THE FOUNDRYMEN'S PRIMER

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A Treatise on the Chemical Constituents of Iron, and Methods of Calculating the Mixtures of Iron by Analysis

PREFACE.

The object of this Primer is to give the foundrymen a good general idea of the effects of the varies different elements, generally contained in iron, upon each other and upon the iron, and to give the causes that produce different fractures in iron.

The object is, further, to show that the fracture of iron is misleading and that the correct way is to have the analysis of the iron and work by that and not by the fracture.

To accomplish this several methods have also been given to calculate the mixture by analysis.

The writer has tried to make the matter plain to all readers, and it may seem as if there was a repetition of some statements, if so, it is to be hoped that these will be well impressed upon the mind of the reader.

INTRODUCTION.

Gentlemen:

These pages contain a valuable treatise on Iron and Calculating the Mixture of Iron by Analysis. I have tried to make it plain to you why you should make the mixture of iron by analysis and not by the fracture. Not only that, I have gone further, and have given you several methods of how to figure the mixture by analysis. This no one, to my knowledge, has ever done, and it is probable that the lack of this knowledge is the reason why the use of analysis in making the mixture is not more general.

It will not be necessary for you to erect a costly laboratory and employ an expert chemist. I have a complete laboratory for accurate work and make it a business to make the analysis for foundries.

I have foundry experience, have the best of help associated with me, and have made the analysis and mixture for years for the largest foundries in the United States, and, if necessary, could furnish the best of reference. I am doing the analytical work for very many foundries all over the United States, and if you are not on the list, I would be pleased to have you, whether you use one car of iron a month or one a day.

I am about to publish a large treatise on iron, of which these pages will be a part. Iwould, therefore, be pleased to have you write me your opinion, good or bad, about these pages, and tell me if there is anything that is not clear or that you do not understand. I will also be pleased to have you tell me what information, not included in these pages, that you would like to see in a larger treatise.

I want to publish a treatise that in as few words as possible will give just such information that is not well understood by the foundrymen. I want my laboratory to do the chemical work for most all the foundries in the United States, and want my laboratory to be known as the most accurate and rapid for all practical purposes.

Send me your samples and let me hear from you. Yours truly.

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NOMENCLATURE.

Iron is a simple substance and one of the elements of chemistry. In its pure state it is found only in laboratories and never in every-day life. When we speak of an article being made of iron, we do not mean that it is made of pure iron, but iron containing the impurities that it generally contains. These impurities are mainly Carbon, Silicon Sulphur, Phosphorus and Manganese.

Pure iron would not be as valuable in commerce as the impure. These impurities, the amounts of each and their relation towards each other is what determines the value of the iron.

In nature iron is found in combination with other substances and forms minerals and ores which are treated in Blast-furnaces.

PIG IRON AND SOWS.

Iron, when made in the blast furnace, is in the molten state, and must be cast into molds or some shapes, so that it can be handled and remelted. In practice the iron is cast in open sand. A gutter is made from the furnace in the sand-casting bed. From the side of this gutter smaller gutters or molds are made and the iron feeds into these.

It must have reminded some one of a sow nursing its little pigs and, therefore, gave the name of sow to the large gutters and pigs to the little ones; hence the name of pig iron and sow.

CHILLED MOLDS.

As the iron runs into the sand bed some of the sand adheres to the iron, so that pig iron has more or less sand attached to it. This sand is detrimental to some processes in which iron is used, and, to overcome this, molds of iron are used and the iron from the blast furnace run into them. Iron is a good conductor of heat, and the molten iron cast into these iron molds cools or chills, and hence the iron is called Iron Cast into Chilled Molds.

BASIC IRON.

The process in which the sand on the pig is detrimental, and for which the iron is cast into chilled molds is the Basic Open Hearth Steel process. Some persons call the iron cast into iron molds, basic iron. This is wrong. While it is true that iron for the basic process is cast into iron molds, still any iron could be cast into iron molds.

The iron best adapted for the Basic steel process should contain these impurities within certain limits, and it is best to call iron within these limits Basic Iron.

BESSEMER AND OFF BESSEMER IRON.

There is a process of making steel invented by a man called Bessemer, and hence the name Bessemer Process. In this process the Phosphorus should not be above .10 per cent., and hence all iron as low as .10 per cent., or lower, in Phosphorus is called Bessemer Iron. Sometimes an iron contains a little more than this amount, say .10 per cent to .20 per cent Phosphorus. This iron is often called Off-Bessemer Iron.

HOT BLAST AND COLD BLAST.

In former days the blast used in the blast furnace was the ordinary air. Nowadays the blast is heated before entering the furnace. To distinguish between the two, the iron made with the unheated blast is called Cold Blast Iron.

WROUGHT IRON.

When Iron is treated in a puddling furnace and most of the impurities are gotten rid of, so that it can be worked and forged, it is called Wrought Iron.

STEEL.

When iron is treated in any other way than in the puddling process, and most of the impurities are gotten rid of, it is called steel. The analysis of steel varies, as there are many kinds, depending upon the use that it is to be put to. According to the use of the steel is put to and according to the name the maker sees fit to give it, we have any amount of steels.

CAST IRON.

When pig iron is melted and poured into some castings, it is called cast iron. Some castings are used for stove plate and some for machinery castings. The quality of the iron taken for stove plate and machinery castings is differ ent, as one is a light casting and the other heavy, and so the two kinds of scrap iron are kept separate, one being sold as stove plate scrap and the other as machinery scrap.

