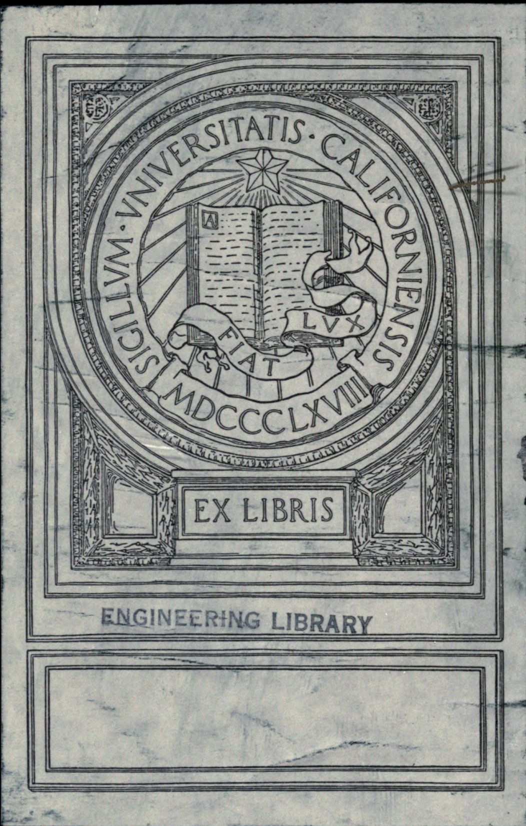
STATIONARY, MARINE, GAS, AND LOCOMOTIVE ENGINES.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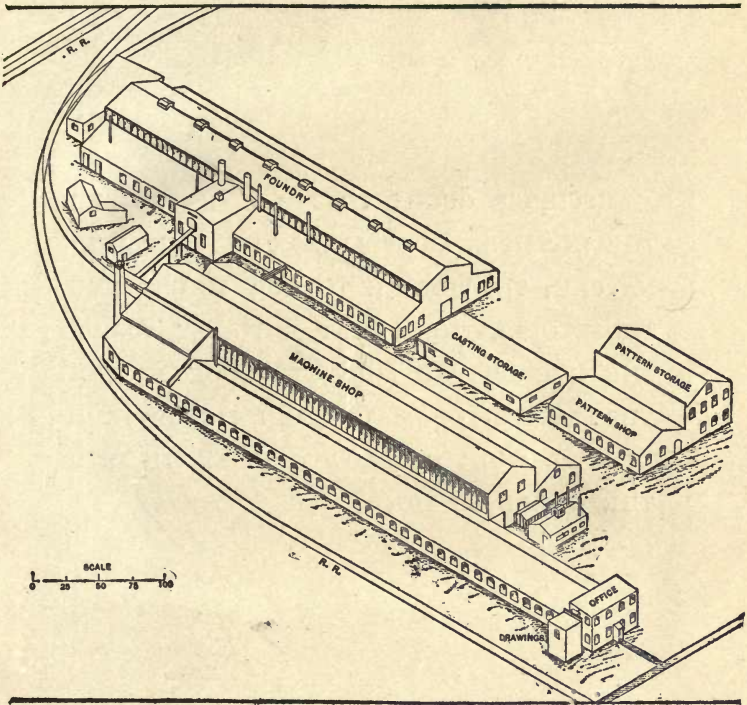


MODEL ENGINE WORKS.

"SCIENCE OUGHT TO TEACH US TO SEE THE INVISIBLE AS WELL AS THE VISIBLE IN NATURE; TO PICTURE TO OUR MIND'S EYE THOSE OPERATIONS THAT ENTIRELY ELUDE THE EYE OF THE BODY; TO LOOK AT THE VERY ATOMS OF MATTER, IN MOTION AND IN REST, AND TO FOLLOW THEM FORTH INTO THE WORLD OF THE SENSES."—*Tyndall.*

The *United States Gazette* of November 24, 1832, remarks:

"A most gratifying experiment was made yesterday afternoon on the Philadelphia, Germantown and Norristown Railroad. The beautiful locomotive engine and tender, built by Mr. Baldwin, of this city, whose reputation as an ingenious machinist is well known, were for the first time placed on the road. The engine traveled about six miles, working with perfect accuracy and ease in all its parts, and with great velocity."

MATTHIAS W. BALDWIN,

Founder of the Baldwin Locomotive Works.

Dedication.

THIS WORK IS RESPECTFULLY DEDICATED TO THOSE

DESIGNERS AND BUILDERS,

WHOSE ENGINEERING SKILL AND DEVOTED EFFORTS
HAVE CONTRIBUTED SO LARGELY
TOWARDS PLACING THE

MODERN STEAM ENGINE

IN ITS SEVERAL TYPES IN THE FRONT RANK OF
THE MOTIVE POWER OF THE WORLD.

NEW CATECHISM

OF

THE STEAM ENGINE

WITH CHAPTERS ON

Gas, Oil and Hot Air Engines,

BY

N. HAWKINS, M. E.

AUTHOR OF THE HAND BOOK OF CALCULATIONS FOR ENGINEERS; MAXIMS AND INSTRUCTIONS FOR THE BOILER-ROOM; AIDS TO ENGINEERS' EXAMINATIONS WITH QUESTIONS AND ANSWERS; NEW CATECHISM OF ELECTRICITY, ETC., ETC.,

Relating to Stationary, Marine and Locomotive Engines; Steam Fire Engines; Pumping, Hoisting and Portable Engines; Gas, Oil and Air Engines. Explaining their principal points and their care and management.

THEO. AUDEL & CO., Publishers,

NEW YORK.

1902.

PREFACE.

The reader is invited in the succeeding pages to examine down to almost microscopic detail the greatest physical thing on earth. To describe the steam engine, to show how skillful one may be in detecting faults in one machine and the superiorities in another, indeed is the most contemptible occupation a writer of a general treatise could perform.

But, to describe, to show how beautiful and how truly admirable in finish and in powers of execution is the modern steam engine, is not indeed the highest, but quite one of the pleasantest and most useful of tasks, and the author feels that it is within his range of power, i. e., to admire and to describe and in a measure at the same time to instruct.

With a high appreciation for noble results achieved, this book is dedicated to the Designers and Builders of the modern steam engine, and the added desire is now expressed, and the kindly suggestion made that these two, the designers and builders of high class engines, should join in fraternal association and each quarter year meet to consult upon matters of mutual profit, to feast together and go away with a wish to meet such good company again.

To such a representation could safely be confided the collection of statistics, the upholding of the dignity of the professional part of the calling, the avoidance of undue competition in prices, and a hundred other advantages, not the least of which would be the discussion of how to meet the new opponent of the steam engine to be found in electrical power creation, from water, gas, etc.

While the name and "layout" of this work suggests inert machinery built of iron, steel and brass, without soul and without feeling, yet from its very inception to the close of the index, *the man* who was to operate the engine has been first in the mind of the author. When an engine has been completed it means the futuie life work of several men to be expended in its care and management. All steam engineering literature is full of the subject of economy in operating the machine, but now and always the author desires to aid in promoting the true economy of the life work and well being of his special patrons, the engineers in charge of the steam plants.

It should always be remembered that an engineer is paid mostly for what he knows rather than for what he performs, and above all else for his well grounded knowledge of the first principles of steam engineering.

To a ready acquaintance with the first things relating to his profession the engineer should have added the power or ability to reason from these first principles and bring his knowledge properly into use in the solution of the infinitely varied problems that come up in his every day practice. Two things are requisite to this—first, the habit of study and mental application; second, the habit of closely reasoning from cause to effect.

Engineering is a science that may be learned in the shop and from the private study of books. Many of the most competent engineers are men whose education was procured entirely outside of the engineering schools. It has been well said that engineers are born, not made; those in demand to fill the positions created by the great installations of power-producing machinery now so common, are men who are familiar with the contents of good books, and as well, are the product of a hard bought practical experience.

The men most desired by engine builders to take charge of their engines after they leave their construction and erecting shops are engineers who have had a practical training, the best of whom are men who have come from the ranks, men who in subordinate positions have observed intelligently, studied principles as well as details, and prepared themselves to assume new and greater responsibilities.

"No study that is worth pursuing seriously can be pursued without effort, but we need never make the effort painful for the purpose of preserving our dignity." These are words written by Ruskin, the great art teacher, and may also indicate the design of the author to make the book a continued pleasure to the casual reader or the careful student.

In order to apply oneself to any advantage, to even the most serious and important affair, it is necessary that a certain warm and hearty interest relating to it should be infused into the mind, hence the author has aimed to make this volume both inviting and instructive.

The first requisite for a plain description of any piece of mechanism or object is a precise terminology. This remark applies to the steam engine and its appliances and for a beginner in the study of its operation the greatest difficulty will be found to be the getting of a correct idea of the terms used. Consequently, the most careful attention should be given to the definitions. But, no matter how much care is exercised in endeavoring to obtain a correct idea of the meaning of a definition, it is almost impossible to comprehend its full scope at the first reading.

The best procedure is to read the definitions without making any particular effort to memorize them, and refer to them whenever the term defined occurs in a subsequent portion of the book. In this way, the full meaning will gradually develop in the student's mind, and he will unconsciously memorize them without any painful mental effort.

Considerable space has been devoted in the following pages to illustrations. In making the pictorial feature prominent, the most modern ideas have been followed. A careful study of the illustrations of engines and appliances described in the work, even with no word of explanation, is an education in itself in steam engineering. The first cost of these diagrams and pictures far exceed in cost all else in the book, and the kind reader is advised first of all to become familiar with them.

In the preparation of this work the author desires to heartily express his obligations to Captain Henry E. Raabe, M. E., Naval Architect, graduate of Marine Academy, Amsterdam, for the drawings and diagrams illustrating the work and especially for assistance in preparing the parts relating to the "marine engines" and "valve construction."

INTRODUCTION.

It is becoming more and more difficult to write a book relating to any of the great lines of modern industrial advance. Especially is this true of steam engines where the variety of work and service is almost infinite. The particular requirements and condition of each machine are so carefully considered that it becomes in fact a special plant for a certain fixed work.

Compare the enormous dimensions of many of the engines described in the following pages with those given in the note and the difficulty of the writer in presenting a too minute presentation of the subject will be apparent,.

The practice and innumerable adaptation of steam power varies year by year, but the first principles of the science remain always the same. Every experiment fails which goes against the unchanging and perfect laws of creation. The success comes with the effort to make useful to mankind the hidden forces of nature.

The complete study of the theory of the steam engine is beyond the scope of so elementary work as this is designed to be, as it involves a thorough acquaintance with chemistry, mechanics, heat, etc.

NOTE.—The smallest steam engine in the world is the production of a resident of Akrona, Canada. The dimensions of this miniature affair are as follows: diameter of cylinder, $\frac{1}{3}$ of $\frac{1}{16}$ of an inch; stroke, $\frac{1}{32}$ of an inch; revolutions, 1,760 per minute. This engine is so small that it can easily be covered with the case of a 22-caliber cartridge.

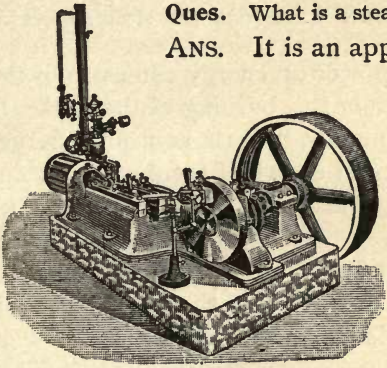
Charles H. Allen, of Rochester, has built a tiny engine which weighs only thirty-one grains and is but three-fourths of an inch in length. It runs perfectly, though it goes easily into an ordinary thimble.

The terms theory and theoretical are properly used in opposition to the words practice and practical. The English word "theory" is derived from a Latin word which means "to look at"; hence the theory of the steam engine is something designed to end only in speculation or contemplation without a view to anything more.

The practical part of the subject is to be found in the illustrations and descriptions of the actual engines to be described hereafter; the theoretical is woven in throughout the book and is considered to be quite a matter of suggestion and "hints" rather than a formal and formidable statement of abstract principles.

NOTE.—"Creation belongs to God, but the application of principles and powers to human wants and their various changes and interchanges, belong to man. It is said that a voyage of a great steamship across the Atlantic ocean spends as much power as would be required to lift all the stones in the largest pyramid in Egypt from the level of the Nile to the places which they now occupy. The power stored in coal is but concentrated sunbeams. To eliminate that power in the form of heat units and convert them into power is the province of man. Power applied through the steam engines and dynamos that are now moving over the civilized world, marks the greatest era of progress and physical development in the history of mankind."

THE STEAM ENGINE.



Ques. What is a steam engine?

ANS. It is an apparatus for converting heat into mechanical power, or more plainly, an ingenious machine worked by steam.

Ques. What is a stationary steam engine?

ANS. An engine which is erected in a certain location and designed to remain in the same position, without change, or more plainly, it is an engine which does its work without changing its place.

Ques. What is a marine engine?

ANS. It is an engine designed for propelling steamships, either screw or side wheelers.

Ques. What is a locomotive engine?

ANS. An engine designed to operate on iron and steel railways. With engine and boiler combined in one machine it becomes a "traveling engine."

Ques. Are there any other steam engines than these three?

ANS. Yes. Portable engines, hoisting engines, the steam hammer, the steam drill, pumping engines, blowing engines, steam fire engines, donkey, steering engines, etc.

Ques. Do these all operate on the same general principle or law, and what is that?

ANS. Yes. The underlying principle or law of nature regulating the building of all these is that which applies to the formation and expansion of gases. Water is changed into gas (steam) by the heat of combustion, and while such, is subject to the laws which govern the expansion, contraction, etc., of all gases.

Questions and Answers.

Ques. Where does the power or energy which drives all steam engines come from?

Ans. From the coal or other fuel.

Ques. Does any of the power come from the steam, water or engine?

Ans. Not any. The power or energy comes from the heat and the heat comes from the burning of the coal. It is the property of an engine that it must continuously get back to a starting point and at each half revolution it gains a fresh supply of energy (heat) to be expended in its appointed work.

Ques. How many types or forms of steam engines are there?

Ans. Very many hundreds, if not thousands, but all operated upon the principles as stated.

Ques. What is the most numerous pattern?

Ans. The common slide valve, stationary engine.

Ques. What type of engines are now leading the advance in economy and effectiveness?

Ans. The automatic cut-off engines are fast superceding and replacing the common slide valve engines.

Ques. Upon what point are the maker, the buyer and the engineer of a steam engine all agreed?

Ans. Upon the matter of its "running" quality.

Ques. What could be considered a fair "running" requirement in a new engine, in the hands of a first-class engineer?

Ans. A satisfactory running engine is one which has the stationary parts of such strength and security that there is absolutely no movement at any point due to the reciprocating of the moving pieces. In an engine which is perfectly satisfactory in this respect, a slender rod with a squared end, such as a common lead pencil, can be placed in a standing position on a level surface at any point and remain there indefinitely without other support than its own base.

Note.—There are very many places from which the slide valve engine will never be displaced, as, from places where fuel is cheap, such as saw and planing mills, etc.; also where an engine has to be started and stopped at frequent intervals, such as first motion hoisting engines.

Questions and Answers.

Ques. What quantity of coal is now considered to be "good practice" per horse power, per hour?

Ans. Very few stationary steam engines have developed a performance of less than 2 pounds of coal per horse power per hour, and 5 pounds is a common consumption of coal for that amount of work. In marine expansion engines—multi-cylinder—the rate has been often reduced below 1⅓ lbs. per horse power per hour.

Ques. About how much of the heat generated in the furnace is utilized in useful work?

Ans. About ten per cent. Some engines upon careful measurement have shown only seven per cent. The waste of heat that forms such a large aggregate common to every steam engine begins at the furnace and only ends with the steam passing out of the exhaust port.

Ques. What attainments should be looked for in a modern steam engine?

Ans. Close regulation of speed; the least conduction of heat from the steam by the cooling of the cylinder; small clearances; free steam openings from steam chest to cylinder, to allow full boiler pressure to enter the cylinder up to the point of cut-off; free exhaust, allowing no back pressure through any fault of the engine; rapid motion of valve at point of cut-off to make such point decisive; tight valves, allowing no waste of steam by leakage; and last, but exceedingly important, the least possible friction in the valves and moving parts of the engine.

Note.—Whatever the grade of material of which the parts are constructed, whatever their strength, however perfect their design and finish, the engine fails of being wholly satisfactory if its running qualities are in any respect imperfect.

An engine to be perfectly satisfactory should be capable of sustaining a maximum load without heating either in the main bearing, crank pin, crosshead pin, or guides; and, furthermore, it should do this without any noise of knocking as the centres are passed; likewise all the reciprocating parts should operate noiselessly and without jar or trembling.

QUESTIONS AND ANSWERS.

Ques. **What is the meaning of the term "cycle"?**

ANS. If a substance like water or gas be subjected t various changes by the action of heat and finally brough back to its original condition it is said to have undergon "a cycle of operations."

Ques. **What is the true measure of the efficiency of an engine?**

ANS. The proportion of the heat converted into worl in pushing the piston is the measure of the engine's effi ciency.*

Ques. **How are steam engines rated?**

ANS. By horse power.

Ques. **What is a horse power?**

ANS. 33,000 foot-pounds per minute, 550 foot-pound per second, or 1,980,000 foot-pounds per hour.

Ques. **What is a foot-pound?**

ANS. One pound of force exerted through one foot o space.

Ques. **Is it correct to say "horse power per minute," "horse powe per hour," etc.?**

ANS. No. If an engine is doing work at the rate of 5 horse power it is doing 50 horse power all the time. It i an error which is frequently made to assume that such a engine is doing 50 horse power per minute, for 50 × 60 = 3,000 horse power per hour.

Ques. **What is a self-contained engine?**

ANS. The self-contained engine is entirely dependen upon its own frame to hold all its parts together, and doe not need a solid foundation.

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*NOTE.—If the steam reaches the piston at 145 pounds above th atmosphere, the heat is about 363 degrees Fahr.; when expanded dow to 30 pounds above the atmosphere, the temperature falls to about 24 degrees Fahr.; so that about 90 degrees of the heat generated has bee utilized. This seems a small proportion, but it can never be mad much greater. The losses from too much clearance, from initial con densation and re-evaporation of condensed steam towards the end o the stroke, may be reduced by intelligent engineering, but there are n prospects that the supreme loss of heat present in the exhaust stea will ever be overcome.

Questions and Answers.

Ques. What is a "right-hand engine"?

Ans. An engine the fly-wheel of which is to the right, as looked at from the cylinder.

Ques. What is a left-hand engine?

Ans. An engine the fly-wheel of which is to the left, as looked at from the cylinder.

Ques. What is meant by an engine running "over"?

Ans. The top of the wheel running away from the cylinder.

Ques. What is meant by an engine running "under"?

Ans. The top of the wheel running toward the cylinder.

Ques. Which way are engines more generally run?

Ans. Over.

Ques. What advantages pertain to running an engine in this way?

Ans. The pressure of the cross-head is always downward upon the guide, for when the pressure is on the head end of the piston the thrust against the connecting rod which is pointing upward reacts to press the cross-head down upon the guides; and when the pressure is on the crank end of the cylinder, the cross-head will be dragging the crank, and as the crank is below the center line, it will still pull the cross-head down upon the lower guide. If on the other hand the engine is run "under," the thrust of the cross-head will be upon the top guide on both the outward and inward strokes, and unless the cross-head is nicely adjusted to its guides, and the guides are perfectly parallel under running conditions, the cross-head will be lifted when subjected to thrust, and fall by its own weight on the centers, making the engine pound.

Note.—The non-self-contained engine is one which is partly depending on the foundation to hold some of its parts in place, as for instance the outward pillow block and crank shaft. The foundations of such engines have to be particularly well designed. Most of the high speed and vertical engines belong to the former class, while the long stroke, slow and medium speed with girder or tangeye bed, and also some vertical engines belong to the non-self-contained engines.

In stationary engineering, there are more single high pressure engines used than any other kind. These, when of a good design and well taken care of, can be very economical.

Questions and Answers.

Ques. When is it desirable to have an engine run under?

Ans. When it is impossible to so locate the engine as to give the proper direction to the belt from an "over" running wheel.

Ques. What is a "single valve" engine?

Ans. An engine in which a single valve controls the admission and distribution of steam for both ends of the cylinder; as in a common slide valve engine.

Ques. What is a "four valve" engine?

Ans. An engine having a separate steam and exhaust valve for each end of the cylinder, as a Corliss engine.

Ques. What is a single acting engine?

Ans. An engine in which, like the Westinghouse, the steam acts on one side of the piston only.

Ques. What is a rotary engine?

Ans. It is one in which piston and crank are formed in one place connected to the shaft and rotating in a chamber. The piston instead of returning to its starting point continues turning in one direction. It is an ordinary engine which does not work upon the principle of expansion.

Ques. What is the meaning of the terms "automatic" and "automatic engine"?

Ans. Automatic means self-acting—in machinery, it describes certain movements commonly made by hand which are made by the machine itself. Hence, an automatic engine is a self-regulating engine.

Note.—"There is good reason for believing that the steam engine is now as nearly perfect as it will ever be made, unless someone discovers a new method of transmitting the power from the boiler to the driven mechanism. That some revolutionary method will be discovered is highly improbable, and so engineers must content themselves to go on improving on details and stopping leaks that defective designs leave open. Meanwhile, about 90 per cent. of the heat generated in the furnace will continue to pass out through the smokestack and exhaust port, and science will continue to look on, impotent to stop or lessen this immense waste of energy."

QUESTIONS AND ANSWERS.

Ques. **What are the reciprocating parts of the engine?**

ANS. All those parts which move to and fro are the reciprocating parts; 1, the piston; 2, the piston rod; 3, the crosshead; and 4, the connecting rod. The connecting rod is attached to the crosshead, the crosshead to the piston rod, the piston rod to the piston and this latter is actuated directly by the steam pressure.

Ques. **What is the action of these various parts?**

ANS. They begin from a state of rest at the commencement of the stroke and are gradually set in motion, slowly at first, and faster and faster until the middle of the stroke, when they are moving with the same velocity as the crank pin. After that their motion is retarded until the end of the stroke, when they again come to rest and the same action is repeated. It thus becomes necessary for the crosshead to come to rest at the beginning and end of each stroke.

Ques. **Into what two classes are engines divided with reference to the manner in which they are governed?**

ANS. Throttling, and automatic cut-off.

Ques. **Into what two classes may the automatic cut-off engines be divided?**

ANS. The single valves, in which the point of cut-off is varied by changing the amount of travel of the valve, and the four-valve engines, in which the cut-off is usually effected by a detaching mechanism or trip under the control of the governor.

Ques. **What is the difference in principle of operation between an automatic cut-off and slide valve throttling engine?**

ANS. The automatic cut-off engine regulates its speed by cutting off the steam at an earlier point of the stroke; this allows the steam to work by expansion, increasing the economy; the pressure thus reduced in the cylinder by expansion will regulate the speed. The slide valve throttling engine regulates its speed by throttling the steam between the boiler and the cylinder.

NOTE.—The end of one stroke is the beginning of another, and two makes one revolution of the engine.

Questions and Answers.

Ques. What particular advantages are claimed for vertical or upright engines?

Ans. A decrease in frictional resistance, especially on the pistons; an increased economy due to the thorough draining of the cylinders; they require less floor space for given power; they are more easily accessible in many of their parts, especially as to valves, stuffing boxes and pistons. Cylinders standing vertically do not corrode on their wearing surfaces, *i. e.*, those parts sustaining the greater wear; their cylinders are less liable to accident from flooding with water from steam and exhaust pipes.

Ques. What are the special advantages claimed for the high speed engine?

Ans. It is said that in high speed engines the uniformity and smoothness of running is much better than it is in slow speed engines owing to the greater quickness of the action of the automatic governor with which they are equipped—hence also more perfect regulation; 2, the moving parts are comparatively lighter, with larger wearing surfaces; 3, they are more compact, using less space for the same power; 4, the direct action and simplicity of parts; 5, less in cost for the same power; 6, they are in line with modern advance.

Note.—That these advantages are becoming more clearly recognized with each year is evident from the development of the high speed engine since its first introduction. At the International Exposition in Vienna in 1873, the average piston speed of the engines there exhibited was about 350 feet per minute and the maximum about 420 feet per minute, while the same makers exhibited in 1888 at the Vienna Industrial Exhibition, engines whose average piston speed was about 480 feet per minute and a maximum of nearly 700 feet per minute. At the International Exposition in Paris in 1889, piston speeds of 780 feet had been attained and at the Electrical Exposition in Frankfurt, in 1891, the maximum was 875 feet per minute. In large engines to day, 900 feet per minute is not considered excessive, and we find even in small electric lighting engines of the type known as high speed engines, meaning high rotary speed, that between 700 and 800 feet per minute is the ordinary piston velocity.

EARLY HISTORY OF THE STEAM ENGINE.

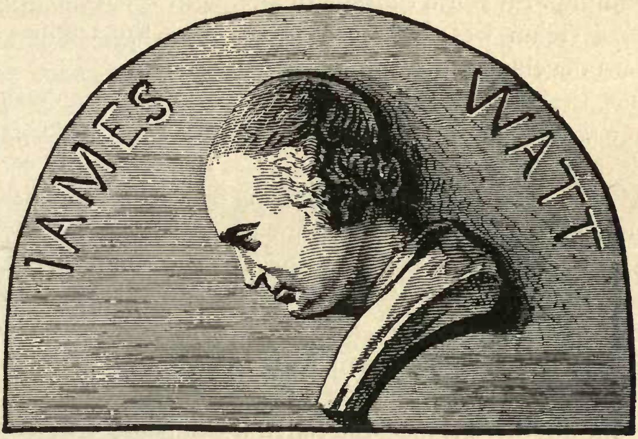

Fig. 1. James Watt.

"A true delineation of the smallest man and his scenes of pilgrimage through life, is capable of interesting the greatest man. All men are to an unspeakable extent brothers; each man's life a strange emblem of every man's; and human portraits, faithfully drawn, are of all pictures the welcomest on human walls."

These are the words of Thomas Carlysle, and to-day the biography of the inventors, designers and builders of the Steam Engine furnishes its most complete and interesting history.

Of this mechanism it has been said that 'Of all the efforts of human ingenuity known, perhaps none has monopolized so large a share of inventive genius as the steam engine. No other object in the entire range of human devices has so irresistibly arrogated to itself the devotion of scientific men as the production of an artificial movement from the vapor of boiling water."

Early History of the Steam Engine.

The first bona-fide engineer was a military chieftain, and the first engine was a battering ram. This was in the beginning of historic times. In after ages when the properties of steam were discovered the two (the engine and steam) developed into the steam engine.

But, the first "engine," so called, was a single beam of heavy wood; next in order, several such were attached to each other, end to end, until a total length of 100 or 150 feet was attained, and borne, in the attack, upon the shoulders of scores of fighting men.

Step three in the progress towards the modern engine, was to plate the end of the awkward, effective beam with iron; fourth, to swing it forward and backward suspended from a tall frame work, which in time grew into a tower manned by soldiers.

Next appeared a machine called a catapault, used to cast rocks and other projectiles, and in course of time still other devices were invented to assist or repel attacks upon towers of defence and enclosed towns.

These warlike contrivances were the first engines, and were so named, and the men who invented and constructed them were called engineers. The term comes from a word in the Latin language—*ingenium*—signifying ingenious The word has been transferred to the French, German and Italian languages, as well as the English, but always retaining its original meaning. Upon the advent of gunpowder, and the introduction of artillery, those who operated the guns continued to be called engineers, and for a long time received four times the pay of a common soldier.

Giovanni Branca, of Lorreto, Italy, in the year 1629, produced a machine combining an engine and boiler, the power from which was derived from the expansion of water

NOTE.—In Branca's time, and for over two huudred years, the Steam Engine was called the *fire engine.* One discoverer says, (in 1608) referring to the then mysterious substance which propelled the machines, "The water is converted into *air* and its vaporization (in a bombshell) is followed by a violent explosion."

EARLY HISTORY OF THE STEAM ENGINE.

into steam. Branca, in his writings, claimed that much useful labor could be accomplished through his device. There were other inventors in the field in the early part of the same century in which Branca lived, but the machines and contrivances to utilize the energy known to be locked up in steam, never (like the one illustrated, Fig. 2), amounted to much more than idle dreams.

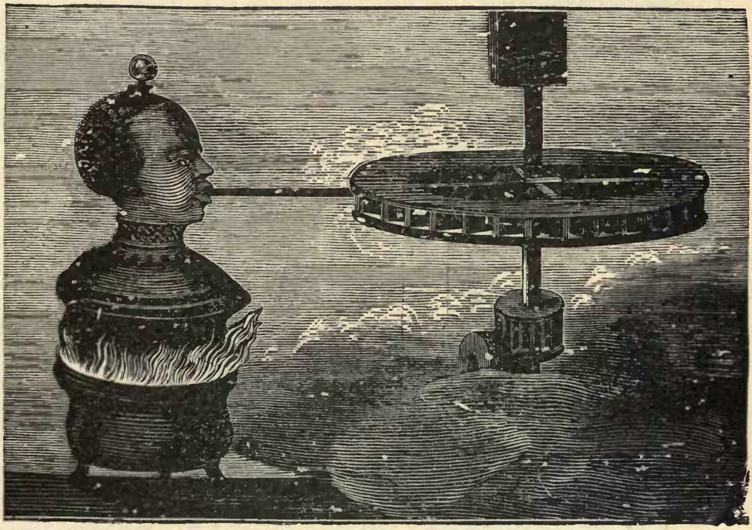

Fig. 2. THE BRANCA ENGINE, 1629.

Fig. 3 illustrates the Newcomen engine, which was patented in 1705. Our space is too limited to go into a detailed statement of its method of action, except we may

NOTE.—One of the Newcomen engines was erected in Holland to aid in draining a lake near Rotterdam. The following were the extraordinary dimensions: Cylinder 52 inches in diameter; stroke 9 feet. The boiler was 18 feet in diameter, and contained 2 flues; but 60 years later engines with 12 feet diameter of cylinder and 10 feet stroke were erected in Holland to do similar work. It was the Newcomen form of engine that Watt and Trevethick found in general use when they began their improvements.

EARLY HISTORY OF THE STEAM ENGINE.

say that the steam was let into the cylinder (*C*) a little above atmospheric pressure, and by its elastic force raised the piston, and the stroke was completed by the condensation of the steam which produced a vacuum and allowed nearly the full pressure of the air to accomplish the desired result of raising the water.

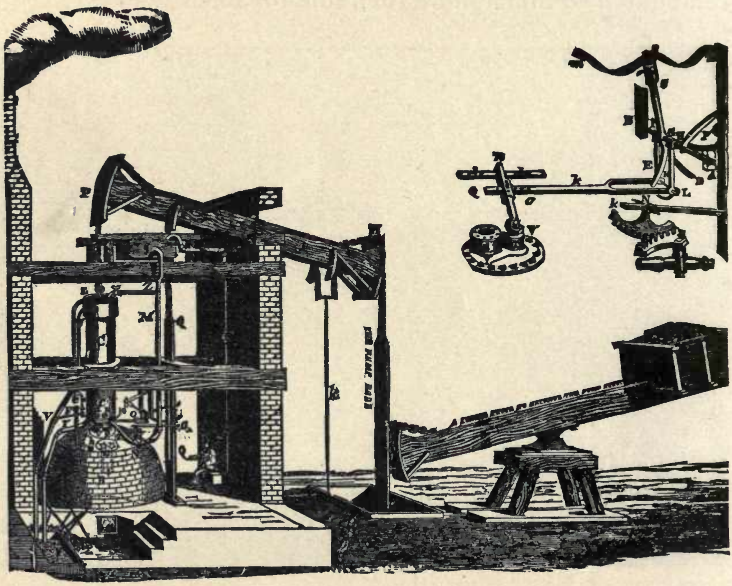

Fig. 3. THE NEWCOMEN ENGINE, 1705.

Between 1765–74, John Smeaton devised a succession of improvements in the atmospheric engine, and carried it to its utmost perfection; in these days it was still named the fire engine. The force was exerted in but one direction, and could not exceed the atmospheric pressure, in fact, was even short of this, for the vacuum was far from being complete.

The improvements of the engine on scientific principles commenced with the days of Watt.

Early History of the Steam Engine.

Fig. 1 is a very rare imprint of the immortal designer and inventer of the modern steam engine and its invaluable adjunct, the Indicator. Fig. 4 represents Watt's Condensing Engine.

James Watt was born at Greenock, Scotland, January 19th, 1736. His grandfather, Thomas Watt, was a school-

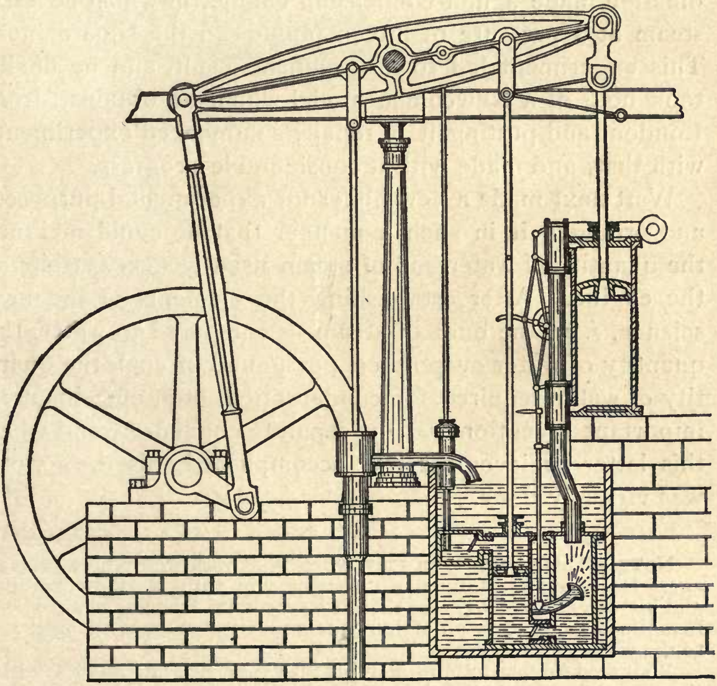

Fig. 4. Watt's Condensing Engine, A. D. 1784.

master, and his father a prominent citizen of Greenock, being a merchant and builder. At the age of eighteen, James went to Glasgow to learn the trade of a mathematical instrument maker, and opened a small shop, by which he earned a scanty living. The introduction of the New-

EARLY HISTORY OF THE STEAM ENGINE.

comen engine into the neighborhood, led him to study the history of the steam engine, and to conduct for himself researches into the properties of steam.

In his experiments he used, at first, apothecaries' phials, and hollow canes for steam reservoirs and pipes, and later a Papin's digester and a common syringe. The latter combination made a non-condensing engine, in which he used steam at a pressure of fifteen pounds to the square inch. This experiment led to no practical result, and he finally took hold of a Newcomen model which he obtained from London, and putting it in repair, commenced experiments with that, and made with it considerable progress.

Watt next made a new boiler for experimental purposes, and arranged it in such a manner that he could measure the quantity of water and of steam used at every stroke of the engine. After establishing the elements of the new science, *i. e.*, the bulk of steam as compared to water, the quantity of water evaporated per pound of coal, the quantity of water required for condensation, etc., etc., his next important invention was the separate condenser, and when this latter achievement was accomplished, his life's work was virtually done.

NOTE.—This was early in 1765, when Watt was twenty-nine years of age. He soon after formed a co-partnership with Matthew Boulton, and his career thereafter was that of a successful business man, whose inventions were nearly all of immediate practical value to the firm and to the world.

Watt died August 19th, 1819, in his 84th year, rich and more honored than many kings. His statue stands in Westminster Abbey, London, amidst those of the noblest of Englishmen, who by their heroic deeds, have become the glory of their country.

NOTE.—By the year 1784, Messrs. Boulton & Watt had brought their engine to a position where it combined all the devices which Watt had either improved from old models or clearly invented himself. There were a pair of their engines erected in London, in this year of sufficient power to drive twenty pairs of millstones. In these engines were to be found the newly applied fly-wheel, the glass water-gauge, the mercury steam gauges, "fly ball" governor, the poppet valve with beveled seat, the cross head and guides, and many minor improvements covered by Watt's numerous patents.

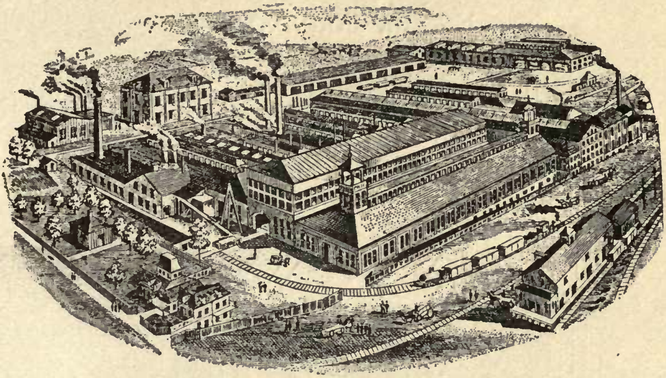

Fig. 5.

ENGINE FOUNDATIONS.

It is essential that a steam engine be placed upon a solid, unyielding foundation. It is unwise to pay for a good machine and then set it upon a foundation that will yield to the weight and working strains in such a way as to throw the parts out of line, bringing about injurious wear and derangement.

Large cut stones make the most solid foundation, but these are costly; hard-burned brick make an excellent substitute. These should be laid in cement, with thin joints. No stones are required except the cope-stone, which should be cemented to the brick-work.

The drawings furnished by engine builders will give the necessary width and depth of foundation, assuming that the bottom rests on solid ground. If this is not reached at the depth indicated, the excavation should be deeper, the bottom rammed hard and filled up to the point at which the foundation proper is to begin with rough stones laid in cement.

NOTE.—Concrete made mixing five parts broken stone, two parts clean sharp sand and one part Portland cement makes a very satisfactory foundation.

ENGINE FOUNDATIONS.

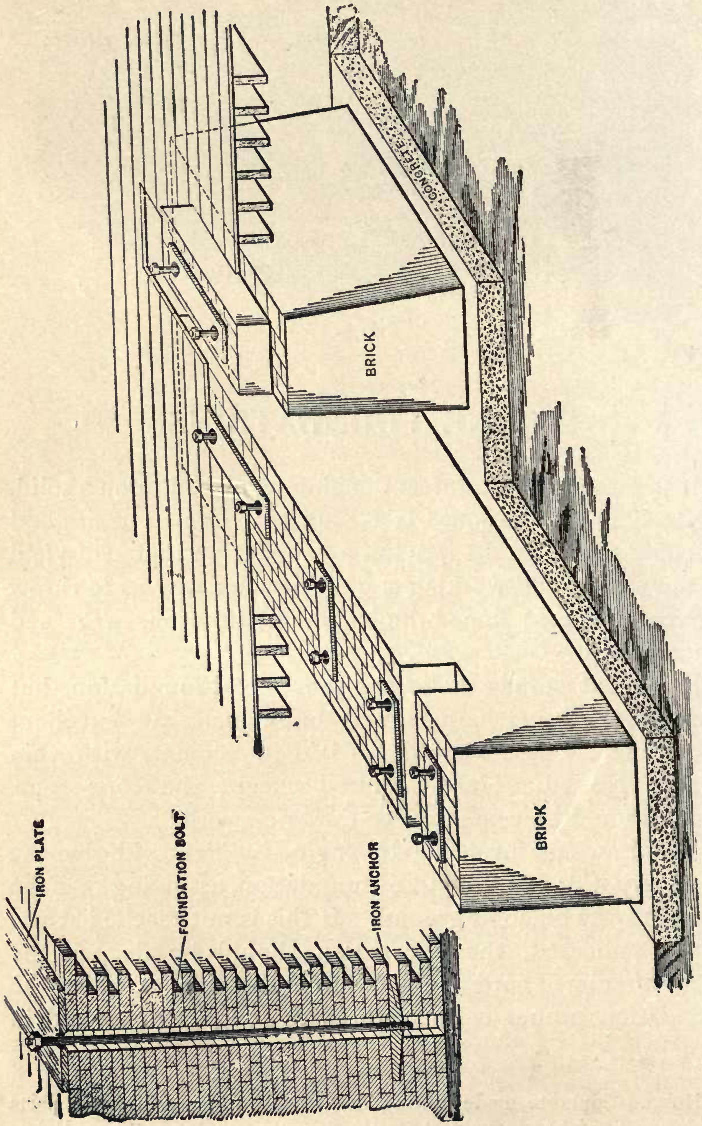

Fig. 6. ENGINE FOUNDATION.

ENGINE FOUNDATIONS.

The foundation should be completed at least fifteen days before the engine is placed on it, by which time, if properly laid, the brick-work will be practically one mass.

The accompanying illustrations show three different shapes of foundations.

Fig. 6 is the form used for girder frame engines, as the Corliss engine generally is built.

A layer of concrete is first spread over the bottom of the excavation, on top of which the brick-work is laid. The fastening of the anchor bolts is shown in Fig. 6, consisting of a heavy cast-iron plate, laid in the brick-work, and drilled and threaded for the bolt; the top is formed of cast-iron plates, on which the pedestals rest.

The bottom plates need not be threaded, but simply drilled, to allow the bolt to pass through, and by allowing an opening to be left in the brick-work underneath the plates, a nut may be screwed to the end of the bolt. Cope stones can take the place of the top plates in either case.

Fig. 7 shows a form of foundation which differs from the first described by a brace being run across, combining the outboard pillow block part with the main body of the foundation, and the bolts being masoned into the brick-work, the foot ends passing through a broad washer.

This foundation is generally used for tangeye bed engines, which usually run at medium speed. The foundation used for high speed self-contained engines is shown in Fig. 8; it simply consists of a solid body of brick-work.

It is very often the case that a timber foundation is found to be the best, or indeed, the only practicable foundation for an engine or for a heavy machine. The number of

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NOTE.—Foundation bolts should be held in position by a wooden template with bolt holes corresponding to those in the engine base. It is better not to build the foundation solidly around the bolts, except at the extreme bottom. Space should be left around each bolt, increasing toward the top, so that at its upper end the bolt has a play of one or two inches.

ENGINE FOUNDATIONS.

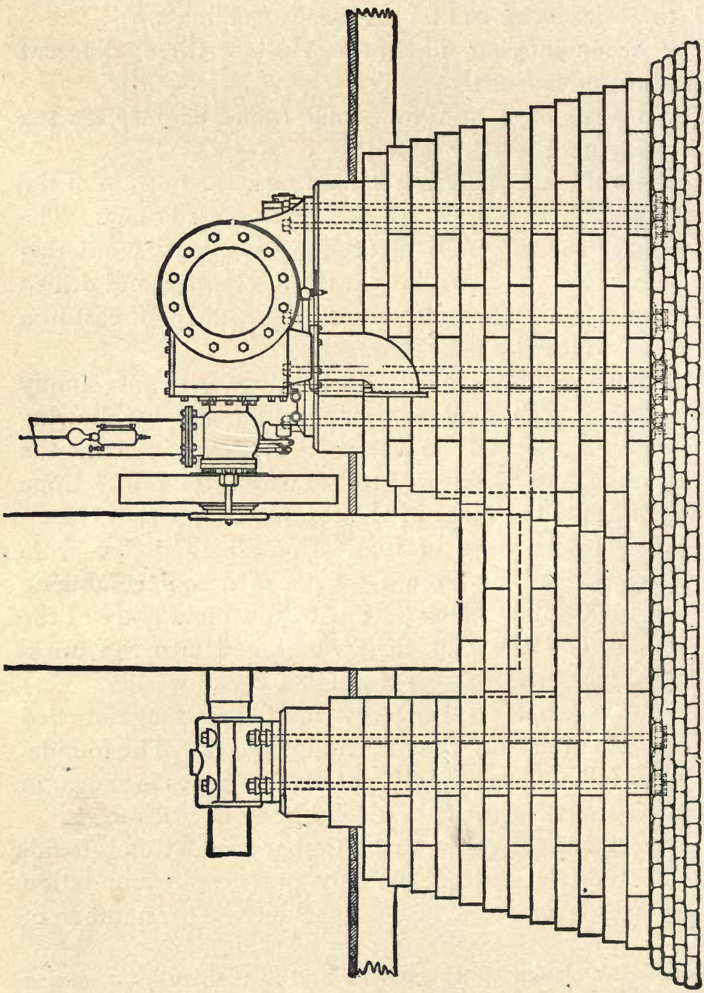

Fig. 7. ENGINE FOUNDATION—End View.

semi-portable steam engines used to run dynamos during engineering work of more or less duration, makes it desirable to have a method of holding the machine down, which will permit of "pulling up stakes" on short notice and settling again promptly at a greater or less distance. In such cases, heavy beams may be used for bed timbers, and to these the engine held down by bolts, or, indeed, by long lag screws; in all cases the thread and bearing surfaces of heads, washers, etc., being smeared with grease and graphite (black lead) before running up. The lengthwise timbers to which the engine is bolted may very easily be secured to heavy cross timbers (to give both weight and lateral rigidity) by dovetail wedges of yellow pine, as shown in Figs. 9a and 9b. In Fig. 9a only one edge of the lengthwise balk is dovetailed, and the wedges along the other side have one flat bearing side.

In Fig. 9b both sides of the lengthwise timbers are dovetailed, and the wedges are cut to correspond. Where the wedges have one vertical face in contact with the lengthwise beam, as in Fig. 9a, they should have more vertical bearing surface, as there indicated.

Such a frame may be locked together in short order, and dismantled quickly and without injury to the timbers. When in service it may be weighted down by rocks or odd castings, or similarly wedged to lengthwise timbers parallel to those on which the engine rests.

Timber foundations may also be fastened together by dogs of this outline ⊓; and this mode is not so bad where round logs are used for the heavy cross-pieces; but when dogs are used care should be taken that they always run obliquely across the intersection of two timbers and never parallel with either of those which they join. This applies the "diagonal brace' principle. If this is neglected the structure, if the under timbers are round and lie crosswise of the cylinder-bore, will very promptly work itself to

ENGINE FOUNDATIONS.

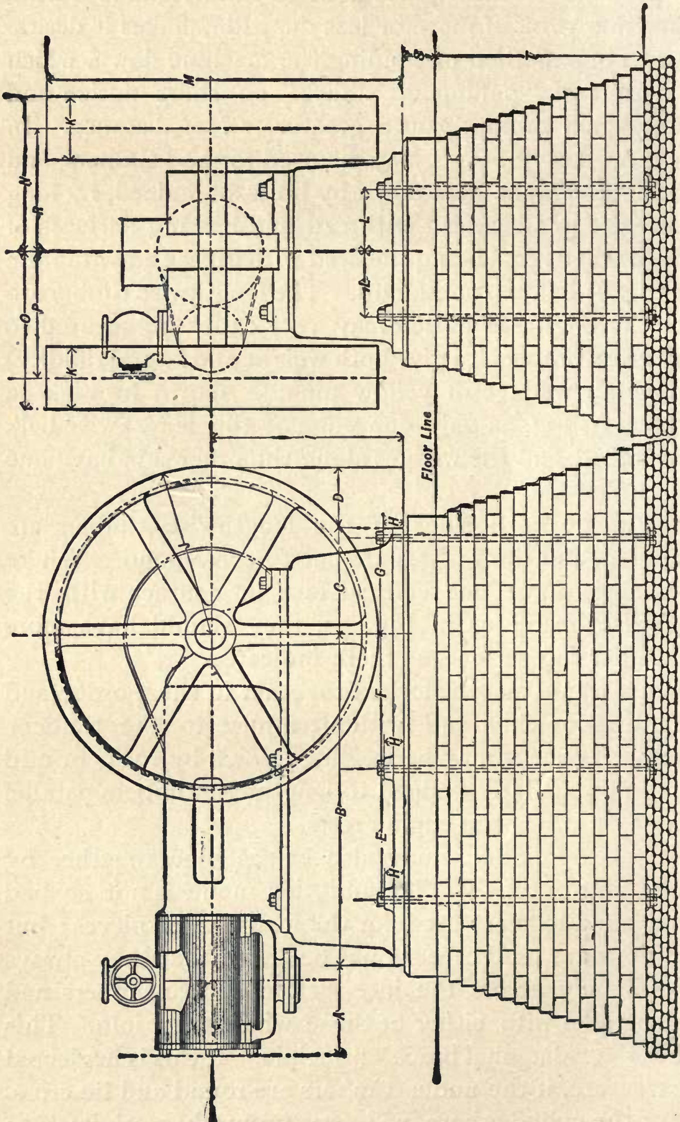

Fig. 8. FOUNDATION FOR HIGH SPEED SELF-CONTAINED ENGINES.

ENGINE FOUNDATIONS.

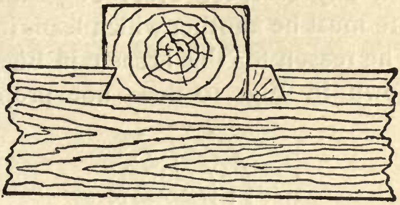

Fig. 9a.

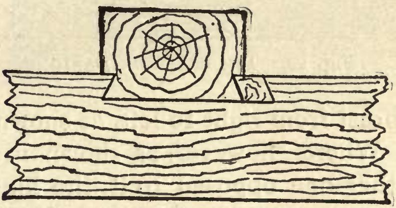

Fig. 9b.

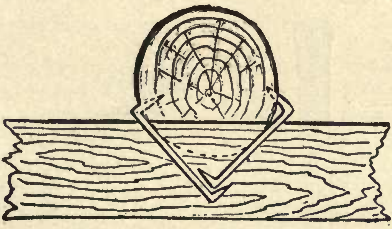

Fig. 9c.

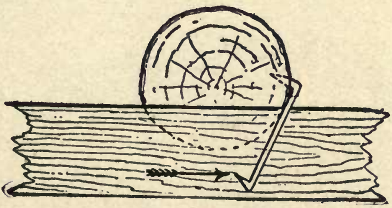

Fig. 9d.

TIMBER FOUNDATIONS.

ENGINE FOUNDATIONS.

pieces; and in any case, for every dog that leans in one direction there must be another which leans in the opposite direction. The reason for this is seen in Figs. 9d and 10. The dog shown in Fig. 10 does not properly resist a

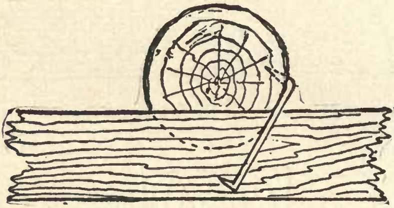

Fig. 10. TIMBER FOUNDATIONS.

lengthwise thrust from right to left, as shown by the arrow in Fig. 9d. Where, however, as shown in Fig. 9c, each dog has another one opposed to it, the hinge business is effectually done away with. Dogs are only desirable where round timbers are used, as these afford less wedging surface than square ones.

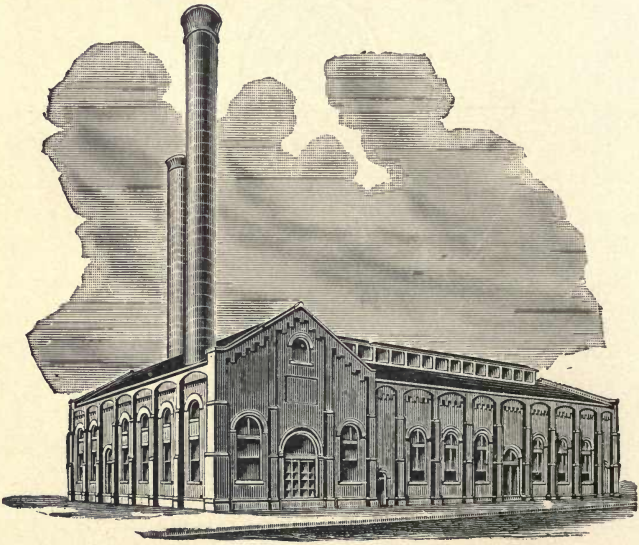

Fig. 11. MODEL POWER STATION.

PARTS OF THE STEAM ENGINE.

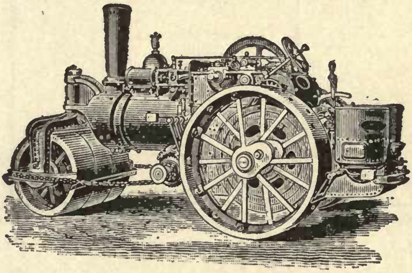

Fig. 12. STEAM ROLLER.

Ques. What is the most important part of a steam engine?

ANS. The cylinder, because within its compass is accomplished the change of energy of the fuel into the work the engine is designed to perform.

Ques. Why is the cylinder the most approved form for its office of transforming the energy of combustion into work?

ANS. Because, 1st, the circular form is the strongest; 2d, it is easier to make and repair; and 3d, it is best adapted to fit the round form of the piston.

Ques. Name some of the parts and uses of the steam cylinder?

ANS. Cylinder heads, with the studs or bolts to hold it to the flange, also the bolts to hold it to the frame; cylinder jackets, to prevent condensation. Fig. 13 and Fig. 14 show in outline the parts and names of the steam cylinder and the valve chest and valve.

NOTE.—In the elementary form of the steam engine the cylinder served the triple purpose of boiler, engine and condenser. In after history the boiler and condenser were made into separate parts to form and condense the steam while the cylinder is used for its true office—the convertion of the energy in the steam into mechanical power.

STEAM CYLINDER AND VALVE.

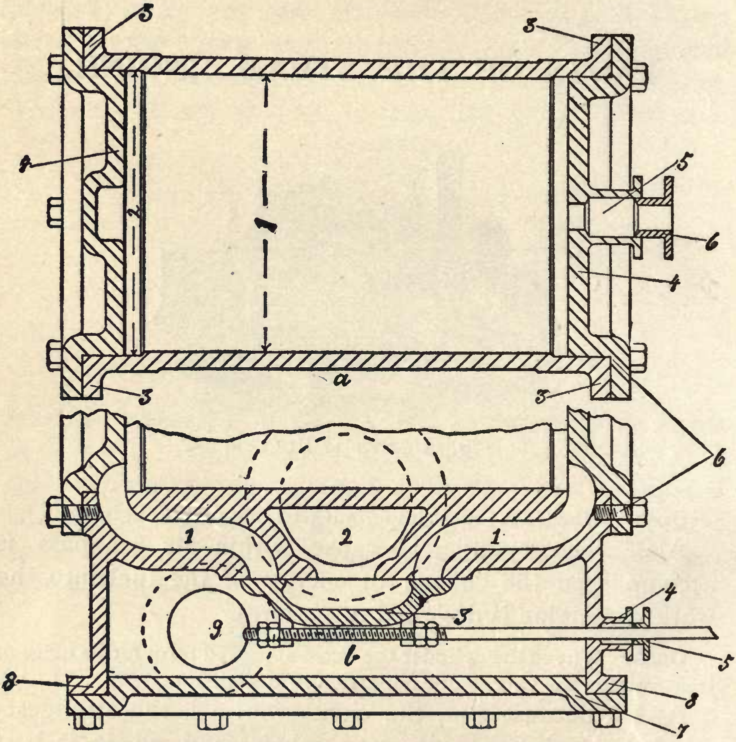

Fig. 13 and Fig. 14. STEAM CYLINDER AND VALVE.
See "a." See "b."

Parts of the cylinder, see Fig. 13, "*a*": 1, bore of cylinder; 2, counter bore; 3, flanges; 4, cylinder heads: 5, stuffiing box; 6, gland.

Parts of the valve chest, see Fig. 14, "*b*": 1, steam ports; 2, exhaust ports; 3, slide valve; 4, valve stem stuffing box; 5, valve stem gland; 6, cylinder head stud bolts; 7, valve chest cover; 8, valve chest flanges; 9, steam inlet.

NOTE.—In spite of all improvements, the cylinder acts in nearly all engines as a steam generator and condenser—at certain parts of the stroke of the piston the steam condenses and at other parts it re-evaporates.

THE STEAM PISTON.

This is a circular disc fitted to the bore of the cylinder and which receives and transmits the pressure of the steam to the other moving parts of the engine. Fig. 15 exhibits an approved form of the steam piston with the piston head or "follower plate" removed so as to show the interior construction.

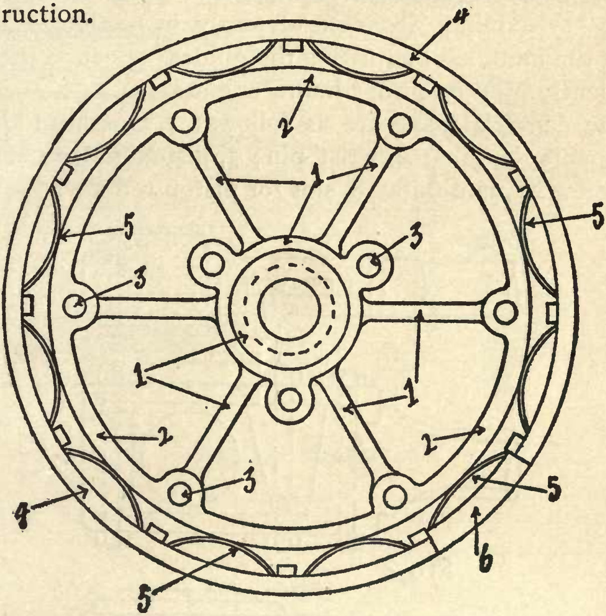

Fig. 15. THE STEAM PISTON.

Parts of the steam piston are shown and may be defined thus: 1, piston web; 2, bull ring; 3, follower bolt holes; 4, packing ring; 5, packing springs; and 6, steam-tight joints.

The forms of pistons are innumerable according to the varying size of the cylinders they are designed to fit, but there are two things necessary for all; they should be steam tight and yet so adapted to the bore of the cylinder that they move with the least possible friction. Besides, they should be strong enough to meet the unequal strains of the pushing of the steam and to **hold the end of the piston rod immovable.**

THE CROSSHEAD.

This is the device which forms the connection between the piston rod and the connecting rod; it is similar to the joints of the human body; it guides the piston rod so as to keep it straight, in spite of the bending motion caused by the angularity of the connecting rod.

Fig. 17 exhibits a crosshead partly in section so as to show the method of adjusting the guides. Such as this are frequently used on girder frame engines.

The names of parts are as follows: 1, crosshead body; 2, slippers; 3, gibs; 4, wrist pin; 5, piston rod socket; 6, set screw; 7, jam nuts; 8, slot for piston rod key.

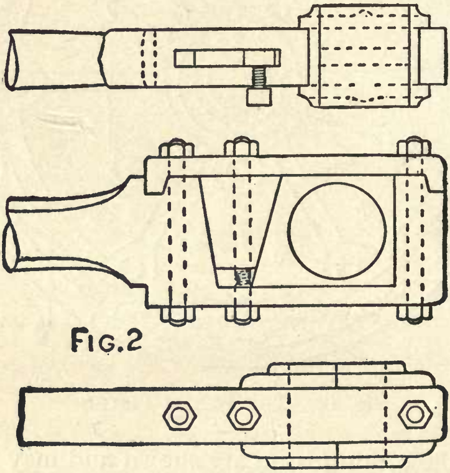

Fig. 16. Connecting Rod Ends.

THE CONNECTING RODS.

A crank is a lever or bar movable about a centre at one end. This, in the steam engine, allows the conversion of reciprocating or sliding motion into circular motion. The connecting rod is the device used between the crank and the crosshead. Fig. 16 shows three forms of connecting rod ends.

THE CONNECTING ROD.

Fig. 18 shows the details of the two ends of a connecting rod, the names and numbers are as follows: 1, crank pin key; 2, crank pin gib; 3, crank strap; 4, crank brasses; 5, connecting rod and crank pin; 6, wrist pin brasses; 7, wrist pin gib; 8, wrist pin strap; 9, set screws; 10, crosshead end of connecting rod.

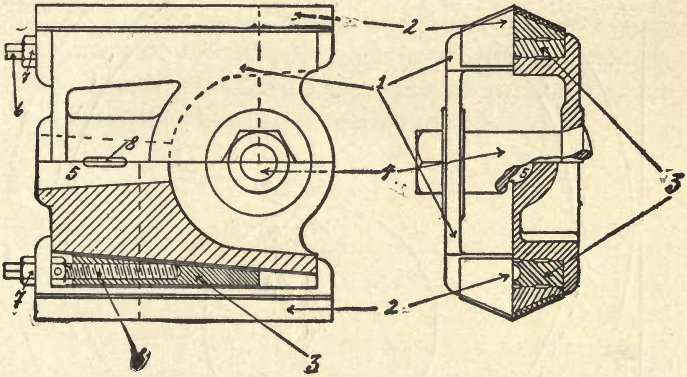

Fig. 17. CROSSHEAD.

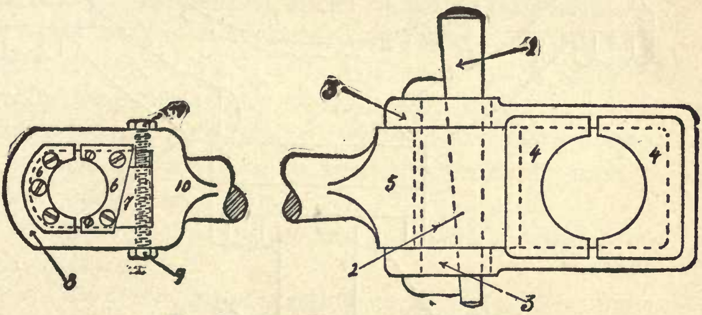

Fig. 18. CONNECTING ROD ENDS.

It may be remarked that the centre of the crank pin end of the connecting rod moves in a true circle, while the centre of the opposite end has the reciprocating—back and forth—rectilinear motion.

THE ECCENTRIC.

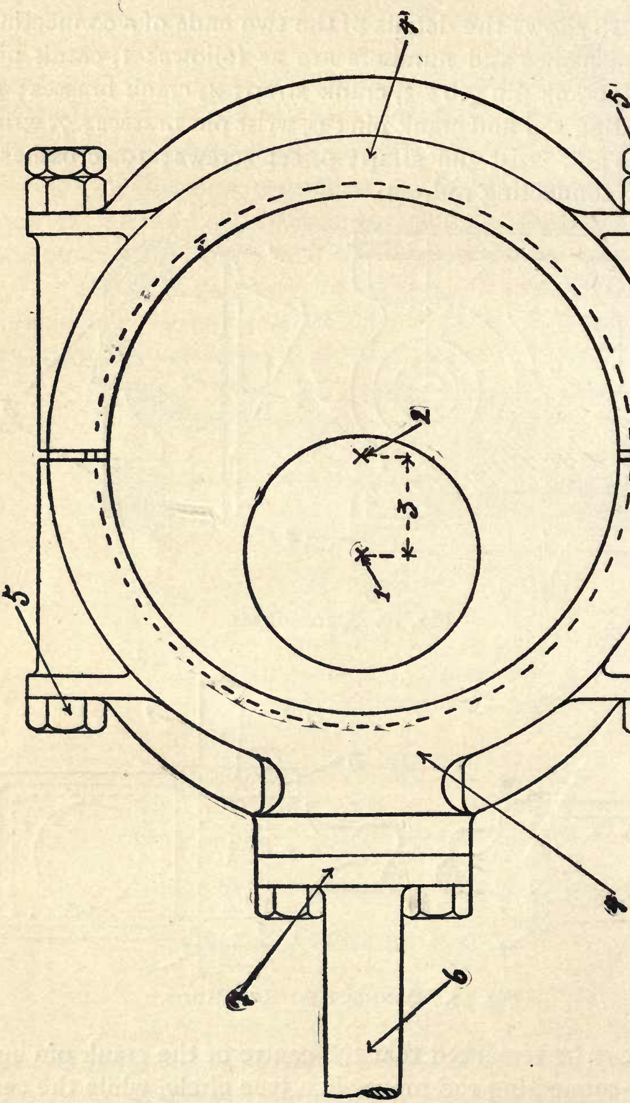

Fig. 19. THE ECCENTRIC.

THE ECCENTRIC.

The eccentric is a species of a crank; its peculiarity being that the "crank pin" is increased to such a size that it exceeds the diameter of the shaft. The distance between the centre of the crank pin and the centre of the shaft being "the radius of eccentricity" which is the distance between the centre of the disc and the centre of the shaft, see Fig. 19, "1" and "2."

Fig. 19 is a drawing in outline of an eccentric, the parts of which may be described: 1, shaft centre; 2, eccentric centre; 3, radius of eccentric; 4, eccentric strap; 5, set bolts; 6, eccentric rod; 7, eccentric rod foot.

THE GOVERNOR.

The governor is the ruling spirit of an engine. The use of a governor of any kind is to supply more or less energy to the engine as needed. Where the changes of load are liable to be very great, or where absolute uniformity of speed of rotation is not essential, the regulation is frequently performed by hand, as in the case of locomotives, hoisting engines, etc. Where the speed remains constant, however, as in the case of factory engines, etc., the prime mover is always equipped with a governor which will automatically vary the supply of water, gas or steam, as the case may be, in proportion to the demands made upon it and in such a manner as to keep the speed of rotation constant, under varying loads.

In steam engines there are two methods of varying the supply of energy.

First.—By varying the pressure under which it is admitted to the cylinder.

Secondly.—By varying the point of the stroke at which it is cut off and allowed to expand.

NOTE.—The "throw" of the eccentric is equal to twice the eccentricity.

THE GOVERNOR.

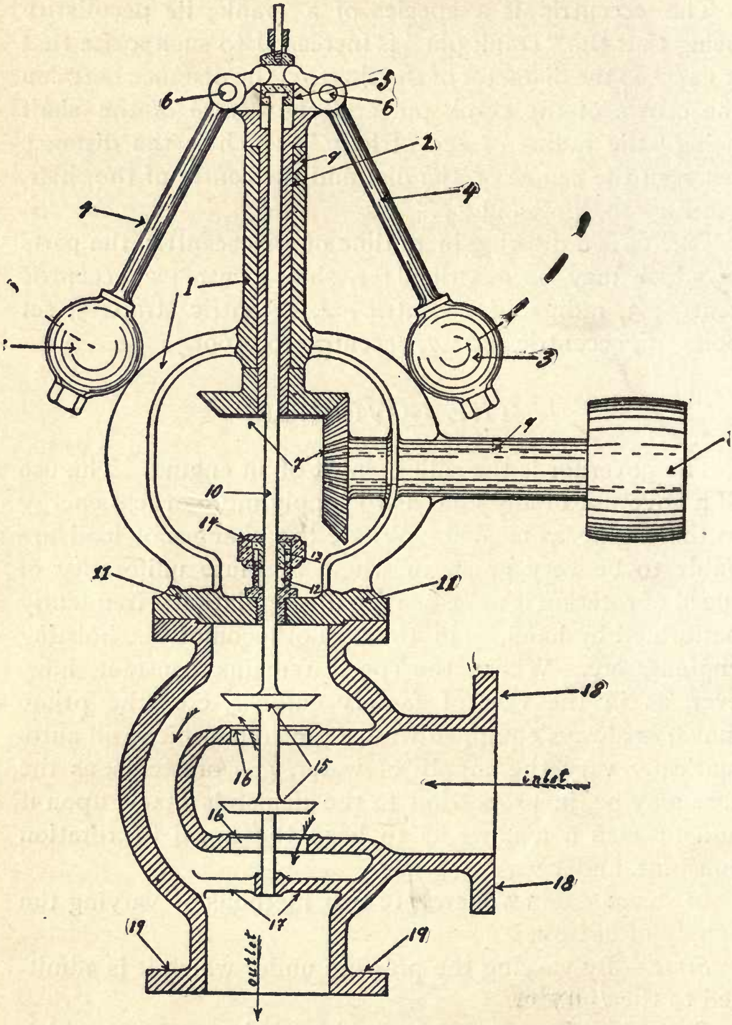

Fig. 20. THE GOVERNOR.

NOTE.—A shaft governor regulates the speed of the engine by changing the cut-off for ordinary variations of load. An inertia governor is also a shaft governor, but uses the inertia stored in the wheel itself or another moving weight, to overcome very sudden changes on the load.

THE GOVERNOR.

The first of these is the older and by far the simpler of the two methods. The governor which acts according to this method, or throttling governor, a simple and modern form of which is shown in Fig. 20, is too well known to require an extended description.

Referring to Fig. 20, the names of the parts of this important adjunct of the steam engine are as follows: 1, standard; 2, governor shaft; 3, governor balls; 4, arms; 5, stem swivel; 6, pivots; 7, gears; 8, pulley; 9, oil holes; 10, stem; 11, bonnet; 12, stuffing box; 13, gland; 14, gland box; 15, valve discs; 16, valve seats; 17, stem guard; 18, throttle valve flange; 19, valve chest flange.

The device shown in the figure is the well known "ball" or throttling governor. This operates upon the princple in physical science explained under the heading of "centrifugal force"; also under heading "elementary mechanics" in technical literature, thus:

A body in motion tends to move in a straight line.

A body when moving cannot stop itself or change its motion, and unless acted on by some other body will go on in the same direction and at the same speed forever.

Inertia is that property of matter by which it is of itself incapable of changing its state whether in motion or at rest. It takes some time, however, to put a body in motion or change its direction.

The governing forces of the ball (fly-ball) governor consist of centrifugal force opposed by gravity. Familiar modifications of this construction are provided with springs as a substitute for gravity. Shaft governors or shifting eccentric governors, represent another type where springs are used to oppose centrifugal force.

Very much more upon this subject will be found in other parts of the work given in connection with description of particular engines and also under the heading of "Care and Management of the Steam Engine."

PIPING OF THE STEAM ENGINE.

The two principal pipes of the ordinary engine are: first, the main steam pipe which leads from the boiler to the engine; and second, the exhaust pipe—that which wastes the steam into the atmosphere after it has done its work.

There are also cylinder drain pipes to carry off the water formed by the condensation of the steam.

Points, relating to Piping an Engine.

1. Run steam and exhaust pipes as straight as possible. If they must be over fifty feet long use one size larger pipe.
2. It should be of such ample size as to cause as little friction as possible.
3. It should be well covered to prevent condensation.
4. The corners should be well rounded and be as free as possible from flanges and valves.
5. The exhaust pipe should be of ample size.
6. The exhaust pipe should also be covered with non-conducting material where the exhaust steam is to be used for heating purposes, at least to the point where it is drawn into the heating system.
7. Support steam and exhaust pipes on suitable hangers.
8. Blow the main steam pipe out thoroughly with steam before making connection to throttle, in order to clear it of any dirt or pieces of scale which might otherwise have to work out through the engine.

The use of an exhaust pipe head is obvious: 1, this device deadens the noise on high speed engines; 2, it preserves the roofs from the disagreeable effects of oil-impregnated water falling upon it.

NOTE.—It will be understood that in the marine type or condensing engine, the exhaust pipe leads to the condenser, where the steam is re-converted to water, hence there is no regular exhaust into the air in low pressure engines.

MATERIALS AND WORKMANSHIP OF THE STEAM ENGINE.

The quality of the materials entering into the construction of a steam engine is an important matter. The principal factor in the construction of a steam engine is the cast iron. It is not alone sufficient that castings should be smooth and sound; it must be known that the important qualities of strength and duration are not lacking. A strong, hard mixture is best for cylinders, pistons, rings, valves, etc., while a softer mixture is more suitable for other parts which are not subject to wear.

The crank shaft, connecting rod, piston rod, crank pin and wrist pin are commonly forged from steel, the quality of which should be assured by a reputable maker and of a specified chemical analysis.

A good hard brass should be used for lining wearing surfaces, such as crank pin boxes, wrist pin boxes, etc.

The crank shaft bearings are generally lined with babbitt metal, made after an approved formula.

Some makers prefer to use a good quality of iron in place of steel for the larger parts of the engine, such as crank shaft.

In the best shops cylinders are carefully tested for straightness and roundness by measuring with micrometer gauges reading to the one-thousandth part of an inch, eight diameters in each cylinder, four parallel to the shaft and four at right angles to it. Bushings for steam chests are turned six one-thousandths of an inch larger than the bore of the steam chest castings, which is the allowance we make for the forcing fit.

CARE AND MANAGEMENT OF THE STEAM ENGINE.

In "keying up" an engine, the engineer should know where his keys are before attempting to adjust them—to know this, the keys should be marked before they are moved; this is best done with a lead pencil, for if it is found that the key has been driven too far it can be easily put back to its former position and when the machine is running in a satisfactory way, the marks can easily be removed.

It is also better to key up an engine in the morning rather than at night; if it is done at night, the engineer does not know "what a night may bring forth" nor that he will be in his place in the morning.

For all joints that have to be broken and remade frequently the ground joint is the best.

By its use one does not have to bring everything to a standstill while a gasket is being hunted up or being cut, all the while the delay costing money. The occasions for doing this should be as few as possible.

In putting rubber packed joints together use either graphite or chalk to prevent the rubber adhering to the iron when the joint has to be remade.

In packing a stuffing box it is of the first importance that the piston rod should be in line and be smooth; if the rod is scored, or rusty, it should be smoothened with emery cloth, otherwise it will act upon the packing in the same manner as a file.

Measure the packing around the rod, and cut it to exact lengths. A very good device for cutting packing, is a piece of hard wood, turned to the exact diameter of the rod.

NOTE.—Many engineers measure the packing rings to length and then cut it, but this is not the best way, for the ends, after the packing is bent around the rod, will not come together flush. It is good practice to put a little graphite in the stuffing box, when packing, as this will lengthen the life of the packing and decrease the friction.

CARE AND MANAGEMENT.

By winding a ring of packing around this, it can be cut off to fit the rod to perfection; always break joints by putting them opposite each other, in adjoining rings; never set up too tight, for if a stuffing box is perfectly packed, it will hold tight with but little tension on the gland, and if packing is jammed too tight, much power is lost in friction.

If the speed of the engine is changed, care should be taken to adjust the springs so that the sound, when they are tapped with a hammer is as near alike as possible. Different sounds indicate an unequal tension, and the result of unequal strain may be "racing" of the engine.

Care should be taken that the dash pot is always full of machine oil, or oil of a heavier grade, or else glycerine, as the dash pot is designed to give stability to the governor when load is changed, and its movement must not be too quick. The dash pot will be next to useless if the filling part is neglected.

When the piston rings do not properly fit the cylinder bore or are faulty in the joints loss is caused by allowing steam to blow from the admission end past the piston into the opposite end, which is open for the exhaust.

A good way to ascertain if the piston is leaky is to put the engine on the dead center on the crank end. Then take off the cylinder cover on the head end and admit steam back of the piston. If it leaks the leak can readily be seen.

Another method is to place the engine on the center—no matter which one—and if the cylinder is piped for indicator, open cock from opposite end from which steam is

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NOTE.—Many engines are so constructed that the space around the piston rod gland is quite small, and so we would suggest that a short solid wrench be made for use in such cases, and always be kept in a convenient place. As it is seldom or never necessary to use much leverage here, a large one will not be needed and it will be much more convenient than to try to use an ordinary monkey wrench.

CARE AND MANAGEMENT.

admitted. While this method would give gooa results if the valve was tight, it would not give the desired result if the valve was leaky.

Packing rings that are found to be too small for the cylinder bore should be set out either by tightening the setting-out bolts or by peneing, the best method obviously being determined by the circumstances. To spread a ring by peneing its inside circumference should receive a succession of blows from the ball, or pene, of the hammer, around its entire length, and care should be taken that the blows should be struck as nearly as possible in the center of the ring and at equal distances apart, otherwise the ring is apt to assume more or less of a spiral form.

To secure smooth running in an engine the packing rings should clear the bore of the cylinder a little at each end of the travel. Many engines are designed so that the rings travel over the bore about 1-32 inch.

Graphite has proven to be a very good lubricant for engine cylinders and valves, and if a cylinder or valve is badly scored, it will lodge in the pits and scratches of the rough surface, and restore it to its original smoothness, saving steam.

The graphite may be fed into the cylinder by means of an ordinary tallow cup, but it is best to use a specially made cup for this lubricant, as shown in Fig. 21.

This device, as well as several oilers and lubricators illustrated in this book, is manufactured by the Lunkenheimer Brass Co., Cincinnati, O.

As the cup is made for the purpose of feeding graphite into the cylinder, there is no chance for it to lodge in a

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NOTE.—It is well to make periodical inspection of cylinder to ascertain whether the piston has lost its proper alignment by wear or other cause, if the cylinder has been cut, if the follower bolts are secure and free from fracture, if shoulders have been formed at ends of bore from improper lining of connecting rod, whether cylinder oil is causing deterioration by acid which it may contain, etc.

CARE AND MANAGEMENT.

Fig. 21.

recess and clog up the feed · it also is a sight-feed lubricator, as will be noticed in the cut.

Fig. 22 shows a way of attaching these cups to Corliss engines. They may also be attached to the steam pipe, but always below the throttle valve, as the graphite may interfere with the tight closing of the valve.

When using graphite, an oil lubricator should also be used, but the quantity of oil can be reduced considerably.

When taking measurements to set piston in center of cylinder don't take them from the bore, but always from the counterbore. The reason for this is that while the bore may be badly worn,

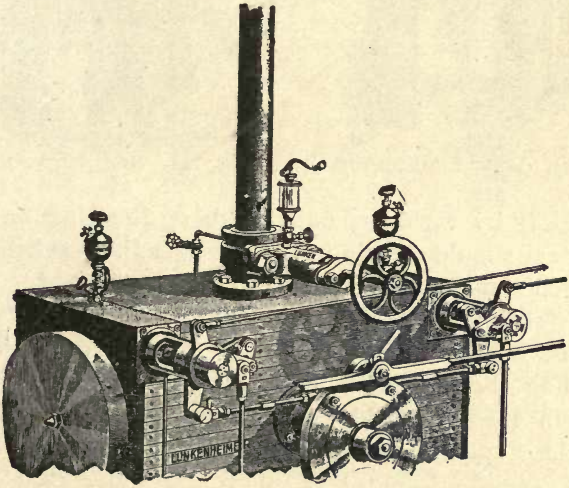

Fig. 22. GRAPHITE CUP ATTACHED TO CORLISS ENGINE CYLINDER.

NOTE.—*Description of parts of* Fig. 21

A—Graphite regulating valve. B—Steam valve. C—Filling plug. E—Nut for taking cup apart. X—Drain plug.

Care and Management.

either vertically or horizontally, the counterbore receives no wear and retains the original alignment.

When an engine has been erected or overhauled for repairs, and before the pistons are put into the cylinders, it should be "blown through." The throttle valve being opened, the steam allowed to blow through steam chest and ports into the cylinder, the valve gear being moved by hand so that the steam will blow through the parts alter-

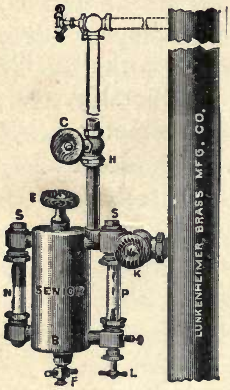

Fig. 23. Drop Lubricator.

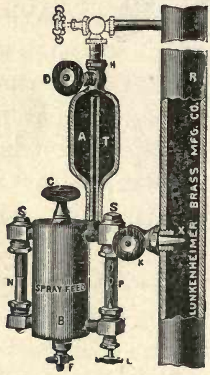

Fig. 24. Spray Lubricator.

nately. If by accident, nuts, washers, iron dust or other substances should remain in the passages they will then be dislodged and a serious menace to safety removed.

The "striking points" should be located, also the "counterbores." The following is a simple, yet effective method of finding these points. After the piston rod has been keyed in the crosshead, move it towards the crank end until the "spider" brings up solidly against the cylinder

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NOTE.—*Description of* Fig. 24.

A—Condensing chamber. B—Oil reservoir. C—Filling plug. D—Upper steam valve. F—Drain valve. K—Lower steam valve. L—Valve fo regulating flow of oil. N—Indicator glass. P—Sight-feed glass. R—Steam pipe. SS—Plugs for cleansing and replacing glass. T—Circulating tube. X—Spray nozzle.

CARE AND MANAGEMENT.

nead. This is the striking point for this end. It should be located on the guide by a center punch mark at the crank end of crosshead. Move the crosshead toward the head end of cylinder until the turned edge of spider against which the ring will bear comes flush with the counterbore. Mark this point also on the guide at same end as before. Next move crosshead along and put in packing ring and riding ring. After these are in position move piston ahead until the ring on head end is flush with the counterbore. Locate this point also on the guide.

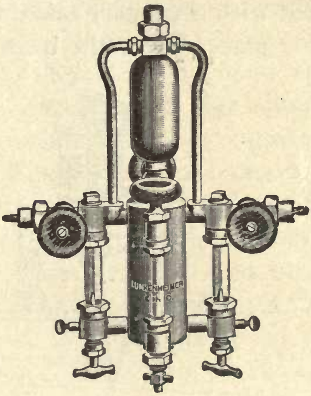


Fig. 25. DOUBLE SIGHT LUBRICATOR FOR COMPOUND ENGINES.

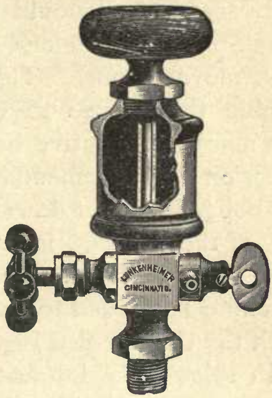


Fig. 26. AUTOMATIC LUBRICATOR.

Put cylinder cover on head and move piston ahead until it strikes. This is the striking point for head end—locate on guide same as before. This makes the job complete and when the connecting rod is put up it can be lined by these marks on guides.

The piston should be moved through cylinder a few times to see if everything works freely.

NOTE.—*Description of* Fig. 23.
B—Oil reservoir. C—Upper valve. E—Filling plug. F—Drain valve. H—Union to connect condenser pipe and valve. K—Discharge valve. L—Valve for regulating flow of oil. N—Indicator glass. P—Sight-feed glass. Valve to drain or blow out sight-feed glass P.

Care and Management.

Follower bolts lose much of their original strength by reason of crystallization caused by alternate cooling and heating. A comparatively small strain will sometimes fracture a bolt that has been in use some years. Many engineers make a practice of renewing these bolts at certain intervals of time, and the practice is highly commendable. When the follower has been taken off for some reason and when the bolts are replaced, it is the best method to bring them up to a bearing before putting a strain on them with a wrench.

Every engine should be fitted with stationary oilers for crank-pin, wrist-pin and all other places where the bearing is a movable one. This will enable the engine to be run for many consecutive hours, if occasion should demand it. To be obliged to shut down to oil any of these places, is to show that whoever is in charge of the machine has failed to keep up with the times. See Fig. 27.

In selecting a lubricator for a steam engine it is well to get one that is so constructed that when it must be filled, the cylinder oil will go directly into the cup, without having to go through a long crooked passage, for many good oils are thick and it is not always convenient to warm an oil before using it.

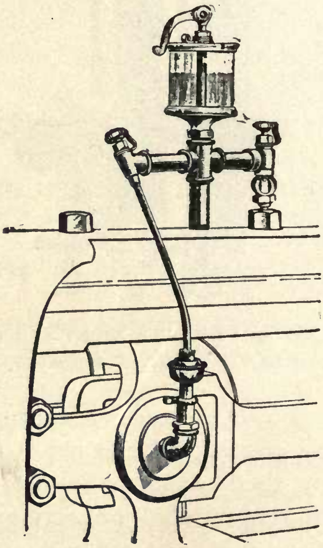


Fig. 27. Stationary Oiling Device for Cross-head and Slide.

DUTIES ON FIRST TAKING CHARGE OF A STEAM PLANT.

After examining the boilers and pipes the new man should carefully inspect the engines and fittings, as a whole, before making any attempt to "start up"; he should be as cautious and deliberate about this as a soldier in the enemy's country, for reasons which it were better not to enlarge upon.

After a general overlooking, the second thing should be a minute inspection of each individual part, of all cocks, of the oil cups, set screws, keys, joints, etc. This examination should be by hand and eye assisted by previous experience, for no man should "take charge" without previous knowledge of engineering.

Next, "turn the engine over," slowly by hand—some assistance may be needed here, if there are no mechanical means for turning it over. If all is right the engine may be "warmed up" and turned over very slowly by steam, making six or seven revolutions as slowly as possible, and if all is right, the speed can be very gradually increased. Now, if the engine should race, it is better to shut down and examine the governor, for it may stick; this can be caused by a bent valve stem, or other parts being worn, so there are shoulders interfering with the motion, it also can be caused by the gumming of impure oil, which should be removed with benzine.

If the engine is pounding, search for the cause of the trouble, but do not attempt too soon to remedy it, and after stopping set up the keys a little, but do not try to do

NOTE.

1. Are the keys set up too tight which may overheat a bearing?
2. Are the old liners on the crank and cross-head brasses in such condition as to make safe the length of the rods?
3. Is the governor sensitively active?
4. Is the fly-wheel keyed on properly?

it all at once, but give the engine a chance to wear into her new bearings and at the next stop take up a little more of the "lost motion."

If the crank and wrist pin boxes are loose, do not attempt to remedy it all by setting up on the keys, but put in a liner of suitable size, to keep the clearance nearly equal on both ends of the cylinder. The next thing relates to the economy of daily operation and here the engineer, with the indicator and the necessary brains to use it is far ahead.

After the engineer has passed his first day in a new steam plant, his greatest trouble is passed, and although he needs not fear any more disaster from his predecessor's mistakes, he always should be extra careful in starting up.

QUESTIONS AND ANSWERS RELATING TO THE STEAM ENGINE.

Ques. How can you tell that an engine will not race dangerously should the main belt break, or the governor belt break?

ANS. On a Corliss engine are, besides the trip cams, safety cams, which, if they are properly adjusted, and the device, which prevents the governor from dropping to its lowest position is disengaged, (as it should be) when the engine is running, these will guard against racing when the governor belt breaks, by not allowing the hooks to take hold of the catch blocks, thus not opening the steam valves. If the main belt should break, the steam will be cut off earlier during the stroke, and thus regulate the speed.

On many shaft governors as well as throttling governors also safety devices are employed, to guard against racing

NOTE.—These are given as specimens of the "questions" once used by an Examining Board of Engineers to test the qualifications of applicants for a first class license. The answers are those given by a practical engineer.

QUESTIONS AND ANSWERS.

in case of accident to governor or belt. If the engine is condensing, air should be admitted to the condenser, to destroy the vacuum.

Ques. Give method of starting large compound condensing engine, jet condenser direct connected?

ANS. Heat the engine up by admitting steam to the cylinders, and driving the air out, also allow the steam to blow into the jet condenser, to drive the air out, then open your injection valve so a vacuum is formed in the condenser, and allow the engine to move around slowly for a few minutes before giving full speed.

The pumps of a direct connected condenser being driven by the main engine are started by starting the engine.

Ques. In keying up crank-pin and wrist-pin brasses, give two reasons for use of the "shim," and under which brass it is put, and why?

ANS. The length of the connecting rod is reduced by the constant keying up, and thus the piston would travel much nearer the front cylinder head, and in time may strike it.

Also the setting up by the key is limited, by its length and the amount of clearance given it in the strap. To remedy this "shims" or "liners" should be laid under the brass, which is next to the end of the rod. In some styles of connecting rods the distance between crank and wrist-pin centres is lengthened by keying up, and the shims should be laid under the brass, furthest from the rod, *i. e.*, between brass and strap.

Ques. Is it necessary in setting valves to block up governor? In what positions would you block it? Explain in detail what you would do, or what points to look out for when governor is so blocked?

ANS. By setting the valve of a throttling engine, it is not necessary to block up the governor. But with an automatic engine it is necessary, because the governor in this case controls the valve. The governor should be blocked in the position it stands, when the engine is running with its ordinary load, and the steam pressure commonly carried. When the governor is so blocked, the valve should be set so as to give an equal cut-off on both strokes.

Questions and Answers.

Ques. Give two reasons why "lead" is usually given a valve?

Ans. Lead is given a valve, to have full steam pressure upon the piston, at the beginning of the stroke, also to assist in getting the reciprocating parts to a dead standstill when the engine is passing the center. Thus relieving the crank pin of undue strain.

Ques. How do you set the valves of a common slide-valve engine?

Ans. First turn the engine on the center and set the eccentric at right angles to the crank. Second set the valve central of its travel by means of lengthening or shortening the valve stem, and then turn the eccentric around the shaft, (leading the crank if there is no rocker arm) till the valve has the necessary lead.

Ques. If the valve stem of steam valve of a Corliss engine should break, what could be done to prevent a shut-down?

Ans. Turn the valve with the broken stem so that it will cover the steam port, and if possible block it in position, disconnect the exhaust valve rod on the same side from the wrist plate and turn the valve so as to be constantly open. The engine will then run single-acting, only develop ½ its power, and will not run quite as steady.

Ques. How do you figure horse power of compound engine?

Ans. The most ready method to figure the horse power of a compound engine is by figuring each engine separate and adding their power together.

Ques. How and when is a cylinder most likely to be flooded from condenser?

Ans. If the condenser is a surface condenser, the cylinder can be flooded by leaky tubes in the condenser. By stopping the engine and air pump the condenser will fill with water and thus flood the cylinder. With a jet condenser it will happen by neglecting to close the injection valve.

Note.—*This man did not get his papers.* Ques. What is a horse power? Ans. The power of a horse. Ques. What is the power of a horse? Ans. His strength. Ques. What is his strength? Ans. How much he can pull. Ques. How much can he pull? Ans. It depends upon what kind of a horse it is. The examining engineer: Well, go away and find out what kind of a horse it is.

QUESTIONS AND ANSWERS.

Ques. Do you open injection valve before or after starting engine, and in stopping is it closed first or last? Why?

ANS. The injection valve should be opened after the engine is warmed up and the air driven out of the condenser, the engine should be started immediately after the valve is opened.

By shutting down, shut the throttle first, and after the engine has made one or two turns, close the injection valve, if there is an independent air pump, this should be stopped last.

In starting the engine, a vacuum has to be formed beforehand, otherwise the exhaust of the engine would have no chance to escape, if no automatic relieve valve is provided, and there soon would be pressure in the condenser. In shutting down the injection valve should be closed after shutting the throttle for the same reason, but should be closed shortly afterwards, to destroy the vacuum, otherwise the engine may continue to run on atmospheric pressure for a long time, if lightly loaded.

Ques. Give several ways vacuum may be lost.

ANS. Vacuum may be lost partly or wholly by a leak in the condenser, a leaking stuffing box on the low pressure cylinder, a leaky air pump, dislocation of the valves of the air pump, not enough circulating water, the circulating water too warm, the circulating pump being out of order, leaky pistons, leaky valves in cylinders. In a jet condenser, injection water too warm and too much of it, not enough injection water, or the spray may be clogged.

Ques. With ordinary cross-compound high-pressure piston stuck on center, how can engine be started without barring wheel?

ANS. By admitting steam to the low pressure piston by means of a by-pass valve on the receiver.

Ques. In triple engine with second cylinder doing much more work than low pressure, how can cut-off be best adjusted in either cylinder to balance load between cylinders?

ANS. By shortening the cut-off on the low pressure cylinder, thus increasing the back pressure on the inter-

QUESTIONS AND ANSWERS.

mediate, and lengthening the cut-off on the intermediate, reducing the pressure on it, also the back pressure on the high pressure cylinder.

Ques. What is effect on receiver pressure of cutting off later in first cylinder?

ANS. The receiver pressure will be raised and the engine will perform more work. The low pressure piston, ir this case, will perform more work than the high pressure piston. On the former the pressure is increased, while on the latter the back pressure.

The cut-off has to be regulated for both cylinders, to make them perform even share of the work.

Ques. What is the meaning of the term "duty" as applied to the steam engine?

ANS. The work of which the engine is capable of performing on a given fuel consumption. This is usually calcnlated for the pounds of coal per indicated horse power, per hour.

Ques. What is a reverse valve?

ANS. It is a valve used to reverse the motion of steering or elevator engines so that they can run either forward or backward.

Ques. How can the accuracy of the piston rod be best known?

ANS. The best test to ascertain whether a rod is sprung is to put it into a lathe and revolve between the centers. When a lathe is not accessible, good results can be secured by cutting Vs in a pair of wooden blocks of equal height and revolving the rods in the recesses.

Ques. What provision should be made on condensers to relieve the pressure of the exhaust, in case the vacuum is lost?

ANS. An automatic relief valve should be attached to the condenser which is a spring or weight loaded valve and will open when the pressure rises to a certain point, the same as the safety valve on the boiler. When the engine is working condensing the valve will be held to its seat by the atmospheric pressure from the outside.

Ques. If high pressure valve gear should be broken, how could you keep compound engine running?

ANS. By uncoupling the high pressure side, removing the high pressure valve and gearing, so as to give free passage to the steam through the exhaust, reducing the steam pressure, and if possible, closing up the steam ports of the high pressure cylinder to keep it from filling with condense water. If there is a valve between high pressure cylinder and receiver, close this, and admit steam direct to the receiver.

LINING UP A HORIZONTAL ENGINE.

The first thing to be done is to remove the cylinder head, piston, piston-rod, connecting-rod and cross-head, next,

Fasten a board across the flange of the cylinder with two opposite studs and their nuts, as shown in Fig. 30, and with a rule find the center of the cylinder bore (approximately), and bore a one inch hole through the board.

Erect a standard at the crank end of the engine, as shown in Figs. 28 and 29, and bore a hole through it, about the heighth of the center of the cylinder above the floor.

Fasten the end of a very fine line, but sufficiently strong to be drawn tight, without sagging, to a stick about 2 or 3 inches in length, and draw it through the hole in the board which is fastened across the cylinder flange, also through

NOTE.—In lining up a horizontal engine, attention should be paid to have it horizontal, to prove that it is so have a line, passed through the center of the cylinder and guides, and tested with a level, the shaft must also be perfectly level. If this is executed with exactness, all other parts can be adjusted more easily. If the engine is a new one, it is easier to do this than with an old engine, as there has been no wear on any of the parts.

