the disk. These tubes are so arranged that one is in the centre of the disk and the others in a circle equidistant from the centre and the periphery. Upon the disk is placed the well-fitting cover, provided with an aperture for the passage of the air. This aperture, about 3 inches square, is provided with a well-fitting slide, so that it can be made larger or smaller at will. As previously stated, it is more suitable to provide the cover with a large number of draught holes arranged in concentric circles and to fit each hole with a wooden stopper. By withdrawing or inserting the stoppers the draught of air can then be properly regulated.

To effect the influx of air from below in such a manner that it not only takes place through the draught holes in the circumference, but also insures its conveyance to the centre of the apparatus, it is recommended to insert in the centre of the lower part in which the fluid collects a tube, *R*, Fig. 10, which is open at both ends and protected above by the hood *H* against the dropping in of alcoholic liquid.

A uniform distribution of the alcoholic liquid upon all portions of the filling of the apparatus would be effected if about the same quantity of liquid dripped from all the threads. This being, however, difficult to attain, it has been sought to give the disk a more

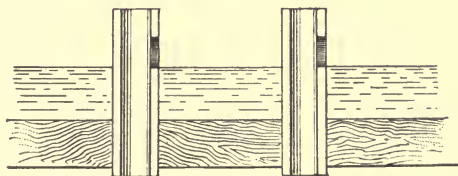
Fig. 10.



Generator with Air-tube in the Lower Portion.

suitable arrangement, which consists, for instance, in the insertion of small wooden tubes with a small aperture on the side (Fig. 11). This arrangement, though very suitable in itself, becomes, however, useless in case of the slightest warping of the disk, a number of the tubes being then raised so high that no fluid runs through them while it passes in a full stream through the others.

Fig. 11.

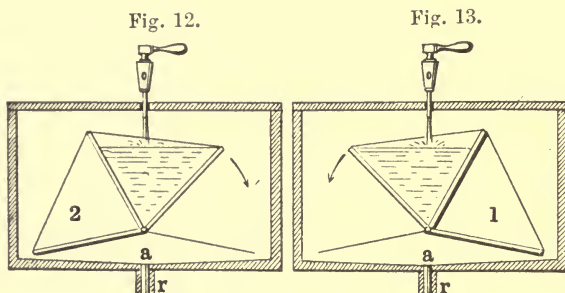


Disk with Wooden Tubes.

These evils connected with the use of a disk can be somewhat diminished by the employment of a so-called "tilting trough" (Figs. 12 and 13), which is arranged as follows:—

Upon a perfectly horizontal axis is placed a rotatory, trough-like vessel divided by a partition into two equal parts.

If the tilting trough is in the position shown in Fig. 12 the alcoholic liquid runs through the cock, placed above, into the partition marked 1.



Tilting Trough.

As soon as this partition is filled to a certain height it turns over in consequence of the disturbance of the equilibrium of the trough and assumes the position shown in Fig. 13. In this position partition 2 is gradually filled with alcoholic liquid, the trough then tilts back into position 1, and so on.

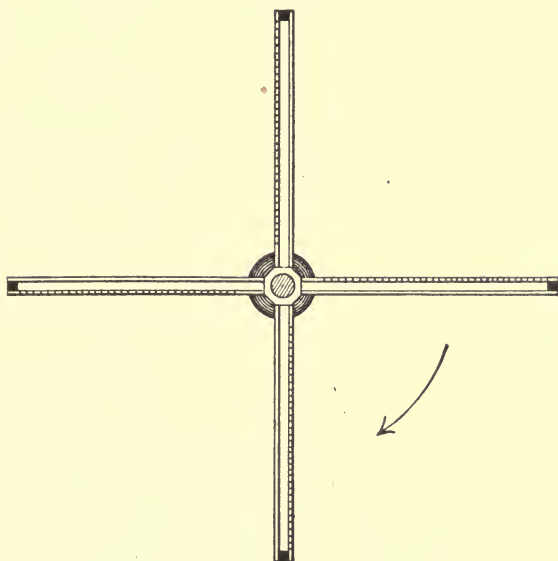
It will be seen that with the assistance of such a tilting-trough the same quantities of liquid can always be poured out at certain intervals, and that this arrangement can be used for distributing the alcoholic liquid upon the disk, the latter in this case being best provided with holes having the form of an inverted cone. The apex of this cone forms a very narrow aperture through which the alcoholic liquid poured upon the disk trickles in very thin jets upon the filling of the generator.

But even this arrangement is not free from objections; it works entirely satisfactorily only as long as the disk remains in a perfectly horizontal position. In the more modern constructions of vinegar generators the disk is generally entirely omitted and the distribution of the alcoholic liquor effected by a so-called "sparger," similar to the one used in beer brewing for sprinkling malt residues. The sparger is arranged like a simple turbine, and is moved by reaction in the direction opposite to that in which the discharge of the fluid takes place. Spargers used in vinegar



factories can be constructed only of a material indifferent to the action of acetic acid, such as wood, glass, hard rubber, etc. Their construction will be understood from Figs. 14 and 15.

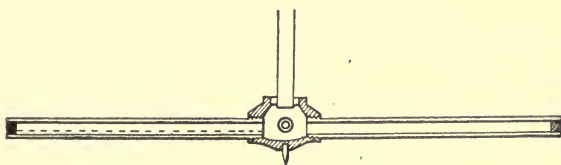
Fig. 14.



Sparger (view from above).

Into a hollow cylinder of wood are screwed four thin wooden tubes, closed at both ends and perforated lengthwise with numerous small holes ; the tubes are so arranged that all the holes are

Fig. 15.

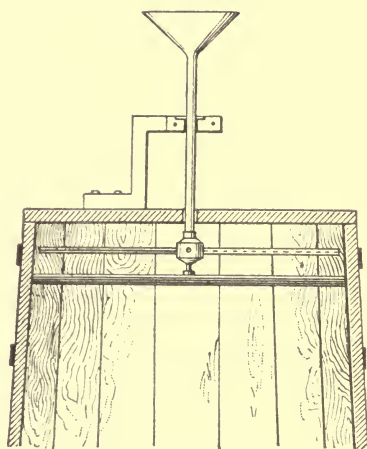


Sparger (cross-section).

directed towards one side. The basin in the centre is closed on top by a glass tube about 20 inches long and of sufficient width to allow of the passage of as much fluid as can at one time run off through all the lateral tubes.

The principal requisite of the correct working of the sparger is that it revolves with ease around its vertical axis. This is effected by placing in the centre of the vessel a glass pin drawn out to a fine point and running in a small glass step; the vertical glass tube is guided in a sharp-edged wooden ring fastened to a stay placed upon the cover of the generator (Fig. 16). The sparger finds its centre of motion upon a lath inserted in the direction of the diameter of the generator. This lath is placed at such a height that the sparger can move freely between it and the cover of the generator. The sparger being in position as shown in Fig. 16, a funnel-form vessel, through which the alcoholic fluid is poured in, is placed upon the glass tube.

Fig. 16.



Sparger placed in the Generator.

By now pouring through this funnel-form vessel the alcoholic liquid in a sufficiently strong stream, so that during its influx the glass tube remains filled, it passes in fine jets through the lateral openings, and, the sparger revolving in an opposite direction, is distributed in the form of a fine spray over the filling in the generator.

The use of the sparger overcomes the difficulties frequently occurring with the disk, especially as regards the position of the latter, and the circulation of air through the apparatus also takes

place in a perfectly uniform manner. A number of apertures in the cover of the generator serve also here for the regulation of the current of air.

A thermometer is an indispensable adjunct to a generator, and should be so placed that the temperature prevailing in the apparatus, and especially in the centre, can be readily read off. This is best effected by introducing at about half the height of the apparatus, through an obliquely bored hole in one of the staves, a glass tube closed at the lower end and reaching to the centre of the filling. This tube serves for the reception of a thermometer fastened to the lower end of a stick of wood. The latter projects from the glass tube, so that the thermometer can be quickly drawn out and the temperature read off.

#### *Filling of the Generators.*

For filling the space between the upper disk and lower lath bottom, material offering a large surface for the distribution of the alcoholic liquid is used. Pieces of charcoal and of pumice stone, washed in hydrochloric acid and well rinsed in water to remove empyreumatic substances, which would render induction of acetous fermentation impossible, have been used for the purpose, as well as old corks or waste of cork. Pumice stone especially has the advantage of being easily cleansed by water and by fire when the liquors, such as those from fruits, contain a great deal of mucilaginous and albuminous substances, which will rapidly accumulate and prevent the proper working of shavings. Grape-stalks, which actually present a very large surface, were formerly much used for filling the generators, but, independently of the fact that they cannot be everywhere obtained in sufficient quantities, they have the disadvantage of becoming in a short time so strongly compressed as to prevent the free passage of air.

But beechwood shavings are now nearly everywhere employed for filling the generators. Indeed, beechwood presents many advantages; it can be had easily and cheap; it curls well and stands without breaking for a length of time. White woods will curl as well, but they will not stand so well as beech; resinous.

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woods are not porous enough, and besides their resin is objectionable, as it may partly dissolve in the vinegar; oak wood does not curl as well and contains too much coloring matter and tannin.

The beech shavings are generally made in special factories. They consist of wooden bands about  $\frac{1}{2}$  millimeter (0.02 inch) thick, 4 centimeters (1.57 inches) wide, and 40 to 50 centimeters (15.74 to 19.68 inches) long. They are rolled into close spirals by a special machine, and each shaving, according to the above dimensions, presents a surface of about 400 square centimeters (62 square inches). Now, as a generator of moderate size contains many thousands of such shavings, it will be readily seen that the surface over which the alcoholic fluid is distributed is an extraordinarily large one.

A shaving of the stated dimensions represents in a rolled state a cylinder with a volume in round numbers of 28 cubic centimeters (1.7 cubic inches). By allowing an interspace of 14 cubic centimeters (.85 cubic inch) between the shavings,  $28 + 14 = 42$  cubic centimeters ( $1.7 + 0.85 = 1.92$  cubic inches), space is required for each shaving. The space to be filled with shavings in a generator 1 meter (3.28 feet) in diameter and 2 meters (6.56 feet) high is equal to 1.57 cubic meters (55.44 cubic feet), and hence 58,000 shavings, with a total surface of 2112 square meters (22,733.56 square feet), are required for the purpose. Now suppose only 5 per cent. of this surface is continually active in the formation of vinegar, we have still a surface of over 100 square meters (1076.43 square feet) at our disposal. But the active surface would seem to be actually much smaller even with the most favorable working of the generator, as otherwise the average quantity of alcohol daily converted into acetic acid in a generator would be much larger than is actually the case.

Beechwood shavings contain a considerable quantity of extractive substances, which if not removed would for a long time impart a disagreeable tang (woody taste) to the vinegar. Hence it is recommended to lixiviate the shavings in water repeatedly renewed, in order to get rid of the substances soluble in cold water and remove the last traces by treatment with steam.

This steaming is best effected in a large tub or a vat, which is later on to be used as a generator. The shavings are thrown in

loosely and covered with a loaded lid. A steam-pipe is introduced through a hole near the lid and the tap-hole near the bottom is opened. The steam-pipe being connected with a boiler, in which prevails a tension of  $1\frac{1}{2}$  to 2 atmospheres, the steam-cock is at first opened but slightly, to prevent the steam entering with great force, from throwing off the lid, or even bursting the vessel. In the commencement of the operation the steam condenses on the shavings, but after some time the vessel becomes very hot, and a dark-colored fluid, consisting of almost boiling water charged with extractive substances of the wood, begins to run off. After continuous steaming for about 20 to 60 minutes—according to the size of the vessel—the fluid running off becomes clearer until finally clear water is discharged, which is indicative of the removal of the extractive substances soluble in water.

Although not absolutely necessary it is advisable to dry the steamed shavings. When air-dried they still contain about 20 per cent. of water, which in the subsequent "acidulation" of the generator must be replaced by vinegar. Hence it is recommended to dry the shavings completely by exposing them for some time to a current of air of  $194^{\circ}$  to  $212^{\circ}$  F.

In a factory provided with a central heating apparatus\* in the cellar, this drying of the shavings can be effected without difficulty, it only being necessary to put them in a vessel with a perforated bottom and open on top, and place the vessel over an aperture of the channel through which the hot air from the heating apparatus ascends, closing all other apertures.

Entirely dry wood absorbing with avidity moisture from the atmosphere, the shavings thus dried should immediately be brought into another vessel and, while still hot, moistened with the vinegar intended for acidulation.

Before using the shavings for filling the generators it is necessary to allow them to swell by placing them in water or alcoholic liquid. If this were omitted and the shavings introduced in a

\* The arrangement of a central heating apparatus will be described later on in speaking of the arrangement of the factory.

dry state they would rise above the generators as soon as moistened, on account of the increase in volume by swelling.

In most factories it is customary simply to pour the shavings into the generator, but for a uniform distribution of the alcoholic fluid it is advisable to proceed with the filling in a certain order. First place the shavings in three or four regular layers upon the lath-bottom, then pour them in loosely to a height of 8 to 12 inches, and after levelling the surface as much as possible pour in again, and continue in this manner until the generator is filled; the uppermost portion should again consist of three or four regular layers.

All the generators used in a vinegar factory should be of the same size and charged with the same number of shavings, which is best effected by filling them with the same quantity by weight. The total surface of shavings being thus nearly the same in all generators, the latter will work uniformly, *i. e.*, with an equal temperature and draught of air; and in the same time convert equally large quantities of alcohol into acetic acid.

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## CHAPTER VII.

### ARRANGEMENT OF A VINEGAR FACTORY.

THE arrangement of the manufacturing rooms formerly customary even in large factories is by no means a suitable one. The generators were generally simply placed in a room adapted for the purpose by its size, while the high temperature required was sought to be maintained by heating. By considering, however, that every considerable variation in the temperature causes also a disturbance in the formation of vinegar, it will be seen that the object of keeping up an undisturbed working of the factory cannot be attained by such primitive means. A suitable arrangement of the room in which the vinegar is to be manufactured is, therefore, absolutely necessary.

The principal requisites to be observed are: the maintenance of a uniform temperature in the room and a suitable arrangement



for ventilation. Further, simple means for the conveyance of the raw materials and the finished product must be provided for and means devised for regaining the acetic acid, with the vapors of which the air in the manufacturing room is constantly saturated.

For the maintenance of a uniform temperature in the workroom, which should remain almost constant even in the coldest season of the year and during abrupt changes in the outer temperature, the walls should be of more than ordinary thickness and the number of windows and doors sufficient only for the necessary light and communication, and so arranged that no unintentional ventilation can occur. The windows and doors should, therefore, be double, and the latter so placed that one can be closed without opening the other. The walls and ceilings should be plastered and preferably papered with stout packing paper.

Asphaltum, being impermeable and also indifferent to the action of acetic acid, is undoubtedly the best material for the floor of the workroom, though it may also be constructed of large slabs of sandstone with the joints filled in with asphaltum. Cement floors can only be recommended provided they are immediately after their construction coated with water-glass until they cease to absorb it. In constructing the floor care must be had to give it such an inclination that the entire surface can be cleansed by a simple jet of water. If the heating channel is conducted lengthwise through the workroom, gutters for the rinsing water to run off must be arranged on both sides.

The height of the room depends on that of the generators.

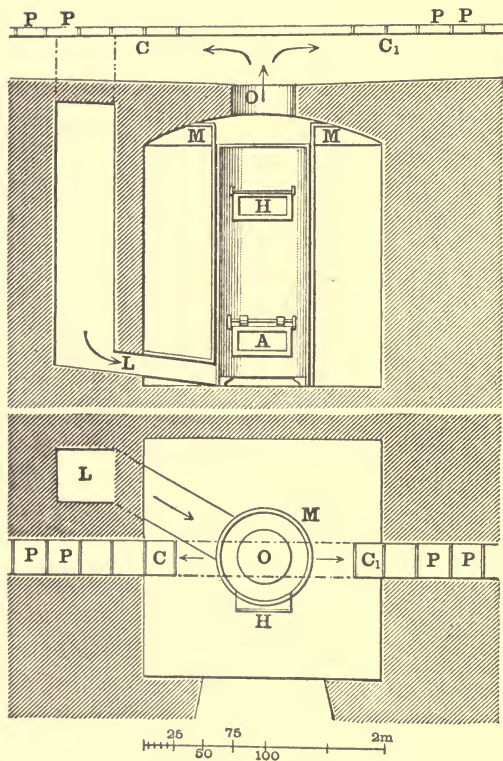
### *Heating of the Workroom.*

Heating by a stove placed in the workroom itself can only be recommended for very small factories; in larger ones a special heating apparatus should always be provided. Where stoves are used it is recommended to arrange them so that the fuel can be supplied and the ashes removed from the outside, *i. e.*, from a room adjoining the actual workroom. In attending to the stoves fine particles of ashes will unavoidably reach the air; from the latter they may get into the generators, and being soluble in acetic acid may injure the vinegar ferment.

For large factories a heating apparatus similar to the one shown

in Figs. 17 and 18 can be recommended. The iron heating cylinder, which is provided with the feeding-door *H* and the air-regulating door *A*, stands in a vault beneath the centre of the room to be heated. It is surrounded on all sides by the sheet-iron jacket *M*, reaching from the floor of the cellar to the top of the vault. In the vault is a circular aperture, *O*, for the reception of the channels *C* and *C*<sub>1</sub>. The latter, ascending slightly, run

Figs. 17, 18.



Ground-plan and Elevation of Heating Apparatus.

along the centre of the room to be heated. Above they are covered by cast-iron plates, *P*, and by pushing these plates apart or substituting a lattice plate for one of them in any part of the channel, warm air can be admitted to the room. If the room is to be heated without renewing the air, the register in the flue *L*, which communicates by a flat iron pipe with the lower part of

the jacket, is opened. The furnace being heated the air in the room is sucked in the direction of the arrow through the flue  $L$ , and passing between the jacket and the furnace, ascends strongly heated through  $O$  and penetrates through the openings in the channel; air is again sucked through  $L$ , and so on.

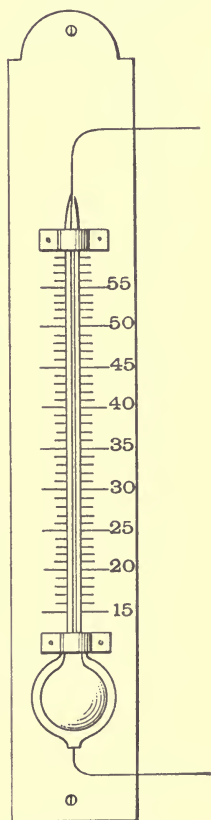
If, however, the air in the workroom is to be entirely renewed, the air-flue  $L$  is closed and a register (not shown in the illustration) in the lower part of the jacket opened. In this case the air in the cellar is sucked in, heated and distributed through the channels  $C$  and  $C_1$ . By partially opening this register and that in  $L$  a portion of the air can be renewed at will.

In order to be able to form a correct idea of the state of the temperature prevailing in the room, it is advisable to have several ordinary thermometers and also a maximum and minimum thermometer. If the latter shows no greater variation than from  $4^{\circ}$  to  $5^{\circ}$ , the process of heating may be considered as satisfactory.

A very suitable apparatus for controlling the temperature in a vinegar factory is an electrical thermometer, which is so arranged that a bell rings in case the temperature rises above or falls below a certain degree. By placing two such thermometers in the room, the bell of the one indicates the rise of the temperature above the limit, and that of the other that it has fallen below it.

Fig. 19 illustrates the principle of a maximum electrical thermometer, *i. e.*, one which rings a bell when the temperature of the room exceeds a certain limit. Into the bulb of an ordinary mercury thermometer is melted a platinum wire; another platinum wire is inserted in the tube up to the mark indicating the temperature not to be exceeded, for instance,  $35^{\circ}$  C. The ends of the platinum

Fig. 19.



Maximum Electrical Thermometer.

wires projecting from the thermometer are connected by insulated copper wires with a galvanic battery consisting of several elements, an ordinary door-bell being inserted in one part of the conductor. If, now, in consequence of a continued increase in the temperature, the mercury rises to the point of the platinum wire at the figure  $35^{\circ}$ , the circuit of the battery is closed at the same time by the column of mercury, and the bell rings and keeps ringing until the circuit is again opened by the mercury falling below  $35^{\circ}$ .

The minimum electrical thermometer, used for indicating the falling of the temperature below a certain degree, is so arranged that one platinum wire is melted into the bulb of the thermometer and the other in the tube at the point below which the temperature is not to fall. As long as the mercury remains above this point a battery, which changes a piece of iron to an electro-magnet, whose anchor opens a second battery which is connected with an electric bell, remains closed. If the temperature falls below the minimum, the circuit of the first battery is opened, and the anchor of the electro-magnet falling down effects the closing of the second battery and sets the bell ringing.

By placing such thermometers not only in the working room but also in every generator, the control of the entire process would be immensely facilitated, but at the present time these useful and at the same time inexpensive instruments are but little used in vinegar factories.

In factories arranged according to the automatic system, the alcoholic liquid is contained in vessels placed at such a level that their contents can run directly into the generators. The alcoholic liquid having to be correspondingly heated, adequate provision must be made for heating the space in which the reservoirs are placed. In order not to increase the height of the entire room, it is recommended to place these vessels in the centre and give only to this portion the required height. This has the further advantage that the pumping up of the alcoholic liquid can be effected by the use of a pump with a short rising-pipe, and the liquid can be readily conducted from the reservoirs to the separate generators by means of pipes.

## CHAPTER VIII.

## ARTIFICIAL VENTILATION OF THE VINEGAR GENERATORS.

THE first experiments in conveying direct air to every generator were made in England; but though this step towards improvement in the fabrication of vinegar must be considered an important advance, the English process failed of being accepted in practice on account of the inadequacy of the apparatus used.

In the English factories by a special apparatus a current of air was sucked from above to below through every generator. As shown in Fig. 20, the tall generators are open on top and divided by false bottoms, upon which the shavings, etc., rest, into several partitions; above each false bottom holes are bored in the circumference of the generators. In the bottom of the generator is inserted a pipe which is connected with an arrangement for sucking in the air, a blower or air-pump being used for the purpose.

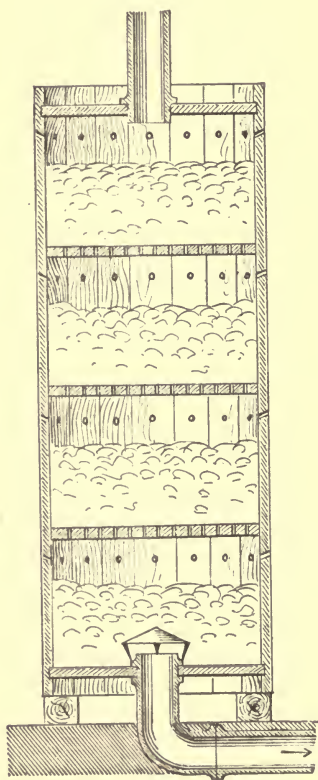
As will be seen from the illustration, the suction of air through all parts of the generator cannot be uniformly effected by the use of this apparatus, the current of air being much more checked in the upper portions, by the false bottoms and holes in the circumference, than in the lower. Hence the effect of the air-pump or blower will chiefly assert itself in the lowest partition. This evil might be remedied by leaving out the false bottoms and placing no air-holes in the circumference of the generator entirely open at the top; by these means the air would be forced to pass in a uniform current through the entire layer of the filling material.

That the passage of the current of air from above to below is entirely incorrect, because contrary to all theoretical requirements, can be readily explained: In a generator in full activity, oxidation of alcohol must already take place in the uppermost portion,



and hence a certain quantity of oxygen is withdrawn from the air. This process being also continued in the lower parts of the

Fig. 20.



Generator with Ventilation from  
above to below.

generator, a current of air already deprived of a portion of its oxygen, and hence less suitable for the further formation of acetic acid, would be sucked in the same direction which the drops of alcohol take.

The principal reason advanced for the use of a current of air from above to below is that by these means a uniform temperature is maintained in all parts of the generators, while it rises considerably in the upper part of those in which the air passes from below to above. This rise of temperature is, however, agreeable to nature. The air entering from below oxidizes the alcohol to acetic acid, becoming thereby poorer in oxygen and again heated. By the higher temperature it acquires, it is, however, capable of a more vigorous chemical activity, so that it will induce the process of the formation of vinegar, even in the uppermost portions of the generator. Besides, the warmer current of air moving upwards has the further advantage of yielding heat

to the drops of alcoholic fluid trickling down. With the use of generators of moderate height, and with a suitable regulation of the draught of air, the maximum temperature will not be exceeded, even in the uppermost portions of the generator.

If no rise of temperature is observed in the lower portions of a generator in which the air passes from above to below, it only proves that the air has lost too much oxygen to further effect a vigorous oxidation of the alcohol. It will be readily understood



that under these conditions a diminution in the loss of substance can, to a certain degree, be effected, but it is doubtful whether the generators are utilized in the manner they should be; besides, the diminution in loss of substance cannot be very considerable. Since a high temperature also prevails in ventilated generators, the current of air passing downward will be loaded with as much vapor of alcohol or of acetic acid as it can absorb at this temperature, and, hence, it would seem no diminution in loss by evaporation could be effected. To render this possible, the current of air sucked from the generator would have to be sufficiently cooled off by a suitable arrangement for the greater portion of the vapors carried away by the current of air to condense to a fluid.

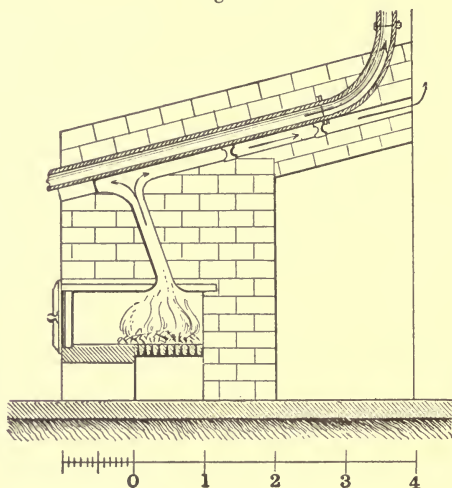
### *Schulze's Ventilating Apparatus.*

The ventilation of the vinegar generators, according to the above-described method, requires the presence of an uninterruptedly acting power for working the air-pump, blower, etc. As is well known, a current of air can, however, be also produced by heating the air passing through an ascending pipe, by which it becomes specifically lighter and ascends, while denser air enters from below, etc. Schulze, as will be seen from Fig. 21, has applied this method to the ventilation of vinegar generators.

Schulze's generator differs somewhat from the ordinary construction, and is arranged as follows: The vat has a height of about 8 feet, and a diameter of 2 feet 6 inches. In the upper part it is terminated by a false bottom, fitting air-tight, and is further provided with a cover, in the centre of which is an aperture about  $2\frac{1}{3}$  inches in diameter, which serves for the entrance of air, while another aperture on the side serves for pouring in the alcoholic liquid. In the false bottom are inserted four glass-tubes, open at both ends and about  $\frac{3}{4}$  inch in diameter, which afford a passage to the air. The generator is filled with pieces of washed and assorted charcoal, so that pieces of the size of a nut are placed upon the lath-bottom, and upon this are poured smaller pieces, gradually decreasing in size until those on the top are only that of a pea. In the centre of the bottom is inserted a wooden tube, open at both ends and provided on top with a hood to prevent

the trickling in of vinegar (see Fig. 10). By a suitable intermediate piece, this tube is connected with the draught-pipe (see Fig. 21), in which the ascension of the air by heating is effected.

Fig. 21.



Schulze's Ventilating Apparatus.

The draught-pipes are of cast iron, and are about  $\frac{1}{2}$ -inch thick and about  $4\frac{1}{2}$  feet long, with a clear diameter of 2 inches. They are placed, strongly inclined, over the flues of a heating apparatus and covered above by a double course of stone. The air in the iron draught-pipes, being heated by the escaping gases of combustion, ascends and effects the passage of a current of air from above to below in the generators. For keeping up a constant ventilation it is claimed to be sufficient to heat the furnace only once a day. With this construction it is necessary to have as many draught-pipes as there are generators; the same effect might, however, also be attained by connecting the pipes leading from several generators with a draught-pipe of a somewhat greater diameter and length.

It is not difficult to prove that a uniform ventilation of the generators cannot be obtained by the use of this construction. As long as the draught-pipes are strongly heated, a very rapid current of air will pass through them and the generators con-

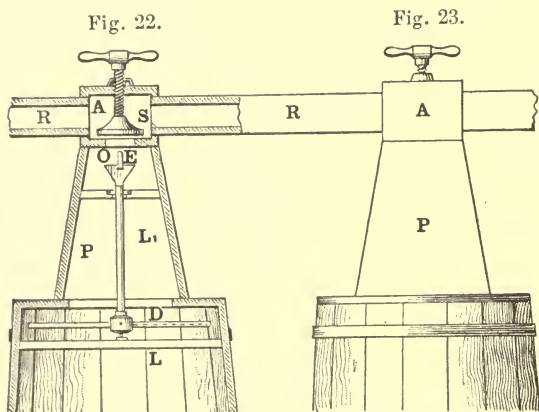
needed with them, which will, however, decrease in the same degree as the pipes cool off. Hence, in the first case, a too rapid current of air accompanied by a correspondingly strong evaporation of alcohol would pass through the generators, and in the latter, ventilation would be so sluggish that the process of the formation of vinegar would not proceed in a normal manner.

*Generators with constant Ventilation and Condensation.*

The object to be attained by the use of special ventilating contrivances is a double one: to conduct a constant current of air through the generators, and, further, not to allow the temperature to rise above a certain limit, so as to decrease by these means the loss by evaporation of alcohol and acetic acid. This object can, however, be attained only by the use of an apparatus which allows of the most accurate regulation of the current of air passing through the generator, and is connected with a contrivance by which the vapors of alcohol and acetic acid carried along by the current of air can be condensed as much as possible. The following apparatus is well adapted for the purpose; its principal parts consist of the generator, the apparatus for condensing the vapors, and the ventilator.

The construction of the lower part of the generator, Fig. 22, is the same as of those previously described; the cover fits tightly upon the upper edge of the vat, the joint being made air-tight by strips of paper pasted over it. In the centre of the cover is a square aperture, from which rises a quadrangular pyramid, *P*, constructed of boards, upon which sits a low prism, *A*. The sparger *D* has its centre of motion upon the lath *L*, placed in the uppermost portion of the generator, and is guided above in the short lath *L*<sub>1</sub>, which carries the sharp-edged ring described on p. 64. *E* is the glass tube through which the alcoholic liquid flows into the funnel of the sparger. On the point where the pyramid passes into the prism *A*, is a bottom provided with a circular aperture, *O*,  $2\frac{1}{2}$  to 3 inches in diameter. Upon the top of the prism *A* is placed a nut, in which runs a wooden screw, provided on the lower end with a wooden disk, *S*, of a somewhat greater diameter than the aperture *O*. By raising or lowering

this screw, the aperture *O* can be closed more or less or entirely, and thus the strength of the current of air regulated at will in every generator. The prisms *A* of all the generators are connected with each other by the conduit *R*, constructed of boards.



Ventilating Apparatus according to Bersch.

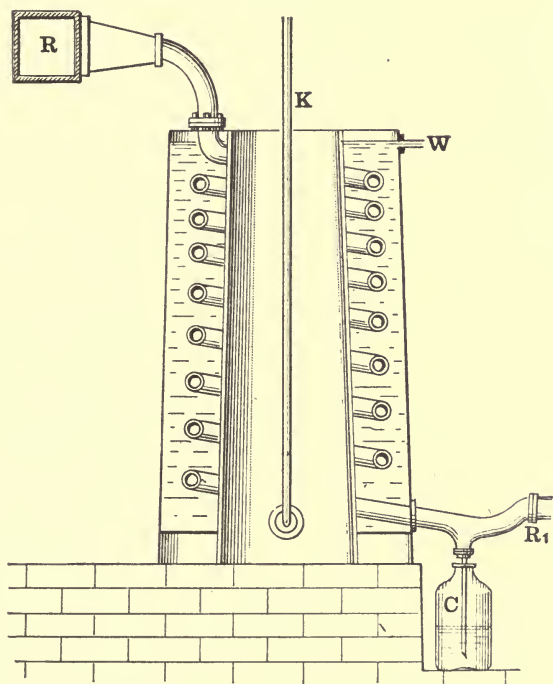
This conduit *R* is connected—best in the centre between an equally large number of generators—with the condensing apparatus, the chief feature of which is a worm similar to that used in a still. Fig. 24 shows the apparatus in cross-section.

In a sheet-iron vessel of the same height as the generator is placed another vessel, so that there is a distance of about  $5\frac{3}{4}$  inches between the walls. From a reservoir situated at a higher level cold water runs into the apparatus through the pipe *K*, and off through the short pipe *W*. In the space between the walls of the two vessels lies a tin coil with very thin walls and a diameter of at least  $2\frac{1}{2}$  inches. On top this tin coil is connected with the wooden tube *R* (Fig. 23) and below with the iron pipe *R*<sub>1</sub>, which leads to the ventilating apparatus. *C* is a glass tube about 16 inches long and  $\frac{1}{2}$  to  $\frac{3}{4}$  inch in diameter, which reaches nearly to the bottom of the flask half filled with water.

The ventilating apparatus consists of an ordinary Meidinger self-regulating stove, but its jacket is closed below so that air can only pass in between the heating cylinder and the jacket through the pipe *R*<sub>1</sub> coming from the condensing apparatus.

The apparatus works as follows: According as combustion in the stove proceeds slowly or quickly by the corresponding position of the regulating register, the air between the heating cylinder and the jacket becomes less or more heated and ascends

Fig. 24.



Condensing Apparatus—Cross Section.

with corresponding velocity. But as the further entrance of air can take place only through the pipe  $R_1$ , the tin coil, and the wooden tube  $R$ , a uniform current of air from below to above must pass through all the generators. To regulate the strength of the current for each generator, it is only necessary to close the aperture  $O$  (Fig. 22) more or less by raising or lowering the screw.

The current of air passing from the wooden tube  $R$  into the tin coil carries with it the total amount of evaporated alcohol or acetic acid. By passing through the tin coil, which is cooled by the water, the air itself becomes cooled off, and the greater

portion of the vapors held by it condense to liquid and run off through the tube *C* into the bottle. The fluid thus obtained consists chiefly of alcohol, water, and acetic acid, and is again used for the preparation of alcoholic liquid. On account of the peculiar form of the cooling vessel but little water is required for feeding it. As the quantity of vapor separated from the air will, however, be the greater the more energetically the tin coil is cooled off, it is recommended to reduce the temperature of the water to nearly 32° F. by throwing in pieces of ice.

It has been proposed to regain the vapors by conducting the air containing them into a large vessel in which water in the form of a fine spray trickles down or is injected. It is, of course, possible in this manner to condense the greater portion of vapors of a higher temperature and tension, but with vapors of at the utmost 95° F. little success would be attained. The greater portion of the vapors remaining uncondensed a very large quantity of fluid containing but little alcohol would be obtained in the course of a day and this fluid could at the best be used only instead of water for the preparation of alcoholic liquid. The value of the material thus regained would not cover the working expenses of the apparatus. By working, however, with the condensing apparatus described above, the condensed alcohol does not even contain the total quantity of water evaporated with it, and it need only be compounded with the corresponding quantity of water and vinegar again to yield alcoholic liquid.

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## CHAPTER IX.

### AUTOMATIC VINEGAR APPARATUS.

THE principal work to be performed in a vinegar factory consists in pouring at stated intervals the alcoholic fluid into the generators. In a large factory several workmen are constantly engaged in this work and losses by spilling are unavoidable. Further it is almost next to impossible always to pour in the same quantity at exactly the same intervals, and sometimes a



generator may even be entirely overlooked and thus remain inactive until the next supply of alcoholic liquid is poured in.

The greatest disadvantage is, however, the interruption for several hours daily of the formation of vinegar in all the generators, so that, for instance, in a factory working 16 hours a day, one-third of the time is lost. Independently of the small return on the capital invested, these interruptions are accompanied by many other conditions injurious to the regular running of the factory.

The greatest of these evils is that with the cessation of the supply of alcoholic fluid the augmentation of the vinegar ferment diminishes and finally ceases altogether. Further, the development of heat in the interior of the apparatus at the same time ceases and the temperature is reduced several degrees, this phenomenon appearing even in factories provided with the best heating apparatus and keeping up a constant temperature in the workroom during the night.

In the morning when work is resumed, it is in most cases necessary to vigorously air the apparatus by opening all the draught holes in order to gradually restore the temperature to the required degree, and it requires some time before the apparatus again works in a normal manner.

The vinegar ferment, however, is very sensitive to changes of temperature as well as to the concentration of the nourishing substance surrounding it, and there can be no doubt that its augmentation is prejudiced by the continuous variations of temperature to which it is exposed during the interruptions of several hours a day. That such is actually the case is shown by the fact that the quantity of vinegar ferment formed in the generators is small as compared with that which under conditions favorable to the ferment forms in a short time upon alcoholic liquids.

Besides the debilitation of the vinegar ferment and the consequent disturbance in the regular working of the factory, the repeated reduction of the temperature in the generators has the further disadvantage that besides the vinegar ferment other ferments for whose development a low temperature is more favorable may be formed, and these ferments may increase to such an extent as to entirely suppress the vinegar ferment. There can scarcely

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liquid flows into each generator, runs above the uppermost row. Another conduit,  $L_1$  common to all the generators, serves for the reception of the fluid (finished vinegar) running off from the lowest row, and conducts it to the collecting vessel,  $S$ . The arrows indicate the course the alcoholic liquid has to traverse.

From all appearances the arrangement of a factory according to the above-described system would be most advisable, there being actually nothing to do but to raise the alcoholic liquid once and to remove the finished vinegar from the collecting vessel. In practice, however, this so-called terrace system presents many difficulties not easily overcome, the greatest undoubtedly being the solution of the heating problem. Experience shows that the temperature in a generator must be the higher the more acetic acid the alcoholic liquid contains. According to this, the highest temperature should prevail in the lowest series of generators (*III*, Fig. 25) and the lowest in the uppermost (*I*).

But in practice just the reverse is the case even with the use of the best heating apparatus: the highest temperature prevails in *I* and the lowest in *III*, as, according to natural law, the warm air being specifically lighter than the cold constantly strives to ascend.

To overcome this evil nothing can be done but to place the series *I*, *II*, and *III* of the generators in as many different stories entirely separated from each other, or, in case there is a central heating apparatus in the cellar, to correctly distribute the warm air in the separate stories by suitably arranged registers. The solution of this problem offers no insuperable difficulties, but requires the arrangement of the entire factory to be carefully planned in accordance with the laws of physics.

An unavoidable evil of the terrace system is the costliness of the factory building, and, finally, that a disturbance occurring in one of the generators must simultaneously affect two others of the vertical series, which must necessarily remain idle until the disturbance is removed. Considering all the disadvantages connected with the terrace system, though it is seemingly so suitable, it is but little adapted to practice; it being much preferable to place all the generators on the same level and to divide them

into three groups, each of which is provided with a reservoir for the alcoholic liquid and a collecting vessel.

The mode of working according to this system is as follows : The alcoholic liquid is pumped into a reservoir, from which it passes through group *I* of generators and collects in a vessel. From the latter it is pumped into a second reservoir placed on the same level with the first, and runs through group *II* of generators into another collecting vessel ; from there it is again pumped into a third reservoir, and after passing through group *III* of generators finally collects as finished vinegar in a third collecting vessel.

Though the arrangement of all the generators on the same level renders it necessary to raise the alcoholic liquid three times, it would seem more suitable than the terrace system for the following reasons : 1. By a suitable regulation of the heating apparatus the required temperature can be readily maintained in the separate groups of generators. 2. In case of a disturbance in one of the groups, the respective generator can be left out without causing an interruption in the work of the other groups. 3. The power required to pump the alcoholic liquid three times into the reservoirs  $V_1$ ,  $V_2$ , and  $V_3$  is not much greater than that which has to be used to raise it to the height of the reservoir in factories arranged according to the terrace system. 4. Notwithstanding the greater area required, the erection of a one-story factory is less expensive than that of a three-story building with complicated heating apparatus and very strong, solid floors, which are required on account of the great weight of the generators.

The uniform distribution of the alcoholic liquid into each generator is very simple in factories arranged according to the terrace system, and can be effected in the following manner :—

The false bottoms are fitted water-tight in the generators ; they are provided either with narrow holes alone, or with apertures loosely filled with cotton-wick, pack-thread, etc. The pipes ascending from the vinegar forming space, which is filled with shavings, are inserted water-tight in the false bottoms. On the reservoir containing the alcoholic liquid is a spigot which can be accurately adjusted, and is securely connected with the conduit



leading to the separate generators. At the place on the conduit where the alcoholic liquid is to be introduced into the generator is a discharge-pipe also provided with a spigot.

When the factory is to be put in operation the reservoir is first filled with alcoholic liquid, the spigots on the several generators being entirely open, but the principal spigot closed. Now, by suddenly opening the latter, the air in the conduit is expelled by the alcoholic liquid flowing in, and the latter rushes in a full stream from the spigots connecting the conduit with the generators. These spigots are then closed so far that only the quantity of alcoholic liquid required for the regular process of the formation of vinegar can enter the generators. To prevent the force of pressure from varying too much in the conduit by the lowering of the level of the fluid in the reservoir, it is recommended to give the latter only a slight height but a large bottom surface.

From the lower portion of the uppermost series of generators the alcoholic fluid then gradually reaches through a pipe the false bottoms of the next series, and from this the lowest series from which it runs off as finished vinegar into the collecting vessel.

It will readily be seen that some time for experimenting is required before a factory arranged according to this system can be brought into regular working order, it being necessary to test the fluids running off from the different groups of generators as to their contents of acetic acid in order to find out whether too much or too little or just enough alcoholic liquid reaches the generator so that the liquid running off from the lowest series contains no alcohol and may be considered as finished vinegar. Any fault in the working of the generators can in this case be overcome by a corresponding adjustment of the spigots so as to regulate the influx of alcoholic liquid.

Theoretically no more simple or convenient process for the fabrication of vinegar than the terrace system could be devised. Provided the spigots supplying the separate generators be once correctly adjusted and the temperature of the different stories suitably regulated, it is only necessary constantly to supply the reservoir with alcoholic liquid and the heating apparatus with fuel in order to carry on the work for any length of time desired.



The disadvantages connected with this system having already been explained need not be further referred to.

*Periodically working Apparatus. The Three-group System.*

In the second system of automatic generators it has been sought to imitate the ordinary working of a vinegar factory by providing the apparatus with certain mechanical appliances which allow of the distribution at certain stated intervals of any desired quantity of alcoholic liquid into the generators. The term "periodical" may be applied to this system of automatic apparatus.

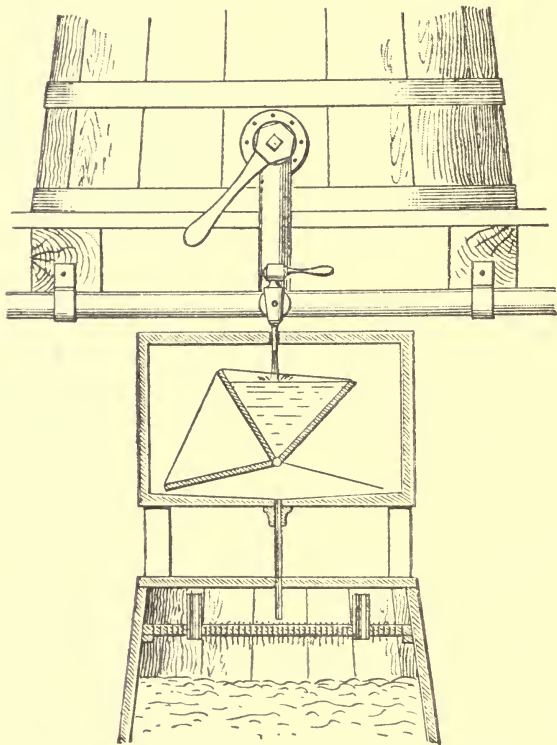
The mechanical appliances used for the purpose of admitting at certain intervals a fixed quantity of alcoholic fluid into the generator may be constructed in various ways, the tilting trough, shown in Figs. 12 and 13, p. 62, being an example. By a modification of the apparatus, as shown in Fig. 26, any desired quantity of fluid can with its assistance be at certain intervals admitted to the generator. The fluid may be either poured out upon the false bottom, or, what is more suitable for its better distribution, used for feeding a sparger.

As seen from the illustration a prismatic box, whose bottom is formed of two slightly inclined surfaces, stands at a suitable height over each generator. In the box a tilting trough is placed so that its axis of revolution runs parallel with the line formed by the two bottom surfaces of the box. On the point of contact of the two surfaces a pipe is inserted which extends to the false bottom or the funnel of the sparger. Above the box is a spigot connected by a conduit with a reservoir for the alcoholic fluid placed at a higher level. This reservoir serves for supplying a large number of generators, and can be shut off by a carefully adjusted spigot. From the latter a vertical pipe leads to the conduit running in a horizontal direction over the generators. The conduit is provided with small spigots which discharge the fluid into the tilting troughs.

By giving each tilting trough such a size that, for instance, each partition holds 5 quarts, and adjusting the spigot so that 30 minutes are required for filling one partition, the trough will, at

the expiration of this time, tilt over and empty the fluid upon the inclined surfaces; from here it runs into the sparger and

Fig. 26.



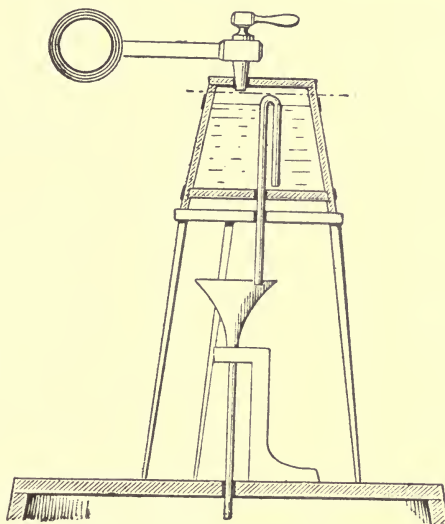
Modification of the Tilting-Trough.

setting the latter in motion is poured in the form of a fine spray over the shavings. Since the other partition of the tilting trough has the same capacity as the first and the quantity of alcoholic fluid remains the same, the trough will, after the expiration of 30 minutes, again tilt over, and again empty 5 quarts of fluid, this being continued as long as the reservoir contains any fluid.

In place of the tilting trough the so-called "siphon-barrel" (Fig. 27) may be used for effecting the discharge of a certain quantity of fluid at a stated interval. In a spherical vessel placed at a higher level than the edge of the funnel of the sparger is a

siphon, the longer leg of which passes through the bottom of the vessel and enters the funnel. On the edge of the vessel is a spigot which is connected with the fluid-conduit and so adjusted that within a previously determined space of time the vessel is filled with fluid up to the height indicated by the dotted line. As soon as the fluid reaches that height, the action of the siphon

Fig. 27.



Siphon-barrel.

commences and the content of the vessel runs through the longer leg into the funnel of the sparger until its level is sunk to the edge of the shorter leg. The action of the siphon then ceases until the vessel is again filled up to the line when it recommences and so on.

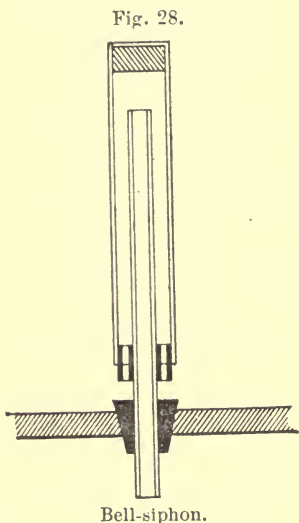
The siphon of bent glass tubes being very liable to breakage, it is frequently replaced by the so-called bell-siphon the arrangement of which is shown in Fig. 28. It consists of a glass tube which forms the longer leg, of the siphon while a glass cylinder secured to this tube by means of a perforated cork represents the other leg. The action of this siphon is the same as the other.

In working with automatic apparatus fixed quantities of fluid being at stated intervals introduced, provision for the reception of

the fluid must be made in the apparatus itself, or for its being conducted to a special reservoir at the rate at which it trickles from the shavings. In the first case the space beneath the lath-bottom must be of sufficient size to receive the fluid passed through

the apparatus in a certain time. This time being suitably fixed for 12 hours the apparatus can during this time work without further assistance, so that the required space beneath the lath-bottom can be calculated by multiplying the number of affusions with the quantity of fluid poured in at one time.

Example:—The generator receives at intervals of 30 minutes an affusion of 5 quarts, hence in 12 hours 24 affusions of 5 quarts each = 120 quarts. The space beneath the lath-bottom must, therefore, be of sufficient capacity to receive up to the height of the draught-holes at least 120 quarts of fluid.



As will be seen from the following general description of a vinegar factory arranged according to the automatic principle, it is decidedly preferable to arrange the generators so that the fluid trickling from the shavings is at once conducted to a collecting vessel.

#### *Arrangement of a Vinegar Factory working according to the Automatic Principle.*

As previously stated, it is not possible to convert all the alcohol contained in the liquid into acetic acid by one affusion; only a portion of the alcohol is converted and this semi-product is brought into a second generator, and, if the liquid used is very rich in alcohol, into a third. In the second apparatus another portion of the alcohol is converted into acetic acid and the process finished in the third.

It being in all cases advisable to prepare vinegar with a high percentage of acetic acid most manufacturers now pass the alcoholic liquid successively through three generators. In practice it is recommended to place the generators which are to receive alcoholic liquid of the same content of acetic acid alongside each other, which leads naturally to the division of the generators into three groups. If, for instance, a factory contains 48 generators, each group contains 16 ; group I is charged with freshly prepared alcoholic liquid ; the generators of group II contain the alcoholic liquid which has already passed through those of group I, and group III is charged with the fluid yielded by group II.

Besides the easy control of the work, this arrangement into groups has another advantage. The generators in which the last remnants of the alcohol of a quite strong fluid are to be converted into acetic acid are best kept at a somewhat higher temperature, and with a suitably arranged heating apparatus and the eventual use of curtains by which the workroom can be divided at will into two or three partitions, it can be readily arranged to convey somewhat more heat to the second group of generators and the greatest quantity to the third.

The height of the actual workroom of the factory should not be greater than required by that of the generators. The reservoir is placed under the roof of the workroom, while the collecting vessels are either sunk in the floor or placed in the cellar.

Below is given a description of a periodically working establishment with 24 generators. The generators are arranged in three groups, I, II, and III, the following articles belonging to each group :—

8 generators ;

1 reservoir ;

1 collecting vessel ;

8 apparatuses for the distribution of the alcoholic liquid into the generators ;

Conduits for the alcoholic liquid to be poured in ;

Conduits for the alcoholic liquid running off.

For the three groups in common :—

A pump to convey the alcoholic liquid from the collecting vessels to the reservoirs.

A channel for the conveyance of the warm air from the heating apparatus in the cellar to and distribution in the workroom.

An apparatus for heating the alcoholic liquid.

The three reservoirs rest upon the joists of the ceiling of the workroom, a small chamber inclosing them being constructed of papered boards. In the floor of these chambers is a manhole by which the reservoirs can be reached. This manhole should *not* be provided with a door, it being of importance that the reservoirs should be constantly surrounded by warm air which ascends through the manhole. To prevent loss by evaporation the reservoirs should be provided with well-fitting covers.

To retain solid bodies such as shavings, flakes of mother of vinegar, etc., which might eventually obstruct the fine apertures in the false bottom or sparger, a filter is placed on the end of the pipe through which the alcoholic liquid passes into the reservoirs. A suitable filter for the purpose is a horse-hair sieve containing a linen bag, the latter being from time to time replaced by a new one.

The conduits for the conveyance of the alcoholic liquid to the distributing vessels and from there to the generators are best constructed of thick glass tubes, the connection of two pieces being effected by pieces of rubber hose pushed over the ends and secured with twine.

Each generator may be furnished with a vessel containing the automatic arrangement, it being, however, in this case necessary to provide for each a special conduit from the reservoir, which for a factory containing a large number of generators is rather expensive. Hence it is recommended to use for each group only one or at the utmost two distributing vessels, and from them to extend smaller conduits to the separate generators. Each of the principal conduits is provided, at the place where it enters the distributing vessel, with a cock, which is adjusted for the discharge of a certain quantity of alcoholic liquid. If, as above mentioned, every generator is to receive an affusion of 5 quarts of alcoholic liquid every 30 minutes, the distributing vessel serving for a group of 8 generators must have a capacity of 40 quarts, and the spigot has to be so adjusted that exactly this quantity passes through it in 30 minutes.



The discharge-pipe of the automatic arrangement must enter a space, in which are inserted eight pipes having the same diameter, which conduct the alcoholic liquid to the separate generators. By this arrangement all the generators receive simultaneously an affusion of an equal quantity of fluid, which either sets the sparger in motion or gradually trickles through the apertures in the false bottom. The alcoholic liquid which has passed through the generators collects either in the space under the lath-bottom or runs directly through conduits to the collecting vessels.

The conduits placed before the discharge apertures of the generators are intended to conduct the alcoholic liquid to the reservoirs, and there being no pressure of fluid in them they might be merely of open gutters. For the sake of cleanliness and to avoid losses by evaporation it is, however, advisable to use glass tubes for the purpose. At the places where the discharge-pipes of the generators are located, the connection of two glass tubes is effected by a wooden joint with an aperture on top in which is placed a glass funnel. For collecting vessels for the alcoholic fluid running off from the generators of one group, vats provided with lids are used. They have to be placed so low that some fall can be given to the conduits, and in each of them is a pipe provided with a spigot, which serves as a suction-pipe for the pump intended to raise the alcoholic fluid.

The manner of working in a factory thus arranged is as follows :\* The collecting vessel  $S_I$  serves for the preparation of the alcoholic liquid, which is then pumped into the reservoir  $V_I$ , from whence it runs through the first group of generators,  $E_I$ , to the collecting vessel  $S_{II}$ . From this it is pumped into  $V_{II}$ , and runs through the second group of generators,  $E_{II}$ , into the collecting vessel  $S_{III}$ . On being pumped up the third time it runs from the reservoir  $V_{III}$  through the third group of generators,  $E_{III}$ , and passes as finished vinegar either into a fourth collecting vessel or is at once conducted into storing barrels.

The distance the alcoholic liquid has to be raised from the bottom of the collecting vessels to the reservoir amounting to not

\* To avoid repetition the collecting vessels are designated :  $S_I$ ,  $S_{II}$ , and  $S_{III}$  ; the reservoirs  $V_I$ ,  $V_{II}$ , and  $V_{III}$  ; the groups of generators  $E_I$ ,  $E_{II}$ ,  $E_{III}$ .

more than from 23 to 25 feet, an ordinary suction-pump may be used for the purpose, though a forcing-pump is better, it doing the work more rapidly. The pump must be constructed of material entirely indifferent to acetic acid (wood, glass, hard rubber, tin, or a strongly silvered metal).

Any metallic vessels used in the factory should be of *pure tin*, *i. e.*, unalloyed with other metals, it being the only metal entirely indifferent towards acetic acid, but unfortunately it is too soft to be suitable for the construction of pumps.

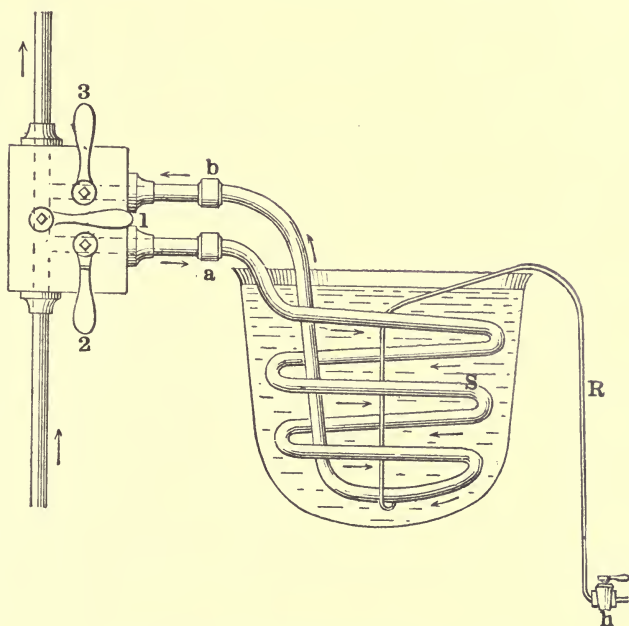
The pump is generally located in the immediate neighborhood of the collecting vessels, its suction-pipe being divided into three branches and fastened into the latter. If one of the collecting vessels is to be emptied, the respective spigot is opened and the spigots of the other suction-pipes closed.

Ordinary well or river water being used in the preparation of the alcoholic liquid, the temperature of the latter does not generally exceed  $54^{\circ}$  F., and if it were thus introduced into the generators acetification would be very sluggish until the temperature rose above  $68^{\circ}$  F. Independently of the loss of time, there would be the further danger of injuring the development of the vinegar ferment; hence it is necessary to heat the alcoholic liquid to the temperature required. This is best effected by passing it through a coil surrounded by hot water. Fig. 29 shows an apparatus especially adapted for heating the alcoholic liquid. In a copper or iron boiler filled with water, which can be heated from below, is a coil, *S*, of pure tin; it enters the boiler above at *a* and leaves it at *b*, so that the place of influx is at the same level with that of discharge. With this form of construction the coil of course remains always filled with liquid, which with the use of pure tin is, however, of no consequence; besides, this can be remedied by placing on the lowest coil a narrow pipe, *R*, which projects above the edge of the boiler and is bent like a siphon. By opening the spigot *h* the fluid contained in the coil runs off through *R*.

The rising pipe of the forcing-pump is provided with an arrangement by which the alcoholic liquid can be brought either directly from the collecting vessels into the reservoirs or first forced through the heating apparatus. It consists of a prismatic wooden body provided with three spigots. By closing spigots 2

and 3 and opening 1, the alcoholic liquid is immediately conveyed from the collecting vessel to the reservoir. By closing spigot 1 and opening 2 and 3, which are connected by short pieces of rubber hose with the ends of the coil *S*, the alcoholic liquid forced upward from the collecting vessels by the pump must pass through the heating coil, and after being heated it returns to the

Fig. 29.



Apparatus for heating the Alcoholic Liquid.

rising pipe which conveys it to the reservoirs. The arrows in the illustration indicate the course the alcoholic liquid has to traverse when spigots 2 and 3 are open and 1 closed.

The diameter and length of the tin coil depend on the quantity of fluid which is to pass through it, though one with a clear diameter of 12 to 14 inches and a length of 23 to 26 feet will, as a rule, suffice; besides by slower or quicker pumping the fluid can be forced with less or greater velocity through the coil and correspondingly more or less heated. The walls of the coil should be as thin as possible so as to yield heat rapidly.

The heating of the alcoholic liquid, of course, can also be effected by heating one portion more strongly than necessary and reducing it to the required temperature by mixing with cold fluid. In working, however, with a fluid containing living vinegar ferment—and such, as will be explained later on, is claimed to be already contained in freshly prepared alcoholic fluid—care must be had not to heat the fluid above 120° F., this temperature being destructive to the ferment.

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## CHAPTER X.

### OPERATIONS IN A VINEGAR FACTORY.

#### *Acidulation of the Generators.*

THE object of acidulation is to completely saturate the filling of the generators with vinegar and to cause the development of the vinegar ferment upon the filling material, shavings, charcoal, etc. The generators are first filled with shavings, wooden blocks, pieces of charcoal, etc.; the false bottoms or spargers are next placed in position and the temperature of the workroom brought close up to 86° F. Acidulation, *i. e.*, saturating the shavings with alcoholic liquid, is then commenced, vinegar of the same strength, *i. e.*, with the same content of acetic acid, as that which is to be manufactured in the generators being used for the purpose. Every cubic meter (35.31 cubic feet) of the space filled with shavings or charcoal requires for complete acidulation the following quantities of vinegar :—

Shavings loosely poured in	230 to 270 liters ( 60.75 to 71.31 gallons).
Shavings piled up alongside	
each other . . . . .	340 to 400 “ ( 89.8 to 105.65 “
Charcoal the size of a walnut	540 to 800 “ (142.6 to 211.3 “

The value of this vinegar used for acidulation has to be considered as *dead capital*.

The first vinegar running off from the generators is not only considerably weaker than that used for acidulation, but, notwithstanding the previous lixiviation of the wood, has a disagreeable

taste so as to render it unfit for the preparation of table vinegar, and can only be utilized, for instance, in the preparation of acetate of lead, etc. When the vinegar running off has acquired a pure taste, it is collected by itself and later converted into a stronger product by mixing it with alcohol and passing again through the generators. By this saturation of the shavings with vinegar, the vinegar ferment locates in abundance upon the surface of the shavings and the generators are fit for the formation of vinegar.

The regular fabrication can, however, be commenced only gradually, as may be illustrated by the following example: At first, for instance, alcoholic liquid is introduced only once a day, either early in the morning or in the evening. In about eight days, or under certain conditions even later, the temperature in the interior has risen to from  $86^{\circ}$  to  $95^{\circ}$  F., and alcoholic liquid may now be introduced twice daily, for instance, early in the morning and in the afternoon. That the generator works, is recognized by the increased temperature and by the flame of a candle held near a draught-hole being drawn inwards. After 8 to 14 days more the thermometer shows  $96^{\circ}$  to  $98^{\circ}$  F., and then alcoholic liquid is introduced three times daily, for instance, early in the morning, in the forenoon, and in the afternoon, whereby the temperature rises to  $102^{\circ}$  to  $104^{\circ}$  F. If now the vinegar running off shows the intended strength, the generators are in good working order and subjected to the regular treatment.

#### *Accelerated Acidulation.*

By closely considering the processes which must take place in acidification and the first stage of the operation, it will be plainly seen that the above-described method cannot be called a rational one, there being a waste of time as well as of material and the commencement of regular working being largely dependent on accident.

The object of acidulation is, as previously stated, first to thoroughly saturate the shavings with vinegar and next to develop the vinegar ferment upon them. This can, however, be attained in a more suitable and a quicker manner than by the above process.





Air-dried wood contains on an average 20 per cent. of water and during acidulation this water must be gradually replaced by vinegar; hence the vinegar trickling from the generators will remain poor in acetic acid and rich in water until the shavings are entirely saturated with pure vinegar and the water is expelled.

The removal of the water from the shavings and its substitution by vinegar are effected by osmose, *i. e.*, the cells of the wood surrounded by vinegar yield a fluid consisting of water and extractive substances of the wood and absorb sufficient of the exterior fluid until both liquids have the same composition. Now, by pouring only a small quantity of vinegar at one time over the shavings in the generators, as is done in the acidulation according to the old method, the course of the process is very slow, 14 days or more, as already mentioned, being required before the vinegar running off shows no longer a change in its concentration.

In a generator in a stage of acidulation an uninterrupted though slight current of air upwards takes place, since even with the use of the best heating apparatus the air in the upper layers is warmer than in the lower. This current of air becomes stronger with the development of larger quantities of vinegar ferment and causes a large absolute loss of vinegar; the greater portion of this loss must be set down as being due to evaporation, which must be considerable on account of the great surface over which the vinegar is distributed, and the smaller portion to consumption by the vinegar ferment.

By placing the shavings in vinegar the above-described process of substitution of vinegar for the fluid contained in the cells of the wood takes place very quickly, and, theoretically, it would therefore seem to be advisable to follow the same course on a large scale, *i. e.*, to saturate the shavings with vinegar before placing them in the generators. By using artificially dried shavings (see p. 67) the saturation is effected in the course of a few hours, the dry woody tissue absorbing the fluid like a sponge.

The shavings, while still hot, are brought into a vat and covered with the vinegar to be used for acidulation. In about 12 hours they are thoroughly saturated; the excess of vinegar is drawn off through the tap-hole in the bottom of the vat, and having absorbed neither water nor extractive substances from the steamed



and thoroughly dried shavings can be immediately re-used for the saturation of another portion of shavings. The saturated shavings are at once used for filling a generator, and the latter, which may now be considered as completely acidulated, can at once be used for the process of the formation of vinegar according to the method described below.

Instead of in a vat the shavings can also be saturated directly in the generator. For this purpose the shavings, after having been artificially dried, are immediately brought into the generator, and vinegar is poured over them either by means of the false bottom or the sparger until a considerable quantity has accumulated in the space below the lath-bottom. This accumulation is then drawn off and again poured over the shavings, this being continued until they are thoroughly saturated, which is effected in a comparatively short time.

*Induction of the Operation with artificially raised Vinegar  
Ferment.*

In the accelerated acidulation of the generators no development of vinegar ferment can of course take place, since by heating the shavings to about 212° F. any fermenting organisms accidentally adhering to them are destroyed. The vinegar ferment increases with astonishing rapidity provided it finds nourishment suitable for its development. Vinegar is, however, a very poor material for this purpose, and this is very likely the reason why weeks are required before fabrication can be commenced in generators acidulated according to the old method. The ferment can, however, be so rapidly augmented in the generators that fabrication can be commenced almost immediately after acidulation is complete.

For this purpose a method similar to that employed in the manufacture of alcohol and yeast has to be pursued and vigorous ferment obtained by cultivation. As previously mentioned the ferment causing acetous fermentation is widely distributed throughout nature and is most abundantly found in the air of thickly populated regions.

The "pure cultivation" of the vinegar ferment, *i. e.*, in which

no other than the desired ferment is developed, is not difficult, it being only necessary to prepare a fluid especially adapted for its nourishment and allow it to stand at a suitable temperature in order to obtain in a few days a vigorous growth produced by a few individual germs reaching the fluid from the air. The best fluid for the purpose is one which contains, besides a large quantity of water, about 85 to 90 per cent., a certain amount of alcohol and acetic acid and very small quantities of nitrogenous substances and mineral salts. Hence its preparation is not difficult, it being only necessary to mix ordinary vinegar and alcohol in suitable proportions and add a small quantity of a fluid containing nitrogenous substances and mineral salts, such as wine, cider, beer or malt extract. Numerous experiments have shown that a fluid containing from 4 to 6 per cent. of acetic acid and the same quantity of alcohol with the addition of a small quantity of one of the above-mentioned fluids is best adapted for the vigorous nourishment of the vinegar ferment. Ordinary table vinegar contains as a rule from 4 to 6 per cent. of acetic acid; the average percentage of alcohol is in wine from 8 to 10; in cider from 4 to 6; and in beer from 3 to 5. Taking this statement as a guide, the preparation of a fluid containing from 4 to 6 per cent. of acetic acid, 4 to 6 per cent. of alcohol, and the required nitrogenous combinations and salts will not be difficult.

Fluids of this composition are obtained by mixing, for instance, equal parts of cider and vinegar, or one part of wine with two of vinegar, or one part of beer with three of vinegar, and adding 5 per cent. of 90 per cent. alcohol to the mixture. Such mixtures possessing the power of vigorously nourishing the vinegar ferment can at the same time be considered as types for the preparation of alcoholic liquid of suitable composition.

To assure the exclusive development of vinegar ferment upon any of the above-mentioned mixtures it is best to heat it to the boiling point of water. Young wine as well as cider contains considerable quantities of albuminous substances in solution, and fluids of this nature being well adapted for the nourishment of the mold ferment, the development of the latter might increase to such an extent as entirely to suppress the vinegar ferment and thus render its cultivation a failure. Beer is also very suitable

for the nourishment of the mold ferment, though in a less degree than young wine, and besides living yeast contains alcoholic ferment.

By heating wine or beer only for a moment to about  $158^{\circ}$  F., a large portion of the albuminous substances in solution becomes insoluble, and on cooling separates as a flaky precipitate, all ferments present in the fluid being at the same time destroyed. Hence for the preparation of a fluid especially adapted for the cultivation of pure vinegar ferment, it is recommended quickly to heat to the boiling point 1 quart of ordinary white wine in a covered porcelain vessel, and, after cooling to the ordinary temperature, to mix it with 2 quarts of vinegar. To remove the separated insoluble albuminous substances it is filtered through blotting paper.

To prepare a nourishing fluid from beer, heat 1 quart to the boiling point, mix it after cooling with 3 quarts of vinegar, add  $\frac{1}{5}$  quart of 90 per cent. alcohol, and filter.

Distribute this fluid in a number of shallow porcelain vessels and place the latter near a window in the heated workroom. To prevent dust from falling into the fluid cover each dish with a glass plate resting upon two small wooden sticks placed across the dish. In two or three days, and sometimes in 24 hours, the commencement of the development of the vinegar ferment will be recognized by the stronger odor of vinegar than that possessed by the original fluid and by the appearance of the surface of the liquid. By observing the latter at a very acute angle, dull patches resembling grease stains and consisting of a large number of individuals of the vinegar ferment will be seen. In a few hours these patches have increased considerably, until finally the entire surface appears covered by a very delicate veil-like layer of vinegar ferment.

By touching the surface with the point of a glass rod a certain amount of the coating adheres to it, and by rinsing it off in a fluid of similar composition not yet inoculated the ferment quickly develops upon it. By placing a drop of the fluid under the microscope a picture similar to that shown in Fig. 2, p. 29, presents itself: the entire field of vision is covered with germs of vinegar ferment.

By the development of mold ferment the cultivation of pure vinegar ferment may sometimes result in failure even with the use of the above-mentioned fluids. The development of this ferment is recognized by the appearance of white dots upon the fluid, which quickly increase to white opaque flakes, and if left to themselves finally combine to a white skin of a peculiar wrinkled appearance. Fig. 30 shows a microscopical picture

Fig. 30.

Abortive Cultivation of Vinegar Ferment.  $\times 500$ .

of such abortive cultivation of vinegar ferment. By observing at the commencement of this phenomenon the fluid with the microscope, very small individuals of vinegar ferment, *b*, will be observed alongside of the much larger oval cells *a*, of the mold ferment. Such fluid being not adapted for our purposes has to be removed and the dish rinsed off with boiling water.

When the fluid in the dishes is entirely covered with pure vinegar ferment, it is poured into a vessel containing the greater portion of the alcoholic fluid intended for the first charge of the generators, and in the course of 10 hours the entire surface of this fluid is covered with vinegar ferment. This fluid being poured into the sufficiently acidulated generators and trickling

gradually through them, the greater portion of the ferment adheres to the shavings, and increases with such rapidity that the strong rise of temperature in the interior of the generators shortly indicates the regular beginning of their activity, and the effusion of alcoholic liquid can be commenced at once.

Vinegar ferment developed upon one of the above-mentioned fluids is evidently so constituted that it can be thoroughly nourished by it, and hence the generators might be continued to be charged with alcoholic liquid of a corresponding composition. It being, however, as a rule, desired to manufacture as strong a product as possible, an alcoholic liquid much richer in alcohol than the above-mentioned nourishing fluids has to be used.

By, however, suddenly changing the nourishing fluid of the vinegar ferment, for instance, from a fluid containing only 4 to 6 per cent. of alcohol to one with 12 to 13 per cent., the action of the ferment would very likely be sluggish before it became accustomed to the new conditions. Further, its activity might suffer serious disturbance and its augmentation decrease very sensibly, so that notwithstanding strong heating of the workroom and thorough ventilation of the generators, the temperature in the latter would suddenly fall, and would only be restored to the required degree after the ferment had become accustomed to the new conditions and recommenced its vigorous augmentation.

To overcome such annoying disturbances it is only necessary to gradually change the composition of the nourishing fluid to that which the alcoholic liquid to be worked in the generators is to have. Commencing, for instance, with an alcoholic liquid containing 5 per cent. of alcohol, the next day one with 6 per cent. is used, the succeeding day one with 7 per cent., and so on until the maximum percentage of alcohol the liquid is to have is reached.

## CHAPTER XI.

## PREPARATION OF THE ALCOHOLIC LIQUID.

UNDER the term "alcoholic liquid" is to be understood every fluid to be converted into vinegar which, besides water and small quantities of nourishing salts and albuminous substances, does not contain over 14 per cent. of alcohol. In the directions generally given for the preparation of such liquids vinegar is mentioned as an indispensable constituent. While it cannot be denied that a content of vinegar in the alcoholic liquid exerts a favorable effect upon the formation of vinegar, it must be explicitly stated that it is not the acetic acid in the vinegar, which in this case becomes active, but the ferment contained in it.

In a vinegar factory vinegar just finished and entirely turbid is always used for the preparation of alcoholic liquid, and a microscopical examination shows such vinegar to contain innumerable germs of vinegar ferment. This ferment on coming in contact with much air in the generators will evidently increase rapidly and contribute to the quick acetification of the alcohol. That it is actually the ferment in the vinegar used which exerts a favorable effect can be shown by a simple experiment. By adding vinegar previously heated to from 140° to 158° F. to the alcoholic liquid the formation of vinegar in the generators proceeds more slowly, the ferment contained in the vinegar having been killed.

The best proof, however, that the alcoholic liquid does not require any considerable quantity of acetic acid for its conversion into vinegar is furnished by the behavior of wine. Correctly prepared wine of a normal composition contains only a few ten thousands of its weight of acetic acid, and this must very likely be considered as a product of vinous fermentation. If such wine be stored for years in a cool cellar, its content of acetic acid does not change. By, however, exposing such wine in a shallow



vessel to the air at from  $66^{\circ}$  to  $78^{\circ}$  F., microscopical examination will show the development of vinegar ferment upon it and a chemical analysis a constant increase, soon amounting to several per cent. of acetic acid. A fluid composed of 5 to 6 per cent. of alcohol, 94 to 95 per cent. of water, and a very small quantity of malt extract acts in a similar manner. In many cases the vinegar ferment is developed without the fluid containing acetic acid.

The alcoholic fluid to be used may from the start contain a sufficiently large percentage of alcohol to correspond to the desired strength of the vinegar to be made; in this case the fluid has to be poured several times into the generators, it being impossible to convert a large quantity of alcohol into acetic acid by passing it through but once. By another method an alcoholic liquid is first prepared containing but little alcohol, which is almost completely converted into acetic acid by one passage through the generators. The fluid running off from the generators is then further mixed with a certain quantity of alcohol and being poured into a generator, in which the vinegar ferment is already accustomed to larger quantities of alcohol and vinegar, is also converted into acetic acid. More alcohol can then be added, and so on. The last method is evidently the best as regards the conditions of life of the vinegar ferment, and actually the only one by which the strongest vinegar (with from 12 to 13 per cent. of acetic acid) can be obtained in generators.

That it is advisable only gradually to increase the content of alcohol in the alcoholic liquid is shown by the behavior of the ferment towards alcohol and acetic acid. Both bodies, if present in large quantities, are decidedly inimical to the augmentation of the ferment, a fluid containing from 14 to 15 per cent. of alcohol, or as much acetic acid, being capable of checking the augmentation of the ferment to such an extent as to disturb the process of fabrication.

Another argument against the use of the total quantity of alcohol in the preparation of the alcoholic liquid to be employed for the first effusion, is the fact that evidently more alcohol will be lost by evaporation than by commencing with a fluid containing less alcohol, and adding a corresponding quantity of the latter after the fluid has once passed through the generators.

The quantity of alcohol for the first effusion should be so chosen that the fluid running off still contains a small quantity of unchanged alcohol, this being an assurance that only alcohol and not unfinished acetic acid has undergone an alteration. As long as alcohol is present in the alcoholic liquid the vinegar ferment is almost entirely indifferent towards acetic acid, but after the oxidation of all the alcohol it attacks the acetic acid and decomposes it to carbonic acid and water. This can be shown by a very simple experiment. If finished vinegar, instead of alcoholic liquid, be poured into a generator in full operation, the vinegar running off shows a smaller percentage of acetic acid than that poured in, the acetic acid wanting having been destroyed by the ferment.

To what an extent even smaller quantities than 14 to 15 per cent. of alcohol or acetic acid exert a restraining influence upon the augmentation and activity of the vinegar ferment can be seen in generators charged with alcoholic liquid of different strengths : those containing less concentrated liquid can in the same time form a much larger quantity of acetic acid than those in which a liquid is used which already contains certain quantities of acetic acid. Hence the greater the quantity of acetic acid already contained in the alcoholic liquid the slower the conversion of the alcohol still present into acetic acid.

It may, therefore, be laid down as a rule that the manufacturer should not strive to prepare vinegar with more than about 12 per cent. of acetic acid. Though in exceptional cases a product with 13 per cent. can be obtained, it will also be observed that the respective generators gradually yield a weaker product or that their activity suddenly ceases to such an extent as to require them to be placed out of operation.

The preparation of high-graded vinegar being undoubtedly subject to greater difficulties than that of a weaker product, the question might be raised whether the manufacture of weak vinegar only would not be the most suitable. This must be largely decided by local conditions. For a manufacturer whose custom lies in the immediate neighborhood, for instance, in a large city, the production of weak vinegar only would be advisable, but if he has to send his product a considerable distance,

the fact that the more freight has to be paid on what is of no value, the weaker the vinegar is, and that the expense of transporting a strong article is relatively less, deserves consideration. The consumer can readily prepare vinegar of any desired strength by diluting the strong product with water.

The quantity of beer required for the purpose of offering suitable nourishment to the vinegar ferment is very small, an addition of 1 per cent. to the alcoholic liquid being ample. Sour or stale beer can of course be used. The reason for the employment of larger quantities of beer in mixing the alcoholic fluids is found in the fact that the vinegar prepared from such mixtures sooner acquires a pure taste than that made from fluids containing but little beer. The addition of beer should, however, not exceed 15 per cent. of the total quantity of alcoholic liquid, as on account of the comparatively high percentage of albuminous substances and the maltose, dextrin, and extractive matters of hops it contains, a larger quantity would be injurious to the process of acetous fermentation, the generators being frequently rendered inactive by the so-called "sliming of the shavings." The production of the latter is due to the fact that by being partially excluded from contact with the air by the comparatively thick fluid passing over it, the vinegar ferment deposited upon the shavings assumes the form of mother of vinegar which adheres to the shavings as a slimy mass.

The quantity of finished vinegar added to the alcoholic liquid varies between 10 and 33 per cent. The use of large quantities is, however, decidedly inexpedient since the only effect produced by the vinegar is, as previously stated, due to the ferment contained in it. Of freshly prepared, turbid vinegar 10 per cent. is ample for the preparation of alcoholic liquid; a greater quantity can only be considered as useless ballast.

Theoretically a certain quantity of alcohol yields exactly a certain quantity of acetic acid; the following table shows the proportions between the two bodies:—

A fluid with per cent. by volume of alcohol.	Consists of kilogrammes of—		And yields—		In the whole.	
	Alcohol.	Water.	Acetic anhydride.	Water.	Vinegar.	With per cent. of acetic anhydride.
1	0.8	99.2	1.0	99.5	100.5	1.0
2	1.6	98.4	2.1	99.0	101.1	2.1
3	2.4	97.6	3.1	98.5	101.6	3.1
4	3.2	96.8	4.2	98.0	102.2	4.1
5	4.0	96.0	5.2	97.6	102.8	5.1
6	4.8	95.2	6.3	97.1	103.3	6.0
7	5.6	94.4	7.3	96.6	103.9	7.0
8	6.4	93.6	8.3	96.1	104.4	8.0
9	7.2	92.8	9.4	95.6	105.0	8.9
10	8.0	91.9	10.4	95.0	105.4	9.9
11	8.9	91.1	11.6	94.6	106.2	10.9
12	9.7	90.3	12.6	94.1	106.7	11.8

Practically less vinegar with a smaller percentage of acetic anhydride is, however, always obtained, this being due to losses of material caused partially by evaporation and partially by the oxidation of the alcohol extending beyond the formation of acetic acid. In preparing the alcoholic liquid these unavoidable losses must be taken into consideration and more alcohol be used for the production of vinegar with a determined percentage of acetic acid than is theoretically required. How much more has to be taken depends on the kind of apparatus used and on the strength the vinegar to be prepared is to show. The higher the percentage of acetic acid which is to be obtained, the greater the losses will be and consequently the greater the content of alcohol in the alcoholic liquid must be. Theoretically one per cent. of alcohol yields one per cent. of acetic acid ; practically the proportions are, however, as follows :—

For the production of vinegar with a content of acetic acid of—						Is required an alcoholic liquid with a content of alcohol of—	
5 per cent.	.	.	.	.	.	5.4 to 5.5 per cent.	
6 "	.	.	.	.	.	6.5 "	6.6 "
7 "	.	.	.	.	.	7.6 "	7.7 "
8 "	.	.	.	.	.	8.7 "	8.8 "
9 "	.	.	.	.	.	9.8 "	9.9 "
10 "	.	.	.	.	.	10.9 "	11.0 "
11 "	.	.	.	.	.	11.9 "	12.1 "
12 "	.	.	.	.	.	13.0 "	13.2 "

The strength of commercial alcohol varying considerably it is of importance to the manufacturer to be able to calculate in a simple manner how many gallons of water have to be added to alcohol of known strength in order to obtain an alcoholic liquid with the desired percentage of alcohol. The calculation is executed as follows :—

Suppose :

P = per cent. of alcohol in the spirits to be used.

E = per cent. of alcohol in the alcoholic liquid to be prepared, the quotient obtained by dividing P by E gives the volume to which the spirits have to be reduced by the addition of water in order to obtain alcoholic liquid with the desired percentage of alcohol.

Example :—

From spirits of 86 per cent. Tralles' alcoholic liquid with 11 per cent. of alcohol is to be prepared.

$$P = 86 ; E = 11 \quad \frac{P}{E} = 7.818.$$

Hence one volume of the spirits to be used has to be brought to 7.818 volumes, or to 1 gallon of spirits 6.818 gallons of water have to be added.

Examples of the composition of alcoholic liquid :—

A. Alcoholic liquid from alcohol, water, and vinegar :

*For vinegar with about 7 per cent. of acetic acid.*—Alcohol of 90 per cent. Tr. 10 parts by volume, water 107, vinegar with 7 per cent. of acetic acid 12.

*For vinegar with about 12 per cent. of acetic acid.*—Alcohol of 90 per cent. Tr. 10 parts by volume, water 65, vinegar with 12 per cent. of acetic acid 7.

It is advisable to add about 1 per cent. of the entire volume of beer to the above alcoholic liquids.

B. Alcoholic liquid from alcohol, water, vinegar, and beer.

*For vinegar with about 5 per cent. of acetic acid.*—Alcohol of 90 per cent. Tr. 10 parts by volume, water 107, vinegar with 5 per cent. of acetic acid 13, beer 14.

C. *For vinegar with about 8 per cent. of acetic acid.*—Alcohol of 90 per cent. Tr. 10 parts by volume, water 92, vinegar with 8 per cent. of acetic acid 10, beer 9.

In many factories it is customary not to determine the composition of the alcoholic liquid by calculation, but simply to work according to certain receipts. Vinegar of a certain percentage is obtained, but its strength cannot be predetermined with the same nicety as by calculating the percentage of alcohol in the alcoholic liquid by the above formula. The following may serve as examples of such receipts:—

D. Alcohol of 50 per cent. Tr. 100 quarts, water 600, vinegar 900.

E. Alcohol of 90 per cent. Tr. 100 quarts, water 1200, vinegar 300.

F. Alcohol of 90 per cent. Tr. 100 quarts, water 1350, vinegar 175, beer 175.

G. Alcohol of 90 per cent. Tr. 100 quarts, water 1400, vinegar 300, beer 100.

H. Alcohol of 80 per cent. Tr. 100 quarts, water 850, beer 750.

I. Alcohol of 50 per cent. Tr. 100 quarts, water 100, beer 100.

The mixtures A, B, and C are only given as examples of how alcoholic liquids which yield vinegar containing the desired percentage of acetic acid are prepared according to receipts. Though it may be very convenient for the manufacturer to work according to such receipts as are given under D to I, their use without a previous examination cannot be recommended. It is far better for the manufacturer to prepare the alcoholic liquid according to a receipt of his own and not shrink from the slight labor it involves; he has then at least the assurance of obtaining vinegar with exactly the percentage of acetic acid desired, and is in the position to obtain an accurate view of the entire process of the operation.

Spirits of wine being the initial point in the preparation of alcoholic liquid, it is necessary to know exactly the per cent. by weight of alcohol it contains. With the assistance of the tables at the end of this volume, the content of alcohol in spirits of wine can be readily determined by means of the alcoholometer and thermometer.

With the temperature of the spirits of wine at exactly 59° F.,



it suffices to determine its specific gravity by testing with an areometer and to find the indicated figure in Table I. (Hehner's alcohol table). The figure in the next horizontal column gives the per cent. by weight and the next the per cent. by volume of alcohol contained in the spirits of wine examined. Tables II., III., and IV. give data relating to the proportion between the specific gravity, and per cent. by weight and volume of spirits of wine of various concentration as well as the decrease in volume by mixing with water. Table V. shows the relation between the statements of Tralles's alcoholometer and a few others used in different places.

The specific gravity as well as the volume of spirits of wine varies with the temperature, and the statements of the areometer for temperatures above the normal of 59° F. require a corresponding correction, the execution of which is simplified by the use of Tables VI. and VII. It being desirable, especially during the cold season of the year, to raise the temperature of the spirits of wine by mixing with water, Table VIII. shows how much water has to be added in order to obtain from 100 liters (105.6 quarts) of spirits of wine of known strength whiskey of any desired concentration.

In order to know exactly the yield of acetic acid which is obtained from a given quantity of alcohol, the acetic acid contained in the vinegar added must necessarily be taken into account as well as the alcohol in the beer, which is of course converted into acetic acid. It is best to make the content of alcohol in the alcoholic liquid so that it produces vinegar whose strength corresponds with that of the vinegar added. If, for instance, vinegar with 7 per cent. of acetic acid is used, alcohol of 7.6 to 7.7 per cent. by weight would have to be employed according to the table on p. 108. The following compilation shows the manner of preparing alcoholic liquid according to rational principles.

Suppose vinegar with 7 per cent. acetic acid is to be prepared. There would be required—

Spirits of wine of 7.6 to 7.7 per cent. by weight	100 liters (105.6 quarts).
Vinegar with 7 per cent. of acetic acid . . . . .	10 " ( 10.56 " )
Beer . . . . .	10 " ( 10.56 " )

Suppose the beer contains, for instance, exactly 3 per cent. by weight of alcohol, hence 300 grammes (10.58 ounces) in 10 liters (10.56 quarts). According to this, a result of 120 liters (126.78 quarts) of vinegar with exactly 7 per cent. of acetic acid could not be expected, since 10 liters (10.56 quarts) of the alcoholic liquid do not contain, as should be the case, 760 to 770 grammes (26.82 to 27.18 ounces) of alcohol, but only 300 grammes (10.58 ounces). Hence actually to obtain vinegar with 7 per cent. of acetic acid a sufficient quantity of spirits of wine will have to be added to the alcoholic liquid to increase the content of alcohol by 460 to 470 grammes (16.22 to 16.57 ounces), or spirit of wine with more than 7.6 to 7.7 per cent. by weight will have to be used from the start.

It will, of course, be understood, that the data given above hold good only for the quality of the vinegar in reference to its content of acetic acid, the factor of the qualitative yield being left out of consideration. The material lost in the course of production amounts, as previously stated, to at least 15 per cent., and in determining the quality of the vinegar to be produced this circumstance has to be taken into consideration.

The content of acetic acid in vinegar can be determined with great ease and accuracy (up to  $\frac{1}{100}$  per cent.) by volumetric analysis, and from the result of such determination it can be readily seen how near the correct proportion of alcohol in the alcoholic liquid has been attained, and should the latter contain too little of it, it can be readily brought up to the determined percentage by the addition of some strong spirit of wine, or, if too much, by the addition of some water.

#### *Constitution of the Fundamental Materials used in the Preparation of Alcoholic Liquids.*

Spirits of wine, water, vinegar, and in most cases beer, constitute the fundamental materials for the preparation of alcoholic liquids.

Any kind of wholesome drinking water is suitable for the fabrication of vinegar; water containing a large amount of organic substance or living organisms or which possesses a specific

taste from the admixture of salts should not be used under any circumstances.

Many well-waters are very hard, *i. e.*, they contain a comparatively large quantity of calcium carbonate in solution. If such water be used in the preparation of alcoholic liquid, the calcium carbonate is decomposed by the acetic acid and the vinegar contains a corresponding quantity of calcium acetate in solution. Other well-waters contain a large quantity of gypsum (calcium sulphate) in solution; which salt is not changed by acetic acid, but remains partially dissolved in the finished vinegar.

When water very rich in gypsum is mixed with alcohol the fluid at first entirely clear becomes in a short time opalescent and finally perceptibly turbid. After long standing a very delicate white sediment separates on the bottom of the vessel, the fluid becoming again clear. This phenomenon is explained by the fact that gypsum while soluble in water with comparative ease is next to insoluble in a fluid containing alcohol, and hence gradually separates in the form of minute crystals.

Water containing no gypsum but much calcium carbonate shows after mixing with spirits of wine a similar behavior; it at first becomes turbid and again clear after separating a delicate white precipitate. Calcium carbonate is soluble only in water containing a corresponding quantity of carbonic acid; on standing in the air the carbonic acid escapes and the calcium carbonate separates.

This behavior of water when mixed with alcohol and standing in the air can be utilized for the almost complete separation of the gypsum and calcium carbonate. Mixtures of water and alcohol, in the proportion the alcoholic liquids are to have, are first prepared and the fluid stored in barrels in a warm apartment near the workroom. The mixtures at first turbid become clear after some time and are then drawn off from the sediment by means of a rubber hose. A comparative examination of the water and the mixtures shows that the latter contain only very small quantities of gypsum and calcium carbonate in solution.

River water, though generally soft, *i. e.*, poor in the above-mentioned salts, is seldom sufficiently clear to be used without previous filtration. It is further very likely that the small worms, known

as vinegar eels, which frequently become very annoying in vinegar factories, reach the alcoholic liquid through the use of river water, and, therefore, the use of well-water wherever possible is recommended.

The constitution of the spirits of wine used in the preparation of the alcoholic liquids is of great importance, the bouquet of the vinegar to be prepared depending on it. Commercial spirits of wine always contains certain foreign bodies known as "fusel oils;" they have a very intense odor and can only be removed by careful rectification. For the vinegar manufacturer it is of great importance to know the behavior of spirits of wine containing fusel oil when converted into acetic acid, and a number of experiments with different varieties (from potatoes, grain, wine) have shown the respective vinegar also possessed of a specific odor, differing, however, from that of the original fusel oil and developing by storing into a bouquet of a peculiar but agreeable scent. This phenomenon is explained by the fact that the energetic oxidizing process which takes place in the generators extends not only to the alcohol but also to the other bodies present, and the greater portion of the fusel oils is thereby converted into odorous combinations or compound ethers.

By treating potato fusel oil (amyl alcohol) with sulphuric acid and an acetate, amyl acetate is formed which in a diluted state smells like jargonelle pears and is used by confectioners under the name of "pear essence" for flavoring so-called fruit bonbons. The same process would seem to take place by passing spirits of wine containing potato fusel oil through the generators; the vinegar prepared from such spirits of wine shows an agreeable scent immediately when running off from the generators, while vinegar prepared from entirely pure spirits of wine has at first a stupefying smell and acquires a harmonious odor only by long storing.

It would, therefore, be advisable for the manufacturer who works with potato alcohol not to use the highly rectified product, but a mixture of it and of crude spirits containing fusel oil, the vinegar prepared from such a mixture acquiring a more agreeable odor than that obtained from the rectified product. How much of the crude spirits has to be used can only be determined

by experience, but, as a rule, only enough should be taken to assure the conversion of the entire quantity of amyl alcohol present.

The fusel oil contained in spirits of wine from grain consists largely of a mixture of fatty acids and offers far greater resistance to oxidation in the generators than amyl alcohol. The same may be said of cœnanthic ether, the fusel oil of brandy. In working with alcoholic liquid prepared with a large quantity of grain spirits containing fusel oil, the smell of unchanged fusel oil is perceptible in the vinegar besides the odors of the products of its decomposition. With the use of small quantities of grain spirits containing fusel oil, vinegar possessing a more agreeable odor than that from entirely pure spirits is obtained.

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## CHAPTER XII.

### EXECUTION OF THE WORK IN A VINEGAR FACTORY.

THE factory being once in a proper state of working, the further execution of the operation is very simple; a previously determined quantity of alcoholic liquid is at stated intervals admitted to the generators and the vinegar running off collected. With the operation running a normal course, attention has only to be paid to the maintenance of the correct temperature in the workroom and in the generators; the chemical process runs its regular course without further assistance. In many cases, however, deviations from the regular order occur. They are due to external influences, such as changes in the temperature in the interior of the generators, variations in the composition of the alcoholic liquid, etc., and will be discussed in a special chapter.

The capacity of a factory depends on the number of generators in operation. A regularly working generator is supposed to be capable of daily converting 3 liters (3.16 quarts) of absolute alcohol, and this quantity will be taken as the basis for calculating the execution of the operation. If, for instance, vinegar with 8 per cent. of acetic acid is to be manufactured, alcohol of 8.8 per cent. by weight has to be used, and to prepare this, 3 liters (3.16



quarts) of 100 per cent. alcohol have to be reduced with water, so that, according to Table I., the fluid shows a specific gravity of 0.9858 at 59° F. According to Table III., 8.98 liters (9.48 quarts) of water have to be added to every liter (1.05 quart) of 100 per cent. alcohol to obtain spirits of wine of 8.8 per cent. by weight; hence 3 liters (3.16 quarts) have to be compounded with 26.94 liters (28.46 quarts) of water (according to Table III., alcohol with 90 per cent. by volume of alcohol contains 11.80 per cent. by volume of water, 80 per cent. alcohol 22.83, etc., which has to be taken into consideration in making the dilution).

According to Table III., the contraction in this case amounts to 0.799 part by volume for every 100 parts by volume of the fluid. Hence the 3 liters (3.16 quarts) of 100 per cent. alcohol yield, when diluted to spirits of wine of 8.8 per cent. by weight,  $26.94 + 3 = 29.94$  liters (31.62 quarts) of fluid. Actually the quantity is somewhat smaller, as in mixing alcohol with water a decrease in volume takes place. If the alcoholic liquid is to contain 10 per cent. each of vinegar and beer, the quantity of fluid is as follows:—

Dilute spirits of wine	. . . . .	29.94 liters (31.62 quarts)
Vinegar with 8 per cent. acetic acid		2.994 " ( 3.162 " )
Beer	. . . . .	2.994 " ( 3.162 " )
		<hr/>
		35.928 " (37.944 " )

Hence the quantity to be worked in a generator in the course of a day amounts to 35.928 liters (37.944 quarts), or taking into account the alcohol (about 90 grammes or 3.17 ozs.) contained in the beer, to about 36 liters (38 quarts). And this quantity has in a corresponding manner to be divided among the separate affusions, so that in a working time of 15 hours an affusion of 2.4 liters (2.53 quarts) would have to be made every hour. However, by this method, too much alcohol would be lost by evaporation, on the one hand, and, on the other, the generators would work comparatively slowly, since it is well known that the conversion into acetic acid is effected with greater rapidity when the alcoholic liquid contains less alcohol. Hence it is recommended to use in the commencement a fluid which contains only about one-half or two-thirds of the total quantity of alcohol and to add a corre-



sponding quantity of strong spirits of wine to every fresh affusion.