MALLEABLE IRON.

When cast iron is treated after it has been cast so that it becomes malleable, it is called Malleable Iron.

SILICA AND SILICON.

The word Silicon is used by chemists and foundrymen. Notice the spelling of the word. The last two letters are "on." This is an element in chemistry, a simple substance. This element can combine with other elements and form other substances. In the cupola, for instance, some of it combines with the oxygen of the air, and goes into the slag. This combination of Silicon and Oxygen forms sand, or often called Silica. Notice that the word ends in "a," and not in "on." Silicon (with an ending of "on") is the element that we speak of in iron, while the white sand and rock is called Silica (ending in the letter "a"). Many persons do not use these words correctly .

METALLURY OF IRON.

Iron made in the blast furnace always contains impurities, the amount of each depending upon the materials used and the working of the furnace. The main impurities to be considered are Carbon, Silicon, Sulphur, Phosphorus and Manganese. These impurities mentioned are elements of chemistry, and so will be called elements, instead of impurities.

CARBON AND SILICON.

Iron contains, when other elements are absent, about 4.5 per cent of Carbon. If Manganese is present then the iron can contain more Carbon, but all other elements make the iron contain less Carbon.

Iron and Carbon form a white metal. The Carbon is all combined. The presence of Sulphur, Phosphorus and Manganese helps to combine the Carbon and make a white iron.

Silicon is the only element (of those considered) which does not help to combine the Carbon with the iron. Silicon in the iron will cause the iron to take up less Carbon, and the more Silicon the iron contains the less will be the Carbon. Silicon also acts in another way. It not only causes the iron to take up less Carbon, but some of that which it contains is thrown out in little flakes, while the iron is cooling, distributing these flakes through the iron, partly in crystallized form and partly in an uncrystallized form. These forms are generally called Graphite and causes the iron to look grey.

Iron, when melted, contains all the Carbon in the sombined slate. Should some of the Carbon have been thrown out, on cooling, as Graphite, it would again combine as soon as remelted. No matter how much Graphite an iron contains, on melting it, this Graphite again changes over to Combined Carbon.

Iron, when melted, contains all the Carbon in the combined state and may also contain some Silicon, but not enough to counteract other elements and tendencies to hold the Carbon combined, so that on cooling there is formed a white, hard iron, that is brittle and has no strength.

Iron, when melted, may contain enough Silicon to counteract the other elements and tendencies to hold the Carbon as Combined Carbon and upon cooling some of this carbon is thrown out as Graphite, producing a strong, close-grained iron.

Iron, when melted, may increase still further in Silicon, so that the greater part of the Carbon is thrown out on cooling at Graphite and form a very soft gray iron.

Iron, when melted, can, however, contain but a limited amount of Carbon and Silicon. We have seen that the amount of Carbon thrown out as Graphite upon cooling increased as the Silicon increased. The Carbon seemed to be dissolved in iron in presence of Silicon and held there as long as the iron was melted and hot, but could not hold it however on cooling. If the Silicon is still further increased, the iron can not hold the Carbon, even in the molten state, and the Graphite is thrown out in the molten iron and rises to the surface, decreasing the amount of Carbon in the iron. This Graphite rising to the surface is called Kish.

Iron containing only Carbon can contain as high as 4.5 per cent., is all combined and forms a white iron and is hard. Silicon will cause some of the Carbon to be thrown out as Graphite upon cooling to form grey iron. The Total Carbon is the same, only some being combined and the rest being present as Graphite. When the amount of Silicon increases, so that the molten iron cannot hold the Carbon in presence of this Silicon, the Total Carbon decreases, and we have 5-6 per cent. Silicon iron, looking white, on account of lack of Carbon, and a 10 per cent. Silicon contains only about 1 per cent. of Carbon. This Carbon is present almost entirely as Graphite, but on account of the lack of Carbon the iron is white and weak, but is soft.

Iron that is white and hard on account of low Silicon and high Carbon has a different fracture and appearance than iron that is white and soft on account of high Silicon and low Carbon.

Carbon makes the molten iron fluid; the same can be said of Silicon. Silicon can combine with iron in any proportion and we have Ferro-Silicon, containing 75 per cet of Silicon.

It can readily be seen that Silicon plays a very important part, and how necessary it is to know the amount of Silicon in iron and in the castings.

SULPHUR.

Sulphur makes the iron brittle and red short and makes it run very sluggish and thick. Sulphur tends to make the iron take up less Carbon, it combines the Carbon in the iron and makes it white. In melting iron with coke the iron takes up the Sulphur in the coke to a great extent, so that the castings will contain more Sulphur on this account.

MANGANESE.

Manganese causes the iron to take up more Carbon. It combines this Carbon and makes the iron white. An iron containing 80 per cent of Manganese contains about 8 per cent of Carbon. Manganese has, however, more attraction for the Sulphur than iron has, and combines with it and neutralizes the effect of the Sulphur. The Sulphur and the Manganese unite and often rise to the surface of the molten metal, decreasing the amount of each thereby and purifying the metal. For this reason molten iron high in Sulphur is dirty, the combination rising to the surface. It can, therefore, occur that by taking an iron, that is hard and white on account of Sulphur, and melting it with an iron, hard on account of Manganese, that a good grey iron is produced.