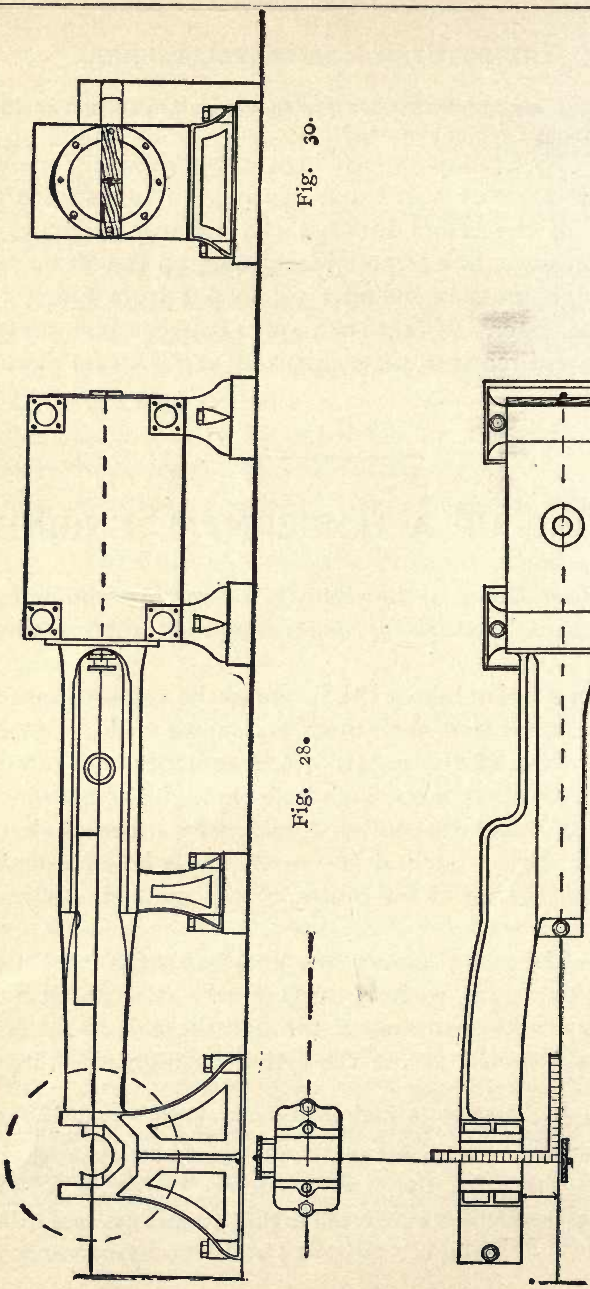


Fig. 30.

Fig. 28.

Fig. 29.

LINING UP HORIZONTAL ENGINE.

Lining Up a Horizontal Engine.

the cylinder and stuffing box, and finally through the hole in the standard; after drawing it tight, fasten to the other end a similar stick, so it will be held in position.

Now with a pair of calipers, or a stick cut to the exact length of one-half the cylinder diameter in the counterbore, center the line at the head end of the cylinder.

The line can easily be moved into the desired position, by shifting the small stick to which it is fastened, and this is the reason that the hole should be sufficiently large.

After this end has been perfectly adjusted, center it in the same manner with the stuffing box; to move it in position on this end, the stick on the standard has to be adjusted, until the line is perfectly central with the stuffing box.

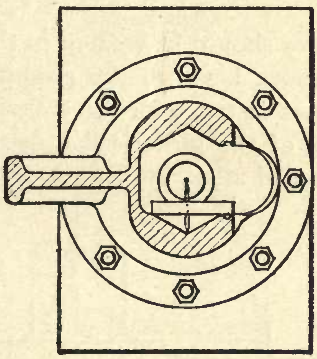


Fig. 31.

This line is the center line of the engine, and all other parts have to be adjusted to agree with it.

The first thing to be adjusted should be the shaft. This may be adjusted at right angles with the line, by the same operation, as described under lining vertical engines, and can be leveled by placing the level on the shaft.

The line should cross the crank pin, when the shaft is in its proper position, at the middle point of the length of the pin as shown in Fig. 33. and when the shaft is turned

LINING UP A HORIZONTAL ENGINE.

over, as explained hereafter, the same point should touch. Now the guides have to be tested. If they are of the locomotive style, it is best to lay a straight edge across the face of the lower guide, and measure the distance from the straight edge to the center line on both ends of the guide, and if there should be any difference it should be corrected by adjusting the guides.

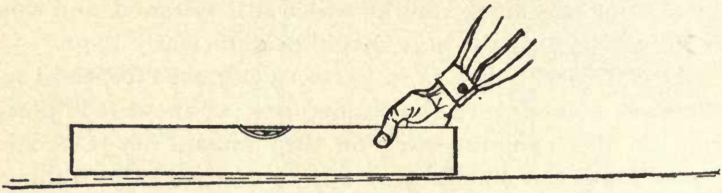


Fig. 32.

The upper guides should be treated in the same manner, and also the distance between the guides should be adjusted to the proper distance for the cross-head.

If the frame is of the girder type, as in Fig. 28, it is well to make a small stick, the length of which should be

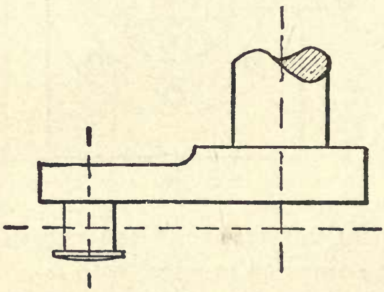


Fig. 33.

equal to the distance between the center of the ridge of the guide, and the line at one end, and fasten it firmly to a piece of board, one edge to be perfectly straight, as illustrated in Fig. 31, which is a cross-section through the guides, showing the application of the gauge. Move this

Lining Up a Horizontal Engine.

gauge along the guide, keeping the lower point of the stick in the center of the ridge, and note, whether the upper point varies sideways or vertically with the line.

If there is any variation, the guide is worn out of true, and should be dressed true, with a coarse file and scraper and straight edge.

Proceed in the same way on the top guide.

To measure whether the cylinder is worn out of true, caliper the bore of the cylinder all around the line, and if there is any difference, it should be rebored as soon as convenient.

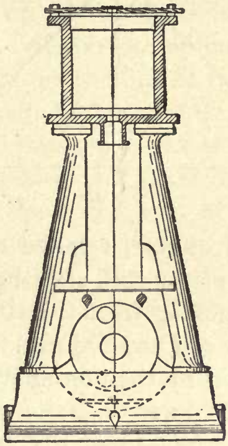


Fig. 34.

To ascertain the proper alignment of the eccentric, fasten a line to the eccentric rod pin, at the middle of its length, and by holding a square against the shaft, press the line against the other leg of the square near the shaft, and move both square and line, until the line touches the leg of the square all over.

Mark the place where the line touches the shaft, and on both sides of this mark, at a distance equal to one-half the thickness of the eccentric, make other marks.

Lining Up a Vertical Engine.

The eccentric has to be placed between these marks to be in proper alignment.

If the engine is of the Corliss type, so there is a rocker arm and the wrist plate to be adjusted in their midway position, a plumb bob is generally employed. To make this adjustment perfect, it is best to ascertain, whether the engine is horizontal, by trying the centerline with a level, as shown in Fig. 28. If it is found that the engine is not level, correction should be made to agree with the plumb bob.

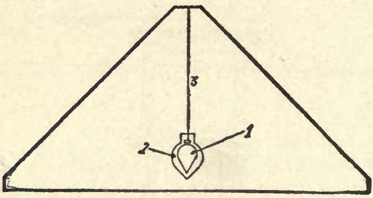


Fig. 35.

To line a vertical engine, remove upper cylinder head and take out piston, piston-rod, cross-head and connecting-rod. Remove the packing from the stuffing box and thoroughly clean the box of any old packing which may have burned on to the sides of the box as it will be of great importance in setting the line.

Bolt firmly across the top of the cylinder a pine brace with a hole bored in the center. At the bottom of the crank-pit, arrange a similar piece, in order to fasten the lower end of the line. A line made of sea grass or silk is preferable on account of its great strength. The line should be as fine as possible without breaking when drawn taut enough to caliper or tram by.

Note.—If a spirit level cannot be had, the engineer can make a set level, as illustrated in Fig. 35. It consists of a triangular board, with one edge planed true, with a pencil mark at right angles to this edge and a plumb bob attached to it in the manner shown in Fig. 35.

Lining Up a Vertical Engine.

To set the line, go to the top of the cylinder and pass the end of the line through the hole in the brace and fasten it to a small stick laid across the hole; drop the other end of the line down through the hole in the bottom of the cylinder to the crank-pit; set the top end of the line as near the center as can be done by the eye and then go down to the crank-pit, pull the lower end of the line through the hole in the brace and pull it taut and make it fast as at the upper end; set the line as near the center of the shaft and as near the center of crank-pin lengthwise as possible; then with tram or caliper set the top end of the line in the center of the cylinder, measuring from the counterbore of the cylinder to the line; then with a small pair of inside calipers try the line in the stuffing box.

Any changes required to bring the line central at this point must be made at the lower end of the line. After the line has been set so as to be exactly in the center of the counterbore of the upper end of the cylinder, and in the center of the stuffing box, you are ready to try the shaft and crank-pin.

To do this roll the shaft until the crank-pin comes as close to the line as possible without touching; then with small inside calipers measure from the end of the pin to the line. Set the calipers so they will not move and roll the shaft back until the crank-pin is next to line at the opposite end of the stroke. If the measurements are the same the crank-pin is in line with the cylinder.

Note.—It would be a good plan to reverse the level then, and see whether it is correct, if the line should not correspond with the level, after it has been turned end for end, the level is out of true, and the difference should be equally divided, this is done, referring to the figure, by raising the line on the low end, equal to one-half the amount it is too low, if it should be too low on the other end of the level, your assistant will have to lower it, till the distance between the end of the level and the line is reduced to one-half. See page 69, and Fig. 35.

Lining Up a Vertical Engine.

Should the measurements vary it will be necessary to raise or lower the shaft until they are the same. Next try the slides to see if they are in line with the cylinder. This is done by measuring with tram or caliper from the line to the face of the slides at each end. Should they be out of line the construction of the engine will have to govern the changes necessary to bring them in line.

To determine if the shaft is square with slides drop a plumb along the edge of the slides, then place a straight

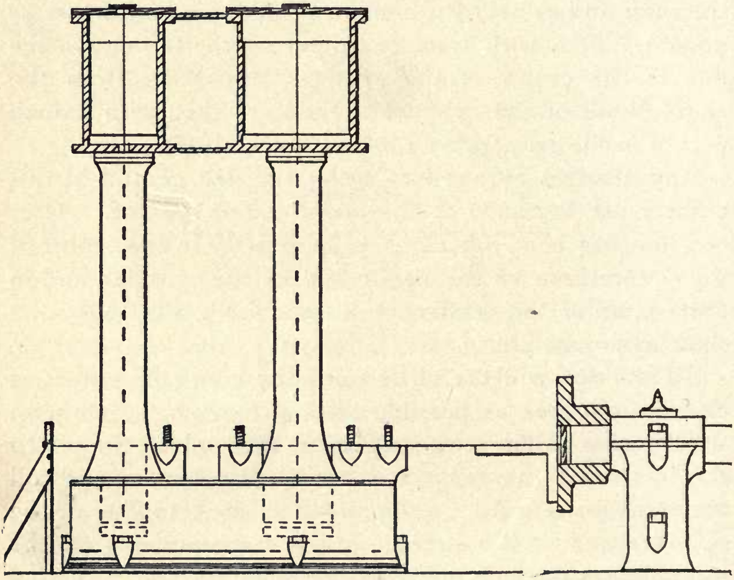


Fig. 36.

edge so that its edge will come up to the lines; then from the center line draw a line parallel and true with the center of the shaft. If this line is at right angles with the straight edge when tried with a square the shaft is true.

To line a vertical marine engine where the crank-shaft is coupled direct to the main shaft: first, strip the engine of piston, piston-rod, cross-head and connecting-rod; remove

LINING UP A VERTICAL ENGNIE.

the caps from the crank-shaft journals, and the bolts from the coupling which couples the crank-shaft to the main or the outboard shaft; remove the crank-shaft from the journals, so that a line can be drawn through them. Raise the stern bearing as far as it will go so that the shaft will be solid in its place, then draw the line, fastening it firmly at top and bottom and adjusting it by the counterbore of the cylinder at the top and by the stuffing box at the bottom, according to the directions for lining a vertical engine.

On all direct coupled or marine engines the male side of the coupling should be on the crank-shaft leaving the female side on the outboard or main shaft for lining up. In fastening the line to the coupling, take a small piece of wood strong enough to stand the necessary strain on the line to prevent it from sagging and equal in length to the diameter of the recess in the coupling marked, bore a hole in the center and drive the piece firmly into the coupling, as shown in Fig. 36, draw a line through the hole in the piece of wood, and fasten a small stick to the end of it.

Carry the line through the bearings and secure the other end of it to a standard as before, and center the line perfectly in the coupling, by means of calipers.

In order to set this line, take a square which is known to be true, place the shank on the face of the coupling allowing the blade to extend over the line as shown in Fig. 38, try the line with the square at top and bottom and on each side, and move the end attached to the standard, until the line comes true with the square; at these four points the line can be said to be true with the shaft.

After this is done, the center lines of the cylinders have to be tried, and these will have to touch the line, which represents the crank shaft; if they do not touch this line,

NOTE.—The bearings should be placed centrally in the pillow block, for this is necessary to suit the length of the reciprocating parts of the engine.

Lining Up a Vertical Engine.

the cylinders are not in line with the shaft, and the main shaft must have been out of line with the engine, as the cylinders cannot possibly get out of line.

The main shaft should be tried, whether some of its bearings have moved, if this is not the case, the whole engine bed has not been adjusted right. Such difficulty will, however, seldom occur.

Next try the journals by measuring from each side of the journals to the line with a tram or small inside calipers. If the line comes in the center they are in line; if not, they must be moved until they become central. The next point is to ascertain if the journals are of proper height, as in vertical engines the wear is up and down. To get this point, caliper the crank-shaft in each of its bearings and find the exact diameter of each one of them; by trying these calipers on a scale we are able to set our inside calipers to one-half the diameter of the shaft, which is the correct height that the line should be from the bottom of the journal boxes.

To test the cross-head guides, the directions given in the former articles must be followed.

There are several styles of guides, and the engineer will have to use his own judgment to a great extent.

But before coming to any conclusion, always be sure whether the lines are set perfectly right, otherwise, instead of improving, the condition of the engine may be made worse.

LINING SHAFTING.

A number of pieces of board are notched at 1 to fit ove- the shaft, and a hole, 2, is cut in the other end, then by means of a plumb line, each piece being hung over the shaft, the point 3 (which may be of tin, or simply a pine

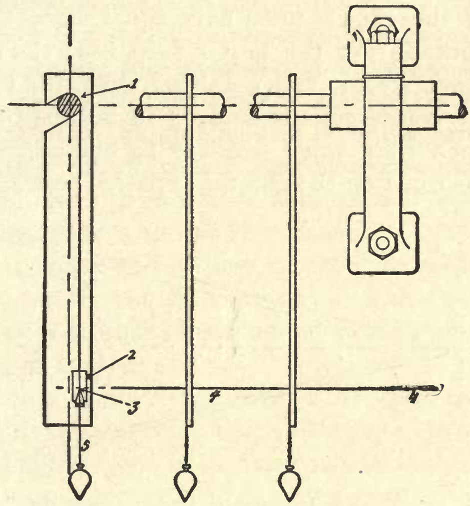


Fig. 37.

1. Shaft. 2. Hole for line and sight point. 3. Sight point. 4. Line. 5. Plumb line.

head) is located so that the distance, 1, 3, is the same on each piece. By hanging these pieces of board over the shaft at different places, and so adjusting the shaft that the points 3 will all come in line when sighted by the eye, the shafting will be properly lined.

NOTE.—It would be worth while to know how many and to what odd "calls" the average engineer is compelled to respond outside his special position and to none more frequently than to oversee and direct the "lining up" of some unruly shaft which will not run true—hence. this device is shown in Fig. 37.

VALVE SETTING.

The slide valve is briefly described on page 40, Fig. 14. It is the simplest form of engine valve, for it operates the steam ports of both ends of the cylinder, as well as the exhaust, and as its form and size cannot be altered at will, any changes made in its location toward one end of the cylinder, will also affect the other end, and as both strokes of the engine must have equal shares or nearly so of the work, to get the best results from the machine, it has to admit steam, and cut it off, open the exhaust and close it at points equally located in both strokes; but as the common slide valve is driven by one eccentric, whose position is fixed on the shaft, in relation to the crank, it is

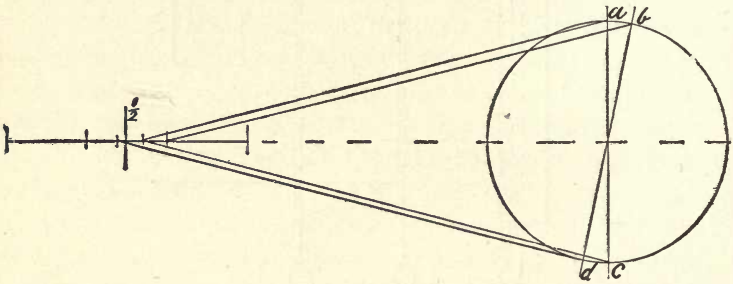


Fig. 38. DIAGRAM OF THE ANGULARITY OF VALVE.

impossible to set it, so that it will give equal cut-off in both strokes. This is due to the angularity of the connecting rod, for if the crank is at right angles with the center line of the engine, on the outward stroke, the piston has passed half stroke, and if the crank is at right angles with the center line on the return stroke, the piston has not reached the half stroke mark.

This is illustrated in Fig. 38, the position *a*, indicates the crank at right angles with the center of the engine, and *b* the position of the crank at ⅔ of the stroke. If the crank is at *c*, the piston will have reached the same mark as when the crank was at *a*, but when the crank is at *d*, opposite to *b*, the piston has not yet reached ⅔ of the stroke.

VALVE SETTING.

Thus if the engine be designed to cut off at ⅔ of the stroke, at its outward stroke, it would cut off the steam a little beyond ½ stroke on the return stroke, as the eccentric remains at the same angle with the crank.

This difference is greatest if the cut-off should be fixed at ½ stroke, and diminishes at earlier and later cut-offs.

The location of the eccentric on the shaft, depends upon the point of the stroke at which the valve is designed to cut off the steam; this point of cut-off cannot be changed with the same valve, thus there is only one correct position for the eccentric, as moving the eccentric further ahead, giving earlier cut-off, would open the valve earlier, giving more lead, close the exhaust and open it earlier, giving more compression, and quicker release.

The first thing to be done in setting the slide valve is to fix its position on the valve stem, so that its edges will travel past each steam port an equal amount during one revolution of the engine.

To do this, remove the cover of the valve chest, and insert a small strip of wood, near the lower edge of the valve, turn the engine over, until the valve is at the extreme of its travel, on either end, and mark the position of the steam edge of the valve on the piece of wood.

If the engine is a large one, so it will be difficult to turn, it is best to loosen the eccentric upon the shaft, and turn it around, until the valve has obtained the above position.

Then turn the eccentric around, until the valve uncovers the port, and mark the steam edge of the port on the strip of wood.

Turn the eccentric, until the valve is at its opposite extreme travel, and proceed as before.

Next measure the distance between the mark of the steam edge of the port, and the corresponding mark of extreme valve travel on both ends, and if there is any difference between these distances. move the valve on the stem

VALVE SETTING.

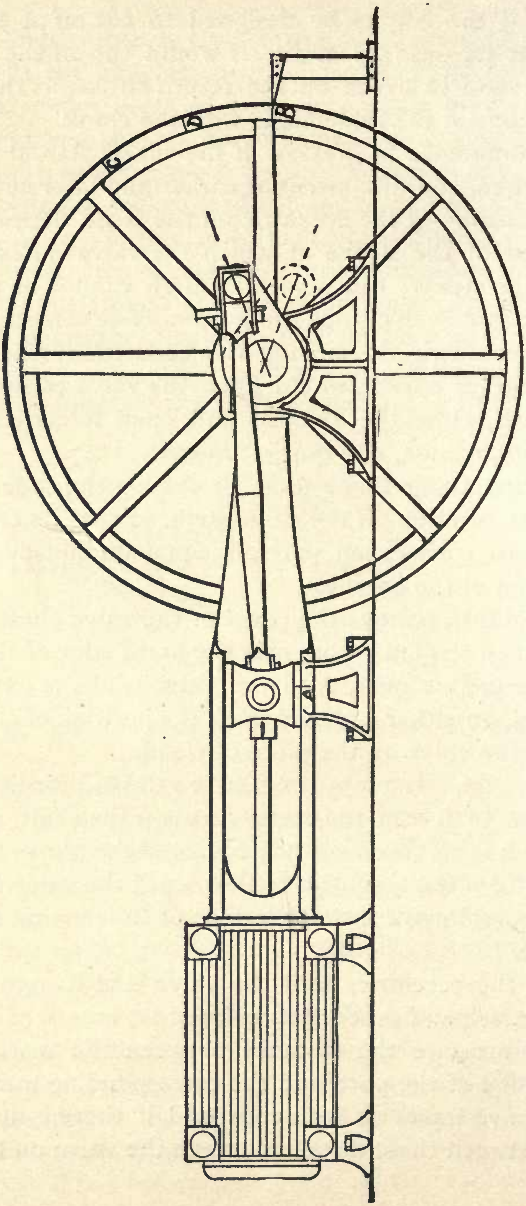


FIG. 39. DIAGRAM ILLUSTRATING RULE FOR PUTTING ENGINE ON THE CENTER.

VALVE SETTING.

toward the end, which measured the least, an amount, equal to one-half the difference between the two distances.

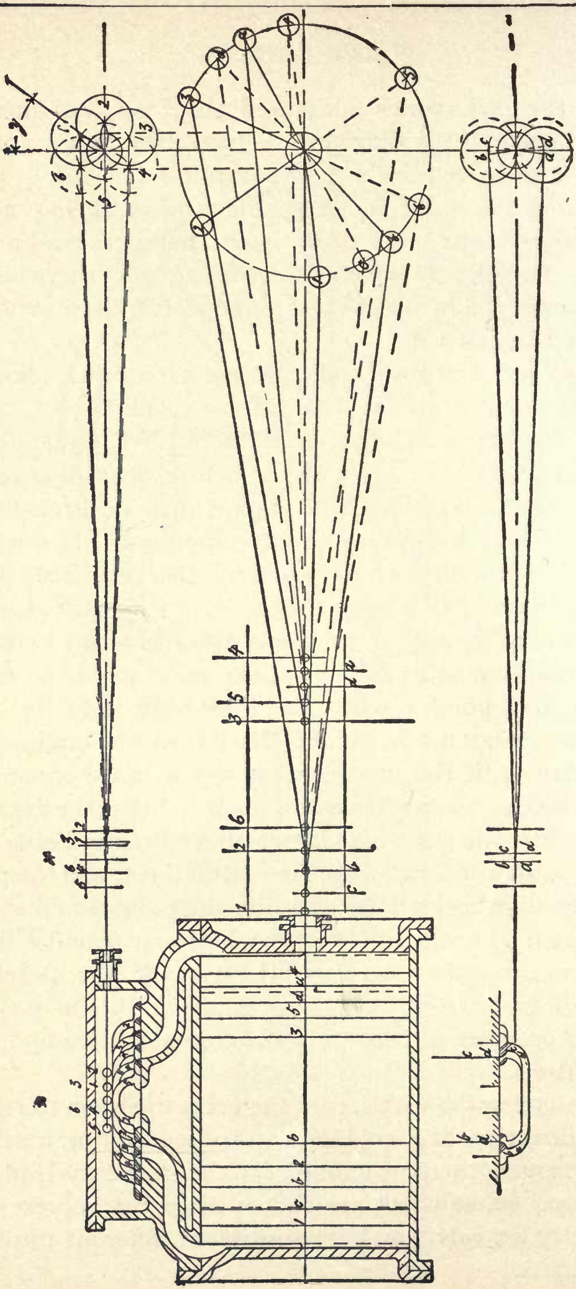
This is done by slacking the nuts on the valve stem, which hold the valve in its position; after having moved the valve, set the nuts tight again, being careful not to jam the bosses with which the nuts engage, otherwise the valve cannot follow up the wear, and would allow steam to leak into the exhaust.

Always jam the nuts tight against each other, allowing a slight amount of lost motion for the valve.

After having set the valve so it will travel equally over both ports, turn the engine on the centre, according to following directions: place the engine in a position where the piston will have very nearly completed its outward stroke, and opposite some point on the cross-head (as a corner); make a mark upon the guide, as shown at *A* in the accompanying figure 39. Against the rim of the fly-wheel place a pointer as at *B* and make a mark upon the wheel opposite this pointer when the cross-head is in line with the mark *A* upon the guide. Now turn the engine over the centre until the cross-head is again in the same position on its downward stroke. This will bring the crank as much below the centre as it was above before, being now in the position indicated by the dotted lines; and the point *C* on the fly-wheel will be opposite the pointer and should be marked. Divide the distance between *B* and *C* accurately, and midway between them mark the point *D*. When *D* is brought opposite the point in the position which *B* occupies in the figure the engine will be upon the true centre.

After having done this, turn the eccentric upon the shaft, in the direction the engine is supposed to run, until the valve uncovers the port enough for the necessary lead.

In Figs. 40 and 41 are shown diagrams, representing a correctly set valve, and its position at different positions of the crank.



Figs. 40 and 41. Diagram of Correctly Set Valve.

Valve Setting.

The piston is shown as one single line, for simplicity, the cross-head pin is indicated by small circles.

The solid lines, representing the connecting rod and crank, are for the outward stroke, and the exhaust stroke on the same side of the piston, while the dotted lines represent the same parts for the return stroke and exhaust on same cylinder end. The respective positions of the eccentric and eccentric rod are also shown in solid and dotted lines.

By following the figures 1, 2, 3, etc., from the piston, the position of valve can be easily traced.

For example:

Suppose the piston to be at 1, the small circle indicating the cross-head pin, marked 1, will be the location of the cross-head, the circle indicating the crankpin marked 1 is the location of the crankpin eccentric 1 and valve 1, 1 the positions of these parts, for the indicated piston position.

The position 1, as will be seen in the diagram, is the position all parts have when admission begins.

It will be observed that when the piston is at position 3, the valve will have taken the same position as when admission commences, except that it travels in the other direction, as will be seen by the position of the eccentric 3.

The valve is marked with two figures for each position, each figure indicating one edge of the valve.

The engine must be assumed to turn in the direction of the hands of a watch, that is, over, from left to right, facing the diagram.

The letters *a*, *b*, etc., indicate the position of the parts at exhaust opening and closure; *a* and *b* being for the head end, and *c* and *d* for the crank end, as indicated by the solid and dotted lines.

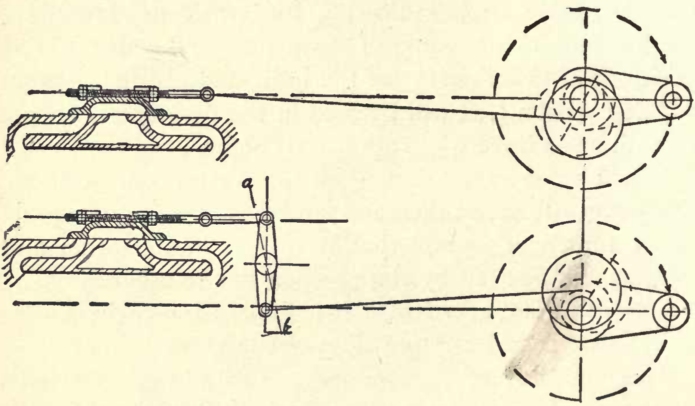
The letter *X* simply indicates the central position of the valve, no corresponding position of the other parts being shown, and the distance *y*, indicated at the eccentric circle

VALVE SETTING.

is the angle of advance, which is the angle, the eccentric is moved ahead of a right angle (*i. e.*, the valve from its central position), when the engine is on its dead centre.

If the valve chest of a slide valve engine is placed on top of the cylinder, as on a locomotive, for instance, it would be difficult to make a direct connection between the eccentric rod and the valve stem, and a rocker arm is employed, as indicated in Fig. 43.

The rocker arm will change the direction of motion of the valve, so that it will move in the opposite direction of the eccentric, and thus the eccentric cannot have the same position in relation to the crank as if it should be directly connected to the valve stem. This will be understood by comparing Figs. 42 and 43.



Figs. 42 and 43. DIAGRAMS FOR VALVE SETTING.

The valve in either figure is shown in its central position, and the eccentric for simplicity set at right angles. Referring to Fig. 42, assuming the crank to be turned in the direction of the hands of a watch, it will be noticed that the eccentric moves the valve over to the left, and when the valve has taken the position shown in Fig. 44, steam is admitted, and acting upon the piston would at once continue to rotate the engine.

Valve Setting.

In Fig. 43, as will be seen, the eccentric is in the opposite direction from that in Fig. 42, but in rotating the crank in the same direction as before, it will draw the lower part of the rocker arm over toward the crank shaft, and thus cause the upper part to move the valve toward the left as before, until the rocker arm takes the position *a–b*, indicated by the dotted line, when the valve will have taken the position in Fig. 44, and steam is admitted.

Thus it will be seen that the rocker arm simply changes the position of the eccentric into the opposite direction from what it would be without the rocker arm. If now the eccentric is turned upon the shaft, with the crank on the dead centre as in Figs. 42 and 43, in the direction the engine is to be run, until the valve takes the position in Fig. 44, it will be observed that the same angle of advance is necessary in both cases, and that the eccentrics are still opposite each other in both cases.

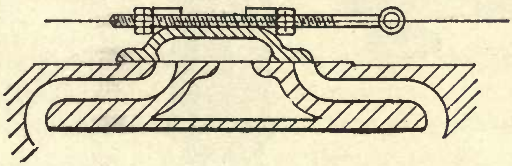


Fig. 44. Valve.

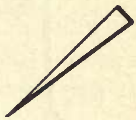
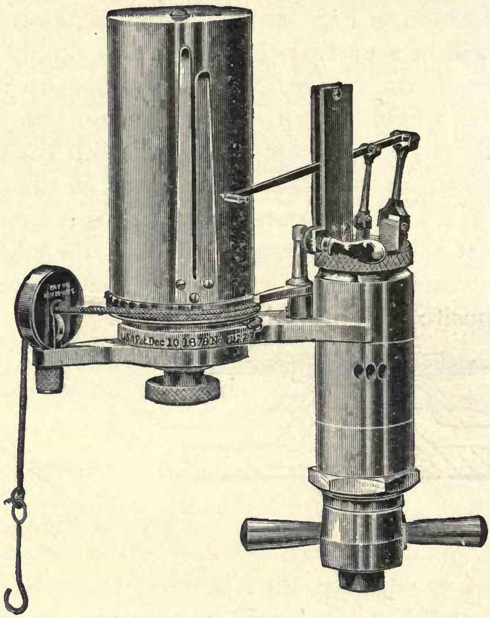


Fig. 45. Wood wedge.

After having adjusted the eccentric properly, make a wedge of wood, Fig. 45, insert it between the valve and steam port edges, and mark with a pencil how far it enters the opening, then turn the engine to the opposite centre, and insert the wedge into the other lead opening. If the wedge enters this opening up to the pencil mark, the lead is equal on both sides, if there should be any difference, this difference has to be divided equally, by moving the valve a slight distance on its stem.

Finally put on the valve cover making sure to have the eccentric clamped tight before starting up.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THE BUCKEYE AUTOMATIC CUT-OFF ENGINE.

This type of steam engine belongs to the double-valve automatic cut-off pattern.

The admission, release and compression are all governed by the main valve which is operated by one eccentric. The point of cut-off is determined by an independent valve operated by the governor eccentric; whatever the cut-off may be, the other conditions remain the same.

The Buckeye engines are built in different styles to adapt them to the different conditions under which they may be placed. Fig. 46 shows a single, medium speed "Tangye" style.

Fig. 48 shows the tandem compound Buckeye engine, Tangye bed, valve gear side.

The governor shown in Fig. 47 is so simple in plan and construction, and so clearly shown in the cut and has been so familiarized to the public through mechanical periodicals, that only a brief outline description here is needed.

Arms *a a* are pivoted to the containing wheel at *b b* and connected at their other ends by links *B B* to ears on loose eccentric *C* in such manner that their outward movement to the position indicated by the dotted lines near one of them, turns the eccentric on the shaft about one-quarter of a revolution in the direction the engine runs, that is, "advances" it. The direction of rotation is indicated by the arrows.

The arms are thrown outward by centrifugal force in opposition to the force of springs *F F*.

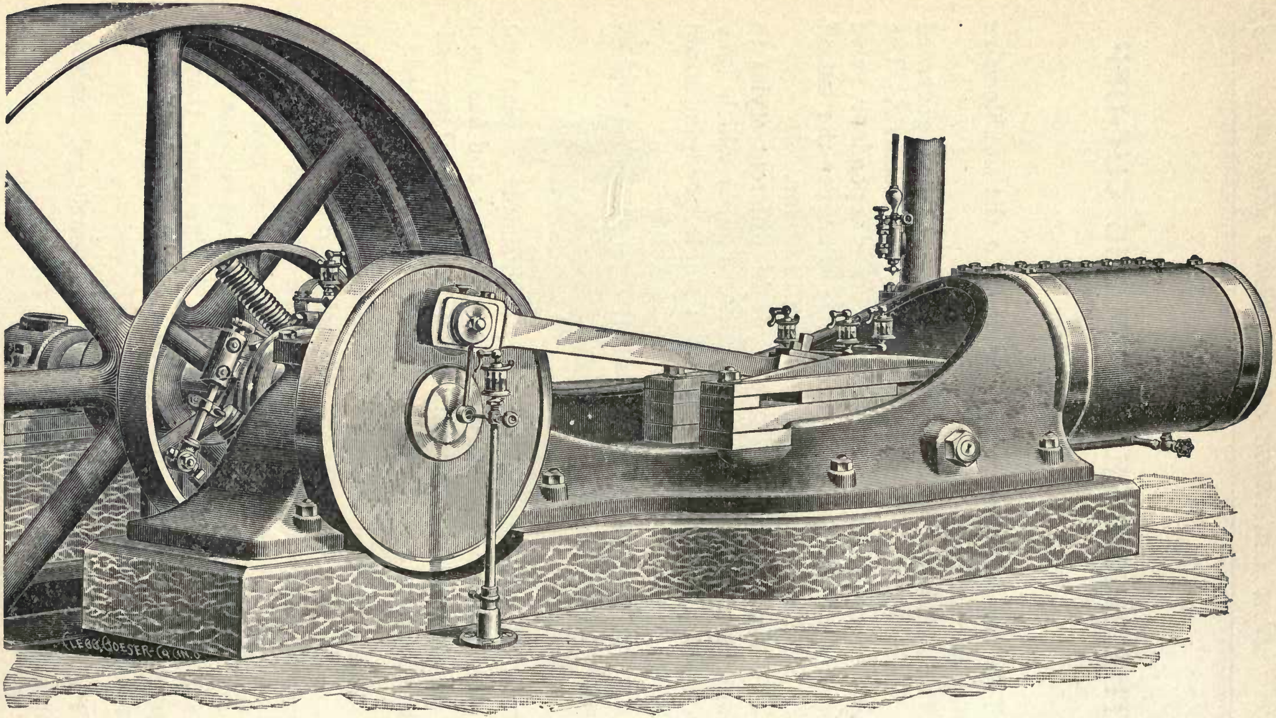


Fig. 46. The Buckeye Automatic Steam Engine.—*Tangye Style.*

THE BUCKEYE GOVERNOR.

They are loaded with more or less weight, at *A A* according to the speed desired, the required effective weight, arm and all, being, other things equal, in inverse proportion to the square of the speed in revolutions in a given time.

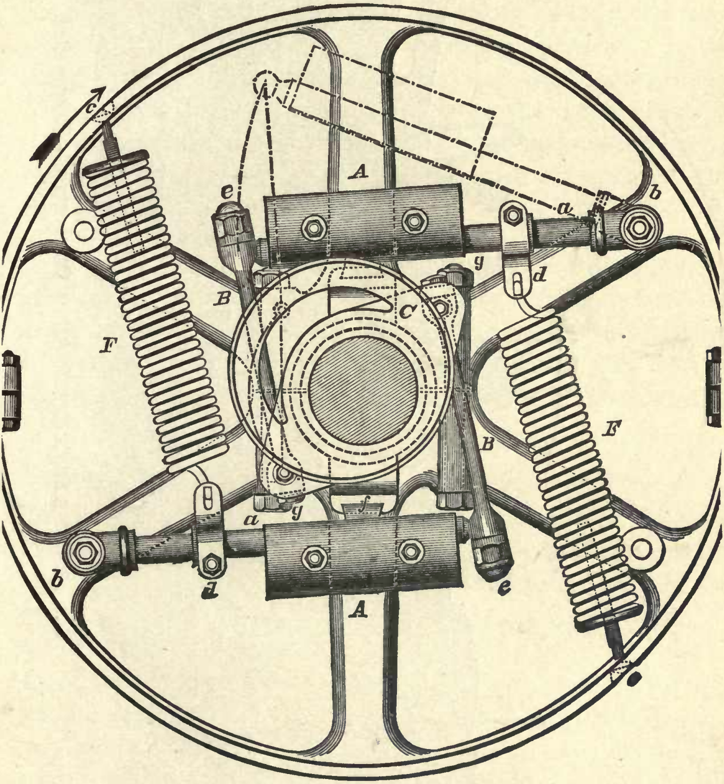


Fig. 47. THE BUCKEYE GOVERNOR.

The tension of springs *F F* is adjusted by screws *c c*. The amount of tension to be given them is determined by the amount of variation of speed due to variation of load. The more tension the less such variation up to the point of almost absolute harmony under favorable load conditions, beyond which unsteadiness of equilibrium would result.

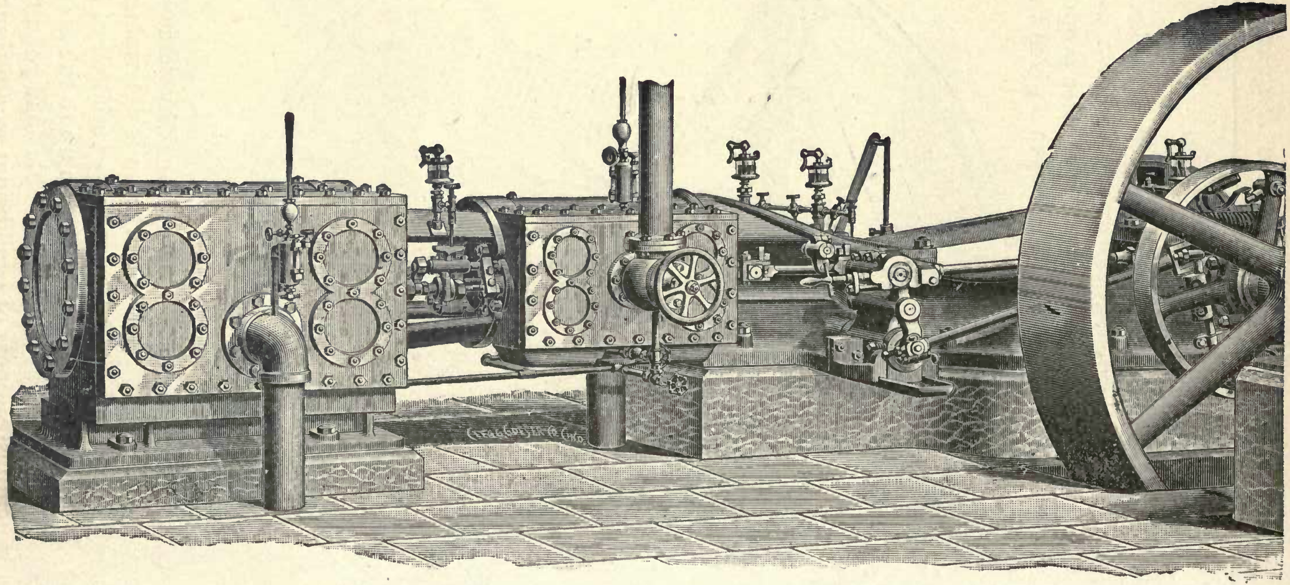


Fig. 48. THE BUCKEYE TANDEM COMPOUND.—*Tangye Bed.*

THE BUCKEYE GOVERNOR.

The auxiliary springs *P P* were introduced a few years ago to obtain the refined closeness of regulation required for electric lighting. For reasons that we have not space to explain, the amount of tension required to give the closest possible regulation could only be carried while the arms were in the outer half of their range of movement. In the inner half it would be in excess, causing unsteadiness. The auxiliary springs tend to throw the arms outward, but act only through the inner half of movement range, leaving contact with the fingers on which they act in mid-movement.

Their force is made such that when the proper tension is given to springs *F F* to give best results, when the arms are in the outer half of their movement range they will start out on starting the engine before the normal speed is exceeded, and the regulation will be steady at all loads.

When they are applied the tension of *F F* must be greater than could be carried without them, otherwise the variation of speed would be increased instead of diminished, and the same result would follow if their force were too great, as would be known by the arms starting outward at a speed too much below the normal, or by too much loss of speed at heaviest loads. For most purposes sufficiently good regulation could be had without them; but they are now always furnished; hence, the importance of a clear understanding of the conditions required for getting the full benefit of them.

To recapitulate, first apply as much tension on the main springs as can be carried without loss of steadiness, which will generally be about one-third to one-fourth more than can be carried without the auxiliary springs; second, the auxiliary springs should have just sufficient force to start

THE BUCKEYE GOVERNOR.

the arms out at very nearly the proper speed; and third, they should leave contact at about mid-movement. Any considerable departure from either of these conditions will defeat their object.

The direction of motion required for the arrangement of parts shown is indicated by the arrow. The parts can be readily changed, however, for motion in the opposite direction. To accomplish this the pivots of the arms are removed to the unoccupied holes shown, and the other parts changed to correspond, so that the arrangement will correspond exactly with a view of the cut as it would appear held up to a strong light and viewed from the back.

Then a new angular position on the shaft is required. The following rule, however, will place it as nearly correct as it can be placed in the absence of any knowledge of special conditions, and for either direction of motion: when the arms rest on their inner stops, as shown, the eccentric *C* and the crank should pass their dead centers at the same time, and in the same direction.

When a condenser is attached the position may require to be a little in advance of this; on the other hand, when the engine is heavily loaded and not liable to run without load it may be back of it; but the test of the correctness of its position is that it shall no more advance than is necessary to hold the engine to speed under its lightest load and highest pressure.

Changes of speed should always be made by changes of the amount of weight attached at *A A*, though slight changes may be made by shifting the weights along the arms, and also by the changes of the tension of springs *F F*, provided increase of tension does not cause loss of steadiness, or diminution does not introduce objectionable variation of speed with changes of load and pressure.

Oil Device—Buckeye Engine.

These engines are manufactured by the Buckeye Engine Co., at Salem, Ohio, at their works established A. D. 1847.

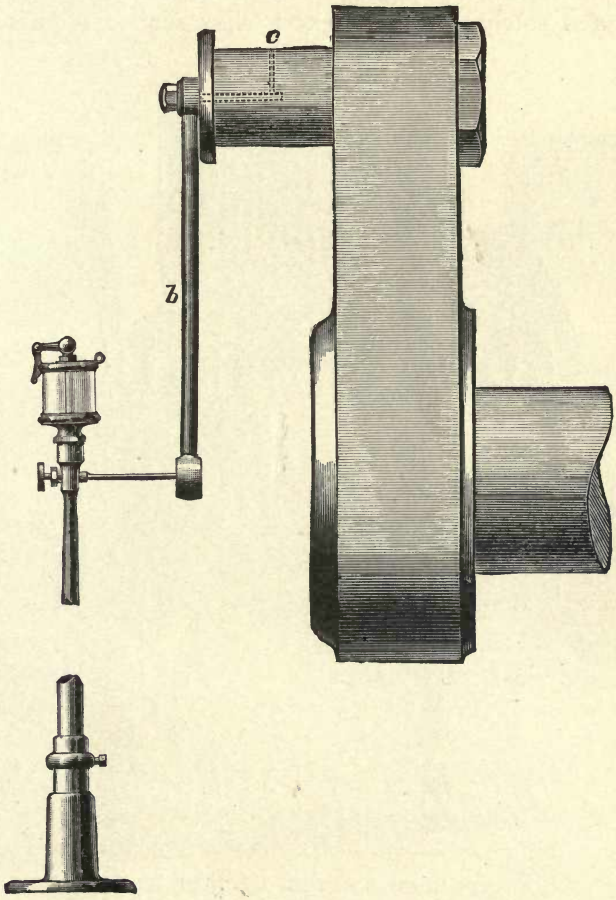


Fig. 49. Crank-pin Oiling Device of the Buckeye Engine.

This company also make single-valve high speed automatic engines with piston valve regulated by the Buckeye shaft governor.

BUFFALO AUTOMATIC CUT-OFF ENGINE.

On page 91, Fig. 51, will be seen illustrated the Buffalo Automatic Cut-off engine, front view, Class A. This is designed solely for the highest class service required in

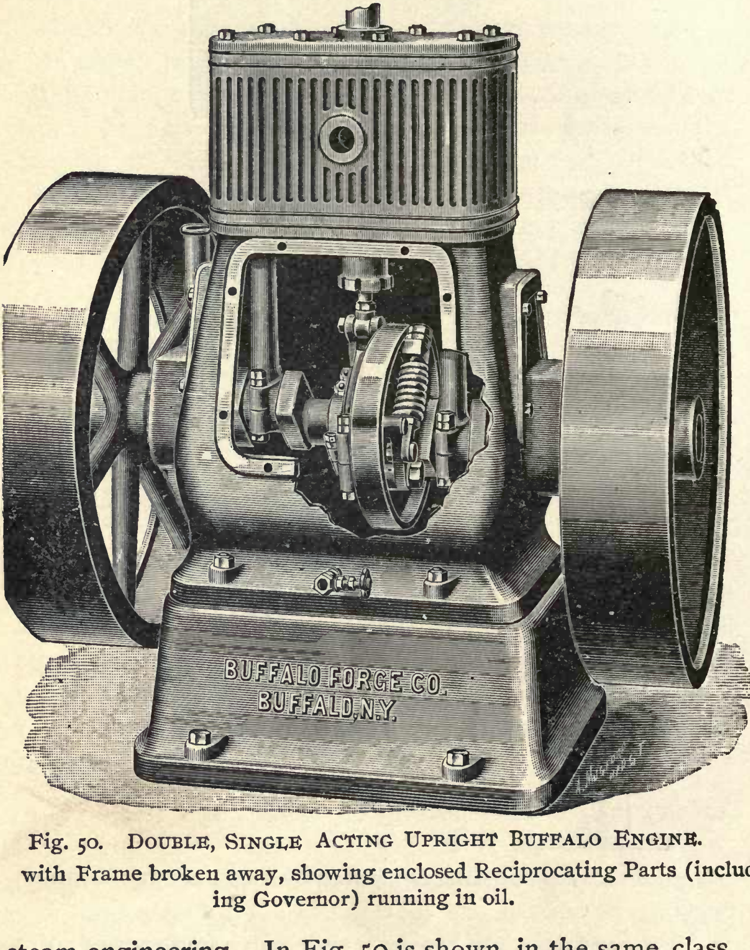


Fig. 50. DOUBLE, SINGLE ACTING UPRIGHT BUFFALO ENGINE. with Frame broken away, showing enclosed Reciprocating Parts (including Governor) running in oil.

steam engineering. In Fig. 50 is shown, in the same class of engine, the system of automatic lubrication employed. This may be described as follows: Centrifugal force,

BUFFALO AUTOMATIC ENGINE.

derived by the motion of the discs, delivers the oil into oil cups and main bearings. It is then forced to the crank

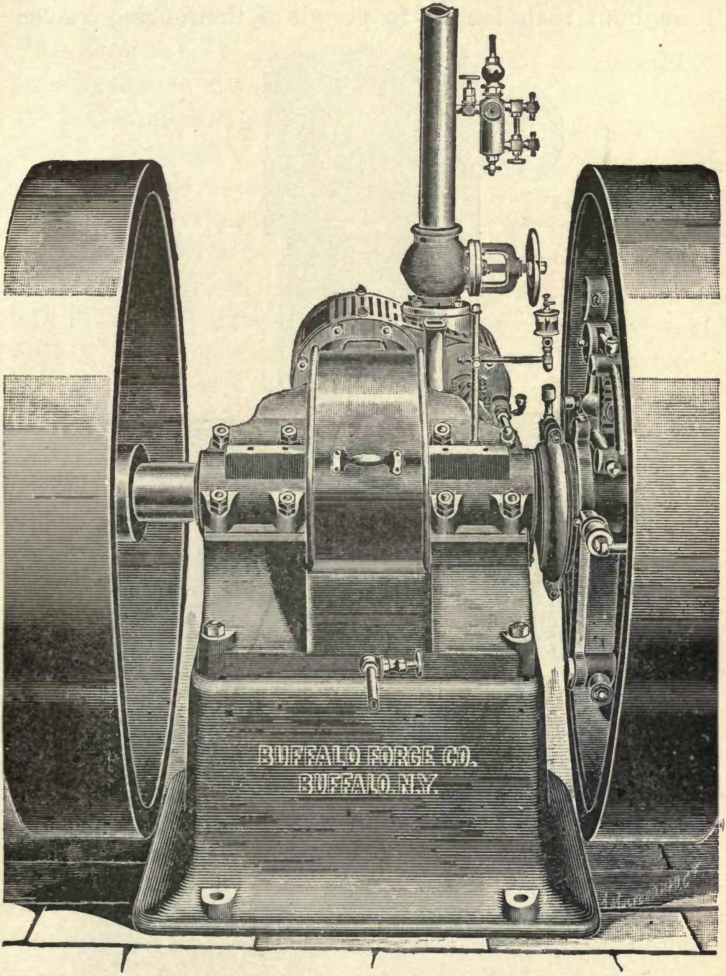


Fig. 51. BUFFALO AUTOMATIC CUT-OFF ENGINE. (Front View.)

shaft bearings and returned to the oil chamber under the crank disc, as clearly shown by cut. The holes through

BUFFALO AUTOMATIC ENGINE.

which the oil passes to the crank are one-half inch in diameter; therefore not easily stopped up. They are straight throughout their length, to permit of their being conven-

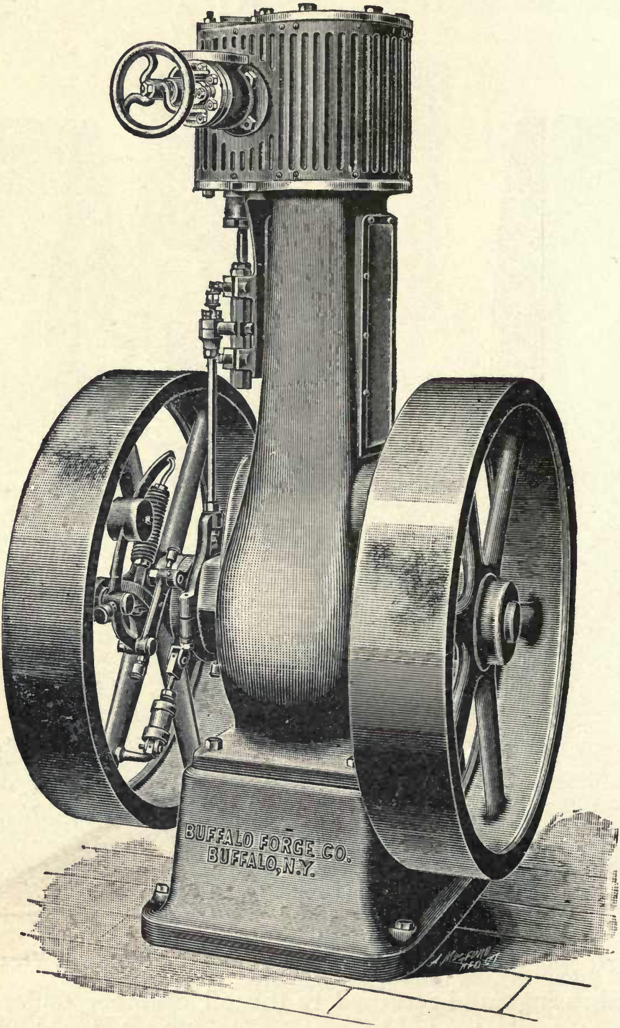


Fig. 52. BUFFALO AUTOMATIC UPRIGHT ENGINE.

BUFFALO AUTOMATIC ENGINE.

iently cleaned. The crank discs are covered by a light dust-proof hood, fitted to the top of the engine frame, entirely without bolts or other fastenings of any description. This hood is built in a unique form, and is really oil-tight. It is readily removable. An oil-tight side plate encloses the crosshead and guides, and affords ready access thereto. No oil can possibly get to the belts or floor. The unique construction of main bearings ensures a minimum amount being drawn to the fly wheels, and any oil finally escaping is caught and held by the flanges thereon; only enough oil should be supplied that the crank disc will dip about an inch into it. A greater quantity is not desirable, as it will cause a churning action. The oiling system in this engine is most cleanly and thoroughly efficient.

The Buffalo slide valve is perfectly balanced, rectangular in shape, with three openings through it. It is of uniform thickness, quite thin, and flat on its two sides. The space in which it works is formed by the valve seat, and a pressure plate with two distance pieces placed below and above. The balanced piston type is provided with a piston at each end, cast hollow to reduce weight and avoid bearing down on the steam chest, which is furnished with cages. Snap rings, fitted identical to the packing rings of piston, are used. With either valve type, provision is made for easy removal, adjustment, and ample relief of over-pressure by water in cylinder. The valve motion is derived by means of an eccentric which carries the valve rod in a straight line, and is provided with means for adjusting any wear. The eccentric rod is connected to a ram box by bronze bearings, and to the strap by two jam nuts. The eccentric strap is oiled from a lubricator placed on a post on the top of the bed. The eccentric rod has but two bearings, a direct line passing through center of same, and they are coupled from the eccentric rod to a ram box bolted to the steam chest hood, insuring strength, rigidity and utmost simplicity. This eliminates any twisting strain on either of the bearings.

BUFFALO AUTOMATIC ENGINE.

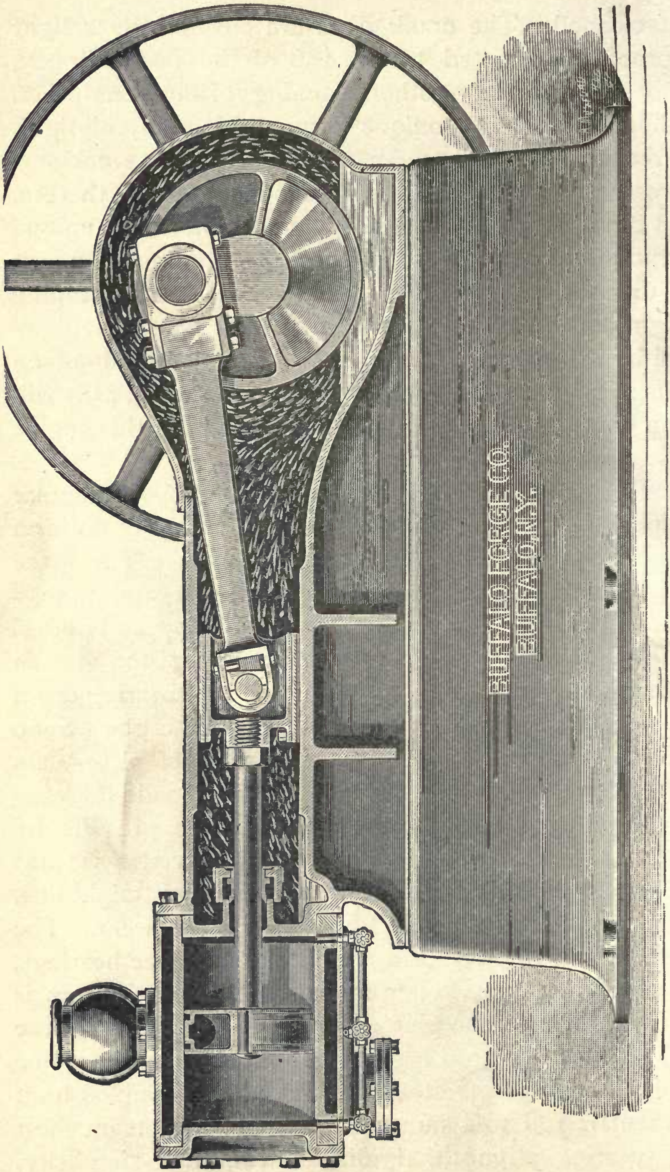


Fig. 53. SIDE SECTION VIEW, SHOWING SELF OILING FEATURE, CYLINDER, CRANK PIN AND CROSSHEAD

BUFFALO AUTOMATIC ENGINE.

This engine, of which the cut, Fig. 50, is a most excellent illustration, was originally designed for the United States Marine Service. The work thereof necessitated unusually high speed, continuous operation with minimum attention, and the highest nicety of speed government. As will be seen, the entire working parts of the engine, including governor, are completely enclosed and run in oil. This prime feature affords positive and ample oiling of all reciprocating parts. Ready access to the working parts is afforded by the large oil-tight doors, both back and front. This type has two single-acting cylinders placed close together. Steam is admitted only at the top end of the piston on the downward stroke. The governor is attached direct to the crank disc, instead of being introduced in the fly wheel, and receiving an oil bath at every revolution, is thoroughly lubricated at all times.

In Fig. 54 is shown the single upright type of the Buffalo automatic engine. Two large oil-tight side plates or doors afford ready access to the interior parts. Repairs, therefore, may be made with the utmost ease under adverse circumstances. The crank shafts may be readily removed without displacing the engine. The steam chests are thoroughly lagged to reduce condensation to a minimum.

Each upright is furnished with two unusually heavy wheels. The governor valve, cross-head, and all parts except the frame, are identically the same design and construction as employed upon the automatic cut-off horizontals. The oiling features of this engine are so regulated that the lubrication is equally thorough at a minimum or maximum speed.

These engines are fitted with automatic stop governors as shown in illustrations. These are so simple in design and action that no extended description is necessary. Regulation is made by the eccentric being thrown across the shaft, thus varying the travel of the valve.

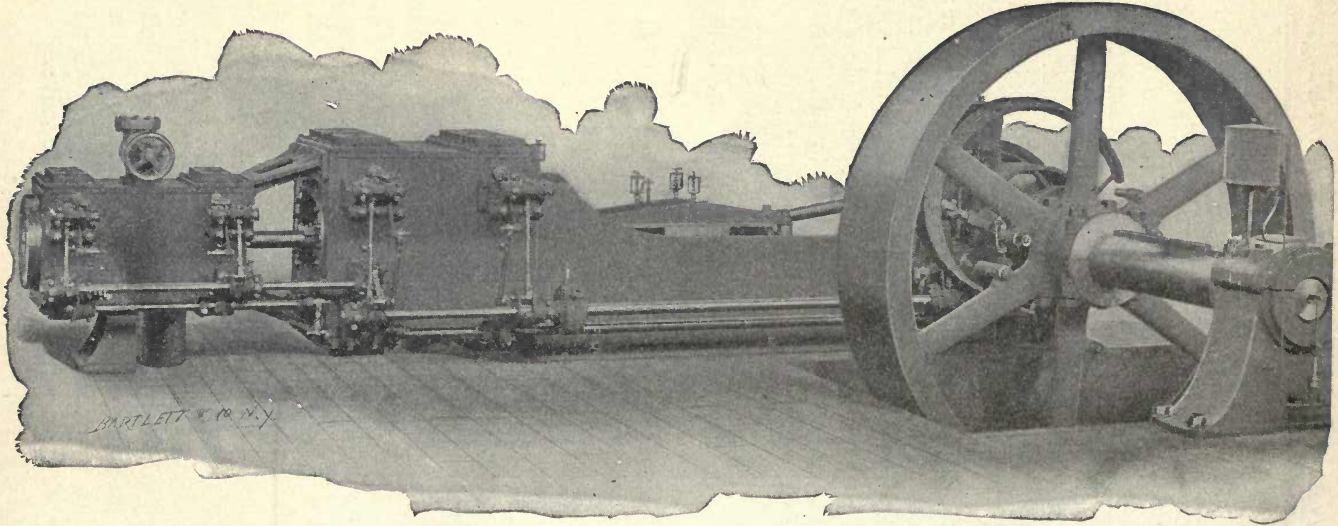


Fig. 54. 400 H. P. McIntosh and Seymour Tandem Compound Engine.
Arranged both for a Direct Driven Railway Generator and for Belting.

McINTOSH AND SEYMOUR ENGINES.

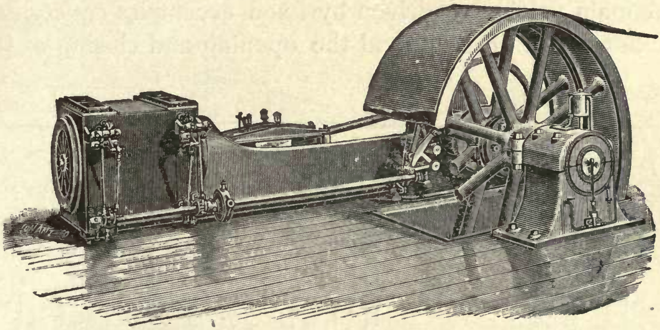


Fig. 55.

The above illustration exhibits the McIntosh and Seymour automatic cut-off engine. Fig. 54 shows half tone engraving of tandem compound engine of the same type.

The prominent special features of these engines are the gridiron valves, driven by a valve motion which is positive throughout, and the shaft governor, which operates the cut-off valves and controls the speed.

Fig. 57 shows cross section through cylinder and valves, also diagram of the exterior valve gearing seen from the end of the cylinder. Fig. 56 shows cylinder and valves in lengthwise section and the diagram of the valve gearing (exterior) seen from the fly wheel side of the engine.

Since the valves are multi-ported, only a very small stroke is necessary to give full opening, varying from ½ to 1½ inches according to size of cylinder. They are driven by means of a toggle motion and move intermittently, standing still when closed, and only require power to operate when open and relieved of the pressure of the steam; hence they give a rapid opening of port with a small amount of wear and little power required to operate; they cannot stick when the engine is started and are easy to lubricate.

THE McINTOSH & SEYMOUR ENGINE.

The valve seats are separate from the cylinder and are removable. The governor operates the cut-off valves only. The main valves are driven by fixed eccentrics controlling the admission of steam and the opening and closing of the

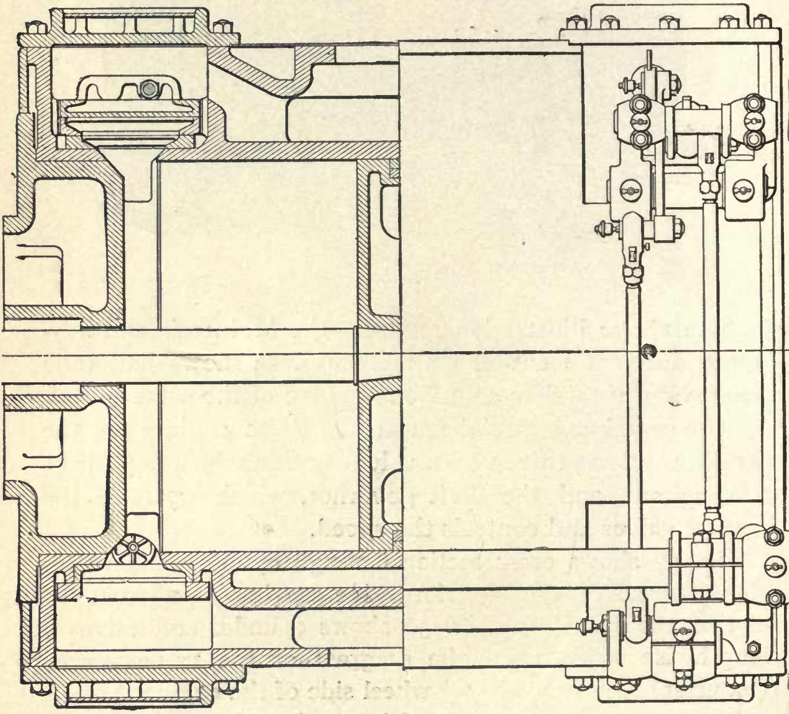


Fig. 56. LONGITUDINAL SECTION THROUGH CYLINDER AND VALVES, McINTOSH AND SEYMOUR ENGINE.

exhaust. One valuable feature of this arrangement is its perfect flexibility; any one of the four operations of cut-off, admission, release or compression, can be varied independently of the others by simple adjustment of the gear.

The cut-off valve operates when moving in an opposite direction to the main valve and gives a very rapid closing

THE McINTOSH & SEYMOUR ENGINE.

of the port. On multi-cylinder engines usually the governor operates the cut-off valves on all the cylinders. By using different strokes the cut-offs in each cylinder are

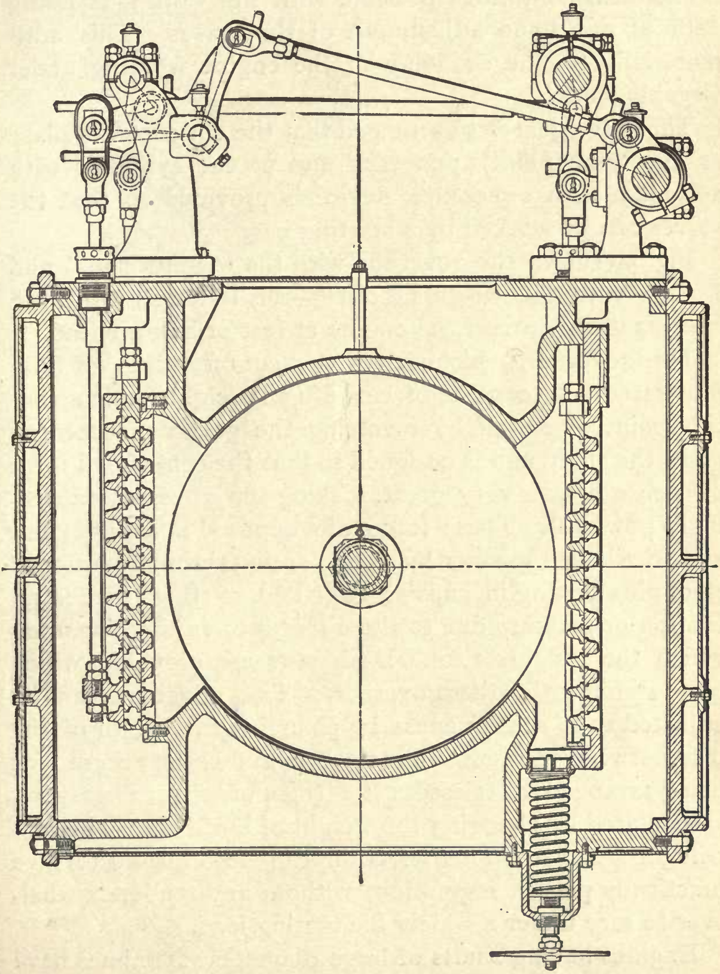


Fig. 57. CROSS SECTION THROUGH STEAM AND EXHAUST VALVES AND CYLINDER, McINTOSH AND SEYMOUR ENGINE.

varied so that the work is divided equally among the cylinders and the drop in temperature of steam is the same in each; hence the engine always works under the most economical conditions possible with the work it is doing without any hand adjustment of the valves. This adds materially to the economy of the engine working under variable loads.

The valve gear is so arranged that the cut-off takes place at the same point upon each end of the cylinders with any load. An unhooking device is provided so that the valves can be worked by a starting bar.

Fig. 59 shows the governor with the weights "in" and Fig. 58 with the weights "out"—the latter showing full speed and the former the engine at rest or below speed.

The governor, which drives the cut-off valves, is fully illustrated. It consists of centrifugal weights which vary the point of cut-off by revolving the governor eccentric upon the shaft, and is designed so that the centrifugal force of each weight is very great, making the governor exceedingly powerful. These forces are opposed in a direct and and frictionless manner by a plate spring through hardened steel pins resting in cups at each end, so that there is no friction or pressure due to these forces upon the pins upon which the weights turn. Dash pots are provided, which give stability to the governor. The governor can be adjusted as to sensitiveness by changing the length of the pins between the centrifugal weights and spring, these pins being arranged to telescope for this purpose. The speed is regulated by changing the weight of bushings in the centrifugal weights. This governor can be adjusted to give practically perfect regulation, without any tendency whatever to race under a widely fluctuating load.

Engines having shafts of large diameter sometimes have the governor mounted upon a small auxiliary shaft driven by a drag link from the crank pin. This greatly reduces

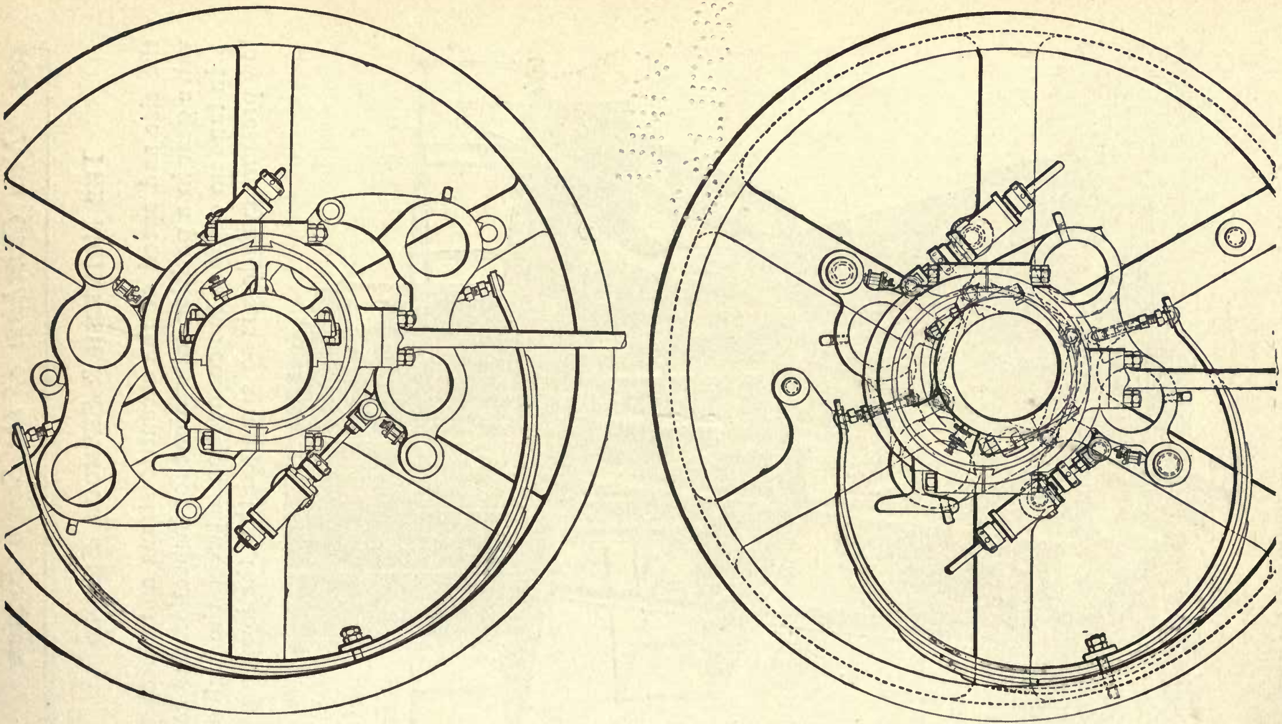


Fig. 58 and Fig. 59, SHOWING GOVERNORS OF THE MCINTOSH AND SEYMOUR ENGINE.

THE McINTOSH & SEYMOUR ENGINE.

the size and speed of the eccentric straps and places the valve gear in a position convenient for inspection and care.

In tandem engines the connection between the high and low pressure cylinders is so arranged that the low pressure

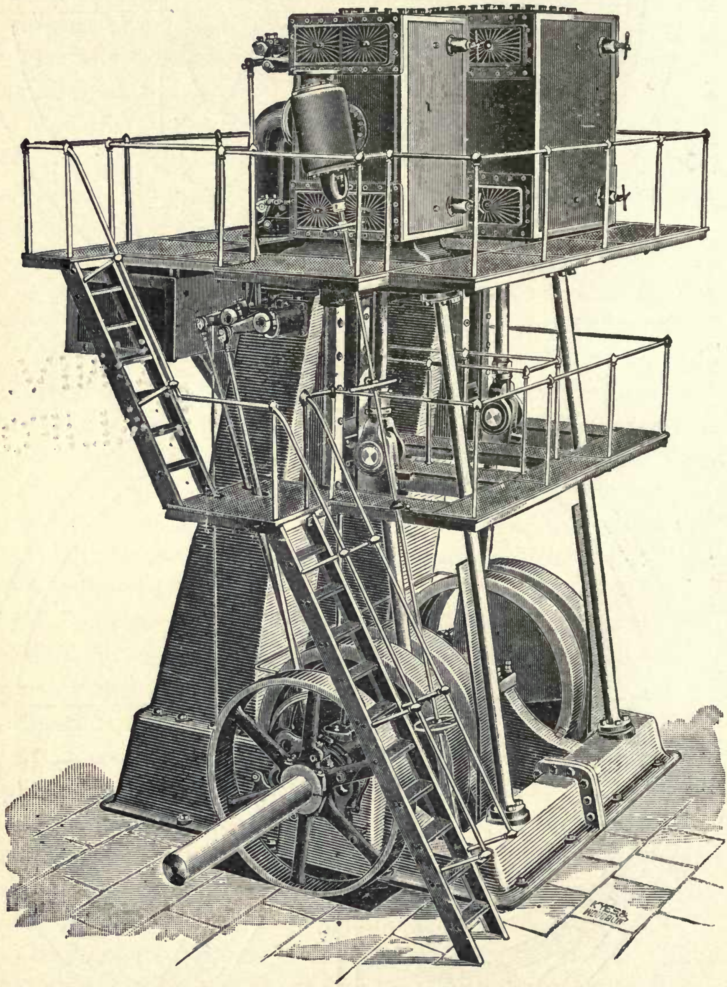


Fig. 60. McINTOSH AND SEYMOUR VERTICAL ENGINE.

The McIntosh & Seymour Engine.

head can be easily withdrawn, giving convenient access to the interior of the low pressure cylinder. Between the cylinders the piston rod runs in a packing tube or sleeve which is babbitted and bored out to fit the rod.

The bearings are provided with a positive feed self-oiling device. Rings at the end of bearings throw off escaping oil into shields, from whence it is conveyed to a large settling reservoir beneath the bearing provided with a gauge glass for determining the height of oil. A small pump driven from the valve gear forces a continuous supply of oil from the lower reservoir to one situated above the bearing, from which it is fed by gravity on top of the bearing, keeping it constantly flooded with oil.

Fig. 60 is a view of the McIntosh and Seymour vertical engine.

The following is a description of McIntosh and Seymour double piston valve: the main valve consists of a hollow cylinder with closed ends. This valve exhausts over the ends, taking steam from its interior through ports. This interior space is subdivided in the middle, and a light cylindrical sleeve, riding on the main valve in the steam chest and running over ports cut in its surface, forms a simple and efficient auxiliary or cut-off valve. The seat is split and contractible by the adjusting screw shown, and is held steam tight between the two fixed seat covers. To adjust the seat is a simple matter. After unhooking the valve connection with the eccentric, by moving the valve by hand, adjustment can be made with great nicety, without any danger of making too tight.

The governor used for double valve engines is precisely similar to that of longer stroke gridiron valve engines described on page 97. For single valve engines the arrangement of spring and centrifugal weights is similar, but the cut-off is varied by moving the eccentric across the shaft instead of revolving it upon the same.

THE IDEAL HIGH ART ENGINES.

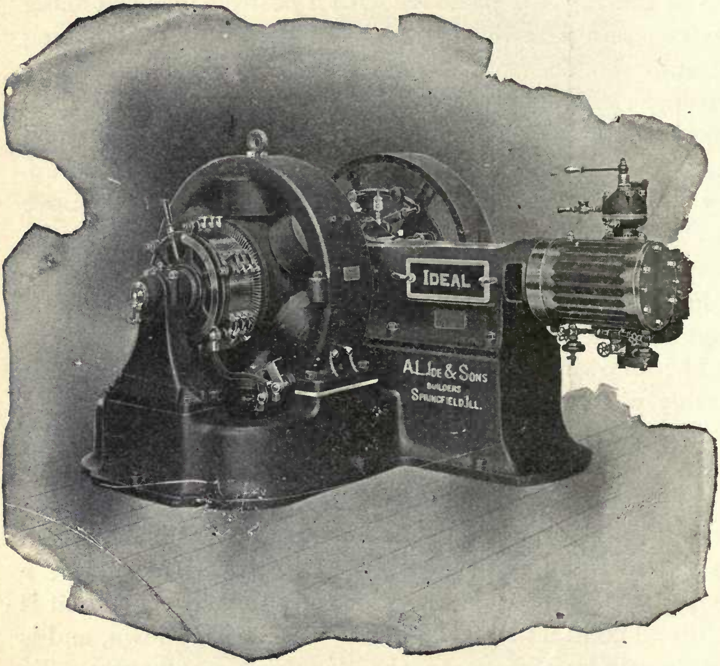


Fig. 61. The Ideal Engine—Direct Connected with Ideal Generator.

The above illustration represents the Ideal Engine (A. L. Ide & Sons, builders, Springfield, Illinois), direct connected to a dynamo.

This engine is in its improved standard form, automatic and self-oiling; it is self-contained, perfectly balanced, and when set upon sub-base the wheels clear the floor.

THE IDEAL ENGINE.

As shown by the engravings, the crank-disc of the Ideal engine is covered by a light hood, fitted to the top of the engine frame, but without bolts or fastenings of any description; it is, therefore, readily removed. The cross-head and guides are likewise fully enclosed; but a side plate for obtaining ready access thereto is also fitted oil-tight and held in position only by two cam handles, a quarter turn of which releases it; no oil can get to the belts or floor. The inside of engine-bed and all the parts that oil comes in contact with are pickled in muriatic acid and thoroughly washed, removing every particle of sand and dirt. The enclosure is dust-proof, and no oil is wasted.

The crank-pin and cross-head pin are not dependent upon the oil that is promiscuously thrown over them for lubrication. Special provisions are made for both. On the back of the crank-discs recesses are turned eccentric to the crank-shaft, from the widest part of this cavity holes are drilled diagonally through the crank-pin, through which oil is freely delivered by centrifugal force when the engine is in motion.

The valve of the Ideal Engine is of the hollow piston type, perfectly balanced, and the wear very slight. As the live steam is entirely on the outside of the tube, and the inside of tube only is in communication with the ends of steam chest, the tightness of the valve may at any time be tested by removing the steam chest covers and turning on full boiler pressure.

In the larger engines this valve is made double ported and the low pressure valve on tandem compound engines is a balanced flat valve, traveling under a cover which is held in place by springs and so arranged that steam is admitted through two ports at once, thus giving a quick opening at the beginning of the stroke.

THE IDEAL ENGINE.

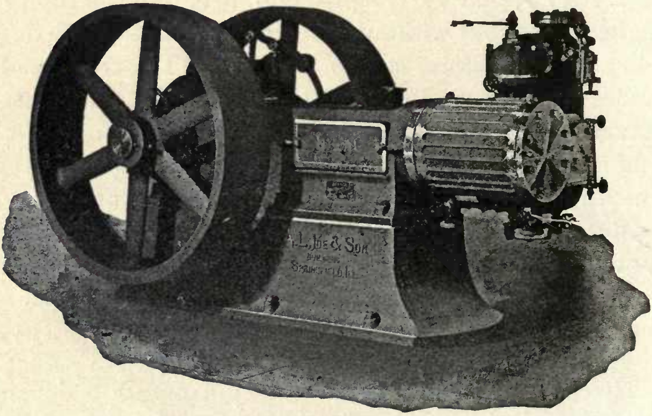


Fig. 62. THE IDEAL HIGH SPEED AUTOMATIC CUT-OFF ENGINE.

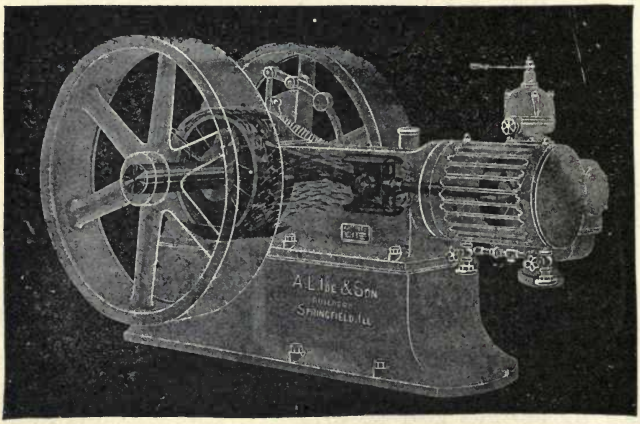


Fig. 63. THE IDEAL ENGINE. Transparent View of Fig. 62.

THE IDEAL ENGINE.

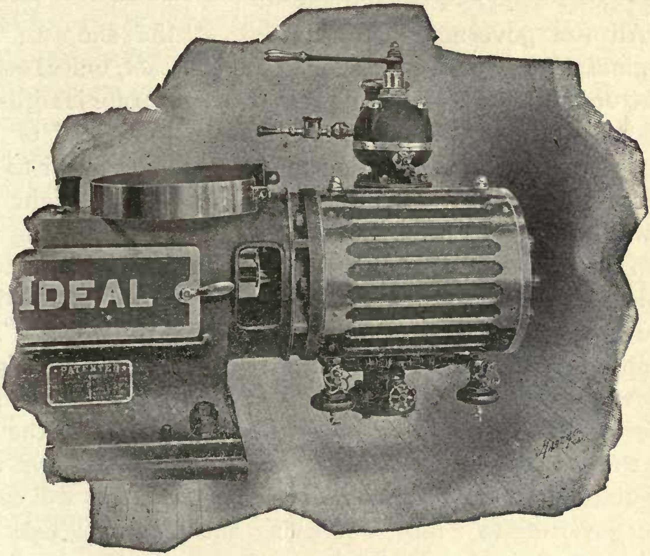


Fig. 64. QUICK-OPENING, SELF-PACKING THROTTLE. PATENT WATER RELIEF. EXPOSED CYLINDER BOLTS, COVERED WITH POLISHED BAND, AND VISIBLE PISTON-ROD STUFFING BOX.

The governor of the Ideal engine is of few parts—consisting as it does of but one spring, one lever (with adjusting weight) and connecting link to the shifting eccentric. All parts are in sight, and placed at such a distance from the shaft as to be readily accessible. The levers are steel and bearings are bushed with phosphor bronze, and all parts are made to gauge and interchangeable.

The dash-pot is to prevent any too sudden movement of the weights and levers, due to an instantaneous change of load, and avoids any violent fluctuations of speed. It also maintains the equilibrium of the force of weights and springs.

The Ideal Engine.

Directions for Governor Adjustment of the Ideal.

All the governors are adjusted at the shop to run engines at the speed called for in the contract, unless otherwise ordered. Assuming, now, that the governor is adjusted to a fixed speed, in order to increase the speed of the engine, move the weight on the governor lever near to the fulcrum pin. To reduce the speed, move the weight out toward the end of the lever. Tightening the spring will also increase the speed, but will cause the engine to "race," unless at the same time the block which holds the end of the spring is moved toward the center of wheel. The proper way to change the speed is by moving the weight, allowing the spring to remain in its marked position. Moving the block which holds the spring towards the rim of the wheel will make the governor more sensitive and regulate more closely, but if moved too far, this will cause the governor to "race." Moving the block towards the hub of the wheel has a tendency to stop the "racing," but if moved too far the speed of the engine will be reduced with the increased load. If any of the bearings of the governor bind, or require oiling or cleaning, the governor will "race." These bearings should be kept clean and in good condition, and the stuffing box to the dash-pot must not be screwed up tight, as that will cause the governor to "race" when set for close regulation.

The face of the slide is marked with a line where the outer edge of block which holds the spring should be. Figures stamped on the face of slide give length of end of eye bolt extending through nuts. This gives the right tension to the spring. Tightening the spring will give closer regulation, but will cause the governor to "race" if the spring is too tight. "Racing" caused by over tension of spring can be stopped by moving block nearer to center of wheel. Fill the cups on governor bearings with grease, and give the cap one quarter turn every day. Screw the

The Ideal Engine.

cap to the stuffing box on dash-pot loosely, only using your hand to turn the cap. The governor should be taken apart every two or three months, and bearings cleaned with coal oil to remove gum. The dash-pot should be refilled with glycerine once or twice a year. Oil may be used in the dash-pot in place of glycerine unless the engine is in a cold room, where the oil is liable to congeal. To refill dash-pot, unscrew cover on end.

In taking the governor apart, allow the sliding block which holds the end of the governor spring to remain with its outer edge on a line with the mark across the face of the slide, and in readjusting the spring, place the same tension on it as before, which can be ascertained by measuring the length of the thread through the nuts before slacking up the spring. The spring should be stretched out so there is $\frac{1}{16}$ inch between the coils. The speed of the governor is changed by moving the weight on the lever.

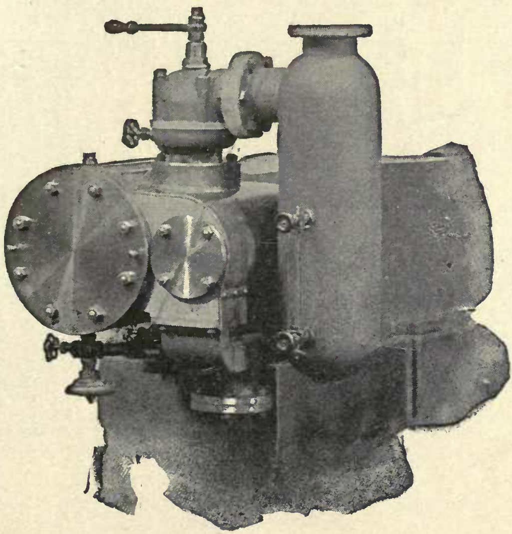
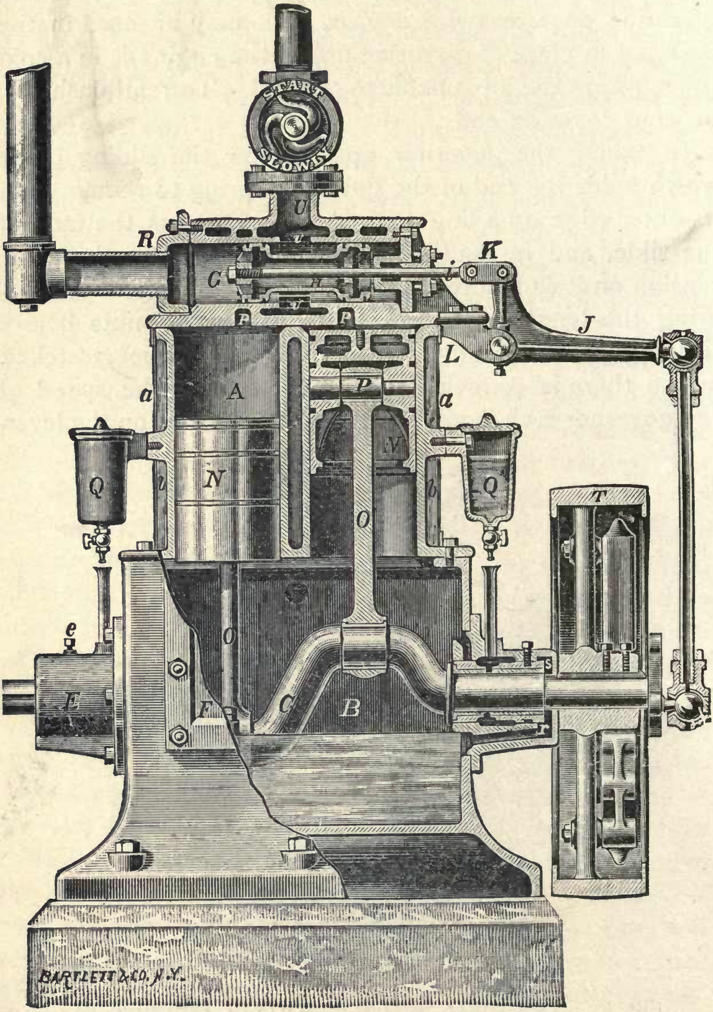


Fig. 65. The Ideal Steam Separator attached to Throttle Valve.

THE WESTINGHOUSE STEAM ENGINE.

This well known type of engine is built at Pittsburgh, Pa., by the Westinghouse Machine Co.

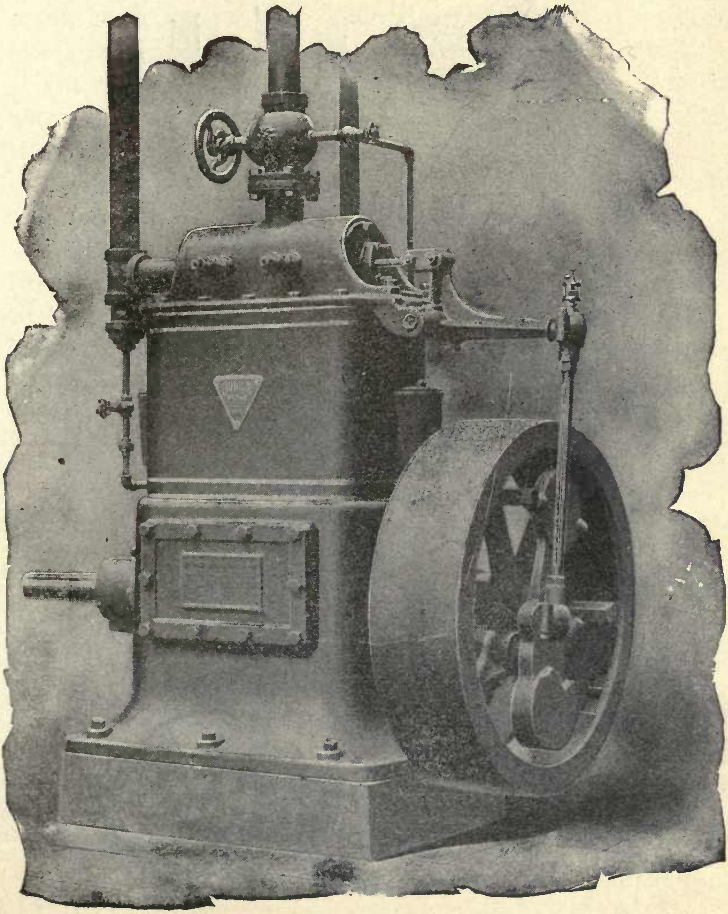


SECTIONAL VIEW OF WESTINGHOUSE JUNIOR ENGINE.

THE WESTINGHOUSE ENGINE.

The three illustrations given are of the class named "Junior" engines; two other principal patterns are also manufactured; the "Standard" engine built in 13 sizes, from 5 H. P. up, and the "Compound" built in 10 sizes, with steam pressure of 100 to 150 lbs.

All these classes are noted for close regulation and the self-oiling features; the details of the "Junior" here given



THE WESTINGHOUSE ENGINE.

apply in all essential particulars to the construction, etc., of the "Compound" and "Standard." Fig. 67 and 68 represent the front and rear view respectively of the "Junior" engine; Fig. 66 is a sectional view of the same.

Referring to the sectional view it will be seen that the valve *H* is of the hollow piston type, packed, steam tight,

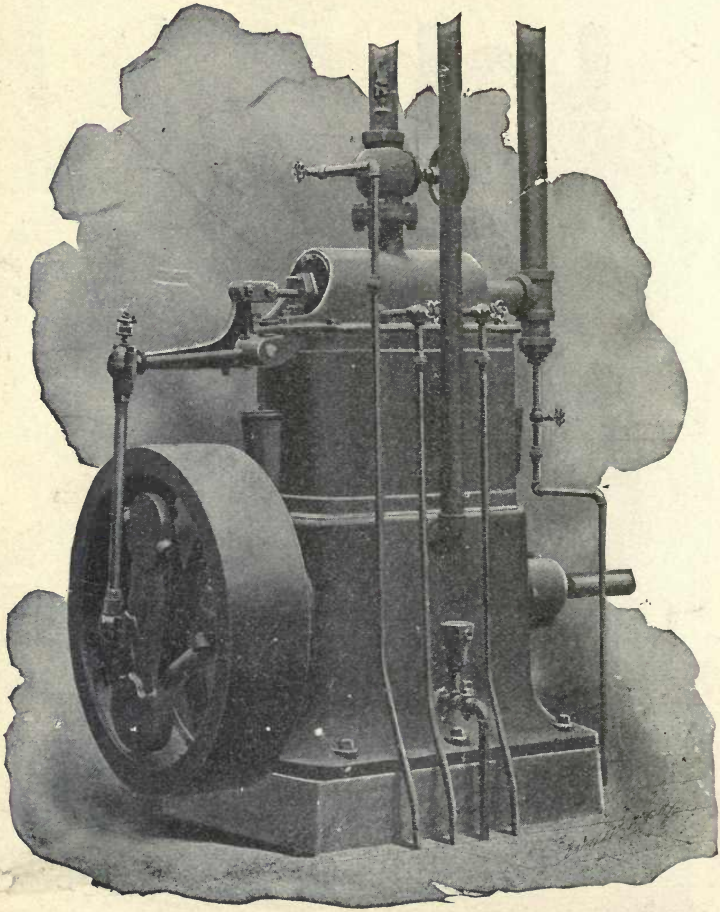


Fig. 68. REAR VIEW OF WESTINGHOUSE JUNIOR ENGINE.

THE WESTINGHOUSE ENGINE.

by springs. The steam ports *P* are in the heads of the cylinders, *A A*, which are single acting; the pistons *N N* are directly connected to the connecting rods *O O* by means of wrist pins.

The crank shaft and cranks *C* are forged in one solid piece and are enclosed in the oil chamber *B* which is formed by the frame of the engine. Access to this oil chamber can be had by the removal of plate *F*. One end of the crank shaft carries the shaft governor wheel *T*, which operates the valve by means of rocker arm *J* and link *K*.