As soon as all the alcohol is converted into acetic acid, the vinegar ferment, as previously mentioned, commences with great energy to oxidize the latter to carbonic acid and water, and hence the amount of spirits of wine added to the alcoholic liquid must be so large that the *vinegar running off* always contains a minute quantity of it.

Much has been written about this gradual strengthening of the alcoholic liquid with alcohol, and explicit directions are given as to the original composition of the alcoholic liquid as well as to how much, how often, and when the alcohol is to be added. These directions may have proved useful in many cases, but local conditions exert too great an influence upon the process of fabrication for them to be of general value. Besides the content of alcohol in the alcoholic liquid, the size of the generators, the strength of the draught in them, the temperature prevailing in the workroom and in the interior of the generators, are factors which must be taken into consideration in determining on a plan of operation actually adapted to existing conditions.

The size of the generators is, of course, fixed once for all; in a proper state of working the strength of the current of air must be so regulated that the temperature in the interior of the generators is *only about 45° F. higher than that of the workroom*, which is readily accomplished with a suitable central heating apparatus. There still remains the determination of the most favorable proportion of the content of alcohol in the alcoholic liquid to be first used and its gradual strengthening by the addition of spirits of wine, which can only be effected by a chemical examination of the fluid running off from the generators.

This chemical examination is restricted to the accurate determination of the quantity of acetic acid in the fluid and to that of the alcohol to 0.1 per cent. The determination of the acetic acid is effected by volumetric analysis, and with some experience requires four to five minutes for its execution; for the determination of the alcohol an examination with the ebullioscope suffices, which can also be accomplished in four to five minutes.\* These

\* The manner of executing these determinations will be described later on.

two determinations, which every vinegar manufacturer should be able to make, are the only means of obtaining an accurate control of the working of the factory, and also serve, of course, for settling the exact plan of operation from the start.

If, with reference to the example given above, vinegar with 8 per cent. of acetic acid is to be prepared, the alcoholic liquid must contain a total of 8.8 per cent. by weight of alcohol. Now if the fabrication is commenced with an alcoholic liquid containing the total quantity of water, vinegar, and beer, but, for instance, only 5 per cent. by weight of alcohol, the following method will have to be pursued in order to accurately determine when and how much alcohol has to be added.

The first portion of the alcoholic liquid being poured into the generator, the fluid running off is tested as to its content of acetic acid and alcohol, the test being repeated after the second and each successive pouring. Each test must show an increase in the content of acetic acid and a decrease in that of alcohol, and the latter must finally have diminished so far that a new addition of alcohol seems to be in order. If the test after the third pouring shows the fluid to contain only 0.3 to 0.4 per cent. of alcohol, this quantity would be quickly and completely oxidized in the fourth pouring, and a certain quantity of acetic acid be at the same time destroyed. Hence it is necessary to add, for instance, 2 per cent. by weight of alcohol to the alcoholic liquid before the fourth pouring. When this  $2 + 0.3$  or  $2 + 0.4$  per cent. of alcohol, which the alcoholic liquid now contains, is again reduced after the sixth or seventh pouring to 0.3 or 0.4 per cent., the last addition of 1.8 per cent. of alcohol is made, the total quantity of alcohol,  $5 + 2 + 1.8 = 8.8$  per cent. having now been used.

When, after a certain number of pourings, a test of the fluid running off shows a content of 8 per cent. of acetic acid and only 0.1 or 0.2 per cent. of alcohol (a small remnant of alcohol should always be present) the process is considered as finished, and a further pouring into the generator would not only be useless labor, but contrary to the end in view, since, after the complete oxidation of the last remnants of alcohol, that of acetic acid would immediately commence, and weaker vinegar would be obtained after each pouring.

If a generator works up the quantity of alcoholic liquid intended for 12 or 15 hours in 10 or 12 hours, it is more proper, on account of the diminished loss by evaporation, to induce slower work by decreasing the draught of air in order to maintain the rule that a generator has to work up 3 liters (3.16 quarts) of absolute alcohol in the working time of a day.

After controlling for several days the work of a generator, by examining the products as to their contents of acetic acid and alcohol, the plan of operation resolves itself from the results of these tests, since it is then accurately known after how many pourings of an alcoholic liquid of known composition an addition of alcohol is required; further, after how many pourings a finished product is present, so that directions for the progress of the operation can be given to the workmen according to time and quantities. The normal working of the generators can always be controlled by from time to time repeating the test of the products.

Now, suppose the work in a newly arranged factory, having reached the point at which acidulation is complete, the actual fabrication, according to the old method, will be gradually commenced by pouring in alcoholic liquid of corresponding concentration.

The shavings in the generator having been saturated with acidulating vinegar, the latter is partially replaced by the fluid poured in, and as much as is expelled runs off. If the generator should at once commence to work regularly the temperature in its interior would be observed to rise, though it would at first be impossible to establish a change in the composition of the fluid running off. Slight variations in the content of acetic acid and a small percentage of alcohol could be determined in the fluid only after the acidulating vinegar originally present has been entirely expelled by a series of pourings.

With the progress in the fabrication of vinegar, it became customary to produce the strongest vinegar possible, the so-called triple vinegar, with about 12 per cent. of acetic acid. On account of its greater commercial value, this article could be sent great distances, the consumer reducing it to a weaker product by the addition of water.

To prepare directly vinegar with such a high percentage of

acetic acid, it would, however, be necessary to acidulate all the generators with vinegar of the same strength, and to use alcoholic liquid very rich in alcohol. By this method the losses of alcohol by evaporation, and also of acetic acid, would, however, be so great as to make the product too expensive. Furthermore, the work would require most careful and constant attention on account of the difficulty with which oxidation takes place in alcoholic liquid containing much acetic acid, and it might only too readily happen that the generators suddenly worked weaker, *i. e.*, that the content of acetic acid in the vinegar running off would decrease, and the quantity of alcohol remaining unchanged correspondingly increase.

On account of these difficulties, it has become customary to charge the greater number of generators with alcoholic liquid yielding the so-called double vinegar with about 8 per cent. of acetic acid, and to work this vinegar with the addition of the required quantity of strong spirits of wine in a number of generators, which, of course, must be acidulated with 12 per cent. vinegar.

It will be readily understood that the employment of this method is not only advantageous for the production of vinegar with the highest attainable content of acetic acid, but also for general purposes. Passing the alcoholic liquid but once through the generators does not suffice, even for vinegar with only 5 to 6 per cent. of acetic acid, an examination always showing a considerable quantity,  $\frac{1}{2}$  per cent. and more, of unconverted alcohol in the vinegar running off. The conversion of alcoholic liquid with a small content of alcohol into vinegar by one pouring can, to be sure, be accomplished, but it necessitates the use of very tall generators and a constant struggle with difficulties on account of the irregular draught of air, caused by the packing together of the shavings.

#### *Group-System.*

Theoretically, as well as practically, the group-system may be considered as the perfection of the quick process. The principle of the operation consists in the division of the generators into two or three groups, each group preparing vinegar of determined strength. In factories which do not produce vinegar of the

greatest attainable strength (12 per cent. vinegar), but only double vinegar with about 8 per cent. of acetic acid, two groups might suffice; the manufacture of a product of the greatest attainable strength being, however, advisable in most cases, it is recommended to arrange the factory for continuous work with three groups of generators.

For this purpose the number of generators must be divisible by three; hence 3, 6, 9, 12, etc., generators have to be provided, of which 1, 2, 3, 4, etc., form one group, so that, for instance, in a factory working with 24 generators each group consists of 8. By designating the generators belonging to one group with the same number, we have groups I, II, and III, and in acidulating and operating the generators belonging to one group are treated in the same manner.

For the preparation of the strongest vinegar (12 per cent.) the generators belonging to group I can, for instance, be acidulated with vinegar of 6 per cent. acetic acid, those of group II with 9 per cent. vinegar, and those of group III with 12 per cent. vinegar. The process of operation is then as follows:—

Group I. The generators belonging to this group are charged with an alcoholic liquid which yields vinegar with a content of 6 per cent. acetic acid, and the fluid running off is poured back into the generators until a test shows the alcohol, with the exception of a small remnant, to have been converted into acetic acid. To this vinegar is then added sufficient strong alcohol to form an alcoholic liquid which will yield 9 per cent. vinegar.

Group II. The alcoholic liquid for 9 per cent. vinegar is poured into the generators belonging to group II, the pourings being repeated until all but a very small quantity of the alcohol is oxidized. The vinegar running off is again compounded with sufficient alcohol to form alcoholic liquid for 12 per cent. vinegar and is brought into

Group III. The pourings are here repeated until the oxidation of the alcohol is nearly complete; the finished product is then subjected to storing or clarification.

As will be seen from the above, in operating according to the group system the entire factory is, so to say, divided into three



factories, I, II, and III, of which I produces vinegar of 6 per cent., II vinegar of 9 per cent., and III vinegar of 12 per cent.; the product of I, after having been converted by a suitable addition of alcohol into alcoholic liquid adapted for the preparation of 9 per cent. vinegar, is directly used for charging the generators of group II and that of II for charging III.

The generators belonging to one group having been acidulated with vinegar of the same strength, the fluid running off from one generator need not necessarily be returned to it. The work can, therefore, be simplified by conducting the fluid running off from all the generators by means of a suitable pipe-system into a common receiver instead of allowing the fluid, which has passed through a generator, to collect under a lath-bottom and then drawing it off and returning it to the same generator. If, for instance, 8 generators belong to one group and 3 liters (3.16 quarts) have at the same time been poured into each, the passage of the liquid through all the generators will be shown by a measuring scale placed in the common receiver, indicating that the latter contains  $3 \times 8 = 24$  liters (25.36 quarts).

The samples for determining the content of acetic acid and alcohol are taken from the common receiver, and the latter also serves for the conversion of the vinegar, after it has acquired the percentage of acid attainable in that group, into stronger alcoholic liquid by the addition of alcohol. In order to effect an intimate mixture and at the same time prevent the vinegar ferment floating in the fluid from suffering injury by coming in contact with the highly concentrated spirits of wine, the required quantity of the latter is introduced in a *thin* jet and with constant stirring.

In many factories it is customary from time to time to alternate with the pourings in the groups or "to cross the generators." By this "crossing" the alcoholic liquid, which, according to the above method, would, for instance, pass from group II to group III, is poured into group I, so that after some time the generators of this group are converted into generators of group III (with 12 per cent. acid), and group III becomes group I, it now containing the weakest alcoholic liquid (with 6 per cent. acid). Crossing, however, cannot be recommended, because a sudden change in the constitution of the nourishing fluid always exerts



an injurious influence upon the augmentation of the vinegar ferment.

Recourse to crossing is most frequently had for the purpose of "strengthening" the vinegar ferment by working weaker alcoholic liquid in the generators of one group—generally that which yields the strongest vinegar—when their activity diminishes. This strengthening of the ferment can, however, be effected in a more simple and suitable manner by diminishing the quantity of alcoholic liquid poured in at one time and by increasing the draught of air, and the consequent change of temperature in the generators, so that the principal reasons for "crossing the generators" (which many manufacturers consider indispensable) have no force.

### *Group-System in Factories with Automatic Arrangements.*

In a factory so arranged that the pourings are at stated intervals effected by an automatic contrivance, the group system as described on p. 93 *et seq.* should be used. The operation of such a factory is very simple. As seen from the description of the arrangement, the generators are divided into three groups, I, II, and III. Besides the generators each group must be provided with a reservoir, which may be designated *V*, and a collecting vessel *S*. (The other component parts, distributing arrangements, and conduits can here be left out of consideration.)

For the production of 12 per cent. vinegar in such a factory it is best so to prepare the alcoholic liquid for the several groups that

Group I contains alcoholic				
liquid with . . . . .	6	p. c. acetic acid and	6.5 to 6.6	p. c. alcohol.
Group II contains alcoholic				
liquid with . . . . .	9	"	"	+3.2 to 3.3 "
Group III contains alco-				
holic liquid with . . . . .	12	"	"	+3.2 to 3.3 "

Group I having been acidulated with 6 per cent. vinegar, group II with 9 per cent. vinegar, and group III with 12 per cent. vinegar, the fluid running off from group I, after being compounded with 3.2 to 3.3 per cent. of alcohol, is used in group

II as alcoholic liquid for 9 per cent. vinegar and yields 9 per cent. vinegar, which after being again compounded with 3.2 to 3.3 per cent. of alcohol yields 12 per cent. vinegar after having passed through group III.

The uninterrupted working of the generators constituting one of the principal advantages of the automatic system, it is advisable to regulate the automatic contrivance so that but a small quantity of alcoholic liquid be at one time poured out, and to fix the intervals between two pourings so that the second pouring takes place after about one-half of the first has run off. Under these conditions there will be in the lower half of the generator an alcoholic liquid in which the alcohol is nearly as much oxidized as it can be by one passage through the generator, while in the upper half will be fresh alcoholic liquid in which oxidation is continued without interruption. A further advantage obtained by this is that a generator will yield quantitatively more than one working only 15 to 16 hours; further, the conditions of temperature in the interior of the generator remain always the same and the ferment constantly finds nourishment.

The alcoholic liquid for group I is pumped into the reservoir  $V_1$ , and passes through the generators of group I into the collecting vessel  $S_1$ . All the alcoholic liquid having run off from  $V_1$ , the fluid collected in  $S_1$ , after having been tested as to its content of acetic acid, is for the second time pumped into  $V_1$  and passes again through the generators of group I. The automatic contrivance is so regulated that the alcoholic liquid, after being twice poured in, contains but a very small remnant of alcohol.

To the vinegar of 6 per cent. collected in  $S_1$  is now added 3.2 to 3.3 per cent. by weight of alcohol, best in the form of 80 to 90 per cent. spirits of wine. The resulting stronger alcoholic liquid is at once pumped into  $V_2$ , and passing through the generators of group II reaches the collecting vessel  $S_2$ . It is then tested, pumped back into  $V_2$ , and again collected in  $S_2$ . If it now shows the required strength, it is mixed with the second portion of 3.2 to 3.3 per cent. by weight of alcohol and is pumped into  $V_3$ , and after passing twice through the generators collects as finished vinegar in  $S_3$ .

It will be seen from the above description of the process that in

making the tests the product of all the generators of one group is treated as a whole. A disturbance may, however, occur in either one of the generators, and it would take considerable time before its existence would be detected by a change in the constitution of the entire product. The thermometer with which each generator is provided is, however, a reliable guide as to the activity of the latter, and if it shows in one of them a temperature varying  $37^{\circ}$  to  $39^{\circ}$  F. from that prevailing in the others, it is a sure sign of the respective generator not working in the same manner as the others, and the product running off from it should be tested by itself as to its content of acetic acid and alcohol.

Generally it will contain either no alcohol or very much of it. In the first case, the temperature of the respective generator is higher than that prevailing in the others, and its activity has to be moderated by decreasing the admission of air; in the other case, the generator works too sluggishly, and the difference is sought to be equalized by increasing the current of air or giving a few pourings of somewhat warmer alcoholic liquid. With a good heating apparatus producing a uniform temperature in the work-room such disturbances will, however, but seldom happen, and by the use of the above means the normal working of the generators can be restored.

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## CHAPTER XIII.

### DISTURBING INFLUENCES IN THE FABRICATION OF VINEGAR.

IN no other industry based upon the process of fermentation are irregularities and disturbances of such frequent occurrence as in the fabrication of vinegar. Besides the nourishing substances dissolved in the fluid and free oxygen, the vinegar ferment requires a certain temperature for its abundant augmentation, by which alone large quantities of alcohol can in a short time be converted into acetic acid. By exercising the necessary care for the fulfilment of these conditions serious disturbances can be

entirely avoided and the slighter ones due to insufficient acetous fermentation of the ferment readily removed.

As regards the nourishing substances of the ferment, irregularities can actually occur only in working continuously with an alcoholic liquid composed exclusively of water and alcohol. In such alcoholic liquid the nitrogenous substances necessary for the nourishment of the ferment are wanting, nor are the phosphates present in sufficient quantity. The consequences are the same as observed in every insufficiently nourished fermenting organism: the fermenting activity suddenly diminishes, augmentation proceeds sluggishly and ceases entirely if abundant nourishment is not introduced. Hence it may happen that from a generator containing alcoholic liquid composed only of water, alcohol, and vinegar, the greater portion of the alcohol suddenly runs off unchanged, the temperature in the interior of the generator at the same time falling and the draught of air ceasing soon afterwards. When these phenomena appear it should first be ascertained whether the disturbance is not due to too slight a current of air. For this purpose the draught-holes are entirely opened, and if the temperature rises the generator gradually resumes its normal working. If, however, no improvement is observed, the disturbance is due to defective nourishment, and the composition of the alcoholic liquid has to be changed, which is best effected by the addition of a few per cent. of beer or of fermented alcoholic mash, both containing a sufficient quantity of phosphates and albuminous substances. The use of sweet beer wort or of malt extract has also been highly recommended for "strengthening weak-working generators." These substances also furnish albuminous bodies and phosphates to the alcoholic liquid; they also contain, however, maltose and dextrin, and as it has not yet been ascertained whether the latter and the carbohydrates in general can be consumed and digested by the ferment, they possibly may pass unchanged into the vinegar. Honey and glucose are also sometimes used for strengthening purposes, but while the former might be useful on account of the abundance of salts and nitrogenous substances it contains, no substances of any value to the ferment are present in the latter. At any rate the addition of beer, mash, or malt extract is to be preferred.

An addition of phosphates to the alcoholic liquid is also said to produce a favorable effect upon the augmentation of the ferment. Commercial solid phosphoric acid is dissolved in water and the solution neutralized with potassium, a solution of potassium phosphate being obtained in this manner. The vinegar ferment being very sensitive towards this salt a very small quantity of the solution, about  $\frac{1}{10000}$  of the weight of the alcoholic fluid, may be added. The experiment must, however, be made very cautiously and the effect upon the working of the generator carefully noted.

*Disturbances referable to the Quantity of newly formed Acetic Acid.*

With a proper state of working the alcoholic liquid brought into the generators should be completely converted into vinegar, and, theoretically, the product running off show the same strength as the vinegar used for acidulation. Actually, there are, however, slight variations not exceeding a few tenths of one per cent. Should greater differences appear a disturbance actually exists and may show itself in various ways: the generator may work *too feebly* or *too vigorously*. In the first case the content of acetic acid in the fluid running off decreases considerably, while that of alcohol increases. The process of the formation of vinegar is, so to say, only half carried through, a great portion of the alcohol being converted, not into acetic acid, but into aldehyde. The greater portion of this combination is lost to the manufacturer on account of its low boiling point (71.6° F.), it escaping in the form of vapor, the stupefying odor of which when noticed in the air of the workroom is accepted by all manufacturers as indicative of a disturbance in the regular working of the generators. This odor, however, becomes perceptible only after the disturbance has continued for some time with the loss of a considerable quantity of alcohol. Hence the control of the working of the generators by a frequent determination of the acid becomes necessary. Repeated observations of the thermometer also furnish valuable hints about the progress of the chemical process. The temperature in this case remains only for a short time unchanged and soon falls, far less heat being liberated in the mere conversion of alcohol into aldehyde than when oxidation progresses to the formation



of vinegar. These phenomena are indicative of the generator not being able to master the alcoholic liquid introduced and may be due to the pourings being too large, or the temperature of the alcoholic liquid poured in being too low, or finally to an insufficient draught of air.

To restore the generator to a proper state of working, it is best to try first the effect of smaller pourings and then an increased draught of air. If the disturbance was due to an insufficient draught of air, the temperature soon rises and the generator will be able to work up the regular quantity of alcoholic liquid. By the use of alcoholic liquid of a somewhat higher temperature the restoration of the normal conditions can be accelerated.

A decrease in the content of acetic acid in the fluid running off from the generators without the presence of alcohol being shown indicates a too vigorous process of oxidation, the alcohol being not only oxidized to acetic acid, but the latter further into carbonic acid and water. The temperature in the interior of the generators rises considerably, about  $45^{\circ}$  F. above that of the workroom.

In this case the restoration of the respective generator to a proper state of working is not difficult and can be effected in two ways: either by considerably decreasing the ventilation of the generator, or by pouring in a larger quantity of alcoholic liquid than previously used.

The heating of the generators is generally due to faulty construction. Generators of large dimensions, as a rule, become too warm much easier than smaller ones, the phenomenon also appearing more frequently in summer than in winter; and "too warm" being just as injurious to the efficacy of the generators as "too cool," they must, during the warm season of the year, be as carefully protected against too high a temperature as against cooling during the cold season. This is effected, on the one hand, by a suitable ventilation of the workroom during the night, and, on the other, by the use of alcoholic liquid of a somewhat lower temperature during the hottest season of the year. Moreover, disturbances from too high a temperature of the exterior air need only be feared in countries with a very warm climate.

It has been frequently proposed to counteract a too vigorous



activity of the generators by the addition of a little oil of cloves or salicylic acid which have the property of checking fermentation. Salicylic acid, especially, is an excellent corrective for the faulty working of a generator; it has to be used, however, with great caution and only be added by the  $\frac{1}{100000}$  of the weight of the alcoholic liquid and just in sufficient quantity to attain the desired result. A large amount is injurious to the ferment and might kill it.

*“Sliming” of the Generators.*

The phenomenon to which this term is applied belongs to a class of disturbances which sometimes occur in a vinegar factory, and whose progress generally ends in throwing the entire operation into complete disorder so that finally no more vinegar can be produced. After fruitless experiments nothing remains but to empty the generators, wash the shavings with hot water, and, after drying and steeping them in hot vinegar, as in the commencement of the operation, return them to the generator.

The evil begins to show itself by the generators commencing to work irregularly; while formerly a certain quantity of alcohol was after a fixed number of pourings converted into acetic acid, a larger number of pourings are now required to attain the same result. The generators work slower and the heat in their interior decreases. By heating the workroom more strongly only a temporary improvement is brought about, and the production of the generators becomes less and less, and, finally, so low that work has to be interrupted. When the disturbance has progressed thus far a disagreeable musty, instead of the characteristic acid odor, is perceived in the workroom. By allowing one of the faulty working generators to stand for a few days without charging it with alcoholic liquid, the temperature in the interior may rise considerably and products of putrefaction be developed to such an extent as to taint the air of the workroom.

Long before this phenomenon becomes apparent an alteration takes place in the shavings. A shaving taken from a normally working generator has the ordinary appearance of wet wood; but one taken from a generator working in the above-mentioned

faulty manner is coated with a slimy mass, which is somewhat sticky and can be drawn into short threads. Viewed under the microscope this slimy coating presents a structureless mass, throughout which numerous germs of vinegar ferment are distributed and sometimes also vinegar eels. Independently of the presence of the latter, this slimy coating presents the same appearance as the so-called mother of vinegar. By placing a shaving coated with slime upright in a shallow dish and filling the latter  $\frac{2}{3}$  the height of the shaving with alcoholic liquid, the previously described delicate veil of vinegar ferment develops upon the surface, while the portion of the shaving covered by the fluid is surrounded by flakes distinguished by nothing from mother of vinegar. Hence there can scarcely be a doubt that the slimy coating actually consists of the same structure to which the term mother of vinegar (see p. 34) has been applied, and in searching for the cause of its formation, it will generally be found to be due to conditions similar to those which give rise to the formation of the latter. An alcoholic liquid overly rich in young beer containing much albumen, or one to which much malt extract or young fruit-wine has been added, is apt to give rise to the formation of mother of vinegar in the generators. The slimy coating thus formed upon the shavings envelops the vinegar ferment and prevents its immediate contact with the air; consequently the alcoholic liquid does not encounter as much ferment as is required for the complete oxidation of the alcohol, and the generators become weaker. This decrease in the production is, of course, followed by a lower temperature in the generators and consequently by a decrease in the augmentation of the ferment, these unfavorable conditions finally becoming so great as to bring the activity of the generators to a standstill.

The settlement of vinegar eels upon the surface of the mother of vinegar has no connection with sliming. Should, however, large masses of these animalcules happen to die in the generators for want of air, due to the constantly decreasing draught, they quickly putrefy on account of the high temperature and give rise to the most disagreeable smells.

A careful manufacturer will observe sliming at the commencement of the evil, when it can be remedied without much diffi-

culty. First of all, the composition of the alcoholic liquid must be changed by discontinuing the use of fluids containing many carbohydrates and albuminous substances, such as young beer, malt extract, young fruit-wine, etc., it being best to use alcoholic liquid of water, vinegar, and alcohol only until the generators are entirely restored to a normal working. The activity of the ferment is at the same time increased by a stronger draught of air in the generators and by raising the temperature of the workroom. In a few days the generators will be again in a proper state of working, which is recognized by the normal conversion of alcohol into acetic acid.

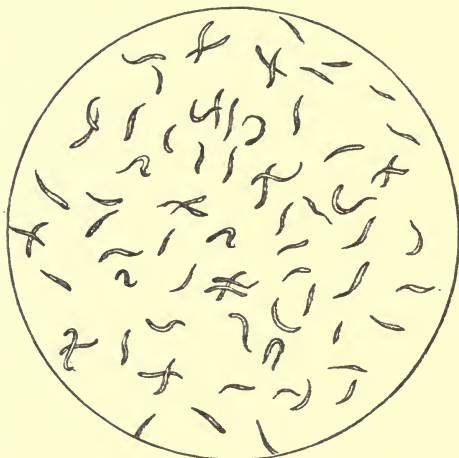
If, however, the evil has progressed to a certain extent nothing can be done but to empty the generators. Though considerable labor is connected with this operation, there is no further use of experimenting, since such nonsensical additions as beer-yeast, tartar, honey, etc., which have been proposed as remedies, only accelerate the final catastrophe—the entire cessation of the formation of vinegar. Should a disturbance occur which cannot be accounted for by defective nourishment of the ferment, want of air, or an incorrect state of the temperature, the condition of the shavings should be at once examined into, and if they show the first stages of sliming the evil should, if possible, be remedied by changing the composition of the alcoholic liquid. If the new alcoholic liquid contains only water, vinegar, and alcohol sliming cannot progress, and the layers of slime upon the shavings will in a short time disappear, they being partially utilized in the nourishment of the ferment and partially mechanically washed off by the alcoholic liquid running down.

#### *Disturbances due to Vinegar Eels.*

In many factories filamentous structures scarcely visible to the naked eye will frequently be observed in the vinegar. When viewed under the microscope they will be recognized as animalcules, to which the term vinegar eel (*Anguilla aceti*) has been applied on account of their form slightly resembling that of an eel. Fig. 31 shows a microscopical picture of a drop of vinegar

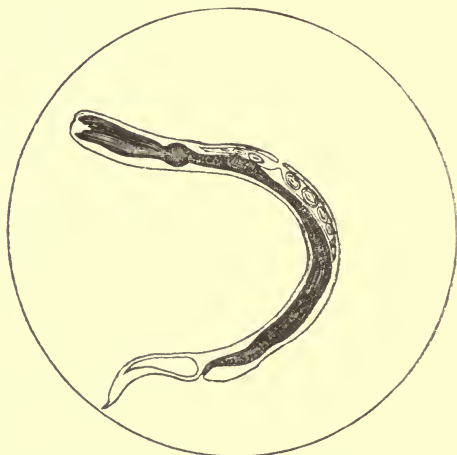
swarming with vinegar eels slightly magnified, and Fig. 32 a vinegar eel strongly magnified.

Fig. 31.



Drop of vinegar swarming with vinegar eels, slightly magnified.

Fig. 32.



Vinegar eel (female) strongly magnified.

The animalcule consists of a cylindrical body running to a sharp point. The mouth-opening is covered with small knots; the throat is globular and passes directly into the long intestinal

tube. The eggs are placed at about the centre of the body in two tubes which unite to a plainly perceptible aperture. The average length of the female is 0.0682 Paris inch and that of the male 0.0486, the former being larger than the latter in the proportion of 1 : 1.3.

Vinegar eels can exist in dilute alcohol of the strength used in the fabrication of vinegar as well as in dilute acetic acid. In alcoholic liquid containing much alcohol and acetic acid they do not thrive as well as in weak liquid. Their part in the fabrication of vinegar is under all conditions an injurious one. The vinegar ferment can only carry on its function correctly when vegetating upon the surface of the fluid and in contact with air. The vinegar eel being an air-breathing animal always seeks the surface and in an alcoholic liquid which contains it and upon whose surface an abundance of ferment grows, actual contests between animalcule and ferment can be observed, the former striving to force the latter, which is inimical to its existence, under the surface and thus render it harmless. (Submerged vinegar ferment, as is well known, changes its conditions of existence and becomes mother of vinegar.) If the conditions are favorable for the development of the animalcules, the latter overcome the ferment and submerge it so that it can continue to exist only as mother of vinegar, and consequently the process of the formation of vinegar will be considerably retarded. Under conditions favorable to the development of the ferment the reverse is the case. The ferment floating upon the fluid consumes nearly all the oxygen contained in the layer of air immediately above the surface and thus deprives the animalcules of a condition necessary for their existence ; a portion of them die and fall to the bottom of the vessel, while another portion escape to the sides of the vessel where they congregate immediately above the surface of the fluid in such masses as to form a whitish ring. These conditions can be readily induced by pouring vinegar containing a large number of vinegar eels into a flat glass dish and adding a fluid upon which vinegar ferment has been artificially cultivated. In a few hours the ferment has spread over the entire surface and the animalcules form the above-mentioned white ring on the sides of the vessel. If by means of blotting paper the veil of ferment be



removed as fast as it augments, the animalcules soon spread over the entire fluid.

From the above explanation it is evident that the appearance of vinegar eels in large masses threatens danger to the regular working. When the animalcules reach the shavings the struggle for existence between them and the ferment commences, and their struggling to dislodge the latter may be the first cause of the formation of slimy masses of mother of vinegar upon the shavings. Since the vinegar eels consume oxygen the air in the generators becomes thereby less suitable for the nourishment of the ferment and consequently the generators will work feebly. By accelerating the draught of air in the generators, which is generally the first remedy tried, the development of the ferment may again become so vigorous that a large portion of the vinegar eels are killed, their bodies being found in the vinegar running off. The dead vinegar eels remaining in the generator, however, finally putrefy and give rise to the previously mentioned disagreeable odor. The processes of putrefaction being also effected by bacteria capable of decomposing nearly all known organic combinations (even small quantities of such strongly antiseptic bodies as salicylic and carbolic acids), it is evident that vinegar containing vinegar eels cannot possess good keeping qualities and must be subjected to a special treatment, which will be referred to later on.

Several remedies for the suppression of vinegar eels in the generators have been proposed, one of them consisting of the introduction of vapors of burning sulphur, *i. e.*, sulphurous acid. Sulphurous acid, it is true, kills the vinegar eels but, at the same time, the vinegar ferment, and if small remnants remain, also the newly introduced ferment. To restore a generator thus treated a large quantity of air must be blown through it which will remove the last traces of sulphurous acid. An alcoholic liquid containing much living ferment is then poured in.

The vinegar ferment can for many hours stand the exclusion of oxygen without being destroyed while the vinegar eels die in a short time. This circumstance may be utilized for the destruction of the animalcules without recourse to other remedies. The generator having first been brought into the highest state of activity by pouring in very warm alcoholic liquid and opening

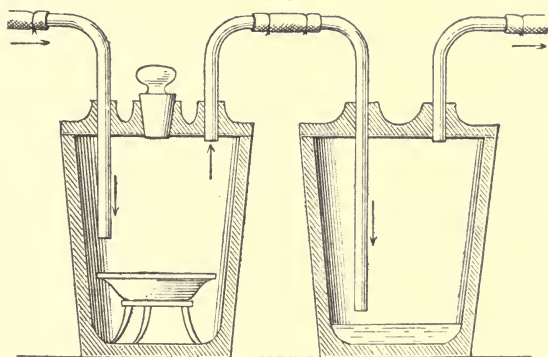


all the draught-holes, is left to itself for 6 to 8 hours after closing all the draught-holes. The ferment in a short time consumes all the free oxygen in the generators and the vinegar eels die from want of it. By opening the draught-holes and pouring in alcoholic liquid the normal formation of vinegar soon recommences.

The killing of a large number of vinegar eels in the above manner is, however, of considerable danger to the regular working of the factory, and the respective generators must be watched with special care in order to meet at once any appearance of putrefaction. It may sometimes succeed to keep up the work undisturbed, the killed vinegar eels being gradually removed from the generators by the vinegar running off. In such critical cases, when the generator may at any moment commence to work irregularly, the use of a very small quantity of salicylic acid as an addition to the alcoholic liquid would be advisable. The acid by checking putrefaction would prevent the immediate decomposition of the killed vinegar eels still present in the generators.

Should, however, signs of putrefaction appear energetic, means should at once be taken to arrest its progress, it being in this case

Fig. 33.



Apparatus for the Development of Sulphurous Acid.

best to sulphur the generator. This is effected by closing all the draught-holes except one, and introducing into the latter the nozzle of the apparatus whose arrangement is shown in Fig. 33.

In a large clay vessel, best glazed inside, stands upon a tripod

a flat plate. The cover of the vessel luted air-tight with clay is provided with three openings. The opening in the centre is closed by a well-fitting clay stopper, while glass tubes bent at a right angle and with a clear diameter of about  $\frac{1}{3}$  inch are cemented in the openings at the side. The tube reaching nearly down to the plate is connected by means of a rubber hose with a double-acting bellows, while the second tube leading directly from the cover is connected with a second clay vessel. From the cover of this vessel a pipe leads to, and is fitted into, the open draught-hole of the generator.

For use the apparatus is put together, as shown in the illustration, and small pieces of sulphur are thrown through the central aperture upon the plate. The sulphur is ignited by throwing in a lighted sulphur match, and after closing the aperture the bellows is put in operation. The product of the combustion of the sulphur passes through the tube into the generator, and ascending dissolves the fluid adhering to the shavings to sulphurous acid. The addition of sulphur and blowing in of air are continued until the odor of burning sulphur is clearly perceptible in the upper portion of the generator. The second vessel which contains some water serves for the condensation of the portion of the sulphur which is not consumed, but only volatilized.

The sulphurous acid kills every living organism in the generator, and consequently *all the germs of the vinegar ferment are also destroyed.*

After allowing the sulphured generator to stand a few hours, fresh air alone is forced through it by means of the bellows; the air-holes are then opened and the generator allowed to stand a few days for the sulphurous acid to be converted into sulphuric acid by the absorption of oxygen. To bring this generator again into operation it is best to introduce at first a number of pourings consisting only of vinegar, with a content of acetic acid corresponding to that of the original acidulation. In consequence of the absorption of sulphuric acid by the shavings this vinegar becomes of no value as a commercial article, but it can be used for the preparation of alcoholic liquid.

The last traces of unchanged sulphurous acid having in this manner been removed from the generators and the greater portion

of sulphuric acid adhering to the shavings washed out, the generator is again acidulated ; this being best effected by pouring in alcoholic liquid just run off from normally working generators.

*Disturbances due to Vinegar Lice (Vinegar-Mites).*

Unless the most scrupulous cleanliness prevails so-called vinegar lice will always be found in the factory ; they prefer places kept constantly moist and to which the air has free access, for instance, the draught-holes and the interior of the generators beneath the lath-bottom. As a rule manufacturers do not pay much attention to their presence, as they apparently exert no influence upon the regular working. That such, however, is not the case will be seen from the following occurrence : In 1881, the proprietor of a vinegar factory in Italy informed Dr. J. Bersch that millions of small animals had appeared in the factory and penetrated into the generators, the shavings up to a certain height being covered with living and dead animals, and the latter putrefying, further working had become impossible. Every drop of

Fig. 34.



Vinegar-Mite, according to Bersch.  $\times 120$ .

vinegar running off from the generators contained one or more of the mites. A small bottle half full of vinegar and closed airtight by a cork accompanied the communication. Though the bottle had been 60 hours on the way, on opening it a number of

living animals were found congregated especially in the fissures of the cork. On examining them with the microscope two forms (male and female?) could be clearly distinguished, many being only one-quarter or one-half the size of others. Figs. 34 and 35

Fig. 35.



Vinegar-Mite (from the under side).  $\times 120$ .

show the two characteristic forms of these animalcules. As far as it was possible to determine their zoological position they belong to the family *Sarcoptidae*. No particulars as to their origin seem to be known, the manufacturer simply stating that they had come from the soil under the supports of the generators and gradually rendered the latter ineffective. The generators were sulphured in the above-described manner and again put into operation.

To prevent the vinegar-mites from collecting in large masses scrupulous cleanliness must prevail in the factory. Especially should the draught-holes be from time to time examined, and, if mites be found, thoroughly cleansed with hot water, which kills them. The mites might also be prevented from penetrating into the interior of the generators by rings of a sticky substance (turpentine) around the draught-holes.

*Vinegar-Flies.*

Though, as far as known, the animals known as vinegar-flies create no disturbance in the regular working of the factory, they deserve mention because they appear wherever a fluid passes into acetous fermentation. In wine cellars, not kept thoroughly clean, these insects are frequently found on the bung-holes of the wine-barrels, and in factories in which the manufacture of wine vinegar is carried on according to the old system, they often occur in great swarms.

The vinegar-fly (*Drosophila funebris*, Meig) is at the utmost 0.11 inch long; it is especially distinguished by large red eyes sitting on both sides of the head and meeting in front. The thorax and legs are red, the abdomen which is provided with six rings, is black, with yellow stripes. The wings are longer than the body. The larva is white, has twelve rings, on the mouth two black hook-like structures, and on the back part of the body four warts two of which are yellow. In eight days the larva is transformed into a yellow chrysalis.

The collection of these flies in large masses can be readily prevented by keeping the factory thoroughly clean and being especially careful not to spill any fluid.

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CHAPTER XIV.METHOD OF THE FABRICATION OF VINEGAR IN APPARATUS  
OF SPECIAL CONSTRUCTION.

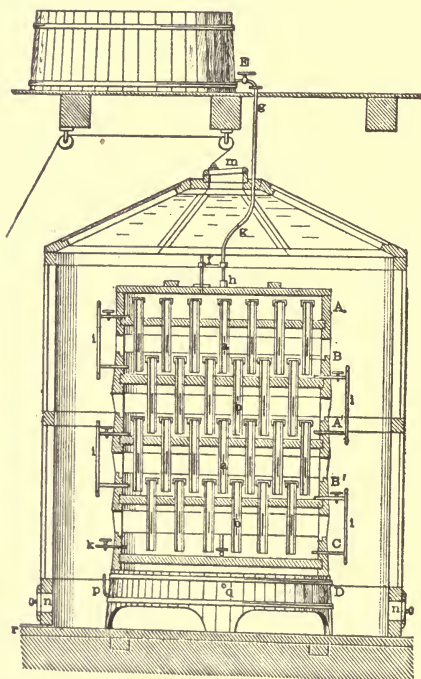
To overcome the frequent disturbances in the working of a factory not provided with suitable heating and ventilating arrangements, several kinds of apparatus and methods have been proposed. Most of these inventions were protected by patent, but the relinquishment of the latter in a short time is the best proof of their non-success in practice. A few of them are here described, not because they are considered an essential progress in the fabrication of vinegar, but simply as illustrations of

the manner in which the respective inventors sought to overcome the difficulties arising from the use of badly constructed apparatus.

*Singer's Vinegar Generator.*

Singer's apparatus consists of a number of shallow vats for the reception of the alcoholic liquid. These vats are connected with each other by a number of tubes so that the alcoholic liquid after it has risen to a certain height in one vat reaches the next one below and finally runs off as finished vinegar into a collecting vessel.

Fig. 36.



Singer's Vinegar Generator (Cross Section).

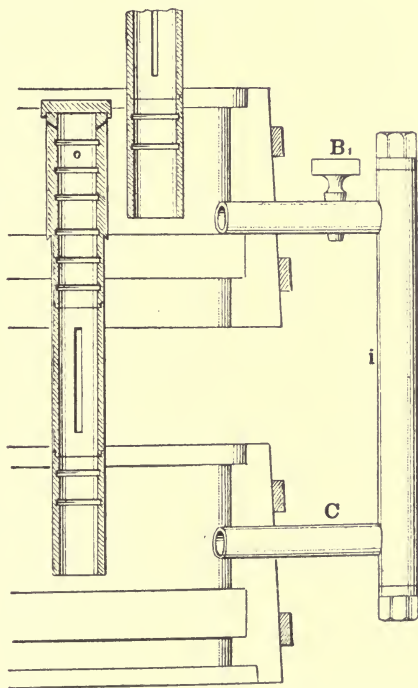
Fig. 36 shows the apparatus in cross section. The five vats are marked *A*, *A*<sub>1</sub>, *B*, *B*<sub>1</sub>, and *C*. In the bottoms of *A* and *A*<sub>1</sub> are placed thirty-seven tubes, and in the bottoms of *B* and *B*<sub>1</sub>



thirty-two. The entire apparatus is inclosed in a glass case provided below with several apertures, *n*, with regulators, and above with a valve, *m*, by which the accurate regulation of the draught of air in the apparatus is to be effected. The rubber hose *g* secured to the reservoir *E* conducts at *h* the alcoholic liquid through the lid covering the uppermost vat *A*. In this vat the liquid rises to a certain height, runs through the apertures in the sides of the tubes into the vat *B*, from this in a similar manner into *A*, *B*, and finally into the collecting vessel *D*.

The process of the formation of vinegar is claimed to proceed in the tubes connecting the vats with each other. Fig. 37 shows

Fig. 37.



Singer's Apparatus (Connection of two Vats with each other).

the arrangement of these tubes on an enlarged scale. The wooden tubes are closed above and provided each with four apertures for the influx of alcoholic liquid. Inside of each tube are six an-

nular depressions, four above and two below. In the centre is a slit for the access of air.

To be able to discharge at will the fluid in one vat of the apparatus (Fig. 36) into the next below, the vats are connected by the pipe *i* closed by spigots. The lowest vat, *C*, is provided with discharge-pipes, *I* and *k*, *I* being directly above the bottom of the vat and *k* about  $1\frac{1}{4}$  inch higher up. The collecting vessel *D* is at *g* connected by means of a rubber hose with the spigot *J* placed on *C*. The glass tube *p*, which is bent at a right angle and can be turned, indicates, when in an upright position, the height of the fluid in *D*, and with the mouth turned downwards serves for discharging the contents of *D*.

The apparatus is operated as follows: By opening the spigot *E*, alcoholic liquid is allowed to run from the reservoir into the uppermost vat, *A*, until it stands about  $\frac{1}{3}$  to  $\frac{3}{4}$  inch above the apertures in the tubes. The spigots on *i* remain closed during the normal working of the apparatus. The alcoholic liquid passes through the apertures, trickles through the tubes into the vessel, and gradually reaches in the same manner the collecting vessel *D*. By a suitable regulation of the influx of alcoholic liquid from *E* completely finished vinegar is claimed to collect in *D*.

#### *Michaelis's Rotatory Vinegar Generator.*

The principal feature of this apparatus, which has been patented in Germany, is a strong barrel placed horizontally and having a diameter of 3.3 feet and the same height. The interior of this barrel is divided into two chambers by a horizontal lath-bottom; the upper smaller chamber is filled with shavings or pieces of charcoal. In the bottom below the lath-bottom a horizontal tube serves for the influx of air and a spigot above in the side of the barrel for its egress.

The alcoholic liquid is poured in close under the lath-bottom, the air-spigot closed, and the barrel revolved so that the shavings become saturated. In about fifteen minutes the barrel is returned to its original position and the air-spigot opened. The commencement of the formation of vinegar is soon indicated by the increased temperature, and the apparatus is now in full working. To make

the formation of vinegar a continuous one, it is only necessary to turn the barrel several times a day in order to saturate the shavings with alcoholic liquid. The progress in the formation of vinegar is indicated by a thermometer placed in the bottom of the upper chamber. The end of the process is indicated by the falling of the thermometer.

The apparatus is cleansed by rinsing the shavings, without removing them from the barrel, with hot water, filling the barrel with strong vinegar and drawing it off after 24 hours.

According to the statements of the inventor, the advantages of his apparatus consist in its cheapness, simple operation, greater yield, saving of alcohol, and better quality of the product.

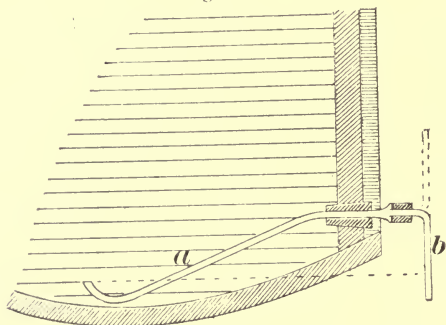
It may, however, be remarked that the operation is not so simple, since every generator has to be several times turned daily, for which labor and space are required. How the apparatus, which works exactly like a generator filled with shavings, is to save alcohol and yield a greater product of a better quality cannot be explained from a chemical standpoint. Just as little can it be explained where the ferment indispensable for the formation of vinegar is to come from if the apparatus is to be cleansed with hot water, which kills all the ferment upon the shavings, and only strong vinegar is to be poured in.

#### *Fabrication of Vinegar with the Assistance of Platinum Black.*

In considering the theory of the formation of vinegar it was mentioned that finely divided platinum possesses the property of converting alcohol into acetic acid. This property of platinum black has been utilized for the purpose of manufacturing acetic acid on a large scale. The apparatus used is composed of a series of shelves about one foot apart, upon which rest a certain number of shallow dishes of porcelain or stoneware. In the centre of each of these and supported by stoneware or glass tripods rest smaller dishes containing the platinum black. The whole is covered with a glass case, if the apparatus is small, or a frame of wood with glass windows and glass top for the production of larger quantities of acetic acid. The air is made to circulate slowly through the apparatus, and the temperature main-

upwards. In front of the bung-hole this tube is provided with an expansion in which is fitted by means of a cork a tube, *b*, bent at a right angle. While the vinegar is stored, this tube stands upright as indicated by the dotted lines, and is secured to a rubber

Fig. 38.



hose reaching to the bung-hole. By turning the tube downward the fluid runs out through the tube *a* until its level has sunk to the dotted line.

Sometimes the vinegar is not rendered entirely clear by storing, and filtering has to be resorted to. Before referring to this operation a few words will be said in regard to the storing of vinegar.

The vinegar brought into the storage barrels contains the following constituents: Water, acetic acid, alcohol (very little), aldehyde (very little), acetic ether, vinegar ferment (living and dead), extractive substances (depending on the nature of the alcoholic liquid used). Moreover, there are frequently found alcoholic ferment (from the beer) and vinegar eels and vinegar mites, if these animals exist in the factory.

By filling the storage barrels to the bung-holes and closing them air-tight, the vinegar eels and vinegar mites die in a short time for want of air and fall to the bottom. The living vinegar ferment present in the fluid must assume the form in which it can for some time exist without free oxygen, *i. e.*, of mother of vinegar. When in consequence of the shrinkage in the volume of the vinegar by cooling the air penetrates through the pores of the wood, it is first utilized for the conversion of the small quantity of aldehyde into acetic acid, and later on enables the vinegar fer-

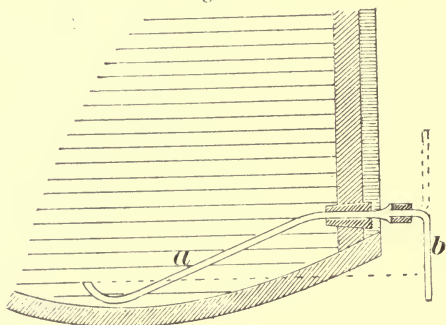
ment to continue to exist upon the surface and to slowly convert the small quantity of alcohol still present into acetic acid.

If the barrels are not closed absolutely air-tight, the vinegar ferment will develop quite vigorously upon the surface, and when all the alcohol is consumed attack the acetic acid, so that when the vinegar is tested a decrease in the content of acetic acid is plainly perceptible. If the finished vinegar still contains considerable quantities of albuminous substances in solution (vinegar from grain, malt, or fruit), or if it contains tartaric and malic acids and at the same time only a small percentage of acetic acid, as most fruit vinegars do (seldom more than 5 per cent.), the mold ferment readily settles upon the vinegar and finally dislodges the vinegar ferment from the surface. The acetic acid is, however, very rapidly destroyed by the mold ferment, and through a luxuriant growth of the latter, which floats upon the surface as a white, membranous coating, the vinegar may in a few weeks lose one or more per cent. of it. This happens so frequently, for instance with fruit-vinegar, that the opinion that such vinegar cannot be made to keep, is quite general.

Vinegar which, besides a considerable quantity of extractive substances, contains the salts of certain organic acids (malic and tartaric acids), for instance, vinegar prepared from apples or wine, must be frequently examined, as it readily spoils and may suffer even if kept in barrels constantly filled up to the bung. In fluids containing the salts of the above-mentioned organic acids a ferment may frequently develop, even when the air is excluded, which first decomposes the tartaric and malic acids, and though these acids are present only in a comparatively small quantity, they influence, to a considerable extent, the flavor of the vinegar on account of their agreeable acid taste. In vinegar in which this ferment has long existed a diminution of acidity can be readily detected by the taste, and by the direct determination of the acid a decrease in its content can be shown which, if calculated as acetic acid, may in some cases amount to one per cent. Besides the loss of its former agreeable taste vinegar thus changed acquires a harsh tang, due no doubt to the formation of certain not yet known products formed by the ferment effecting the destruction of the tartaric and malic acids. Moreover, wine

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or fruit-vinegars in which this ferment has for a considerable time flourished, lose their characteristic agreeable bouquet which may be considered the greatest damage.

In the presence of a large number of vinegar eels their bodies may decay and impart to the vinegar a very disagreeable putrid odor, even if stored in barrels closed air-tight.

The advisability of filtering the vinegar before bringing it into the storage barrels will be readily understood from the above statement. By filtration it is, however, only possible to remove the vinegar eels and vinegar mites swimming in the fluid and larger flakes of mother of vinegar. The ferments and bacteria inducing putrefaction cannot be thus removed, so that even filtered vinegar is liable to spoil when stored.

### *Heating the Vinegar.*

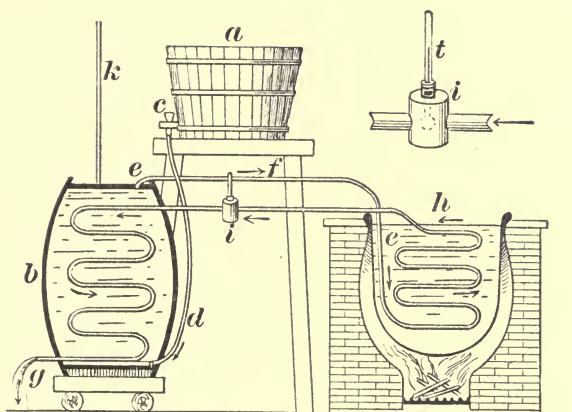
In order to destroy all organisms which might cause the spoiling of the vinegar, it is recommended to heat the latter to about 140° F. before running it into the storage barrels. A few moments exposure at this temperature being sufficient for the purpose, a large volume of vinegar can in a short time be heated with the use of a suitable apparatus, such as is shown in Fig. 39.

In the head of the barrel *b* is secured a pipe of pure tin with very thin walls and a clear diameter of about  $\frac{1}{8}$  inch. It is coiled in a boiler filled with water, which it enters at *e f* and leaves at *h*. It then passes into the barrel *b*, in which it is also coiled, and ends outside the barrel at *g*. At *i* it expands to a capsule in which a thermometer, *t*, is placed. A vat, *a*, placed at a certain height above the barrel is provided with a wooden stopcock, *c*, to which is secured a rubber hose, *d*, which enters the barrel *b* above the bottom. The pipe *k*, which is secured on top of the barrel *b*, is open on both ends and of sufficient length to project above the vat *a*.

The boiler is filled with water and placed in an ordinary hearth. The vat *a* is filled with the vinegar to be heated and kept constantly supplied. The water being heated to boiling the stopcock *c* is opened. The vinegar now runs through *d* into the barrel *b*, and, after filling it, flows at *e* into the tin coil and passes

through it in the direction of the arrows, whereby it is heated. The thermometer *t* dipping into the hot vinegar indicates the temperature, and the influx of vinegar is accordingly regulated by opening or closing the cock *e*. As shown in the illustration,

Fig. 39.



Apparatus for heating Vinegar.

the hot vinegar runs through the coil surrounded by cold vinegar into the barrel *b*, whereby it is cooled off and the vinegar in the barrel preparatively heated. The pipe *k*, open on both ends, allows the escape of the gases developed.

In consequence of the albuminous substances becoming insoluble by heating, the vinegar running off at *g* is, as a rule, more turbid than before. It is brought into the storage barrels, which need, however, not be closed air-tight, the further processes taking place in the vinegar being of a purely chemical nature and not caused by organisms. The latter have been killed by heating, and, together with all other foreign bodies suspended in the vinegar, gradually fall to the bottom of the barrel. If the vinegar after heating is allowed to lie for a sufficiently long time, it clarifies completely and can be drawn off entirely bright from the sediment.

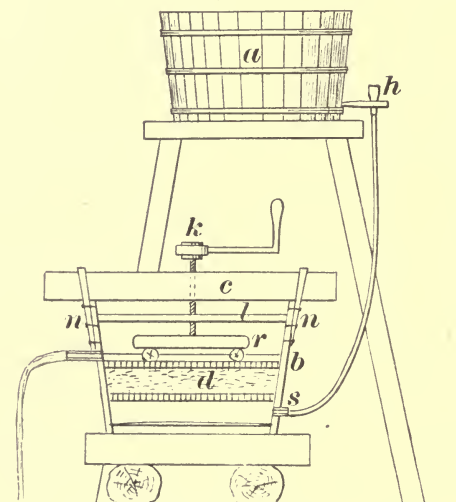


*Filtration of the Vinegar.*

The bodies suspended in the vinegar and causing its turbidity being very small, it takes some time before they settle on the bottom and the fluid becomes entirely clear. To accelerate clarification the vinegar is filtered.

Fig. 40 shows a filter suitable for the purpose. It consists of a small, strong wooden vat provided with two perforated false-bottoms, *s* and *b*. Upon the lower false-bottom is spread a linen cloth and upon it fine sand which is not attacked by acetic acid, or small pieces of charcoal. Upon the smoothed surface of the

Fig. 40.



Filter for Vinegar.

sand is spread a layer of paper pulp  $\frac{3}{4}$  to 1 inch deep which is covered with a linen cloth and then placed upon the false bottom *b*, the latter being forced down by means of the screw *k* and the pieces of wood *r*. The vinegar to be filtered is in the vat *a* which is connected with the filtering vat by the stop-cock *h* and the rubber hose *s* 8 to 10 feet long. By opening the stop-cock *h* the filter stands under the pressure of a column of fluid 8 to 10 feet high and the filtered vinegar runs off through an aperture in the side of the filtering vat. By filling the filter below the paper

pulp with fine bar sand the latter retains the greater portion of the solid bodies suspended in the vinegar, and it will be a considerable time before the pores of the paper pulp become choked up to such an extent as to require its renewal.

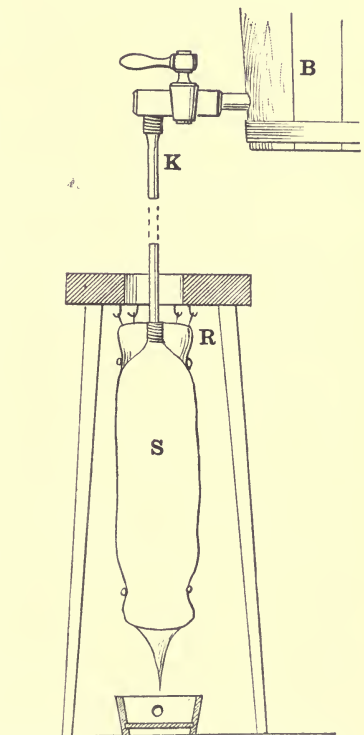
An arrangement suitable for filtering larger quantities of fluid under an increased pressure is shown in Fig. 41.

It consists of a strong linen bag, *S*, about 16 inches in diameter, and a jute or hemp hose, *R*, open at both ends and about 6 inches in diameter. The bag is tied by means of pack-thread to a cylindrical piece of wood which is secured to a suitable support. The bag is then connected by means of the rubber hose *K* with the reservoir *B*, which contains the vinegar to be filtered, and is placed about 10 to 13 feet above the support carrying the bag. The bag is folded so that it can be inserted in the hose *R*, the latter being also secured to the cylindrical piece of wood.

By slowly opening the stop-cock on the reservoir the bag is filled with vinegar, but being enveloped by the hose *R* cannot entirely expand but only as far as permitted by the diameter of *R*, so that though its entire surface acts as a filter a large number of folds are formed, and it is thus protected from bursting even under the pressure of a column of fluid of considerable height. The fluid filtering through the bag runs down on the hose and collects in a vessel placed under it.

At first this filter generally does not act entirely satisfactorily,

Fig. 41.



Bag Filter for Filtering Vinegar under Pressure.

the fluid running off turbid ; and this continues until the pores of the filter have become sufficiently contracted to retain the small bodies suspended in the fluid. This can, however, be remedied by stirring some charcoal powder into the first portion of vinegar to be filtered ; the charcoal powder adheres to the sides of the bag and contracts the pores of the tissue so that the fluid runs off entirely clear.

By subjecting the freshly-prepared vinegar to heating and filtering, a commercial article is obtained which is perfectly clear and does not spoil by keeping. By storing it, however, for some time in barrels it gains considerable in fineness of odor and taste. Wine-vinegar, cider-vinegar and fruit-vinegars in general should positively be stored for some time, the odoriferous bodies which make these varieties so valuable developing only by that means.

### *Sulphuring of Vinegar.*

Sulphuring has long been employed as the most convenient method for the preservation of wine, and, if correctly applied, can also be used for that of vinegar. But as sulphurous acid readily dissolves in vinegar the latter must not be brought in direct contact with the gases arising from the burning sulphur.

The sulphuring of vinegar is best executed as follows : The barrel intended for the reception of the vinegar is thoroughly rinsed and immediately placed in the store-room. Then place a sulphur match consisting of a strip of linen about 6 inches long and  $\frac{3}{4}$  to 1 inch broad dipped in melted sulphur, into a perforated sheet iron cylinder about 8 inches long and 1 inch in diameter, secure this cylinder to a wire, and after igniting the sulphur match lower it from the bunghole to the centre of the barrel. The sulphurous acid formed by the combustion of the sulphur is at once dissolved by the water adhering to the interior of the barrel. A sulphur match of the above size suffices for a barrel of 100 to 125 gallons.

¶ If the sulphured barrel be now immediately filled with vinegar, the sulphurous acid becomes distributed throughout the fluid and kills the vinegar ferment as well as all other ferments present, so that the vinegar cannot undergo any further change except it come again in contact with living ferments.



The sulphurous acid dissolved in the vinegar is after some time converted into sulphuric acid and its presence can be readily detected. It may, however, be remarked that the quantity of sulphuric acid reaching the vinegar in the above manner is an exceedingly small one, and, moreover, is partially fixed to the mineral bases (lime and magnesia) contained in the water used in the preparation of the alcoholic liquid. Hence a manufacturer who sulphurs his barrels need not fear being accused of having adulterated his vinegar by the direct addition of sulphuric acid. Sulphured vinegar must be stored at least several weeks before it is salable, the odor of sulphurous acid adhering to it perceptibly, and disappearing only at the rate at which the sulphurous acid is converted into sulphuric acid.

### *Fining of Vinegar.*

In a manner similar to that of wine, vinegar can be obtained bright by "fining" with isinglass. This method offers no advantages as compared with filtration, though it is employed by many manufacturers. The isinglass to be used is prepared as follows: One to two grammes (0.56 to 1.12 drachms) of isinglass per hectoliter (22 imp. gallons) are cut into narrow strips with the scissors and soaked in water in a porcelain dish for twenty-four hours. The jelly-like, nearly colorless mass is pressed through a linen cloth. A solution of 0.6 to 1.2 gramme (0.033 to 0.067 drachm) of tannin per hectoliter (22 imp. gallons) is then added to the isinglass and the mass diluted with vinegar. The whole is then thrown into the barrel and thoroughly mixed with the contents. The clarified vinegar is finally drawn off from the sediment.

### *Coloring Vinegar.*

Vinegar prepared from alcohol is either clear as water or only slightly colored. Before the general introduction of the quick process consumers were accustomed to the dark yellow product prepared from wine or beer, and many are still prejudiced against slightly-colored vinegar, considering it weaker. Unfounded as

this prejudice is, the manufacturer is nevertheless obliged to recognize it and color his vinegar by artificial means. This is best effected by caramel or burnt sugar prepared from glucose, which is entirely harmless. It is best prepared by melting the glucose in a shallow iron vessel over a fire, stirring constantly with a long-handled spoon. The melted mass soon browns and rises in the vessel. The conversion of the sugar into caramel being much hastened in the presence of an alkaline body,  $1\frac{1}{2}$  to 2 per cent. of the weight of the glucose used of pulverized ammonium carbonate is added at this stage. The mass is now heated with constant stirring until it becomes black, runs from the spoon in viscous, dark brown threads, and a sample dropped upon a cold surface congeals to a black mass impervious to light except on the edges. The vessel is then lifted from the fire and the contents poured out upon metal or stone plates. The taste of the congealed mass should not be bitter or at least only slightly so. On exposure to the air the caramel deliquesces to a thick black fluid, and, hence, it should immediately after its preparation be converted with water into a solution of the consistency of syrup, such concentrated solution keeping better than a dilute one which easily molds. Immediately before use the solution is diluted with water, and enough of it added to the vinegar to give it the desired coloration.

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## CHAPTER XVI.

### PREPARATION OF VINEGAR FROM VARIOUS MATERIALS.

SINCE acetic acid is formed by the oxidation of alcohol, vinegar can, of course, be prepared from every fluid containing alcohol, such as beer, wine, cider, as well as from the juice of sacchariferous fruits which has passed into alcoholic fermentation. By allowing grain to germinate, a body, to which the term diastase is applied, is formed which possesses the property of converting starch into fermentable sugar and dextrin when brought into contact with it under certain conditions. Vinegar can, therefore, be prepared from starch—though in a round-about way—by treating

the latter with grain containing diastase (malt), whereby it is converted into maltose and dextrin. This fluid (sweet mash) is compounded with yeast, and the sugar (and with a correct execution of the process the dextrin also) converted into alcohol by vinous fermentation. The resulting alcoholic liquid can then be used for the fabrication of vinegar.

Alcohol or spirits of wine obtained in the above-described manner from the starch contained in potatoes or grain being at present the chief material used in the manufacture of vinegar, the greater portion of the latter brought into commerce might actually be designated potato or malt vinegar according to the elementary material used. The great progress made in modern times in the fabrication of malt, brewing of beer, and in the distilling industry has been accompanied by a constantly extending division of labor. While formerly every brewer and distiller prepared his own malt, there are at present numerous establishments exclusively engaged in this branch of the industry which sell their product to the brewer and distiller. The manufacturer of vinegar who did not use materials containing finished alcohol (beer or wine) had to undertake the laborious work of fabricating the malt, and preparing and fermenting the mash in order to obtain an alcoholic liquid which he could finally convert into vinegar. With the present improvements in the fabrication of malt and the distilling of alcohol, the vinegar manufacturer can work more cheaply by buying the alcohol, and the manufacture of so-called malt or grain vinegar would pay only where heavy taxes prevent the direct use of alcohol.

Formerly, when, in consequence of defective processes, many a brewing or batch of malt spoiled it was used for the fabrication of vinegar. But, as a rule, the vinegar obtained was not of a fine taste and remained turbid, and besides the operation was frequently interrupted by all sorts of incidents, which led to the opinion of malt-vinegar not possessing keeping properties.

Beer-wort judged by its composition does not seem a suitable material for the fabrication of vinegar. Besides a certain quantity of fermentable sugar (maltose), it contains a considerable amount of dextrin and other fermentable bodies. For the purpose of the fabrication of vinegar the maltose alone can be considered, it

being the only fermentable constituent of beer-wort. Hence, vinegar prepared from beer-wort always contains a considerable quantity of dextrin and extractive substances, and, consequently, is of a more thickly-fluid nature than belongs to vinegar, and clarifies with difficulty. Moreover, this evil exerts a disturbing influence upon the behavior of the vinegar when stored, it being frequently changed by further processes of fermentation into a slimy fluid, and acquires an insipid taste and loses a large portion of its content of acetic acid.

Alcoholic mashes containing in consequence of faulty preparation a considerable quantity of dextrin show, when used for the fabrication of vinegar, a behavior similar to that of beer-wort; the vinegar obtained clarifies with difficulty and does not keep well. Fermented whiskey-mashes properly prepared contain, however, only very small quantities of dextrin and extractive substances, and, when freed by filtration from admixed husks, can be used as a material for the manufacture of vinegar and yield an entirely normal product.

According to experience, the process of the formation of vinegar proceeds in the most uniform manner by preparing the alcoholic liquid from dilute alcohol, and, consequently, in a vinegar factory connected with a distillery it would be best to dilute *non-rectified* spirits of wine with the required quantity of water and add from 10 to 20 per cent. of the weight of the alcoholic liquid of fermented mash. The latter containing salts and nitrogenous substances suitable for the nourishment of the vinegar ferment serves, in this case, as a substitute for the beer generally used in vinegar factories for the preparation of alcoholic liquid.

### *Manufacture of Vinegar from Malt and Grain.*

Under certain local conditions the manufacture of vinegar from malt, with or without an addition of grain, can be profitably carried on in connection with that of compressed yeast. Such factories being for evident reasons not established on an extensive scale, a description of the fabrication of vinegar in connection with that of compressed yeast without the use of expensive machinery will be given.

The preparation of the fundamental material, malt, requiring much labor and knowledge, it will be best for the manufacturer to buy the article already prepared. Malt kiln-dried at as low a temperature as possible and yielding a light-colored extract when treated with warm water should be chosen. Many malt houses prepare such malt especially for distilling purposes. Malt prepared for brewing purposes is after the actual kiln-drying heated to a temperature frequently exceeding  $158^{\circ}$  F. for the formation of certain aromatic combinations and coloring substances which are to impart to the beer a specific taste and dark coloration. Independently of the dark color of the vinegar prepared from such malt, it contains a considerable quantity of dextrin and consequently acquires an insipid by-taste, clarifies with difficulty, and is readily subject to injurious alterations. Malt, as is well known, contains diastase, which in mashing the malt with water effects the conversion of the starch into maltose and dextrin. By kiln-drying at a very high temperature a portion of the diastase is, however, rendered ineffective, and in mashing comparatively little maltose but a large quantity of dextrin is formed. Mashing, in this case, would have to be continued for a long time in order to obtain a larger quantity of maltose.

With the use of but slightly kiln-dried malt, in which the efficacy of the diastase has not been injured by a high temperature, the greatest directly obtainable quantity of maltose and the smallest amount of dextrin are procured. The proportion of maltose to dextrin is in this case as 4 : 1, or, in other words, the finished mash contains about 80 per cent. of maltose and 20 per cent. of dextrin. The dextrin cannot be directly converted into acetic acid by the vinegar ferment and consequently would be found in the finished product. It is, however, possible to treat the finished mash in such a manner that the total quantity of dextrin contained in it can be converted into maltose and the latter into alcohol. In this case the theoretically calculated yield of vinegar from the malt will be nearly approached in practice, and the product thus obtained contain only a small quantity of extractive substances of the malt which are not decomposed by alcoholic or acetous fermentation.

Before entering upon a description of the mashing process,



the theoretical part in mashing will be briefly discussed. Malt contains starch and diastase. By bringing the comminuted malt in contact with water of about  $131^{\circ}$  to  $133^{\circ}$  F. the starch is formed into paste and the diastase passes into solution. By the action of the diastase upon the starch the latter is converted into maltose and dextrin, the finished mash containing 80.9 per cent. of maltose and 19.1 of dextrin. For reasons given later on the finished mash is heated for a short time to  $140^{\circ}$  to  $140.8^{\circ}$  F., without, however, exceeding this temperature, and then cooled off to the degree required for the induction of alcoholic fermentation.

Mash prepared in this manner contains, besides the stated quantities of maltose and dextrin, *effective* diastase, *i. e.*, such as possesses the power of liquefying starch. (By heating to above  $158^{\circ}$  F. the diastase entirely loses this property.) By compounding a mash of this nature with yeast, the diastase with the simultaneous action of the yeast is able to convert all the dextrin present in the fluid into maltose, and, consequently, the total quantity of starch originally present is converted into alcohol by this peculiar process to which the term *after-effect of the diastase* has been applied.

The yield of acetic acid which can be obtained from a given quantity of malt can be calculated in a simple manner. Air-dried malt contains in round numbers about 68 per cent. of starch and dextrin. Theoretically 1 kilogramme of starch yields 71.612 liter per cent. of alcohol; in practice, however, only about 55 liter per cent., and, after deducting a loss of 15 per cent. during the conversion of alcohol into vinegar, the quantity of acetic acid which can be actually obtained from a given quantity of malt can be determined.

*Example:* What is the yield of 10 per cent. vinegar in working 500 kilogrammes of barley malt?

Five hundred kilogrammes of malt with 68 per cent. of starch (and dextrin) contain 340 kilogrammes of starch (and dextrin).

Three hundred and forty kilogrammes of starch (and dextrin) give (with a yield of 55 per cent.) 18.700 liters per cent. of alcohol.

One hundred and eighty seven liters of alcohol (specific gravity at  $59^{\circ}$  F. = 0.795) are equal to 148.665 kilogrammes of alcohol.



One hundred kilogrammes yield, according to theory, 130.4 kilogrammes of acetic acid; in practice, after deducting a loss of 15 per cent. during the formation of vinegar, 110.84 kilogrammes.

148.665 kilogrammes of alcohol (15 per cent. of loss) yield 164.78 kilogrammes of 100 per cent. acetic acid.

164.78 kilogrammes of (100 per cent.) acetic acid yield in round numbers 1647 liters of 10 per cent. vinegar.

The above calculation is, however, only approximately correct, as all the losses occurring in practice cannot be determined with complete accuracy.

Unmalted grain being cheaper than malt and the latter containing sufficient diastase to convert a very large quantity of starch into maltose and dextrin, a mixture of malt and unmalted grain (equal parts of both;  $\frac{2}{3}$  grain and  $\frac{1}{3}$  malt, etc.) can be used instead of malt alone. The latter is, however, preferable for the manufacture of vinegar, it yielding a product of a finer taste than unmalted grain. The mode of preparing the mash is exactly the same as for the distillation of alcohol, and as the necessary information can be obtained from any treatise on that subject only a brief sketch of the operation will be given here.

The malt carefully ground is mixed with cold water to a thin paste which is stirred until all small lumps are dissolved. This mixing of the ground malt with water, or *doughing in* as it is called, can be effected with the assistance of a crutch or rake, but best in a vat provided with a mechanical stirring apparatus.

Doughing in being finished, water of 140° to 149° F. is permitted to run in until the mash shows a temperature of about 131° to 133° F. During this operation the mash should be constantly stirred. The at first thickly-fluid mass will soon be observed to become thinly-fluid by the starch paste being converted into soluble bodies. Mashing is finished in 2 to 2½ hours, and will be the more complete the more accurately the temperature is maintained at 131° to 133° F. The completion of the process is recognized by a filtered sample cooled to the ordinary temperature remaining colorless after the addition of iodine solution.

The mash having reached this state, sufficient hot water is added with constant stirring to raise the temperature to 140° or 141.8° F.

The purpose of this operation is to render all ferments present in the mash ineffective. Lactic acid ferment and frequently also butyric acid ferment always adhere to the malt, and, if allowed to develop in the mash, would form lactic and butyric acids during fermentation which would be injurious to the process of alcoholic fermentation as well as to the properties of the vinegar to be manufactured. The mash is now reduced to a temperature of about  $57^{\circ}$  or  $59^{\circ}$  F. by bringing it into the cooling-back or passing it through a system of refrigerating pipes. When working on a small scale the mash can be suitably cooled by allowing cold water to pass through a coil placed in the vat containing it.

The strength of the vinegar to be manufactured depends on the concentration of the mash; mashings showing a saccharometer statement of 20 per cent. contain after fermentation about  $9\frac{1}{2}$  per cent. of alcohol which yields vinegar of about 8 per cent.; mashings showing 18 per cent. yield vinegar of about 7 per cent., so that 1 per cent. of acetic acid in the vinegar may be calculated on for about every  $2\frac{1}{2}$  degrees indicated by the saccharometer.

The mash is now set with yeast, though the latter may be added when the mash still shows a temperature of  $71.5^{\circ}$  to  $75^{\circ}$  F., the yeast having then time to vigorously augment. Mashings prepared from malt alone are uncommonly rich in nourishing substances for the yeast, the latter augmenting abundantly and inducing a very vigorous process of fermentation. This can be profitably utilized by combining the manufacture of vinegar and that of compressed yeast, a valuable product being thus obtained without any extra expense and with but little labor. At a certain stage of the alcoholic fermentation the yeast comes to the surface of the fluid and can be lifted off. By washing the yeast once or twice with cold water and then freeing it from the excess of water by pressing, compressed yeast is obtained which, with the exception of the portion to be used for setting fresh mashings, can be sold.

Up to the completion of alcoholic fermentation the treatment of the mash, as can be seen from the preceding description, does not essentially differ from that to which mashings for the manufacture of alcohol are subjected. If, however, the completely fermented "ripe" mash is to be used for the fabrication of vinegar,

it should be subjected to a special treatment the object of which is to prepare a fluid containing no living yeast.

By filtering the mash through a closely woven linen cloth the particles of malt-husks, etc., are retained but not the cells of alcoholic ferment which may be present and which, on account of their minuteness, are difficult to separate from the fluid by filtration. It is, therefore, best to heat the mash before filtration to about  $140^{\circ}$  F. whereby the ferment is killed and at the same time a certain quantity of the albuminous substances dissolved in the fluid rendered insoluble and separated. The heating of the mash is best effected by passing it through a coil of tin-pipe placed in a boiler filled with water kept constantly boiling. The temperature of the fluid can be readily regulated by increasing or decreasing the velocity with which it passes through the coil. If the fluid heated to  $140^{\circ}$  F. were allowed to cool in the air, a large portion of the alcohol contained in it would be lost by evaporation, and it is therefore allowed, after heating, to pass through a second coil of pipe which is surrounded by cold water whereby it is cooled to at least  $86^{\circ}$  F. This fluid is then filtered through a linen bag, it being repeatedly poured back into the filter until it runs off sufficiently clear. It will not, however, be obtained perfectly clear in this manner, the yeast cells being too minute to be retained by such a filter, but having been killed by heating, their presence in the fluid is connected with no disadvantage.

By mixing the filtered fluid with from 10 to 15 per cent. of its volume of vinegar, an alcoholic liquid is obtained which can be worked in the usual manner in the quick-process generators, and yields an agreeable aromatic vinegar which clarifies rapidly and improves by storing.

According to the slow process, the fermented malt-wort is run into casks placed in apartments called "stoves," since they are heated by stoves or steam at a temperature ranging from  $70^{\circ}$  to  $80^{\circ}$  F. The casks are arranged in parallel rows, resting upon long wooden beams elevated about 18 inches from the ground, and having their bungs uppermost while a small hole on top of the front head of each causes the circulation of air.

A large saving of labor will be effected by connecting elevated tanks holding the fermented wort with pipes and movable flexible

hose which will allow of the rapid and easy filling of the casks. The vinegar produced is siphoned off into inclined troughs, which deliver it to a central underground tank, from which it is pumped into the storing tanks.

Malt vinegar generally contains a great deal of mucilaginous matter difficult to settle, preventing its keeping, while giving nourishment to vinegar eels. It is therefore necessary to filter it, and for this purpose it is pumped into the *refining* or *rape* vessels. These vessels are often filled with wood shavings, straw, or spent tanner's wood, but nothing acts so well in producing by filtration a clear bright vinegar as the stalks and skins of grapes or raisins technically called "*rape*." Where there is power and a large quantity of vinegar is manufactured, the filtering is effected under a considerable hydrostatic pressure. The rape is placed in a closed vessel between two false perforated bottoms. A circuit of pipes is connected at the lower and upper part of the vessel, and by means of a pump the vinegar is made to pass again and again through the rape.

This mode of manufacture is frequently effected by "*fielding*." In this case, as the term implies, the process is conducted in the open air. The casks rest on strong frames  $1\frac{1}{2}$  feet high, being supported by firm pillars of brick-work or wood. The operation generally begins in spring and continues during the summer. The fermented liquor is run into the casks by the bung-holes, the latter being left open in dry and loosely covered with a tile in wet weather. Gradually the alcohol of the "*gyle*," as the fermented liquor is called, becomes oxidated, and acetic acid is produced, of course simultaneously affording vinegar. The latter is then drawn off and transferred to the refining or rape vessels where it passes through the process of filtration already described.

In some factories large quantities of sour ale and beer are converted by similar processes into vinegar, but the product is much inferior to the vinegar made from malt-wort. The large amount of nitrogenous and other extractive substances which those liquids contain undergoes a second or putrid fermentation after the alcohol has been oxidized into acetic acid, and in doing so reacts upon the acid, leaving a liquid of a disagreeable odor slightly resembling very stale beer. By the addition of sulphuric acid this

second fermentation is postponed for some time, but the vinegar has nevertheless a nauseous smell which renders it objectionable.

### *Preparation of Vinegar from Sugar-Beets.*

The juice of the sugar-beet contains a considerable quantity of cane sugar and is readily brought into alcoholic fermentation, so that seemingly this root would form a very suitable material for the fabrication of vinegar. Sugar-beets contain on an average 12 per cent. of cane sugar, the latter yielding, when completely fermented, a fluid containing about  $6\frac{1}{2}$  per cent. by weight of alcohol; a fluid with this percentage of alcohol yields vinegar with 6 per cent. of acetic acid.

Besides sugar the juice of the beet-root contains, however, a large number of other substances which exert an influence upon the course of alcoholic fermentation, and, besides alcohol, a large quantity of fusel oils is formed so that the alcohol has to be thoroughly rectified before it is fit for use. The fermented beet-root juice itself has, however, a disagreeable taste and odor, and the vinegar prepared from it showing similar properties will not be fit for household purposes until a remedy for these evils is found. Numerous experiments made for the purpose of freeing beet-root vinegar from the substances which impart to it the disagreeable odor and taste have given no favorable results; filtering through charcoal and even distilling the vinegar and treating the distilled product with strongly oxidizing bodies do not produce the desired effect. From these experiments it would seem impossible to directly obtain from sugar-beets vinegar fit for household use.

### *Vinegar from Sugar, Fruits, and Berries.*

By fermenting sugar solution with pure yeast and pouring off the clear alcoholic fluid, the latter shows a slightly acid reaction (from succinic acid), but is not converted into vinegar even if standing for several weeks in the most suitable temperature, because the vinegar ferment is wanting. By adding, however, an excess of yeast so that it remains partially suspended in the fluid,



which can be effected by the addition of solution of gum or starch paste, the nourishment for the spores of the vinegar ferment reaching the fluid from the air is provided and acetification takes place.

Cadet-Gassicourt advises the fermentation together of 124 parts of sugar, 868 of water, and 80 of yeast, and to filter after one month. Or, according to another formula: sugar 245 parts, gum 61, water 2145, yeast 20. Allow to ferment at 68° F. Fermentation begins the same day and is completed in 15.

Doebereiner gives the following directions: Dissolve 10 lbs. of sugar in 180 quarts of hot water, add 6 lbs. of pulverized crude tartar (it dissolves only partially), and after cooling to 77° F. induce fermentation by  $4\frac{1}{2}$  quarts of beer yeast. In about 8 days, when fermentation is finished, add about 15 quarts of spirits of wine of at least 50 per cent. Tr. or 8 quarts of alcohol of 90 per cent. Tr., and bring the mixture into the acetifying vessel. This fluid would also be suitable for the quick process.

For making vinegar on a small scale for domestic use, brown sugar with water alone, or sugar with raisins, currants, and especially ripe gooseberries, may be used. These should be mixed in the proportions which would give a strong wine, put into a small barrel filled to about three-fourths of its capacity, with the bung-hole very loosely stopped. Some yeast should be put in and the barrel set in the sun in summer or a little way from the fire in winter, and fermentation will soon begin. This should be kept up constantly, but moderately, till the taste and smell indicate that the vinegar is complete. It should then be poured off clear, and bottled carefully. It will keep much better if it is boiled for a minute, cooled, and strained before bottling.

With the exception of apples and pears, the different varieties of fruit cannot be had in such abundance as that they could be used for the manufacture of vinegar on a large scale, and hence only a brief description of their utilization for that purpose will be given.

It is characteristic of most of our varieties of fruits, and especially of berries, that in proportion to their content of sugar they have a much greater content of free acids than grapes, and this circumstance must be taken into consideration, as otherwise wine



would be obtained which contains a considerable quantity of unfermented sugar. The following table shows the average content of sugar and free acid in the most common varieties of fruits :—

	Sugar.	Free acid calculated as malic acid.
Cherries . . . . .	10.00	—
Apples . . . . .	6.25 to 13.99	0.691
Pears . . . . .	8.78	—
Currants . . . . .	6.40	2.147
Strawberries . . . . .	5.09 to 11.31	1.363
Gooseberries . . . . .	6.93	1.603
Bilberries . . . . .	5.78	1.341
Raspberries . . . . .	4.02	1.484
Blackberries . . . . .	4.44	1.188

According to the above table, currants, gooseberries, raspberries, etc., contain on an average scarcely 6 per cent. of sugar, and consequently their juice, after complete fermentation, would give a fluid with about 3 per cent. of alcohol, from which vinegar with about  $2\frac{1}{2}$  per cent. of acetic acid could be obtained. Such vinegar being, however, too weak, those berries would not seem suitable for the direct preparation of vinegar. Moreover, the complete fermentation of the juice of most berries is very difficult, the free acids, among which malic acid preponderates, exerting an injurious influence upon the progress of fermentation.

Vinous fluids of an agreeable taste can, however, be prepared from berries, and from them an aromatic and finely flavored vinegar, by decreasing the content of acid in the juice and increasing that of sugar. The juice of currants, as seen from the above table, contains in round numbers 6 per cent. of sugar and 2 per cent. of malic acid. By diluting this juice with an equal volume of water a fluid containing 3 per cent. of sugar and 1 per cent. of acid is obtained, and the content of the former can be increased at will by the direct addition of sugar.

By compounding, for instance, 100 quarts of currant juice with 100 quarts of water and adding 34 lbs. of sugar, the resulting fluid contains about 20 per cent. of sugar and after complete fermentation gives a fluid with about 9.5 per cent. of alcohol, which yields vinegar of nearly 9 per cent. strength. The taste of this

vinegar is, however, stronger and more agreeably acid than that of vinegar from alcohol, it containing besides acetic acid about 1 per cent. of malic acid. Moreover, vinegar obtained from berries contains a certain quantity of extractive substances and odoriferous products of fermentation, so that it possesses an agreeable bouquet and thus appears more valuable than the ordinary product.

In many regions bilberries grow in abundance and can be bought very cheap. Treated in the above manner they yield an excellent vinegar, possessing, however, a somewhat harsh by-taste, due to the tannin contained in the berries. The latter can be removed from the fermented fluid before using it for the preparation of vinegar by compounding it when quite clear with gelatine solution or fresh white of egg, both forming insoluble combinations with the tannin, which separate in the form of flakes.

In regard to the preparation of vinegar from berries it remains to be remarked that, after pressing the bruised berries, the juice is compounded with water and sugar and at once brought into fermentation by the addition of yeast (best fresh wine-yeast, or if this be wanting, compressed yeast divided in water). Fermentation should take place at quite a high temperature, 68° to 72° F. The separated yeast is carefully removed from the fermented liquid and the latter stored away in barrels kept constantly filled up to the bung or at once used for the preparation of vinegar. By converting fruit-wine into vinegar by means of the vinegar ferment floating upon the fluid a much finer product is obtained than by the quick process.

### *Cider Vinegar.*

Cider, as is well known, is the sparkling liquid which is prepared by fermenting the juice of apples ground in a mill. The manufacture of cider will be described in another portion of this work, and, hence, only its utilization for the preparation of vinegar will be given here.

The preparation of vinegar from good cider is not difficult, the process of acetification by means of the vinegar ferment floating upon the surface yielding an aromatic product of a fine flavor

which is nearly of as good a quality as wine vinegar. On account of its content of malic acid, the vinegar is more acid than ordinary vinegar with the same content of acetic acid. But in order to produce cider vinegar of the first quality one must have good cider ; vinegar made of watered cider will be thin and weak.

S. E. Todd\* describes a simple contrivance for making cider vinegar. A kind of cupboard is made of inch boards about  $3\frac{1}{2}$  feet high by seven feet long. Inside of this box fit shelves about  $3\frac{1}{2}$  inches apart. On the upper side of these shelves gouge out channels running nearly from one end to the other until the upper side is covered with zigzag grooves running from end to end. There should be cleats fastened to the under side of each shelf to prevent it from warping ; and the cleats should be put on with screws. The channel must be made slightly slanting. The top shelf must slant so as to be about two inches lower than the other side, and the shelf below it should slant about two inches in the opposite direction. By this arrangement a long zigzag channel is made for the liquid to flow in. At its end, in the upper shelf, bore a hole through so that the vinegar may drop to the next shelf and traverse the channel. Thus it continues to flow from end to end until it has reached the end of the channel in the lower shelf, when it falls into a receptacle. When commencing to make vinegar in this manner, place the apparatus in some small room and keep the temperature about  $90^{\circ}$  or  $95^{\circ}$  F. Have a barrel, or tub, or hogshead placed a little higher than the box and near the end where the first channel commences in the top shelf. In this barrel have a faucet so that you can regulate the amount of cider which it is designed to have flow in the channel. The aim should be to keep a very small stream moving gently through the apparatus, affording every drop ample time and opportunity to absorb the desired amount of oxygen before the liquid reaches the end of the channel in the last shelf. A few gallons, or a half barrel of good strong vinegar should be run through first, so that the shelves will be well acidulated before letting other mixtures run through. It is a good idea to add one-third or one-fourth of good vinegar to any mixture of

\* "The Apple Culturist." New York, 1871.

cider before allowing it to run through the apparatus. Open the faucet so that a stream not larger than a straw shall fall into the channel of the top shelf. As it falls through the last hole into the barrel placed below the apparatus, the cider will have changed to strong and pure vinegar. When once started the process must continue night and day until the supply fails. In warm weather no fire will be required in the vinegar apartment, which should be well supplied with fresh air to facilitate oxidation. If the liquid is allowed to flow too rapidly, it will not have time to oxidize.

*Vinegar from apple-pomace.*—After the cider has been extracted and the cheese removed from the press, the pomace may be placed in a pile upon a suitably-constructed platform and allowed to ferment. In the course of a few days considerable heat will be evolved; at this time a few pails of warm water (not boiling) should be poured upon the pile and in the course of twenty-four hours the pomace will be in a proper condition to grind. It should then be run through a grater-mill and relaid upon the press in a cheese in the same manner as originally laid in cider making, when it may be subjected to heavy pressure until the liquid contained in the cheese be extracted. This liquid may then be exposed in shallow open casks in a warm room and in a short time will be found good vinegar. Or, the liquid may be immediately passed through a generator.

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## CHAPTER XVII.

### PREPARATION OF VINEGAR SPECIALTIES.

THESE specialties may be divided into two groups: into those with a specific odor, and those with a specific odor and taste. As an example for both kinds we will take tarragon (dragon's-wort) vinegar. If it is prepared by simply dissolving in the vinegar the volatile oil of dragon's-wort (*Artemisia dracunculus*), obtained by distillation with water, the product is simply *perfumed* vinegar, the odor of the volatile oil being mixed with that of the acetic acid, but the taste remains unchanged. If, however, the fresh

leaves of the plant are macerated with vinegar, not only the volatile oil is dissolved but also certain extractive substances peculiar to this plant, and the taste of the vinegar is also changed; the product in this case being *aromatized* vinegar.

By dissolving in vinegar oil of roses or rosewater (perfumed) rose vinegar is obtained; by treating raspberries with vinegar the latter absorbs not only the odoriferous substances of the raspberries, but also the non-odoriferous extractive substances, and the product is aromatized vinegar.

By skillful manipulation every volatile oil can be dissolved in vinegar, and consequently as many different varieties of perfumed vinegar can be prepared as there are volatile oils. In fact perfumers prepare a number of such varieties which contain one or more volatile oils whose odors harmonize and are sold as volatile spirit of vinegar, fumigating vinegar, etc. Such vinegars can be prepared in various ways, the finest odors being, however, obtained by distilling the fresh parts of the plants with water and mixing the distillate, which actually represents a solution of the volatile oil in water, with strong vinegar. The finest rose vinegar, orange blossom vinegar, etc., are prepared in this manner.

For this rather tedious process of preparing perfumed vinegar, the one in which *freshly* prepared volatile oils are used may be advantageously substituted. To be sure the volatile oils dissolve only sparingly in vinegar, but sufficiently so to impart their characteristic odor to it. By using an excess of volatile oil it does not dissolve, but distributes itself in fine drops throughout the vinegar, rendering the latter opalescent, so that fining with tannin and isinglass is necessary to make it bright again.

This evil can be avoided by a simple manipulation which is based upon the fact that a body dissolving with difficulty dissolves the more readily the greater the surface it offers to the solvent.

Prepare glass-powder as fine as the best wheat flour by heating pieces of glass, throwing them into cold water, and pulverizing and elutriating in a mortar. By the sudden cooling the glass becomes so brittle that it can be readily converted into a fine powder. Bring a suitable quantity of this powder into a porcelain dish and drop volatile oil upon it with constant rubbing until it is uniformly moistened. Pour the vinegar to be perfumed upon

this glass powder and stir gently with the pestle. The fluid is then poured into the barrel intended for the reception of the perfumed vinegar and a fresh quantity of vinegar poured upon the glass-powder, this being continued until all the glass-powder has been brought into the barrel by stirring and pouring over fresh vinegar. The barrel is then entirely filled with vinegar, and after being closed, rolled in order to effect a uniform mixture of its contents. It is then allowed to rest for a few days for the glass-powder to settle. The entirely clear perfumed vinegar is then drawn off into bottles, which are to be kept in a dark cool room, the odor of the volatile oil being injured by light and heat.

For the preparation of volatile fumigating or toilet vinegars it is best to dissolve the volatile oils in uncolored vinegar prepared from alcoholic liquid. Where the remaining of a small residue after the volatilization of the perfumed vinegar is of no importance, pulverized sugar may be substituted for the glass powder, as it acts in the same manner; the only difference is that the glass-powder being an insoluble body falls to the bottom of the barrel, while the sugar dissolves together with the volatile oil in the vinegar.

By the above-described process perfumed vinegars with the odor of dragon's-wort, peppermint, anise, rose, etc. etc., may be prepared, and by a suitable mixture of those whose odors harmonize a great number of fumigating and toilet vinegars.

The preparation of aromatized vinegars by means of the extractive substances of plants is very simple. The parts of plants to be extracted are placed in a suitable vessel, a barrel or large flask, and after pouring vinegar over them and closing the vessel, are allowed to rest for a few weeks in a moderately warm room. In case glass vessels are used they have to be kept in a dark room, light exerting an injurious influence upon the odors. The vegetable substances used for aromatizing vinegar containing, as a rule, a large quantity of water, strong vinegar (with 10 to 11 per cent. acetic acid) should be used.

In the following a few formulæ for toilet and table vinegars are given :—



*Toilet Vinegars.*

*Mohr's volatile spirits of vinegar.* Equal parts of acetic acid and acetic ether perfumed with a few drops of oil of cloves.

*Aromatic vinegar.* Concentrated acetic acid 8 ounces, oil of lavender 2 drachms, oils of rosemary and cloves each 1 drachm, oil of camphor 1 ounce.

First dissolve the bruised camphor in the acetic acid, then add the perfumes; after standing for a few days with occasional agitation it is strained and is then ready for use.

*Henry's vinegar.* Dried leaves of rosemary, rue, wormwood, sage, mint, and lavender flowers each 1 ounce, bruised nutmeg, cloves, angelica root and camphor, each  $\frac{1}{2}$  ounce, alcohol (rectified) 8 ounces, concentrated acetic acid 32 ounces.

Macerate the materials for a day in the alcohol; then add the acid and digest for a week longer at a temperature of about 59° F. Finally press out the now aromatized vinegar and filter it.

*Vinaigre des quatre voleurs.* Fresh taps of common wormwood, Roman wormwood, rosemary, sage, mint and rue each  $\frac{3}{4}$  ounce, lavender flowers 1 ounce, garlic, calamus aromaticus, cinnamon, cloves, and nutmeg each 1 drachm, camphor  $\frac{1}{2}$  ounce, alcohol or brandy 1 ounce, strong vinegar 4 pints.

Digest all the materials, except the camphor and spirit, in a closely covered vessel, for a fortnight, at summer heat; then express and filter the vinegar produced and add the camphor previously dissolved in the brandy or alcohol.

*Hygienic or preventive vinegar.* Brandy 1 pint, oils of cloves and lavender each 1 drachm, oil of marjoram  $\frac{1}{2}$  drachm, gum benzoin 1 ounce.

Macerate these together for a few hours, then add 2 pints of brown vinegar and strain or filter.

*Cosmetic vinegar.* Alcohol 1 quart, gum benzoin 3 ounces, concentrated aromatic vinegar 1 ounce, balsam of Peru 1 ounce, oil of neroli 1 drachm, oil of nutmeg  $\frac{1}{2}$  drachm.

*Table Vinegars.*

*Anise vinegar.* Convert into a coarse powder anise seed 5 parts, caraway seed  $\frac{3}{8}$ , fennel and coriander seed each  $\frac{1}{3}$ , pour 5 parts of alcohol and 45 parts of strong vinegar over the powders, close the vessel air-tight and let the whole digest in a warm place for 6 to 8 days, shaking frequently. Then strain the liquid off, press out the residue, filter the vinegar, and put it up in bottles.

*Anchovy vinegar.* Reduce 1 pound of boned anchovies to a pulp in a mortar and pass the mass through a hair-sieve. The bones and parts which do not pass through the sieve are boiled for 15 minutes in a pint of water and strained. To the strained liquor add  $2\frac{1}{2}$  ounces of salt and the same quantity of flour together with the pulped anchovies, and allow the whole to simmer for 3 or 4 minutes; as soon as the mixture is cold add  $\frac{1}{4}$  pint of strong vinegar.

*Tarragon vinegar.* Pick the young tender leaves of dragon's-wort (*Artemisia dracunculus*) when the first flower-buds appear. Bruise the leaves, place them in a suitable vessel, pour good wine-vinegar over them, and let the whole stand for a few days. Then strain the vinegar through a cloth, filter and bottle. The bottles must be filled entirely full, as otherwise the vinegar will not keep.

*Compound tarragon vinegar.*—Comminute leaves of dragon's-wort 100 parts, common bean leaves 25, leaves of basil and marjoram each  $12\frac{1}{2}$ , bay leaves and orris root each 25, cloves  $3\frac{1}{3}$ , cinnamon  $6\frac{1}{2}$ , and shallots 25. Put all in a suitable vessel, pour 700 to 750 parts of pure, strong vinegar over it, let it stand in a warm place and digest 5 or 6 days, frequently agitating it. Then strain the vinegar through linen, press out the residue, add 25 parts of alcohol, and filter. Keep the vinegar in well-corked bottles in a cool, dark place.