Iron that contains Manganese is white and it looks like the white of a mirror, and hence some German gave it that name. The German name for a mirror is Spiegel, and hence it is called Spiegel Eisen. Lately an iron is made that contains more Manganese—in fact, more Manganese than iron. To designate this, and because everything must have a name, all iron containing a smaller amount of Manganese, say up to 30 per cent of Manganese, is called Spiegel Iron, and if it contains more it is called Ferro-Manganese, the word Ferro meaning iron. Spiegel Eisen is generally made to contain about 20 per cent and Ferro Manganese about 80 per cent Manganese. In buying either, the analysis should always be checked up.

Ferro-Manganese can be bought broken into small pieces or ground. It is a good article to have around the foundry, for reasons explained above, namely: It combines with the Sulphur and rises to the surface, thus decreasing the amount of Sulphur and purifying the iron. It combines with the Sulphur that does not rise to the surface and neutralizes its bad effect. The Sulphur being thus reduced, the Silicon which was required to counteract the bad effects of the Sulphur is free to act upon the Carbon, and thus directly and indirectly the addition of Manganese when Sulphur is present makes an iron softer, more grey, etc., etc.

When Sulphur is not present to a great extent, and the iron is too open, Manganese will combine the Carbon and make it a closed grain and stronger iron.

Manganese, therefore, softens the iron in one case, and under different condition hardens it. By knowing the analysis of the iron, the foundrymen can tell whether the addition of Manganese will be beneficial or not and the amount required.

It must not be supposed, however, like the Indian who took some medicine that little does good, that more would do heap good. The amount of Manganese added, or whether any should be added, depends, of course, upon the amount of Sulphur, and this can and should always be ascertained by analysis.

Most of the irons in the United States contain between .50 per cent and 1.00 per cent of Manganese, which is about the amount required for the general run of castings. If the iron contains less, then Manganese should be added. Some irons now made contain between 2.00 per cent and 3.00 per cent of Manganese, and can be used to mix with low Manganese irons or irons that contain Sulphur. It is necessary, of course, to have these irons analyzed to know just what they contain.

PHOSPHORUS.

Phosphorus combines the Carbon and makes makes the iron sensitive to sudden strains. A pillar of a house, for instance, that is high in Phosphorus will carry the load easily, but it apt to break when a heavy wagon runs along the street.

Phosphorus combines the Carbon and makes the iron white, and the Combined Carbon again makes the Phosphorus act stronger. Silicon counteracts the action of the Phosphorus indirectly by decreasing the combined Carbon. Phosphorus makes the iron very fluid, and for that reason it is well liked, provided that it does not contain too much. For stove plate the Phosphorus runs as high as .90 per cent to 1.00 per cent, while in good machine castings it is never so high. It is, therefore, very important to know the Phosphorus of the iron, and every car should be analyzed.

Amounts of Different Elements May Vary in Good Castings

The action of any one element depends not only upon the amount present, but whether some other elements are present, and the amount of these. For instance, as explained, a casting may be high in Sulphur, but still be a good casting, because it contains Manganese, while the same castings without Manganese would be worth nothing. Silicon in iron can be increased or decreased, as the presence of other elements may require, so that it can readily be seen that there are a number of combinations that can be made and have good results. This of course, can only be done intelligently and correctly by knowing the analysis of the iron.

FRACTURE OF IRON.

Take a ladle of iron and pour several castings. One in a dry sand mold; another in a green sand mold, making the casting rather large in all dimensions, and gradually decreasing to a thin stove plate and one cast against a chill.

The molten iron is alike and has the same ingredients. Still, upon breaking the cold castings, we find a vast difference in the fracture. The large and dry sand castings are open grain and look like a number one iron, but as the castings decrease in size the fracture becomes closer and the iron is harder, and stove plate is probably white and cannot be drilled, and the casting against the chill is white and hard.

Now, if what has been said above about the chemical constituents of iron is true, then these castings should all be alike, or else there is some other action that we have not taken into account. We analyze these castings and find the total Carbon, Silicon, Sulphur, Phosphorus and Manganese are the same, but the state of the of course, is nonsensical talk. Did a foundry ever make $400 worth of castings and not have them examined? Every casting is examined, and when it does not suit the party, they will reject the casting. Foundrymen should always have each car of iron checked up for Silicon and Phosphorous, and ,if the occasion requires, for Sulphur and Manganese.

COKE.

Every foundry should use good coke. As to the analysis, this is deceiving. The cokes that have the least ash and most Carbon are not necessarily the best. The coke should not have too much ash, but the most important part of coke, to get a hot iron is the density and structure. An open, porous coke does not give the heat of a dense coke. An open coke requires less blast. The Sulphur in the coke is important, and it is well to analyze the coke for Sulphur, as most of it goes into the iron, and a high Sulphur coke will, of course, raise the Sulphur in the casting.

Calculating the Mixture by Analysis.

One great drawback in making the mixture by analysis was not only the lack of knowledge of the effects the different elements had upon the iron, but the lack of information as to how to calculate the amounts of the different irons when the analysis had been made.

The following methods of calculating will show the foundrymen how to mix the irons, and it is hoped will cause many foundrymen to change over from the old way of making the mixture by fracture to the only correct way of having each car analysed and working by this analysis:

When one figures that a car of iron contains, as a rule, twenty-five tons, and then divides the cost of analysis by this to see the cost per ton, it can easily be seen that it pays well to have analysis made. The proofs of this are so numerous that when a foundry once starts to have analyses made, the advantages will be so many that they will be surprised that they did not start long ago. The saving to a foundry using analysis over the time when they did not have the iron checked up and analyzed is often astonishingly great. Aside from the money question, it has been clearly shown that the only correct way to make the mixture of iron is by analysis.