The cut-off is regulated by an eccentric pin being thrown across the shaft through the action of the governor, thus varying the travel of the valve.

The steam enters at *U* at the center of the valve *H*, and exhausts at the ends through the exhaust pipe R.

The main bearings *E* are lubricated by the oil cups *Q* from the outside; all drips from the main bearings run through the channels *r*, into the oil chamber *B*.

The following is from the engineer's reference book furnished by the Westinghouse Company:

> "Having lubricated the engine thoroughly and set the several oil cups to feeding properly, open the cylinder cocks and the drain from the throttle; open the throttle slightly and start the engine very slowly.
>
> Let the engine gradually come up to full speed, and when the water has worked out of the cylinders and steam pipe, close the cylinder cocks and throttle drain. If there is any lost motion in the connections there will be a slight noise in the engine while it is below speed, but which will disappear when full speed is attained.
>
> "In shutting down, open the cylinder cocks and close the throttle very slowly, in order that the engine may lose its speed gradually."

Racine High Speed Engine.

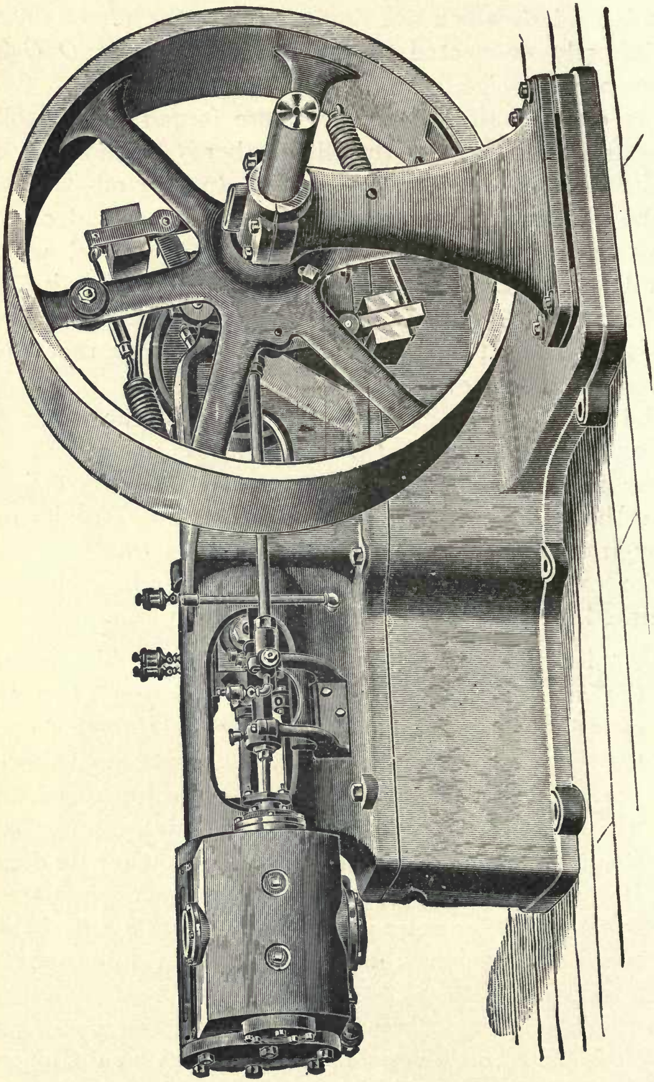


Fig. 69. Racine High Speed Automatic Engine.

RACINE AUTOMATIC ENGINES.

This type is shown in Fig. 69, representing a high speed automatic, self-contained, side crank engine. It is equipped with the automatic shaft governor, assuring economical use of steam and quick action in response to variations in the load carried.

The frame is rigid and of exceedingly tasteful design, adding greatly to the pleasing appearance of the entire

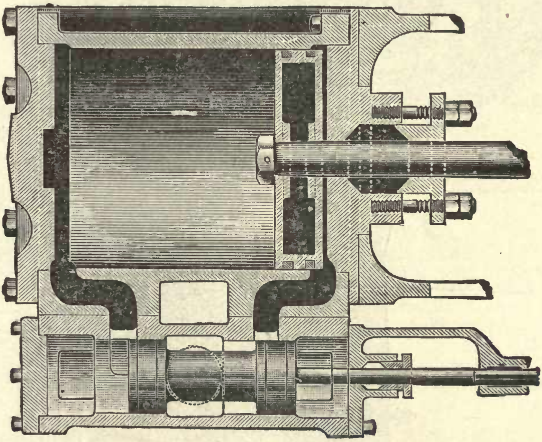


Fig. 70. Section Through Valve and Cylinder.

engine; a broad outbearing which gives additional steadiness of motion. The slides for the cross-head are cast solid in the frame, as also are the broad boxes for the shaft.

The valve is of the hollow piston type, balanced and fitted with rings which keep the joints tight and take up the wear as the surfaces wear down. Its average point of cut-off when the engine is giving its rated horse power is at one-quarter stroke, the remaining three-quarters of piston stroke being all accomplished by the expansive power of steam. The steam ports are of ample size, with easy curves, thus reducing wire drawing. Other details relating to the piston valve and cylinder are shown in Fig. 70.

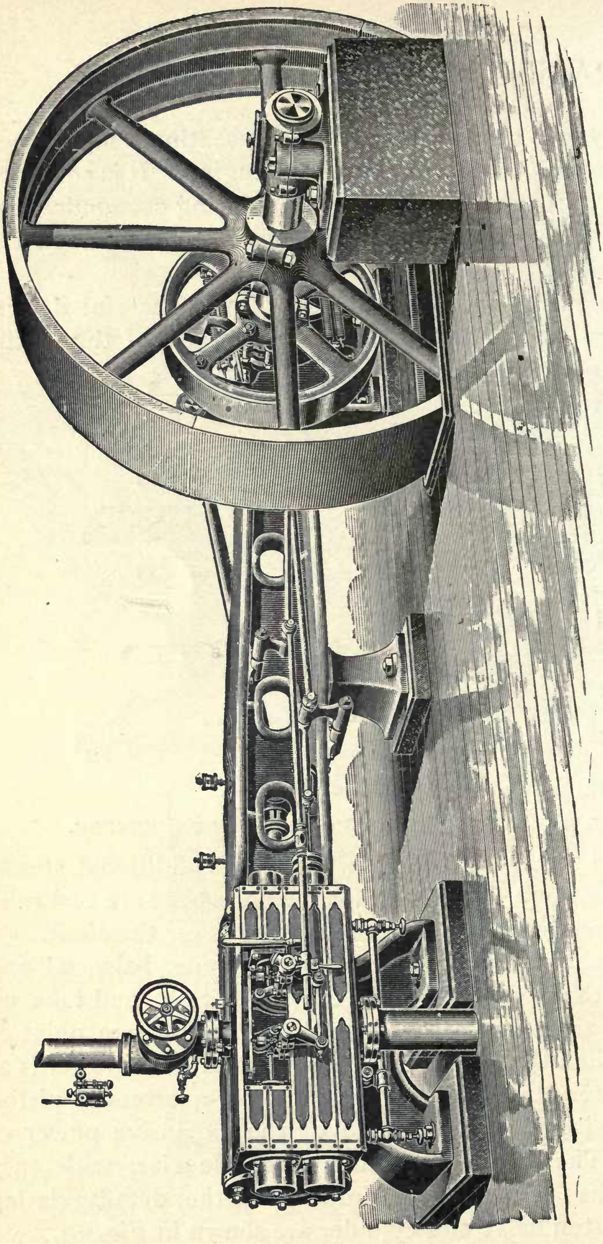


Fig. 71. The Fitchburg Automatic Engine.

THE FITCHBURG ENGINE.

This engine is made by the Fitchburg (Mass.) Steam Engine Co.* Fig. 71 shows the latest design of the horizontal automatic variable cut-off engine; Fig. 72 shows the improved wrist plate motion used to actuate the steam valves of the Fitchburg engine. The former wrist plate motion with its sleeve rod has been supplanted by this new device. It reduces the travel of the valves one-half and moves but one valve at a time, requiring, however, no change in the long used, perfectly balanced, expansible, double-ported valves, except in reduction by one-half of

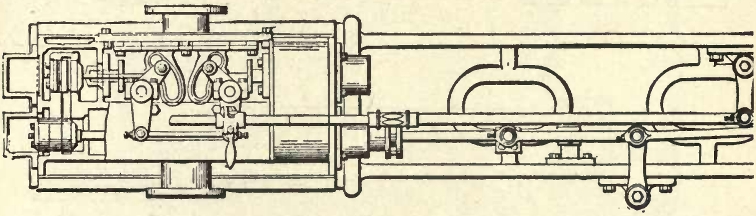


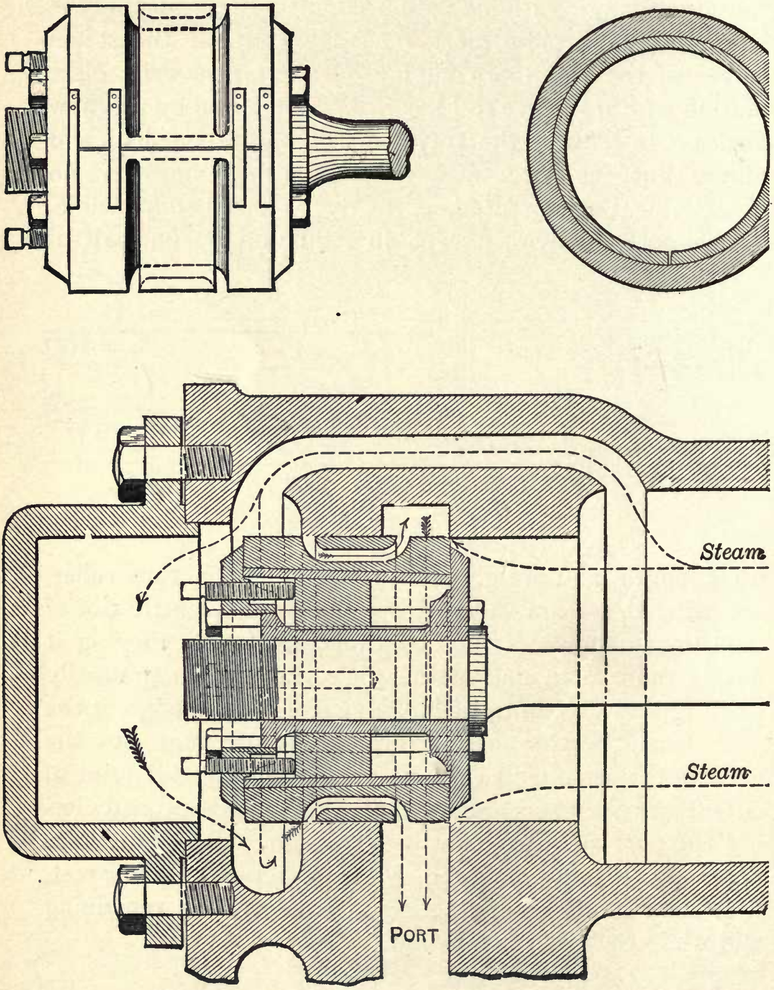
Fig. 72.

their length and weight. The wrist pin, or cam roller, actuating the steam valves, travels in the concentric slot of the cam, as shown plainly by the cut, without moving it during more than half of the pin's travel, then gradually starting the valve until its lap edge reaches the edge of the port, when by the special form given the cam slot the valve is thrown open suddenly, remaining open till point of cut-off and then as suddenly closed, thus opening and closing the port swiftly, the valves traveling only as far as is necessary to fully open the ports and return to their rest, the valves at either end acting alternately, one remaining still while the other is moving.

* Established 1871.

The Fitchburg Engine Valve.

The point of cut-off is automatically varied from nothing up to two-thirds of stroke with absolutely even speed. The quick movement of valves in opening and closing the ports, with the double ports in the valves, gives clean admission and cut-off.



Figs. 73, 74, 75.

The Fitchburg Engine Governor.

Two eccentrics are used for driving the independent steam and exhaust valves, all valves being perfectly balanced.

The steam inlet valves are worked direct by the cam wrist plate. The valves, as shown in Fig. 73, are of the piston type, four in number, and are expansible "by slacking the bolts bearing on the head of valve and tapped into

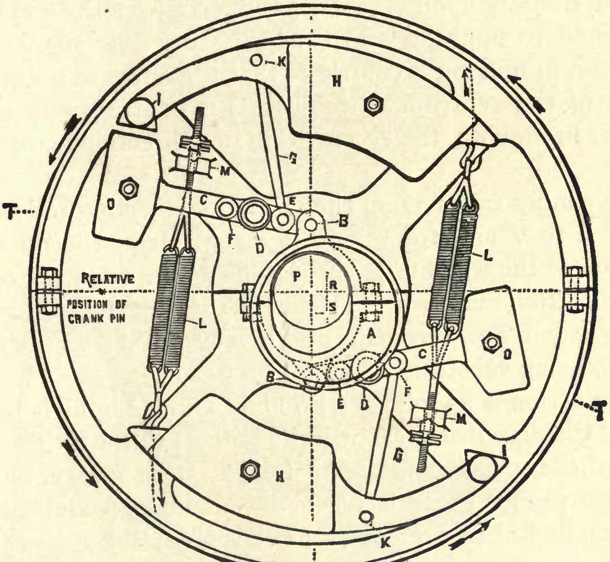


Fig. 76.

the central taper plug, then tightening those tapped through head and bearing against the taper plug, the latter is forced in and the valve expanded in diameter—the ten-thousandth part of an inch, or any amount needed up to one-sixteenth inch."

The cut needs no description, as the construction is so entirely simple as to be readily understood.

The governor, Fig. 76, is fastened to the crank shaft and is therefore a part of the shaft, making it impossible for the engine to run away, or for the governor to become detached

THE FITCHBURG ENGINE.

The weights O, acting over generous steel pins D as fulcra, are to exactly balance the weight of the eccentric and its strap, and in vertical engines the valve and valve rods also, leaving no work upon the governor but to shift the eccentric when the load upon engine changes. The connecting rod G is attached to the suspension arm C at E, acting directly upon eccentric, while the opposite rod G′ is attached to opposite arm C at F, acting over pin D as a fulcrum in moving eccentric so that the outward motion of both of the centrifugal weights H is exerted with equal power in moving the eccentric in one direction across the shaft.

By simply transferring the ends of connecting rods G G′ from E to F and from F to E respectively, the outward motion of the weights H throws the eccentric in the opposite direction and they are right for running the engine the other way, a new eccentric, also in halves and with opposite offset, being substituted.

The action is as follows: So long as the engine is below speed the eccentric is kept in its longest throw by the tension of the springs and steam follows ¾ of stroke, but as soon as proper speed is reached centrifugal action causes the weights H to overcome the tension of the springs and to move outward in direction of arrows, at same time lengthening the springs;—by means of the connecting rods G G′ the outward motion of the weights turns the suspension arms C upon their fulcra D and through the ears B the eccentric is carried across the shaft from S toward R, and as the arcs described by the centres B B are in opposite curves they compensate each other and the centre S of eccentric follows a straight line in its movement. This manifestly decreases the eccentricity and increases the advance of the eccentric, giving an earlier cut-off to the valve until when the eccentric is swung squarely back of the crank the valve opens only the lead, there being all

THE FITCHBURG ENGINE.

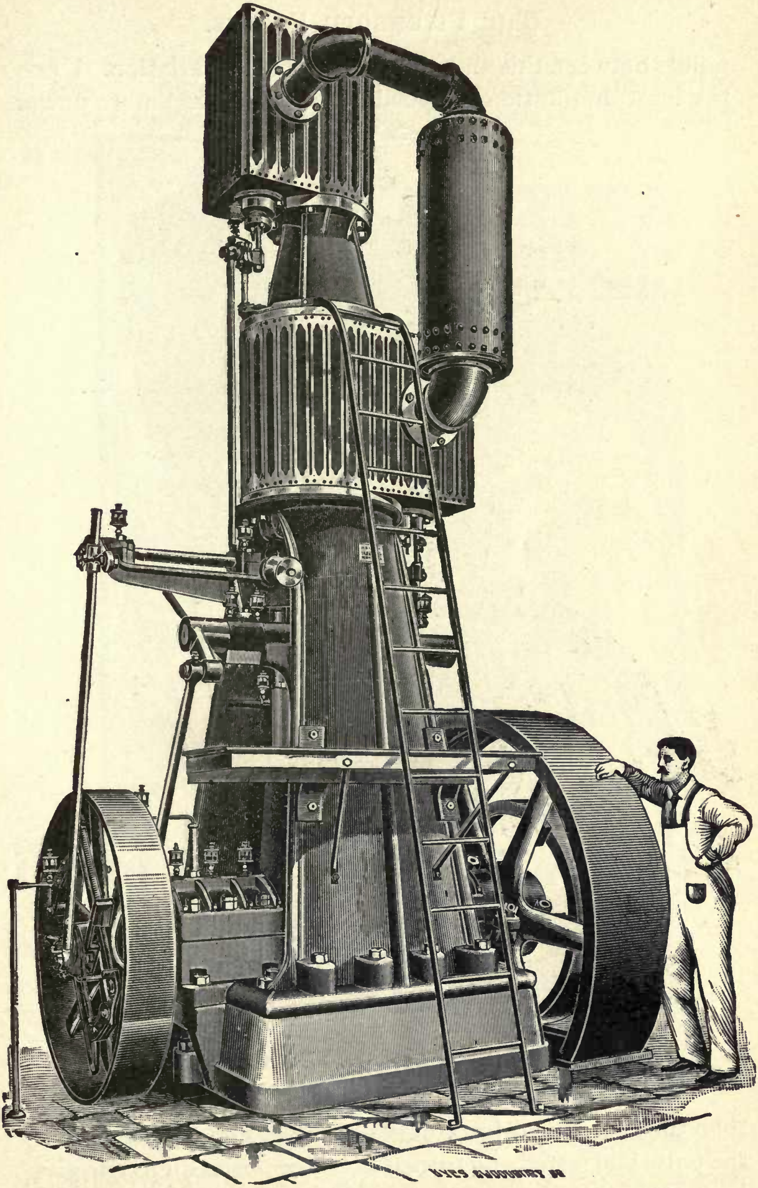


Fig. 77. THE FITCHBURG ENGINE, COMPOUND STEEPLE TYPE.

THE FITCHBURG ENGINE.

points between this and extreme cut-off for variation. Upon the least diminution of speed the springs have more power

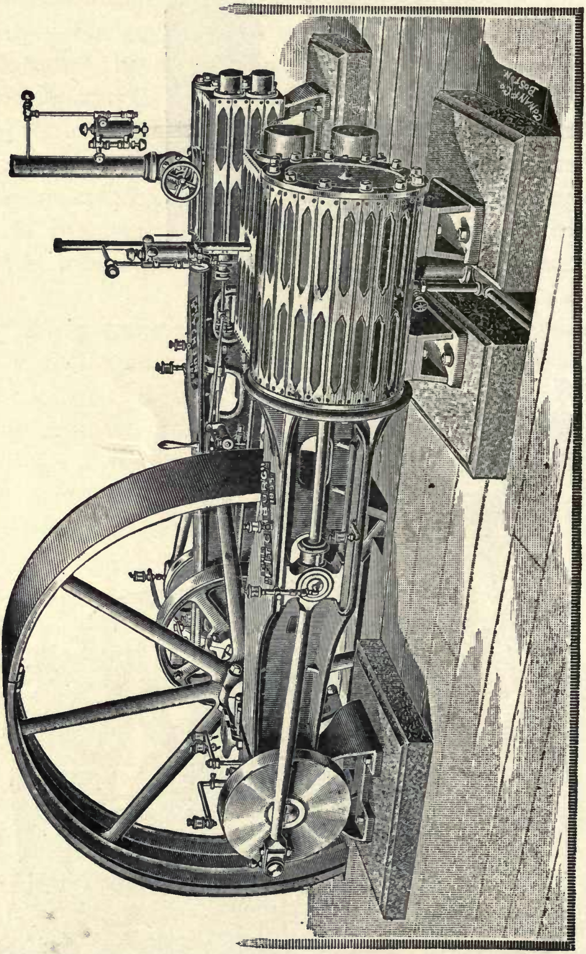


Fig. 78. THE FITCHBURG ENGINE, CROSS COMPOUND.

than the centrifugal force of the weights, and the motion of the parts is arrested and turned in the opposite direction, giving a later cut-off as more work is performed by the engine.

THE FITCHBURG ENGINE.

Fig. 77 represents the Fitchburg engine built in the steeple compound type. Fig. 78 shows the Fitchburg cross-compound.

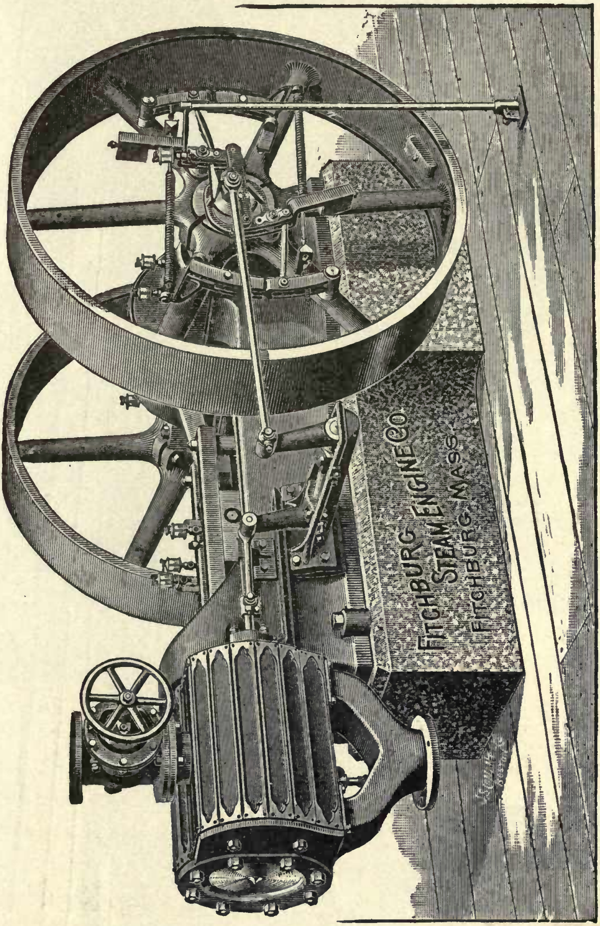


Fig. 79. HIGH SPEED AUTOMATIC FITCHBURG ENGINE.

This company also build high speed automatic cut-off engines with single valve and shaft governor, see Fig. 79.

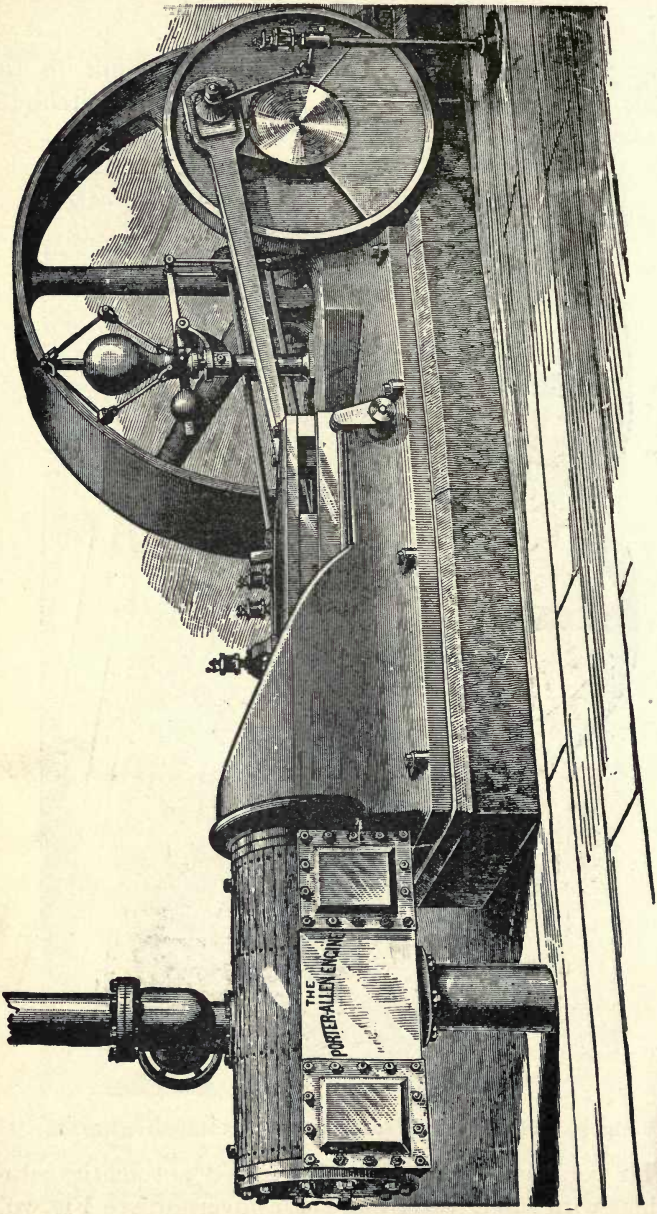
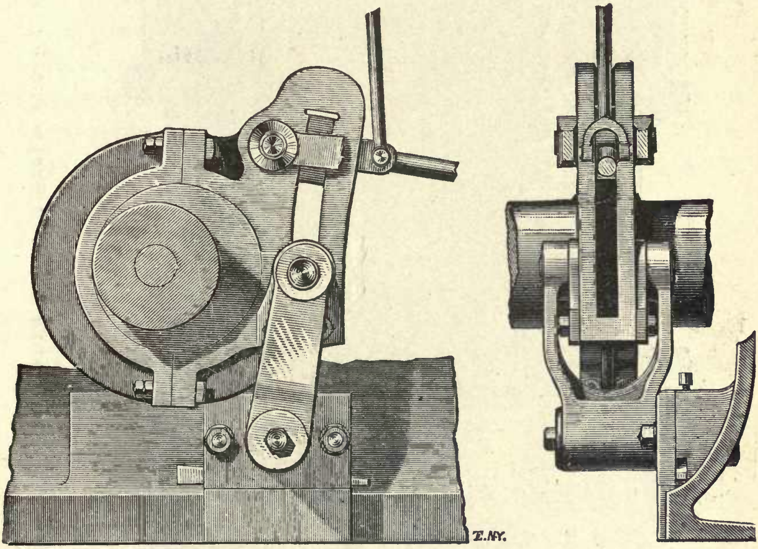


Fig. 80. Porter-Allen High Pressure Engine.

THE PORTER-ALLEN STEAM ENGINE.

These engines are built by the Southwark Foundry and Machine Co., Philadelphia, Pa., and claim the distinction of being the original high speed steam engine.

Fig. 80 represents the latest design of the Porter-Allen high pressure engine; this belongs to the class of four valve engines with two independent admission valves, controlled



Figs. 81 and 82. ECCENTRIC AND LINK, SIDE AND FRONT ELEVATION.

automatically, each adjustable without dismantling; and two exhaust valves operated independently of the admission, and giving a constant compression adjustable to different speeds. All four valves are absolutely balanced with four simultaneous openings to each port for admission and release of steam.

This engine employs a link motion of peculiar form to regulate the cut-off. The construction of the link is shown in Fig. 81. It is of the form known as the stationary link,

THE PORTER-ALLEN ENGINE VALVE.

and consists of a curved arm, partly slotted, formed in on piece with the eccentric strap, and pivoted at its middle

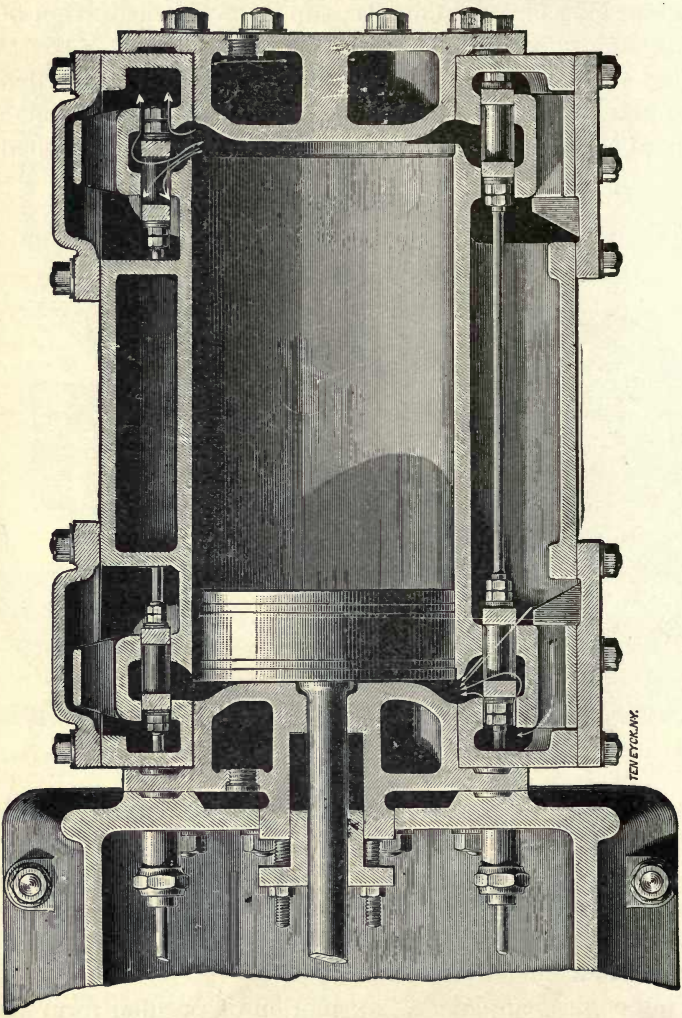


Fig. 83. HORIZONTAL SECTION OF CYLINDER THROUGH STEAM AND EXHAUST VALVES.

point on trunnions, which vibrate in an arc whose chord is equal to the throw of the eccentric, about a sustaining pin

THE PORTER-ALLEN ENGINE VALVE.

secured rigidly to the bed. The radius of the link is equal to the length of the first rod by which its motion is communicated to the admission valves.

In the slot is fitted a block from which the admission valves receive their motion. This block is moved by the action of the governor, which thus varies the point of cut-off. If the centre of the block is brought to the centre of the trunnions, the port is not opened at all, except by the lead given to the valves, and this opening is closed before the piston has advanced a sensible amount. If, on the other hand, the block is brought to the end of the slot, as here represented, the steam is not cut off until the piston has reached about six-tenths of the stroke, which is the limit of the admission.

The exhaust valves are driven from a fixed point on the link, and have, of course, an invariable motion. The movements of the link at this point are admirably suited to this function, causing the steam, wherever it may have been cut off by the admission valves, to be held until near the termination of the stroke, when it receives a free and ample release, and is confined again near the end of the stroke by the closing of the exhaust valves at a point which provides the compression required to arrest the motion of the reciprocating parts, and at the same time fill the end clearance of the cylinder with the compressed steam.

The peculiar motion of the link is given to it by a combination of the horizontal and the vertical throws of the eccentric. The horizontal throw alone only moves the link from one to the other of the lead lines, which motion only draws off the lap of the valves. The opening movement is produced by the tipping of the link alternately in the opposite directions beyond the lead lines, and these tipping motions are given by the vertical throws of the eccentric.

Its upward throw tips the link in the direction from the shaft, and opens the port at the further end of the cylinder;

THE PORTER-ALLEN ENGINE.

and its downward throw tips the link towards the shaft, and opens the port at the crank end of the cylinder. At the same time its horizontal throw is drawing the valve back, and when in this return movement, that point in the link at which the block stands, crosses the lead line, the steam is cut off.

The eccentric is placed on the shaft in the same position with the crank, and cannot be altered from this position. The lead of the valves is adjusted by other means. The first requirement of this system is, that the crank and the eccentric shall have coincident movements, and so shall arrive on their dead points, or lines of centres, simultaneously.

To insure the permanence of the eccentric in its correct position it is made to form one piece with the shaft.

The exhaust valves open and close their ports in such a manner that the opening is made while the valve is moving swiftly, and one-half of the opening movement has been accomplished when the piston arrives at the end of its stroke. The valves are so constructed that this portion of the movement opens the full area of the port, which does not begin to be contracted again until the centre line of the link has recrossed the lead lines on its return. The speed of the piston is then also diminishing, and the exhaust is not throttled at all until the port is just about to be closed.

The admission valves are both operated by two separate rods which in turn are operated by a wrist motion consisting of bell cranks and being connected by means of carrier arm to the sliding block in the link.

The valves are relieved of all steam pressure by pressure plates, the construction of which is represented in the section of the cylinder, Fig. 83.

On the lower side of the horizontal section both admission valves are shown, working between their opposite parallel seats, one of which is formed on the cylinder, and

THE PORTER-ALLEN ENGINE.

the other on the pressure plates, the latter having cavities opposite the ports.

The valve at the further end of the cylinder is at the extremity of its lap, while the one at the crank end has commenced to open the four passages for admission of the steam.

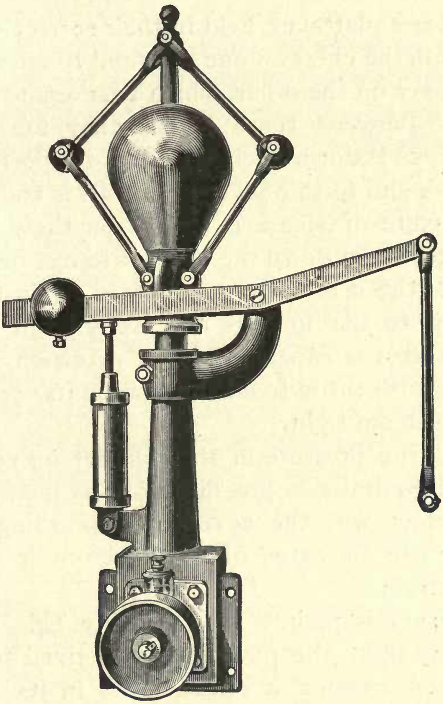


Fig. 84.

The pressure plates are made hollow, and most of the steam supplied to two of the openings passes through them; they are arched to resist the pressure of the steam without deflection, and rest on two inclined supports, one above and the other below the valve. These inclines are steep,

The Porter-Allen Engine.

so that the plates will be sure to move freely down them under the steam pressure, and also that they be closed up to the valves with only a small vertical movement.

They are prevented from moving down these inclines by a screw, passing through the bottom of the chest, the point of which, as also the plug against which it bears, is of hardened steel.

The pressure plates are held in their correct positions by projections in the chest on one side, and tongues projecting from the cover on the other, which bear against them near each end. Between these guides they are capable of motion up and down their inclined supports, and also directly back and forth between the valves and the covers.

The pressure of steam is always on these plates, and tends to force them down the inclines to rest on the valves. By means of the screws they are forced against the steam pressure, up to the inclines and away from the valves. This adjustment is capable of great precision, so that the valves work with entire freedom between its opposite seats, and still are steam tight.

Whenever the pressure in the cylinder exceeds that in the chest, the admission pressure plate is instantly moved back to contact with the cover, thus affording an ample passage for the discharge of water before it can exert a dangerous strain.

The governor is plainly shown in Fig. 84. The active parts are very light, the power being derived from a high rotative speed, causing a sensitiveness in its movements that will arrest fluctuations and produce uniformity in the running of the engine. The balls being propelled outward by centrifugal force will raise the pear-shaped weight and also one arm of a lever, thus lowering the other arm of the same lever, which in turn lowers the sliding block in the link by means of the connecting link shown in the cut, thus shortening the cut-off.

THE PORTER-ALLEN ENGINE.

To set the admission valves place the engine on its dead centre, then raise the governor, bringing the centre of the block between the centre of the trunnions of the link. With the governor in this position, set the valve that is about to open, giving from $\frac{1}{16}''$ to $\frac{3}{16}''$ lead according to the size and speed of the engine. Then turn the engine to the opposite centre and set the other admission valve in the same manner, bearing in mind that both admission valves travel to centre of cylinder to admit steam. After letting the governor down it will be noticed that the valve has moved a short distance, but this is as it should be, as when the engine is on the other centre it will give the same movement to the other valve; this is intended to equalize the cut-off on both strokes at the same points in the stroke from zero cut-off to the limit of cut-off of engine.

To set the exhaust valves have the engine on its dead centre and set the valve to open when the piston is from two inches to eight inches from the end of its stroke. The opposite exhaust valve is set in the same manner. The opening point is controlled by the speed and size of the engine. The brass check nuts on the valve stems must not be screwed up hard against valves, as that will cause them to bind. They should be free to move on the stem, but not too loose, as to cause knocking. Care must be taken in setting up the pressure plates and is best done when the engine is well warmed up, by opening the indicator cocks and backing the plate off until it allows steam to leak into the cylinder and then letting it down till the leak stops. After this work has been done the engine is ready for steam, when the indicator should be used for any further adjustment of the valves, especially the exhaust valves.

Fig. 85.

THE AJAX STEAM ENGINE.

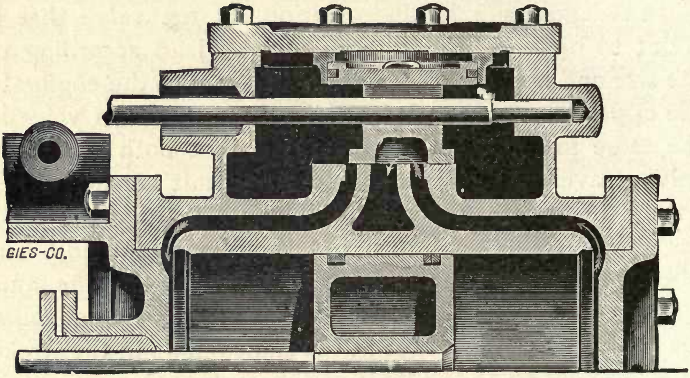


Fig. 86. BALANCED VALVE.

This engine is of the single slide valve type, with overhanging cylinder and locomotive guides.

The valve is balanced from all pressure higher than the exhaust by a relief plate on the back. The ports are long and extend below the bottom of the cylinder, thus providing perfect drainage. A single casting forms the cylinder and steam chest, which saves the necessity of packing the most difficult joint in the whole engine. The piston is cast hollow, thus making it as light as the requirements of strength will permit. The packing consists of narrow cast-iron rings turned eccentrically and larger than the bore of the cylinder, and sprung into grooves in the piston. These rings require but little adjustment, cause no undue friction or wear, and leave the piston free to move.

The above cut represents a sectional view of the valve, ports and piston of the engine. The valve is a common "D" slide valve, accurately balanced by a circular plate fastened to the back with hollow brass collar bolts, which

NOTE.—These engines are built at the Ajax Iron Works, Corry, Pa.

THE AJAX ENGINE.

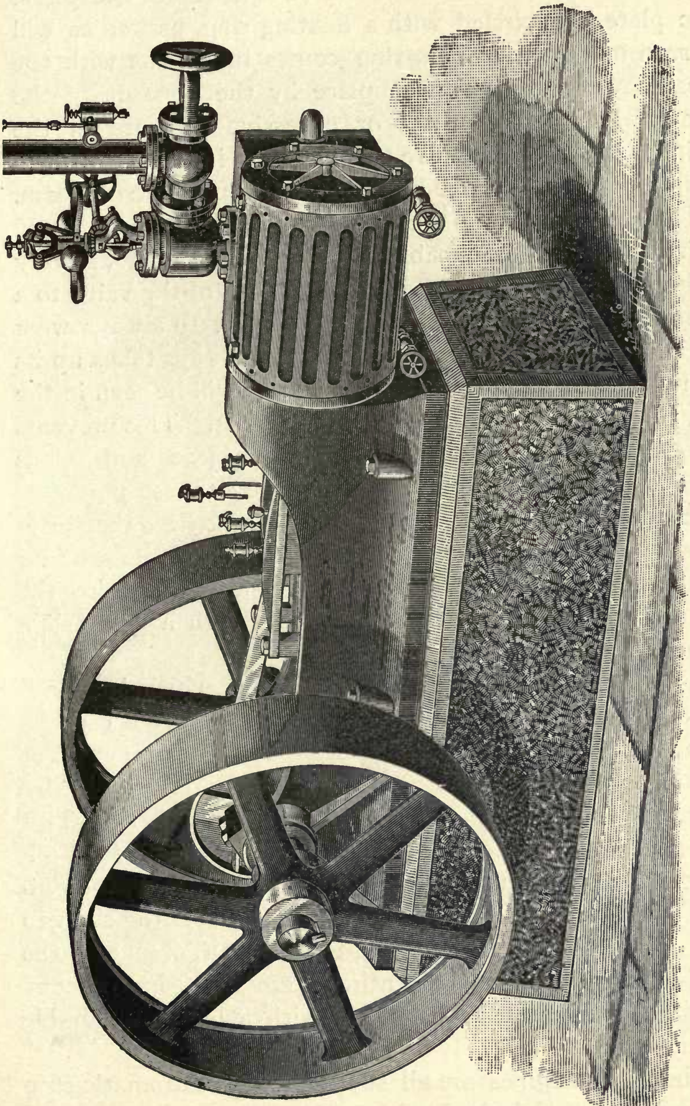


Fig. 87. AJAX STEAM ENGINE, BALANCED VALVE CENTRE CRANK.

THE AJAX ENGINE.

permit the exhaust steam to act on the top of the plate. The plate is encircled with a floating ring, packed as will be seen in the cut. This ring comes in contact with the chest cover and is kept in place by the pressure of the steam. In case of water or excessive pressure in the cylinder it allows the valve to raise from its seat, it can be easily operated with one hand under full pressure of steam.

The area of ports is ample for the highest piston speed which the engine is capable of sustaining. They are very long and narrow, which reduces the travel of the valve to a minimum, and permits the valve and seat to always wear straight, never concave or convex, and always takes up its own wear and remains steam tight. As will be seen in the cut, the ports enlarge after leaving the seat. This prevents wire drawing. The exhaust port is large and opens directly under the cylinder, whence the exhaust pipe may be conducted to either side. In the largest sizes the steam chest is nearly as long as the cylinder. The ports are four in number: two steam and two exhaust, which makes the steam passages as short as is possible with a "D" slide valve.

A variable eccentric is an attachment which is placed upon all Ajax throttling engines, and deserves especial mention; it can be reversed if desired, or steam cut off at any desired point from zero to three-quarter stroke by simply adjusting the eccentric across the shaft. This eccentric is graduated for three different points of cut-off. To change the point of cut-off, loosen two nuts on the outside of the eccentric, move the eccentric across the shaft to the desired point, and tighten the nuts. To reverse the engine, move the eccentric entirely across the shaft, accomplishing the result as easily as with a link and double eccentric.

The Ajax engines are all supplied with automatic stop governors, but if desired, with automatic cut-off governors.

WILLIAMS' ENGINE.

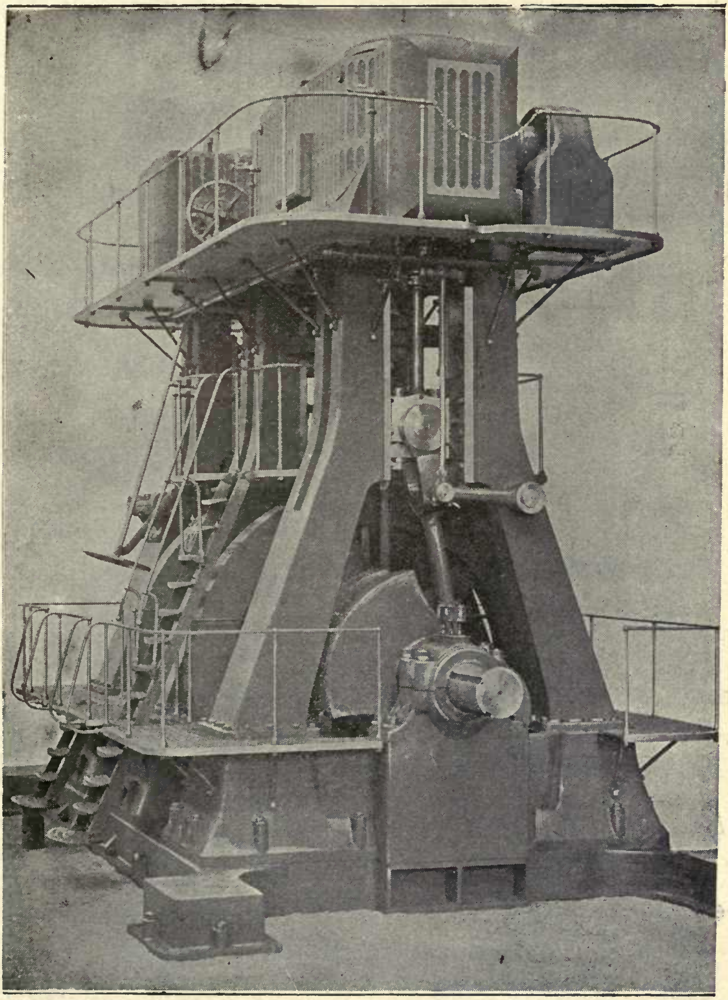
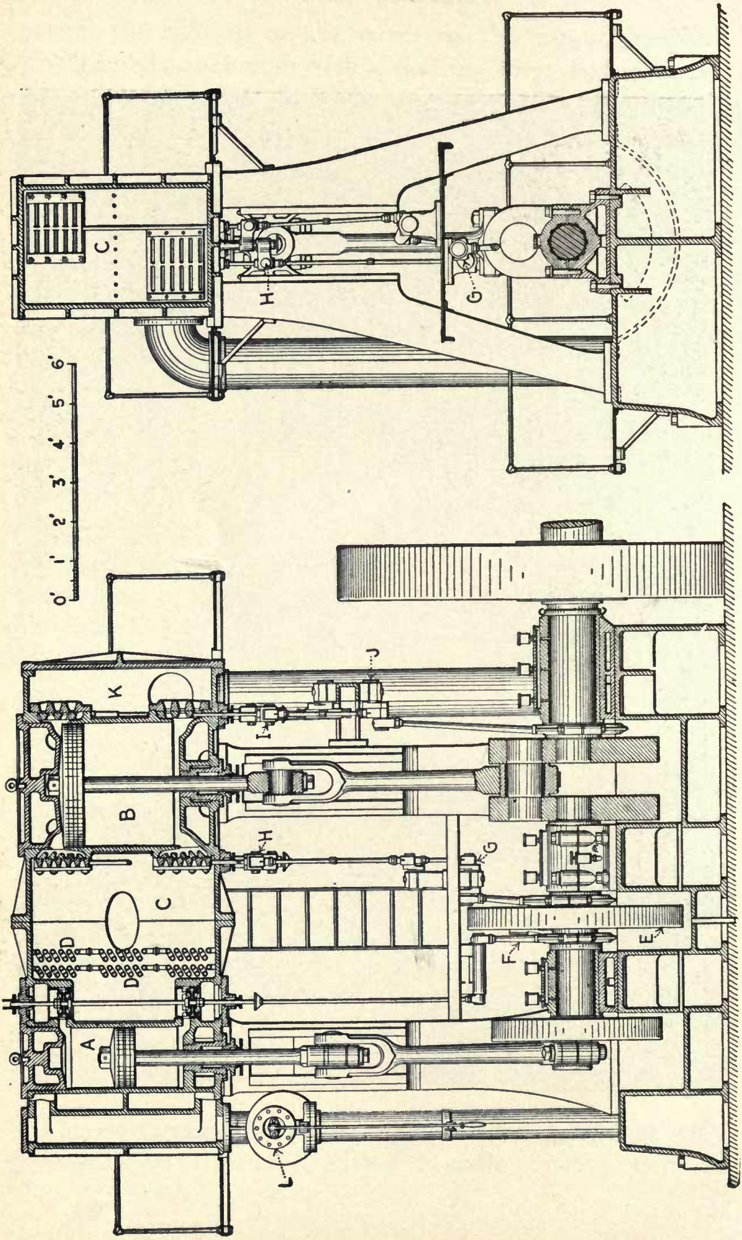
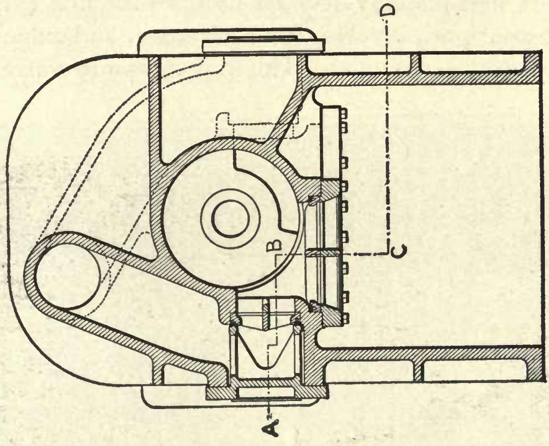


Fig. 88. WILLIAMS' IMPROVED COMPOUND VERTICAL ENGINE.

WILLIAMS' ENGINE.

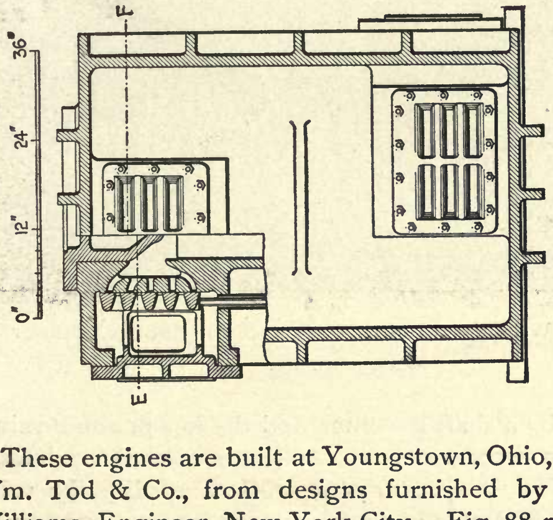


WILLIAMS' IMPROVED VERTICAL ENGINES.



Sectional Plan E-F.

Fig. 92.



Vertical Section A-B-C-D.

Fig. 91.

VALVES OF WILLIAMS' ENGINE.

These engines are built at Youngstown, Ohio, by Messrs. Wm. Tod & Co., from designs furnished by Mr. E. F. Williams, Engineer, New York City. Fig. 88 represents a **1200 H. P. compound vertical engine of this type.** In

Williams' Engine.

Figs. 89 and 90 are two sectional views of the Williams' vertical standard engine, 600 H. P., all parts drawn to scale. It will be seen that piston valves are used on the first cylinder, and flat multiported valves for both steam and exhaust on the low pressure cylinder. The high pressure valve is

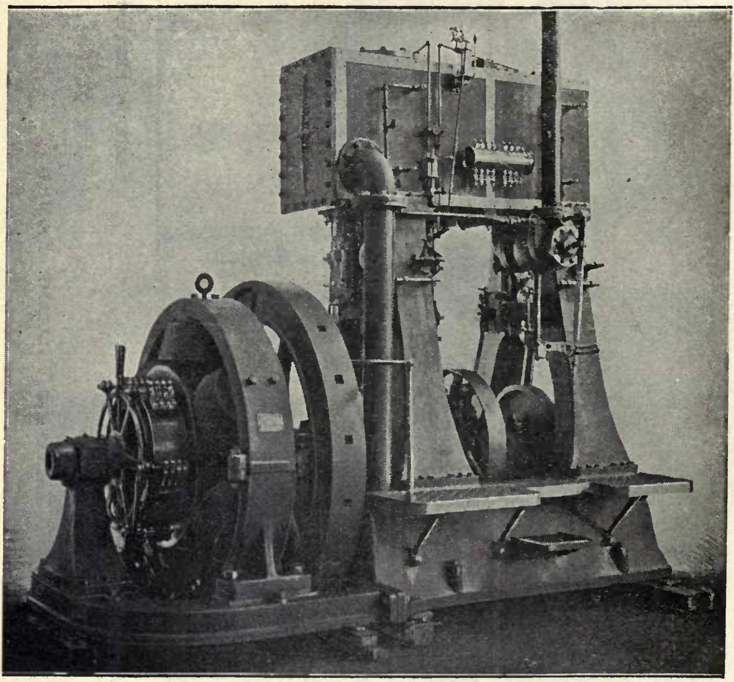


Fig. 93. Williams' Vertical Compound Engine, Direct Connected.

controlled by a shaft governor, and the low pressure valves driven from separate eccentrics (for steam and exhaust), and in each case quarter crank rockers modify the valve movements in such a manner as to get large openings with small travel.

WILLIAMS' ENGINE.

The piston valves may be briefly described. Two packing rings are used which are self-adjusting to wear, being held out against the bushing (thereby preventing leakage) by the steam pressures. To prevent the rings being set out too hard, as commonly occurs when "free ring" pack-

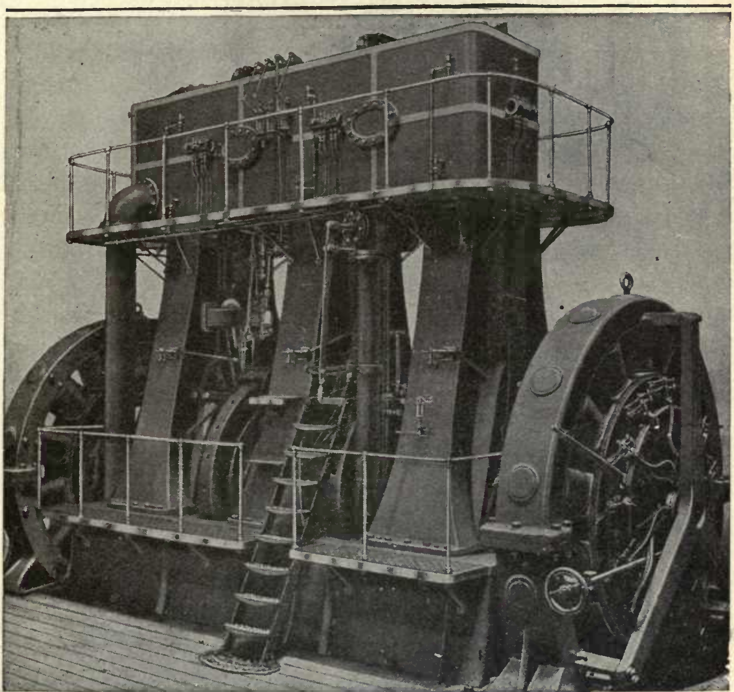


Fig. 94. WILLIAMS' VERTICAL TRIPLE EXPANSION ENGINE, DIRECT CONNECTED TO DYNAMO.

ing is used, a peculiar construction is introduced by fitting the rings steam-tight against the flange joints and forcing them against it by the introduction of short helical springs between the upper or steam ring and the central ring, which is one solid band, separating the packing rings. The result is a light-running, durable, tight piston valve.

WILLIAMS' ENGINE.

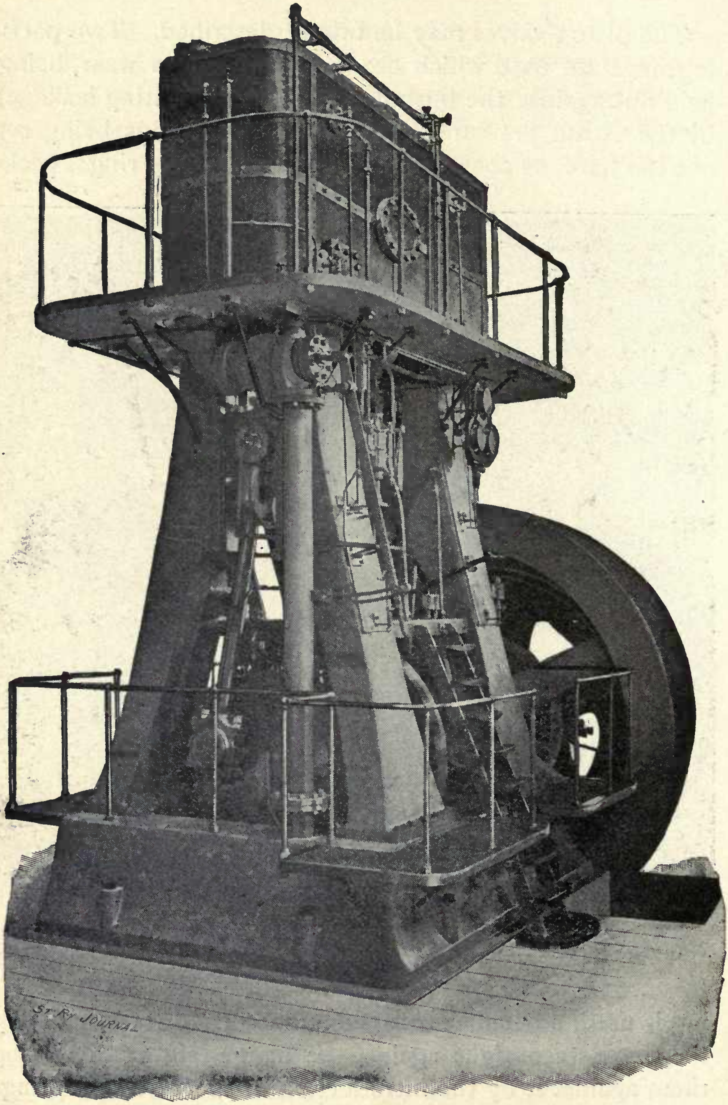


Fig. 95. WILLIAMS' IMPROVED VERTICAL ENGINE, DIRECT CONNECTED TO A GENERATOR FOR RAILWAY AND POWER SERVICE.

WILLIAMS' ENGINE.

The standard Williams' engines have piston valves in the high pressure cylinders of compounds and in the high pressure and intermediate cylinders of triple engines. They are not confined to this valve system, however. The engravings, Figs. 91 and 92 show the arrangement of multi-ported flat valves (gridiron type) as they are applied to the high pressure cylinders of compound engines when flat valves are desired for both cylinders. By arranging the steam and exhaust valves as shown, they are quite accessible and the percentage of cylinder clearances is reduced to a proper amount, not exceeding 5 or 6 per cent.

The governor is mounted on the shaft as shown in the figures. Two weight arms are used—on same side of shaft —and two springs, and in some cases a small adjusting spring. The weight arm is pivoted on roller bearings and the springs are hung on knife edges. Cut-off is regulated by the governor turning the eccentric upon the shaft.

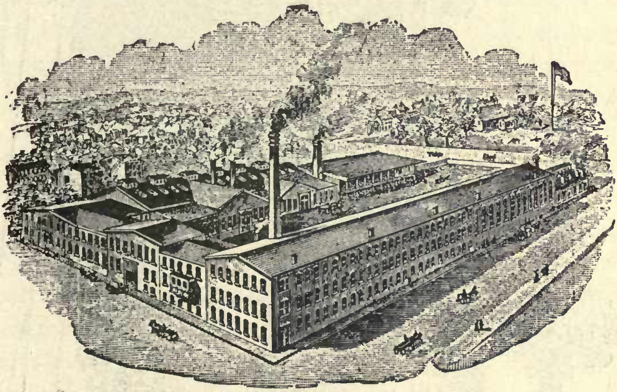


Fig. 96. MODERN STEAM ENGINE WORKS.

THE METROPOLITAN ENGINE.

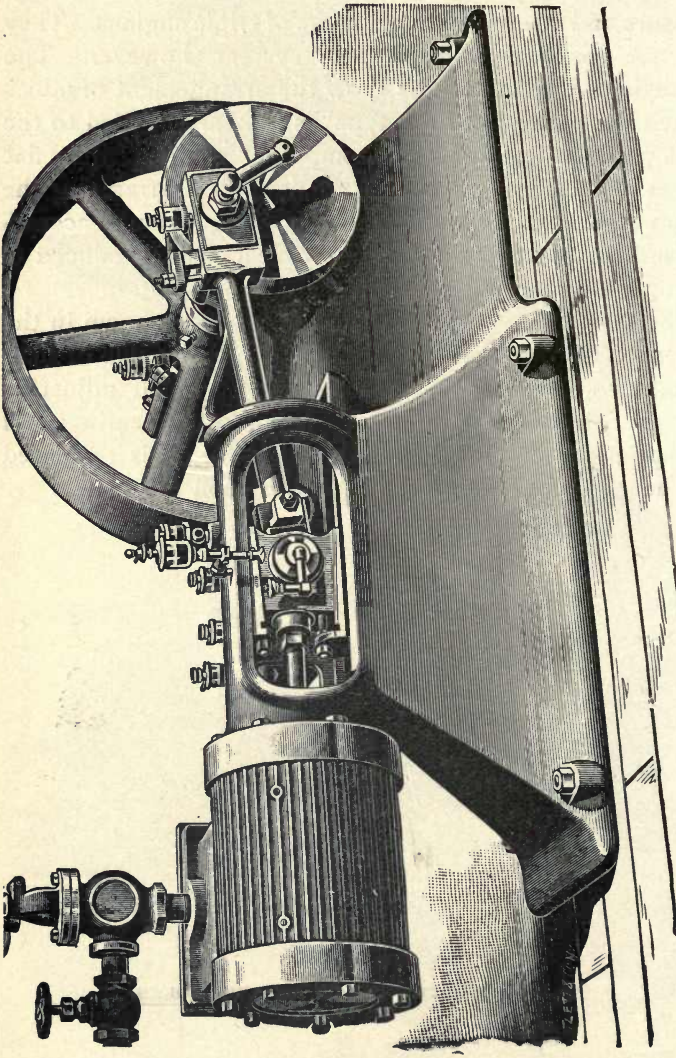


Fig. 97. THE METROPOLITAN SIDE CRANK SELF-CONTAINED ENGINE.

THE METROPOLITAN ENGINE.

This engine is self-contained with side crank as shown in Fig. 97, its essential features being the arrangements for taking up the wear, also the self-contained base.

The guide portion of the frame is cast in the form of a hollow cylinder, the front side being removed to give access to the cross head, and the edges of the opening are strengthened. A strengthening ring is also cast about the end next to the crank which firmly connects the top guide with the bed, avoiding any tendency to spring. The form of the bed, with outer pedestal connected, combines a rigid base so that the engine runs very steadily upon no other foundation.

The bed is extended beyond the main bearings, as well as at the cylinder end, and at an angle of 45 degrees, and includes the outboard bearings, making the engine side crank, self-contained, setting entirely upon its own base. The space between the main and outboard bearings is sufficient to admit the eccentric, governor belt pulley and driving wheel; the shaft is extended beyond the outboard bearing for an extra pulley. The head or back end of the bed is turned and faced true with the guides, and forms the front head of the cylinder, which is of the over-hanging type, and is scraped and bolted substantially to the bed in such a manner as to secure perfect alignment and security against leakage.

The piston-rings are self-adjusting, and are furnished with steel springs and set bolts. The piston-rod is of steel, screwed into the cross-head and secured with a jamb nut. The cross-head sets vertically and is provided with wedge-shaped shoes made of gun metal and shaped oval top and bottom, which are easily adjusted on the studs with a nut on each side of the flanges. The cross-head pin is hollow with drop oiler attached so as to oil when running.

NOTE.—Made by Donegan & Swift, No. 6 Murray St., N. Y.

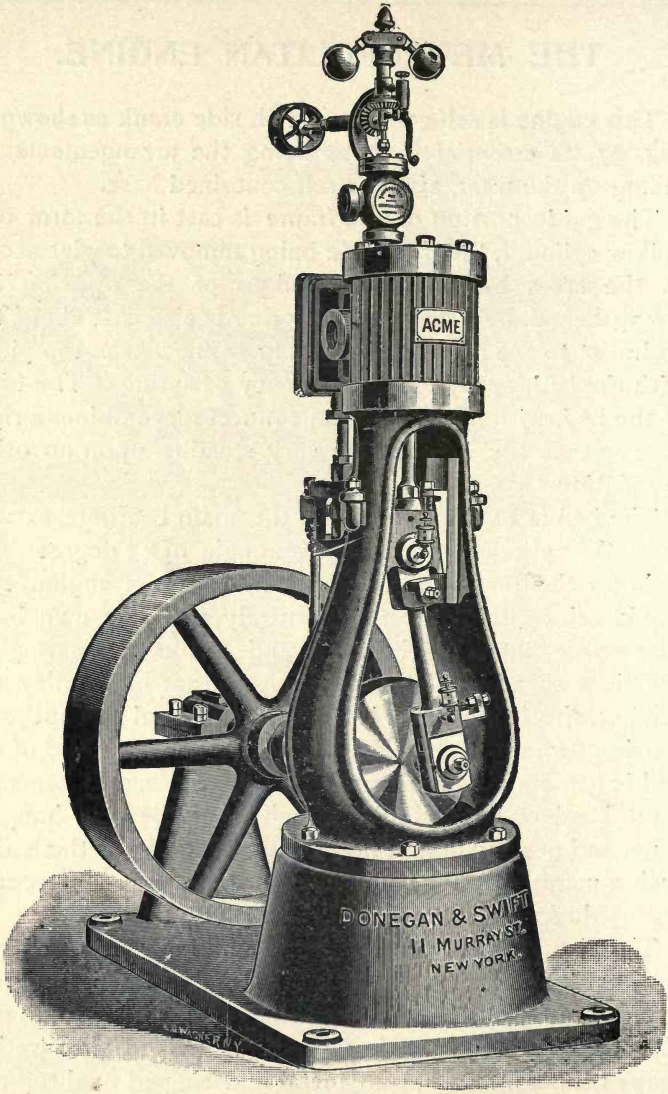


Fig. 98.

The eccentric rod and valve stem are of steel; a plain D slide valve is used, and the ports are ample for the rated horse power.

In Fig. 98 is shown a vertical engine of the same type.

THE BALL ENGINE.

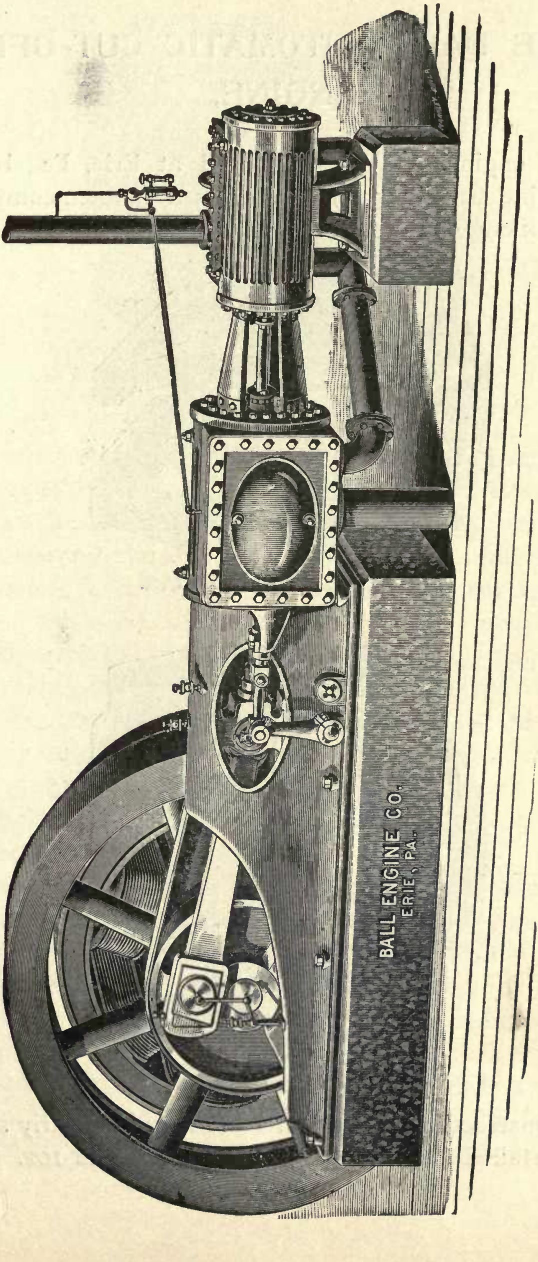


Fig. 99. THE BALL TANDEM COMPOUND ENGINE.

THE BALL AUTOMATIC CUT-OFF ENGINE.

These engines are manufactured at Erie, Pa., by the Ball Engine Co. Fig. 99 represents a tandem-compound side crank engine, direct connected to a dynamo.

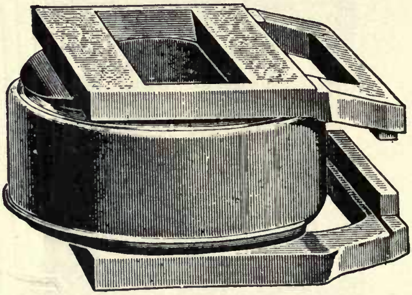


Fig. 100. THE BALL VALVE.

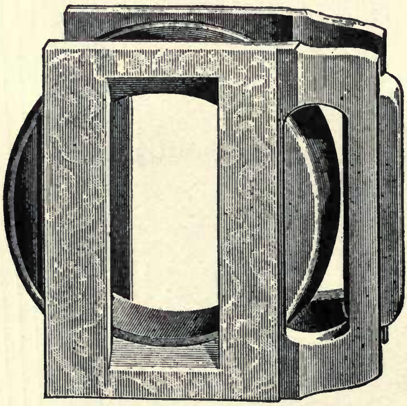


Fig. 101. THE BALL VALVE.

The construction of the Ball valve is quite clearly shown by the detailed illustrations, Figs. 100, 101 and 102.

THE BALL ENGINE.

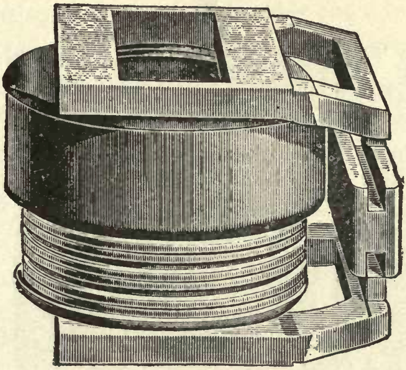


Fig. 102. THE BALL VALVE.

It consists of two parts telescopically connected; this permits each part to adjust itself to its seat. Referring to Fig. 100, the manner of its adjustment to its seats will be made clear by the explanation that steam enters at the top, forcing, in its efforts to escape, the upper and lower parts of the valve apart until each rests squarely, and steam-tightly against its seat, and this forcing apart is continuous, and constant from one end of the stroke to the other. Fig. 101 is here embodied simply to indicate position the valve may take in the various constructions, while Fig. 102 is given showing exaggerated separation to indicate what slight frictional contact one part of the valve has to the other.

In Fig. 103 is presented a vertical sectional view of the steam chest and valve which will make clear the manner of operating the valve, and the steam distribution to the cylinder, and, it will be noted that, the combined port areas represent most liberal openings through which the steam passes to each end of the cylinder up to very nearly the point of actual closing of the valve, while the same freedom is present for the discharge of steam from the cylinder into the chest and thence into the exhaust pipe.

THE BALL ENGINE.

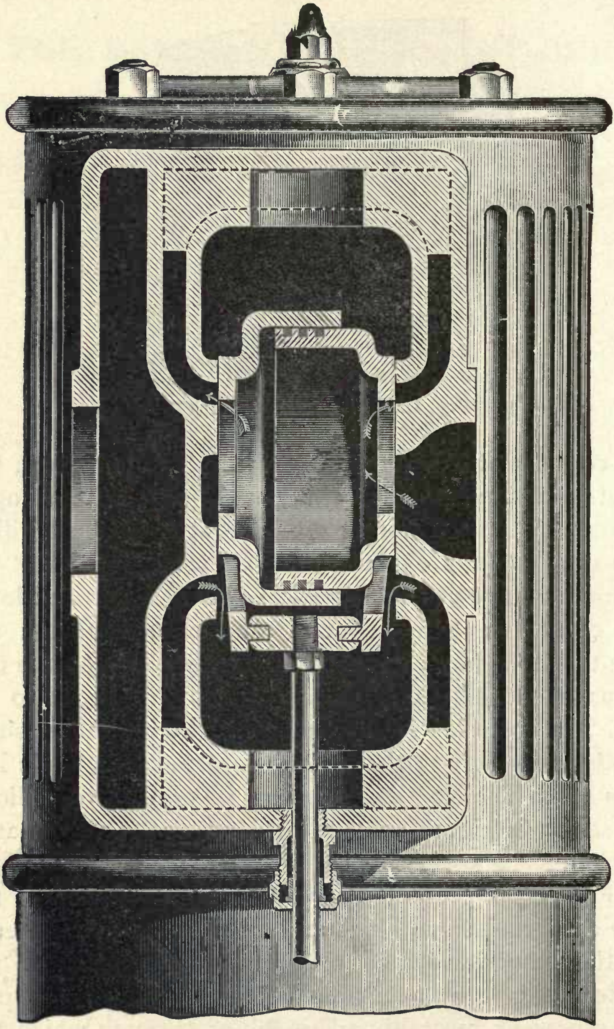


Fig. 103. THE BALL VALVE—CHEST AND VALVE—SECTIONAL VIEW.

The regulator (Fig. 105) is an adaptation of the "Rites governor system" by which all the working parts are practically reduced to a single moving piece swinging

The Ball Engine.

on a common supporting pin thereby reducing the friction to a minimum, with no joints to interfere with the best action of the governor.

The Ball engine is made in the various forms usual to the modern construction. Fig. 104 represents the vertical cross-compound engine.

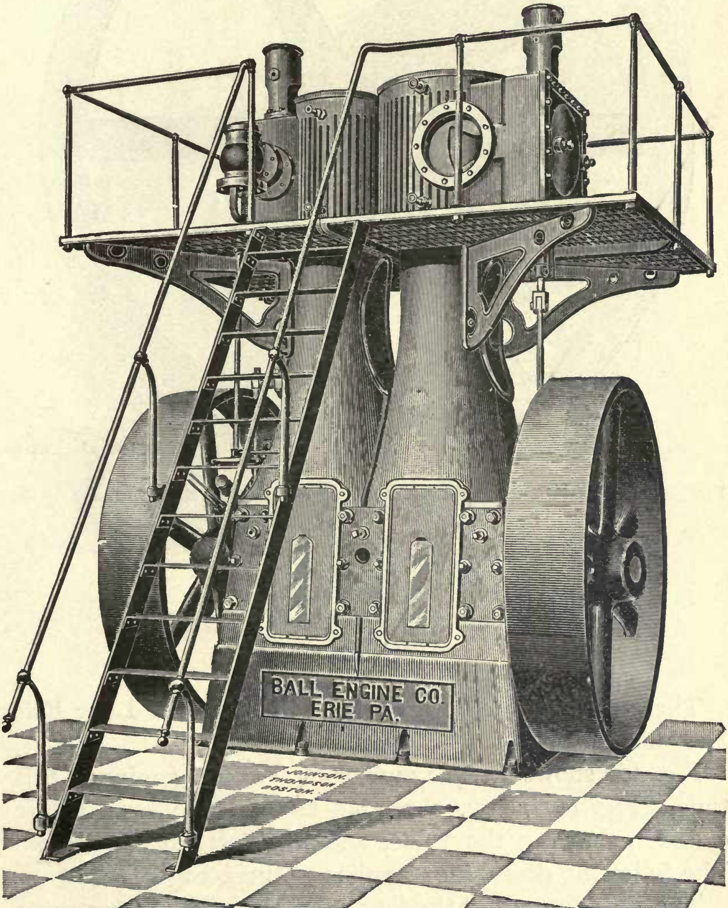


Fig. 104. Vertical Ball Cross Compound Engine.

THE LAKE ERIE ENGINE.

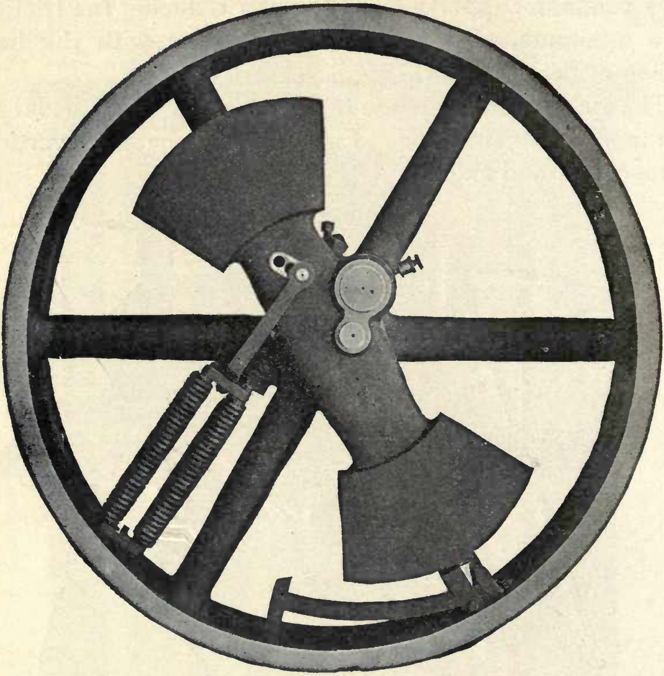


Fig. 105. THE RITES GOVERNOR AS APPLIED TO THE BALL ENGINE.

LAKE ERIE ENGINES.

These engines are designed and built by the Lake Erie Engineering Works, at Buffalo, N. Y.

Fig. 106 shows a triple expansion, vertical engine of this type. Fig. 107 shows a section through the low pressure cylinder, showing the valves and working parts in detail. The following description applies to these engines.

The cylinders are of the four valve type, having two ports for steam and two ports for exhaust. The clearances vary

THE LAKE ERIE ENGINE.

from two and one-half or three per cent. to seven per cent., according to the diameter of the pistons, being least on the greater diameters.

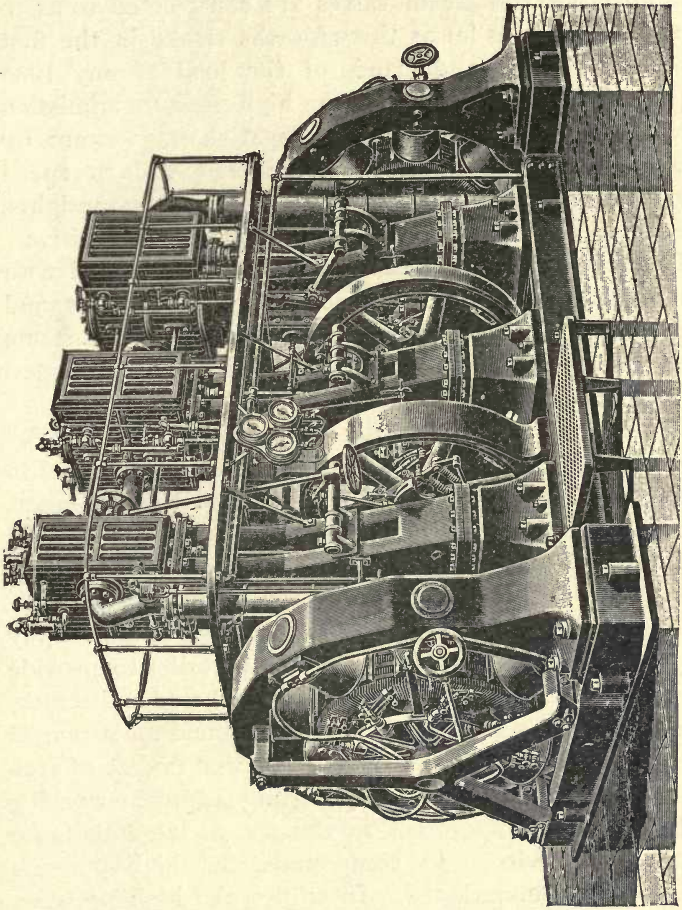


Fig. 106. LAKE ERIE ENGINE—TRIPLE EXPANSION.

The valves are of the double-faced slide type, and are small, light and four ported. The high pressure steam valve is wnolly balanced, and the others, working under

THE LAKE ERIE ENGINE.

light pressures, are operated by independent gear. The lap is adjustable, permitting of the most advantageous setting for either condensing or non-condensing service. The governor and steam valves are constructed so as to carry the steam as far as three-fourths stroke in the first cylinder, should the demands of the load at any time require it. The movement of the high pressure admission valve is controlled by the centrifugal shaft governor, by means of which the engine is regulated as regards the speed of revolution. The governor, which has only two weights, one spring and four pivoted joints, is extremely sensitive.

The cylinders are substantially and neatly lagged with iron, and the intervening spaces between cylinders and lagging filled with non-conducting material. The steam chest covers are provided with panelled or corrugated hoods and polished on the exterior surface.

The frames supporting the cylinders are of the "A" type of double box columns of cast iron securely bolted to flanges on the bottom of the cylinder and the bed plate. The slides are on the inner surfaces of the columns, the bed plate is heavy and substantially designed, and especially arranged for direct coupled generators when desired.

On account of the severe service to which street railway engines especially are subjected, and in order to provide for emergencies, all bearings are water jacketed and removable. The slides are also water jacketed and are arranged so they can be easily removed and renewed in case of accident. This point of water jacketing all main working parts is of vital importance in the use of large units for continuous service. In compounds, the high pressure cylinder is steam jacketed. In triples, the high pressure, as well as the intermediate pressure, is steam jacketed.

THE LAKE ERIE ENGINE.

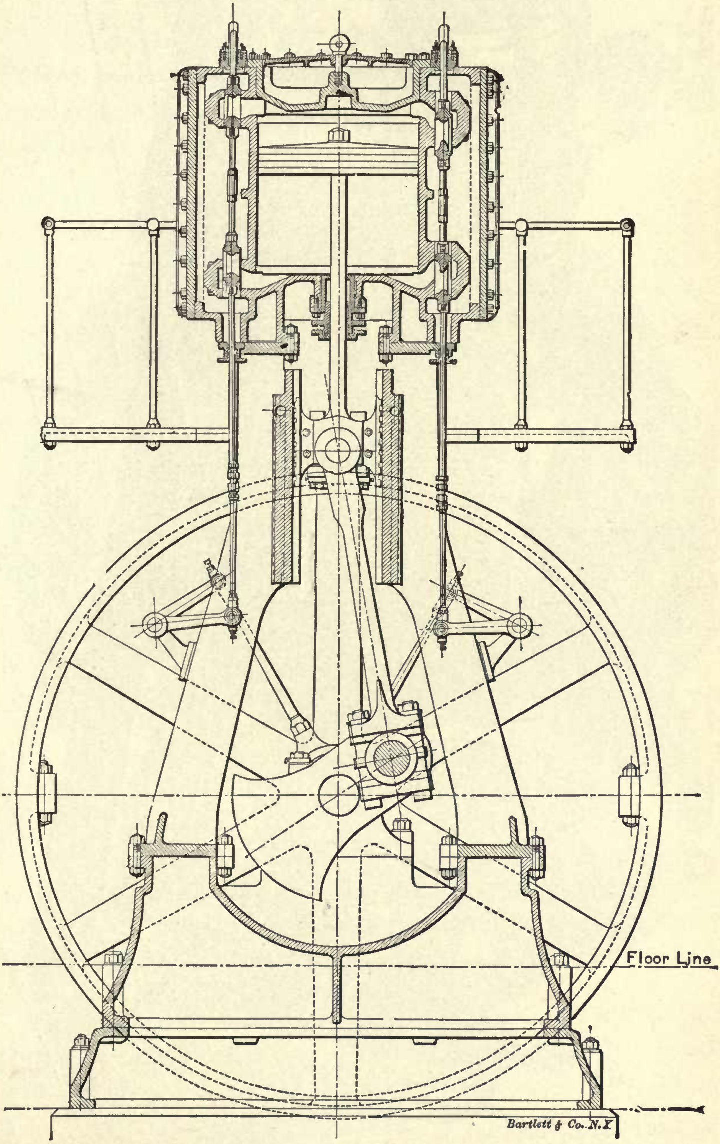


Fig. 107. SECTION THROUGH LOW PRESSURE CYLINDER OF LAKE ERIE ENGINE.

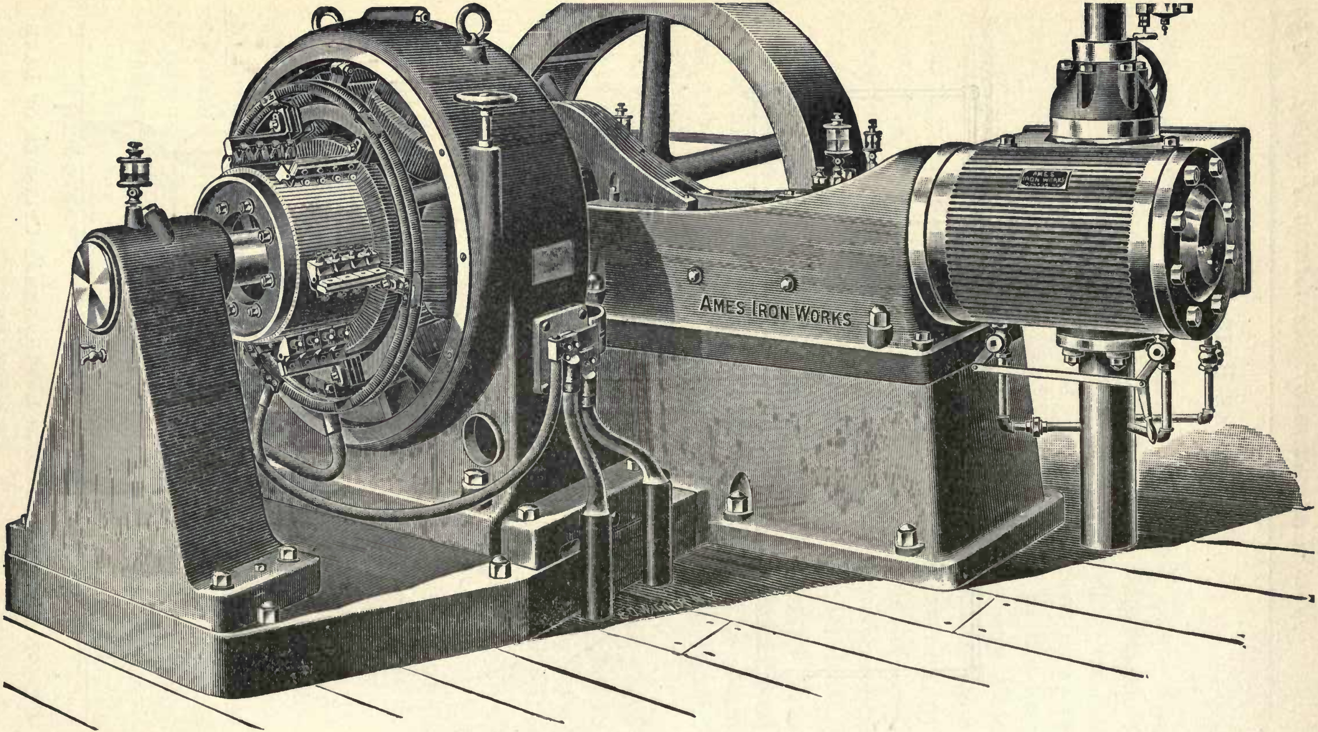


Fig. 108. AMES SINGLE CYLINDER ENGINE.

THE AMES ENGINE.

These engines are all automatic. Fig. 108 exhibits the Ames Iron Works' Single Cylinder Engine direct connected to dynamo.

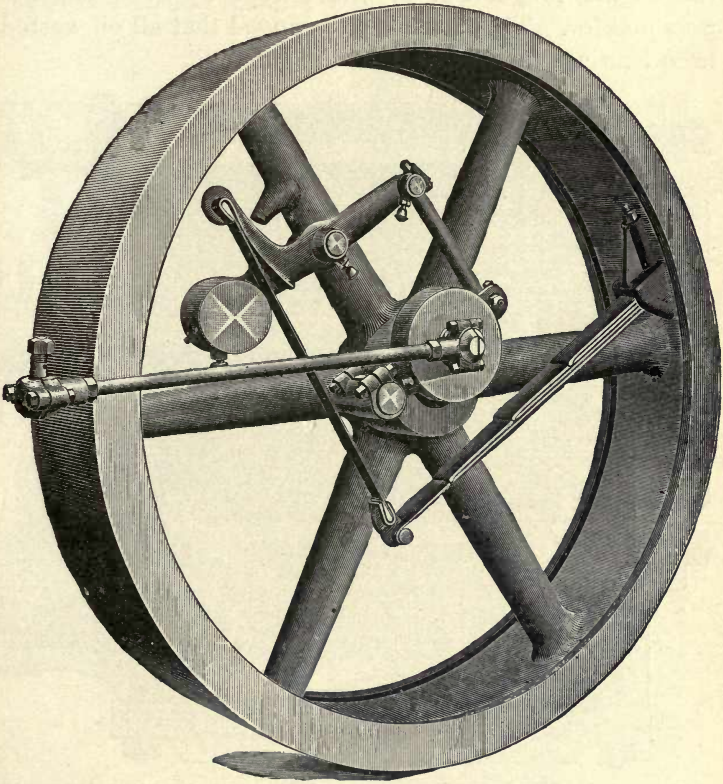


Fig. 109. GOVERNOR FOR AMES ENGINE.

The frame is made very deep, and carried well above the center line, the strains thus being resisted by metal in direct line between the cylinder and main bearings. The frame

NOTE.—These engines are built by the Ames Iron Works, Oswego, N. Y.

THE AMES ENGINE.

will not spring perceptibly under any strain whatever that it may be called upon to carry. The lower guide, valve-rod guide, and seats for main bearing shells are cast integral with it, making it impossible for any portion of the engine to get out of line except by wear, which is provided for. The frame is so arranged that all oil wasted from bearings finally drains to the crank-pit.

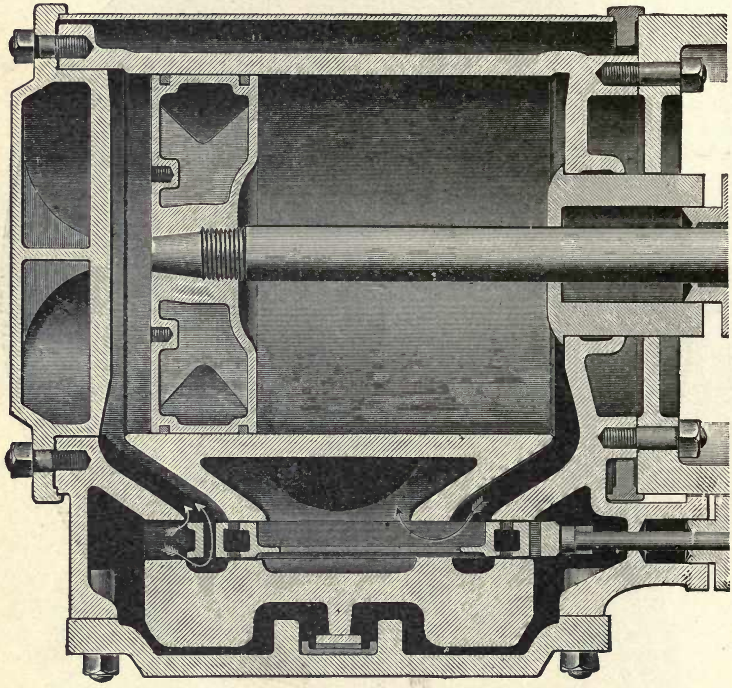


Fig. 110. HORIZONTAL SECTION OF CYLINDER OF AMES ENGINE.

The governor is of extreme simplicity, yet capable of accurate control of the engine, see Fig. 109.

All the parts are very accessible, and may be entirely removed from the wheel by loosening three nuts.

The balanced slide valve used is clearly shown in the cuts, Figs. 110 and 111, and consists of a flat, rectangular

THE AMES ENGINE.

casting finished on both sides and to an exact thickness. This valve works frictionless between the seat and a heavy pressure plate which is maintained at a proper distance from the seat by two strips of iron ground about $\frac{2}{1000}$ inch thicker than the valve.

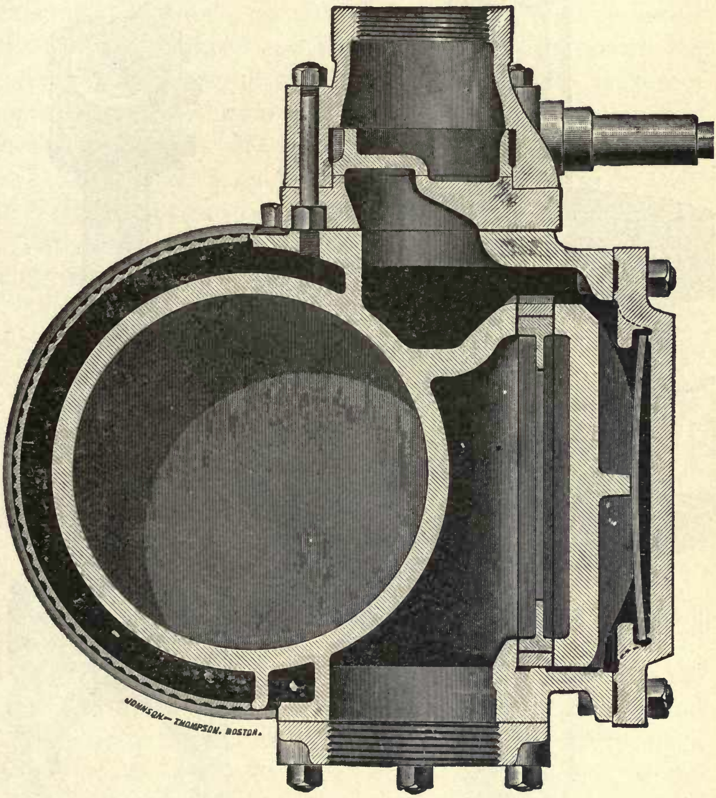
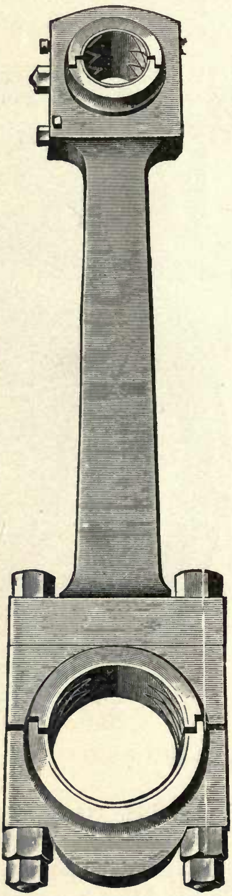


Fig. III. CROSS SECTION OF CYLINDER OF AMES ENGINE.