*Effervescing vinegar.*—Dissolve 500 parts of loaf sugar in 5000 parts of water, add lemon juice and rind cut up in the proportion of 1 lemon to 1 lb. of sugar,  $1\frac{1}{2}$  parts of the best cinnamon, and 12 parts of beer yeast thoroughly washed. Place the whole in a barrel, and after agitating it thoroughly let it ferment at a temperature of  $55^{\circ}$  to  $60^{\circ}$  F. When fermentation has ceased the vinous fluid is strained and mixed with 1000 parts of best wine-

vinegar, previously boiled up, and yeast in the proportion of 1 spoonful to 5 lbs. of sugar. The fluid is then distributed in several earthenware pots and exposed to a temperature of  $77^{\circ}$  to  $88^{\circ}$  F. until it has been converted into strong vinegar. This, while remaining in the pots, is mixed with 200 parts of French brandy and after two days bottled in small bottles. To each pound of this vinegar are added  $\frac{2}{5}$  part of crystallized tartaric acid, pulverized, and  $\frac{1}{2}$  part of bicarbonate of soda. The bottles, as soon as the respective portion of the mixture has been added to each, must be corked as quickly as possible and then stored in a cool place.

*Herb vinegar.*—Chop fine the leaves of marjoram and thyme each  $13\frac{1}{3}$  parts, common bean leaves  $6\frac{1}{2}$ , leaves of mint, basil, and celery each  $3\frac{1}{3}$ , and fresh shallots  $1\frac{1}{2}$ . Pour 600 or 700 parts of good vinegar over the herbs and treat in the same manner as given for compound tarragon vinegar.

*Pine-apple vinegar.*—This excellent vinegar soon loses its flavor, and it is therefore best to prepare a small quantity at a time and keep in bottles closed air-tight.

Bruise the slices of pine-apple and pour over them a considerable quantity of vinegar. Close the vessel air-tight and let it stand 12 hours; then pour off the vinegar and filter.

*Celery vinegar.*—Celery seed  $4\frac{1}{2}$  ozs., vinegar 1 pint. Digest 14 days; filter.

*Clove vinegar.*—Cloves  $3\frac{1}{2}$  ozs., vinegar 1 pint. Digest 7 days and strain.

*Mustard vinegar.*—Black mustard seeds 2 ozs., vinegar 1 pint. Digest one week and filter.

*Lovage vinegar.*—Lovage root 2 ozs., lovage seed 1 oz., vinegar 10 ozs. Digest one week and filter.

### *Preparation of Acetic Ether.*

Among the numerous combinations into which acetic acid enters with other bodies, acetic ether is of special value for the vinegar manufacturer, it being directly used in the fabrication of vinegar. It is readily formed on alcohol coming in contact with acetic acid, and it would seem with special ease when the latter

is in a nascent state. Hence a small quantity of it is found in nearly all red wines not prepared by fermentation in closed vats, its presence being due to the formation of a small quantity of acetic acid from the alcohol, which immediately combines with the ethyl oxide or ether.

In vinegar containing a small quantity of unchanged alcohol some acetic ether formed by the conversion of this alcohol into acetic acid is always present, and imparting a very delicate and agreeable bouquet to the vinegar, it is recommended to conduct the fabrication of a fine article so that it contains a small quantity of it.

It is, however, not absolutely necessary to leave a small quantity of alcohol in the vinegar, as either acetic ether or alcohol can be directly added to the finished product. But in both cases the vinegar has to be stored for several weeks; in the first, for the purpose of harmonizing the odors of acetic ether and of acetic acid, and in the latter, for the formation of acetic ether.

A fluid quite rich in acetic ether and very suitable for imparting bouquet to table vinegar can in a very simple manner be prepared by mixing in a flask one volume of highly concentrated acetic acid with two volumes of 95 or 96 per cent. alcohol, and after closing the flask air-tight, allowing the fluid to stand in a warm room for several months. The resulting fluid is used as an addition to the vinegar whose odor is to be improved. Entirely pure acetic ether is best prepared in the following manner: To 9 parts of concentrated sulphuric acid 3.6 parts of commercial absolute alcohol are added by means of a funnel tube which reaches to the bottom of the vessel, at the same time keeping the liquid well stirred. After standing for 24 hours this mixture is added to 6 parts of sodium acetate which has previously been fused and broken into small fragments, and after 12 hours the mixture is distilled. Thus 6 parts of pure acetic ether are obtained, from which, by rectifying over calcium chloride, all traces of water are removed.

Pure acetic ether or ethyl acetate has the composition  $\left. \begin{array}{l} \text{C}_2\text{H}_5\text{O} \\ \text{C}_2\text{H}_3\text{O} \end{array} \right\}$  and represents a fluid clear as water with an agreeable but stupefying odor. Its specific gravity is 0.932 and it boils at  $165.2^\circ \text{F}$ .

On account of its volatility it has to be kept in well-stoppered bottles, best in a cool place.

About  $3\frac{1}{2}$  to 7 ozs. of acetic ether suffice for the improvement of the odor of 100 quarts of vinegar.

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## CHAPTER XVIII.

### FABRICATION OF WINE-VINEGAR.

WINE being an alcoholic liquid with a content of alcohol varying between 6 and 14 per cent. evidently furnishes an excellent material for the fabrication of vinegar. However, only in rare cases wine still palatable is used, the chief supply for this purpose being derived from wine, especially wines with from 8 to 9 per cent. of alcohol, which have deteriorated on account of incorrect treatment in the cellar and consequently have become unsalable as a beverage. Stronger wines are less difficult to keep in the cellar, and in case they should spoil and become unfit for a beverage can be more profitably utilized in the fabrication of cognac.

Wine-vinegar differs from the ordinary varieties not only in containing, besides peculiar extractive substances, tartaric acid, tartrates, etc., but also in possessing a very agreeable odor due to the change of the odoriferous substances contained in the wine.

In wine-growing countries large sums are annually lost on account of spoiled wine, the latter being generally sold at a very low price to vinegar factories, where it is worked as alcoholic liquid either by itself or in connection with other materials. On account of the process used the quality of the resulting product is not what it should be, the wine being worked into vinegar either in quick-process generators or by a method to be described later on, to which the term "vinegar boiling" may be applied. Vinegar, to be sure, is obtained in both cases, but the product is not especially fine, because wine-vinegar of an excellent quality can only be prepared by not allowing the process of oxidation to

proceed too rapidly and preventing the appearance of other fermenting processes besides that of acetous fermentation.

Every vinegar, no matter from what kind of raw material it may have been prepared, acquires a finer odor by storing; and this is especially the case with wine-vinegar, which, when freshly made, has not an agreeable, but rather an unpleasant and stupefying, odor. By storing such vinegar in an apartment in which the ordinary temperature of a living room prevails, it acquires in the course of a few weeks an agreeable bouquet, which, similar to that of wine, increases in fineness for a certain time, and can be preserved unchanged for a long time by excluding the air and storing in a cool room; finally, however, it decreases.

Drinkable wine can be profitably used for the manufacture of vinegar only in countries where, in consequence of a very abundant harvest, it can be bought at astonishingly low prices, as for instance in Hungary, where a hectoliter (22 imp. gallons) of ordinary wine can in some seasons be bought for a few dollars. Otherwise only spoiled or "sick" wines, which are cheap enough, are used for the purpose.

The term "sick" is generally applied to wines in which alterations take place by the activity of a certain ferment, which when progressed to a certain degree renders the wine unfit for a beverage. "Turning sour" is, for instance, a sickness frequently occurring in wines poor in alcohol; it manifests itself by the development of large masses of a certain ferment which quickly destroys the tartaric acid contained in the wine. Another sickness chiefly occurring in red wines is the so-called "turning bitter," the wine, as the term implies, acquiring in a short time by the action of a peculiar ferment such a disagreeable bitter taste as to render it absolutely unfit for drinking. Such wine cannot be used even for vinegar, the latter showing the same disagreeable bitter taste. Wine attacked by what is called "lactic acid degeneration" can be used for the manufacture of vinegar, but yields a product of very inferior quality, because on the wine being subjected to acetous fermentation the lactic acid contained in it is readily converted into butyric acid, which possesses a disagreeable rancid odor completely killing the pleasant aroma of the bouquet substances. There only remains as a material



actually fit for the preparation of wine-vinegar, wine attacked by "acetous degeneration," *i. e.*, wine already so much changed by the vinegar ferment as to render it unfit for a beverage, and, further, wine which though not sick is unsound, showing a taste of mold, of the barrel, etc.

Wine no longer young and not overly rich in alcohol is especially adapted for the nourishment of the vinegar ferment. Such wine need only be exposed to a somewhat higher temperature in order to induce acetous fermentation, which, if not disturbed in its progress, will finally convert all the alcohol in the wine to acetic acid.

It may here be remarked that every normal wine always contains, besides the bodies belonging to the series of fatty acids, acetic acid, though only about a few ten-thousandths of its weight. By storing the wine, the acetic acid does not increase, but becomes rather less, it being consumed in the formation of compound ethers. Hence, a rapid increase of the acetic acid is an indication of the wine being attacked by acetous degeneration, and if examined with the microscope the ferment characteristic of acetous fermentation will be found upon its surface. Many remedies have been proposed for the cure of acetous degeneration, but none of them is of any value except heating the wine to about 140° F., whereby the vinegar ferment is killed and the further progress of acetous fermentation checked. There is, however, absolutely no remedy for the removal or neutralization of the acetic acid already present in the wine. Heating the wine can only be recommended when the evil has been in existence but a short time and the increase of acetic acid can be detected only by a very sensitive tongue. Mixing wine attacked by acetous degeneration with sound wine in order to cover up the acid taste is especially inadvisable; nothing can be attained by it except a short delay in the reappearance of the evil and the transmission of the infection to the sound wine. There are but two ways in which wine attacked by acetous degeneration can be in anywise profitably utilized: by employing it for the preparation of cognac or converting it into wine-vinegar. For the first a distilling apparatus is required, and, consequently, cannot be effected

by every wine-grower, while for the latter nothing is necessary but a few vessels readily procured.

Young white wine if attacked by acetous degeneration is also fit for nothing else than the preparation of vinegar. On account of its large content of albuminous substances it is, however, more suitable for the nourishment of the mold ferment than for that of the vinegar ferment, and consequently many difficulties occur in its conversion into vinegar. These difficulties can, however, be prevented by mixing such wine with much air and storing it for some time in barrels filled up to the bung, or heating it after mixing with air to about  $140^{\circ}$  F., the separation of the albuminous substances being effected by both means, though more rapidly by the latter. Before being further worked the wine has to be filtered to remove the now insoluble albuminous substances, whose presence might otherwise give rise to other injurious complications.

Before the appearance of the phylloxera in France and the consequent decrease in the production of very ordinary wines and a better chance of disposing of slightly sick wines doctored by heating, the manufacture of wine vinegar was extensively carried on in many communities, the sale of this product realizing very large sums. A number of commercial travellers regularly visited the wine-growing districts simply for the purpose of buying up sick wines to be worked into vinegar by the factories represented by them. And, notwithstanding the process of manufacture in general use was rather incomplete, it furnished a highly valued article, though only with a considerable loss of substance. Pasteur made some experiments regarding the mode of manufacture and recommended very valuable improvements.

The question, what constitutes the superiority of wine vinegar over the ordinary product obtained from alcohol, is not difficult for those who have an accurate knowledge of the constitution of wine to answer. Wine, besides the ordinary alcohol (ethyl alcohol), contains very small quantities of other alcohols, for instance, amyl alcohol, which, in the same manner as ethyl alcohol is converted into acetic acid, are changed into acids possessing a peculiar odor. Moreover, wine very likely contains a series of odoriferous substances which together produce the peculiar aroma

termed bouquet or flower, the œnanthic ether found in every wine forming so to say the keynote in the harmony of the odoriferous substances constituting the bouquet. In the conversion of wine into vinegar these bouquet substances are also changed in such a manner that bodies distinguished by a characteristic odor are formed. Furthermore, wine contains glycerin, a series of non-volatile organic acids; tartaric, malic, succinic acids etc., and finally the so-called extractive substances. What change these bodies undergo is not accurately known, but all of them are very likely subject to certain modifications because a smaller quantity of extractive substances and of non-volatile acids is found in the vinegar than in the original wine. The following table shows the composition of wine and of the vinegar formed from it:—

Wine contains—	Wine-vinegar contains—
Water,	Water,
Ethyl alcohol,	Ethyl alcohol (none or very little),
Other alcohols,	Other alcohols (changed),
Glycerin,	Glycerin (less?),
Acetic acid (traces),	Acetic acid (much newly formed),
Tartaric acid,	Tartaric acid (less),
Tartar,	Tartar (less),
Malic acid,	Malic acid (less),
Succinic acid,	Succinic acid (less),
Tannin,	Tannin (changed), [changed),
œNanthic ether,	œNanthic ether (changed and un-
Bouquet substances,	Bouquet substances } changed,
Extractive substances,	Extractive “ } changed,
Coloring substances.	Coloring “ } changed,
	Acetic ether and other } newly compound ethers } formed.

The above comparison shows the thorough modification wine undergoes in being converted into vinegar, and that the resulting product must have a bouquet or flower having a certain connection with that of the wine.

Before entering upon a description of the various methods of fabricating wine-vinegar it may be mentioned that an actually fine product can only be obtained by a *slow* process of acetification, numerous experiments having shown that wine treated by the quick process yields a product very poor in bouquet.

*Boiling of Wine-Vinegar.*

The oldest method for the preparation of wine-vinegar is that to which the term "boiling of wine-vinegar" (Weinessig-Siederei) has been applied. A barrel was filled  $\frac{3}{4}$  full with wine to be converted into vinegar; a portion of the fluid was then heated to boiling and poured back into the barrel. Upon the wine thus heated to about 86° F. the development of the vinegar ferment commenced, and in the course of a few months the greater portion of the alcohol was converted into acetic acid. The greater portion of the contents of the barrel was then drawn off as "ripe wine-vinegar," the barrel again filled  $\frac{3}{4}$  full with wine, and a portion of this heated; the operation was continued in this manner until so much slimy sediment had accumulated in the barrel as to render its complete emptying and cleansing necessary. This crude process, which, as mentioned, was known in Germany as "vinegar boiling," was similar to the method formerly in general use in France, and which, being still partially practised there in some large wine-vinegar factories, for instance in Orleans, may be designated as the

*Old French Method of Manufacturing Wine-Vinegar.*

The casks, called *mothers*, which are employed hold not more than 22 gallons, each cask being filled  $\frac{4}{5}$  full. Immediately above the level of the fluid a hole is bored in the surface of the front end of each cask, this hole as well as the bung-hole remaining open; a stop-cock for the discharge of the fluid is placed in the lower part of the cask. The casks are placed in rows in the open air, eight, ten, fifteen, or twenty such rows constituting what is termed a *vinegar field*. This so-called fielding, which is carried on from spring to fall, may be suitable for the southern part of France, but cannot be recommended for more northern regions, as the temperature may fall very low during the night and rise very high during the day. Experience has shown that the augmentation and efficacy of the ferments are very much injured by strong variations of temperature, and consequently it is decidedly preferable to keep the casks in a room the temperature

of which can be maintained at least at  $68^{\circ}$  F. The wine remains in these casks until it is converted into vinegar; the latter is then drawn off by means of the above-mentioned stop-cock and the casks are again filled with wine, etc. The hole in the front end of the cask and the bung-hole permit the free access of air to the surface of the wine. In other French factories the work is carried on according to a method somewhat different from the one just described. Casks having a capacity of up to 100 gallons are used, each cask having in the surface of the front end a square aperture, which serves to charge the casks with wine as well as for the influx of air. The casks are placed in three rows one above another in a room which can be heated. In the beginning of the operation a certain quantity of strong vinegar is brought into the casks; about one-fourth of its volume of wine is then added, and at intervals of eight days about 10 quarts more. When the cask is nearly filled up to the above-mentioned aperture, the regular process of drawing off vinegar and filling up again with wine is commenced. If, for instance, 10 quarts of finished vinegar are drawn off, the same quantity of wine is replaced in the cask, and suppose that, according to the manner of working, 7, 8, or 10 days are required for the conversion of this quantity into vinegar, 10 quarts of vinegar are again drawn off after the expiration of that time, this being continued until a disturbance occurs.

In the course of time large masses of slimy matter, consisting of albuminous substances which have become insoluble, coloring substances, vinegar ferment vegetating below the surface (the so-called mother of vinegar), decayed vinegar ferment, etc., form a deposit in the cask, and finally accumulate to such an extent as to occupy half the volume of the cask, so that the latter has to be emptied and thoroughly cleansed. Sometimes the operation has to be interrupted much sooner on account of the contents of the cask acquiring a disagreeable, putrid odor. This appearance of putrefaction is generally due to vinegar eels settling in the interior of the cask—as a rule, immediately above the level of the fluid—and developing to such an extent that they form a slimy coating on the barrel and upon the fluid and suppress the development of the vinegar ferment. These animalcules are destroyed



by being deprived of air, and, hence, when the vinegar ferment is brought to vigorous development it withdraws so much of the oxygen from the air in the cask that many of them die and their bodies sink to the bottom, where they sooner or later putrefy. If this putrefying process takes place before a cleansing of the casks is considered necessary, it progresses to such an extent that the entire contents of the cask are converted into a stinking mass which has to be removed as quickly as possible. The casks in which such disturbances take place must of course be carefully cleansed by sulphuring and washing with boiling water before they are again used.

*Modern French Method of Preparing Wine-Vinegar.*

The description of the older French methods given above shows that they are very crude; their improvement is, however, not difficult, the principal being to place the casks in a room subject to but slight variations of temperature, which can be best effected by providing a good self-regulating stove. The temperature near the ceiling being higher than that immediately above the floor, the formation of vinegar will take place more rapidly in the casks placed in the uppermost tier than in those in the lowest, and consequently the wine in them will in a shorter time be converted into vinegar.

The first thing in starting the operation according to the old French method is to acidulate the casks by pouring 10 to 20 quarts of boiling hot vinegar into each and then adding 10 to 15 quarts of wine; after some time, when the wine is acidulated, the cask is filled up to the previously mentioned aperture and left to itself until the contents are sufficiently acetified, when a portion of the vinegar is drawn off and replaced by wine, this drawing off of vinegar and refilling with wine being continued until the cask on account of the accumulation of sediment has to be cleansed.

This method, which is sometimes very minutely described in books, could only develop at a time when nothing was known of the chemico-physiological process of the formation of vinegar or only erroneous opinions in regard to it prevailed. It is full of



defects from beginning to end. The acidulation of the casks with boiling vinegar is simply preposterous, because by heating the vinegar and pouring it boiling hot into the cask not only the vinegar ferment contained in it is destroyed but also that present in the cask or wine itself. That acetous fermentation takes place notwithstanding is very likely due to the following causes :—

The hot fluid in the cask gradually cools off and is finally reduced to the degree of temperature most favorable to the development of the vinegar ferment ; in the same proportion as cooling off takes place the air contracts in the cask and air enters from the outside. The latter, however, carries with it germs of vinegar ferment which rapidly develop upon the fluid when reduced to the proper temperature and cause its acetification. The air penetrating into the cask may, however, accidentally contain no vinegar ferment, or that contained in it may not reach the wine ; in such case the wine may for weeks remain in the cask without any perceptible acetification taking place until the latter finally appears by an accidental development of the vinegar ferment. This uncertainty can, however, be readily avoided by the direct cultivation of the vinegar ferment upon the wine to be acetified. Milk, as is well known, turns sour on exposure to the air by the milk sugar being converted into lactic acid by the action of a ferment frequently occurring in the air, this souring taking place in several hours or several days according to the temperature to which the milk is exposed. It is further a well-known fact that the addition of a few drops of sour to sweet milk suffices to immediately induce the formation of lactic acid in the latter ; the ferment of lactic acid fermentation being in the true sense of the word sowed upon the milk. The ferment develops very rapidly, converts the sugar into lactic acid, and in a short time turns the entire quantity of milk sour.

Exactly the same course may be pursued as regards the vinegar ferment, it being only necessary to mix the wine with a fluid containing living vinegar ferment and place it in a sufficiently warm room in order to immediately start the process of the formation of acetic acid ; in this case the vinegar ferment is sowed upon the wine, or, in other words, the wine is infected with vinegar ferment and intentionally made "sick." This method of

transmitting ferment to the fluid to be fermented has for a long time been in use in the fabrication of beer and of alcohol. In the brewery the wort, and, in the distillery, the mash, is brought into fermentation by "setting" it with yeast, *i. e.*, alcohol ferment is intentionally added. The "setting of wine" with vinegar ferment is the only correct method for the preparation of vinegar from wine.

Before entering upon a description of this process it will be necessary to discuss a few undesirable phenomena which may appear in the conversion of wine into vinegar. A thick white skin having the appearance of a ruffle may frequently form upon the surface of the wine set for acetification, the wine in this case becoming constantly poorer in alcohol, but not sour. Sometimes the previously steady increase in the content of acid in the wine to be acetified suddenly ceases and a very rapid decrease in the content of acid takes place, the development of the white skin upon the surface being also in this case observed.

The formation of this white coating upon the surface is due to the development of mold ferment whose cells in a short time augment to such an extent as to form a thick membranous layer, the folds being formed by the superposition of the cells. The mold ferment has the property of converting alcohol as well as acetic acid into carbonic acid and water, and consequently if it settles upon wine the latter becomes poorer in alcohol, and if upon wine containing already a certain quantity of acetic acid the latter is also decomposed. The mold ferment requires, however, considerable quantities of nitrogenous combinations for its vigorous development, and, therefore, readily settles upon *young* wine which contains a large quantity of albuminous bodies in solution. This fact explains the reason why young wine is seldom attacked by acetous generation, but it readily becomes moldy, and, consequently, cannot be recommended as material for the fabrication of vinegar except the albuminous substances be first separated by heating the wine to 140° F., which is best effected by means of the apparatus shown in Fig. 39, p. 149.

Another serious annoyance in the fabrication of wine-vinegar is the appearance of vinegar eels, which, if not checked in time, may lead to the interruption of the entire process. These ani-

malecules are but seldom found in factories working with pump or well water, but frequently in those using river water, and consequently their introduction is likely due to such water. In case of their appearance in large masses it is best to interrupt the process in time in order to prevent the previously mentioned phenomena of putrefaction. The fluid containing the vinegar-eels should be drawn off into a thoroughly sulphured barrel. The sulphurous acid kills the vinegar eels as well as the vinegar ferment, and the filtered fluid, after standing a few weeks, whereby the sulphurous acid is converted into sulphuric acid, can again be used as alcoholic liquid. The vessels in which the vinegar eels have settled must also be thoroughly sulphured and then repeatedly washed with water before being re-used for the fabrication of vinegar.

In the apartment containing the vessels used for the fabrication of wine-vinegar the greatest cleanliness should prevail; in fact one cannot be too scrupulous in this respect, as otherwise by-fermentations readily take place, and another plague, the vinegar-lice, or more correctly vinegar-mites (see p. 137), may appear. Should any of these evils happen the apartment, fluids, and vessels must be thoroughly disinfected by means of sulphurous acid.

*Method of the Fabrication of Wine-Vinegar according to Bersch.*

As previously mentioned, the fabrication of wine-vinegar by the quick process cannot be recommended, the odoriferous substances which give the product its special value being almost entirely lost thereby; but neither can it be recommended to work according to one of the French processes previously described, as they require too much time, are accompanied by large losses as regards yield, and render it difficult to maintain the necessary cleanliness during the operation. All these evils can be avoided by following the method first proposed, in 1876, by Dr. Josef Bersch, and for some time practised on a manufacturing scale.

The essential part of the entire process is the infection of the wine in suitable vessels with artificially cultivated vinegar ferment under conditions in which the latter can rapidly augment.

The vessels are so arranged that the finished vinegar can be removed and replaced by wine to be acetified without disturbing the ferment, one being thus enabled to uninterruptedly continue the process of the formation of vinegar for a long time, and producing vinegar unsurpassed by any other product as regards delicacy of taste and odor. According to the above statement, the operation includes the cultivation of the vinegar ferment on a small scale and on a large scale, the former for the production of pure ferment and the latter for obtaining wine-vinegar.

The cultivation of pure vinegar ferment on a small scale is best effected by heating wine in a porcelain or glass dish to  $140^{\circ}$  or  $150^{\circ}$  F., then mixing it with an equal volume of vinegar and pouring the resulting fluid into shallow porcelain plates, which are placed in a warm room. In a short time, generally in 24 to 30 hours, the veil-like layer of vinegar ferment previously described is observed upon the surface of the fluid. If, besides the *dull* spots which are characteristic of pure vinegar ferment, spots of a pure white color are formed, it is an indication of the development of mold ferment. The contents of the plates showing this phenomenon have to be boiled and then again exposed to the air.

The wine to be acetified is in large, shallow vats, and is brought to fermentation by carefully submerging in it one of the above-mentioned plates containing pure vinegar ferment, so that the latter is distributed upon the surface; the plate is then withdrawn. The ferment augments very rapidly, so that, in 24 hours, the surface of the wine in the vat is entirely covered with a thin veil of it. By keeping the temperature of the room in which the vats are placed at about  $68^{\circ}$  F., the acetification of the wine proceeds rapidly, tests repeated at intervals of 24 hours showing a constant increase in the content of acid, until in about 8 days all the wine is converted into vinegar and is drawn off. To avoid the necessity of especially infecting the next quantity of wine the finished vinegar is not entirely drawn off, a small quantity (about  $\frac{3}{4}$  to 1 inch deep) upon the surface of which the vinegar ferment floats being allowed to remain in the vat. By now introducing a fresh lot of wine the vinegar ferment propagates upon it and after some time converts it into vinegar.

With sufficient care the process of the formation of vinegar could thus be uninterruptedly carried on for any length of time by transferring the vinegar ferment from the finished vinegar to the wine, if a cleansing of the vat were not from time to time required, on account of the accumulation on the bottom of the vessel of decayed vinegar ferment and flakes of albumen which have become insoluble. When the vat is to be cleansed the last batch of vinegar is drawn off as long as it runs off clear, and the turbid remainder in the bottom of the vat collected in a special cask, where it is allowed to repose until clear. The vat is then thoroughly cleansed with water, and after filling it again with wine, the latter is mixed with pure vinegar ferment in the manner already described.

If, as may happen in very rare cases, mold ferment in the form of the above-mentioned white spots appears upon the surface besides vinegar ferment, the vat must be at once emptied. The process should also be interrupted in case of the development of the so-called mother of vinegar. The latter appears generally in the form of a soft mass of the consistency of jelly submerged in the fluid, and consists of vinegar ferment, which, however, does not, on account of not being in direct contact with the air, produce acetic acid. The fluid to be acetified can be readily separated from the mother of vinegar by filtering through a close cloth; the mother of vinegar remaining upon the latter and finally drying to a whitish mass resembling very thin tissue paper.

From the above it will be seen that the rational preparation of wine-vinegar is a very simple matter; but there are some difficulties which can, however, be entirely prevented or readily removed. The vinegar ferment is very sensitive towards sudden changes in the composition of the fluid upon which it lives, as well as towards quick changes in the temperature. The sudden change in the composition of the fluid is prevented by not drawing off all the finished vinegar, but allowing a small portion to remain in the vat. The fresh supply of wine entering from below then lifts up the remainder of vinegar, together with the ferment floating upon it, and the mixture of both fluids is effected so gradually that the change in the composition of the nourishing



fluid proceeds very slowly. A sudden change in the temperature of the workroom can, of course, be readily prevented by proper heating.

*Execution of the Preceding Process on a Manufacturing Scale.*

The manufacturer of wine-vinegar has but little choice in the selection of his material; he must take the spoiled wines as they come. The only difference as regards the value of the material is in the content of alcohol; the greater the latter, the more valuable the material. Wines with a content of alcohol not much above 6 per cent. are best used as they are, as they yield vinegar with about  $5\frac{1}{2}$  per cent. of acetic acid. It is advisable, however, to dilute stronger wines with a content of alcohol up to 10 per cent., so that they contain not more than about 6 per cent. For the dilution of such wine either water or ordinary vinegar can be used. The strength of the latter must be so chosen that the wine-vinegar prepared from a mixture of wine and vinegar contains  $5\frac{1}{2}$  to 6 per cent. of acetic acid. The proportions in which vinegar and wine are to be mixed for this purpose are found by a simple calculation after accurately determining the content of alcohol in the wine and that of acetic acid in the vinegar.

The workroom should be so situated as to be protected against sudden changes in the temperature and provided with a furnace or self-regulating stove. The vessels for the formation of vinegar are placed upon suitable supports, and a table for holding the plates for the cultivation of the vinegar ferment should be provided. If the size of the room permit, it is advisable to store in it a few barrels of the material to be worked, the fluid thereby gradually acquiring the proper temperature.

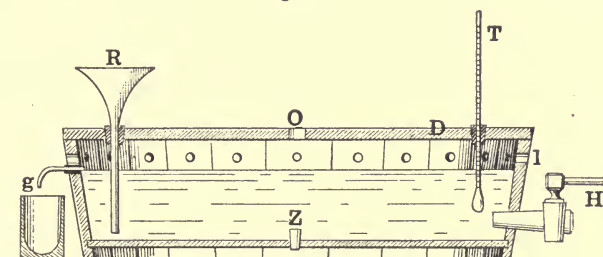
For the formation of the vinegar very shallow vats, best with a diameter of  $3\frac{1}{2}$  to 5 feet and a depth of 9 to 14 inches, are used.

The iron hoops are protected from the action of the acetic vapors by a coat of asphalt lacquer. The vats are placed in the position they are to occupy in the workroom and filled with water up to about  $1\frac{3}{4}$  to  $3\frac{3}{4}$  inches from the top, the height of the level of the fluid being marked on the inside wall. At distances



of  $3\frac{3}{4}$  inches apart, and  $5\frac{3}{4}$  inches in larger vats, holes, *l*, Fig. 42, of 0.39 inch diameter are then bored in the wall of the vat ; one hole is, however, bored in a place about 0.39 inch deeper than *l*, and in this hole is fitted a glass tube, *g*, bent at a right angle,

Fig. 42.



Vat for the Preparation of Wine-Vinegar.

under which is placed an ordinary tumbler. In the bottom of the vat is a tap-hole, *Z*, closed by a stopper.

If the vat be filled during the operation with wine, the latter can only rise until it begins to run off at *g*. The level of the fluid being but little below the holes *l*, an uninterrupted change in the layer of air above the fluid takes place. A wooden spigot, *H*, is fitted in the vat about  $\frac{3}{4}$  to 1 inch above the bottom. In the centre of the lid *D*, which lies loosely upon the vat, is an aperture, *O*; in a second aperture a thermometer, *T*, is inserted, whose bulb dips into the fluid; and in a third aperture is fitted a glass funnel, *R*, reaching nearly to the bottom of the vat.

The operation in such a factory commences with the cultivation of the vinegar ferment. For this purpose as many shallow porcelain plates as there are vats are placed upon the table and wine to the depth of  $\frac{1}{2}$  to  $\frac{3}{4}$  inch poured in each; the room should be heated and kept at a temperature of  $86^{\circ}$  F. The manner of the development of the vinegar ferment upon the fluid in the plates as well as the precautions which have to be taken has already been described. In the commencement of the fabrication the cultivation of the ferment requires great attention, it being frequently disturbed by the development of mold ferment, but when the factory is once in a proper state of working it is readily effected because the air of the workroom then contains a large

quantity of the ferment, which rapidly augments on coming in contact with a fluid favorable for its development.

The vats are charged by allowing the fluid to be converted into vinegar to flow in until it begins to run out through *g*. The setting with ferment is then effected by carefully emptying the contents of one of the plates upon the surface of the fluid, so that the greater portion remains floating upon it. Finally the lid is placed upon the vat and the latter left to itself.

The ferment soon covers the entire surface of the fluid in the vat, and the commencement of the process of oxidation is in a short time recognized by the rise of the thermometer dipping into the fluid. As long as the quantity of alcohol in the fluid is comparatively large the process of the formation of acetic acid and the augmentation of the ferment take place very rapidly and the thermometer rises constantly; but with an increase in the quantity of acetic acid these processes become slower, which is indicated by a fall in the temperature of the fluid. The energy of the process must, however, not be allowed to sink below a certain limit, care being had to keep it up by raising the temperature of the workroom, but not higher than is absolutely necessary for the correct working, as otherwise there would be a loss of acetic acid or alcohol by evaporation.

The most convenient and business-like manner of operating a factory arranged as above described is to *simultaneously* charge all the vats with alcoholic liquid, it being then entirely in one's power to regulate the heating of the workroom according to the indications of the thermometer dipping into the fluid. If, for instance, the operation commences at 77° F., the thermometer will soon be observed to rise even if the temperature of the workroom remains unchanged. By the oxidation of the alcohol sufficient heat is liberated to increase the temperature of the fluid to above 95° F.; it is, however, advisable not to allow it to rise above 86° or 90° F., as otherwise the losses by evaporation are too great. Hence, if the fluid reaches this limit of temperature the heating of the workroom is so regulated as to prevent a further rise of the thermometer, and a constant temperature is maintained for several days until it commences to fall almost simultaneously in all the vats. This fall in the temperature, as

previously mentioned, is an indication of the fluid now containing a comparatively large amount of acetic acid and of the slow oxidation of the remaining alcohol. In order to maintain the most favorable conditions for the efficacy of the vinegar ferment and to smoothly and rapidly complete the process the workroom is now so heated as to show a constant temperature of  $86^{\circ}$  F. as long as the fluid remains in the vats.

Side by side with the observation of the statements of the thermometer a chemical examination of the fluid has to be carried on, this examination gaining in importance the further the formation of vinegar progresses. If the content of alcohol in the wine to be worked is known, the test is up to a certain stage limited to the determination of the acetic acid, but if the process has so far advanced that to judge from the content of the fluid it contains scarcely 1 per cent. of alcohol, the latter has also to be determined by means of the ebullioscope. From this moment on the course of the process must be very carefully controlled and interrupted when still 0.15 or at the utmost 0.2 per cent. of alcohol is present; this small amount of unchanged alcohol exerts a favorable effect upon the quality of the vinegar, acetic ether being formed from it and a corresponding quantity of acetic acid during the time the vinegar has to be stored.

The interruption of the process is best effected by separating the fluid from the layer of ferment floating upon it. The stop-cock *H*, Fig. 42, is opened and left open as long as fluid runs out. A layer of vinegar about  $\frac{3}{4}$  to 1 inch deep upon which floats the vinegar ferment, remains in the vat, and the stop-cock being closed a fresh supply of alcoholic liquid is introduced through the funnel *R* until it begins to run out through *g*. The process then commences anew in the manner above described.

Theoretically unlimited quantities of wine could be converted into vinegar by means of such an apparatus, as the vinegar ferment which floats upon the fluid remaining in the vat, rapidly augments upon the fresh supply of wine and converts it into vinegar. In practice an occasional short interruption of the process is, however, necessary. During the conversion of the wine the greater portion of albuminous substances held in solution in it separates as flakes, and, further, a portion of the vinegar ferment

sinks below the level of the fluid and assumes the form of the flaky masses called mother of vinegar. The result after a number of operations is a slimy sediment, which finally accumulates to such an extent that it has to be removed; this is effected, after the finished vinegar is drawn off, by opening the tap-hole *Z* and removing the slimy mass by means of a broom or crutch. The vat is then thoroughly washed with water and can be immediately recharged with wine. The slimy mass is best collected in a tall vat and allowed to rest. In a few days it separates into two layers, the upper one consisting of quite clear vinegar which can be used for filling up storage-barrels, and the lower one of a thickly-fluid mass from which a certain quantity of vinegar can be obtained by filtration.

The vinegar drawn off from the vats is brought into storage barrels which are filled up to the bung and closed air-tight. The volume of the vinegar decreasing by cooling, the barrels must from time to time be examined and kept filled up to the bung-hole. While stored in the barrels the vinegar almost completely clarifies, and by carefully siphoning off the clear portion it can be at once brought into commerce without further treatment. When a considerable quantity of slimy sediment has collected in the storage-barrels it is drawn off and brought into the above-mentioned clarifying vat, or is clarified by filtration.

In case of disturbances in the fabrication by the appearance of mold ferment or vinegar eels, the process once commenced must be carried through as well as possible and then the entire operation interrupted for the purpose of thoroughly cleansing the vessels by washing with boiling water or steaming. Under no circumstances should it be attempted to continue working with vats infected with mold or vinegar eels, as it would only lead to a considerable loss of material and the cleansing of the vessels, which would have to be finally done, would be more difficult.

In conclusion it may be remarked that it is best to bottle the vinegar after it has become refined and bright by storing, and close the bottles with new corks; by placing the bottles horizontally in the cellar the vinegar acquires a finer odor without injury to its content of acetic acid or to its taste.

Though vinegar prepared in the above-described manner and

racked when entirely bright into bottles remains, as a rule, unchanged, it may happen to become turbid and form a sediment which is shown by the microscope to consist of organisms. This phenomenon is generally accompanied by a change in the odor of the vinegar, and the acid taste loses sharpness and shows a peculiar insipidity. From an accurate chemical examination the cause of this alteration must be attributed to the decomposition of the tartaric and malic acids in the fluid by a ferment. The only sure remedy for this and all other alterations is to heat the vinegar to 140° F. whereby all organisms are killed. For heating larger quantities it is recommended to pass the vinegar through a coil of tin-pipe surrounded by boiling water and after rapidly cooling the hot fluid to the ordinary temperature to store it for some time in a barrel for the separation of the solid bodies. Smaller quantities can be treated by bringing the vinegar into glass bottles of 10 to 15 quarts' capacity, placing the bottles in a boiler filled with water and heating to the required temperature. A favorable result from heating can, however, only be obtained with vinegar which has already acquired a fine taste and odor by several months' storing. Freshly-prepared wine-vinegar still showing the previously mentioned stupefying odor, if heated, does not acquire the fine bouquet it otherwise would by storing.

#### *Preparation of Wine-Vinegar from Lees.*

The lees left from the pressing of the wine consist of the stems, husks, and seeds of the grapes and contain a not unimportant quantity of must which in many regions is sought to be obtained by pouring water over them and subjecting them again to pressure. The must thus obtained, though poorer in sugar and extractive substances than that of the first pressing, yields a drinkable wine which is generally used for household purposes. All the valuable constituents are, however, not extracted even by this treatment, and the remainder can be profitably used for the preparation of vinegar. In countries yielding wine of ordinary quality it might even be advisable to entirely omit this treatment of the lees with water in order to obtain an inferior quality of must, and use them directly for the preparation of vinegar.



If the fresh lees are thrown in a pile and allowed to ferment, considerable heat will be developed in the course of a few days, in fact so much that the mass commences to steam. When fermentation is finished, or shortly before, an agreeable odor of acetic ether is evolved, which is due to the commencement of the development of vinegar ferment upon the lees and the formation of acetic acid, the latter combining with a certain quantity of the alcohol formed by fermentation to acetic ether. (At this stage in the change of the lees a small quantity of acetic ether can be obtained from them by distillation.)

The odor of acetic ether is soon overcome by that of acetic acid, the conversion of the newly-formed alcohol into acetic acid now progressing rapidly on the surface of the lees. Later on the sharp odor of acetic acid again decreases, the greater portion of it being destroyed by mold and other ferments, the development of which now progresses with great rapidity in the thoroughly heated mass of lees; lactic acid is formed, and later on the mass acquires a rancid odor calling to mind that of old cheese, which is due to butyric acid, valerianic acid, etc. The lees gradually acquire a darker color and finally putrefaction sets in.

If only the sugar still contained in the lees is to be obtained and vinegar to be prepared in the most simple manner, the following process may be used: The mass of lees as it comes from the press is broken up and put in a pile, where it is left to itself until it becomes warm and acquires the odor of alcohol and acetic ether. The mass is then shovelled into a vat and gently pressed together with a shovel. For every 220 lbs. of lees used, about 10 quarts of water are now sprinkled over the mass by means of a watering-pot. By the entrance of air while shovelling the pile of lees into the vat the action of the vinegar ferment has been accelerated and a considerable quantity of alcohol converted into acetic acid, which is indicated by the stronger vinegar odor. The water permeating the lees almost completely displaces the fluid containing the alcohol and acetic acid, the latter running off through an aperture in the bottom of the vat. It is collected in a shallow vessel placed in an apartment having the ordinary temperature of a living room, and is allowed to rest. The vinegar ferment present in abundance in the fluid rises to the surface,



where it quickly augments and converts the remainder of the alcohol in the fluid into acetic acid. The only difficulty to be overcome in preparing the vinegar according to this method is the appearance of the mold ferment upon the surface of the fluid. This can, however, be met by removing the growth of this ferment, which is recognized by its pure white color, by means of a spoon as soon as it has attained the thickness of a few millimeters. The vinegar ferment then soon commences to augment and suppresses the further growth of the mold ferment.

If the grapes originally used contained from 18 to 20 per cent. of sugar, the vinegar from the lees prepared according to this method shows, if not too much water has been used, a content of at least 4 or 5 per cent. of acetic acid, and consequently is immediately fit for table use. By long storing in barrels kept filled up to the bung-holes, it acquires a flavor resembling that of vinegar prepared from wine.

On account of the simplicity and the slight expense connected with it the above-described process is especially adapted for the preparation of vinegar for household purposes. But for commercial purposes on a large scale it is advisable to obtain a stronger and consequently more valuable product by a somewhat modified process.

For the preparation of stronger vinegar from a fluid it is necessary to give it a higher content of alcohol or sugar. As is well known, 1 per cent. of sugar in a fluid yields after fermentation in round numbers 0.5 per cent. of alcohol, and the latter about 0.4 per cent. of acetic acid. These figures, though not absolutely correct, are sufficiently so for practical purposes. Hence, if the content of acetic acid is to be increased 1 per cent., 1.2 per cent. of alcohol or 2.4 per cent. of sugar has to be added to every hectoliter (22 imp. gallons) of the fluid to be worked into vinegar.

The substances which impart to wine-vinegar its greater value as compared with ordinary vinegar are derived from the grape; they are found in abundance in the must as well as in the fresh lees, and are yielded by the latter to water. Hence, excellent wine-vinegar can be prepared from the lees by working according to the following method:—

The lees are brought directly from the press into a vat and

twice or three times a day their weight of water is poured over them. After standing 24 to 36 hours in not too cool a place, the generally strongly fermenting fluid is drawn off and what is retained by the lees gained by pressing. In this manner a fluid is obtained differing from the must only in a smaller content of sugar and tartaric acid, the so-called extractive substances contained in the must which impart to the wine its characteristic properties being present in abundance.

The must obtained from the lees is now examined as to its content of sugar. If, for instance, it shows 10 per cent. of sugar, it will, when fermentation is finished, have a content of nearly 5 per cent. of alcohol and yield vinegar with about 4 per cent. of acetic acid. By the addition of sugar or alcohol according to the above-mentioned proportions a fluid can, however, be obtained which contains 5 or 6 or more per cent. of acetic acid. For the final result of the process it is indifferent whether sugar or alcohol is added to the fluid, the choice depending on the current value of these articles.

If sugar is used, it is dissolved directly in the fluid obtained from the lees and the latter allowed to ferment at about 68° to 77° F. When working with alcohol it is advisable, in order to avoid loss by evaporation, to ferment the fluid from the lees by itself, and only add the alcohol when acetous fermentation is to be induced.

During fermentation the must from the lees separates yeast in abundance, and being consequently turbid, is allowed to clarify in barrels kept full up to the bung. When clear, it is siphoned off from the sediment of yeast.

The conversion of this wine from lees into vinegar is best effected by the process of acetification, by means of ferment growing upon the fluid described on p. 185 *et seq.* The only difficulty which can present itself is that the wine, being young wine, contains a considerable quantity of albuminous substances, and is consequently more inclined towards the nourishment of mold ferment than towards that of vinegar ferment. This can, however, be met by setting the fluid at a higher temperature, about 86° F., with pure cultivated vinegar ferment, and carefully watching the surface for the formation of white spots of mold

ferment, and immediately removing them. By proceeding in this manner, the entire surface will in a few hours be covered with vinegar ferment, when there will be no further danger of the dislodgment of the latter by mold ferment.

The process of acetification being finished, the vinegar is drawn off into storage barrels, which must be kept full up to the bung, and subjected to the same treatment as the product obtained from wine.

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## CHAPTER XIX.

### CHEMICAL EXAMINATION OF THE RAW MATERIALS AND CONTROL OF THE OPERATIONS IN A VINEGAR FACTORY.

#### *Determination of Sugar.*

THE sacchariferous materials used by the vinegar manufacturer are either whiskey-mashes, malt-extracts, or must prepared from wine-lees, apples, etc. The determination of sugar contained in these fluids is effected by means of various instruments, which are really hydrometers, with different names and graduations. The instruments mostly used for the determination of sugar in whiskey-mashes and malt-worts are known as saccharometers, and directly indicate the content of sugar in the fluid in per cent. A similar instrument, known as the must-aerometer, serves for the determination of the content of sugar in grape-must. According to the arrangement of their scales, the must-aerometers indicate either direct sugar per cent., or degrees; in the latter case the use of special tables accompanying the instrument is required for finding the per cent. of sugar corresponding to a certain number of degrees.

No special saccharometer for fruit-must having as yet been constructed, the determination of the content of sugar has to be effected either by a tedious method unsuitable for practice, or, what can be more quickly done, by fermenting a sample of the respective must, and after determining the quantity of alcohol, ascertaining from it the content of sugar.

In place of special saccharometers or must-aerometers, an ordinary aerometer indicating the specific gravity can also be used, and the content of sugar corresponding to a certain specific gravity found from a reducing table. Tables X. to XIII. at the end of this volume give the content of sugar especially for wine-must, but also with sufficient accuracy for apple- or pear-must, according to the statements of the respective must-aerometers.

### *Determination of Alcohol.*

In a factory using commercial spirits of wine as the fundamental material for the fabrication of vinegar, the percentage of absolute alcohol contained in it has to be accurately determined in order to enable one to correctly calculate, in the manner explained on p. 104, the quantity of water required for the preparation of alcoholic liquid of determined strength.

For the determination of the content of alcohol in pure spirits of wine consisting only of water and alcohol, instruments called *alcoholometers* are generally used; they indicate the volumes of alcohol contained in 100 volumes of the spirits of wine. They are, however, not suited for this purpose when, as is frequently the case in a vinegar factory, the spirit of wine contains other bodies besides water and alcohol. In this case, either the alcohol contained in a sample has to be distilled off, and after determining its strength by the alcoholometer, the content of alcohol in the total quantity of fluid ascertained by calculation, or the determination is effected in a short time and with sufficient accuracy for practical purposes by the use of a special apparatus.

### *Determination of the Alcohol with the Alcoholometer.*

For the vinegar manufacturer the alcoholometer is an important instrument in so far as it serves for quickly ascertaining the degrees of the spirits of wine used. It is best to use an instrument which is combined with a thermometer, one being thus enabled to ascertain the temperature of the fluid simultaneously with reading off the statement of the alcoholometer. Tables I. to VIII. appended to this work give the necessary assistance for

the determination of the actual content of alcohol in a fluid whose temperature is above or below the normal temperature (59° F.).

For the purpose of examining fluids with a very small content of alcohol, alcoholometers have been constructed which accurately indicate at least 0.1 per cent. For the demands of the fabrication of vinegar, four alcoholometers will, as a rule, suffice; they should be so selected that one is to be used for fluids with from 0 to 4 per cent. of alcohol, the second for indicating 4 to 8 per cent., the third 8 to 12 per cent., and the fourth 12 to 16 per cent. The scale of such alcoholometers comprising only 4 per cent. each, is sufficiently large to allow of the easy reading off of one-tenth per cent. These instruments serve for the determination of the content of alcohol in alcoholic liquid consisting only of spirits of wine and water, and are used in examining the progress of the formation of vinegar during fabrication.

#### *Determination of the Alcohol by the Distilling Test.*

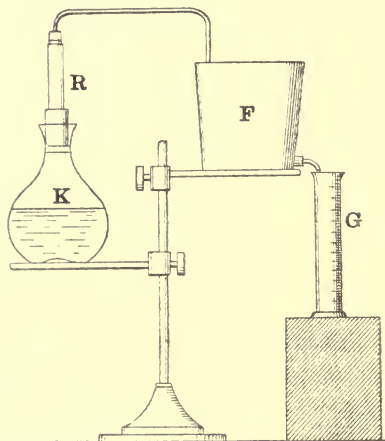
The content of alcohol in a fluid containing other bodies besides alcohol and water cannot be directly determined by means of the alcoholometer, as the statement of the latter would be incorrect on account of the foreign bodies exerting a considerable influence upon the specific gravity. Hence, the content of alcohol in alcoholic liquid containing a certain quantity of acetic acid, or of fermented whiskey-mash, beer, wine, etc., cannot be ascertained by immersing the alcoholometer in the respective fluid. In order to determine the content of alcohol in such a fluid a determined volume of it is subjected to distillation and the latter continued until it may be supposed that all the alcohol present is volatilized and again condensed in a suitable cooling apparatus. By diluting the fluid distilled over with sufficient water to restore it to the volume of the fluid originally used and immersing the alcoholometer the content of alcohol is determined.

A rapid and at the same time accurate execution of all examinations being of great importance in practice, a suitable apparatus should be used for the distilling test. Such an apparatus is shown in Fig. 43. It consists of a glass boiling flask, *K*, having a capacity of  $\frac{1}{2}$  liter in which sits by means of a perforated



cork a glass tube, *R*, which is about  $\frac{3}{4}$  inch in diameter and  $7\frac{3}{4}$  inches in length. On top this tube is closed by a perforated cork. From the latter a glass tube bent twice at a right angle leads to a cooling coil, which is placed in a vessel, *F*, filled with water, and ends over a graduated cylindrical glass vessel, *G*.

Fig. 43.



Distilling Apparatus for the Determination of Alcohol.

The uppermost mark on *G* indicates the height to which the vessel must be filled to contain  $\frac{1}{2}$  liter = 500 cubic centimeters. Generally vessels are used which are so graduated that the distance between two marks is equal to  $\frac{1}{20}$  liter or 50 cubic centimeters. The boiling flask stands upon a plate of thin sheet-iron (to prevent bursting from an immediate contact with the flame), and together with the cooling vessel is screwed to a suitable support.

In distilling a fluid containing acetic acid the vapors of the latter pass over together with those of alcohol and water, and, consequently, the statement of the alcoholometer would be incorrect. This evil is overcome by placing a few pieces of chalk the size of a hazelnut in the tube *R*. By the vapors coming in contact with the chalk the acetic acid is fixed to the lime contained in it, not a trace reaching the cooling vessel.

The manner of executing the test with this apparatus is as fol-



lows : Fill the vessel *G* to the uppermost mark with the fluid whose content of alcohol is to be examined, then pour it into the boiling flask *K*, rinse out *G* with water, and after pouring the rinsing water into *K* put the apparatus together as shown in the illustration. The contents of *K* are then heated to boiling by a spirit or gas flame under the sheet-iron plate upon which *K* rests, the flame being so regulated that the distillate flows in drops into *G*. By too strong heating the contents of *K* might foam up and pass into *G*, which would necessitate a repetition of the experiment with another quantity of fluid. Wine, beer, and whiskey-mashes frequently foam up on heating, which can, however, be almost completely overcome by the addition of a small quantity of tannin solution to the contents in *K*.

The heating of the boiling flask is continued until sufficient fluid is distilled over into *G* to fill it from  $\frac{1}{3}$  to  $\frac{1}{2}$ , this being a sure indication of all the alcohol present in the fluid having passed over. The flame is then removed, the vessel *G* filled to the uppermost mark with distilled water, and the fluids intimately mixed by shaking, the mouth of *G* being closed by the hand. The fluid now contained in *G* consists only of water and alcohol, and its volume is equal to that of the fluid originally used. By testing the fluid with an alcoholometer the content of alcohol found corresponds exactly to that possessed by the fluid examined (alcoholic liquid, beer, fermented whiskey-mash, etc.).

#### *Determination of the Alcohol by Means of the Ebullioscope.*

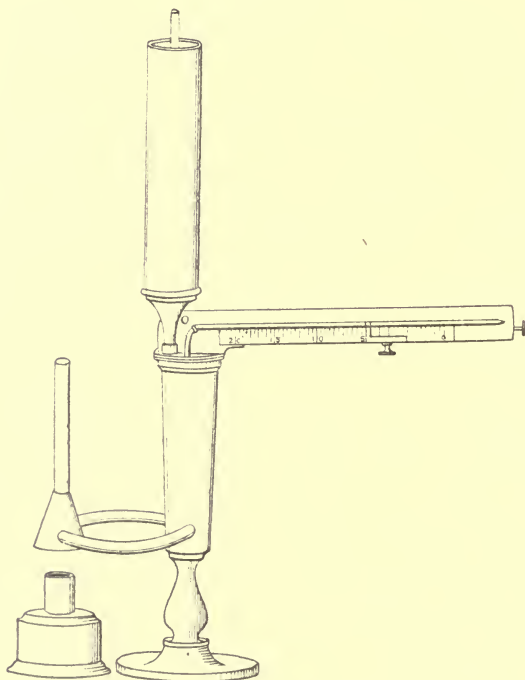
Many determinations of the content of alcohol in the alcoholic fluid having to be made in a well-conducted vinegar factory, the above-described distilling test is objectionable on account of the time (about twenty minutes) required for its execution. Good results are, however, obtained by the use of the ebullioscope, and but a few minutes being required for the test with this apparatus it can be frequently repeated, and thus even a more accurate idea of the working of the generators obtained than is possible with a single determination by the distilling test. The apparatus is very simple, is easily managed, and allows of the direct reading off,

without the use of an aerometer or table, of the content of alcohol in a fluid containing not much over 12 per cent. It is much used in France for the examination of wine. The principle of the apparatus is based upon the initial boiling point of the fluid to be examined, an alcoholic fluid boiling at a lower temperature the more alcohol it contains. For instance, wine with—

12	per cent. by volume of alcohol	boils at	196.7° F.
10	“ “ “ “ “	“	198.3 “
8	“ “ “ “ “	“	201.0 “
5	“ “ “ “ “	“	203.3 “

Fig. 44 shows Vidal-Malligaud's ebullioscope. To a round cast-iron stand is screwed a thick-walled brass cup which expands

Fig. 44.



Vidal-Malligaud's Ebullioscope.

somewhat towards the top; a screw-thread is cut in the upper edge. A hollow-brass ring is soldered into the cup near its base,

one end of the ring entering it somewhat higher than the other. On filling the cup with the fluid to be examined this hollow ring also becomes filled. On the one side the ring carries a small sheet-iron chimney, and by placing a small spirit-lamp under this the fluid in the cup is heated, this arrangement securing a quick circulation of the fluid during heating. Upon the upper edge of the cup, a lid is screwed, in which a thermometer is inserted air-tight. The mercury bulb of the thermometer is on the lower side of the lid, and in determining the boiling point dips into the fluid. The tube of the thermometer is bent at a right angle outside the lid, the latter carrying the scale, which is divided not into degrees but in per cent. by volume of alcohol. The scale can be shifted upon a supporting plate so that it can be fixed at any desired place, and, consequently, also so that the thermometer when dipped into boiling water indicates 0. The scale is secured by small screws. Into a second aperture in the lid is screwed the cooling pipe which is surrounded by a wide-brass tube for the reception of the cooling water. During the determination of the alcohol, which requires about ten minutes, the cooling water need not be renewed, the boiling point remaining constant during the short time (one to two minutes) necessary for making the observation. In heating wine the gases and besides a few light volatile varieties of ether, as acetic ether, aldehyde, ethylamine, propylamine, and similar combinations escape through the cooling pipe which is open on top, and in heating beer, carbonic acid. For the determination of the alcohol in sacchariferous wines, the ebullioscope is less adapted, nor does it give accurate results with the use of dilute wines.

It has been ascertained by the French Academy that the statements of the ebullioscope as regards the quantity of alcohol in the wine differ on an average  $\frac{1}{6}$  per cent. from those found by accurate distillation. The entire apparatus with the exception of the thermometer being of metal, it is not liable to breakage. The mercury bulb of the thermometer is comparatively large. For the vinegar manufacturer the ebullioscope is a very valuable instrument, as it enables him to accurately determine to within  $\frac{1}{5}$  per cent. the content of alcohol in a fluid in a shorter time than is possible with any other instrument. Its use is especially

recommended when the working of one or more generators is to be ascertained in a short time, perfectly reliable results being obtained in connection with the determination of the acid by titration.

*Determination of the Content of Acetic Anhydride in Vinegar, or Acetometry.*

The content of acetic acid in vinegar is sometimes ascertained by a species of hydrometer termed an *acetometer*. The statements of these instruments are, however, very unreliable. Vinegar made from dilute alcohol or ripe wines in which no great excess of albuminous or other matter is present might to a certain limit be tested with sufficient accuracy by the acetometer, but vinegars made from malt, poor wines, and such liquids as contain an excess of organic matters, do not admit of being tested with the required degree of accuracy by this method, since the apparent quantity of real acetic acid is increased by the presence of foreign bodies which add to the density of the liquid. In some cases the vinegar is saturated with chalk or milk of lime, the solution filtered, and the specific gravity of the acetate of lime liquor ascertained, by which a nearer approximation is arrived at than by the direct testing of the vinegar, yet implicit reliance cannot be placed on either of these two methods.

The best method of ascertaining the percentage of acetic acid in vinegar is by titration or volumetric analysis. For the execution of the test a few instruments are required, which shall be briefly described as follows: For measuring off small quantities of liquids, serve a burette and pipette, the latter a glass tube of the form shown in Fig. 45. It is filled by dipping the lower end into the liquid and sucking on the upper with the mouth until the liquid has ascended nearly to the top. The upper end is then quickly closed with the index finger of the right hand. By slightly lifting the finger, the liquid is then allowed to flow off by drops until its level has reached a mark above the convex expansion, when it will contain exactly the number of cubic centimeters indicated opposite to the mark.

The burette is a cylindrical glass tube open on the top, gradu-

ated, commencing from the top, into whole, one-tenth, and one-fifth cubic centimeters. The lower end of the tube is drawn out

Fig. 45.

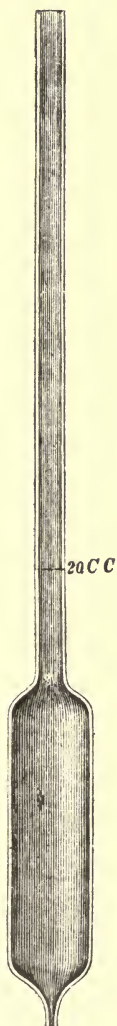
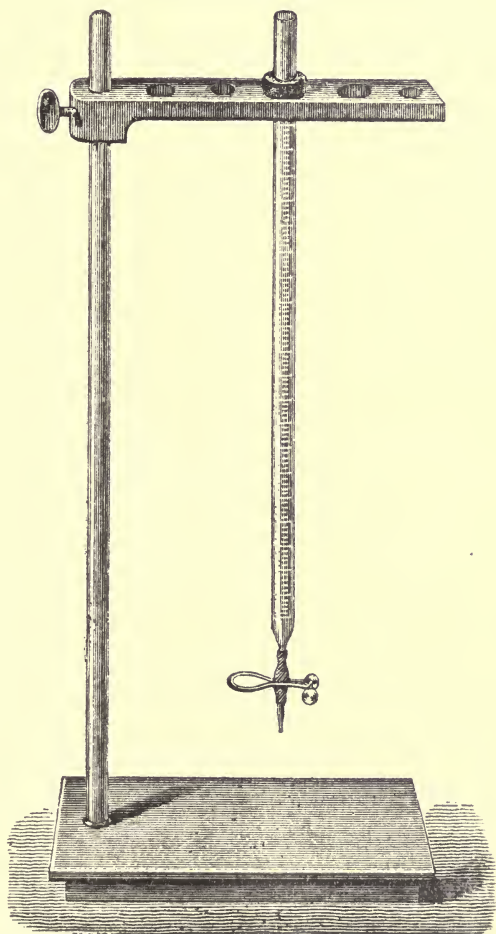


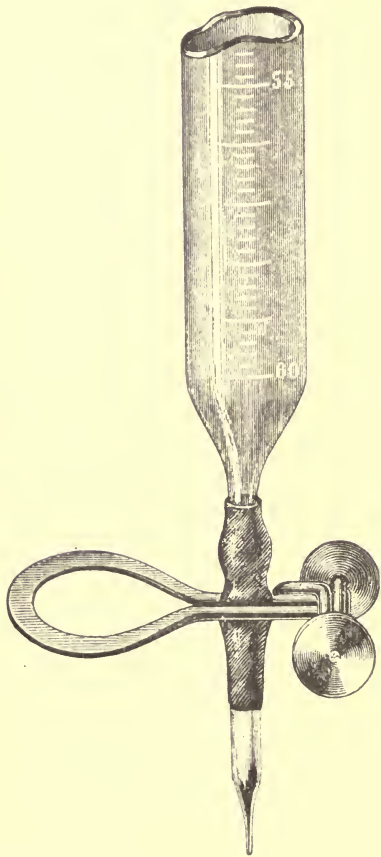
Fig. 46.



to a somewhat distended point, so as to allow a rubber tube to be drawn over it and securely fastened. In the lower end a glass

tube drawn out to a fine point is inserted. The rubber tube is compressed in the centre by a pinch-cock or clip, whereby the

Fig. 47.



lower end is closed. Fig. 46 shows a burette secured in a stand and Fig. 47 the lower part, with the clip on a larger scale. The burette is filled with liquid from above by means of a small funnel. By a quick, strong pressure upon the handle-joint of the clip, some liquid is then allowed to flow in a jet into a vessel. By this the tube below the clip is filled with liquid and the air contained in it expelled. By a slight or stronger pressure the liquid can, after some experience, be ejected in drops or in a stronger jet. The number of cubic centimeters which have been allowed to flow out can be readily read off by keeping the surface of the fluid in the tube on a level with the eye. The test liquor generally used is normal caustic soda solution, one cubic centimeter of it corresponding to 0.06 gramme

of acetic anhydride, and for especially accurate determinations decinormal solution, one cubic centimeter of it corresponding to 0.006 gramme of acetic anhydride and  $\frac{1}{10}$  cubic centimeter to 0.0006 gramme.

For determining the acetic acid the burette is filled to the O point with soda solution; a corresponding quantity of vinegar is then accurately measured off by means of the pipette, and after bringing it into a beaker, colored red by the addition of one or



two drops of litmus tincture and diluted with four to six times its quantity of distilled water. The beaker is placed upon a white support under the burette and the soda solution in the latter ejected in a strong jet by pressing with the right hand the handle-joint of the clip, the fluid being constantly agitated by gently swinging the beaker with the left. The influx of soda solution is interrupted as soon as a *blue* coloration on the point where it runs in is observed. After thoroughly stirring the fluid with a glass rod, the soda solution is again allowed to run in, but now drop by drop, the fluid being stirred after the addition of each drop. This is continued until the fluid has acquired a violet color with a strong reddish shade, and the addition of one drop more of soda solution changes the color to blue. The appearance of the violet coloration is called the *neutralizing point*, while the change of color from violet to blue indicates that the fluid is now neutral, *i. e.*, contains neither free acetic acid nor an excess of caustic soda. The determination is based upon the coloring substance of litmus appearing *red* in acid, *violet* in neutral, and *blue* in alkaline solutions.

Instead of soda test liquor a solution of ammonia is sometimes used to saturate the acid. The solution is prepared by adding water to concentrated ammonia till the specific gravity is 0.992; 1000 grains of this dilute ammonia contain one equivalent of ammonia, which is capable of saturating one equivalent of acetic acid. The application of this test is similar to that already described.

There is some difficulty in preserving the dilute ammonia of the same strength, which is an objection to its use; but a uniformity of concentration may be insured by introducing into the bottle two glass hydrometer bulbs so adjusted that one remains barely touching at the bottom, and the other floats just under the surface of the liquid as long as the test liquor retains the proper strength. If a part of the ammonia volatilizes, the specific gravity of the liquor will become proportionally greater, and the glass bulbs rise; the lower one higher from the bottom, and the upper one partly above the surface. When this happens, more strong ammonia is added, till the hydrostatic drops are properly readjusted.

Determinations of acetic acid by titration having to be frequently executed in a vinegar factory it is advisable to use an apparatus which will facilitate the operation. Such an apparatus is shown in Fig. 48. Upon a table stands a two-liter

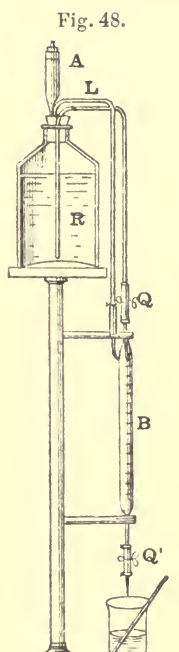


Fig. 48.

flask holding the normal soda solution. The flask is closed air-tight by a cork provided with three perforations. In one of these perforations is inserted a glass-tube, *A*, in the lower end of which is a stopper of cotton upon which are placed small pieces of burnt lime. On top, the tube is closed by a glass-tube drawn out to a fine point. Through another of these perforations passes a glass-tube, *R*, bent twice at a right angle and reaching to the bottom of the flask; the portion of this tube outside of the flask, as will be seen in the illustration, is somewhat longer than that in the flask, and, consequently, the tube forms a siphon. The outside portion of this tube is connected by a short rubber tube with the upper portion of the burette *B*. The latter is secured in a vertical position by two rods placed on the stand holding the flask. Below the burette is connected with a short rubber tube in which is inserted a glass-tube drawn out to a fine point.

On the side near the top of the burette is a small tube bent at a right angle, which is connected by a short rubber tube with the tube *L*, the latter reaching only to below the edge of the cork. Above and below the burette is closed by the clips *Q* and *Q'*.

For working with the apparatus the flask is filled with normal soda solution and the cork inserted air-tight after removing from it the tube *A* and substituting for it a small glass-tube. Now open the upper clip *Q* and blow vigorously through the glass-tube substituted for *A*, whereby the fluid is forced through the tube *R* into the burette. This being done cease to press upon *Q*, whereby the latter closes and stops a further discharge of the fluid. The tube, *A*, is then placed in position. By now pressing on the clip *Q* the fluid passes into the burette, the air contained

in the latter entering the flask through the tube *L*. The burette being emptied by the discharge of the fluid through *Q*<sub>1</sub>, it is re-filled for another determination of acid by simply pressing on *Q*, and this can be repeated as long as the flask contains soda solution.

In discharging the fluid from the burette by opening *Q*<sub>1</sub>, air from the outside passes into the apparatus through *A*. In doing so it must, however, pass through the line which fixes the carbonic acid contained in it, so that the fluid in the flask remains free from carbonic acid even after standing for months.

The calculation of the quantity of acetic acid present in the vinegar examined is made as shown by the following example:—

For 10 cubic centimetres of vinegar were consumed 70 cubic centimetres of decinormal soda solution.

One cubic centimetre of decinormal soda solution being equal to 0.006 gramme of acetic acid, hence 70 cubic centimetres 0.42 gramme.

Now, as 10 cubic centimetres contain 0.42 gramme of acetic acid, 100 cubic centimetres contain 10 times 0.42 gramme = 4.2 grammes of acetic acid; or the vinegar examined contains 4.2 per cent. by weight of acetic acid.

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## CHAPTER XX.

EXAMINATION OF VINEGAR AS TO THE PRESENCE OF FOREIGN ACIDS AND OF METALS, AS WELL AS TO ITS DERIVATION.

### *Detection of Acids.*

SOME unscrupulous manufacturers, in order to pass off weak or inferior vinegars, adulterate them with mineral acids. Such adulteration is not only a fraud, but dangerous to health, and it is necessary to indicate the means by which such additions can be detected.

*Sulphuric acid.*—Add to a sample of the vinegar a few drops of a solution of barium chloride. If the vinegar becomes slightly cloudy, the impurities are due to sulphates naturally present in the water or in the substances from which the vinegar has been made. A heavy white cloud slow in subsiding will indicate free sulphuric acid in small proportion. If the quantity of sulphuric acid is more than a thousandth, the sulphate of baryta produces a precipitate and falls rapidly to the bottom of the test-glass.

The presence of free sulphuric acid in vinegar can also be determined by coating a porcelain plate with strong sugar solution and allowing the latter to dry up. By bringing a few drops of vinegar to be examined upon the plate and placing the latter in a moderately warm place, pure vinegar evaporates, leaving a slightly brownish stain; vinegar containing free sulphuric acid leaves a dark-brown stain which on heating the plate turns black.

The presence of free sulphuric acid in vinegar can be determined with still greater sharpness by the following test: Divide a piece of starch the size of a grain of wheat in 50 cubic centimetres of vinegar and reduce the fluid one-half by boiling. To the clear fluid cooled to the ordinary temperature add a drop of a solution of iodine in spirits of wine. Vinegar containing no free sulphuric acid at once acquires a blue coloration; if free sulphuric acid be present, the fluid remains colorless. This test is based upon the fact that starch by continued boiling with sulphuric acid is converted into dextrin and finally into sugar. Neither of these bodies reacts upon iodine, while a very small quantity of starch gives with iodine the characteristic blue coloration.

*Hydrochloric acid.* Take about 100 cubic centimetres of the vinegar to be tested and distill off one-half by means of the apparatus Fig. 43, p. 200. Compound the fluid distilled off with a few drops of solution of nitrate of silver. In the presence of hydrochloric acid a white, caseous precipitate is immediately formed which consists of chloride of silver and dissolves in liquid ammonia added in excess.

*Nitric acid* is not a frequent adulteration. It is detected by saturating with carbonate of sodium or of potassium several ounces of vinegar and evaporating the whole to dryness. The

addition of sulphuric acid and copper turnings will cause the evolution of nitrous vapors if nitric acid be present.

*Lactic acid.* In many varieties of vinegar small quantities of lactic acid occur, which can be detected by slowly evaporating 100 cubic centimetres of vinegar in a porcelain dish until but a few drops remain. If these drops show a very strong pure acid taste, the vinegar examined contains lactic acid. The presence of lactic acid is, however, not due to an intentional addition, but to the material used in the manufacture of the vinegar, that prepared from grain, malt, or beer always containing it.

*Sulphurous acid.* This acid occurs only in vinegar prepared by fermentation when stored in freshly sulphured barrels. It may, however, occur in vinegar whose content of acetic acid has been increased by the addition of high graded acetic acid prepared from wood-vinegar. The most simple method of detecting the presence of sulphurous acid is by placing 100 cubic centimetres of the vinegar to be examined in a glass-distilling apparatus, and connecting the latter by a gas-tube with a vessel containing 50 cubic centimetres of pure water compounded with about 10 drops of nitric acid. After distilling over  $\frac{1}{10}$  of the vinegar the acidulated water is heated to boiling for a few minutes and solution of barium chloride added. If the vinegar contains sulphurous acid, a heavy white precipitate is formed.

### *Detection of Metals.*

The occurrence of metals in vinegar is due to the vessels employed in the manufacture or the storage, and, hence, the use of metallic utensils, such as stop-cocks, pumps, etc., should be avoided as much as possible. Besides iron, copper, zinc, and tin are occasionally found in vinegar.

*Iron.* The presence of this metal imparts a black color to the vinegar, which is increased by a few drops of tincture of gall-nuts. If the color of vinegar compounded with a few drops of solution of tannin is not changed after standing a few hours, the vinegar contains no iron, or only so small a quantity as to be of no importance.

*Copper.* While the presence of a small quantity of iron is of

little importance in a hygienic respect, that of copper, zinc, or tin is more serious, the combinations of these metals having a poisonous effect upon the organism. Copper can be detected in vinegar by evaporating to dryness about 1 quart of the vinegar to be examined and dissolving the residue in a few drops of nitric acid. By compounding a portion of this solution with ammonia in excess the fluid acquires a perceptible blue coloration in the presence of copper; the latter can be shown with still greater sharpness by dipping polished iron into another portion of the fluid. If the iron becomes coated with a perceptible red film (consisting of actual copper), the presence of this metal is shown.

*Tin.* Evaporate to dryness at least 2 or 3 quarts of the vinegar; dissolve the residue in hydrochloric acid, and conduct sulphuretted hydrogen through it until the fluid has acquired a strong odor of the latter. If a precipitate is formed, it is filtered off, dissolved in strong hydrochloric acid, and the solution divided into several portions. Compound one of these portions with dilute solution of chloride of gold; if after some time it becomes red and precipitates red flakes, the vinegar contains tin. The presence of tin is also indicated if another portion of the solution of the precipitate in hydrochloric acid does not acquire a blue color after the addition of potassium ferrocyanide. The behavior of the fluid towards solution of potassium permanganate may serve as a controlling test; if the fluid contains tin, the solution of potassium permanganate becomes discolored.

#### *Determination of the Derivation of a Vinegar.*

The examination of a vinegar as regards the materials used in its preparation is generally effected by the senses of odor and taste; there are, however, many easily executed tests which assist the judgment of the tongue and nose.

Vinegar prepared from dilute spirits of wine is colorless or only colored slightly yellowish. If such vinegar has a dark yellow color resembling that of wine, it is generally due to the addition of sugar color, the addition being chiefly made on account of the erroneous opinion prevailing among the public that vinegar clear as water or only slightly colored lacks strength.



Vinegar prepared from spirits of wine leaves, when carefully evaporated in a porcelain dish, a very small residue of a whitish or very slight yellow color, which chiefly consists of the salts contained in the water used for the preparation of the alcoholic liquid, an accurate examination showing it to consist of calcium acetate, gypsum, and a very small quantity of sodium chloride. If the residue is of a dark brown color, swells up when heated, and leaves a lustrous black coal, the vinegar has been colored with sugar color.

Beer and malt vinegars are dark yellow, generally with a reddish shade. On account of their content of dextrin they foam when shaken, and, when carefully evaporated, leave a brown, gum-like residue. The latter consists chiefly of dextrin, and contains, besides, the other extractive substances occurring in beer and malt vinegar, such as salts of ashes, especially much phosphoric acid. On heating strongly an odor calling to mind that of toasted bread is evolved. At a still higher temperature the residue turns black and finally acts like caramel : it evolves pungent vapors and leaves a lustrous coal.

The great content of phosphoric acid characteristic of malt or beer-vinegar may also serve for the determination of the derivation of such vinegar. By compounding beer or malt-vinegar with some nitric acid and a solution of ammonium molybdate and heating, the fluid, after standing, separates a yellow precipitate, which contains the phosphoric acid present in the fluid.

Wine-vinegar is best recognized by its characteristic odor, the latter becoming especially perceptible by rinsing out a large tumbler with the vinegar, and after allowing it to stand for a few hours examining the odor of the few drops remaining in the tumbler. The greater portion of the acetic acid having then volatilized the vinous odor becomes more prominent. Cider-vinegar, the odor of which is somewhat similar to that of wine-vinegar, can in this manner be plainly distinguished from the latter, the residue in the tumbler having an entirely different odor.

The presence of potassium bitartrate is a characteristic sign of wine-vinegar. By evaporating wine-vinegar to a brownish syrupy mass, boiling the latter with some water, rapidly filtering the boiling fluid into a test tube, and adding double its volume

of strong spirits of wine, a sand-like precipitate falls to the bottom of the test-tube, which consists of very small crystals of tartar. This, however, does not prove the sample to be genuine wine-vinegar, tartar also being contained in imitations. With a sufficiently sharp sense of smell this is, however, the surest means of distinguishing genuine wine-vinegar from a spurious article.

In case the derivation of a vinegar is to be established with absolute certainty it has to be subjected to an accurate chemical analysis, and this being better made by an analytical chemist only a few hints are here given which may serve as a guide for such analyses.

In a vinegar prepared from a fermented fluid a certain quantity of glycerin and succinic acid will, as a rule, be present, these bodies being always formed by the fermentation of a sacchariferous fluid, and, consequently, when found, the respective vinegar cannot have been prepared from an alcoholic liquid consisting only of spirits of wine and water. If they are found only in very small quantities, the alcoholic liquid used for the fabrication of the vinegar consisted very likely of spirits of wine and water with the addition of beer or fermented whiskey-mash, and in this case small quantities of dextrin and of phosphates will also be found. The total absence of tartaric acid and the presence of malic acid indicate the derivation of the vinegar under examination from fruit, though not necessarily from apples or pears, other sacchariferous fruits also containing malic acid. A content of tartaric acid is, however, no proof of genuine wine-vinegar, as its presence may be due to an intentional addition, and it is very difficult to arrive at a certain conclusion about the genuineness of a pretended wine-vinegar, especially in the case of cider-vinegar to which tartaric acid has been added.

Should pepper, chillies, etc., be added to vinegar for the purpose of conferring more pungency, they may be detected by neutralizing the acid with carbonate of soda and tasting the liquor; if these bodies be present, the solution will still retain the sharpness peculiar to such spices.

## CHAPTER XXI.

## MANUFACTURE OF WOOD-VINEGAR.

AMONG the numerous organic substances which by distillation in closed vessels give rise to acid products, wood is employed in the arts for the manufacture of acetic acid. Wood-vinegar, or acetic acid from wood, is also known when impure under the name of *pyroligneous acid*.

Wood essentially consists of woody fibre, small quantities of salts and sap, and a variable quantity of hygroscopic water. Woody fibre or cellulose constitutes about 96 per cent. of dry wood, and is composed of  $C_6H_{10}O_5$ ; in 100 parts, of carbon 44.45; hydrogen 6.17; oxygen 49.38. The vegetable sap consists chiefly of water, but contains organic as well as inorganic matters, partly in solution and partly suspended. The inorganic constituents (the ash left after the incineration of the wood) are the same in all kinds of wood. The quantity of water contained in wood is generally larger in soft than in hard woods. One hundred parts of wood recently felled contain, according to Schübler and Neuffer, the following quantities of water:—

Beech . . . .	18.6	Common fir . . . .	39.7
Birch . . . .	30.8	Red beech . . . .	39.7
Oak . . . .	34.7	Alder . . . .	41.6
Oak ( <i>quercus pedunculata</i> )	35.4	Elm . . . .	44.5
White fir . . . .	37.1	Red fir . . . .	45.2

The branches always contain more water than the trunk.

Wood is called air-dry when its weight no longer changes at an ordinary temperature; in this state it contains still 17 to 20 per cent. of water. The latter can be expelled by continued heating at  $212^{\circ}$  F., but wood thus dried re-absorbs about 20 per cent. of water from the air.

When felled nearly all kinds of wood are lighter than water; a few are, however, heavier, but these are the harder kinds in which

the cellulose is so closely packed that very little room is left for the retention of air. The following table exhibits approximately the specific gravity of various woods :—

Larch . . . . .	0.47	Ash . . . . .	0.64
Fir and pine . . . . .	0.55	Oak . . . . .	0.70
Beech . . . . .	0.59	Hornbeam . . . . .	0.76
Birch . . . . .	0.62		

The content of ash is not the same in all woods; it varies considerably in different parts of the same tree and also with its age. According to Violet, in the cherry tree the content of ash is greatest in the leaves (about 7 per cent.), next in the lower parts of the roots (5 per cent.); considerably greater in the bark than in the wood, in the former from 1.1 to 3.7 per cent., and in the latter 0.1 to 0.3 per cent. Saussure found in the bark of the oak 6 per cent., in the branches 0.4 per cent., and in the trunk 0.2 per cent. of ash. The ash consists chiefly of carbonates of calcium, potassium, and sodium, further of magnesia and the phosphates of different bases.

The average composition of 100 parts of air-dry wood is: carbon 39.6 parts, hydrogen 4.8, oxygen and nitrogen 34.8, ash 0.8, hygroscopic water 20; and that of artificially dried wood: carbon 49.5, hydrogen 6, oxygen and nitrogen 43.5, ash 1.

*Decomposition of wood.*—Cellulose when carefully treated remains unchanged for a long time, even thousands of years. Wood is, however, subject to greater changes, though under especially favorable circumstances it may last for several centuries. In the presence of sufficient moisture and air the nitrogenous bodies of the sap are, no doubt, first decomposed, and the decomposition being next transferred to the woody fibre, the latter gradually loses its coherence, becomes gray, then brown, and finally decays; hence, wood rich in water decays more rapidly than dry wood.

Wood to be preserved should, therefore, be as dry as possible, and the nitrogenous bodies, which can be but incompletely removed by lixiviation, be converted into insoluble combinations; tar and one of its most effective constituents—creasote—mercuric chloride, blue vitriol, chloride of zinc, and many other substances having been recommended for this purpose. Moreover, it has been successfully attempted to produce certain insoluble bodies, such

as aluminium and copper soaps, in the interior of the wood by saturating it with soda soap and then with aluminium chloride or blue vitriol, or such as barium phosphate by saturating with sodium phosphate and then with barium chloride, etc.

By heating to  $212^{\circ}$  F. the wood remains unchanged; it yields up only sap constituents. If, however, the temperature be increased, for instance to  $392^{\circ}$  F., a small quantity of sugar is, according to Mulder, formed from cellulose in a closed vessel, and from wood, according to G. Williams, an acid not yet thoroughly known, methyl alcohol (see further on), an oil boiling between  $277^{\circ}$  and  $421^{\circ}$  F. and a small quantity of furfural.

In the presence of water, wood in a closed vessel is, however, already decomposed at about  $293^{\circ}$  F., if this temperature be kept up for a long time, for instance, a month, the wood, according to Sorby, being converted into a lustrous black mass with the formation of acetic acid and gases.

According to Daubrée, pine, when heated for some time with water in an entirely closed vessel to  $752^{\circ}$  F., is converted into a mass having the appearance of stone-coal and approaching anthracite in its behavior. Baroulier made similar observations, masses resembling stone-coal being formed by pressing sawdust, stems, and leaves together in moist clay and heating continuously to from  $392^{\circ}$  to  $572^{\circ}$  F., so that the vapors and gases could escape only very slowly.

By avoiding all heating concentrated sulphuric acid converts cellulose into a gum-like body, dextrin, which by diluting with water and long digesting is converted into sugar (starch sugar); when heated the wood, however, turns black with development of sulphurous acid and complete destruction. By dilute sulphuric acid cellulose is converted into starch, or at least a starch-like body colored blue by iodine and dextrin. Wood is, however, but little affected by it at an ordinary temperature, while at a higher temperature a certain quantity of sugar (starch sugar) is formed, water being absorbed at the same time. This behavior has been utilized for obtaining alcohol by fermenting the sugar with yeast after neutralizing the acid by calcium carbonate, for instance, chalk. The unattacked woody fibre can be used as material for paper.

Concentrated hydrochloric acid colors wood rose color to violet red and then rapidly destroys it. Dilute hydrochloric acid, on heating, forms sugar; but, according to Zetterlund, the quantity of absolute alcohol obtainable in this manner is very small, amounting to about 2.3 per cent. of the weight of the wood.\* By macerating wood with dilute hydrochloric acid at an ordinary temperature, the cellulose is not changed, but the so-called lignin seems to be dissolved. By forcing dilute hydrochloric acid by a pressure of two atmospheres into trunks provided with the bark, and subsequent washing out in the same manner with water, and drying by means of a current of air at  $98.6^{\circ}$  F., wood acquires great plasticity. In a moist state wood thus treated can be pressed together to one-tenth of its original volume.

Hydriodic acid reduces the wood to several hydrocarbons, water being formed and iodine liberated.

Concentrated nitric acid, or, still better, a mixture of it and sulphuric acid, converts cellulose, for instance, cotton, into gun-cotton; wood is colored yellow and partially dissolved. Dilute nitric acid, for instance, of 1.20 specific gravity, has no effect in the cold, and but little when heated.

By bringing cellulose in contact with dilute aqueous solutions of alkalis, it is colored blue by iodine, and consequently a starch-like substance is formed, but no humus-like bodies; from wood only the lignin is extracted, the woody fibre remaining unchanged. By heating with strong alkaline lyes, or, still better, by fusing with solid caustic alkalis, acetic acid is, according to Braconnot, first formed and then oxalic acid. The latter acid is frequently obtained by this process.

On heating shavings with sodium sulphide an abundant quantity of acetic acid (sodium acetate) is formed; the addition of sulphur to caustic soda seems to have the effect of preventing the formation of oxalic acid.

\* According to prior experiments by Bachel, it is, however, claimed that up to 23 per cent. of sugar can be obtained from wood by boiling 10 to 12 hours with water containing one-tenth of hydrochloric acid.



*Decomposition of Wood at a Higher Temperature.*

All organic bodies, except those which sublime without change, are decomposed when exposed to heat in closed vessels, their constituents interchanging with one another and forming new compounds, which are of sufficient stability to resist the particular temperature employed. Thus, the elementary components of wood, after a certain amount of heat is applied, arrange themselves into combinations quite distinct from those in which they originally were. Some of them are gaseous, but at moderate temperatures by far the greater part are liquid, the quantity of the latter depending entirely upon the greater or less degree of heat applied in this distillation.

The main cause of decomposition of such an organic body as wood by heat is that the strong affinity of its contained oxygen for carbon and hydrogen and the comparatively greater stability of the more simple compounds of these bodies, cause their formation the moment there is a sufficient amount of commotion amongst the atoms of the original body to allow them to commingle freely. Heat sets up the necessary vibration, and those compounds are at once formed which can resist without rupture of their constituents from each other, the multitude or amplitude of the vibrations corresponding to the temperature at which they are evolved.

As a general rule, those bodies containing much oxygen are decomposed at comparatively low temperatures. Acetic acid is an exception; a dull red heat does not cause its constituents to fly sufficiently apart from each other to cause their total separation, and the compound, therefore, remains unchanged. To this circumstance is due the large amount of acetic acid which is produced during the destructive distillation of wood. As previously stated, the composition of cellulose is  $C_6H_{10}O_5$ . The hydrogen and oxygen being in the proportions to form water, the withdrawal of carbon would form acetic acid thus:  $2C_6A_{10}O_5 - 2C = 4C_2H_4O_2$ . As might be anticipated, acetic acid is amongst the earliest and most abundant products of the distillation of wood, and, being volatile, escapes decomposition at the higher temperatures employed later. As the distillation progresses,

marsh gas ( $\text{CH}_4$ ), olefiant gas ( $\text{C}_2\text{H}_4$ ), tetrylene ( $\text{C}_4\text{H}_8$ ), and volatile oils, such as benzol ( $\text{C}_6\text{H}_6$ ), toluol ( $\text{C}_7\text{H}_8$ ), naphthalin ( $\text{C}_{10}\text{H}_8$ ), paraffin ( $\text{C}_{20}\text{H}_{42}$ ), phenol ( $\text{C}_6\text{H}_6\text{O}$ ), etc., are given off. The actual facts which are observed in the distillation of wood are as follows : 1. The water passes off which is extraneous to the wood ; 2. The wood itself is decomposed and gives rise to water and the crude acetic acid, which is next eliminated ; 3. Condensable matters containing an excess of carbon forming the tar and oily substance pass over ; 4. Toward the close of the operation, carbonic oxide and marsh gas are evolved, leaving in the retort a charcoal similar in form to the wood introduced.

### *Distillation of Wood.*

The distillation of wood is carried on in retorts made of cast-iron or wrought-iron, and sometimes of clay. The latter have the advantage of not burning through, but it is difficult to keep them entirely tight, a number of small cracks being formed through which a portion of the vapors escapes. Cast-iron retorts do not readily burn through, and are but little affected by the vapors of the acid, but they frequently burst, and defective places are difficult to repair. Wrought-iron retorts gradually burn through on the bottom, where they come in contact with the fire ; they can, however, be repaired by riveting strong boiler-plate upon the defective place, and are less affected by the acetic acid vapors than might be supposed, because some protection is afforded to them by the deposition of a layer of coal from decomposed tar vapors and gases upon their interior surface. Experience having shown that wrought-iron is more strongly attacked on the less hot places than on the hottest, it is customary to provide wrought-iron retorts with cast-iron doors and discharge apertures. To retard burning through, the exterior of the retorts is coated with a thick layer of lime or clay, or with a mixture of lime, iron-filings, and water glass. The riveting must be carefully executed, and the joints luted with clay or trass-mortar.

*Form of the retorts.*—Clay-retorts are mostly  $\sqcap$ -shaped like those for the manufacture of coal-gas.

Cast-iron retorts are either cast in one piece, having in this case a cylindrical form with a circular cross section, or flat pieces are connected together by screws to parallelopiped boxes; the latter form is preferable for the distillation of birch bark, which fills up the room to the best advantage by placing it in flat, even pieces.

*Dimensions of the retorts.*—The size of the retorts varies greatly, but the most suitable for horizontal cast-iron or wrought-iron retorts is a length of from  $5\frac{1}{2}$  to  $6\frac{1}{2}$  feet with a diameter of from  $2\frac{1}{4}$  to  $3\frac{1}{4}$  feet. In England retorts of a still greater size are in use, for instance, wrought-iron ones, which with a length of  $6\frac{1}{2}$  feet have a diameter of  $4\frac{1}{2}$  feet, and cast-iron ones with a length of from  $8\frac{3}{4}$  to  $9\frac{1}{2}$  feet and a diameter of 3 feet. Wrought-iron retorts are generally from 0.27 to 0.31 inch thick.

For vertical wrought-iron retorts Vincent recommends a height of 6 feet and a diameter of 4 feet, and Gillot, as well as Rothe, a diameter of from 4 to 5 feet and a height of  $7\frac{1}{2}$  feet.

For rectangular wrought-iron boxes: length  $4\frac{1}{4}$  feet, width 2.62 feet, height 3.28 feet. For rectangular cast-iron boxes: length 8.85 to 9.18 feet, width 3.28 to 4 feet, height 4 to  $4\frac{1}{2}$  feet.

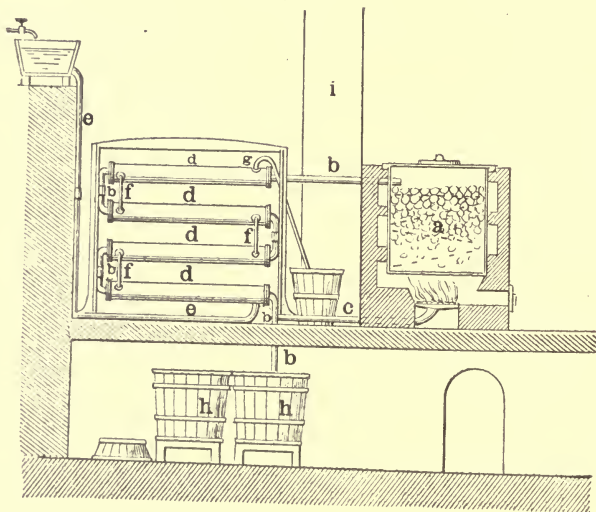
*Position of the retorts.*—In France vertical wrought-iron cylindrical or rectangular boxes are most frequently used. This arrangement allows of the vessel, when distillation is finished, being lifted from its position by means of a crane and inserting a new one in its place, so that the high temperature which the brick work has acquired is utilized almost without loss. The disadvantage is the inconvenient filling and emptying of such vessels, both operations having to be executed from above. To facilitate the emptying, an aperture is occasionally provided near the bottom, but in this case it is difficult, on account of the high temperature, to make the aperture tight by a clay luting. Further, the vapors escaping from the lower portion of the wood to be distilled, especially those specifically heavier than tar, rise only with difficulty to the discharge aperture, and having consequently to remain an unnecessarily long time in the hot space are partially decomposed to permanent gases. Even with the best condensing apparatus they carry along a certain quantity of acetic acid and especially of wood spirit, and the non-condensing portion is then

only used as fuel. This evil could be overcome by providing a discharge aperture for the heavier vapors on the lower half of the retort; but this has again the disadvantage that the exchange of the hot vessels cannot be effected as rapidly.

In England and Germany horizontal retorts, which are uniformly surrounded by the flame, are in general use. To prevent a disadvantage similar to the one mentioned above, the retorts, however, must not be too long, as the vapors from the front have to pass over the glowing back portion to reach the discharge aperture.

*Vertical retorts.*—Fig. 49 shows Kestner's apparatus, which is in extensive use in France. The retort *a* has a capacity of 3 cubic meters (105.94 cubic feet). It is surrounded by flues which lead to the chimney *i*. Large sticks are set upright in the retorts; those too thick should be split, and small wood packed close. The retort is closed at the top by an iron cover secured by screws or clamps.

Fig. 49.



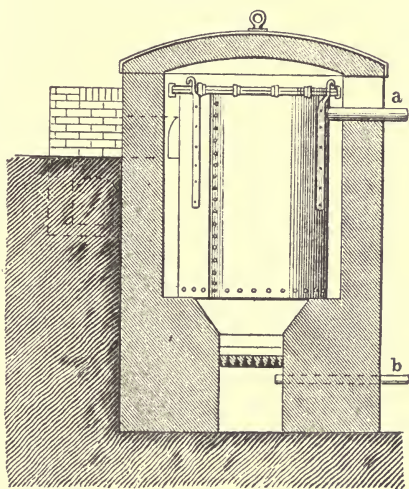
The products of distillation are condensed in the copper pipes *b*, which are inclosed in wider cast-iron or copper pipes *d*. In the latter a current of water passes from *e* through the connecting pipe *f* from below to above, and effects the cooling off of the vapors. The non-condensed vapors and gases are conducted through *c*

into the fire-place. The pipe conducting the wood-vinegar and the tar into the vats *h* dips somewhat into the fluid. From the vats the fluids are pumped into large reservoirs placed at a higher level, so that they can be readily discharged into the stills.

The apparatus is not movable, *i. e.*, the retort remains fixed in its place.

Movable retorts, as shown in Fig. 50, were first introduced in France. They are entirely surrounded by the fire gases, the fire-place being closed on the top by a brick cover held together by means of iron hoops. The vapors and gases pass out through the pipe *a* which is placed on the side immediately below the cover. When no more volatile products appear the lid is removed,

Fig. 50.



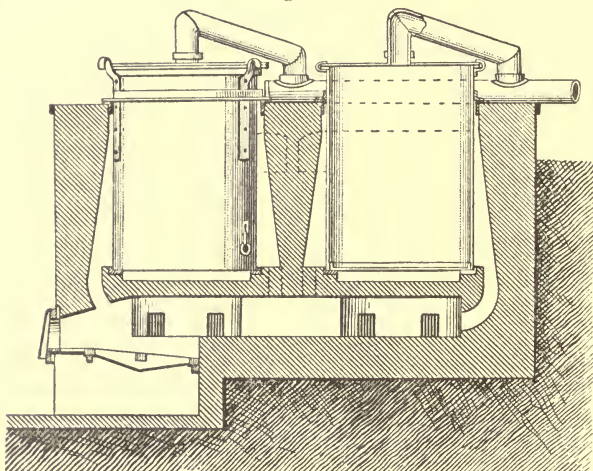
and, after interrupting the connection with the condenser, and closing the pipe *a* with clay, the glowing retort is lifted out by means of a crane. A new retort already filled with wood is then immediately placed in the hot furnace and distillation recommenced. The pipe *b* conducts the non-condensed vapors and gases into the fire-place.