Calculating the Mixture of Iron for Silicon, When Two Irons are Used.

When iron is melted in a cupola it loses some of its Silicon by oxidation. The amount differs in different cupolas, depending upon the mixture, the size of the cupola, the blast, etc. Knowing the average Silicon of the mixture and the Silicon of the molten iron, the difference will be the loss in melting. It is an easy matter to ascertain this. This loss must always be added to the amount of Silicon the casting is to contain, which will give us the amount of Silicon the mixture should contain.

Let us suppose that this is .30 per cent and the casting is to be a machine casting containing 1.80 per cent Silicon, then the mixture must contain 1.80 plus .3, equaling 2.10 per cent Silicon.

Let us suppose that we have two irons in the yard containing 1.50 per cent Silicon and 2.40 per cent Silicon and we want to make a mixture of 2.10 per cent Silicon.

If the mixture should contain 2.10 per cent and the low Silicon iron contains 1.50 per cent Silicon, then, by subtracting 1.50 per cent from 2.10 per cent, we have .60 per cent, the amount that the low Silicon iron requires to bring it up to the mix.

If the mixture should contain 2.10 per cent and the high Silicon iron contains 2.40 per cent, then, by subtracting 2.10 per cent from 2.40 per cent, we have .30 per cent, the amount that the high Silicon iron has too much.

For every part of low Silicon iron used, we have .60 per cent too little, and must add so much of the high Silicon iron to make up this .60 per cent. If we use one part of the high, we have only .30 per cent too much, so that it requires as many parts of the high as it takes to make .60 per cent. Now, .60 per cent divided by .30 per cent is equal to 2, so that it takes 2 parts of the high to one part of the low.

Proof:

1	part	of	1.50	per	cent	equals	1.50	per cent.
2	"	"	2.40	"	"	"	4.80	" "
3	" mix (or 2.10 per cent)					"	6.30	" "

One part of the mix would contain 2.10 per cent Silicon.

Again, if for every part of high Silicon iron we have .30 per cent too much, then we must use as many parts of a low Silicon iron, so that the amount too little is equal to .30 per cent. Now, if we use one part of low, we have .60 per cent too little. We see then that we must use less. We must use so many parts so that multiplied by .60 per cent it makes .30 per cent. Dividing .30 per cent by .60 per cent, we have .50

times, so that we take .50 parts of the low to every part of the high.

Proof:

1 part	of	2 40	per	cent	equals	2.40	per	cent.
.50 "	"	1.50	"	"	"	.75	"	"
1 50 "	mix	2.10	"	"	"	3.15	"	"

Again, if it takes 1 part of the low and 2 parts of the high to make 3 parts of the mixture, thn to make 1 part of the mixture, it would take 1 divided by 3 of the low Silicon iron and 2-3 of 1 of the high, so that we have .333 parts of the low and .666 parts of the high.

Thus we have our mixture given in how many parts of the high to one part of the low. How many of the low to one part of the high, and how many of each to mak one part? We can take as many parts as we like. Suppose we call a part a pound; then we multiply the number of parts by whatever number of pounds we want to take.

For instance: If we want to make a mix of 500 pounds, we see that we must take 500 times .333 of the low Silicon and 500 times .666 of the high Silicon iron, which would be 166 pounds of low and 333 pounds of high. Or, if it takes 3 parts to make the mix, then in 500 pounds, 1 part would be 500 divided by 3, which is 166, an the other would be 2 times 166, or 500 pounds, less 166, which would be 333 pounds. In practice we would (as we do not weigh closer than 50 pounds) call this 150 of the low and 350 of the high. This would make the Silicon a little higher, but it would be as close as we generally weigh.

We have then all we need in a little calculating of subtraction and division. Looking over our figures, we find that we have the following rule:

RULE. Subtract the Lower Silicon Iron From the Amount of the Mixture, and the Amount of the Mixture From the High Silicon Iron. Divide one Difference by the Other and the Answer Will be the Number of Parts of the Divisor to One Part of the Dividend.

Above example the

Mixture	2.10	per	cent.	High	2.40	per	cent.
Low Mix Si.	1.50	"	"	Mix.	2.10	"	"
	.60	"	"		.30	"	"

.30) .60 (2
60

.60) .300 (.5
300

The low difference is .50 per cent and the high difference is .30 per cent. When we divide .60 per cent, we get amount of high to 1 of low which is 2, and when we divide the .30 pr cent we get the amount of low to 1 of high, which is .50. The number you divide is the number you get one part of.

This rule is very simple. In the example taken the figures divided evenly. This was done to explain easier. In practice this does not always come out that way.

To further illustrate the method of making the mixture, let us take another example. We have two irons, one of 3.40 per cent Silicon and the other 2.00 per cent Silicon, and the mixture is to contain 2.50 per cent Silicon.