Any wear can be taken up by a good mechanic in a short time. Wearing down by its own weight does not open a leak, and as the sides are vertical and subjected to equal pressures, friction is reduced to a minimum, making the

Fig. 113.
CONNECTING ROD
FOR
AMES ENGINE.



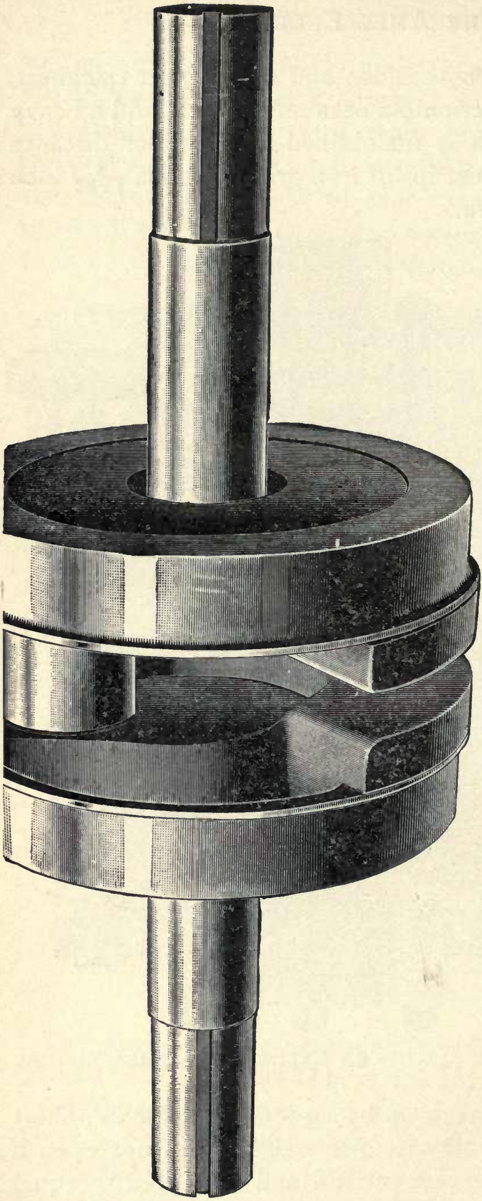


Fig. 112. CRANK SHAFT OF THE AMES ENGINE.

THE AMES ENGINE.

valve very durable and capable of running a long time without attention. It will also act as a safety valve, and will relieve the cylinder, without injury, of a dose of water.

The rocker arm is horizontal; the center bearing works in a bath of oil, which requires renewing only at long intervals. Motion is communicated to the valve by means of a slotted crosshead and square block, which carries the valve rod in a straight line and is provided with means of compensating for any wear. The eccentric rod is connected to the rocker-arm and also to the governor by ball and socket bearings. It is hollow, and through it the bearing at the governor end is oiled.

The throttle consists of a flat valve rotated through one-half a revolution by means of a worm and hand wheel.

The crosshead is a single casting of the slipper-guide pattern; the sliding surface is very large and is scraped to a perfect bearing.

The connecting rod is shown in Fig. 113. The adjustment of crosshead end is by a wedge moved by an adjusting screw on the top of rod. The crank end is of the "Marine" type, the adjustment being by means of lock nuts so arranged that the outer one of each pair is of finer pitch than the inner one.

The lubrication of the Ames is as follows: A chamber is provided under each of the main bearings, into which all oil wasting from their outer end drains. This oil is returned to the bearings by rings, which, riding on the shafts and dipping into the chamber below, continually carry up a stream of oil. All oil wasting from the inner ends of the main bearings is caught and carried to the crank-pin. The holes through which the oil passes to the crank are one-half inch in diameter, so as not to be readily stopped up. They are also straight throughout their length, that they may be conveniently cleaned.

THE ARMINGTON AND SIMS ENGINE.

This engine, represented in Fig. 114, belongs to the high speed automatic single valve type.

The valve is a hollow piston valve, packed steam tight, admitting steam at the center, and exhausting at the ends.

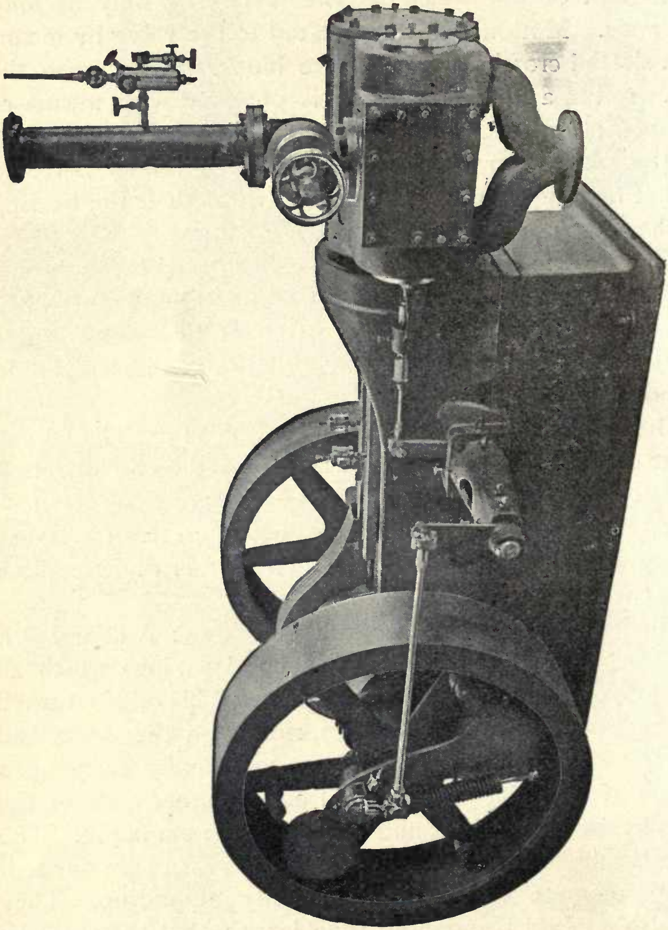


Fig. 114. Armington & Sims High Speed Automatic Engine.

The valve is operated by an eccentric pin, whose position is regulated by the governor, which is a modification of the Rites single weight governor system, Fig. 115.

Armington & Sims Engine.

As will be seen the weight and arm forms one piece, swinging about a pin in the governor wheel. The end of the arm, which is attached to the pin, is extended, and to it is attached the eccentric pin, and on the extreme end a counterbalance weight and dashpot.

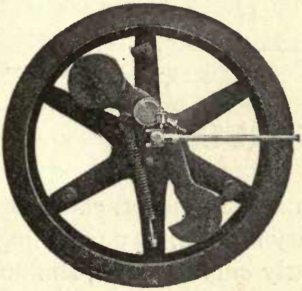


Fig. 115.
Rites Improved Governor.

The spring, which counteracts the centrifugal force, is attached to the weight-arm between the pin and weight, its other end being attached to an arm of the governor wheel. When the weight is thrown outward by the centrifugal force, it swings the eccentric pin toward the center of the shaft, thus shortening the valve travel and cut-off.

The self-oiling arrangement is shown in Fig. 116.

The main bearing is lubricated by a chain, which hangs over the shaft, into an oil reservoir, and by the rotation of the shaft it carries the oil upwards, and thus into the bearing.

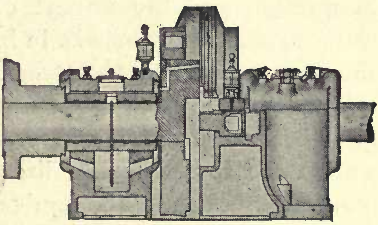


Fig. 116 Armington & Sims Oiling Device.

Around the main shaft, between the crank disc and the main bearing, is located an eccentric disc; oil from a stationary cup located on the main bearing is fed into this disc, and by the rotation of the engine is thrown to the highest point of this disc, from thence it flows through suitable ducts directly on to the crank pin bearing. The lower surface of the cross-head runs in oil, the top surface being recessed out, forming a small oil reservoir which is fed from a stationary oil cup on the top of the guides. These two upper surfaces are connected by an oil duct leading across the top of the cross-head pin, thus furnishing ample lubrication for these wearing surfaces. The crank discs are partially covered with an attractive hood.

THE STEAM TURBINE.

The steam turbine is simply an impact motor, changing the velocity of the steam into rotary motion, by compelling it to act upon a number of peculiarly curved vanes, similar to those used in the Pelton water wheel, thus it is not a pressure engine, but an impact motor.

Essentially the steam turbine consists of two pieces, and no mechanism can have less, a wheel and its axle, with a suitable frame or support. It uses steam of high pressure, expanding it before it is used. The energy of the steam is transferred by free expansion into the energy of a mass in motion, and the impact of the particles of steam or water against the vanes is, in brief, the method of utilizing the energy stored in the steam.

Two general types of steam turbines are now in use; one in which the revolving discs are slotted at an angle and work close to stationary discs similarly slotted, but in the reverse direction. The equivalent of the compounding of a steam engine is obtained by multiplying the number of discs and the thrust of the shaft is wholly overcome or utilized to advantage by the arrangement of the discs in such a way as to modify the strain.

The other type is a disc having buckets or cups of peculiar shape fastened to the sides and to balance the thrust of the shaft steam is directed against both sides of the disc.

THE STEAM TURBINE.

volume at each turbine, till it arrives at the next series of turbines; these are of larger diameter, and consequently greater peripheral speed and capacity, and they allow of further gradual expansion.

The steam then flows to the last series of turbines, where, the expansion being completed, it passes to the exhaust pipe. The rows of turbine blades are formed of hard brass, and accurately shaped; those keyed into the shaft project outwardly, and nearly touch the case; those keyed into the case project inwardly between the moving rows, and nearly touch the shaft. The turbines are so proportioned that the steam passes from one row to the next throughout the entire turbine with the most suitable velocity for economical working under the prescribed conditions. On the right are the dummy or rotating pistons to balance the end pressure of the steam.

Both types of turbine have given results in the development of power on a steam consumption about equal to that used by high class engines.

The compound steam turbine of the "parallel flow type" consists of a series of parallel flow turbines set one after the other on the same shaft, so that each turbine takes steam from the preceding one and delivers it to the next. The steam, entering by an inlet all around the shaft, passes through the successive turbines of gradually increasing area of passageway.

NOTE.—At the Bordeaux Exhibition a one hundred horse power De Laval turbine ran on 21 pounds of steam per hour per horse power on a seven hour test, with 113 pounds initial pressure and 26 inches of vacuum. With a load of 50 horse power the consumption per horse power increased to only 23.27 pounds. A satisfactory item as bearing upon the continued efficiency, is that after nine months of use the turbine generated a horse power on 19.58 pounds. At Troyes a 2 horse power turbine running with only 71 pounds initial developed a horse power on the same amount—19.58.

THE STEAM TURBINE.

In these several passageways the steam expands gradually by small increments.

In a moderate-size turbo-motor there may be from thirty to eighty successive rings, and when the steam arrives at the last ring the expansion has been completed.

On the left side of the steam inlet are the dummy or rotating pistons, which are fixed to and rotate with the shaft. On their outside are grooves and rings which project into corresponding grooves in the case. By means of the thrust bearing of the motor, the longitudinal position of the shaft is adjusted, and grooves and projecting rings kept nearly touching, so as to make a practically tight joint. The object of these pistons is to steam-balance the shaft and relieve end pressure on the thrust bearing.

With compound condensing turbines, a steam efficiency comparable with the best compound or triple-expansion condensing engines was at length reached, and it was then resolved to test the application of the compound turbine to the propulsion of ships, for which purpose it seemed well suited.

An account of an experimental ship built to test the system for marine propulsion is given on page 421 of this book; the steam turbine is invading the field of stationary engineering and, once its experimental period is passed, may be expected to become a prominent factor in large station work, as for electrical service it possesses especial advantages.

THE CORLISS STEAM ENGINE.

The Corliss engine differs mainly from all other engines by its peculiar construction of the valves.

The valves are four in number, two for steam and two for exhaust. They are set at right angles with the center line of the engine, and are either semi-rotary valves or flat slide valves, but in both cases the construction of the valve mechanism is the same, the only difference being that the flat valve consists of a cast-iron plate, which slides on a smooth surface at the end of the cylinder, and includes

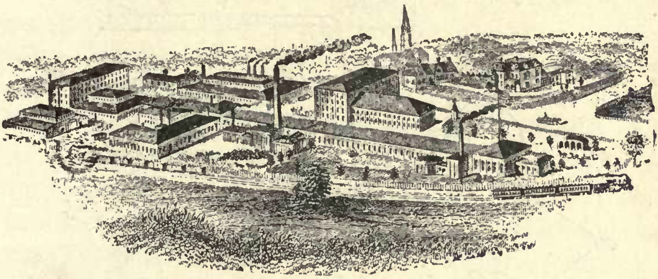


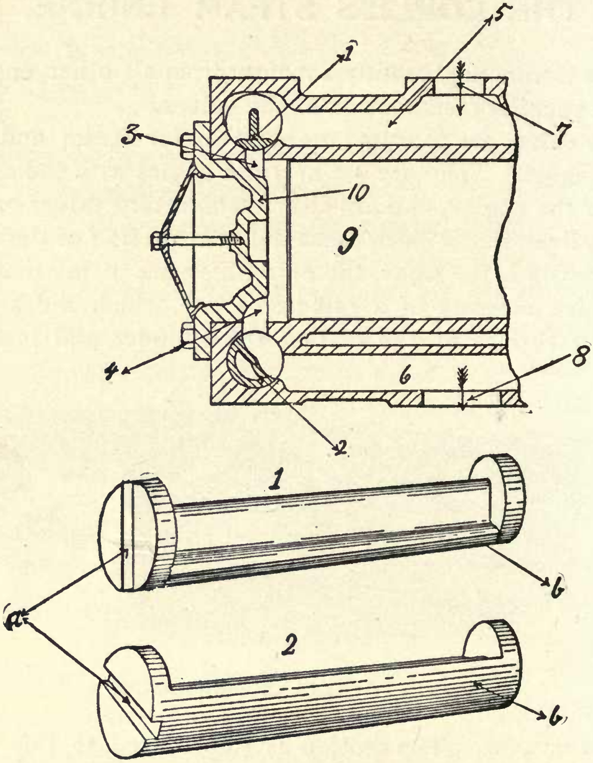
Fig. 119. WORKS AT PROVIDENCE.

the steam port. The motion is transmitted to this plate from the rotating valve stem by means of links and bell cranks fastened to the valve stem inside of the valve chest, so that, if the valve stem commences to rotate, the flat plate will be drawn parallel with the cylinder, across its seat, thus uncovering the port. These valves are, however, not very frequently used.

The more popular type of Corliss valve is the semi-rotary valve, shown in Fig. 121, and its location in the cylinder casting is shown in Fig. 120, the upper valve, 1, being the steam valve, the lower one, 2, the exhaust valve.*

*NOTE.—Only one-half of the vertical section of the cylinder is shown, the other two valves being the same as those shown.

THE CORLISS STEAM ENGINE.



Figs. 120 and 121.

Table Showing Lap and Lead of Valves of Corliss Engine.

Cylinder Diameter in Inches.	Wrist Plate on its Center. Steam Lap.	Wrist Plate on its Center. Exhaust Lap.	Steam Lead Engine on Center.
8, 10 & 12.	3-16″	1-32″	1-32″
14, 16, 18 & 20.	¼″	1-16″	1-32″
22, 24, 26, 28 & 30.	5-16″	3-32″	3-64″
32, 34 & 36.	⅜″	⅛″	1-16″

THE CORLISS STEAM ENGINE.

Steam enters at Fig. 120 and passes through the steam port, 3, into the cylinder, and is exhausted through exhaust port, 4.

In Fig. 121 these valves are shown in perspective on an enlarged scale, 1 being the steam valve, and 2 the exhaust valve.

The recesses *a*, Fig 121, cut across the face of the circular end of the valves, are to receive a T-shaped head of the valve stems, which transfers the rotary motion of the latter to the valves, and still allows the valves to be withdrawn from their respective chambers, by removing the covers on the front side of the engine.

It also enables the valves to leave their seats, if forced by water or overpressure, and to follow up near without binding the valve stem. The steam valve is riding upon the port, which connects the steam chest, 5, with the cylinder, and is held to its seat by steam pressure, while the exhaust valve is held to a port connecting exhaust chamber, 6, with the exhaust valve chamber, thus the steam pressure always holds it to its seat.

An important feature of the Corliss engine is the valve-gear. Economy in the use of steam requires that it shall be admitted to the cylinder at and near the beginning of the stroke of the piston at a pressure not much below that in the boiler; that this pressure shall be maintained practically constant for a portion of the stroke, and that then the supply shall be cut off quickly, the remaining portion of the stroke being completed under the expansion of steam in the cylinder. Under these conditions the pressure of steam in the cylinder will be so far reduced at the conclusion of the stroke that little or no more useful work can be performed by it. Then this steam must be exhausted so freely that back pressure in the cylinder will be reduced to a minimum.

CORLISS ENGINE GOVERNOR.

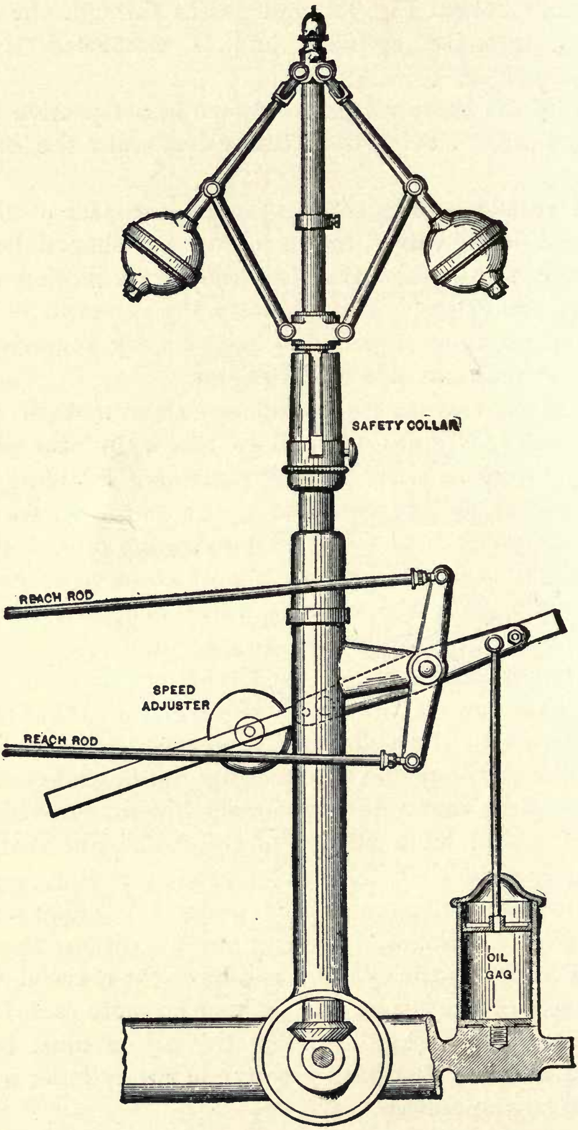


Fig. 122.

CORLISS ENGINE GOVERNOR.

This is accomplished in the Corliss engine, by the use of very short valve ports, which reduce the friction to a minimum.

Another great advantage of the use of 4 ports is, that the steam entering the cylinder need not pass through ports cooled down previously by the exhaust.

The sharp and quick cut-off is gained by the use of a releasing mechanism, Figs. 123 and 124, which only opens the valve, the closing being done by dashpots shown at *D* Fig. 125.

These dashpots consist of cast iron cylinders, in which a piston is working air tight; when the valve is opened by means of the hook *C* and bell crank *B*, the rod *O* is also lifted, which in turn raises the piston of the dashpot, and no air being admitted below it, a vacuum is created.

Now if the hook is tripped by the cam *S*, operated by the governor, the air acting with a pressure of 15 pounds to the square inch upon the dashpot piston, will force it down almost instantly, and thus close the valve, shutting off the steam, which by its expansion continues the stroke.

To avoid pounding of the dashpot piston, when it strikes the bottom of the cylinder, another cylinder is arranged, in which air is compressed, thus cushioning the descending piston.

The governor shown at Fig. 122, operates cam *S* by means of reachrod *G* and lever *H*, Fig. 125.

If the engine speeds up, the governor balls will rise, and by way of their connection with rod *G* push cam *S* toward the hook *C*, thus tripping it earlier in the stroke, which operation cuts off steam quicker.

Again if the engine slows down, the governor balls in descending will pull the cam away from the hook, allowing admission of steam to be continued further along the stroke.

THE CORLISS ENGINE.

The travel of the exhaust valves is constant at all speeds.

The oilgag which will be noticed on the governor is to prevent too sudden actions of the governor, at very varying loads, which would cause the engine to race.

The type of engine invented by Corliss, and which bears his name, has produced such remarkable results in the field of steam engineering that all must be interested in the man

George Henry Corliss was born on June 2, 1817, in Easton, Washington Co., N. Y. He died in Providence, R. I., on February 21, 1888. The highest known honors ever accorded to any engineer have been given to him by foreign governments and scientific societies. It has been well said that the combined work of the two men, Watt and Corliss, has changed the face of the entire world.

Mr. Corliss was not fitted by any special education for his great work of taking the steam engine up where it was left by the immortal Watt, and bringing it to its present high state of perfection. He never saw the inside of a machine shop until he was 24 years of age. He attended an ordinary village school at Greenwich until he was 14 years of age, and a few years in various lines of the leather business, naturally, for him, resulted in the invention of a harness sewing machine which long preceded the famous sewing machine invented by the Howe brothers.

Mr. Corliss first came to Providence in 1844 to complete an invention of his, for sewing harness leather. He went to the High Street Furnace Company, but soon took his work to the steam engine works of Fairbanks, Bancroft & Company. His sewing machine was fully completed, but he showed such adaptability as an inventor and draughtsman, that he was induced by the above firm to enter their service, which involved an abandonment of the harness-sewing machine.

The details of invention of the engine and its introduction in 1845 and in the years following, would fill a volume.

THE CORLISS ENGINE.

At the present day the Corliss engine is made in England, Germany, France and in fact in every civilized country in the world.

While many improvements have been made in the valve gear of the Corliss engine its great distinguishing features, the four valves, releasing gear with the dash-pot, cut-off, etc., remain the same in principle as first proposed by the inventor. Very many of the original engines built by the inventor are still in use every day most satisfactory, for instance, one in Phillipsburg, New Jersey, (Warren Pope Works) is still running with the identical valve gear first introduced by Corliss.

The Corliss system of valve gear has also proved to be well adapted to the compounding of steam. Of the compound engine it has been said that it has some advantages over the simple engine, such as a better distribution of strains and a more nearly uniform rotative effect on the crank-pin, and hence on the shaft. For a given power the first cost of a compound engine exceeds that of a simple engine; but this is partially balanced by the saving in boiler capacity, and is very soon saved in less cost of fuel.

There are different plans of compounding, one of which is to use, in effect, two engines connected to cranks on the ends of the shaft. The tandem compound, with cylinders arranged one forward of the other: this has the advantage of occupying a narrow space compared with the two engines side by side, and does not present so many moving parts to be cared for. It also has the advantage due to the cylinders being placed close together, so that the certain loss due to passing the steam a considerable distance, from the high to the low pressure cylinder, is avoided.

Valve Gear of Corliss Engine with Directions for Setting Corliss Valve.

There is a great variety of releasing gears as applied to the Corliss engine, yet they differ only in detail and not in principle, and may, for convenience, be divided into two classes.

Those engines, whose valves rotate toward the center of the cylinder in admitting steam, may be considered as the first class, and include the "crab-claw gear," Fig. 123, as originally applied by Corliss and still used in a modified form by several later builders. The Reynolds-Corliss, Philadelphia-Corliss engines, and several other makes, belong to this class also, but are equipped with a device known as the "half-moon gear."

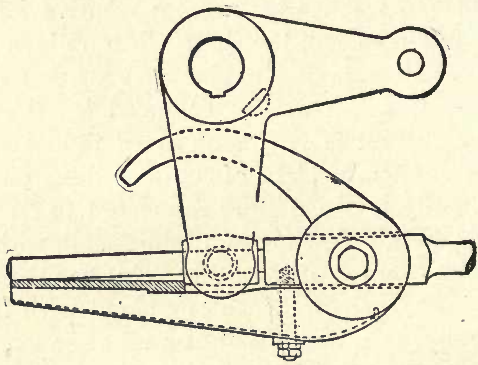


Fig. 123. Crab Claw Releasing Gear.

The second class is made up of those engines in which the steam valves rotate toward the ends of the cylinder, or outward, when opening for admission, generally using a form of gear styled the "oval arm gear," Fig. 124. To this class belong the Allis-Corliss and Hewes and Phillips-Corliss engines.

Directions for Setting Corliss Valves.

Fig. 125 shows all the essential parts of the valve gear. The bonnets on the crank end are omitted from the drawing in order to show the marks made by the builders for setting the valves. The steam valves work in the chambers *S*, *S*, and the exhaust valves work in the chambers *E*, *E*. The double-armed levers *A*, *C* work loosely on the hubs of the valve stem brackets and the lever arms *B*; the former are connected to the wrist plate *W* by the rods *M*; the levers *B* are keyed to the valve stems *V*, and are also connected by the rods *O* to the dash pots *D*, *D*. The

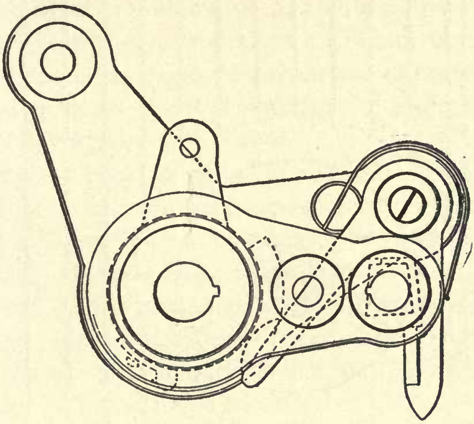


Fig. 124. The Releasing Mechanism of the Corliss Valve Gear.
Shown upon an enlarged scale of Fig. 125.

double-armed levers carry at the outer ends *C* hardened steel catch plates, which engage with arms *B*, making the two arms *B* and *C* work in unison until steam is to be cut off. At this point another set of levers *H*, connected by the cam rods *G* to the governor, come into play, causing the catch plates to release the arms *B*, the outer ends of which are then pulled downward by the weight of the dash-pot plunger, causing the steam valves to rotate on their axes and thus cut off steam.

DIRECTIONS FOR SETTING CORLISS VALVES.

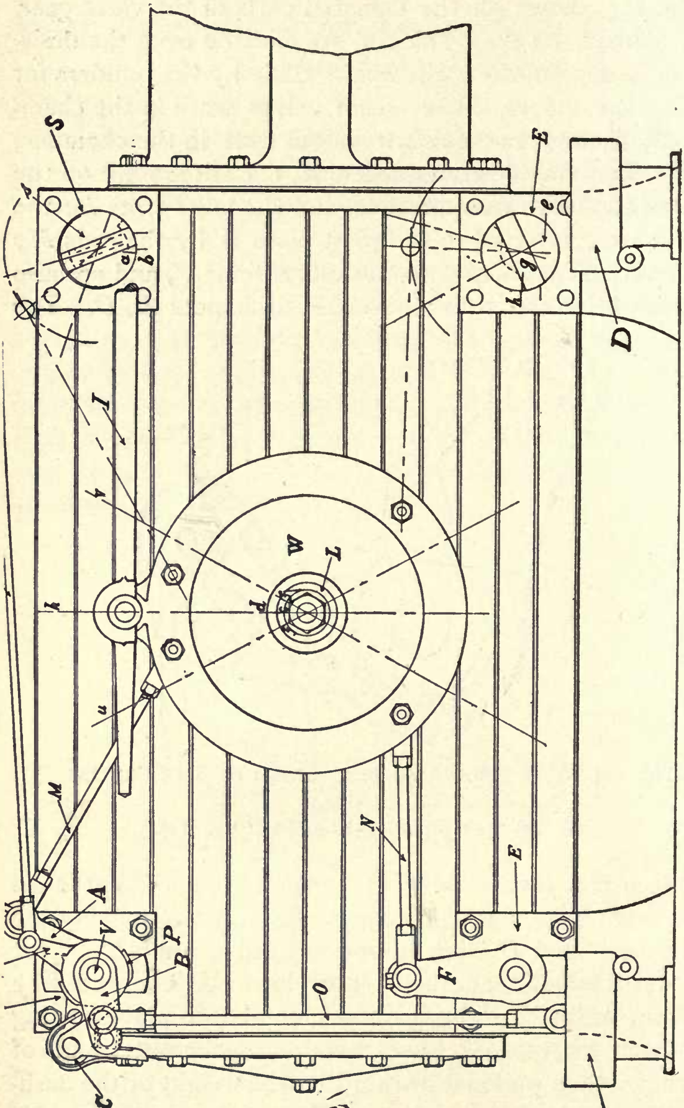


Fig. 125. THE CORLISS VALVE GEAR.

Directions for Setting Corliss Valves.

These are the essential features of the Corliss gear, although the design of the mechanism is greatly modified by different builders.

The exhaust valve arms *F* are connected to the wrist plate by the rods *N*, and it is seen that all the valves receive their motion from the wrist plate; the latter receives its motion from the hook rod *I*. This rod is generally attached to a rocker arm, not shown; to this arm the eccentric rod is also attached. The carrier arm is usually placed about midway between the wrist plate and eccentric, and in the centre of its travel stands in a vertical position.

The setting of the valves is not a difficult matter when, on the wrist plate, its support, valves and cylinder, the customary marks have been placed for finding the relative positions of wrist plate and valves.

Now, when the back bonnets* of the valve chambers have been taken off, there will be found a mark or line *a* on the end of each steam valve *s*, coinciding with the working or opening edge of each valve; another line *b* will be found on each face of the steam valve chamber coinciding with the working edge of the steam port. The exhaust valves and their chambers are marked in a similar way, *i. e.*, the line *g*, on the end of each exhaust valve, coincides with the working edge of the valve, and the line *h*, on the face of each exhaust valve chamber, coincides with the working edge of the exhaust port. On the hub of the wrist plate will be found a line *d* coinciding with the centre line *d*, *k*; lastly, there are three lines, *f*, *c*, *f* on the hub of the wrist plate support, placed in such a way that when the line *d* coincides with the line *c*, the wrist plate will stand exactly in the centre of its motion, and when the line *d* coincides with either of the lines *f*, *f*, the wrist plate will be at one

Note.—These marks, in this case, are shown on the front of the valve and chamber, on the right hand side of Fig. 125 the conditions are the same as in the back.

Directions for Setting Corliss Valves.

of the extreme ends *u* or *v* of its travel. It should be noticed that since the lines *f*, *c*, *f* are drawn on periphery of the hub of the wrist plate support, and the line *d* is drawn on the periphery of the wrist plate hub, these lines cannot stand in a vertical position, as shown. We have adopted this way of showing them simply for the purpose of making the matter plain.

In setting the valves, the first step will be to set the wrist plate in its central position, so that the lines *c* and *d* will coincide, and fasten the wrist plate in this position by placing a piece of paper between it and the washer *L* on its supporting pin. Now set the steam valves so that they will have a slight amount of lap, that is to say, the lines *a* must have moved a little beyond the lines *b*; the amount of this lap depends much on individual preference and experience; it ranges from $\frac{1}{16}$ to $\frac{1}{4}$ inch for small engines, and from $\frac{1}{4}$ to $\frac{9}{16}$ inch for comparatively large engines. This lap is obtained by lengthening or shortening the rods *M* by means of the adjusting nuts.

Now place the exhaust valves *e*, by lengthening or shortening the rods *N* by means of the adjusting nuts, in a position so that the working edges will just open the exhaust ports, or, in other words, place the lines *g* and *h* in line with each other. Some engineers prefer a slight amount of lap, others prefer a slight opening of the exhaust ports when the valves are placed in this position; under these conditions the lines *g* and *h* cannot be in line, but will stand apart, as indicated in the illustration; the distance between these lines will, of course, be equal to the desired amount of opening; for small engines it is about $\frac{1}{16}$ inch, and for larger engines may be increased to $\frac{3}{16}$ inch, but in any case the amount of this opening should be less than the lap of the steam valves, otherwise there will be danger of blowing through.

DIRECTIONS FOR SETTING CORLISS VALVES.

The paper between the wrist plate and the washer on the supporting pin should now be taken out, so that the wrist plate connected to the valves can be swung on its pin.

The next step will be to pay some attention to the rocker arm. Set this arm in a vertical position by means of a plumb-line, and connect the eccentric rod to it; then turn the eccentric around on the shaft, and see that the extreme points of travel are at equal distances from the plumb-line. To secure this a little adjustment in the stub end of the eccentric rod may be necessary. Now connect the hook rod *I* to its pin on the wrist plate, and again turn the eccentric around on the shaft, and thus determine the extreme points of travel of the wrist plate. If all parts have been correctly adjusted, the line *d* will coincide with the lines *f*, *f* at the extreme points of travel; if this is not the case, the hook rod will have to be adjusted at its stub end so as to obtain the desired equalized motion of the wrist plate.

The next step will be to set the valves correctly with the position of the crank; to do so the lengths of the rods *M* and *N* must not be changed, but the following mode of procedure should be followed: Place the crank on one of its dead centres, and turn the eccentric loosely on the shaft in the direction in which the engine is to run, until the steam valve nearest to the piston shows an opening or lead of $\frac{1}{32}$ to $\frac{1}{8}$ inch, according to size of engine, the smaller lead, of course, being adopted for small engines. After the proper lead has been given to this valve, secure the eccentric and turn the shaft with eccentric in the same direction in which the engine is to run until the crank is on the opposite dead centre, and notice if the opening or lead at this end of the cylinder is the same as on the other steam valve; if not, shorten or lengthen slightly, as may appear necessary, the connection between wrist plate and eccen-

DIRECTIONS FOR SETTING CORLISS VALVES.

tric: of course, much adjustment in the length of these connections is not admissible without setting the valves with reference to the wrist plate.

The only thing which remains now to be done is to adjust the cam rods *G*. To do so, secure the governor balls in their highest position and disconnect the hook rod from wrist pin; lengthen or shorten the cam rods *G*, so as to bring the detachment apparatus into action, swing the wrist plate back and forward and make such adjustment in the rods *G* as to permit the steam valves to be released when the steam port has been opened about ⅛ inch. This adjustment is for the purpose of keeping the engine under the control of the governor, in case, for some reason or another, the load on the engine is suddenly thrown off, so that the valves are not opened at all when the governor is at its highest position. After this adjustment the governor balls should be placed in their lowest position. The releasing gear is constructed in such a manner as to close the steam valves automatically, in case the belt leading to the governor should be broken.

To set the cut-off even, proceed as follows: Block up the governor where it stands when an average load is on the engine and mark on the guides the extreme travel of the cross-head. With the governor blocked up move the engine slowly, either by hand or by admitting a very little steam, until the valve is tripped, and note the exact distance traveled by the cross-head up to this point. Turn the engine to the other center, hook up the valve and repeat the process on the other stroke. If the distance traveled by the cross-head is not the same in both cases lengthen one point of cut-off and shorten the other until the travel of the cross-head is exactly the same on both strokes, up to the point where the valves are unhooked.

The dash-pot rod should be adjusted in length so the steam valve arm, resting thereon, when the dash-pot

DIRECTIONS FOR SETTING CORLISS VALVES.

plunger is home, or at the bottom of the pot, is in such a position that the latch is sure to hook over the latch stud and the stud lies midway between the latch die and the closing shoulder. This will insure on the one hand the positive engagement of the latch, and on the other hand prevent the shoulder from jamming down upon the latch stud. If the dash-pot rod is too short, the latch will not hook on.

The dash-pot is provided with a leather packing in the vacuum plunger underneath the dash-pot proper. This should be kept moist and in good condition. To spread the packing, introduce some liners of paper inside the flange on cup leather. When leather is adjusted just right, the pot will work promptly and softly. The valve in the air opening is to regulate the amount of air cushion by adjusting the screw in the escape hole.

The regulator gag-pot is used on Corliss engines to prevent over-sensitiveness of the governor and its response to trivial changes. Use only coal or kerosene oil in this pot, and remove one or more of the screws in the piston if required to give greater freedom of motion. See that all parts of the governor move freely.

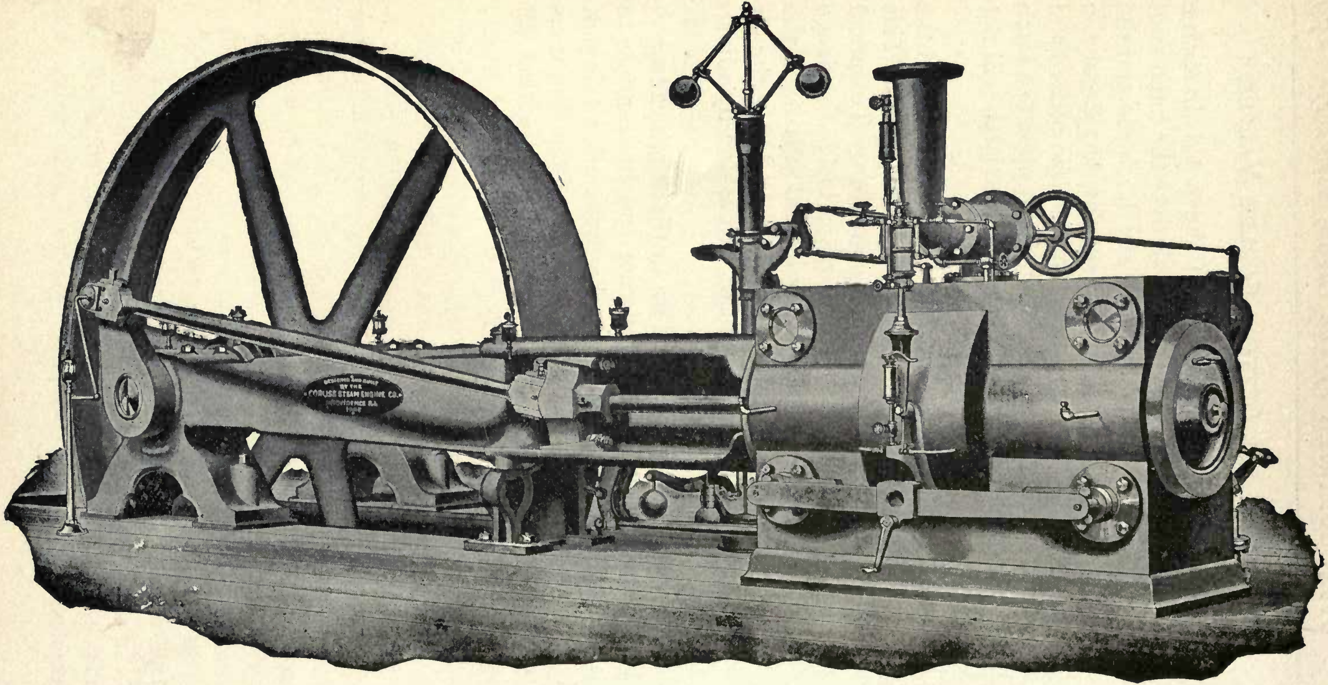


Fig. 126. THE CORLISS ENGINE—CRANK SIDE.

THE CORLISS ENGINE.

The engravings Fig. 126 and Fig. 127 represent the valve gear side and crank side of the single cylinder engine built by the Corliss Steam Engine Co. in works established by Geo. H. Corliss, the original inventor of the Corliss Engine, and incorporated 1856.

The frame of the engine is of the Corliss Girder type, made of a substantial pattern with heavy support at the end of the guide.

These guides are circular in form, so that the crosshead slides have bearing for full width. The wrist lever, instead of being the usual round wheel form, is a skeleton frame making connections very short to the steam and exhaust arms, and so proportioned as to give a very rapid opening and closing of the inlet and outlet valves.

The dash pots are noiseless in their action and are easily adjusted. The engine is furnished with a fly ball governor with patented improvements for obtaining perfect regulation and for instantly shutting off steam in case of necessity, or breakage of the regulator belt.

The Corliss Steam Engine Co. also build this type of machine in compounds and triple expansion.

The cylinder is steam jacketed both in the barrel and in the heads, barrel jacket and cylinder proper being one casting. Casing is of sheet steel and each exhaust port is provided with a patent safety relief attachment for allowing the escape of entrained water.

NOTE.—The claim is sometimes made by interested parties that the Corliss valve gear is complicated in its detail, and not easily comprehended except by experts. The direct contrary of this is true of the valve gear of these engines. The motion and the arrangement of parts are remarkably simple, and can be understood by any one of ordinary intelligence.

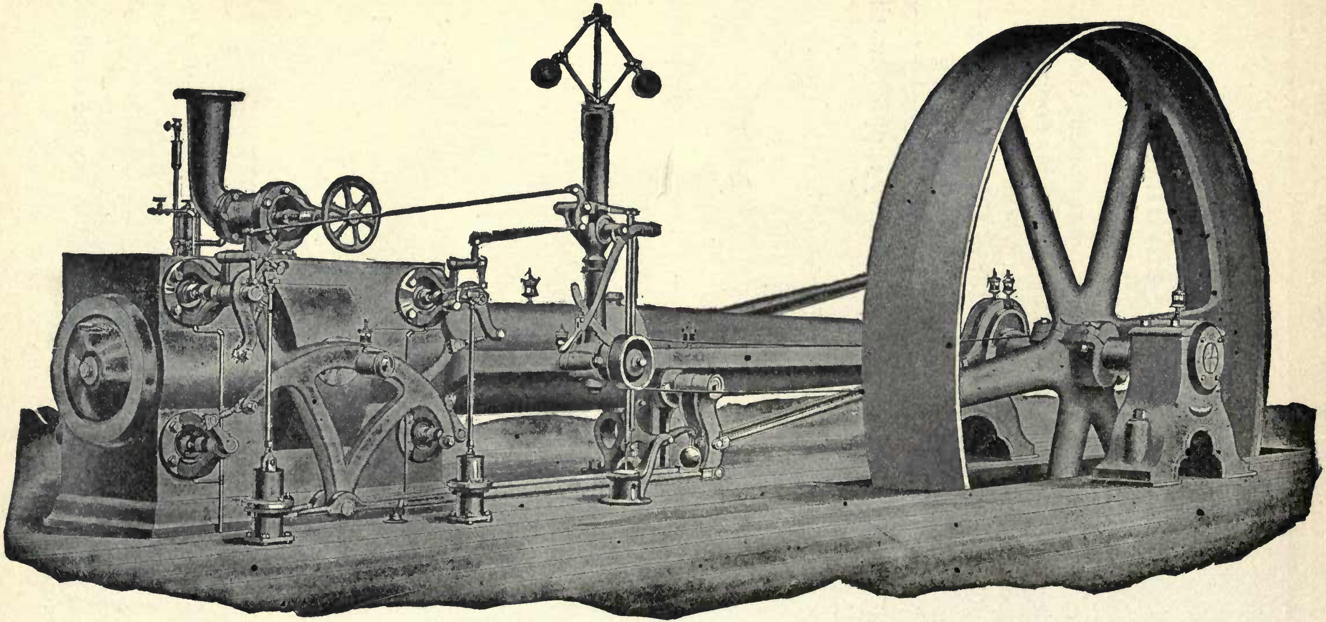


Fig. 127. THE CORLISS ENGINE—VALVE GEAR SIDE.

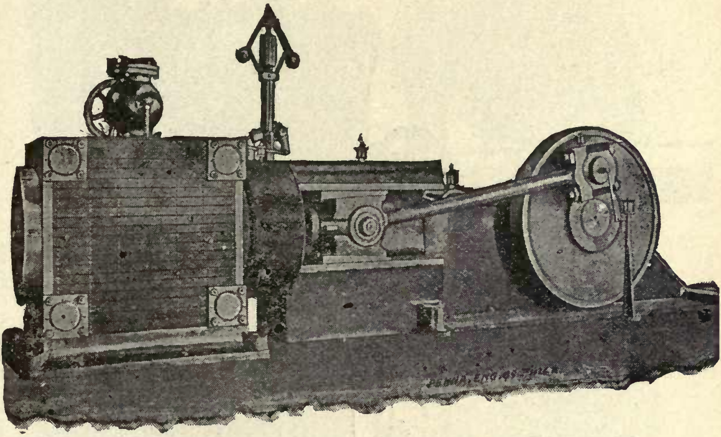


Fig. 128. HIGH SPEED PHILADELPHIA CORLISS ENGINE.

THE PHILADELPHIA CORLISS ENGINE.

This engine is built by the Philadelphia Engineering Co., Philadelphia, Pa. Its noted feature being the releasing gear, which is called the "Gordon Improved Corliss Valve Gear."

Fig. 129 and 130 show the horizontal engine and Fig. 133 the Gordon gear. The difference between the latter and the ordinary Corliss gear may be plainly seen in the illustration. The dash pots are cast in one piece with the exhaust bonnets.

The parallel rod does not hook into a pin, as commonly employed, but slides through an opening, in a pin, which is free to turn in the wrist plate. The length of the rod is fixed by a pin, which springs into a hole in the rod; the pin is released by slacking the handle, after which a further turn to the right (not to exceed half a turn in all) causes the sleeve enclosing the pin to jam the parallel rod tight and fast, thus taking all wear off the parallel rod and the opening in which it is held.

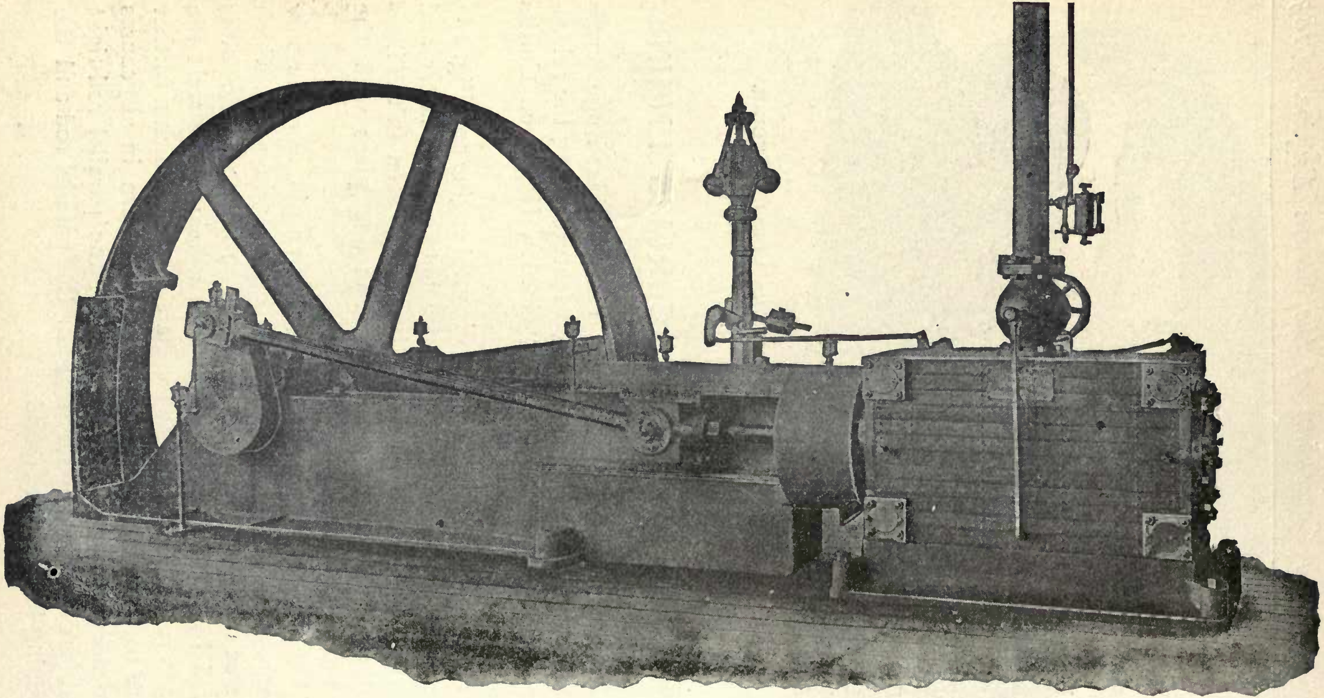


Fig. 129. Philadelphia Corliss Engine—Front View.

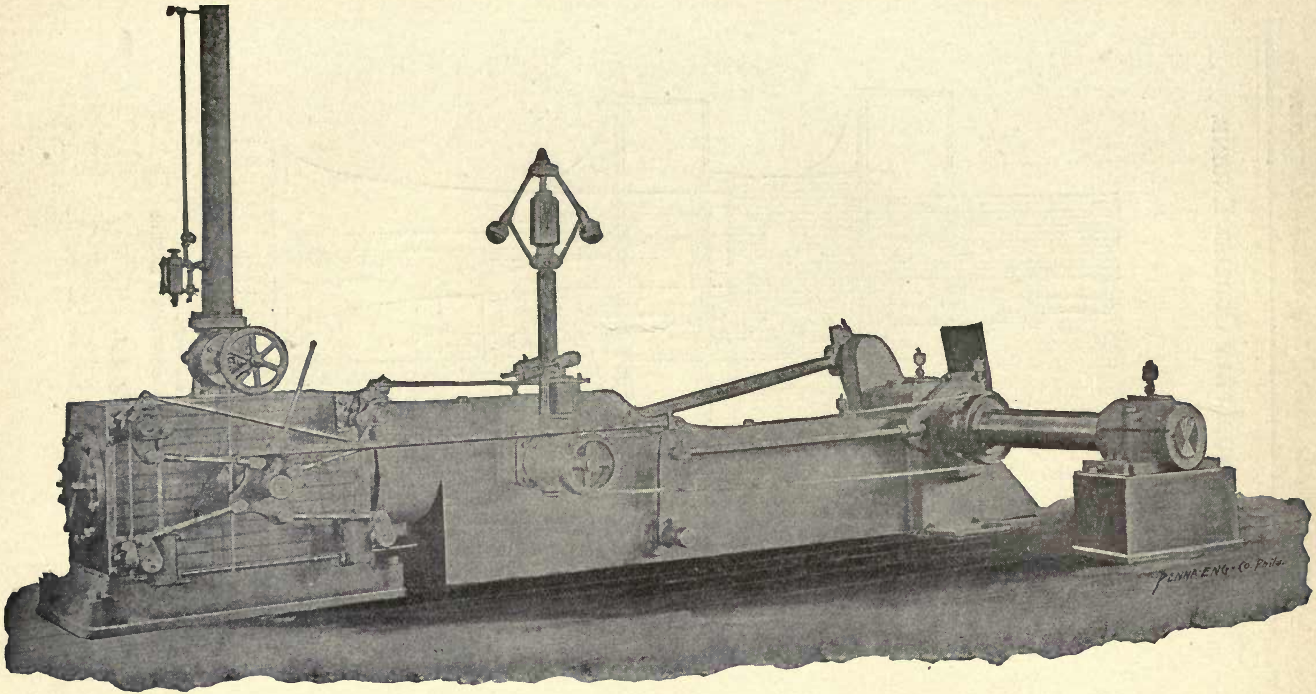
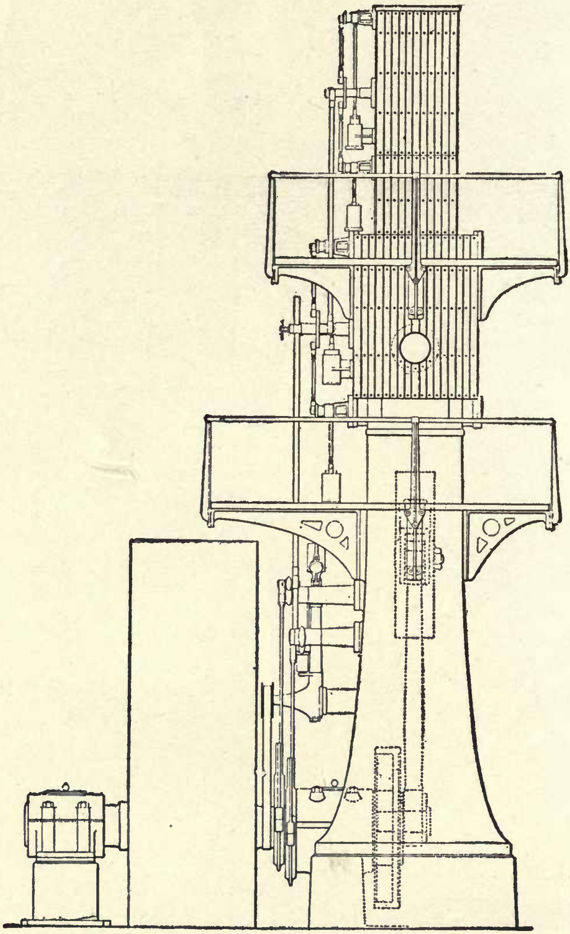


Fig. 130. PHILADELPHIA CORLISS ENGINE—BACK VIEW.

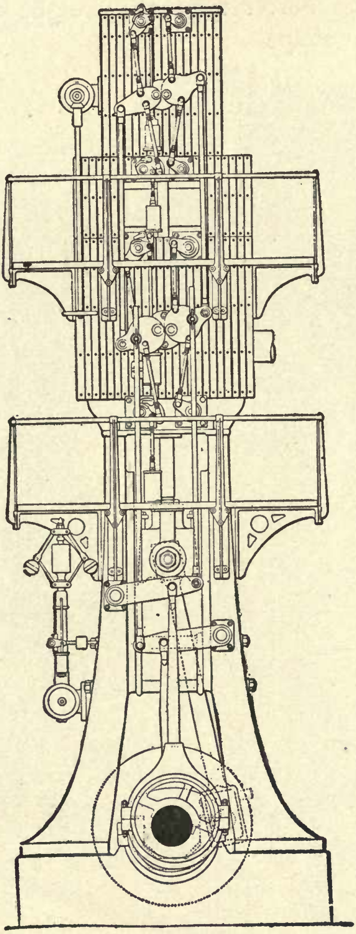
THE PHILADELPHIA CORLISS ENGINE.



FRONT ELEVATION.
VERTICAL TANDEM COMPOUND ENGINE.

Fig. 131.

THE PHILADELPHIA CORLISS ENGINE.



SIDE ELEVATION.

VERTICAL TANDEM COMPOUND ENGINE.

Fig. 132.

GORDON'S IMPROVED CORLISS ENGINE GEAR.

The piston is shown in Figs. 135 and 136, and the governor is of the Porter type, the weight being cylindrical instead of pear shape.

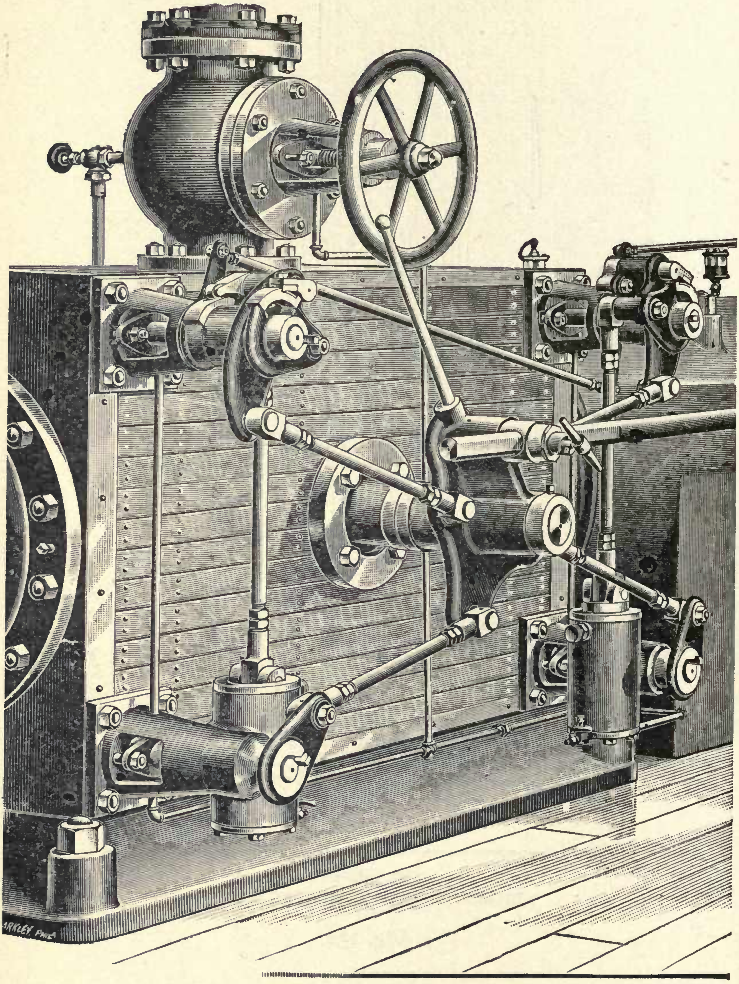
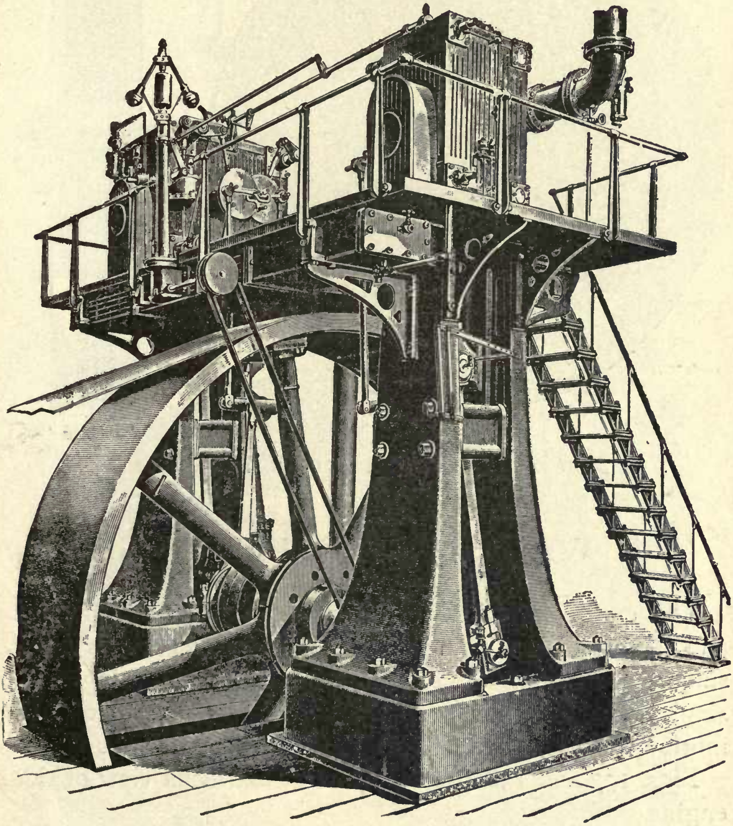


Fig. 133. GORDON'S IMPROVED CORLISS VALVE GEAR.

Figs. 131 and 132 show the front and side view of the vertical compound Philadelphia Corliss engine. Fig. 134 shows a cross compound and Fig. 128 a high speed Philadelphia Corliss engine.



VERTICAL CROSS COMPOUND PHILADELPHIA CORLISS ENGINE.

Fig. 134.

Fig. 135 shows the construction of the piston used in this engine, being the front view with part of the follower ring cut away to show the set screws and rings. Fig. 136 exhibits the side view with one half in section.

THE WHITEHILL CORLISS ENGINE.

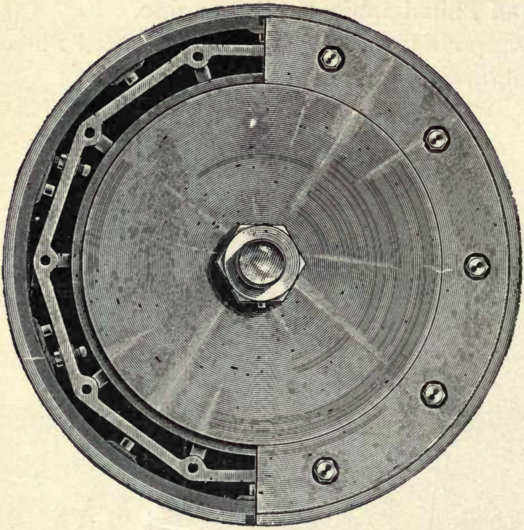


Fig. 135.

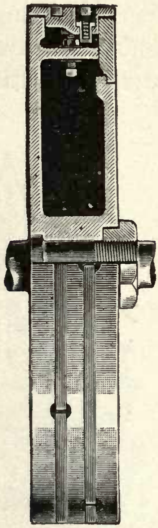


Fig. 136.

PISTON OF THE PHILADELPHIA CORLISS ENGINE.

THE WHITEHILL CORLISS ENGINE.

This engine is built by the Newburg, (N. Y.) Ice Machine and Engine Co. The Whitehill Corliss engine is built simple or compound, condensing or non-condensing, with single wrist plate valve motion or double wrist plate valve motion with separate eccentric for steam and exhaust.

Figs. 137 and 138 present a front and back view of this engine.

The valve gear is of the approved general type belonging to the Corliss engine and the governor is the familiar ball governor.

The Whitehill Corliss engine is made in all styles and for all duties, and embodies in its design the approved details and proportions demanded by the requirements of modern engineering practice.

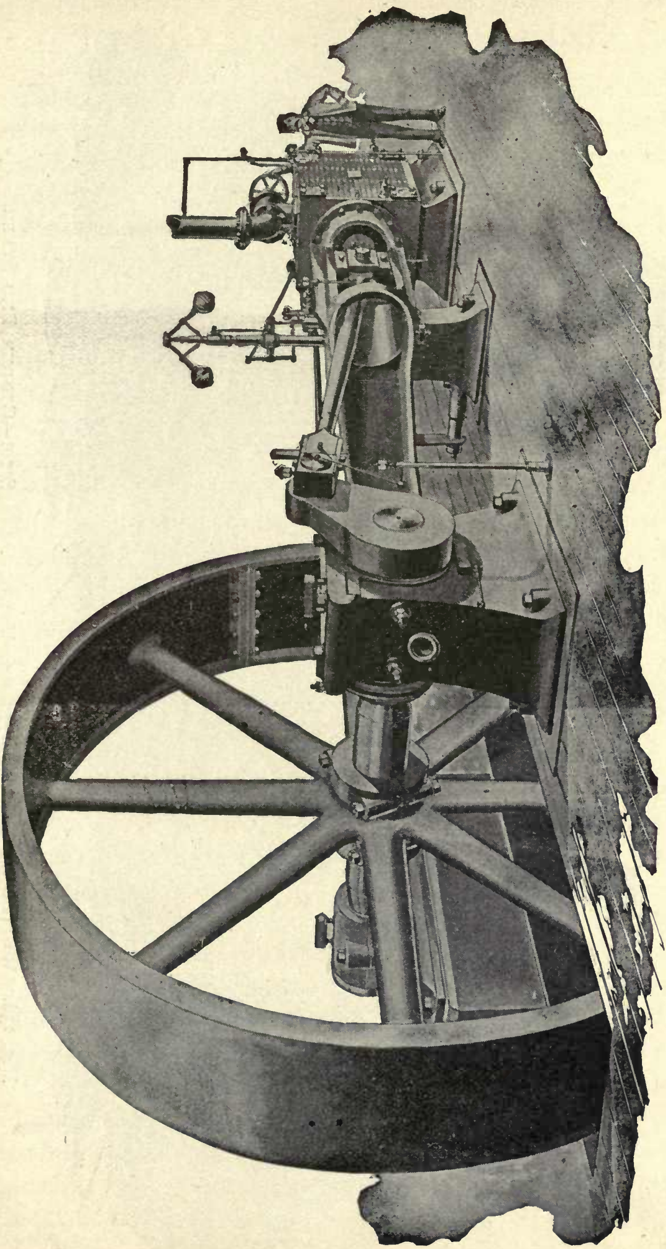


Fig. 137. WHITEHILL CORLISS ENGINE—CRANK END VIEW—GIRDER BED STYLE.

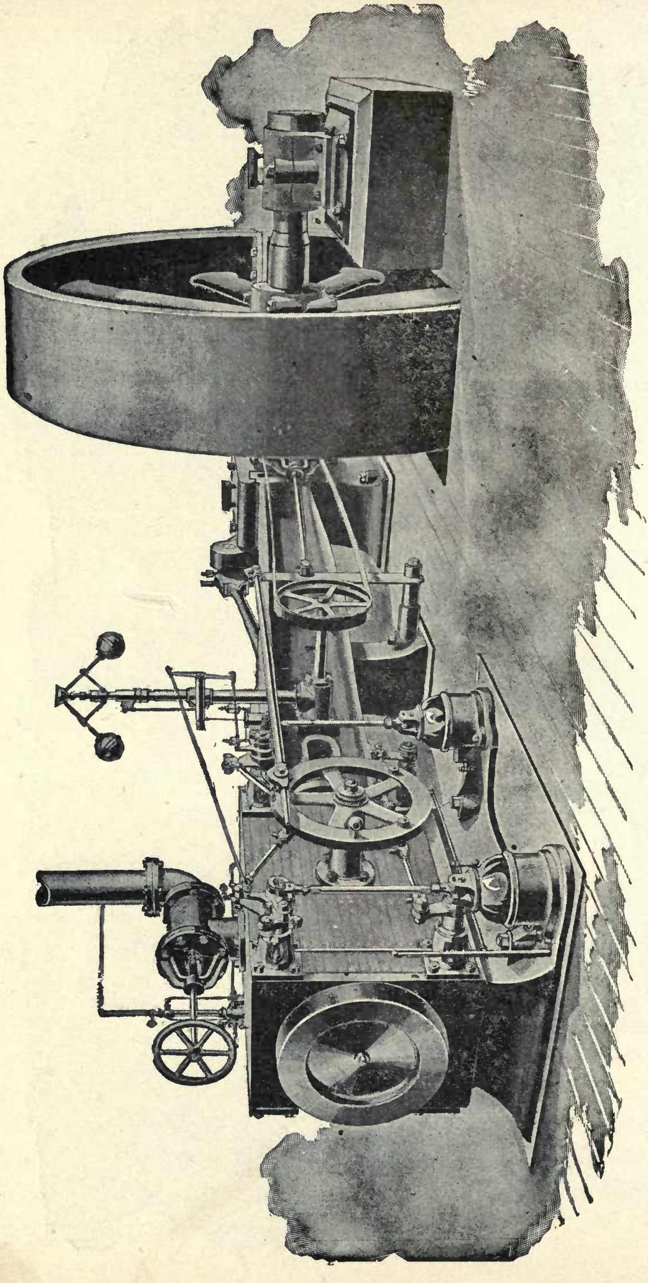


Fig. 138. WHITEHILL CORLISS ENGINE—VALVE GEAR SIDE—GIRDER BED STYLE.

THE BATES-CORLISS ENGINE.

This engine is constructed by the Bates Machine Co., at Joliet, Illinois. Fig. 139 illustrates a left hand Bates-Corliss. The principal feature of the Bates-Corliss engine is its exceedingly simple liberating device.

Fig. 140 shows valve gear in full. W is wrist plate which gives motion to both steam and exhaust valves. R R are valve rods which operate the steam valves. L L are connecting links and are supported by steel pins I I securely fastened in wrist plate. P P are small steel wrist pins connecting valve rods R R with links L L. C is a centre line drawn from centre of pins O and I, which indicates the line of strain between the two points. D D are tripping arms moving to and from each other, varying point of cut-off to suit load. They are actuated by governor through rods G G. H H are dash pots which instantly close steam valves as soon as released at wrist plate. Observe that the center of pin P on right side which connects link L to valve rod R is below centre line C.

The operation is as follows: The wrist plate W moving in the direction indicated by arrow would cause link L to tighten and keep its hold on valve rod R until the end of link L comes in contact with roller D at which point the centre of pin P is raised above center line C, allowing the dash pot to instantly close steam valve, the link assuming similar position to that shown on left hand. When wrist plate completes its motion in direction indicated the left hand link L and rod R will fold together like that on right side.

Figs. 141 and 142 represent an automatic stop with which all the Bates-Corliss engines are equipped and of which the following is the description:

C and D are independent discs between which is placed spring F connected to the hub of C and rim of D. The tension of this spring is resisted by pawl E on disc C, thus causing discs C and D to work as one. Rod A connects direct to the governor. Rods B connect to tripping device

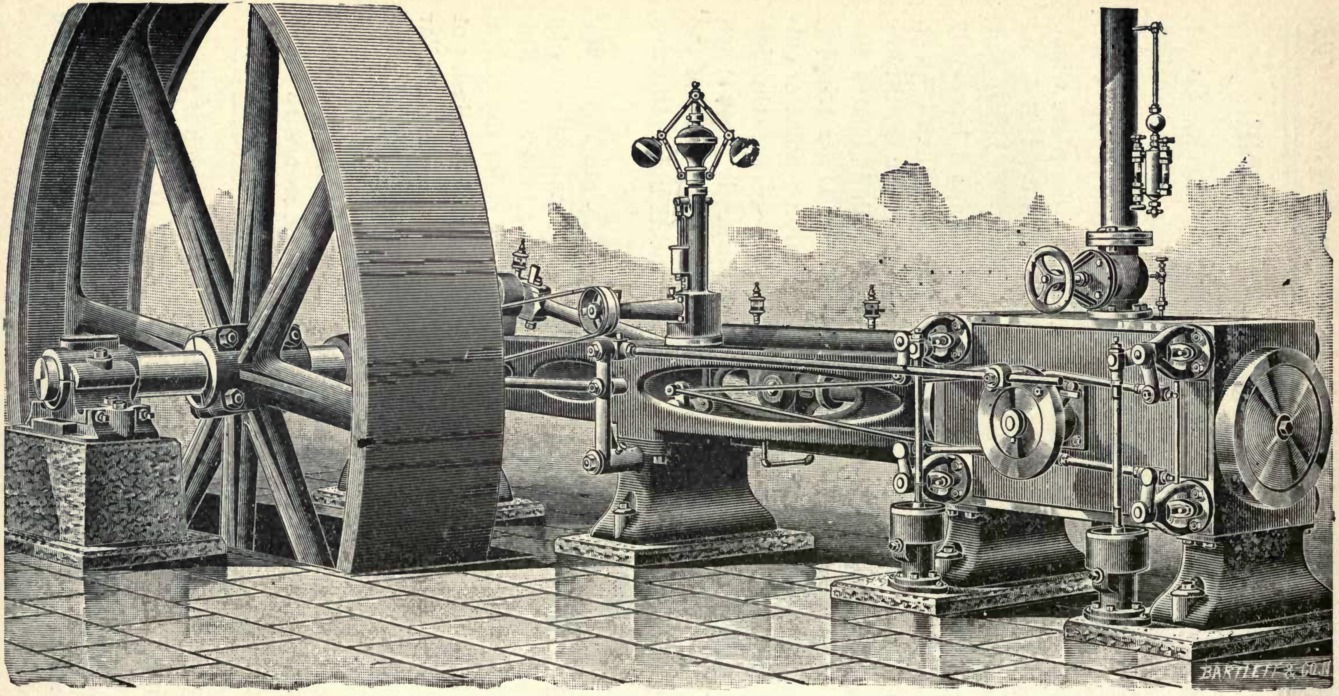


Fig. 139. BATES-CORLISS ENGINE.

THE BATES-CORLISS ENGINE.

at valve motion. Should any accident befall the governor it would immediately descent until pawl E came in contact with adjustable screw G, disengaging it from disc D, thus allowing the spring F to throw the rods B back to the

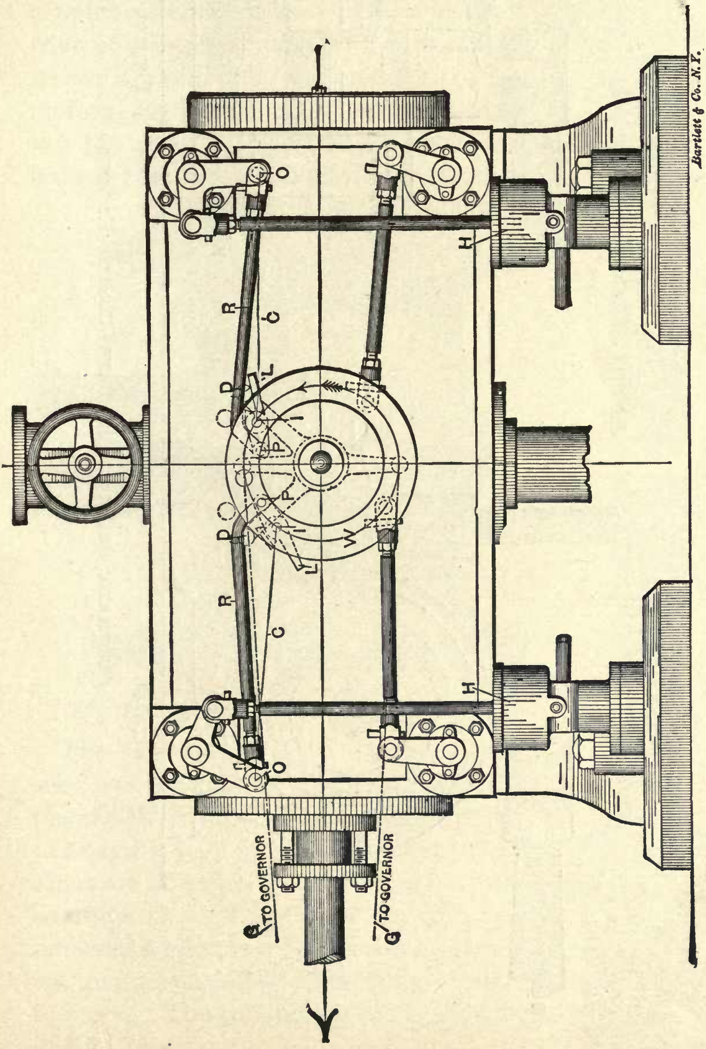


Fig. 140. VALVE GEAR—BATES-CORLISS ENGINES.

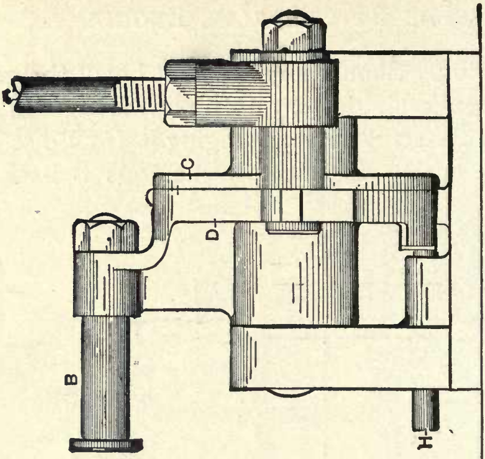


Fig. 142.

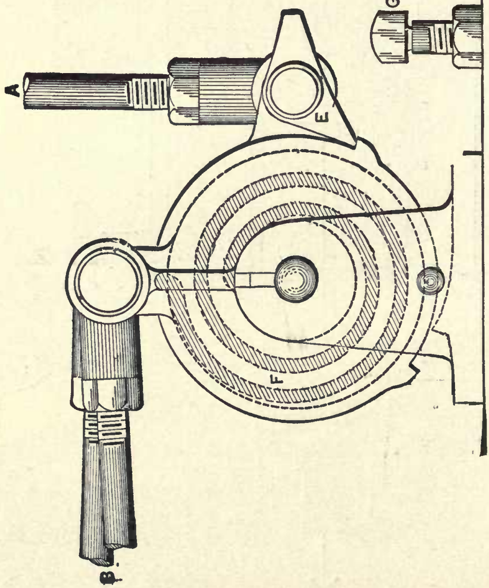


Fig. 141.

AUTOMATIC SAFETY STOP, BATES-CORLISS ENGINE.

earliest point of cut-off, shutting off steam and stopping the engine. When the engineer stops his engine and the governor descends, he pushes pin H into a recess in disc D, thus stopping the downward travel of the governor at a point where pawl E will lack just a trifle of being in contact with adjustable screw G. When the engine is started in motion again and the governor rises, the pin H is automatically forced out leaving the automatic stop free to act.

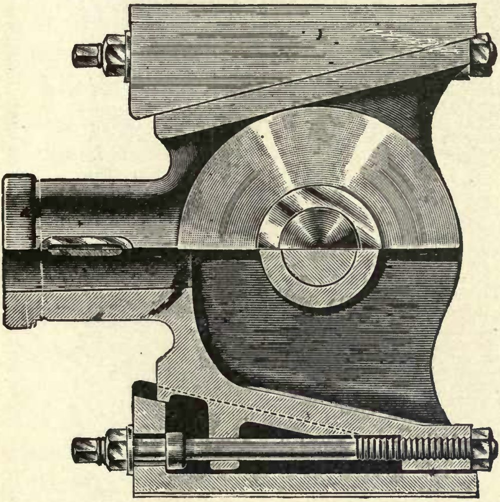


Fig. 143. CROSS-HEAD, BATES-CORLISS.

The cross-head, Fig. 143, is of the solid box form, fitted with a forged steel pin which is tapered and ground to a joint and is held in place with nut; the shoes are adjustable with wedges having bearings the entire length and can be removed while the cross-head is in place without disengaging connecting or piston rods. The connecting rod is shown in Fig. 144.

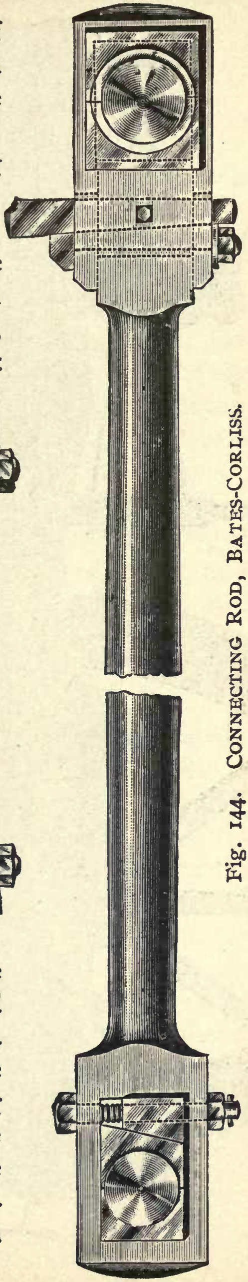


Fig. 144. CONNECTING ROD, BATES-CORLISS.

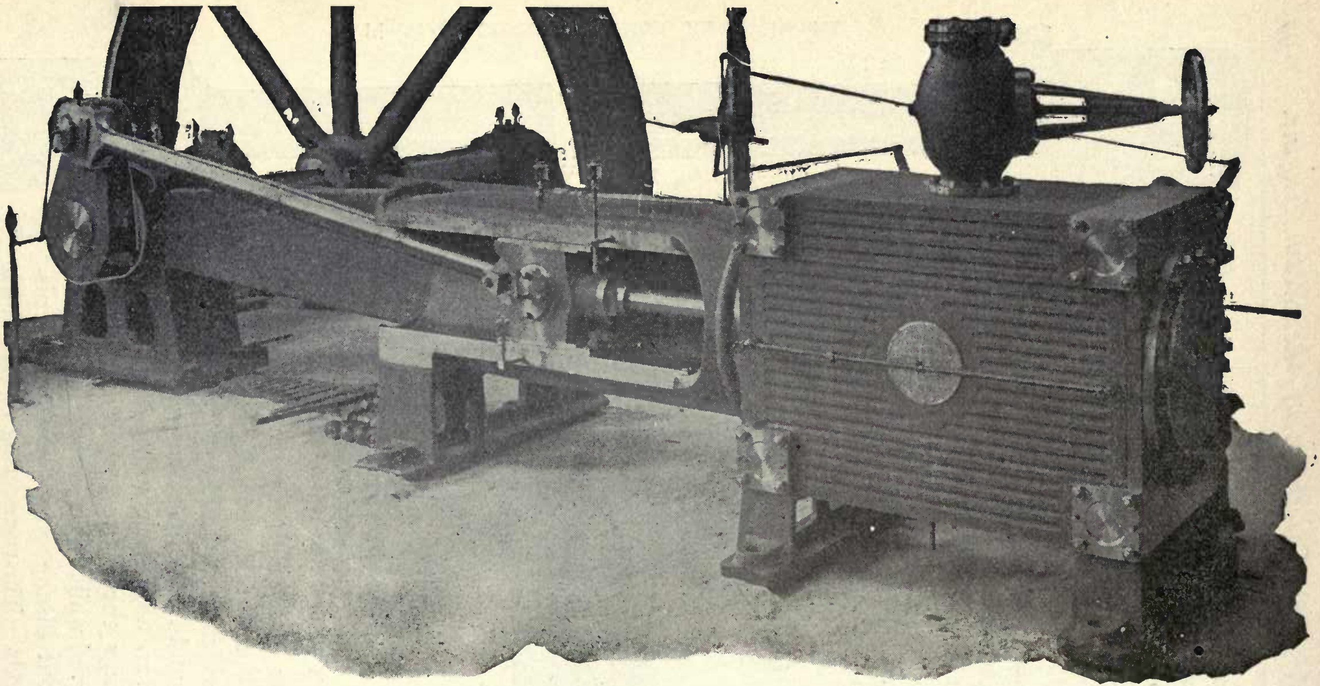


Fig 145. Standard St. Louis Corliss Engine—Front View.

THE ST. LOUIS CORLISS ENGINE.

The St. Louis Corliss Engine is built by the St. Louis (Mo.) Iron & Machine Works, established 1854.

Fig. 145 shows a front view of a single right hand engine, Fig. 146 a rear view of the same engine.

The valve gear, see Fig. 147, is the standard hook releasing type, and is operated by an eccentric on the engine shaft; the releasing devices on the steam valves are controlled automatically by the action of the governor. The four valves are each circular, with valve stems which operate the valves, made from phosphor bronze.

All the valve rods are also provided with bronze stub ends, having adjustable boxes for taking up wear; valve stems and hooks are also made from phosphor bronze, and all pins are made from the best forged crucible steel, and are fitted to gauge.

The wrist plate is circular, with all pins located near the circumference to give a rapid movement to the valves.

Where the piston travel exceeds 700 feet per minute, double ported steam valves are used to insure prompt steam admission.

The dash pots are of the vacuum type, with plungers enclosed and protected from all dust. They are entirely self contained and are positive in action under all variations of load or steam pressure. An air valve is provided for regulating the cushion of the plunger chamber.

The governor is the standard automatic centrifugal ball type, driven by a belt from the small pulley on the engine shaft. It is of the slow speed, heavy ball type; it is fitted with an automatic safety stop, which shuts down the engine should any accident happen. It is also fitted with an oil dash pot to prevent the chasing of the engine, and a weighted lever to adjust the speed of the engine four or five revolutions faster or slower.

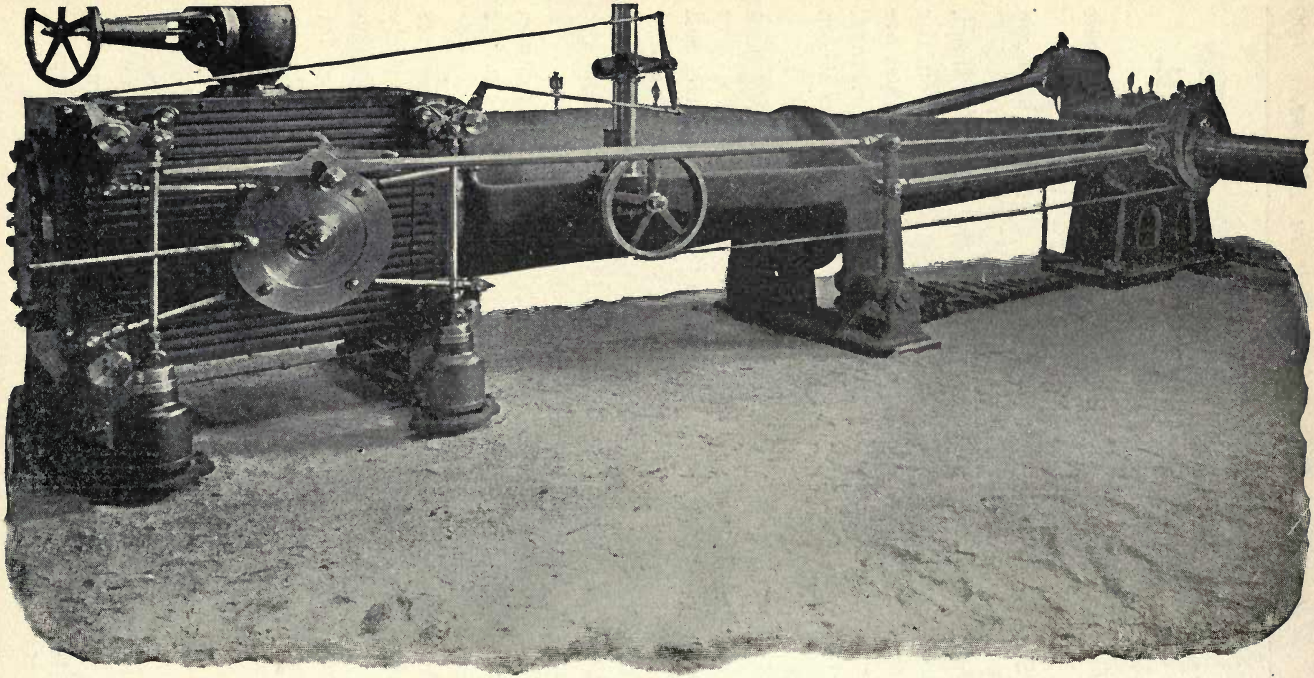


Fig. 146. STANDARD ST. LOUIS CORLISS ENGINE—REAR VIEW.

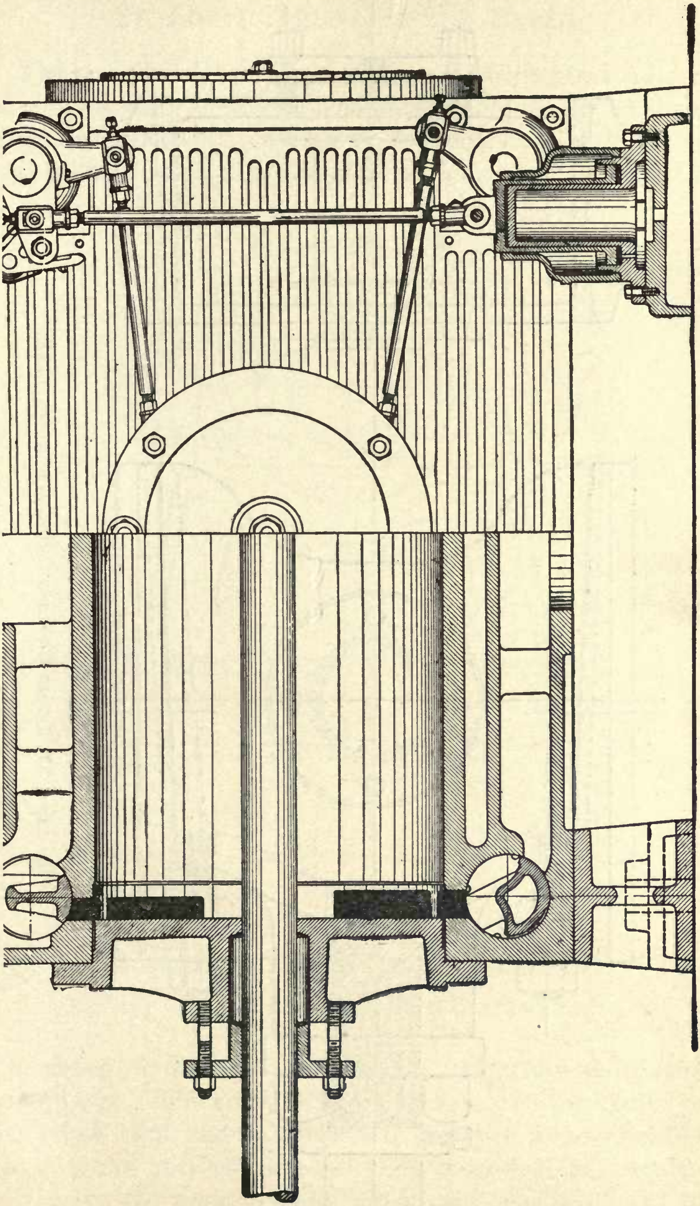


Fig. 147. St. Louis Corliss Valve Gear and Cylinder Outline.

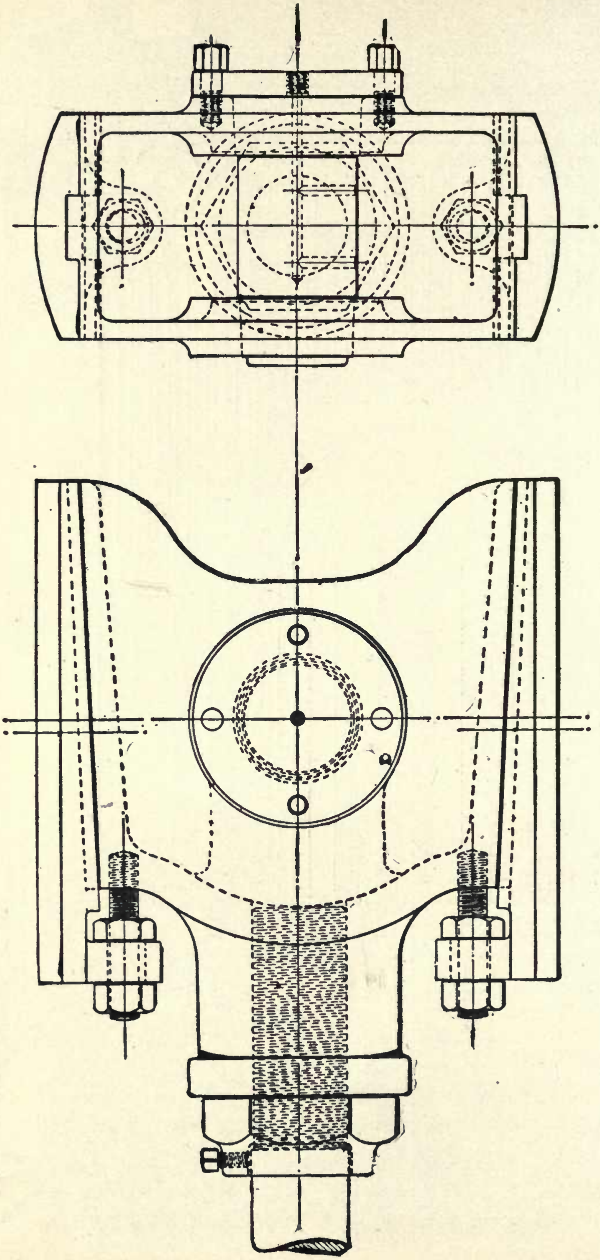


Fig. 148. St. Louis Corliss Cross-Head Outline.

St. Louis Corliss Engine Detail.

The cross head, see Fig. 148, is made with taper adjustable shoes, each lined with best anti-friction metal. Adjustment is obtained by means of the studs and nuts at the end of each shoe, and the closest adjustment is possible.

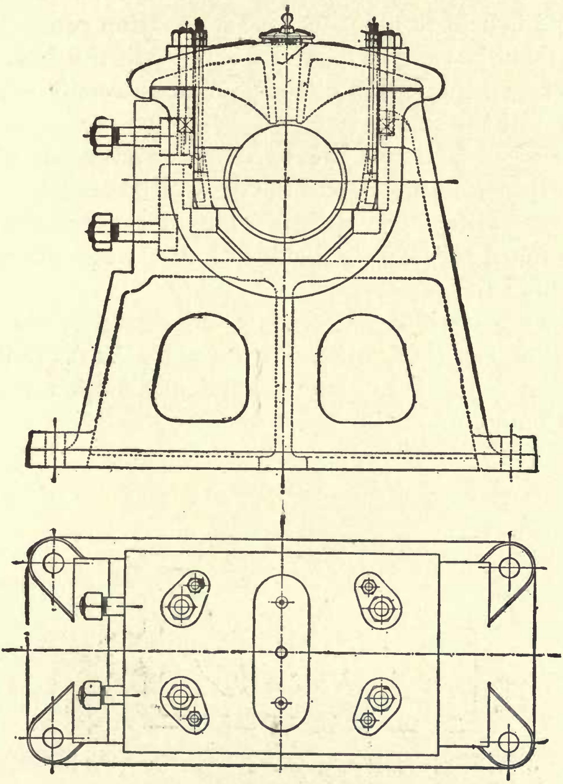


Fig. 149. St. Louis Corliss Main Pillow Block.

The shoes are fitted to the cross head tightly with tongue and groove. The cross head pin is located in the center of the cross head, and is ground to a taper fit and held in place by the two cap screws. The cross head is threaded to receive the crucible steel piston rod, which is fitted to

St. Louis Corliss Engine.

the cross head tightly and held from turning by a hexagon jam nut.

The main pillow block, and the method for adjusting for wear, is shown, Fig. 149; it is of heavy design, and has a broad bearing at the bottom where it rests on the foundation, and is held in place by four foundation rods.

The main bearing in diameter is one-half the bore of the cylinder, and the length of the journal is usually twice the diameter of the shaft.

The lower box and the two quarter boxes are all lined with anti-friction metal, and the quarter boxes are adjusted by means of the steel wedges running the full length of the journals, and having bolts and adjusting nuts running up through the cap.

These illustrations and descriptions relate to the single condensing Corliss Engine, but the same Works build also the same type of Engine in Tandem Compound and in Cross Compound.

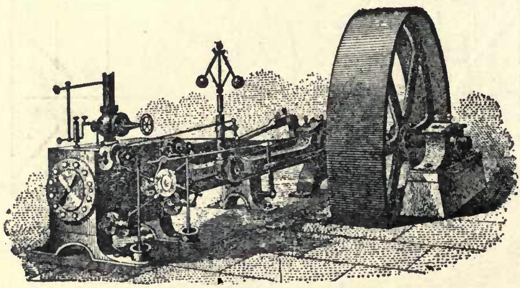


Fig. 150.

THE ECLIPSE CORLISS ENGINE.