In modern times this apparatus has been modified, as shown in Fig. 51, and in this form is in general use in France. The developing pipe for the volatile products has been transferred to the



lid. The fire-place has the form of a truncated cone, and the retort is surrounded by it only to about five-sixths of its height, while the upper end projects about one foot. The movable cover being omitted the exchange of the retorts is facilitated. The brick work of refractory material is held together at the top by a strong iron ring. The bottom of the fire-place is formed by an arch below which is the hearth whose flames surround the curved surface as well as the bottom of the retort. At the top the fire-

Fig. 51.



place is terminated by an iron ring placed on the retort. To save fuel the fire-place serves for two retorts, as shown in the illustration.

The fire burns constantly upon the hearth ; it is regulated by means of two registers placed in the upper end of the fire-place in the draught apertures. The four rectangular apertures below the vault introduce the gases from the condenser.

When a retort, for instance, that at the left of the figure, is distilled off, the register and gas conducting channel belonging to this retort are closed. The retort is then lifted out, placed upon an iron wagon running upon a track, and taken away to cool. Another retort filled with wood, and made tight by a clay luting, is then inserted by means of a crane, and the register and gas

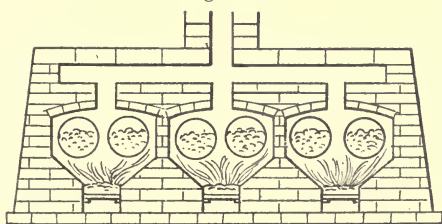


conducting channel are reopened. When after about one hour the water is expelled from the wood, and acid vapors appear, a copper pipe is connected with the condenser, and the joints made tight by a clay luting. The gases appearing in constantly increasing abundance during distillation, are now conducted under the second retort in order to heat it sufficiently towards the end of the distillation, as otherwise the charcoal will show "brands," *i. e.*, pieces not entirely carbonized.

A retort holding 2 cubic meters (70.63 cubic feet) of wood is distilled off in 8 hours.

*Horizontal retorts.*—Generally two wrought iron retorts are placed in one fire-place, for instance, 6 retorts in three fire-places with a common chimney, as shown in Fig. 52, one-third to two-thirds of their circumference being, as a rule, bricked in. In front and back they are closed by cast-iron disks, the front one being

Fig. 52.

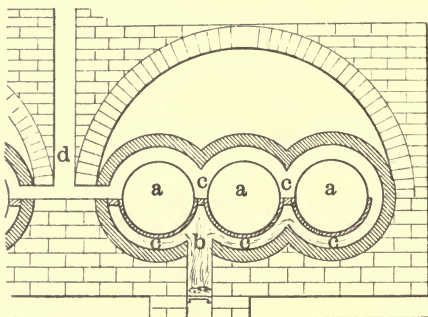


movable so that, when an operation is finished, it can be readily removed, and replaced. From the back disk a pipe leads to the condensing apparatus. For the back disk is sometimes substituted a conical shoulder which ends in a pipe about 8 inches in diameter to which the discharge pipe is secured (Fig. 54).

Each cast-iron retort has a special fire-place, and the cylindrical, as well as the rectangular retorts, are bricked in only at the bottom. The brickwork is held together by several iron clamps. The retorts rest upon the arch above the fire-place in such a manner that they are not directly struck below by the flame but only surrounded by it from the side and above. It is also advisable to expose, not only the cylindrical space holding the retorts to the fire, but also the annexed conical one. The narrow pipe projects about one foot above the wall.

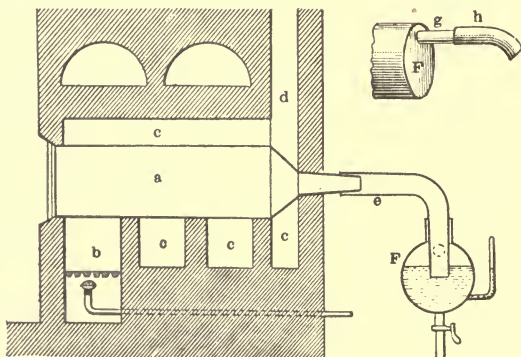
In Figs. 53 and 54 *a a a* are the wrought-iron retorts, *b* the hearth, *c c* the flues, *d* the chimney. Over the somewhat conical neck of the retort is pushed an elbow pipe *e* which dips into the receiver *F*. The latter is a cast-iron pipe 1 to 2 feet in diameter

Fig. 53.



(according to the number of the retorts) and extending the entire length of the oven. For the neck of each retort it carries a tubulure  $5\frac{3}{4}$  to  $7\frac{3}{4}$  inches long. The object of the receiver is to receive the products of distillation from all the retorts

Fig. 54.



and at the same time to hydraulically close the elbow-pipe of each receiver. Hence the vapors not precipitated in the receiver can continue their way through *g* to the other condensing appa-

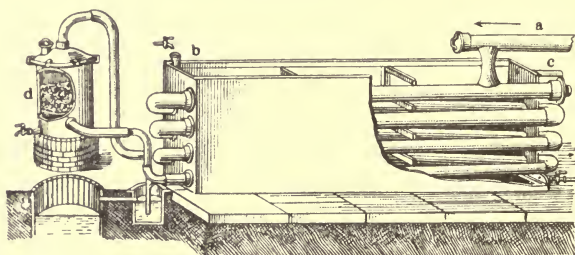
ratus *h*, but cannot re-enter the retorts. This is of no slight importance, for if there were no water joint and the vapors should from any cause suddenly cool off, the external air might penetrate into the retort and the latter being filled with inflammable gases and vapors of a high temperature an explosion would necessarily follow. For making the water-joint it suffices for the elbow-pipes to dip  $\frac{3}{4}$  to 1 inch into the fluid in the receiver. But as the fluid constantly increases provision must be made for its discharge through a pipe, placed below or on the side, into a collecting vessel located in another apartment. The charcoal is at the end of the operation raked into sheet-iron boxes or square pits sunk in the floor and lined with fire brick; both chests and pits are fitted with close fitting covers, since if air is not excluded the charcoal from its power of condensing gases in its pores, becomes so much heated as to take fire spontaneously. By shutting the charcoal in, the absorption is so far retarded as to keep the heat below the point of ignition.

In many factories the charcoal is abstracted from the carbonizing cylinders by means of the following apparatus: An iron diaphragm about the size of the interior of the retort is placed near the mouth of the latter, having a chain attached to it which runs through the whole length of the carbonizer. The workman by seizing this chain with a suitable instrument draws out nearly the whole of the charcoal at once, and with less risk of breaking it than when rakes are employed.

*Condensers.*—Wood, as will be shown later on, yields more than half its weight of condensable fluids and among them some with a low boiling point. The necessity for good condensation is, therefore, evident, and the more so as the quantity of non-condensable gaseous bodies is very large and with incomplete cooling would carry away a considerable portion of valuable bodies. Kestner's apparatus, Fig. 55, answers all demands. In a long, narrow trough of wrought-iron or wood lies a series of straight, wide copper pipes, with a gradually decreasing diameter. The pipes are slightly inclined, so that the fluid running in at the highest point flows out at the lowest. Outside the trough the pipes are connected by movable elbow-joints. One end of each pipe is firmly fixed to the wall of the trough, while the other, to permit

free expansion, sits loosely in a slightly conical socket. The lower end of the last pipe divides into two branches, one of them leading downward and dipping into the receiver, while the other, as a rule, conducts the gases directly under the fire-place. There should be but a small space between the collecting pipe *a*,

Fig. 55.



which conducts the vapors to the condenser, and the first condensing pipe, as otherwise obstructions might readily be formed by the deposit of tar dried by the hot vapors. A constant stream of water is conducted through *b*, along the bottom of the trough, the heated water running off at *c*.

The development of gas from the wood being very irregular and by no means in the proportion desirable for the heating of the retorts, it is preferable to collect it in a gasometer and distribute it from there as may be necessary, instead of conducting it directly into the fire. But little gas is developed in the beginning of the operation, and much towards the end, while the reverse proportion is desirable.

In case condensation is not very complete, the pipe leading to the hearth or gasometer is more or less attacked by acetic acid precipitated in it by the access of air. To prevent this evil it is advisable to place on the pipe small receptacles provided with cocks for the collection and discharge of any fluid deposited. These receptacles may also be filled with quick lime, which at least fixes the acetic acid, thus rendering it harmless for the pipe. The lime is from time to time extracted with water to regain the soluble calcium acetate.

To further cool off the current of gas and render the vapors of acetic acid carried along with it harmless for the pipe, Vincent

uses a cylindrical copper receptacle, *d*, Fig. 55, provided with a false bottom, upon which is placed a layer of crystallized soda from  $2\frac{1}{4}$  to  $2\frac{1}{2}$  feet deep. The vapors of water and acetic acid dissolve the soda, and the temperature thereby being lowered, a further portion of the volatile bodies, especially wood spirit, is precipitated. By distilling the fluid thus obtained, the wood spirit is regained, and the residue in the still used for the preparation of sodium acetate.

For a condenser for four retorts of a capacity of 4 cubic metres (141.26 cubic feet) each, Gillot gives the following approved dimensions, provided the period of distillation is 72 hours: The diameter of the pipe at its entrance into the water trough is  $15\frac{3}{4}$  inches, and at its exit  $5\frac{3}{4}$  inches; its total length is 164 to 180 feet, this length being divided between 6 straight pieces and their elbow-joints. The vat is  $26\frac{1}{4}$  feet long with a depth of  $5\frac{1}{4}$  feet.

The arrangements suitable for the carbonization of wood having been described in the preceding pages, the most important products will now be more closely considered. Before doing this a few remarks as to the most suitable varieties of wood, and their constitution, may be acceptable.

Oak, beech, hornbeam, ash, and birch give the largest yield of wood vinegar, less being obtained from the conifers, poplar, willow, and aspen. On the other hand, the conifers as well as the bark of birch yield considerable quantities of volatile oils.

Woods about 20 years old seem to be especially suitable for the purpose of distillation. The trees should be felled in the winter, and the wood allowed to lie for six months and not over two years. It should be protected from rain and snow. To facilitate drying, it is best to free the wood from the bark, this being of special importance in regard to birch, the bark of which yields about 40 per cent. of tar and empyreumatic oil, and the wood only 2 per cent., hence the removal of the bark essentially facilitates the purification of the wood-vinegar. The removal of the bark is best effected by the introduction of steam of about one atmospheric pressure into a wooden vat covered with felt, and provided with a perforated false bottom, upon which the pieces of wood rest. After allowing the steam to act for about three hours, the bark can be readily detached. By drying the air-dry wood in the semi-



cylindrical space above the retorts (Fig. 54) the content of water can be reduced to 10 per cent., and consequently less water has later on to be removed by evaporation; besides, the distilling time is shortened, and a larger yield of wood-vinegar obtained.

### *Charcoal.*

The substance called charcoal is not pure carbon; it containing, besides this element, hydrogen, oxygen (together with traces of nitrogen), and ash. The composition of charcoal, and consequently its properties, vary very much according to the degree of temperature to which the retort has been exposed, the duration of heating, and the variety of wood.

By heating the wood in the retorts the hygroscopic water escapes first; then, at a temperature somewhat above 212° F., wood-vinegar makes its appearance and gradually increases in strength until its maximum strength is reached at 424° F.; it then again becomes weaker. Next the formation of tar begins, and inflammable gases now make their appearance. If the operation be continued to the end, the products are: black charcoal, wood-vinegar, tar, and gases. If distillation is, however, interrupted when the greater portion of the wood-vinegar is separated and the formation of tar would commence, *charbon roux* or torrified charcoal, i. e., a product containing the greater portion of the constituents of the tar and the gases, remains. Experience has shown that torrified charcoal is as well adapted for use in the blast-furnace as black charcoal. The yield is about forty per cent. of the wood used, and being firmer and harder than black charcoal it is better adapted for transport.

To a product intermediate between wood and torrified charcoal the name *red-wood* (roasted wood, *bois roux*) has been given. It is brown, can be worked like wood, is but slightly hygroscopic, highly inflammable, and has nearly double the heating power of wood. Its average composition is: carbon 52.6 per cent., hydrogen 5.8, oxygen (together with nitrogen) 36.6, ash 0.4, water (moisture or constitutional) 4.5.

For technical purposes charcoals obtained at a temperature of above 518° F. are only available, those obtained at a lower temperature containing the so-called brands with a content of carbon of,



at the utmost, 68 per cent., of hydrogen about 5 per cent., and of oxygen more than 26 per cent.

With a distilling temperature of 464° F. there remains, of 100 parts of wood dried at 302° F., a residue of 50.8 parts of brands, and with a distilling temperature of 518° F. 37 parts.

With a temperature above 644° F. the result is black coal, the quantity and composition of which vary according to the temperature. Between 644° F. and 810° F. remains 31.5 to 19 per cent. of charcoal with a composition of from 75 to 81.6 per cent. of carbon, 4.4 to 2 of hydrogen, and 20 to 15 of oxygen, and 0.5 to 1.1 of ash.

At still higher temperatures the quantity of charcoal decreases but little; it amounts, for instance, at the melting point of bar-iron, to 17.3 per cent., and at that of platinum, to 15 per cent. The content of carbon, however, constantly increases until at the last-mentioned temperature it reaches 96.5 per cent.

Violette further confirmed the fact long known that the degree of carbonization exerts a great influence upon the result, slow carbonization yielding far more charcoal, than quick.

The variety of wood also exerts an influence upon the yield of charcoal. At 572° F. there were, for instance, obtained from—

Oak . . . . .	46 per cent.
Fir . . . . .	40.7 “
Aspen . . . . .	34.9 “
Beech, alder, birch . . . . .	34.4 “
Ash . . . . .	33.3 “
Linden . . . . .	31.8 “

Later on Violette found that the elementary composition of these charcoals varied. There are contained, for instance, in charcoal from—

	Carbon.	Hydrogen.	Oxygen (and nitrogen).	Ash.
Oak . . . . .	67.4	4.1	28.5	0.2
Aspen . . . . .	68.2	5.5	25.7	0.6
Birch . . . . .	71.1	4.5	23.5	0.7
Ash . . . . .	70.4	4.5	24.4	0.7

These figures are, however, only correct for charcoal kept air-tight after its preparation and immediately analyzed. Ordinary charcoal contains at least 5 per cent. of hygroscopic water.

The specific gravity of charcoal depends on the carbonizing temperature. The specific gravity of charcoal from bird-cherry carbonized at 590° F. is 1.42, at 810° F. 1.71, at 1873° F. 1.84, at 2732° F. 1.87, and at the fusing point of platinum 2.0.

The power of charcoal of conducting heat and electricity also increases to a remarkable extent with the increase in the carbonizing temperature.

The inflammability of charcoal is the greater the lower the temperature at which it was prepared.

Charcoal possesses the property of absorbing gases and of taking up liquid and solid bodies from fluids, for instance, fusel oil, coloring substances, and alkaloids. Lead salts, for instance, lead acetate and nitrate, are decomposed on boiling with charcoal, the latter absorbing the lead oxide and liberating a corresponding quantity of acid.

Charcoal also absorbs aqueous vapor from the air, and the more the lower the temperature at which it was formed; the quantity varies from 4 to 20 per cent. Hence the charcoal exposed to the air contains only about  $\frac{2}{3}$  of its weight of carbon.

### *Wood-Vinegar.*

After standing for several days in the previously-mentioned reservoir, the greater portions of the wood-vinegar and tar separate and form two layers, less often three. In the latter case the upper layer, which amounts to but little and may be entirely wanting, consists of specifically light volatile oils holding tar and acetic acid in solution. The second layer forms the principal mass and is the actual wood-vinegar. The lowest layer is tar, rich in specifically heavy volatile oils, especially phenol (creasote), containing, however, also acetic acid; it is of a yellow-brown to black color, of a syrupy consistency, and specific gravity 1.07 to 1.11.

The layers are drawn off separately by means of stop-cocks placed at different heights on the reservoir.

Wood-vinegar is a strongly acid fluid, generally perfectly clear, of a brown-yellow to red-brown color, and a strong odor (par-

tially of smoke). Its specific gravity varies between 1.018 and 1.03. When mixed with water it frequently becomes turbid.

Wood-vinegar is a mixture of very dissimilar bodies. Besides its principal constituent, acetic acid, it contains several other acids belonging to the series of fatty acids with the general formula  $C_nH_{2n}O_2$ ; further wood-spirit, acetone (see below), metacetone  $C_6H_{10}O$ , methyl acetate  $\left. \begin{matrix} C_2H_3O \\ C_2H_5 \end{matrix} \right\} O$ , aldehyde, dimethyl acetal

$\left. \begin{matrix} C_2H_4 \\ C_2H_4 \end{matrix} \right\} \begin{matrix} OCH_3 \\ OCH_3 \end{matrix}$ , furfural, allyl alcohol  $C_3H_6O$ , small quantities of ammonia and of methylamine  $CH_3H_2N$ , and finally plenols and guaiacols; besides empyreumatic resins.

To carbolic acid, one of the plenols, is due the property of wood-vinegar to preserve meat and other organic substances.

On mixing wood-vinegar with soda-lye it becomes turbid, but on a further addition of alkali soon clarifies again and acquires a dark brown color, a brown body being separated. On mixing it with 5 to 10 per cent. by volume of concentrated sulphuric acid it becomes turbid and after 24 hours the greater portion of the tar separates in fine drops. Potassium bichromate colors wood-vinegar brown, and nitrate of silver is reduced at an ordinary temperature, a silver mirror being produced (this reduction is due to the content of aldehyde and creasote).

In the distillation the more volatile bodies, of course, pass over first; they form a yellowish fluid which contains wood-spirit, acetone, etc. Then follows a turbid slightly acid water of a yellowish color; it gradually becomes richer in acid, but remains yellowish to the end. The wood-vinegar boiling in the retort constantly becomes darker, and finally a clear dark brown fluid of a syrupy consistency and of an acid, and at the same time bitter, taste remains.

In order to understand what follows it will be necessary to give the more important properties of the most valuable constituents—wood-spirit and acetone—occurring, besides acetic acid, in crude wood-vinegar.

*Wood-Spirit (Methyl Alcohol), CH<sub>4</sub>O.*

Wood-spirit is a colorless, very mobile liquid, of specific gravity 0.798 when chemically pure, and with a boiling point varying between 150° and 160° F. The specific gravity of its vapor is 1.12. It is soluble in all proportions in water, ether, and alcohol and is a solvent for resins and gums, especially when it contains a small proportion of acetone. With calcium chloride and with anhydrous barium it combines with crystallizable bodies, which are, however, immediately decomposed by water. Potassium and sodium dissolve in wood-spirit with the evolution of hydrogen. On cooling the compounds CH<sub>3</sub>OK, or CH<sub>3</sub>ONa crystallize out which are decomposed by water, wood-spirit and caustic alkali being formed.

Pure wood-spirit does not become turbid on being mixed with water; in the crude article turbidity is however caused by the presence of various hydrocarbons.

Wood-spirit is chiefly used for the preparation of methyl iodide and methyl nitrate, both these combinations being employed in the fabrication of aniline colors. It is further used for the manufacture of varnishes, for laboratory lamps, etc., and, in certain cases, in medicine.

*Acetone or Dimethyl Ketone (C<sub>3</sub>H<sub>6</sub>O).*

Acetone is formed when the vapor of acetic acid is passed through a red-hot tube, and further by the destructive distillation of sugar, tartaric, lactic and citric acids, etc. The best method, however, to obtain it in large quantities will be given later on in describing the acetates (see barium acetate).

Acetone is a very mobile, colorless liquid, boiling at 132.8° F., and having a peculiarly strong but pleasant odor; its specific gravity is 0.814. It burns with a brilliant flame and is soluble in all proportions in water, alcohol, and ether; it is a solvent for fats, resins, camphor, and gun-cotton, and yields crystallizable combinations with the hyposulphites; it does not, however, combine with calcium chloride. The combinations with the alkaline hyposulphites, for instance sodium hyposulphite, are insoluble in

the excess of the saturated solutions of hyposulphites, but soluble in water and boiling alcohol. By boiling such a combination with an alkaline carbonate, for instance, soda, it is decomposed. If acetone is left standing over quicklime for some time, and afterwards distilled, mesityl oxide  $C_6H_{10}O$  and phorone  $C_9H_{14}O$  are formed; the former is a colorless fluid smelling like peppermint and boiling at  $262^{\circ} F.$ , and the latter a crystallizable body melting at  $82.4^{\circ} F.$  and boiling at  $385^{\circ} F.$  By heating acetone with a little iodine and then adding alkaline solution until discoloration takes place a lemon-color, crystalline precipitate of iodoform soon forms. Methyl alcohol not showing this behavior, this furnishes a means of recognizing a content of acetone in wood-spirit.

*Determination of the Strength of Wood-Vinegar.*

C. Mohr gives the following method: Weigh off 10 grammes of wood-vinegar, heat in a beaker with about 3 grammes of pure barium carbonate until effervescence ceases, and filter. The solution of barium acetate is strongly colored, but the carbonate remaining undissolved, very little. The residue after washing is dried and weighed and the quantity of acetic acid present calculated; each gramme of dissolved carbonate corresponding to 0.609 gramme of acetic anhydride or 10 grammes of wood-vinegar contain 6.09 per cent.

The quantity of undissolved carbonate can, however, be determined in a more simple manner by titration with normal nitric acid. The latter is prepared by diluting commercial, pure, colorless, nitric acid until an equal volume of it exactly saturates normal sodium. Bring, for instance, 5 cubic centimetres of the commercial acid into a beaker, add a few drops of litmus tincture, and then by means of a burette normal soda lye until the color just turns blue. If, for instance, 4 cubic centimetres have been consumed, the 5 cubic centimetres of acid must be diluted to 40 cubic centimetres or 125 cubic centimetres to 1 liter.

The undissolved residue of barium carbonate together with the filter is now brought into a porcelain dish or beaker and a measured volume, for instance 20 cubic centimetres, together with

some litmus tincture, added; the whole is then heated until the precipitate is dissolved and effervescence has ceased, but the solution retains a slight red coloration. Now add drop by drop normal sodium until the color turns blue. If, for instance, 3 cubic centimetres of normal sodium have been used,  $20 - 3 = 17$  cubic centimeters of normal nitric acid have been required for the solution of the barium carbonate. Since 1 equivalent of barium carbonate saturates 1 liter of normal nitric acid, or 98.5 grammes of the former 1000 cubic centimetres of the latter, each cubic centimetre of normal nitric acid consumed indicates 0.0985 gramme of barium carbonate; hence in our example 1.674 gramme of carbonate has not been dissolved by the acid; there was therefore dissolved  $3 - 1.674 = 1.326$  gramme. And finally, as, according to the above, each gramme of barium carbonate indicates 6.09 per cent. of acetic anhydride, this wood-vinegar contains  $1.326 \cdot 6.09 = 8$  per cent.

L. Kieffer's method is based upon the following: Dissolve sulphate of copper in water, and after taking a small portion (about  $\frac{1}{100}$ ) of it away, gradually add to the remainder ammonia until the pale green precipitate at first formed is redissolved; then add the retained portion of the solution, and, after shaking and corking the flask, allow it to stand for a few hours. The dark blue fluid is only fit for use when the ammonia is thoroughly saturated with oxide of copper, *i. e.*, when some of the precipitate remains undissolved. The solution is now filtered and standardized to normal nitric acid.

By gradually adding this solution to an acid, for instance normal nitric acid, the oxide of copper as well as the ammonia is fixed by the acid and two soluble salts are formed, in this case nitrate of copper and of ammonia. If finally the acid is saturated and a drop of the blue solution be added, a pale blue precipitate is formed, because the ammonia contained in the drop combines with an equivalent quantity of nitric acid in the nitrate of copper so that not only the oxide of copper dissolved in the drop is precipitated (as hydrate), but also the quantity combined with the nitric acid.

Thus take, for instance, 5 cubic centimetres of normal nitric acid and add the blue solution drop by drop with shaking from a



burette. If up to the appearance of the precipitate 3.5 cubic centimetres have been used, 3.5 cubic centimetres of the copper solution must be diluted to 5 cubic centimetres or 700 cubic centimetres to 1 liter. This forms the ammoniacal copper solution standardized to normal nitric acid.

To determine the strength of the wood-vinegar with this fluid, dilute 10 grammes of it with water, and add, with constant agitation, copper solution until turbidity appears. The copper solution being standardized to normal nitric acid and the latter to normal sodium, the quantity of copper solution consumed is evidently just as large as the quantity of normal sodium would have been if used for titration.

#### *Working up the Wood-Vinegar.*

Only a small quantity of wood-vinegar is used for antiseptic purposes and in medicine, the greater portion being manufactured into wood-spirit, acetone, and acetic acid, as well as into acetates.

There are two methods by which this can be effected. By the first the acetic acid of the wood vinegar is directly converted into acetate by saturating with hydrate of lime (slaked lime) and the wood-spirit distilled off. This can be effected in a cast-iron still, distillation being continued as long as a fluid specifically lighter than water passes over. The distillate is crude wood-spirit, and the residue is the still impure calcium acetate.

By the second method, which is in general use, the more volatile portion (about one-tenth) of the crude wood-vinegar is distilled off in order to obtain wood-spirit as the distillate. This has to be effected in a copper still. If the crude wood-vinegar is not entirely clear, it is best for either method to first pass it through a sand or charcoal filter.

By the second method the wood-vinegar is subjected to distillation in a copper still of about 106 cubic feet capacity, Fig. 56, over a free fire, or less often by means of steam. What passes over first contains, besides water, wood-spirit, methyl acetate, acetone, and acetic acid. The vapors are, however, not allowed to completely condense at once but are rectified on the way by being conducted, as shown in the figure, through two or three rectifying vessels arranged in the same manner as in Pistorius's alcohol

still. Fig. 57 shows the arrangement of the rectifying vessels. The stop-cock introduces a certain quantity of water which passes

Fig. 56.

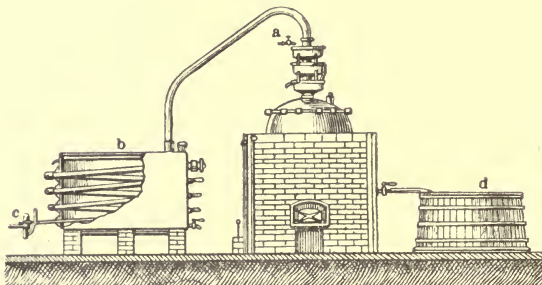
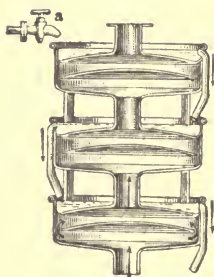


Fig. 57.



from the upper to the middle basin and then to the lower one where it runs off. By its passage through the basins the more condensable vapors, consequently also those of water and acetic acid, are condensed, so that the non-condensed portion which is only condensed in the cooling apparatus *b*, Fig. 56, possesses a certain strength, it generally showing a specific gravity of 0.965. At *c*, Fig. 56, immediately at the end of the discharge-pipe, is placed a small accurate aerometer, so that the specific gravity of the distillate can at any time be read off.

Distillation is continued until the specific gravity is 1, all the distillable bodies having then passed over. Before being brought into commerce the crude wood-spirit thus obtained is generally subjected to purification, which will be described later on.

If *distilled wood-vinegar* is to be obtained, for instance, for the preparation of crude lead acetate, distillation is continued, after changing the receiver, until oily drops appear at *c*, this being an indication of portions of the tar now passing over. Firing is then interrupted, and after allowing the apparatus to cool off somewhat, the tar remaining in the still is drawn off into the vat *d*, Fig. 56.

The tar is then combined with the upper and lower layers of

the crude product obtained by the distillation of the wood in the retorts, and either brought into commerce as wood tar, or further worked to obtain the substances occurring in it, such as illuminating oils, carbolic acid, etc., or it is used in the manufacture of wagon grease, lubricants, etc.

Wood-vinegar can, however, not be entirely purified by distillation nor by passing it over freshly glowed charcoal. Although seven-eighths of it passes over entirely colorless, the product has a strong empyreumatic taste and odor, gradually turns brown in the air, and gives brown salts with bases. Stoltze has proposed several methods for the purification of the rectified acid, the most simple and cheapest being to add 5 pounds of finely pulverized pyrolusite to every 100 quarts of acid, keeping it at nearly a boiling heat for 6 hours, then digesting it in the same manner with 40 pounds of freshly glowed charcoal pulverized and sifted while hot, and finally distilling off to dryness in a shallow cast-iron still. But on account of its tediousness and the necessary large consumption of fuel this process, though frequently modified, has been almost entirely abandoned.

According to Terreil and Château, the wood-vinegar is purified by compounding it, according to its more or less dark color, with 10 or 5 per cent. of concentrated sulphuric acid, whereby the greater portion of the tar separates in 24 hours. By distilling the decanted acid it is obtained almost colorless, but it darkens somewhat on exposure to the air, and by saturation with soda a slightly colored salt is obtained which can, however, be discolored with a small consumption of animal charcoal.

Rothe employs a peculiar method for the purification of wood-vinegar. The greater portion of the tar being separated by standing, the wood-vinegar with an addition of charcoal is rectified from a copper still. The pale yellow watery wood-spirit is caught by itself, and the succeeding clear, but strongly empyreumatic, distillate is pumped into a vat placed at a considerable height from which it runs into a purifying apparatus. The latter consists of a cylindrical pipe of strong tin-plate ; it is about 26 feet high and  $1\frac{1}{4}$  feet in diameter, and is filled with pieces of coke about 0.122 cubic inch in size, which rest upon a strongly tinned iron grate placed about  $1\frac{1}{2}$  feet above the bottom of the pipe. Over this

column of coke the wood-vinegar is poured in an uninterrupted fine spray, while in the space between the bottom and the grate a slow current of air heated to  $104^{\circ}$  F. is constantly blown in through a nozzle. The empyreumatic oils mixed with the wood-vinegar are oxidized by the oxygen of the warm air, and, in consequence, the temperature in the interior of the column of coke rises to  $122^{\circ}$  F., and more. (The pipe is protected from cooling off by a thick layer of felt.) The products of the oxidation of the empyreumatic oils are partially of a resinous nature and adhere to the coke, and partially volatile. The acetic acid running off through an S-shaped pipe on the bottom of the pipe is clear, of a pure acid taste and suitable for the preparation of all the acetates as well as of acetic acid. The very slight empyreumatic odor completely disappears by forcing the product through a pipe filled with pieces of animal charcoal freed from lime. The vinegar thus obtained is used for the table. Though a quantity of acetic acid is carried off in the form of vapor by the warm dry current of air, this loss can be prevented by passing the air through another pipe filled with calcined soda or lime.

For obtaining acetic acid for technical purposes, for instance, for the preparation of aniline, acetate of lead, white lead, verdigris, etc., where a slight empyreumatic odor and taste are of no consequence, it is best to prepare *calcium acetate* and to decompose the latter with crude hydrochloric acid.

By saturating crude wood-vinegar with slaked lime a dark-brown turbid solution is obtained, and much tar is separated, especially with the use of an excess of lime. By evaporating the filtered solution dark-brown rust-like flakes are separated and a nearly black non-crystalline salt of a strong odor remains behind which cannot be freed of its color and odor even by re-dissolving it several times. Purification succeeds better with the use of calcined soda for saturating the crude wood-vinegar, because the sodium salt crystallizes readily and the greater portion of the impurities remains in the mother-lye. But even here it is not possible to obtain the salt pure by frequently repeated re-crystallization. The calcium salt as well as the sodium salt can, however, be obtained entirely colorless by boiling the solution with animal charcoal, though it will not be completely freed from odor.

By saturating, however, at an ordinary temperature distilled wood-vinegar with slaked lime, the filtered clear yellowish solution becomes turbid after standing for some time or by heating, and a yellow-brown substance is separated by evaporation; if the salt solution is then sufficiently concentrated, a quite strongly colored salt is again obtained.

By slightly acidulating the solution of the calcium salt during evaporation with hydrochloric acid, a small quantity of a yellow-brown substance is separated, the previously strongly-colored fluid becoming pale yellow; by evaporating to dryness a calcium salt of a yellowish-gray color is obtained. By slightly roasting this salt and then distilling with hydrochloric acid, acetic acid of  $8^{\circ}$  B. = 1.06 specific gravity, *i. e.*, with about 48 per cent. of acetic anhydride, is obtained.

#### *Preparation of Crude Calcium Acetate.*

When all bodies lighter than water have been distilled off from the crude wood-vinegar, the retorts are allowed to cool off, and after carefully opening the stop-cock, the tarry deposit is first drawn off; the wood-vinegar is then conducted into a large vat in which the saturation is to be effected. When the point of neutralization is reached, the solution is allowed to stand several hours for the impurities of the lime to separate on the bottom and the tarry substances dissolved in the wood-vinegar on the surface; the latter are then removed.

The fluid is now slightly acidulated with hydrochloric acid (at the utmost 4 pounds of crude hydrochloric acid to 22 imp. gallons) and allowed to rest, whereby a deposit consisting chiefly of phenol and other slightly acid substances is formed. The clear fluid is then drawn off and evaporated in a cast-iron boiler over a free fire. The tarry substances oxidized by the action of the air and separating on the surface are constantly removed. When the specific gravity (measured hot) has increased to 1.116, the separation of calcium salt in the form of crusts begins; these crusts are removed with an iron spatula. From this time on heating is carefully continued until the contents of the boiler are converted into a thick paste. The fire is then extinguished, the calcium



salt decomposing very readily at too high a temperature. As it is, however, impossible, on the one hand, to properly observe the temperature in the semi-cylindrical boiler, and, on the other, the complete dryness of the salt is required so that as many of the tarry substances as possible remain undissolved during the subsequent re-dissolving, the paste is removed in small portions and spread out in flat cast-iron pans several of which are heated by one fire-place. During the drying the salt must be thoroughly stirred with iron shovels to prevent overheating. By careful treatment a salt containing 75 to 78 per cent. of pure acetate is obtained.

By heating the calcium acetate in small cast-iron cylinders provided with a good cooling apparatus *crude acetone* is obtained which can be purified by rectifying in a water-bath, shaking the distillate with saturated solution of sodium hyposulphite, and distilling the separated crystalline body with soda solution and dephlegmated by rectifying over calcium chloride.

Calcium acetate is readily prepared, can be sent long distances in a dry form from which the acetic acid can be readily separated by a process to be described later on. Entirely pure acetic acid, however, is not obtained from this salt, and it cannot be used for household or medicinal purposes, nor in the fabrication of valuable chemical products, for instance, certain aniline colors. Sodium salt will have to be taken for the preparation of acid to be used for these purposes.

#### *Preparation of Crude and Pure Sodium Acetate.*

*a.* The wood-vinegar freed from wood-spirit, acetone, etc., is saturated in a vat with calcined soda (sodium carbonate), which is gradually added, as otherwise the escaping carbonic acid causes strong foaming up. The tarry substances appearing on the surface are removed, and the brown fluid, after clarifying by standing, is drawn off into flat cast-iron pans which are heated by the fire-gases escaping from the carbonizing retorts. The concentration of the fluid and skimming off of the tarry substances are continued until the aerometer in the pan nearest the oven shows  $27^{\circ}$  B. = 1.23 specific gravity. The register is then closed so that the fire-



gases escape directly into the chimney, and the first pan is emptied into the crystallizing boxes. The latter are oblong sheet-iron vessels placed alongside each other and slightly inclined towards one of the narrow sides. The emptied pan being filled from the next, and the latter with fresh solution, the register is re-opened and evaporation commenced anew.

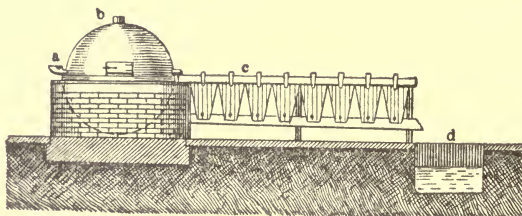
When crystallization is finished the mother-lye is drawn off into a vat, and, after draining off, the salt is freed from the still adhering mother-lye by means of a centrifugal. The crystals are then brought into an iron pan heated by steam and re-dissolved with just sufficient water to at once yield a hot solution of  $28^{\circ}$  B., which is again brought into the crystallizing boxes.

The crystals now obtained are larger and of a pale brown color, and moist with mother-lye. After draining off they are moistened with a saturated solution of pure acetate and separated from the mother-lye by means of a centrifugal. The crystals while in the centrifugal may be again moistened with a small quantity of the pure acetate solution, and are then obtained sufficiently pure to be at once distilled with sulphuric acid. The acid thus obtained, though not entirely pure, is much better than that from calcium salt.

To obtain entirely pure sodium acetate, the pale brown salt obtained from the second crystallization is calcined, or, what is more simple and better, its hot solution filtered through animal charcoal. The salt is dissolved in water by means of steam, so that a nearly boiling solution of  $15^{\circ}$  to  $16^{\circ}$  B. is obtained, which is then slowly filtered through a layer of animal charcoal the size of a pea in an iron cylinder, which is covered with thick felt in order to retain the heat. When the charcoal ceases to act it is washed with water and the washwater used for dissolving a fresh quantity of salt. The charcoal is revived by drying and glowing in closed cast-iron pots and re-used. The aqueous solution of the pale brown acetate, together with 10 per cent. of its weight of bone-black, can also be heated for a few hours with constant stirring in an iron or copper boiler, and, after settling, decanted. The solution is treated with animal charcoal, and after crystallizing and passing through the centrifugal, yields an entirely pure salt.

According to an older process, the pale brown salt is melted in its water of crystallization, and then roasted in not too large portions and with constant stirring in another boiler heated to  $716^{\circ}$  or  $752^{\circ}$  F., to destroy the remnants of tarry bodies. The sodium salt will stand this temperature without being decomposed, but a few degrees above it, it will be decomposed and charred so that only a mixture of sodium carbonate and coal remains behind. The stirring which has to be kept up constantly in order to prevent the temperature from getting too high in some places, can be done by hand, but being laborious work it is better to provide the boiler with a lid through the centre of which runs a mechanical stirrer. When after roasting for  $1\frac{1}{2}$  hours the tar is destroyed, the fused salt is thrown by means of an iron shovel into water in a hemispherical iron boiler provided with a lid (Fig. 58). The salt is thrown into the gutter *a*, from which it runs into the boiler *b*. The lid is necessary on account of explosions which are unavoidable in throwing in the hot salt.

Fig. 58.



By dissolving the roasted acetate in water, the carbonaceous portions remain undissolved; the solution is, therefore, filtered through linen bags *c*, and the filtrate collected in the pit *d*. If necessary, the solution is further filtered through bone-black and then evaporated to  $24^{\circ}$  B. By disturbing the crystallization small crystals which are scarcely colored are obtained. This is effected by the use of round copper crystallizing vessels with a diameter of 5.72 feet, and a depth of about 10 inches (Fig. 59) and the use of a mechanical stirrer. When crystallization is finished, the entire mass is brought into a copper boiler provided with a large number of apertures about 0.11 inch in diameter,

through which the mother-lye drains off. The crystals are finally washed with a saturated solution of pure salt and passed through a centrifugal. The salt thus obtained is entirely pure; but its preparation requires very careful and skilled workmen.

*b.* Since the reduction in the price of soda the method of saturation described under *a* has been generally introduced. Formerly the sodium acetate was prepared by means of Glauber's salt (sodium sulphate) and lime. Notwithstanding its many defects, this method, which was introduced by Mollerat, is still in use in some factories.

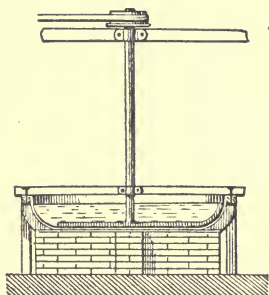
The wood-vinegar is saturated with slaked lime and the calcium salt decomposed with Glauber's salt; gypsum (calcium sulphate) is precipitated while sodium acetate remains in solution. Or, a mixture of Glauber's salt and lime (for 5 parts of crystallized Glauber's salt 1 part of burnt lime) is employed for saturation and constantly stirred while the wood-vinegar is added.

Crude wood-vinegar can be used instead of the product freed from wood-spirit, the distilling off of the wood-spirit and acetone, together with the saturation, being executed in one operation, as follows:—

The crude wood-vinegar is distilled in a large copper boiler holding about 106 cubic feet over an open fire or by means of steam. The vapors pass through a pipe into a similar boiler which is heated by the heat escaping from the first. In this boiler the mixture of Glauber's salt and milk of lime is kept in constant agitation by a stirring apparatus making about 25 revolutions per minute. The wood-spirit, etc., which is not fixed in the second boiler, passes into the condensing apparatus.

In order to see whether the point of saturation is reached, samples are from time to time taken by means of a stop-cock on the bottom of the second boiler; litmus paper being first colored blue and finally red. When this is the case, the flue

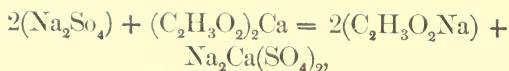
Fig. 59.



under the second boiler is closed by a register, and the contents of the boiler being emptied into a large iron trough, the boiler is at once refilled with a new mixture of Glauber's salt and milk of lime, while a fresh portion of wood-vinegar is brought into the first boiler, etc.

In the trough an abundant precipitate is formed from which the fluid is drawn off by means of several cocks placed at different heights. The wash-waters serve for mixing fresh quantities of Glauber's salt and lime. The solution of sodium acetate is evaporated, and further worked, as given under *a*.

This method is, however, inferior to the one described under *a*, because much fuel is required for the complete distilling over of the wood-vinegar, which is not the case in *a*, and further because the substitution between Glauber's salt and calcium acetate is not as smooth as above supposed for the sake of simplicity; the precipitate consisting not only of gypsum, but of a double salt of gypsum and sodium sulphate which dissolves with difficulty. The actual process is expressed by the equation:—



which shows that only half of the sodium contained in the Glauber's salt is converted into acetate, the other half being lost. Moreover, there is a large quantity of insoluble precipitate which has to be thoroughly washed in order to avoid considerable loss; and, finally, the solution of the acetate constantly deposits gypsum during evaporation, necessitating cleansing of the pans.

The mother-lye from which the sodium acetate has crystallized out contains a considerable quantity of the latter. It is therefore again evaporated to 27° B. and on cooling yields crystals. By repeating this concentrating and cooling finally nothing more crystallizes out, the whole forming a crystalline mass, which, by absorption of water from the air, becomes semi-fluid, and consists of very little sodium acetate mixed with the sodium salts of the other fatty acids previously mentioned.

Barré, in 1869, showed that besides acetic acid the following acids occur in wood-vinegar: formic acid,  $\text{CH}_2\text{O}_2$ , propionic acid,

$C_3H_6O_2$ , butyric acid,  $C_4H_8O_2$ , valerianic acid,  $C_5H_{10}O_2$ , and caproic acid,  $C_6H_{12}O_2$ .

By decomposing the above-mentioned salt-mass with concentrated sulphuric acid, a black oily layer consisting of a mixture of the above acids separates on the surface. They are but incompletely separated by fractional distillation, the separation, however, succeeding better by converting them into compound ethers and subjecting the mixture of these to fractional distillation.

According to Vincent, 100 parts of syrupy mother-lye are mixed with 20 of 95 per cent. alcohol, and after gradually adding 70 parts of concentrated sulphuric acid, the whole is allowed to cool. After some time a black layer separates on the surface, which is taken off, and after shaking with weak soda solution until it shows no acid reaction, and dephlegmating over calcium chloride, is carefully distilled, the distillates passing over between  $131^\circ$  and  $136.4^\circ$  F.,  $165^\circ$  and  $170.6^\circ$ ,  $203^\circ$  and  $208.4^\circ$ ,  $237.2^\circ$  and  $246.2^\circ$ ,  $271.4^\circ$  and  $276.8^\circ$ , and  $323.6^\circ$  and  $329^\circ$  being collected by themselves. By decomposing these products with barium-water alcohol is formed, which is removed by evaporation, and the barium salts of the fatty acids. The latter are crystallized, and then the acids separated by sulphuric acid. The first distillate yields formic acid, the second propionic acid, etc.

#### *Manner of Obtaining Wood Spirit (Methyl Alcohol).*

Crude wood spirit is a mixture of methyl alcohol with methyl acetate, dimethylacetal, acetone, metacetone, aldehyde, various hydrocarbons, acetates of ammonium and methylamine, and free acetic acid.

These substances cannot be separated by fractional distillation alone, because the boiling point of some of them is nearly the same (methyl alcohol  $152.6^\circ$  F., dimethylacetal  $147.2^\circ$ , acetone  $132.8$ , methyl acetate  $131^\circ$ ). The crude wood spirit is digested in a still with slaked lime, whereby, with the development of considerable heat, the free acetic acid always present combines with the lime; ammonia and methylamine are also evolved, and the methyl acetate is gradually decomposed into calcium acetate and methyl alcohol. (By the action of the lime new combinations

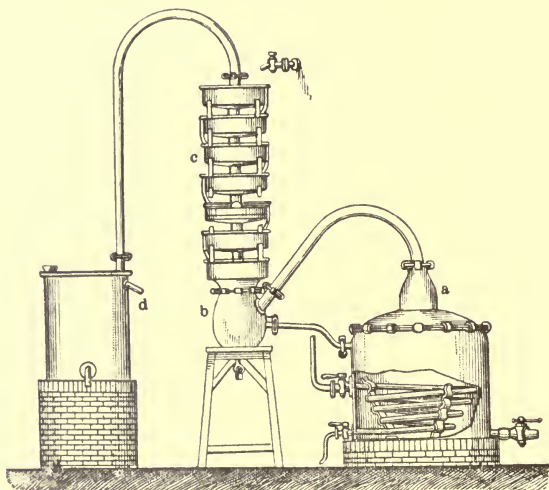




with a boiling point above  $212^{\circ}$  F. are gradually formed from the acetone.)

After several hours' digestion the mixture is distilled by means of steam. In Fig. 60, *a* represents the copper still, *b* an ellipsoidal

Fig. 60.



or egg-shaped vessel which serves as a receiver, and *c* the rectifying apparatus, consisting of a series of Pistorius's basins (see Fig. 57, p. 238), into the uppermost of which a moderate current of water is conducted; *d* is the condenser.

The still *a* has a capacity of 1000 to 1200 quarts; the steam pipe placed in it is 2 inches in diameter and 32 feet long. The vapors pass out through the wide pipe in the cover, and what is condensed in *b* runs back through a narrower pipe into *a*. In the rectifying vessel or rather dephlegmator, the rising vapors are forced to pass around a copper disk placed in each basin and thus to come in contact with the surface of the basin cooled by water. From this it is evident that the less volatile bodies are condensed in the basins and run back into *b* and from there into *a*, while the more volatile vapors pass through the swan-neck and are condensed in *d*. Much, of course, depends on the quantity (and temperature) of the water running into the rectifying vessel.

With a rectifying vessel consisting of seven basins, each 1.64



feet in diameter, and with a correctly conducted influx of water, a product of 0.816 specific gravity is obtained by one operation from crude wood spirit of 0.965 specific gravity.

This product can be used for many purposes, for instance in the preparation of varnishes. It is, however, not entirely pure, it being rendered turbid by water which is due to a content of the previously-mentioned hydrocarbons; it further contains some acetone, methyl acetate, aldehyde, ammonia, methylamine, and is not fit for the fabrication of aniline colors.

For further purification this rectified wood-spirit is diluted with water until it shows a specific gravity of 0.934 and is then allowed to rest a few days, when the greater portion of the hydrocarbons has separated as an oily layer on the top. The clear fluid is now again rectified with an addition of 2 to 3 per cent. of lime, whereby a distillate is obtained which does not become turbid with water but turns yellow in time.

But neither this twice-rectified wood-spirit is suitable for all purposes, for instance, not for the preparation of methyl iodide. To remove traces of ammonia and methylamine and to precipitate the last particles of tarry substances, it is again rectified after adding some sulphuric acid, this time, however, in a distilling apparatus standing in a water-bath, whereby a temperature of  $147.2^{\circ}$  to  $152.6^{\circ}$  is sought to be maintained. One cubic metre (35.31 cubic feet) of wood yields 2 to 3 quarts of methyl alcohol which is not rendered turbid by water.

For the purification of wood-spirit on a small scale, the above-mentioned property of methyl alcohol to form a solid crystallizable combination with calcium chloride can be utilized. Mix the wood-spirit once rectified over lime with dry powdered calcium chloride, pour off the oily layer of foreign substances, which separates, after some standing, upon the surface of the solid combination formed, and heat the solid body in a water-bath to  $212^{\circ}$  F. It is not decomposed at this temperature, while the still-adhering impurities at least partially volatilize. Mix the dry residue with water, whereby the combination is broken up, and distill in a water-bath; the distillate is quite pure methyl alcohol.

The examination of commercial wood-spirit extends chiefly to the presence or absence of the previously-mentioned hydro-

carbons, which can be readily ascertained by mixing the sample with water; further to the presence of acetone, methyl acetate, and ordinary alcohol, the latter being sometimes found as an adulteration. The presence of acetone is recognized by the colorless crystalline precipitate formed on shaking with a saturated solution of sodium hyposulphite. The presence of methyl acetate is shown when, by boiling the wood-spirit with soda lye and subsequent distilling off, a residue remains in which acetic acid can be found. Ordinary alcohol can be detected by distilling the wood-spirit with double to four times its volume of concentrated sulphuric acid. By the action of the latter upon the wood spirit dimethyl ether  $(\text{CH}_3)_2\text{O}$  is formed; but by the action of the excess of sulphuric acid upon alcohol, ethene  $\text{C}_2\text{H}_4$ . The first is readily soluble in water, 1 volume of the latter dissolving 37 volumes of the gas; the latter, however, dissolves with difficulty, 7 volumes of water absorbing only about 1 volume of it. Hence, if alcohol be present in the wood-spirit, ethene will remain by shaking the gas mixture with its equal volume of water. By adding bromide ethene dibromide,  $\text{C}_2\text{H}_4\text{Br}_2$ , a colorless oily liquid, having a sweetish smell and taste, is formed.

*Yield of Charcoal, Wood-Vinegar, and Wood-Spirit, as well as of Tar.*

The statements as to the obtainable yield of products resulting from the distillation of wood vary very much, which is but natural, as the yield depends on many factors: on the variety of the wood, its age, even on the soil upon which it is grown, the time it has been stored, on the degree of dryness, the dimensions, the position of the retorts, the degrees of temperature, and especially on the duration of carbonization.

Stoltze, in 1820, published experiments, made with the greatest care, to show the amount and strength of the products obtained from the distillation of several varieties of wood. The quantity of each kind of wood submitted to destructive distillation was *one pound*, a quantity suitable, in the generality of cases, to form a precedent for the manufacturer on the large scale. The woods were all collected at the same time of the year (towards the end

of January) and only those of nearly the same growth were chosen. From Stoltze's table the following figures for the most important varieties of wood have been calculated:—

	Wood vinegar, pounds.	Therein acetic anhydride, pounds.	Tar, further pounds.	Char- coal, pounds.	Gases, cubic metres.
100 pounds of birch	44.9	8.9	8.6	24.4	9.8
“ “ beech	44	8.6	“ 9.5	24.6	10.8
“ “ hornbeam	42.5	7.6	“ 11.1	23.9	10
“ “ oak	43	7.7	“ 9.1	26.1	10
“ “ fir	42.3	4.2	“ 11.9	26.6	12.5

or,

1 cubic metre (35.31 cubic feet) = 750 pounds of birch, yields 333 pounds of wood-vinegar of 20 per cent. = 66.6 pounds of acetic anhydride; further, 64 pounds of tar, 181 pounds of charcoal, and 73 cubic metres (2578.06 cubic feet) of gases.

1 cubic metre (35.31 cubic feet) = 850 pounds of beech, yields 371 pounds of wood-vinegar of 19.6 per cent. = 72.7 pounds of acetic anhydride, 80.7 pounds, 207.4 pounds of charcoal, and 85 cubic metres (3001.86 cubic feet) of gases.

1 cubic metre (35.31 cubic feet) = 950 pounds of hornbeam, yields 402 pounds of wood-vinegar of 18 per cent. = 72.3 pounds of acetic anhydride, 105 pounds of tar, 225 pounds of charcoal, and 94 cubic metres (3311.8 cubic feet) of gases.

1 cubic metre (35.31 cubic feet) = 850 pounds of oak, yields 367 pounds of wood-vinegar of 18 per cent. = 66 pounds of acetic anhydride, 77.8 pounds of tar, 223 pounds of charcoal, and 86 cubic metres (3037.17 cubic feet) of gases.

1 cubic metre (35.31 cubic feet) = 650 pounds of fir, yields 271 pounds of wood-vinegar of 10.1 per cent. = 27.4 pounds of acetic anhydride, 72.6 pounds of tar, 138.5 pounds of charcoal, and 80 cubic metres (2825.28 cubic feet) of gases.

Gillot has confirmed Stoltze's statements in so far as he found that, in manufacturing on a large scale, with slow and carefully-conducted carbonization and a distilling period of 72 hours, 7 to 8 per cent. of the (hard) wood of acetic anhydride can be obtained.

The results obtained by Assmus in manufacturing on a large scale are as follows:—

100 pounds of—	Yield wood vinegar, pounds.	Which yield calcium acetate, pounds.	Or acetic anhydride, pounds.	Tar, pounds.	Charcoal, pounds.	Crude light oil, pounds.	Crude heavy oil, pounds.
Birch 25 to 40 years old	46	5.2	3.9	8	23.5	1.2	4.5
Birch-bark, first extract	22	0.6	0.4	30	18.5	21.6	3.0
“ second “	20	0.7	0.5	20	22	12	4.7
Oak . . . . .	42	6.0	4.5	8.8	27.5(?)	0.8	3.3
Fir . . . . .	42	3.2	2.4	10.5	22	1.3	5.7
Pine . . . . .	44.5	3.0	2.3	9.5	22.6	0.6	3.5

According to Rothe's experience, the trunk-wood of birch from 60 to 80 years old and grown upon a high dry soil with a limestone sub-soil surpasses the best red beech in the yield of acetic acid. He obtained from 100 pounds of this kind of wood dried at 140° to 158° F., with heating for 48 hours, at a final temperature not exceeding 750° F., 40 pounds of wood-vinegar of 25 per cent. acetic anhydride, further 2 or 3 per cent. of tar, and 30 per cent. of red charcoal suitable for the manufacture of powder.

The yield of salable, though not entirely pure methyl alcohol, is  $\frac{1}{2}$  lb. and at the utmost  $1\frac{1}{2}$  lbs. from 110 lbs. of wood; according to Vincent, 2 to 3 quarts from 35.31 cubic feet. This higher yield is said to be obtained by moistening the wood with soda solution and drying. In case this statement is correct, it would be advisable to saturate saw-dust with soda solution, and after drying distill in Halliday's apparatus.\* It consists of a horizontal, cast-iron cylinder. The saw-dust, spent dye-wood, etc. are introduced through a hopper placed above the front end. In the cylinder a vertical screw or worm revolves at such a speed as to convey the material in the proper quantities to the cylinder placed in a horizontal position and heated by means of a furnace. Another revolving screw or worm keeps the saw-dust, etc., introduced in the retort in constant motion and at the same time moves it forward to the opposite end of the retort. During their

\* Muspratt's Chemistry, Vol. I. p. 23.

progress through the retort the materials are completely carbonized and all the volatile products disengaged. Two pipes branch off from the extremity of the retort, one of which passes downwards and dips into an air-tight vessel of cast-iron or a cistern of water into which the carbonized substance falls; the other is an ascending pipe and carries off the volatile products of the distillation into the condenser, which consists of copper or iron pipes immersed in or surrounded by water.

According to statements by Hargreaves and others, saw-dust from resinous woods gives as much wood-vinegar in 24 hours with 8 or 10 retorts 14 inches in diameter, as with 16 retorts 3 feet in diameter.

In another comparison of the two systems, 8 Halliday retorts consuming 22 tons of saw-dust weekly produce:—

Wood-vinegar of specific gravity 1.05	.	.	2494 gallons.
Tar	.	.	240 “

While a ton of oak (2240 lbs.) carbonized in large retorts gives:—

Wood-vinegar of specific gravity 1.03	.	.	1277 pounds.
Charcoal	.	.	600 “

To make the comparison more satisfactory it would have been necessary to state the kind of gallon employed and the percentage of real acid in the wood-vinegar, since hydrometers and specific gravities give indications of very little value in this case.

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## CHAPTER XXII.

### PREPARATION OF PURE CONCENTRATED ACETIC ACID.

THE strongest vinegar which can be prepared by the process of fermentation contains somewhat above 13 per cent. of acetic acid, and it is difficult, even with the greatest care, to continuously obtain a product of this strength. The difficulties encountered are due to the fact that the vinegar ferment is incapable of vigorous vegetation in a fluid containing, besides 10 per cent. of

acetic acid, a sufficient quantity of alcohol for the further formation of 3 per cent. of acetic acid, and it requires the greatest vigilance and utmost care as regards the maintenance of the correct temperature and ventilation in the factory to convert, under these conditions, alcohol into acetic acid.

It has frequently been asked whether it is advisable to increase the content of acetic acid in vinegar prepared from alcohol, which contains only 7 or 8 per cent., to 12 or 14 per cent. by the addition of concentrated acetic acid obtained from wood. This question may be answered in the affirmative, provided absolutely pure acetic acid, free from all empyreumatic substances, be used, and it is advisable in all cases to test the acetic acid as to a content of these substances as well as to the presence of sulphurous acid and of metals (copper, tin, etc.).

To establish the presence of empyreumatic substances, dilute the concentrated acetic acid with twice or three times its volume of distilled water, and add a few drops of a solution of potassium permanganate. In the presence of empyreumatic substances or sulphurous acid the red coloration of the fluid disappears at once. The manner of detecting the presence of sulphurous acid and of copper and other metals has already been given on p. 211.

Acetic acid which gives negative results with these tests may be considered as chemically pure, and can without hesitation be used for increasing the strength of vinegar prepared from alcohol; in fact, the employment of the so-called vinegar essence for this purpose is constantly increasing. The fluid occurring in commerce under this name is highly concentrated acetic acid with a content of acid varying between 60 and 80 per cent. By diluting this fluid with water so that its content of acetic acid is equal to that of ordinary table vinegar, a product is obtained which, as regards taste, can be scarcely distinguished from ordinary vinegar prepared from alcohol. Chemically there is also but little difference, the vinegar prepared from alcohol containing a small quantity of acetic ether and of extractive substances which do not occur in vinegar essence obtained by distillation.

For the preservation of fruit, cucumbers, and the so-called mixed pickles, and, in fact, for all purposes where only a fluid containing acetic acid and water is required, acetic acid obtained



from wood can be advantageously used. For seasoning food, vinegar prepared from malt, beer, or wine is, however, preferable, it being more agreeable to the senses of taste and smell on account of its content of other substances besides pure dilute acetic acid.

From strong vinegar acetic acid is obtained by distillation, the separation from the non-volatile substances being only possible by these means. If the acid is to be entirely pure, the vinegar is subjected to distillation in a copper still with a head and worm of silver or silver-plated, though this costly apparatus is now generally replaced by a head and worm of stone-ware. If absolute purity is not required, the head and worm may be of copper, or the head of copper and the worm of lead. Tin or tinned copper is less suitable, since a trace of tin which may be dissolved causes opalescence in the distilled vinegar, and, besides, imparts to it a peculiar disagreeable odor. By using pure copper, distilling quickly and without interruption and cleaning the apparatus immediately after finishing the operation, some traces of copper will only be found in the first portion of the distillate. With the use of a leaden worm a content of lead can be almost entirely avoided by allowing the end of the worm to dip in water or vinegar, or by inserting in the end of the worm a perforated cork provided with a U-shaped tube, the latter preventing the access of air. The first portion of the distillate only contains lead; it is removed and can be used, for instance, for acetate of lead. The distillate is from time to time tested with solution of sulphuretted hydrogen; the distillate is free from lead when it no longer acquires a brown coloration.

The distilled acid is, however, always weaker than the vinegar; the boiling point of acetic acid being higher than  $212^{\circ}$  F., an acid rich in water will evidently at first pass over. Distillation, however, cannot be carried on to dryness, as, on account of the foreign substances in the vinegar, the contents of the still would inevitably burn and the distillate acquire a disagreeable odor. Hence distillation must cease just at the time when the strongest acid would pass over. Stein has, therefore, recommended to increase the boiling point of the vinegar by the addition of one-third of its weight of rock salt. Though all the acetic acid is not obtained

by these means, the amount is considerably larger than without such an addition. The rock salt remaining unchanged, the residue can be repeatedly used. Comparatively weak acetic acid can, however, only be obtained by this method. For a stronger product it is necessary to use an acetate and decompose it by a mineral acid.

The cheapest way is to fix the acetic acid on lime and to distill the calcium acetate with crude hydrochloric acid. After neutralizing the vinegar with milk of lime and bringing the solution of the acetate to dryness, 100 lbs. of the salt are dissolved in 110 to 120 lbs. of crude hydrochloric acid of 1.16 specific gravity and the whole is subjected to distillation. The acetic acid obtained by this method is not entirely free from hydrochloric acid, but can be readily purified by rectification over acetate of sodium or of calcium.

*Preparation of Acetic Acid from Commercial Acetates and from those obtained from Wood-Vinegar.*

The most highly concentrated acetic acid, known as glacial acetic acid, was formerly exclusively obtained by the dry distillation of crystallized verdigris (normal cupric acetate). By drying this salt at between 320° and 356° F. and heating, a mixture of acetone and glacial acetic acid is obtained which only requires rectification. The yield of acetic acid amounts to  $\frac{1}{3}$  of the verdigris used (see Acetates). This process has, however, been almost entirely abandoned, cheaper methods having been introduced.

The principal acetates now used for the purpose are those of lead, barium, calcium, and sodium; the latter two, being the cheapest, are exclusively used for the manufacture on a large scale, though the former are very suitable for the production on a small scale.

By decomposing normal lead acetate, frequently called sugar of lead, with one equivalent of sulphuric acid (4.9 lbs. of sulphuric acid to 19 lbs. of the salt) sulphate of lead remains in the retort while acetic acid distills over. The sulphate of lead adheres, however, very tightly to the retort, and, being insoluble in water, it can, as a rule, not be removed without injury to the retort.

Hence it is better to use 2 parts of sodium bisulphate and 1 part of crystallized lead acetate, a mixture of lead sulphate and neutral sodium sulphate then remaining in the retort, which can be softened with water and readily removed. Instead of bisulphate any desired quantity of Glauber's salt may be added to the lead acetate and the whole distilled with the above-mentioned quantity of sulphuric acid. An excess of the latter is to be avoided, the acetic acid being decomposed at a high temperature by concentrated sulphuric acid. Distillation is carried on in a sand-bath. For very concentrated acetic acid lead acetate dephlegmated by gentle heating is used instead of the crystallized acetate and decomposed with one-third of its weight of concentrated sulphuric acid.

The acetic acid is, however, not entirely pure in either case, as it contains a small quantity of sulphurous acid formed by the action of the sulphuric acid upon the acetic acid. This impurity can be readily removed by rectification over brown lead oxide ( $\text{PbO}_2$ ) or finely powdered peroxide of manganese ( $\text{MnO}_2$ ), sulphate of lead remaining in the retort in the first case, and in the latter a mixture of manganous sulphate and hyposulphate.

Bucholz gives the following direction which saves rectification, the required quantity of peroxide of manganese being at once added to the mixture of lead acetate and sulphuric acid: 192 parts of lead acetate, 24 of Glauber's salt, 6 of peroxide of manganese, 56 of sulphuric acid, and 72 of water; the yield is 178 parts of entirely pure acetic acid of 1.045 specific gravity.

By decomposing solution of lead acetate or of barium acetate with sulphuric acid, pure acetic acid which has, however, but little strength, can be prepared without distillation, as it is only necessary not to use an excess of the salts or of sulphuric acid. Completely anhydrous barium acetate should be used, the crystallized product being less suitable for the purpose as it readily loses its water of crystallization. For 100 parts of barium acetate, 38.4 parts of concentrated sulphuric acid are required and for 100 parts of normal lead acetate 25.9 parts of sulphuric acid. The solution of barium acetate should not be too concentrated, as otherwise the barium sulphate does not appear in the ordinary form of

a fine dense powder, but as a gelatinous precipitate which settles with difficulty and pertinaciously retains acetic acid.

Finally, the lead acetate can also be decomposed by nitric acid, this method having the advantage of yielding a valuable by-product, lead nitrate. Christl obtained from 100 parts of lead acetate and 53 of nitric acid of 1.38 specific gravity, 65 parts of acetic acid of 1.06 specific gravity and 80 parts of crystallized lead nitrate. A weaker acid, for instance of 1.04 specific gravity, can be obtained by dissolving the lead acetate in hot water, adding the above-mentioned quantity of nitric acid, and after allowing the greater portion of the lead nitrate to crystallize out, distilling the mother-lye. To see whether the acid thus obtained is free from nitric acid, compound a sample with a drop of very dilute solution of indigo and boil for some time: discoloration proves the presence of nitric acid.

Calcium acetate and sodium acetate form the basis for the preparation of acetic acid on a large scale; the former, if the acid is to be used for ordinary technical purposes, where absolute purity is not required, as, for instance, in the fabrication of lead acetate, crystallized verdigris, aniline (from nitrobenzole and metallic iron), etc., and the latter, if the acid is to be free from empyreumatic odor and taste and suitable for use in the fabrication of aniline colors, for photographic, pharmaceutical, and household purposes, etc.

According to Völckel's method, for 100 pounds of dry yellowish gray calcium acetate 90 to 95 pounds of crude hydrochloric acid of 1.16 specific gravity are used, the acid obtained showing a specific gravity of 1.058 to 1.061. By adding to the above mixture 25 pounds of water distillation proceeds with greater ease, 95 to 100 pounds of acid of 1.050 specific gravity being obtained. In order to ascertain the required quantity of hydrochloric acid more accurately than is possible from the above-mentioned approximate statements, it is necessary to distill two small samples of the thoroughly mixed acetate, for instance, 100 grammes, with 95 or 90 grammes of hydrochloric acid, and to test the distillate for hydrochloric acid. This is readily effected by adding a few drops of dilute solution of nitrate of silver, a white precipitate or white turbidity indicating hydrochloric acid.

The mixture of acetate and hydrochloric acid is not distilled at once, but allowed to stand 12 hours for the substances to act upon each other, and for the removal of the tarry bodies which separate on the surface. It is then brought into a copper still and heated over an open fire. At first weak, and later on, stronger acid passes over. What remains is calcium chloride contaminated by tarry substances which have, however, become almost entirely insoluble. The thin pasty mixture is drawn off through a pipe on the bottom of the still, and, as a rule, thrown away. By evaporating it, however, to dryness and roasting it for some time with access of air, or dissolving it in water, filtering and evaporating to dryness in an iron boiler, it may serve for the preparation of glacial acetic acid (see below).

Cast-iron stills can also be used and are quite durable as far as moistened by the acid mixture. The places exposed to the vapors of acetic acid are, however, quickly attacked, and it is, therefore, recommended to provide the upper portion of the still with a lining of sheet-copper.

The acid thus obtained has a strong empyreumatic odor, is not entirely colorless, and sometimes contains traces of hydrochloric acid. By rectifying it over 1 to  $1\frac{1}{2}$  per cent. of potassium bichromate the odor, coloration, and content of hydrochloric acid disappear, but a slight empyreumatic taste remains.

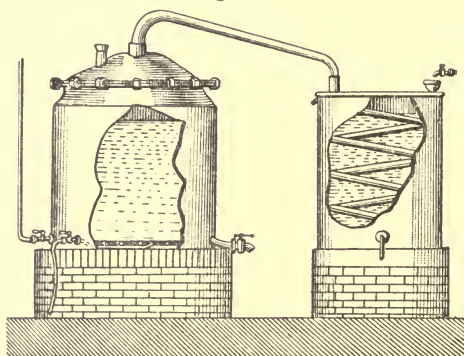
When, however, the empyreumatic odor is not objectionable and only the hydrochloric acid is to be removed, the latter object can be attained at less cost by rectification over some calcium acetate or over burnt lime. A test on a small scale is also made in this case to ascertain the required quantity of salt or lime. Or the acid is titrated with solution of nitrate of silver and the quantity of lime or calcium acetate found by calculation added. The process with the use of decinormal solution of nitrate of silver, *i. e.*, such as contains in 1 liter 17 grammes of crystallized nitrate of silver, is as follows: Mix 100 cubic centimetres of the acetic acid in a beaker or porcelain dish with a drop of saturated solution of bichromate, and add from a burette, with constant stirring with a glass rod, drop by drop of the decinormal solution of nitrate of silver until the white precipitate just commences to acquire a red coloration. Now read off and multiply the num-



ber of cubic centimetres of nitrate of silver solution consumed by 0.028, or, still better, as the lime is seldom pure, by 0.03. The product gives the quantity of lime in grammes required for 1 liter of acetic acid. If calcium acetate is to be used, multiply by 0.079, or by 0.08 if the calcium acetate is not absolutely pure.

Rectification is executed with steam. In Fig. 61 the steam enters through the vertical pipe near the bottom of the still and

Fig. 61.



circulates in a coil ; the condensed water can be discharged through a pipe near the influx aperture.

The first and last portions are not entirely clear ; they are collected by themselves, and, after mixing, allowed to clear by standing, when the greater portion can be siphoned off. The turbid residue is added to a fresh mixture of acetate and hydrochloric acid to be subjected to distillation.

Völekel has further found that it is not necessary to use the roasted gray calcium acetate, but that, with a slight modification of the process, the acetate prepared from crude wood-vinegar answers nearly as well. The crude wood-vinegar is filtered through charcoal and being freed from wood-spirit and acetone by distillation, is saturated or even slightly supersaturated in an iron boiler with slaked lime (litmus paper should be colored slightly blue). The solution is boiled for some time, and, after clarifying, is evaporated in an iron pan to about one-half its volume, the resinous and sooty impurities appearing upon the surface being constantly removed.



The purpose of the excess of lime is to expel the volatile basic bodies, ammonia and methylamine, and to decompose the volatile oils. The non-volatile bodies dissolved in the crude wood-vinegar separate partially in saturating with lime and partially in boiling and evaporating. A portion of these foreign substances remains, however, in solution, combined with the lime so that the clear fluid obtained by decantation or filtration has a brown red color.

It is now slightly acidulated with crude hydrochloric acid, 4 pounds of the latter being at the utmost required for 22 imperial gallons of wood-vinegar. A considerable quantity of tarry substances is separated and after their removal the solution appears less highly colored. By now evaporating to dryness and roasting in the previously described manner, or sharply drying upon heated iron plates, the salt is obtained as a dirty gray-brown mass. The acetic acid separated from it is, however, scarcely more impure than that obtained from gray salt, and by using somewhat more potassium bichromate, about 2 or 3 per cent., in the rectification, there is no difference in the quality of the acid.

Reichenbach destroys the empyreumatic bodies in crude calcium acetate by distilling with an excess of concentrated sulphuric acid. According to his statements, a clear colorless acetic acid of great strength and showing no empyreumatic odor is obtained. The crude distillate, however, contains sulphurous acid, so that it has to be rectified over pyrolusite and sulphuric acid or over minium or potassium bichromate.

According to Schnedermann, the wood-vinegar freed from wood-spirit is exposed with an excess of quicklime to the air for 24 hours, whereby the separation of the tarry substances is claimed to be promoted. The clear dark-brown solution of the calcium salt is drawn off and after heating to boiling mixed with calcium chloride solution as long as the latter produces a discoloring effect. The now yellowish brown solution is evaporated and finally decomposed with sulphuric acid (or hydrochloric acid). The acetic acid obtained by distillation is claimed to possess only a slightly yellow color and to be suitable for many technical pur-

poses. The acid thus obtained, however, undoubtedly contains hydrochloric acid and has to be rectified over sodium acetate.

Acetic acid of a pure taste suitable for household use as well as for technical purposes is, as previously mentioned, exclusively obtained from sodium acetate either by distillation or without it.

Sodium acetate is, to be sure, completely decomposed by 1 equivalent of sulphuric acid (36 lbs. of acid to 100 lbs. of crystallized salt) and, on a small scale in glass retorts, it is effected without difficulty, because a strong heat can finally be applied without injury. On a large scale, however, where the distillation is executed by means of steam\* of two atmospheres, 1 equivalent of sulphuric acid is not advantageous, because the remaining solid neutral sodium sulphate retains much strong acetic acid. It is, therefore, recommended to gradually pour 2 equivalents of sulphuric acid (72 lbs. of acid to 100 lbs. of the salt) upon the crystallized salt in a copper still and introduce steam after allowing the whole to rest several hours. The residue remaining in this process is sodium bisulphate, which remains entirely fluid at the distilling temperature and from which all the acetic acid can be expelled. A further advantage of this method is that at first very strong acetic acid passes over, which can be collected by itself and worked into glacial acetic acid (see below). Later on comes more dilute acid, because the water of crystallization of the acetate, which was at first retained by the bisulphate, also passes over.

The bisulphate while still hot is poured into slightly conical shallow copper pans in which it congeals on cooling. It might thus be brought into commerce, but as the manufacturer would have to compete with large chemical works producing mineral acids, it is more advantageous to utilize it by distilling it with crude sodium acetate in the proportion of 3 : 2, whereby 2.5 parts of neutral anhydrous sodium sulphate remain behind, which, as previously mentioned, can be again used for the preparation of sodium acetate, while 2 parts of acetic acid with about 40 per cent. of acetic anhydride, which is pure enough for many purposes, pass over.

\* With the use of a free fire, the stills suffer very much.

From 100 lbs. of crystallized sodium acetate 80 lbs. of acetic acid with 55 per cent. of acetic anhydride (1.065 specific gravity) are obtained, or 100 lbs. of acid with 44 per cent. of acetic anhydride. As a rule, the acid is, however, not entirely pure; it generally contains traces of hydrochloric acid, of sulphurous acid and of copper. It is, therefore, again distilled in the same apparatus, now provided, however, with a neck and worm of silver or of stoneware, some sodium acetate, or, still better, minium or potassium bichromate being added. In each case the hydrochloric acid remains behind as metallic chloride (chloride of sodium, lead, potassium and chromium). In the first case the first portions passing over contain some sulphurous acid and may have a slightly empyreumatic odor; but the acid passing over later on is pure. In the second and third case the sulphurous acid is converted into sulphuric acid by the disposable oxygen of the minium of the bichromate and retained as sulphate, the empyreumatic substances being also destroyed.

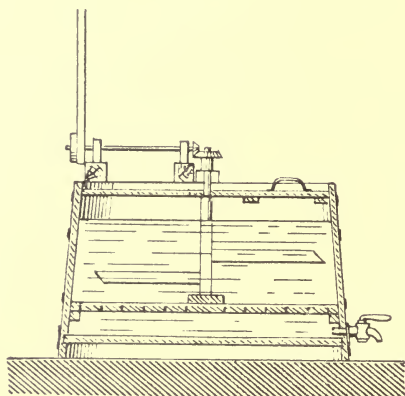
The portion of acid of a pure taste, which passes over first in rectifying, being weakest, is used for household purposes; later on comes a stronger acid up to  $10^{\circ}$  B. = 1.075 specific gravity.

Although in thoroughly rectified acid no impurity can be established by the most sensitive reagent, for instance, potassium permanganate, its taste is not as pure as that of acid prepared without distillation. This imperfection can, however, be concealed by the addition of a small quantity of acetic ether or of alcohol (about 1 quart to 22 imp. gallons), which is converted into acetic ether.

Mollerat's method renders, however, even this resort unnecessary. According to it, pure sodium acetate obtained in small crystals by disturbing crystallization is decomposed with 1 equivalent of concentrated sulphuric acid (65 lbs. of acid to 100 lbs. of salt) in a large vat provided with a false bottom. The substances being thoroughly mixed by means of a stirring apparatus, Fig. 62, the mixture is allowed to stand till the next day. Decomposition is completely effected in this time at an ordinary temperature, the acetic acid being liberated and the greater portion of the neutral sodium sulphate, which dissolves but little in the acid, crystallized out. To prevent the perforations of the false

bottom from being obstructed by the sulphate crystallizing out, sufficient pure acetic acid is previously poured into the vat to cover the perforated bottom. By opening the stop-cock the acetic acid runs off, which, however, contains a small quantity of

Fig. 62.



sodium sulphate in solution. The remaining sulphate is washed with water, and, after mixing the latter with the acid, the mixture is brought into stoneware-pots which are placed in cold water for about 8 days, whereby the greater portion of the sodium sulphate is crystallized out. The very small quantity remaining imparts, however, a laxative quality to the salt, and hence must be converted into a salt which does not possess this medicinal property. This is effected by mixing the acid siphoned off in a vat with pure calcium acetate, the required quantity of which has to be determined by a test on a small scale. The gypsum formed gradually settles to the bottom, while a corresponding quantity of newly-formed sodium acetate remains dissolved in the acid, which is, however, not injurious.

The process may also be executed by bringing 100 pounds of the salt in very small crystals or finely pulverized into a stoneware vessel, and adding at one time 35 or at the utmost 35.5 pounds of concentrated sulphuric acid in such a manner that it lies on the bottom of the vessel below the salt. Mixing is then gradually effected so as to avoid heating as much as possible.

Decomposition is complete in a few hours and the sodium sulphate crystallized out on the bottom, the supernatant acetic acid being partially in a fluid and partially in a crystallized state. The acid is then siphoned off and pure calcium acetate added as above. The sodium sulphate is then regained and can be again used in the fabrication.

The acid thus obtained need only be reduced to the strength desired by the consumer by diluting with water.

### *Glacial Acetic Acid.*

Glacial acetic acid can be prepared by distilling 12 pounds of pure anhydrous sodium acetate with 11 pounds of concentrated sulphuric acid. The last portion, which is frequently somewhat empyreumatic, is collected by itself and the portion first passed over rectified over sulphuric acid and pyrolusite to remove traces of sulphurous acid.

A better method published by Melsens is based upon the property of neutral calcium acetate to absorb 1 equivalent of hydrated acetic acid and to form a solid acid salt which decomposes only, at  $392^{\circ}$  F., into hydrated acetic acid, which passes over, and into neutral acetate which remains behind. Hence, by decomposing sodium acetate with 2 equivalents of sulphuric acid and collecting the strong acid first passing over as long as it shows from  $10^{\circ}$  to  $8^{\circ}$  B., it is only necessary to pour it into a copper still upon fused potassium acetate coarsely powdered after cooling, and after standing for several hours to distill over a free fire, the still being provided with a silver neck and a worm of the same material. When the temperature exceeds  $248^{\circ}$  F. all the weaker acid has passed over and the receiver is changed. At  $392^{\circ}$  F. glacial acetic acid passes over which is again rectified over fused potassium acetate and then exposed to a low temperature to freeze.

Glacial acetic acid can also be prepared in the same manner from acetic acid of 1.061 specific gravity obtained by Völckel's method or by distilling it over anhydrous calcium chloride and cooling the distillate, whereby one portion crystallizes. The portion which remains liquid is poured off and again distilled over

calcium chloride. The glacial acetic acid thus obtained contains considerable hydrochloric acid, but can be readily freed from this impurity by distilling over anhydrous sodium acetate, or, still better, over anhydrous potassium acetate. As by this method calcium chloride is obtained as a by-product (see p. 259), and can be freed from all organic substances by glowing with the access of air, the preparation of glacial acetic acid in this manner is just as readily executed as, though it has no advantage over, Melsen's process.

Perfectly pure hydrated acetic acid dissolves oil of lemon in every proportion, but if one drop of water be added a portion of the oil immediately separates. This behavior may be utilized for ascertaining at what moment the strongest acid is to be collected at the last rectification. The pure but weaker acid obtained in the fabrication is used in the preparation of pure acetates.

Below 59.9° F. glacial acetic acid forms large, colorless, transparent crystals, which above that temperature fuse to a thin colorless liquid, of exceedingly pungent and well-known odor; it raises blisters on the skin. It is miscible in all proportions with water, alcohol, and ether, and dissolves camphor and several resins. In a liquid state glacial acetic acid has a density of 1.063 and boils at 248° F.; its vapor is inflammable.

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## CHAPTER XXIII.

### ACETATES AND THEIR MANUFACTURE.

A CONSIDERABLE quantity of the vinegar obtained from alcohol and wood (as well as the acetic acid prepared from it) is worked into acetates, there being, for instance, factories which use their entire product in the fabrication of lead acetate or sugar of lead. Only the more important technical acetates (combinations of acetic acid with metallic oxides, or, according to the view of modern chemists, acetic acid in which 1 molecule of hydrogen is replaced by a metal) will here be described.

Acetic acid is a monobasic acid, *i. e.*, it contains 1 atom of



hydrogen which can be replaced by a metal :  $C_2H_4O_2 = C_2H_3O_{21}H$ . If this hydrogen is replaced by a univalent metal (for instance, K or Na), a salt of the formula  $C_2H_3O_2Na$  or  $C_2H_3NaO_2$  is formed. If, however, 2 atoms of hydrogen in 2 molecules of acetic acid be replaced by a bivalent metal,  $(C_2H_3O_2)_2Ba$ , etc., is formed, and finally with a trivalent metal,  $(Al)(C_2H_3O_2)_3Al$ .

Most of the acetates are readily soluble in water; the acetates of molybdenum are insoluble; and those of argentic monoxide and of mercurous oxide dissolve with great difficulty.

The preparation of the acetates is effected partially by dissolving the oxides or carbonates in acetic acid, which must, however, not be too concentrated for the barium and calcium salts, and partially by double decomposition, generally by means of the lead salt and a sulphate of another metal.

The acetates of potassium, sodium, and ammonium show a slightly alkaline reaction and the readily soluble basic lead acetates a strong alkaline one; the remaining lead acetates react neutral or slightly acid.

The acetates of the fixed alkalis and alkaline earths, submitted to dry distillation, yield water and acetone, while the oxide, and sometimes the reduced metal, remain in the distilling apparatus. The solutions of alkaline acetates become mouldy after a time.

The acetic acid may be set free from its combinations by sulphuric acid, and is easily recognized by its characteristic odor; its salts, in common with those of organic acids, become black by the action of heat.

*Potassium neutral acetate*,  $KC_2H_3O_2$ .—Acetic acid is present in the sap of many plants, and is generally combined with potassium, forming neutral potassium acetate. When wood is calcined the potassium acetate is decomposed, the acetic acid being replaced by carbonic acid. It is by this interchange that the carbonate of potassium found in wood ashes is formed.

It is prepared by dissolving pure carbonate of potassium in a slight excess of acetic acid, evaporating and fusing. The excess of acid is necessary to replace that which is lost during evaporation; without it the salt turns yellow or brown.

Another method of obtaining it is by decomposing normal

acetate of lead (sugar of lead) with pure carbonate or sulphate of potassium. To detect the presence of lead it should be tested with sulphuretted hydrogen, which in the presence of this metal produces a slightly brown precipitate. To obtain a pure product the decanted liquid is treated with sulphuretted hydrogen, and, after separating from the precipitate and adding a small quantity of acetic acid, is evaporated in a stone-ware vessel.

Potassium acetate is readily soluble in water and ordinary alcohol; it is quite soluble in absolute alcohol, but insoluble in ether. It is a very deliquescent salt and difficult to crystallize. The entirely pure salt in dilute aqueous solution should not give precipitates with potassium or with sulphuretted hydrogen, nor with barium chloride or nitrate of silver.

At an ordinary temperature 100 parts of water dissolve 230 parts of the salt; a saturated solution, which boils at  $336.2^{\circ}$  F., contains for 100 parts of water 800 of the salt. From the alcoholic solution of the salt potassium carbonate is thrown down by a stream of carbon dioxide.

Potassium acetate melts without decomposition at  $482^{\circ}$  F. to an oily liquid, and on cooling forms a crystalline, foliated mass; at a red heat it is decomposed into acetone, hydrocarbons, empyreumatic products, and a residue of carbon and potassium carbonate.

By the decomposition of acetate of potassium by electrolysis Kolbe first obtained free methyl.

Potassium acetate, when treated with potassium hydrate in excess, becomes converted into carbonate of potassium and marsh gas. When heated with arsenious acid, cacodyl (Cadet's fuming liquid) is produced. This reaction is so decided, and the alliaceous odor evolved so strongly marked, that it forms one of the best tests for small quantities of acetic acid.

Potassium acetate is an important medicine; it is employed as a diuretic; it is also recommended for the preservation of microscopic objects, and it is occasionally used for the preparation of pear ether (amyl acetate).

*Potassium acid acetate or potassium diacetate*,  $\text{KC}_2\text{H}_3\text{O}_2\text{C}_2\text{H}_4\text{O}_2$ , is formed by evaporating a solution of the neutral salt in excess

of acetic acid; it crystallizes by slow evaporation in long, flattened prisms. It is very deliquescent and decomposes at  $392^{\circ}$  F., giving off crystallizable acetic acid.

*Sodium acetate*,  $\text{NaC}_2\text{H}_3\text{O}_2$ .—The manner of preparing this salt in the fabrication of wood-vinegar has already been described. It can be obtained in a manner similar to that of the potassium salt by dissolving carbonate of soda in acetic acid, evaporating the solution, and setting the liquor aside to crystallize. The crystals form large, colorless, oblique rhombic prisms. Their composition is  $\text{NaC}_2\text{H}_3\text{O}_2 + 3\text{H}_2\text{O}$ ; they are soluble in 3 parts of cold, in a less quantity of boiling water, and in 5 of alcohol.

The taste of sodium acetate is cooling and saline. When exposed to dry air it loses its three equivalents of water, but regains them in a moist atmosphere. After being melted it is deliquescent and takes up 7 equivalents of water; it then becomes a liquid, supersaturated solution which crystallizes, with evolution of heat, immediately after a fragment of dry or crystallized sodium acetate is thrown into it.

Sodium acetate is used for the preparation of acetic acid, acetic ether, and in medicine. Sacc recommends it for the preservation of animal and vegetable substances. His method consists in the use of powdered acetate of sodium instead of common salt. To keep meat fresh it is placed in a barrel with layers of acetate of sodium interposed between the layers of meat in the proportion of one-fourth of the weight of the meat. In summer the action of the salt is immediate; in winter it is necessary to place the barrel in a heated room. As the salt abstracts the water from the meat, the barrel is turned about. The operation is complete in about 48 hours, and the meat may then be packed with its pickle or it may be dried in the air. If the barrels are not full, they may be filled up with a fresh pickle made by dissolving 1 part of sodium acetate in 3 of water. When the pickle is drawn off from the meat half the salt is deposited in crystals and may be again used.

Meat which has been thus treated is prepared for cooking by steeping for at least 12 and not more than 24 hours, according to the size of the piece, in tepid water, to which a small quantity of sal ammoniac has previously been added. This salt decom-

poses the acetate of sodium which remains in the meat, forming sodium chloride or common salt, and ammonium acetate. The meat swells and resumes the color and reactions of fresh meat. Animals, particularly fish and poultry, may be preserved entire for market purposes in a pickle of sodium acetate, the only precaution necessary being the removal of the intestines. Under the influence of the pickle the meat loses about one-fourth of its weight and another quarter disappears when it is dried. The process is also said to be very well adapted to the preservation of vegetables. These generally lose thereby five-sixths of their weight. When needed for use, it is only necessary to soak them for twelve hours in water and then cook them as if entirely fresh.

A mixture of dephlegmated sodium acetate with saltpetre explodes with great violence on heating. According to Violette, a mixture of saltpetre 75 parts, sulphur 12.5, and sodium acetate 25, acts more vigorously than gunpowder and can be granulated.

*Ammonium acetate, neutral acetate of ammonia*,  $\text{NH}_4\text{C}_2\text{H}_3\text{O}_2$ .—This substance is obtained by neutralizing acetic acid with carbonate of ammonia, or, better, by saturating glacial acetic acid with dry ammonia gas. It is very difficult to obtain in the crystalline form on account of its aqueous solution giving off ammonia when evaporated, thus becoming converted into the acid salt. When subjected to dry distillation ammonia gas escapes first; above  $320^\circ$  F. there is formed, besides water, chiefly acetamide ( $\text{C}_2\text{H}_5\text{NO}$ ), a white crystalline body which is also formed, besides alcohol, on heating acetic ether with liquid ammonia in a closed vessel to about  $266^\circ$  F.

In medicine ammonium acetate has long been used as a diaphoretic.

*Calcium acetate*  $\text{Ca}(\text{C}_2\text{H}_3\text{O}_2)_2$  is prepared from burnt lime or calcium carbonate (marble, chalk) and dilute acetic acid. The preparation of the crude calcium acetate (brown salt) has been previously described under wood-vinegar. To obtain the pure salt crystallized, add to a concentrated aqueous solution several times its volume of ordinary alcohol; the salt deposits in the course of 24 hours.

The crystals of the pure salt form white acicular prisms which effloresce in the air and are soluble in water and in alcohol; they

have a bitter, salty taste. They are decomposed by heat into acetone and calcium carbonate. A mixture of this salt and of potassium oxalate gives, on heating, propylene ( $C_3H_6$ ), while a mixture of carbonates remains behind. By the dry distillation of equal equivalents of acetate and benzoate of calcium acetophenone ( $C_8H_8O$ ) is obtained, which by treatment with nitric acid is converted into nitro-acetophenone ( $C_8H_7NO_3$ ). By heating the latter with zinc-dust and soda-lime, Emmerling and Engler claim to have obtained artificial indigo-blue. But the quantity of the latter thus obtained is always very small, and it appears to be very difficult to ascertain the precise condition under which the transformation takes place.

With calcium chloride calcium acetate enters into a crystallizable combination; it also dissolves some sulphate of lead.

*Barium acetate* ( $C_2H_3O_2$ )<sub>2</sub>Ba +  $1\frac{1}{2}H_2O$ .—This substance is prepared from barium carbonate or barium sulphide and dilute acetic acid. Since barium carbonate, which is found native as witherite, and barium sulphide, which is prepared by heating barium sulphate with bituminous coal, always contain iron and this iron passes into solution, it is separated by adding some barium water after the point of neutralization is reached. The solution is then filtered and the filtrate again neutralized with acetic acid.

At a low temperature the solution yields colorless crystals derived from a rhombic prism; they are extremely deliquescent, readily soluble in water, but with difficulty in ordinary alcohol and almost insoluble in absolute alcohol. They show a slight alkaline reaction, contain 3 equivalents (17.5 per cent.) of water, and are isomorphous with normal acetate of lead (lead sugar), to be described later on. By allowing the concentrated solution to crystallize at a somewhat higher temperature the salt absorbs, however, only 1 equivalent (6.5 per cent.) of water.

By mixing a concentrated solution of the salt with sulphuric acid, the barium sulphate does not separate in the ordinary form of a fine white powder, but as a semi-transparent, gelatinous mass which retains acetic acid; for this reason barium acetate is not suitable for obtaining strong acetic acid.

When subjected to dry distillation barium acetate does not yield acetic acid, but only acetone (and very little empyreumatic



oil) while barium carbonate remains behind. It is the best material for the preparation of acetone. The decomposition is best effected in a cast-iron vessel. With barium nitrate it gives a well crystallizing double salt.

*Strontium acetate*.—This salt is prepared in a manner similar to that of the preceding. The crystals obtained at 32° F. contain 5 equivalents of water and those at 59° F. 1 equivalent.

With strontium nitrate it gives a double salt forming beautiful crystals which contain 3 equivalents of water. On heating they first yield their water of crystallization and then detonate, a beautiful purple flame being formed.

*Magnesium acetate* is prepared by dissolving *magnesia alba* or *usta* in acetic acid. It crystallizes with difficulty and is readily soluble in water and spirits of wine. Only a very small portion of the solution is decomposed by ammonia. By dry distillation it yields acetic acid, while magnesia remains behind.

*Aluminium acetate*.—The neutral salt  $\text{Al}_2(\text{C}_2\text{H}_3\text{O}_2)_6$  has never been obtained in the dry state, it being only known in solution. The pure combination can be prepared by introducing freshly precipitated and thoroughly washed aluminium hydrate into heated acetic acid.

Aluminium acetate is of great importance in calico printing and is used as a mordant under the name of *red liquor*. It is manufactured for the use of the calico printer by adding to every gallon of calcium acetate liquor  $2\frac{3}{4}$  lbs. of alum, agitating the mixture briskly and then leaving it to rest, in order that the calcium sulphate may settle down. The decomposition of the acetate is known by testing a small portion of the filtered liquid in a tube with a concentrated solution of alum; if a precipitate of calcium sulphate falls, more alum must be added, till the acetate of lime is completely decomposed. The liquor is next filtered off, and the solution concentrated by evaporation till it acquires a specific gravity of 1.087 to 1.1; it is then allowed to repose for some time to deposit any sulphate of lime and finally drawn off for use. The quality of this liquid as a mordant is inferior on account of the imperfect decomposition of the lime-salt, and the presence of a small portion of lime still retained in the red liquor



which impairs very much the beauty and gloss of the color given to the cloth.

A better mordant is made by decomposing alum by lead acetate. Since lead sulphate is insoluble the decomposition of the alum solution is more perfect than when it is acted upon by acetate of lime; nevertheless, red liquor is not a true acetate, but a mixture of aluminium acetate, sulphate and hydrate, with potassium sulphate, as will be seen from the receipts in general use for its manufacture. In practice it is found advantageous to employ equal parts of alum and sugar of lead, or even a rather less quantity of the latter. The alum is dissolved in boiling water, and the powdered lead acetate added to the solution. About one-tenth of crystallized carbonate of soda, or a little carbonate of lime, is added to the alum to combine with the free acid. The three following receipts serve to indicate the proportions employed:—

I. Dissolve 100 pounds of alum in 50 gallons of boiling water, and add 10 pounds of acetate of lead in fine powder, stirring the mixture well at first, and likewise several times during cooling.

II. Dissolve 100 pounds of alum in 50 gallons of boiling water, add slowly 10 pounds of crystallized carbonate of soda, and then stir in 50 pounds of acetate of lead in powder.

III. Dissolve 100 pounds of alum in 50 gallons of boiling water, and add in small portions 6 pounds of crystallized carbonate of soda, and then stir in 50 pounds of acetate of lead, in powder, as before.

When used by the calico printer the red liquor is thickened with gum or some other suitable material, and with it the design is impressed upon the cloth by a wood block, or by any other means; on subsequently submitting the goods to the drying-bath, acetic acid is partly volatilized, and the aluminous basic compound remains perfectly combined with the cloth.

Crace Calvert states, from practical observations, that a sulphate of alumina is to be preferred as giving the most satisfactory results. He considers that a mordant of such a composition is best adapted for fixing the colors, on account of the excess of alumina in such a solution above those which contain, besides the

aluminous salts, salts of the alkalies, which are inert in the uses for which red liquor is manufactured.

He recommends the following formulæ :—

I. Ammonia alum, 453 pounds ; lead acetate, 379 ; water, 1132.

II. Aluminium sulphate, 383 pounds ; lead acetate, 379 ; water, 1132.

III. Alum, 453 pounds, and a quantity of solution of acetate of lime, amounting to 158 pounds.

IV. Aluminium sulphate, 333 pounds, with the same amount of acetate of lime solution.

On agitating the foregoing mixtures, decomposition takes place ; sulphate of lead or of lime is thrown down and a sulphacetate remains with an equivalent of ammonium sulphate from the ammonia alum.