Applying the rule and, for simplicity sake, dropping the per cent Silicon, we have the following calculations:

High 3.40	**Mix 2.50**	.50).90(1.8	.90).50(.555
Mix 2.50	**Low 3.00**	50	450
.90	**.50**	400	500
		400	450

1 part	**of 3.40**	**equals**	**3.40**		
1.8 "	" 2.00	"	3.60		
2.8 "	" 2.50	"	7.00		

1 part	**of 2.00**	**equals**	**2.00**
.55 "	" 3.40	"	1.88
1.55 "	" **2.50**	"	3.88

If it takes 1 part of 3.40 per cent iron and 1.8 part of 2.00 per cent iron, or a total of 2.8 parts to make the mix, then, if we want to make a mix of say 560 pounds, 1 part would be equal to 560 pounds, divided by 2.8, which would be 200 pounds; the amount of the 3.40 per cent iron, and the difference of 560 and 200, which is 360 pounds, would be the amount of the 2.00 per cent iron. The amount of 2.00 per cent iron could also be obtained by taking 1.8 times 1 part or 1.8 times 200 pounds, which is 360 pounds. If, instead of having the mix be equal to 560 pounds, it might have been say 1000, or any other number. Whatever the amount, the calculation would be similar by dividing the amount by the total number of parts, which in this instance is 2.8, and subtracting the result from 1000 to obtain the amount of the other iron.

Calculating the Mixture of Iron for Silicon When More Than Two Irons are to be Used.

When we have two irons we can make but one mix. When we have three irons, so that one is higher than the mix, or vice versa, then any amount of mixtures can be made. For two of them can be taken as above and form a mix. Then one of these two irons and the third can form a mix, and the proportion of these mixes that can be taken to make the mixture is indefinite.

Hence, in making a mixture with more than two irons, one must assume a given amount of some of them.

Calculating the Mixture of Iron for Silicon, When More Than Two Irons are to be Used, and the Amount of Iron Assumed Does Not Equal to the Total Weight of the Mixture.

If the mixture is to contain, say 1000 pounds at 2.50 per cent Silicon, then the 1000 pounds would contain 1000 times 2.50 per cent Silicon, which is equal to 2500 per cent Silicon. If the mixture was to contain 600 pounds, then the total mix would contain 600 times 2.50 per cent Silicon, which is equal to 1500 per cent Silicon.

The total amount of Silicon a mixture contains is obtained by multiplying the average amount of Silicon the mixture contains by the number of pounds in the mixture.

Let us suppose that we have a mixture of 1000 pounds of 2.50 per cent Silicon, using 300 pounds of gates at 2.20 per cent Silicon, 200 pounds of 2.00 per cent Silicon iron, 300 pounds of 3.40 pr cent Silicon iron, and the balance of scrap iron, containing 1.75 per cent Silicon, and as much more of the above-named irons as is necessary to make the correct mixture.

For simplicity sake, we will omit the per cent Silicon in calculating, assuming for instance, that when we say 2.50 we mean 2.50 per cent Silicon.

We then have:

300 of 2.20 equals	660
200 of 2.00 equals	400
300 of 3.40 equals	1020
800	2080
1000 of 2.50 equals	2500
200	420

Average of 2.10.

If the mix is to be 1000 pounds at 2.50, then the total amount will be 1000 times 2.50, equal to 2500. We have in the assumed mix 800 pounds of iron, the total Silicon of which is equal to 2080, so hat we must add 200 pounds that will have a total Silicon of 420. Dividing 420 by 200, we have 2.10, which is the average amount of Silicon the 420 pounds must contain.

We now have the problem of making a mixture of 420 pounds at 2.10 per cent Silicon, using the 1.75 per cent iron and 3.40 per cent iron.

Using the rule for making the mixture of two irons we have the following:

High 3.40	**Mix** 2.10	.35)1.30(3.714
Low 2.10	**Low** 1.75	1.05
1.30	.35	250
		245

1	part of 3.40	equals	3 40
3.714	" " 1.75	"	6.4995
4.714	" " 2.10	"	9.8995

Or one part of 3.40 and 3.714 parts of 1.75 makes 4.714 parts of the 2.10 mixture. If the amount of the mixture is to be 200 pounds, then one part will be 200, divided by 4.714 equals to 42.44 pounds, the amount of the 3.40 iron required, and 200 pounds, less 43.44 pounls, equals to 157.56 pounds, equals the amount of 1.75 iron required. Adding the 42.44 pounds of 3.40 iron to the originally assumed 300 pounds, we have the following for our mixture:

300	pounds gates @ 2.20 equals ..	660
200	pounds of iron @ 2.00 equals..	400
157.56	pounds or iron @ 1.75 equals..	276.85
342.44	pounds of iron @ 3.40 equals..	1162.22
1000.00		2499.07

This would give us a mixture of 2.50, but as we do not weigh, as a rule, closer than 50 pounds, we change the 157.56 to 150 and the 342.44 to 350.

Calculating the Mixture of Iron For Silicon, When More Than Two Irons are to be Used, and the Amount of Iron Assumed Equals to the Total Weight of the Mixture, but the Total Silicon is Either Greater or Less Than the Total Mixture Should Contain.

Suppose that we take the same iron as in the previous example, but, instead of not taking the full amount of iron, we make our mix the full weight and see how near we would get at the correct total Silicon. For simplicity sake, we drop the per cent Silicon, rembering that when we say the iron contains, for instance, 2.50, we mean 2.50 per cent Silicon.

Let us assume the following mixture:

300 pounds gates at 2.20........	660
200 pounds gates at 2.00........	400
200 pounds gates at 1.75........	350
300 pounds gates at 3.40........	1020
1000	2430

We see that our total weight is 1000 pounds, but the total Silicon is not 2500, but 2430, or it is 70 short. The mixture is too low in Silicon, and we must take more of the 3.40 and less of the 1.75.