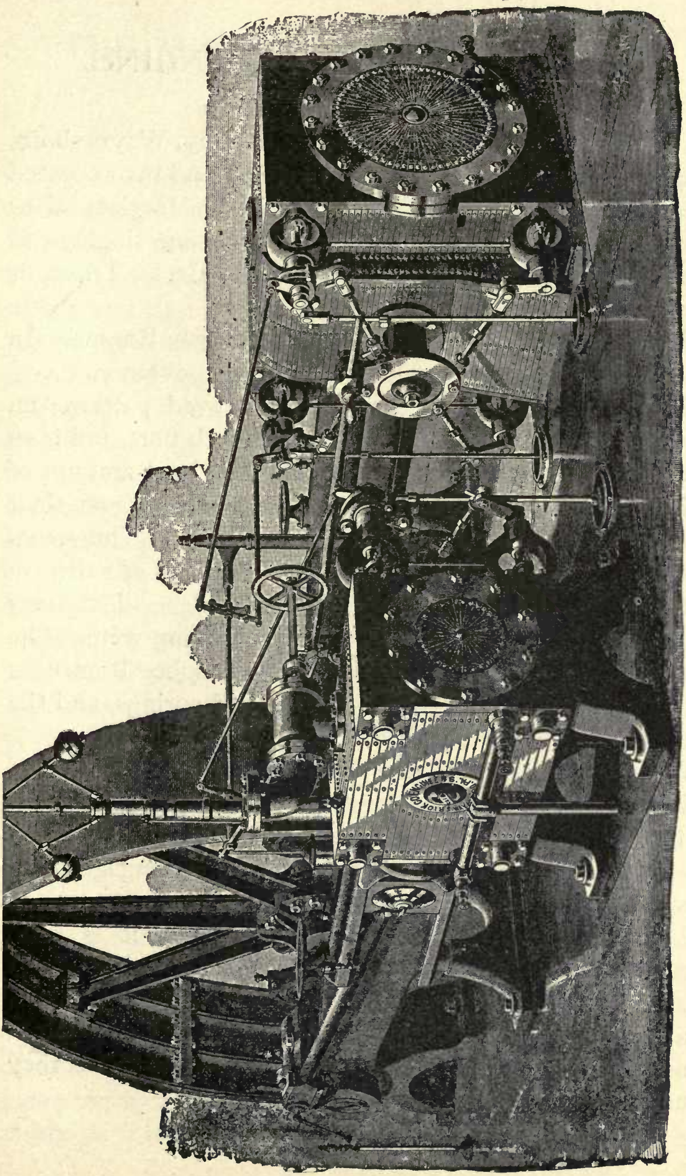


Fig. 151. THE ECLIPSE CROSS COMPOUND CORLISS ENGINE.

THE ECLIPSE CORLISS ENGINE.

This engine is built by the Frick Company, Waynesboro, Franklin Co., in works established 1853 and incorporated 1885. They make the Corliss Engine in Horizontal or Vertical form, Condensing or Non-Condensing, single or in pairs. "Compound" Engines, Tandem, Cross, Triple, or Quadruple.

Fig. 151 shows a cross compound Eclipse Engine. In the cut is exhibited the valve gearing and governor.

The valve gear is of the most approved pattern; an independent and separate valve controls each port, and is so placed that a short passage leads with the least amount of waste room to the piston; the exhaust valves, from their position, drain the water from the cylinder. The steam valves are so constructed that they act as relief valves in certain cases, and the valves themselves are solid castings from end to end, and separate from the driving stem. The valve stems are made of Deoxidized Phosphor Bronze, as are also the trunnions, glands, shoes and springs, and the stems are made interchangeable,

The wrist plate motion opens the steam valves quickly, giving boiler pressure at closest cut-off, and kept in motion up to the point of extreme travel, permitting the point of cut-off to be exactly determined and disengagements effected positively. Both the steam and exhaust valves are given a peculiar dwell movement where it is most needed. The reversal of the valves is brought about without shock, the movement being so easy from a state of rest to a rapid motion, and that without straining the connections, that wear and tear of moving parts—as light as they sometimes are made—is scarcely perceptible.

THE WATTS-CAMPBELL CORLISS STEAM ENGINE.

Fig. 152 represents a "right hand" rear view of a non-condensing Corliss engine, arranged for another engine to be added if desired. It will be noticed that the end of the shaft projects beyond the pillow-block already provided with a key way. The shaft is made strong enough and the band wheel of sufficient size to take care of double the power of one engine.

Fig. 153 exhibits a diagram of the valve gear used in this engine, and Fig. 154 shows an enlarged view of the steam valve gear. As will be noticed this differs from the gear ordinarily used in the Corliss engine; it operates upon the same principle but without the "hook" so familiar to engineers. The illustration is so plain that a detailed description would seem to be unnecessary.

Figs. 155 and 156 present a view of the dash-pot used with the Watts-Campbell type of the Corliss engine. Fig. 156 is the outside view and Fig. 155 is the view in section of the same. Its operation is as follows:

The vacuum which serves to close the valve is maintained in the chamber above the central post. As the piston descends, closing the steam valve, any small quantity of air that may have found its way into this chamber is displaced through the automatic valve shown in the top of post.

The cushioning is accomplished in the annular chamber at the bottom. The piston in falling is first partially obstructed in the tapered upper part of the annular chamber; then, as it passes this tapered portion, it is more completely resisted, the only escape for the imprisoned air being such as is provided by the adjusting screw. By means of this screw any desired adjustment of cushion can

WATTS-CAMPBELL CORLISS ENGINE.

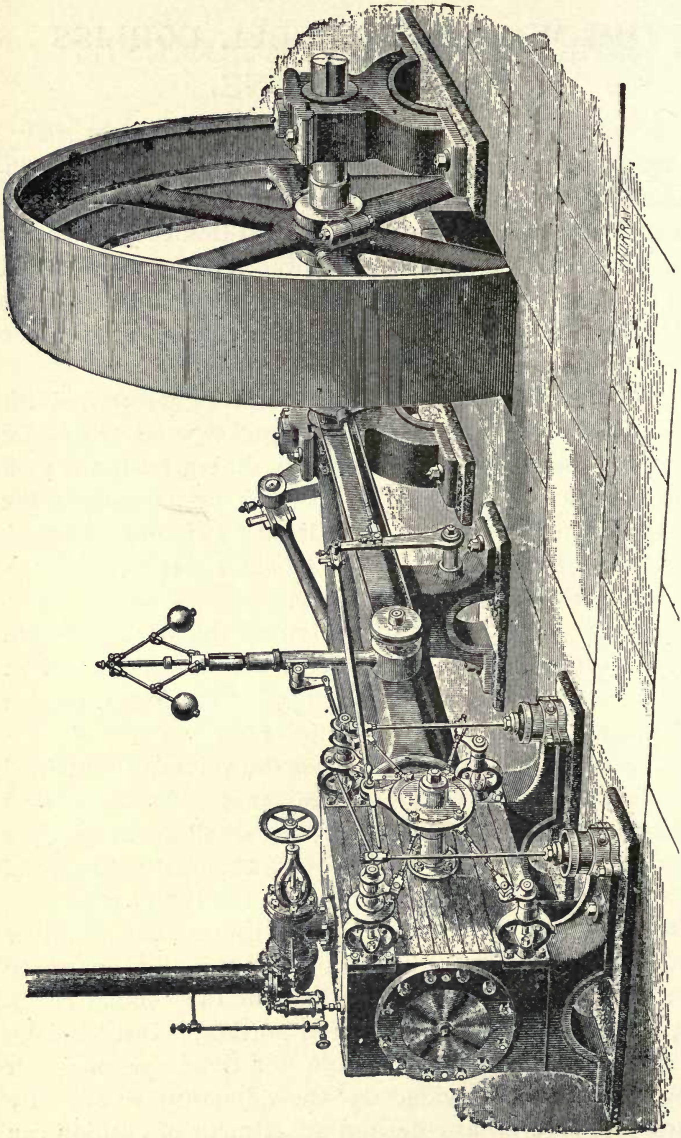


Fig. 152. WATTS-CAMPBELL, NON-CONDENSING CORLISS ENGINE.

WATTS-CAMPBELL CORLISS ENGINE.

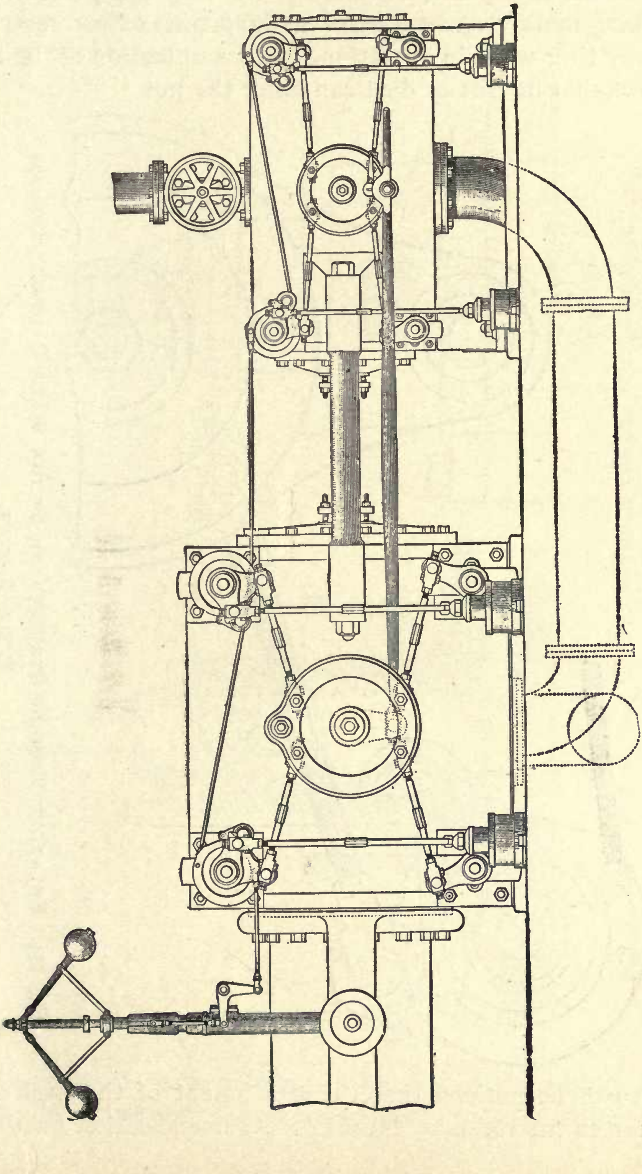


FIG. 153. DIAGRAM OF THE VALVE-GEAR OF THE WATTS-CAMPBELL CORLISS STEAM ENGINE

WATTS-CAMPBELL CORLISS ENGINE.

be made, interposed leathers preventing the parts from striking metal to metal while making such adjustment, or at any time while in operation. An examination of the cut shows that no dirt or dust can enter the pot.

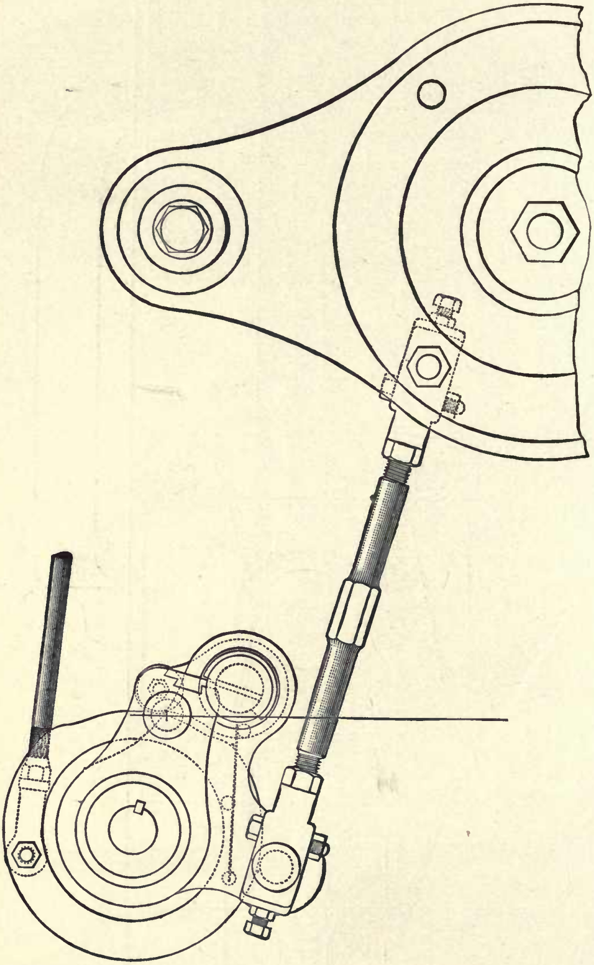


Fig. 154. ENLARGED VIEW OF STEAM-VALVE OF THE WATTS-CAMPBELL CORLISS STEAM ENGINE.

It will be noticed that the attachment of the dash pot piston to the rod is by means of a ball-and-socket bearing,

WATTS-CAMPBELL CORLISS ENGINE.

This permits the piston to turn freely on the central post, thus promoting uniformity of wear and increasing the durability of the parts.

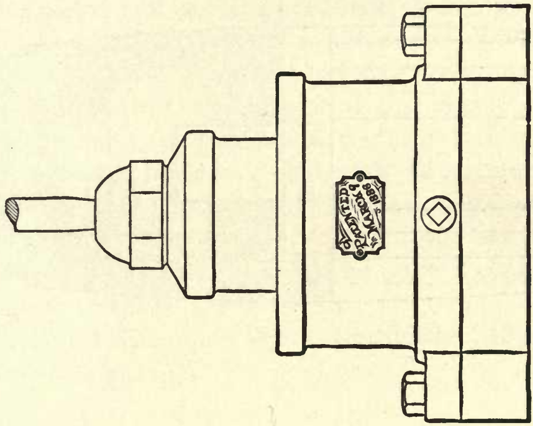


Fig. 156.

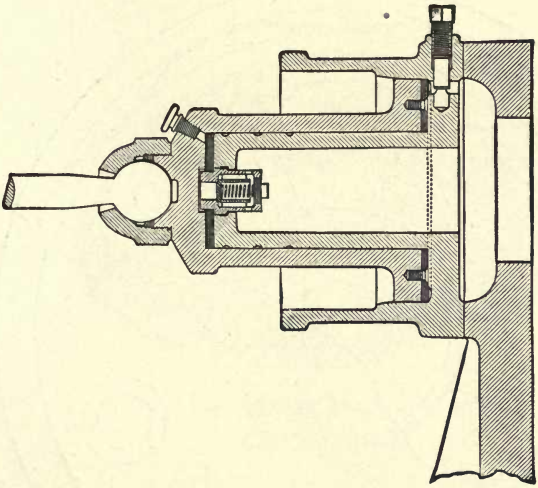
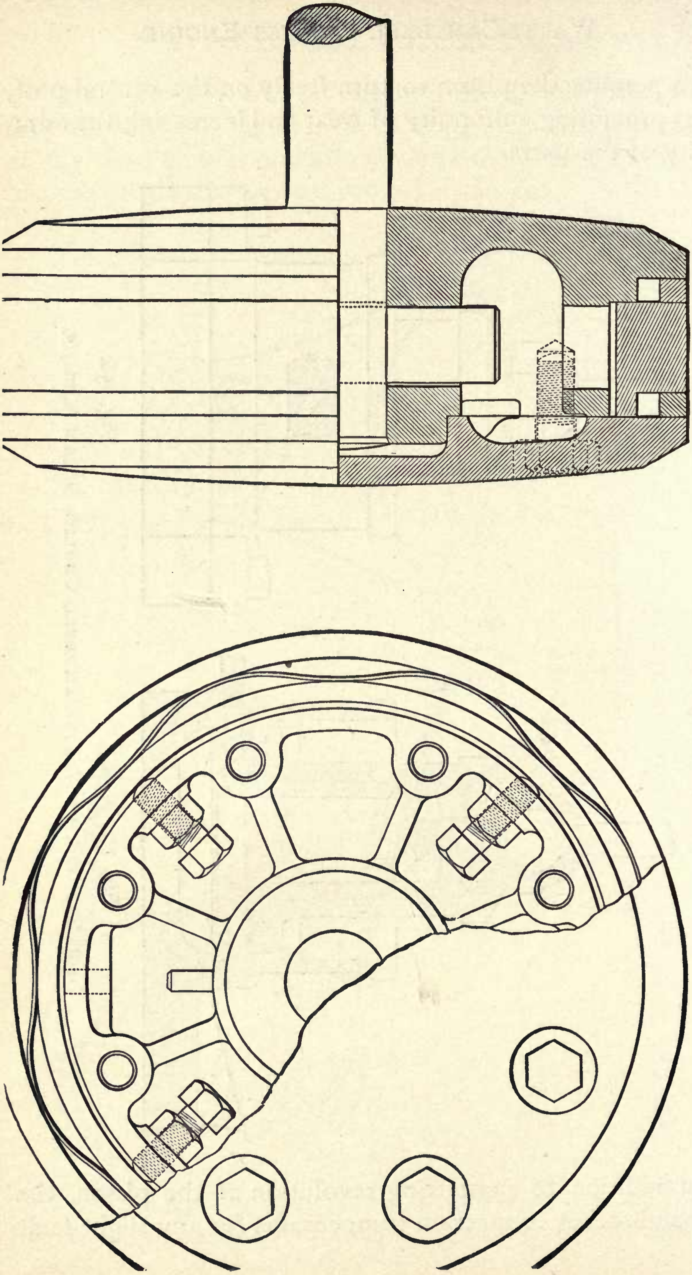


Fig. 155.

DASH-POT OF THE WATTS-CAMPBELL CORLISS STEAM ENGINE.

In addition to permitting revolution of the piston, the ball-and-socket connection compensates for any slight fault



Figs. 157 and 158. Piston of the Watts-Campbell Corliss Steam Engine.

Watts-Campbell Corliss Engine.

in alignment, avoiding all danger of binding; it also forms an oil reservoir, from which the oil cannot leak, thereby insuring perfect lubrication.

The piston and packing are illustrated in Figs. 157 and 158. As will be seen, the weight rests upon the center ring, to which the piston and follower are securely attached. When by wear of the bottom of the center ring, and of cylinder, the piston gets below the center, it can be accurately centered by means of the adjusting screws.

The packing consists of two small rings, one at either edge of the center ring. Light springs are supplied, as shown, which assist in keeping the rings in contact with the cylinder until they are worn out.

The Watts-Campbell Works (established 1851) are located at Newark, N. J.

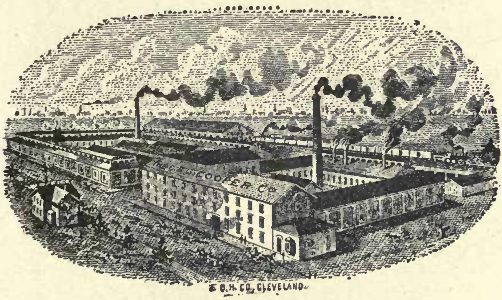


Fig. 159. Model Engine Works.
(See page 215.)

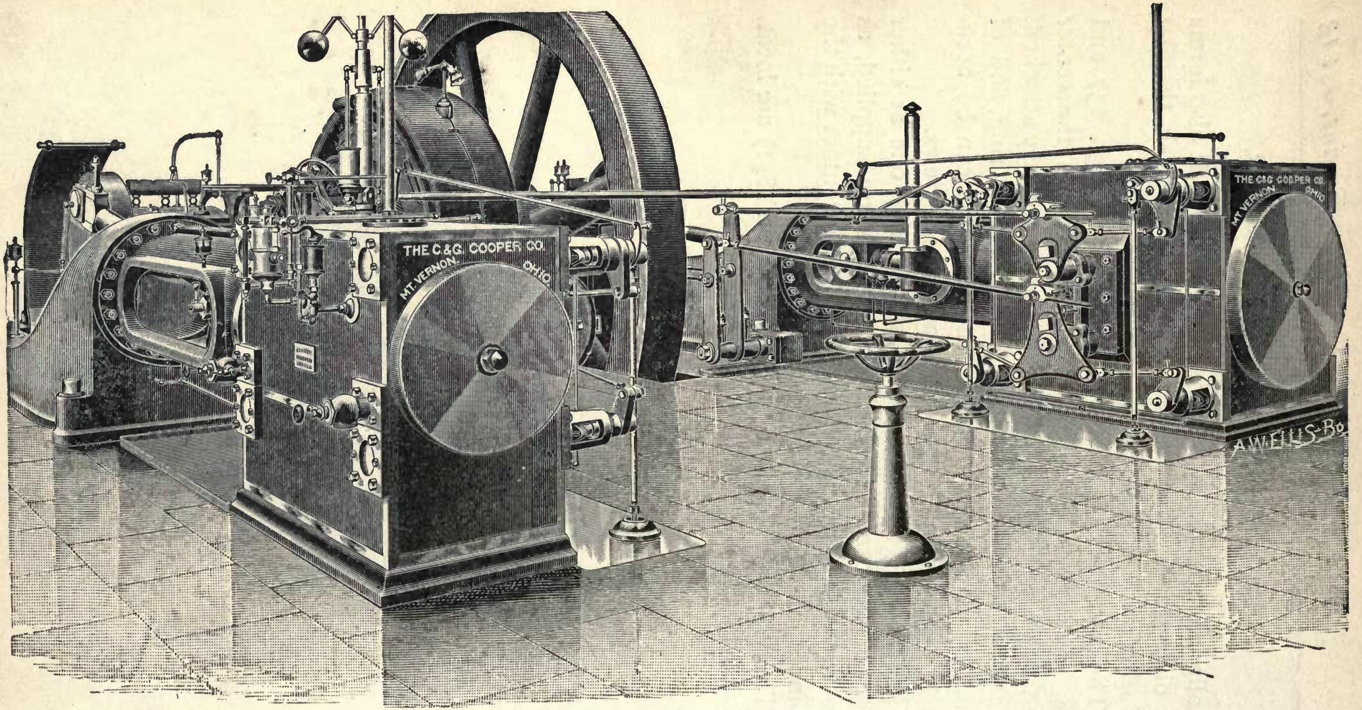


Fig. 160. COOPER-CORLISS ENGINE—CROSS COMPOUND.

THE COOPER-CORLISS ENGINE.

These engines are built at Mount Vernon, Ohio, by Messrs. C. & G. Cooper Co., in works established A. D. 1833.

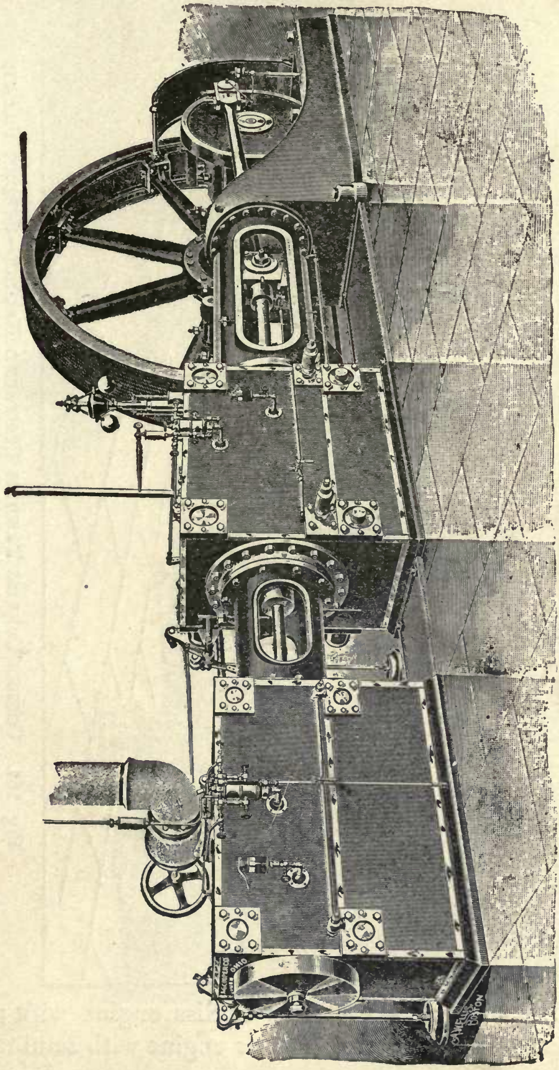


Fig. 161. Cooper-Corliss Tandem Compound—Left Hand Engine—Front View.

Fig. 160 shows a Cooper-Corliss, cross compound engine direct connected to an electric generator.

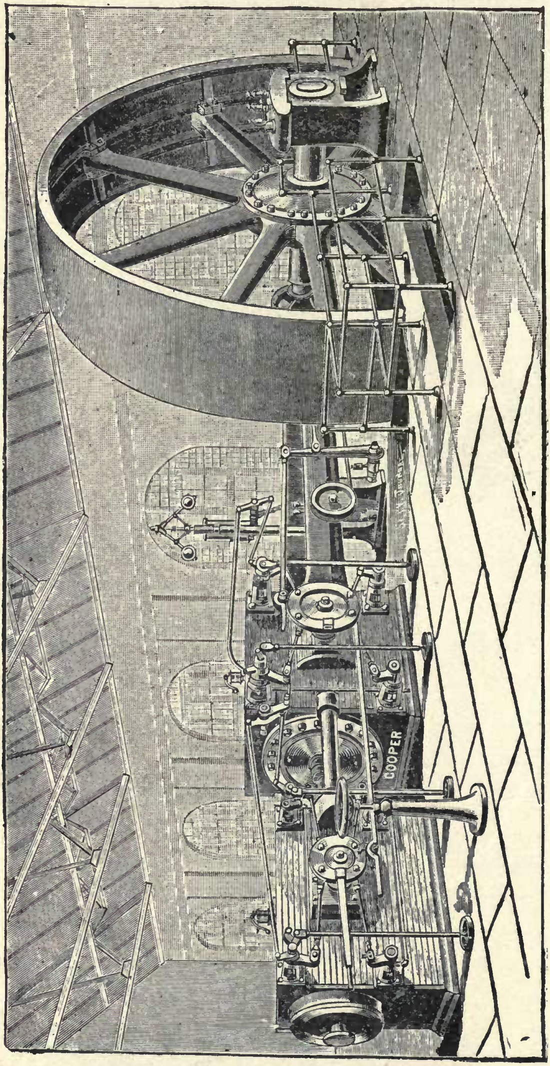


Fig. 162. Cooper-Corliss Tandem Compound Engine—Girder Frame.

Fig. 162 illustrates a Cooper-Corliss engine with girder frame and Fig. 161 shows a similar engine with semi-tangye frame.

THE HEWES & PHILLIPS CORLISS ENGINE.

These engines are built at Hewes & Phillips Iron Works (established A. D. 1857), in sizes varying from 50 up to 1000 H. P. in non-condensing engines and from 150 to 2000 H. P. in compound condensing engines.

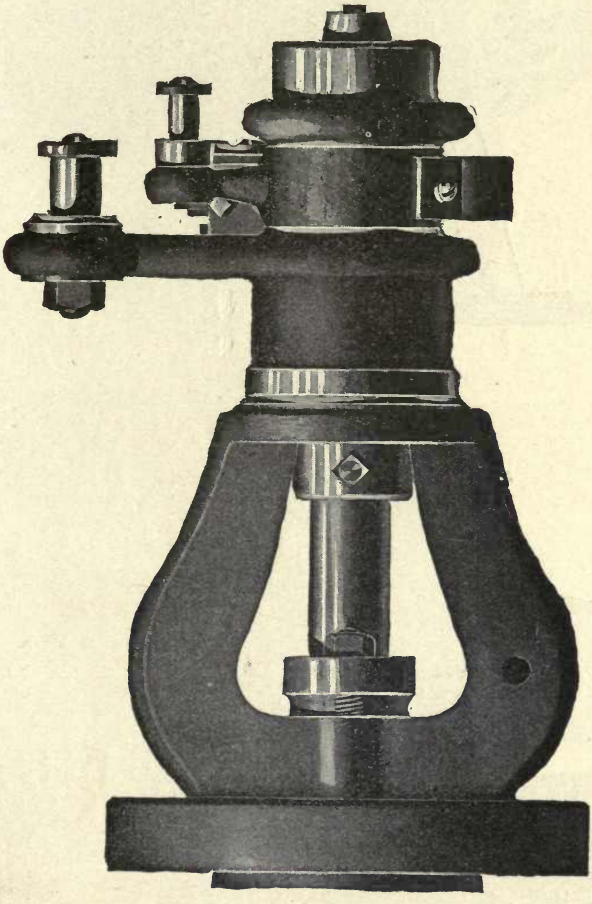


Fig. 163. Steam Valve Bonnet with Releasing Gear.

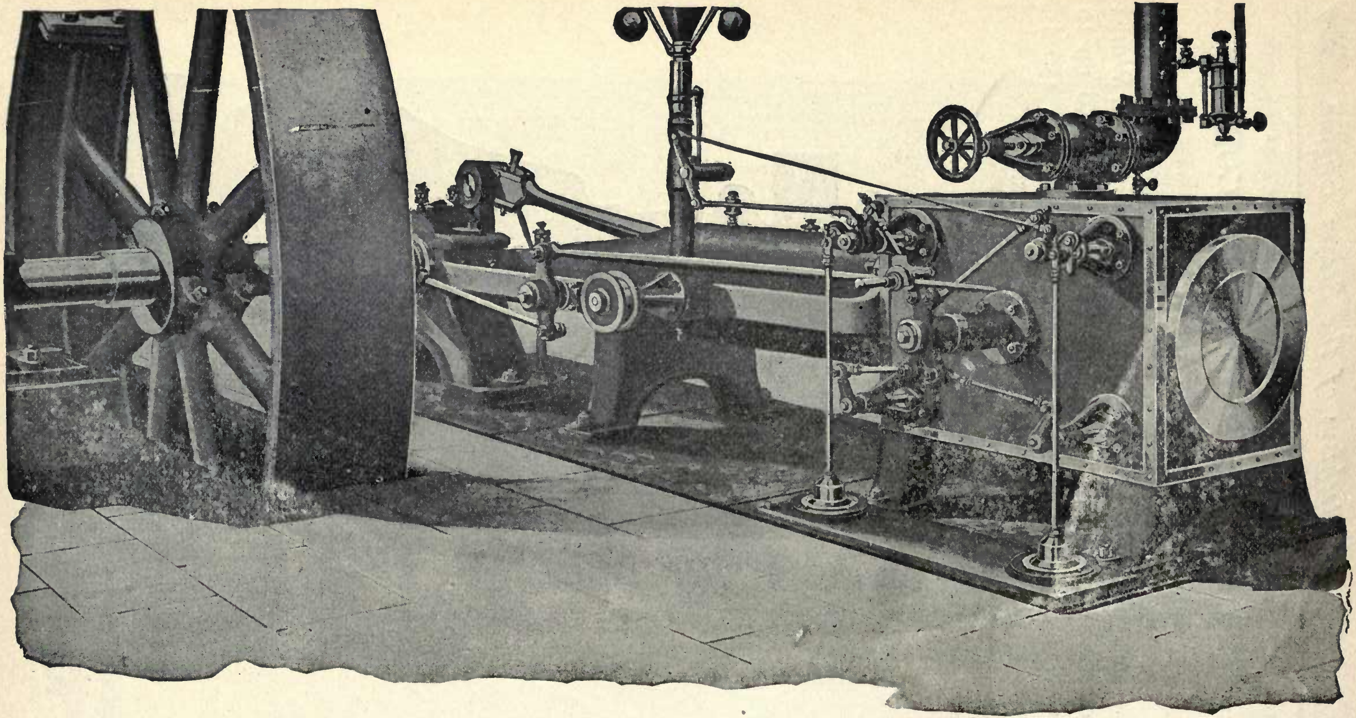


Fig. 164. Hewes & Phillips Corliss Steam Engine.

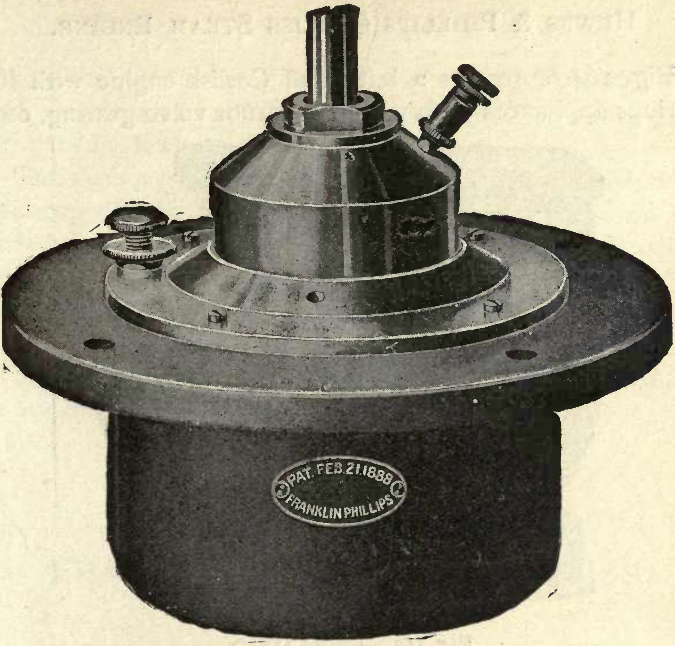


Fig. 165. DASH POT ELEVATION.

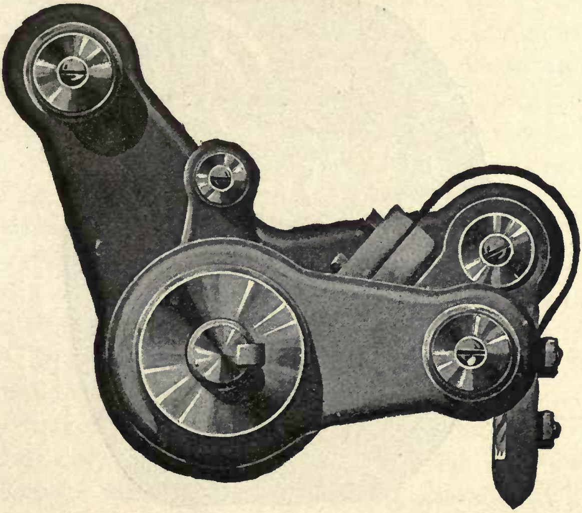


Fig. 166. SIDE VIEW OF RELEASING GEAR.

Hewes & Phillips Corliss Steam Engine.

Fig. 164 represents a left hand Corliss engine with its various appliances of flywheel, governor valve gearing, etc.

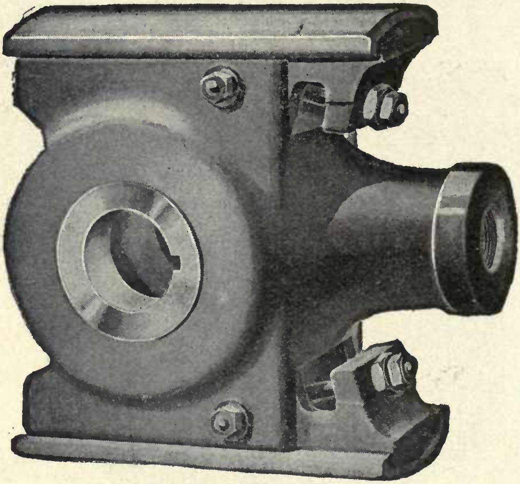


Fig. 167. Cross Head.

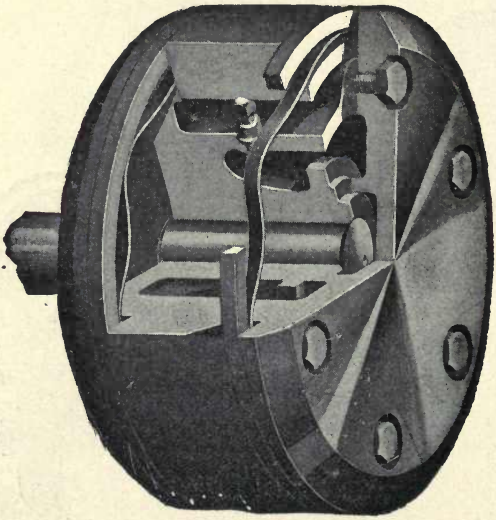


Fig. 168. Piston.

Fraser & Chalmers Corliss Engine.

The valve gear, parts of which are shown in Figs. 163 and 166, correspond with the approved Corliss valve gear described elsewhere.

The dash-pot (Fig. 165) is arranged to let in flush with the top of the bed plate of the engine. The dash-pot rods being connected to the plungers by ball and socket joint, which allows them to turn freely while being adjusted.

The construction of the piston (Fig. 168) and cross-head (Fig. 167) is so plainly illustrated that no further description is needed.

FRASER & CHALMERS' CORLISS ENGINE.

These engines are built at Chicago, Ills., U. S. A., and at Erith, Kent, England, by Messrs. Fraser & Chalmers.

Fig. 169 exhibits a horizontal Corliss Engine, in which the valve gear does not vary much from the ordinary patterns, a description of which will be found in the general description of the Corliss engines. As will be seen in the figure, hooks are employed instead of the less familiar crab-claw, to open the valve.

Fig. 170 shows a vertical Corliss with the Porter governor, and with valve gear similar to that used in the horizontal engine shown in Fig. 169.

The figures are so plainly shown that little further explanation is needed.

On their compound and triple expansion engines, the governor only regulates the cut-off of the high pressure cylinder, the intermediate and low pressure cut-off being set by hand.

FRASER & CHALMERS CORLISS ENGINE.

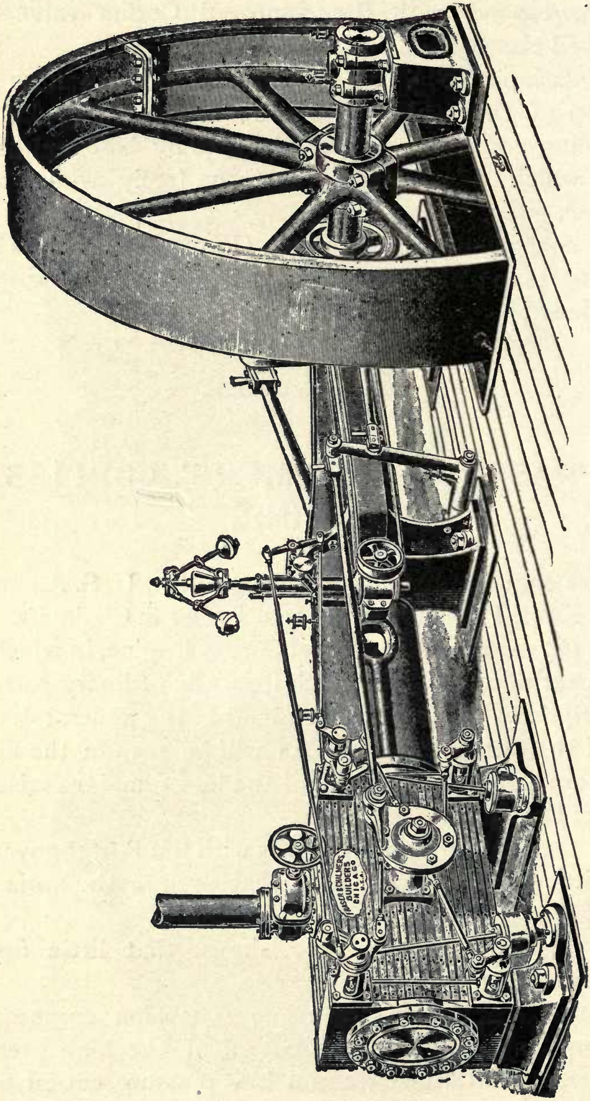


Fig. 169. FRASER & CHALMERS HORIZONTAL CORLISS-ENGINE.

FRASER & CHALMERS CORLISS ENGINE.

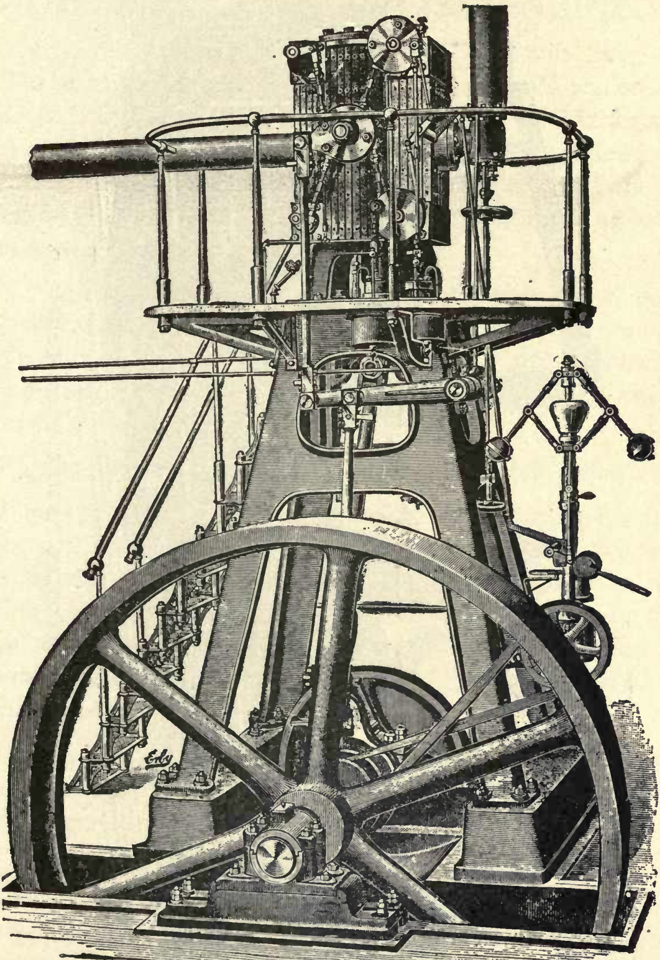


Fig. 170. FRASER & CHALMERS' VERTICAL CORLISS ENGINE.

THE REYNOLDS-CORLISS ENGINE.

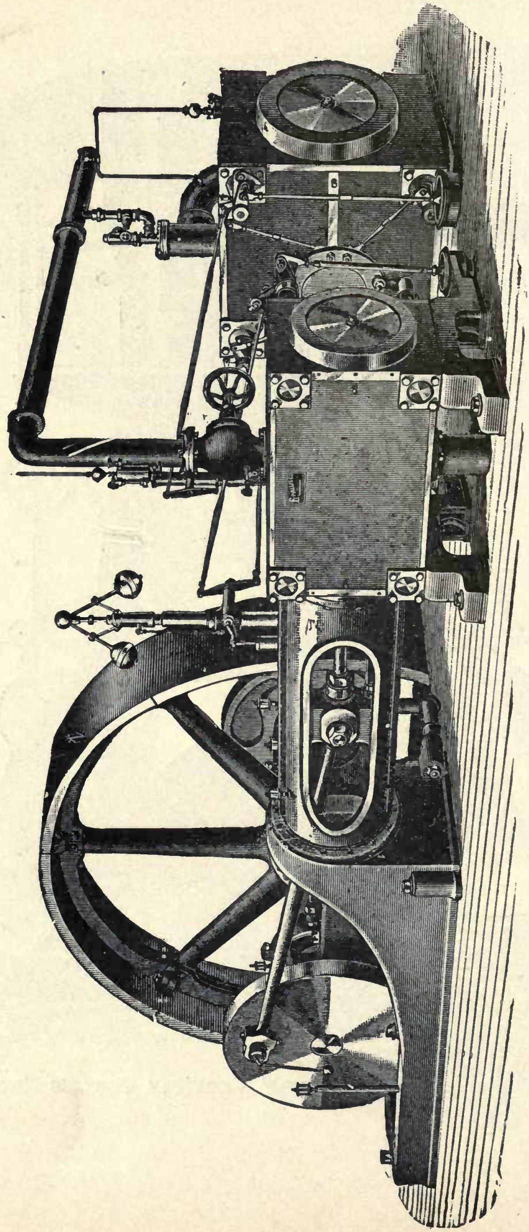


Fig. 171. REYNOLDS-CORLISS ENGINE, CROSS COMPOUND.

THE REYNOLDS-CORLISS ENGINE.

These engines are built at the Reliance Works (E. P. Allis & Co.) Milwaukee, Wis., from designs of Mr. Edwin Reynolds. In about twenty years this company has manufactured over three thousand Corliss Engines, and among them will be found some of the most notable samples of steam engineering in the world.

To meet the requirements of modern practice both horizontal and vertical engines are made, and these are built in full variety, single, double, triple and quadruple expansion, condensing or non-condensing, arranged either as tandem or twin engines.

Fig. 171 shows a cross compound Reynolds-Corliss.

Figs. 172 and 173 show a single Reynolds-Corliss Engine, front and rear views. The gear shown is that which was introduced in 1876 from designs of Mr. Reynolds. Its action is such that it imposes little or no work on the regulator, thereby securing close regulation, and it can be operated at speeds usually deemed impracticable with a drop cut-off gear.

It is not necessary to give a detailed account of the valve gear, as it corresponds closely to that already described in the general article under the heading of "Valve Gear of the Corliss Engine," page 172.

Under the division of Pumping Engine, Fig. 187, is shown the same description of engine used for operating water works, and in Fig. 235, under heading of "Hoisting Engines," the same type of engine appears.

In Fig. 174 is shown a graphic view of the valve gear as designed and built for this make of the Corliss Engine.

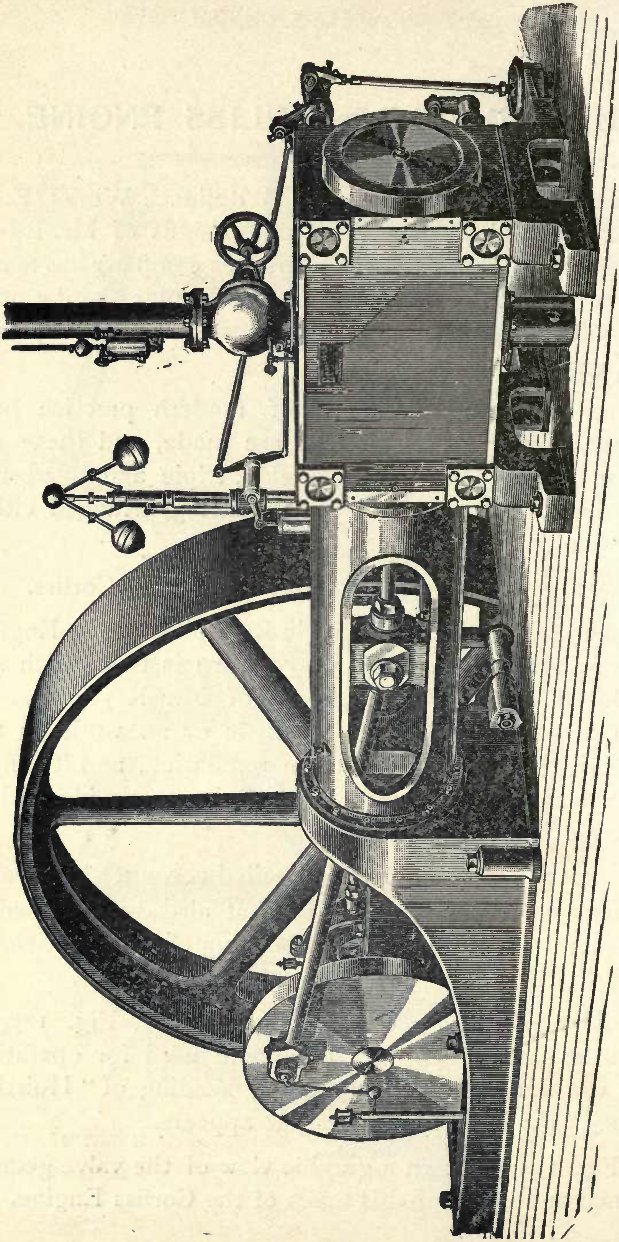


Fig. 172. Reynolds Corliss Single Engine.—Front View.

THE REYNOLDS CORLISS ENGINE.

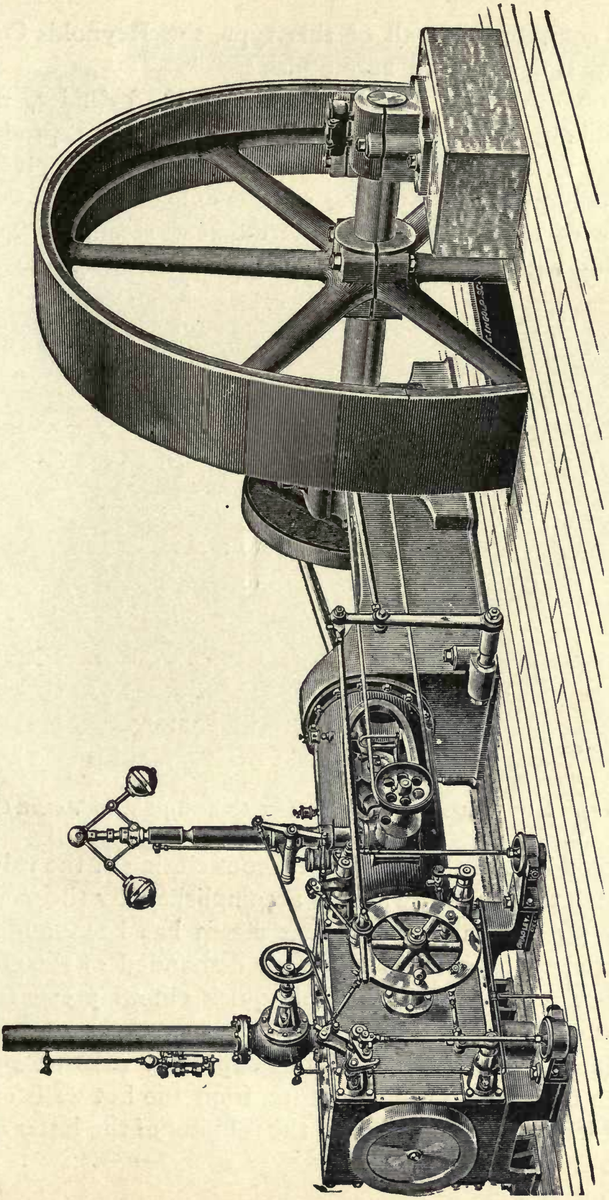


Fig. 173. REYNOLDS-CORLISS SINGLE ENGINE.—Rear View.

Reynolds Corliss Engine.

In common with all of this type, the Reynolds Corliss engine is designed to accomplish:

First. A high initial pressure in the cylinder, made possible by the rapid opening of the inlet valves, produced by the well-known wrist plate motion, which also gives an exceedingly quick opening of the exhaust valves at the point of release, allowing the exhaust steam to escape quickly with practically no back pressure.

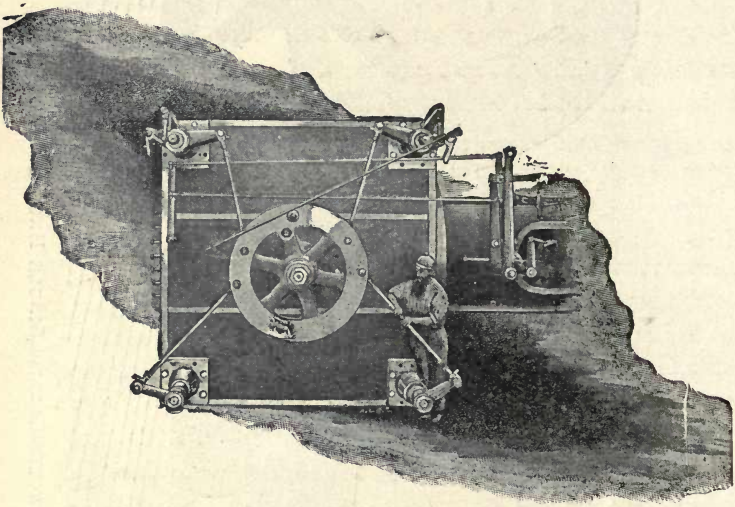


Fig. 174. Reynolds-Corliss Engine Cylinder and Valve Gear.

Second. An almost instantaneous closing of the valve at the point of cut-off, which is accomplished by the vacuum dash pot, when just sufficient steam has been admitted into the cylinder to do the work demanded of the engine at that particular time. This quick cut-off prevents the wire-drawing of steam.

Third. The isolation of the expanded exhaust steam, which is lowered in temperature, from the hot walls of the cylinder, thereby preventing the robbing of the latter of its heat.

THE PUMPING ENGINE.

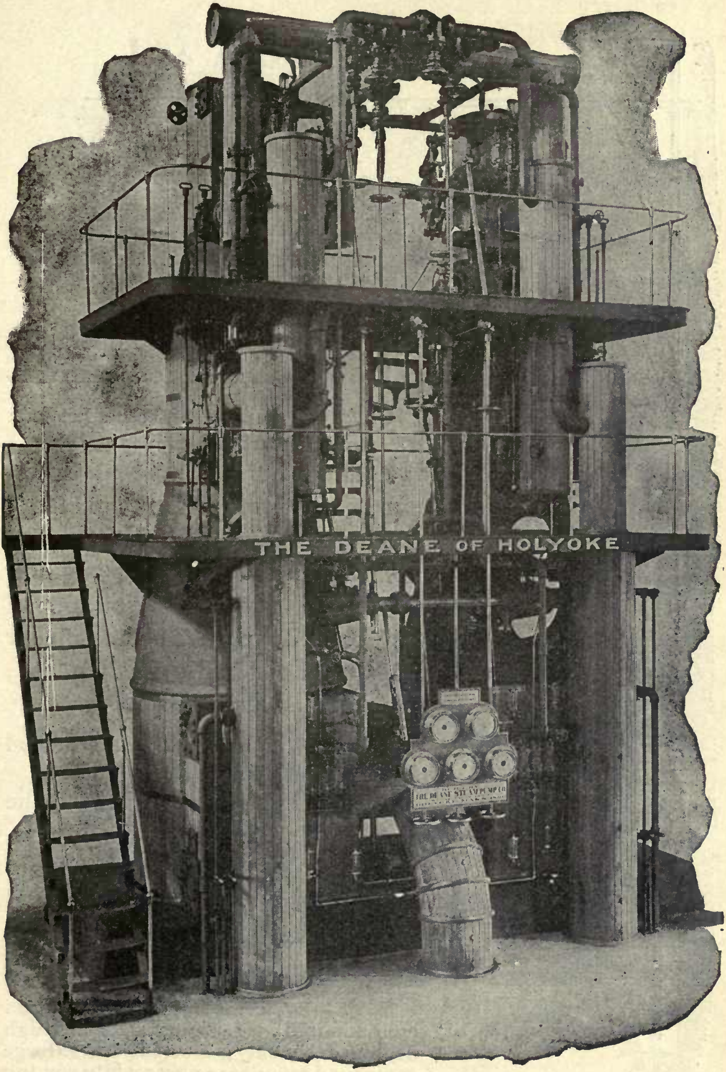


Fig. 175. THE DEANE VERTICAL TRIPLE EXPANSION CONDENSING DUPLEX HIGH DUTY PUMPING ENGINE.

PUMPING ENGINES.

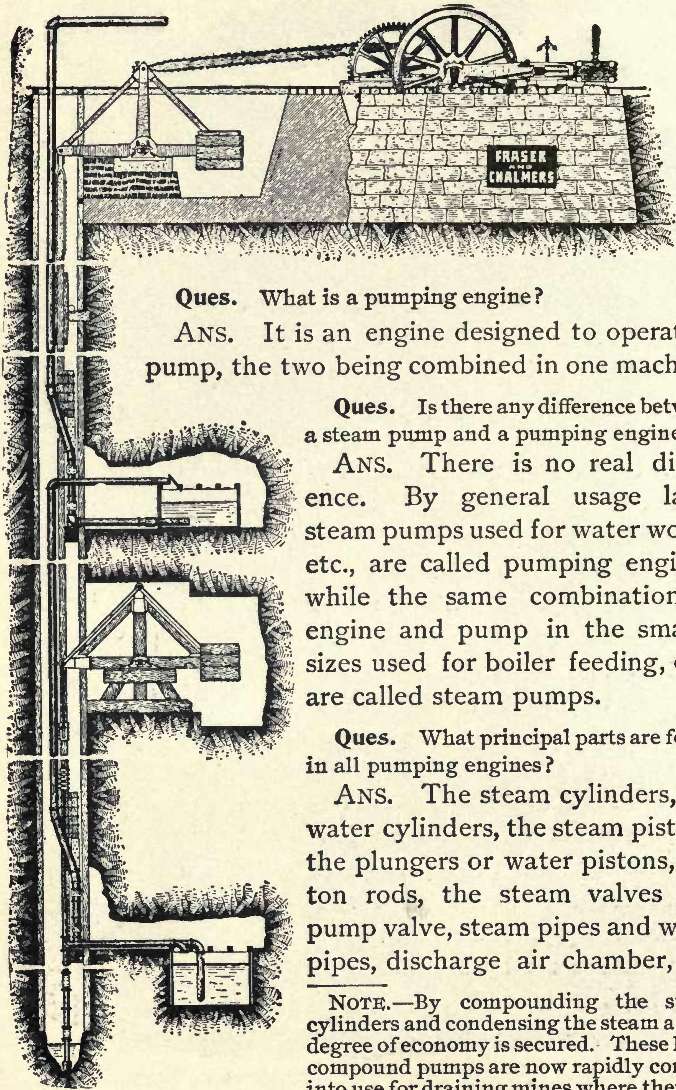


Fig. 176.
THE CORNISH PUMP.

Ques. What is a pumping engine?

ANS. It is an engine designed to operate a pump, the two being combined in one machine.

Ques. Is there any difference between a steam pump and a pumping engine?

ANS. There is no real difference. By general usage large steam pumps used for water works, etc., are called pumping engines, while the same combination of engine and pump in the smaller sizes used for boiler feeding, etc., are called steam pumps.

Ques. What principal parts are found in all pumping engines?

ANS. The steam cylinders, the water cylinders, the steam pistons, the plungers or water pistons, piston rods, the steam valves and pump valve, steam pipes and water pipes, discharge air chamber, etc.

NOTE.—By compounding the steam cylinders and condensing the steam a high degree of economy is secured. These large compound pumps are now rapidly coming into use for draining mines where they are placed under lifts of a thousand feet or more with great success.

THE PUMPING ENGINE.

The history of the pumping engine is the history of the steam engine, for originally and for many years the only way in which the steam engine was utilized was for pumping water out of the coal mines of England.

In 1698 Capt. Thomas Sevary secured Letters Patent for a machine for raising water by steam. It consisted of two boilers and two receivers for the steam, with valves and the needful pipes. One of the receivers being filled with steam, its communication with the boiler was then cut off and the steam condensed with cold water outside of it; into the vacuum thus formed the atmosphere forced the water from below, when the steam was again caused to press upon the water and drive it still higher.*

This engine was used extensively for draining mines and the water was, in some instances, made to turn a water wheel, by which lathes and other machinery were driven.

In 1705, Thomas Newcomen, with his associates, patented an engine which combined, for the first time, the cylinder and piston and separate boiler. This soon became extensively introduced for draining mines and collieries, and the engines grew to be of gigantic size, with cylinders 60 inches in diameter and other parts in proportion.

This engine was, in course of years, used in connection with the Cornish Pump, whose performance in raising water from mines came to be a matter of the nicest scientific investigation, and adopted as the standard for the duty or work, by which to compare the multitudinous experimental machines introduced from the time of Watts and to that of Corliss.

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*NOTE—This principle is illustrated in the operation of the well-known Pulsometer Pump.

THE PUMPING ENGINE.

Like the marine engine, each pumping engine is fitted to its specified "duty" or work, hence no description can be given covering the whole subject. It may not be out of place to describe a pumping engine of 75 million gallons per day, which is truly a marvelous piece of mechanism. It is a pumping engine used in the Calument Hecla mines of Michigan.

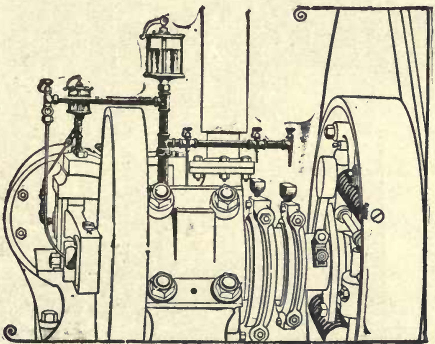
Briefly, it is a triple expansion pumping engine with a capacity of 60,000,000 gallons, standing nearly fifty feet in height and requiring 1,500 horse power for its operation. It has been proved by actual tests that the nominal capacity can be easily maintained for an indefinite time without injury or strain, and that pushed to its full capacity the pump could handle approximately 75,000,000 gallons in twenty-four consecutive hours.

Fig. 176 exhibits the Cornish pump as connected with the more modern Corliss engine. We quote from data furnished by Messrs. Fraser & Chalmers:

NOTE.—The duty of this pump is to furnish water for the great stamp mills of the Calumet and Hecla Company, which has twenty-two steam pumps in continuous operation, daily pulverizing 5,000 tons of conglomerate rock into sand so fine that it can be carried away by a stream of swiftly running water. The pump is housed in a special building near the shore of Torch Lake and below the mills, and it forces a steady stream of water to the upper portions of the mill, where innumerable small jets play upon the great slime tables and jigs. Here the specific gravity of the fine particles of copper contained in the rock separate the mineral from worthless sand, and the size and force of the streams of water are so nicely regulated as to wash away the sand and yet carry with it the minimum of copper. This pumping engine will do the work with scarcely as much noise as is made by the operation of an old style sewing machine. Outside the doors of the great building which houses it no sound is heard from within, and, standing beside the monster, upon the brink of the pit connected with the lake from which the water is taken, almost the only sound heard is the noise of the suction, as with every stroke more than a thousand gallons are lifted.

The Pumping Engine.

"The Cornish Pump is well established in favor for permanent pumping plants in mines requiring the removal of large volumes of water. It is of the greatest economy of operation, both for fuel and repairs. It is conveniently located above ground, and in this respect avoids the heating and annoyance of direct-acting pumping plants, below the surface. The system of arrangement for deep mines is shown in Fig. 176. At bottom of mine is a telescope suction, and lift or bucket pump; above this, at intervals of about 250 feet, are force-pumps. At each force-pump level is a receiving tank. The pump plungers are operated by wood rods, in 30 or 40 foot sections, bolted together with wrought iron strapping plates. These are worked from engine by a connecting rod and bob at the surface, supplemented, if the weight of rods requires it, by balance bobs at lower levels."



Oiling Device.

THE WORTHINGTON PUMPING ENGINE.

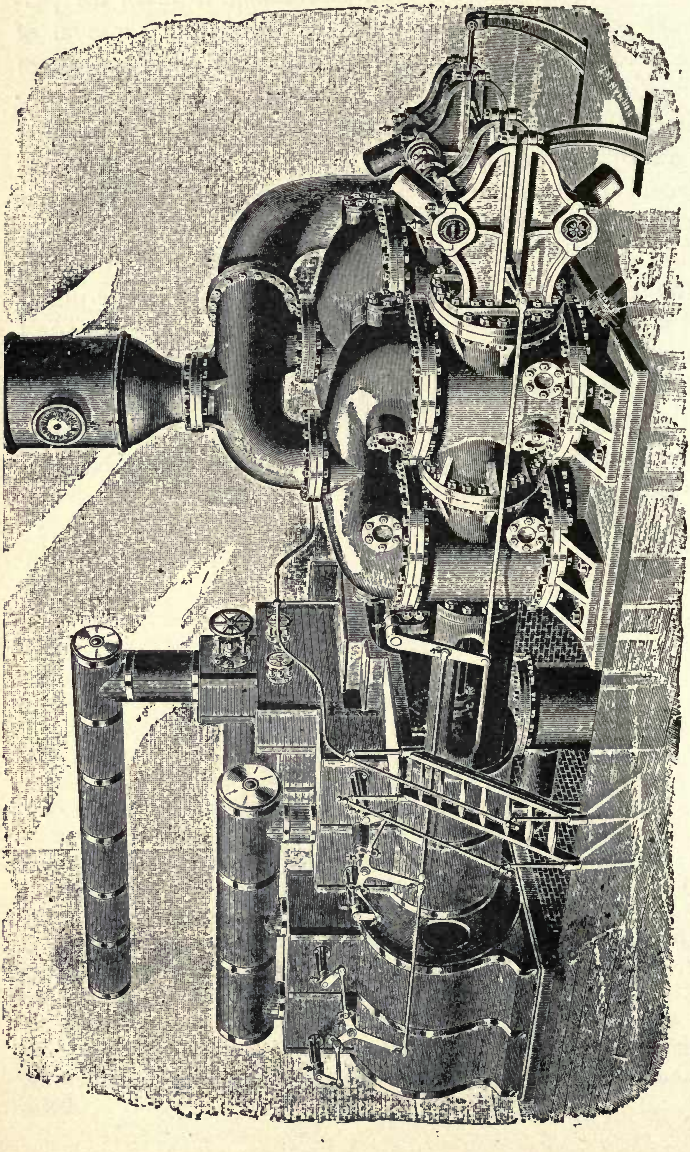


Fig. 177. WORTHINGTON HIGH DUTY PUMPING ENGINE—(Duplex Compound).

WORTHINGTON HIGH-DUTY PUMPING ENGINES.

Figs. 177 and 178 illustrate the latest pattern of the Worthington High-Duty Pumping Engine, having cylinders arranged on the compound, direct-acting principle. The general features of construction are shown in the cuts, one of which is a longitudinal section, showing the general arrangement of the principal parts; and the other, an outside view of an engine of the same design.

The steam cylinders are all jacketed, both on the sides and heads, with steam of boiler pressure, and reheaters are provided, through which the steam passes on its way from the high to the low cylinders, which are likewise steam jacketed.

The steam which is used in the jackets is that derived from the drain pipe of the separator which belongs to the engine, and the steam from this point passes in succession through the reheaters, which are at the highest elevation, and thence through the jackets of the four cylinders, finally being delivered into a common drain pipe, which proceeds to a tank in which the water of condensation is collected. The jacket tank is drained by a small duplex steam pump working automatically, the throttle valve being under the control of the float in the tank, and this water is pumped into the boilers.

The valves are circular in shape, instead of flat, and are driven by vibrating levers, instead of the reciprocating motion of the valve rod. They have cylindrical shaped seats, in which is fitted a liner that can be removed and replaced by the new one, if needed.

The valves are nicely fitted to their seats, and are connected to the valve rods by means of a slot milled across the end of the valve, into which fits a tee head that is on the end of the valve rod, making a perfect and positive connection without the aid of bolts or nuts.

The Worthington Pumping Engine.

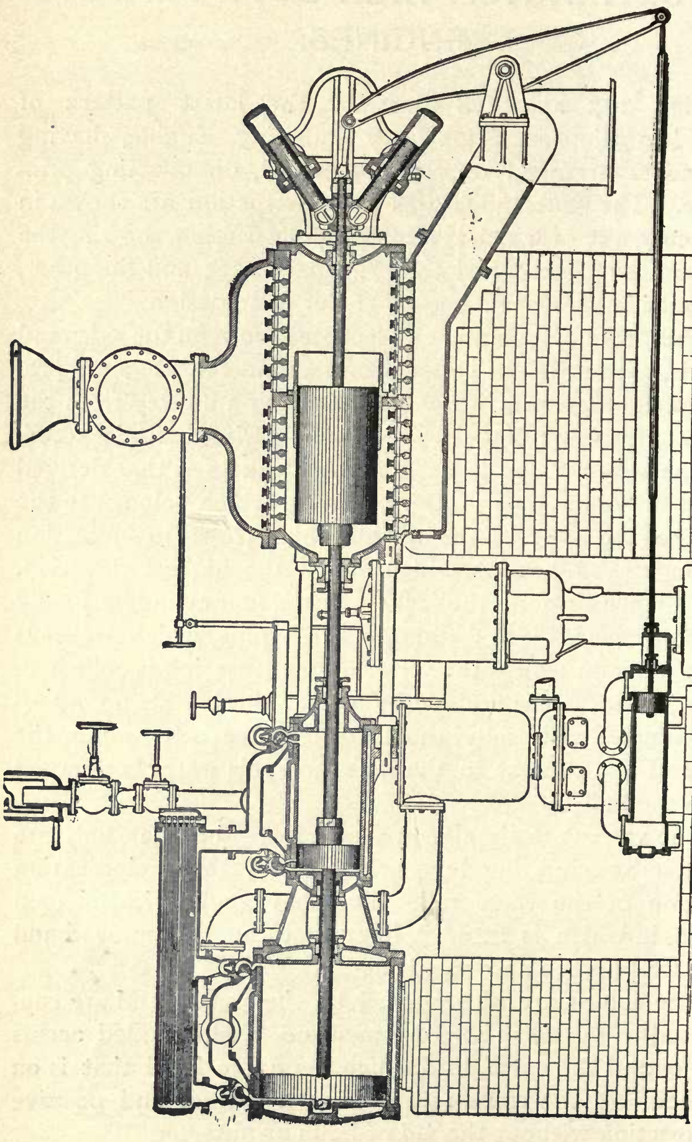


Fig. 178. Worthington High Duty Pumping Engine.—(Sectional View).

THE WORTHINGTON PUMPING ENGINE.

The ingenious device intended to permit the cutting off of the steam in the cylinder and its subsequent expansion, while at the same time the force exerted by the steam upon the pump plunger shall remain uniform during the entire stroke. See Fig. 178.

To the ordinary compound direct-acting steam pump as usually built there is attached a plunger rod which projects through the outer end of the pump chamber, and around which there is the usual stuffing box for packing the same. On the end of this plunger rod is fastened a cross head which moves in guides that are bolted on the outer end of the pump. On this cross head, and opposite to each other, are semicircular recesses.

On the guide plates are cast two journal boxes one above and the other below the plunger rod, both equidistant from it and at a point equal to the half stroke of the cross head. In these journal boxes are hung two short cylinders on trunnions which permit the cylinders to swing backwards and forwards in unison with the motion of the plunger rod.

These cylinders consist of cylindrical chambers, closed at one end and provided at the other with stuffing-boxes, through which the compensating plungers of the attachment work; they are called "compensating cylinders" and are filled with water, except when the pumping engines are used on oil lines, when they are filled with oil.

A pressure on the compensating plungers is produced by connecting these cylinders through their hollow trunnions with an accumulator, the ram of which moves up and down as the plungers of the compensators move in and out. On the top of the ram of the accumulator is an enlarged piston working in an air cylinder, which is connected to the air chamber of the engine. The pressure in the air cylinder is thus controlled by the pressure in the main delivery pipe. The important effect of this arrangement is to make the operation of the compensating cylinders automatic, varying in intensity as the pressure on the pump varies. These compensating plungers act in such a way with respect to the motion of the engine as to resist its advance at the commencement of the stroke and assist at the end, the air, meanwhile, exerting its unvarying pressure at each point of the stroke.

The two cylinders act in concert, and, being placed directly opposite each other, relieve the cross-head, to which they are attached, of any sliding frictional resistance, and the engine of any lateral strain.

By thus alternately taking up and exerting power through the difference in the angle at which their force is applied with respect to the line of motion of the plunger rod, these two cylinders, in effect, perform the functions of a fly-wheel, but with the important mechanical difference that they utilize the constant pressure of compressed air instead of the enregy of momentum. Their action is readily controlled, and their power can not only be exactly proportioned to the work to be overcome, but is entirely unaffected by the speed of the engine. The same amount of expansion can be obtained in the same engine, whether running at a piston speed of 10 feet per minute or at 150.

The operation is as follows:

"We will suppose the pump about to begin its outward stroke. At this time the compensating cylinders will be turned so as to point toward the outer end of the pump, with their plungers at the extreme point of their outward stroke, and at an acute angle with the pump plunger rod, and with the full pressure of the accumulator load pushing them against the advance of the pump plunger. As the pump plunger begins its outward stroke, each forward movement it makes changes the angle of the compensating plungers, until at one-half stroke the two plungers will stand exactly opposite each other and at right angles with the pump plungers, and of course in a position where they can neither retard nor advance the movement of the plunger.

The Worthington Pumping Engine.

"Now, as the pump plunger passes the center of its stroke, the compensating plungers being as before said attached to the cross-head of the pump plunger rod, begin to turn in an opposite direction from which they started, and by degrees, owing to the increasing acuteness of the angle they make with the plunger rod, they begin to exert the power to push the pump plunger along, whereas, before and up to the half stroke, they resisted the movement of the plunger.

"This pushing force increases constantly, until at the extreme end of the outward stroke, and when the compensating plungers are, as at the beginning, at their most acute angle, they exert their greatest force in helping to aid the pump plunger in its outward movement. It is, perhaps, unnecessary to add that the return stroke of the pump is made under precisely the same conditions as the previous stroke."

The cut-off valves consist of semi-rotating plug-valves, placed in the admission ports of the cylinders and operated by means of direct connections. Their action is secured without the use of any eccentrics, gears, or cams. When the point of the cut-off has been once fixed, it need never be altered.

These well-known pumping engines are built at the Henry Worthington Works, New York City.

Oil Wiping Device.

The Deane Pumping Engine.

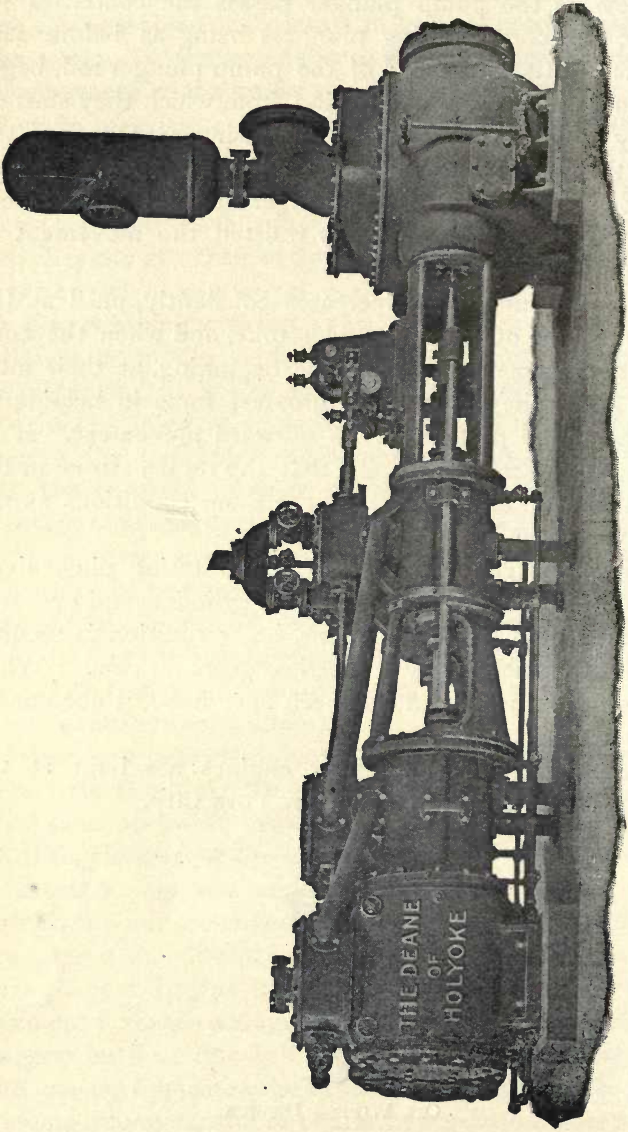


Fig. 179. The Deane Triple Expansion Duplex Pumping Engine.

THE DEANE PUMPING ENGINES.

These are manufactured at Holyoke, Mass., at works established A. D. 1867 by the Deane Steam Pump Co.

Fig. 175 exhibits (out of several designs) a vertical, triple expansion, condensing, duplex, high duty pumping engine.

Fig. 179 shows a more simple design in which the valves are ordinary slide valves, as generally used on duplex pumps, with the usual gear, connecting the piston rods with the valve stems of the opposite valves.

These engines may be readily converted into powerful fire pumps by means of the Deane patent switch valve. This appliance consists of a valve of such construction that steam may be allowed to enter the cylinders as usual for compounding, or may be diverted by simply moving a lever, when all four cylinders receive steam at boiler pressure, each exhausting independently to the atmosphere. The change is instantaneous and makes each steam cylinder available for its maximum power.

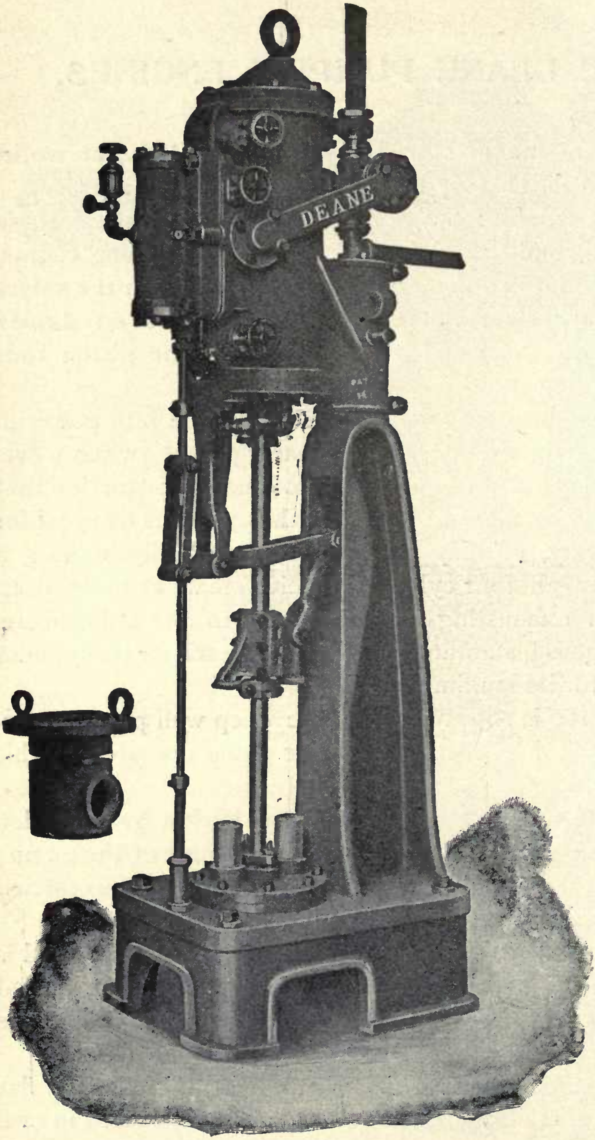
In Fig. 180 is shown the Deane deep well pumping engine, and in Fig. 181 is shown the pump operated by this engine.

The piston rod is connected to the bucket by a wooden rod, which passes through the discharge pipe of the pump; the weight of the rod however deep the well is thus carried by the water, on account of the lightness of the wood.

The valve of this engine is of the Deane pattern, and is steam thrown, by a supplemental piston, which is governed by a supplemental valve, driven by valve stem and levers from the piston rod.

Both the main valve and the supplemental valve are flat slide valves, readily understood and easily re-seated in case of wear.

THE DEANE PUMPING ENGINE.



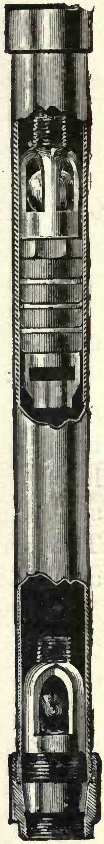


Fig. 181.
PUMP.

Fig. 180. THE DEANE DEEP PUMPING WELL ENGINE.

THE DEANE PUMPING ENGINE.

The supplemental piston, which has a compensating steam jacket, is driven by the direct pressure of steam on alternate ends, complemented when necessary by the whole power of the main engine, so that it runs equally well vertically or horizontally, exhausting into open air or into a condenser.

The mechanical connection between the main piston and its valve renders it absolutely certain that the valve shall always lead the piston, so that there is no possibility of any pounding on the cylinder heads, and the clearance in the cylinder is reduced to the minimum.

A Deane triple expansion duplex high duty pumping engine is represented in Fig. 175, page 229. As will be seen the piston rods directly operate the plungers, no shaft or balance wheel being used.

The valves are semi-rotary, operated by wrist plates, which receive their motion from the piston rods, as in a regular duplex pump.

There are two high pressure, intermediate and low pressure cylinders, the steam passing from the high pressure cylinders into receivers, which supply the intermediates, from whence it again passes through receivers into the low pressure cylinders, and then into the condenser.

The arrangement of steam pipes, receivers and exhaust pipe is plainly shown in Fig. 175.

In each set of engines, the cylinders are arranged with the low pressures below, the intermediates next, and the high pressures above, connected in steeple type.

HOLLY PUMPING ENGINE.

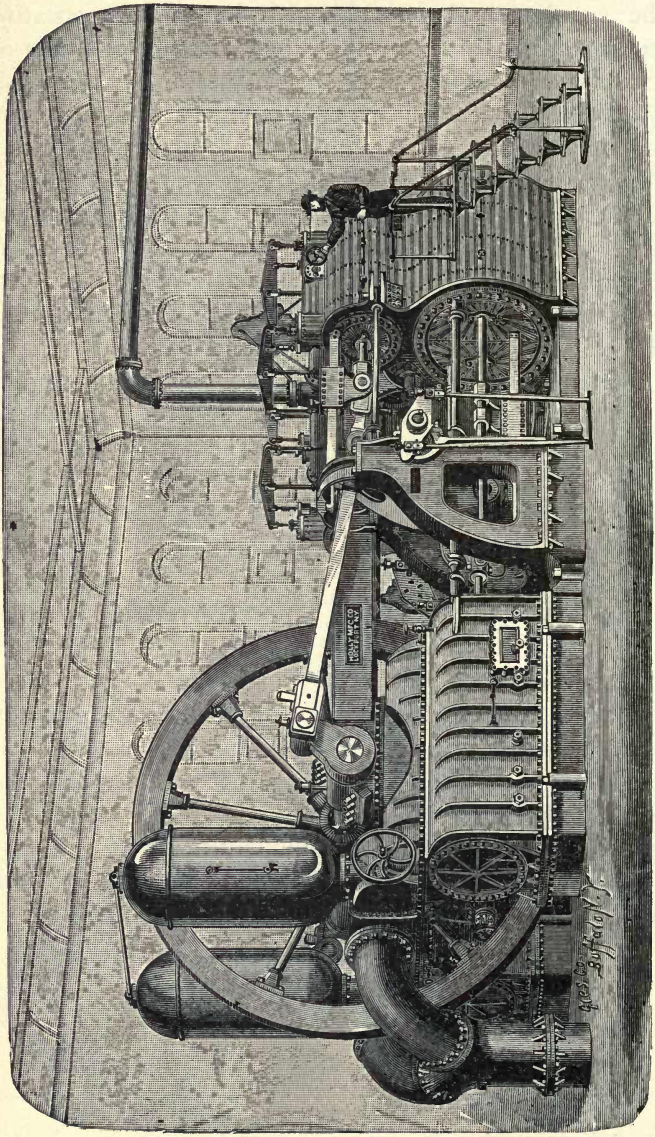


Fig. 182. HOLLY HIGH DUTY PUMPING ENGINE.—(Gaskill Design.)

THE HOLLY HIGH DUTY PUMPING ENGINES.

These engines are made at Lockport, N. Y. They may be briefly described as follows:

"The engine is horizontal, of the rotative beam, non-receiver, compound type, and involves several novel features of construction, whereby a large capacity and a high economy is obtained.

"On a pair of iron bed plates are mounted the two pumps, and in direct line therewith the two low pressure steam cylinders (see cuts, Figs. 182 and 183), with the piston rods of the low pressure steam cylinder connected to the pump piston rods. Between the pumps and steam cylinders are placed beam supports which are firmly bolted to the bed plates and also rigidly stayed by wrought-iron struts to the pumps and steam cylinders. These beam supports carry the beam shafts and beams the lower end of the latter being connected to the cross heads of the low pressure cylinders by means of links.

"On the top of the pumps are placed the main shaft bearings, which support the shaft, fly-wheel and cranks, the latter being keyed to the shaft at right angles to each other. On the top of the low pressure steam cylinder are mounted the two high pressure steam cylinders, with their centers in the same horizontal plane as the center of the main crank shafts. The cross heads of the high pressure steam cylinders are connected by means of links to the upper ends of the beams, and the beams are in turn connected by means of connecting rods to the crank pins. From the high pressure steam cylinders heavy cast-iron girders extend to the pillow blocks. On the inner end of each of the beam centers an arm is keyed, from which the air pumps are driven.

Holly Pumping Engine.

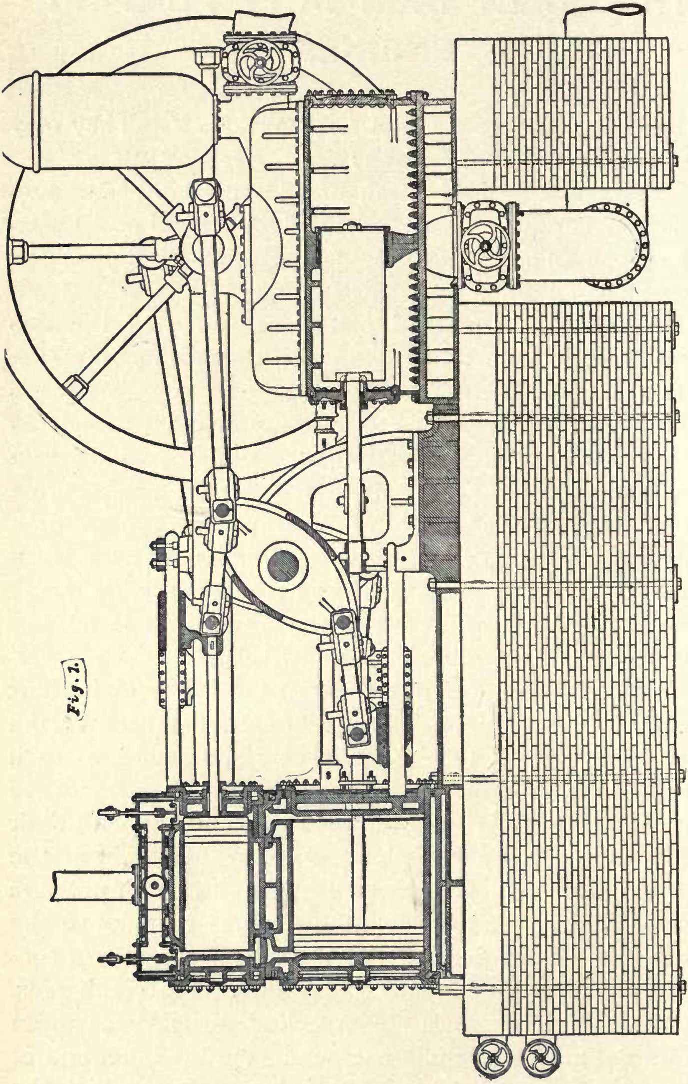


Fig. 183. Holly High Duty Pumping Engine.—Sectional View Gaskill Design.)

HOLLY PUMPING ENGINE.

"The valves of the steam cylinders are operated by means of eccentrics on a shaft, which is driven from the main shaft through small bevel gears. The admission valves to the high pressure steam cylinders are of the double beat puppet pattern, so arranged as to open at the proper time and to close at any desired point of the stroke as shown. The exhaust valves from the high pressure cylinders are also admission valves to the low pressure steam cylinders, and are ordinary slide valves, remaining open somewhat less than the time required to make a complete stroke. The exhaust valves from the low pressure cylinders are also plain slide valves, operating the same as the high pressure exhaust valves.

"The pump plungers are arranged to work through glands in the center of the pumps, and are accessible from the covers at the end of the machine. The pump valves are placed on horizontal plates below and above the line of plunger travel. The glands above mentioned divide the valves of one end of the pump from those of the other end at the center of the valve plates.

"The operation of the machine is as follows:

"Steam is admitted through the automatic cut-off valves into the high pressure steam cylinders, urging the pistons forward under full boiler pressure until the point of cut-off is reached. The admission valve then closes and the remaining portion of the stroke is accomplished by the elastic force of the steam. When the piston has nearly reached the end of its travel, the exhaust valve between the high and low pressure cylinders opens and the steam remaining in the high pressure cylinder rushes into the low pressure cylinder and against its piston, which at that time is at the end of its travel and at the opposite of the high pressure piston.

"The low pressure cylinder piston is then in turn urged forward by the incoming steam, which is expanded to four

HOLLY PUMPING ENGINE

times the volume it occupied in the high pressure cylinder at the time of its release therefrom. The release from the low pressure cylinders is accomplished by means of the exhaust valves in the return strokes. This operation is repeated on each side and at each end at proper times. The close connection between the two cylinders reduces the clearance spaces to a minimum, which with thorough jacketing insures the most economical use of steam.

"This engine is also built to operate as a non-compound engine, in which case the upper or high pressure cylinders and connections are omitted, and the lower steam cylinders are provided with automatic cut-off valves. Steam is admitted to these cylinders direct from the boiler and exhausted into the condenser.

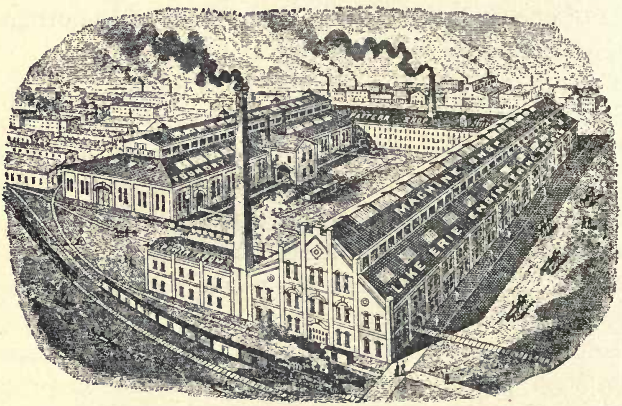


Fig. 184. MODEL STEAM ENGINE WORKS.

RIEDLER PUMPING ENGINES.

The Riedler system of pumping engines has obtained a foothold both in England and in Continental Europe; they are used extensively in pumping plants for mines and water-works.

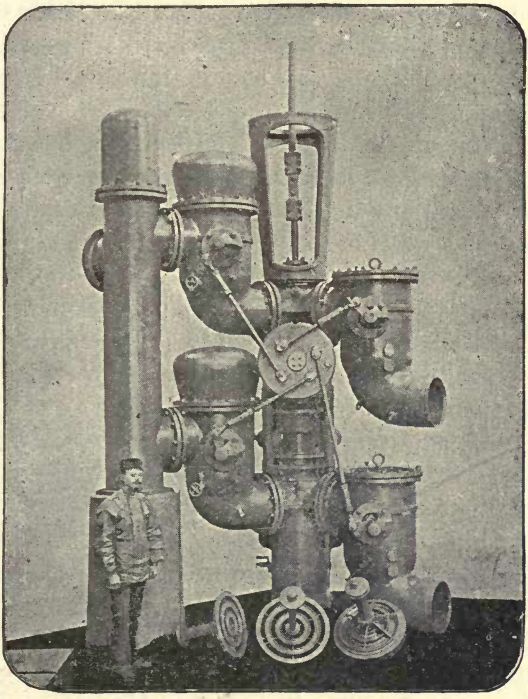


Fig. 185. THE RIEDLER PUMP.

The peculiarity of the Riedler pump lies in the valves which are so arranged that they open automatically at full lift at the commencement of the stroke, but at or near the end of the piston stroke the valves are controlled by a quick-acting positive motion, thus enabling the pump to be run at high speed.

THE RIEDLER PUMPING ENGINE.

The mechanism for operating the valves is exceedingly simple. Each valve is closed at the moment the stroke of the piston changes, and this closing is done by means of a spindle projecting into the valve chamber.

Near the end of the stroke a very small free lift is allowed to the valve, which can be regulated at will; thus enabling the valves to accommodate themselves to variable pressure, or variable conditions of working under high speed.

In high speed pumps, and also in pumps used for gritty water, springs are inserted either between the valve and its gear, or in the rods of the gear, thus allowing a compression of the spring without injuring the valves or their seats, or the gear, in case any hard material gets between the valve and its seat, or relief is required for water remaining in the pump.

This spring serves to accommodate the action of the valve to any variable pressure or speed. The springs are so arranged that the ordinary resistance of the valves will not compress them.

The Riedler system is applied to a variety of styles of pumping and air compressing engines, vertical and horizontal. Most of those built in this country have been driven by high-duty Corliss engines to the usual speed of which the Reidler system of positively-moved water valves adapts itself. The closure of the valves is effected by forks and bell cranks upon rocker arms; relief and cushioning being afforded by springs so that the seating is gentle as well as positive. The illustration, Fig. 186, shows the

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NOTE.—Riedler pumps are very much in use for deep mines. Sixteen of them placed in different mines in Europe are raising the water in one lift 1,800 to 2,200 feet high at high speed. The engine shown in Fig. 186 is in use by the Boston and Montana mines (U. S.), with 5⅝ in. and 8 in. plungers, and 16 in. and 25 in. steam pistons, all 24 in. stroke. Its duty is 900 gallons per minute, lifted 600 feet in height.