In 1872, Messrs. Storek & Co., of Asnières, France, patented a process for the manufacture of aluminium acetate from the phosphate. Aluminium phosphate is converted into acid phosphate by dissolving it in phosphoric acid. Soluble aluminium acetate and insoluble lead sulphate are thus formed. The aluminium acetate is then separated by filtration, and subsequently treated in a manner similar to that obtained for industrial purposes by the double decomposition with aluminium sulphate. The phosphate of lead is either used to produce pure phosphoric acid by decomposing it by sulphuric acid, or sulphuretted hydrogen, or an alkaline phosphate is formed thereof by treating it with an alkaline sulphide. It may likewise be used for the production of phosphorus ; in this case it is mixed with charcoal and subjected to distillation.

*Manganese acetate*,  $\text{Mn}(\text{C}_2\text{H}_3\text{O}_2)_2$ . This substance is prepared by dissolving freshly precipitated manganous carbonate ( $\text{MnCO}_3$ ) in heated acetic acid, evaporating the solution and crystallizing. The crystals are of the rhombic prism, and occasionally in plates of an amethystine color ; they are permanent in air, soluble in alcohol, and in about three times their weight of water.

On a large scale this salt is manufactured by precipitating a solution of manganous sulphate\* by one of lime acetate and

\* Manganous sulphate is prepared by mixing the dioxide (pyrolusite) with half its weight of concentrated sulphuric acid and heating in a Hessian cru-

agitating the liquor to decompose the whole of the manganese salt.

It sometimes happens that a portion of the manganese salt is not acted upon by the acetate of lime ; in this case a concentrated solution of acetate of lead is employed towards the end of the process to effect the complete decomposition. The mixed precipitate of sulphate of lime and lead is filtered off, and the filtrate evaporated and crystallized. The best acetate of manganese is made by adding to 4 parts of manganous sulphate dissolved in 3 parts of water, 7 parts of crystallized acetate of lead dissolved in 3 parts of water, agitating the solution, and drawing off the clear liquor for use.

Acetate of manganese is used in dyeing and calico printing to give a brown color to fabrics. Its principle of action depends upon the further oxidation of the manganese.

*Iron acetates.*—Acetic acid combines with ferrous oxide ( $\text{FeO}$ ) as well as with ferric oxide ( $\text{Fe}_2\text{O}_3$ ), but only the ferrous acetate crystallizes in small greenish white needles, very prone to oxidation ; ferric acetate is a dark, brownish red, uncrystallizable liquid, of powerful and astringent taste. Both salts dissolve freely in water, and are of importance for dyeing and calico printing.

*Ferrous acetate*,  $\text{Fe}(\text{C}_2\text{H}_3\text{O}_2)_2$ . For dyeing purposes this salt is prepared by dissolving wrought-iron turnings in wood-vinegar, care being had that some iron remains undissolved, as otherwise the salt, on exposure to the air, is gradually partly converted into the ferric salt. This oxidation proceeds, however, but slowly, the empyreumatic substances contained in the wood-vinegar rendering the conversion rather difficult ; the pure salt oxidizes with greater rapidity. For commercial purposes this compound is manufactured as follows : Into a large wooden vat or into barrels a quantity of iron turnings, hoops, or nails are introduced, and hot crude wood-vinegar, freed by distillation from wood-spirit, is poured upon them. During the solution of the iron much tarry matter separates which is skimmed off, and the solution is frequently

cible until no more vapors escape. The residue is dissolved in water, filtered, and allowed to crystallize at an ordinary temperature. The solution of the salt when decomposed with crystallized soda gives a precipitate of manganous carbonate.

agitated to free it as much as possible from the tar. After 24 hours the solution is drawn off. The iron being entirely coated with tar so that it is not again attacked by the wood-vinegar, it is taken from the vat and the tar ignited. The iron being freed from the oxide formed by sifting can be again used. The solution thus obtained shows  $13^{\circ}$  or  $14^{\circ}$  B.

The pure salt is obtained by dissolving iron in acetic acid or by double decomposition from ferrous sulphate (14 parts) and lead acetate (19 parts); and cheaper, but less pure, from ferrous sulphate and calcium acetate.

If crude calcium acetate instead of wood-vinegar is to be used in the preparation of this salt, a solution of the calcium acetate of specific gravity 1.08 is mixed with half its weight of ferrous sulphate dissolved in  $2\frac{1}{2}$  times its weight of water. On agitating the mixture the decomposition is rendered complete, the clear liquor which is siphoned off after the subsidence of the sulphate of lime showing  $13^{\circ}$  B. It is kept in a closed barrel in which is hung a bag containing a quantity of iron turnings.

In some factories the ferrous acetate is manufactured by decomposing the carbonate of iron ( $\text{FeCO}_3$ ) with lead acetate; lead carbonate precipitates, and the blackish supernatant liquor is the acetate of iron in a very pure state. It is kept from oxidizing by immersing in it some bright iron filings. The lead salt formed repays the cost of the manufacture of the acetate.

Solution of ferrous acetate is used as a mordant by dyers, for staining wood and leather and in the manufacture of ink. The commercial article generally shows a specific gravity of 1.10 ( $12^{\circ}$  B.).

On account of the avidity with which ferrous acetate absorbs oxygen, it is of great value as a reducing agent. It is, for instance, used in the preparation of aniline from nitrobenzole and for similar reducing processes.

*Neutral ferric acetate or sesquiacetate of iron*,  $\text{Fe}(\text{C}_2\text{H}_3\text{O}_2)_3$ .—For technical use this combination is obtained by dissolving wrought-iron in wood-vinegar so that it has a chance to oxidize in the air. For this purpose wood-vinegar is poured over iron turnings in a vat, and after drawing off the solution, in a few days the iron is for some time left to the action of the oxygen of the

air. It quickly oxidizes and by pouring back the solution and several times repeating the drawing off and pouring back, a quite concentrated solution of a dark red brown, nearly black color is in a short time obtained. Heat must not be employed in the preparation of this salt, as in such case it readily decomposes.

Neutral ferric acetate may be obtained in the pure state by decomposing a solution of lead acetate by addition of ferric sulphate in slight excess. In the course of 24 hours the excess of ferric sulphate precipitates as a basic salt. It is also produced, though more slowly, by dissolving ferric hydrate or ferric carbonate obtained by precipitation, in strong acetic acid. This method occupies more time, but affords better guarantees for the purity of the compound.

By dissolving one part of nitric acid or aqua regia, precipitating the solution with ammonia and dissolving the washed ferric hydrate in 10 parts of acetic acid of 1.042 specific gravity and evaporating the solution at from 140° to 176° F. an amorphous salt soluble in water and alcohol remains, which is, however, not neutral, as it contains only 2 instead of 3 equivalents of acetic acid for 1 equivalent of ferric oxide. By dissolving this amorphous salt in acetic acid and exposing the dark red solution to a low temperature, the neutral salt crystallizes out in hydrated, lustrous, dark red laminae.

On heating the strongly diluted solution of this salt nearly to the boiling point its color becomes more intense and it evolves a distinct odor of acetic acid without, however, producing a precipitate. The salt has nevertheless become more basic, and an addition of any soluble sulphate or even of free sulphuric acid immediately precipitates the whole of the iron as insoluble basic ferrous sulphate. By heating, however, the dilute solution of the pure acetate to boiling it disengages acetic acid and separates a basic salt, which, if boiling be continued, also loses its acid so that ferric hydrate remains behind. The properties of this hydrate differ, however, from those of ordinary ferric hydrate, it being only dissolved in concentrated hydrochloric acid by long-continued digestion or boiling and scarcely attacked by boiling concentrated sulphuric acid. In acetic acid or dilute nitric acid it dissolves, however, to a red fluid, transparent to transmitted, but opaque to



reflected, light. By adding the slightest quantity of a sulphate or of concentrated nitric or hydrochloric acid, a granular precipitate is formed, which, however, redissolves on diluting the fluid with water. If a solution of ferric acetate is heated in a closed vessel to  $212^{\circ}$  F. for a few hours, the fluid seen by reflected light appears opaque and opalescent; it has also lost its metallic taste and no longer shows the other reactions of ferric salts, *i. e.*, addition of ferrocyanide produces no precipitate nor does the sulphcyanide augment its red color. A trace of sulphuric acid or any alkaline salt suffices to precipitate the whole of the iron in solution as ferric hydrate of red color, which is totally insoluble in all acids at an ordinary temperature; dilute mineral acids do not, however, produce a similar precipitate. It is remarkable that this ferric hydrate dissolves in water to a dark red fluid which can be again precipitated by concentrated acids or alkaline salts (Péan de St. Giles).

From the iron acetates the iron is precipitated as black ferrous sulphide by sulphuretted hydrogen.

With ferric nitrate ferric acetate yields a crystallizable double salt,  $\text{Fe}(\text{C}_2\text{H}_3\text{O}_2)_2\text{NO}_3 + 3\text{H}_2\text{O}$ , the solution of which decomposes on boiling, nitric and acetic acids being disengaged. A similar combination exists between the acetate and ferric chloride.

The acetates of iron are employed in woollen dyeing to produce blue with potassium ferrocyanide and ferricyanide; in cotton dyeing and printing, and in silk dyeing they are used for blacks, russets, etc. Ferrous acetate is used with madder, for violet; or together with red liquor, for brown; it is also used for dyeing hats and furs black and for blackening leather, wood, etc. Some dyers prefer the ferrous acetate, because, by the oxidation of the iron subsequently to dyeing, the colors are more resistant; but greater uniformity of the ground is insured by the use of ferric acetate. For the preparation of ink ferrous acetate is to be preferred.

A mixture of ferric acetate with alcohol and acetic ether forms Klaproth's tincture of iron, which is used in medicine.

*Chromium acetates.*—Acetic acid enters into combination with chromous ( $\text{CrO}$ ) as well as with chromic oxide ( $\text{Cr}_2\text{O}_3$ ). The salts are not used in the industries and are only of scientific interest.



*Chromous acetate*,  $(C_2H_3O_2)_2Cr + H_2O$ , is prepared by mixing a solution of chromous chloride with sodium acetate. The salt separates out in small, lustrous red crystals which are sparingly soluble in water and alcohol and quickly oxidize to a greater degree on exposure to the air, the succeeding salt being formed.

*Chromic acetate*.—A neutral salt is known and there are very likely several basic ones. The solution of the neutral salt, which is obtained by dissolving chromic hydrate in heated acetic acid, forms a red fluid, green in a reflected and red in a transmitted light. It is not decomposed by boiling, but by ammonia. The precipitate, however, redissolves, on adding ammonia in excess, to a violet-red fluid because the hydrate is soluble in ammonium acetate. Hence, a solution of the salt acidulated with acetic acid is not precipitated by ammonia.

There are also known crystallized combinations of this salt with chromic chloride and sulphate and nitrate of chromium.

If the solution of the neutral salt is for some time digested with chromic hydrate, it acquires a darker color, the acid re-action disappears, and on evaporating a green powder soluble in water remains behind. Ordway has described a purple basic salt.

*Nickel acetate* forms small green crystals soluble in water, but not in alcohol.

*Cobalt acetate* forms small red crystals, the concentrated solution of which turns blue on heating but again red on cooling, and can, therefore, be used as sympathetic ink.

*Zinc acetate*,  $Fn(C_2H_3O_2)_2$ .—This salt may be prepared by dissolving metallic zinc, zinc oxide or zinc carbonate in acetic acid, or by the decomposition of zinc sulphate by acetates of lime or lead similar to the acetate of manganese. The acetate is in the first three instances simply obtained by evaporation, and in the latter, after agitating the mixture, filtering and evaporating the filtrate. The salt crystallizes in flexible, opalescent, six-sided tables which effloresce slightly in the air. Technically the best receipt is to dissolve 4 parts of the sulphate of zinc and  $7\frac{1}{2}$  parts of acetate of lead each in 3 parts of hot water, mixing the solutions, agitating, and after the sulphate of lead has deposited, drawing the clear liquid off to crystallize.

*Acetates of copper.* *Cuprous acetate*,  $\text{Cu}_2(\text{C}_2\text{H}_3\text{O}_2)_2$ .—This salt is produced by subjecting crystallized verdigris to dry distillation. It is a white substance crystallizing in fine needles, which are decomposed by water into yellow cuprous hydrate and cupric acetate.

With cupric oxide acetic acid forms a normal and several basic salts.

*Neutral cupric acetate ; crystallized verdigris*,  $\text{Cu}(\text{C}_2\text{H}_3\text{O}_2)_2$ .—The normal cupric acetate may be prepared by dissolving pure cupric oxide or cupric hydrate in pure acetic acid or by employing, instead of the pure oxide, copper scales whose content of metallic copper and of cuprous oxide is converted into cupric oxide by moistening with nitric acid and gentle glowing ; the cupric oxide thus obtained is washed to remove foreign substances. The conversion of the cuprous oxide into cupric oxide is especially essential when the acetic acid is not entirely free from hydrochloric acid, as otherwise cuprous chloride is formed which dissolves with difficulty.

If copper scales cannot be obtained, hydrated basic carbonate of copper can be prepared by precipitating sulphate of copper with soda, and, after washing and pressing, dissolving in acetic acid. Sulphate of soda remains dissolved in the water, and this solution can eventually be utilized for the conversion of crude calcium acetate into sodium salt. Instead of soda, milk of lime can also be used for the decomposition of the sulphate of copper : a mixture of calcium sulphate and cupric hydrate is precipitated. By adding acetic acid the latter is redissolved while the calcium sulphate remains suspended. When the latter has settled the solution is drawn off and evaporated. The calcium sulphate is repeatedly washed with small portions of water, and the washwaters used for dissolving fresh quantities of sulphate of copper.

In case the sulphate of copper contains iron the latter is removed by digesting the solution for several days with basic carbonate of copper. The presence of iron is recognized by the sulphate not dissolving entirely in ammonia in excess, but leaving behind a red-brown residue (ferric hydrate).

The neutral acetate can also be prepared by dissolving the basic salt, verdigris (described below), in acetic acid. The solu-

tion is filtered and evaporated until a crystalline film is formed. This method is, however, expensive.

The method by double decomposition may be recommended for preparing the neutral acetate on a small scale, but not for manufacturing purposes. Sulphate of copper (125 parts) and sodium acetate (136 parts) decompose each other, neutral cupric acetate crystallizing out while sodium sulphate remains in solution. The yield is, however, somewhat smaller than theoretically might be expected, because the sulphate of copper is not entirely insoluble in sodium sulphate solution. By this process the object is quickly accomplished and for this reason is decidedly to be preferred to the following: Sulphate of copper (125 parts) and normal lead acetate (190 parts) decompose completely only in dilute but not in concentrated solutions. Hence strong evaporation is required whereby acetic acid is lost. Further, with the use of lead acetate some of the newly formed lead sulphate is obtained in solution; but the lead cannot be separated with sulphuretted hydrogen because the latter would decompose also the copper salt. The disadvantage of substituting calcium acetate for the lead acetate is that it is not crystallized and hence furnishes no external criterion of purity; in fact it always has a slightly varying composition. If a small excess of calcium salt has been used, the latter, after the calcium sulphate is filtered off and the solution evaporated, does not remain in the mother lye, but crystallizes out as double salt (see below), together with the copper salt. Since these acetates create difficulties, and as each of them must first be prepared by the manufacturer by means of acetic acid, it would seem more rational to directly use this acetic acid for dissolving the cupric oxide, whereby no by-products of little value, such as sulphate of lead, calcium and sodium, are formed.

The evaporation of the solution of cupric acetate obtained by any of the above methods is effected in a copper boiler over an open fire, or, still better, by steam. It is recommended to close the boiler so that the escaping vapors of water and acetic acid are condensed in a worm. Independently of the fact that by these means the escaping acetic acid is regained and can be used for other purposes, a great advantage is that the air of the workroom is thereby not contaminated by flying particles of salt.

Crystallization is generally effected in stone-ware pots into which dip a number of slender wooden rods. The pots are placed in a warm room. Crystallization is finished in about 14 days. The crystals turn out especially beautiful when the acid somewhat preponderates and the cooling of the solution is effected very slowly.

The salt forms dark green\* rhombic prisms of a nauseous metallic taste, which dissolve in 14 parts of cold and 5 parts of boiling water, and are also soluble in alcohol. Heated in the air the crystals burn with a green flame.

Neutral cupric acetate contains in 100 parts, cupric oxide 39.8, anhydrous acetic acid 51.1, water 9.

On heating, the dilute solution of the neutral salt yields acetic acid and deposits a basic salt; hence the use of strongly diluted acetic acid or even distilled vinegar is not suitable for the preparation of crystallized verdigris. By long-continued digestion with freshly glowed charcoal the dilute solution yields its entire content of copper to the latter; hence vinegar containing copper can be purified in this manner (2 or 3 per cent. of charcoal being sufficient). The crystals of normal cupric acetate, after drying *in vacuo*, lose no more water at 212° F., but give off 9 per cent. of their water between 230° and 284° F. By destructive distillation cupric acetate yields strong acetic acid which contains acetone and is contaminated with copper. Cuprous oxide ( $\text{Cu}_2\text{O}$ ) is obtained in red octahedral crystals when the neutral salt is heated with organic substances, such as sugar, honey, starch, etc. With the acetates of potassium, sodium, and calcium, normal cupric acetate gives double salts of a vivid blue color, which form fine crystals.

The chief use of normal cupric acetate in the arts is in making pigments and for resisting the blue color which the indigo would communicate in the indigo bath of the calico printer. In the latter case its mode of action depends on the readiness with which it parts with oxygen, whereby the indigo is oxidized before it can exert any action on the cloth, being itself reduced to the

\* There is also another salt of a beautiful blue color, which contains, however, 5 equivalents of water (Wöhler). It is prepared by exposing a solution of the salt mixed with free acetic acid to a low temperature. At 95° F. it passes into the ordinary green salt.

state of acetate of suboxide of copper. Crystallized verdigris is occasionally employed as a transparent green water color or wash for tinting maps. In medicine it is used for external application. It is poisonous like all soluble copper salts.

*Basic cupric acetates.* *Sesquibasic cupric acetate*  $(\text{Cu}(\text{C}_2\text{H}_3\text{O}_2)_2)_2$   $\text{CuO} + 6\text{H}_2\text{O}$ .—This compound is obtained pure by gradually adding ammonia to a boiling concentrated solution of the normal acetate until the precipitate, which is at first formed, is redissolved. As the liquor cools the new salt then crystallizes out in beautiful blue-green scales, which at  $212^\circ \text{F}$ . lose 10.8 per cent. of their water. Their aqueous solution is decomposed by boiling, acetic acid being given off and the black oxide of copper precipitated.

*Dibasic cupric acetate*,  $\text{Cu}(\text{C}_2\text{H}_3\text{O}_2)_2\text{CuO} + 6\text{H}_2\text{O}$ , constitutes the greater part of the blue variety of verdigris. It forms beautiful, delicate, blue, crystalline needles and scales, which when ground form a fine blue powder. When heated to  $140^\circ \text{F}$ . they lose 23.45 per cent. of water and become transformed into a beautiful green, a mixture composed of the neutral and tribasic acetates. By repeated exhaustion with water the dibasic is resolved into the insoluble tribasic salt, and a solution of the normal and sesquibasic cupric acetates.

*Tribasic cupric acetate*,  $\text{Cu}(\text{C}_2\text{H}_3\text{O}_2)_2 2\text{CuO} + 3\text{H}_2\text{O}$ .—This compound is the most stable of any of the acetates of copper. It is prepared by boiling the aqueous solution of the neutral acetate, by heating it with alcohol, by digesting its aqueous solution with cupric hydrate, or by exhausting blue verdigris with water, as mentioned above. The first methods yield the salt in the form of a bluish powder composed of needles and scales, the last as a bright green powder. This salt gives off all its water at  $352^\circ \text{F}$ .; at a higher temperature it decomposes and evolves acetic acid. Boiling water decomposes the solid tribasic acetate into a brown mixture of the same salt with cupric oxide.

Under the name of *verdigris* two varieties of basic cupric acetate are found in commerce: *French verdigris* which occurs in globular, bluish-green, crystalline masses, but also in amorphous masses, and *English verdigris* of a pure green color and



crystalline structure, which is, however, also manufactured in Germany and Sweden.

The first variety is chiefly manufactured in the region around Montpellier, France. The refuse of grapes, after the extraction of the juice, is placed in casks until acetous fermentation takes place. The casks or vessels are covered with matting to protect them from dirt. At the end of two or three days the fermenting materials are removed to other vessels in order to check the process, to prevent putrefaction. The limit to which fermentation should be carried is known by introducing a test-sheet of copper into the mass for 24 hours; if, on withdrawing it at the end of that time, it is found covered with a uniform green coating, the proper degree of fermentation is reached.

Sheets of copper are prepared by hammering bars of the metal to the thickness of about  $\frac{1}{24}$  of an inch (the more compact the copper sheets the better), and they are then cut into pieces of 6 or 8 inches long by 3 to 4 broad. Sometimes old ship-sheathing is used and cut into pieces of the required size. The sheets are immersed in a concentrated solution of verdigris and allowed to dry. When the materials are all found to be in proper condition, the copper sheets are laid on a horizontal wooden grating in the middle of a vat, on the bottom of which is placed a pan of burning charcoal, which heats them to about 200° F. In this state they are put into large stoneware jars with alternate layers of the fermenting grape lees; the vessels are covered with straw mats and left at rest. At the end of 10 to 20 days they are opened to ascertain if the operation is complete. If the upper layer of the lees appears whitish and the whole has worked favorably, the sheets will be covered with silky crystals of a green color. The sheets are then taken from the jars and placed upright in a cellar, one against the other. At the end of two or three days they are moistened with water and again placed to dry. This moistening with water is continued at regular intervals of a week for six or eight times. This treatment causes the sheets to swell and become incrustated with increased coatings of the copper salt, which are detached from the remainder of the sheets by a copper knife. The scraped plates are submitted to a fresh treatment till the whole of the copper is converted into verdigris. The salt



scraped off is made into a consistent paste by kneading with a little water, and in this state is packed into leathern bags which are placed in the sun to dry until the mass hardens and forms the tough substance which constitutes the commercial article.

In England, Germany, and Sweden copper sheets are moistened with a solution of verdigris in vinegar and placed in a warm room, or woollen cloths moistened with the above solution are used, which are placed alternately with the copper sheets in a square wooden box. The woollen cloths are moistened with the solution every three days for 12 or 15 days when small crystals commence to form on the sheets. The sheets are then drawn every six days through water and replaced in the box, but not in direct contact with the woollen cloths, small disks of copper or small pieces of wood being placed between each cloth and sheet. The woollen cloths are now more thoroughly saturated than before, but with a weaker solution. With a temperature of from  $54^{\circ}$  to  $59^{\circ}$  F., 6 to 8 weeks are required before the verdigris can be scraped off. The product is not identical with that obtained by the French method, it being somewhat poorer in acetic acid, and hence its color is not bluish-green but almost pure green.

According to Philipps the composition of the two varieties of verdigris is as follows:—

	French verdigris.	English crystallized verdigris.
Cupric oxide . . . . .	43.5	43.25
Anhydrous acetic acid . . . . .	29.3	28.3
Water . . . . .	25.2	28.45
Impurities . . . . .	2.	—

On account of having more body the globular verdigris is preferred by painters, notwithstanding its being more expensive and less pure than the green article. It is frequently adulterated with gypsum or chalk and also with heavy spar. If effervescence is produced by pouring pure hydrochloric or nitric acid over the verdigris and the filtrate precipitated by sulphuric acid, chalk is present. If a white residue remains on digesting the verdigris with an equal weight of acetic acid of 1.045 specific gravity, gypsum or heavy spar has been added. In case this residue, after washing with a mixture of acetic acid and spirits of

wine until a sample of the filtrate is no longer colored blue by ammonia, and then treating with distilled water, yields a fluid which produces precipitates with barium chloride as well as with ammonium oxalate, it consists of or contains gypsum; in the other case heavy spar is present.

Considerable quantities of the neutral as well as of the basic cupric acetate are used in calico printing, for painting in oil, and for the manufacture of paints, especially of the so-called Schweinfurth green, which is a crystalline combination of copper acetate and arsenite.

By gradually adding through a fine brass sieve a thin paste of 5 parts of verdigris rubbed up in 5 parts of lukewarm water to a boiling solution of 4 parts of arsenious acid in 50 parts of water, an amorphous yellowish-green precipitate is formed which consists of copper arsenite and is called *Scheele's green*. By continuing the heating and adding acetic acid to the boiling mixture it gradually becomes crystalline and acquires a very beautiful green color; it is then known as Schweinfurth green, and only requires washing with a little water and drying. The same combination can also be obtained from cupric sulphate and sodium arsenate and acetate.

Schweinfurth green as found in commerce is a fine crystalline powder of a lustrous green color, which, however, becomes paler and loses some of its beauty by rubbing. It is insoluble in water, but is decomposed by long-continued boiling in water and then becomes brown. Like all copper salts it dissolves with a blue color in ammonia and is decomposed by alkalies and alkaline earths, pale-blue cupric hydrate being separated. By boiling the mixture the cupric hydrate is first converted into black oxide and then reduced by the arsenious acid to red oxide, the solution now containing alkaline arsenate. Mineral acids and even glacial acetic acid decompose the pigment by taking away the cupric oxide and liberating the arsenious acid.

Schweinfurth green is much used, especially in the manufacture of colored paper, wall-paper, artificial flowers, and light fabrics. It is, however, very poisonous, and the use of articles dyed with it has frequently caused sickness and even death by the dust reaching the respiratory organs.

Dibasic cupric acetate and mercuric chloride (corrosive sublimate) combine to a blue crystallizable combination which dissolves with difficulty in water; it is decomposed by boiling with water.

### *Lead Acetates.*

With plumbic oxide acetic acid gives a neutral as well as several basic salts. The most important of these combinations are the neutral salt, known in commerce as sugar of lead, and a basic salt by means of which white lead is obtained.

*Neutral acetate of lead (sugar of lead),*  $\text{Pb}(\text{C}_2\text{H}_3\text{O}_2)_2 + 3 \text{HO}$ .—According to Völckel's method, acetic acid prepared from wood-vinegar and rectified over potassium bichromate is saturated with litharge, filtered or decanted, and after a further addition of acetic acid until a slightly acid reaction takes place, evaporated to the crystallizing point.

By saturating acetic acid with litharge, a solution of basic salt is obtained, which is later on converted into neutral salt by the addition of acetic acid. This is more suitable than using only as much litharge as the acetic acid requires for the formation of the neutral salt, because the litharge dissolves with greater ease in solution of sugar of lead than in acetic acid.

Solution of sugar of lead, like solution of neutral cupric acetate, permits the evaporation of acetic acid in boiling; and, hence, it is best to use strong acetic acid, because less will have to be evaporated and the loss of acetic acid be consequently smaller. By taking, for instance, acetic acid of 1.057 specific gravity, for 100 lbs. of it 82 lbs. of litharge are required for the formation of the neutral salt. A larger quantity is, however, taken (from 100 to 180 lbs.), so that a basic salt is formed, or, with 100 lbs., a mixture of neutral and basic salts. To recognize the point of neutralization in the subsequent addition of acetic acid, litmus paper is used, or, still better, dilute solution of corrosive sublimate (1 part of corrosive sublimate in 100 of water), which does not change the neutral salt, but produces turbidity in the basic (Büchner). Hence, by from time to time testing the lead solution with this reagent, the point of neutralization is reached the

moment turbidity ceases. This test is better than with litmus, considerable experience being required to hit the right point with the latter on account of solution of sugar of lead showing a slight, but perceptible, acid reaction.

The solution of litharge in acetic acid is promoted by heat, and is effected either in a copper pan, the bottom and sides of which are brought in contact with a few bright sheets of lead (to prevent the copper from being attacked), or in a lead pan over an open fire, or in a wooden vat into which steam is introduced. The clear solution is evaporated. If this is to be done over an open fire, it is recommended to have a preparatory heating pan for each evaporating pan, as described in the preparation of calcium acetate, the preparatory heating pan, which is heated by the escaping gases, being used for the solution of the litharge in acetic acid. Lead pans, if used, should rest upon strong cast-iron plates. The dimensions of the pans vary very much; according to Assmus, they are  $6\frac{1}{2}$  feet long, 4 feet wide, and from 12 to 14 inches deep, while the depth of the preparatory heating pans is from 24 to 28 inches. From the latter, which stand at a higher level, the clear solution is discharged, through a stop-cock just above the bottom, into the evaporating pans. Evaporation should be effected at a moderate heat; actual boiling must be strictly avoided, as otherwise large losses of acetic acid are unavoidable and the solution readily acquires a yellow coloration.

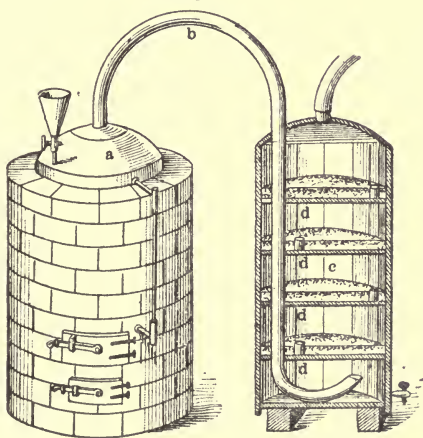
According to the degree of evaporation (to  $36^{\circ}$  B. or to  $46^{\circ}$  B. or more) of the sugar of lead solution, distinct crystals are obtained or only a radiated crystalline mass. With a perfectly pure solution, the first method is the best, since crystals bring a better price. The mother-lye, after being again acidulated, is once more evaporated and acidulated, and yields more crystals.

Stein recommends the conducting of the vapors of acetic acid or of vinegar into litharge mixed with a very small quantity of water. This method is in general use in Germany. But as the extract remaining in the still retains a considerable quantity of acetic acid, especially if beer had been added to the liquid used in the preparation of the vinegar, it is advisable to increase the boiling point of the latter by the addition of one-third of its weight of common or rock salt. At first the water condenses in the receiver

and the volume of the fluid containing the litharge increases, but, when the boiling point is reached, in the condensing vessels, only the acetic acid is retained, while the litharge is first converted into sexbasic and then into tribasic acetate. To obtain, however, neutral salt, either the vapors must be somewhat expanded or several condensing vessels placed one after the other.

Fig. 63 shows the distilling apparatus, consisting of a boiler, *a*, of strong sheet-copper. The vapors pass through a copper-pipe, *b*, into the wooden vat *c*, lined with lead, and about 35 inches in diameter and 67 inches deep. In this vat are four bottoms, *d*, of thick lead provided with fine perforations. Short lead pipes, soldered into these bottoms and arranged as shown in the figure, serve to conduct the vinegar vapors in the vat to and fro in the interspaces between the lead bottoms. For each still at least three of such vats are connected with each other. Upon the lead bottoms is first placed a layer of linen or of flannel, and next a layer of litharge 2 to 4 inches deep. To prevent the litharge from packing, it is mixed with an equal volume of

Fig. 63.



pebbles about the size of a pea. The vats are provided with lids of sheet-copper coated with lead. From the lid of the last vat a pipe leads to a worm surrounded with cold water. The stop-cocks on the bottoms of the vats permit the discharge of the



collected lead solution, which is effected (with the use of acetic acid) when it shows a specific gravity of at least  $36^{\circ}$  B. The solution being, however, basic, it is acidulated with strong acetic acid and brought into the crystallizing vessels.

This method is decidedly the best, because the evaporation of the solution is entirely or almost entirely omitted and the air of the workroom is not contaminated by particles of sugar of lead, which is very injurious to the health of the workmen. Furthermore, this method does not require the use of pure acetic acid, since the impurities remain in the still. This, however, holds good only for non-volatile impurities. For the production of colorless salt, the crude acetic acid from wood-vinegar must necessarily be purified, as above mentioned, by potassium chromate and sulphuric acid.

The crystallizing pans are either of stone-ware or of wood lined with lead or thin copper, to which is soldered a strip of lead down the sides and across the bottom, with the idea of rendering the metal more electro-negative so as to prevent the acetic acid from acting on it. The wooden crystallizing pans are about 4 feet long by 2 feet wide and from 6 to 8 inches deep, sloping inwards at the edges. Shallow, slightly conical copper vessels 6 inches deep with a diameter of  $29\frac{1}{2}$  inches at the bottom and  $31\frac{1}{2}$  inches at the top are also used. The stone-ware pans are placed upon a slightly inclined level covered with lead. In these small pans crystallization is complete in 24 hours, while from 48 to 72 hours are required with the use of the larger wooden vessels. Crystallization being complete, the mother-lye is removed and the vessels placed upon a wooden frame over a gutter of sheet-lead to drain off, as shown in Figs. 64 and 65.

If especially beautiful crystals are to be obtained, the first crystals, which are not very distinct, are again dissolved in the water obtained by the condensation of the vapors escaping from the still. The solution being evaporated to the proper density is again allowed to crystallize. The crystals after sufficient draining are placed upon linen spread over wooden hurdles and dried at a moderate heat, not exceeding  $75^{\circ}$  F. In some factories the heated air of a stove, placed outside the drying house, is conveyed through pipes passing round the interior; at



other places steam heat is employed for this purpose, which is much to be preferred on account of its being more easily regulated.

Fig. 64.

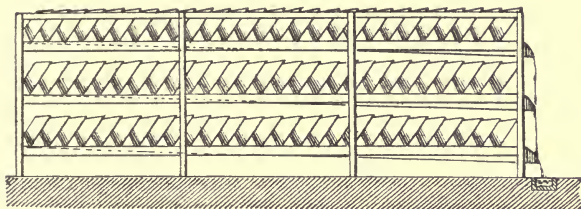
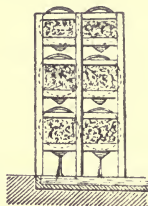


Fig. 65.



When working on a large scale a centrifugal is advantageously employed for the separation of the mother-lye in the same manner as recommended for the preparation of sodium acetate (p. 243).

Litharge being quite impure plumbic oxide never dissolves entirely, and frequently contains over 10 per cent. of impurities, consisting of sand, clay, red lead or minium ( $\text{Pb}_3\text{O}_4$ ), metallic lead, traces of silver, cupric, and ferric oxides. The cupric oxide passes into the sugar of lead solution and colors it slightly blue. To separate the copper bright sheets of lead are dipped into the solution, the copper separating upon them in the form of a dark slime. The sheets of lead must be frequently cleansed (scraped), as otherwise they lose their effect. When there is a large accumulation of litharge residue, it can be worked for silver.

Sugar of lead can also be prepared from metallic lead, the process having been recommended first by Berard, and is said, by Runge, to yield a good product with great economy. Granulated lead, the tailings in the white lead manufacture, etc., are put in several vessels, say eight, one above the other, upon steps, so that the liquid may be run from one to the other. The upper one is filled with acetic acid, and after half an hour let off into the second, after another half an hour into the third, and so on to the last or eighth vessel. The acid causes the lead to absorb oxygen so rapidly from the air as to become hot. When the acid runs off from the lowest, it is thrown on the uppermost vessel a second time and carries off the acetate of lead formed; after pass-

ing through the whole series the solution is so strong that it may be evaporated at once so as to crystallize.

Apparently this method has a considerable advantage over that with litharge, metallic lead being cheaper and producing more sugar of lead (entirely free from copper) than litharge, because 103.5 lbs. of pure lead yield 189.5 lbs. of sugar of lead, while the same quantity is only obtained from 111.5 lbs. of pure litharge. Furthermore, commercial lead is always purer than litharge. On the other hand, this process has the disadvantage of a considerable quantity of acetic acid being lost by evaporation on account of it having to pass through several vessels. The manufacture of sugar of lead is most suitably combined with that of white lead, it being thus possible to utilize the tailings, etc. to greater advantage than, as is frequently done, by melting them together and remelting, which always cause considerable loss.

Sugar of lead is further formed by boiling lead sulphate with a very concentrated solution of barium acetate, barium sulphate (permanent white) being thereby precipitated. For 100 parts of lead sulphate 84 parts of anhydrous or 100 of crystallized barium acetate are required, the yield being 125 parts of sugar of lead. Sulphate of lead is obtained in large quantities as a by-product in the preparation of aluminium acetate.

For many purposes of dyeing and printing the use of pure sugar of lead is not necessary, the *brown* acetate of lead answering all requirements. For its preparation ground litharge is introduced in small portions, and with constant stirring into distilled pyroligneous acid in a vat until red litmus paper is colored blue, and, hence, a basic salt is formed. The impurities separating on the surface are removed and the clear fluid is then transferred to a copper pan provided with strips of lead, and evaporated to about two-thirds its volume, the brown smeary substances rising to the surface during evaporation being constantly removed. By again diluting and slightly acidulating the concentrated fluid a further portion of the foreign substances can be removed. Finally evaporation is carried to the crystallizing point, *i. e.*, until a few drops congeal when allowed to fall upon a cold metal plate. An addition of animal charcoal for the purpose of discoloration is of no advantage; the coloration is not completely

removed, and the little effect produced is attained by a considerable loss of salt which is absorbed by the animal charcoal.

By disturbing crystallization by constant stirring during cooling a nearly amorphous mass having the appearance of yellow wax is obtained, which is much liked by many consumers. The product thus obtained is not always a neutral salt, but sometimes a mixture of neutral and basic salt (besides empyreumatic substances). After cooling it must, therefore, be quickly and well packed in order to protect it from the moisture and the carbonic acid of the air. The sugar of lead solution may, however, also be evaporated only so far that some mother-lye remains after cooling; the crystallized mass is then allowed to stand in a moderately warm room for some time. In consequence of capillarity the impurities, which occur chiefly in the mother-lye, gradually rise up between the crystals, a slight coating of a yellow, or brown, smeary substance being finally formed upon the mass of crystals and can be readily removed.

The linen upon which the crystals are dried must be carefully protected from fire, as it ignites from the slightest spark and burns like tinder.

If the hot solution be set aside to cool rapidly, the sugar of lead crystallizes in clusters of fine needles; but if the evaporation be conducted slowly the crystals are truncated and flattened, quadrangular and hexahedral prisms derived from a right rhombic prism. Acetate of lead has a sweet astringent taste, is soluble in  $1\frac{1}{2}$  parts of water and in 8 parts of ordinary alcohol. The crystals are permanent in the air, but are apt to effloresce and become anhydrous if the temperature ranges between  $70^{\circ}$  and  $100^{\circ}$  F.

Acetate of lead consists of—

Plumbic oxide	.	.	.	.	.	.	.	.	58.9
Anhydrous acetic acid	.	.	.	.	.	.	.	.	26.9
Water	.	.	.	.	.	.	.	.	14.2
									<hr/>
									100.00

Aqueous solution of sugar of lead slightly reddens litmus paper, but shows an alkaline reaction upon turmeric, browning this coloring substance.

At  $167^{\circ}$  F. the crystals of acetate of lead melt, and but slowly yield up their water; by heating the entirely dephlegmated salt



more strongly it fuses at 536° F. to a clear, oil-like, colorless fluid and decomposes above this temperature, evolving all the compounds usually obtained in the destructive distillation of the acetates of the heavy metals, leaving a residue of metallic lead in a very minute state of division with some charcoal. When this distillation is conducted in a glass tube closed at one end and having the other drawn out for convenience of sealing, at the end of the operation, the well-known lead pyrophorus is made. The particles of metallic lead are so small that, when thrown into the air, oxygen molecules come into such intimate contact with them that ignition is effected from the rapidity with which lead oxide is formed.

A slight decomposition occurs when the neutral salt is exposed to an atmosphere of carbonic acid, carbonate of lead being formed; the portion of acetic acid thus liberated protects the remainder from further change.

Cold solution of sugar of lead is not immediately changed by ammonia; by adding, however, a strong excess, sesquibasic acetate of lead is gradually separated; on boiling yellow-red crystalline lead oxide is precipitated.

The introduction of chlorine gas into a solution of sugar of lead produces in a short time a brown precipitate of plumbic dioxide; bromine acts in a similar manner, but on account of its insolubility iodine produces scarcely any effect.

Solution of calcium chloride at once produces a yellow precipitate, which gradually becomes brown.

Sugar of lead containing considerable copper has a bluish appearance; if the content of copper is small, it is recognized by the solution acquiring a blue coloration with ammonia, or, still better, by mixing the solution of sugar of lead with an excess of solution of Glauber's salt and testing the filtrate with potassium ferrocyanide; a dark red precipitate indicates copper.

Sugar of lead, as well as the basic lead salts to be mentioned further on, possesses poisonous properties.

Sugar of lead is chiefly used for the preparation of aluminium acetate as well as of other acetates. Large quantities of it are also consumed in the manufacture of colors, for instance, of neutral and basic lead chromate, chrome yellow, chrome orange, and

chrome red. Upon the cloth-fibre (especially wool) chrome yellow and chrome orange are produced by means of sugar of lead, especially with the brown variety; the latter product being also very suitable for the production of the so-called chrome green, which is obtained by the joint precipitation of chrome yellow and Berlin blue.

Neutral lead acetate gives crystallizable double salts with potassium acetate and sodium acetate as well as with lead nitrate, lead chloride, lead bromide, etc.

*Basic lead acetates.*—Several of these compounds are known. Those with 2 and 3 equivalents of plumbic oxide to 1 equivalent of acetic acid are soluble in water, show a strong alkaline reaction, and with carbonic acid the solutions yield at once and in every degree of concentration abundant precipitates of white lead (basic carbonate of lead), while, when the operation is at a suitable moment interrupted, neutral salt remains in solution. In this manner white lead is manufactured according to the so-called French method (of Thénard and Roard) at Clichy and other places in France as well as in different German factories. If, however, the introduction of carbonic acid be continued until no more precipitate is formed, a part of the lead of the neutral salt is also precipitated as carbonate, which, however, is neutral, and an acid solution remains behind.

The soluble salt known as *lead-vinegar* or *extract of lead* is prepared by digesting 2 parts of sugar of lead dissolved in 5 of water with 1 of finely powdered litharge. The proportional quantities of sugar of lead, litharge, and water prescribed by the Pharmacopœias of the different countries vary very much, and, consequently, also, the compositions and specific gravities (from 1.20 to 1.36) of the solutions of lead prepared in accordance with them. The litharge dissolves very readily in the sugar of lead solution, in fact with greater ease than in acetic acid, and especially with greater rapidity if the sugar of lead solution be heated in a silver dish to the boiling point and the litharge gradually introduced. For the manufacture on a large scale, the sugar of lead solution and the litharge may be brought into a barrel revolving around its axis. If the operation is to be conducted at the ordinary temperature, the barrel must be closed to prevent the



access of the carbonic acid of the air. Very remarkable is the behavior of the tribasic acetate towards hydrogen dioxide; plumbic dioxide is first formed, but in a short time this exerts a decomposing influence upon the hydrogen dioxide which may be present in excess, so that both dioxides now lose one-half of their oxygen, which evolves in the form of gas, and water and plumbic oxide are formed.\* Now, as freshly precipitated plumbic dioxide possesses the further property of decomposing solution of potassium iodide, Schoenbein recommends tribasic acetate of lead together with paper coated with paste prepared with potassium iodide as the most sensitive re-agent for hydrogen dioxide.

*Lead sesquibasic acetate, triplumbic tetracetate.*—This salt is obtained by heating the diacetate until it becomes a white, porous mass; this is re-dissolved in water and set aside to crystallize. Sesquibasic acetate is soluble in both water and alcohol; its solutions are alkaline.

*Tribasic acetate of lead* is prepared by digesting 189.5 lbs. of sugar of lead with 223 lbs. of plumbic oxide (pure) or 3 lbs. of sugar of lead to 4 lbs. of litharge; or, according to Payen, into 100 volumes of boiling water are poured 100 volumes of aqueous solution of sugar of lead saturated at  $86^{\circ}$  F., and afterwards a mixture of pure water at  $140^{\circ}$  F., with 20 volumes of ammonia liquor free from carbonate. The vessel is then immediately closed, and in a short time an abundance of the tribasic acetate crystallizes out. This salt presents itself under the form of long needles. It is insoluble in alcohol, very soluble in water, its solution being alkaline. Tribasic acetate is the most stable of all the subacetates of lead. It takes a leading part in the manufacture of white-lead by the Clichy process; it is, in point of fact, a solution of this salt which is decomposed by the carbonic acid, and gives rise to the carbonate of lead, being itself at the same time converted into lead diacetate. In the Dutch process the formation of lead carbonate is, according to Pelouze, also due to the formation of tribasic acetate on the surface of the sheets of lead, which is, in its turn, decomposed by the carbonic acid.

*Sesquibasic acetate of lead.*—This body is prepared by digesting

\* Schoenbein in Wagner's Jahresbericht, 1862.



any of the preceding salts with lead oxide. It is a white powder slightly soluble in boiling water, from which it crystallizes out in silky needles which consist of 2 equivalents of the salt combined with three equivalents of water.

*Uranium acetate*.—With uranous oxide acetic acid combines to a dark green crystallizable salt, and with uranic oxide to a yellow basic salt, which, combined with water, appears in two different forms of crystals. It is remarkable for giving, with many other acetates, well crystallizing salts, of a beautiful color and partly showing magnificent dichroism (Wertheim and Weselsky).

*Tin acetate* is prepared by dissolving stannous hydrate\* in heated strong acetic acid, or by mixing stannous chloride ( $\text{SnCl}_2$ ) with acetate of sodium or calcium. It forms small colorless needles which have a strong metallic taste and readily decompose in the air. The salt is sometimes used as a mordant in calico printing.

*Bismuth acetate*.—Bismuth nitrate prepared by gradually introducing pulverized metallic bismuth into cold dilute nitric acid is mixed with pure concentrated sugar of lead solution. The salt separates in small, colorless needles.

*Mercurous acetate* can be prepared by dissolving pure mercurous oxide or its carbonate in acetic acid, or by mingling hot solutions of mercurous nitrate and acetate of sodium or of potassium. The pure mercurous carbonate is heated to boiling with 8 parts of water, and concentrated acetic acid added until all is dissolved; the hot, filtered liquid free from oxide being allowed to cool. Or, acidulated nitrate is diluted with 6 to 8 parts of water, heated and mixed with one equivalent of acetate of sodium or potassium, dissolved in 8 parts of hot water containing a little free acid and cooled. The salt, when separated, is washed with a little cold water, dried in the dark at a gentle heat, and kept from the light in covered bottles.

It crystallizes in fine, white, silvery scales, flexible and unctuous to the touch, with a nauseous metallic taste, easily decomposed by

\* The hydrate is obtained by precipitating stannous chloride with soda lye and washing the precipitate.

light; it is dissolved with difficulty in cold water, requiring 33 parts at the ordinary temperature. It is partially decomposed by boiling water into acid and basic salts of both oxides and metallic mercury. It is used in pharmacy.

*Mercuric acetate*.—Dissolve red oxide of mercury in concentrated acetic acid with a gentle heat and evaporate to dryness, or partially to crystallization, or by spontaneous evaporation. By the first process, it is a white saline mass; by the second, it forms crystalline scales; and by the third, four-sided plates, which are partly transparent, partly pearly and translucent; anhydrous, of a nauseous metallic taste, fusible without decomposition, solidifying to a granular mass, but its point of decomposition is near that of fusion. It dissolves in 4 parts of water at 50° F., in 2.75 at 66.2° F., and in 1 at 212° F., but by boiling it is partly decomposed, with separation of red oxide; even in the air its solution suffers the latter change and contains a basic salt. With free acetic acid it is not decomposed; 100 parts of alcohol dissolve  $5\frac{2}{3}$  of this salt, and this solution behaves like the aqueous one. It generally contains, except when carefully crystallized, some mercurous oxide.

*Silver acetate*.—This salt is obtained by precipitating a concentrated solution of silver nitrate with a concentrated solution of sodium acetate. It forms a white crystalline precipitate. It dissolves in about 100 parts of cold, but readily in hot water, and only sparingly in alcohol. On exposure to light it acquires a dark color, being partially reduced. On heating, it yields acetic acid, metallic silver remaining behind.

If the salt be heated with bisulphide of carbon in a closed glass tube to 329° F., silver sulphide, carbonic acid, and anhydrous acetic acid are formed (Broughton).

On treating the dry salt with iodine, lively decomposition takes place, whereby silver iodide, some metallic silver, and coal remain behind, while methyl oxide, acetic acid, acetylene, and hydrogen appear. With iodine a solution of this salt yields acetic acid, silver iodide, and iodate of silver (Birnbaum).

## PART II.

### MANUFACTURE OF CIDERS, FRUIT-WINES, ETC.

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#### CHAPTER XXIV.

##### INTRODUCTION.

THE term wine in general is applied to alcoholic fluids which are formed by the fermentation of fruit juices and serve as beverages. According to this definition, there may be actually as many kinds of wine as there are fruits whose juices, in consequence of their content of sugar, are capable of vinous fermentation ; and, in fact, besides the apple and pear, there are many other fruits which are likewise applicable to wine-making. Among these may be named currants, gooseberries, mulberries, elderberries, cherries, oranges, dates, pine-apples, raspberries, strawberries, etc. But, in order to make the product from such fruits resemble the standard wine made from grapes, various ingredients have to be added, as, for instance, an acid, spices, coloring, and an astringent, to replace the extractive matter. The acid generally used is the tartaric, and elderberry and whortleberry juice are used for the coloring, while the water used in the manufacture of wine should in all cases be pure and soft.

*Ripening of fruits.*—In order to form a clear idea of the processes which take place during the growth, ripening, and final decomposition of a fruit, it is necessary to refer to the constituents which are already found in an unripe fruit at its first appearance.

Besides water, the quantity of which varies between 90 and 45 per cent., fruits contain partly soluble and partly insoluble substances. The juice obtained by pressure contains the soluble constituents, such as sugar, gum, tannin, acids, salts, etc., while the

remaining insoluble portion consists chiefly of cellulose, starch, a gum-like body, a few inorganic substances, and, further, the characteristic constituent of unripe fruits, to which the term *pectose* has been applied. It forms the initial point for the phenomena observed during the growth and ripening of fruits, and, therefore, requires a somewhat closer examination.

In regard to its behavior, pectose approaches cellulose and starch; it is chiefly found in the pulp of unripe fruits, but also in certain roots, especially in carrots, beets, and others. It is insoluble in water, spirits of wine, and ether, but during the ripening of the fruit it undergoes a change, induced by the acids and heat, and is converted into pectine, which is readily soluble in water. To pectose are due the hardness of unripe fruits and also the property of many fruits and roots of boiling hard in water containing lime, the pectose combining with the lime.

The formation of pectine commences as soon as the fruits are exposed to the action of heat, and then depends on the influence of the vegetable acid present upon the pectose. To be convinced of this it suffices to express the pulp of an unripe apple. The juice thus obtained contains scarcely a trace of pectine, but, by boiling it for a few minutes with the pulp of the fruit, the fluid, in consequence of the formation of pectine, acquires a viscous quality, like the juice obtained from ripe fruits.

Pectine, nearly pure, is white, soluble in water, non-crystallizable, and without effect upon vegetable colors. From its dilute solution it is separated as a jelly by alcohol, and from its more concentrated solution, in long threads. Brought into contact with alkalies or alkaline earths, pectine is transformed into pectic acid. Under the influence of a peculiar ferment called pectase, which will be described later on, pectine is transformed into pectosic acid, and by dilute acids into metapectic acid.

By boiling a solution of pectine in water for a few hours, it partially loses its viscous condition and separates a substance called parapectine, which shows the same behavior as pectine, except that it is not precipitated by neutral lead acetate. When treated with dilute acids the parapectine is transformed into metapectine, which might be called metapectous acid, as it shows a decidedly acid reaction and colors litmus paper strongly red.

Metapectine is soluble in water, non-crystallizable, and, like pectine and parapectine, insoluble in alcohol, which precipitates it from its solutions in the form of a jelly. On being brought into contact with bases it is also transformed into pectic acid. It differs from pectine and parapectine in that the solution is precipitated by barium chloride.

Pectase, the peculiar ferment previously referred to, is similar in its mode of action to diastase and emulsin. It can be obtained by precipitating the juice of young carrots with alcohol, whereby the pectose, which was at first soluble in water, becomes insoluble, without, however, losing its effect upon the pectous substances.

By adding pectase to a solution of pectine, the latter is immediately converted into a jelly-like body, insoluble in water. This phenomenon is the *pectous fermentation*, which may be compared with lactic acid fermentation. It is not accompanied by an evolution of gas, and may take place with the air excluded, a temperature of 86° F. being most favorable for its progress.

Pectase is an amorphous substance; by allowing it to stand in contact with water for a few days, it decomposes, becomes covered with mold-formations, and loses its action as a ferment, the latter being also destroyed by continued boiling. In the vegetable organism it occurs in a soluble as well as insoluble state.

Roots such as carrots, beets, etc. contain soluble pectase, and their juice added to a fluid containing pectine in solution immediately induces pectous fermentation, while the juice of apples and other acid fruits produces no effect upon pectine, the latter being present in them in the modified insoluble form and accompanying the insoluble portion of the pulp. On adding the pulp of unripe apples to a pectine solution it gelatinizes in a short time in consequence of the formation of pectosic and pectine acids.

Pectosic acid is the result of the first effect of the pectase upon pectine; it is, however, also formed by bringing dilute solutions of potash, soda, ammonia, or alkaline carbonates in contact with pectine. In all these cases salts are formed which, when treated with acids, yield pectosic acid. The latter is jelly-like and dissolves with difficulty in water; in the presence of acids it is entirely



insoluble ; by long boiling in water, by pectase, or by an excess of alcohol it is soon transformed into pectic acid.

By allowing pectase to act for some time upon pectine, pectic acid is formed ; the same conversion taking place almost instantaneously by dilute solution of potash, soda, ammonia, alkaline carbonates, as well as by barium, lime, and strontium water. Its formation in the above-described manner is preceded by that of pectosic acid, which, as previously mentioned, is converted by the same agents into pectic acid.

Pectic acid is insoluble in cold, and scarcely soluble in hot, water ; by boiling it, however, for a certain time in water, and constantly replacing the water lost by evaporation, it disappears entirely, and is converted into a new acid soluble in water. By nitric acid it is transformed into oxalic acid and muric acid ; alkalies decompose it very rapidly, the final result being metapectic acid, which is soluble in water, but non-crystallizable ; on boiling in hot water, the solution forms a jelly after cooling.

Pectic acid further possesses the special property of dissolving in a large number of alkaline salts and forming with them true double salts which always show a decidedly acid reaction, dissolve in water, and on cooling form consistent jellies.

By boiling for a few hours a solution of a pectous salt, the latter is transformed into a parapectous salt which, when decomposed by a dilute acid, yields parapectic acid. It is non-crystallizable, shows a strong acid reaction, and forms soluble salts with alkalies ; it is precipitated by barium water in excess.

Metapectic acid is formed in various ways, among others by leaving an aqueous solution of parapectic acid to itself for some time, but also by the action of the lime contained in the cell-tissue of roots and fruits upon pectose. It is insoluble in water, does not crystallize, and gives soluble salts with all bases. With an excess of bases the salts acquire a yellow coloration ; they are precipitated by basic lead acetate.

What has been said in the preceding may be briefly condensed as follows :—

1. By the influence of heat upon pectose pectine is formed.
2. Pectine is transformed into parapectine by boiling its aqueous solution for several hours.



3. Parapectine, when treated at a boiling heat with dilute acids, is converted into metapectine.

4. Pectase converts pectine into pectic acid.

5. By long-continued action of pectase upon pectine pectic acid is formed.

6. Pectic acid is transformed by boiling water into parapectic acid.

7. An aqueous solution of parapectic acid is quickly converted into metapectic acid.

All these bodies are derived from pectose, which through all these transformations has not even suffered a change in the proportion of weight of its constituents (carbon, hydrogen, and oxygen); hence all have the same qualitative and quantitative composition. This may, perhaps, sound odd, but chemistry presents numerous analogies for such cases, and hence the term *isomeric* has been applied to bodies which with the same quantitative composition exhibit very different chemical properties.

The changes pectose undergoes by the influence of heat, a peculiar ferment, acids and alkalies, and the resulting combinations mentioned above, have of course been artificially effected by chemical means. They resemble, however, so closely the state of fruits in the course of their growth and ripening, and the influences and conditions to which fruits are exposed in nature are sufficiently similar to those artificially induced, that their action may be reasonably supposed to be the same. We know from daily experience that heat promotes the development and ripening of fruit; fruits contain pectose and acids, and alkalies or bases are conducted to them from the soil; hence in fruit in a normal state of development none of the chemical agents are wanting which the chemist uses for the production of derivatives of pectose.

If the transformation of substances under the influence of others be considered as dependent on chemical processes, the development of a fruit from its first formation to complete ripeness, and even to its decomposition, rotting, and putrefaction, is a chemical process in the widest sense of the word. This is evident, not only from what has been said in the preceding, but has also been plainly shown by special chemical researches into the changes

fruits undergo during their development and perfection. The results of these researches are briefly as follows :—

1. The quantity of water contained in the pulp of a fruit is considerable ; it varies between 45 and 90 per cent. In many fruits the content of water remains unchanged during the different periods of ripening, but, as a rule, it is somewhat greater in the commencement.

2. Fruits of the same kind examined at the same season of the year always contain the same quantity of water ; the same holding good as regards the various parts of the pulp of a fruit.

3. The solid constituents in the pulp of fruits amount to between 10 and 25 per cent.; they consist of soluble substances, which dissolved in the water form the juice of the fruits ; and of insoluble bodies which compose the membranes of the cells.

4. The quantity of soluble substances always increases with increasing ripeness, while the weight of the insoluble decreases ; hence it may be said the soluble substances contained in the juice of a fruit are formed at the expense of the insoluble portion of the pulp. The bodies which become soluble are starch, pectose, and a gum-like substance capable of being converted into gum.

On this modification of the solid portion of the pulp of a fruit depend also the changes a fruit undergoes in regard to hardness and transparency during ripening.

According to the mode of action of the pectase and acids upon the pectose, all ripe fruits contain pectine.

5. Various acid fruits, such as plums, cherries etc., are frequently observed to secrete a neutral juice which, in consequence of the evaporation of the water, leaves a gum-like substance upon the exterior of the fruit. This phenomenon throws some light upon the separation of gum as it appears in many trees, and which, when it occurs very abundantly, is an actual disease.

In fruits becoming thus covered with gum a transparent, neutral substance insoluble in water occurs stored in the cells of the pulp. Under the influence of nitrogenous substances, which act as a ferment, and perhaps also of acids, this gum-like substance is modified and transformed into actual gum, which is then converted into sugar in the interior of the pulp of the fruit ; an ex-

cess of this gum-like substance is secreted and forms a firm coating upon the exterior of the fruit.

6. The sugar occurring in ripe fruits is evidently derived from various sources. The occurrence of a large quantity of starch in many unripe fruits, especially in apples, and its complete disappearance at the time of ripeness, allow of no other explanation than that the sugar occurring in fruits is formed by the conversion of the starch under the influence of the acids present; other indifferent substances, such as gum, vegetable mucus, etc., undergo similar transformations and yield in this manner a certain portion of sugar. Even tannin, which occurs in all unripe, but not in ripe fruits, can be changed by acids and ferments so as to form sugar.

Thus far nothing justifies the supposition that the acids in fruits, such as tartaric, citric, malic acids, are converted into fruit-sugar. To entertain such an opinion it would have to be supposed that the molecules of these acids, which are far more simple than those of fruit-sugar, become more complex and are converted into sugar; in such natural transformations the reverse is, however, generally the case, the molecules always endeavoring to become the more simple the farther they withdraw from organized structures.

7. It has been attempted to explain in various ways the very remarkable phenomenon of the gradual disappearance of the acids in ripening fruits. It might not be impossible that the acid of a fruit is neutralized by the bases conducted to it through the juice; or that it is covered by the sugar or the mucous substances formed in the juice; or, finally, that it disappears at the moment of ripeness by suffering actual combustion. An examination of these various opinions leads to the conclusion that the acid is neither neutralized nor covered by the sugar or the mucous substances, but that it actually undergoes slow combustion.

During development and ripening a fruit passes through two different stages sharply separated from each other by definite chemical phenomena. In the first stage, which may be designated as that of growth, whilst the fruit remains green, its relation to the atmosphere appears the same as that of leaves, for it absorbs carbonic acid and evolves oxygen. During this epoch it

increases rapidly in size, and receives through the stem the inorganic substances indispensable for its development, and water. If, at this stage, it is taken from the tree, it soon commences to wither and decay. But in the second period, when it fairly begins to ripen, its green color is, as a rule, replaced by a yellow, brown-red, or red. Oxygen is now absorbed from the air and carbonic acid is evolved, whilst the starch and cellulose are converted into sugar under the influence of the vegetable acids, and the fruit becomes sweet. When the sugar has reached the maximum the ripening is completed ; if the fruit be kept longer, the oxidation takes the form of ordinary decay.

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## CHAPTER XXV.

### FRUITS AND THEIR COMPOSITION.

For the preparation of fruit-wines, not only the fruits cultivated in our gardens and orchards on account of their fine flavor are used, but sometimes also others which do not by any means possess an agreeable taste, and whose juices after fermentation yield a product which has at least only a very doubtful claim to the name of "wine." The utilization of such material for wine-making can only be explained by special fancy, and hence here only such fruits will be considered as, on account of the nature of their juices, will yield with rational treatment a beverage of a sufficiently agreeable taste to be liked.

For the fabrication of fruit-wine, sugar not only by itself but also in its proportion to the free acid present, is undoubtedly the most important constituent of the fruit. The following compilation from Fresenius gives the average percentage of sugar in different varieties of fruit.

Peaches . . . .	1.57 p. c.	Currants . . . .	6.10 p. c.
Apricots . . . .	1.80 "	German prunes . .	6.25 "
Plums . . . . .	2.12 "	Gooseberries . . .	7.15 "
Reine Claudes . .	3.12 "	Pears . . . . .	7.45 "
Greengages . . . .	3.58 "	Apples . . . . .	8.37 "
Raspberries . . . .	4.00 "	Sour cherries . . .	8.77 "
Blackberries . . . .	4.44 "	Mulberries . . . .	9.19 "
Strawberries . . . .	5.73 "	Sweet cherries . . .	10.79 "
Whortleberries . . .	5.78 "	Grapes . . . . .	14.93 "

II. Compilation according to average percentage of free acid expressed in malic acid.

Pears . . . . .	0.07 p. c.	Blackberries . . . .	1.19 p. c.
Greengages . . . .	0.58 "	Sour cherries . . . .	1.28 "
Sweet cherries . . . .	0.62 "	Plums . . . . .	1.30 "
Peaches . . . . .	0.67 "	Whortleberries . . .	1.34 "
Grapes . . . . .	0.74 "	Strawberries . . . .	1.37 "
Apples . . . . .	0.75 "	Gooseberries . . . .	1.45 "
German prunes . . . .	0.89 "	Raspberries . . . . .	1.48 "
Reine Claudes . . . .	0.91 "	Mulberries . . . . .	1.86 "
Apricots . . . . .	1.09 "	Currants . . . . .	2.04 "

III. Compilation according to the proportion between acid, sugar, pectine, gum, etc.

	Acid.	Sugar.	Pectine, gum, etc
Plums . . . . .	1	1.63	3.14
Apricots . . . . .	1	1.65	6.35
Peaches . . . . .	1	2.34	11.94
Raspberries . . . . .	1	2.70	0.96
Currants . . . . .	1	3.00	0.07
Reine Claudes . . . .	1	3.43	11.83
Blackberries . . . . .	1	3.73	1.21
Whortleberries . . . .	1	4.31	0.41
Strawberries . . . . .	1	4.37	0.08
Gooseberries . . . . .	1	4.93	0.76
Mulberries . . . . .	1	4.94	1.10
Greengages . . . . .	1	6.20	9.92
Sour cherries . . . . .	1	6.85	1.43
German prunes . . . .	1	7.03	4.35
Sweet cherries . . . .	1	11.16	5.60
Grapes . . . . .	1	20.18	2.03
Pears . . . . .	1	94.60	44.40

IV. Compilation according to the proportion between water, soluble and insoluble substances.

					Composition of the juice, in 100 parts, without the insoluble substances.	
		Water.	Soluble substances.	Insoluble substances.	Water.	Soluble substances.
Raspberries	. . .	100	9.12	6.88	91.64	8.36
Blackberries	. . .	100	9.26	6.46	91.53	8.47
Strawberries	. . .	100	3.39	5.15	91.42	8.58
Plums	. . .	100	9.94	0.87	91.13	8.87
Currants	. . .	100	11.00	6.62	90.09	9.91
Whortleberries	. . .	100	12.05	16.91	89.25	10.75
Gooseberries	. . .	100	12.18	3.57	89.14	10.86
Greengages	. . .	100	13.04	1.53	88.46	11.54
Apricots	. . .	100	13.31	2.07	88.25	11.75
Pears	. . .	100	14.25	5.54	87.52	12.48
Peaches	. . .	100	14.64	2.10	87.23	12.77
German prunes	. . .	100	15.32	3.15	86.71	13.29
Sour cherries	. . .	100	16.48	1.31	85.85	14.15
Mulberries	. . .	100	16.57	1.47	85.79	14.21
Apples	. . .	100	16.89	3.61	85.46	14.54
Reine Claudes	. . .	100	18.52	1.22	84.37	15.63
Sweet cherries	. . .	100	18.61	1.53	84.30	15.70
Grapes	. . .	100	22.81	5.81	81.42	18.58

V. Composition of the juice according to its content of sugar, pectine, etc., in 100 parts.

		Sugar, p. c.	Pectine, etc., p. c.			Sugar, p. c.	Pectine, etc., p. c.
Peaches	. . .	1.99	10.05	German prunes	. . .	7.56	4.70
Reine Claudes	. . .	2.04	6.98	Gooseberries	. . .	8.00	1.24
Apricots	. . .	2.13	8.19	Whortleberries	. . .	8.12	0.77
Plums	. . .	2.80	5.40	Pears	. . .	8.43	4.02
Greengages	. . .	4.18	6.45	Apples	. . .	9.14	4.59
Raspberries	. . .	4.84	1.73	Mulberries	. . .	10.00	2.22
Blackberries	. . .	5.32	1.72	Sour cherries	. . .	10.44	2.17
Strawberries	. . .	6.89	0.13	Sweet cherries	. . .	15.30	2.43
Currants	. . .	7.30	0.16	Grapes	. . .	16.15	2.07

VI. Content of free acid in 100 parts of juice.

Pears	. . .	0.09 p. c.	Blackberries	. . .	1.42 p. c.
Reine Claudes	. . .	0.59 "	Sour cherries	. . .	1.52 "
Greengages	. . .	0.67 "	Strawberries	. . .	1.57 "
Grapes	. . .	0.80 "	Gooseberries	. . .	1.63 "
Apples	. . .	0.82 "	Plums	. . .	1.72 "
Peaches	. . .	0.85 "	Raspberries	. . .	1.80 "
Sweet cherries	. . .	0.88 "	Whortleberries	. . .	1.88 "
German prunes	. . .	1.08 "	Mulberries	. . .	2.02 "
Apricots	. . .	1.29 "	Currants	. . .	2.43 "



Tables V. and VI. represent the proportion in which the soluble constituents of the fruits are found in the juice or must obtained from them ; in the practical execution of the fabrication of fruit wines we will have occasion to refer to these tables.

For the preparation of wine only the soluble substances, which pass into the must and from which the wine is formed, are chiefly of interest, and it will be necessary to consider them somewhat more closely.

*Grape-sugar or glucose.*—This sugar is widely diffused throughout the vegetable kingdom, occurring in most kinds of sweet fruits, in honey, etc. Artificially it can be readily obtained by heating a solution of cane sugar with a dilute acid ; it is also formed by dissolving cane sugar in wine. On a large scale it is prepared by boiling starch with very dilute sulphuric acid for several hours, neutralizing the liquid with chalk and evaporating the solution.

Grape-sugar is much less sweet than cane-sugar ; in alcohol of 90 per Tr. it is sparingly soluble ; in hot water it dissolves in every proportion ; of cold water it requires, however, about  $1\frac{1}{2}$  parts for solution. It crystallizes from an aqueous solution with one molecule of water in cauliflower-like masses and from hot alcohol in warty, anhydrous needles. A solution of crystallized grape-sugar turns the plane of polarization to the right, but one of anhydrous grape-sugar to the left.

*Acids.*—The acid reaction of fruit juices is partly due to malic acid and partly to citric acid, and also, as in the case of grapes, to tartaric acid. As a rule all these acids are present ; in currants citric acid predominates ; in apples, etc., malic acid.

The presence of potassium in grape-must gives rise to the formation of potassium bitartrate or crude tartar. Tartar requires for its solution 240 parts of cold water ; in alcoholic fluids it is less soluble, and hence it is found as a crystalline deposit in wine casks. Fruit-musts contain no tartaric acid, and, consequently, the wines prepared from them cannot deposit tartar. The salts formed by malic and citric acids with potassium being readily soluble and even deliquescent form no deposit in the wine.

*Albuminous substances.*—By this general term are designated several nitrogenous vegetable substances which have the same

composition ; they are vegetable albumen, fibrin, and glue. The quantities of these substances in the different musts are, on the one hand, too small, and the difficulty of accurately distinguishing them from each other is, on the other, so great that it is scarcely possible to definitely determine the kind present in the fruit juice ; most likely all three are present at the same time.

For the preparation of wine these bodies are of importance ; they furnish the material for the development of the yeast-fungus during fermentation.

*Pectous substances.*—In the paragraph “ ripening of fruits,” the pectous substances have been sufficiently discussed ; they are scarcely ever wanting in a fruit juice, but being insoluble in alcoholic fluids they are entirely separated with the yeast, and hence are not present in fruit-wines.

*Gum and vegetable mucilage.*—Our knowledge as regards gum is still limited. Gum-arabic, which may be studied as a representative of this class, is an exudation from certain species of acacia and consists essentially of arabin. It is generally supposed to be soluble in water, but on endeavoring to filter a somewhat concentrated solution not a drop will be found to run off, and the little which possibly may pass through the filter is by no means clear.

Closely related to gum-arabic is bassorine, the gum which exudes from the cherry, plum, almond, and apricot trees. It does not give a slime with water, but merely swells up to a gelatinous mass.

Wine brought in contact with the smallest quantity of gum-arabic remains permanently turbid and cannot be clarified by filtering or long standing. From this behavior of gum it may be concluded that, though it may occur dissolved in the must, it is not present in the wine.

The various kinds of vegetable mucilage have also not yet been accurately examined ; it is only known that there are quite a number of them. It is, however, likely that only a few of them are actually soluble in water. Though the mucilage of certain seeds, such as linseed and quince-seed, may be considered as readily soluble in water as gum-arabic, and perhaps more so, because it is a perfectly clear fluid drawing threads,

yet on filtering it will be found that what passes through above contains scarcely a trace of a mucilaginous substance. Hence, it is doubtful whether mucilages exist which are actually soluble in water, and whether they occur in wine. Artificial dextrin is, however, an exception, as it forms with water a perfectly clear fluid, which can be filtered. We will here call attention to an easy method of distinguishing between solution of gum-arabic and of dextrin; the first cannot be heated, even for a minute, over an open fire without scorching, while the latter can be completely boiled down without fear of burning.

*Tannin*.—Several kinds of tannin occur in plants, which can, however, be finally reduced to two modifications, viz: *pathological* and *physiological tannin*. The first occurs in large quantity in nut-galls, especially in the Chinese variety, also in sumach (the twigs of *Rhus Coraria*) and in many other plants. Pathological tannin is characterized by splitting under the influence of dilute acids as well as by fermentation into gallic acid and grape-sugar. Furthermore, it completely precipitates glue from its solutions, but is not suitable for the conversion of the animal skin into technically serviceable leather which will withstand putrefaction. Besides, only the gallic acid obtained from pathological tannin yields pyrogallie acid by dry distillation.

Physiological tannin is chiefly found in materials used for tanning; it cannot be split by dilute acids or fermentation, does not yield gallic acid, and the product of dry distillation is not pyrogallie acid, but pyrocatechin or oxyphenic acid; it converts the animal skin into perfect leather.

There can be but little doubt that physiological tannin is the variety found in fruits or fruit-juices. Generally speaking, a content of tannin in wine is not exactly a desirable feature, as it is readily decomposed. It can only have an advantageous effect when the wine contains an excess of albuminous substances which the tannin removes by entering into insoluble combinations with them. This may be the reason why wine containing tannin is considered more durable, because if it contained albuminous substances in large quantity it would be still more readily subjected to changes. Under such circumstances a small addition of tannin to the wine may be of advantage, though instead of tannin it

is advisable to use an alcoholic extract of grape-stones, which are uncommonly rich in tannin.

*Inorganic constituents.*—The inorganic constituents of the different varieties of fruit are very likely the same, namely, potash, lime, magnesia, sulphuric and phosphoric acids; they vary only in the proportions towards one another and in the total quantity of all the substances. Moreover, their quantity is too small to exert an influence upon the quantity of the wine to be produced, being of interest only in regard to the exhaustion of the soil. Though lime and sulphuric acid in sufficient quantity occur almost everywhere in the soil, this cannot be said of potash and phosphoric acid. Unfortunately there are no accurate statements regarding the amount of these substances which is withdrawn from the soil by the crop of one year, but there can be no doubt that it is very large, and that consequently fruit-trees from time to time require a certain amount of manure in order to return to the soil what has been taken from it.

*Fermentation.*—Fermentation is a chemical process which is always caused by the presence of a ferment or a substance in a peculiar state of decomposition. Although to induce fermentation the presence of a ferment is necessary, it does not take part in the decomposition of the fermenting substance. The products of fermentation vary according to the nature of the fermenting body, as well as according to the nature of the ferment. Each peculiar kind of fermentation requires a certain temperature, and it is nearly always accompanied by the development of certain living bodies (infusoria or fungi).

When yeast is added to a dilute solution of dextrose or another glucose, vinous fermentation speedily sets in; whilst a solution of cane-sugar undergoes fermentation but slowly, the cause being that this sugar must first be converted into inverted sugar before fermentation can commence. Vinous fermentation proceeds most rapidly at 77° to 86° F., and does not take place below 32° or above 95° F. The presence of a large quantity of acids or alkalis prevents fermentation, while if the liquid has a faint acid reaction, fermentation proceeds best.

The yeast which is formed in the fermentation of the juice of grape and other kinds of fruit is produced from soluble albuminous

bodies contained in fruit. It consists of one of the lowest members of the vegetable kingdom (*Torula cerevisiæ*), and under the microscope is seen to be made up of little oval transparent globules, having a diameter of not more than 0.1 millimetre and often adhering in clusters and strings. They are propagated by budding, and die as soon as they have reached their highest state of development. In contact with air and water yeast soon undergoes putrefaction.

The chief products of vinous fermentation are alcohol and carbon dioxide; a small quantity of sugar is at the same time converted into other products, about 2.5 per cent. being transformed into glycerin and 0.6 to 0.7 per cent. into succinic acid. A further portion of the sugar, about one per cent., is assimilated in the form of cellulose by the yeast and separated. By the simultaneous formation of these different secondary products about 5.5 to 6.5 per cent. of sugar is lost in the formation of alcohol. As they are not always formed in equally large quantity no conclusion can be arrived at from the content of sugar in the must as to the quantity of alcohol corresponding to theory in the finished wine; it is, as a rule, supposed that the sugar yields one-half its weight of alcohol, which is sufficiently correct for all practical purposes.

Absolute alcohol, *i. e.*, alcohol entirely free from water, is a very mobile fluid, clear as water and almost odorless; it boils at 173° F., and when it is cooled down to 148° F. it becomes viscid, but does not solidify. Its specific gravity at 32° F. is 0.80625, and at 59° F. 0.79367. It is very inflammable, and burns with a blue, non-luminous flame. It absorbs moisture with great avidity, and is miscible with water in all proportions, the mixture evolving heat and undergoing contraction.

The methods for determining the content of alcohol in a fluid have already been given on p. 198.

*Succinic acid.*—No accurate researches have as yet been made in regard to the quantity of this acid in wine, its influence upon the quality of the wine, and the conditions under which more or less of it is formed during fermentation. According to Pasteur, the more succinic acid is formed the slower fermentation progresses; the weaker the development of yeast and the less nour-



ishment offered to the latter. In acid fluid more succinic acid is formed than in neutral.

Succinic acid is quite readily soluble in a mixture of alcohol and water, and consequently also in wine; its taste is not very sour, but disagreeable, and adheres for some time to the tongue; hence its presence can scarcely be expected to give an agreeable taste to the wine.

*Glycerin.*—Glycerin being found in grape-wines, in which it is formed from the sugar by fermentation, there can scarcely be any doubt of its formation under the same conditions in fruit-wines. According to Pasteur, the quantity of glycerin in wine is in a definite proportion to the succinic acid formed, and, hence, more glycerin would be produced with slow fermentation and in an acid fluid. In red wines Pasteur found 4 to 7 per cent. of glycerin.

Pure glycerin is a colorless, very viscid liquid having a specific gravity of 1.27. It can be mixed with water and alcohol in all proportions and possesses a very sweet taste. It is very likely that the mild sweet taste of many ripe wines is due to a certain content of glycerin.

A solution of 7 parts of glycerin in 1000 of water (the proportion in which Pasteur found glycerin in wine) does not possess a sweet taste and differs from water only in being more insipid. By adding to such a solution 100 parts of alcohol the mixture shows a taste different from that of alcohol alone diluted in the same proportion, the predominant taste of the latter being decreased by the glycerin and that of the mixture becoming milder. Hence a certain importance has to be ascribed to the glycerin.

*Carbonic acid.*—The greater portion of the carbonic acid formed by fermentation escapes as a gaseous body during the process, but a certain portion remains dissolved in the wine as long as the temperature of the latter is not raised. The temperature of cellars generally increases, however, towards the end of spring, which causes anew a slight development of carbonic acid in consequence of which the wine again becomes turbid. The presence of carbonic acid is of advantage only in young wine, as it protects it from the direct action of the air by forming a layer upon the surface; in old wines it conceals, however, the fine aroma and taste, making them appear younger than they actually are.



Though it cannot be said that carbonic acid plays an essential part in the preparation of wine, it deserves attention on account of its deleterious influence upon the workmen. To avoid all injurious consequences provision should be made for a thorough ventilation of the cellar by means of windows and doors. If fermentation is carried on in barrels, the carbonic acid developed in a number of them should be conducted by means of tubes secured air-tight in the bungs to a zinc-pipe which passes through a suitable aperture into the open air.

How large the quantity of carbonic acid is which is developed during the fermentation of a barrel holding 1200 liters of must at 10 per cent. = 240 kilogrammes of sugar is shown by the following calculation: 180 grammes of grape-sugar yield 88 grammes of carbonic acid at 32° F. 1 gramme of carbonic acid occupies a volume of 0.50848 liter, which, with a cellar temperature of 50° F., corresponds to 0.527294 liter. Hence we have for the calculation of the total quantity of carbonic acid developed

$$\frac{88 \times 0.527294 \times 4000^*}{3} = 61,869 \text{ liters, or nearly as much as}$$

the contents of 52 barrels containing each 1200 liters.

*Alkaloid in wine.*—It has been frequently asserted that an alkaloid exists in young wine, which not being contained in the must or the yeast must have been formed from the nitrogenous constituents of the yeast or of the fluid during fermentation. It has not been found in old wine, and it is therefore concluded that it in time decomposes. Should this observation be confirmed, it would explain the difference in the effects of the very intoxicating young wines and of old wines.

$$* \frac{240000}{180} \text{ reduced by } 60 = \frac{4000}{3}.$$

## CHAPTER XXVI.

## PRACTICE OF THE PREPARATION OF CIDER AND FRUIT-WINES.

THE first step in the preparation of fruit-wines is the gaining of the juice or must from the fruit. Stamping or grinding and subsequent expressing of the paste thus formed by means of strong pressure suffice in most cases for berries and other small fruits. With apples, etc., this manner of reduction is not only difficult, but also connected with considerable loss caused by larger and smaller pieces jumping from the trough.

The earliest appliance known was simply a trough in which the apples were reduced to an imperfect pomace by rolling them with a heavy cylindrical stone or by pounding them as in a mortar. An improvement was the production of the English cider-mill. This consisted of a pair of coarsely corrugated iron cylinders from which the apples fell to a second pair close together and finer in their surfaces and passed through finely mashed to the pomace vessel underneath. In 1852, Mr. W. O. Hickock, of Harrisburg, Pa., invented a portable cider-mill which consisted of a pair of small horizontal cylinders armed with small spirally arranged teeth or spikes revolving close together, one at a higher velocity than the other. The apples were first broken by the action of a coarsely-fluted roller which revolved against a table under the hopper, and after passing between the cylinders the apples were not only bruised but also grated into the required pomace. This machine was capable of grinding 100 bushels of apples per day. Numerous modifications have been made in the plan of Mr. Hickock's mill, some being simply spiked cylinders against which the apples were carried and held till grated by reciprocating plungers.

Our limits will not permit us to notice all the various styles of portable mills before the public or the multitude of graters or

apple-grinders, many of which possess excellent points and are worthy of commendation. An excellent apparatus for crushing apples is the crushing-mill shown in Figs. 66 and 67, *B C* (Fig. 67) representing the cylinders provided with teeth. A hopper, *A*, receives the apples, which pass between the cylinders, where they are crushed and fall into the receiver *F* placed underneath. Two

Fig. 66.

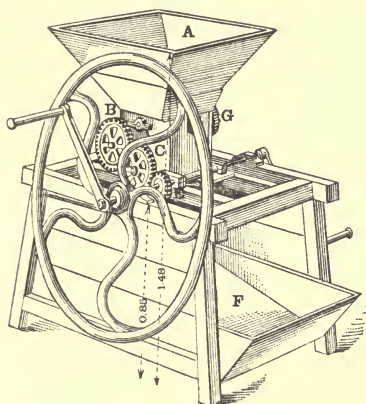
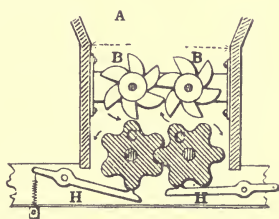


Fig. 67.

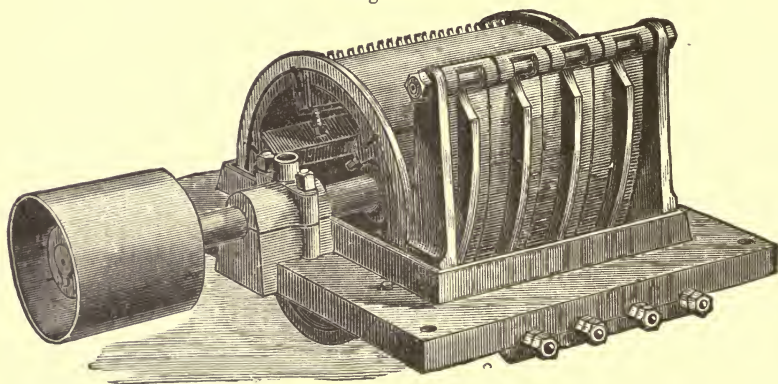


men operate this mill by means of cranks. Larger and stronger mills are used when the quality of apples seems to require them, and in that case horse-power is applied.

Fig. 68 shows Davis's star apple-grinder, several sizes of which are manufactured by the G. H. Bushnell Co., of Thompsonville, Conn. The grinder shown in the illustration is a heavy machine weighing 340 lbs. The cylinder is 12 inches in diameter and 12 inches long, is turned and carefully balanced, has grooves planed in to receive the knives, six in number, which are finely made and tempered. Each knife furnished is made of steel-plated iron, the steel being very thin and having a back of iron; there is no danger of breaking, although made very hard. The end of the cylinder is banded with wrought-iron bands and the knives are set with set-screws. The shaft is of steel and runs in anti-friction metal. The concaves are hung at top, so they can swing back at the bottom to allow stone, pieces of iron, etc. to pass through without injuring the knives. The concaves are held to their place by a

bolt which allows the concave to be set as close as desired to the cylinder, and is held to its place by coil-springs which will give enough to allow stones to pass and yet hold rigid in grinding even frozen apples. The frame is one casting, and as the concaves are fast to the frame they cannot get out of line or be displaced, as is the case when the concave is fast to the hopper. The hopper

Fig. 68.



can be readily removed to adjust knives and all parts are adjustable and easy to get at. This machine can be gauged to grind from 200 to 400 bushels per hour. Power required to grind six bushels per minute about six horse-power or about as many horse-power as desired to grind bushels per minute.

*Presses.*—For obtaining the juice from berries, etc. a press is generally not required, or at least only a slight pressure; the greater portion of it runs out from the must by placing the latter upon a cloth spread over a perforated bottom in a vat. The juice retained by the lees, which is, as a rule, very sour and has to be diluted with water, can be extracted with the latter more completely than is possible with the strongest press.

For obtaining the juice from apple pomace, etc. a good press is, however, an important auxiliary. Before the introduction of screws the method of extracting the juice of the apple was by the use of heavy weights, wedges, and leverage. Until within a late period a large wooden screw was used and is even now employed in some sections of the country. Of these screws two

and frequently three and four, set in a strong frame-work of double timbers, were found no more than sufficient to separate the cider from the pomace. In order to operate these screws a long heavy wooden lever became necessary, which required the united services of four or five men to handle, and not unfrequently the strength of a yoke of oxen was called into requisition before the work could be accomplished. An improvement upon the wooden screw was made by the substitution of the iron screw and iron nut. But the objectionable feature of having to handle heavy and cumbersome levers still remained, making labor irksome and expensive. In modern presses this difficulty has been entirely overcome, and the juice is extracted from the pomace with great ease and completeness.

Of the many presses before the public we illustrate a hand-press and a power-press manufactured by the G. H. Bushnell Co., of Thompsonville, Conn., the same concern furnishing presses of all sizes between these two. Fig. 69

shows the "Farmer's cider-press." It is 7 feet 1 inch high with a width between the rods of 3 feet  $1\frac{3}{4}$  inches. It will hold 15 to 16 bushels of apples at a pressing and is especially designed for individual use. It is also admirably adapted for squeezing the juice from small fruits, berries, etc.

Fig. 70 shows the "Extra power cider-press," with revolving platform. It is 13 feet 4 inches high, 6 feet 4 inches wide between the rods, and has a platform 13 feet 3 inches long. It gives a pressure of 250 tons. The press is always loaded in one place, and consequently the grater can be located immediately over the middle of the cheese, avoiding the necessity of conveying the pomace from one end of the press to the other. This press can easily make a pressing of 12 barrels of cider each hour.

Fig. 69.

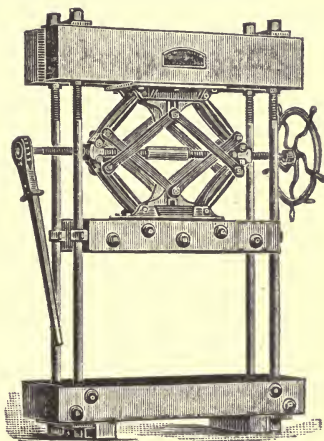
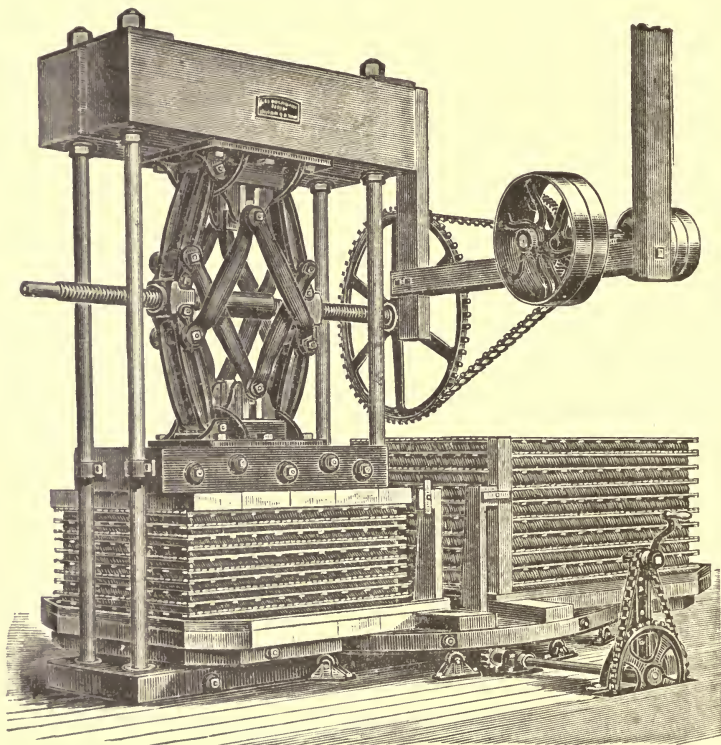




Fig. 71 shows the revolving platform belonging to the above press, for which the manufacturers claim the following advan-

Fig. 70.

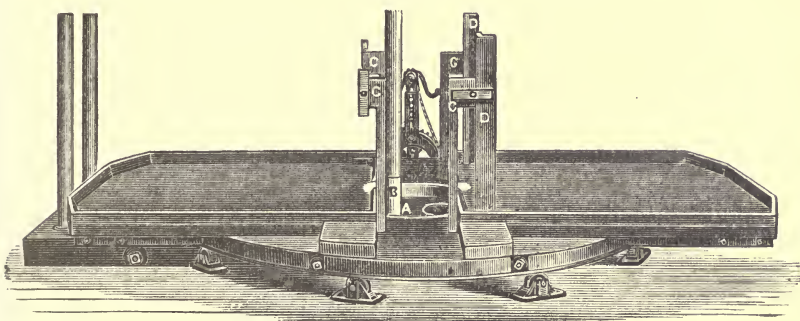


tages : 1. Both ends of the platform are loaded and unloaded in the same place. 2. It is so geared that one man can easily and quickly revolve it. 3. The grinder can be directly over the centre of the cheese, thus avoiding all the labor of shovelling the pomace. 4. The pomace being dropped in the centre of the cheese, it is an easy matter to spread it with equal density over the entire surface, thus building a cheese that is not liable to tilt or slide. The cider runs into a copper basin in the centre of the platform between the two cheeses. The basin is so arranged that it receives the cider while the platform is being revolved as well as while the press is working.



*A* is the copper basin to receive the cider from platforms, and has an outlet through the bottom, about 6 inches in diameter, for the cider to pass off into the tank below. *B* is a copper tube

Fig. 71.



encasing the rods. *C, C, C, C* are four posts fastened to the platform to hold guide-pieces for racks. *D, D* are rack guides.

*Ferguson's improved racks.*—The single racks are made of some light and tough wood—bass-wood or spruce seems best—cut into strips about  $\frac{1}{2} \times \frac{7}{8}$  inch and placed about  $\frac{1}{4}$  inch apart, with four, five, or more elm strips, 2 inches wide and about  $\frac{3}{8}$  inch thick, placed across and nailed to the narrow slats. The 2-inch slats extend beyond the narrow ones on each side about 4 inches. This is to support the wings, which are fastened to the rack by 3 or more bronze hinges. These wings, with the aid of 2 retaining bars, make the box to form the pomace in. The slats are rounded on the edges so as not to injure the press-cloth. Steel wire nails or wire staples are used of sufficient length to clinch.

Double racks are made by using slats  $\frac{5}{16} \times \frac{7}{8}$  inch. The slats on one side are laid directly across the slats on the other side. Four wide slats are put at the outer edges, then these are all fastened together by steel wire nails or staples. These racks have the advantage of having an even surface on each side. The press-cloth will last much longer than when used on single racks, where it is strained over 4 to 9 elm slats.

To lay up a cheese with the Ferguson improved rack, commence on the platform of the press and lay a rack; then turn up

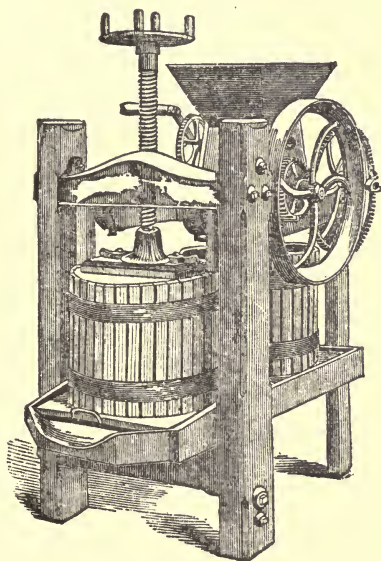
the wings on each side of the rack and place the retaining bars on each end, with the hooks on the outside of the wings, so as to hold them up. Over this box spread the cloth, fill the box evenly full of pomace, then turn in the sides and ends of the cloth over the pomace, the cloth being of sufficient size to cover it. The retaining bars are then removed, allowing the wings to fall in place. Another rack is placed on the cheese just made, the retaining bars placed in position to hold up the wings, another cloth placed on the box, etc., and this operation is continued until there is the right number of layers in the press. A rack should be placed on the top of the last layer. A guide should be used in laying up the cheese, so as to bring each rack directly above the other.

*Plain racks.*—These are made, either single or double, of slats of the same description and dimensions as are used in the Ferguson racks, but in the place of wings and retaining bars, a form square in size and 4 inches deep is used to form the sides of a box for the pomace. In laying up a cheese commence by placing a rack on the platform, and upon this place the form, spread a cloth over the form and fill even up with pomace; then fold the ends and sides of the cloth over on to the pomace, as described with the other style of rack, and remove the form. Place another rack on the layer just formed, and put the form on that and proceed as before until the cheese is complete. It will require one cloth less than the number of racks used for a cheese. Care must be exercised in laying a cheese to have the racks come evenly, as they are liable to tilt if they overhang. The best way to avoid the liability to slide or tilt is to lay the racks alternately the length and breadth of the press.

Fig. 72 shows Willson's telegraph wine and cider mill. The upper roller is furnished with sharp projecting ribs, which cut the apples into pieces sufficiently small to be readily received between the lower rollers. The two lower crushing rollers are cast with ribs and grooves, and these draw in the pieces prepared by the upper roller, and by this means the fruit is thoroughly mashed between the smooth segments, which breaks all the cells of the apples and makes the subsequent labor of pressing much

easier ; and should the pomace be allowed to stand a short time a large portion of the cider will run off without pressing. Both the upper and lower rollers are adjustable, and can be set to mash grapes for wine without breaking the seeds. It is peculiarly adapted to grinding the wine plant, mashing it without sepa-

Fig. 72.

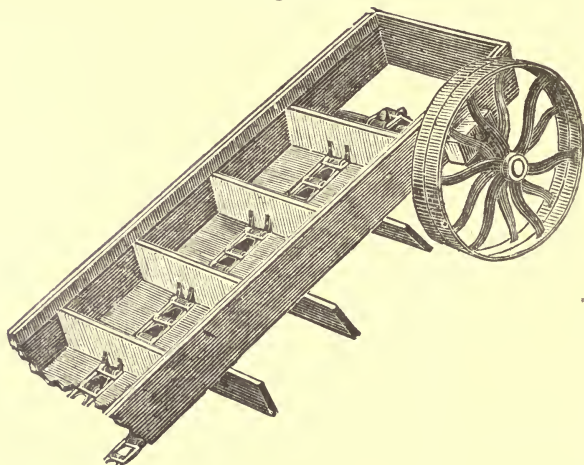


rating the fibre. The hopper is adjustable, and can be removed in an instant for cleaning the mill. The follower is brought up out of the tub by simply raising the screw. Several sizes of this mill are manufactured.