Now, if we take one pound more of the 3.40 and one pound less of the 1.75, we do not change the weight, but we increase the Silicon. One pound more of 3.40 and one pound less of 1.75 would increase the mix 3.40—1.75, equals 1.65. We want to increase the mix 70; so that if one pound changes the mix 1.65, then, to change it to 70, we must change as many pounds as it requires to make 70, or 70 divided by 1.65 equals 42.424. We will then have to increase the 3.40 iron 42.43 pounds and decrease the 1.75 the same amount, and we have the same results as we have calculating the amounts the last method.

Had our assumed mix been greater than the required amount, we would decrease the higher Silicon iron and take more of the low Silicon iron.

Let us suppose the Phosphorus of the iron to be as follows:

2.20 Gates...................	.93
3.40 per cent Silicon iron to be	1.40 per ct. Phos
2.00 per cent Silicon iron to be	.80 per ct. Phos
1.75 per cent Silicon iron to be	.50 per ct. Phos

Then the mixture would be as follows:

300 pounds gates	@	.93 equals..	2.79
200 pounds 2.00	@	1.60 equals..	1.20
150 pounds 1.75	@	.50 equals..	.75
350 pounds 3.40	@	1.30 equals..	4.55
1000			9.29

Or an average of .93 per cent Phosphorus.

If the mixture was to have been lower in Phosphorus, then less of the high Phosphorus iron would have to be used, and in case the Phosphorus was to have been higher more of the high Phosphorus iron would have to be used.

Another example:

To make a mixture of 1500 pounds at 3 per cent Silicon.

The total Silicon of this mixture would be 1500 times 3 per cent, which is equal to 4500 per cent.

We will assume the following mixture as a trial, and see how near we come to the correct amounts to be used.

		Per Ct.		Per Ct.
400	pounds of gates	@ 2.70	equals....	1080
200	pounds of iron	@ 1.82	equals....	364
150	pounds of iron	@ 2.00	equals....	300
200	pounds of iron	@ 2.43	equals....	486
100	pounds of iron	@ 3.10	equals....	310
150	pounds of iron	@ 3.20	equals....	480
300	pounds of iron	@ 4.50	equals....	1350
1500				4370
15	pounds at	3.00	equals....	4500
				130

The total weight of the mixture is correct, but the total Silicon, instead of being 4500 per cent, is only 4370 per cent, or it is 130 per cent too low. The mixture must be increased in Silicon. One pound more of the 4.50 per cent and one pound less of the 3.20 per cent would increase the Silicon 4.50 per cent less 3.20 per cent, equals 1.30 per cent. To increase the mixture 130 per cent it would take as many pounds as 1.30 per cent is contained in 130 per cent, which is 100. One hundred pounds more of the 4.50

per cent iron and 100 pounds less of the 3.20 per cent iron would make the mix correct.

Again. One pound more of the 4.50 per cent iron and one pound less of the 1.82 per cent would increase the Silicon 4.50 per cent less 1.82 per cent, equals to 2.68 per cent.

To increase the mixture 130 per cent it would take as many pounds as 2.68 per cent is contained in 130 per cent, which is 48.4—practically 50 pounds. We have made the change in each case by increasing one iron and taking the same amount less of another iron, changing the amounts in but two irons. We do not have to confine ourselves to two irons, but can take several irons.

One pound more of the 4.50 per cent iron and one pound less of the 3.20 per cent iron would increase the mixture 4.50 per cent less 3.20 per cent, equals to 1.30 per cent. Taking 50 pounds we would increase the mixture 50 times 1.30 per cent, equals to 65 per cent. The total assumed mixture is 130 per cent too low, so that by this change we would still be 130 per cent less 65 per cent, equals to 65 per cent, too low.

One pound more of 2.43 per cent iron and one pound less of 1.82 per cent iron would increase the mixture 2.43 per cent less 1.82 per cent, equals to .61 per cent. Taking 100 pounds, we would increase the mixture 100 times, .61 per cent, equals to 61 per cent. We would then be

65 per cent less 61 per cent, equals to 4 per cent, too low on the total mixture. This is calculating about as close as possible within 50 pounds. We have, however, two irons very near alike, namely, 3.20 per cent and 3.10 per cent. One more of 3.20 per cent and one pound less of 3.10 per cent would increase the mixture 3.20 per cent less 3.10 per cent, equals to 10 per cent. Fifty pounds more would increase the amount 50 times 10 per cent, equals to 5 per cent. The total Silicon of the mix would then be 5 per cent less 4 per cent, equals to 1 per cent too high.

Notice that we took 50 pounds less of 3.20 per cent iron with the 4.50 per cent iron, and now take 50 pounds more of the 3.20 per cent iron with the 3.10 per cent iron, so that we might have taken the 4.50 per cent iron and the 3.10 per cent. But we did not suppose to know this.

This example illustrates very well how the method can be used. In assuming the amounts of iron, the total Phosphorus should be figured the same way as the total Silicon. As the Phosphorus is too high or too low, that will decide what changes had best be made. In the example given many more changes could have been made. Some irons might have been discarded altogether. The Phosphorus would determine that to a great extent.

Calculating the Mixture of Iron for Silicon, When More Than Two Irons are to be Used, by Making Separate Mixtures of Two Irons, and Combining These Separate Mixtures.

We have had the method of calculating the mixture of iron for Silicon where two irons are to be used. The method is here used, and then the different mixtures are combined to make a grand total mixture.

To illustrate the method, let us suppose that we have three kinds of iron in the yard that analyzes 3.40 per cent, 2.00 per cent and 1.75 per cent Silicon, and we want to make a casting that will contain 2.20 Silicon. Suppose that the loss in the cupola is .30 per cent; then the mixture would have to be 2.50 per cent Silicon.