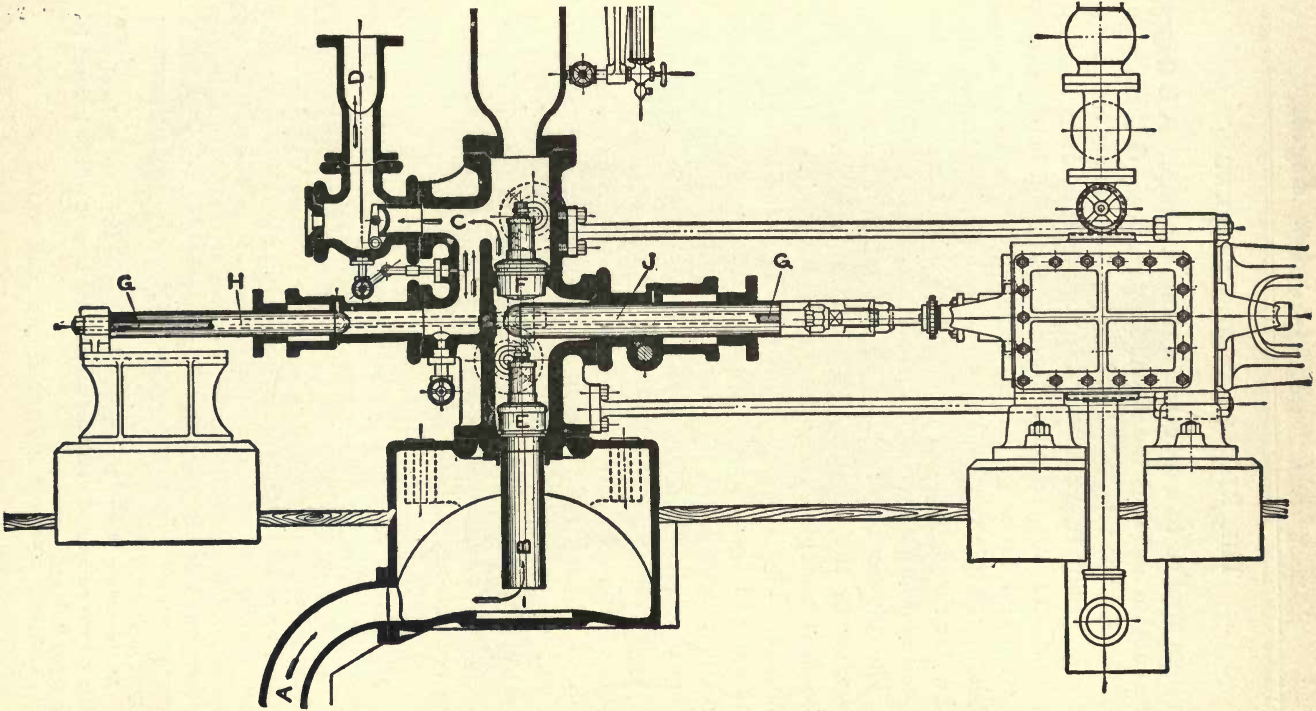

Fig. 186. THE RIEDLER PUMPING ENGINE.

THE RIEDLER PUMPING ENGINE.

system applied to a differential plunger pump. A B shows the suction and C D the discharge passages. G G are rods connecting the plungers H and J, and enabling the body of the pump to be made very compact. In the Riedler system the largest pumps are constructed with single suction and discharge valves, as shown at E and F, and though the plungers may be run at high speeds, the flow of water through the valve epenings is at a relatively low speed in a large unbroken current.

The differential feature of the pump shown is (not peculiar to the Riedler system, but) often advisable. It provides a single acting suction and a double acting discharge. The cut shows an opening in the body beyond the end of larger plunge. This is a feature of construction and is plugged and closed in operation. It will then be seen that all the suction is accomplished by the larger plunger in single strokes. On the return strokes the larger plunger circulates the whole body of water, but only lifts half of it past the check valve, the remaining half being forced on the return stroke of the smaller plunger. The forcing is thus more continuous and uniform than if single-acting, while the construction is lighter than if the suction were double-acting.

NOTE.—The Riedler pump at the Chapin Mine is a triplex differential Riedler pump, plungers 6⅞ in. and 9⅝ in. diam. x 30 in. stroke, driven by a horizontal triplex tandem compound condensing Corliss engine; steam cylinders 22 and 36 in. diam. x 30 in. stroke; capacity 2,200 U. S. gallons per minute against a total head of 1,700 ft. when running about 74 revs. per minute. It is designed to run economically with steam pressure at engine of 110 lbs. per sq. in., or by compressed air with a pressure of 60 lbs. per sq. in. at engine. This pumping engine is undoubtedly the largest underground pumping engine in the world.

At the present time the pump is working on the 1,310 ft. level, and raising 2,200 gallons of water per minute, but later it will be lowered to the 1,700 ft. level.

ALLIS' PUMPING ENGINES.

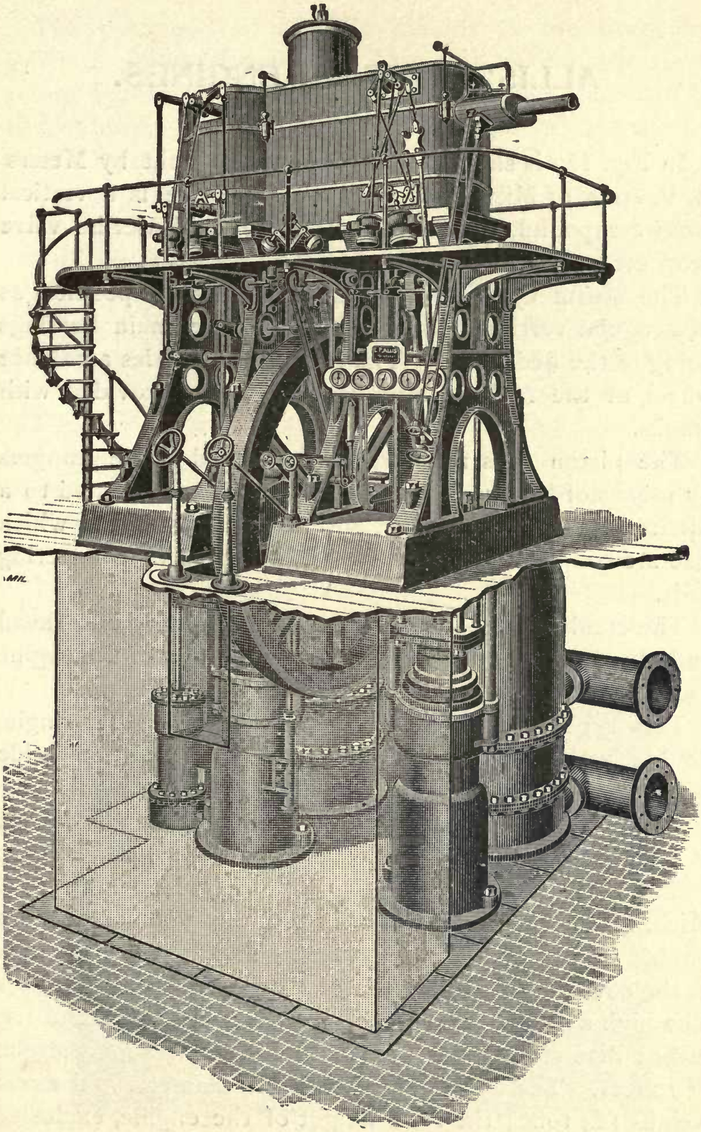

Fig. 187. ALLIS' VERTICAL COMPOUND PUMPING ENGINE.

ALLIS' PUMPING ENGINES.

In Fig. 187 is shown a pumping engine, built by Messrs. A. P. Allis, of Milwaukee, Wis. The engine is a vertical cross compound, with the regular Reynolds-Corliss valve gear, controlled by a governor.

The steam cylinders are placed in the same position as in a regular vertical compound engine, the main bearings being in the bed plate. The crank shaft carries a balance wheel, at the middle point, the end being provided with cranks.

The piston rods are directly connected to the plungers by means of four rods, the ends of which are fastened to a square head on the plunger, and to the cross-heads, which also are connected to the cranks by means of connecting rods.

The cranks turn between the rods, connecting cross-head and plungers. The pumps are below the floor of the engine room, all of which may be easily seen in the Figure.

This type of engine is constructed with either single, double acting or differential plungers, outside or inside packed as the service requires.

A very modern style of Cornish mining pump is shown in the engraving, Fig. 189, which was built by the E. P. Allis Co. for the Chapin Mining Company, Iron Mountain, Mich. The machine is designed to pump 3,000 gallons per minute from a depth of 1,500 feet. The figure of the man in the cut will give some idea of its enormous proportions. The high and low pressure steam cylinders are 50 and 100 inches diameter respectively, and have a common stroke of 10 feet. The fly wheel is 40 feet in diameter and alone weighs 164 tons; the total weight of the engine, exclusive of pumps and shaft work, being 600 tons.

ALLIS' PUMPING ENGINES.

The pump-rod is attached directly to the beam end which overhangs the shaft. The pumps are of the single acting Cornish type, with plungers 28 inches diameter by 10 feet stroke—the number of strokes per minute varying from 4 to 10.

The pumps are arranged in series, each set having a lift of about 200 feet. Modification of this type of machine can be designed to suit the requirements of any location.

Fig. 190 represents a pumping engine, also built by the above firm, for handling large quantities of water, under low or moderate heads, from 5 feet to 25 feet, and is especially adapted for sewerage and drainage work.

The pump is of the centrifugal type, lying horizontally instead of being set vertically, as is the common practice. They are run at comparatively low speed, usually less than 100 revolutions per minute. The weight of pump and shaft is taken up by a suitable thrust bearing.

The engine shown is of the triple expansion type, the connecting rods all driving one single crank, which has its motion horizontally.

Fig. 188. TANK FOR WATER WORKS.

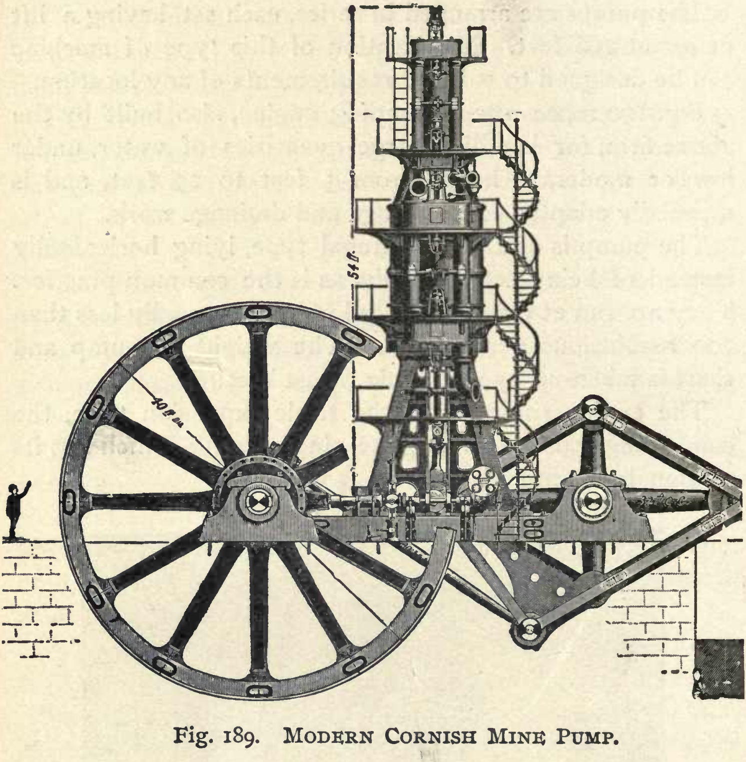

Fig. 189. MODERN CORNISH MINE PUMP.

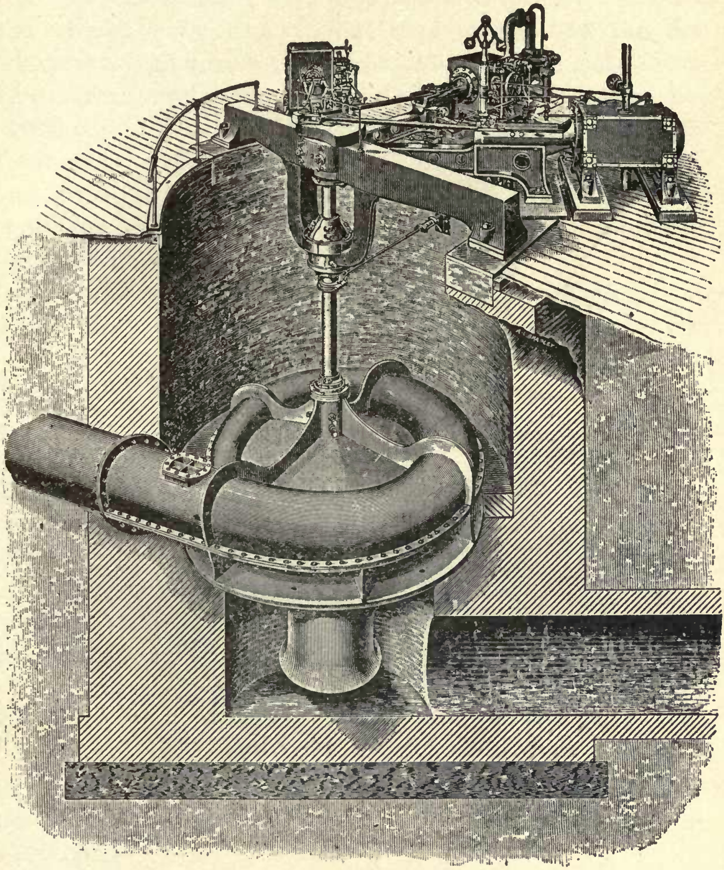

Fig. 190. SEWAGE PUMP.

This is the likeness of the great founder of the modern steam railway system. Geo. Stephenson was born March 4th, 1781, at Wylan, near Newcastle-on-the-Tyne, England. His father was a fireman of the pumping engine boilers at a neighboring colliery, at a wage of twelve shillings ($3.00) per week including rent for a little one-room cottage; the son George was, at the age of 15, to his great joy, appointed a fireman at a wage of a shilling per day.

GEORGE STEPHENSON.

Stephenson became, in due order of advancement, a mine breakman, engine-wright, locomotive builder, railroad contractor and capitalist. He died full of honor on the 12th day of August, 1848, aged 67 years. His wealth was estimated at upwards of five million dollars; and his son who succeeded him became Sir Robert Stephenson.

THE LOCOMOTIVE.

The early history of the locomotive is illustrated by two specimen machines now in the British Museum, Patent section, the oldest has a label with this inscription: "This is the oldest locomotive engine in existence, and the first which ran with a smooth wheel upon a smooth rail. It was constructed under Mr. Hedley's patent (A. D. 1813, No. 3666) for C. Blocket, Esqr., the proprietor of the Uylam Colliery, near New Castle-upon-Tyne. After many trials and alterations it commenced regular working in 1813 and was kept in use until June 6, 1872, when it was purchased for the Patent Museum."

The history of the second relic has been well preserved. This little locomotive "The Rocket" weighing four and one-half tons, with boiler six feet long by four feet in diameter, built by George Stephenson & Co., was the engine that settled the question, of horse versus steam-power as applied to railways. It was built in competition with others for a prize of £500. On its first trial it ran twelve miles in less than an hour, and on one occasion late in its history, it covered a distance of four miles in 4½ minutes.

The modern locomotive may readily be called a travelling steam plant, for it is in all respects self-contained, and independent of its surroundings.

It consists of a forged steel frame, to which is attached the boiler, and the saddle and cylinder casting.

The frame, in turn, rests upon the wheels, or more properly their axles, which are running in bearings capable of moving up and down between guides, which form part of the frame.

NOTE.—Just previous to the decisive achievements of this historic engine, a writer in the *Quarterly Review* who, however was in favor of the construction of the road and of the use of the locomotive upon it, said: "What can be more palpably absurd and ridiculous than the prospect held out, of locomotives traveling *twice as fast* as stage-coaches! We would as soon expect to see the people of Woolwich to suffer themselves to be fired off from one of Congreve's Rockets, as trust themselves to the mercy of such a machine going at such a rate."

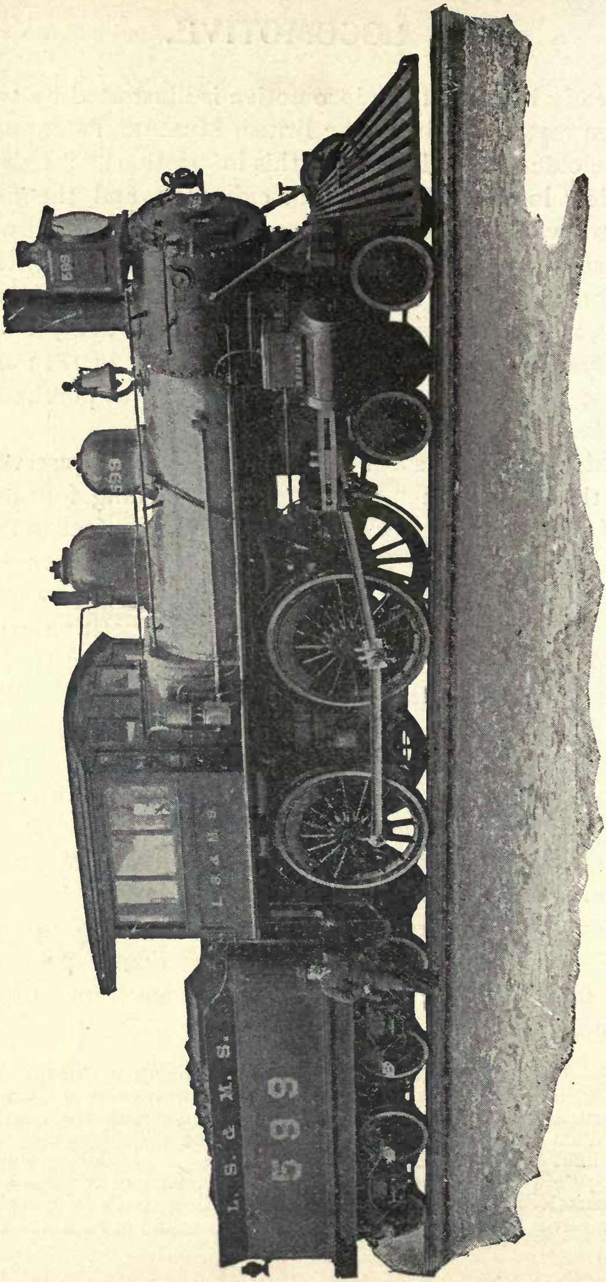

Fig. 191. Brooks Eight-Wheel Locomotive.

THE BROOKS LOCOMOTIVE.

The weight of the engine is not directly resting upon the axle bearings, but is intermittently carried by springs, which are fastened to the frame, and axle bearings, thus preventing the engine from jarring too much when on rough road, and always keeping the wheels in contact with the rails, no matter how uneven the track.

Motion is transmitted to the driving wheels by means of the same reciprocating parts, as on any other engine, but as the center of the axles is movable, and not always in line with the centerline of the cylinders, the clearance between cylinder head and piston has to be larger than on other engines, to prevent the piston from striking the cylinder heads.

The cylinders, which are two in number, are ordinarily cast in one piece each with one half of the saddle, which carries the front end of the boiler, and to which also the frame is attached; the fire box end of the boiler is also attached to the frame, and there are intermediate supports, between frame and boiler, their number being determined by the length of the engine, thus making practically one piece of boiler, frame and cylinders.

In locomotives, having more than one set of driving wheels, the different pairs are connected by means of coupling rods, thus all receiving their due share of the rotary motion, induced by the connecting rods.

NOTE.—Data relating to the Brooks 8 wheeled type locomotive....................................gauge 4 ft. 8½ ins.

Diameter and stroke of cylinders	17 x 24 ins.
Diameter of driving wheels	72 ins.
Diameter of boiler	52 ins.
Number and diameter of flues	202, 2 ins.
Length and width of fire box	78 x 34 ins.
Weight on drivers	65,000 lbs.
Total weight	104,600 lbs.
Tank capacity	3,100 galls.

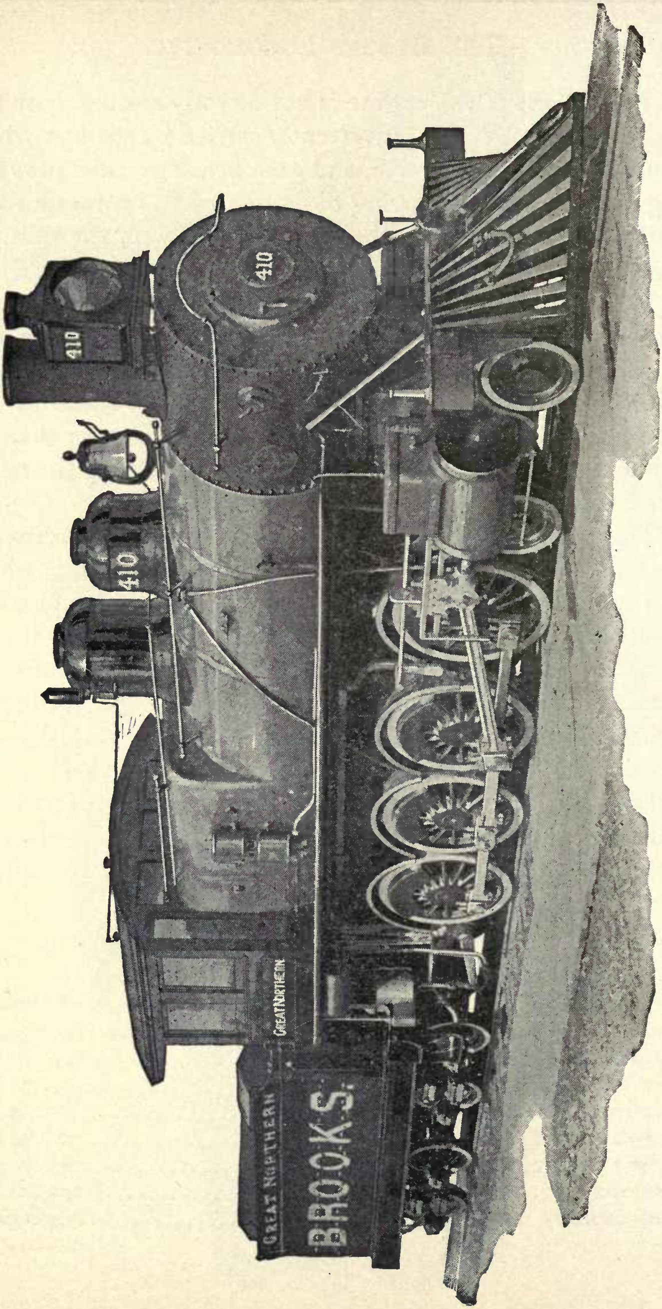

Fig. 192. BROOKS TWELVE-WHEEL LOCOMOTIVE.

THE BROOKS LOCOMOTIVE.

The valve motion is derived from one of the driving axles, by means of eccentrics, which are connected by their rods to a link motion, which in turn connects with a rocker arm, from which the valves are driven by means of the valve rods; one of each pair of eccentrics is for the forward motion, the other for the backward motion.

The steam is transmitted from the boiler to the cylinders by means of a pipe, which runs along in the steam space of the boiler to the smoke box, where it branches off to the cylinders on each side. The throttle valve is inside of the boiler, and is operated by means of a rod passing through a stuffing-box in the boiler head and connected with a lever in the cab.

The exhaust steam of both cylinders is blown by means of the exhaust nozzle up the stack, and serves as a blower to maintain a draft which otherwise would be impossible on account of the low stack.

The reversing is done by means of a lever in the cab on the right hand side of the boiler, which again with reach rod and bell crank is connected to the link.

Between the driving wheels is the brake, Fig. 194, which consists of a cylinder in which a piston is operated by steam pressure, and is connected to a toggle joint which forces the brake shoes against the drivers.

Some locomotives are equipped with a boiler feed pump, but all carry an injector. To operate the brakes of the

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NOTE.—Data relating to 12-wheeled type.

Freight locomotive	gauge 4 ft. 8½ ins.
Diameter and stroke of cylinder	20 x 26 ins.
Diameter of driving wheels	55 ins.
Diameter of boiler	68 ins.
Number and diameter of flues	250, 2¼ ins.
Length and width of fire box	114 x 32 ins.
Weight on drivers	134,000 lbs.
Total weight	160,000 lbs.
Tank capacity	4,000 galls.

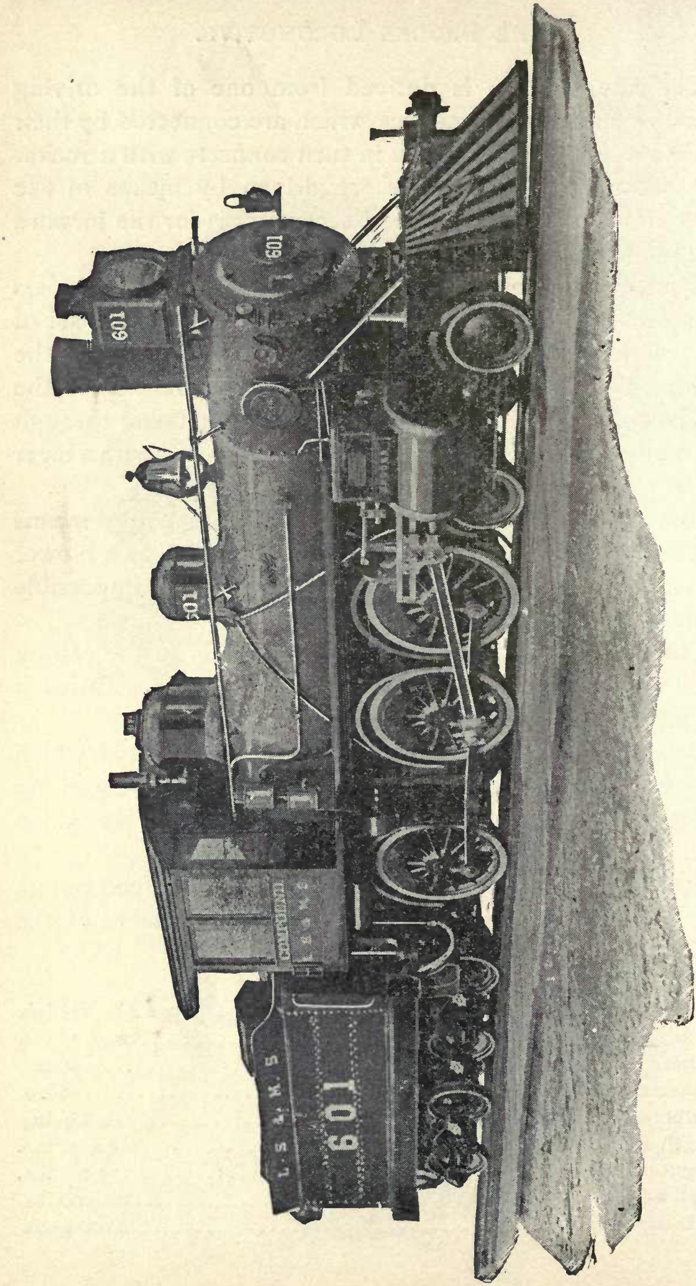

Fig. 193. Brooks Compound Locomotive.

THE BROOKS LOCOMOTIVE.

train, an air brake is provided which consists of an air pump with reservoir in which compressed air is stored, and by means of the train pipe and valve is conveyed to the brake cylinders of the cars.

In starting the engine the wheels are liable to slip on the rails, to prevent this a sand box is arranged on top of the boiler, from which by means of the sand valve, operated by a rod and lever in the cab, sand is thrown in front of the wheels which allows them to "take hold" of the rails.

The fuel and water supply is carried by the tender, coupled to the locomotive immediately behind it.

Besides the driving wheels there is on larger locomotives at the front or both ends a truck, composed of small wheels, which carry part of the weight and also guide the engine on the track.

The forward sloping attachment serves to clear the track of any obstruction, as cattle, etc.; it is named "the cowcatcher."

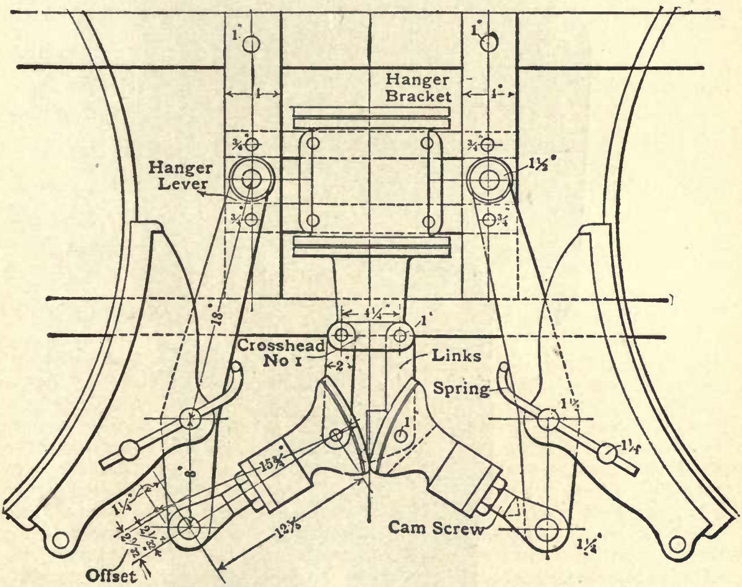

Fig. 194. LOCOMOTIVE BRAKE.

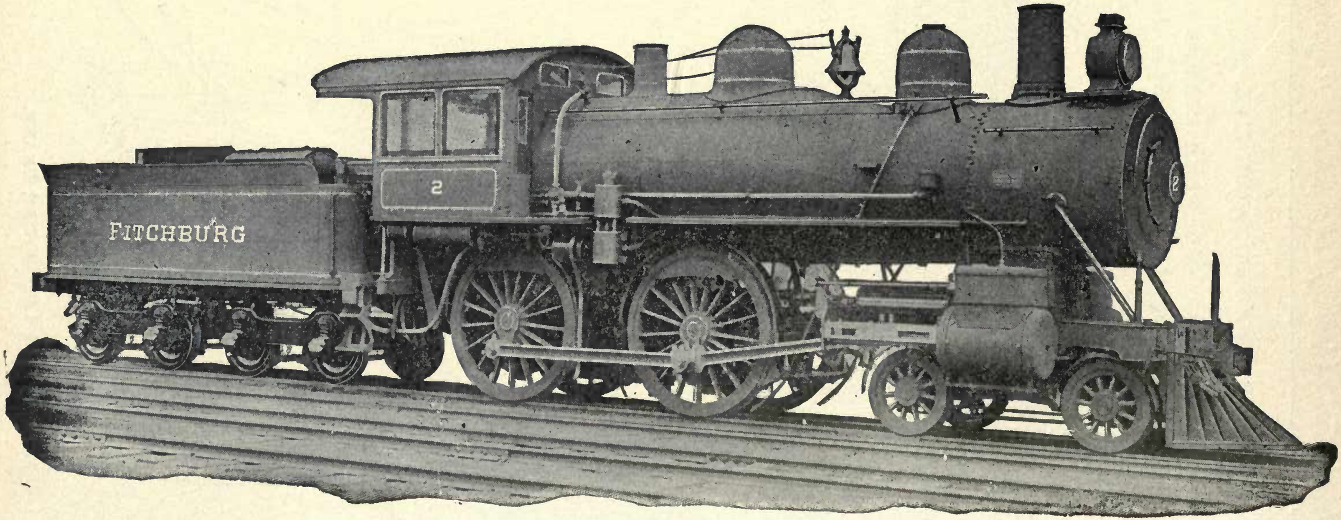

Fig. 195. SCHENECTADY FREIGHT LOCOMOTIVE.

RAILWAY SIGNALS.

One pull of the bell cord signifies "stop."
Two pulls mean "go ahead."
Three pulls signify "slack up."
One whistle signifies "down brakes."
Two whistles mean "off brakes."
Three whistles signify "back up."
Continued whistles indicate "danger."
Rapid short whistles "a cattle-alarm."

A sweeping parting of the hands on a level with the eyes, signifies "go ahead."

A slowly, sweeping, meeting of the hands over the head means "back slowly."

Downward motion of the hands, with extended arms, means "stop."

Beckoning motion of one hand indicates "back."

A red flag waved up the track, signifies "danger."

A red flag standing by the roadside means "danger ahead."

A red flag carried on a locomotive, signifies "an engine following."

A red flag raised at a station, is a signal "to stop."

A lantern at night raised and lowered vertically, is a signal to "start."

A lantern swung at right angles across the track, means "stop."

A lantern swung in a circle, signifies "back the train."

NOTE.—A locomotive engineer has a keen affection for his "iron steed." But if one may believe an engineer, locomotives are extremely fickle. He declares that his engine will take a train over a steep grade with a rush on one day, while perhaps on the very next day, with the same train and the same grade, the artful coquette will pretend to be shy, will draw back in feigned timidity, fence, flirt and finally do what it is asked to do with a pout. "It's hard," he says, to realize that your engine isn't alive. She acts like a horse. She will shy and balk at a grade when she feels like it, and, again, will take the bit in her teeth and jerk the load clean over the hill. You can't help calling such an engine 'her.' Sometimes I feel like speaking to her when she is sulking. Maybe I do without realizing it."

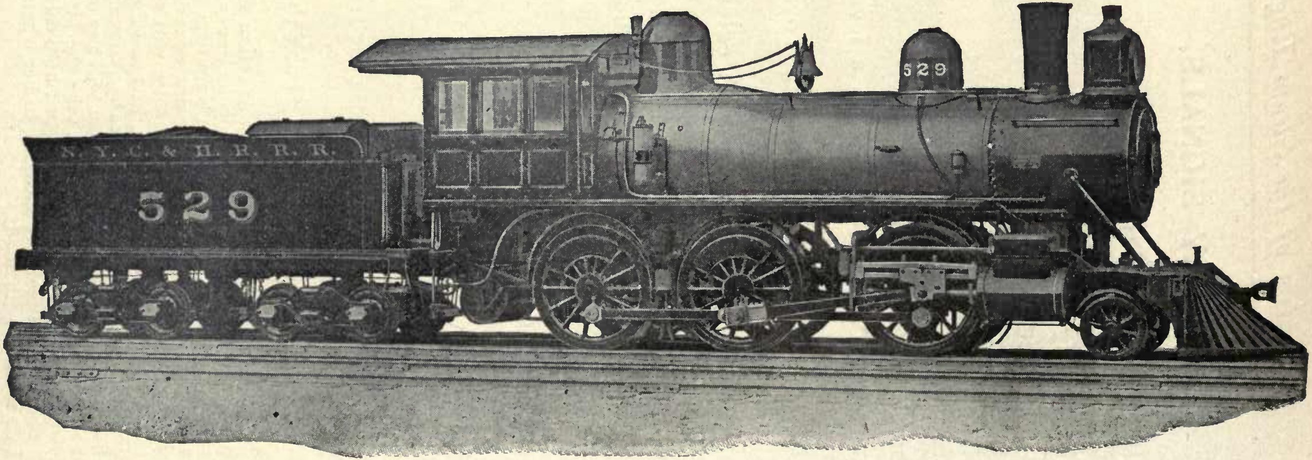

Fig. 196. Schenectady Eight-Wheel Locomotive.

THE WESTINGHOUSE BRAKE.

The Westinghouse Improved Quick Action Automatic Brake consists of the following essential parts:

1st. ***The Steam Engine and Pump,*** which furnishes the compressed air.

2d. ***The Main Reservoir,*** in which the compressed air is stored.

3d. ***The Engineer's Brake and Equalizing Discharge Valve,*** which regulates the flow of air from the main reservoir into the brake pipe for releasing the brakes, and from the main train or brake pipe to the atmosphere for applying the brakes.

4th. ***The Main Train or Brake Pipe,*** which leads from the main reservoir to the engineer's brake and equalizing discharge valve, and thence along the train, supplying the apparatus on each vehicle with air.

5th. ***The Auxiliary Reservoir,*** which takes a supply of air from the main reservoir, through the brake pipe, and stores it for use on its own vehicle.

6th. ***The Brake Cylinder,*** which has its piston rod attached to the brake levers in such a manner that, when the piston is forced out by air pressure, the brakes are applied.

7th. ***The Improved Quick Action Automatic Triple Valve,*** which is suitably connected to the main train pipe, auxiliary reservoir and brake cylinder, and is operated by the variation of pressure in the brake pipe (1), so as to admit air from the auxiliary reservoir (and under certain desirable conditions, as will be explained hereafter, from the train pipe) to the brake cylinder, which applies the brakes, at the same time cutting off communication from the brake pipe to the auxiliary reservoir, or (2) to restore the supply from the train pipe to the auxiliary re-

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NOTE.—Locomotives with large wheels are swiftest. Those with small ones are strongest, or in other words, they can move greater weights at slower speeds.

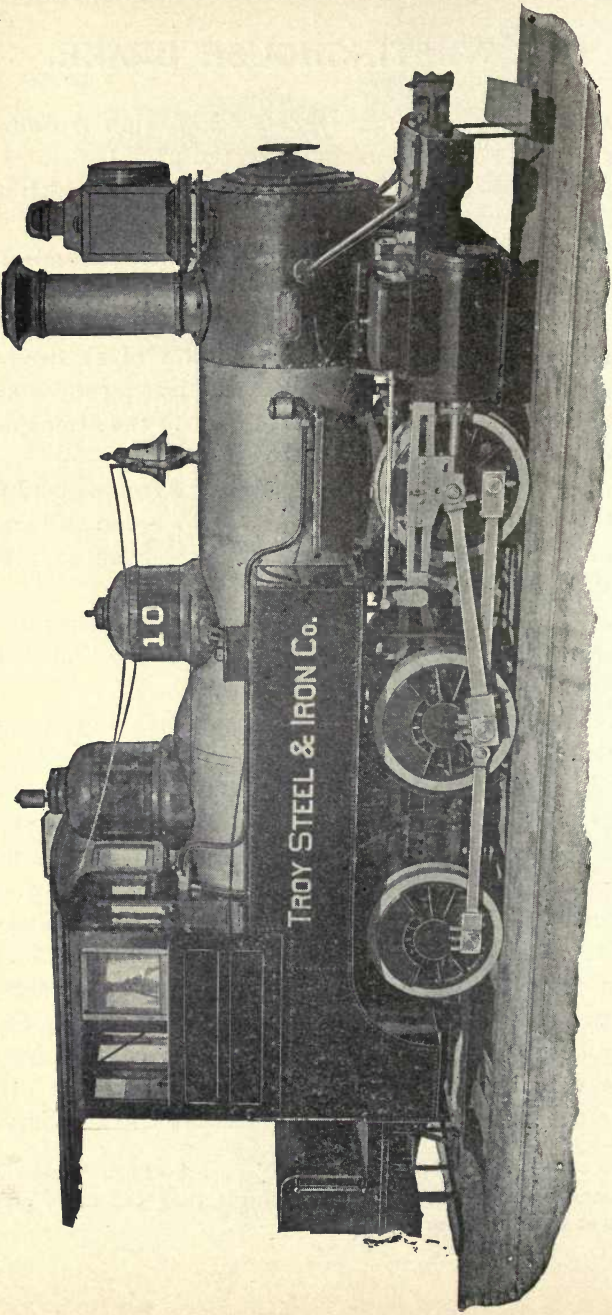

Fig. 197. Schenectady Tank Switching Locomotive.

THE WESTINGHOUSE BRAKE.

servoir, at the same time letting the air in the brake cylinder escape, which releases the brakes.

8th. ***The Pump Governor,*** which regulates the supply of steam to the pump, stopping it when the maximum air pressure desired has been accumulated in the train brake pipe and reservoirs.

The automatic action of the brake is due to the construction of the triple valve, the primary parts of which are a piston and slide valve. A moderate reduction of air pressure in the train pipe causes the greater pressure remaining stored in the auxiliary reservoir to force the piston of the triple valve and its slide valve to a position which will allow the air in the auxiliary reservoir to pass directly into the brake cylinder and apply the brake. A sudden or violent reduction of the air in the train pipe produces the same effect, and in addition to this causes supplemental valves in the triple valve to be opened, permitting the pressure in the train pipe to also enter the brake cylinder, increasing the pressure derived from the auxiliary reservoir about 20 per cent., producing instantaneous action of the brakes throughout the train.

When the pressure in the brake pipe is again restored to an amount in excess of that remaining in the auxiliary reservoir, the piston and slide valve are forced in the opposite direction, to their normal position, opening communication from the train pipe to the auxiliary reservoir, and permitting the air in the brake cylinder to escape to the atmosphere, releasing the brakes.

NOTE.—Data relating to Schenectady tank switching

locomotive 6 wheel type	gauge 4 ft. 8½ ins.
Diameter and stroke of cylinders	17 x 22 ins.
Diameter of driving wheels	44 ins.
Diameter of boiler	50 ins.
Number and diameter of flues	176, 2 ins.
Length and width of fire box	90 x 34½ ins.
Weight on drivers	89,000 lbs.
Total weight	89,000 lbs.
Tank capacity	1,200 galls.

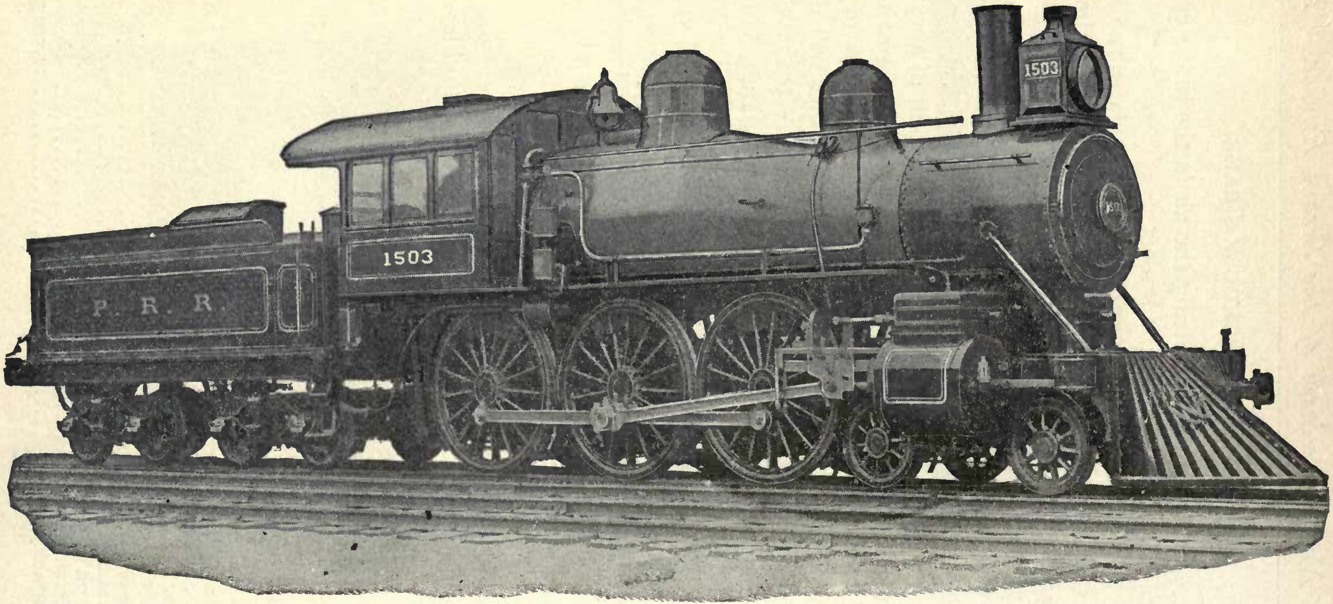

Fig. 198. SCHENECTADY COMPOUND PASSENGER LOCOMOTIVE.

THE WESTINGHOUSE BRAKE.

If the engineer wishes to apply the brake, he moves the handle of the engineer's brake valve to the right, which first closes a port, retaining the pressure in the main reservoir, and then permits a portion of the air in the train pipe to escape.

To release the brakes, he moves the handle to the extreme left, which allows the air in the main reservoir to flow freely into the brake pipe restoring the pressure and releasing the brakes.

A valve called the conductor's valve, is placed in each car with a cord running throughout the length of the car, and any of the trainmen, by pulling this cord, can open the valve, which allows the air to escape from the train pipe, applying the brake.

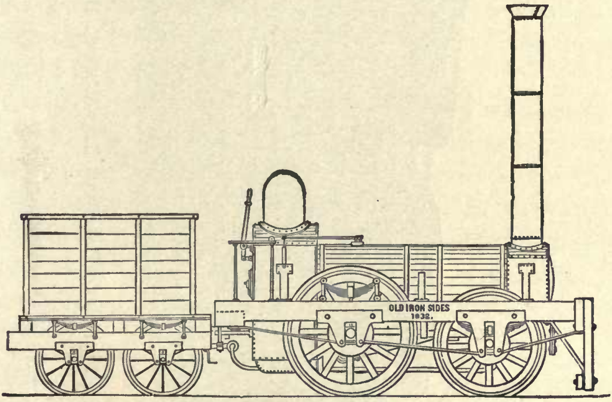

Fig. 199. THE "OLD IRONSIDES," 1832.

NOTE.—Data relating to the Schenectady 10 wheel type Fig. 198.

Compound passenger locomotive	gauge 4 ft. 9 ins.
Diameter and stroke of cylinders	H. P. 20 x 24 ; L. P. 30 x 24 ins.
Diameter of driving wheels	74 ins.
Diameter of boiler	58 ins.
Number and diameter of flues	268, 2 ins.
Length and width of fire box	96¼ x 39¼ ins.
Weight on drivers	106,000 lbs.
Total weight	143,000 lbs.
Tank capacity	3,500 galls.

THE WESTINGHOUSE BRAKE.

Should the train break in two, the air in the brake pipe escapes and the brakes are applied to both sections of the train.

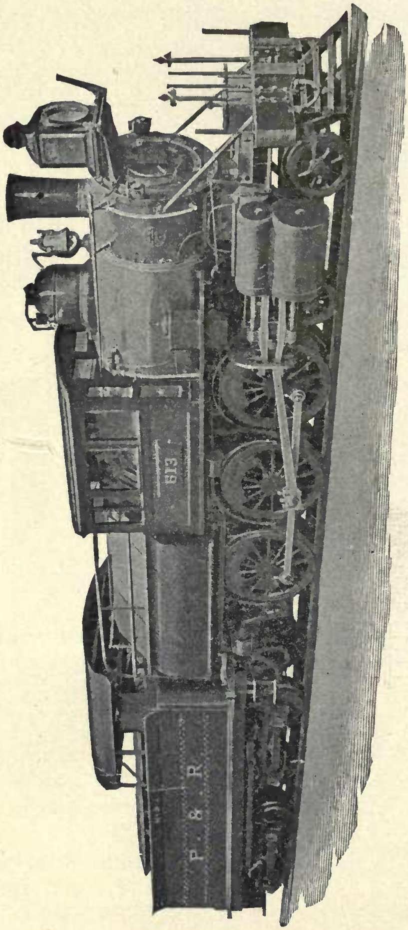

Fig. 200. BALDWIN TEN-WHEEL FREIGHT LOCOMOTIVE.

The brakes are also automatically applied should a hose or pipe burst.

It will be seen that any reduction of pressure in the train pipe applies the brakes.

THE BALDWIN LOCOMOTIVE.

The Baldwin Locomotive Works are located at Philadelphia, Pa., and date their origin from the very inception of steam railroads in America. In the year 1831 the Philadelphia, Germantown and Morristown Railroad Company, whose short line of six miles was operated by horse power, gave the order for the "Old Ironsides (see Fig. 199, page 273), which was completed and tried upon the road Nov. 23d, 1832. At the date of the issue of this volume the organization of the works is based upon an annual capacity of 1,000 locomotives per annum, equal to three and one-third locomotives per working day.

More than 15,000 locomotives have been constructed since the "Old Ironsides" in 1831. That engine was nearly a year in building and thirty years were occupied in building the first one thousand, which was the number completed in the single year 1889.

In October, 1889, the first compound locomotive in the practice of the works was completed and placed on the Baltimore and Ohio Railroad. It was of the four-cylinder type, as designed and patented by Mr. S. M. Vauclain, who had been connected with the works since 1883 and its General Superintendent since February 11, 1886. The economy in fuel and water and the efficiency in both

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NOTE.—In 1889 a test case was made to see in how short a time a locomotive could be built. On Saturday, June 22d, Mr. Robert H. Coleman ordered a narrow-gauge "American" type passenger locomotive and tender, which it was agreed should be ready for service on his railroad in Lebanon County, Pa., by the fourth of July following. The boiler material was at once ordered and was received Tuesday, June 25th. The boiler was completed and taken to the Erecting Shop on Friday, June 28th, and on Monday, July 1st, the machinery, frames, wheels, etc., were attached and the locomotive was tried under steam in the works. The tender was completed the following day, Tuesday, July 2d, thus making the record of construction of a complete locomotive from the raw material of the art in eight working days.

passenger and freight service given by this design led to its introduction on many leading railroads. Following the first four-cylinder compound locomotive built in 1889, three were built in 1890, eighty-two in 1891, two hundred and thirteen in 1892, one hundred and sixty in 1893, thirty in 1894, fifty-one in 1895, and one-hundred and seventy-three during 1896.

The principal features of construction of the Vauclain Compound Engine are as follows:

The cylinders consist of one high-pressure and one low-pressure for each side, the ratio of the volumes being nearly three to one; they are cast in one piece with the valve-chamber and saddle, the cylinders being in the same vertical plane, and as close together as they can be with adequate walls between them.

Where the front rails of the frames are single bars, the high-pressure cylinder is usually put on top, but when the front rails of frames are double, the low-pressure cylinder is usually on top.

The former is used in "eight-wheel" or American type passenger locomotives, and in "ten-wheeled" locomotives, while the latter is used in Mogul, Consolidation, and Decapod locomotives; for the various other classes of locomotives the most suitable arrangement is determined by the style of the frames.

Fig. 201 shows the arrangement of the cylinders in relation to the valve.

The valve employed to distribute the steam to the cylinders is of the piston type, working in a cylindrical steam-chest located in the saddle of the cylinder casting between the cylinders and smoke-box, and as close to the cylinders as convenience will permit; the steam-chest is bored out enough larger than the diameter of the valve to permit the use of a hard cast-iron bushing. This bushing is forced into the steam-chest under such pressure as to

THE BALDWIN LOCOMOTIVE.

prevent the escape of steam from one steam passage to another except by the action of the valve.

The valve, which is of the piston type—double and hollow—controls the steam admission and exhaust of both cylinders. The exhaust steam from the high-pressure cylinder becomes the supply steam for the low-pressure

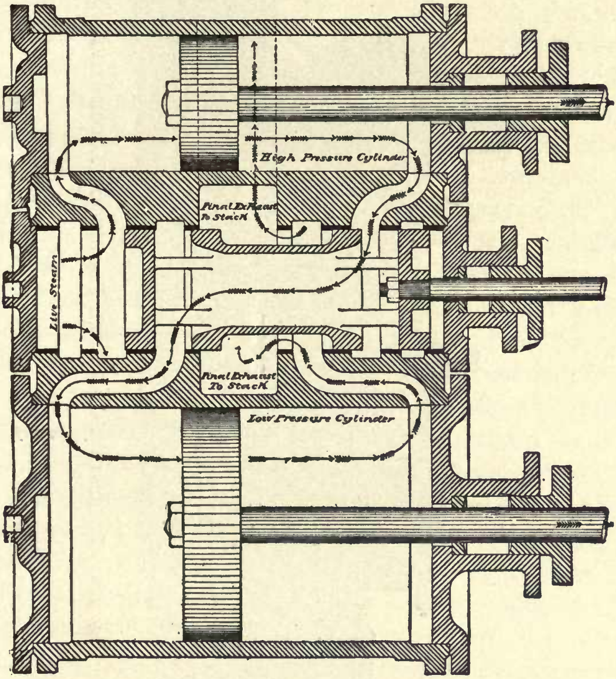


Fig. 201. VAUCLAIN VALVE SYSTEM.

cylinder. As the supply steam for the high-pressure cylinder enters the steam-chest at both ends, the valve is in perfect balance, except the slight variation caused by the area of the valve stem at the back end. This variation is an advantage in case the valve stem or its connection to the valve rod should be broken, as it holds them together.

THE BALDWIN LOCOMOTIVE.

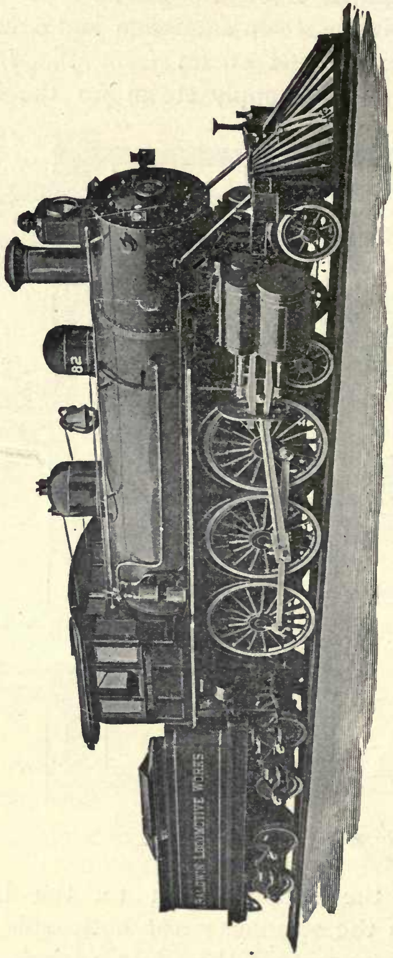


Fig. 202. BALDWIN TEN-WHEEL PASSENGER LOCOMOTIVE.

THE BALDWIN LOCOMOTIVE.

Cast-iron packing rings are fitted to the valve and constitute the edges of the valve. They are prevented from entering the steam-ports when the valve is in motion by narrow bridges across the steam-ports of the bushing. The operation of the valve is clearly shown by Fig. 201, the direction of the steam being indicated by arrows.

When the low-pressure cylinder is on top, the double front rail prevents the use of the ordinary rock-shaft and box, and the valve motion is then what is called "direct acting," changing the location of the eccentrics on the axle in relation to the crank-pin. When the low-pressure cylinder is underneath, the rock-shaft is employed, and the eccentrics are placed in the usual position, the valve motion is termed "indirect acting." Great care should be taken by mechanics, when setting the valves on these locomotives, to observe this difference and not get the eccentrics improperly located on the axle. If the crank-pin is placed on the forward center, the eccentric-rods will not be crossed when the rocker-arm or indirect motion is used, but will be crossed when no rocker-arm or direct motion is used. Serious complications have arisen from this being disregarded.

Various methods have been employed to transfer the motion from the links to the valve rod, that most commonly used being a small cross-head sliding between two guide bars. It is preferable, however, to use a rock-shaft when possible, as there is then less departure from ordinary locomotive practice.

It is obvious that in starting these locomotives with full trains from a state of rest, it is necessary to admit steam to the low-pressure cylinder as well as to the high-pressure cylinder, which is accomplished by the use of a starting valve. This is merely a pass-by valve which is opened to admit steam to pass from one end of the high-pressure cylinder to the other end and thence through the exhaust to the low-pressure cylinder. The same cock acts as a cylinder cock for the high-pressure cylinder and is operated by the same lever that operates the ordinary cylinder cocks, thus making a simple and efficient device, and one that need not become disarranged.

As is usual in all engines, air valves are placed in the main steam passage of the high-pressure cylinder. Additional air valves, placed in the low-pressure cylinders to supply them with sufficient air to prevent the formation of a vacuum, which would draw cinders into the steam-chest and cylinders.

Water relief valves are applied to the low-pressure cylinders, and attached to the front and back cylinder heads, to prevent the rupture of the cylinder in case a careless engineer should permit the cylinders to be charged with water, or to relieve excessive pressure of any kind.

In all other respects the locomotive is the same as the ordinary single-expansion locomotive, otherwise described.

Fig. 200 shows a Baldwin ten-wheel freight locomotive and Fig. 202 a ten-wheel passenger locomotive of the latest design.

THE RICHMOND LOCOMOTIVE.

These machines are built by the Richmond Locomotive Works at Richmond, Va.

Fig. 203 represents Passenger Engine No. 100, the outlines of the main parts of the same are shown in Fig. 204.

Fig. 206 shows a front view of a Compound Locomotive with outlines Fig. 207 of the Richmond type.

It will be observed that these two engines shown in Fig. 203 and Fig. 206 are compound locomotives. The following is a general description of their operation:

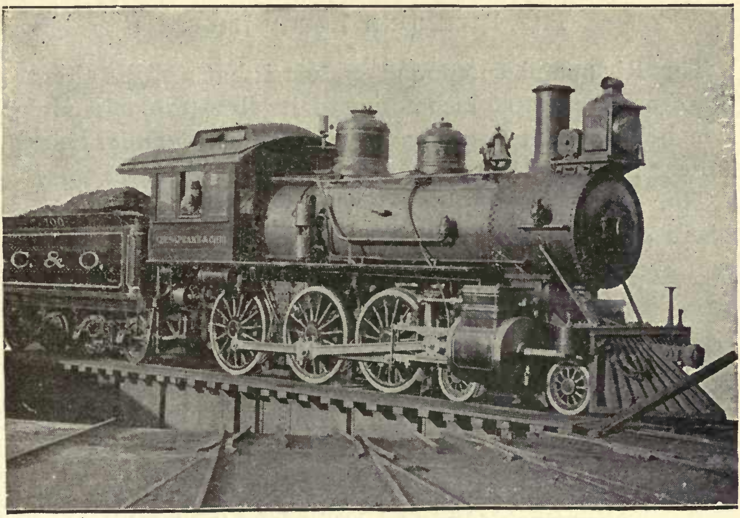


Fig. 203. THE RICHMOND LOCOMOTIVE.

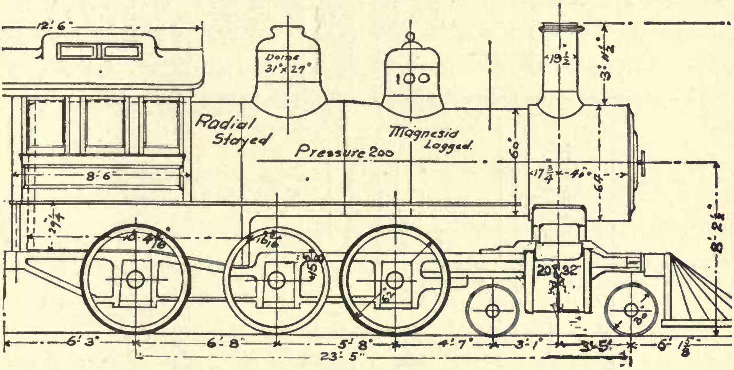


Fig. 204. OUTLINES OF ABOVE LOCOMOTIVE.

NOTE.

Tubes 256
Tubes—diam. No. 12 B. W. G. 2 in.
Tubes—length........ 13 ft. 5¼ in.
Tube Heating Surface............... 1793.25 sq. ft.
Fire-box Heating Surface............... 164.85 sq. ft.
Total Heating Surface............... 1958.10 sq. ft.

Grate Surface.......... 38.5 sq. ft.
Valve Travel. . 5½ in. H. P., 6 in. L. P.
Weight on Drivers......... 111,000
Weight on Truck........... 82,450
Total Weight of Engine.... 143,450
Weight of Engine and Tender (24 in. W.)........... 203.750

The Richmond Locomotive.

The Richmond compound system is but a slight alteration from the simple locomotive of its class, the only addition being an intercepting valve, and one cylinder being larger than the other.

The compounding differs from the "Vauclain," elsewhere described, in using but two cylinders, one high and

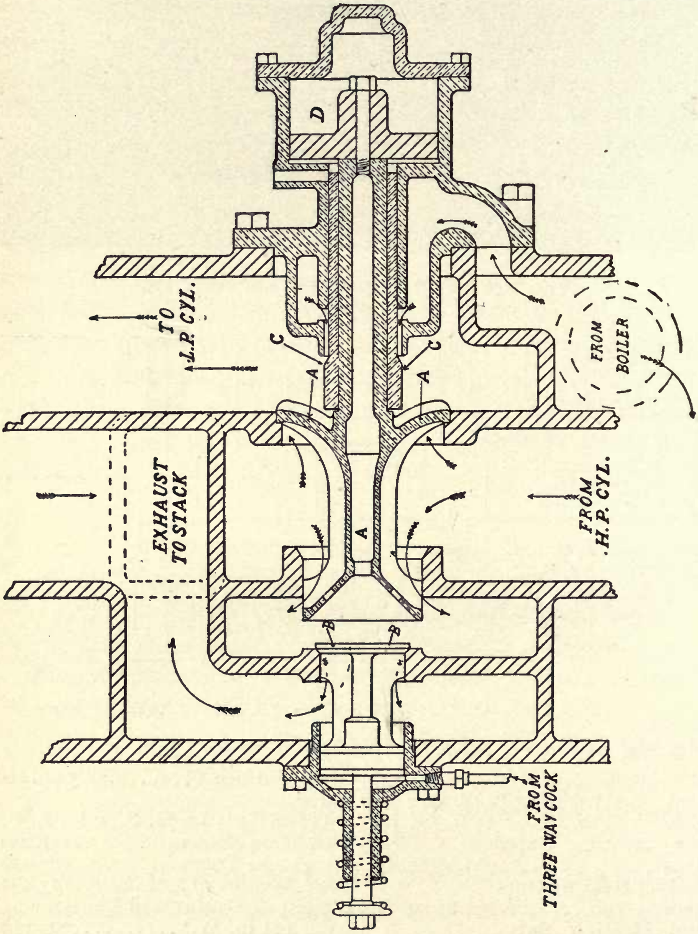


Fig. 205. Section Richmond Compound, Intercepting Valve.

THE RICHMOND LOCOMOTIVE.

one low pressure instead of four cylinders. These are set one on one side of the engine and one on the other with cranks at right angles, as in the simple engine.

The intercepting valve shown in Fig. 205 is used to start the engine with live steam on both cylinders, and also, if necessary, to run the engine simple.

As the area of the low pressure cylinder is much larger than that of the high pressure, the steam has to be reduced to a certain pressure; this is accomplished by the reducing valve *C* in Fig. 205.

The following is a description of the intercepting valve:

Steam goes from the dry pipe direct to the high pressure steam chest, and also to the cavity surrounding the reducing valve.

The exhaust from the high pressure cylinder goes into the cavity surrounding the intercepting valve *A*, and can either pass to the low pressure steam chest, or direct to the stack, dependent on the positions of the valves.

The low pressure exhaust goes direct to the stack at all times.

The intercepting valve opens and closes the connection between the two cylinders.

The emergency valve *B* opens and closes the connection between the high pressure exhaust and the atmosphere.

In starting the engine, observe the following operation:

1. The reducing valve *C*, which has a movement of one inch on the stem of the intercepting valve *A*, admits live steam to the low pressure chest, and also regulates the live steam pressure in the low pressure cylinder.

The air dashpot *D* on the stem of the intercepting valve *A* prevents any slamming of the valve. The arrows show the directions of steam currents.

2. The pressure having reached 72 pounds in the low pressure steam chest, closes the reducing valve by the steam pressure on its large end, and thus cuts off live

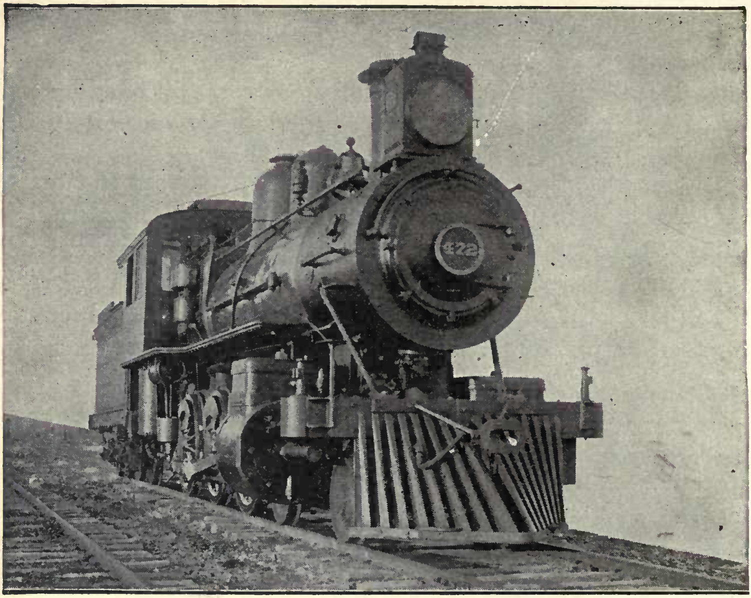


Fig. 206. The Richmond Locomotive.

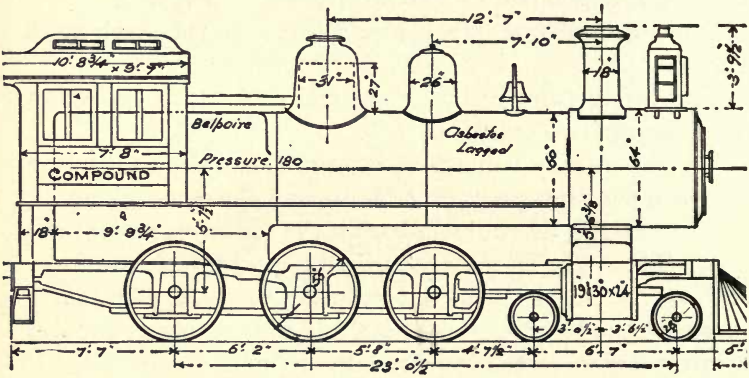


Fig. 207. Outlines of above Locomotive.

Note.

Grate Surface...... ...31.3 sq. ft.	Tubes........................241
Valve Travel...............5.6 in.	Tubes—diam.... ....2 in.
Weight on Drivers.........112,000	Tubes—length.......13 ft. 11½ in.
Weight on Truck...........32,000	Tube Heating Surface..1,756 sq. ft.
Total Weight of Engine....144,000	Fire-box Heating Surface................172 sq. ft.
Total Weight of Engine and Tender.................211,800	Total Heating Surface.1,928 sq. ft.

THE RICHMOND LOCOMOTIVE.

steam from the low pressure chest at the desired pressure, 72 pounds (with 180 pounds boiler pressure). When the steam in the low pressure chest falls, the reducing valve opens again. The other valves have not changed their positions.

3. The intercepting valve *A* is pushed wide open by the accumulated exhaust pressure from the high pressure cylinder. This movement closes the reducing valve *C*, thus permanently cutting off live steam from the low pressure chest.

In running the engine simple, the emergency valve *B* is pushed open by live steam from a three-way cock in the cab. The exhaust steam from the high pressure cylinder, which is the same as receiver steam, has escaped to the main exhaust, and the intercepting valve is shut by the force of this steam rushing around its end, assisted by the live steam pressure on the reducing valve shoulder. This live steam now enters the low pressure chest past the reducing valve. The high pressure cylinder is exhausting into the atmosphere, and the steam in the low pressure chest is at 72 pounds (with 180 pounds boiler pressure).

NOTE.—Assuming 180 pounds boiler pressure, the high pressure exhaust reaches 52 pounds when the engine is working compound. This pressure is the receiver pressure and also the initial pressure in the low pressure cylinder.

When working simple, the reducing valve permits 72 pounds of live steam to pass to the low pressure cylinder, thus greatly increasing the power of the engine. The high pressure piston also exerts an equal increased power when working simple, since the back pressure of 52 pounds is removed.

The live steam passage around the reducing valve, and the exhaust passage around the emergency valve are so contracted that engineers are compelled to work "compound" when running over 8 miles an hour in order to make time.

The lubricator pipe to the low pressure cylinder enters the live steam passage around the reducing valve, and insures constant lubrication to this valve.

Should either side of the engine break down, the emergency valve can be opened and the engine brought in on one side like a simple engine.

THE RICHMOND LOCOMOTIVE.

It will be seen, from the previous description, that in order to start the engine compound, all the engineer needs to do is to open the throttle as in a simple locomotive. The intercepting valve automatically changes her from simple to compound.

The only additional duty to perform while running simple is to keep the steam on the piston of the emergency valve, by means of the three-way cock. The exhaust of the high pressure cylinder while running simple goes direct to the stack—the exhaust from the low pressure cylinder in either simple or compound running, goes also to the stack.

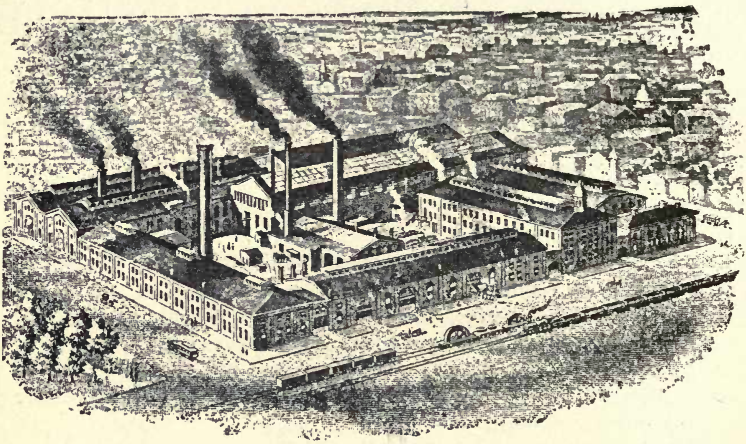


Fig. 208. MODEL ENGINE WORKS.

THE GAS ENGINE.

Ques. What is a Gas Engine?

ANS. Simply an engine run by an explosive force applied directly to the piston. An explosive mixture composed principally of air, in which has been blended a little gas or gasoline, is introduced into the cylinder, compressed and then ignited, when the expansion creates one of the greatest forces known. The piston connected with the crank-shaft yields, and thus the force is converted into power.

Ques. What is the difference between a steam and a gas engine?

ANS. It is only in the method of supplying and distributing the working fluid that the steam engine and the gas engine show any radical difference; that is to say, in the valve and governing mechanisms.

Ques. What is the main problem involved in both steam and gas engines?

ANS. The conversion of the pressure of an expansive fluid into rotary motion and consequently mechanical work. Those principles of design as applied to the main working parts, which have been successful in one instance, such as the cylinders, pistons, crank-shafts, connecting rods, bearings, etc., are equally applicable in the other.

Ques. What is another difference between a steam and gas engine besides the one already given?

ANS. In the steam engine the pressure is generated in a boiler separately in order to carry a reserve of energy. In the gas engine the necessary energy is created directly within the cylinder for each working stroke.

Ques. How many ways is the gas exploded in modern engines?

ANS. Two, with either an electric spark or a hot tube.

Ques. How would you describe the method by the electric spark?

ANS. It is accomplished by a battery which consists of proper cells for the fluid and of electrodes in the cylinder, with connecting wires. When the electrodes are clean and have proper contact, and the battery of proper strength,

THE GAS ENGINE.

a spark is created at the proper time that explodes the mixture in the cylinder. With the electric spark, the engine can be started in a moment, and the time of ignition made positive, thus producing the most satisfactory results.

Ques. What is the essential and peculiar mechanism always found in the gas engine to develop and control the power?

ANS. There must be inlets for the air and gas, an igniter, and an outlet for the exhaust. So far all engines are alike. The difference in them consists in the construction of these primary parts, and the appliances for operating them.

Ques. How is the power of a gas engine stated or calculated?

ANS. In indicated horse power or in brake horse power or both.

NOTE.—Unfortunately there is no standard commercial rule upon which to base the rated power of a gas engine, as is the case with the steam engine. In buying a steam engine, the purchaser, knowing the diameter of cylinder, stroke of piston, and speed, can by a simple calculation determine the capacity of the engine under any given conditions of steam pressure and cut-off. On the other hand, the purchaser of a gas engine has little else to guide him than the arbitrary rating of the builder, and is often misled by a lack of knowledge as the basis on which the rating is fixed.

It is essential that the non-technical purchaser should understand the difference between the two terms. The indicated horse power is *calculated* from the pressures shown throughout the stroke of the piston, by means of an indicator diagram taken from the cylinder. The actual useful work which the engine is capable of performing is less, by an amount varying from 15 per cent. upward, depending on the mechanical efficiency of the engine. On account of the high pressure and temperatures involved, and the suddenness with which the explosions take place, the indicator is, at best, a very imperfect instrument for measuring the power of a gas engine, its usefulness being restricted practically to determining by the characteristics of the diagram whether or not the general action of the explosive mixture in the cylinders is correct.

The brake horse power is the useful work delivered from the shaft of the engine; it is not a theoretical computation, but an actual *measurable* quantity capable of being accurately determined, and represents the capacity of the engine after eliminating all losses in the machine itself.

The Gas Engine.

Ques. Upon what two plans are gas engines built; and what is the four stroke cycle?

Ans. Gas engines are built on four-cycle and two-cycle plans. The first requires one cycle to draw in the mixture, another to compress it, a third to explode it, and the last to get out the exhaust, completed in two revolutions of the fly wheels, and taking gas every other revolution, when under full load. The two-cycle engine keeps the mixture under pressure, and admits it to the cylinder without previously clearing out the exhaust. These engines take gas every revolution.

Ques. How would you define an explosion such as takes place in the gas engine cylinder?

Ans. An explosion is simply a quick expansion—the flame of the burning gas coming into direct contact with the air in the cylinder causes its quick expansion, the resulting increased pressure develops the propelling power acting on the piston.

Ques. How would you describe the hot tube method of igniting?

Ans. The tube is simply a piece of gas pipe closed at one end with the other screwed into the cylinder. It is entirely closed by a chimney and is heated by a Bunsen burner, the fuel being either gas or gasoline. The flame is small, not observed and entirely safe. A few minutes time must be taken to heat the tube, which the attendant can employ in oiling and cleaning up.

Note.—The cost of running a gas engine has been reduced during the past ten years from 25 per cent to 50 per cent., because the gas companies, seeing the advantage gained by selling gas during the day for power purposes have reduced the price of gas. In 29 of our principal cities in the past 8 years, gas has been reduced to an average of $1.00 per 1,000 cubic feet, and in some cases as low as 80 cents per thousand.

It has been stated by competent writers that in Berlin one gas engine is used to every 1,300 of population.

Note.—In point of attention the battery requires greater and more intelligent care. In expense the battery renewals and igniting points are about the same as the tubes and fuel by which they are heated. The tubes can be made by the user himself. Composition tubes that will last several months can be procured at comparatively small cost.

The ignition in a gas engine is of greatest importance, and the igniting parts should be easy of access for purpose of cleaning them easily.

THE GAS ENGINE.

Ques. What is necessary to be done in view of the heat in the cylinders produced by the explosions of gas?

ANS. The heat from the explosions being very great, to keep all parts in proper relation to each other the cylinder must be kept cool. This is done by a circulation of water in a jacket around it, furnished by connection with city pipes, or from a tank supplied by a pump operated by the engine, or by a circulating tank. With the first two methods the water flows away when used; with the latter the heated water is returned to the tank, and cools as it circulates to the bottom.

Ques. What is the difference between Gasoline, Naphtha, Benzine, and Kerosene?

ANS. These are various products of mineral oil or petroleum and they differ in the manner in which they are distilled and in exploding qualities.

Ques. What is illuminating gas, such as is so generally used in operating gas engines?

ANS. It is a vapor (gas) distilled from coal.

The grading and quality of the various products of petroleum do not seem to be well understood, and as a guide a few of the more common grades in use are mentioned in this table.

		Specific Gravity.
Kerosene...	Common....................	43° to 48°
Benzine.....	Common.......	57° to 63°
Naphtha....	Common for painters' use.....	57° to 63°
Naphtha....	Special for boat use..........	76°
Gasoline....	Common for gasoline engines.	72°
Gasoline....	Special for gasoline engines...	76°
Gasoline....	Illuminating gas machines...	87°

NOTE.—There are several engines made which use crude petroleum, or kerosene oil. The action of crude petroleum depends somewhat on the proportion of its ingredients, as some of them are much more inflammable than others. The force of the explosion depends largely on the proportion of air that is mixed with the vapor, one of the latter to six of the former giving very good results.

THE OTTO GAS ENGINE.

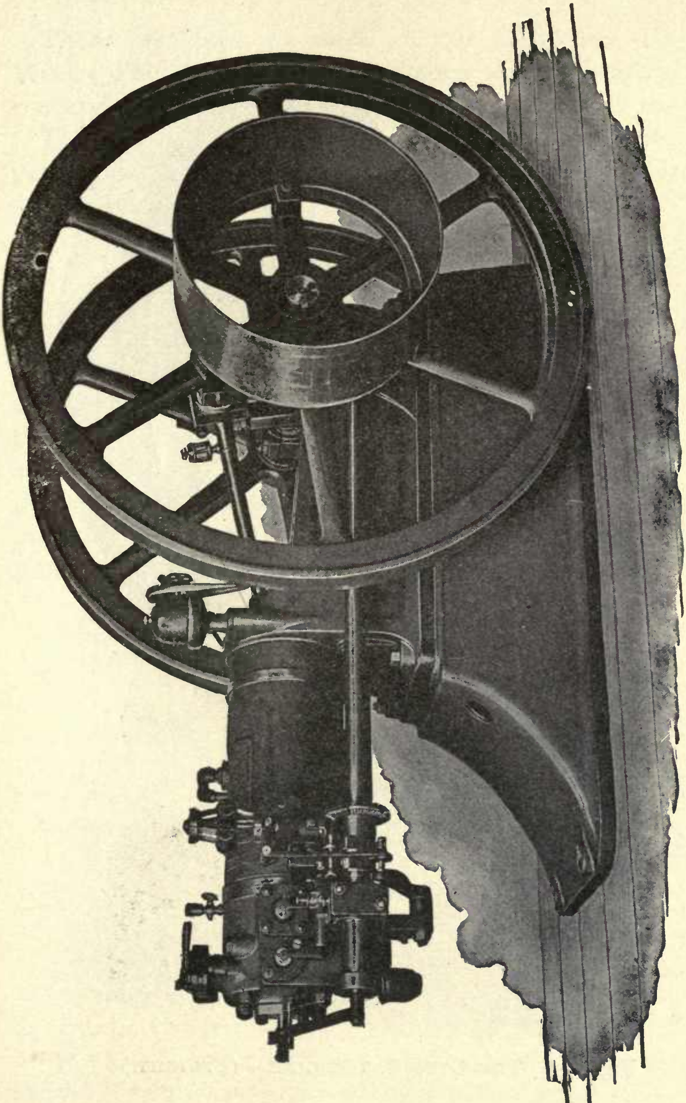


Fig. 209. THE OTTO GAS ENGINE.—(HORIZONTAL.)

THE OTTO GAS ENGINE.

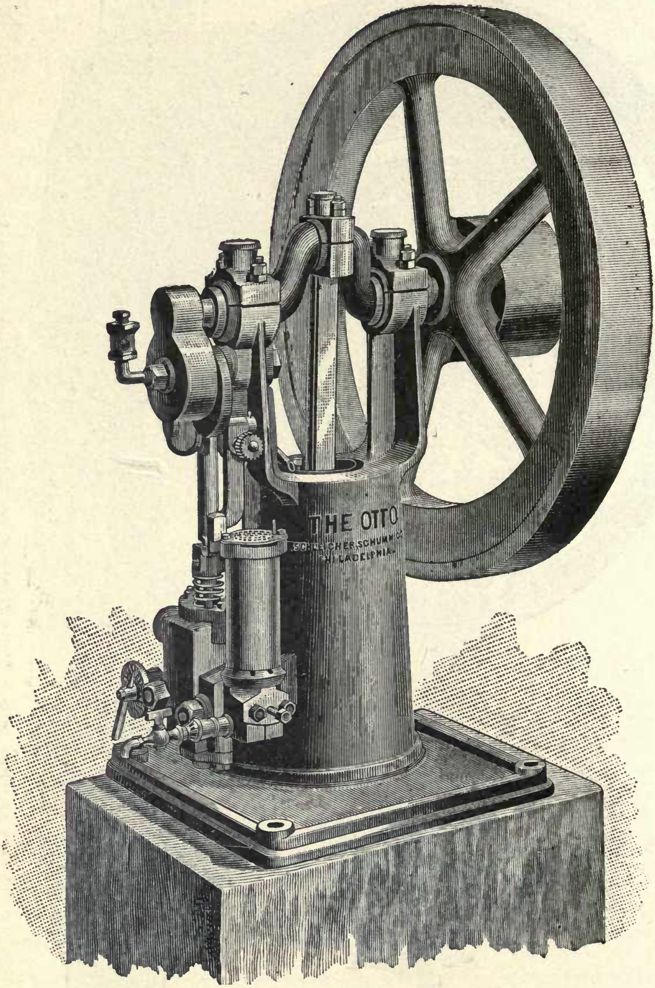


Fig. 210. THE OTTO GAS ENGINE.—(UPRIGHT.)

THE OTTO GAS ENGINE.

These machines are made at the Otto Gas Engine Works, Philadelphia, Pa., established over a quarter of a century, of a present capacity of 1,200 engines per annum.

This engine is fitted with patent alloy tube igniter and pendulum governor. Its vertical design saves considerable space, and it is extremely simple in its working parts.

Fig. 209 represents the horizontal Otto gas engine. Fig. 210 exhibits one of the smaller sizes, one-third horse power.

The operation of the Otto engine is as follows: The piston being started on its first outward stroke draws in a charge of air and gas. On the return stroke of the piston this mixture is compressed and while the crank passes the center it is ignited and by the resulting great pressure the piston is forced outward and the cycle of operation is completed. On the return stroke, by the exhausting of the products of the combustion into the atmosphere.

Sizes and Dimensions of "Otto" Gas Engines.

Size.	Indicated H. P.	Actual H. P.	Floor Space. (Approximate.)	Weight, Pounds.	weight, including Iron Base, Pounds.
No. 2	2.2	1.8	3 ft. 3 in. x 2 ft. 6 in.	875	1,075
" 3a	4.5	3.5	5 " 2 " x 2 " 3 "	1,000	1,460
" 3b	6	5	5 " 4 " x 2 " 5 "	1,120	1,570
" 4a	9	7	6 " 4 " x 3 " 0 "	1,450	1,890
" 4b	11	8.5	6 " 7 " x 3 " 1 "	1,600	2,040
" 5a	13.5	11	7 " 6 " x 3 " 4 "	2,600	3,350
" 5b	16	13.5	7 " 9 " x 3 " 6 "	2,820	3,570
" 6	23	19	8 " 5 " x 4 " 6 "	4,135	5,050
" 7	30.5	25	9 " 0 " x 5 " 2 "	7,500	10,200
" 8	42	36	9 " 6 " x 5 " 5 "	8,000	10,700
" 9	48	42	11 " 3 " x 6 " 0 "	12,300	15,600
" 11	65	56	12 " 6 " x 6 " 9 "	16,000	21,500
" 12	122	102	16 " 0 " x 6 " 9 "	24,000	28,300

NOTE.—In 1867, Dr. N. Aug. Otto brought out the first commercially successful gas engine, and obtained for it a gold medal at the Paris Exhibition of that year. Since then 47,500 "Otto" gas and gasoline engines have been sold, representing some 250,000 horse-power.

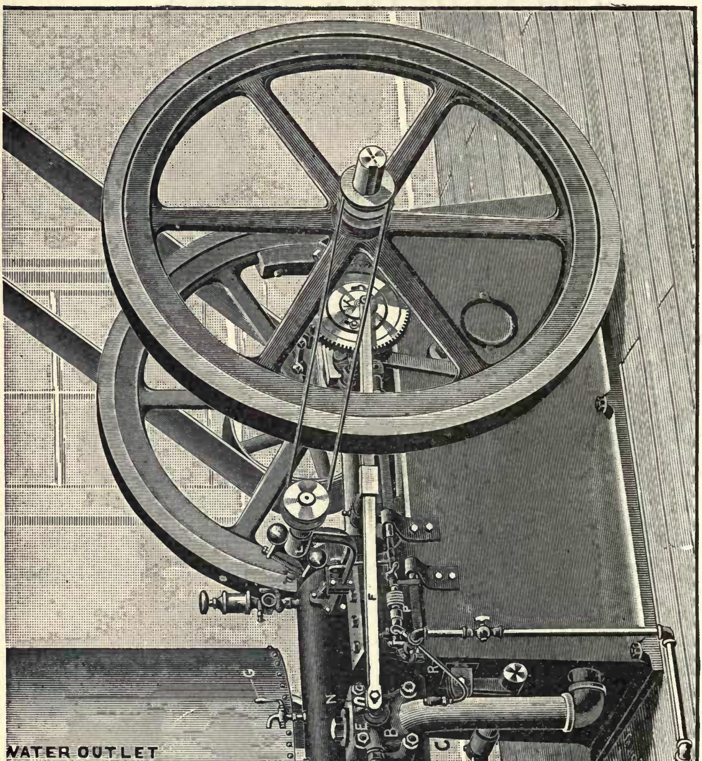


Fig. 211. Foos Gas and Gasoline Engine.

THE FOOS GAS AND GASOLINE ENGINE.

This Fig. 211 shows the Foos Machine, made at Springfield, Ohio, by the Foos Gas Engine Co.

The operation of this engine where gas is used is similar to that of others already described.

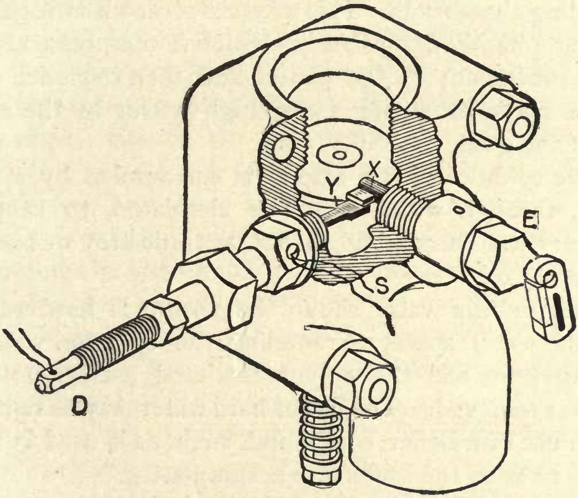


Fig. 212. The Foos Engine Electric Igniter.

In the use of gasoline the device varies considerably from others. Referring to Fig. 211 the letters on illustration may be defined as follows:

A, exhaust pipe, exhaust chamber and exhaust valve; B, exploding chamber; C, inlet valve in exploding chamber B; D, stationary electrode; E, revolving electrode; N, spring crank; F, rod which gives a revolving motion to electrode E; R, brass pipe conveying gasoline from pump P to mixing pipe M; G, stop cock for escape of compressed gas; K, crank disc for regulating time of explosion of gas in exploding chamber B; L, governor; M, mixing pipe for admission of pure air; P, gasoline pump.

The Foos Gas and Gasoline Engine.

The operation of the engine is as follows:

"The motive power is produced by pure air being drawn into pipe 'M' and there mixed with a few drops of gasoline thrown into this pipe by pump 'P' at every other revolution of the fly wheel, and thence drawn by the suction of the piston in its outward movement into the cylinder through exploding chamber B. This mixture of air with the gasoline forming a highly explosive gas which is compressed by the return movement of the piston, and then exploded by an electric spark, producing a very high power by the expansion of the gas.

"The cylinder of the engine is surrounded by a water jacket, through which water is circulated, to keep the cylinder from becoming so hot as to destroy or burn the lubricating oil.

"Soft or rain water should be used. If hard water is used the water space, surrounding the cylinder, would fill up with lime and the engine rendered useless until the lime was removed. The use of hard water may be remedied by the use of a boiler compound such as is used in steam boilers to keep the lime from accumulating."

A is the exhaust chamber valve and pipe, through which the exhaust passes from the cylinder. The spiral spring, which closes the exhaust valve, may, by long use, become too weak to close the valve quickly. To remedy this raise the collar on the valve stem which will compress the spring and cause it to act quickly. If gas escapes through the exhaust valve, it shows the valve does not fit the valve seat close enough and should be removed and the valve and valve seat cleaned, or it may be necessary, sometimes, to re-grind them with fine emery, after long use, to make them fit tight.

B is the exploding chamber. The gas is conducted into this chamber (and thence into the cylinder) through pipe "M" and then exploded by an electric spark, caused by

THE FOOS GAS AND GASOLINE ENGINE.

the contact and quick separation of the inside ends of the two electrodes D and E. Connected with the exploding chamber is the inlet valve C, which is opened and closed at every alternate revolution of the fly wheels, letting into chamber B a charge of gas from mixing pipe M. This valve requires no attention further than to see that it works freely. It may, occasionally, need cleaning.

It is very important that the poppet valves and valve seats in chambers A and B should fit so perfectly that when an explosion takes place in the cylinder the gas will not escape. Should the gas escape through these valves the engine would not give its highest power. In time these valves and valve seats may become rough and so imperfect that they will permit the gas to escape. When this occurs the valves and valve seats should be re-ground. The valves can be removed by taking out the large screw caps on top of chambers A and B. These chambers should be kept clean, especially of any metal filings, as they would destroy the insulation of electrode D.

By longer use the springs which operate the two poppet valves in chambers A and B may become too weak to close the valves quickly. This can be remedied by raising the collars on the valve stems which will compress the spring and cause it to act quickly. In time, it may be necessary to replace the old springs with new ones. If new ones are put on care must be taken that they are of the best quality.

There are two electrodes, D and E. When the two points or ends, X and Y, are brought together (as shown in cut) the electric current is closed, and when quickly separated an electric spark is emitted, the gas in exploding chamber B and cylinder is ignited and the piston in cylinder put in motion by the expansion of the gas.

The connection and separation of electrodes D and E is caused by the revolving motion of electrode E, bringing the points X and Y together at every revolution of elec-

THE FOOS GAS AND GASOLINE ENGINE.

trode E. Electrode D is made to screw further in so that when the inside "Y" is worn off it can still be kept in contact with electrode E at X. Care must be taken not to screw it in so far but that there will be a separation of an eighth of an inch (not less) between the points X and Y of the two electrodes at every revolution of electrode E.

In screwing electrode D further in or putting in a new electrode, first remove the large screw cap on top of exploding chamber B. This will enable the inside of the chamber to be seen and tell just how far to insert electrode D, so that the inner end X of electrode E will wipe it at every revolution. It must be noticed that both ends of electrode D are flat. Care must be taken that the flat surface be left in a horizontal position, otherwise the inside end, which is a flat steel spring, will not lie level on the end of X and will be broken the first revolution of electrode E. A large brilliant white spark is necessary to explode the gas in chamber B. A red spark will not do it, and is evidence that the electric battery is exhausted and should at once be renewed with new parts.

Electrode D is insulated. Care must be taken that the insulating asbestos or other insulating material should not get damp or wet. If it should, the insulation would be destroyed and would have to be re-packed with fresh insulating material.

When natural gas is used that has sulphur in it, it will be necessary to remove electrodes D and E and polish or brighten the inside ends X and Y, about once in 6 or 8 days, as it will eat and corrode the inside ends of the electrodes.

The inside wearing points of the electrodes are made of hardened sheet steel, and when worn out can easily be replaced with new ones.

Stop cock G is used for relieving the gas pressure in cylinder when starting the engine. By opening it a part of

THE FOOS GAS AND GASOLINE ENGINE.

the compressed gas in the cylinder will escape and less power will be required to turn the fly wheel. As soon as an explosion takes place part of the exploded gas in cylinder will escape through stop cock "G." When this occurs close stop cock G and the engine will continue to run.

Crank disc K, to which the vibrating rod F is attached at its rear end, is for the purpose of regulating the time of explosion of gas in chamber B. This is done by loosening the two screws and turning the disc slightly to the right to make it explode sooner, or to the left to explode later. The explosion should take place the moment the piston has reached its farthest forward movement. When the disc is properly set the two screws should be firmly tightened to prevent the disc from slipping. If the disc is out of time the engine would fail to do good work.

The inside end of electrode E should have just separated from the inside end of electrode D when the piston has reached its farthest point on the inward stroke.

This governor (L) is remarkably sensitive. If the engine should run too fast turn in the acorn headed screw at end of shaft. If it runs too slow withdraw the screw, always being careful to tighten the lock nut. The speed of engine may also be controlled by compressing or loosening the governor springs by means of the nuts at each end of the springs.

To ascertain if electric battery is in good working condition:

Disconnect wire from end of electrode D and pass the bare end quickly across any part of exploding chamber B. If the battery is in good condition a large brilliant white spark will be emitted. If a small red spark is emitted it will not explode the gas and the battery should be renewed with new zincs, copper oxide plates, potash and oil.

Be very careful that the insulation of electrode D does not get wet or damp from water, oil or other liquids. If

THE FOOS GAS AND GASOLINE ENGINE.

it should, no electric spark would be produced in the exploding chamber B, and you would have to re-pack it with fresh asbestos or other insulating material. You can always tell if the insulation of electrode D is imperfect by turning fly-wheel until the piston is at the end of its outward stroke. Then detach the insulated wire from end of electrode D, and draw the bare end across the end of electrode D. If, in doing this, a spark is emitted the insulation is destroyed. There should be no spark because when the piston is at the end of its outward stroke the inner ends of electrode D and E are separated and no spark could be emitted if the insulation was good. In such a case, you must remove electrode D. Take off the brass boxing or cover, clean out any metal particles or dirt that may be in chamber B or in the brass covering around the asbestos insulating ring. If the ring is damp or not in good condition new ones should be put in.

One of the important things connected with operating an engine is to see that it is properly oiled. See that the oil cups are kept filled and that all the wearing points are oiled frequently. This is important if you expect good service from the engine.

A small oil cup is placed on upper side of electrode E for the purpose of oiling the shaft. Oil should be put in this cup two or three times a day. Means are supplied for oiling crank shaft, connecting rod, boxes, etc.

If the cylinder is not kept well oiled a knocking sound will be produced in the cylinder. It is very important to use only the best lubricating oil.

The motive power of the engine is produced by mixing certain portions of air and gasoline, forming an exploding gas, which being introduced into the cylinder and compressed by the piston and exploded, a very high power is obtained by the expansion of the gas operating against the piston.

The Foos Gas and Gasoline Engine.

The first thing to do in starting the engine is to produce the gas and convey it into the cylinder. To do this you take hold of the small brass handle attached to the pump plunger and give the plunger three or four strokes so as to fill pipe R and also force a small quantity of gasoline into pipe M. Then by turning the fly-wheels from the cylinder as rapidly as possible you will set the piston in motion, and by its outward stroke draw or suck pure air into and through pipe M into exploding chamber B and thence into the cylinder. The air, in passing through pipe M, will absorb the gasoline in the pipe and form an explosive gas. This gas is compressed on the inward stroke of the piston and is then exploded by an electric spark at the very moment the piston has reached its farthest point on its inward stroke. If the gas exploded before the piston had reached its farthest point, there would be a concussion and the engine would stop.

Now, if you have followed the instructions given and the engine fails to run, examine carefully and see if the electric battery is in good working condition and gives off a large brilliant white spark. See that the insulation of electrode D is good and that the inside ends X and Y come in contact and separate not less than ⅛ of an inch at each revolution of electrode E. See that the gasoline pump is in good order and that it supplies the proper amount of gasoline to the engine. Be careful that you have a good quality of 74 degree gasoline.