In the equipment of a first-class modern cider mill nothing gives better satisfaction for the money expended than an apple elevator. The expense is a small matter compared with the convenience of having the mill so arranged that apples may be brought from any part by a perfect working elevator and carrier. Fig. 73 shows a section of an elevator manufactured by the G. H. Bushnell Company, of Thompsonville, Connecticut. The chain runs over and is operated by a sprocket gear at the head with fast and loose pulleys. The scrapers are of wood, 3 inches

wide and  $11\frac{1}{2}$  inches long, bolted to lugs or projections on the chain. When run at from 50 to 70 revolutions per minute it

Fig. 73.



will elevate from 5 to 10 bushels per minute. It works at an inclination or carries on a level.

*Testing the Must as to its Content of Acid and Sugar.*

With the exception of the grape but few varieties of fruit contain acid and sugar in such proportion and in such quantity (generally too much acid and too little sugar) as that the must obtained from them will yield, when subjected to fermentation, a drinkable and durable wine. Wine whose content of acid exceeds 1 per cent. is too sour to the taste, and one containing less than 5 per cent. of alcohol cannot be kept for a long time. Now as all fruit wines may be called artificial wines, and a natural product has consequently to be improved in order to make it more agreeable and wholesome, it is necessary to find ways and means by which the object can be accomplished in a manner most conformable to nature. For this purpose a knowledge of the content of acid and sugar in the fruit-must is required.

To find the quantity of acid, compound a determined quantity, about 50 cubic centimetres, of must with about 5 grammes of

purified animal charcoal,\* boil the mixture about five minutes, and after cooling replace the exact quantity of water lost by evaporation. After shaking bring the whole upon a coarse paper, filter in a glass funnel, and let it run off. Of the clear and generally colorless filtrate bring 6.7 cubic centimetres into a small beaker, add sufficient distilled water to form a layer of fluid 2 to 3 centimetres deep, and color red with 5 to 10 drops of litmus tincture. While holding the beaker in the left hand and constantly moving it slowly in a horizontal direction allow to run or drop in from a pipette graduated in  $\frac{1}{10}$  cubic centimetres and filled to the O mark, decinormal liquid ammonia until the last drop no longer changes the color of the fluid and the place where the drop falls appears as if made clear by a drop of water. Now prevent a further flow of the ammonia by closing the pipette with the index finger of the right hand, and read off the quantity of ammonia consumed. The must examined contains as many thousandths of malic acid as cubic centimetres of liquid ammonia were required to color the fluid blue.

Now if the examination shows that a must contains more than 8 parts of acid per thousand, it is evidently too sour for the preparation of a palatable and wholesome fruit wine, and hence must be diluted to such degree as to reduce the content of acid to 6 or at the utmost to 8 parts per thousand. The calculation for this dilution is very simple, and consists in multiplying the acid per thousand parts present by 100 and dividing with the content of acid the wine is to have, the entire volume containing the desired acid per thousand being thus obtained. If, for instance, 18 parts per thousand of acid have been found in currant-must and the wine is only to show  $6\frac{1}{2}$  parts per thousand, then  $\frac{100 \times 18}{6\frac{1}{2}} = 276.923$ , in round numbers = 277, *i. e.*, 277 parts by measure of water have to be added to every 100 parts by measure of must.

The content of acid in the must thus forms the initial point for the dilution in order to obtain, after fermentation, wine with

\* Bone-black which is first boiled with solution of sodium carbonate for some time, and then after washing and extracting with hydrochloric acid is again washed and dried.



a determined quantity of acid. To be sure the content of acid is sometimes increased by fermentation, some succinic acid, as previously mentioned, being formed and perhaps also some acetic acid; sometimes, however, the content of acid decreases, which is very likely partially due to the water used for the dilution of the must containing earthy carbonates (lime, magnesia). It is, therefore, best not to have too much acid in the must, since, if the finished wine should be lacking in acid, it can be readily remedied by a suitable addition of tartaric acid, which is, however, not the case when it contains too much free acid.

The determination of the sugar in must is less difficult and has already been fully described on p. 197, hence there remains only the question how much sugar has to be added to the must in order to obtain a durable wine.

Numerous analyses have shown that there is scarcely any grape-wine which contains less than 7 per cent. by weight of alcohol, while in more generous wines the content rises to 12 per cent. and more. Fruit-wines in order to possess good keeping properties should never show less than 7 per cent. by weight of alcohol, but there is no reason why they should not contain as much as 10 per cent. The advantage of the latter content is evident, the wines being thereby almost absolutely protected from spoiling while they improve in aroma and taste, the various kinds of ether being only formed in wine rich in alcohol.

The manner of calculating the quantity of sugar which has to be added to the must to give the wine the desired content of alcohol will be best shown by the following example: Suppose 135 liters of must which contains 4 per cent. of sugar are to be changed into must with 15 per cent. of sugar.

For this purpose deduct from the weight of the must (which for the sake of simplicity we will consider equal to its volume) the weight of the sugar contained therein, multiply by the difference the per cent. of sugar the must is to contain, divide the product by 100 less the per cent. of sugar and deduct from the quotient the per cent. of sugar already present in the must. For instance: 135 liters of must with 4 per cent. of sugar are to be changed into must with 15 per cent. of sugar. In 135 liters are contained 5.4 kilogrammes of sugar,  $135 - 5.4 = 129.6$ , which multiplied by



$15 = 1944$ ; this number divided by  $100 - 15 = 85$  gives 22.87. Deduct from this 5.4, and there remain 17.47 kilogrammes of sugar which have to be added to the must to give it 15 per cent. of sugar.

For 325 liters of must with  $3\frac{1}{2}$  per cent. of sugar to be changed into must with 20 per cent. of sugar the calculation would be as follows :—

$$\frac{(325 - 11.375)20}{100 - 20} = \frac{313.625 \times 20}{80} =$$

$$\frac{313.625}{4} = 78.406 - 11.375 = 67.03 \text{ kilogrammes of sugar to be added.}$$

600 liters of must with 6 per cent. of sugar are to be changed into must with 22 per cent. of sugar :  $\frac{544 \times 11}{39} - 36 = 117.4$  kilogrammes of sugar.

The above examples will suffice to enable any one to execute the calculations as required.

The above calculations are based upon pure, anhydrous grape-sugar, an article which does not exist in commerce, and hence has to be replaced either by commercial grape-sugar (glucose) or cane-sugar. Glucose, however, containing as a rule only 67 per cent. of anhydrous grape-sugar,  $1\frac{1}{2}$  times the quantity calculated above must be used, thus in the last example 176 kilogrammes instead of 117.4. With cane-sugar the proportion is the reverse, 171 parts by weight of cane-sugar being equal to 180 parts by weight of anhydrous grape-sugar; hence the per cent. of anhydrous grape-sugar calculated according to the above method must be multiplied by the fraction  $\frac{17}{181}$  or the factor 0.95. According to this, instead of the 117.4 kilogrammes of grape-sugar in the last example, 111.73 kilogrammes of cane-sugar will have to be used.

*Glucose.*—Pure glucose being identical with the sugar in sweet fruits its use for sweetening fruit-juices intended for the preparation of wine is perfectly justifiable. With the dispute still carried on with honest weapons, whether it is permissible to assist nature with glucose when it fails to succeed in its labor of forming sugar in abundance, we have here nothing to do, since we know that the principal product—alcohol or spirits of wine—and almost the

only one which passes into the wine by the fermentation of sugar, possesses the same properties whether it is formed from fruit-sugar or from glucose, and that neither one nor the other can be injurious to health in the state of dilution in which it presents itself in the wine, provided the latter be used in moderation. The must might be sweetened, as is frequently done, with cane-sugar which occurs in sugar-cane, in beet-root, in sugar-maple, etc. But with the use of glucose we are one step in advance, since cane-sugar before fermenting is first resolved into a mixture of dextrose (glucose) and levulose.

Commercial glucose is never pure, as it contains, besides about 15 per cent. of water, of which about 6 per cent. is water of crystallization, about 18 per cent. of dextrin or similar substances, and some gypsum. It has a white color and is found in commerce packed in boxes into which it is poured while in a fluid state and gradually congeals to a hard mass. It is odorless and has a faint sweet taste. On heating it becomes smeary and finally melts to a yellowish syrup. Its content of anhydrous fruit-sugar varies between 62 and 67 per cent. Inferior qualities contain either less sugar or have a more or less dark color and a disagreeable odor and taste. Independently of the content of sugar, glucose to be suitable for the preparation of wine should show no odor or by-taste.

The accurate determination of the content of pure sugar in glucose is connected with some difficulty. But few manufacturers are provided with the necessary materials for making the analysis with Fehling's solution, and besides a certain amount of skill is required for obtaining accurate results by chemical tests. In consideration of this, Anthon of Prague has devised tables which are based upon the varying specific gravity of different saturated solutions of glucose, or rather upon its solubility in water. While 1 part of anhydrous grape-sugar requires for its solution 1.224 parts of water at 53.6° F., the foreign admixtures accompanying it dissolve in every proportion in water. Hence a saturated solution of glucose will show a greater specific gravity the more foreign substances it contains. In Anthon's tables is found the specific gravity and from this the content of anhydrous grape-sugar or glucose in the solution. In preparing a solution of

starch-sugar for examination care must be had that it is completely saturated. Heat must not be used for effecting the solution, but a certain quantity of the glucose to be examined is rubbed in a mortar with one-half its weight of water at 53.6° F., and after pouring the thickish, turbid fluid into a tall beaker it is allowed to stand until clear. Anthon's table is as follows:—

Specific gravity of the solution saturated at 53.6° F.	Contains of foreign substances.	Specific gravity of the solution saturated at 53.6° F.	Contains of foreign substances.
1.2066	0 per cent.	1.2522	25 per cent.
1.2115	2.5 “	1.2555	27.5 “
1.2169	5.0 “	1.2587	30.0 “
1.2218	7.5 “	1.2631	32.5 “
1.2267	10.0 “	1.2665	35.0 “
1.2309	12.5 “	1.2703	37.5 “
1.2350	15.0 “	1.2740	40.0 “
1.2395	17.5 “	1.2778	42.5 “
1.2439	20.0 “	1.2815	45.0 “
1.2481	22.5 “		

## CHAPTER XXVII.

### CIDER FROM APPLES AND PEARS.

*Cider from apples.*—The expressed juice of well-selected apples, properly prepared, forms a lively, sparkling liquor far superior to many wines. It is quite a favorite article of home production, nearly every farmer in regions where apples are grown making his barrel of cider for use through the winter, but a large amount finds its way into the city markets. A considerable quantity is also consumed in the shape of bottled cider, “champagne cider,” “sparkling cider,” and similar substances for, or imitations of, champagne wines; large quantities of this clarified cider being produced in some parts of the country, notably New Jersey. Most of the cheaper kinds of champagne (American champagne) are made in this way.

In England and France considerable quantities of cider find

their way into the markets, though it is there, as here, largely an article of home consumption. Certain parts of those countries are famous for the quality of their ciders, notably Normandy, in France, and Herefordshire and Devonshire, in England. France produced in 1883, 23,493,000 hectoliters (620,211,200 gallons) of cider, or one-half of the quantity of wine produced or three times as much as the total quantity of malt liquors.

Rousseau has published the mean of twenty analyses of Brittany cider, but his results are so low that it is thought by French authorities that his samples had been watered :—

Alcohol, per cent. by volume . . . . .	2.5
Extract grammes per liter . . . . .	19.3
Sugar . . . . .	2.5
Total ash . . . . .	1.52
Ash soluble in water . . . . .	1.17

The following are analyses of pure ciders from different parts of France made in the Paris municipal laboratory ; the figures are in grammes per liter :—

	Pure cider, 1877, Bois-Guillaume.	Pure cider made in 1876, Yvetot.	Old cider.	Pure cider, 1878, Yvetot.	Pure cider, "gross cider," 1880.	Cider No. 2.	Cider, 1st class.	Pure cider, "gross cider," 1880, Bagneux.
Alcohol, in weight, per liter . . . . .	47.40	41.08	37.92	34.76	23.70	7.90	25.30	19.75
Extract dried at 212° F. . . . .	57.60	30.90	20.90	61.30	53.20	69.70	81.20	63.80
Extract dried <i>in vacuo</i> . . . . .	60.10	37.60	27.00	72.70	60.80	82.00	92.60	75.00
Total ash . . . . .	3.50	2.50	2.50	3.00	2.60	2.54	2.30	2.80
<i>Analysis of the Ash.</i>								
Phosphates insoluble in water . . . . .	0.38	—	0.25	0.30	0.45	0.62	0.17	20.55
Carbonate of potash . . . . .	2.23	—	1.40	2.00	1.80	1.51	—	—
Other alkaline salts . . . . .	0.89	—	0.85	0.70	0.35	0.41	—	—
Reducing sugar . . . . .	20.00	7.50	4.40	3.70	16.50	36.00	39.00	25.00
Acidity expressed as H <sub>2</sub> SO <sub>4</sub> . . . . .	3.60	4.07	5.36	4.54	3.23	2.68	—	2.08
Acidity of the cider dried <i>in vacuo</i> . . . . .	2.50	2.40	2.59	2.31	2.68	1.11	—	1.48

Of these samples the first four had undergone a good fermentation. They furnish the following average composition for the principal constituents:—

Alcohol, per cent. by volume . . . . .	5.2
Extract, per liter, at 212° F. . . . .	41.18
Sugar . . . . .	8.90
Ash . . . . .	2.87

The other four samples were partially unfermented, or sweet, ciders. Their average composition was as follows:—

Alcohol, per cent. by volume . . . . .	1.70
Extract, per liter, at 212° F. . . . .	66.98
Ash . . . . .	2.56

From these means the municipal laboratory deduces the following as a type of composition for pure ciders:—

Alcohol, per cent. by volume . . . . .	5.66
Extract, per liter, at 212° F. . . . .	30.00
Ash . . . . .	2.80

Recent analyses of pure ciders, from different parts of France, published by M. G. Lechtartier, have shown great variations from this type, and show the necessity for the examination of large numbers of samples from various parts of the country for the establishment of a proper standard of analysis.

*Analyses of ciders by the United States Agricultural Department.*  
—The samples for the investigation were purchased in the city in the same manner as samples of wine and beer:—

Designation.	Serial No	No of analysis.	Specific gravity.	Alcohol by weight.	Alcohol by volume.	Total solids.	Free acids, as malic.	Sugar, as dextrose.	Ash.	Albuminoids.	Carbonic acid.	Polarization cane-sugar scale.
<i>Well fermented ciders.</i>				<i>p.ct.</i>	<i>p.ct.</i>	<i>p.ct.</i>	<i>p.ct.</i>	<i>p.ct.</i>	<i>p.ct.</i>	<i>p.ct.</i>	<i>p.ct.</i>	<i>°</i>
Draft cider ("extra dry")	4830	1	1.0132	4.15	5.23	3.31	.602	( <sup>1</sup> )	.396	.038	—	—19.5
Bottled cider, known to be pure	4832	2	1.0003	8.09	10.05	1.88	.456	—	.279	.063	trace	—7.0
Bottled cider . . .	4833	3	1.0007	6.28	7.83	1.80	.376	—	.340	.044	—	—6.1
Bottled "extra dry russet" cider	4834	4	1.0264	4.48	5.61	5.52	.339	—	.393	.031	—	—35.2
"Champagne cider," bottled	4835	5	1.0223	4.08	5.10	5.02	.567	—	.310	.050	.161	—23.4
"Champagne cider," bottled	4836	6	1.0143	5.45	6.79	3.69	.361	—	.415	.038	.120	—20.4
"Sparkling cider," bottled	4927	7	1.0306	3.63	4.54	5.92	.113	—	.506	—	( <sup>2</sup> )	—33.8
Average . . .	—	—	1.0154	5.17	6.45	3.88	.402	—	.377	.044	—	—
<i>"Sweet" or incompletely fermented ciders.</i>												
Draft cider . . .	4829	1	1.0337	0.65	0.81	9.34	.565	—	.315	.069	—	—41.6
"Sweet" cider . . .	4831	2	1.0516	0.61	0.77	9.59	.302	—	.270	.063	—	—31.2
"Sweet" cider (draft) . . .	4837	3	1.0567	0.20	0.25	9.53	.375	—	.283	.075	—	—18.4
Do. . . . .	4838	4	1.0203	3.46	4.33	3.84	.802	—	.374	.014	—	—24.2
Do. . . . .	4839	5	1.0552	0.55	0.67	9.75	.409	—	.336	.031	—	—18.5
Do. . . . .	4841	6	1.0355	2.96	3.71	6.98	.478	—	.348	.069	—	—39.1
Average . . .	—	—	1.0455	1.40	1.76	8.17	.405	—	.321	.059	—	—

<sup>1</sup> A circumstance arising after the samples had been thrown away seemed to throw considerable doubt upon the determinations of sugar, which were made by an assistant, and the entire set had to be thrown out.

<sup>2</sup> Determinations of the carbonic acid in three different bottles gave the following results: .728, .634, .482.

The choice of the varieties of apples is of great importance in the manufacture of cider. All apple juice will not make equally good cider, even if it is equally well handled. It is not always the best flavored apple or the best tasting juice that will make the best cider. Indeed, as a rule, the best cider is made from apples which are inferior for table use, such as the crab-apple and the russet. But it is a pretty general rule that the most astringent apple will make the best cider. This astringency is due to an excess of tannin. While a portion of this tannin is changed



to sweetness a considerable portion remains, which serves to render the cider more easily and thoroughly clarified and to make it keep better. The tongue alone being, however, not sufficient to detect the tannin in apples, the following will serve as a reliable test: Express the juice of a few apples and add a few drops of isinglass, which combines with the tannin and forms a precipitate. From the greater or smaller quantity of this precipitate a conclusion can be drawn as to the quantity of tannin present. The specific gravity of the juice, which may vary between 1.05 and 1.08, should be determined. The greater the specific gravity of the juice the better the respective variety of apple is for the fabrication of cider. According to these directions, the raw material should be selected, though in most cases it will be necessary to use a mixture of different varieties. In France, for a quality of cider which will keep well, the apples are mixed in the following proportions:  $\frac{2}{3}$  bitter-sweet and  $\frac{1}{3}$  sweet apples. If a sweet cider is wanted not intended to be kept for a long while,  $\frac{1}{3}$  bitter-sweet and  $\frac{2}{3}$  sweet apples are used.

The most noted varieties of apples said to possess peculiar and natural properties for the manufacture of refined cider or apple-wine are the "Harrison" and "Canfield" of New Jersey, from which the celebrated New Jersey cider is almost exclusively manufactured. Of the Harrison 600 lbs. suffice for the manufacture of 30 gallons of cider. Another variety is the "Hagloe crab," which is also excellent for cooking. Other varieties recommended by P. Barry\* are the Dartmouth, Hyslop, and Hewe's Virginia crab. The Siberian crab (*Pyrus baccata*) is also highly recommended for the fabrication of cider as well as for jelly.

The following is a select list of apples recommended by P. Barry for cultivation in the Eastern and Middle States.†

*Summer*.—Early Harvest, Early Strawberry, Golden Sweet, Large yellow Bough, Pimate, Red Astrachan, Williams's Favorite.

\* Barry's Fruit Garden, New York, 1883.

† The name given to each fruit is the recognized name of the American Pomological Society as far as recorded in their catalogue.

*Autumn.*—Chenango Strawberry, Duchess of Oldenburgh, Fall Pippin, Gravenstein, Hawthornden, Jefferis, Jersey Sweet, Keswick Cadlin, Lowell, Lyman's Pumpkin Sweet, Porter, St. Lawrence, Stump.

*Winter.*—Baldwin, Esopus, Spitzenburgh, Fameuse, Golden Russet of Western New York, Hubbardston, Nonsuch, Jonathan, King of Tompkins County, Lady Apple, Monmouth Pippin, Mother, Northern Spy, Peck's Pleasant, Pomme Grise, Red Canada, Rhode Island Greening, Roxbury Russet, Sutton Beauty, Talman's Sweet, Twenty-ounce, Wagener, Yellow Bellflower.

*For the West and South.*—Nearly all the summer and fall varieties succeed well at the West and South. In California and Oregon our best northern sorts generally succeed, but the winter varieties of the South will be better adapted to the warmer districts of California than our Northern winter sorts.

The apples intended for the preparation of cider should be allowed to attain complete maturity, which is recognized by their color, the dark hue of the pips, little specks covering the skin, and by the sharp and agreeable ethereal odor emanating from them. In fact they should be allowed to remain on the trees as long as vegetation is active or until frosts are apprehended, for thus the conversion of the starch into sugar is best effected and their keeping better secured than by storing. They should be gathered by the hand to prevent bruising and coming in contact with dirt. They are then placed in piles and allowed to sweat. This sweating process has a tendency to ripen the fruit and make it uniform, thereby improving the flavor as well as the quality and strength of the cider in consequence of the apples having parted with six or eight per cent. of water. The strongest cider is made from apples containing the smallest percentage of juice, and, in its aqueous solution, the largest proportion of saccharine matter. If the weather be fine, the piles may be exposed in the open air upon clean sod or where this is wanting upon boards or linen cloths, but under no circumstances should the apples be placed upon the bare ground or upon straw, as they contract an earthy or musty taste which is afterwards found in the cider.

After sweating and before being ground the apples should be wiped with a cloth to free them from exudations and adhering

particles of dirt, and if any are found bruised or rotten they should be thrown out. Ripe, sound fruit is the only basis for a good article of cider, and the practice of mixing rotten apples with the sound, as is frequently done and even advocated by some, cannot be too strongly condemned. Mellow or decaying apples have lost almost all their perfume, a certain quantity of water by evaporation, and a large portion of their sugar. Rotten apples yield a watery liquid of an abominable taste, which prevents the cider from clarifying and accelerates its acetification.

The apples being wiped, sorted, and, if necessary, mixed in the desired proportions, are now brought into the grinder and reduced to an impalpable pulp. By this operation the numerous infinitesimal cells of the apple should be thoroughly broken up so as to permit the free escape of the juice when under pressure, and the machine which accomplishes this most effectually is the best for the purpose. If the cells are not thoroughly torn asunder, their tendency is to restrain and hold, as it were, in a sack much that otherwise would escape. As regards the crushing of the seeds there is a diversity of opinion, some holding that they communicate to the cider a disagreeable bitterness and acidity, while others consider them as rendering the cider more alcoholic and making it keep better.

According to M. Bergot, for cider of superior quality it is preferable not to crush the seeds, because the diffused odor of the essential oil would undoubtedly injure the fine taste of certain notable products. For ordinary cider the crushing of the seeds will, on the other hand, be of advantage, because their essential oil helps to give to the cider the bouquet which it otherwise lacks. For cider intended to be converted into brandy the seeds must, however, be crushed. The grinder should be cleansed with hot water every evening or at least every third day.

The treatment to which the pulp obtained by grinding is subjected varies according to the color the cider is to have. Where the consumer prefers a pale-yellow color the pulp must at once be pressed, while for a darker color it is allowed to stand 12 to 18 hours.

The next step in the operation is pressing. The various kinds of presses, racks, and manner of laying up the cheese have

already been described. The primitive custom of laying the cheese was to lay upon the platform of the press a quantity of straw, upon which a quantity of pomace was placed, and the edges secured by laps of straw, thus alternating straw and pomace until the pile was complete. The object of using the straw was to hold the mass together while it was being submitted to pressure, and also to serve as a means of exit for the cider. An improvement was in the substitution of hair-cloths, and within the past few years the adoption of the cotton press-cloth and racks to hold the pomace in laying up the cheese for the press. The racks have already been described; the press-cloth is woven from yarn made expressly for the purpose and is of equal strength in warp and filling. The G. H. Bushnell Company, of Thompsonville, Connecticut, furnishes several grades of cotton press-cloth, medium, heavy, and extra heavy. The use of straw in laying up the cheese should be entirely discarded, as the slightest mustiness imparts an unpleasant odor to the cider.

The pressure applied to the cheese should be slow at starting and then gradually increased until finally the full force is applied. The juice as it comes from the press runs through a fine hair-sieve into a receiver. With a good press about 65 to 75 per cent. of the juice will be obtained.

After the cider has been extracted and the cheese removed from the press the pomace may be utilized for the manufacture of vinegar, as described on p. 168. In France it is, however, used for the manufacture of the small cider. The method is as follows:—After the extraction of the pure cider by the first pressing, the pomace is taken from the press, and after adding 15 liters of water for every hectoliter of apples used, the mass is allowed to macerate 15 to 20 hours, care being had to stir every two or three hours. Then this pulp is put a second time under pressure and a quantity of juice extracted equivalent to the amount of water added.

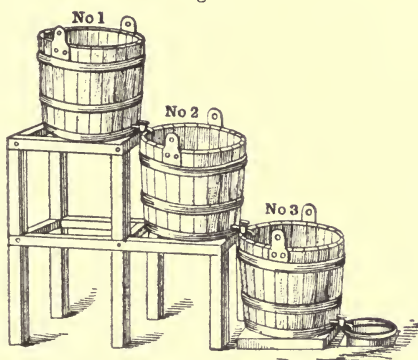
*Extraction of the juice by diffusion.*—Diffusion, which gives such excellent results in the extraction of sugar-beets, has also been applied to extract the soluble constituents of the apple, but in such a primitive manner that the juice thus obtained produces

after fermentation a beverage very deficient in alcohol and difficult to keep.

M. Jules Nanot, of Paris, France, proposes the following improved method :—

Suppose we take 150 kilogrammes of apples reduced to pulp, divide them in 3 lots of 50 kilogrammes each and put each lot in a vat or tub. These tubs are then placed on steps one above the other as shown in Fig. 74. They communicate with each other by means of spigots provided in the interior with small convex screens. Care must be had to keep the tubs covered not

Fig. 74.



only to prevent the pulp from floating but also to prevent oxidation, as otherwise, on account of the mass remaining exposed to the air for a long time (3 times 24 hours), would yield cider which afterwards would turn black.

*First manipulation.*—Pour 50 liters of water into tub No. 1, and macerate 24 hours.

*Second manipulation.*—Draw off the liquid in No. 1, by opening the spigot into No. 2, and pour again 50 liters of water into No. 1, and macerate for 24 hours.

*Third manipulation.*—Draw off the liquid from No. 2 into No. 3 and the liquid from No. 1 into No. 2. Pour 50 liters of water into No. 1 and macerate for 24 hours.

*Fourth manipulation.*—Draw off the liquid from No. 3. Then draw off the liquid from No. 2 into No. 3, and from No. 1 into No. 2. Now remove No. 1 and replace its exhausted pulp with



freshly ground apples ; then instead of putting it in the highest place, place it at the bottom and shift Nos. 2 and 3 one step higher up, so that No. 2 becomes 1, No. 3, 2, and No. 1, 3. Then draw off the liquid in No. 2 into No. 3 and that of No. 1 into No. 2.

Now pour 50 liters of water into the upper tub No. 1 and repeat this every 24 hours. The liquid which is drawn off every 24 hours from the lowest tub is poured into the barrel in which it is to ferment.

At first this fourth manipulation seems complicated, but after having done it once there will be found no difficulty in its execution. What seems to complicate it somewhat is the indispensable placing of the tub with the freshly crushed apples on the base of the steps in order to have the richest juice discharged into it. To briefly recapitulate: the most exhausted apples are always placed at the top of the steps and the less dense liquid added to them and the freshest apples on the bottom to receive the richest juices.

By this disposition the apples are thoroughly exhausted, and after having passed through the operation the liquid obtained will show an alcoholic strength equal to  $\frac{3}{4}$  of the alcohol contained in the pure juice, and is at all events greatly superior to the juice obtained by the old methods of diffusion.

The use of this method would be suitable for persons having no cider press and only a small quantity of apples to manipulate.

The quantity of cider is nearly equal to that obtained by three pressures and the juice obtained by diffusion is almost as rich as the juice yielded by the press.

After one or two manipulations it is quite easy to operate successfully without weighing the apples and also the water to be used. It is sufficient for that purpose to mark on the inner side of the tub the height to which a certain quantity of crushed apples come, and measure the water in the same manner. In order to pass the liquid into the next lower tub and draw it off finally from the last tub, it is sufficient to open the spigots and allow the liquid to run off naturally. The quantity of liquid thus drawn off is less by about  $\frac{1}{10}$  the amount poured in at the



commencement of the operation. It is impossible to extract all as that would require the use of a press.

Unfortunately this process of diffusion is very slow on account of the necessarily small size of the tubs, and their capacity can scarcely be increased as in that case two men would have considerable difficulty in raising them from one step to the other.

In order to accelerate this method and apply it to the production of large quantities of cider large tubs would be required, and instead of disposing them on steps they would have to be placed on the floor of the room and the passage of the liquids from one tub to the other be effected by a system of pumps. The number of tubs might then be increased to five or six ; and by the application of heat a more complete exhaustion of the apples could be reached.

Recent successful experiments in expressing the juice of the grape by means of the centrifugal would indicate that the same method might also be applied to apples.

The juice of the apples obtained by either of the preceding methods is now tested with the must areometer as to its saccharine content. If it is too low it will be useless to try to make cider of it unless that quality is strengthened. Generally good juice will range from 10 to 14 per cent. If it is any less than 10 per cent. it will not make a cider which will keep, though, if the flavor in other respects is all right, a very light cider for immediate use may be produced from it.

The juice having been tested and, if found wanting in saccharine strength, corrected by the method given on p. 326, the next step in the operation is fermentation. For this purpose the juice is brought into clean, sound barrels or into large vats. After a few hours an active fermentation will commence, which is usually permitted to continue, with the bung loose, until the hissing sound, so readily discernible when carbonic acid gas is escaping, shall cease. The cider is then drawn off into clean barrels, separating it from the sediment. The barrels are placed in a cellar or a cool room having a uniform temperature, one of 57° to 64° F. being most suitable. Abrupt variations in temperature should be carefully avoided and provided against. The barrels must be carefully watched, and as soon as white bubbles are perceived rising at the

bung-hole, the cider is again racked off into other barrels whereby fermentation is, of course, interrupted. The distinguishing characteristic between the fermentation of wine and cider may here be referred to. Wine is allowed to completely ferment without interruption, but the fermentation of cider must be checked at a certain time as otherwise acetic acid commences to form, the progressive development of which would in a year render the cider unfit to drink. For the preparation of cider on a large scale skill in handling the must areometer is absolutely necessary, and care should be had not to allow the entire content of sugar to be converted into alcohol. Generally speaking cider must be racked three times, but each time only when the previously mentioned white bubbles appear at the bung-hole. Where the barrels can be placed in a cellar having a temperature of  $32^{\circ}$  F., or not much above it, fermentation can be readily checked. Such cellars being, however, rare, recourse must be had to artificial means to effectually prevent any further fermentation. Various methods have been practised with a view to accomplish that object, one of which was to thrust a lighted sulphur match into the bung-hole of the barrel. This method is, however, but little used at the present time. Another plan which can be recommended is to submerge in the barrel ground brown mustard-seed tied in a bag. But the most effectual method, and which is generally used by professional cider makers, is to add from  $\frac{1}{8}$  to  $\frac{1}{4}$  oz. of sulphite of lime to each gallon of cider in the barrel, first mixing the powder in about a quart of the cider, then pouring it back into the barrel and giving it a thorough shaking or rolling. The *sulphite* of lime must be used, and not the *sulphate*. It will preserve the sweetness of cider for many years, but care must be had not to use too much, as otherwise it will impart a taste of sulphur to the cider.

For the preparation of very fine cider throw  $\frac{1}{4}$  lb. of white sugar into the barrel and suspend a bag of raisins in it by squeezing one corner between the bung and bung-hole.

The oiling process is another method of checking fermentation. It consists in pouring into the bung-hole of a barrel about half a pint of sweet oil. The oil should be warm when poured in to enable it to spread in a thin coat over the surface and keep

spreading as the cider is drawn down, thereby preventing the air from coming in contact with the surface of the cider and converting it into acetic acid.

We will here call attention to salicylic acid, which as an agent for checking fermentation might be even more effective than sulphite of lime or powdered mustard-seed. The "salicylic acid question," as it is called, has received a great deal of attention for several years in Europe, and much has been written *pro* and *con* on the question of the propriety of its use as a preserving agent in articles of food and drink. In France its use as a preservative in any form of food or drink was forbidden by ministerial decree on the 7th of February, 1881. This decree was based upon the decision of the consulting committee of hygiene that its constant use was dangerous to health.

In Germany its use is prohibited except in beers intended for export to other countries where its use is allowed.

Its prohibition in France called forth a great deal of opposition, and experiments were made and published indicating that its constant use in small doses exerted no injurious influence upon the system. In this country but little attention seems to have been given to the use of salicylic acid as a preservative, and, as far as we know, no experiments have been made with it in checking fermentation in cider. Whether its use for many years and without regard to age, sex, or personal idiosyncrasy is harmless or not, is at least still an open question. Moreover, the quantity used is so exceedingly small that its injurious effect upon the health of moderate drinkers of beer, wine or cider would seem rather doubtful. For wine the limits of its addition lie between 0.02 and 0.1 gramme per liter. For use dissolve the salicylic acid to a concentrated solution best in pure spirits of wine free from fusel oil or in the wine itself and add the determined quantity. To find the latter dissolve 5 grammes of crystallized salicylic acid in 100 cubic centimetres of spirits of wine or of wine and add a series of quantities of this solution, commencing with 1 cubic centimetre and gradually increasing to 2 cubic centimetres, to the wine. These quantities represent 0.5 to 0.1 gramme of salicylic acid per liter. A larger content of sugar in proportion to the content of alcohol requires somewhat more salicylic acid.

The cider being protected from further fermentation by either one of the above-mentioned methods is allowed to lay undisturbed until April, when it can be bottled or for quick consumption tapped from the barrel. But before being offered for sale it has to be clarified like other wine. According to the old method this was done with isinglass, 30 grammes of which were allowed for each barrel. This quantity was dissolved in  $\frac{1}{2}$  liter of cider over a moderate fire and the solution when cold poured with constant agitation into the barrel. Drawing off can be commenced after eight days.

A better mode of clarification, which at the same time increases the purity of the taste of the cider, is as follows: For each barrel of 30 gallons take 4 lbs. of fresh wheat bran, and after washing it twice in hot water to remove all soluble substances, press out thoroughly. Now dissolve about 2 drachms of alum in a bucketful of hot water and pour the solution upon the bran. After 6 to 8 hours take the latter from the alum water and press as before. The bran is best used before the cider is racked off for the third and last time. Stir it into the cider and then draw off the latter through a fine strainer into the actual storage barrel. The cider first passing through the strainer is generally somewhat turbid, and must be poured back until it runs off clear.

In France the cider is generally clarified by dissolving 60 grammes of catechu in 1 liter of cider and adding the solution to 1 hectoliter of cider, with constant stirring. The tannin thus added precipitates the albuminous matters, the result being a clear cider which will not blacken in the air.

Cider intended for export must be made somewhat richer in alcohol, which is generally done by adding sufficient French brandy to increase its content of alcohol 2 per cent. Sometimes, also,  $\frac{1}{4}$  lb. of sugar for every 2 quarts of juice is added during fermentation. For shipping to tropical countries experiments might be made with salicylic acid, adding it in the same proportion as to beer, which is for beer sent in barrels 20 grammes per hectoliter, and for bottled beer 15 grammes.

There are several methods of improving the taste of cider, but they are rather questionable, because tastes differ, and what might be considered an improvement by one would be declared

a defect by another. A favorite means of improvement is as follows: For 45 gallons of cider measure off 3 quarts of French brandy and mix it with the following substances, all finely powdered: 0.7 drachm of bitter almonds, 0.7 drachm of mace, and  $7\frac{1}{2}$  drachms of mustard-seed, and finally  $3\frac{1}{2}$  drachms of catechu, previously dissolved in water. Pour this mixture into the cider and shake the barrel frequently during the next 14 days. Then allow it to rest three or four months, and should it then not run off clear, when tapped, clarify it with  $1\frac{1}{4}$  oz. of isinglass or the whites of a dozen eggs. If the color of the cider is to remain pale yellow, catechu cannot be used, and instead of isinglass or white of egg, skimmed milk is to be used for clarification. For a reddish color which is sometimes desired use  $1\frac{3}{4}$  drachms of powdered cochineal in place of the catechu.

Sometimes cider is prepared in the same manner as other fruit-wines. In this case  $\frac{1}{4}$  lb. of sugar is added to every liter of juice, and the latter is allowed to completely ferment in the same manner as grape-wine. According to another direction, add to every 2 quarts of juice 2 lbs. of white sugar and boil as long as scum is formed; then strain through a fine hair-sieve and allow to cool. Now add a small quantity of yeast, stir thoroughly, let the whole ferment three weeks, and after clarifying rack off into bottles.

*Red apple-wine*, or, as it is frequently called, *red wine from cider*, is prepared as follows: Boil for 2 hours 50 quarts of apple juice, 27 lbs. of honey, 1 oz. of tartar, 6 lbs. of comminuted red beets, and 3 lbs. of brown sugar. Let the fluid completely ferment, and if no apple juice is on hand to fill up the barrel during this process use solution of sugar. When fermentation is finished pour a mixture of 1 quart of French brandy and about 1 drachm each of pulverized cinnamon and ginger into the barrel. After three months clarify the wine and rack off.

*Sweet cider* can be prepared in the following simple manner: Boil the juice as soon as it comes from the press for two hours, removing the scum which arises. Then pour the hot fluid into bottles previously placed in warm water, cork and seal with a mixture of resin and tallow, in the proportion of 1 lb. to 4 drachms, kept in a fluid state. After sealing hold the neck of



the bottle in cold water for one minute. Thus treated the sweet cider will keep seven or eight months.

In his treatise on Cider, Dr. Denis-Dumont gives the following directions for bottling cider. The cider is to be bottled at three distinct periods. It should never be bottled before the tumultuous stage of fermentation is entirely completed and the liquid clarified.

*First period.*—At the termination of the tumultuous fermentation the cider still contains considerable sugar; fermentation continues in the bottle and produces in a few weeks a large quantity of carbonic acid. In order to prevent the bottles from being broken by the pressure, champagne bottles should be selected and care taken to have them stand upright until about the month of July, *i. e.*, until the development is considerably reduced. The bottles are then laid on their side, as otherwise the cider would cease to be sparkling. This cider has to be kept for a number of years, it being good to drink only when old.

*Second period*, when fermentation is more advanced, about six weeks or two months after the first period. Mineral water bottles are strong enough to hold this cider, it liberating less carbonic acid than the preceding. The bottles are left in an upright position for a few weeks only.

This cider has a good flavor and is fit to drink much sooner than the preceding. It keeps for a long time.

*Third period*, when fermentation is complete or almost so, any quality of bottles may be used, a great deal less of carbonic acid being developed than in the preceding cases. The bottles should be laid down immediately after filling, in order to retain the carbonic acid which will still be developed.

This cider is not sparkling; it is, however, lively, strong, and has a fine flavor.

The bottles should in every instance be well corked and the corks, for the sake of safety, tied. The cider is very good when kept in small bottles, better in quart bottles, and best in jars holding two quarts. A few moments before opening a bottle of sparkling cider it is advisable to provide a minute opening for the escape of the gas by piercing the cork with a fine punch. As soon as the tension of the gas has become sufficiently weak the



cork is allowed to blow out in the same manner as with champagne. Without this precaution most of the cider might be thrown up to the ceiling.

In the Island of Jersey, where the manufacture of cider is carried on in a very rational manner, the juice as it comes from the press is allowed to ferment in large open vats placed in a cellar having a uniform temperature of from  $53^{\circ}$  to  $59^{\circ}$  F. On account of the large surface presented to the air tumultuous fermentation soon sets in and in about four or five days, or at the utmost a week, fermentation is over. The liquid is then drawn off in barrels, thoroughly cleansed and sulphured, in which fermentation continues slowly. These barrels are not entirely filled, and when the development of carbonic gas has proceeded so far that the flame of a lighted candle introduced by the bung-hole is extinguished, the liquid is drawn off into other barrels sulphured like the first. This transfer from one set of barrels to another is continued until no escape of gas is perceptible, *i. e.*, until fermentation is quite complete.

Prepared in this manner the cider will keep perfectly good for several years, and stand transportation by sea without any difficulty.

*Devonshire-cider* is made from a mixture of one-third of bitter-sweet apples with a mild sour. These being gathered when thoroughly ripe are allowed to undergo the sweating process before grinding; the cider is then pressed in the usual manner and strained through a hair-sieve into hogsheads, where it remains for two or three days previous to fermenting. It is then drawn off into clean casks to stop the fermentation, but if this is very strong only two or three gallons are first put in, and, after burning cotton or linen rags saturated with sulphur in the cask, thoroughly agitated. This completely stops fermentation in that quantity and usually checks it in the other portion with which the cask is then filled up. In a few weeks the cider becomes very fine. If this be not satisfactorily accomplished by the first operation it is repeated until fermentation is completely checked and the cider is in a quiet state and in a proper condition for drinking and bottling.

*Heating of cider.*—G. Lechartier has made numerous experiments to preserve cider by heating in bottles or in barrels holding from 25 to 230 quarts. The experiments showed that a tempera-

ture of  $140^{\circ}$  F. suffices to suppress every kind of fermentation in cider which contained only 3 to 6 per cent. of alcohol. But in all cases the cider thus treated acquired a peculiar taste calling to mind that of dried fruit. The following experiments show how this evil can be removed: On April 16, 1888, barrels holding from 25 to 50 quarts were filled with cider previously heated to from  $140^{\circ}$  to  $149^{\circ}$  F.; on June 14, of the same year, the peculiar taste, referred to above, was noticed, though no change in the composition by alcoholic or acetous fermentation had taken place. To the content of every barrel was now added a bottle of the same cider not previously heated, whereupon regular alcoholic fermentation set in anew. On July 9, of the same year, the cider had lost the taste of dried fruit and re-acquired its original taste. On July 11, of the same year, it was drawn off into bottles, was sparkling in September, and retained its normal taste. The process having been tested by experts, the Congress of the "Association pomologique de l'Ouest," held at Havre, expressed a favorable opinion of it and declared the problem of keeping cider sweet as solved.

*Freezing of cider.*—G. Lechartier also made experiments in this direction, his object being to answer the following questions: 1. Are the aroma, taste, and clearness of cider changed by cold? 2. Of what nature are the products obtained by freezing, and does the latter take place without sensible loss of substance? 3. Are the ferments killed by sufficiently long cooling, and is cider thus treated protected from external influences?

For all the experiments the cider was subjected to a temperature of from  $-0.4^{\circ}$  to  $-4^{\circ}$  F. A portion of the fluid congeals, and the temperature rises to from  $26.6^{\circ}$  to  $24.8^{\circ}$  F. As soon as a sufficient quantity has become solid the fluid portion is poured off, which has a higher specific gravity than the original cider. The ice crystals melt to a nearly colorless fluid, which has a specific gravity of 1 and contains only 0.3 per cent. of alcohol. From ciders with 4 to 5 per cent. of alcohol were obtained by freezing concentrated ciders with 7 to 8 per cent. of alcohol, and 60 to 80 grammes of dry extract per liter, which corresponds with the composition of the richest Normandy cider. These ciders, after remaining for several months in bottles, differed but little as regards color, content, and taste from the best products

of Normandy as certified to by the Congresses of the "Association pomologique de l'Ouest," held in Versailles and Havre. The results thus obtained are entirely different from those by an addition of sugar to the must. While the addition of sugar only increases the content of alcohol, by freezing all the constituents derived from the apple are concentrated, and the same time also the *taste* and *aroma*. For this reason, ciders having a slight by-taste cannot be improved by freezing. The value of light ciders of a pure and agreeable taste is, however, greatly enhanced by the treatment. As regards the third question, G. Lechartier arrives at the conclusion that must and cider in various stages of fermentation are not sterilized even by cooling for 212 hours, the process of fermentation only being retarded during the time of cooling.

*Champagne-cider.*—The manufacture of this beverage has recently become quite important—it resembling the ordinary but more expensive champagne-wine, and being frequently sold as such. Since the devastation of the vineyards by the phylloxera, a large trade in this spurious champagne-wine is carried on in France. Champagne-cider, manufactured in New Jersey, is exported to France, where it is repacked and provided with genuine champagne labels. It is then re-shipped to New York as genuine champagne. This champagne-cider if sold under its right name is an excellent beverage. It is prepared as follows: To 50 gallons of apple-juice add 12 quarts of brandy and 14 lbs. of sugar or honey. Mix the whole thoroughly, and allow it to ferment for one month in a cool place. Then add about 4 drachms of orange-blossom water, and clarify with 2 quarts of skimmed milk. The champagne is now ready and is racked off into bottles, into which a small piece of white sugar is thrown, and the corks of which are wired. The duration of fermentation has been stated as one month; it may, however, last a few days more or less, it being entirely a matter of observation when the most suitable time for racking off has arrived. No more rising of bubbles of gas should be observed, but fermentation must not be completely finished.

According to another direction, 40 quarts of fermented apple-juice are mixed with 2 quarts of solution of sugar,  $\frac{1}{2}$  quart of

rectified alcohol, and 2 ounces and 4 drachms of pulverized tartar. The mixture is allowed to stand 24 hours and then racked off into bottles, each bottle receiving a drachm of bicarbonate of soda. Cork and wire.

Another process consists in bringing into a vat of 40 quarts of apple-juice, 5 pounds of white sugar,  $\frac{1}{4}$  pound of tartar, 1 pint of rectified alcohol,  $\frac{1}{4}$  pint of yeast, and 1 ounce,  $2\frac{1}{2}$  drachms of acetic ether. The mixture shortly before fermentation is finished is drawn off into bottles, each of which has been previously provided with a small piece of sugar. Clarification with isinglass, white of egg, or skimmed milk must, of course, precede the drawing off into bottles. The bottles must be thoroughly corked and wired in the same manner as genuine champagne, and laid in a cool cellar.

Cider serves frequently as a basis for artificial wines, *genuine* Burgundy, sherry, or port-wine, prepared from cider mixed with suitable substances, being frequently served even in first-class hotels. Nothing could be said against these beverages if they were sold under their proper names, because they consist of harmless substances, which cannot always be said of the genuine wines, they being only too frequently adulterated with substances injurious to health.

*Burgundy*.—Bring into a barrel 40 quarts of apple-juice, 5 pounds of bruised raisins,  $\frac{1}{4}$  pound of tartar, 1 quart of bilberry juice, and 3 pounds of sugar. Allow the whole to ferment, filling constantly up with cider. Then clarify with isinglass, add about 1 ounce of essence of bitter almonds, and after a few weeks draw off into bottles.

*Malaga-wine*.—Apple-juice, 40 quarts; crushed raisins, 10 pounds; rectified alcohol, 2 quarts; sugar solution, 2 quarts; elderberry flowers, 1 quart; acetic ether, 1 ounce, 2 drachms. The desired coloration is effected by the addition of bilberry or elderberry-juice; otherwise, the process is the same as given for Burgundy.

*Sherry-wine*.—Apple-juice, 50 quarts; orange flower water, about 2 drachms; tartar, 2 ounces, 4 drachms; rectified alcohol, 3 quarts; crushed raisins, 10 pounds; acetic ether, 1 ounce, 2 drachms. The process is the same as for Burgundy.

*Claret-wine*.—Apple-juice, 50 quarts; rectified alcohol, 4 quarts; black currant-juice, 2 quarts; tartar, 2 ounces, 4 drachms. Color with bilberry-juice. The further process is the same as for Burgundy.

*Diseases of cider*.—Ciders are subject to diseases which may be due to the bad quality of the apples used, a faulty method of fabrication, or bad management in the cellar.

Badly fermented cider, especially such as has merely passed through the stage of tumultuous fermentation, or has been acidified by contact with the air, is liable to produce serious disorders. The first, says Dr. E. Decaisne, being heavy and indigestible, inflates the intestines and produces diarrhœa; the second, though of a sweet taste and a piquant and agreeable flavor, does not quench the thirst, but excites the nervous system and produces flatulency; the third, which is really spoiled cider, causes inflammation of the intestines by the large amount of malic and acetic acids it contains. When in the fabrication of cider, water containing organic matter has been used, putrid fermentation is produced in the mass, the products of which impart some very deleterious properties to the cider.

*Acidity* in cider may be due either to an excess of malic acid or of acetic acid.

Some ciders contain too much malic acid when manufactured from apples not sufficiently ripe, or when, in mixing the apples, too large a proportion of sour apples has been taken. In both these cases the acidity may be neutralized by adding to the apple-juice 3 ounces, 8 drachms of potassium tartrate per 22 gallons. Sometimes there is an excess of acetic acid, due to the oxidation of the alcohol by long contact with the air. This defect is difficult to remedy; it might have been prevented by means of a thin coat of olive oil, as previously mentioned, or by hermetically closing the bungs. The acidity will, however, disappear by putting in the bottles a pinch of bicarbonate of soda. It must, however, be done immediately on detecting the defect.

*Viscosity or greasy appearance* of cider is recognized by the cider becoming stringy, viscous, and greasy, and is due to too great an abundance of gummy substances in the fruit, a lack of tannin, and, finally, to defective fermentation. In order to check



this malady from its first appearance, add to every 228 quarts 1 pint of alcohol or 2 grammes of catechu dissolved in 3 quarts of water. Cider may also be prevented from turning viscous by the addition of sugar to the juice when it comes from the press, which promotes fermentation.

The cause of cider *turning black* is an excess of oxide of iron which, on coming in contact with air, becomes a peroxide and gives the beverage a brown color. The oxide of iron has been introduced into the cider either by the water used in its fabrication, or by fruit grown on ferruginous soil. By mixing such cider with 12 drachms of powdered oak-bark per 22 gallons, a quantity of tannin is introduced which combines with the iron salt to an insoluble product that settles on the bottom of the barrel. Tartaric acid may also be used.

*Turbidity* or lack of clarification of cider is caused by too small a quantity of sugar in the juice, or by imperfect fermentation.

In rainy seasons the apples ripen imperfectly and contain but little sugar. Cider prepared from such fruit generally remains turbid. During seasons in which abrupt changes of temperature take place, and also when cold weather sets in very early, fermentation does not progress well, and clarification is imperfect. When the cider remains turbid after the first racking off, add a solution of 2 pounds of sugar in 1 gallon of water to every 132 gallons of the liquid; this sugar becomes converted into alcohol and renders the cider limpid. The use of lead salt, formerly much employed in Normandy, is very dangerous; persons drinking the cider thus adulterated feel sharp pains in the abdominal region, which present all the symptoms of lead colic, and may prove fatal.

An admixture of lead salt is readily recognized. Add to the cider a solution of potassium iodide, if lead salt be present a yellow precipitate of iodide of lead will be formed.

*Adulteration of cider.*—Cider is but little subject to adulteration according to most of the authorities on food. Even Hassall, who generally enumerates under each article of food a list of every conceivable adulteration that has ever been found or supposed to have been used in such food, only speaks of the addition of water, of burnt sugar as a coloring matter, and of the use of antacids for the correction of the acidity of spoiled cider. On the



other hand, in France, where, as previously mentioned, the consumption of cider is very large, its adulteration is by no means uncommon. Dr. Bremont, in his address at the inauguration banquet of the cider exhibition, at Paris, in 1888 said: "People in Paris who have never travelled do not know what good cider is. The stuff sold as such at the bars and wine-shops here is simply abominable. A few years ago, it is true, it was possible to obtain good cider in Paris, because the demand for it was very small. Since, however, the wine sold became, in consequence of the phylloxera and the greed of the wine dealers, both very dear and very bad, the poorer classes took to drinking cider instead of wine, because it was much cheaper and, at that time, pure. The demand set the adulterators at work and increased the price of the drink. Cider now costs 12 cents a quart in every wine-shop, and in one case out of twenty it is pure and unadulterated. In most cases it is a filthy effusion of water poured on apples, sweetened with glucose and strengthened with vile alcohol."

The above statement is fully confirmed by the report of the Paris municipal laboratory. Besides the washings of the dregs or residue, and watering, which is almost generally practised, some coloring matters are added; salicylic acid and sulphites are also used to insure its keeping while in course of transportation, and an excess of acidity is covered by means of lime or of carbonate of soda. Brandies of inferior quality are added in order to correct the flavor, and, as already stated, white lead has been used to overcome an excess of acidity. Finally a frequent falsification is the fabrication of cider from apples crushed and dried by heat and starch-syrup. Of 63 samples examined in 1881, in the municipal laboratory, 39 were pronounced "bad," among which were 26 artificially colored; in 1882, 59 samples were examined of which 30 were declared "bad," of which 7 samples were artificially colored; 2 samples contained salicylic acid. The following is considered in the municipal laboratory as a minimum limit for the composition of a pure cider and any sample which falls below it in any constituent is considered as watered:—

Alcohol, per cent. by volume . . . . .	3.00
Extracts, in grammes per liter . . . . .	18.00
Ash . . . . .	1.7

This is for a completely fermented cider; in sweet ciders the content of sugar should exceed the limit sufficiently to make up for the deficiency of alcohol, to which it should be calculated.

In the samples of American ciders investigated by the United States Agricultural Department (see p. 332) it was fully expected to find a considerable number preserved with antiseptics. This supposition failed to be confirmed, however, for no salicylic acid was found, and in but one case was any test obtained for sulphites. None of the samples fell below the standard proposed by the French chemists, given above, and no metallic or other adulteration was discovered.

There was, however, a single exception, No. 4927 in the table of analyses (p. 332), which was an embodiment in itself of nearly all the adulterations which have been enumerated as possible in cider. It was handsomely put up in neatly capped bottles, and was of a clear, bright color. Its tremendous "head" of gas when uncorked gave rise at once to the suspicion that it had received some addition to produce an artificial pressure of gas. The low content of free acid, together with the large amount of ash and a very variable content of carbonic acid in different bottles, established the fact that bicarbonate of soda had been added, probably a varying quantity to each bottle, while the dose of sulphites added was so large that a bottle has stood open in the laboratory all through the summer without souring.

*Manufacture of brandy from cider.*—Brandy is a mixture of water and alcohol produced by the distillation of a fermented liquor; it owes its aroma to the essential oil peculiar to the substances subjected to distillation.

In Normandy the heavy ciders only are distilled, *i. e.*, those containing the most alcohol.

In years when there is an abundant crop of apples, it will generally be found of advantage to distill the cider made from fallen fruit and also from early apples. The cider yielded by them does not keep well and brings a very low price, especially when there is a large product from late apples.

Sour ciders should not be distilled, they being better utilized for the manufacture of vinegar. Spoiled cider, as a rule, makes bad brandy.

Different qualities of cider should be distilled separately; a

skilful distiller can classify them by the taste and separates them in order to obtain brandy of first and second qualities.

The cider is distilled when it is completely fermented, *i. e.*, when the largest possible quantity of sugar has been converted into alcohol. Cider from early apples generally ferments faster than that from late apples and can be distilled towards the end of December, *i. e.*, from six weeks to two months after its fabrication. Cider from late apples, made during December and January, is ready for distillation three or four months later, *i. e.*, in March or April.

*Preparation of the juice for distillation.*—When there is an abundant crop of apples and barrels are scarce, the juice as it comes from the press is brought into large open vats in which fermentation progresses rapidly, but in this case some beer yeast previously mixed with a small quantity of cider is added to each vat and the temperature must be maintained between 59° and 68° F. Under these conditions the juice ferments very promptly and may be distilled eight or ten days later.

Sometimes the whole of the pulpy mass obtained by grinding the apples is submitted to distillation. In order to accelerate fermentation a small quantity of hot water containing some sugar in solution is added to the mass, also one or two thousandths of sulphuric acid, the latter regulating the progress of fermentation.

Fermentation being finished the mass is subjected to distillation. In order to prevent the mass from adhering to the still and burning, distillation must be conducted as slowly as possible and a small quantity of straw placed upon the bottom of the still, or, better, a piece of cloth to prevent direct contact of the mass with the heating surface.

Plums, damsons, etc., are also subjected to distillation and produce good brandy; they ferment more slowly than wild cherries which produce the well-known cherry-bounce. Attention may here be called to the distillation of wild plums, which should be gathered in the fall when the leaves begin to drop. Some connoisseurs consider brandy made from plums equal to that from cherries. On a farm no fruit containing sugar should go to waste as it can be converted either into brandy or vinegar.

*Distillation.*—For distilling cider on a small scale no expensive



apparatus is necessary, an ordinary still answering all requirements. Cider is distilled like wine. The still is filled about  $\frac{3}{4}$  full and after placing the head in position the joints are carefully luted by pasting strips of cloth or even paper over them. The tub holding the worm is filled with cold water and the fire started. The vapors escaping from the boiling liquid condense in the worm and run into the receiver. Heating should be done slowly in order to vaporize as little water as possible and especially to avoid sudden ebullition as the boiling liquid, getting into the head, would pass through the worm and become mixed with the liquor already distilled; in such an event it would be necessary to begin distillation anew. The operation is continued until the liquid produced contains hardly any alcohol which can be ascertained by the use of the alcoholometer or by the taste. It is unnecessary to say that care must be had to constantly renew and keep cold the water in the tub holding the worm.

Distillation being finished the boiler is emptied and after thorough cleansing is refilled for a second operation.

The liquid produced by successive distillations is mixed together and brought into the still a second time, whereby a liquor richer in alcohol and of a better taste is produced. It would be desirable if this second distillation or rectification could be effected by means of steam. This would prevent the empyreumatic taste which is often noticed in apple-brandy. The first and last runs of the still being of inferior quality are collected separately and poured back into the still when refilling for the next operation.

Calculations have been made to establish by means of figures the immense advantage offered in a financial point of view by the distillation of cider. These theoretical calculations are, however, frequently very deceptive. If, on the one hand, the producer knows the content of alcohol of his cider and, on the other, the market value of the alcohol and of the cider, it will be easy for him to decide which product will pay him best.

*Pear-cider.*—The manufacture of pear-cider is very limited and no great future can be promised for it, as even when most carefully prepared, it is far inferior to cider and other fruit-wines. Its fabrication is best understood in England, and how little it is appreciated there is shown by the fact that three-fourths of the

quantity manufactured is consumed by the farm-laborers. But any one who has large pear crops at his disposal and wishes to use a portion of them for the manufacture of a beverage should add to the pear-must one-quarter its quantity of must of bitter-sweet apples or a few quarts of black currant juice, which will improve the taste of the cider and its keeping qualities. The mode of preparation is the same as for apple-cider, though still greater care must be exercised in the choice of the raw material. The pears must have a sufficient content of sugar as otherwise the cider would not be sufficiently rich in alcohol and at the same time they must contain a bitter substance to prevent the cider from turning sour as soon as the conversion of the sugar is effected. Hence the use of fine table pears for the preparation of cider would be simply a waste of material. The only varieties suitable for the purpose are those which when eaten from the tree produce a long continued sharp heat in the throat and lie half a day undigested in the stomach which, however, become sweet by long storing and lose enough of their acerbity to be no longer disagreeable to the palate. In England the wild pear grown in hedges is generally used for the purpose. They must be ripe but not soft or mellow.

In the northern part of France pear-must is sometimes used for the preparation of "port-wine," the taste of which is very much praised. The process consists in heating 50 lbs. of must to  $176^{\circ}$  or  $185^{\circ}$  F. and adding 5 lbs. of raisins. At this degree of heat must and raisins are brought into a barrel which is tightly bunged and placed in a cool place. When in the course of a day the must is cooled to  $59^{\circ}$  or  $68^{\circ}$  F., the raisins, which are generally put in a bag, are taken from the barrel and after bruising returned (but not inclosed in the bag) to the must, which is then allowed to ferment for 14 days. The wine is then drawn off into stone jugs which are well corked and sealed.

*Quince-wine.*—A very spicy wine can be prepared from quinces in the following simple manner: Place the quinces for a few moments in hot water and then rub them with a cloth to remove the down. Next remove the cores by means of a knife or in any suitable manner. Now pour hot water over the quinces thus prepared and boil them slowly over a moderate fire until



soft. Then press out the juice and add white sugar in the proportion of  $1\frac{1}{2}$  lbs. to every 20 lbs. of fruit. Allow the whole to ferment in a cool room and from time to time add some sugar-water during the process. Clarification and racking off is effected in the same manner as with cider.

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## CHAPTER XXVIII.

### FRUIT-WINES.

#### *a. From small fruits.*

ONE of the principal objections to wine from small fruits is that it easily turns; this can, however, be overcome by adding, after fermentation is finished, 5.64 drachms of salicylic acid to every 100 quarts. By increasing the dose to 8.46 drachms less sugar can be added to the must which, of course, makes the beverage poorer in alcohol. A saving of sugar can be further effected without injury to the keeping quality of the wine by a suitable mixing of juices. By working, for instance, the juices of currants, or of raspberries by themselves, a considerable addition of sugar, about 1 pound per quart, has to be made, which can, however, be reduced one-half by mixing with a juice containing some bitter principle, and later on treating the wine with salicylic acid. Thus a large field for experimenting is opened to all, and only a few hints will here be given. Raspberry-juice should be mixed with one-quarter its volume of blackberry-juice; and in the preparation of currant-wine it is especially recommended to use four-fifths of red to one-fifth of black currants, the wine obtained being far more spicy and possessing better keeping qualities. Moreover, black currants used within limits are an excellent material for improving the flavor of almost all fruit-wines. The flavor and keeping qualities of fruit-wine are also improved by throwing a couple of handfuls of crushed hazel-nuts or walnuts into the barrel, and also by the addition of 2 ounces, 3 drachms of bitter almonds, the peels of 10 lemons, 3 ounces, 5 drachms



of cassia, and a few handfuls of bruised wild plums. By these means wine with a moderate content of alcohol acquires a strong taste, while its keeping quality is at the same time improved; the latter can also be effected by bringing 2 ounces, 3 drachms of tartar into the barrel during fermentation. A few other mixtures of juices may be mentioned. Blackberry-juice is better adapted to ferment by itself than any other juice from small fruits, but by the addition of  $\frac{1}{8}$  to  $\frac{1}{4}$  its weight or its volume of strawberry-juice the aroma of the wine is greatly improved. Strawberry-juice is least suitable for fermentation by itself, and should be mixed with must containing a bitter principle; the addition of  $\frac{1}{6}$  of the volume of the juice of the Siberian crab-apple (*Pyrus baccata*) can be highly recommended for the purpose, it being especially suitable for improving the keeping quality of fruit-wine. The juice of rhubarb stems may be added to that of elderberries, while the juice of gooseberries is suitable for mixing with that of mulberries. Moreover, a combination of several juices may also be used, an excellent wine being, for instance, prepared from equal parts of blackberry, raspberry, currant, and strawberry-juice, with an addition of walnuts as given above. In the receipts for the different varieties given below, the customary addition of sugar for unmixed fermentation and the omission of salicylic acid is retained; it may, however, be repeated that with the assistance of these means the cost may be reduced one-half. In order to avoid repetition the following general rules are here given which hold good not only for the preparation of wine from small fruits, but also from stone-fruits.

The fruit to be used should be sound and ripe, though not over-ripe, and must be freed from adhering dirt by washing in warm water. Large quantities are best expressed by means of a press while for small quantities a bag of coarse linen is sufficient which is kneaded and squeezed until no more juice runs out. Over the residue pour as much hot water as juice is obtained and after allowing it to stand for two hours press again and mix the juice obtained with the first. Now add sugar in the proportion of one pound to a quart of juice and bring the whole into a thoroughly cleansed barrel previously rinsed out with salicylated water. Fermentation should take place in a room having a uni-

form temperature of from 59° to 64° F. During this process lay a piece of gauze upon the open bung-hole and secure it by means of a stone, piece of iron, etc.; this prevents the access of foreign substances to the must. Every other day the barrel is filled up to the bung-hole with sugar-water prepared in the proportion of  $\frac{1}{2}$  lb. of sugar to 1 quart of water. As soon as the "hissing" in the barrel ceases bung the barrel tightly and after 14 days draw off the contents into another barrel placed in the same room. After 6 months the wine can be drawn off into bottles, being, however, 8 days previously clarified with the whites of a dozen eggs or 1 oz. of isinglass slowly dissolved over a moderate fire in 1 pint of wine. Whatever fining is used add it to the wine with constant stirring. If salicylic acid is to be used it is best done in the manner described for cider when the wine has acquired the desired degree of ripeness. The bottles should be rinsed with salicylated water and closed with corks previously soaked for a few hours in hot salicylated water. Sealing the bottles is not necessary but in order to be sure that the corks fit closely shake each bottle, with the neck downwards, with the right hand holding the left under the cork. If the slightest moisture is observed, the bottles must be recorked, as carelessness in this respect may cause a portion of the supply of wine to spoil. The corked bottles are laid in the cellar.

This general method, according to which all kinds of wine from small fruits can be prepared, may be supplemented by the following receipts:—

*Currant-wine.*—Among all varieties of berries the currant contains the largest quantity of free acid, about 2 per cent., and comparatively little sugar, about 6 per cent. The proportion between these two principal constituents is very unfavorable for the manufacture of wine, and currant juice fermented by itself would yield a product which does not deserve that name.

Free the thoroughly ripe currant from the stems and after crushing press out the juice. To the residue add twice or three times as much water as juice obtained and after again pressing add the juice obtained to the first. Now examine the juice as to its content of acid and if necessary dilute further with water. Then calculate the sugar in the manner given on p. 326. Sugar

and acid having been brought to the right proportion, the juice is allowed to ferment.

Currant-wine is frequently prepared as a sweet liqueur-wine, the following directions being much used for the purpose: Juice 100 parts, water 200, sugar 100. According to an analysis by Fresenius, the wine thus prepared showed after two years the following composition:—

Alcohol	.	.	.	.	.	.	.	10.01
Free acid	.	.	.	.	.	.	.	0.79
Sugar	.	.	.	.	.	.	.	11.94
Water	.	.	.	.	.	.	.	77.26
								<hr/>
								100.00

According to another receipt,  $17\frac{1}{2}$  lbs. of thoroughly ripe currants freed from the stems are bruised in a wooden vessel with the addition of  $3\frac{1}{2}$  quarts of water. The paste thus obtained is gradually brought into a bag of coarse linen, which is laid upon an oblique board, and pressed out by means of a rolling-pin. The press-residues are returned to the wooden vessel and, after adding 7 quarts of water, thoroughly worked with a pestle, and then again pressed in the above manner. The juice thus obtained is brought into a barrel having a capacity of  $34\frac{1}{2}$  quarts, a solution of 12 lbs. of sugar in 14 quarts of water is then added, and finally sufficient water to fill up the barrel to within 3 inches of the bung. After covering the bung-hole with a piece of gauze, the whole is allowed to ferment in a room having a temperature of from  $59^{\circ}$  to  $64^{\circ}$  F. When the principal fermentation is over the barrel is entirely filled with water and closed with a cotton bung. The wine is then allowed to further ferment for 6 months in a cellar having a temperature of from  $54^{\circ}$  to  $59^{\circ}$  F., when it is drawn off into another barrel or into bottles. By adding to the fermenting juice  $\frac{1}{8}$  lb. of comminuted raisin stems a product closely resembling Tokay-wine is obtained.

A very strong beverage is obtained by adding to the expressed juice of currants twice the quantity of water and stirring in 2 tablespoonfuls of yeast. Allow the juice to ferment for 2 days, then strain it through a hair-sieve, and after adding 1 lb. of sugar for every quart, allow it to ferment. When fermentation is nearly finished add French brandy in the proportion of 1 quart to 40

quarts of the juice, and bung up the barrel two days later. The wine is ripe in four months.

According to another receipt the currants, separated from the stems, are pressed and the juice mixed with an equal quantity of water. Then add to each gallon of liquid  $2\frac{1}{2}$  lbs. of sugar, 2 ozs. of cream of tartar, and 1 oz. of pulverized nutmegs, with 1 quart of alcohol. Allow the whole to ferment, then fine with isinglass, draw off and bottle.

Another method is to express all the juice possible, then take an equal amount of boiling water, and pour on the pressed fruit; let it stand for 2 hours, squeeze out as much as there is of juice and mix; then add 4 lbs. of brown sugar to each gallon of the mixture; let it stand for 3 or 4 weeks, until fairly worked, with the bung out, and when it is done working, bung it up, then place it in a cool cellar.

*Strawberry-wine.*—For the preparation of wine very fragrant strawberries should be selected. The aroma of the strawberry is so delicate that it readily undergoes a change and soon disappears entirely. Hence to secure it and transfer it into the juice the strawberry requires special treatment, whereby neither the content of acid nor that of sugar is taken into consideration. This treatment consists in mixing the sound, ripe berries, without previous crushing or bruising, with the same weight of pulverized sugar and allowing the mixture to stand in a glass or stoneware vessel in a cool place until all the sugar is dissolved to a clear syrup in which the shrunk and tasteless berries float. To separate the latter, strain the juice through a woollen cloth previously rinsed with some lemon-juice or tartaric acid, dilute with the same quantity of water, bring the acid to 0.5 per cent., and subject the whole to fermentation in the usual manner at a temperature of from  $50^{\circ}$  to  $59^{\circ}$  F.

Some allow the berries to ferment with the juice, but the wine obtained is somewhat harsh and not as delicate.

By finally adding to the finished wine from 4 to 5 per cent. of rock-candy, a liqueur-wine is obtained which, as regards aroma, cannot be surpassed and is especially liked by ladies.

Excellent strawberry-wine is also obtained according to the following directions: Press out 10 lbs. of different varieties of

small and large cultivated strawberries, which give about  $2\frac{1}{2}$  quarts of juice. Pour water over the residue and press again, so as to obtain about 3 quarts more of juice or a total of  $5\frac{1}{2}$  quarts. Next dissolve 4 pounds of rock-candy in 5 quarts of cold water, bring the solution, together with the  $5\frac{1}{2}$  quarts of juice, into a small cask, and allow the whole to ferment in a cellar having a temperature of  $61^{\circ}$  F. In four weeks the wine is ready for drawing off into bottles. It is of a beautiful pale yellow color and possesses an excellent bouquet, and if made sparkling furnishes an excellent beverage.

According to a receipt in the "Weinzeitung," 40 quarts of strawberries and 41 quarts of water, with an addition of 12 lbs. of sugar,  $3\frac{1}{2}$  ozs. of tartar, and a gallon of whiskey free from fusel oil are allowed to ferment and the resulting wine is treated in the usual manner.

Another method is to pour 1 quart of hot water upon 1 quart of crushed strawberries and pressing out after allowing the mass to stand for 2 days. Then add to every quart of juice 1 lb. of sugar, and to every 40 quarts of juice the grated peel and juice of 2 lemons and 2 oranges and 4 quarts of French brandy. Allow the whole to ferment, and treat the resulting wine in the usual manner.

*Gooseberry-wine.*—The proportion between sugar and acid is somewhat more favorable in the gooseberry than in the currant, but not sufficiently so as that the pure juice would yield a good wine by fermentation. Hence the juice must be converted into suitable must, as regards sugar and acid, in accordance with the rules given on p. 325. The yellow varieties are preferable, they alone having a distinctly vinous taste; the wine obtained from the red and green varieties is somewhat insipid. The juice is obtained in the same manner as from currants, the berries being bruised, the juice allowed to run off and the residue washed several times with water, so that each volume of juice receives an addition of 1 volume of water, though as the mixed juice has to be tested as to its content of acid, the direction in regard to the addition of water need not be accurately followed. The must may contain as much as 30 per cent., because the fermentation of gooseberry-must is generally carried on in the warmer season



of the year, so that all or the greater portion of the sugar ferments and the wine, on account of the quantity of alcohol formed, will keep for an almost indefinite time. Gooseberry-wine made from must rich in sugar generally acquires by age an odor of Madeira-wine, which frequently deceives even connoisseurs.

Gooseberry-wine like currant-wine being liked sweet, a larger quantity of sugar may be added to the must from the start though for a quicker progress of fermentation it is better to add the desired quantity of sugar to the fermented wine; if the must has been made quite sweet so that a wine rich in alcohol is formed no fear need be had of the wine fermenting anew on account of the addition of sugar.

There are a number of receipts for the preparation of gooseberry-wine, but when more closely examined the products prepared according to them will be found either more or less rich in alcohol or to contain more or less free acid and be either sweet or not sweet, so that the proportion can evidently be changed in any manner desired. It is further evident that nothing is gained thereby as regards quality, because the type for all artificial wines is grape-wine obtained in a good season. In such wines the proportions between alcohol and free acid are well known and within such narrow limits that they cannot be essentially exceeded on either side, and they alone can serve as a basis for the rational preparation of gooseberry-wine as well as of all artificial wines. With the aroma or bouquet which is to be imparted to such wine it is, of course, different, but no special directions are required as every one manages it according to his own taste or according to that of those who buy and drink the wine. Thus, it is also with the addition of sugar; one likes a sweet wine, the other one less sweet and the third one without any sugar. The principle aim is to prepare a wine which contains the necessary quantity of alcohol to insure its keeping properly, and the power of resistance against decomposing influences and from which the greater portion of the fermenting substances is removed by fermentation. In most cases the natural conditions are of great use in this respect, for in order to decrease the content of free acid it becomes necessary to dilute the fruit juices whereby the quantity of fermenting substances is also relatively decreased, and sometimes even to such



an extent that they do not suffice for the complete fermentation of the sugar. Such wine, if not wanting in alcohol, will keep for an almost indefinite time and may be exposed to the access of air and a high temperature without the appearance of the formation of acetic acid.

*Gooseberry-champagne.*—The taste of this beverage closely resembles that of genuine champagne. There are several modes of its fabrication. In France a light wine which does not contain too many fermenting substances is used. Somewhat less than 2 per cent. of sugar, or about 15 grammes to a bottle of 800 cubic centimetres' capacity, is dissolved in the wine and the latter drawn off into strong champagne bottles which are then hermetically corked and tied with twine. The wine is then allowed to ferment in a room having a temperature of from 77° to 99° F. When fermentation is finished, the bottles are brought into a cool cellar and placed first horizontally and then gradually bottom uppermost so that the yeast may collect on the cork and the wine become clear. When all the yeast is precipitated to the neck of the bottle, the sediment is carefully removed—*degorgie* as it is termed—by first raising the string securing the cork and then the latter, the bottle being held in a horizontal position. The cork being no longer held by the string is forced out together with the deposit of yeast while the clear wine impregnated with carbonic acid remains behind. To prevent the unavoidable loss of wine, the cork together with the yeast and wine forced out is collected in an upright barrel with a large aperture towards which the mouth of the bottle is held during the operation.

The wine thus impregnated with carbonic acid, however, is not yet champagne; it only becomes so after the addition of a solution of fine rock candy in brandy with which the bottle is filled up. Each bottle after receiving the necessary quantity of the solution, or *liqueur* as it is termed, is at once closed with a cork which is secured with twine or wire. Removing the deposit of yeast is the most difficult portion of this operation, long experience being required before the workman possesses the necessary skill.

According to another method, which is also called the impregnating method, the sugar required for sweetening is dissolved in the wine, and after clarifying the solution by filtering through

paper pulp in a bag, or, if necessary, with some isinglass, it is taken to the impregnating apparatus, one similar to that used for mineral water answering the purpose. The wine is then saturated under a pressure of  $4\frac{1}{2}$  to 5 atmospheres with the desired quantity of carbonic acid and at once drawn off into bottles, which are corked and wired as above.

The advantage of this method consists in the rapidity with which champagne can be made, 30 to 36 months being required for the first method before the champagne is ready for transportation.

The following method is the most simple of all, but does not yield as fine a product. Each bottle is finished by itself and no special apparatus is required. The wine is sweetened and clarified in the same manner as in the impregnating method and then drawn off into bottles. In case the wine is not rich enough in alcohol, the content of the latter may be increased by 10 per cent.

After having filled the bottles about 1.52 cubic inches less than generally, add first to each bottle 11 drachms of pure crystallized bicarbonate of potash and immediately afterwards 1 oz. of pure crystallized tartaric acid in pieces. Then close the bottle with the cork and secure the latter by tying or wiring it cross-wise. The potash and acid are now brought to solution by gently swinging the bottle to and fro, the contents becoming at the same time turbid by the separation of bitartrate of potash. By placing the bottle bottom upwards the separated tartar is collected as much as possible upon the lower surface of the cork and after the wine is clear removed in the same manner as described in the first method. It is not absolutely necessary to remove all the tartar as it settles on the bottom and the champagne will pour out clear.

According to any of these methods all fruit-wines can be converted into champagne or sparkling wines.

Semler gives the following directions for the preparation of gooseberry-champagne. Pour 20 quarts of warm water over 20 quarts of crushed gooseberries and add 6 lbs. of sugar,  $4\frac{1}{2}$  lbs. of honey, 1 oz. of pulverized tartar,  $\frac{1}{2}$  oz. of dried lemon peel, and  $\frac{1}{2}$  oz. of dried orange peel. After standing for two days strain the

mixture through a hair-sieve into a barrel and add 2 quarts of French brandy. When the "hissing" in the barrel ceases clarify the wine and after a few days draw it off into bottles securing the corks with wire. Before filling the bottles throw a piece of sugar and  $\frac{1}{2}$  drachm of bicarbonate of soda into each.

*Raspberry-wine.*—Raspberries have such an agreeable and refreshing taste and odor that while they are not very sweet and the proportion of acid to sugar is not very favorable they are great favorites. Their aroma passes into the wine and would be even too predominant if for the preparation of wine the juice had not to be strongly diluted with water in order to decrease the acid.

As in all other fruit, the quality of the raspberry depends on the weather, and when this is favorable during the time of the development and maturing of the fruit, the latter is sweet and palatable, but in cold and wet seasons sour and harsh. No other fruit suffers as much from such conditions as the raspberry.

We have the wild and cultivated raspberry. The wild raspberry is smaller than the cultivated but possesses a stronger aroma; unfortunately it is too frequently infested with the larva of many insects to render it always palatable. The cultivated raspberry is considerably larger, and is less attacked by worms, but possesses less aroma and is frequently even watery.

To obtain the juice for the preparation of wine the thoroughly ripe raspberries are crushed to a paste in a wooden tub by means of a wooden pestle. To separate the grains the paste is forced through a fine wire sieve, which, in order to protect it from the acid, is best provided with a coat of asphalt or shellac varnish. It is, however, no disadvantage to allow the grains to ferment with the pulp, some tannin being thereby introduced into the wine which under certain circumstances may be even desirable.

The content of acid in the raspberry varying considerably in different years, a test of the juice in this respect becomes absolutely necessary in order to enable one to dilute it in the correct proportion with water. For this purpose press out a small quantity of the crushed raspberries and determine the acid in the manner given on p. 325. The sugar contained in the raspberry need not be taken into consideration, since by dilution it is

reduced to 1 per cent. and still less. The must is simply brought up to 25 per cent. of fruit-sugar and allowed to ferment in the usual manner. The treatment of the wine after fermentation is the same as for other fruit-wines.

*Blackberry-wine* is prepared in the same manner as raspberry-wine. Of the numerous directions for its preparation we give the following: Gather the berries on a dry day, crush them with the hand into a kettle, and add just enough hot water to cover the mass. Then add a handful of bruised raisins and a handful of strawberry leaves, from the heart of the mother plant, or, still better, from the suckers, and allow the mass to stand for four days, when a crust of yeast will have formed on the surface. The mass is now pressed out and sugar in the proportion of 1 pound to every 4 quarts added. Fermentation is allowed to go on for two weeks; the barrel is then bunged up and the wine drawn off after six months. During fermentation, and especially in the beginning of it, care must be had to fill up the barrel.

To make from blackberries a beverage resembling port-wine the following method is recommended: Press out the juice and allow it to stand for 36 hours. While fermenting during this time remove all scum from the surface. Now add one-fourth the quantity of juice, of water, and 3 pounds of brown sugar to every 4 quarts of fluid and filter after 12 hours. Fermentation, which requires but a few days, being finished, bung up the barrel tightly and after six months draw off the wine. The latter improves by age.

*Mulberry-wine*.—Press the juice from the fruit, dilute with the same quantity of water, add 1 pound of sugar for every quart of liquid, and boil the whole  $\frac{1}{4}$  hour. Then add for every 100 quarts 3 quarts of alcohol,  $6\frac{1}{2}$  ounces of tartar, 1 ounce of cassia, and  $\frac{1}{2}$  ounce of bruised bitter almonds, and allow the whole to ferment. The further treatment of the wine is the same as for other fruit-wines.

*Elderberry-wine*.—Boil equal quantities of berries and water one-half hour, pour the whole into a hair-sieve, press the pulpy portion of the berries gently through with the hand and remove the residue. Compound the strained juice with sugar in the proportion of  $\frac{3}{4}$  pound to 1 quart and boil 20 minutes. As soon as

cool bring it into a barrel to ferment. Fermentation being finished paste stiff brown paper over the bung-hole, and after eight weeks draw off the wine into bottles.

Another method is to boil 50 quarts of water, 10 quarts of elderberries, 40 pounds of sugar, 5 ounces of pulverized ginger, and  $2\frac{1}{2}$  ounces of cloves for 1 hour, with constant skimming. Then bring the liquid together with 4 pounds of crushed raisins into a barrel and allow it to ferment. At the termination of the fermentation it will yield a wine similar to the Cypria or Greek-wine.

*Juniperberry-wine.*—70 quarts of water, 35 pounds of crushed raisins, 10 quarts of juniperberries, 4 ounces of tartar, 1 quart of French brandy, and a handful of fresh marjoram leaves are brought into a barrel and the mixture is allowed to ferment for 12 hours.

*Rhubarb-wine.*—Add to every 5 pounds of the thinly-sliced stalks  $2\frac{1}{2}$  quarts of soft water and bring the whole into a clean wooden vessel. Cover the latter and stir the contents with a wooden stick three times daily for one week. Then pass the fluid through a wide-meshed sieve and add to every 3 quarts 4 pounds of white sugar, the juice of 2 lemons, and the peel of 1 lemon rubbed upon sugar. Allow the mixture to ferment in a barrel, and after clarifying draw the wine off into bottles in March.

The variety of rhubarb, known as Victoria, is best adapted for the preparation of wine which can also be effected according to the following directions: Cut up the stalks and express the juice. To every gallon of juice add 1 gallon of soft water and 7 pounds of brown sugar. Bring the mixture into a barrel and allow it to ferment until clear with the bung out, keeping the barrel filled with sweetened water as it works over, then bung the barrel tightly or draw the wine off into bottles. It makes an agreeable and healthful wine, affording a good profit, as nearly 1800 gallons of wine may be obtained from each acre of well-cultivated plants. The stalks will furnish about three-fourths their weight in juice.

*Tomato-wine.*—Press out the juice from ripe tomatoes, add to each quart of it 1 pound of brown sugar, and allow the whole to



ferment. After three months the wine can be drawn off into bottles.

*Parsnip-wine.*—Cut 12 pounds of parsnips into thin pieces, add 15 quarts of water and boil until soft. Then press out the juice and after straining through a hair-sieve sweeten with  $\frac{3}{4}$  pound of sugar per quart. After again boiling for  $\frac{3}{4}$  hour it is brought, when cold, into a barrel and a tablespoonful of yeast is added. Stir the juice daily for 10 days then bung up the barrel tightly and after six months draw off the wine into bottles.

In the same manner wine may be prepared from carrots, clover-heads, corn-stalks, etc. It is, however, recommended to add to the juice some aromatic substance such as a handful of marjoram, almonds, plum-kernels, currants, walnuts, ginger, or still better a few quarts of black currant juice.

#### *b. From Stone-Fruits.*

*Cherry-wine.*—Stone sweet cherries and after crushing the pulp to a paste allow it to ferment in stoneware pots for 12 hours. Then press out the juice which is returned to the pots and allowed to stand until yeast fungi rise to the surface. Now add 1 pound of sugar to every 3 quarts of must, bring the latter into a barrel and allow it to ferment 8 days. Then rack the wine into bottles and keep in a cool place. The preceding is the method followed in England where pure cherry-wine is made. It may, however, be remarked that it is somewhat insipid. A mixture of the juice of cherries with that of the raspberry or currant can, however, be highly recommended, it yielding a beverage similar to port-wine. It is an American receipt and much preferable to the English. Press the freshly gathered cherries, black or red, but selecting those with the softest pulp, without crushing the stones. To the juice obtained add one-eighth of its quantity each of raspberry and black currant juice and sweeten with lump sugar in the proportion of 1 pound to  $2\frac{1}{2}$  quarts of juice. The whole is then brought into a barrel to ferment. When fermentation is finished close the barrel tight and allow it to rest for three months. Then clarify the wine and draw it off into bottles. It is fit to drink in six weeks.



*Morello-wine.*—Press 60 pounds of morellos so as to crush the stones, mix the juice obtained with 20 quarts of sherry-wine and the same quantity of warm water, and bring the whole into a barrel to ferment. Suspend in the barrel a bag containing  $1\frac{1}{4}$  ounce each of cinnamon, powdered nutmeg, and mace, allowing it to remain until drawing off the wine. The latter is very palatable in two months after fermentation is finished.

*Plum-wine.*—Not all varieties of plums are suitable for the preparation of wine, but the Reine Claude and Mirabelle can be highly recommended, the latter especially making as spicy and agreeable wine as any variety of fruit. With the almost innumerable varieties of plums it is not possible to say which are suitable for the preparation of wine, and which are not. It can only be determined by experiment, though right sweet varieties only should be chosen. In this country the small sweet variety known as the wheat-plum, etc., is frequently used for the purpose. The process is as follows: Stone the plums, then bruise the pulp, and add to every 8 pounds of the latter 3 quarts of hot water. After 2 days press out the juice and add to every 2 quarts of it one pound of sugar. Now bring the juice into a barrel in a cool room and add the crushed kernels of  $\frac{1}{5}$  of the stones. Allow the whole to ferment completely. After 12 months the wine is clarified and drawn off into bottles, each of which receives a small piece of sugar, which improves the keeping quality of the wine.

*Apricot and peach-wines.*—Both these varieties are used when nearly ripe. Remove the stones and crush the pulp to a paste. For every 8 pounds of the latter add 1 quart of fresh soft water, and let the mass stand 24 hours. Then press out the juice, add for every 2 quarts of it 1 pound of sugar, and allow it to ferment. During fermentation it is recommended to throw a handful of the crushed stones into the barrel, which gives to the product a more spicy flavor.

*Sloe or wild plum-wine.*—This beverage is not to be despised if prepared in the manner given for plum-wine. The sloes must, however, remain on the bushes until after the first frost, which sweetens them.



## PART III.

### CANNING AND EVAPORATING OF FRUIT, MANUFACTURE OF CATCHUPS, FRUIT-BUTTERS, MARMALADES, JELLIES, PICKLES, AND MUSTARDS.

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#### CHAPTER XXIX.

##### PRESERVATION OF FRUIT.

THE use of hermetically closed tin cans is the only method for preserving fruit which has become of commercial importance. Before discussing it, the various ways which have proved more or less satisfactory for household purposes will be briefly mentioned. The following rules apply, however, to all methods:—

1. The fruit must be gathered in dry weather and when free from dew ; it is to be kept as free from dust as possible.

2. Absolutely sound fruit, not over-ripe, should only be selected.

3. The fruit should be preserved immediately after gathering.

4. The utensils used must be kept scrupulously clean.

5. The preserving vessels should not be placed directly upon the fire.

6. A good quality of white sugar only should be used ; brown sugar injures the taste and color of the fruit.

7. Copper or brass kettles alone should be used for boiling, if the latter is not effected in glass ; the spoons should be of wood or of bone.

8. The jars or cans should be thoroughly rinsed best with salicylated water, and if corks are to be used they should be perfectly sound and scalded in hot water to which some salicylic acid has been added.

9. Small jars or cans are preferable to large ones, and they should be kept in a dark, cool, dry place.

We will first mention the old French method, known as *au Baine-Marie*, which, on account of its simplicity, is still much used. Berries require no preparation, but peaches, apricots, and plums must be stoned and halved, and cherries and small plums stoned. Apples and pears are peeled and quartered and immediately thrown into boiling water for 4 minutes to bleach. They are then laid a few minutes upon a sieve to dry, and brought, like other fruit by means of a spoon into wide-necked glass jars which are filled to within 2 inches of the edge. In placing the fruit in the jar press it well together. The empty space is then filled up with hot syrup composed of 2 parts of sugar and 1 part of water, and the jars, after heating them somewhat upon a stove, are placed in boiling water for 8 minutes for kernel fruit and for 10 minutes for stone fruit or berries. The jars are then immediately corked and sealed.

According to another French method, the flesh of the fruit is preserved without boiling. Stone-fruits and berries only can be used. The fruit is pressed through a hair-sieve and the pulp mixed with an equal weight of pulverized sugar. The mixture is then brought into glass bottles which are corked and sealed. This fruit-pulp keeps, however, only through the winter, or if kept in a cold place or in a refrigerator.

The following method gives better satisfaction: The fruit, such as cherries, berries, plums, peaches, apricots, etc., is, without the addition of water, brought into wide-necked glass jars in such a manner that a layer of fruit alternates with a layer of sugar, the top layer being sugar. The jars are then tied up with salicylated parchment paper, placed in a water-bath, and the water kept boiling for 15 to 30 minutes, according to the variety of fruit, small fruit requiring less time than large, and berries only about 15 minutes. The jars are then stored in a cool, dark place. For closing jars with narrow mouths corks are preferable. They are soaked in hot salicylated water and sealed.

Fruit thus preserved retains its fresh, natural appearance and keeps for a considerable time. If appearance is, however, of secondary consideration, it is better to boil the fruit, as is done with kernel-fruit, melons, and all large varieties. The preparation for this method varies according to the nature of the fruit.

Apples and pears must be peeled, and, if not too large, only cored, otherwise they have to be halved or quartered. Melons are peeled and cut into strips. Quinces are steamed until soft, then peeled as clean as possible, quartered, and the cores removed. After this preparation the fruit is brought into the preserving kettle and as much water as is necessary for boiling added. Boiling should be done very slowly and continued until the fruit commences to get soft. It should not be boiled too soft, but only sufficiently to enable it to absorb the sugar-liquor. When this is the case the fruit is taken from the fire and strained; with the liquor a syrup of the following composition is prepared: For each pound of fruit take one pound of sugar and soak it in  $\frac{1}{2}$  pint of the liquor. It is then placed upon the fire and the resulting syrup skimmed. When it boils the fruit is introduced and slowly boiled, or rather simmered, because it must not fall to pieces, for five to ten minutes, according to its softer or harder nature. The fruit while still warm is then brought into the jars in which no vacuum must remain. Hence they must be filled up to the cork, or, if bladder or parchment paper is used, for closing them up to the rim. In the latter case it is advisable to place upon the surface a close-fitting piece of paper, previously saturated with a concentrated solution of salicylic acid in rum. Currants, barberries, and grapes are sometimes preserved in their natural clusters. They are first washed in fresh water, then slowly boiled soft, and strained. With the liquor a syrup of the previously mentioned composition is prepared, which is boiled and skimmed and poured upon the fruit in the jars.

Fine table pears are sometimes preserved in the following manner: 8 large pears are placed in a syrup prepared from 6 ounces of sugar, 3 ounces each of cloves and allspice,  $\frac{1}{2}$  pint of water, and  $\frac{1}{4}$  pint of port-wine or other sweet red wine. In this syrup they are boiled very slowly—as much as 3 hours—until soft, and, while still warm, are brought together with the syrup into jars, which are treated in the manner previously described. By taking equal parts of pears and of fine plums a very beautiful product is obtained.

The boiling down of fruit in large stoneware pots is frequently accompanied by mishaps, and is more and more superseded by

other methods. It consists in dissolving  $\frac{1}{2}$  to  $\frac{3}{4}$  pound of sugar in water and boiling the resulting syrup together with the fruit until the whole forms a jelly-like mass. While still warm the pots, which must be full, are tied up with bladder. A piece of salicylated paper should be placed upon the surface of the fruit before tying up the pots.

*Preserving in Air-Tight Cans.*

This method, as previously mentioned, is the only one which has become of commercial importance; for the United States and England it has even become of the same national importance as the fabrication of beet-sugar for France and Germany. The number of factories, briefly termed canneries, in both the countries named, has largely increased during the last few years, and not a few of them employ 1000 hands during the fall. Of course these factories do not limit themselves to the canning of fruit, as otherwise they would have to cease operations during the winter months, but that branch of the business preponderates over all others. The search after other suitable material is constantly more extended, and it is difficult to tell what may not be canned in the future. The trade-list of a large English factory now contains 200 different articles; it includes, however, all Southern fruits, a portion of which is, singularly enough, returned in this state to the tropics. The American trade-lists embrace, as a rule, three groups, viz:—

1. Apples, pears, peaches, apricots, plums, strawberries, raspberries, blackberries, currants, cranberries, whortleberries, nectarines, grapes, cherries, quinces, cocoanuts, pineapples, marmalade, jelly, green walnuts.

2. Peas, beans, beans with pork, corn, tomatoes, asparagus, carrots, onions, pickles, cauliflower, horseradish, mushrooms, catchups, succotash, plum-pudding, sweet potatoes.

3. All kinds of poultry, venison, salmon, lobster, crawfish, oysters, crabs, beef, mutton, pork, eels, salt-water fish, ham, pig's feet, beef tongue, lamb's tongue, frog legs, mussels, etc.

All the varieties of fruit named in the first group being not equally well adapted for canning, the less suitable kinds are only



used in small quantities. Plums and cherries have up to the present time caused the greatest difficulty, because for economy's sake they were canned without removing the stones, in which the germ had to be destroyed by the application of a high degree of heat. When this was omitted the contents of the cans would spoil as soon as shipped to warm countries, in consequence of the germination of the stones. If, on the other hand, the cans were sufficiently heated, the plums or cherries would fall to pieces, and in this pasty condition were unsaleable in many markets, for instance in England. To overcome this evil the manufacturers have recently commenced to stone these varieties of fruit as well as peaches and apricots. It may here be remarked that both plums and cherries are comparatively dear in the United States, the cause of their not thriving well being partially due to the climate and partially to numerous enemies. Heart-cherries, black raspberries, and whortleberries are the worst varieties of fruit for canning, as they lose their agreeable taste by steaming. Strawberries also become somewhat insipid, but red raspberries are excellent provided they are canned as soon as possible after being gathered. Blackberries are not quite so good, though, if brought into the can immediately when plucked, they furnish an agreeable dish. Currants have too many seeds, and are better used for jelly. Black currants are well suited for canning, and in this state are much used by bakers for tarts. Gooseberries canned before entirely ripe are very good. Among the smaller stone fruit the Mazard cherry has few superiors; if carefully canned, it retains its shape, color, and aroma as on the tree. Most plums are suitable for canning, provided they are stoned. Among the kernel fruits the quince occupies the first rank, as it is the only variety of fruit which gains by steaming. Pears are very suitable for canning, as even the inferior qualities can be used for the purpose. Apples, however, must be carefully selected, and only sweet varieties with firm flesh should be used; the Siberian crab-apples can be highly recommended for the purpose.