Now, by applying our rule for two cars at a time, we have the following calculation:

Taking 3.40 and 2.00 we have

High 3.40	Mix 2.50	.50).90(1.8	.90).50(.555
Mix 2.50	Low 2 00	50	450
.90	.50	400	500
			450
			500
			450

1.	part of	3.40	equals	3.40	
1.8	" "	2.00	"	3.60	
2.8	" "	2.50	"	7.00	

1.	part of	2.00	equals	2.00
1.55	" "	3.40	"	1.88
1.55	" "	2.50	"	3.88

1 divided by 2.8 equals .357, or .357 parts of 3.40 per cent and .643 parts 2.00.

Taking the 3.40 and the 1.75 we have

High 3 40	Mix 2.50	.90).750(.833	.75).90(1.2
Mix 2.50	Low 1.75	720	75
.90	.75	300	150
		270	150
		300	
		270	
		300	

1	part of	3.40	equals	3.40
1.2	" "	1.75	"	2.10
2.2		2 50		5.50

1	part of	1.75	equals	1.75
.833	" "	3.40	"	2.83
1.833	" "	2.50	"	4.58

Dividing 1 by 2.2 equals .4546, hence .4546 parts of 3.40 and .5454 parts of 1.75. If the casting is to be 2.50 per cent Silicon, then the gates or return scrap will be 2.20 per cent Silicon, which will require a higher Silicon iron to bring it to 2.50 per cent. Taking, then, the gates with the 3.40 per cent iron, we have

High	3.40	Mix	2.50	.90) .300 (.333
Mix	2.50	Gates	2.20	270
	.90		.30	300
				270
				30

1	part of gates	2.20	equals	2.20
.33	" "	3.40	"	1.13
1 33 parts		2.50	"	3.38

Dividing 1 by 1.333 equals .75, or .25 parts of 3.40 and .75 parts of Gates.

Taking one part to mean one pound we have from the above:

100 pounds of Gates require 33.33 pounds of 3.40 per cent Silicon iron.

100 pounds of 2.00 per cent requires 55.55 pounds of 3.40 per cent Silicon iron.

100 pounds of 1.75 per cent requires 83.33 pounds of 3.40 per cent Silicon iron.

With two kinds of iron only one mixture can be made, but with two or more, and figuring for but one element, any amount of mixtures can be made. This is evident, for it is taken as granted that the first and second will make a mix and the first and third will make a mix. Now the amounts taken of these two mix to make a mix can vary almost inefinitely. Hence, in making a mix we must decide upon the amounts of some of the irons and let the balance be taken as re quired to make the mix.

To illustrate, let us suppose that we make a mix of 1000 pounds. We desire to use up our gates, which amount to 300 pounds a charge also want to use 300 pounds of the 2.00 per cent iron and the rest of 1.75 per cent and 3.40 per cent iron. From the above table we see that

300 lbs. of gates require	100 lbs. of 3.40 per cent.	
200 lbs. of 2.00 per cent.	111 lbs. of 3.40 per cent.	
500 lbs. of iron require	211 lbs. of 3.40	per cent

Or making a total of 711.11 pounds of iron. The mixture is to contain 1000 pounds, so that we have 1000, minus 711.11 pounds, equals 288.8 gates, to make with the 3.40 per cent iron and the 1.75 per cent.

Looking up the 1.75 iron, we find that it requires .4546 of the 3.40 per cent and .5454 of the 1.75 per cent iron to make one part. Then to make 288.90 parts, it will take 288.89 times this amount, or 131.33 of the 3.40 per cent and 157.56 of the 1.75 per cent iron.

Adding the three different amounts of 3.4 per cent iron to be used, we have 341.83 pounds

The mixture, as calculated, will then be as follows:

300	lbs. of gates at	2.20	660.
200	" " iron "	2.00	400.
157.56		1.75	276.85
342.44		3.40	1162.22
1000	pounds of mix	2.50	2499.07

This is practically 2500, or average of 2.50 per cent.

We find above that we use 157.56 of 1.75 per cent iron and 342.44 of 3.40 per cent iron. Now in practice we do not weigh so close, but only within an even 50 pounds. Of course, every one can weigh as close as they see fit. It is always better to have the iron a little higher in Silicon than lower (chilled iron excepted); so we round off the mix above and call it 150 pounds of 1.75 per cent and 3.50 of 3.40 per cent iron. The mix will then be

300 pounds of 2.20 per cent iron
200 pounds of 2.00 per cent iron
150 pounds of 1.75 per cent iron
350 pounds of 3.40 per cent iron

1000

This will make the average about 2.51 per cent.

If there had been another kind of iron that was above the mixture in Silicon, then this could have also been used. The main idea is to get the amount that is required with 100 pounds of iron and the amounts of each to make 100 pounds, and we have all that is required to make any mix.

Calculating For Two Elements.

It is impossible to calculate for more than one element at a time. If it is desired to figure the mixture for two elements, for instance, Silicon and Phosphorus, then two or more mixtures must first be figured for Silicon and these mixtures taken and figured for Phosphorus.

For Silicon it requires but two kinds of iron, but to figure for Silicon and Phosphorus it requires three or more kinds of iron, and the Phosphorous in these irons must be so that when two of these irons are taken together the Phosphorus of two of them will be above the required Phosphorus of the mix and the second two will be below the required Phosphorus of the mix.