The operation of the gasoline pump is thus explained:

The gasoline pump P is connected with the gasoline tank by a small iron or lead pipe, as shown in cut. The bottom of tank should be as high as the pump and may be higher if more convenient; it is necessary to see that the plunger works free; dirt in the gasoline or in the pipe may be carried to the pump and stop the flow of gasoline, or it may get under the valves so they will not close tight and

THE FOOS GAS AND GASOLINE ENGINE.

give the engine too much gasoline. If dirt gets into the pump it can be removed by taking out the valves and letting a little gasoline run through.

The valve, at the end of pipe R just where it is connected with pipe M, can also be removed. Then, if the gasoline is turned on and the valves in the pump fit tight, no gasoline will pass through. If, however, gasoline runs through without the pump being worked, it would show that the valves are not tight and should be taken out and the pump cleaned. It may be found that the valve spring is broken or the valve or valve seat do not fit perfectly. If the spring is broken a new one must be put in of the same size and strength. If the valves are worn and do not fit tight so the gasoline will not pass except at the proper time, the valve and valve seat should be cleaned and smoothed so they will fit.

The amount of gasoline delivered by the pump to engine can be increased or diminished by increasing or diminishing the stroke of the pump plunger. The stroke can be shortened by turning in the nut at end of shaft lying just below and parallel with the pump or increased by withdrawing the nut.

If the gasoline tank gets so empty as air would get in the pipe and prevent the flow of gasoline to pump, it will be necessary to occasionally put new packing in the pump.

The tank can be set 100 feet away from the engine if desired, using a small iron pipe to convey the gasoline to pump at engine. It is necessary that the bottom of the gasoline tank be as high as the pump on engine to insure a flow of gasoline to the pump. The gasoline must be kept clean, also the pipe leading to the engine.

The tank may be of wood, galvanized iron or boiler iron. For a two-horse power engine a 50-gallon tank would be a suitable size; a 10-horse power, 500 gallons.

THE FOOS GAS AND GASOLINE ENGINE.

In setting up the engine, bolt the engine firmly to the foundation. See that the fly-wheels are keyed tightly to crank-shaft. Then run the exhaust pipe into a clean chimney flue through the roof or out through side of building, as may be most convenient. Then run an inlet water pipe from water connection at top of cylinder to water tank, as shown in cut. A drain cock should be placed on inlet water pipe near its connection with the cylinder to draw off the water from the cylinder in freezing weather. If the water is left in, it would freeze and burst the cylinder.

A stop cock should also be placed on same pipe near the water tank to shut off the water. As soon as the cylinder becomes slightly heated the water will commence passing from the tank to cylinder and from the cylinder back to the tank.

The consumption of gasoline is regulated by the governor in proportion to the work done by the engine. On an average, the quantity of gasoline consumed for ten hours, should not exceed one gallon for each rated horse-power of any given size engine.

NOTE.—There is a peculiar field of usefulness for gasoline motors connected with dynamos for isolated lighting in situations where a steam engine, for one reason or another, is not desirable. Recent improvements have brought these motors to a very high state of efficiency, and reduced to a considerable extent the dangers that formerly accompanied their use. They are now constructed so that they can be readily adapted for direct connection to dynamos of moderate speeds, and their regulation has been improved until it is comparable to that of second-class steam engines.

GOULD PUMP AND GAS ENGINE.

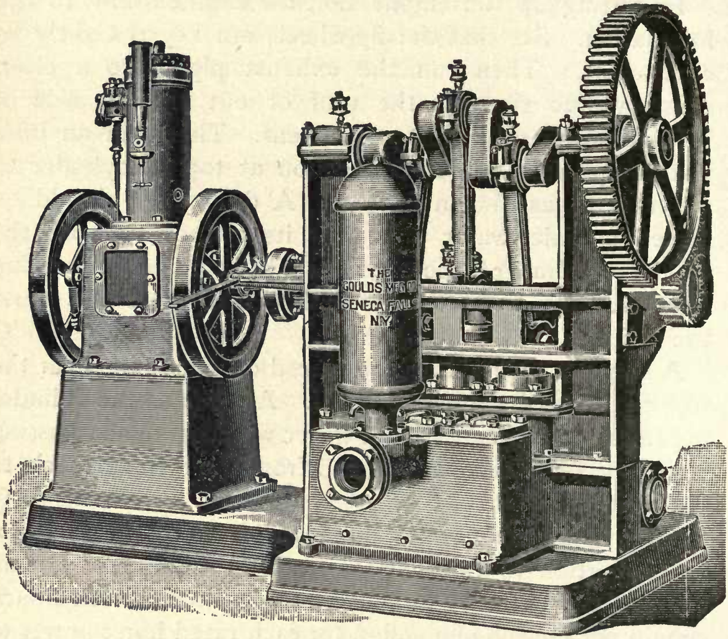


Fig. 214. GOULD PUMP AND GAS ENGINE.

In Fig. 214 is shown a device, introduced by the Gould Mfg. Co., of Seneca Falls, N. Y., in which a gas engine is used to operate one of their triple power pumps.

Any type of gas engine can be used by the manufacturers for this combination, which is very serviceable, for railroad tank pumps and other isolated stations; the arrangement generally used is shown by the illustration. The friction clutch may be dispensed with for the smaller pumps, in which case the pinion is mounted on the crank-shaft.

This device emphasizes the idea that the gas engine finds a most appropriate use as an auxiliary to the steam engine in odd places where a minimum amount of power is needed temporarily or otherwise—and for an enlargement or use in convenient places.

NEW ERA GAS AND GASOLINE ENGINES.

These engines are constructed at Dayton, Ohio, by the New Era Iron Works Company. Fig. 215 shows the New Era Gasoline Engine. The New Era engine is built to use both gas and gasoline; in fact, to change from one to the other without stopping the engine, and to start the engine with either.

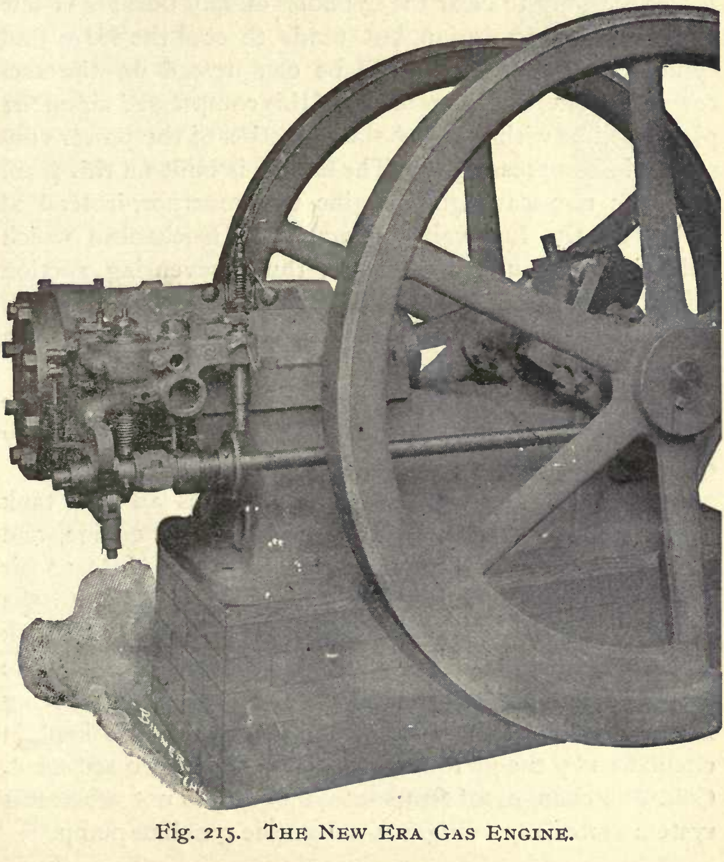


Fig. 215. THE NEW ERA GAS ENGINE.

THE NEW ERA GAS ENGINE.

Four-cycle engines may be divided into two classes, namely, self-scavenging and non-self-scavenging. A self-scavenging engine is one whose governor operates on the inlet fuel valve. Under less than full load, and when a speed is attained higher than that for which the governor is set, the inlet fuel valve remains closed, and instead of a mixed charge of gas and air, only one of pure air is sucked into the engine by the action of the piston and this is in due time emitted through the exhaust valve. This process serves not only to clear the cylinder of any burnt gas left from the last explosion, but tends to cool the valve and cylinder. The pure air will be compressed on the succeeding stroke, but the reaction of this compressed air on the piston will be within a very small fraction of the power consumed in compressing it. The engine is built on this plan.

In the non-scavenging engine the governor, instead of acting on the fuel valve, operates on mechanism which holds the exhaust valve open, thus preventing suction taking place through the inlet valve, but, by reason of its greater area, allows the suction to take place through the exhaust valve.

Gasoline must be the fuel for gas engines in a multitude of places. It is not dangerous unless used on the gravity or carburetor system.

In the New Era system the gasoline is all in a tank under ground, from which it is pumped to the engine, and sprayed by an injector, a few drops at a time, into an air chamber, where it is converted into gas, passed into the cylinder of the engine, compressed and exploded. A tank is buried at a distance from the building, from which the gasoline is pumped by the engine, the surplus, if any, being returned to the tank. The gasoline in the tank is kept in circulation by the pumping process, so there is no sediment. Cold and changes of temperature or air do not affect this system materially. Fig. 216 shows the gasoline pump.

THE NEW ERA GAS ENGINE.

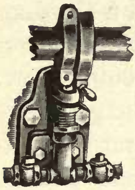


Fig. 216.
GASOLINE PUMP.

The governor, Fig. 218, is of the familiar ball type, driven from the lateral shaft by bevel gears. It is set to control any desired speed, and simply makes the engine take gas often enough to keep up this speed and resultant power. By an arrangement peculiar to this engine, the gas valve cannot remain open when the engine is at rest.

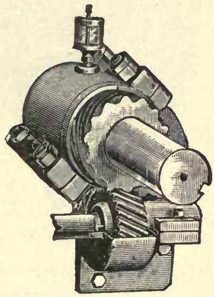


Fig. 217.
SPIRAL GEAR TO DRIVE LATERAL SHAFT.

The auxiliary exhaust is a valveless port in the side of the cylinder, so placed that it is automatically uncovered by the piston at the end of its outward stroke, allowing the burnt gas to escape to the exhaust vessel or pipe.

The only duty left for the regular exhaust valve to perform, therefore, is to allow the escape of what is left in the cylinder.

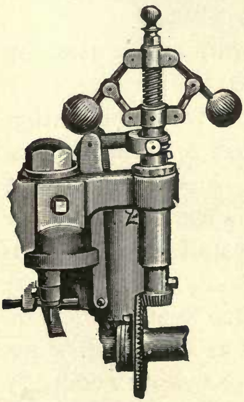


Fig. 218.
GOVERNOR FOR NEW ERA GAS ENGINE.

The engine is started by turning the fly wheels once or twice. A small quantity of gas or gasoline is first turned on, which is changed to the proper amount after the engine is up to speed. To make the engine easy to start, there are appliances to lessen the compression, and fire late. A self-starter is furnished with the larger sizes.

To stop the engine, simply shut off the gas or gasoline. No other attention is necessary but to look after the oilers, and keep the engine clean and in proper condition.

THE SIMPLEX NAPHTHA ENGINE.

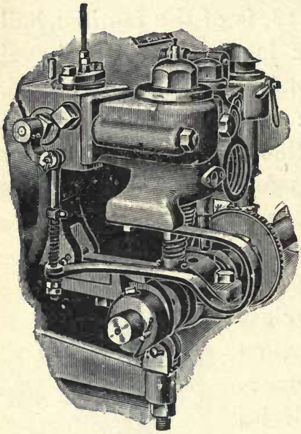


Fig. 219.

IGNITING DEVICE SHOWING VALVE GEAR.

The engine is built on the plan of a lateral shaft rotated by a spiral gear on the crank-shaft, which in turn drives the governor by bevel gears, and operates directly on the valves by means of cams.

The valves are set so that they can be taken out, or ground in, by merely removing the nut that holds them in, without disturbing any other part. This must be done occasionally, hence this handy construction.

Fig. 219 shows the igniting device and valve gear for operating the inlet and outlet of the gases to the cylinder.

THE SIMPLEX NAPHTHA ENGINE.

These engines are built for boat and other uses, by Messrs. Chas. P. Willard & Co., Chicago, Ill.

The Simplex Naphtha engine differs from most other vapor engines in not depending upon atmospheric evaporation for its supply of gas. Attached to the engine is a generator, which is heated by the exhaust pipe from the cylinder, thus producing a uniform gas independent of atmospheric temperature or humidity.

In starting the engine no fire is used to heat the generator, it being provided with an improved vaporizing arrangement, which furnishes the engine with the vapor necessary for starting up. After running a few minutes, the generator is sufficiently heated to produce a generated gas to take the place of the vaporized gas.

THE SIMPLEX NAPHTHA ENGINE.

In the Simplex engine the gases are admitted to the cylinder through an ordinary throttle valve, and by means of this the speed can be varied at will.

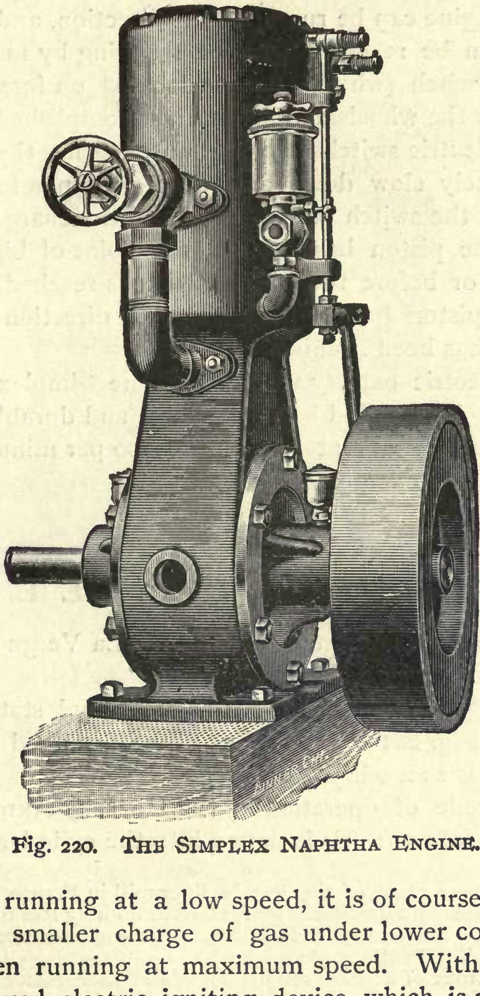


Fig. 220. THE SIMPLEX NAPHTHA ENGINE.

When running at a low speed, it is of course necessary to fire a smaller charge of gas under lower compression than when running at maximum speed. With the aid of an improved electric igniting device, which is a combination circuit opener, closer, and sparker, and is so constructed as to permit the spark to be fired at any desirable point of the stroke, and owing to the uniform quality of the gas, we are able to successfully fire a very small charge under low compression.

The engine can be run in either direction, and in skillful hands can be reversed without stopping by means of the electric switch (which may be located up forward in the boat near the wheelsman). This is accomplished by means of the electric switch being cut out, causing the engine to immediately slow down and when within a few turns of stopping, the switch is thrown in and the charge fired just before the piston has reached the point of highest compression, or before the end of stroke is reached, thus forcing the piston back in the opposite direction to that in which it has been running.

The electric battery with which the Simplex engine is furnished is a sealed battery, simple and durable, furnishing a strong spark at the rate of 500 per minute for two weeks on one charge.

THE HORNSBY-AKROYD OIL ENGINE.

These engines are made by the De La Vergne Refrigerating Machine Co., New York City.

Fig. 223 represents the Hornsby-Akroyd stationary oil engine. Fig. 221 exhibits the engine arranged with traction wheels as a self-propeller.

The mode of operation of the Hornsby-Akroyd oil engine is as follows: Air is drawn into the cylinder and oil is

The power plant of the Pantin flour mill in France, comprises a single-cylinder Simplex gas engine, rated at nothing less than 320 indicated H. P. The brake H. P. is 250. The engine is worked by producer gas. The Pantin mills engine has a 34½ inches cylinder, with a length of stroke of a little over 39 inches, and, as a result of a 194-hour test, showed a consumption of 1.043 pounds of coal per brake H. P. per hour.

THE HORNSBY-AKROYD OIL ENGINE.

pumped into a vaporizer communicating with the same by a narrow neck. When the piston returns it forces the air under pressure into the vaporizer where it combines with the hot oil vapor and in consequence of the resulting increase of pressure the piston is forced out; the governor controls the supply of oil, so that only just sufficient oil is thrown into the vaporiser to do the work required and the work may be thrown on and off or varied to any extent within the range of power of the engine.

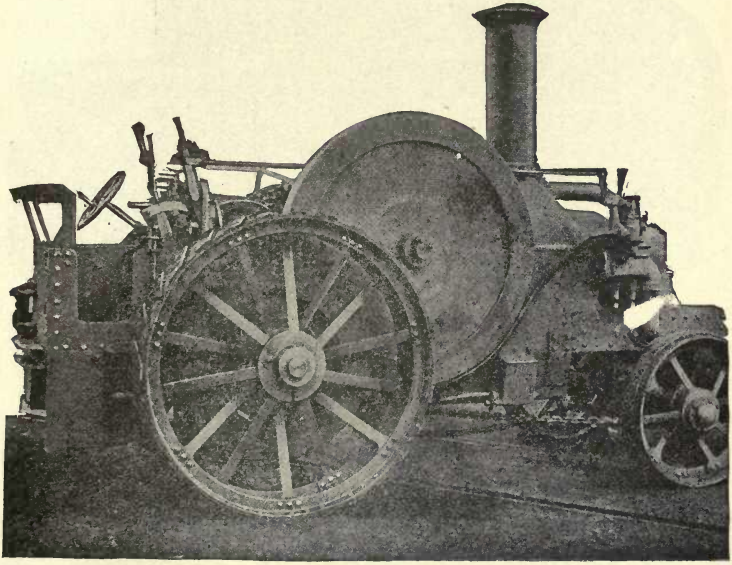


Fig. 221. THE HORNSBY-AKROYD TRACTION OIL ENGINE.

The portable type, Fig. 222, is mounted on a channel iron frame having a wrought iron box or tank suspended underneath it. Instead of the usual arrangement of having a large tank full of water for cooling the cylinder, only a small quantity is used, which is pumped through the cylinder jacket and then allowed to run down to a series of trays placed inside the box or tank.

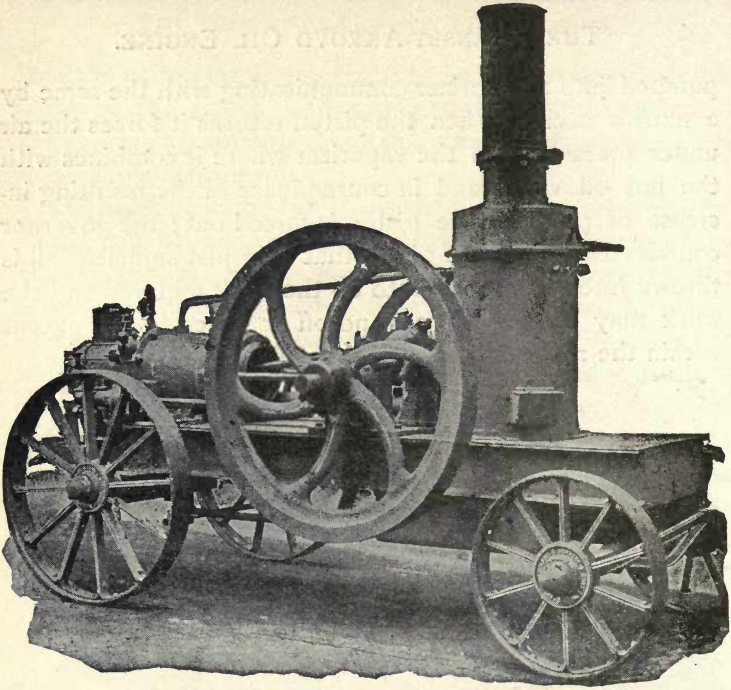


Fig. 222. THE HORNSBY-AKROYD PORTABLE OIL ENGINE.

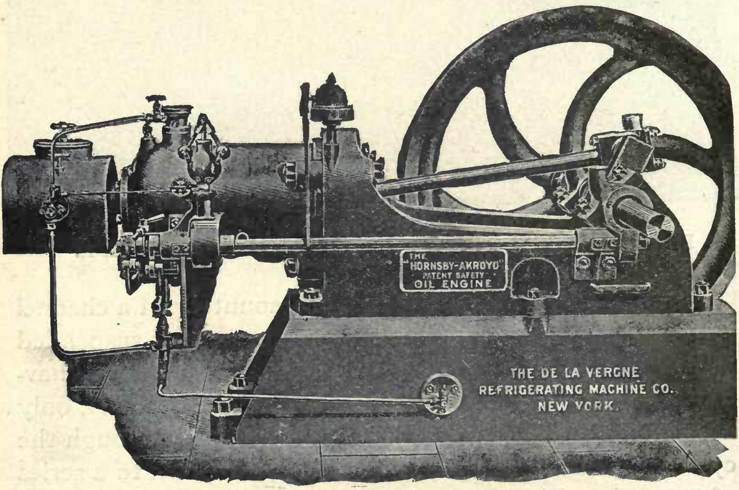


Fig. 223. THE HORNSBY-AKROYD STATIONARY OIL ENGINE.

THE WESTINGHOUSE GAS ENGINE.

These are built at Pittsburgh, Pa., by the Westinghouse Machine Co., in sizes ranging from 5 to 500 horse-power.

In its general design this engine embodies the features characteristic of the steam engine constructed by the same firm; the upright self-contained construction and the self-lubricating principle being particularly apparent.

The cylinders are two in number on the smaller sizes and three on the larger sizes; the pistons are of the trunk pattern, made very long in order to serve the purpose of a cross-head, without causing perceptible wear on the cylinder walls; the piston is packed with cast-iron spring rings, and is provided with a case-hardened steel wrist pin, with which the upper end of the connecting rod engages.

The connecting rod ends are fitted with adjustable bronze boxes lined with babbitt metal.

The bearings are adjustable, the lower halves being set up by wedges operated by screws. As the wear on the bearings is always downward, the upper halves preserve their original position. In taking up the wear, the wedges are drawn across until the shaft is brought up against the upper halves of the bearings.

The lubrication of the main bearings is taken care of by sight feed oil cups, supplied with the regular Westinghouse crank case oil. The crank case is filled with water up to the division in the crank pin brasses, when the engine is on its bottom center, and a layer of crank case oil about one-half inch thick is added on top of the water. The motion of the cranks beats the oil and water into an emulsion, which is thrown over the internal working parts, lubricating them copiously and thoroughly. When the engine is once started, there is enough surplus oil from the main bearings passing into the crank case to keep up the supply. A gauge glass on the back of the crank case always indicates the proper height of the oil and water.

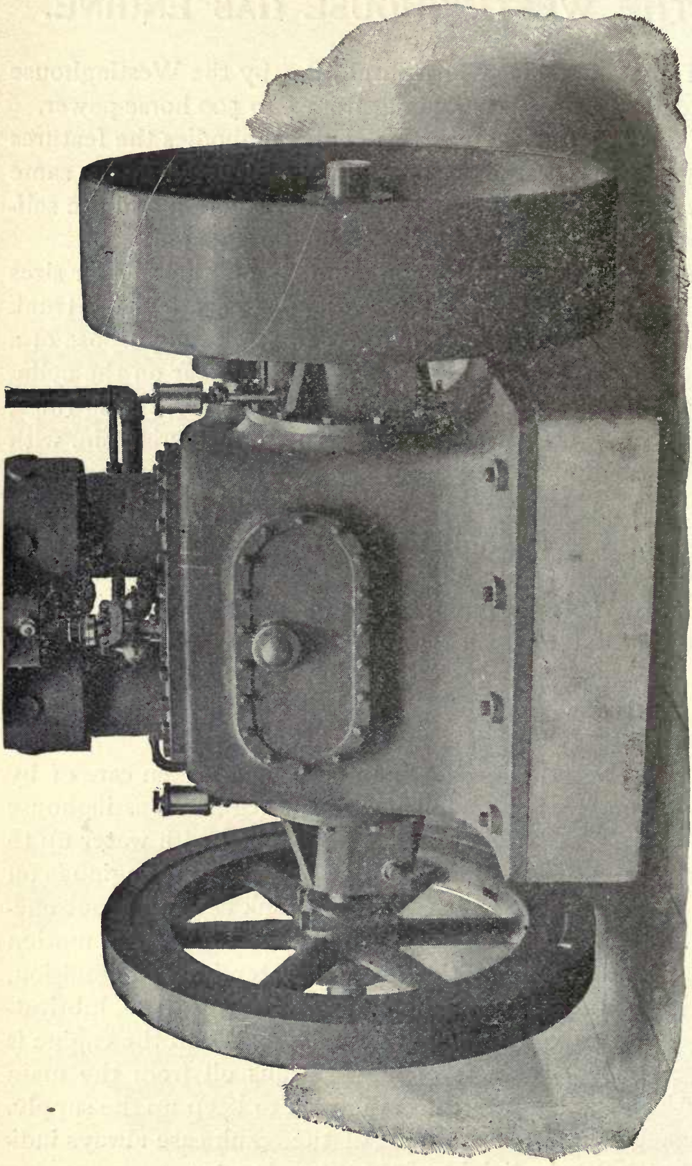


Fig. 224. The Westinghouse Gas Engine.

THE WESTINGHOUSE GAS ENGINE.

The operation of the engine is as follows:

On the first outward stroke the piston draws in a charge of the explosive mixture, (air and gas), which it compresses on the return stroke. As the crank passes the center, the charge is ignited and expansion takes place on the next forward or working stroke. During the succeeding return stroke the burnt gases are expelled, leaving the cylinder ready to repeat in regular order the same series of operations. The single acting piston receives in consequence only one impulse for each four strokes, or each two revolutions of the crank.

By the use of two cylinders alternating the working strokes of the pistons, the engine receives an impulse at every revolution. A sensitive governor regulates the amount of the explosive mixture admitted for each charge, in proportion to the load on the engine, giving an impulse at every revolution whether running fully loaded or entirely light.

The ignition of the explosive mixture is accomplished by the electric spark. The igniters are simple in construction and exceedingly durable. They are mounted in small castings, easily removed and replaced. In sizes from 15 H. P. up, there are double igniters in each cylinder. One igniter only in each cylinder is in operation at any one time, the other being held in reserve. In case of accident to the igniter in service, the battery wire can be instantly shifted to the binding post of the reserve igniter and the engine kept in service until it can conveniently be shut down for examination.

Small gas engines are easily set in operation by giving the fly-wheel several turns by hand until a charge of gas and air has been drawn in, compressed and exploded. In the larger sizes this method is too laborious, requiring the combined efforts of several men, besides being attended with more or less danger from the sudden starting when explosion takes place.

The Westinghouse Gas Engine.

With the engines which are too large to be readily started by hand is furnished a simple and effective air compressor and an air storage tank of ample capacity. The air compressor can be operated by hand to charge the tank for the first time, after which it is run by a belt from any convenient pulley either on the engine itself or on the shafting. By running the compressor a few minutes every day the tank is kept fully charged and ready for starting the engine at any time.

A pipe leads from the air tank to one cylinder of the engine, in which pipe is a valve arranged to be opened and closed at each revolution of the engine, by means of a cam on the end of the shaft which operates the exhaust valves, the opening occurring just as the crank is passing its upper center. A single motion of a lever on the crank case sets the exhaust valve on this cylinder so that it opens on every return stroke of the piston, instead of every other stroke, as when the engine is in normal operation.

A turn of a screw throws the admission valve on the same cylinder out of operation. It will readily be seen that one cylinder of the engine is now converted into a compressed air motor, without disturbing the functions of the other cylinder or cylinders. The engine being set with the crank a little past its upper center, the air and gas inlet valves properly adjusted, and the stop valve on the air tank opened, it starts up and continues to run on the air pressure until explosion takes place in the other cylinder. The stop valve is then closed, the inlet and exhaust valves set again to work in the regular manner, and the engine is in full operation. The air admission valve can be disengaged from its cam when not in use.

Three or four revolutions with the air pressure are generally sufficient.

These engines are built to run on gas of any kind or quality, or on gasoline, as may be desired.

THE BACKUS GAS ENGINE.

This engine is made at Newark, N. J., by the Backus Water Motor Co. Fig. 225 shows the horizontal and Fig. 226 the vertical engine.

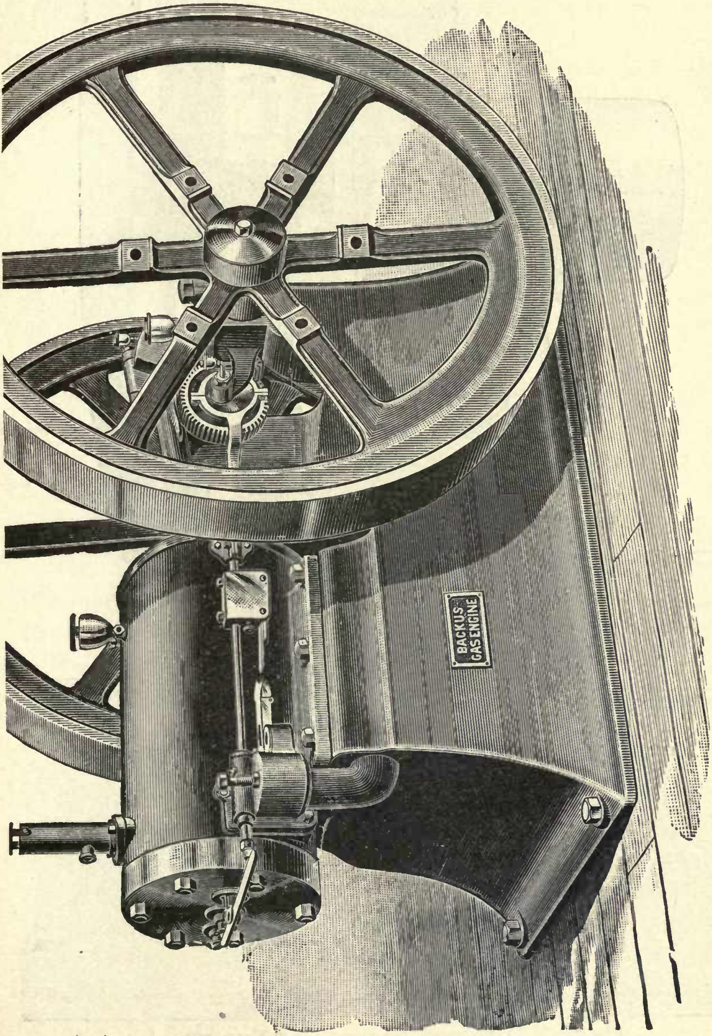


Fig. 225. HORIZONTAL BACKUS GAS ENGINE.

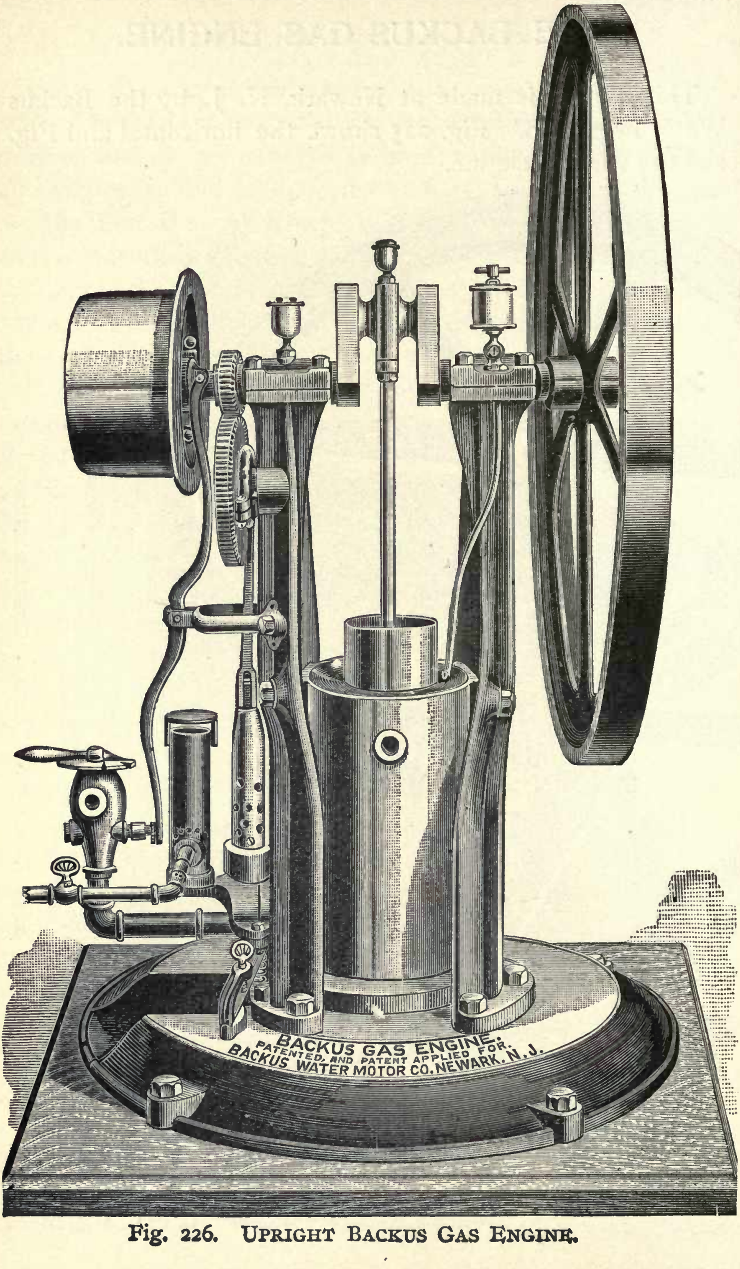


Fig. 226. UPRIGHT BACKUS GAS ENGINE.

THE DE LAMATER-ERICSSON HOT-AIR PUMPING ENGINE.

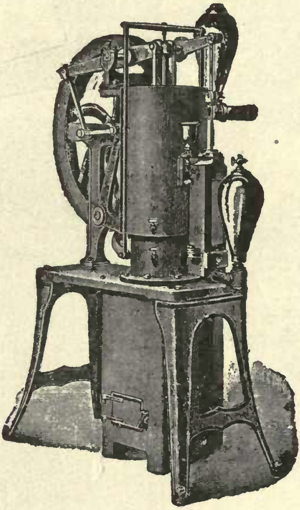


Fig. 227.

The De Lamater-Ericsson Hot-Air Pumping Engine is a single-cylinder engine in which are two pistons, one called the main or air piston, which receives and transmits the power, and the other called the transfer piston, the office of which is to transfer the air contained in the machine alternately and at the proper time from one end of the cylinder to the other.

The cylinder is provided at its upper end with a water jacket, through which all the water passes on its way from the well to the tank. This keeps the upper end of the cylinder cool, while the lower end is exposed to the fire and becomes as hot as it is practicable to make it. By the peculiar arrangement of connections between the air and transfer pistons the proper relative motions between these pistons are obtained.

De Lamater-Ericsson Hot Air Engine.

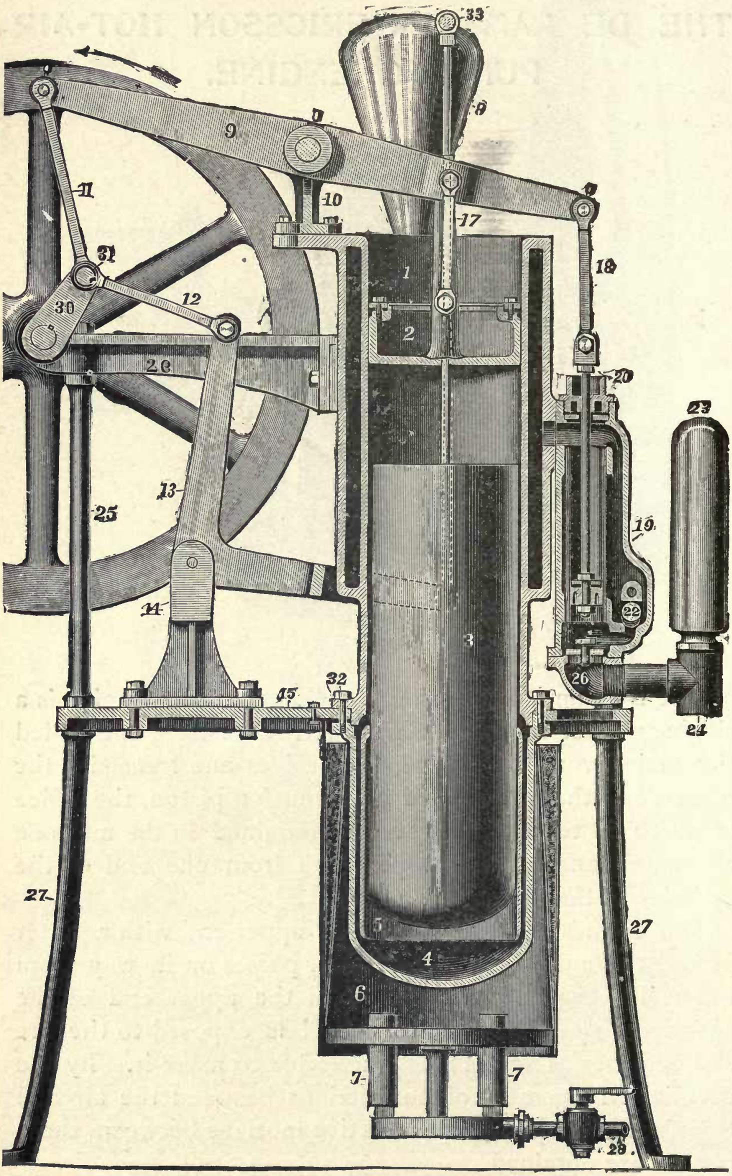


Fig. 228. The De Lamater-Ericsson Hot air Engine.

De Lamater-Ericsson Hot Air Engine.

The operation is as follows: After the lower end of the cylinder has been sufficiently heated—which usually takes only a very few minutes—the engine must be started by hand by giving it one or two revolutions. The air contained in the machine is first compressed in the cold part of the cylinder; it is then transferred to the lower end, where it is instantly heated and expanded, thus furnishing the power.

This engine, like all other hot-air engines, is only single-acting. The momentum of the flywheel continues the revolution until it receives an additional impulse by the repetition of the above-mentioned conditions, which occur once in every revolution. The same air is used continuously, and is cooled, compressed, heated and expanded in the regular order and without noise.

Fig. 228 represents an enlarged sectional view of the engine, with the following "List of Parts," with numbers to correspond with those on the engraving:

1. Cylinder.
2. Air Piston.
3. Transfer Piston.
4. Heater.
5. Telescope.
6. Furnace.
7. Gas Burners.
8. Air Chamber.
9. Main Beam.
10. Beam Centre Bearing.
11. Connecting Rod.
12. Bell-Crank Link.
13. Bell Crank.
14. Bell-Crank Bracket.
15. Bed Plate.
16. Flywheel.
17. Air-Piston Links.
18. Pump Link.
19. Pump Chamber.
20. Pump Gland.
21. Foot Valve.
22. Discharge Valve.
23. Vacuum Chamber.
24. Suction Pipe.
25. Stanchion.
26. Foot-Valve Chamber.
27. Legs.
28. Gas Cock.
29. Crank-Shaft Bracket.
30. Crank.
31. Crank Pin.
32. Heater Bolts.
33. Transfer Piston-Rod Crosshead.

THE DE LAMATER-RYDER HOT-AIR ENGINE.

Fig. 229 represents the De Lamater-Ryder, and the same engine is shown in enlarged sectional view in Fig. 230. The description and operation of the device is as follows:

The compression piston, *A*, extends downwards to the base of the engine, closely fitting the compression cylinder, *B*, which also extends downwards, nearly to the bottom of the cooler, *K*. The lower part of the compression cylinder, *B*, is sufficiently smaller than the inside shell of the cooler, *K*, to form a thin annular passage for the air, which becomes thoroughly cooled on its way to the bottom, and through which passage it flows on its way back to the heater.

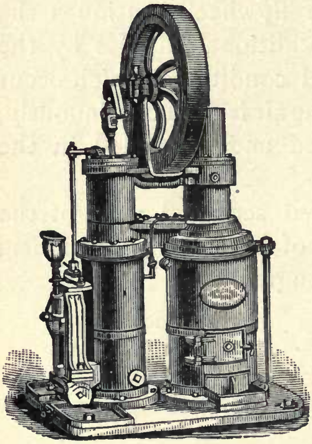


Fig. 229.

The power piston, *C*, likewise extends downwards into the heater, *E*, which in shape resembles the bottom of a champagne bottle—that is, rising in the center, and presenting to the action of the fire a narrow annulus all around the bottom. Within this heater is the telescope, which is a thin iron cylinder, about one-fourth of an inch less in diameter than the interior of the heater. It is fitted to the interior of the power cylinder, *F*, and extends nearly to the bottom of the heater. Its office is to cause the air which flows from the compression cylinder to be presented in a thin sheet all around the interior surface of the heater, and particularly at the lower and hotter portion. By this means the air is thoroughly and rapidly heated. The same air is used continuously, as there is neither influx nor escape, the air being merely shifted from one cylinder to another.

De Lamater-Ryder Hot Air Engine.

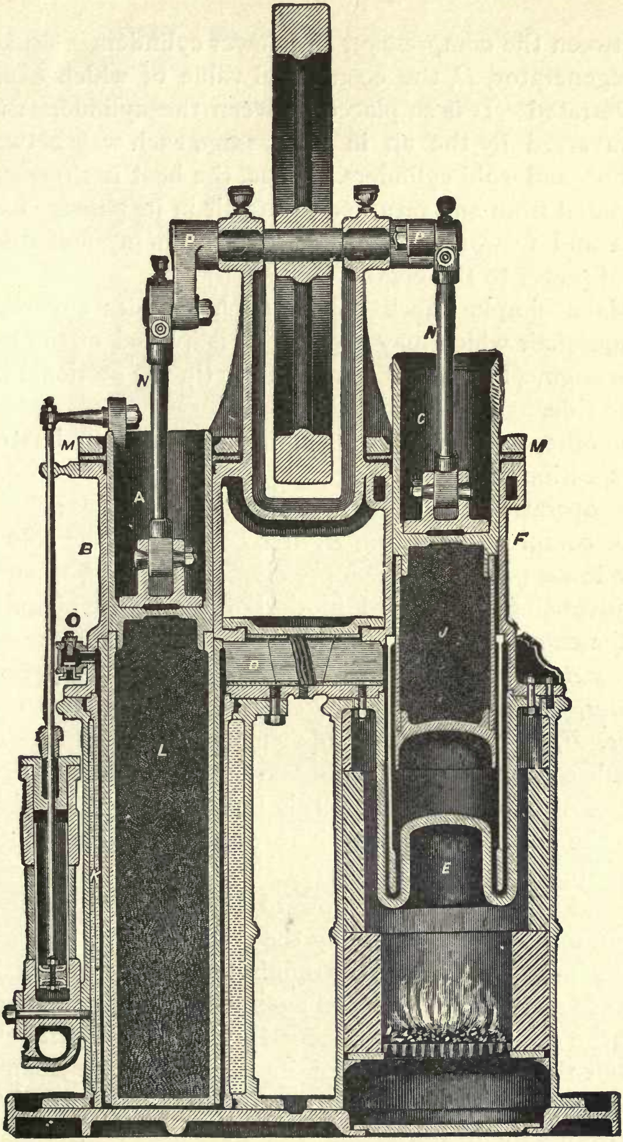


Fig. 230. De Lamater-Ryder Hot Air Engine.

De Lamater-Ryder Hot Air Engine.

Between the compression and power cylinders is situated the regenerator, *D*, the economical value of which cannot be overrated. It is so placed between the cylinders as to be traversed by the air in its passage each way between the hot and cold cylinders. Thus, the heat is alternately abstracted from and returned to the air in its passage backwards and forwards, imparting great economy and steadiness of power to the engine.

O is a simple check valve which supplies any slight leakage of air which may occur. It is placed at the back of the engine, but is necessarily shown (in the sectional cut) on the side.

The other portions of the engine are readily understood on inspection of the cut.

The operation of the engine is briefly as follows:

The compression piston, *A*, first compresses the cold air in the lower part of the compression cylinder, *B*, when by the advancing or upward motion of the power piston, *C*, and the completion of the down stroke of the compression piston, *A*, the air is transferred from the compression cylinder, *B*, through the regenerator, *D*, and into the heater, *E*, without appreciable change of volume. The result is a great increase of pressure, corresponding to the increase of temperature, and this impels the power piston up to the end of its stroke. The pressure still remaining in the power cylinder and reacting on the compression piston, *A*, forces the latter upward till it reaches nearly to the top of its stroke, when, by the cooling of the charge of air, the pressure falls to its minimum, the power piston descends and the compression again begins. In the meantime, the heated air, in passing through the regenerator, has left the greater portion of its heat in the regenerator plates, to be picked up and utilized on the return of the air towards the heater.

These engines are built by the De Lamater Iron Works (Established A. D. 1841), New York City.

THE HOISTING ENGINE.

The hoisting engine may be made stationary or portable, according to the work it is called upon to do.

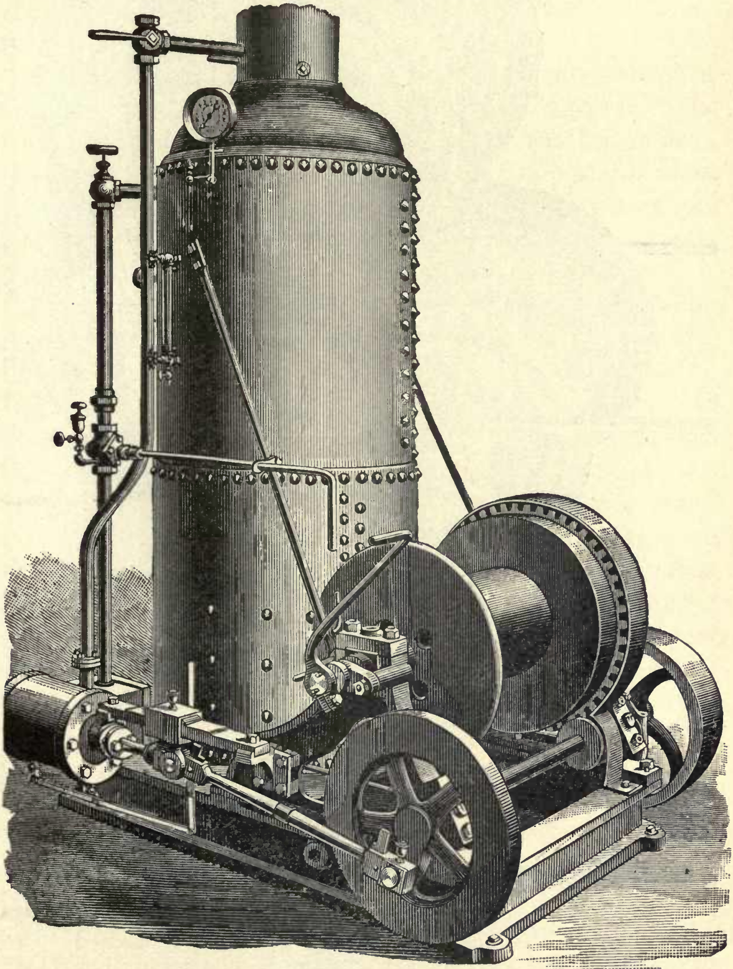


Fig. 231. PORTABLE HOISTING ENGINE.

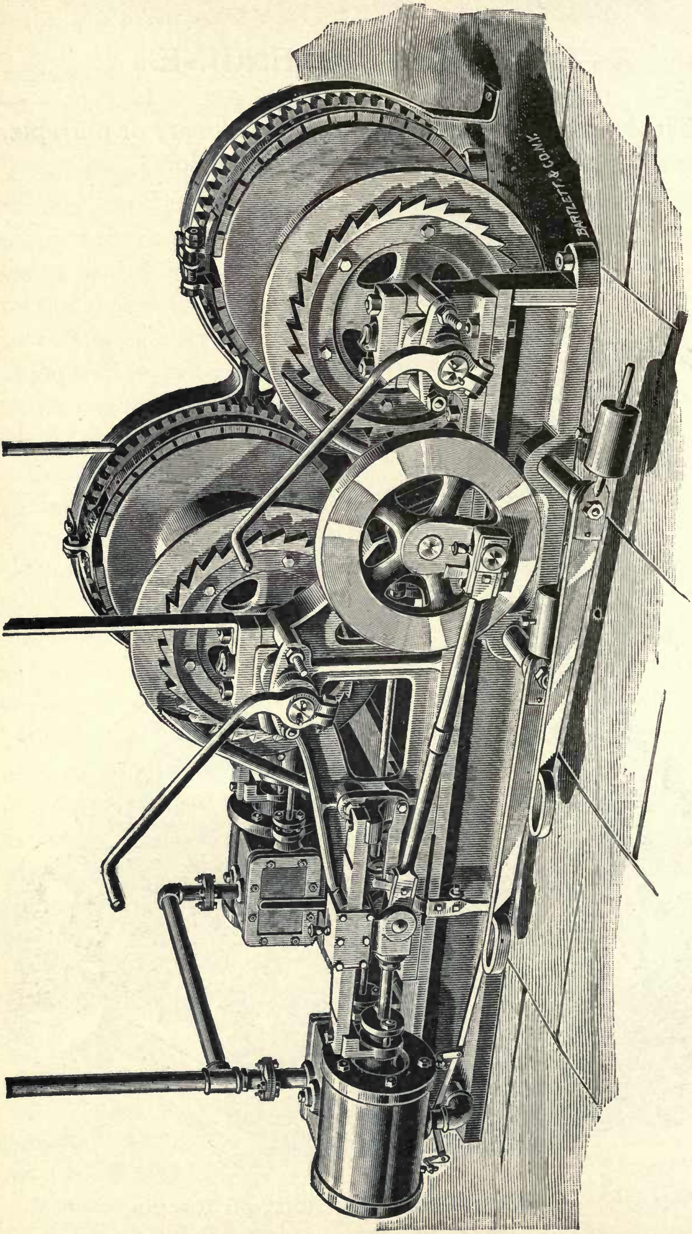


Fig. 232. Double Cylinder Double Friction Drum Hoisting Engine.

Hoisting Engines.

The ordinary portable hoisting engine, which is used for hod hoisting, pile driving, etc., generally consists of an engine and upright boiler, combined on one frame. The hoisting rope is wound upon a drum, which is driven by the engine shaft through friction cones, and can be thrown "in or out" at will.

Some hoisting engines have the drum directly upon the engine shaft and are provided with reversing gear. The stationary hoisting engines mostly are of the larger sizes, but serve for the same general duties as the portable ones.

On the following pages are described several of the leading hoisting engines, of various sizes and styles, adaptable for different purposes.

Fig. 231 represents a portable single cylinder hoisting engine, built by the Lidgerwood Mfg. Co., New York, Chicago and Boston.

The engine shaft is connected by means of spur gear and pinion. The drum can turn upon its shaft; it is thrown into gear by a small end motion along the shaft, which is effected by means of a lever, screw, pin, cross-key and collar; the extreme power of this arrangement being such that a very slight pressure will hold the drum in gear against any load the engine can hoist, while it is released by means of a spiral spring interposed between the drum and gear wheel. The sectors of wood forming the friction cone being secured to the spur wheel by bolts and nuts, which can be adjusted from the outside of the drum, can thus always be kept tight without trouble. The end thrust caused by applying the friction is taken up by a thrust bearing and screw collar.

This engine is the well-known and most familiar hod hoisting and pile driving engine.

In Fig. 232 is shown the Standard Double Cylinder Double Drum Engine, without boiler, which is largely used by contractors for all classes of derrick work, and is an extremely useful and popular type of engine.

HOISTING ENGINES.

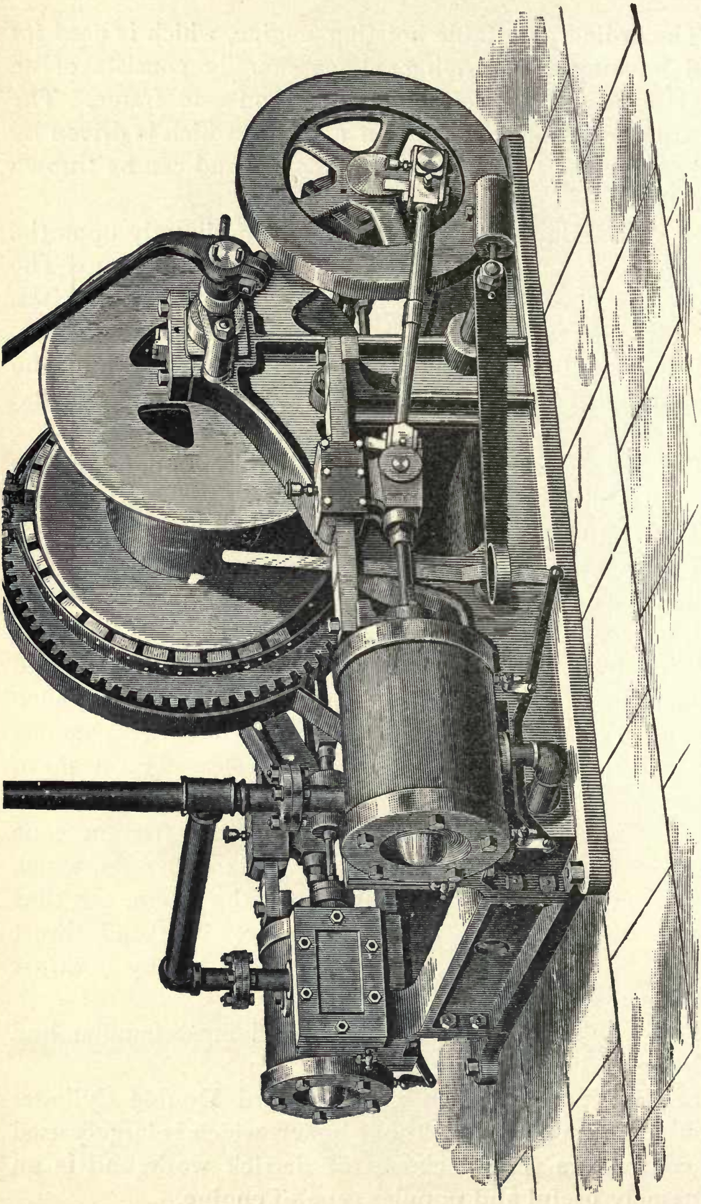


Fig. 233. DOUBLE CYLINDER PATENT FRICTION DRUM HOISTING ENGINE.

HOISTING ENGINES.

The engines being light can be easily shifted when required, without much trouble. Having double-friction drums of improved type they will either handle one derrick or two, as desired. In the former case one drum is used for hoisting and the other for raising the boom, and in the latter, one drum is used for each derrick in the usual way. Each drum is provided with ratchets and pawls of ample strength to hold securely any load the engines can lift. Winch heads are attached to the end of each drum shaft and can be used for any hoisting or hauling desired. Foot brakes are recommended strongly for these engines. They are not absolutely necessary for the successful operation of the engine, but wherever there is much lowering to be done they are very desirable, as they remove the wear from the drum friction, which is very much greater in lowering than in hoisting. They are also very convenient in every way, and of decided advantage in all general hoisting work.

For small suspension cableways this style of engine is well adapted, and by lagging up the drums a fair rate of hoisting speed is attained. Foot brakes are always used in this connection.

Fig. 233 illustrates a double cylinder single friction drum hoisting engine with foot brake.

They are easier to operate and are safer than the single cylinder type. They are very simple in design and construction, and are exceedingly compact—occupying comparatively little space. They are a very desirable style of engine for use on docks upon which a boiler cannot be placed, as, by locating the boiler near the end of the dock, and leading the main steam pipe the entire length of the dock with suitable branch pipes, the engines can be put wherever most suitable for loading and unloading the vessels. Or by using flexible steam hose connections, the engines can be mounted upon dock wheels and moved about the dock; thus they can be concentrated at any point

Hoisting Engines.

to unload a cargo quickly or can be distributed at different points. In this way a few engines can be made to cover a large dock in an efficient and economical manner.

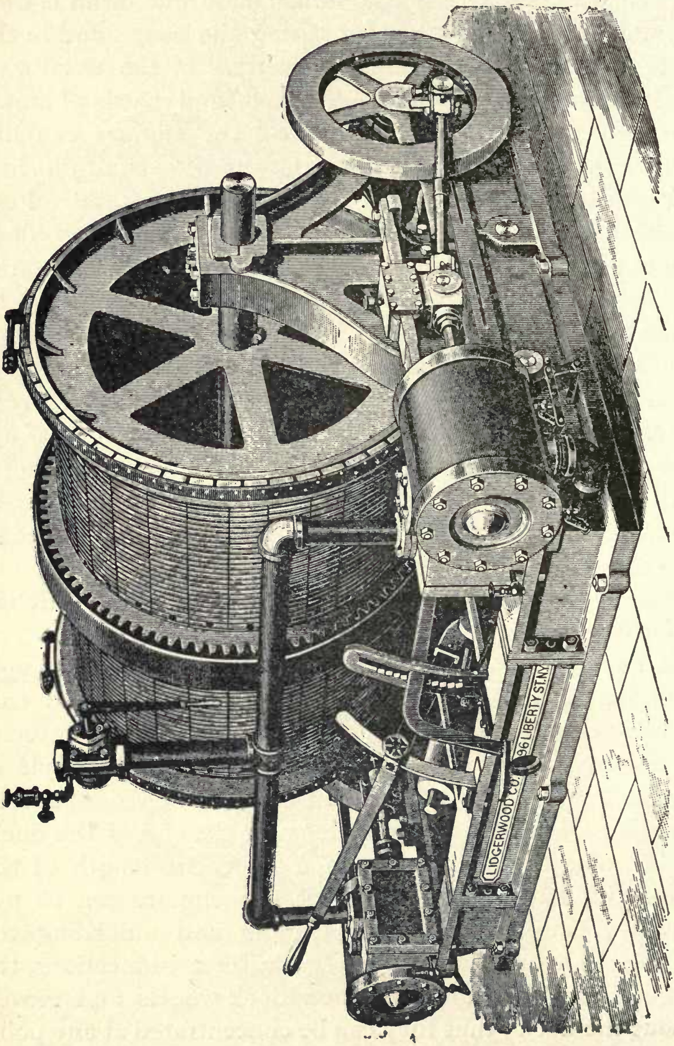


Fig. 234. Double Drum Reversible Hoisting Engine.

HOISTING ENGINES.

They are also well adapted for use on steamers and sailing vessels, for hoisting cargo, sails, anchor, etc., and also for driving the ship's pumps. For this latter purpose, if rope be used for driving, a grooved wheel is put on the drum shaft next to the spur wheel, and if chain is used, then a chain or sprocket wheel is substituted.

For small mines they are a very efficient form of engine, and many are in use for this purpose. They are small, and therefore easily moved about.

The engraving, Fig. 234, represents a Double Drum Reversible Link Motion Hoisting Engine, which is especially adapted for double compartment shafts or double track inclines where the hoists are made automatically, the loaded cage or cars ascending while the empty cage or cars are descending.

The drums are made on substantial cast iron centre and side flanges with hard wood lags, the gear being in the centre between the drums, the whole being keyed to the shaft. On the outer end of each drum are powerful band brakes which are connected by a cross shaft and arranged so that they are applied simultaneously by a foot lever. This lever works in a yoke with serrated teeth on one side so that the brakes may be applied and the cages held suspended at any point.

Hoisting systems may be divided into first motion and second motion systems.

The first motion consists of two engines with cranks at right angles to each other, attached to the drum shaft direct. They are provided with the Stephenson reversing link motion or other approved reversing valve gear, operated by power or hand. The drum is controlled by a strap brake sufficiently powerful to hold it when loaded in any position, the lever for operating it is in a frame which carries the reversing lever, this frame being near the throttle valve lever.

Hoisting Engines.

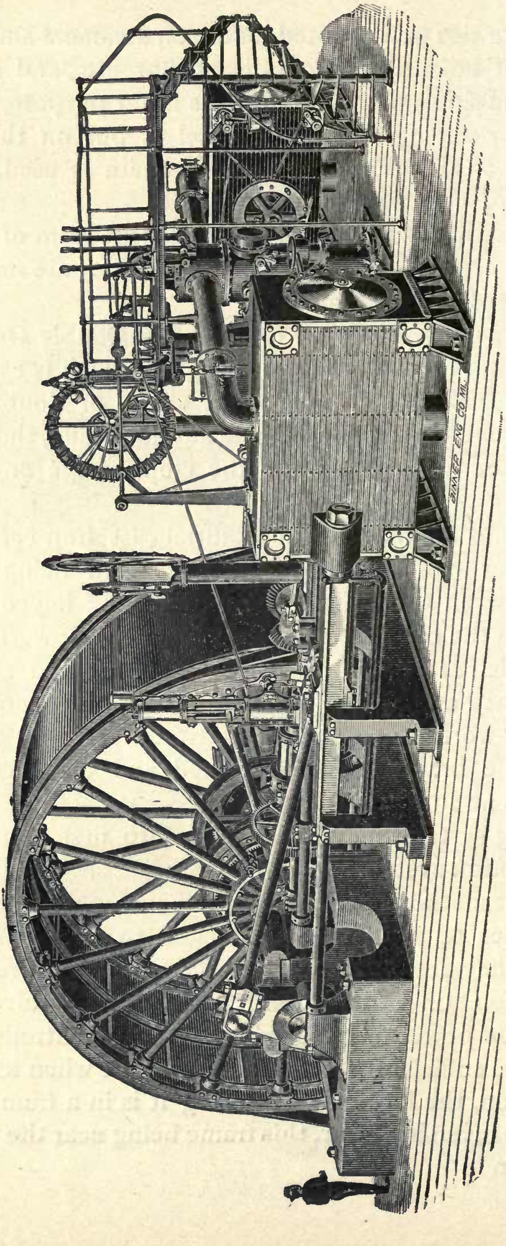


Fig. 235. The Allis Hoisting Engine.

Hoisting Engines.

The drum may be double, or single, conical, or straight. The double drum economizes time, as one hoists while the other is descending. The conical drum is to be preferred for deep pits.

When the engine shaft carries a pinion which works into a spur gear on the drum shaft, the arrangement constitutes the second motion system, and the engines may or may not be provided with a reversing valve gear. If the reversing gear is omitted, the hoisting cage is lowered by means of a friction brake, and elevated through the intervention of a friction clutch. It can be worked with a single engine as it runs constantly. Automatic cut-off engines, high pressure, condensing, simple, or compound can be used as well as a slide-valve engine.

Figs. 231, 232, 233 and 234 are second motion hoisting engines, while Figs. 235 and 236 belong to the first motion system. In Fig. 236 is illustrated a Dickson First Motion Hoisting Engine, with double conical drum and Stevenson reversing gear.

The engine illustrated in Fig. 235 belongs to the first motion hoisting engines, and was built by the E. P. Allis Co., of Milwaukee, Wis. Both cylinders have Corliss valves, with Reynold's automatic cut-off. The gear is so attached that the cut-offs are inoperative when the engines are starting a load, or moving slowly, but they can be instantly applied at any time by the operator, and by their use perform a given amount of work with an appreciable saving in steam. The engines are equipped with steam reversing gear and steam operated brakes. All levers for handling the engines are located on a raised platform. Suitable miniatures are provided which show the location of the cages in the mine shaft. The cylinders of this engine are 42 inches diameter and 84 inches stroke. The drum is 30 feet diameter by 11 feet face. This engine has raised thirty-nine cars per hour for six consecutive hours from a depth of 3,180 feet; load per car, three gross tons.

HOISTING ENGINES.

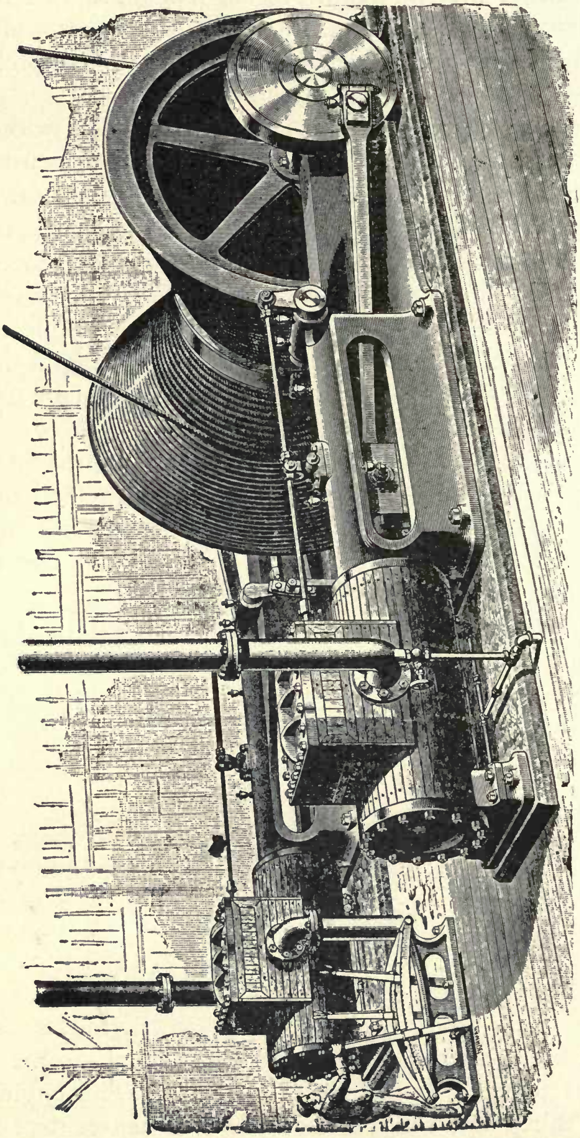


Fig. 236. DICKSON HOISTING ENGINE.

BLOWING ENGINES.

The blowing engine is almost identical with the air compressor. The chief difference between them being the ratio of steam cylinder to air cylinder. While the air compressor furnishes a comparatively small amount of air at a very high pressure, the blowing engine delivers a very large volume at a lower pressure.

Blowing engines are mainly used in large smelting works and foundries, to furnish the air blast for cupolas, air furnaces and smelting ovens.

In Fig. 237 is shown a blowing engine of very large size, built by the E. P. Allis Co., of Milwaukee, Wis. The steam cylinder is 42 inches in diameter, the air cylinder 84 inches, and the stroke 60 inches.

The valve gear is of the Reynolds-Corliss type. The piston rod is attached to a cross-head whose ends extend over the sides of the cylinder, and after passing through the guides, which are formed by the frame, are arranged with wrist pins, from which the two connecting rods are suspended with their other ends attached to the cranks as shown in figure. The piston rods are connected to the cross-head at points near the guides. There are two air piston rods, which are attached to the same piston.

The crank shaft is located below the steam cylinder, as indicated in the cut. The flywheels, which also form the cranks, are attached to the ends of the shaft. This construction represents the return connecting rod engine.

Both the air and steam valve gears are driven from eccentrics on an auxiliary shift, which is driven by bevel gears from the main shaft, see Fig. 237.

A blowing engine built by Fraser & Chalmers, of Chicago, Illinois, is shown in Fig. 238. This engine is horizontal, also operated by the Corliss valve gear.

The air valves are operated by separate eccentrics on the shaft, one eccentric operating the suction, the other the delivery valves.

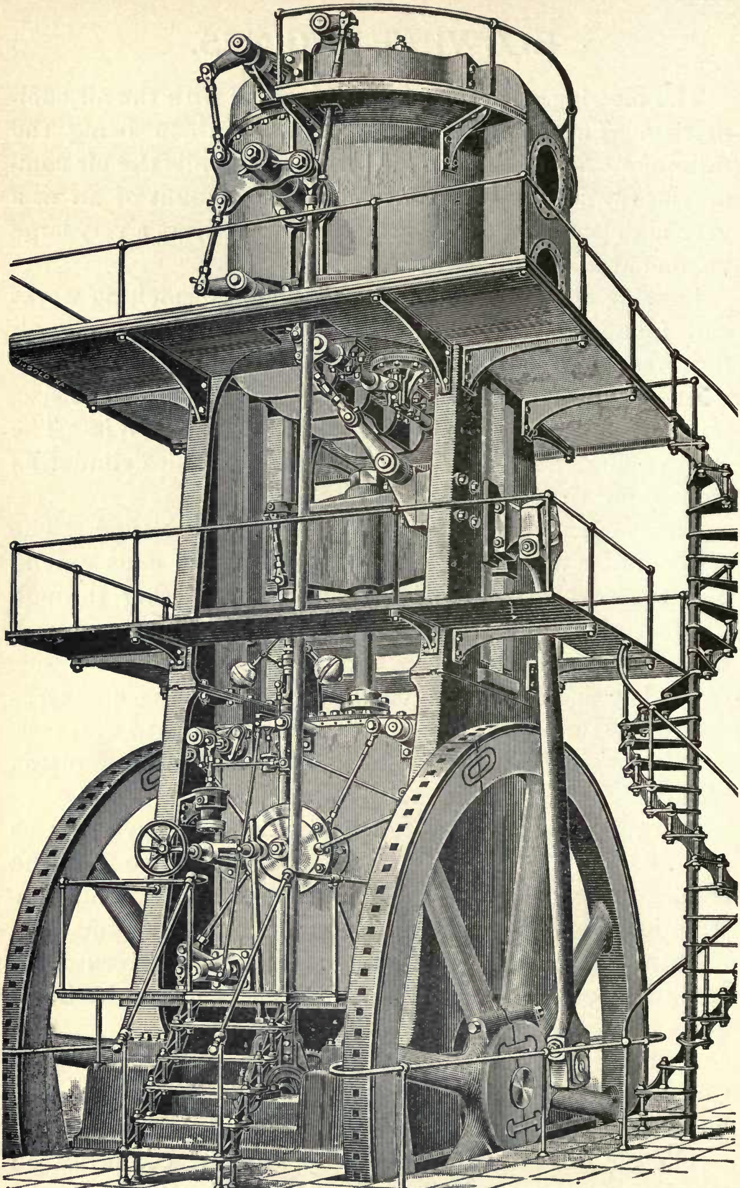


Fig. 237. ALLIS VERTICAL BLOWING ENGINE.

BLOWING ENGINES.

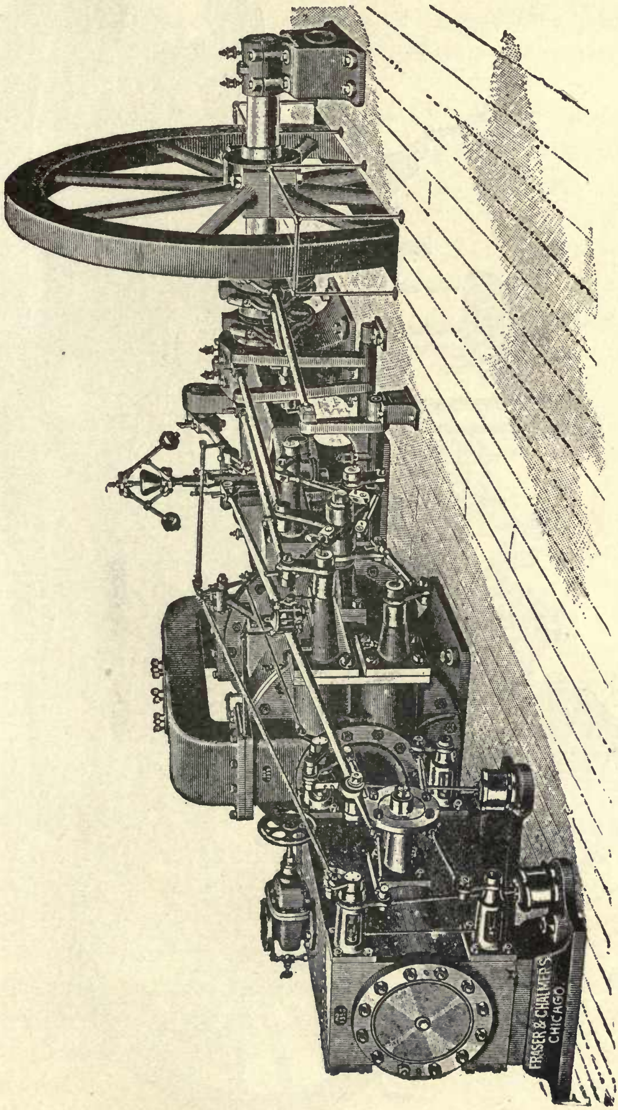


Fig. 238. FRASER & CHALMERS BLOWING ENGINE.

STEAM FIRE ENGINES.

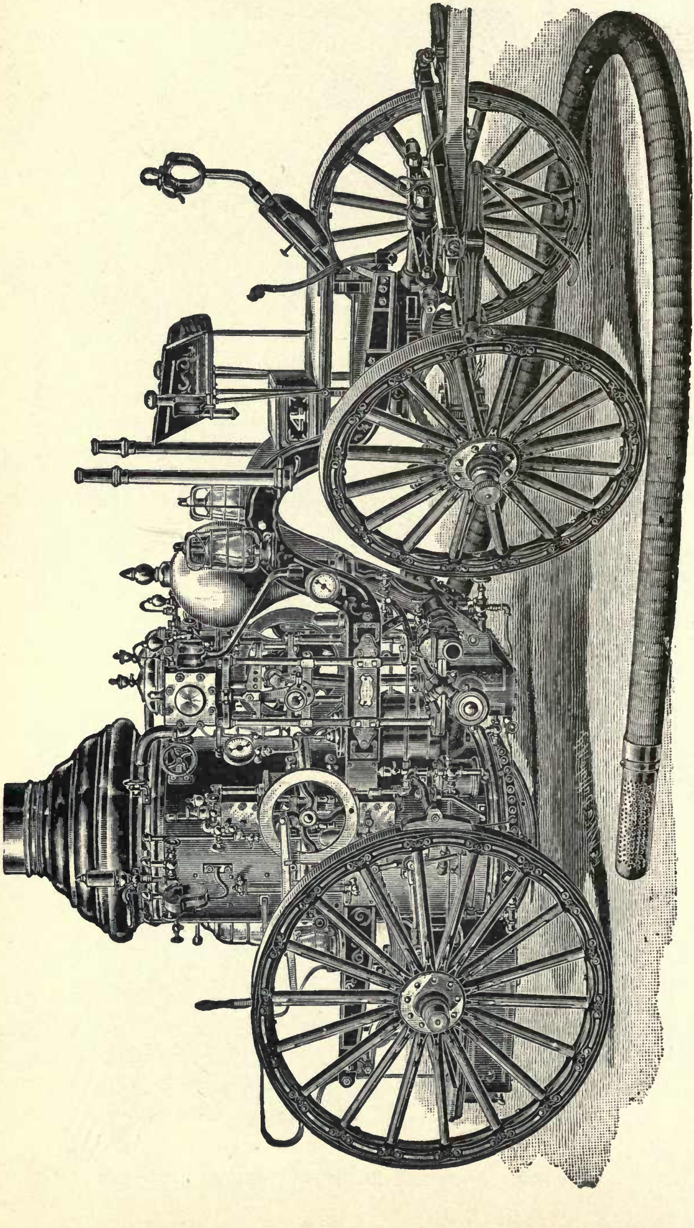


Fig. 239. THE AMERICAN STEAM FIRE ENGINE.

THE STEAM FIRE ENGINE.

The steam fire engine is practically a portable pumping engine. It is in all respects a complete water works on a small scale.

The boiler, which is generally of the upright semi-water tube type, is combined with the engine by means of a strong iron frame, which carries all the appliances as well as the driver's seat, and also forms the body of the truck.

The pumps may be of the reciprocating or rotary type, and are generally placed in front of the boiler. If of the reciprocating type, two pumps are placed alongside each other, and are operated by a double engine, either slide valve or piston valve.

The piston rods connect directly with the plunger rods and are also connected to a crank shaft by means of either connecting rods or yokes, the cranks being set at right angles, so that one pump is always acting, while the other passes the center, thus giving a practically steady stream.

The engine exhausts into the stack, which gives the necessary draft. Some engines are equipped with a boiler feed pump, others only depend upon an injector, or feed directly from the main pump. The coal box, which also forms a platform for the engineer to stand upon while under way, is placed back of the boiler.

All engines are equipped with two suctions and two discharge openings, so that either side may be connected up. The tool box and driver's seat are in front of the engine. The frame rests upon springs, to make the machine easy running on rough roads or uneven pavements.

In Figs. 239 and 242 are shown some very popular types of fire engines, some details with the necessary descriptions being also given. The American fire engine, with reciprocating pump, is represented in Fig. 239. This engine is built by the American Fire Engine Co., of Seneca Falls, N. Y., and Cincinnati, Ohio.

Steam Fire Engines.

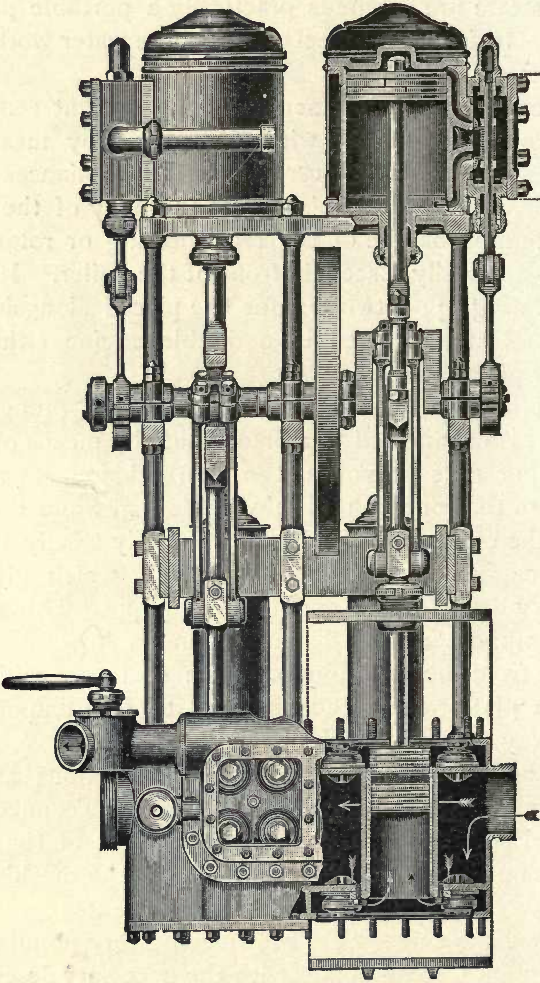


Fig. 240. The American Steam Fire Pump.
(Upright type, front view.)

STEAM FIRE ENGINES.

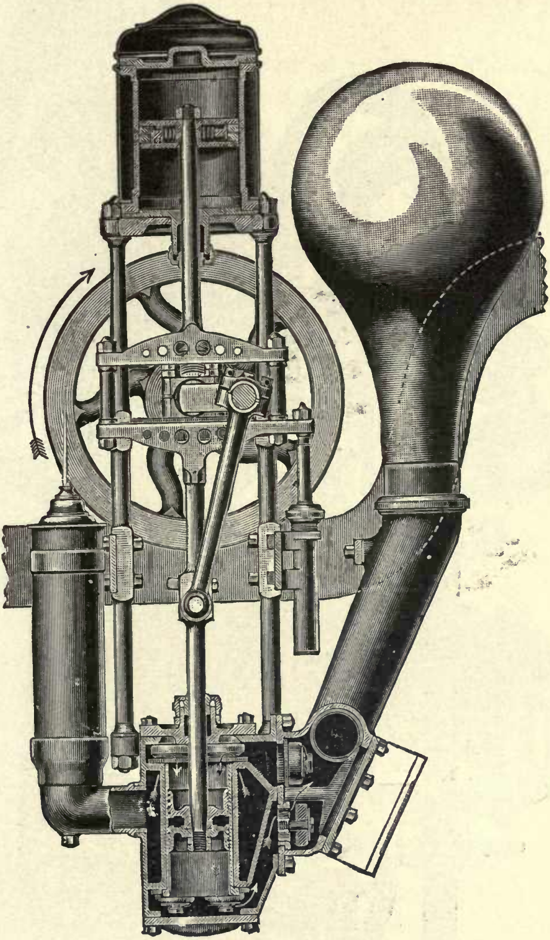


Fig. 241. THE AMERICAN STEAM FIRE PUMP.
(Upright type, side view.)

Steam Fire Engines.

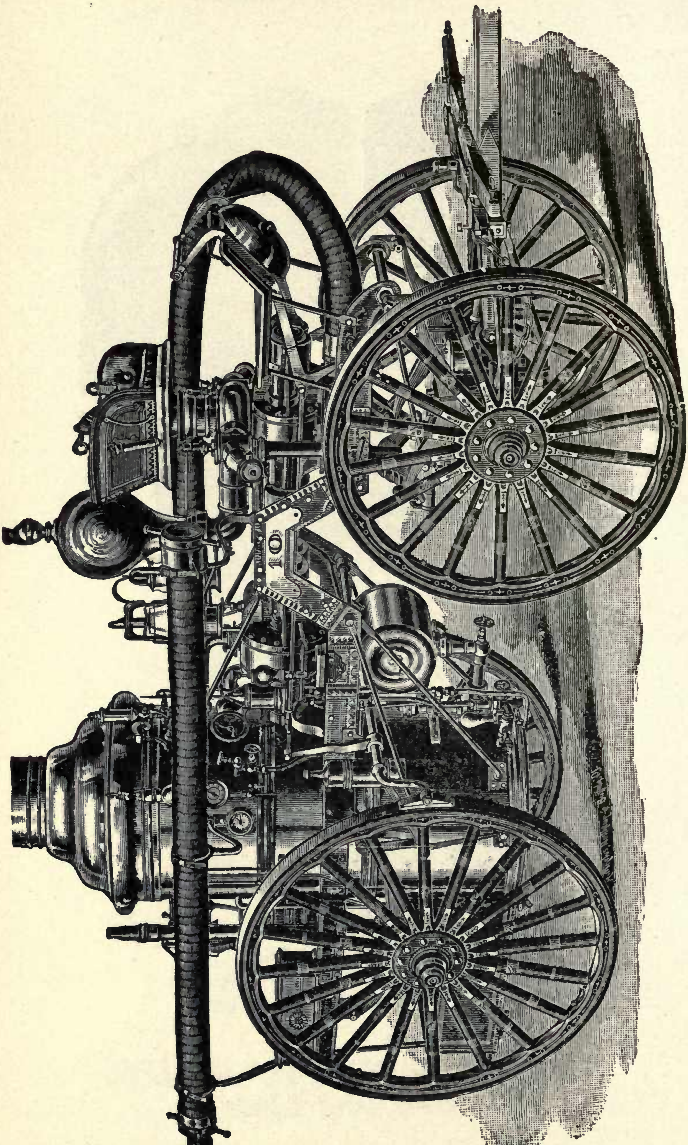


Fig. 242. The American Steam Fire Engine, with Rotary Pump.

STEAM FIRE ENGINES.

As will be seen in the illustration, it is equipped with a boiler feed pump, which also can be operated by hand, by means of a hand lever.

The pump used on this type of engine is shown in Figs. 240 and 241, Fig. 240 being the front view, one side of it shown in section, exposing the interior parts for explanation, and Fig. 241, representing the side elevation, also in section.

The pumps, which are double acting, are united in a gun-metal casting, which forms a single body for both, and permits them to be placed much closer as to centers than could otherwise be done. This method provides an ample suction-chamber which is common to both.

In cross section the pump somewhat resembles a box girder. This peculiarity of the pump's combined form furnishes a rigid base for the entire structure, simplifies the driving mechanism and enables it to endure extraordinary strains without vibration.

It will be seen by reference to the cuts that any of the valves can be easily and quickly examined, and, if necessary, replaced, by simply removing the caps and heads.

The pump barrels are provided with removable linings, which can readily be replaced with new ones in case the same should become worn after years of service. These, as well as the valve seats, are made of gun metal, no cast iron or other material subject to corrosion by water being used in any part of the pumps.

Both the suction and discharge valves are supplied with patent improved valve springs, the tension of which is, at all times, the same ; and being made of phosphor bronze, the springs retain their elasticity and will not corrode.

The steam cylinders used in connection with this pump are of the ordinary slide-valve type, with which most mechanics are familiar, and are thus easily repaired when necessary. The cylinders and pumps are detached from

STEAM FIRE ENGINES.

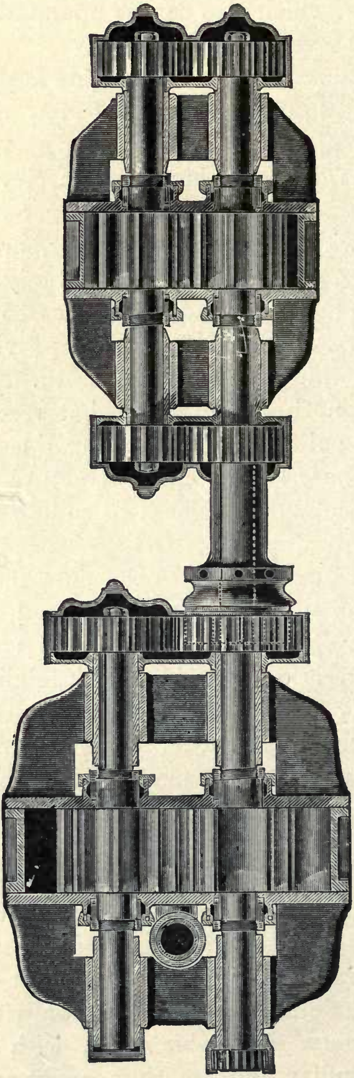


Fig. 243. ROTARY STEAM FIRE PUMP.

STEAM FIRE ENGINES.

the boiler, and are separated therefrom sufficiently to allow every facility for getting at each and every part. All connections, both steam and water, are made outside of the boiler.

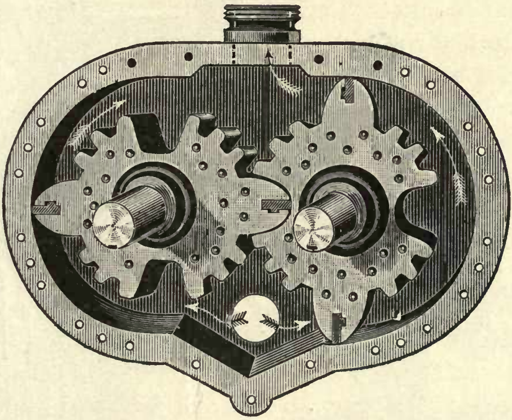


Fig. 244. STEAM CYLINDER.

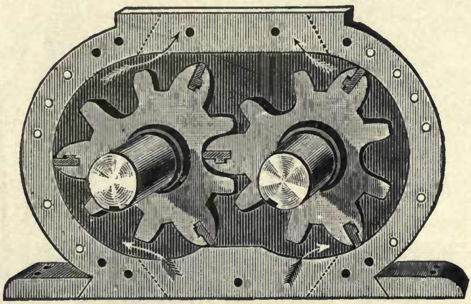


Fig. 245. PUMP.

Another style of engine, of the same make, is the one illustrated in Fig. 242, which is equipped with a rotary engine and pump, shown in Fig. 243, this being a horizontal section seen from the top.

Steam Fire Engines.

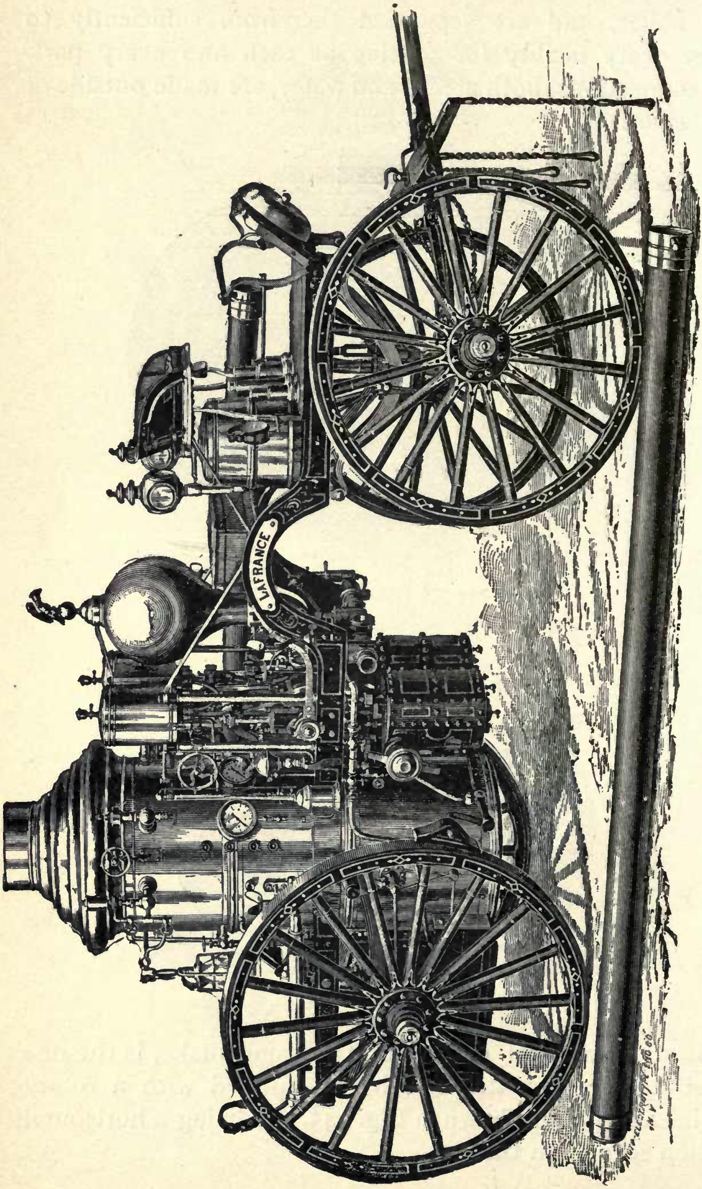


Fig. 246. La France Steam Fire Engine.

Steam Fire Engines.

The steam cylinder, a cross section of which is shown in Fig. 244, consists of two rotary cams which work together within an elliptical steam-tight case. Live steam is admitted to the bottom of the case, and, pressing apart the long teeth, it revolves the two cams in its passage, and exhausts from the top into the stack and feed-water heater. Each cam is provided with teeth adapted to mesh in recesses in the other, so that a tight joint is maintained between them, and steam is prevented from passing directly upward to the exhaust. The cams have their sides turned to fit the heads of the case and are so adjusted that, while being steam-tight, ample allowance is made for contraction and expansion due to cold and heat.

In the ends of the long teeth of the cams are placed removable packing strips, which are forced out into contact with the walls of the cylinder by springs. These packing strips can be taken out in a few minutes through openings in the sides of the case and set out, it being on the ends of these that the only wear comes.

The construction of the pump, Fig. 245, is the same as the steam cylinder, excepting that there are three long teeth in each cam, instead of two, increasing a steady flow of water. One shaft of the pump is coupled to the corresponding shaft of the cylinder, there being outside gears on both cylinder and pump to steady the motion of the cams and equalize the pressure.

The water-ways being large, direct, and unobstructed, anything liable to enter the suction will pass through the pump without injury or interruption in its working; and there being an entire absence of valves in this pump, leaves, sticks, sawdust, mud, and other foreign substances can be safely worked with the machine. The motion of the pump being equable, continuous and rotary, no blows are given to the water, which enters and leaves in one steady flow, and there is, therefore, no irregular motion to the stream.

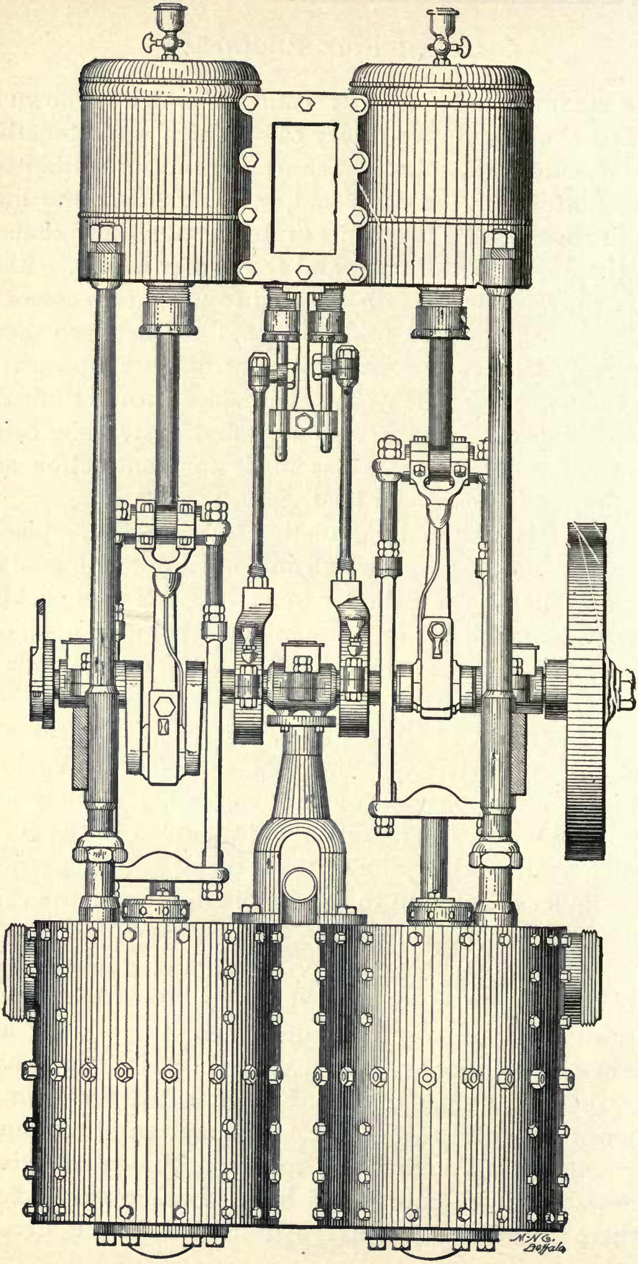


Fig. 247. La France Steam Fire Engine Pump.