As a general rule, fruit for canning should have a firm flesh and fine aroma. We find these conditions in all the varieties preferred by the North American factories, whose canned goods can be found in every large city of the world. The peaches are

of the early and late Crawford\* varieties, and the apricots Moor-parks. Among plums we find the following varieties: Washington, Columbia, Reine Claude, Coe's golden drop, yellow gage. Royal Ann is the favorite variety of cherries, though the different varieties of Bigareans and the black Tartarian heart-cherry are also used. Muscat, Muscat Alexandria, and Malaga are the favorite varieties of grapes. Among apples the Newtown pippin is pre-eminent; it is considered one of the finest apples in this country. Several varieties of pears are highly esteemed in the Eastern States for canning purposes, but in California the Bartlett pear is almost exclusively used. With this pear the Californian packers say they have conquered the foreign markets, and they will not risk their reputation by abandoning it.

Next to the variety of fruit the cans are of the greatest importance. Much has been said and written in regard to them, and the discussion *pro* and *con* will very likely be continued until a new and important improvement is discovered. And it is actually necessary that the inventors should set their wits to work for the production of a can which would overcome all complaints, as thereby they could create a beneficial revolution in the fruit industry. The well-known patent cans are excluded from use on a large scale on account of their high price. Glass jars have some advantages: they are comparatively cheap, allow of an inspection of their contents, and the ready recognition of a leak, and are not attacked by the vegetable acid. But, nevertheless, they have not been introduced into general use because they are liable to break, and, being heavy, increase the cost of transportation, and, finally, it is difficult to close them air-tight. The sealing of a bottle with a narrow mouth is quite a different thing from sealing one with an aperture three inches in diameter. It may do for pickles, marmalade, or jelly, but for preserved fruits which are to be transported long distances it cannot be depended on. The same objections may be made to stoneware jars, which possess the further disadvantage that their contents cannot be inspected and a leak is difficult to discover. Nevertheless, they are used by some large English factories for the reason, it is claimed, of keeping their

\* The name given to each fruit is the recognized name of the American Pomological Society as far as recorded in their catalogue.

products free from influences deleterious to health. To facilitate sealing the jars are generally small—of about one pound capacity. Tin cans have many defects, but their use is very extensive, and in the United States they are almost exclusively employed. In California they are manufactured of a size that, when filled, they weigh  $2\frac{1}{2}$  lbs., while in the Eastern States, as well as in England, they weigh, filled, only 2 lbs. Complaint has been frequently made that the use of tin cans is deleterious to health because they contain lead, which is dissolved by the vegetable acid and transferred to the fruit-syrup. In reply it has been said that only the inferior qualities of tin contain lead, and that only in an infinitesimal quantity; but it cannot be denied that the solder may readily become injurious to health, and in cases of poisoning examined in the United States and in England, it could every time be shown that the respective cans were soldered on the inside. In England, if we are correctly informed, soldering the cans inside is now prohibited, and the passage of a similar law in the United States is agitated. At any rate the time is very likely not very distant when such soldering will be entirely done away with, if only for competitive reasons. To completely overcome all complaints against solder, as well as against a content of lead in the tin, cans are now manufactured in England which are provided inside with a thin coating whereby the contents are protected from contact with the metal. The insoluble constituent of this coating consists of silicate of lime or glass-powder previously treated with hydrofluoric acid, while the soluble constituent is silicate of soda or of potash. Any silicate of earthy bases or metals may be used, or a precipitated gelatinous silicate. The alkali is fixed or removed by means of a bath containing a dilute solution of hydrofluosilicic acid, or a dilute solution with any other suitable acid. For preparing the composition mix the soluble with the insoluble silicate. The tin plates are coated with this mixture by means of a brush, or dipped in a bath of it and then dried by heat. The plates thus acquire a glass-like coating, which remains fixed no matter how the plates may be handled and worked.\*

\* In this country some packers of lobsters, shrimps, etc., line the cans with parchment paper.

In the canneries in the United States the cans are manufactured in a special department, and the division of labor is carried so far that every can passes through eight hands before it is finished; but only with such a system is it possible to turn out large quantities in an incredibly short time. This far-reaching division of labor is, however, not limited to this department alone, but is the supreme law in the entire establishment. In the same department the solder is cut by a machine into small three-cornered pieces. Each workman receives a certain quantity by weight of solder and of charcoal with which he is expected to solder a certain number of cans. The workmen are paid by the piece, and each solderer has a number which is stamped in every can he solders, so that those which prove leaky may be returned to him for repair. By this system there is no waste of material, and the leaky cans do not exceed 5 in 1000.

In another department the fruit is carefully inspected on long tables; the unsound is thrown out, and the sound turned over to the peelers and stoners, who of course work with the most improved machines. There are carriers bringing uninterruptedly fresh fruit and off-bearers removing and sorting the waste. Nothing is thrown away, the waste being used partially in the manufacture of jelly and partially in distilling; even the stones are utilized, as they are sold either to nurserymen or to chemical factories. Other workmen are occupied in placing the peeled and stoned fruit in the cans, which are handed over to boys, who place them upon small trucks running upon rails and transport them to the department where the filling in takes place. In the same department the syrup of sugar and water is prepared, but if the proportion of composition were asked a different answer would be received in every cannery. In regard to this point every manufacturer has his own ideas, which also extend to modifications for the different varieties of fruit. One factory we know of did not use any syrup whatever. The fruit was simply pressed quite tight into the can, and had to depend on its own juice. The fruit retained its natural color, taste, and aroma better than with the use of syrup, but the important question whether its keeping quality was equally good we are unfortunately not able to answer. All manufacturers agree, however, that the best quality of white

sugar should be used for light-colored fruits, and light brown sugar for dark-colored, and that the syrup must be perfectly clear, and, hence, very carefully skimmed in boiling. In most factories the syrup used consists of 1 lb. of sugar dissolved in 1 pint of water. The filling of the cans with the fruit and syrup, the latter being generally kept warm, is effected with the assistance of a scale, so that each can has exactly the weight upon which the selling price is based. The caps previously provided with a hole the size of a small pea are then soldered upon the cans. The hole in the cap serves for the escape of the air during the succeeding process.

Different kinds of apparatus are used for the expulsion of the air by heating the cans. In large factories a steam retort is used which resembles in shape a ship's steam boiler. It is provided with a door closing air-tight, and is divided in the centre so that it can be filled either half or entirely with steam, as may be required. The cans to the number of from 400 to 600 are placed upon trucks which run upon rails leading into the retort. Eight such trucks can be introduced at one time, so that it is possible to steam from 30,000 to 40,000 cans per day. The retort being filled the door is closed and the pipe communicating with the steam boiler opened. The cans remain in the retort from 15 to 30 minutes, according to the variety of the fruit: berries 15 minutes, stone-fruits 20, apples and pears 25, quinces and tomatoes 30. The door is then opened, and after the steam has somewhat dispersed the trucks are quickly pushed to the tin-shop, where the cap-holes are soldered up. To cleanse the cans and make them shiny they are next put in a bath of soda water and then rinsed off with cold fresh water. They are then transferred to the store room, where they remain standing quietly for one week, when they are tested by striking the cap of each a short sharp blow with a wooden hammer. If everything is in order, the cap sinks slowly down, but if it is elastic and jumps back the can is what is called a "swellhead," and is returned to the tin-shop for repairs and is then again steamed. The perfect cans are labelled and packed and are now ready for market.

Another apparatus which can be highly recommended for small factories consists of a round iron plate resting upon a brick basis



about one foot high. Two round iron rods run up opposite to each other from the edge of this plate and serve as a support for a movable iron cylinder open at the bottom and closed on top. Upon the iron plate the cans are placed in the form of a pyramid, and the cylinder is then drawn down and screwed air-tight to the plate. A pipe communicating with the steam-boiler enters the cylinder, and as soon as the latter is connected with the plate steam is admitted. After a certain time, which corresponds with that previously given, the steam is shut off, the cylinder pushed up, and the cans removed, the further treatment of which is the same as given above.

In many factories the cans are still heated, according to the old method, in boiling water. For this purpose the cans—100 at a time—are placed upon an iron plate attached to a steam-crane and submerged for 15 to 20 minutes in boiling water in a large shallow kettle. In this case the caps are not perforated, but soldered down air-tight. A workman watches the cans while they remain in the water and by means of a tool removes those from which small bubbles arise; such cans being not air-tight are returned to the tin-shop for repairs. The rest after being heated are also brought to the tinshop, where the caps are perforated with a hole the size of a small pea, which is again soldered up after the escape of the heated air.

The canning of tomatoes, asparagus, and other vegetables is effected in a similar manner except that no syrup is used. For the following description of tomato canning, which may serve as a type for all the rest, we are indebted to Mr. Richard T. Starr, of Salem, N. J.

The tomato was for many years found only in hot-houses and conservatories of the rich. It was known as the love-apple and considered a curiosity. Our ancestors had no idea that this small red berry, for such was about its size, would ever, even under careful cultivation, become of mammoth size and form one of our most important articles of food. But such is actually the case to-day. The exact time when the now great industry of canning this vegetable commenced cannot be established with any certainty. The taste for it seems to be an acquired one, and for years the industry struggled in its infancy until the breaking



out of the War of the Rebellion caused a demand that rapidly grew into gigantic proportions, and to-day finds the tomato-canning industry employing an army of men, women, and children, while millions of dollars are invested in the payment of labor and the erection of plants.

In order that our readers may have a clear idea of the business we will commence with the beginning. Having made up his mind to engage in the business on an average scale, the packer will first find a suitable plot of ground, on a navigable stream, if possible. Having secured this, the next thing is the erection of the buildings; these are generally one story in height and as large and roomy as the capital will warrant. The next step is to secure the requisite supply of fruit, and for this purpose the farmers are drawn on and contracts entered into with them in which the packer agrees to take the entire marketable product of a certain number of acres or else to take so many tons. These contracts are generally made about the first of the year, and as soon as the sun drives the frost from the ground the farmer prepares his beds and sows his seed. While the latter is growing the land which is to be planted is heavily manured and plowed and carefully worked until it becomes mellow, and then hills about four feet apart are made, and into each one is put a small quantity of compost or phosphates. The tomato plants, having by this time grown to the height of 6 or 8 inches, are taken from the beds, and on a cloudy day or the latter part of a bright day transplanted and tended about as other growing crops. With a favorable season the farmer should commence delivering to the factory about the middle of August.

The arrangement of a canning factory is, of course, a matter of taste, but the most complete, in our opinion, is one where everything moves in a straight line, and in which none of the help is obliged to interfere with one another. The first thing to be done with a load of tomatoes is, of course, to weigh them, and for this purpose platform scales are built at an end door and the wagons driven on them. After being weighed the tomatoes are handed over to the scalding. Tomatoes arriving in all kinds of weather and conditions must, of course, not only be washed but scalded, so as to thoroughly loosen the skin from the pulp, and to do this

quickly and properly, a heavy box of white pine is fitted with both steam and water pipes and attached to it is an iron cradle swinging on hinges and raised and lowered by a wheel and pulley suspended above. On the back of this is placed a box, and as the farmer hands off his baskets they are emptied into this box, and at the command of the man at the rope, who is called the "scalders," they are dumped into the boiling water beneath. A few seconds suffice to clean and scald them; the cradle is then raised and the tomatoes are poured into kettles set in front of the scalders to receive them.

While this has been going on a group of women and girls have been filing into the factory and seating themselves along the trays that are to receive the tomatoes from the scalders. These trays are of different construction, but are similar as regards length, breadth, and depth, the only difference being in the various ways of getting rid of the water and juice. This is generally done by making a slat frame fit in the bottom and over a trough fastened under the tray. This leads to a drain, which carries it to the creek or wherever else it is to go. At each tray are from ten to twelve women, each of them furnished by the packer with a bowl and knife, and provided at their own expense with a neat water-proof apron. The tomatoes are dumped from the kettles in front of them, and they remove rapidly the already loosened skins and cores and deposit the prepared fruit in a bucket sitting beside them. They become so efficient that a smart active woman will frequently skin from 40 to 60 buckets a day, and as they receive 4 cents per bucket it will be seen they make fair wages. Standing just beyond the women are the machines which fill the cans. To describe them would be impossible, there being so many shapes and many makes. Some are very good, some very poor, every man thinks his the best, and so it goes, but in one respect they all agree: they have a hopper into which the fruit is poured from the buckets, and all have the plunger which forces the fruit into the cans; the treadles of some of them are moved by hand and some by steam. The machines rapidly fill can after can, which are then set on the "filling table" and receive "top them off," or in other words the fruit is cleared away from the top of the can so that the solder used in capping them will not become chilled. They are

then placed in trays each holding either 10 or 12 cans and removed to the "wiping table," where everything is cleared from the top, wiped dry with sponges, and the cap placed over the opening. The "cappers" stand directly in front of the wiping table, and each one has his own fire pot, irons, files, and everything he uses before him. Taking the tray, he rapidly applies by means of a small brush the acid or flux necessary to make the solder flow freely around the cap, and then with the iron melts the solder and puts it in the groove. The can is then vented and is ready for the "bath." The baths except in size are constructed similarly to the scalding and a thin cedar cover fits over each one. The cans are placed in wire or iron crates, lowered into the boiling water, and allowed to remain as long as necessary to cook them. The time of working varies in the different factories, but all the way from 30 to 50 minutes is required. They are then taken from the bath and placed on a slat-floor, where the air can pass through them, and when they are cold are "tested" generally by striking them with an awl. The testers become so expert that they can instantly detect by the sound an imperfect or leaking can; these are thrown out, mended, re-pressed, and put back in the pile. The cans are now ready for the next thing, which is labelling.

Labelling is done in different ways, and some canners with an idea of saving labor employ devices which are not only hard on the young girls who do the work, but which often result in much confusion and poor work. The best method is to divide the help into parties of five, one girl sitting on one side of the table with paste-pan, brush, and labels and the other four opposite her. The one girl, if quick and active, will paste the ends of the labels as fast as the other four can put them on the cans. The table is of course alongside the pile of cans, and two smart boys will place the cans on the table. As a girl labels a can she pushes it from her, when it is taken by the boxer, put in the box, and nailed up. This mode is simple and effective, and as the gang will label from 700 to 900 cases in a day the work progresses rapidly.

In many of the larger factories patent processing kettles, capping irons, and improved machinery are used, but as the result

is, of course, the same, and they do not affect the mode of packing, it is not thought necessary to enter into any description of them.

In the foregoing an outline of the packing process has been given, but nothing has been said of the many trials and vexations of a canner's life. If everything went always smoothly, it would be as pleasant as any other business, but it does not. The canner will early in the season employ his hands and commence in a small way. He may start and run only two or three hours, and for that length of time boilers will have to be fired up, help got together, and at the close the factory cleansed the same as if he had run the day out. Then, as the crop rapidly matures, work becomes heavier, and at last the inevitable "glut" commences, and he finds the products of 400 or 500 acres of perishable fruit at his doors, may be 50 wagons, each owned by an impatient farmer standing in the street waiting his turn to unload. That is the time he has need of nerve; help must be secured, everything and everybody pushed to their utmost endurance, and from early morning until way into the night, day after day, the work goes on, help succumbs, and machinery breaks, but the factory must move in storm and in sunshine. The work must go on, and at last the agony is over, and the crop coming in again gradually gives a little relief to the overworked people. And now the crop is in, the farmer has brought his "good-bye" load, the force places everything in winter-quarters, and with farewells and thoughts of the future they separate for their homes and the season in a tomato-canning factory is over.

The taste for tomatoes being, as previously mentioned, an acquired one, and the people of European countries being slow to take hold of them, the principal market the canner has is in this country and the demands made by sea-going vessels. The mining regions of Pennsylvania and of other States use large quantities, and they have now become a necessity in many households, some of the working classes using them largely in place of meat. That they are a nutritious, healthy article of food has been clearly proved, and the low prices of the past few years have placed them within the reach of all. It would be an impossibility to correctly state the amount of capital invested or the

number of persons employed in the industry. The States of New Jersey, Maryland, and Delaware pack a large proportion of the goods, the late falls and the nature of the soil being particularly well adapted for raising tomatoes, and in every little village in these States factories have sprung up like mushrooms within the past few years. The business has been brought to a solid basis, and with careful handling and the opening of a prosperous business future it seems as if it ought to become one of the substantial enterprises of this country.

In connection with the canning of tomatoes it may be of interest to our readers to give the preparation of

### *Catchups.*

Under the name of catchup or catsup a thickly-fluid sauce comes into commerce, which is used as a condiment with meat and the fabrication of which has become of some importance. Everywhere where Anglo-Saxons reside catchup is found, though it has also been introduced on the continent of Europe and in the tropics. The varieties most liked are tomato and walnut catchups, and immense quantities of them are manufactured in the American canning establishments. The mode of preparation is so simple that it can be introduced into every kitchen.

*Tomato catchup.*—The receipts for making this favorite catchup are innumerable, and should we take those of every packer and housewife in the land and put them together they would make a good-sized volume. We must therefore limit ourselves to giving a few approved receipts.

Some factories will accumulate the skins and refuse of a tomato-canning season, storing the same in vaults and vats until the season is over, then cook the mass up and trust to a liberal supply of oils and condiments to impose it on an unsuspecting public as "fresh tomato catchup," but it is not fresh and should not be called so. The proper way to make a good sweet article is to place each day in vats or hogsheads the skins, etc., of the day. These will by the next morning have become slightly fermented, and the skin and pulp can be readily separated by rubbing them either with a steam rubber or by hand in a fine copper sieve. In



this manner all seeds, etc. are removed, and the pure, sweet juice of the tomato alone remains. Take this, and, having your kettles perfectly clean, place it in them and bring it *slowly* to a boil, carefully skimming off the scum that will rise to the top. When it has cooked down about one-half put in your cloves and allspice, which should be in bags, and let them remain boiling with the rest. Shortly afterwards put in your other spices, salt, pepper, etc.; a small dash of ground cinnamon will add much to the flavor, although the person making it must be guided by his taste. From a third to half as much vinegar as there is juice should be put in when it is about half cooked, and the mustard must be thoroughly mixed with vinegar before being put in. Let all now boil until it gets thoroughly done, and if too thick, thin it *while hot* with vinegar and bottle or barrel as desired. There can be no receipt given that will suit all in regard to the amount of the different condiments to be used, as each person has ideas of his own, but all catchup should be made hotter than desired, as it will undoubtedly lose some of its strength when it becomes cold. The best of spices and vinegar should always be used, and every vessel into which it is put should be perfectly clean and free from any mold or dust. Seal the bottles carefully, and if you have them thoroughly air-tight it will like wine improve with age.

The following receipts can be recommended :—

I. Take 15 quarts of thoroughly ripe tomatoes, 4 tablespoonfuls each of black pepper, salt, and allspice, 8 red peppers, and 3 teaspoonfuls of mustard. The pepper and allspice must be ground fine and the whole boiled slowly 3 to 4 hours; then pass all through a fine sieve and when cold put it in bottles, which must be immediately sealed.

II. Boil 4 quarts of tomatoes together with 2 quarts of vinegar, 2 tablespoonfuls of red pepper, 4 tablespoonfuls of black pepper, 1 tablespoonful of cloves, 1 teaspoonful of salt, and 1 ground nutmeg to a thick paste. Strain through a coarse-meshed sieve and sweeten the sauce obtained with  $\frac{1}{2}$  lb. of sugar. Fill in bottles and shake once every day for a week.

III. Cut up perfectly ripe tomatoes and place them upon the fire until they commence to bubble. Then take them from the



fire, and when cool rub them with the hand through a hair-sieve and season according to the following proportions: For each quart of sauce add 1 teaspoonful of ground allspice, 1 teaspoonful of ground cloves, 1 tablespoonful of salt, and 1 quart of wine-vinegar. Stir the whole thoroughly together, replace it upon the fire, and boil for one hour, with constant stirring. When cool put the catchup in bottles and seal immediately.

*Walnut catchup.*—I. In June, when the walnuts are still soft, take 10 dozen of them, and after crushing pour over them 2 quarts of wine-vinegar, add the following spices, all ground: 2 tablespoonfuls of black pepper,  $1\frac{1}{2}$  oz. of nutmeg, 40 cloves,  $\frac{1}{2}$  oz. of ginger, and  $\frac{1}{4}$  oz. of mace, and boil the whole  $\frac{1}{2}$  hour, stirring constantly. When cold strain through a hair-sieve and put the catchup in bottles.

II. Crush about 10 dozen of young, soft walnuts, sprinkle  $\frac{3}{4}$  lb. of salt over them, and then add 1 quart of vinegar. Let the whole stand six weeks, stirring frequently. Then strain through a bag, with constant pressing with the hand. Pour 1 pint of vinegar over the residue, let it stand over night, and strain again through the bag. Combine the fluid with that previously obtained and season with the following spices, all ground:  $1\frac{1}{2}$  oz. of black pepper,  $\frac{1}{2}$  oz. of nutmeg,  $\frac{1}{2}$  oz. of ginger,  $\frac{1}{4}$  oz. of mace, and 40 cloves. Then boil  $\frac{1}{2}$  hour, strain through a hair-sieve, and bottle.

*Cucumber catchup.*—Thoroughly ripe cucumbers, before turning yellow, are peeled and grated upon a coarse grater. This paste is brought into a colander to allow the juice to run off, then pressed through a coarse hair-sieve to remove the seeds, and finally brought into small, wide-mouthed bottles, which are filled  $\frac{3}{4}$  full. The remaining space is filled up with good wine-vinegar. This catchup has the taste and odor of fresh cucumber, and is used as a condiment with meat. Before bringing it to the table it is seasoned to taste with salt and pepper.

*Horseradish catchup.*—The mode of preparation is the same as for the preceding, putting the grated mass in a colander and straining through a hair-sieve being, however, not necessary. Both varieties of catchup must be immediately corked, sealed, and kept in a cool place. Within the last few years both have

been prepared on a large scale in the United States and in England, and have become an article of export. They are packed in small, wide-mouthed bottles, sealed, and provided with gayly-colored labels. Some English factories use small earthenware pots of a cream color, closed with corks over which is tied strong colored paper. The pots are very good, but the manner of closing them is not ; the corks should be sealed.

*Currant catchup.*—Heat nearly to the boiling point, with constant stirring, 4 lbs. of thoroughly ripe currants together with  $1\frac{1}{2}$  lb. of sugar. Then add 1 tablespoonful each of cinnamon, salt, cloves, and pepper—all finely pulverized—and 1 quart of vinegar. Boil the mixture one hour and then treat in the same manner as tomato catchup.

*Gooseberry catchup.*—This product also comes into commerce under the name of “spiced gooseberries ;” it is an excellent condiment with roast fowl. Take 6 quarts of gooseberries, ripe or unripe as may be desired, and carefully remove the stems and pistils. Then bring them into a kettle, and after pouring some water and scattering 5 lbs. of pulverized sugar over them, boil for  $1\frac{1}{2}$  hour. After boiling for  $1\frac{1}{4}$  hour add 4 lbs. more of sugar and 1 tablespoonful each of allspice, cloves, and cinnamon. The catchup is not strained, but brought at once and while warm into wide-mouthed bottles or pots, which are immediately corked and sealed. It is advisable, before closing the bottles, to lay a closely-fitting piece of salicylated paper upon the surface of the catchup. The bottles should be kept in a cool place.

It is scarcely necessary to remark that catchup can be prepared not only from the above, but from all varieties of fruit, as it is only necessary to take one of the above receipts as a type. But, with few exceptions, those given are the only catchups prepared on a large scale and brought into commerce.

Another subject which may be referred to in connection with the preservation of fruit is the preparation of

### *Fruit-butter, Marmalade, and Jelly.*

*Fruit-butter.*—The manufacture of apple-butter, which may serve as a type of that of all other fruit-butters, is effected as

follows: Fill the boiler two-thirds full with the juice of sweet and bitter-sweet apples in about the same proportion as given for the manufacture of cider. The other third of the boiler is filled up with slices of ripe, juicy apples, and the mixture boiled, with frequent stirring. When the slices of apples are so soft that they commence to fall to pieces, they are carefully removed from the boiler by means of a skimmer, care being had to allow the juice to run off. The same quantity of fresh slices of apples is then brought into the juice and boiled in the same manner as the preceding. When these have acquired the necessary degree of softness, the entire contents of the kettle, together with the slices of apples previously boiled, are brought into a stoneware pot and allowed to stand covered for 12 hours. The mass is then replaced upon the fire and boiled, with constant stirring, until it has acquired the consistency of soft soap. If desired, it can at the same time be seasoned with cinnamon, nutmeg, etc. To prevent scorching the second boiling is effected in vessels standing in boiling water.

In the same manner fruit-butter can be prepared from all varieties of fruit, pear or apple juice forming, however, always the boiling liquor. Apple and peach butters are commercially of the greatest importance, though butter of quinces, pears, blackberries, cherries, plums, and cranberries is also manufactured on a large scale. Whortleberries, which grow in enormous quantities in some parts of the country, might also form an excellent material for this product. In the foregoing only the varieties are mentioned which are manufactured on a large scale by American and English factories that chiefly control the trade in fruit-butters, but these do not by any means exhaust the list; green gages can, for instance, be highly recommended for the purpose.

The excellent product brought from France into commerce under the name of *raisiné* is prepared in the above manner by slowly boiling sliced apples and pears in unfermented grape-juice.

Fruit-butter is packed in wooden buckets of 5 or 10 lbs. capacity. Tin cans holding 2 lbs. are also sometimes used, but they are not liked. The buckets are slightly conical towards the top and are provided with a wire handle. Resinous wood should not be used in their construction, as it would impart an odor to the fruit-

butter. The buckets are filled up to the edge, and a closely fitting round piece of paper previously saturated with concentrated solution of salicylic acid in whiskey is laid on top of the butter. The tight-fitting lid is placed upon the bucket without being sealed or otherwise closed. A large label occupying the space between the lower and upper hoops finishes the packing.

*Marmalade.*—The same product is sometimes called marmalade and sometimes jam. The French prepare only marmalade, while the Englishman brings the same product into commerce as jam or as marmalade, just as it may suit him best, and the German is not much better. The manufacturers, to be sure, would sometimes like the public to believe that marmalade is a finer product containing more sugar and spices than jam, but such is not the case, because the raw material and the mode of preparation are the same. The term marmalade was originally applied to a jam prepared from quinces, it being derived from *marmelo*, the Portuguese word for quince. The term was gradually given to all jams in order to give them a more distinguished character, and this has led to a confusion of terms which sometimes extends even to jelly. There is, however, a wide distinction: marmalade or jam is prepared from the pulp of fruit and jelly from the juice, while fruit-butter, as above indicated, is a blending of both with the omission of sugar.

For the manufacture of marmalade on a large scale all the rules and receipts can be condensed as follows: The fruit must be of excellent quality, entirely free from blemishes and washed perfectly clean. Kernel fruit is peeled, quartered, and freed from the cores; peaches are also peeled, halved, and stoned; other stone-fruit is only stoned and halved, while berries are carefully freed from the stems. Melons and pumpkins are peeled and cut into small pieces. Rhubarb should not be washed but rubbed with a moist cloth and be then cut into small pieces. Tomatoes are to be peeled, which is facilitated by previously placing them for one minute in hot water. Being thus prepared the fruit is brought into a copper kettle and as much water as is required for boiling added. While the fruit is boiling, weigh off as many pounds of white sugar as there is fruit, soak it in water, boil and skim carefully. The fruit should be boiled quickly, and when perfectly

soft is allowed to cool off somewhat and then rubbed through a wide-meshed hair-sieve. The mass passing through the sieve is combined with the sugar and replaced upon the fire. The whole is then boiled, with constant stirring, to the required consistency. The latter is tested by taking a small sample with a wooden or bone spoon—nothing else should be used—and if it draws threads between the fingers the boiler is removed from the fire. The marmalade is then brought into straight jars, and after laying a piece of salicylated paper on top, the jars are tied up with white parchment paper or sometimes covered with a glass cover and labelled. It may be remarked that in the last stage of boiling the marmalade is sometimes flavored, which is generally effected by stirring in lemon juice, cinnamon, and nutmeg according to taste. The liquor obtained by boiling crushed kernels of plums or peaches is also frequently at the same time added as flavoring. Frequently the sugar is not treated as stated above, but added in the form of powder.

The quantity of sugar has above been given in the proportion of 1 lb. to 1 lb. of fruit. Though this is the customary rule, many manufacturers use only  $\frac{3}{4}$  lb. of sugar, a method which can be highly recommended. In fact there is frequently a perfect waste as regards the addition of sugar, some adding even  $1\frac{1}{2}$  lb. of it to the pound, whereby the taste of fruit is entirely lost and the product, on account of its sweetness, becomes repugnant to many. It may be laid down as a rule that in all fruit boiling no more sugar than is absolutely necessary should be used. The secret of the great reputation the products of the principal American factories enjoy in all portions of the world is simply due to the fact that they use as little sugar as possible, whereby the products are rendered not only cheaper but they retain their natural fruit taste, and that is what the consumer desires and not a sugary paste having only the color of the preserved fruit. The durability of the product need not necessarily suffer if due care is exercised in its preparation. Marmalade should not be made, as it is only too frequently done, from fruit which has been gathered for several days and shows signs of decay. Fruit not over-ripe and freshly gathered should be used and the boiling finished as quickly as possible. By then rinsing the jars with salicylated water and



covering the marmalade with a piece of paper saturated with concentrated solution of salicylic acid or with alcohol,  $\frac{3}{4}$  lb. of sugar to 1 lb. of fruit will be ample, and even  $\frac{1}{2}$  lb. with sweet fruits such as pears, raspberries, etc. Independently of the saving of sugar, such marmalade will give better satisfaction than an article twice as sweet, and will keep well in a dark cool place.

From France a very fine perfumed apple marmalade is brought into commerce. It is prepared from equal parts of Calvilles and Pippins, and after boiling is sprinkled with rose-water or violet essence.

The term *tutti-frutti* is applied to marmalade prepared from a mixture of different kinds of fruit. As the name implies it is of Italian origin. The composition is made according to taste and the fruits at disposal.

*Jelly*.—This product is, unfortunately, often made expensive and at the same time spoiled by too large an addition of sugar. Many housekeepers do not like to prepare jellies under the pretext that it requires too much sugar; but this is an error, because in France, in factories as well as in households, they use only  $\frac{1}{2}$  pound, or at the utmost  $\frac{2}{3}$  pound, of sugar to the pound of fruit, instead of 1 pound or even  $1\frac{1}{2}$  pound, as is customary in England, Germany, and parts of the United States. Moreover, the apple-jelly which is made in the United States and sent to all parts of the world is made without any addition of sugar. Instead of apples, as the raw material, apple-juice is used, which must be perfectly sweet and treated immediately after it comes from the press. A moderate temperature is absolutely necessary for success, for, if the juice commences to ferment—and it does very rapidly in warm weather—the keeping quality of the jelly is injured, except it be mixed with a considerable quantity of sugar. A temperature of  $41^{\circ}$  F. is considered the most suitable, and if it rises to above  $66^{\circ}$  F. the manufacture is at once stopped. The juice runs directly from the press into the boiler, under which a strong fire is kept because the starchy matters contained in the juice are only converted into sugar if the boiling down is quickly effected. For this reason shallow pans offering a large surface to the fire are used. When the juice commences to boil it is clarified, and the acid it contains neutralized by the addition



of one teaspoonful of elutriated chalk to each quart of juice. The chalk weighed off in this proportion is mixed with the juice, and appears in a few minutes as a thick scum upon the surface from which it is carefully removed with a skimmer. By this operation the jelly is clarified, and all the albuminous substances contained in it being removed by the chalk, filtering is not required. The process is similar to the defecation of the juice of sugar-cane and beets by lime. The juice is now boiled to the consistency of  $30^{\circ}$  or  $32^{\circ}$  B., which is found on cooling to be the proper point for perfect jelly. It is then filled direct from the pan into tumblers, which are treated in the same manner as marmalade jars.

Successful jelly boiling on a large scale is impossible without the use of the saccharometer. It is the only reliable guide for the addition of sugar, for if the product is to be protected from spoiling it must show from  $30^{\circ}$  to  $32^{\circ}$ . If this result can be reached without the addition of sugar, it is so much the better.

Pear and mulberry jellies are prepared in exactly the same manner as above. Other fruits containing more acid require an addition of sugar, especially currants, which next to apples and pears are most used for jelly, but in no case is the same weight of juice and sugar required.

To prepare jelly from berries and other small fruit, pour hot water over the fruit in order to free it from adhering dirt and to facilitate the separation of the juice. When the water is cool take the berries out, express the juice, and bring the latter immediately into a copper or brass kettle over a lively fire. Then stir in pulverized sugar, the quantity of which varies according to the variety of fruit. For raspberries, strawberries, and blackberries  $\frac{1}{2}$  pound of sugar to the pound of juice will be sufficient, and  $\frac{3}{4}$  pound or at the utmost  $\frac{3}{4}$  pound for currants, barberries, elderberries, and whortleberries. The sugar being added stir in the chalk in the proportion previously given, and after allowing the juice to boil not longer than 15 minutes, take it from the fire and strain it at once into the glasses. In this manner a clear, beautiful jelly of an agreeable taste will be obtained. If, on the other hand, the juice is boiled slowly over a weak fire, the result will be a turbid product which has lost its fruity taste.

Stone-fruit is boiled, and after boiling it with a small quantity of water until soft the juice is pressed out and  $\frac{2}{3}$  pound of sugar added for every pound. It should be boiled quickly, and not, as some receipts have, for  $\frac{3}{4}$  hour. Quinces are peeled and then treated like stone-fruit. Rhubarb is cut into small pieces and then treated in the same manner. A quite good jelly can also be prepared from the medlar, provided it is allowed to become completely ripe, and is then slowly steamed with a very small quantity of water. When thoroughly soft the juice is pressed out and  $\frac{3}{4}$  pound of sugar added to each quart. The mass is sharply boiled for 20 minutes, when the result will be a clear jelly.

In France, as previously mentioned, perfumed marmalade is prepared from equal parts of Calvilles and Pippins. From the same material, which is considered best for the purpose, a perfumed jelly is also prepared. The apples are not peeled, but cut into slices, and boiled with a small quantity of water until soft enough to be pressed in a filter-bag. To every pound of juice  $\frac{1}{2}$  pound of sugar is added, and five minutes before the saccharometer indicates  $30^{\circ}$  B.,  $\frac{1}{4}$  or  $\frac{1}{2}$  pound of violet blossoms is stirred into the juice, a few drops of cochineal being generally added to improve the color. The jelly, when finished, is strained through a hair-sieve into wide-mouthed bottles which are corked and sealed.

A jelly is made from raspberries, and sometimes also from strawberries and blackberries, in which the berries remain intact. The process consists in dissolving 2 pounds of white sugar in water and boiling until thickly fluid. Two pounds of berries are then brought into the kettle and carefully mixed with the sugar so as to avoid crushing. The kettle is then taken from the fire and allowed to stand covered for 15 minutes, when it is replaced and the sugar boiled up once more. The product is kept in jars well corked and sealed.

In conclusion we give the process of manufacturing apple-jelly in the largest factory in Oswego County, New York, as described by Mr. Dewitt C. Peck. There are some features peculiar to this establishment which may be new and interesting. •

The factory is located on the Salmon Creek, which affords the necessary power. A portion of the main floor, first story, is occu-

pieced as a saw-mill, the slabs furnishing fuel for the boiler furnace connected with the evaporating department. Just above the mill, along the bank of the pond and with one end projecting over the water, are arranged eight large bins holding from 500 to 1000 bushels each, into which the apples are delivered from the teams. The floor in each of these has a sharp pitch or inclination towards the water, and at the lower end is a gate through which the fruit is discharged, when wanted, into a large trough half submerged in the pond.

Upon hoisting a gate in the lower end of this trough considerable current is caused, and the water carries the fruit a distance of from 30 to 100 feet, and passes into the basement of the mill, where, tumbling down a four-foot perpendicular fall into a tank, tight in its lower half and slatted, so as to permit the escape of water and impurities, in the upper half, the apples are thoroughly cleansed from all earthy or extraneous matter. Such is the friction caused by the concussion of the fall, the rolling and rubbing of the apples together, and the pouring of the water, that decayed sections of the fruit are ground off and the rotten pulp passes away with other impurities. From this tank the apples are hoisted upon an endless chain elevator, with buckets in the form of a rake-head with iron teeth, permitting drainage and escape of water, to an upper story of the mill, whence by gravity they descend to the grater. The press is wholly of iron; all its motion, even to the turning of the screws, being actuated by the water-power.

The cheese is built up with layers inclosed in strong cotton cloth, which displaces the straw used in olden times and serves also to strain the juice. As it is expressed from the press tank the juice passes to a storage tank and thence to the defecator. This defecator is a copper pan 11 feet long and about 3 feet wide. At each end of this pan is placed a copper tube 3 inches in diameter and closed at both ends. Lying between and connecting these two are twelve tubes also of copper,  $1\frac{1}{2}$  inch in diameter, penetrating the larger tubes at equal distances from their upper and under surfaces; the smaller being parallel with each other, and  $1\frac{1}{2}$  inch apart. When placed in position the larger tubes, which act as manifolds, supplying the smaller with steam, rest

upon the bottom of the pan, and thus the smaller pipes have a space of  $\frac{3}{4}$  inch underneath their outer surfaces.

The apple-juice comes from the storage tank in a continuous stream about  $\frac{3}{8}$  inch in diameter. Steam is introduced to the large or manifold tubes, and from them distributed through the smaller ones at a pressure of from 25 to 30 lbs. per inch. Trap-valves are provided for the escape of water formed by condensation within the pipes.

The primary object of the defecator is to remove all impurities and perfectly clarify the liquid passing through it.

All portions of pomace and other minute particles of foreign matter, when heated, expand and float in the form of scum upon the surface of the juice. An ingeniously contrived floating rake drags off this scum and delivers it over the side of the pan. To facilitate this removal, one side of the pan, commencing at a point just below the surface of the juice, is curved gently outward and upward, terminating in a slightly inclined plane, over the edge of which the scum is pushed by the rake into a trough and carried away.

A secondary purpose served by the defecator is that of reducing the juice by evaporation to a partial syrup of the specific gravity of about 20° B. When of this consistency the liquid is drawn from the bottom and the less agitated portion of the defecator by a syphon and thence carried to the evaporator, which is located upon the same framework and just below the defecator.

The evaporator consists of a separate system of six copper tubes, each 12 feet long and 3 inches in diameter. These are jacketed, or inclosed in an iron pipe of 4 inches internal diameter, fitted with steam-tight collars so as to leave half an inch space surrounding the copper tubes. The latter are open at both ends, permitting the admission and egress of the syrup and the escape of the steam caused by evaporation therefrom, and are arranged upon the frame so as to have a very slight inclination downward in the direction of the current, and each nearly underneath its predecessor in regular succession. Each is connected by an iron supply-pipe, having a steam-gauge or indicator attached, with a large manifold, and that by other pipes with a steam boiler of 30 horse-power capacity.

Steam being let on at from 25 to 30 lbs. pressure, the stream of syrup is received from the defecator through a strainer, which removes any impurity possibly remaining, into the upper evaporator tube; passing in a gentle flow through that, it is delivered into a funnel connected with the next tube below, and so back and forth through the whole system. The syrup enters the evaporator at a consistency of from  $20^{\circ}$  to  $23^{\circ}$  B. and emerges from the last tube, some three minutes later, at a consistency of from  $30^{\circ}$  to  $32^{\circ}$  B., which is found on cooling to be the proper point for perfect jelly. This point is found to vary one or two degrees, according to the fermentation consequent upon bruises in handling the fruit, decay of the same, or any little delay in expressing the juice from the cheese. The least fermentation occasions the necessity for a lower reduction. To guard against this, no cheese is allowed to stand over night, no pomace left in the grater or vat, no juice in the tank; and further to provide against fermentation a large water-tank is located upon the roof and filled by a force-pump, and by means of hose connected with this, each grater, press, vat, tank, pipe, trough, or other article of machinery used can be thoroughly washed and cleansed. Hot water instead of juice is sometimes sent through the defecator, evaporator, etc., until all are thoroughly scalded and purified.

If the saccharometer shows too great or too little reduction, the matter is easily regulated by varying the steam pressure in the evaporator by means of a valve in the supply pipe.

If boiled cider instead of jelly is wanted for making pies, sauces, etc., it is drawn off from one of the upper evaporator tubes, according to the consistency desired; or it can be procured at the end of the process by simply reducing the steam pressure.

As the jelly emerges from the evaporator it is transferred to a tub holding some 50 gallons, and by mixing a little therein any slight variations in reduction or in the sweetness or sourness of the fruit used are equalized. From this it is drawn through faucets, while hot, into the various packages in which it is shipped to market.

A favorite form of package for family use is a nicely turned little wooden bucket with cover and bail, of two sizes, holding 5



and 10 pounds respectively. The smaller packages are shipped in cases for convenience in handling.

The present product of this factory is from 1500 to 1800 pounds of jelly each day of 10 hours. It is calculated that improvements now in progress will increase this to something more than a ton per day. Each bushel of fruit will produce from 4 to 5 pounds of jelly, fruit ripening late in the season being more productive than other varieties. Crab-apples produce the finest jelly, sour crabbed natural fruit makes the best-looking article, and a mixture of all varieties gives most satisfactory results as to flavor and general quality.

*Saving of the apple-seeds.*—As the pomace is shovelled from the finished cheese it is again ground under a toothed cylinder, and thence drops into large troughs through a succession of which a considerable stream of water is flowing. Here it is occasionally agitated by raking from the lower to the upper end of the trough, as the current carries it downward, and the apple-seeds becoming disengaged drop to the bottom into still water while the pulp floats away upon the stream. A succession of troughs serves to remove nearly all the seeds.

The value of the apple-seeds thus saved is sufficient to pay the daily wages of all the hands employed in the establishment.

The apples are measured in the wagon-box, one-and-a-half cubic feet being accounted a bushel.

The establishment is owned by George B. Bloomer, of New York, who is also the inventor of the defecator, evaporator, and much of the other machinery in use. It was erected late in the season of 1880, and manufactured that year about 45 tons of jelly, besides considerable cider exchanged to the farmers for apples, and some boiled cider.

The price paid for apples in 1880, when the crop was superabundant, was 6 to 8 cents per bushel; in 1881, 15 cents.

Such institutions are important to the farmer in that they use much fruit, not otherwise valuable and very perishable. Fruit so crabbed and gnarled as to have no market value, and even frozen apples, if delivered while yet solid, can be used. Such apples are placed in the water while frozen, the water draws the frost sufficiently to allow of their being grated, and passing through



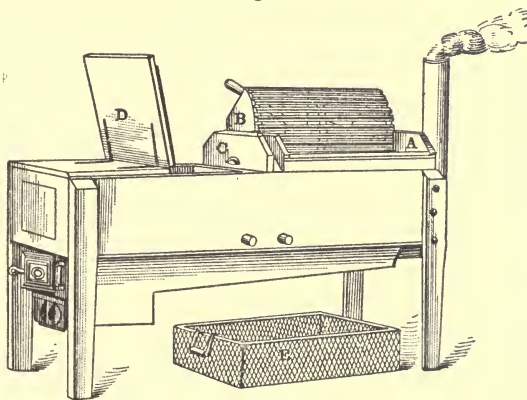
the press and evaporator before there is time for chemical change, they are found to make very good jelly. These establishments are valuable to the consumer by converting the perishable, cheap, almost worthless crop of abundant years into such enduring form that its consumption may be carried over to the years of scarcity, and furnish healthful food in cheap and pleasant form to many who would otherwise be deprived, and lastly they are of great interest to society in that they give to the juice of the apple twice the value for purposes of food which it has or can have, even to the manufacturer, for use as a beverage.

We will finally devote some space to the description of the most important apparatus required in the preservation of fruit, viz :

### *The Kettle.*

Without entering into a discussion of the various kettles used in other countries, we give in Fig. 75 an illustration of a very practical apparatus much used in American preserving establishments. A few words will suffice for explanation. A, B, C indi-

Fig. 75.



cate a washing apparatus for washing the fruit, and which can be lifted out. When this is done a lid similar to *D* is hung near the chimney. The basket or crate *E*, as here shown, is of wire, in which form it serves for fruit to be dipped into hot water for a few moments only, as, for instance, peaches which are to be pared.

For boiling down in a water bath a copper basket is used. The fire-place is of double sheet iron, the doors and grate of cast-iron. The kettle is of copper and jacketed on the four sides with two inch boards. In the centre it is divided by a movable copper partition. It is 10 inches deep, 48 inches wide, and 60 inches long. The entire apparatus weighs 150 pounds. It is, of course, scarcely necessary to mention that this kettle is manufactured in all sizes according to the requirements of the manufacturer. As seen in the illustration, the fire-place extends beneath the entire width and length of the kettle whereby the contents are quickly heated with a comparatively small consumption of fuel. The apparatus being transportable it can be placed wherever most convenient, and being accessible from all sides its use is very convenient and saves time.

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## CHAPTER XXX.

### EVAPORATION OF FRUIT.

OF all the methods employed for preserving fruit for any length of time none has a greater future before it than the one to be discussed in this chapter. The reason for this can be readily given: the process does not require great technical skill; it excels in cheapness because neither vessels, sugar, nor other auxiliaries are required, the product possesses excellent keeping qualities, retains its natural flavor, and being healthier and more agreeable than fruit preserved by any other method, is especially suitable for food for the masses.

Evaporated fruit of to-day is entirely different from the dried fruit of a dozen years ago. Who does not remember the shrivelled, dark-colored, wedge-shaped pieces of apple and peach that were sold by the family grocer? They possessed the tenacity of sole-leather and were uninviting to look and smell. Before they could be used in the home-made pies they required to be boiled and stewed for hours at a time. The preparation of dried fruits of those days was primitive. Farmers' wives and daughters pared

and sliced the apples by hand and placed them on wooden trays, which were set out in the sun. It took days to dry the fruit, and exposure to showers and the night air had to be avoided or the lot would be spoiled. The advent of steam evaporators and scientific methods has wrought a great change in the business. Large evaporating establishments have been put up, thousands of men given employment, and a prosperous industry created. The superiority of the evaporated fruits to the sun-dried article has caused an immense demand for them, and aside from the consumption in this country large amounts are shipped abroad. The new processes now in use produce fruit that retains much of its original color, and that is as palatable as though it were in its fresh and natural condition.

The following statement may suffice to show to what proportions the business has grown: Within a radius of 40 miles of Rochester, New York, there are 1500 evaporators, from the small farmhouse apparatus, with a capacity of 25 bushels per day, to the large steam evaporators drying from 800 to 1000 bushels of apples every 24 hours. These evaporators employ over 30,000 hands during the fall and early winter months. Large quantities of apples of a quality that was formerly wasted are utilized, and the profits of fruit raising largely increased. The annual product of evaporated fruit in the State of New York alone is now estimated at 30,000,000 pounds worth at first cost about \$2,000,000. In order to produce this quantity of dried fruit no less than 5,000,000 bushels of apples are required and 15,000 tons of coal consumed. A constant attendance, night and day, of an army of men, women, and children, numbering 30,000, is necessary. The process of evaporation eliminates 225,000 tons of water, reducing the green fruit to about one-eighth of its original weight, each 100 lbs. yielding when properly evaporated 12 lbs. of fruit.

Aside from the fact that evaporated fruit can be transported to any clime without deterioration, the advantage in the cost of freight is great. A case of concentrated product costs 30 cents for transportation to Liverpool; in the green state the  $8\frac{1}{2}$  bushels required to produce the 50 lbs. contained in each case, would cost \$2.25, and in the canned state the cost would be \$2.10. The total exports of evaporated and dried apples for the fiscal year



ending June 30, 1888, were 1,803,161 lbs., of the value of \$812,682. Some idea may be gathered of the enormous increase of the fruit-growing industry from the fact that in 1850 the fruit crop of the United States was valued only at \$8,000,000, while in 1886 it was estimated at \$137,000,000.

The process of evaporating fruit is a comparatively recent one, it being not more than fifteen years since the granting of the Alden patent. Like all other new inventions some years were required before its merits became thoroughly understood, though at the Paris Exhibition of 1878 the first prize was unanimously awarded to the fruit dried by that process. Since then it has spread from California, where it was first introduced, throughout the entire country, and has created a complete revolution in the fruit industry. A number of other apparatuses have been invented, but they are all based upon the same principle. At first only kernel and stone-fruits were evaporated, but at the present time the list comprises the following articles: apples, pears, peaches, apricots, plums, nectarines, figs, cherries, blackberries, grapes, green corn, peas, potatoes, sweet potatoes, onions, tomatoes, pumpkins, rhubarb, asparagus, hops, tobacco, meat, oysters, fish, and eggs. This list is not by any means complete, because what has been said of the canning industry also holds good as regards the evaporating establishments: they every year include within the sphere of their activity new suitable articles. And it is no wonder, because their products bring double the price of those dried in the sun or in the oven. A great advantage of evaporated fruit is that it, even after years, regains its natural form and freshness when placed a few hours in fresh water and then boiled up with an abundant addition of water. No leathery skin nor unnatural taste of sugar is observed. To all who desire the natural taste of the fruit there can be no question that evaporated fruit is preferable to that preserved with sugar in cans, which at the present time is its principal competitor. And this result is obtained by less expensive means and with greater certainty. The tin cans cost sometimes four times as much as the fruit they contain, and the loss by leakage amounts on an average to 10 per cent., though occasionally to the entire value of the shipment. Complaints have been made by nearly every expedition to the North Pole that a considerable portion of their canned goods had to be thrown overboard, making retrench-

ment necessary, which sometimes amounted to actual want. When, in 1881, the steamer "Rodgers" was ready to sail from San Francisco in search of the "Jeanette" it was detained for eight days by the discovery that of the stock of canned goods on board 4000 cans were leaky, and contained provisions already in a state of decay. Every sea-captain can tell of the same kind of experience. The blame rests partially upon the manufacturers who permit the work to be done carelessly, and do not take into consideration that the slightest access of air spoils the contents of the can, but partially also upon the mode of preservation itself, because even faultlessly closed cans have the disadvantage that when once opened their contents must be immediately used, while the packages containing evaporated fruit may remain open for years in every climate. Moreover, in eating the latter, lead poisoning need not be feared, and, as previously stated, it has the further advantage of a great reduction in the cost of freight. Green peas, of which, as is well known, immense quantities are canned, may serve as another example. In the canned state seven boxes of them weigh 350 lbs., while one box of evaporated peas, which contains the same quantity of substance, but deprived of its content of water, weighs only 43 lbs., though when placed upon the table there is not the slightest difference as regards quality between the two articles. Taking into account all these advantages, and considering at the same time that by a good method of drying the hazards and annoyances connected with the preservation of fruit in a fresh state can be largely overcome, it must be concluded that the evaporating process is destined to play in the future a still greater part in the preservation of fruit than it does already at the present time.

Before entering upon a description of the apparatus and its use, it will be necessary to explain the principle upon which it is based and the theory of evaporating fruit.

The object to be attained is not only to make the fruit keep, but also to retain the properties for which it is valued. This can only be reached by withdrawing the content of water, and at the same time converting a portion of the starch into sugar in as short a time as possible without boiling the fruit. The latter would injure the taste of the fruit, and slow drying gives a flavor calling to mind decay. The quicker the watery portions are removed



from thoroughly ripe fruit the richer and more durable its taste will be; and the more completely the oxygen of the air is excluded during this process the more perfectly will it retain its color. Rapidity of the drying process sometimes increases the content of sugar by 25 per cent., and this increase is in an exact proportion to a slower or quicker evaporation of the content of water, always provided, however, the fruit does not suffer injury from the heat.

Any one who has boiled down the juice of the maple, sorghum, sugar-cane, or sugar-beet knows that with slow evaporation sugar is not formed, the content of sugar being then converted into acid. Now, the change of substance must be constantly kept in view: starch is converted into sugar (in this case very largely already in the plant), sugar into alcohol, and alcohol into vinegar. This experience must also hold good in drying fruit. The chemical process by which the content of starch of the fruit, when brought into a high temperature, is converted into sugar is similar to that during the ripening process on the tree, only it takes place more rapidly.

A few days of warm sunshine produce sufficient sugar in gooseberries and grapes to change the sour unpalatable fruits to a refreshing article of food. A few hours in an evaporating apparatus, in which the proper degree of heat is maintained, can produce a still greater change, provided the fruit be not placed in it before it has reached perfection in a natural manner. It must be remembered that 212° F. is the boiling point, and that subsequent treatment, no matter how careful, cannot restore the taste lost in such a temperature. Of no less importance is another point: the surface of the fruit to be dried must be kept moist and soft, so that the internal moisture may find a way by which it can readily and quickly escape, and a strong hot current of air must uninterruptedly pass over the fruit to carry off the escaping moisture. Hence, cold air must under no circumstances have access to drying fruit, and above the latter an aperture must be provided for the escape of the air saturated with moisture.

The apprehension that fruit cannot be dried in a hot moist apparatus is refuted by the well-known scientific fact, that air of the temperature of the freezing point absorbs  $\frac{1}{180}$  part of its weight of moisture, and that its capacity for absorption doubles with every 15° C. (59° F.) of higher temperature. Thus, if the tem-

perature is  $59^{\circ}$  F. it absorbs  $\frac{1}{80}$  part of its weight of water,  $86^{\circ}$  F.  $\frac{1}{40}$  part,  $113^{\circ}$  F.  $\frac{1}{20}$  part,  $140^{\circ}$  F.  $\frac{1}{10}$  part,  $167^{\circ}$  F.  $\frac{1}{5}$  part,  $194^{\circ}$  F.  $\frac{4}{5}$  part, and  $221^{\circ}$  F. its own weight, which is nearly equal to one pound of water to every  $\frac{1}{8}$  cubic foot of air.

The fruit would evidently never become dry if the air loaded with such moisture remained stationary, but set it in motion with a velocity of 880 feet per minute, which is equal to 20 miles per hour, and the cause of the rapid drying, or, in other words, of the withdrawal of water, becomes apparent. Now if we figure to ourselves an apparatus of 225 cubic feet content, the air heated to  $212^{\circ}$  F. in it contains, according to the above statement, 60 pounds of water, 50 pounds of which have been withdrawn from the fruit, while the remaining 10 pounds were contained in the air prior to its entrance into the apparatus, because its temperature is supposed to be  $62.5^{\circ}$  F. With sufficient circulation to empty the apparatus every 20 minutes, 150 pounds of water will each hour be carried from a quantity of fruit supposed to amount to 800 pounds. Hence, in 5 hours, the time generally required for apples, 750 pounds of moisture could be removed if present.

Moreover, reference to a drying apparatus is not required to prove that heat alone does not suffice for drying. Is it not the wind which dries up the puddles after a rain more quickly than the hottest rays of the sun? The sun alone would effect nothing else but envelop the moist earth in a dense mantle of vapor destructive to both men and animals. Thus in the drying apparatus also it is rather the current of air which dries than the heat, but, of course, both must work in conjunction. The rapidity of the process prevents decay, and causes the color and aroma of the fresh fruit to be retained. The greater advantage of this rapidity consists, however, in the conversion of a considerable quantity of starch into sugar, which in sweet fruits, such as peaches, is sometimes formed in such abundance as to appear in small congealed drops upon the surface.

From the preceding it will also be readily understood why drying in the sun or in the oven must yield unsatisfactory results. Even with favorable weather the process lasts about 14 days; during this long time a fermentation sets in which partially destroys the content of sugar, and essentially changes the color and taste in an unfavorable direction. Such fruit when

boiled tastes as if it had been preserved after the appearance of decay. Besides, during this process, the fruit is frequently selected as a breeding place by insects, in consequence of which it soon spoils, and when shipped to a distance resembles on arrival at its place of destination a heap of maggots. Such cases are not rare, especially if the dried fruit is shipped to tropical countries.

Drying in the oven has the disadvantage that the dry heat immediately closes the pores of the fruit, thereby rendering the escape of the internal moisture very difficult. If the heat is not very strong the fruit remains moist in the interior, which causes it to spoil, and with a strong heat the surface carbonizes more or less. A portion of the sweetness is lost by being converted into caramel, the appearance of the fruit suffers by the tough shrivelling of the surface, and the taste is injured by carbonization.

All these disadvantages are avoided by the modern evaporating process, which may be called a preservation of the fruit in its own juice with the assistance of steam.

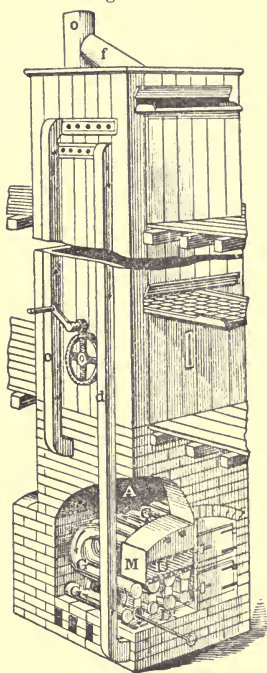
A chemical analysis of a parcel of Baldwin apples shows best the changes effected in the composition of fruit by drying in the oven and by evaporation, and how the results with these two methods compare with each other. The first column gives the composition of 500 parts of fresh Baldwin apples. The second column gives the composition of the same parcel of apples after being reduced to 100 parts (loss of 400 parts of water) by drying in the oven, and the third column the result of 100 parts of the same parcel reduced by evaporation.

	Fresh.	Dried in the oven.	Evapo- rated.
Water (free and fixed) . . . . .	411.15	12.42	16.62
Cellulose . . . . .	9.60	10.54	10.22
Starch . . . . .	32.95	30.95	29.75
Protein . . . . .	0.75	0.80	0.76
Pectine . . . . .	12.35	11.35	10.88
Gum . . . . .	6.75	7.22	4.33
Fruit acids . . . . .	6.70	4.88	3.43
Mineral constituents . . . . .	0.85	0.87	0.78
Chlorophyl . . . . .	0.15	0.12	0.15
Dextrin . . . . .	—	2.10	—
Grape sugar . . . . .	18.75	18.75	23.08
Volatile oils, traces . . . . .	—	—	—
	<hr/> 500.00	<hr/> 100.00	<hr/> 100.00

Attention must especially be drawn to the fact that dextrin, the formation of which is due to *dry* heat, is only found in the second column, and must be considered as an essential disadvantage of drying in the oven. The absence of this substance in evaporated fruit, as well as the presence of a larger quantity of water (chemically fixed), is to be ascribed to the influence of moisture during evaporation.

A presentation of the process of evaporating fruit must be preceded by a description of the apparatus used. Fig. 76 shows the Alden apparatus as recently perfected. *A* is the air-furnace, which is formed by the fire-box *D*, the ash-box *D*<sub>1</sub>, and the doubled horizontal pipes *G*, of which, according to the size of the apparatus, there are from 3 to 6, each 4 inches in diameter, and running parallel to each other; the products of combustion pass through them in the direction of the arrows, and escape through the smoke-pipe *O* at the back of the apparatus. The fire-box is surrounded with an air-space provided at *M* with apertures. Similar apertures to permit the entrance of cold air are provided on the side near the foot of the brick casing. The cold air comes first in contact with the lower, only moderately heated, pipes, then rises to the second, and finally to the third and hottest series of pipes. It is thus gradually heated, and the pipes lying close together, each atom of air comes in contact with them, which is considered a better mode of heating than by radiation, formerly used. The pipes are of cast-iron, and an escape of smoke into the drying-tower is impossible. By always keeping the pipes clean, which can be conveniently done, the heat passes rapidly through their walls, and ascends immediately into the drying-tower without the possibility of super-heating.

Fig. 76.



The draught-pipe *d* connects the exit of the drying-tower with the fire-box of the furnace. The importance of this ventilation is sufficiently shown by the statement that for combustion 25,000 cubic feet of air per hour are required, which are introduced from the neighborhood of the opening of the tower through the pipe *d* into the fire-box. The removal of such a considerable quantity of air produces a vacuum in the upper portion of the tower, and consequently a very quick current of air over the trays of fruit in the tower—an absolute requirement for attaining great perfection in the art of drying fruit by evaporation. Besides, a saving of fuel is effected by the introduction of air already heated into the fire-box. The smoke-pipe *O* is surrounded by a wooden jacket leaving a small intermediate space in which the heat radiating from the pipe collects, and is forced to enter the tower below the discharge-door. This also accelerates the current of air in the tower and prevents the condensation of the moisture, so that the fruit completely dries off in a short time. The branch-pipe *f* connects the opening of the tower with the smoke-pipe, which by its power of absorption also increases the current of air. The draught-pipe *e* is provided, as will be readily seen, for the purpose of uniformly distributing the heat in the tower.

The bulb of the thermometer, with which the apparatus is provided, is placed in the interior of the tower and the scale on the outside, so that the temperature can be read off without opening a door, whereby cold air would enter, which must be avoided. The air-furnace is constructed of brick, and the tower, as well as the draught-pipes *d* and *e* and the jacket of the smoke-pipe *O*, of double boards.

The hurdles or trays for the fruit consist of wooden frames with galvanized iron wire bottoms. They hold from 20 to 60 lbs. of fruit each, and when charged are pushed through the door over the air-furnace into the tower, where they rest upon pins of an endless chain set in motion by a wheel, as seen in the illustration. The trays sit close to the walls on two sides of the tower, while in the other direction there is an interspace of two inches. The first tray is pushed tight against the back wall, the mentioned interspace thus remaining in front of the door.

After six to ten minutes, according to the variety of fruit, the



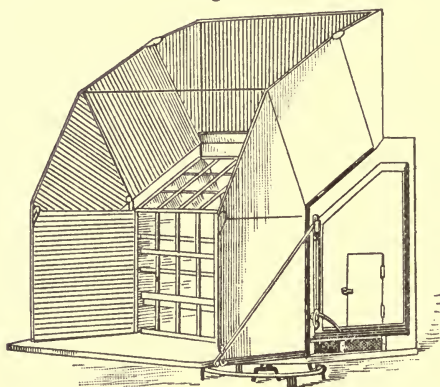
tray is raised five inches by means of the endless chain ; the second tray is then placed in position, but so that the above-mentioned intermediate space is at the back wall. At regular intervals the trays, when placed in position, are raised by the endless chain and the fresh trays pushed in, so that they touch alternately the front and back wall, the current of hot air being thus forced to ascend in a zigzag. When the tower is filled with trays it contains—taking apples as an example—from 1200 to 3000 lbs. of fruit, every 50 lbs. of each yield from 40 to 45 lbs. of water, which ascends as vapor, which by surrounding the fruit with a moist mantle prevents its burning and keeps the pores open. When the tray first placed in position arrives at the discharge-door it has been in the tower for about five hours, and its contents have been converted into evaporated fruit which will keep for many years. Thus fruit can be gathered, evaporated, and sold all in one day.

By considering the construction of the tower it will be seen that the fruit during its ascent remains in a uniform moisture and heat, so that up to the moment it is taken from the apparatus, its content of water can escape through the opened pores and, on the other hand, the heat can act to its very centre. A uniform, perfect product can be obtained only by these means. When the fruit arrives at the discharge-door it is cool and as soft as fresh fruit.

We will here call attention to a sun-drying apparatus, shown in Fig. 77, which may be recommended to those who do not wish to employ artificial heat, and are forced to give the preference to as cheap an apparatus as possible. The apparatus is constructed of boards and window-glass. The board walls, which are somewhat inclined outwardly, project above the panes of glass and serve, as is readily seen, for catching the rays of the sun. They are lined inside with tin, thus becoming reflectors. The side door serves as an entrance to the apparatus when the panes of glass are to be cleansed or repairs are to be made in the interior. The trays containing the fruit are pushed in from the back, the entrance of each tray being covered by a wooden flap. According to the size of the apparatus two or three rows, each consisting of twelve trays, are placed alongside each other. Above

the uppermost entrances for the trays are slides, which can be opened or closed according to whether the heat in the interior is to be increased or moderated.

Fig. 77.



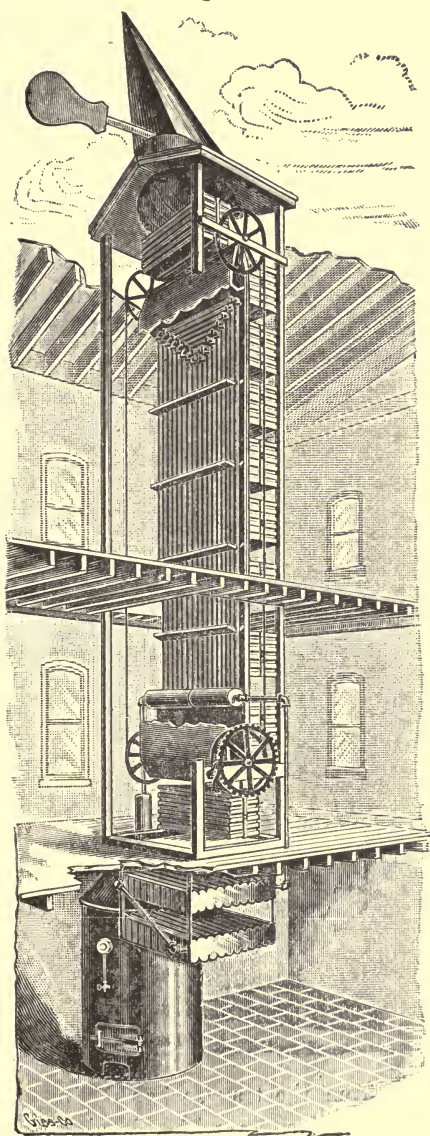
The apparatus stands upon a turn-table, so that the front can from morning to evening be exposed to the full rays of the sun. When the latter no longer reach the apparatus the reflectors, which are hinged, are laid over the panes of glass, which prevents the radiation of heat and protects the fruit from dew.

The time required for drying fruit in this apparatus cannot, of course, be definitely stated, but on an unclouded hot summer day apples pared by a machine can be dried in eight hours. The product obtained is not of as good a quality as evaporated fruit, but it is incomparably superior to that produced by the primitive method of drying in the open air or in the oven.

Referring back to the Alden apparatus previously described, it remains to be said that there are a number of other evaporators based upon the same principle but with various modifications and improvements.

Fig. 78 shows the improved Williams evaporator manufactured by S. E. Sprout, of Muncy, Pa. The apparatus is heated by steam radiators located at the base of the vertical tower, and has vertical radiating pipes up the centre of the vertical tower, around which the trays of fruit revolve, with deflectors at intervals of two feet projecting from each side of said pipes to direct the heat

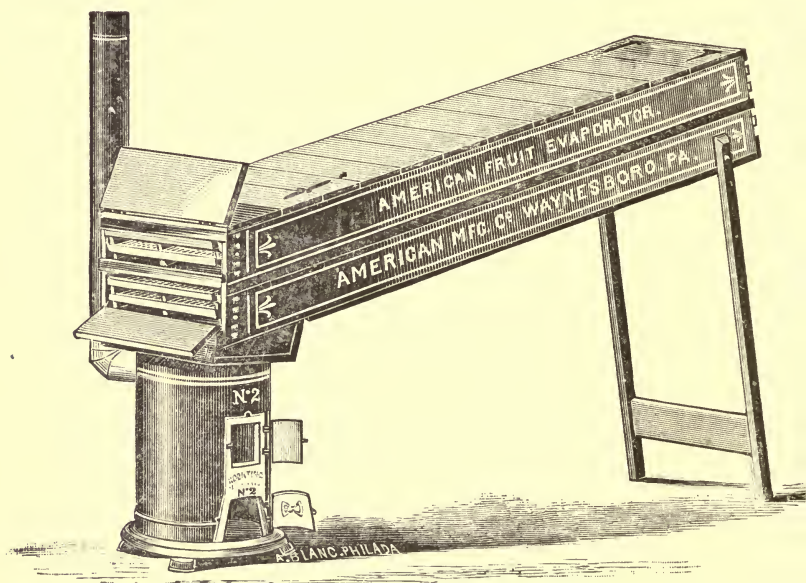
Fig. 78.



under the trays of fruit as they revolve around the pipes. (The trays and hanger are left out in the illustration to show the in-

terior arrangement of the pipes.) These pipes or radiators extending up the tower from bottom to top produce a uniform heat the entire length of the tower, and increase the draught by increasing the heat at the top, which produces a more rapid circulation than when the heat is all at the bottom, as with the hot-air furnace; and the capacity of the apparatus is also increased in proportion to the increase of the heat and the draught through the tower. The trays of fruit in passing up the tower are exposed from one side to the pipes, and on descending are exposed from the other, which causes the fruit to dry uniformly. The tower being vertical the heat is utilized until it reaches the top. In this apparatus a very strong heat can be had throughout the entire length of the tower, without incurring any risk of

Fig. 79.



fire from siftings from the trays, when drying cores and skins, falling on the hot-air furnace, which is always placed directly under the tower. Several sizes of this evaporator are manufactured.

Fig. 79 shows the American fruit evaporator, several sizes of



which are manufactured by the American Manufacturing Company, of Waynesboro, Pa. It differs from the preceding in having an inclined trunk. The advantages claimed for it by the manufacturers are that separate currents of pure, dry air, automatically created, pass underneath and diagonally through the trays and then off over them, carrying the moisture out of the evaporator without coming into contact with the contents of the trays previously entered. The greatest heat is concentrated upon each tray or group when first entered, these in turn being moved forward into a lower temperature by those entered in sequence, hence no steaming or cooking becomes possible. The evaporator shown in the illustration is  $9\frac{1}{2}$  feet long and 28 inches wide; it has 22 trays of galvanized iron cloth, and a capacity of 10 to 12 bushels of apples per day. It consumes about 80 pounds of coal or its equivalent in wood or coke. The furnace supplies strong currents of dry, hot air, which pass through the two chambers of the evaporator-trunk and carry off the moisture or vapor discharged from the fruit over and above the line of trays in each chamber. No steaming, cooking, or retrograde or diffusive features attend the operation. The trays in groups of two at a time are entered in front in the upper (hotter) chamber and moved forward by insertion of the next group, and finished in the lower chamber and at a lower temperature. Thus the process is continuous, and each tray receives the same treatment and conditions, viz., greatest heat when first inserted, and finishing at a gradually lowering temperature and safety from scorching. The evaporators are manufactured in several sizes ranging in price from \$25 to \$450, and for extensive commercial plants with sundry modifications and mechanism for coffee, tea, etc., of great capacity costing \$1000 and upwards.

The manner of operating the Alden apparatus is as follows: The maintenance of a uniform temperature in the tower being essential, the thermometer should indicate  $194^{\circ}$  to  $212^{\circ}$  F.; berries and stone fruit are to be kept somewhat cooler. The introduction of too much cold air into the air-furnace must be avoided. As a rule an aperture two feet square suffices.

The upward motion of the trays must be effected at regular intervals. How long these intervals are to be cannot be definitely



stated, it depending on the content of water in the fruit and on the temperature of the tower. The following table may, however, serve as a guide :—

Apples	.	.	.	.	.	interval	6 to 10 minutes.
Pears	.	.	.	.	.	"	8 " 12 "
Peaches	.	.	.	.	.	"	12 " 20 "
Stoned plums	.	.	.	.	.	"	15 " 20 "
Apricots	.	.	.	.	.	"	8 " 15 "
Stoned cherries	.	.	.	.	.	"	10 " 20 "
Berries	.	.	.	.	.	"	10 " 20 "
Potatoes	.	.	.	.	.	"	6 " 8 "
Green corn	.	.	.	.	.	"	5 " 7 "
Onions	.	.	.	.	.	"	12 " 20 "
Tomatoes	.	.	.	.	.	"	20 " 25 "

It is supposed that the temperature directly above the air-furnace is  $212^{\circ}$  F., and it is best to keep it that degree except for berries and stoned fruit, for which it may be from  $41^{\circ}$  to  $50^{\circ}$  less. As previously stated, it is an essential condition that the fruit should not boil. This will, however, not be the case at the temperature mentioned because the fruit remains too short a time in it, and in rising upwards meets a somewhat more moderate heat. As a rule it may be said that as high a temperature as possible is most advantageous provided boiling be avoided.

The evaporated fruit when taken from the tower is spread out in an airy room, where it remains for a few hours to dry off. Care must be had that during this time it does not come in contact with insects, and to prevent this the windows and air-holes must be provided with screens or the fruit covered with musquito netting. The fruit when ready for packing is put up in boxes as follows: Line the box with colored paper with the ends projecting above the edge. Then fill the box with fruit; kernel fruit is piled up about one inch above the edge of the box while stone fruit is not piled so high, it being subsequently not subjected to pressure. To press down the contents even with the edge of the box a weight, or, still better, a press is used. After pressing fold the ends of the paper over the fruit, nail down the lid, and put on the label.

Sliced evaporated apples are packed as follows: Line the box with white paper, one piece on the bottom and four pieces on the

sides long enough to fold over. Then nail down the lid, take off the bottom, and commence packing by placing one layer of slices in the manner of roof-tiles. Sufficient fruit to make up the required weight is then piled in, and after pressing down the box is nailed up and labelled. A general rule as regards weight has not been introduced, though in California all varieties of evaporated fruit are packed in boxes holding 50 pounds net.

Now a few words in regard to the varieties of fruit to be used. To be sure every kind of fruit can be evaporated, but poor qualities remain bad after evaporation. No one who wishes to be successful in the business should for one moment entertain the idea that fruit unpalatable in a fresh state is good enough for evaporating. For commercial purposes the selection of varieties must be made as carefully as for fresh fruit, or, briefly stated, only table fruit should be evaporated, this referring especially to apples and pears, of which the mellow and luscious varieties alone should be selected. The intelligently conducted evaporating establishments in this country are very careful in this respect, they having like the canning establishments certain favorites, for instance, of apples, the Gravenstein, Red Astrachan, Autumn Pippin, Newtown Pippin, Bellflower, Baldwin, Northern Spy; of pears, the Bartlett, Autumn Butler Pear, Clapp's Favorite; of plums, Reine Claude, Coe's Golden Drop, Columbia, Washington; of cherries, Royal Ann and Elton. No discrimination is made in regard to berries, peaches, and apricots, all varieties being used.

Apples should be pared with a machine and sliced. So many different styles of apple parers are in the market that it is difficult to say which is the best. One which pares, cores, and slices the apple at one operation should be selected. Pears are better pared by hand, and peaches with a rotary knife parer.

Stone-fruit is sometimes stoned, which is effected with the well known stoning machine, but as the different kinds of machines in the market are by no means perfect, it is best for prime ware to remove the stones by hand until some ingenious head invents a machine which will bruise the fruit as little as the human hand.

Apples and pears when pared acquire a brown coloration, which is not lost by drying no matter by what method. Now how is it that many apples and pears of a white yellow or pale yellow

color are brought into the market? The color has nothing to do with the quality of the product, but its sale depending on its appearance the apples and pears are bleached before evaporating. The process is very simple: a number of trays are placed on top of each other, and a bundle of sulphur matches ignited under them. Sometimes lime is slacked under such a pile of trays, the fruit being in both cases bleached by the ascending vapors. Others again place the fruit for some time in a water-bath impregnated with sulphur. These methods are mentioned, not to recommend them, but rather to warn against them, and, besides, because it is frequently believed that the pale color of the fruit is due to a more perfect method of drying. The use of sulphur for this purpose deserves censure, it being injurious to health, and the consumer should prefer naturally colored evaporated fruit to the bleached article, which is readily recognized by its pale color. There is but one method leading to the same result which can be unhesitatingly used, that is, to throw the fruit when pared into salt water, where it is allowed to remain until placed in the trays. The color is not as pale as that obtained by bleaching, but it is more natural which, in our opinion, is an advantage. Decay setting in immediately after the fruit is cut, it should be brought into the evaporating tower as soon as possible. A warm salt-water bath is also frequently used for stone fruit which is to be evaporated without removing the stones, in order to better retain its natural appearance. The same purpose can, however, be better attained by the use of a bath of lukewarm or cold alum water, which can also be advantageously employed in preserving the fruit in jars and cans. Plums after evaporating are generally brought into a bath of sugar-water in order to give them the lustrous and uniformly dark appearance observed in French prunes. For this purpose brown sugar is dissolved in an equal quantity of hot water, and the prunes in a wire basket submerged in the bath for half a minute. They are then spread out upon hurdles and packed when perfectly dry.

The trays which are to be placed in the evaporating tower must not be loaded too heavily with fruit. Stone-fruit not freed from the stones is placed close together with the stem end upwards, but only in one layer. Quartered or halved stoned-fruit, as well

as sliced apples, are placed close together edge upward until the bottom of the tray is covered. Sliced pears are arranged in a similar manner. Of berries several layers an inch deep may be made, but they must be covered with tissue-paper. Grapes are but seldom converted into raisins in the evaporating apparatus, because the process would require 40 hours, it being impossible to use a temperature exceeding  $176^{\circ}$  F. Hence it is considered more advantageous to dry grapes in the sun. For the northern limits of grape-culture the evaporating process for raisins may, however, prove of great importance if only for supplying the home market, especially when experience shows, as it has during the last few years in California, that the production pays on an average better than that of wine. It need only be remembered that the principal producers of raisins, the Spaniards and Greeks, are entirely dependent on the weather, which frequently causes them heavy losses. The evaporating apparatus, however, makes the manufacturer independent of the weather, and no Spanish or Greek sun is required for the production of excellent raisins.

Tomatoes are peeled but not sliced, and placed close together in one layer in the trays. Pumpkins are peeled and cut in pieces two or three inches thick. For several years a flour has been made from the dried pieces which serves as a substitute for rice flour. Sweet potatoes are treated in a similar manner, their flour serving as a substitute for chicory.

Green corn is first steamed on the ear for not more than five minutes. The grains are then picked off, placed in two-inch deep layers in the trays and thoroughly evaporated, but not at too high a temperature,  $185^{\circ}$  to  $194^{\circ}$  F. being sufficient. When dry it is rubbed and passed through a fanning-mill to remove the hulls loosened by rubbing. It is packed in boxes holding 10, 20, and 50 lbs. each, and brings wholesale from 10 to 12 cents per pound.

The following must also be steamed before evaporating: green peas and beans, asparagus, beets, carrots, lettuce, cabbage, and parsnips. Vegetables are cut up with a cabbage-cutter, and roots in slices like apples.

Onions are first freed from their external red or yellow peel and then cut into slices one-fourth inch thick with a cabbage-cutter. The slices are steamed for five minutes, which, with a suitable steaming

apparatus, is best effected by spreading the slices in a two-inch deep layer in the trays, placing the latter in the steaming apparatus, and immediately after the above mentioned time in the evaporator. They are packed in tin boxes holding 50 lbs. each, which are placed in a wooden box. By evaporation, 100 lbs. of onions are reduced to 12 lbs. The average wholesale price is about 30 cents per pound.

Potatoes must be thoroughly washed. This is best effected in a cradle, the bottom of which is provided with wide perforations so that the water constantly pouring in can run off quickly. The potatoes are then placed in trays, and from four to six of the latter, according to the size of the steaming apparatus, brought into the boiler. Steam is then admitted, and after 35 minutes the potatoes are taken out, care being had, however, not to steam them much, as otherwise they become of no value for the evaporating process. The loosened peels are then rubbed off with the hand, and the peeled potatoes brought into a press, the bottom of which consists of a perforated wooden plate or of woven wire. The lid must fit tight to the interior walls of the press, so that the entire mass of potatoes falls coarsely crushed through the bottom. The crushed potatoes are placed in layers two or three inches deep in the trays and levelled with an instrument made by driving small nails into a board so that their points project one-half inch. They are then evaporated at not too high a temperature—185° F. is sufficient—to prevent scorching; taking care, however, to dry them through. The evaporated mass is coarsely ground in a suitable mill, and the resulting flour packed in zinc canisters, holding 28 and 56 lbs. each. Two such canisters are placed in a wooden box, and are then ready for shipment.

It is of the utmost importance to select only perfectly sound potatoes and remove all which sour or are injured in any other way during the process. Success depends on the rapidity and regularity from the commencement to the end of the process. All potatoes which become cold before being brought into the evaporating apparatus are worthless, and the same may be said of those which have been steamed too long; they are converted into paste.

From a statement by an English commission house, in reference to a shipment of evaporated potatoes from the Pacific coast, it was



learned that the price obtained was 40 shillings for 110 lbs. The commission, freight, etc., of the entire shipment of 20 boxes, each containing 108 lbs. net, amounted to £5 15s. 7d. Annexed to the statement was the following suggestion: The potatoes should be packed in canisters holding 56 lbs. and made of black sheet-iron painted red on the outside. In the top should be a round hole large enough to admit the hand, and closed by a slide. A large label with the words "Preserved Vegetables" should be pasted on the side of the canisters.

The bushel of potatoes in an evaporated state and ready for shipment costs about 50 cents.

In conclusion it remains to say a few words about drying fruit in the oven, and we describe the French method, which is decidedly the best, as proved by the prunes brought into market from that country. The prunes having been sorted by a machine into three qualities are placed upon trays and exposed to the sun until the skin commences to shrivel. They are then placed in a bake-oven previously used for baking bread. If no bread is to be baked, the oven is very moderately heated to prevent the rapid closing of the pores and the formation of a crust upon the surface. They are allowed to remain in the oven for 12 hours when they are taken out, and when perfectly cold, moistened with alum water and replaced in the oven, which must now be somewhat hotter. After 12 hours they are again taken out, moistened with alum water, and replaced for the third and last time, together with a dish full of water, in the oven which must now be still hotter than before. The prunes when taken from the oven are submerged for a short time in a bath of sugar-water, and are then packed in boxes. It will be seen that this process is quite tedious, and the product as shown at the Paris Exhibition is not as good as that obtained by evaporation.

Besides prunes the French bring into market dried pears, which have also become celebrated. The process is as follows: Fine table-pears are pared, quartered, and boiled in sugar syrup for five minutes. They are then placed in a moderately warm oven, where they remain for 12 hours; they are then taken out, allowed to cool off, and replaced in the oven, which must now be hotter than the first time, until sufficiently dried.

The French method can be recommended, but it would be still better if it were executed in the improved manner practised here and there in central England and in the New England States. This improvement consists in the previous boiling of the fruit, which must, however, not be continued longer than five minutes. The fruit is not gradually heated but submerged in boiling water for five minutes, and, without being allowed to cool, brought at once into a moderately hot oven. Steaming instead of boiling the fruit is still better. It should be exposed to the steam for not longer than five minutes, and must then as quickly as possible be brought into a moderately hot oven.

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## CHAPTER XXXI.

### PREPARATION OF PICKLES AND MUSTARD.

*Pickles.*—Enormous quantities of pickles are brought into commerce, especially by American and English factories. The most remarkable varieties are piccalilli or Indian pickles, mixed pickles, and walnut pickles. The packing is always the same; some of the oldest and largest English factories still adhere to stoneware pots, which have the advantage of entirely excluding the light from the product, thus contributing to its keeping quality. Both the French and Americans use glass bottles, the chief difference being in the diameter of the mouth, which is smaller in the American bottles. The latter style is to be preferred, because in the former the pickles, when frequently opened, are more exposed to the air than is good for them. Stone pots, which are no doubt best for family use, are too expensive for commercial purposes, not only as regards the first cost, but also on account of their weight, which increases the cost of transportation. The bottles are always provided with neat labels, and the corks generally covered with tin-foil.

The following general rules apply to the preparation of pickles: The best quality of fruit must be gathered at the right time, washed in fresh cold well-water, and placed for some time in

strong brine. They are then laid upon fruit hurdles to completely dry in the air, and finally brought into the bottles which must be nearly filled. The interspaces are then filled up with hot-spiced vinegar, and the bottles immediately corked, and, when cold, sealed. Strong vinegar must be used, the manufacturers generally employing wine-vinegar, known in commerce as No. 24. Fruit-vinegar, clarified and spiced and evaporated to three-fourths its volume, also answers very well. Pickles for immediate use are soaked in hot brine, but as a commercial article they must be treated with cold brine only. Moreover, hot brine must not be used for fruits of a soft and juicy nature such as cabbage and cauliflower; and besides cold or only slightly heated vinegar should be poured over such articles. Soft and delicate fruits must, as a rule, not remain as long in the brine as hard and coarse-fibred ones; and the softest are most advantageously pickled by pouring cold spiced vinegar over them. The same may be said of red beets and other roots which are cut into strips. Sometimes the spice is put whole into the bottle, but it is better and more economical to bring it powdered into the vinegar while heating the latter, or if the vinegar is to be used cold, to previously boil the powdered spice in a small portion of the vinegar, and when cold add it to the rest. The spiced vinegar is prepared as follows:—

To 1 quart of vinegar add  $2\frac{1}{2}$  ounces of salt,  $\frac{1}{2}$  ounce of black pepper, and  $2\frac{1}{2}$  ounces of ginger. Let the mixture boil up once or twice in an enamelled iron pot, filter through a flannel cloth, and pour the liquid, hot or cold, over the fruits.

For a more strongly spiced vinegar reduce in a mortar 2 ounces of black pepper, 1 ounce of ginger, and  $\frac{1}{2}$  drachm of cayenne pepper, and for walnuts, 1 ounce of eschalots, and add to the mixture in a stoneware pot 1 pint of vinegar, and tie up the pot with a bladder. Place the pot for three days near the fire, shaking it several times, and then pour the contents upon the fruits by allowing it to run through a filtering cloth.

In the preparation of pickles the use of metallic vessels must be avoided, the vinegar as well as the brine dissolving copper, brass, and zinc, and becoming thereby poisonous. Ordinary earthen pots should also be mistrusted. Stoneware pots, which can be heated in a water-bath or upon a stove, are best for the purpose.

Moreover, air and light must be kept away from the pickles as much as possible, and they should be touched only with wooden or bone spoons. An essential condition for success is to treat the fruits immediately after being gathered. The method of some manufacturers, who add verdigris to the pickles or boil the vinegar in a copper boiler until it is sufficiently "greenish" to communicate its green color to the product, cannot be too strongly condemned. That this crime against the health of the consumer is unfortunately committed to a considerable extent, is conclusively proved by numerous chemical examinations recently made in the large cities of Europe and the United States, and undertaken with the laudable purpose of bringing the adulterators of food to justice. Many of the pickles in the market, and most of the imported canned peas, contain copper, and this notwithstanding the fact that there are very innocent means for coloring pickles green, it being only necessary to put a handful of spinach or wine leaves in the boiling vinegar which acquires thereby a green coloration and communicates it later on to the pickles.

The following list comprises the fruits which are chiefly used for the preparation of pickles in factories :—

*Barberries.*—The berries are gathered before they are ripe and washed with salt water. The vinegar is added cold.

*Beans.*—Cold vinegar is poured over the young pods, previously soaked in cold water.

*Cabbage, red and white.*—The heads are cut up into fine strips which are placed in a strong brine for two days, then dried upon hurdles for 12 hours, next brought into bottles, and after pouring cold vinegar upon them, at once sealed up.

*Cauliflower.*—The heads are broken up into small pieces which are placed in brine, and finally treated with hot vinegar.

*Cucumbers.*—Young cucumbers are placed in salt water for one week. The brine is then poured off and after being made boiling hot is poured back over the cucumbers. The next day the cucumbers are dried upon a sieve, slightly rubbed off with cloth, and then boiling vinegar is poured over them.

*Elderberry flowers.*—The umbels are gathered just before the flowers open, and treated in the same manner as cauliflower. These pickles are much liked in England.

*English bamboo*.—Young elder shoots are freed from the bark, placed in a brine for 12 hours, and after drying brought into bottles, and hot vinegar is poured over them. They are highly esteemed as an addition to boiled mutton.

*Gooseberries*.—The unripe fruits are treated like cauliflower.

*Mixed pickles*.—Components : White cabbage, cauliflower, bean pods, cucumber, onions. They are prepared like cucumbers.

*Mushrooms*.—Wash young mushrooms the size of coat buttons in cold water, and carefully dry them with a cloth. Then put them into a bottle, and pour boiling vinegar over them.

*Onions*.—Small onions are peeled, and hot vinegar is poured over them ; sometimes the onions are previously placed in brine for one day.

*Peaches*.—The fruits, not entirely ripe, are treated like cucumbers.

*Peas* are treated like beans and cauliflower.

*Picalilly*.—Take one head of white cabbage cut up into fine strips, 2 heads of cauliflower broken into small pieces, some bean pods, 1 root of horseradish cut into strips, 2 dozen of small white onions, and 1 dozen small cucumbers ; pour boiling brine over them, and dry them the next day upon a sieve. Then put the mixture into a pot and add garlic, ginger, mustard-seed, all comminuted, of each 1 ounce, capers  $\frac{1}{2}$  ounce, red pepper  $\frac{1}{4}$  ounce, and pour boiling vinegar over it. Tie up the pot with a bladder, let it stand for 4 weeks, shaking it occasionally, and then distribute the contents into bottles.

*Tomatoes* must not be entirely ripe ; they may be even green and half grown. They are pickled in the same manner as cucumbers.

*Walnuts*.—Place the young, soft nuts in strong brine for one week, then dry upon a sieve and pour hot vinegar over them. A better method is to expose the walnuts, after they have been in the brine for nine days, upon a cloth to the sun until they are black, and then put them into bottles, which are filled up with hot vinegar. These pickles are much liked with fish, and when well sealed and stored in a dark place keep for ten years. If they are to be used in the first three months after being made, the brine must be heated for one hour.



*Mustard*.—Mustard of commerce is the seed, whole or ground, of several species of the genus *Brassica*, cruciferous plants which grow wild and are cultivated under very various conditions. The two common varieties are the black or brown mustard, which has a very small seed, and furnishes the most aroma, and the white, which is two or three times as large, often used in the whole condition in pickles and ground, either by itself or oftener in mixture with the brown seed, for the purpose of obtaining the desirable qualities of both.

The most rational manner of preparing mustard for table use has been introduced into the English factories. The seed is freed from the husk, ground to flour, and the fat oil, which can be used as an illuminating oil, pressed out. Generally speaking, the preparation of mustard consists in several times grinding in a mill a mixture of white and brown mustard with an addition of wine-must, either fresh or strongly boiled down, or of wine vinegar until it forms a moderately fine or very fine pasty mass, and adding different substances as a seasoning. In the Düsseldorf mustard the seasoning consists of cinnamon, cloves, and sugar, in the Frankfort mustard of cloves, allspice, and sugar, in the English mustard of wheat flour, common salt, and pepper, and in the French mustard of tarragon, ginger, cinnamon, thyme, marjoram, onions, garlic, cloves, etc. An addition of flour is almost generally made, as it modifies the sharpness of the mustard and holds the mass better together. The quantity of the constituents vary; the usual proportions being from 20 to 30 per cent. of white, and 5 to 10 per cent. of brown ground mustard, 1 to 2 per cent. of common salt,  $\frac{1}{4}$  to  $\frac{1}{2}$  per cent. of pulverized spices, and 40 to 50 per cent. of must or vinegar. According to the English method the use of mustard-seed freed from oil is only recommended. In the following a few special receipts are given:—

*Gumpoldskirchner must-mustard*.—Evaporate 30 quarts of freshly pressed wine-must to one-half its volume over a moderate fire, dissolve in it 5 lbs. of sugar, and strain the whole over 2 or 3 roots of horseradish cut in thin slices. Then add in the form of fine powder, cardamoms 0.35 oz., nutmeg 0.35 oz., cloves 0.63 oz., cinnamon 1 oz., ginger 1 oz., mustard-seed, ground

and freed from oil, brown 6 lbs. and white 11 lbs. Grind the whole several times in a mill and strain.

*Moutard des Jesuites*.—Make a paste of 12 sardines and 280 capers, and stir it into 53 ozs. of boiling vinegar, and mix with it ground mustard-seed freed from oil, brown  $5\frac{1}{2}$  ozs. and white  $14\frac{1}{2}$  ozs.

*French mustard*.—Ground mustard 2 lbs., and  $\frac{1}{2}$  oz. each of fresh parsley and tarragon, both cut up fine are thoroughly mixed together; further 1 clove of garlic, also cut up very fine, and 12 salted anchovies. Grind the mixture very fine, add the required must, and 1 oz. of pulverized common salt, and for further grinding dilute with water. To evaporate the water after grinding the mustard, heat an iron red hot and cool it off in the mixture, and then add wine vinegar of the best quality.

*Ordinary mustard*.—I. Stir gradually 1 pint of good white wine into 8 ozs. of ground mustard-seed, add a pinch of pulverized cloves, and let the whole boil over a moderate fire. Then add a small lump of white sugar, and let the mixture boil up once more.

II. Pour  $\frac{1}{2}$  pint of boiling wine vinegar over 8 ozs. of ground mustard-seed in an earthen pot, stir the mixture thoroughly, then add some cold vinegar, and let the pot stand over night in a warm place. The next morning add  $\frac{1}{2}$  lb. of sugar,  $\frac{3}{4}$  drachm of pulverized cinnamon,  $\frac{1}{2}$  drachm of pulverized cloves,  $1\frac{1}{4}$  drachm of pepper, some cardamom and nutmeg, half the rind of a lemon and the necessary quantity of vinegar. The mustard is now ready, and is kept in pots tied up with bladder.

III. Pound in a mortar the flesh of a salt herring, and 2 ozs. of capers to a paste, and mix this with 2 ozs. of pulverized white sugar and 13 ozs. of ground mustard seed; then pour  $1\frac{3}{4}$  pint of boiling wine vinegar over it, stir, and let the whole stand near a fire for several hours. Finally add  $\frac{3}{4}$  pint of boiling vinegar, stir thoroughly and pour the mustard into glass bottles.

*Frankfort mustard*.—Mix 1 lb. of white mustard-seed, ground, a like quantity of brown mustard-seed, 8 ozs. of pulverized sugar, 1 oz. of pulverized cloves, 2 ozs. of allspice, and compound the mixture with white-wine or wine-vinegar.

*Wine mustard*.—Ground mustard-seed, white, 23 ozs., brown

12 ozs., common salt  $2\frac{3}{4}$  ozs., wine-vinegar  $8\frac{1}{2}$  ozs., a like quantity of white-wine, and water 16 ozs.

*Aromatic or hygienic mustard.*—Ground mustard-seed, white 23 ozs., brown 12 ozs., wine-vinegar  $17\frac{1}{2}$  ozs. Extract allspice 0.35 oz., cassia, white pepper, and ginger of each 0.17 oz., with alcohol  $1\frac{1}{2}$  oz., and water  $8\frac{1}{2}$  ozs., add  $3\frac{1}{2}$  ozs. of common salt and a like quantity of sugar, filter the whole and add it to the mustard.

*Düsseldorf mustard.*—Ground mustard-seed freed from oil, brown 3 ozs., white  $8\frac{1}{2}$  ozs., boiling water  $26\frac{1}{2}$  ozs., wine-vinegar 18 ozs., cinnammon 0.17 oz., cloves 0.1 oz., sugar 11 ozs., white-wine 18 ozs.

*Sour Düsseldorf mustard.*—Fill 2 casks with vinegar, steep in one of the casks 2 lbs. of origan leaves, and in the other an ordinary bucket full of onions cut up, and let them digest for 2 days. Then bruise 44 lbs. of white mustard-seed and 66 lbs. of brown; put this in a vat and add 1 lb. of pulverized cloves,  $1\frac{1}{2}$  lb. of pulverized coriander-seeds, and  $4\frac{1}{2}$  gallons of each of the prepared vinegars. Stir the whole thoroughly and grind it twice in a mill. To every gallon of this add and mix thoroughly with it 1 lb. of salt dissolved in 1 quart of the onion vinegar.

*Sweet Kremser must-mustard.*—Ground mustard-seed, brown 10 lbs., white 5 lbs., is intimately mixed with 3 lbs. of freshly pressed must, and boiled down to the desired consistency.