In the example for Silicon we had three kinds of iron. Let me take these same irons and give the Phosphorous:

3.40 Silicon	1.40 per cent Phosphorus
2.00 Silicon	.80 per cent Phosphorus
1.75 Silicon	.50 per cent Phosphorus

Taking the 3.40 per cent and 2.00 per cent, we see in the Silicon table that it takes .357 parts of 3.40 and .643 parts of 2.00.

The Phosphorus in 100 pounds would then be

3577	times 1.40 equals	49.98
64.3	times .80 equals	51.44
100		1101.42

Mix would then be 2.50 Si.; 1.01 Phos. Call this "A."

Taking 3.40 per cent and 1.75 per cent, we see from the Silicon table that it takes .4546 parts of 3..40 per cent and 5454 parts of 1.75 per cent.

The Phosphorus in 100 pounds would then be:

45.46	times 1.40	equals	53.64
54.54	times .50	equals	27.27
100			80.91

Mix would then be 2.50 per cent Silicon; .8091 Phosphorus. Call this "B."

Let us suppose the castings should be .93 per cent Phosphorus. Then, figuring the same way as in Silicon, we have:

1.014	**.93**	**.084) 121 (.144**	**.121) 0840 (.694**
.93	**.809**	**84**	**726**
.084	**.121**	**370**	**1140**
		336	**1089**

1	**part of .809**	**equals**	**.809**
1.44	**" " 1.469**	**"**	**1.460**
2.44			**2 269**
1	**part of 1.014**	**equals**	**1 014**
.694	**" " .809**	**"**	**.5614**
1 694			**1.5764**

Dividing 1 by 2.44, we have .4098, hence .4098 of .809 Phosphorus and .5902 of 1.014 Phosphorus would make the mix. The mix would then be 40.98 of "A" and 59.02 of "B."

40.98A.	**.357 of 3 40 per cent equals**	**14.62986**
	.643 of 2.00 " " "	**26.35014**

59,02B.	.4546 of 3.40 per cent equals	26.830492
	.5454 " 1.75 " " "	32.189508
		100.000u00

Adding the two amountts of 3.40 per cent Silicon, we have:

41.460 of 3 40	per cent Silicon	1 40 per cent Phos.
26.350 of 2 00	" " "	.80 " " "
32 190 of 1 75	" " "	.50 " " "
1000.000 of 2.00	" " "	.93 " " "

This is calculated to 100 pounds. Of course, any amount could be taken by multiplying the above. If another iron was on hand, this could be figured like above and another mixture made. This is all very easy, it being only a matter of a few figures.

Any of the methods for calculating the Silicon can be used to make a mixture with the correct Silicon. The Phosphorus that these mixtures contain must be calculated. Two or more mixtures are made and the Silicon item not considered. The Phosphorus is then calculated the same manner as the Silicon has been.

Facts Worth Thinking About.

By having analysis made you can tell whether the furnace sent you the iron ordered.

By having each car checked the furnace will be more particular as to what they send you. Otherwise they are apt to think that you will not know any better.

By analysis you can use the iron to the best advantage and save money.

By analysis you can have the same mixture day after day and have better castings, changing your irons as you please.

By analysis you are not dependent upon any particular brand, but can buy from whoever sells the cheapest.

A car of iron generally contains 25 tons of iron and costs between $400 and $500. Would not any one be willing to pay a dollar or two more to know that the iron is all right, and have the correct analysis so that the iron can be used to the best advantage?

Any foundryman that cannot save many, many times the cost of analysis ,in making the mixture, have better castings and less loss, had better give up his position.

SAMPLING IRON.

Take three to six pieces (the more the better) of iron from different parts of the car. If the iron is broken and the fracture can be seen, then select different-looking pieces. Take borings of these pieces, throwing away the first cut, so that you get clean borings. Mix these borings well, and put about an ounce in a small envelope. On this envelope put the car number, name of iron or casting, or place any number or mark on it, so that you will know what it contains. Mark the elements that you want analyzed on this envelope. The same for any casting. I furnish a special printed envelope to my customers. Place this envelope or several envelopes in a large one and mail to

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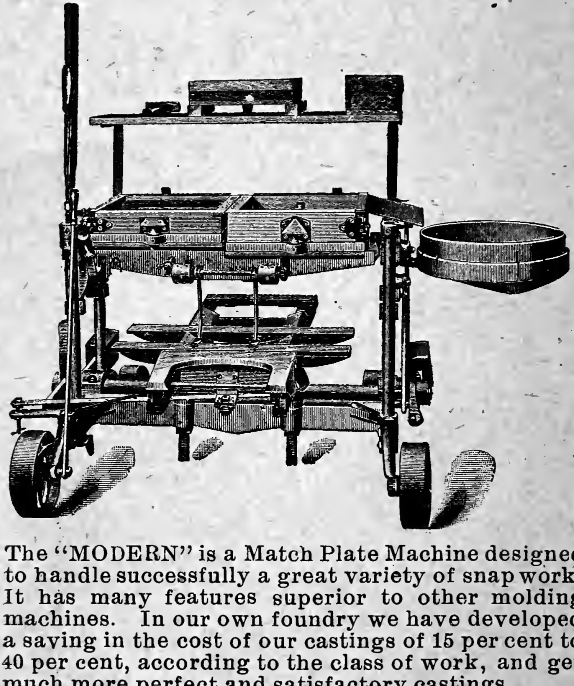

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