*Sour Kremser must-mustard.*—Boil to a stiff paste 15 lbs. of brown mustard ground, and 5 lbs. of white mustard ground, together with 4 lbs. of must, and after cooling stir in 4 lbs. of vinegar.

*Moutarde de maille.*—Cut up 8 ozs. of fresh tarragon leaves without the stems,  $2\frac{1}{2}$  ozs. of basil, 2 ozs. of bay leaves and 4 ozs. of rocambole (a species of garlic). Place these ingredients in a glass alembic, pour  $2\frac{1}{2}$  quarts of strong wine-vinegar over them, and, to allow the vapors to escape, tie up the mouth of the alembic with a piece of perforated moist bladder. Place the alembic upon hot sand for 4 days, then filter the fluid first through linen and then through blotting paper. Add to this aromatic vinegar, 1 oz. of common salt, then stir it into a thick paste with ground brown mustard-seed, and keep the mustard in earthenware jars tied up with bladder.

*Moutarde aux épices* is prepared by extracting 18 ozs. of tarragon leaves, 7 ozs. of basil,  $1\frac{3}{4}$  oz. of bay leaves,  $3\frac{1}{2}$  ozs. of white pepper,  $1\frac{3}{4}$  oz. of cloves, and 0.35 oz. of mace with vinegar and mixing the extract with mustard prepared in the ordinary manner from ground mustard-seed, brown 44 lbs., white 11 lbs., and vinegar  $8\frac{1}{2}$  lbs.

*Moutarde aromatisée*.—Boil ground mustard-seed, brown 22 lbs., white 44 lbs. with 9 lbs. of vinegar, and add oil of tarragon 1 oz., oil of thyme  $\frac{1}{2}$  oz., oil of mace 0.35 oz., and oil of cloves 0.17 oz., all previously dissolved in very strong vinegar.

*English mustard*.—Ground mustard-seed 9 lbs., wheat flour 9 ozs., common salt  $1\frac{3}{4}$  lb., cayenne pepper  $2\frac{3}{4}$  ozs., and as much vinegar and water as required.





# APPENDIX.





TABLE I.—*Hehner's alcohol table.*

Specific gravity at 60° F.	Per cent. by weight of absolute alcohol.	Per cent. by volume of absolute alcohol.	Specific gravity at 60° F.	Per cent. by weight of absolute alcohol.	Per cent. by volume of absolute alcohol.	Specific gravity at 60° F.	Per cent. by weight of absolute alcohol.	Per cent. by volume of absolute alcohol.	Specific gravity at 60° F.	Per cent. by weight of absolute alcohol.	Per cent. by volume of absolute alcohol.
1.0000	0.00	0.00	0.9957	2.45	3.07	0.9913	5.06	6.32	0.9869	8.00	9.95
			6	2.51	3.14	2	5.12	6.40	8	8.07	10.03
0.9999	0.05	0.07	5	2.57	3.21	1	5.19	6.48	7	8.14	10.12
8	0.11	0.13	4	2.61	3.28	0	5.25	6.55	6	8.21	10.21
7	0.16	0.20	3	2.65	3.35				5	8.29	10.30
6	0.21	0.26	2	2.71	3.42	0.9909	5.31	6.63	4	8.36	10.38
5	0.26	0.33	1	2.78	3.49	8	5.37	6.71	3	8.43	10.47
4	0.32	0.40	0	2.84	3.55	7	5.44	6.78	2	8.50	10.56
3	0.37	0.46				6	5.50	6.86	1	8.57	10.65
2	0.42	0.53	0.9949	2.89	3.62	5	5.56	6.94	0	8.64	10.73
1	0.47	0.60	8	2.94	3.69	4	5.62	7.01			
0	0.53	0.66	7	3.00	3.76	3	5.69	7.09	0.9859	8.71	10.82
			6	3.06	3.83	2	5.75	7.17	8	8.79	10.91
0.9989	0.58	0.73	5	3.12	3.90	1	5.81	7.25	7	8.86	11.00
8	0.63	0.79	4	3.18	3.98	0	5.87	7.32	6	8.93	11.08
7	0.68	0.86	3	3.24	4.05				5	9.00	11.17
6	0.74	0.93	2	3.29	4.12	0.9899	5.94	7.40	4	9.07	11.26
5	0.79	0.99	1	3.35	4.20	8	6.00	7.48	3	9.14	11.35
4	0.84	1.06	0	3.41	4.27	7	6.07	7.57	2	9.21	11.44
3	0.89	1.13				6	6.14	7.66	1	9.29	11.52
2	0.95	1.19	0.9939	3.47	4.34	5	6.21	7.74	0	9.36	11.61
1	1.00	1.26	8	3.53	4.42	4	6.28	7.83			
0	1.06	1.34	7	3.59	4.49	3	6.36	7.92	0.9849	9.43	11.70
			6	3.65	4.56	2	6.43	8.01	8	9.50	11.79
0.9979	1.12	1.42	5	3.71	4.63	1	6.50	8.10	7	9.57	11.87
8	1.19	1.49	4	3.76	4.71	0	6.57	8.18	6	9.64	11.96
7	1.25	1.57	3	3.82	4.78				5	9.71	12.05
6	1.31	1.65	2	3.88	4.85	0.9889	6.64	8.27	4	9.79	12.13
5	1.37	1.73	1	3.94	4.93	8	6.71	8.36	3	9.86	12.22
4	1.44	1.81	0	4.00	5.00	7	6.78	8.45	2	9.93	12.31
3	1.50	1.88				6	6.86	8.54	1	10.00	12.40
2	1.56	1.96	0.9929	4.06	5.08	5	6.93	8.63	0	10.08	12.49
1	1.62	2.04	8	4.12	5.16	4	7.00	8.72			
0	1.69	2.12	7	4.19	5.24	3	7.06	8.80	0.9839	10.15	12.58
			6	4.25	5.32	2	7.13	8.88	8	10.23	12.68
0.9969	1.75	2.20	5	4.31	5.39	1	7.19	8.96	7	10.31	12.77
8	1.81	2.27	4	4.37	5.47	0	7.27	9.04	6	10.38	12.87
7	1.87	2.35	3	4.44	5.55				5	10.46	12.96
6	1.94	2.43	2	4.50	5.63	0.9879	7.33	9.13	4	10.54	13.05
5	2.00	2.51	1	4.56	5.71	8	7.40	9.21	3	10.62	13.15
4	2.06	2.58	0	4.62	5.78	7	7.47	9.29	2	10.69	13.24
3	2.11	2.65				6	7.53	9.37	1	10.77	13.34
2	2.17	2.72	0.9919	4.69	5.86	5	7.60	9.45	0	10.85	13.43
1	2.22	2.79	8	4.75	5.94	4	7.67	9.54			
0	2.28	2.86	7	4.81	6.02	3	7.73	9.62	0.9829	10.92	13.52
			6	4.87	6.10	2	7.80	9.70	8	11.00	13.62
.9959	2.33	2.93	5	4.94	6.17	1	7.87	9.78	7	11.08	13.71
8	2.39	3.00	4	5.00	6.24	0	7.93	9.86	6	11.15	13.81

TABLE I.—(continued.)

Specific gravity at 60° F.	Per cent. by weight of absolute alcohol.	Per cent. by volume of absolute alcohol.	Specific gravity at 60° F.	Per cent. by weight of absolute alcohol.	Per cent. by volume of absolute alcohol.	Specific gravity at 60° F.	Per cent. by weight of absolute alcohol.	Per cent. by volume of absolute alcohol.	Specific gravity at 60° F.	Per cent. by weight of absolute alcohol.	Per cent. by volume of absolute alcohol.
0.9825	11.23	13.90	0.9781	14.73	18.14	0.9739	18.15	22.27	0.9695	21.69	26.49
4	11.31	13.99	0	14.82	18.25	8	18.23	22.36	4	21.77	26.58
3	11.38	14.09				7	18.31	22.46	3	21.85	26.67
2	11.46	14.18	0.9779	14.91	18.36	6	18.38	22.55	2	21.92	26.77
1	11.54	14.27	8	15.00	18.48	5	18.46	22.64	1	22.00	26.86
0	11.62	14.37	7	15.08	18.58	4	18.54	22.73	0	22.08	26.95
			6	15.17	18.68	3	18.62	22.82			
0.9819	11.69	14.46	5	15.25	18.78	2	18.69	22.92	0.9689	22.15	27.04
8	11.77	14.56	4	15.33	18.88	1	18.77	23.01	8	22.23	27.13
7	11.85	14.65	3	15.42	18.98	0	18.85	23.10	7	22.31	27.22
6	11.92	14.74	2	15.50	19.08				6	22.38	27.31
5	12.00	14.84	1	15.58	19.18	0.9729	18.92	23.19	5	22.46	27.40
4	12.08	14.93	0	15.67	19.28	8	19.00	23.28	4	22.54	27.49
3	12.15	15.02				7	19.08	23.38	3	22.62	27.59
2	12.23	15.12	0.9769	15.75	19.39	6	19.17	23.48	2	22.69	27.68
1	12.31	15.21	8	15.83	19.49	5	19.25	23.58	1	22.77	27.77
0	12.38	15.30	7	15.92	19.59	4	19.33	23.68	0	22.85	27.86
			6	16.00	19.68	3	19.42	23.78			
0.9809	12.46	15.40	5	16.08	19.78	2	19.50	23.88	0.9679	22.92	27.95
8	12.54	15.49	4	16.15	19.87	1	19.58	23.98	8	23.00	28.04
7	12.62	15.58	3	16.23	19.96	0	19.67	24.08	7	23.08	28.13
6	12.69	15.68	2	16.31	20.06				6	23.15	28.22
5	12.77	15.77	1	16.38	20.15	0.9719	19.75	24.18	5	23.23	28.31
4	12.85	15.86	0	16.46	20.24	8	19.83	24.28	4	23.31	28.41
3	12.92	15.96				7	19.92	24.38	3	23.38	28.50
2	13.00	16.05	0.9759	16.54	20.33	6	20.00	24.48	2	23.46	28.59
1	13.08	16.15	8	16.62	20.43	5	20.08	24.58	1	23.54	28.68
0	13.15	16.24	7	16.69	20.52	4	20.17	24.68	0	23.62	28.77
			6	16.77	20.61	3	20.25	24.78			
0.9799	13.23	16.33	5	16.85	20.71	2	20.33	24.88	0.9669	23.69	28.86
8	13.31	16.43	4	16.92	20.80	1	20.42	24.98	8	23.77	28.85
7	13.38	16.52	3	17.00	20.89	0	20.50	25.07	7	23.85	29.04
6	13.46	16.61	2	17.08	20.99				6	23.92	29.13
5	13.54	16.70	1	17.17	21.09	0.9709	20.58	25.17	5	24.00	29.22
4	13.62	16.80	0	17.25	21.19	8	20.67	25.27	4	24.08	29.31
3	13.69	16.89				7	20.75	25.37	3	24.15	29.40
2	13.77	16.98	0.9749	17.33	21.29	6	20.83	25.47	2	24.23	29.49
1	13.85	17.08	8	17.42	21.39	5	20.92	25.57	1	24.31	29.58
0	13.92	17.17	7	17.50	21.49	4	21.00	25.67	0	24.38	29.67
			6	17.58	21.59	3	21.08	25.76			
0.9789	14.00	17.26	5	17.67	21.69	2	21.15	25.86	0.9659	24.46	29.76
8	14.09	17.37	4	17.75	21.79	1	21.23	25.95	8	24.54	29.86
7	14.18	17.48	3	17.83	21.89	0	21.31	26.04	7	24.62	29.95
6	14.27	17.59	2	17.92	21.99				6	24.69	30.04
5	14.36	17.70	1	18.00	22.09	0.9699	21.38	26.13	5	24.77	30.13
4	14.45	17.81	0	18.08	22.18	8	21.46	26.22	4	24.85	30.22
3	14.55	17.92				7	21.54	26.31	3	24.92	30.31
2	14.64	18.03				6	21.62	26.40	2	25.00	30.40

TABLE II.—Which indicates the specific gravity of mixtures of alcohol and water.

The figures in the column to the left show the per cent. by volume of alcohol; the figures in the column to the right give the specific gravities which correspond to the content of alcohol at 60° F.

Per cent. by volume of alcohol.	Specific gravity at 60° F.	Per cent. by volume of alcohol.	Specific gravity at 60° F.	Per cent. by volume of alcohol.	Specific gravity at 60° F.	Per cent. by volume of alcohol.	Specific gravity at 60° F.
1	0.9985	26	0.9698	51	0.9323	76	0.8747
2	0.9970	27	0.9688	52	0.9303	77	0.8720
3	0.9956	28	0.9677	53	0.9283	78	0.8693
4	0.9942	29	0.9666	54	0.9263	79	0.8665
5	0.9928	30	0.9655	55	0.9242	80	0.8639
6	0.9915	31	0.9643	56	0.9221	81	0.8611
7	0.9902	32	0.9631	57	0.9200	82	0.8583
8	0.9880	33	0.9618	58	0.9178	83	0.8555
9	0.9878	34	0.9605	59	0.9156	84	0.8526
10	0.9866	35	0.9592	60	0.9134	85	0.8496
11	0.9854	36	0.9579	61	0.9112	86	0.8466
12	0.9843	37	0.9565	62	0.9090	87	0.8436
13	0.9832	38	0.9550	63	0.9067	88	0.8405
14	0.9821	39	0.9535	64	0.9044	89	0.8373
15	0.9812	40	0.9519	65	0.9021	90	0.8339
16	0.9800	41	0.9503	66	0.8997	91	0.8306
17	0.9790	42	0.9487	67	0.8973	92	0.8272
18	0.9780	43	0.9470	68	0.8949	93	0.8237
19	0.9770	44	0.9452	69	0.8925	94	0.8201
20	0.9760	45	0.9435	70	0.8900	95	0.8164
21	0.9750	46	0.9417	71	0.8875	96	0.8125
22	0.9740	47	0.9399	72	0.8850	97	0.8084
23	0.9729	48	0.9381	73	0.8825	98	0.8041
24	0.9719	49	0.9362	74	0.8799	99	0.7995
25	0.9709	50	0.9343	75	0.8773	100	0.7946



TABLE III.—*Proportion between per cent. by weight and by volume of alcoholic fluids at 59° F.*

(According to Stampfer.)

100 liters of the alcoholic liquid contain—		Density or specific gravity of the fluid.	1 hectoliter of the fluid weighs kilogrammes.	In 100 kilgr.	In 1 hl.	100 liters of the alcoholic liquid contain—		Density or specific gravity of the fluid.	1 hectoliter of the fluid weighs kilogrammes.	In 100 kilgr.	In 1 hl.
Alcohol, liters.	Water, liters.			Of the alcoholic liquid are contained alcohol, kilogr.		Alcohol, liters.	Water, liters.			Of the alcoholic liquid are contained alcohol, kilogr.	
100	0.00	0.7951	79.51	100.00	79.51	49	54.70	0.9366	93.66	41.59	38.96
99	1.28	0.8000	80.00	98.38	78.71	48	55.68	9385	93.85	40.66	38.16
98	2.54	8046	80.46	96.83	77.92	47	56.66	9403	94.03	39.74	37.37
97	3.77	8089	80.89	95.35	77.12	46	57.64	9421	94.21	38.82	36.57
96	4.97	8130	81.30	93.89	76.33	45	58.61	9439	94.39	37.90	35.78
95	6.16	8169	81.69	92.45	75.53	44	59.58	9456	94.56	37.—	34.98
94	7.32	8206	82.06	91.08	74.74	43	60.54	9473	94.73	36.09	34.19
93	8.48	8242	82.42	89.72	73.94	42	61.50	9490	94.90	35.18	33.39
92	9.62	8277	82.77	88.37	73.15	41	62.46	9506	95.06	34.30	32.60
91	10.76	8311	83.11	87.04	72.35	40	63.42	0.9522	95.22	33.40	31.80
90	11.88	0.8344	83.44	85.74	71.56	39	64.37	9538	95.38	32.52	31.01
89	13.01	8377	83.77	84.74	70.76	38	65.32	9553	95.53	31.63	30.21
88	14.12	8409	84.09	83.22	69.97	37	66.26	9568	95.68	30.75	29.42
87	15.23	8440	84.40	81.96	69.17	36	67.20	9582	95.82	29.88	28.62
86	16.32	8470	84.70	80.72	68.38	35	68.12	9595	95.95	29.01	27.83
85	17.42	8500	85.00	79.51	67.58	34	69.04	9607	96.07	28.14	27.03
84	18.52	8530	85.30	78.29	66.78	33	69.96	9620	96.20	27.27	26.24
83	19.61	8559	85.59	77.09	65.99	32	70.89	9633	96.33	26.41	25.44
82	20.68	8588	85.88	75.91	65.10	31	71.80	9645	96.45	25.56	24.65
81	21.76	8616	86.16	74.75	64.40	30	72.72	0.9657	96.57	24.70	23.85
80	22.83	0.8644	86.44	73.59	63.67	29	73.62	9668	96.68	23.85	23.06
79	23.90	8671	86.71	72.43	62.81	28	74.53	9679	96.79	23.—	22.26
78	24.96	8698	86.98	71.30	62.02	27	75.43	9690	96.90	22.16	21.47
77	26.03	8725	87.25	70.16	61.22	26	76.33	9701	97.01	21.31	20.67
76	27.09	8752	87.52	69.04	60.43	25	77.23	9711	97.11	20.47	19.88
75	28.15	8778	87.78	67.93	59.63	24	78.13	9721	97.21	19.63	19.08
74	29.20	8804	88.04	66.82	58.84	23	79.02	9731	97.31	18.79	18.29
73	30.26	8830	88.30	65.72	58.04	22	79.92	9741	97.41	17.96	17.49
72	31.30	8855	88.55	64.64	57.25	21	80.81	9751	97.51	17.12	16.70
71	32.35	8880	88.80	63.68	56.45	20	81.71	0.9761	97.61	16.29	15.90
70	33.39	0.8905	89.05	62.50	55.66	19	82.60	9771	97.71	15.46	15.11
69	34.44	8930	89.30	61.43	54.86	18	83.50	9781	97.81	14.63	14.31
68	35.47	8954	89.54	60.38	54.07	17	84.39	9791	97.91	13.80	13.52
67	36.51	8978	89.78	59.33	53.27	16	85.29	9801	98.01	12.98	12.72
66	37.54	9002	90.02	58.29	52.48	15	86.19	9812	98.12	12.15	11.93
65	38.58	9026	90.26	57.25	51.68	14	87.09	9822	98.22	11.33	11.13
64	39.60	9049	90.49	56.23	50.89	13	88.—	9833	98.33	10.51	10.34
63	40.63	9072	90.72	55.21	50.09	12	88.90	9844	98.44	9.69	9.54
62	41.65	9095	90.95	54.20	49.30	11	89.80	9855	98.55	8.78	8.75
61	42.67	9117	91.17	53.19	48.50	10	90.72	0.9867	98.67	8.06	7.95
60	43.68	0.9139	91.39	52.20	47.71	9	91.62	9878	98.78	7.24	7.16
59	44.70	9161	91.61	51.20	46.92	8	92.54	9890	98.90	6.43	6.36
58	45.72	9183	91.83	50.21	46.12	7	93.45	9902	99.02	5.62	5.57
57	46.73	9205	92.05	49.24	45.32	6	94.38	9915	99.15	4.81	4.77
56	47.73	9226	92.26	48.26	44.53	5	95.30	9928	99.28	4.—	3.98
55	48.74	9247	92.47	47.40	43.73	4	96.24	9942	99.42	3.20	3.18
54	49.74	9267	92.67	46.33	42.94	3	97.77	9956	99.56	2.40	2.39
53	50.74	9288	92.88	45.37	42.14	2	98.11	9970	99.70	1.60	1.59
52	51.74	9308	93.08	44.41	41.35	1	99.05	9985	99.85	0.80	0.80
51	52.73	9328	93.28	43.47	40.55	0	100.00	1.0000	100.00	0.00	0.00
50	53.72	0.9348	93.48	42.53	39.76						

TABLE IV.—*The actual content of alcohol and water in mixtures of both fluids, and the contraction which takes place in mixing.*

Specific gravity.	100 volumes contain volumes—		Contraction.	Specific gravity.	100 volumes contain volumes—		Contraction.
	Alcohol.	Water.			Alcohol.	Water.	
1.0000	0	100.000	0.000	0.9323	51	52.705	0.705
0.9985	1	99.055	055	03	52	51.711	711
70	2	98.111	111	0.9283	53	50.716	716
56	3	97.176	176	63	54	49.722	722
42	4	96.242	242	42	55	48.717	717
28	5	95.307	307	21	56	47.712	712
15	6	94.382	382	0.9200	57	46.708	708
02	7	93.458	458	0.9178	58	45.693	693
0.9890	8	92.543	543	56	59	44.678	678
78	9	91.629	629	34	60	43.664	664
66	10	90.714	714	12	61	42.649	649
54	11	89.799	799	0.9090	62	41.635	635
83	12	88.895	895	67	63	40.610	610
32	13	87.990	990	44	64	39.586	586
21	14	87.086	1.086	21	65	38.561	561
11	15	86.191	191	0.8997	66	37.526	526
0.9800	16	85.286	286	73	67	36.492	492
0.9790	17	84.392	392	49	68	35.457	457
80	18	83.497	497	25	69	34.423	423
70	19	82.603	603	0.8900	70	33.378	378
60	20	81.708	708	75	71	32.333	333
50	21	80.813	813	50	72	31.289	289
40	22	79.919	919	25	73	30.244	244
29	23	79.014	2.014	0.8799	74	29.190	190
19	24	78.119	119	73	75	28.135	135
09	25	77.225	225	47	76	27.080	080
0.9698	26	76.320	320	20	77	26.016	016
88	27	75.426	426	0.8693	78	24.951	2.951
77	28	74.521	521	65	79	23.877	877
66	29	73.617	617	39	80	22.822	822
55	30	72.712	712	11	81	21.747	747
43	31	71.797	797	0.8583	82	20.673	673
31	32	70.883	883	55	83	19.598	598
18	33	69.958	958	26	84	18.514	514
05	34	69.034	3.034	0.8496	85	17.419	419
0.9592	35	68.109	109	66	86	16.324	324
79	36	67.184	184	36	87	15.230	230
65	37	66.250	250	05	88	14.125	125
50	38	65.305	305	0.8373	89	13.011	011
35	39	64.361	361	39	90	11.876	1.876
19	40	63.406	406	06	91	10.751	751
03	41	62.451	451	0.8272	92	9.617	617
0.9487	42	61.497	497	37	93	8.472	472
70	43	60.532	532	01	94	7.318	318
52	44	59.558	558	0.8764	95	6.153	153
35	45	58.593	593	25	96	4.968	0.968
17	46	57.618	618	0.8084	97	3.764	764
0.9399	47	56.644	644	41	98	2.539	539
81	48	55.669	669	0.7995	99	1.285	285
62	49	54.685	685	46	100	0.000	000
43	50	53.700	700				

TABLE V.—*For comparing the different areometers with Tralles's alcoholometer.*

The statements of figures of the other areometers corresponding to the per cent. by volume according to Tralles's alcoholometer stand in the same horizontal line.

Per cent. by volume according to Tralles.	Per cent. by weight.	Areometer of—				Per cent. by volume according to Tralles.	Per cent. by weight.	Areometer of—			
		Richter.	Beck.	Beaumé.	Cartier.			Richter.	Beck.	Beaumé.	Cartier.
0	0.	0.0	0.0	10	11	51	43.47	—	12.3	—	—
1	0.80	—	—	—	—	52	44.42	—	12.7	—	—
2	1.60	—	—	—	—	53	45.36	—	13.1	21	—
3	2.40	—	—	—	—	54	46.32	—	13.5	—	21
4	3.20	—	1.0	—	—	55	47.29	41.00	13.9	—	—
5	4.10	4.00	1.2	11	12	56	48.26	—	14.3	22	—
6	4.81	—	1.4	—	—	57	49.23	—	14.8	—	22
7	5.62	—	1.6	—	—	58	50.21	—	15.2	23	—
8	6.43	—	1.9	—	—	59	51.20	—	15.6	—	—
9	7.24	—	2.1	—	—	60	52.20	45.95	16.1	—	23
10	8.05	7.50	2.3	12	—	61	53.20	—	16.5	24	—
11	8.87	—	2.5	—	—	62	54.21	—	17.0	—	—
12	9.69	—	2.7	—	13	63	55.21	—	17.5	25	24
13	10.51	—	2.9	—	—	64	56.22	—	18.0	—	—
14	11.33	—	3.1	—	—	65	57.24	51.40	18.4	—	25
15	12.15	10.58	3.3	—	—	66	58.27	—	18.9	26	—
16	12.98	—	3.5	13	—	67	59.32	—	19.4	—	—
17	13.80	—	3.6	—	—	68	60.38	—	20.0	27	26
18	14.63	—	3.8	—	—	69	61.42	—	20.5	—	—
19	15.46	—	4.0	—	14	70	62.50	57.12	21.0	28	27
20	16.28	13.55	4.2	—	—	71	63.58	—	21.5	—	—
21	17.11	—	4.4	—	—	72	64.66	—	22.1	—	—
22	17.95	—	4.6	—	—	73	65.74	—	22.6	29	28
23	18.78	—	4.8	14	—	74	66.83	—	23.2	—	—
24	19.62	—	4.9	—	—	75	67.93	62.97	23.8	30	29
25	20.46	16.60	5.1	—	—	76	69.05	—	24.4	—	—
26	21.30	—	5.3	—	15	77	70.18	—	25.0	31	30
27	22.14	—	5.5	—	—	78	71.31	—	25.6	—	—
28	22.96	—	5.7	—	—	79	72.45	—	26.2	32	—
29	23.84	—	5.9	15	—	80	73.59	69.20	26.8	—	31
30	24.69	19.78	6.1	—	—	81	74.74	—	27.4	33	—
31	25.55	—	6.4	—	—	82	75.91	—	28.0	34	32
32	26.41	—	6.6	—	—	83	77.09	—	28.7	—	—
33	27.27	—	6.8	—	16	84	78.29	—	29.4	35	33
34	28.13	—	7.0	16	—	85	79.50	75.35	30.1	—	—
35	28.99	23.50	7.2	—	—	86	80.71	—	30.8	36	34
36	29.86	—	7.5	—	—	87	81.94	—	31.5	37	35
37	30.74	25.50	7.7	—	—	88	83.19	—	32.2	—	—
38	31.62	—	8.0	—	17	89	84.46	—	33.0	38	36
39	32.50	—	8.3	17	—	90	85.75	81.86	33.8	—	—
40	33.39	27.95	8.6	—	—	91	87.05	—	34.7	39	37
41	34.28	—	8.9	—	—	92	88.37	—	35.5	40	38
42	35.18	—	9.2	—	18	93	89.71	—	36.4	41	—
43	36.08	—	9.5	18	—	94	91.07	—	37.3	—	39
44	36.99	—	9.8	—	—	95	92.46	89.34	38.2	42	40
45	37.90	28.30	10.2	—	—	96	93.89	—	39.2	43	—
46	38.82	—	10.5	19	19	97	95.34	—	40.3	44	41
47	39.74	—	10.9	—	—	98	96.84	—	41.5	45	42
48	40.61	—	11.2	—	—	99	98.39	—	42.7	46	43
49	41.59	—	11.6	—	—	100	100.00	100.00	43.9	47	—
50	42.52	36.46	11.9	20	20						

*Determination of the true strengths of spirit for the normal temperature of 59° F.*

When for the determination of the strength of a spirit of wine the stand of the alcoholometer and of the thermometer has been read off, we possess two figures, by means of which the true strength of spirit of the spirits of wine to be examined, *i. e.*, the number of liters of absolute alcohol contained in 100 liters of the fluid to be examined, when the latter possesses a normal temperature of 59° F., is found as follows: If the observed temperature of the fluid is = 59° F., which is indicated on the scale of the thermometer with a red mark, the figure read off on the scale of the alcoholometer indicates at once the "true" strength of spirit. If, however, the thermometer shows a different temperature, in which case the figure read off on the scale of the alcoholometer is termed the "apparent" strength of spirit, the true strength of spirit is found from the figure read off on the scale of the alcoholometer and the temperature with the assistance of the following table:—

Table VI. has two entries; one in the uppermost horizontal line for the observed statements of the alcoholometer, hence the apparent strengths from 31 to 44 per cent.; the other in the first vertical column for the statements of Fahrenheit's thermometer from —13 to +99.5. On the place where a vertical and horizontal column cross, the strength corresponding to the normal temperature of 59° F., *i. e.*, the true strength of spirit is found.

If, for instance, the alcoholometer immersed into a sample of spirits of wine, indicates an apparent strength of 77 per cent., and the thermometer the temperature of the fluid as 25.5° F., the figure 77 has to be found in the uppermost horizontal column, and then the vertical column belonging to it is followed downward until the horizontal line is reached in which stands the figure 25.5 in the column containing the degrees of temperature. Here the statement 82.4 will be found as the true strength of spirit, and this figure indicates that at the normal temperature of 59° F. 100 liters of the spirit of wine examined contain 82.4 liters of absolute alcohol.

When the apparent strength read off on the alcoholometer consists of a whole number and a fraction, the true strength corresponding to the whole number is determined in the above manner, and the surplus fraction added to the number found.

If, for instance, the temperature read off is  $74.75^{\circ}$ , and the apparent strength  $81\frac{3}{4}$  per cent., the true strength belonging to 81 per cent. and  $74.75^{\circ}$ , which is  $= 78.4$ , is first found in the table and to this is added the fraction  $\frac{3}{4} = 0.75$  or sufficiently accurate  $= 0.7$ . This gives  $78.4 + 0.7 = 79.1$  per cent. as the nearest accurate true strength.



TABLE VI.—*Determination of the true strengths of spirit for the normal temperature of 59° F. (15° C.).*

Temperature, degrees C.	Temperature, degrees F.	31	32	33	34	35	36	37	38	39	40	41
True strengths of spirit for the above apparent strengths.												
—25	—13	47.9	48.7	49.5	50.3	51.1	51.9	52.7	53.6	54.4	55.2	56.0
—23.75	—10.75	47.4	48.2	49.0	49.8	50.6	51.5	52.3	53.1	53.9	54.7	55.5
—22.5	—8.5	46.9	47.7	48.5	49.3	50.1	51.0	51.8	52.6	53.4	54.3	55.1
—21.25	—6.25	46.4	47.2	48.0	48.8	49.6	50.5	51.3	52.1	53.0	53.8	54.6
—20	—4	45.8	46.7	47.5	48.3	49.2	50.0	50.8	51.7	52.5	53.3	54.2
—18.75	—1.75	45.3	46.1	47.0	47.8	48.7	49.5	50.3	51.2	52.0	52.9	53.7
—17.5	+0.5	44.8	45.6	46.5	47.3	48.2	49.0	49.9	50.7	51.6	52.4	53.3
—16.25	+2.75	44.2	45.1	46.0	46.8	47.7	48.5	49.4	50.2	51.1	51.9	52.8
—15	+5	43.7	44.6	45.4	46.3	47.2	48.0	48.9	49.7	50.6	51.5	52.3
—13.75	+7.25	43.2	44.1	44.9	45.8	46.7	47.5	48.4	49.3	50.1	51.0	51.9
—12.5	+9.5	42.7	43.5	44.4	45.3	46.2	47.1	47.9	48.8	49.7	50.6	51.4
—11.25	+11.75	42.1	43.0	43.9	44.8	45.7	46.6	47.5	48.3	49.2	50.1	51.0
—10	+14	41.6	42.5	43.4	44.3	45.2	46.1	47.0	47.9	48.8	49.7	50.6
—8.75	+16.25	41.1	42.0	42.9	43.8	44.7	45.6	46.5	47.4	48.3	49.2	50.1
—7.5	+18.5	40.6	41.5	42.4	43.3	44.2	45.1	46.0	46.9	47.9	48.8	49.7
—6	+20.75	40.1	41.0	41.9	42.8	43.7	44.6	45.6	46.5	47.4	48.3	49.2
—5	+23	39.5	40.5	41.4	42.3	43.2	44.2	45.1	46.0	46.9	47.8	48.8
—3.75	+25.25	39.0	39.9	40.9	41.8	42.7	43.7	44.6	45.5	46.4	47.4	48.3
—2.5	+27.5	38.4	39.4	40.3	41.3	42.2	43.2	44.1	45.0	45.9	46.9	47.8
—1.25	+29.75	37.9	38.9	39.8	40.8	41.7	42.7	43.6	44.5	45.5	46.4	47.3
0	+32	37.4	38.3	39.3	40.3	41.2	42.2	43.1	44.0	45.0	45.9	46.9
+1.25	+34.25	36.8	37.8	38.8	39.7	40.7	41.7	42.6	43.5	44.5	45.4	46.4
+2.5	+36.5	36.3	37.3	38.2	39.2	40.2	41.1	42.1	43.0	44.0	45.0	45.9
+3.75	+38.75	35.7	36.7	37.7	38.7	39.7	40.6	41.6	42.5	43.5	44.5	45.4
+5	+41	35.2	36.2	37.2	38.2	39.1	40.1	41.1	42.0	43.0	44.0	44.9
+6.25	+43	34.7	35.7	36.7	37.6	38.6	39.6	40.6	41.5	42.5	43.5	44.5
+7.5	+45.5	34.1	35.1	36.1	37.1	38.1	39.1	40.1	41.0	42.0	43.0	44.0
+8.75	+47.75	33.6	34.6	35.6	36.6	37.6	38.6	39.6	40.5	41.5	42.5	43.5
+10	+50	33.1	34.1	35.1	36.1	37.1	38.1	39.0	40.0	41.0	42.0	43.0
+11.25	+52.25	32.5	33.6	34.6	35.6	36.6	37.5	38.5	39.5	40.5	41.5	42.5
+12.5	+54.5	32.0	33.0	34.0	35.0	36.0	37.0	38.0	39.0	40.0	41.0	42.0
+13.75	+56.75	31.5	32.5	33.5	34.5	35.5	36.5	37.5	38.5	39.5	40.5	41.5
+15	+59	31.0	32.0	33.0	34.0	35.0	36.0	37.0	38.0	39.0	40.0	41.0
+16.25	+61.25	30.5	31.5	32.5	33.5	34.5	35.5	36.5	37.5	38.5	39.5	40.5
+17.5	+63.5	30.0	31.0	32.0	33.0	34.0	35.0	36.0	37.0	38.0	39.0	40.0
+18.75	+65.75	29.5	30.5	31.5	32.5	33.5	34.5	35.5	36.5	37.5	38.5	39.5
+20	+68	29.0	30.0	31.0	31.9	32.9	33.9	35.0	36.0	37.0	38.0	39.0
+21.25	+70.25	28.5	29.5	30.4	31.4	32.4	33.4	34.4	35.5	36.5	37.5	38.5
+22.5	+72.5	28.0	29.0	29.9	30.9	31.9	32.9	33.9	34.9	36.0	37.0	38.0
+23.75	+74.75	27.5	28.5	29.4	30.4	31.4	32.4	33.4	34.5	35.5	36.5	37.5
+25	+77	27.0	28.0	28.9	29.9	30.9	31.9	32.9	33.9	34.9	36.0	37.0
+26.25	+79.25	26.5	27.5	28.4	29.4	30.4	31.4	32.4	33.4	34.4	35.5	36.5
+27.5	+81.5	26.0	27.0	28.0	28.9	29.9	30.9	31.9	32.9	33.9	35.0	36.0
+28.75	+83.75	25.6	26.5	27.5	28.4	29.4	30.4	31.4	32.4	33.4	34.4	35.5
+30	+86	25.1	26.0	27.0	27.9	28.9	29.9	30.9	31.9	32.9	33.9	35.0
+31.25	+88.25	24.6	25.5	26.5	27.4	28.4	29.4	30.4	31.4	32.4	33.4	34.5
+32.5	+90.5	24.1	25.0	26.0	26.9	27.9	28.9	29.9	30.9	31.9	32.9	34.0
+33.75	+92.75	23.6	24.5	25.5	26.4	27.4	28.4	29.4	30.4	31.4	32.4	33.5
+35	+95	23.1	24.1	25.0	25.9	26.9	27.9	28.9	29.9	30.9	31.9	32.9
+36.25	+97.25	22.7	23.6	24.5	25.4	26.4	27.4	28.4	29.4	30.4	31.4	32.4
+37.5	+99.5	22.2	23.1	24.0	24.9	25.9	26.9	27.9	28.9	29.9	30.9	31.9

TABLE VI.—(continued.)

Tempera- ture, degrees C.	Tempera- ture, degrees F.	42	43	44	45	46	47	48	49	50	51	52
True strengths of spirit for the above apparent strengths.												
—25	—13	56.8	57.6	58.4	59.3	60.1	61.0	61.8	62.7	63.6	64.5	65.4
—23.75	—10.75	56.3	57.2	58.0	58.8	59.7	60.6	61.4	62.3	63.2	64.1	65.0
—22.5	—8.5	55.9	56.7	57.6	58.4	59.3	60.1	61.0	61.9	62.8	63.7	64.6
—21.25	—6.25	55.4	56.3	57.1	58.0	58.8	59.7	60.6	61.5	62.4	63.3	64.2
—20	—4	55.0	55.8	56.7	57.6	58.4	59.3	60.2	61.1	61.9	62.9	63.8
—18.75	—1.75	54.6	55.4	56.3	57.1	58.0	58.9	59.7	60.6	61.5	62.5	63.4
—17.5	+0.5	54.1	55.0	55.8	56.7	57.6	58.4	59.3	60.2	61.1	62.1	63.0
—16.25	+2.75	53.7	54.5	55.4	56.3	57.1	58.0	58.9	59.8	60.7	61.7	62.6
—15	+5	53.2	54.1	55.0	55.8	56.7	57.6	58.5	59.4	60.3	61.2	62.2
—13.75	+7.25	52.8	53.6	54.5	55.4	56.3	57.2	58.1	59.0	59.9	60.8	61.8
—12.5	+9.5	52.3	53.2	54.1	55.0	55.9	56.8	57.7	58.6	59.5	60.4	61.4
—11.25	+11.75	51.9	52.8	53.7	54.5	55.4	56.3	57.2	58.2	59.1	60.0	61.0
—10	+14	51.4	52.3	53.2	54.1	55.0	55.9	56.8	57.8	58.7	59.6	60.6
—8.75	+16.25	51.0	51.9	52.8	53.7	54.6	55.5	56.4	57.3	58.3	59.2	60.2
—7.5	+18.5	50.6	51.5	52.4	53.3	54.2	55.1	56.0	56.9	57.9	58.8	59.8
—6	+20.75	50.1	51.0	51.9	52.9	53.8	54.7	55.6	56.5	57.5	58.4	59.3
—5	+23	49.7	50.6	51.5	52.4	53.3	54.3	55.2	56.1	57.0	58.0	58.9
—3.75	+25.25	49.2	50.1	51.1	52.0	52.9	53.8	54.8	55.7	56.6	57.6	58.5
—2.5	+27.5	48.8	49.7	50.6	51.6	52.5	53.4	54.3	55.3	56.2	57.2	58.1
—1.25	+29.75	48.3	49.2	50.2	51.1	52.0	53.0	53.9	54.9	55.8	56.8	57.7
0	+32	47.8	48.8	49.7	50.7	51.6	52.5	53.5	54.4	55.4	56.3	57.3
+1.25	+34.25	47.4	48.3	49.3	50.2	51.2	52.1	53.0	54.0	54.9	55.9	56.9
+2.5	+36.5	46.9	47.8	48.8	49.8	50.7	51.6	52.6	53.5	54.5	55.5	56.4
+3.75	+38.75	46.4	47.4	48.3	49.3	50.2	51.2	52.1	53.1	54.1	55.0	56.0
+5	+41	45.9	46.9	47.9	48.8	49.8	50.7	51.7	52.7	53.6	54.6	55.6
+6.25	+43	45.4	46.4	47.4	48.3	49.3	50.3	51.2	52.2	53.2	54.2	55.1
+7.5	+45.5	44.9	45.9	46.9	47.9	48.8	49.8	50.8	51.8	52.7	53.7	54.7
+8.75	+47.75	44.5	45.4	46.4	47.4	48.4	49.4	50.3	51.3	52.3	53.3	54.2
+10	+50	44.0	44.9	45.9	46.9	47.9	48.9	49.9	50.9	51.8	52.8	53.8
+11.25	+52.25	43.5	44.5	45.5	46.4	47.4	48.4	49.4	50.4	51.4	52.4	53.4
+12.5	+54.5	43.0	44.0	45.0	46.0	47.0	48.0	48.9	49.9	50.9	51.9	52.9
+13.75	+56.75	42.5	43.5	44.5	45.5	46.5	47.5	48.5	49.5	50.5	51.5	52.5
+15	+59	42.0	43.0	44.0	45.0	46.0	47.0	48.0	49.0	50.0	51.0	52.0
+16.25	+61.25	41.5	42.5	43.5	44.5	45.5	46.4	47.5	48.5	49.5	50.5	51.5
+17.5	+63.5	41.0	42.0	43.0	44.0	45.0	46.0	47.1	48.1	49.1	50.1	51.1
+18.75	+65.75	40.5	41.5	42.5	43.5	44.5	45.6	46.6	47.6	48.6	49.6	50.6
+20	+68	40.0	41.0	42.0	43.1	44.1	45.1	46.1	47.1	48.1	49.1	50.2
+21.25	+70.25	39.5	40.5	41.6	42.6	43.6	44.6	45.6	46.6	47.6	48.7	49.7
+22.5	+72.5	39.0	40.0	41.1	42.1	43.1	44.1	45.1	46.1	47.2	48.2	49.2
+23.75	+74.75	38.5	39.5	40.6	41.6	42.6	43.6	44.6	45.7	46.7	47.7	48.7
+25	+77	38.0	39.0	40.1	41.1	42.1	43.1	44.2	45.2	46.2	47.2	48.3
+26.25	+79.25	37.5	38.5	39.6	40.6	41.6	42.6	43.7	44.7	45.7	46.8	47.8
+27.5	+81.5	37.0	38.0	39.1	40.1	41.1	42.2	43.2	44.2	45.2	46.3	47.3
+28.75	+83.75	36.5	37.5	38.6	39.6	40.6	41.7	42.7	43.7	44.8	45.8	46.8
+30	+86	36.0	37.0	38.1	39.1	40.1	41.2	42.2	43.2	44.3	45.3	46.4
+31.25	+88.25	35.5	36.5	37.6	38.6	39.6	40.7	41.7	42.7	43.8	44.8	45.9
+32.5	+90.5	35.0	36.0	37.1	38.1	39.1	40.2	41.2	42.3	43.3	44.4	45.4
+33.75	+92.75	34.5	35.5	36.6	37.6	38.6	39.7	40.7	41.8	42.8	43.9	44.9
+35	+95	34.0	35.0	36.1	37.1	38.1	39.2	40.2	41.3	42.3	43.4	44.4
+36.25	+97.25	33.5	34.5	35.6	36.6	37.6	38.7	39.7	40.8	41.8	42.9	43.9
+37.5	+99.5	33.0	34.0	35.1	36.1	37.1	38.2	39.2	40.3	41.3	42.4	43.4

TABLE VI.—(continued.)

Tempera- ture, degrees C.	Tempera- ture, degrees F.	53	54	55	56	57	58	59	60	61	62	63
True strengths of spirit for the above apparent strengths.												
—25	—13	66.3	67.2	68.1	69.1	70.0	70.9	71.8	72.7	73.6	74.4	75.3
—23.75	—10.75	65.9	66.8	67.7	68.7	69.6	70.5	71.4	72.3	73.2	74.1	75.0
—22.5	—8.5	65.5	66.4	67.3	68.3	69.2	70.1	71.0	71.9	72.8	73.7	74.6
—21.25	—6.25	65.1	66.0	67.0	67.9	68.8	69.7	70.6	71.5	72.4	73.3	74.2
—20	—4	64.7	65.6	66.6	67.5	68.4	69.3	70.2	71.1	72.0	72.9	73.9
—18.75	—1.75	64.3	65.2	66.2	67.1	68.0	68.9	69.8	70.8	71.7	72.6	73.5
—17.5	+0.5	63.9	64.8	65.8	66.7	67.6	68.5	69.5	70.4	71.3	72.2	73.1
—16.25	+2.75	63.5	64.4	65.4	66.3	67.2	68.1	69.1	70.0	70.9	71.8	72.7
—15	+5	63.1	64.0	65.0	65.9	66.8	67.8	68.7	69.6	70.5	71.4	72.4
—13.75	+7.25	62.7	63.6	64.6	65.5	66.4	67.4	68.3	69.2	70.2	71.1	72.0
—12.5	+9.5	62.3	63.2	64.2	65.1	66.0	67.0	67.9	68.9	69.8	70.7	71.6
—11.25	+11.75	61.9	62.8	63.8	64.7	65.7	66.6	67.6	68.5	69.4	70.3	71.3
—10	+14	61.5	62.4	63.4	64.3	65.3	66.2	67.2	68.1	69.0	70.0	70.9
—8.75	+16.25	61.1	62.0	63.0	63.9	64.9	65.9	66.8	67.7	68.7	69.6	70.5
—7.5	+18.5	60.7	61.6	62.6	63.6	64.5	65.5	66.4	67.4	68.3	69.2	70.2
—6	+20.75	60.3	61.2	62.2	63.2	64.1	65.1	66.0	67.0	67.9	68.9	69.8
—5	+23	59.9	60.8	61.8	62.8	63.7	64.7	65.6	66.6	67.5	68.5	69.4
—3.75	+25.25	59.5	60.4	61.4	62.4	63.3	64.3	65.3	66.2	67.2	68.1	69.1
—2.5	+27.5	59.1	60.0	61.0	62.0	62.9	63.9	64.9	65.8	66.8	67.7	68.7
—1.25	+29.75	58.7	59.6	60.6	61.6	62.5	63.5	64.5	65.4	66.4	67.3	68.3
0	+32	58.3	59.2	60.2	61.2	62.1	63.1	64.1	65.0	66.0	67.0	67.9
+1.25	+34.25	57.8	58.8	59.8	60.7	61.7	62.7	63.7	64.6	65.6	66.6	67.5
+2.5	+36.5	57.4	58.4	59.3	60.3	61.3	62.3	63.3	64.2	65.2	66.2	67.1
+3.75	+38.75	57.0	57.9	58.9	59.9	60.9	61.9	62.8	63.8	64.8	65.8	66.7
+5	+41	56.5	57.5	58.5	59.5	60.5	61.4	62.4	63.4	64.4	65.4	66.3
+6.25	+43	56.1	57.1	58.1	59.0	60.0	61.0	62.0	63.0	64.0	64.9	65.9
+7.5	+45.5	55.7	56.6	57.6	58.6	59.6	60.6	61.6	62.6	63.5	64.5	65.5
+8.75	+47.75	55.2	56.2	57.2	58.2	59.2	60.2	61.2	62.1	63.1	64.1	65.1
+10	+50	54.8	55.8	56.8	57.8	58.7	59.7	60.7	61.7	62.7	63.7	64.7
+11.25	+52.25	54.3	55.3	56.3	57.3	58.3	59.3	60.3	61.3	62.3	63.3	64.3
+12.5	+54.5	53.9	54.9	55.9	56.9	57.9	58.9	59.9	60.9	61.9	62.9	63.9
+13.75	+56.75	53.5	54.4	55.4	56.4	57.4	58.4	59.4	60.4	61.4	62.4	63.4
+15	+59	53.0	54.0	55.0	56.0	57.0	58.0	59.0	60.0	61.0	62.0	63.0
+16.25	+61.25	52.5	53.5	54.6	55.6	56.6	57.6	58.6	59.6	60.6	61.6	62.6
+17.5	+63.5	52.1	53.1	54.1	55.1	56.1	57.1	58.1	59.1	60.1	61.1	62.1
+18.75	+65.75	51.6	52.6	53.7	54.7	55.7	56.7	57.7	58.7	59.7	60.7	61.7
+20	+68	51.2	52.2	53.2	54.2	55.2	56.2	57.2	58.3	59.3	60.3	61.3
+21.25	+70.25	50.7	51.7	52.7	53.8	54.8	55.8	56.8	57.8	58.8	59.8	60.8
+22.5	+72.5	50.2	51.3	52.3	53.3	54.3	55.3	56.3	57.4	58.4	59.4	60.4
+23.75	+74.75	49.8	50.8	51.8	52.8	53.9	54.9	55.9	56.9	57.9	58.9	60.0
+25	+77	49.3	50.3	51.4	52.4	53.4	54.4	55.5	56.5	57.5	58.5	59.5
+26.25	+79.25	48.8	49.9	50.9	51.9	53.0	54.0	55.0	56.0	57.0	58.1	59.1
+27.5	+81.5	48.4	49.4	50.4	51.5	52.5	53.5	54.5	55.6	56.6	57.6	58.6
+28.75	+83.75	47.9	48.9	50.0	51.0	52.0	53.1	54.1	55.1	56.1	57.2	58.2
+30	+86	47.4	48.4	49.5	50.5	51.6	52.6	53.6	54.7	55.7	56.7	57.7
+31.25	+88.25	46.9	48.0	49.0	50.1	51.1	52.1	53.2	54.2	55.2	56.2	57.3
+32.5	+90.5	46.4	47.5	48.5	49.6	50.6	51.7	52.7	53.7	54.8	55.8	56.8
+33.75	+92.75	46.0	47.0	48.1	49.1	50.2	51.2	52.2	53.3	54.3	55.3	56.4
+35	+95	45.5	46.5	47.6	48.6	49.7	50.7	51.8	52.8	53.8	54.9	55.9
+36.25	+97.25	45.0	46.0	47.1	48.2	49.2	50.3	51.3	52.4	53.4	54.4	55.4
+37.5	+99.5	44.5	45.6	46.6	47.7	48.7	49.8	50.8	51.9	52.9	53.9	55.0

TABLE VI.—(continued.)

Temperature, degrees C.	Temperature, degrees F.	64	65	66	67	68	69	70	71	72	73	74
True strengths of spirit for the above apparent strengths.												
—25	—13	76.2	77.1	78.0	79.0	79.9	80.8	81.7	82.6	83.5	84.4	85.3
—23.75	—10.75	75.9	76.8	77.7	78.6	79.5	80.4	81.3	82.2	83.2	84.1	85.0
—22.5	—8.5	75.5	76.4	77.3	78.2	79.1	80.1	81.0	81.9	82.8	83.7	84.6
—21.25	—6.25	75.1	76.0	77.0	77.9	78.8	79.7	80.6	81.6	82.5	83.4	84.3
—20	—4	74.8	75.7	76.6	77.5	78.4	79.3	80.3	81.2	82.1	83.0	84.0
—18.75	—1.75	74.4	75.3	76.2	77.2	78.1	79.0	79.9	80.9	81.8	82.7	83.6
—17.5	+0.5	74.0	74.9	75.9	76.8	77.7	78.6	79.6	80.5	81.4	82.4	83.3
—16.25	+2.75	73.7	74.6	75.5	76.4	77.4	78.3	79.2	80.2	81.1	82.0	82.9
—15	+5	73.3	74.2	75.1	76.1	77.0	77.9	78.9	79.8	80.7	81.7	82.6
—13.75	+7.25	72.9	73.9	74.8	75.7	76.7	77.6	78.5	79.5	80.4	81.3	82.3
—12.5	+9.5	72.6	73.5	74.4	75.4	76.3	77.2	78.2	79.1	80.1	81.0	81.9
—11.25	+11.75	72.2	73.1	74.1	75.0	75.9	76.9	77.8	78.8	79.7	80.7	81.6
—10	+14	71.8	72.8	73.7	74.6	75.6	76.5	77.5	78.4	79.4	80.3	81.3
—8.75	+16.25	71.5	72.4	73.4	74.3	75.2	76.2	77.1	78.1	79.0	80.0	80.9
—7.5	+18.5	71.1	72.1	73.0	73.9	74.9	75.8	76.8	77.7	78.7	79.6	80.6
—6	+20.75	70.7	71.7	72.6	73.6	74.5	75.5	76.4	77.4	78.4	79.3	80.3
—5	+23	70.4	71.3	72.3	73.2	74.2	75.1	76.1	77.0	78.0	79.0	79.9
—3.75	+25.25	70.0	71.0	71.9	72.9	73.8	74.8	75.7	76.7	77.7	78.6	79.6
—2.5	+27.5	69.6	70.6	71.5	72.5	73.5	74.4	75.4	76.3	77.3	78.3	79.2
—1.25	+29.75	69.3	70.2	71.2	72.1	73.1	74.0	75.0	76.0	77.0	77.9	78.9
0	+32	68.9	69.8	70.8	71.8	72.7	73.7	74.7	75.6	76.7	77.6	78.5
+1.25	+34.25	68.5	69.5	70.4	71.4	72.3	73.3	74.3	75.3	76.2	77.2	78.2
+2.5	+36.5	68.1	69.1	70.0	71.0	72.0	72.9	73.9	74.9	75.9	76.8	77.8
+3.75	+38.75	67.7	68.7	69.6	70.6	71.6	72.6	73.5	74.5	75.5	76.5	77.4
+5	+41	67.3	68.3	69.9	70.2	71.2	72.2	73.1	74.1	75.1	76.1	77.1
+6.25	+43	66.9	67.9	69.3	69.8	70.8	71.8	72.8	73.7	74.7	75.7	76.7
+7.5	+45.5	66.5	67.5	68.5	69.4	70.4	71.4	72.4	73.4	74.3	75.3	76.3
+8.75	+47.75	66.1	67.1	68.1	69.0	70.0	71.0	72.0	73.0	74.0	74.9	75.9
+10	+50	65.7	66.7	67.6	68.6	69.6	70.6	71.6	72.6	73.6	74.6	75.5
+11.25	+52.25	65.3	66.3	67.2	68.2	69.2	70.2	71.2	72.2	73.2	74.2	75.2
+12.5	+54.5	64.8	65.8	66.8	67.8	68.8	69.8	70.8	71.8	72.8	73.8	74.8
+13.75	+56.75	64.4	65.4	66.4	67.4	68.4	69.4	70.4	71.4	72.4	73.4	74.4
+15	+59	64.0	65.0	66.0	67.0	68.0	69.0	70.0	71.0	72.0	73.0	74.0
+16.25	+61.25	63.6	64.6	65.6	66.6	67.6	68.6	69.6	70.6	71.6	72.6	73.6
+17.5	+63.5	63.2	64.2	65.2	66.2	67.2	68.2	69.2	70.2	71.2	72.2	73.2
+18.75	+65.75	62.7	63.7	64.7	65.8	66.8	67.8	68.8	69.8	70.8	71.8	72.8
+20	+68	62.3	63.3	64.3	65.3	66.3	67.4	68.4	69.4	70.4	71.4	72.4
+21.25	+70.25	61.9	62.9	63.9	64.9	65.9	66.9	68.0	69.0	70.0	71.0	72.0
+22.5	+72.5	61.4	62.4	63.5	64.5	65.6	66.5	67.5	68.6	69.6	70.6	71.6
+23.75	+74.75	61.0	62.0	63.0	64.1	65.1	66.1	67.1	68.1	69.2	70.2	71.2
+25	+77	60.5	61.6	62.6	63.6	64.6	65.7	66.7	67.7	68.7	69.8	70.8
+26.25	+79.25	60.1	61.1	62.1	63.2	64.2	65.2	66.3	67.3	68.3	69.4	70.4
+27.5	+81.5	59.6	60.7	61.7	62.7	63.8	64.8	65.8	66.9	67.9	68.9	70.0
+28.75	+83.75	59.2	60.2	61.3	62.3	63.3	64.4	65.4	66.4	67.5	68.5	69.5
+30	+86	58.7	59.8	60.8	61.9	62.9	63.9	65.0	66.0	67.1	68.1	69.1
+31.25	+88.25	58.3	59.3	60.4	61.4	62.5	63.5	64.5	65.6	66.6	67.7	68.7
+32.5	+90.5	57.8	58.9	59.9	61.0	62.0	63.1	64.1	65.1	66.2	67.2	68.3
+33.75	+92.75	57.4	58.4	59.5	60.5	61.6	62.6	63.7	64.7	65.8	66.8	67.9
+35	+95	56.9	58.0	59.0	60.1	61.1	62.2	63.2	64.3	65.3	66.4	67.4
+36.25	+97.25	56.5	57.5	58.6	59.6	60.7	61.7	62.8	63.8	64.9	65.9	67.0
+37.5	+99.5	56.0	57.1	58.1	59.2	60.2	61.3	62.3	63.4	64.4	65.5	66.6



TABLE VI.—(concluded.)

Temperature, degrees C.	Temperature, degrees F.	75	76	77	78	79	80	81	82	83	84	85	86
True strengths of spirit for the above apparent strengths.													
—25	—13	86.2	87.1	88.0	88.9	89.7	90.6	91.4	92.3	93.1	93.9	94.7	95.5
—23.75	—10.75	85.9	86.8	87.7	88.5	89.4	90.3	91.1	92.0	92.8	93.6	94.4	95.3
—22.5	—8.5	85.5	86.4	87.3	88.2	89.1	90.0	90.8	91.7	92.5	93.3	94.2	95.0
—21.25	—6.25	85.2	86.1	87.0	87.9	88.8	89.6	90.5	91.4	92.2	93.0	93.9	94.7
—20	—4	84.9	85.8	86.7	87.6	88.5	89.3	90.2	91.1	91.9	92.8	93.6	94.4
—18.75	—1.75	84.5	85.4	86.3	87.2	88.1	89.0	89.9	90.8	91.6	92.5	93.3	94.1
—17.5	+0.5	84.2	85.1	86.0	86.9	87.8	88.7	89.6	90.4	91.3	92.2	93.0	93.8
—16.25	+2.75	83.9	84.8	85.7	86.6	87.5	88.4	89.3	90.1	91.0	91.9	92.7	93.6
—15	+5	83.5	84.4	85.4	86.3	87.2	88.1	88.9	89.8	90.7	91.6	92.4	93.3
—13.75	+7.25	83.2	84.1	85.0	85.9	86.8	87.7	88.6	89.5	90.4	91.3	92.1	93.0
—12.5	+9.5	82.9	83.8	84.7	85.6	86.5	87.4	88.3	89.2	90.1	91.0	91.9	92.7
—11.25	+11.75	82.5	83.5	84.4	85.3	86.2	87.1	88.0	88.9	89.8	90.7	91.6	92.5
—10	+14	82.2	83.1	84.1	85.0	85.9	86.8	87.7	88.6	89.5	90.4	91.3	92.2
—8.75	+16.25	81.9	82.8	83.7	84.7	85.6	86.5	87.4	88.3	89.2	90.1	91.0	91.9
—7.5	+18.5	81.5	82.5	83.4	84.3	85.3	86.2	87.1	88.0	88.9	89.8	90.7	91.6
—6	+20.75	81.2	82.1	83.1	84.0	85.0	85.9	86.8	87.7	88.6	89.5	90.5	91.4
—5	+23	80.9	81.9	82.8	83.7	84.6	85.6	86.5	87.4	88.3	89.2	90.2	91.1
—3.75	+25.25	80.5	81.5	82.4	83.4	84.3	85.2	86.2	87.1	88.0	88.9	89.9	90.8
—2.5	+27.5	80.2	81.1	82.1	83.0	84.0	84.9	85.9	86.8	87.7	88.6	89.6	90.5
—1.25	+29.75	79.8	80.8	81.8	82.7	83.7	84.6	85.5	86.5	87.4	88.3	89.3	90.2
0	+32	79.5	80.4	81.4	82.4	83.3	84.3	85.2	86.2	87.1	88.0	89.0	89.9
+1.25	+34.25	79.1	80.1	81.1	82.0	83.0	83.9	84.9	85.8	86.8	87.7	88.6	89.6
+2.5	+36.5	78.8	79.7	80.7	81.7	82.6	83.6	84.5	85.5	86.4	87.4	88.3	89.3
+3.75	+38.75	78.4	79.4	80.3	81.3	82.3	83.2	84.2	85.2	86.1	87.1	88.0	89.0
+5	+41	78.0	79.0	80.0	81.0	81.9	82.9	83.9	84.8	85.8	86.7	87.7	88.6
+6.25	+43	77.7	78.6	79.6	80.6	81.6	82.5	83.5	84.5	85.4	86.4	87.4	88.3
+7.5	+45.5	77.3	78.3	79.3	80.2	81.2	82.2	83.2	84.1	85.1	86.1	87.0	88.0
+8.75	+47.75	76.9	77.9	78.9	79.9	80.8	81.8	82.8	83.8	84.8	85.7	86.7	87.7
+10	+50	76.5	77.5	78.5	79.5	80.5	81.5	82.4	83.4	84.4	85.4	86.4	87.3
+11.25	+52.25	76.2	77.1	78.1	79.1	80.1	81.1	82.1	83.1	84.1	85.0	86.0	87.0
+12.5	+54.5	75.8	76.8	77.8	78.8	79.7	80.7	81.7	82.7	83.7	84.7	85.7	86.7
+13.75	+56.75	75.4	76.4	77.4	78.4	79.4	80.4	81.4	82.4	83.4	84.3	85.3	86.3
+15	+59	75.0	76.0	77.0	78.0	79.0	80.0	81.0	82.0	83.0	84.0	85.0	86.0
+16.25	+61.25	74.6	75.6	76.6	77.6	78.6	79.6	80.6	81.6	82.6	83.6	84.6	85.6
+17.5	+63.5	74.2	75.2	76.2	77.2	78.2	79.2	80.3	81.3	82.3	83.3	84.3	85.3
+18.75	+65.75	73.8	74.8	75.8	76.8	77.9	78.7	79.9	80.9	81.9	82.9	83.9	85.9
+20	+68	73.4	74.4	75.1	76.5	77.5	78.5	79.5	80.5	81.5	82.6	83.6	84.6
+21.25	+70.25	73.0	74.0	75.7	76.1	77.1	78.1	79.1	80.1	81.2	82.2	83.2	84.2
+22.5	+72.5	72.6	73.6	74.4	75.7	76.7	77.7	78.7	79.8	80.8	81.8	82.9	83.9
+23.75	+74.75	72.2	73.2	74.3	75.3	76.3	77.3	78.4	79.4	80.4	81.5	82.5	83.5
+25	+77	71.8	72.8	73.9	74.9	75.9	76.9	78.0	79.0	80.0	81.1	82.1	83.2
+26.25	+79.25	71.4	72.4	73.5	74.5	75.5	76.5	77.6	78.6	79.6	80.7	81.7	82.8
+27.5	+81.5	71.0	72.0	73.0	74.1	75.1	76.1	77.2	78.2	79.3	80.3	81.4	82.4
+28.75	+83.75	70.6	71.6	72.6	73.7	74.7	75.7	76.8	77.8	78.9	79.9	81.0	82.0
+30	+86	70.2	71.2	72.2	73.3	74.3	75.3	76.4	77.4	78.5	79.5	80.6	81.7
+31.25	+88.25	69.7	70.8	71.8	72.9	73.9	74.9	76.0	77.0	78.1	79.1	80.2	81.3
+32.5	+90.5	69.3	70.4	71.4	72.4	73.5	74.5	75.6	76.6	77.7	78.7	79.8	80.9
+33.75	+92.75	68.9	69.9	71.0	72.0	73.1	74.1	75.2	76.2	77.3	78.3	79.4	80.5
+35	+95	68.5	69.5	70.6	71.6	72.7	73.7	74.8	75.8	76.9	77.9	79.0	80.1
+36.25	+97.25	68.1	69.1	70.1	71.2	72.2	73.3	74.3	75.4	76.5	77.5	78.6	79.7
+37.5	+99.5	67.6	68.7	69.7	70.8	71.8	72.9	73.9	75.0	76.1	77.1	78.2	79.3



TABLE VII.—*Determination of the true volume of alcoholic fluids from the apparent volume at different temperatures.*

(According to A. F. W. Brix.)

Degrees C.	Degrees F.	55-57	58-60	61-64	65-69	70-74	75-79	80-84	85-89	90-94
Reducing factors for the above strengths of spirits of wine.										
-10	+14	1.0198	1.0203	1.0207	1.0213	1.0220	1.0227	1.0233	1.0238	1.0246
-8.75	+16.25	0189	0193	0197	0203	0210	0217	0222	0227	0235
-7.5	+18.5	0180	0183	0187	0193	0200	0206	0211	0216	0223
-6	+20.75	0170	0173	0177	0183	0189	0195	0200	0205	0211
-5	+23	0161	0164	0168	0173	0179	0185	0190	0194	0200
-3.75	+25.25	0152	0155	0158	0163	0169	0175	0179	0183	0189
-2.5	+27.5	0143	0146	0148	0153	0159	0164	0168	0172	0178
-1.25	+29.75	0133	0136	0138	0143	0148	0153	0157	0161	0166
0	+32	0123	0126	0128	0132	0138	0142	0146	0150	0154
+1.25	+34.25	0114	0117	0118	0122	0127	0131	0135	0139	0142
+2.5	+36.5	0105	0107	0108	0112	0116	0120	0124	0128	0130
+3.75	+38.75	0095	0097	0098	0102	0105	0109	0113	0116	0118
+5	+41	0085	0087	0088	0091	0094	0098	0101	0104	0106
+6.25	+43.25	0075	0077	0078	0080	0083	0086	0089	0092	0094
+7.5	+45.5	0066	0067	0068	0070	0072	0075	0078	0080	0082
+8.75	+47.75	0056	0057	0058	0060	0061	0064	0066	0068	0070
+10	+50	0046	0047	0048	0050	0050	0053	0054	0056	0058
+11.25	+52.25	0036	0037	0038	0039	0039	0041	0042	0044	0045
+12.5	+54.5	0026	0027	0027	0028	0028	0029	0030	0031	0032
+13.75	+56.75	0015	0016	0016	0017	0017	0017	0018	0019	0019
+15	+59	1.0005	1.0005	1.0005	1.0005	1.0006	1.0006	1.0006	1.0006	1.0006
+16.25	+61.25	0.9995	0.9995	0.9995	0.9995	0.9994	0.9994	0.9994	0.9994	0.9993
+17.5	+63.5	9985	9985	9984	9984	9983	9983	9982	9982	9981
+18.75	+65.75	9975	9975	9974	9973	9972	9971	9970	9969	9968
+20	+68	9965	9965	9963	9962	9861	9960	9958	9957	9955
+21.25	+70.25	9955	9955	9952	9951	9950	9949	9946	9945	9942
+22.5	+72.5	9945	9944	9941	9940	9939	9937	9934	9932	9929
+23.75	+74.75	9934	9933	9930	9929	9927	9925	9922	9919	9916
+25	+77	9923	9922	9919	9917	9915	9912	9909	9906	9903
+26.25	+79.25	9912	9911	9908	9906	9903	9901	9897	9893	9890
+27.5	+81.5	9901	9900	9897	9894	9891	9889	9885	9880	9877
+28.75	+83.75	9890	9889	9886	9882	9879	9876	9872	9867	9864
+30	+86	9879	9877	9874	9870	9866	9863	9859	9854	9851
+31.25	+88.25	0.9868	0.9865	0.9862	0.9858	0.9854	0.9850	0.9846	0.9841	0.9837

*Explanation of Table VII.*

Alcohol, or alcohol and water, heated above or cooled below the normal temperature expands or contracts. Now, for instance, what is the volume of 10,000 liters of a mixture of 82 per cent. by volume at  $+5^{\circ}$  C. ( $41^{\circ}$  F.) at the normal temperature.\*—In the horizontal column below 80-84 and in the vertical column at  $+5^{\circ}$  C. ( $41^{\circ}$  F.)

\* The table is calculated for a normal temperature of  $15.5^{\circ}$  C. ( $60^{\circ}$  F.).

is the reducing factor 1.0101; hence 10,000 liters are  $10,000 \times 1.0101 = 10,101$  liters. 82 being exactly the means of 80–84, the reduction is accurate. At  $83^{\circ}$  the factor would have to be increased by  $\frac{1}{5}$ ; at 84 by  $\frac{2}{5}$ , and consequently the factor for  $83^{\circ}$  would be  $1.0101 + (1.0104 - 1.0101) \frac{1}{5} = 1.01016$ . For the practice the above factors suffice without change.—The measuring of the temperature and reading off of the percentage of spirit should be done in the storage-cellar, and not in a warmer room, for instance, the office, as is frequently the custom to the disadvantage of the seller.

TABLE VIII.—*Preparation of whiskey of various strengths from spirits of wine.*  
(According to Brix.)

To prepare whiskey of per cent.	From 100 liters of a spirit of wine of per cent.															
	94	93	92	91	90	89	88	87	86	85	84	83	82	81	80	79
Liters of water must be added.																
30	220.5	216.9	213.4	209.8	206.3	202.7	199.2	195.6	192.1	188.6	185.1	181.6	178.1	174.6	171.1	167.6
31	210.4	206.9	203.5	200.0	196.6	193.1	189.7	186.3	182.9	179.4	176.0	172.6	169.2	165.8	162.5	159.1
32	200.9	197.5	194.2	190.8	187.5	184.1	180.8	177.5	174.2	170.9	167.6	164.3	161.0	157.7	154.4	151.1
33	192.0	188.7	185.4	182.2	178.9	175.7	172.4	169.2	166.0	162.8	159.6	156.4	153.2	150.0	146.8	143.6
34	183.5	180.4	177.2	174.0	170.9	167.7	164.6	161.4	158.3	155.2	152.0	148.9	145.8	142.7	139.6	136.5
35	175.6	172.5	169.4	166.3	163.3	160.2	157.1	154.1	151.0	148.0	144.9	141.9	138.9	135.9	132.8	129.9
36	168.1	165.1	162.1	159.1	156.1	153.1	150.1	147.1	144.2	141.2	138.2	135.3	132.4	129.4	126.5	123.6
37	161.0	158.0	155.1	152.2	149.3	146.3	143.4	140.5	137.5	134.8	131.9	129.0	126.1	123.3	120.4	117.6
38	154.2	151.4	148.5	145.6	142.8	139.9	137.1	134.3	131.5	128.7	125.8	123.0	120.3	117.5	114.7	111.9
39	147.8	145.0	142.2	139.4	136.6	133.9	131.1	128.3	125.6	122.9	120.1	117.4	114.7	111.9	109.2	106.5
40	141.7	139.0	136.2	133.5	130.8	128.1	125.4	122.7	120.0	117.3	114.6	112.0	109.3	106.7	104.0	101.4
41	135.9	133.2	130.5	127.9	125.2	122.6	119.9	117.3	114.7	112.1	109.4	106.8	104.2	101.6	99.0	96.5
42	130.3	127.7	125.1	122.5	119.9	117.3	114.7	112.2	109.6	107.0	104.5	101.9	99.4	96.9	94.3	91.8
43	125.0	122.4	119.9	117.3	114.8	112.3	109.8	107.2	104.7	102.2	99.7	97.2	94.8	92.3	89.8	87.3
44	119.9	117.4	114.9	112.4	109.9	107.5	105.0	102.5	100.1	97.6	95.2	92.8	90.3	87.9	85.5	83.1
45	115.1	112.5	110.2	107.7	105.3	102.9	100.5	98.0	95.7	93.3	90.9	88.5	86.1	83.7	81.3	79.0
46	110.4	108.8	106.6	103.2	100.9	98.5	96.1	93.7	91.4	89.1	86.7	84.4	82.0	79.7	77.4	75.1
47	106.0	103.6	101.3	98.9	96.6	94.3	91.9	89.6	87.3	85.0	82.7	80.4	78.2	75.9	73.6	71.3
48	101.7	99.4	97.1	94.8	92.5	90.2	87.9	85.7	83.4	81.2	78.9	76.7	74.4	72.2	70.0	67.8
49	97.6	95.3	93.1	90.8	88.6	86.3	84.1	81.9	79.7	77.4	75.2	73.0	70.8	68.6	66.5	64.3
50	93.6	91.4	89.2	87.0	84.8	82.6	80.4	78.2	76.0	73.9	71.2	69.5	67.4	65.2	63.1	61.0

TABLE IX.—*For the reduction of specific gravities to saccharometer per cent.*

(According to Balling).—Temperature 63.5° F.

Specific gravity.	Corresponding saccharometer, statement in per cent.	Specific gravity.	Corresponding saccharometer, statement in per cent.	Specific gravity.	Corresponding saccharometer, statement in per cent.	Specific gravity.	Corresponding saccharometer, statement in per cent.	Specific gravity.	Corresponding saccharometer, statement in per cent.	Specific gravity.	Corresponding saccharometer, statement in per cent.
1.0000	0.000	1.0040	1.000	1.0080	2.000	1.0120	3.000	1.0160	4.000	1.0200	5.000
1.0001	0.025	41	025	81	025	121	025	161	025	201	025
2	0.050	42	050	82	050	122	050	162	050	202	050
3	075	43	075	83	075	123	075	163	075	203	075
4	100	44	100	84	100	124	100	164	100	204	100
5	125	45	125	85	125	125	125	165	125	205	125
6	150	46	150	86	150	126	150	166	150	206	150
7	175	47	175	87	175	127	175	167	175	207	175
8	200	48	200	88	200	128	200	168	200	208	200
9	225	49	225	89	225	129	225	169	225	209	225
1.0010	250	1.0050	250	1.0090	250	1.0130	250	1.0170	250	1.0210	250
11	275	51	275	91	275	131	275	171	275	211	275
12	300	52	300	92	300	132	300	172	300	212	300
13	325	53	325	93	325	133	325	173	325	213	325
14	350	54	350	94	350	134	350	174	350	214	350
15	375	55	375	95	375	135	375	175	375	215	375
16	400	56	400	96	400	136	400	176	400	216	400
17	425	57	425	97	425	137	425	177	425	217	425
18	450	58	450	98	450	138	450	178	450	218	450
19	475	59	475	99	475	139	475	179	475	219	475
1.0020	500	1.0060	500	1.0100	500	1.0140	500	1.0180	500	1.0220	500
21	525	61	525	101	525	141	525	181	525	221	525
22	550	62	550	102	550	142	550	182	550	222	550
23	575	63	575	103	575	143	575	183	575	223	575
24	600	64	600	104	600	144	600	184	600	224	600
25	625	65	625	105	625	145	625	185	625	225	625
26	650	66	650	106	650	146	650	186	650	226	650
27	675	67	675	107	675	147	675	187	675	227	675
28	700	68	700	108	700	148	700	188	700	228	700
29	725	69	725	109	725	149	725	189	725	229	725
1.0030	750	1.0070	750	1.0110	750	1.0150	750	1.0190	750	1.0230	750
31	775	71	775	111	775	151	775	191	775	231	775
32	800	72	800	112	800	152	800	192	800	232	800
33	825	73	825	113	825	153	825	193	825	233	825
34	850	74	850	114	850	154	850	194	850	234	850
35	875	75	875	115	875	155	875	195	875	235	875
36	900	76	900	116	900	156	900	196	900	236	900
37	925	77	925	117	925	157	925	197	925	237	925
38	950	78	950	118	950	158	950	198	950	238	950
39	975	79	975	119	975	159	975	199	975	239	975

TABLE IX.—(continued.)

Specific gravity.	Corresponding saccharo- meter, statement in per cent.	Specific gravity.	Corresponding saccharo- meter, statement in per cent.	Specific gravity.	Corresponding saccharo- meter, statement in per cent.	Specific gravity.	Corresponding saccharo- meter, statement in per cent.	Specific gravity.	Corresponding saccharo- meter, statement in per cent.	Specific gravity.	Corresponding saccharo- meter, statement in per cent.
.0240	6.000	1.0290	7.219	1.0340	8.438	1.0390	9.657	1.0440	10.857	1.0490	12.047
241	024	291	244	341	463	391	681	441	881	491	071
242	048	292	268	342	488	392	706	442	904	492	095
243	073	293	292	343	512	393	731	443	928	493	119
244	097	294	316	344	536	394	756	444	952	494	142
245	122	295	341	345	560	395	780	445	976	495	166
246	146	296	365	346	584	396	804	446	11.000	496	190
247	170	297	389	347	609	397	828	447	023	497	214
248	195	298	413	348	633	398	853	448	047	498	238
249	219	299	438	349	657	399	877	449	081	499	261
1.0250	244	1.0300	463	1.0350	681	1.0400	901	1.0450	095	1.0500	285
251	268	301	488	351	706	401	925	451	119	501	309
252	292	302	512	352	731	402	950	452	142	502	333
253	316	303	536	353	756	403	975	453	166	503	357
254	341	304	560	354	780	404	10.000	454	190	504	381
255	365	305	584	355	804	405	023	455	213	505	404
256	389	306	609	356	828	406	047	456	238	506	428
257	413	307	633	357	853	407	071	457	261	507	452
258	438	308	667	358	877	408	095	458	285	508	476
259	463	309	681	359	901	409	119	459	309	509	500
1.0260	488	1.0310	706	1.0360	925	1.0410	142	1.0460	333	1.0510	523
261	512	311	731	361	950	411	166	461	359	511	547
262	536	312	756	362	975	412	190	462	381	512	571
263	560	313	780	363	9.000	413	214	463	404	513	595
264	584	314	804	364	024	414	238	464	428	514	619
265	609	315	828	365	048	415	261	465	452	515	642
266	633	316	853	366	073	416	285	466	476	516	666
267	657	317	877	367	097	417	309	467	500	517	690
268	681	318	901	368	122	418	333	468	523	518	714
269	706	319	925	369	146	419	357	469	547	519	738
1.0270	731	1.0320	950	1.0370	170	1.0420	381	1.0470	571	1.0520	761
271	756	321	975	371	195	421	404	471	595	521	785
272	780	322	8.000	372	219	422	428	472	619	522	809
273	804	323	024	373	244	423	452	473	642	523	833
274	828	324	048	374	268	424	476	474	676	524	857
275	853	325	073	375	292	425	500	475	690	525	881
276	877	326	097	376	316	426	523	476	714	526	904
277	901	327	122	377	341	427	547	477	738	527	928
278	925	328	146	378	365	428	571	478	761	528	952
279	950	329	170	379	389	429	595	479	785	529	976
1.0280	975	1.0330	195	1.0380	413	1.0430	619	1.0480	809	1.0530	13.000
281	7.000	331	219	381	438	431	642	481	833	531	023
282	024	332	244	382	463	432	666	482	857	532	047
283	048	333	268	383	488	433	690	483	881	533	071
284	073	334	292	384	512	434	714	484	904	534	095
285	097	335	316	385	536	435	738	485	928	535	119
286	122	336	341	386	560	436	761	486	952	536	142
287	146	337	365	387	584	437	785	487	976	537	166
288	170	338	389	388	609	438	809	488	12.000	538	190
289	195	339	413	389	633	439	833	489	023	539	214



TABLE IX.—(concluded.)

Specific gravity.	Corresponding saccharo- meter, statement in per cent.	Specific gravity.	Corresponding saccharo- meter, statement in per cent.	Specific gravity.	Corresponding saccharo- meter, statement in per cent.	Specific gravity.	Corresponding saccharo- meter, statement in per cent.	Specific gravity.	Corresponding saccharo- meter, statement in per cent.	Specific gravity.	Corresponding saccharo- meter, statement in per cent.
1.0540	13.238	1.0577	14.119	1.0614	15.000	1.0651	15.860	1.0688	16.721	1.0730	17.681
541	261	578	142	615	024	652	883	689	744	732	725
542	285	579	166	616	046	653	907	1.0690	767	734	772
543	309	1.0580	190	617	070	654	930	691	790	736	818
544	333	581	214	618	093	655	953	692	814	738	863
545	357	582	238	619	116	656	976	693	837	1.0740	909
546	381	583	261	1.0620	139	657	16.000	694	860	742	954
547	404	584	285	621	162	658	023	695	883	744	18.000
548	428	585	309	622	186	659	046	696	907	746	045
549	452	586	333	623	209	1.0660	070	697	930	748	090
1.0550	476	587	357	624	232	661	093	698	953	1.0750	137
551	500	588	381	625	255	662	116	699	976	752	181
552	523	589	404	626	278	663	139	1.0700	17.000	754	227
553	547	1.0590	428	627	302	664	162	701	022	756	272
554	571	591	452	628	325	665	186	702	045	758	318
555	595	592	476	629	348	666	209	703	067	1.0760	363
556	619	593	500	1.0630	371	667	232	704	090	762	409
557	642	594	523	631	395	668	255	705	113	764	454
558	666	595	547	632	418	669	278	706	136	766	500
559	690	596	571	633	441	1.0670	302	707	158	768	545
1.0560	714	597	595	634	464	671	325	708	181	1.0770	590
561	738	598	619	635	488	672	348	709	204	772	636
562	761	599	642	636	511	673	371	1.0710	227	774	681
563	785	1.0600	665	637	534	674	395	711	250	776	727
564	809	601	690	638	557	675	418	712	272	778	772
565	833	602	714	639	581	676	441	713	295	1.0780	818
566	857	603	738	1.0640	604	677	464	714	318	782	863
567	881	604	761	641	627	678	480	715	340	784	909
568	904	605	785	642	650	679	511	716	363	786	954
569	928	606	809	643	674	1.0680	534	717	386	788	19.000
1.0570	952	607	833	644	697	681	557	718	409	1.0790	045
571	976	608	857	645	721	682	581	719	431	792	090
572	14.000	609	881	646	744	683	604	1.0720	454	794	136
573	023	1.0610	14.904	647	767	684	627	722	500	796	181
574	047	611	928	648	790	685	650	724	545	798	227
575	071	612	952	649	814	686	674	726	590	1.0800	19.272
576	095	613	976	1.0650	837	687	697	728	636		

TABLE X.—*Comparative synopsis of the areometers for  
must generally used.*

Specific gravity, degrees (Oechsle).	Extract, per cent. by weight (Balling).	Sugar, per cent. by weight.		Degrees (Wagner).	Specific gravity, degrees (Oechsle).	Extract, per cent. by weight (Balling).	Sugar, per cent. by weight.		Degrees (Wagner).
		Babo.	Pillitz.				Babo.	Pillitz.	
1.051	12.5	10.5	8.2	7	91	21.8	18.3	17.5	—
52	12.8	10.7	8.5	—	92	22.1	18.5	17.8	—
53	13.0	10.9	8.7	—	93	22.3	18.6	18.0	—
54	13.2	11.1	8.9	—	94	22.5	18.8	18.2	—
55	13.5	11.3	9.1	—	95	22.7	18.9	18.4	—
56	13.7	11.5	9.4	—	96	22.9	19.0	18.6	—
57	14.0	11.7	9.7	—	97	23.1	19.2	18.8	—
58	14.2	12.0	9.9	8	98	23.3	19.3	19.0	—
59	14.4	12.2	10.1	—	99	23.5	19.5	19.2	13
60	14.7	12.4	10.4	—	1.00	23.7	19.7	19.4	—
61	14.9	12.6	10.6	—	01	23.9	19.9	19.6	—
62	15.1	12.8	10.8	—	02	24.2	20.1	19.9	—
63	15.4	13.0	11.1	—	03	24.4	20.3	20.1	—
64	15.6	13.3	11.3	—	04	24.6	20.5	20.3	—
65	15.8	13.5	11.5	—	05	24.8	20.8	20.5	—
66	16.1	13.7	11.8	9	06	25.0	21.0	20.7	—
67	16.3	13.9	12.0	—	07	25.2	21.2	20.9	14
68	16.5	14.1	12.2	—	08	25.4	21.4	21.1	—
69	16.8	14.3	12.5	—	09	25.7	21.6	21.4	—
70	17.0	14.4	12.7	—	10	25.9	21.8	21.6	—
71	17.2	14.6	12.9	—	11	26.1	22.0	21.8	—
72	17.5	14.8	13.2	—	12	26.3	22.2	22.0	—
73	17.7	15.0	13.4	—	13	26.5	22.4	22.2	—
74	17.9	15.2	13.6	10	14	26.7	22.6	22.4	—
75	18.1	15.4	13.8	—	15	26.9	22.8	22.6	—
76	18.4	15.6	14.1	—	16	27.1	23.0	22.8	15
77	18.6	15.8	14.3	—	17	27.4	23.2	23.1	—
78	18.8	15.9	14.5	—	18	27.6	23.5	23.3	—
79	19.0	16.1	14.7	—	19	27.8	23.8	23.5	—
80	19.3	16.3	15.0	—	20	28.0	24.1	23.7	—
81	19.5	16.5	15.2	—	21	28.2	24.3	23.9	—
82	19.7	16.7	15.4	11	22	28.4	24.6	24.1	—
83	20.0	16.9	15.7	—	23	28.6	24.9	24.3	—
84	20.2	17.1	15.9	—	24	28.9	25.2	24.6	—
85	20.4	17.3	16.1	—	25	29.1	25.5	24.8	16
86	20.7	17.4	16.4	—	26	29.3	—	25.0	—
87	20.9	17.6	16.6	—	27	29.5	—	25.2	—
88	21.1	17.8	16.8	—	28	29.7	—	25.4	—
89	21.4	18.0	17.1	—	29	29.9	—	25.6	—
90	21.6	18.2	17.3	12	30	30.1	—	25.8	—

TABLE XI.—*Table to Oechsle's areometer for must.*

Specific gravity.	Degrees of Oechsle's areometer for must.	Percentage of crystallized grape-sugar.	Specific gravity.	Degrees of Oechsle's areometer for must.	Percentage of crystallized grape-sugar.	Specific gravity.	Degrees of Oechsle's areometer for must.	Percentage of crystallized grape-sugar.	Specific gravity.	Degrees of Oechsle's areometer for must.	Percentage of crystallized grape-sugar.
1041	41	8.0	1059	59	13.0	1076	76	17.2	1093	93	21.7
1042	42	8.3	1060	60	13.2	1077	77	17.5	1094	94	21.9
1043	43	8.6	1061	61	13.4	1078	78	17.8	1095	95	22.2
1044	44	8.9	1062	62	13.6	1079	79	18.0	1096	96	22.5
1045	45	9.2	1063	63	13.9	1080	80	18.3	1097	97	22.7
1046	46	9.4	1064	64	14.0	1081	81	18.5	1098	98	23.0
1047	47	9.7	1065	65	14.2	1082	82	18.8	1099	99	23.2
1048	48	9.9	1066	66	14.4	1083	83	19.1	1100	100	23.4
1049	49	10.2	1067	67	14.7	1084	84	19.4	1101	101	23.7
1050	50	10.5	1068	68	15.0	1085	85	19.7	1102	102	23.9
1051	51	10.8	1069	69	15.2	1086	86	20.0	1103	103	24.2
1052	52	11.1	1070	70	15.5	1087	87	20.2	1104	104	24.5
1053	53	11.4	1071	71	15.8	1088	88	20.4	1105	105	24.8
1054	54	11.7	1072	72	16.1	1089	89	20.7	1106	106	25.0
1055	55	11.9	1073	73	16.3	1090	90	20.9	1107	107	25.2
1056	56	12.2	1074	74	16.5	1091	91	21.2	1108	108	25.4
1057	57	12.5	1075	75	16.9	1092	92	21.4	1109	109	25.7
1058	58	12.7									

TABLE XII.—*To Massonfour's areometer.*

Degrees, according to Massonfour.	Weight of a liter, grammes.	Degrees, according to Massonfour.	Weight of a liter, grammes.	Degrees, according to Massonfour.	Weight of a liter, grammes.
1	1008	8	1059	15	1116
2	1015	9	1067	16	1125
3	1022	10	1075	17	1134
4	1029	11	1083	18	1143
5	1036	12	1091	19	1152
6	1043	13	1099	20	1161
7	1051	14	1107		

TABLE XIII.—*For comparing per cent. of sugar with per cent. of extract and the specific gravity. By Pillitz.*

Sugar, per cent. (Pillitz.)	Extract, per cent. (Balling.)	Specific gravity.	Sugar, per cent. (Pillitz.)	Extract, per cent. (Balling.)	Specific gravity.	Sugar, per cent. (Pillitz.)	Extract, per cent. (Balling.)	Specific gravity.
0	4.3	1.0172	9	13.3	1.0543	18	22.3	1.0930
1	5.3	1.0212	10	14.3	1.0585	19	23.3	1.0975
2	6.3	1.0253	11	15.3	1.0627	20	24.3	1.1017
3	7.3	1.0294	12	16.3	1.0670	21	25.3	1.1060
4	8.3	1.0335	13	17.3	1.0713	22	26.3	1.1103
5	9.3	1.0376	14	18.3	1.0757	23	27.3	1.1146
6	10.3	1.0417	15	19.3	1.0800	24	28.3	1.1189
7	11.3	1.0459	16	20.3	1.0844	25	29.3	1.1232
8	12.3	1.0501	17	21.3	1.0887			

TABLE XIV.—*For determining the content of per cent. of acetic acid contained in a vinegar of — specific gravity. Temperature 15° C. (59° F.)*

(According to A. C. Oudemans.)

Anhydrous acetic acid, per cent.	Specific gravity.	Anhydrous acetic acid, per cent.	Specific gravity.	Anhydrous acetic acid, per cent.	Specific gravity.
100	1.0553	66	1.0717	32	1.0436
99	1.0580	65	1.0712	31	1.0424
98	1.0604	64	1.0707	30	1.0412
97	1.0625	63	1.0702	29	1.0400
96	1.0644	62	1.0697	28	1.0388
95	1.0660	61	1.0691	27	1.0375
94	1.0674	60	1.0685	26	1.0363
93	1.0686	59	1.0679	25	1.0350
92	1.0696	58	1.0673	24	1.0337
91	1.0705	57	1.0666	23	1.0324
90	1.0713	56	1.0660	22	1.0311
89	1.0720	55	1.0653	21	1.0298
88	1.0726	54	1.0646	20	1.0284
87	1.0731	53	1.0638	19	1.0270
86	1.0736	52	1.0631	18	1.0256
85	1.0739	51	1.0623	17	1.0242
84	1.0742	50	1.0615	16	1.0228
83	1.0744	49	1.0607	15	1.0214
82	1.0746	48	1.0598	14	1.0200
81	1.0747	47	1.0589	13	1.0185
80	1.0748	46	1.0580	12	1.0171
79	1.0748	45	1.0571	11	1.0157
78	1.0748	44	1.0562	10	1.0142
77	1.0748	43	1.0552	9	1.0127
76	1.0747	42	1.0543	8	1.0113
75	1.0746	41	1.0533	7	1.0098
74	1.0744	40	1.0523	6	1.0083
73	1.0742	39	1.0513	5	1.0067
72	1.0740	38	1.0502	4	1.0052
71	1.0737	37	1.0492	3	1.0037
70	1.0733	36	1.0481	2	1.0022
69	1.0729	35	1.0470	1	1.0007
68	1.0725	34	1.0459	0	0.9992
67	1.0721	33	1.0447		

TABLE XV.—*For determining the content of per cent. of acetic acid contained in a vinegar of — specific gravity.*

(According to Mohr.)

Anhydrous acetic acid, per cent.	Specific gravity.	Anhydrous acetic acid, per cent.	Specific gravity.	Anhydrous acetic acid, per cent.	Specific gravity.
100	1.0635	66	1.0690	33	1.0440
99	1.0655	65	1.0680	32	1.0420
98	1.0670	64	1.0680	31	1.0410
97	1.0680	63	1.0680	30	1.0400
96	1.0690	62	1.0670	29	1.0390
95	1.0700	61	1.0670	28	1.0380
94	1.0706	60	1.0670	27	1.0360
93	1.0708	59	1.0660	26	1.0350
92	1.0716	58	1.0660	25	1.0340
91	1.0721	57	1.0650	24	1.0330
90	1.0730	56	1.0640	23	1.0320
89	1.0730	55	1.0640	22	1.0310
88	1.0730	54	1.0630	21	1.0290
87	1.0730	53	1.0630	20	1.0270
86	1.0730	52	1.0620	19	1.0260
85	1.0730	51	1.0610	18	1.0250
84	1.0730	50	1.0600	17	1.0240
83	1.0730	49	1.0590	16	1.0230
82	1.0730	48	1.0580	15	1.0220
81	1.0732	47	1.0560	14	1.0200
80	1.0735	46	1.0550	13	1.0180
79	1.0735	45	1.0550	12	1.0170
78	1.0733	44	1.0540	11	1.0160
77	1.0732	43	1.0530	10	1.0150
76	1.0730	42	1.0520	9	1.0130
75	1.0720	41	1.0510	8	1.0120
74	1.0720	40	1.0510	7	1.0100
73	1.0720	39	1.0500	6	1.0080
72	1.0710	38	1.0490	5	1.0070
71	1.0710	37	1.0480	4	1.0050
70	1.0700	36	1.0470	3	1.0040
69	1.0700	35	1.0460	2	1.0020
68	1.0700	34	1.0450	1	1.0010
67	1.0690				



TABLE XVI.—*Comparison of the scales of Réaumur's, Celsius's, and Fahrenheit's thermometers.*

Réaumur.	Celsius.	Fahrenheit.	Réaumur.	Celsius.	Fahrenheit.
—15	—18.75	—	33	41.25	106.25
14	17.50	0.50	34	42.50	108.50
13	16.25	2.75	35	43.75	110.75
12	15.00	5.00	36	45.00	113.00
11	13.75	7.25	37	46.25	115.25
10	12.50	9.50	38	47.50	117.50
9	11.25	11.75	39	48.75	119.75
8	10.00	14.00	40	50.00	122.00
7	8.75	16.25	41	51.25	124.25
6	7.50	18.50	42	52.50	126.50
5	6.25	20.75	43	53.75	128.75
4	5.00	23.00	44	55.00	131.00
3	3.75	25.25	45	56.25	133.25
2	2.50	27.50	46	57.50	135.50
+1	1.25	29.75	47	58.75	137.75
0	0	32.00	48	60.00	140.00
1	1.25	34.25	49	61.25	142.25
2	2.50	36.50	50	62.50	144.50
3	3.75	38.75	51	63.75	146.75
4	5.00	41.00	52	65.00	149.00
5	6.25	43.25	53	66.25	151.25
6	7.50	45.50	54	67.50	153.50
7	8.75	47.75	55	68.75	155.75
8	10	50.00	56	70.00	158.00
9	11.25	52.25	57	71.25	160.25
10	12.50	54.50	58	72.50	162.50
11	13.75	56.75	59	73.75	164.75
12	15.00	59.00	60	75.00	167.00
13	16.25	61.25	61	76.25	169.25
14	17.50	63.50	62	77.50	171.50
15	18.75	65.75	63	78.75	173.75
16	20.00	68.00	64	80.00	176.00
17	21.25	70.25	65	81.25	178.25
18	22.50	72.50	66	82.50	180.50
19	23.75	74.75	67	83.75	182.75
20	25.00	77.00	68	85.00	185.00
21	26.25	79.25	69	86.25	187.25
22	27.50	81.50	70	87.50	189.50
23	28.75	83.75	71	88.75	191.75
24	30.00	86.00	72	90.00	194.00
25	31.25	88.25	73	91.25	196.25
26	32.50	90.50	74	92.50	198.50
27	33.75	92.75	75	93.75	200.75
28	35.00	95.00	76	95.00	203.00
29	36.25	97.25	77	96.25	205.25
30	37.50	99.50	78	97.50	207.50
31	38.75	101.75	79	98.75	209.75
32	40.00	104.00	80	100.00	212.00

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