STEAM FIRE ENGINES.

nor uneven or pulsating pressure in the hose. The pump does not require priming, and will when started immediately draft water up to 29 feet vertical lift without the use of check valve. It will also force water and do good fire duty through 3,000 feet of hose or upwards, without danger of bursting the hose. The boiler feed pump is driven from a small gear on one of the engine shafts shown in Fig. 243.

Fig. 246 represents the La France Fire Engine, built by the La France Fire Engine Co., Elmira, N. Y.

The illustration represents a piston fire engine, the pump with which this engine is equipped being shown in Fig. 247. It also consists of a double plain slide valve engine operating a double pump.

The steam piston rod of each side connected with its pump rod, by means of square bars, two of which are on each side of the crank shaft. The crank is operated by the cross-head through a connecting rod; the arrangement of these parts can be seen in Fig. 247. The cross-head guide is entirely done away with, as the stiffness of the connection between the two piston rods takes the thrust of the connecting rod.

The pump barrel is enclosed by an outer casing. The space between barrel and casing is always kept filled with water which is supplied through the suction pipe.

When the pump barrel is being filled with water the suction valves are lifted from their seats, which allows the water to pass into the space between the valve-seat plates and thence into the pump barrel.

When the pump barrel is being emptied the suction valves are closed while the discharge valves are open, which allows the water to pass into a triangular shaped space between the front plate and valve-seat plates thence upward to the discharge pipe.

STEAM FIRE ENGINES.

The pump barrel, outer casing and top and bottom are all cast in one piece.

The suction and discharge valves of this pump being all grouped together, it is only necessary to remove the plates, which can be seen bolted to the front of the pumps, Fig. 247, and form part of the outer casing.

The fact that these plates are directly in front of the pump, where nothing can prevent the removal of the bolts, which may be quickly unscrewed by using a T-wrench, makes it very easy to get at and to repair the valves.

This engine is also equipped with boiler feed pump, which can be operated by hand or power. The La France engines are also built with rotary pumps, which differ but little from the previous described ones.

Table of Dimensions. Class A, La France Steam Fire Engines.

	FIRST SIZE.	SECOND SIZE.	THIRD SIZE.	FOURTH SIZE.	FIFTH SIZE.	SIXTH SIZE.
Height over all,	9 ft. 2 in.	9 ft. 2 in.	9 ft.	9 ft.	8 ft. 11 in.	8 ft. 11 in.
Length over all,	22 ft. 10 in.	22 ft.	21 ft.	20 ft. 10 in.	20 ft. 5 in.	20 ft. 3 in.
Width over all (ordinarily), .	6 ft.	6 ft.	6 ft.	6 ft.	6 ft.	6 ft.
Weight without supplies about	7,800 lbs.	7,000 lbs.	6,500 lbs.	5,800 lbs.	4,800 lbs.	4,200 lbs.
Capacity, gallons per minute, ...	850	700	600	500	400	350

Instructions for the Care and Management of Steam Fire Engines.

1st. When standing in the engine house, keep the water so as to show in the glass gauge.

2d. Keep the furnace charged with shavings and kindling wood, coal in tender, and all things ready to start at a moment's warning.

3d. In case quick steam is required, draw the water down to the second cock, located at rear of boiler to right of tender.

4th. If quickest possible steam is required, draw the water down to the second cock, which is located on the engineer's side, just under the tool box.

5th. Let the proximity of the fire determine how soon steam is wanted. In many cases steam can be generated by starting with water in glass gauge, as quickly as hose can be laid and water called for. By carrying out these directions, the amount of water to be heated is proportioned to the time steam is required, and the peculiar construction of the boiler admits of this being done with perfect safety.

6th. Start soon as you have forty to sixty pounds of steam, and as fast as possible feed the boiler until you have from two to four inches in the glass gauge. Keep the water at this point as uniformly as possible. A little practice will enable you to regulate the feed so as to keep it nearly stationary.

7th. Do not depend too much on the glass gauge; use the "try-cocks" frequently.

8th. Should your feed-pump get out of order or your water get too low while running, feed from "main way." In such case, should the water pressure happen to be less than the steam pressure, shut down the outlet valves until the water pressure is sufficient to feed.

Steam Fire Engines.

9th. If you are using bad water, and your boiler shows signs of "foaming," use the surface-blower freely.

10th. Clean out boiler once or twice a year, or oftener, if much bad water is used. To do this remove the mud-plugs at bottom of boiler and those above the crown-sheet, insert a stiff wire and loosen the sediment; then rinse thoroughly with water through upper holes.

11th. If you desire to keep your machine clean, and looking well, wipe it thoroughly soon as you get in, and while hot. Polish the nickel with a paste composed of Vienna lime, or whiting and spirits, and a little ammonia.

12th. To examine the pump valves, unscrew the lids with the wrench supplied for the purpose; simply loosen the nuts on stud bolts which run between the lids, and lift the lids off.

13th. When running, keep the engine and pump, and all other bearings, well oiled. Oil the engine frequently by means of the oil-pump.

14th. Use the best quality lard oil in summer and machine sperm oil in winter.

15th. After running, remove or take up the suction; open all the small pet cocks, and close the valves to the outlets; start engine again, and pump up about five pounds of air pressure; this will blow out all the water. After the pipes are drained, open one of the outlets and feed four or five cups of oil into the pump. This will distribute oil thoroughly over the pump surfaces, and prevent rusting while standing in the house. Also, oil the engine last thing before shutting down.

16th. If your engine is of the rotary type, turn the engine several times around with a spanner once or twice a week to prevent the cams remaining too long in one position. This should not be neglected.

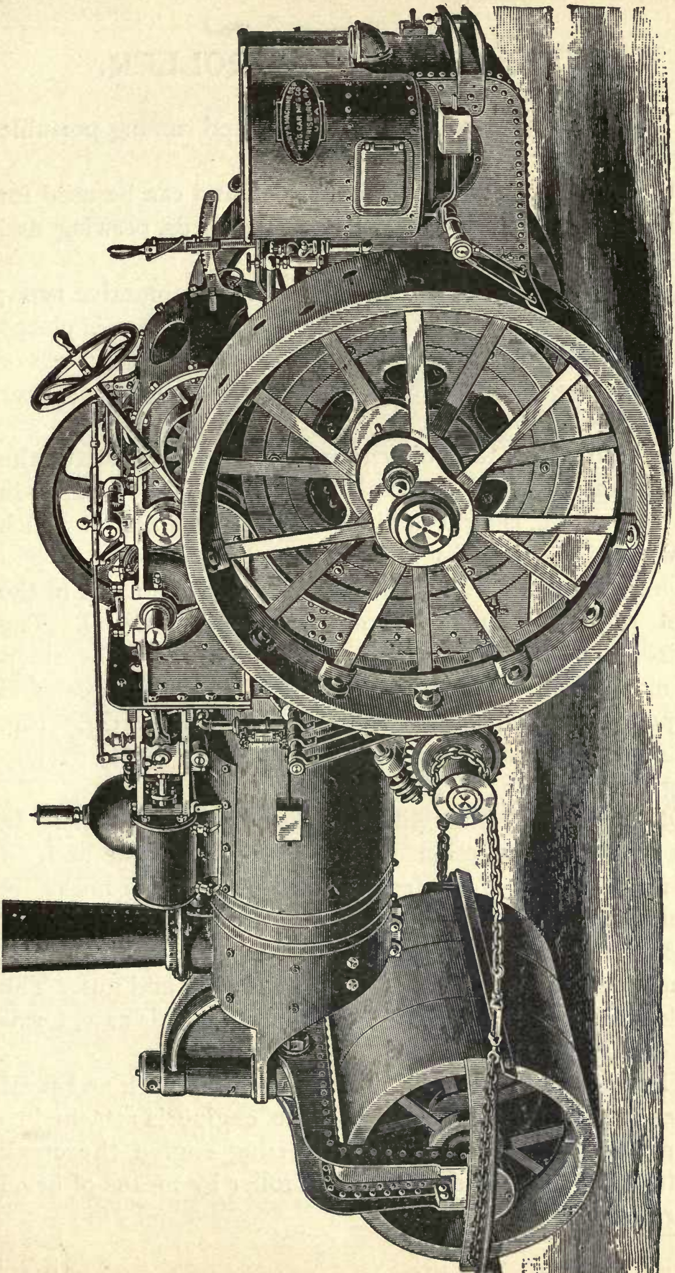


Fig. 248. Steam Road Roller.

THE STEAM ROAD ROLLER.

The steam road roller may be classed among portable engines.

It is built in various sizes and styles, and can be used for rolling down highways, breaking up old roads, plowing, and hauling heavy loads, etc.

Some road rollers have a boiler of the locomotive type; on these styles, the engine being a horizontal one, is placed on top of the boiler, and connected to the driving wheels or back rollers by means of sprockets and chain, or gear wheels.

In these rollers the boiler forms the principal part of the frame; the front of it, which forms the smoke box, as in the locomotive, is built out into "the goose neck," to which is swiveled the yoke by means of the king bolt.

The yoke being able to swing, rests upon the axle of the front roller, which also forms the steering wheel. The horizontal swinging motion is imparted to it by the steering mechanism, which consists of chain and worm gear, and is operated by a hand-wheel near the reversing lever. Fig. 248 shows a roller of this type, which is built by the Harrisburg Car Mfg. Co., of Harrisburg, Pa.

Other types are built with upright boiler and engine. In this type of construction a heavy frame forms the body of the machine and is carried out into "the goose neck" in front, which does not differ from the former one described, except the steering device being attached to the king bolt by means of a lever, is operated by a screen and nut. The back roller carries the rear end, and also, in this case, forms the driving wheel.

The boiler is nearly half way between the back and front roller, resting on the frame, and the engine is attached to it on one side It is a double reversing engine, the crank shaft being connected to the back roller by means of bevel gear and pinion.

The Steam Road Roller.

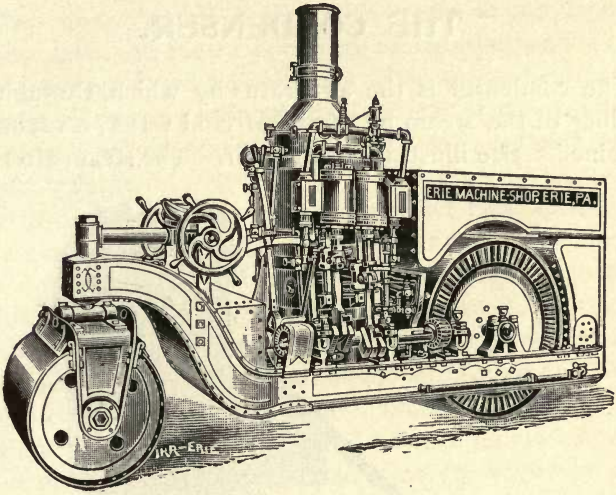


Fig. 249.

A roller of this type is shown in Fig. 249, built by the Erie Machine Shops, of Erie, Pa.

As will be seen in the illustration, the tank is placed above the back roller, almost surrounding it. In all road rollers, it is necessary, on account of unevenness of roads, to allow the front roller to swing in a vertical plane with its yoke; to accomplish this the king bolt is not directly fastened to the yoke, but has an eye on its lower end, through which a bolt passes, which suspends the yoke on it, and allows it to swing. In case one side of the front roller should run over a stone, or any other obstruction, it is thus relieved; otherwise it would put a heavy strain on the king bolt, and might break it. This construction is plainly shown in both illustrations.

For breaking up old roads, the rear rollers in Fig. 248 are provided with holes, into which pins are set, which are forced down into the road bed by the weight of the machine, and by the revolving of the wheels, break up the surface.

THE CONDENSER.

The condenser is the apparatus by which, through the cooling of the steam by means of cold water, a vacuum is obtained. See illustration, Fig. 251. The steam after hav-

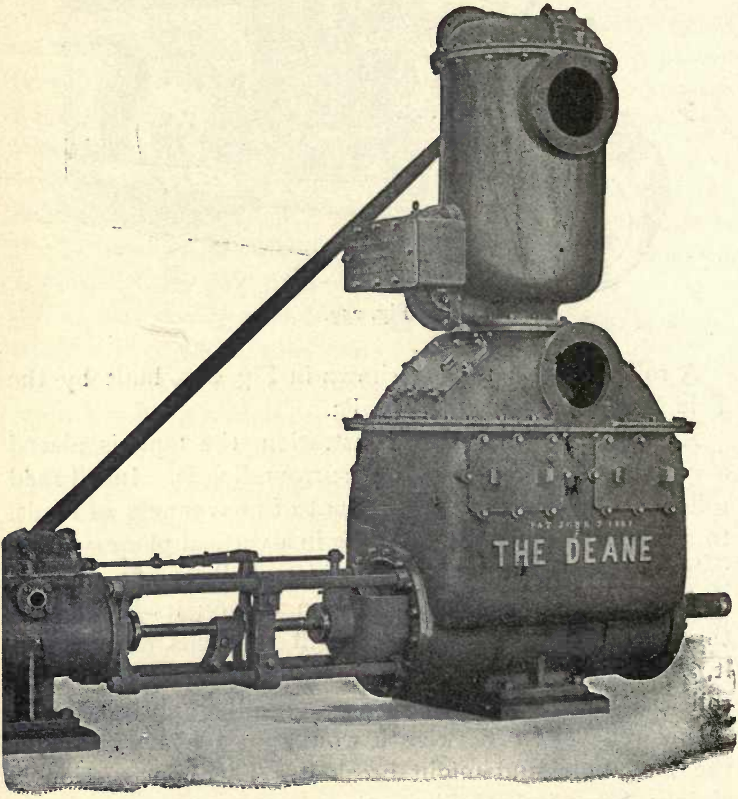


Fig. 250. THE DEANE CONDENSER.

ing expelled the air from the condenser, fills it with its own volume, which is at atmospheric pressure, nearly 1700 times that of the same weight of water.

THE CONDENSER.

When now a vessel is filled with steam at atmospheric pressure, and this steam is cooled by external application of cold water, it will immediately give up its heat, which will pass off in the cooling water, and the steam will again appear in a liquid state, occupying only $\frac{1}{1700}$ part of its original volume.

But if the vessel be perfectly tight and none of the outside air can enter, the space in the vessel not occupied by the water contains neither steam nor air nor water, i. e., nothing.

This absolute absence of any substance is technically termed a vacuum. The air exerting a pressure of nearly 15 pounds to the square inch of the surface of the vessel tries to collapse it with tremendous force; now if we take a cylinder fitted with a piston and connect its closed end to this vessel by means of a pipe, the atmospheric pressure will push this piston down, forcing the air below it into the vessel.

The old low pressure engines were operated almost entirely upon this principle, the steam only served to push the piston back and exhaust the air out of the cylinder. When high pressure steam came into use the condenser became less necessary, but still it is to be recommended, for it will increase the economy of the engine by adding to its power with the same steam consumption; in marine practice the condensed steam being nothing but pure water, is more desirable for feeding boilers than salt water.

Condensers are classified into two divisions: surface condensers and jet condensers, both again being divided into direct connected and indirect connected condensers.

The surface condenser (see Fig. 251) is mainly used in marine practice because it gives a better vacuum, and keeps the condensed steam separate from the cooling water; it consists of a vessel, of varied shapes, through which a number of brass tubes are passing. The ends of this vessel are closed by double heads, into the inner one on one end the tubes are expanded, passing with their other ends through stuffing boxes in the inner head on the other end.

THE CONDENSER.

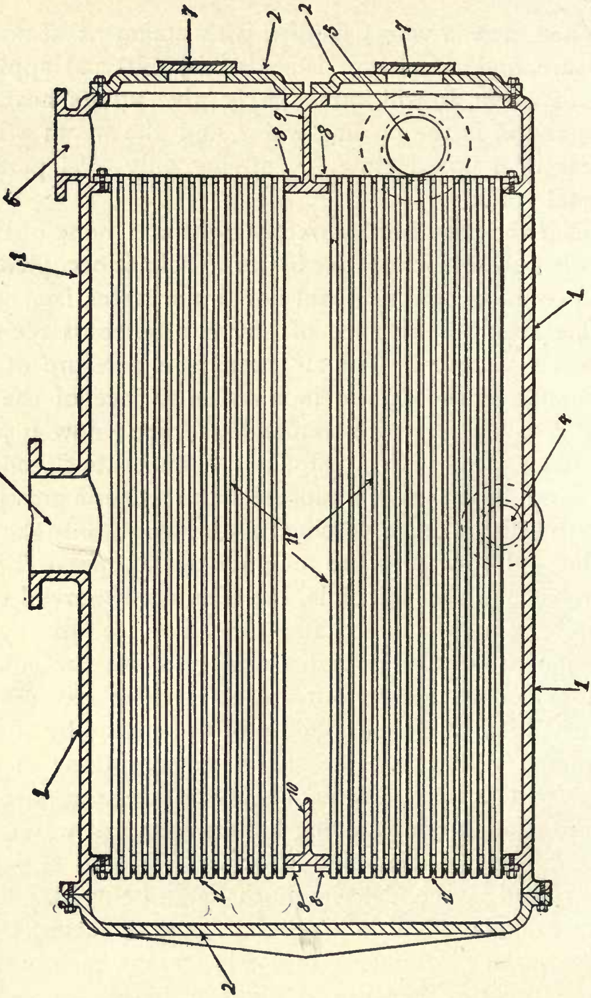


Fig. 251. SURFACE CONDENSER.

The following list gives the numbers with the corresponding names of the parts of the surface condenser, Fig. 251: 1, condenser walls; 2, outside heads; 3, exhaust inlet; 4, exhaust outlet; 5, water inlet; 6, water outlet; 7, peep holes; 8, tube heads; 9, partition; 10, rib; 11, tubes; 12, stuffing boxes.

THE CONDENSER.

The cooling water is passed through these tubes by means of the circulating pump, while the steam entering the vessel and coming into contact with these tubes, condenses, the water of condensation and the air contained in the steam is removed by the air pump and discharged into the hot well. The vacuum thus formed assists the piston of the engine in performing its duty.

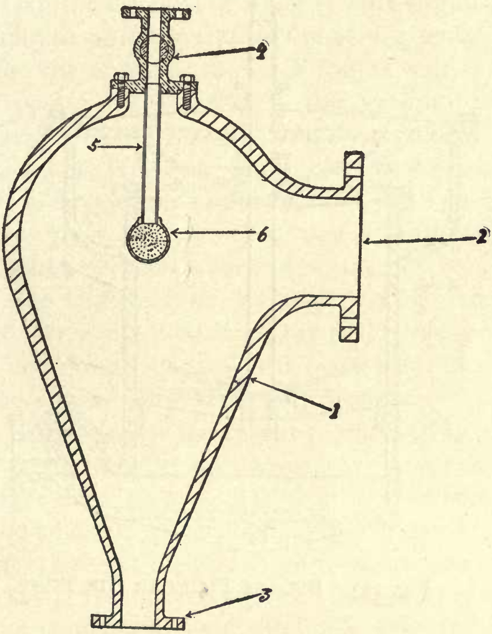


Fig. 252. JET CONDENSER.

The numbers and names of parts in Fig. 252 are as follows: 1, condenser body; 2, exhaust inlet; 3, discharge; 4, injection valve; 5, spray pipe; 6, spraying device.

THE CONDENSER.

The jet condenser (see Fig. 252) is generally employed where it is not desirable to feed the condensed steam into the boilers again. It consists of a vessel, less bulky than the surface condenser, into which the engine exhaust, and a spray of cold water entering it condenses the steam, after which process the condensed water with the cooling water is removed by means of the air pump.

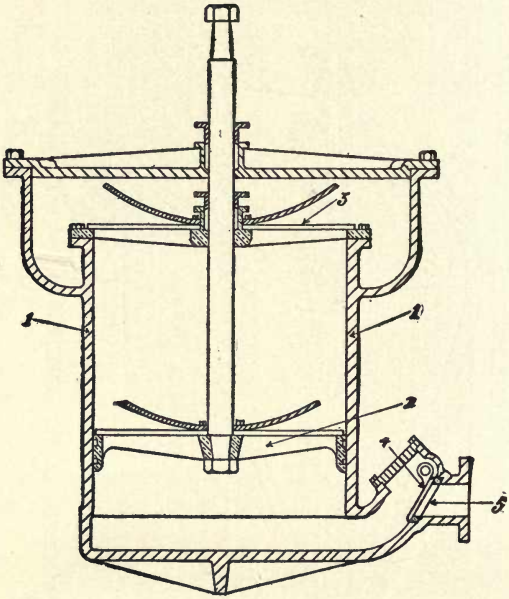


Fig. 253. BUCKET PLUNGER AIR PUMP.

In Fig. 253 the numbers and names are as follows: 1, pump barrel; 2, bucket; 3, discharge valve; 4, foot valve; 5, foot valve seat.

This condenser requires a much larger air pump than the surface condenser, for the air pump, besides removing the water of condensation, has to remove all the cooling water, with the air entering with it. It does not, however, always

THE CONDENSER.

require a pump to force the water into it, as the water can flow to it by gravity, or if the condenser is not too high above the water level, it will, after the air is once exhausted and a vacuum formed, lift its own cooling water. The advantages of the jet condenser are simplicity of construction, cheapness, minimum floor space, and less liability to get out of order.

Direct connected condensers are those whose pumps are directly driven from the main engine, as for instance, from the low pressure crosshead of some marine engines.

There are also in the market, so named, gravity condensers, in which the water of condensation as well as the cooling water passes off by gravity, the vacuum depending upon the height of the water column.

The amount of injection water necessary for condensation depends largely on circumstances, and no inflexible rule can be given. Under ordinary conditions, at this latitude, about seventy gallons of water per horse power, per hour, are sufficient on an engine that requires not more than thirty pounds of steam per horse power, per hour. A compound engine will need less than seventy gallons, and a plain slide valve engine more.

A good jet condenser with tight piping will lift water up to twenty feet in height, and do its work properly.

This height must be measured from the surface of water to the point where injector pipe enters condenser.

The temperature of the discharge for a jet condenser with ordinary load is about 110 degrees. A good heater placed between the engine and condenser will raise this temperature of the feed water to about 125 degrees, with twenty-six inches of vacuum.

The injection pipe of the jet condenser where it enters the water should have a good foot valve at this end, which should be at all times at least three feet under water. A good screen should also be fitted over the pipe at this end,

THE CONDENSER.

to prevent foreign substances from getting into the air pump. Care should be taken to see that this strainer has an area considerably in excess of the injection pipe.

The economy of condensing is due to the removal of the greater part of the atmospheric pressure from the engine piston and the vacuum thus formed on one side of the

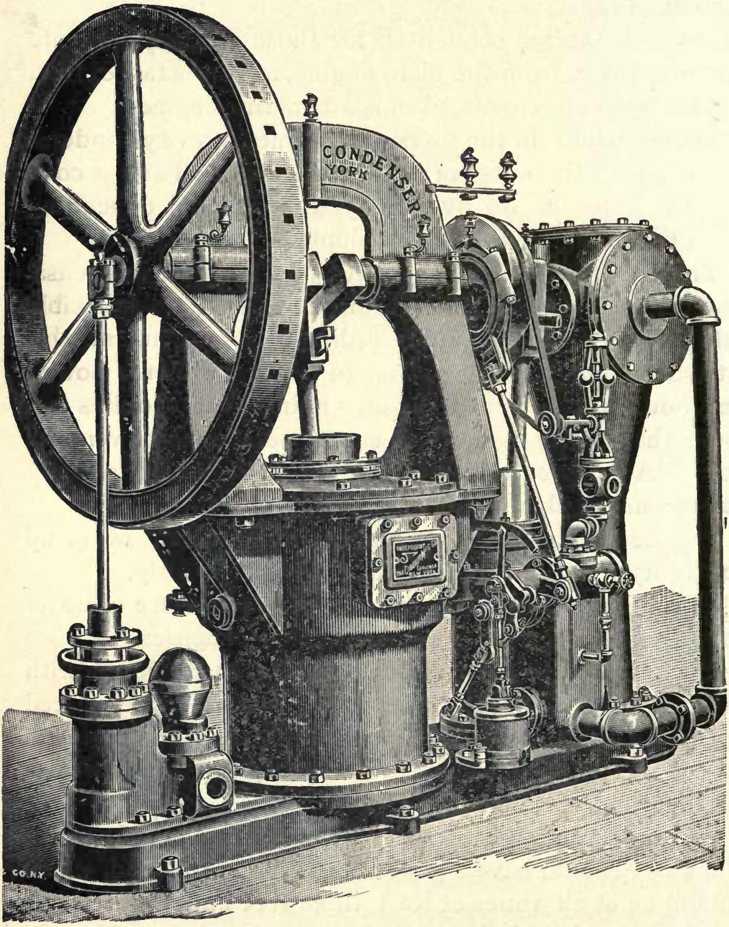


Fig. 254. CONOVER INDEPENDENT JET CONDENSER.

THE CONDENSER.

piston allows the steam on the other side to do useful work, even after the pressure falls below that of the atmosphere.

In any engine where the piston and valves are practically tight, and a suitable steam pressure can be carried, economy always results with the addition of a condenser, either in a saving of fuel, or in giving additional power without burning any more coal. It is possible, and, in fact, often the case, that a condenser is a positive loss when put in to save fuel; and this is when the engine is leaky and allows the steam to escape past valves and piston without doing work. A loss is more frequently occasioned by the condenser employed being in itself very wasteful of steam.

Suppose, for instance, that a certain condenser requires five horse power to operate it, and uses 125 pounds of steam per horse power. It is a very clear fact, that if the condenser is driven by the main engine, which requires but 25 pounds of steam per horse power, and the condenser also uses five horse power, then, on the basis of 25 pounds of steam per horse power, the first condenser is using twenty-five horse power, or five times as much as the second.

A vacuum, as employed in a condenser, means practically absence of atmospheric air pressure, and it is absolutely essential to obtain the best results to have all connections between engine and condenser perfectly air-tight.

The condenser itself and the engine cylinder must also be tight. Especial attention must be paid to the stuffing boxes on the engine. A simple and good test for tightness that any one can make, is to see if the vacuum will hold up after the engine has been stopped and all valves closed. If the vacuum gauge runs down quickly, a test should be made by putting a water pressure on the entire piping, including engine, cylinder and condenser. All leaks that show with twenty pounds pressure should be stopped, no matter how trifling.

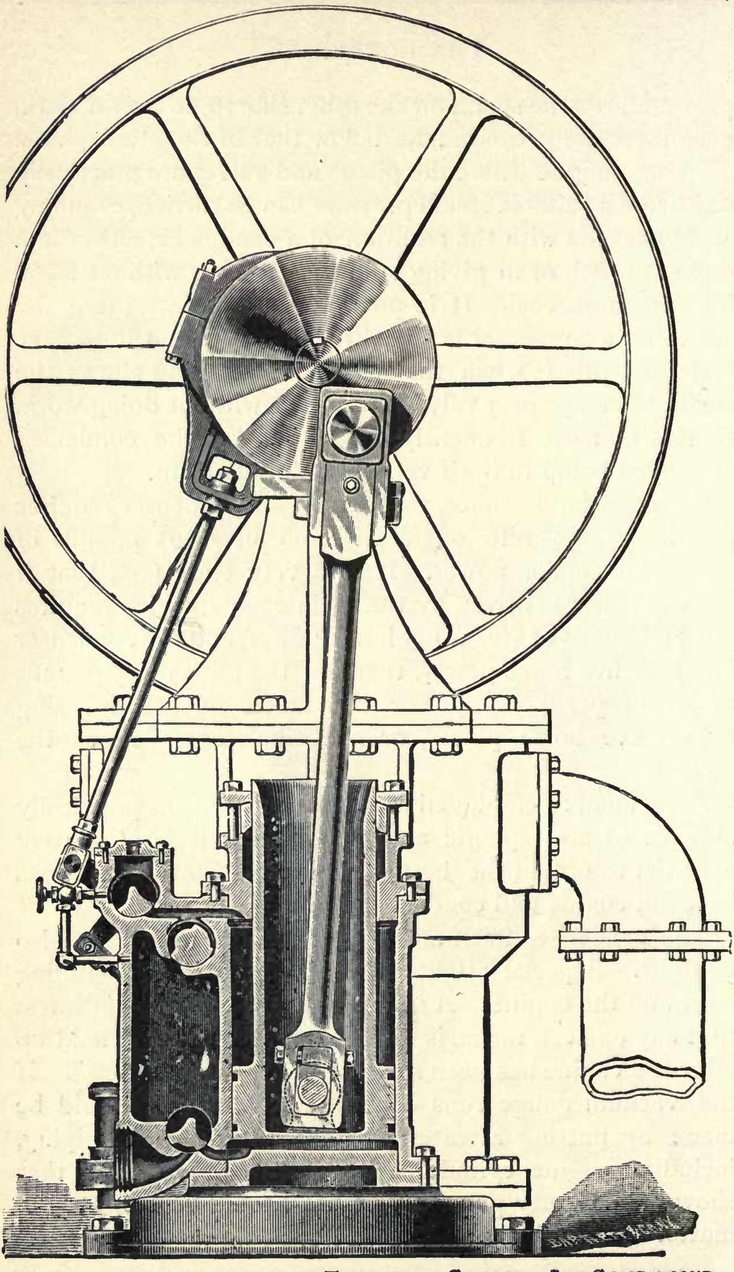


Fig. 255. SECTION THROUGH ENGINE OF CONOVER JET CONDENSER.

THE CONDENSER.

The injection valve that regulates the amount of water to the condenser should not be opened wider than is necessary. The proper amount of opening can always be determined by watching the vacuum gauge and closing the valve until the vacuum begins to lower; then open slightly, and you have the best point. Too much water will flood the condenser and reduce the vacuum.

It may be noted that the office of the air pump is merely to remove the water from the condenser; and as this water is charged with a considerable amount of air, it is due to this fact that the air pump owes its name.

In Fig. 253 is represented a most popular type of air pump, which is a single acting bucket pump. This may be direct driven by the main engine or by an independent engine. Its operation is as follows: When the bucket is drawn upward, the water rushes into the pump through the foot valve by gravity, also a large quantity of air. On the return stroke the foot valve closes, and as there is no other way of escape for the water and air it passes through the bucket valve, and is forced out into the discharge chamber on the next upward stroke of the bucket.

This type of pump can be used for either surface or jet condensers.

In Fig. 254 is shown a very compact form of independent condenser, built by the Conover Mfg. Co., of 26 Cortlandt St., New York City.

The apparatus combines a jet condenser with air pump, boiler feed pump, and engine to drive both, combined as one machine. The air pump is a single acting bucket plunger pump, driven by a crank shaft, which also drives the boiler feed pump, and is turned by the engine, which is a single cylinder compound automatic cut-off engine, a detailed description of it is given in Fig. 255; it is of the trunk pattern, and the small space around the trunk on the top side of the piston forms the high pressure cylinder.

THE CONDENSER.

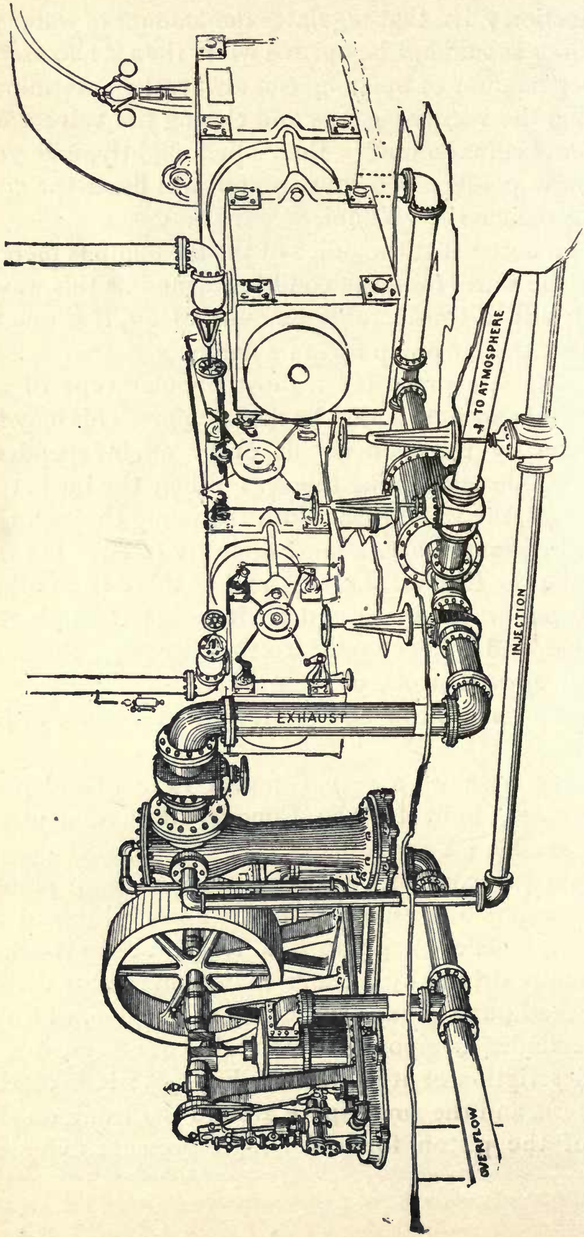


Fig. 256, ARRANGEMENT OF "CONOVER" INDEPENDENT CONDENSER IN CONNECTION WITH TRIPLE EXPANSION CORLISS ENGINE.

THE CONDENSER.

Steam is admitted to the high pressure side at boiler pressure, and is cut off and expanded and exhausts into the receiver, where it is admitted to bottom side of piston, and again cut off and expanded, and then exhausted to condenser.

The piston makes the down stroke when the air pump makes the up stroke; and it will be seen by referring to the cut that the engine does nearly all its work when making the downward stroke. The steam is acting on the top side of piston at high pressure, and at the same time the vacuum is acting on the full area of the piston on its under side.

When the engine makes the up stroke, the steam at low pressure from the receiver acts to push the piston up; and as the air pump is doing no work then, being on its down stroke, the engine is only called upon to keep the machine up to speed.

It will thus be seen that the engine is made to suit the demand of the large power on one stroke, and very little on the other, thus adapting itself very perfectly to the requirements.

The valves are of the Corliss type, the cut-off being set by hand, not requiring to be changed or altered, as the speed is controlled by a throttling governor.

Fig. 256 shows in diagram form the connection of this type of condenser to a triple expansion Corliss engine. The engine running the air pump also exhausts into the condenser.

The Deane independent condensing apparatus is shown in Fig. 250. The condensing chamber is placed on the top of the air pump, which is double acting, and is driven by a direct acting steam cylinder.

The valve is of the regular Deane pattern, a brief description of which will be found under the head of Deane pumping engines.

THE CONDENSER.

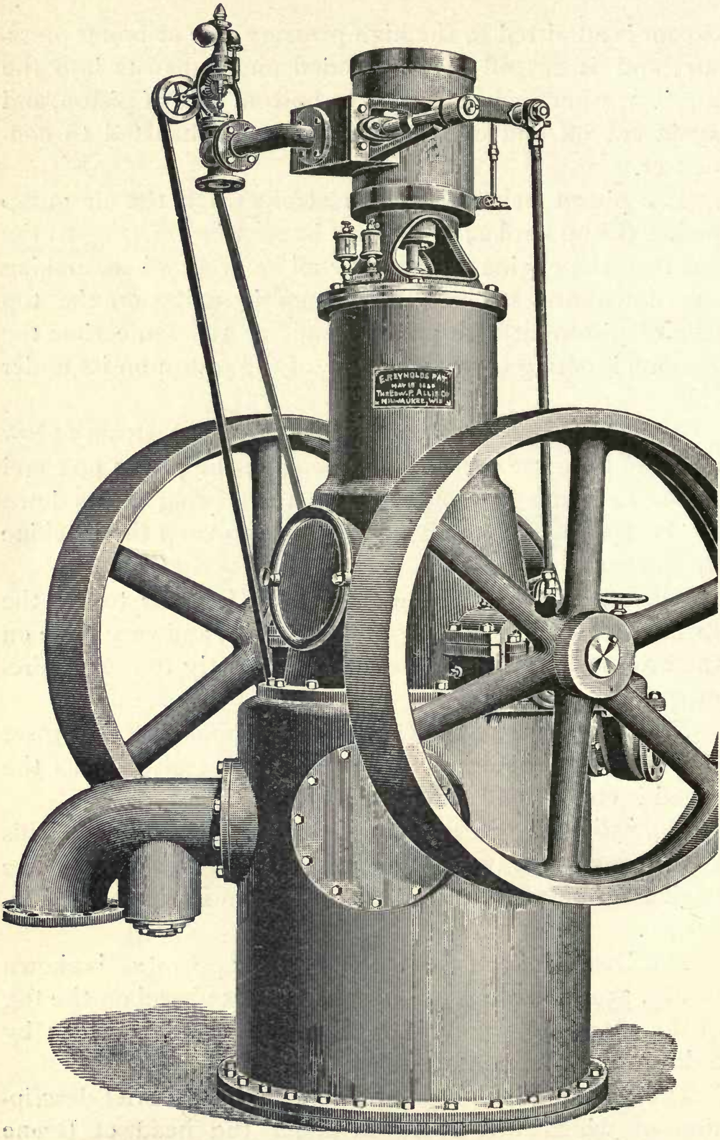


Fig. 257. REYNOLDS' SURFACE CONDENSER.

THE CONDENSER.

By placing the condensers above the air pump, the water of condensation easily runs into the pump by gravity. Access to the pump valves can be had by removing the plates at the side of the pump.

The exhaust pipe of the steam end of the apparatus is also connected to the condenser, as will be seen in the engraving.

Fig. 257 represents the Reynolds independent jet condenser, with air pump attached, which is built by the E. P. Allis Co., Milwaukee, Wis.

The air pump is single acting in this case, being driven by the steam cylinder seen on top of the apparatus, and controlled by a throttling governor.

The jet condenser is used more in stationary plants than in marine service, for in most places it is possible to obtain good water to feed the boilers. In plants where the water has to be taken from city mains or where there is not a very large supply of water, the same water may be used over again by the use of a cooling tower, in which the heated water is run over a series of screens or tiles, thus offering a very large cooling surface, over which cold air is blown by a fan, thus cooling it down to the temperature of the air.

If there is some ground available near the steam plant which cannot be utilized for any other purpose, a number of trenches may be dug, in which the water is circulated and thus cooled down, so it can be used again.

THE STEAM SEPARATOR.

This is a device designed to eliminate the water from the steam just before its use in the cylinder; this is sometimes the water of condensation and sometimes the water of the boiler carried over bodily, and one of the ill effects of foaming.

The water entrained with the steam and carried with it into the cylinder often occasions a disagreeable slapping in the cylinder, and loosening of the connecting rod boxes and injury to the engine, more or less disastrous according to the amount of water and circumstances under which the engine is being run, is only a question of time; water in steam will cut the edges of the valves and ports and cause leakage, improper distribution of steam and improper strain upon the working parts; it will also sometimes neutralize the oil in the cylinder, and permit cutting the surface the same as if no oil were used.

The advantages of placing a steam separator in the steam pipe at the engine are many; where there are a number of engines drawing steam from the pipe, it is evident that dryer steam can be obtained by placing a separator at each engine than by placing one large separator in the main steam pipe.

The separator also becomes a receptacle for scale and grit from the steam pipes, which is blown out through the opening in the bottom of the separator to the sewer pipe connection.

The water gauge on the side of the separator shows the height of accumulated water in the separator.

On page 109 is shown in Fig. 65 a steam separator attached to the Ideal Engine, which is one of the many designs introduced to effect the separation of the condensed water from the steam before it reaches the steam chest.

AIR AND GAS COMPRESSING ENGINES.

Compressed air engineering is one of the most interesting and growing of the newer branches of engineering science. While the same rules which govern the steam engine apply to air compressors there are certain "points" to be looked after in the care and management of the latter in order to have the best results.

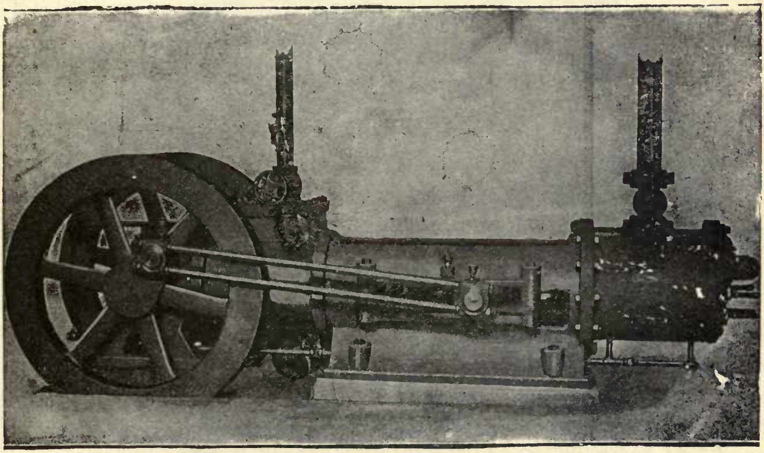


Fig. 258. RAND AIR COMPRESSOR.

Compressed air is already used in the operation of

1. Cranes, hoists and jacks of all types and of all capacities.
2. Portable drilling, reaming and tapping machines.
3. Riveters and stay-bolt cutters, calking and chipping tools.
4. Shop tools of all kinds.
5. Air brakes.
6. Sand blasts.
7. Rock drills and coal mining machines.
8. Pneumatic locomotives and street cars.

NOTE.—Prof. Unwin, in his work on "The Development and Transmission of Power," says: "Compressed air transmission is a perfectly general method of distributing power for all purposes."

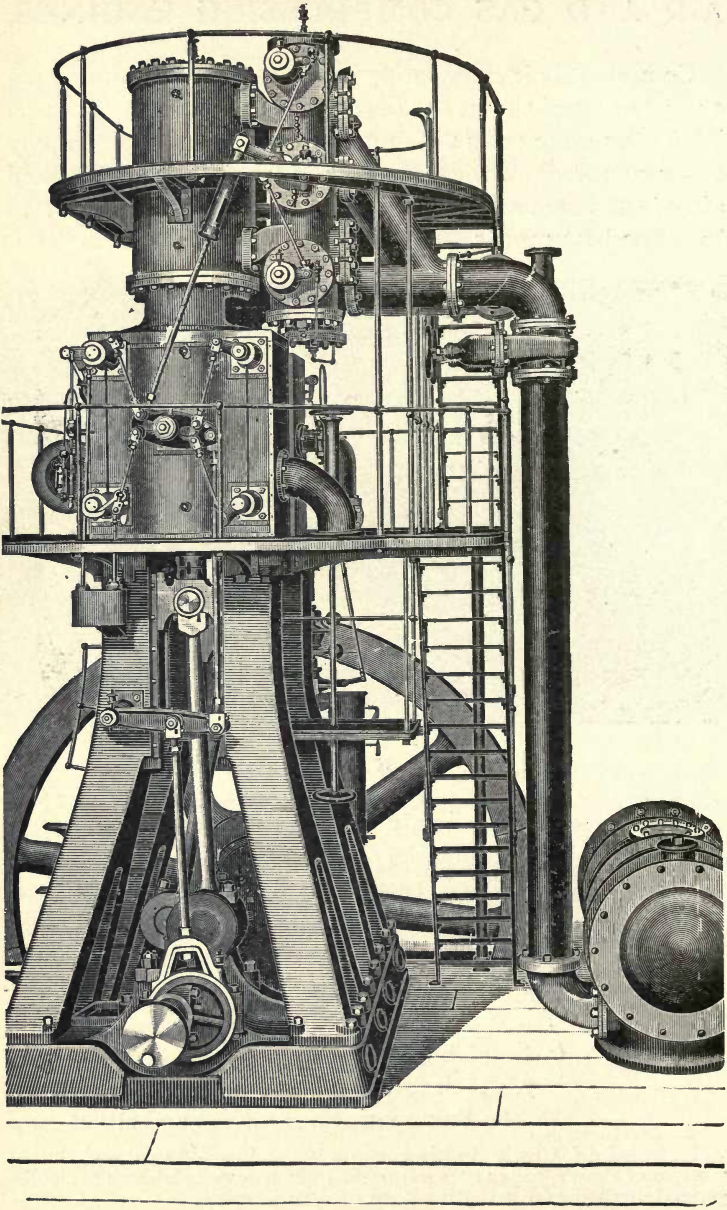


Fig. 259. REIDLER COMPRESSOR ENGINE.

AIR AND GAS COMPRESSING ENGINES.

and for

1. Pumping water, sewage, oil and acids.
2. Raising sunken vessels.
3. Refrigerating and ice making.
4. Transmitting messages through pneumatic tubes.
5. Cleaning carpets and railroad cars and seats.
6. Sinking caissons and driving tunnels through soft ground.
7. Tapping iron furnaces.
8. Transmitting power for all purposes.

The office of the air compressor is to store up air at a high pressure, which can be utilized at a greater or less distance, without there being any loss by condensation in the pipes, as is the case by carrying steam pipes a long distance.

The air which is stored up in a reservoir, can, by being released, do the same amount of work as it took to compress it, and that, in an ordinary steam engine, undergoing the same change as the steam in a cylinder.

The admission of the air being through a single tube, it creates a constant flow of air in one direction only, thus filling the cylinder at each stroke with air at atmospheric pressure. This movement gives a momentum to the air which causes it to fill the cylinder to its fullest extent at each stroke.

Air compressors may be driven in various ways, but the most commonly used are those which are connected directly to a steam engine, thus doing away with intermediate machinery. When the air piston draws in a charge of air, the air fills the cylinder at atmospheric pressure, or a little below, and on the return stroke of the piston it has to be compressed to the same pressure as in the receiver before it can lift the delivery valve, and as the valve is held to its seat by a spring, and also by its own weight, the pressure has to be considerably above that of the receiver

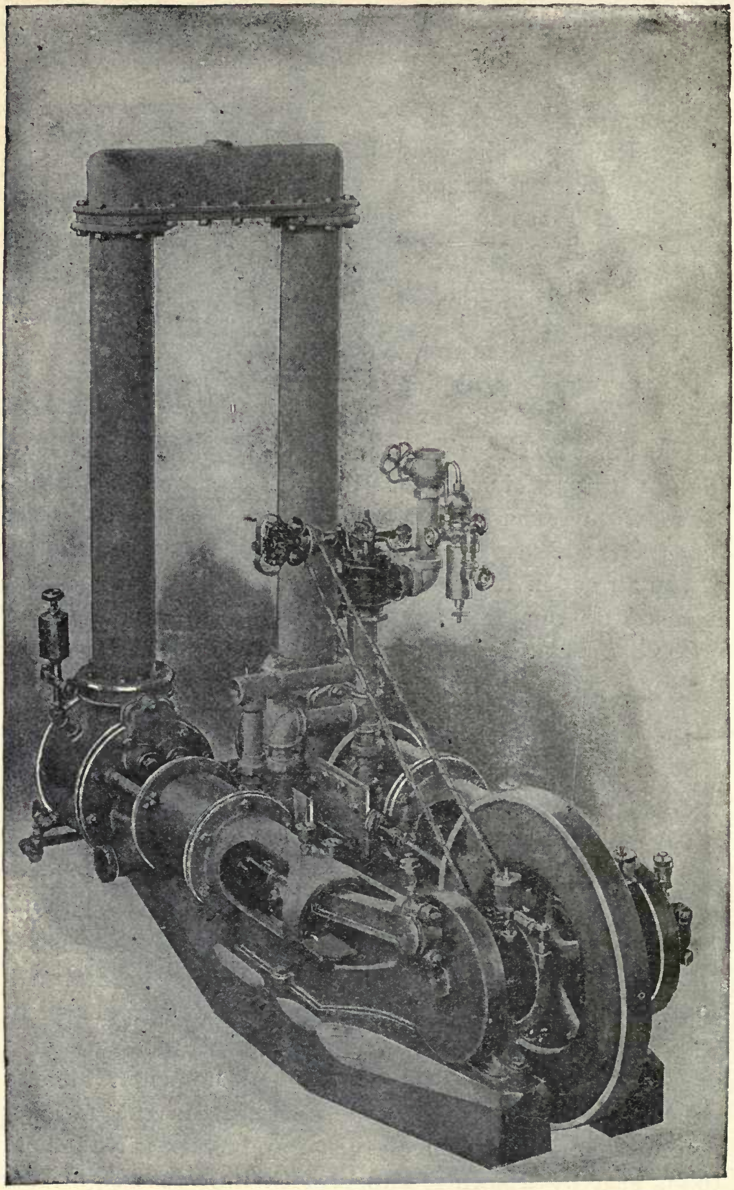


Fig 260. Rand Air Compressor.

AIR AND GAS COMPRESSING ENGINES.

before the valve will lift. To overcome this the valves are operated by mechanical means, which will lift them at a point of the stroke, when the pressure in the cylinder corresponds with that of the receiver.

This arrangement avoids pounding of the valves and the noise caused by the air when rushing at much higher pressure from the cylinder into the receiver.

For the sake of economy, air compressors are compounded, as a steam engine, by drawing the air into a large cylinder and compressing it to a certain stage, when it again is drawn into a smaller cylinder, which compresses it to a still higher pressure.

In a simple compressor, which compresses very high, there is at the end of the stroke a large amount of air left in the clearance space, which has to be expanded on the return stroke, to atmospheric pressure, before another charge of air can be drawn in.

But in the compound compressor, the air is delivered to the high pressure cylinder from the low pressure receiver far above atmospheric pressure, thus the remaining air need not expand so far, allowing the cylinder to take a larger volume of air. The load is also distributed more evenly.

Fig. 259 shows a vertical compound Riedler air compressor, built by Fraser & Chalmers, Chicago, Ill.

The steam cylinders as well as the air cylinders are compounded, the air cylinders being placed above the steam cylinder, and their pistons connected by one continuous rod.

NOTE.—Lifting water by means of compressed air is one of the new things in engineering. In pumping from wells the compressed air is conveyed from the receiver through the pipes to the bottom of the several wells. When released it begins to expand and carries the water up with it. When the water is first started from the wells it requires a higher pressure to lift it to the surface until the flow commences, when there is a mixed column of air and water, the water rushing in from the adjacent strata as fast as it is lifted from the bottom of the well. This process is continued as long as there is water in the ground and the compressor is kept in operation.

Air and Gas Compressing Engines.

In Paris, four large Riedler compressors with triple expansion engines of two thousand horse-power each, are used for a system of pneumatic power distribution.

Figs. 258, 260 and 262 show various types of air compressors, built by the Pneumatic Engineering Co., 100 Broadway, New York City.

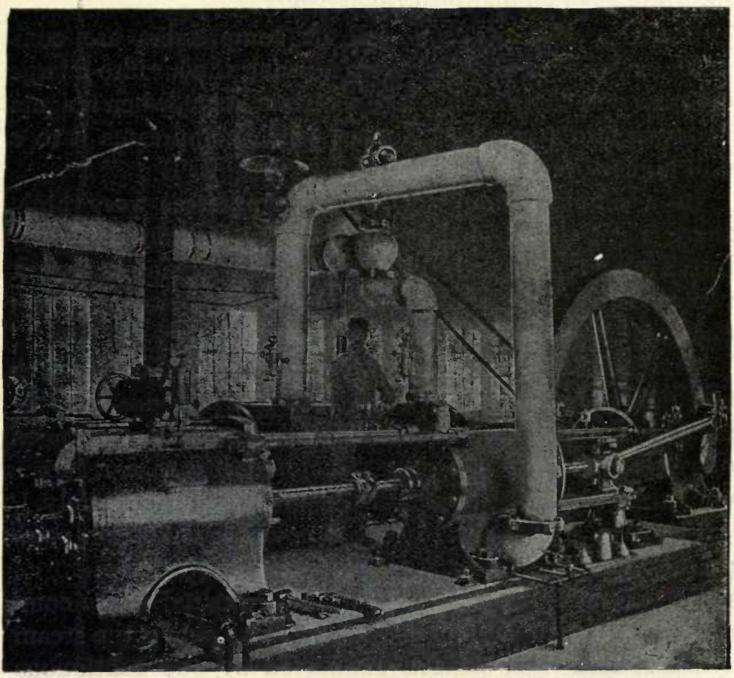


Fig. 261. Rand Air Compressor.

The steam valve gearing used on these compressors may be of the Corliss type, or slide valve.

The air valves are poppet valves, held to their seats by springs; the pressure of these springs is released by the valve gear, which consists of a sliding bar driven by the steam valve stem, provided with arms, which engage with the springs and pull them away from the shoulders, which bear against on the valve. Thus the air can open the valve with but little effort. At the proper time for the valve to close, the springs are released, and thus they close the valve. The mechanical valve gear only releases the pressure of the springs, the opening of the valve being done by the air, so it always will open at the proper moment.

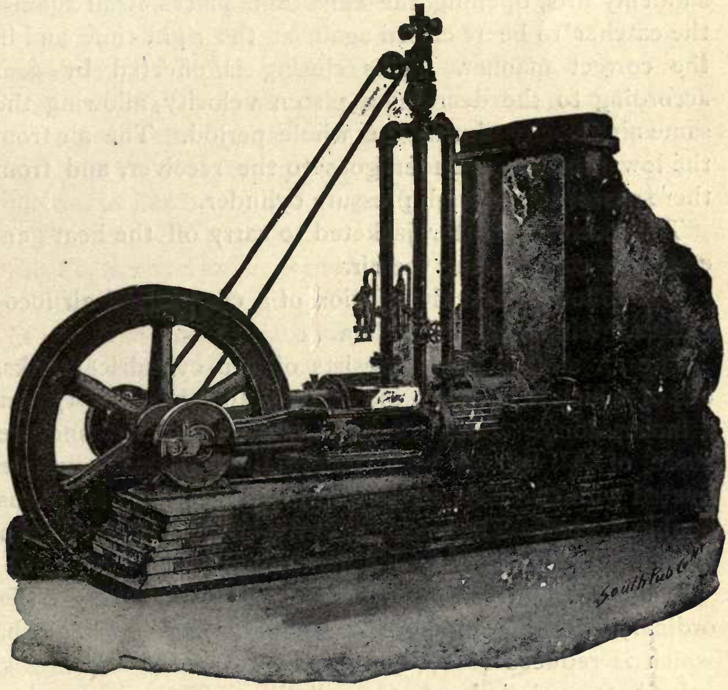


Fig. 262. RAND AIR COMPRESSOR.

The steam valves are of the Corliss type, driven by an eccentric, from which also the air valves derive their motion.

The arrangement of the air valves is as follows:

In the lower and upper parts of the valve chamber are placed the delivery valves, while both suction valves are in the middle part. All four valves are connected together and geared in the same manner.

AIR AND GAS COMPRESSING ENGINES.

The valve consists of two parts, the valve-body, or catcher, and the loose valve ring. The catcher is connected with mechanism by which it is moved positively, and guides and limits the movement of the loose valve ring. This valve ring, the seating part of the valve, remaining pressed against the valve seat by the air pressure when the catcher is withdrawn by the gear. At a given moment the ring suddenly lifts, opening the valve and places itself against the catcher to be re-closed again at the right time and in the correct manner. This closing is effected by gear according to the decreasing piston velocity, allowing the same air velocity during the whole period. The air from the low pressure cylinder goes to the receiver, and from there passes to the high pressure cylinder.

The receiver is water jacketed to carry off the heat generated by compressing the air.

The following is a description of a compressed air locomotive, giving interesting data.

The air storage plant consists of two cylindrical tanks, one of which is 15 feet 2 inches long and the other 17 feet 2 inches long. Both are $31\frac{5}{8}''$ inside diameter, and are made of $\frac{9}{16}''$ plates with longitudinal seams sextuple riveted with two welt strips, and the circumferential seams double-riveted. The thickness of the heads is $\frac{13}{16}''$, and each front head is provided with a manhole.

The maximum charging pressure is 600 pounds and the ordinary working pressure 400 pounds per sqnare inch, which is reduced to 140 pounds by means of a reducing valve before admission to the cylinders. The valve motion is of the Stevenson link type, set for equal cut-off. The cylinders are 9″x14″, the weight is 25,000 pounds, and the capacity of the tanks is 160 cubic feet. It is able to haul its loads around curves of 75 feet radius. In these locomotives the air is passed through a hot water tank before entering the cylinder, which adds greatly to the efficiency

AIR AND GAS COMPRESSING ENGINES.

of the locomotive. The valve gear is so arranged as to get the full benefit from the expansion of the air in the cylinders without the disadvantage of back pressure.

The time occupied in charging the locomotives is very small, being less than one minute at 600 pound pressure, including the time taken in making and breaking couplings.

The following are valuable "points" relating to the care and management of air compressors.

As in a steam line, elbows should be avoided wherever possible, and unlike a steam pipe, should be larger.

A mistake is sometimes made in purchasing a compressor in a low altitude and trying to run it in a higher; the machine then experiences the same trouble that some people do, in not being able to get breath enough.

The use of cheap oils, and these in an air cylinder is a most serious mistake, as the least tendency to gum will prevent the valves from properly seating, and even with the best of oils, it is well to use a small amount of coal oil at times.

In localities where the water is bad, the water jacket will require a little attention, as it gets as badly scaled as some boilers, due principally to a very slow or retarded circulation, which will allow the sediment to settle, and should the water supply be shut off, even for a few minutes, the cylinder will heat enough to bake it so hard as to give considerable trouble. It is a good plan to put a good boiler compound in the water jacket, and run the machine for some time without any circulation. In this, care must be used not to run too long or too fast, as the cylinder will heat very quickly and is liable to be damaged.

There are many emergency ways of stopping small leaks; any good sticky substance, such as tar, wax, tallow candles, or even chewing gum, melted and applied on narrow strips of cloth and wound as a bandage, will be found handy.

It should be remembered that leaks in an air line are as bad as in a steam line, and should receive the same care.

Theory of Air Compression.

The theoretical operation of air compressors may be thus explained:

If a tight cylindrical vessel, containing one cubic foot of air at atmospheric pressure, be fitted with a piston which is free to move up and down but still perfectly tight, the air in the vessel will have no means of escape, and the pressures within and without the vessel both being atmospheric, are balanced.

Now if the piston should be loaded with a weight, the pressure on the outside would be that due to the atmosphere, plus the weight, while the pressure from the inside is simply equal to atmospheric pressure; thus the piston will have to descend, but as the air inside of the cylinder has no means of escape, the volume it fills being diminished, its pressure has to rise until the pressure under the piston balances that above it.

If, for example, the area of the piston should be 100 square inches, and the weight with which it is loaded be 100 pounds, assuming the piston to be weightless, the pressure from below will have to react with an equal force to hold the piston stationary, which in this case would be 1 pound to the square inch above atmospheric pressure, and the piston would have to descend enough to cause this increase of pressure, which descent would be equal to $\frac{1}{16}$ of the total fall of the piston. By adding another 100 pounds the pressure would rise to 2 pounds to the square inch. The cylinder may thus be said to be charged with compressed air.

If now the bottom of the cylinder should be connected by means of a pipe to another vessel of larger capacity called a receiver, the pipe having been closed by a valve in it during compression, and the valve would be opened, the piston would at once commence to descend further, the compressed air escaping into the receiver, until the pressure in the receiver and cylinder is equalized, or the piston reaches the bottom of the cylinder, which it will, if the

THEORY OF AIR COMPRESSION.

receiver is large enough. Next the valve is closed, stopping communication between cylinder and receiver, and the piston drawn upward; at the same time air is again admitted to the cylinder by another valve, which is closed when the piston reaches the top, and the same operation repeated.

The receiver can thus be charged with compressed air and by loading the piston very heavy the pressure can be raised very high.

If now, the piston, instead of being loaded by weights be connected to the piston rod of a steam engine, or by means of a connecting rod to a crank which is turned by a belt or some other driving mechanism, and the valves be operated automatically, as the valves on a water pump, the simple apparatus is converted into a perfect air compressor, which really is nothing else than an air pump, and the air can be pumped into the receiver against a high pressure the same as water is forced against a head by a pump.

As air is a compressible gas, it acts a little different in the air cylinder than the almost incompressible water in a pump.

If the valves of an air compressor would have to be lifted by the air pressure in the cylinder against the pressure of their springs besides the receiver pressure, the air would have to be compressed considerably above the receiver pressure before can lift the valve which allows it to flow from the cylinder into the receiver, and then the valve would not open freely as a pump valve, but would scatter, causing a disagreeable noise, and damages the valve.

To avoid this, the valves of an air compressor are operated by mechanical means, some of which are described in the foregoing pages. Some devices operate the valve directly as soon as the pressure in the cylinder reaches that of the receiver, while others simply release it of the spring pressure, the valve itself being lifted by the air itself. Such devices give the valves a free full opening, without noise.

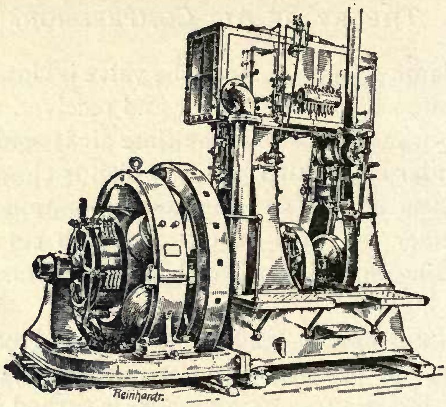


Fig. 264.

COMPOUNDING.

If steam is used at very high pressure in a single cylinder engine, and allowed to undergo the same stage of expansion as has been described under cut-off engines, the economy decreases rapidly after a certain number of expansions has been passed.

The steam entering the cylinder at high temperature will immediately give up some of its heat to the cylinder walls and head, thus heating them to a temperature almost equal to the entering steam.

As soon as cut-off has taken place, the pressure in the cylinder will fall as the piston advances In the stroke, and correspondingly the temperature will fall below that of the cylinder walls, which now are compelled to give up their heat to the cooler steam, until exhaust takes place, when they will be cooled down to almost exhaust temperature during the exhaust stroke.

NOTE.—The saving of fuel effected by compounding is illustrated by the remarkable statement that upon a trial trip of four hours, one of the first marine triple expansion engines ever made, developed a horse power with an expenditure of 1.28 of coal per hour.

Compounding.

If the engine exhausts into the atmosphere without back pressure, the temperature of the exhaust would be 212 degrees, and if the boiler pressure is 120 pounds to the square inch, a temperature of nearly 350 degrees; the steam upon entering the cylinder will strike a surface 138 degrees cooler, and a considerable portion of it is condensed, which extra amount the boiler has to supply in order to fill the cylinder volume before cut off.

To expand steam from 120 pounds boiler pressure to atmospheric pressure, its volume will have to be increased nine times, that is, the engine would have to cut off at one-ninth of the stroke.

If now the cut-off be changed to one-third of the stroke, the steam would be only expanded three times, the pressure at exhaust opening being 40 pounds, and the corresponding temperature would be 275 degrees, a change of only 75 degrees, and consequently less cylinder condensation.

But at the end of the stroke the steam would be able to do a good deal of useful work, its pressure being 40 pounds above the atmosphere.

By allowing the steam to pass into another cylinder of such ample volume that its pressure need not be raised to fill the cut-off space, and then expanding it again three times, it will reach atmospheric pressure, and the change of temperature in this cylinder has been from 275 to 212 degrees = 63 degrees.

In the single engine a great portion of the heat which has been given up to the cylinder by the entering steam, is taken up again by the condensed steam during expansion, and the exhaust stroke, but still it is wasted through the exhaust pipe, while in the compound engine all the heat which is lost during admission, after being taken up again by the steam during expansion and exhaust, is used over again in the low pressure cylinder.

COMPOUNDING.

Thus it follows that in a compound engine the only loss by cylinder condensation is that taking place in the low pressure cylinder, which will be seen from the foregoing figures, is considerably less than one-half of that in the single engine.

Of course, there is some loss of heat in both types by outward radiation, which in either case is lost, but is reduced to a minimum in covering the cylinders with non-conducting material. If both engines would be run by a compressed gas, as air, for instance, so there would be no cylinder condensation, there would be no difference in the economy.

The amount of saving in favor of the compound over the single cylinder engine can safely be stated to be 20 per cent., but certainly varies with different engines, the only comparison can be made between engines of the same type and condition. The triple expansion engine is again 20 per cent. more economical than the compound.

There are different systems of compounding. First, tandem compound, in which both cylinders are in line, and both their pistons arranged upon the same rod. The cylinders may be placed one before the other, as in a horizontal engine, or above each other, as in a vertical engine. The latter type is often called a steeple compound, and is frequently used in marine practice; these engines are often run without receiver.

NOTE.—The consumption of single cylinder non-condensing engines may be stated as 24 to 26 pounds of steam per horse power per hour, the same engines condensing, 19 to 21 pounds per horse power per hour. Compound non-condensing, 19 to 21 pounds per horse power per hour. Compound condensing engines, 14 to 16 pounds per horse power per hour. Triple expansion engines, 12 to 13½ pounds per horse power per hour. Quadruple expansion engines are advisable where very high steam pressures are employed, and where, for mechanical reasons, a four-cylinder machine is desirable. For all ordinary pressures the economy is about the same as triple expansion engines.

In general, it is desirable to make both cylinders of a compound engine contribute equal quantities of work.

COMPOUNDING.

Second, cross compound; in these engines both cylinders are operating separate cranks, which may be set at right angles to avoid dead centres and to distribute the load more evenly about the crank shaft; or the cranks may be set opposite to each other, as in the old Scotch non-receiver compound.

Most compound engines of the present designs are supplied with a receiver, which consists of an inclosed vessel of at least the same capacity as the high pressure cylinder, into which the high pressure cylinder exhausts; the steam passes from the receiver into the low pressure cylinder.

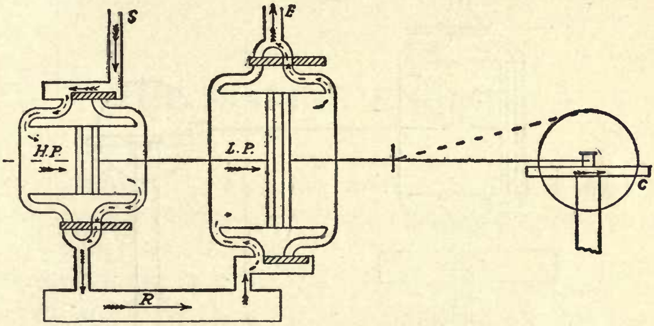


Fig. 265. DIAGRAM OF TANDEM COMPOUND ENGINE.

In a tandem compound engine the receiver is not such a necessity as in a cross compound with cranks at right angles, as both pistons start at the same time on their stroke, and thus the steam can pass directly over from the high pressure cylinder into the low pressure, while in a cross compound engine with cranks at right angles, the leading cylinder has completed one-half its stroke when the other begins, thus there has to be a receiver to take care of the high pressure exhaust until the low pressure cylinder begins its stroke, when the high pressure crank is leading, and if the low pressure cylinder is leading there has to be a volume of steam stored for it to begin its stroke with. If a tandem compound engine cuts off early in the stroke, a receiver will also be necessary in this type.

COMPOUNDING.

Fig. 265 represents a diagram of the arrangement of a tandem compound engine, while Fig. 266 is the same engine cross compounded.

The steam from the boiler enters at S, in the direction of the arrows, through the open steam port, into the high pressure cylinder marked H P, Figs. 265 and 266; the high pressure exhaust passes in the direction of the arrows into the receiver R, from whence it passes into the low pressure cylinder L P, from thence it is exhausted at E into the condenser.

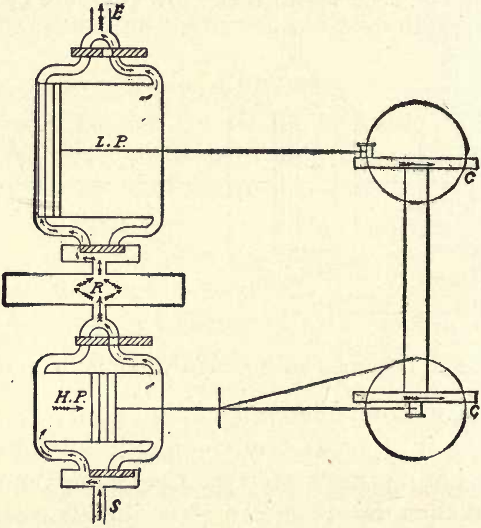


Fig. 266. DIAGRAM OF CROSS COMPOUND ENGINE.

The tandem compound has a single crank C, while the cross compound has two cranks, C C, set at right angles to each other.

It will be noticed that the hlgh pressure crank, as shown in Fig. 266, is in its vertical position; the high pressure piston having completed more than one half stroke, while the low pressure piston is only at the commencement of the stroke.

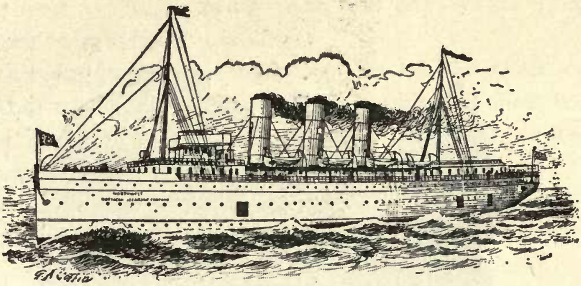


Fig. 267. LAKE STEAMER.

THE MARINE ENGINE.

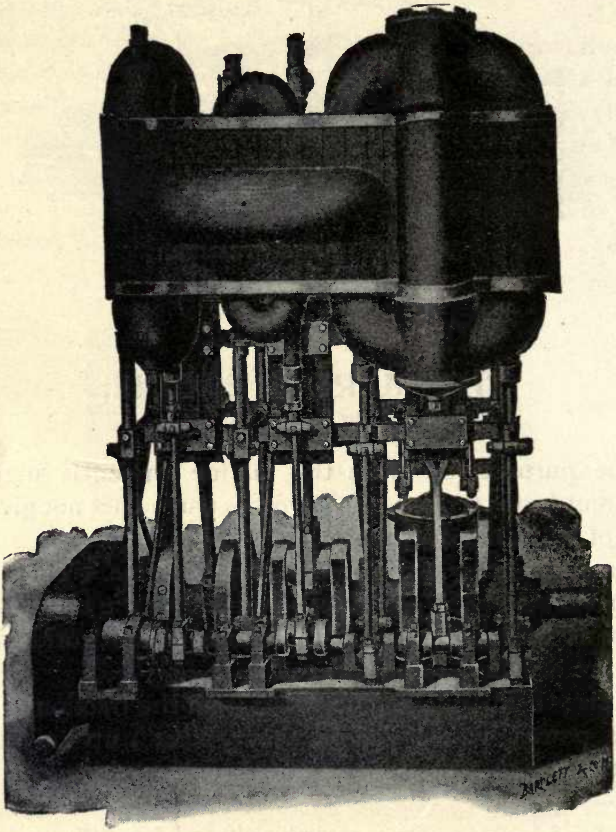
The purpose for which the marine engine is used is apparent from its name—however, its name does not give an idea of all its characteristics.

There are many types of the marine engine. These are governed largely by the class of work they are called upon to do, as well as the general sections of the world where they are designed to do service.

In size the marine engine varies from the fraction of one horse power, with cylinders about 2″x2″, up to fifteen thousand or more horse power all in one machine.

NOTE.—A marine engine is at work night and day, with no chance of stoppage for repairs, it may be for two or three weeks and then only for a few hours. It has to propel a ship carrying hundreds of people and thousands of dollars worth of cargo. A weak spot in the engine may mean the loss of these lives and the goods.

A 3,000 ton steamer will make the passage from England to Australia or to New Zealand without calling at a port on the way. Usually a stop is made for coal at Las Palmas or at the Cape of Good Hope, but these are exceptions. One or two voyages have been made from London to Wellington, New Zealand, or to Dunedin, 16,000 miles, without a break.



COMPOUND MARINE ENGINE.

The Marine Engine.

The compound inverted, vertical engine is undoubtedly in the first rank, it being used for the screw propeller steamers so widely known.

In this engine the cylinders are above the shaft, carried by either cast iron or steel columns, which at their base are supported by the bed plate, bolted to the engine keelson. The cranks are mostly set at right angles.

The triple and quadruple expansion engines belong to the same class, the difference being more cylinders, thus affording more expansion and even more economy.

Another type is the horizontal marine engine for screw steamers. This type is only used on board of twin screw war vessels, its great advantage being the possibility of getting the engines entirely below the surface of the water, its disadvantage being its need of greater floor space. It resembles the vertical engine in all but the bed plate and frame.

Another popular, and in the United States almost exclusively used for side wheelers, is the walking beam engine. This consists of a single cylinder of very large size and long stroke. The piston rod is connected to one end of a balanced beam, the other end of which is connected by means of a connecting rod to the crank. These engines run at a very slow speed, and at low pressure condensing. The valves are of the double beat poppet type, four valves being used, which practice decreases the clearance to a minimum. The engines are very economical. The reversing gear is somewhat different from the ordinary link motion. Some engines have the loose eccentric reversing gear while others have their respective eccentrics for "ahead" and "astern," the eccentric rods being hooked as in many stationary engines.

The loose eccentric reversing gear consists of a single eccentric, which is free to turn upon the shaft and a disc keyed to the shaft, which is provided with a circular groove

The Savannah was launched August 22, 1818. She sailed from Savannah, Ga., on the 22d day of May, 1819, bound for St. Petersburg, via Liverpool. She could carry only 75 tons of coal and 25 cords of wood, but reached the latter port on June 21st, having used steam eighteen days out of twenty-six, and thus demonstrated the feasibility of trans-atlantic steam navigation. Nothing of much interest is detailed in the daily records of the log book, which are, on the whole rather monotonous. On the 2d of June they "stopped

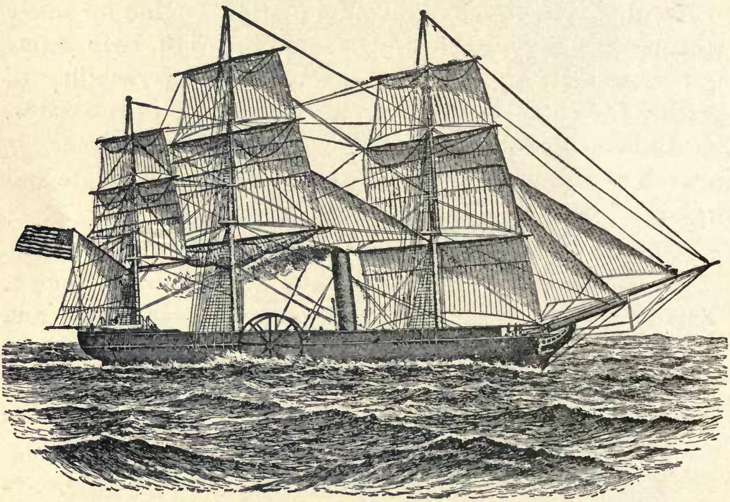


Fig. 268. STEAMSHIP SAVANNAH, 1818.

the wheels to clean the clinkers out of the furnace; at 6 p. m. started the wheels again; at 2 a. m. took in the wheels." Upon its arrival the steamer was seen from the telegraph station at Cape Clear and reported as a ship on fire. The Admiral, who lay in the Cove of Cork, despatched one of the King's cutters to her relief, but great was their wonder at their inability, with all sail set, in a fast vessel, to come up with a ship under bare poles.

THE MARINE ENGINE.

in which slides a block, attached to the eccentric. The ends of this groove limit the position of the eccentric to the proper angle it has to make with the crank. To reverse the engine, the valve gear has to be operated by hand for at least one-half a revolution, for which a hand lever is used.

The valves, 3, Fig. 269, lift squarely off their seats, thus operating frictionless, and are balanced.

The rock shafts are operated by the eccentrics by means of the rock shaft arms, 8, the one seen at the left in Fig. 270 is for the steam valves, the other for the exhaust. To the rock shafts are attached the wipers, 6, for the steam valves, and 7, for the exhaust valves, which, when vibrated by the eccentrics, strike the lifting toes, 5, which are attached to the lifting rods, 4, raising these quickly, and thus by means of the attachment to the valve stems shown in Figs. 269 and 270, raise the valves off their seats, thus admitting steam to the cylinder, and exhausting.

To operate the valve gear by hand, the hand lever, **11**, is released from the hook which supports it at rest in its midway position, and by vibrating it up and down. The steam valves are operated by means of the wipers, 13, and the exhaust valves by means of wipers, 14 attached to the small rock shaft, 10, and striking the lifting toes, 12.

After the engine is well started the eccentric rods, 9, are released by means of a lever, shown on the rock shaft, which holds them clear of the rock shaft arms, and the hand lever is hooked up in its stationary position, remaining at rest while the engine is running. The engine shown is provided with loose eccentric reversing gear.

The valve chests, 2, 2, are bolted to the cylinder, 1, Figs. 269 and 270, the steam is passing through the column at the left, Fig. 270, and the exhaust through the right hand column.

These columns also support the bearings for the rock shafts, their inner ends being supported by a bracket bearing attached to the cylinder as shown in Figs. 269 and 270.

THE BEAM ENGINE.

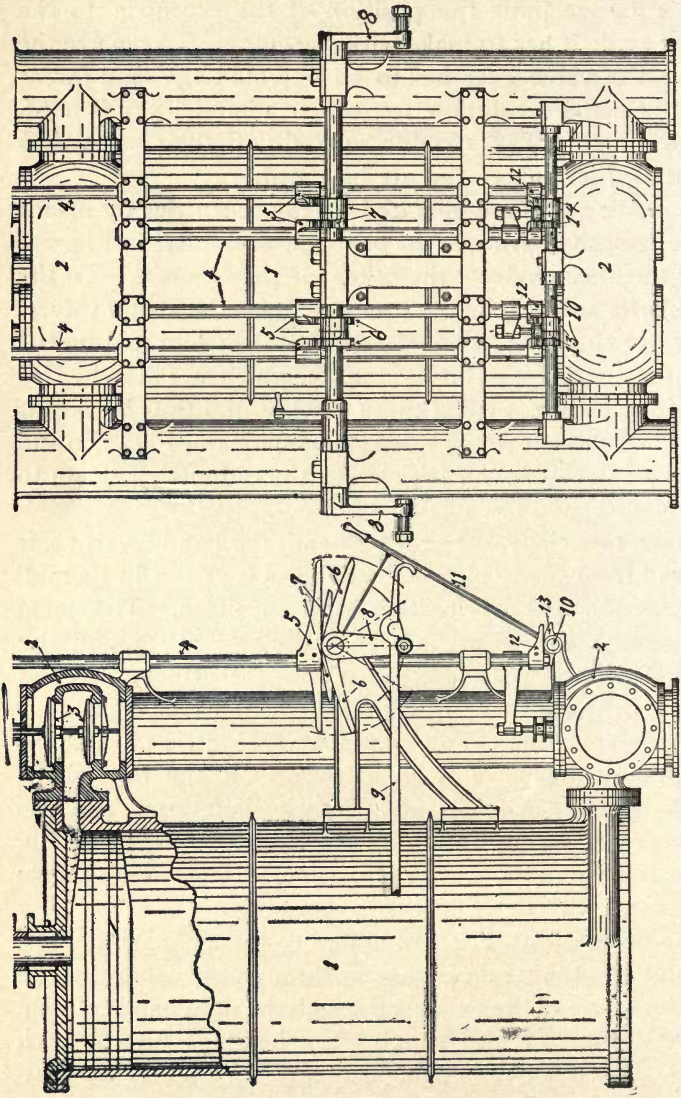


Fig. 269. Side View. Fig. 270. Front View.

CYLINDER AND VALVE GEAR OF BEAM ENGINE.

THE BEAM ENGINE.

Rule for setting the valves of beam engines:

Assuming that the rock shaft arm, 8, is keyed on to the rock shaft in its proper relation to the center line of motion of the eccentric rod, 9, and that the wipers, 6, 7, are keyed on to the rock shaft, in their proper relation to the rock shaft arm, which is always the case in properly constructed engines, the first step is to ascertain the proper length of the eccentric rod, and the most convenient starting point for doing so, is from the centre of motion of the valve gear.

Hence, the first thing to be done in setting beam engine valves is to set and hold the rock shaft at the center of its motion, which is when the lifting rods, 4, are down, the valves, 3, seated, and the lifting toes, 5, adjusted the right distance from the rock shaft, and straight with each other, so that the ends of both wipers will be the same distance from their respective toes.

Next put the main crank on the center, and turn the throw of the eccentric directly in line towards the center of the eccentric hook pin; then make a fine center-punch mark on the edge of toe pin, and one on the edge of the hook strap, and set a pair of compasses corresponding to the distance between those marks, and measure it.

Add to that distance half the throw of the eccentric; reset the compasses to that length, and move the eccentric until the center-punch marks and compasses again correspond, and adjust the length of eccentric rod so that the hook will just engage the eccentric hook pin while the eccentric is held at that position; then slack up the rock shaft so that it can be moved, hook on the eccentric rod, and turn the eccentric in the direction to raise the required valve until it has the proper lead.

NOTE.—There can be no general rule given as to how the eccentrics should be placed in relation to the crank, as that depends on the relative arrangement of the lifters, valves, wipers, and rock shaft arms.

The Oscillating Engine.

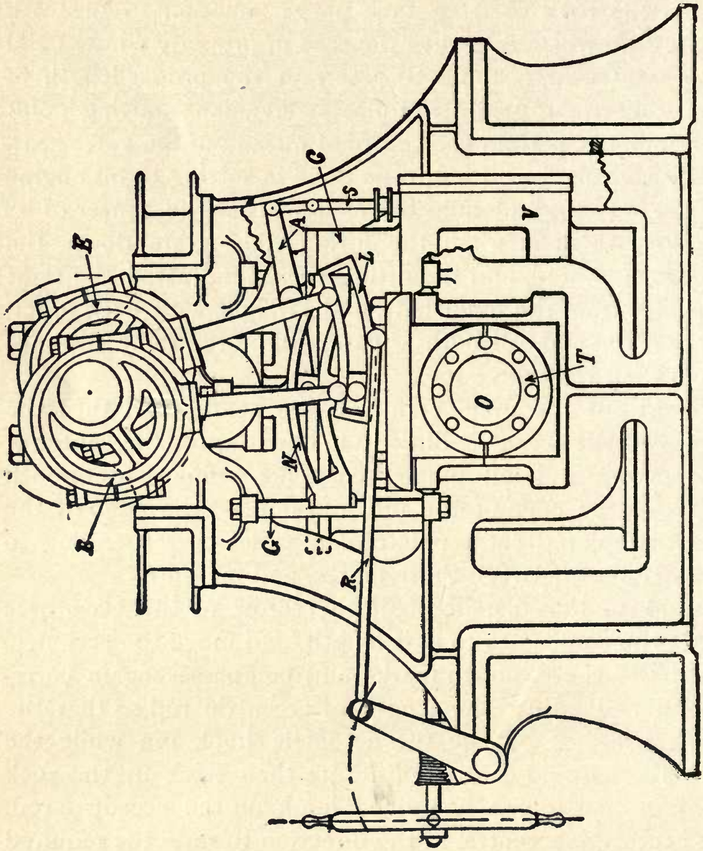


Fig. 271. Oscillating Engine. Side View.

THE MARINE ENGINE.

Then (if the engine is of the style that has two eccentrics and two rock shafts), proceed in the same manner with the exhaust valve gear and the valves are set.

To prove the accuracy of adjustment turn the main crank to its opposite center, and if there is a difference in the lead, either lengthen or shorten the eccentric rod to make up half the difference, and turn the eccentric to make the other half, fasten the eccentric on the shaft and the valves will be right.

Another engine used for side wheelers is the inclined compound or triple expansion engine, which differs from the ordinary marine engine by its upwards sloping angle, the shaft being above.

The oscillating engine differs from the ordinary engines by the direct connection of the piston rod to the crank. The valve is operated by a rocker arm, A, Fig. 271, one end of which is connected to the valve stem, S, while to the other end is pivoted a block, running in a quadrant, N, which is operated by the eccentrics, E, E

The cylinder, C, and piston rod vibrate the same as the connecting rod on other engines, the cylinder being suspended on both sides by trunnions, T, which also serve to convey the steam to the valve chest, and the exhaust to the condenser.

The pipes are inserted into the openings, O, the joint being made steam tight by means of packing rings, allowing the cylinders to oscillate. The steam passes through a channel in the cylinder casting to the valve chest, V, and is controlled by a slide valve in the ordinary way.

The reversing gear may be of the loose eccentric type, or the well known Stephenson link motion, as shown in Fig. 271.

The eccentric rods are connected to the link, L, which slides over the link block attached to a pin in the quadrant N, and by means of the reach rod, R, and the reversing gear shown in the figure, either eccentric may be made operative.

The quadrant slides vertically between guides, G, one of which is removed to allow other parts to be visible. On the upper part of the quadrant is a short rod, which slides in a bushing and steadies it against any twisting motions.

The office of the quadrant is to prevent the oscillating motion of the cylinder to have any effect upon the valve movement.

THE MARINE ENGINE.

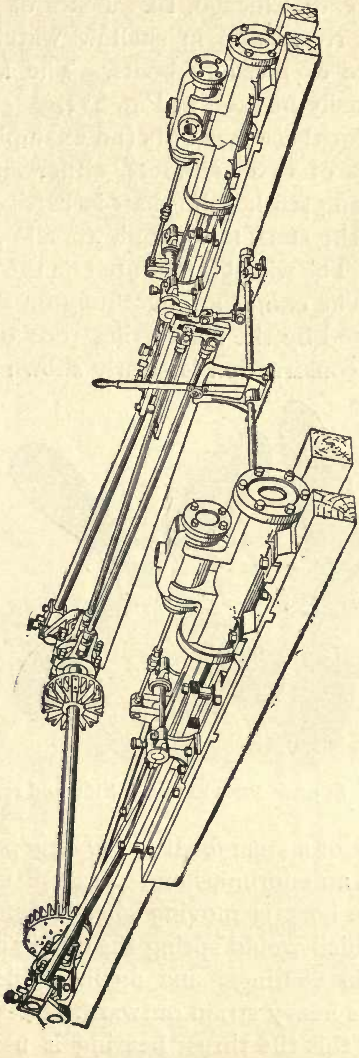


Fig. 273. STERN-WHEEL MARINE ENGINES.

The Marine Engine.

In Fig. 272 is shown a stern-wheel launch, built by Chas. P. Willard & Co., of Chicago, Ill. Boats of this class are used largely on rivers and in shallow water, for towing, passenger service or pleasure boats. The attachment of the wheel can easily be seen in Fig. 272.

The engines for these steamers (an example is shown in Fig. 273) consist of two cylinders, either simple or compound, with a long stroke, the shaft is carried by brackets, extending over the stern far enough to allow the wheel to clear the boat. The wheel is mounted on the shaft between the brackets. The cranks are overhung on the ends of the shaft and operated by the connecting rods on each side of the boat. The construction is clearly shown in Fig. 273.

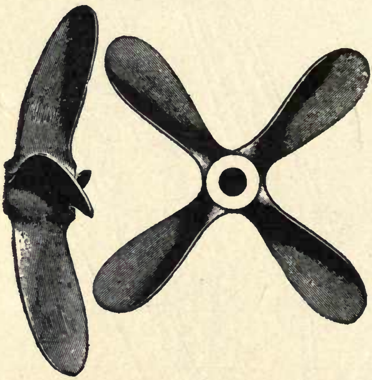


Fig. 274. Screw Propeller. Side and rear view.

The propeller of a steamboat is the only part moving the hull, and exerts an enormous end pressure upon the shaft, which, when the boat is moving ahead, tends to force the shaft inward, which would spring the cranks and bind them against the main bearings, and again, while going astern would exert this heavy strain outward.

To overcome this the thrust bearing is used, which consists of a series of collars, shown at 5, Fig. 275, upon the shaft, which revolve between horse shoe bearings, Fig. 276, supported by a frame.

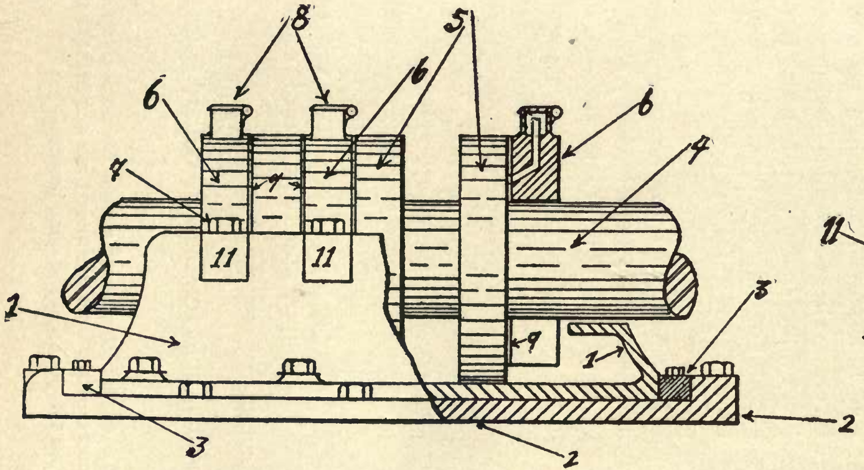


Fig. 275. THRUST BEARING OF PROPELLER SHAFT.

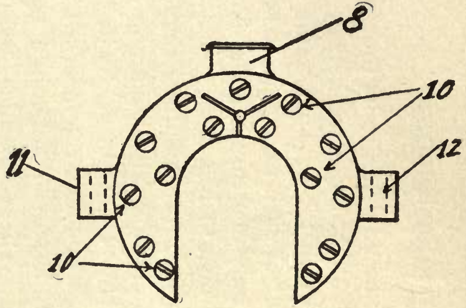


Fig. 276. HORSE SHOE BEARING.

1. Frame.
2. Base Plate.
3. Adjusting Key.
4. Shaft.
5. Thrust Collars.
6. Horseshoe Bearings.
7. Jam Bolts.
8. Oil Cups.
9. Brass Lining.
10. Screws to hold Brass Lining.
11. Bosses.
12. Holes for Jam Bolts.

THE MARINE ENGINE.

The thrust bearing can be adjusted to its proper position with the cranks by means of the adjusting keys, 3, Fig. 275.

There are other forms of thrust bearings, some of which provide for the adjustment of each bearing separately, and on some smaller engines only one thrust collar is used; an example of this kind is shown in Fig. 285.

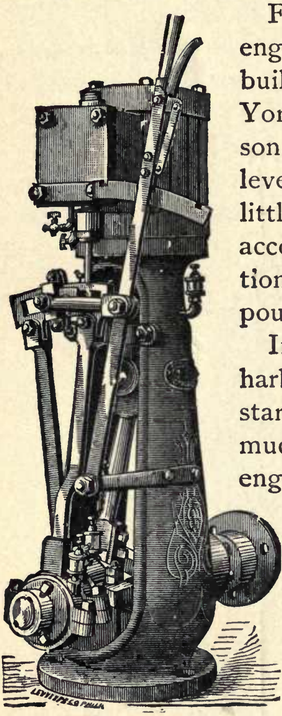


Fig. 277.
UPRIGHT MARINE ENGINE.

Fig. 277 represents a single marine engine for a small pleasure or tug boat, built by Donegan & Swift, of New York. The reversing gear is a Stephenson link motion, operated by a hand lever. These engines require very little floor space in the boat, but on account of their greater steam consumption, need a larger boiler than compound engines.

In small pleasure boats and small harbor tugs, which have to stop and start at short intervals, there is not much advantage in using a compound engine, as many times live steam has to be admitted to the low pressure cylinder in starting, which decreases their economy, and the single engine in Fig. 277 would be the most desirable, their first cost being much lower than the compound, and they are of extreme simplicity.

The engine shown in Fig. 278 is a steeple compound, built by Chas. P. Willard & Co., of Chicago, Ill.

NOTE.—The steeple compound almost equals the cross compound engine in economy, and requires but little more than one-half the floor space needed for a cross compound of the same power.

The Marine Engine.

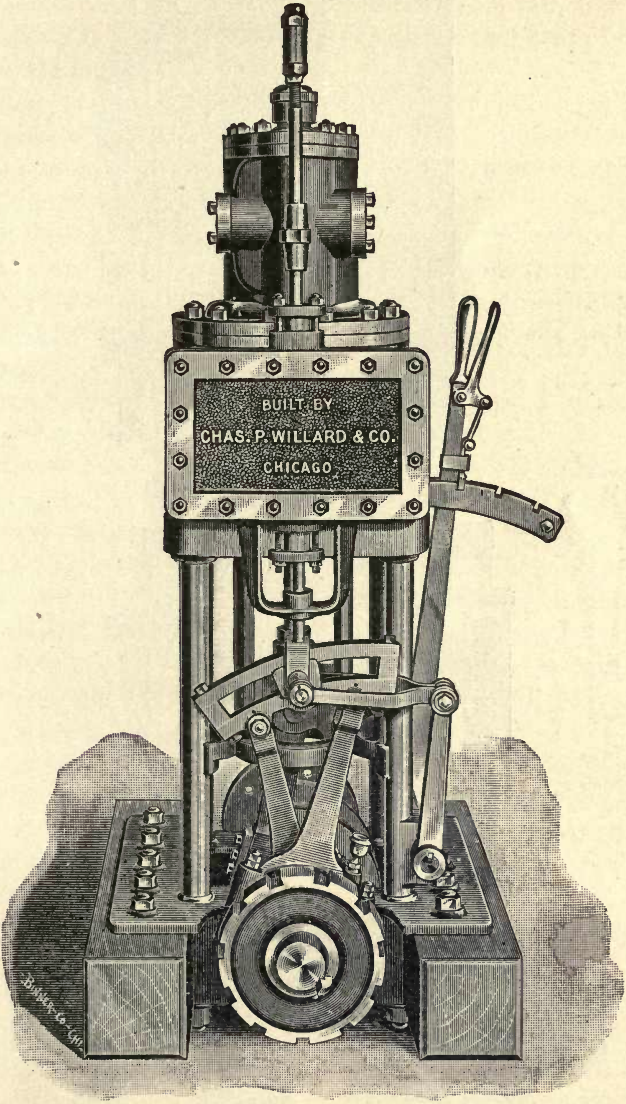


Fig. 278. Steeple Compound Marine Engine.

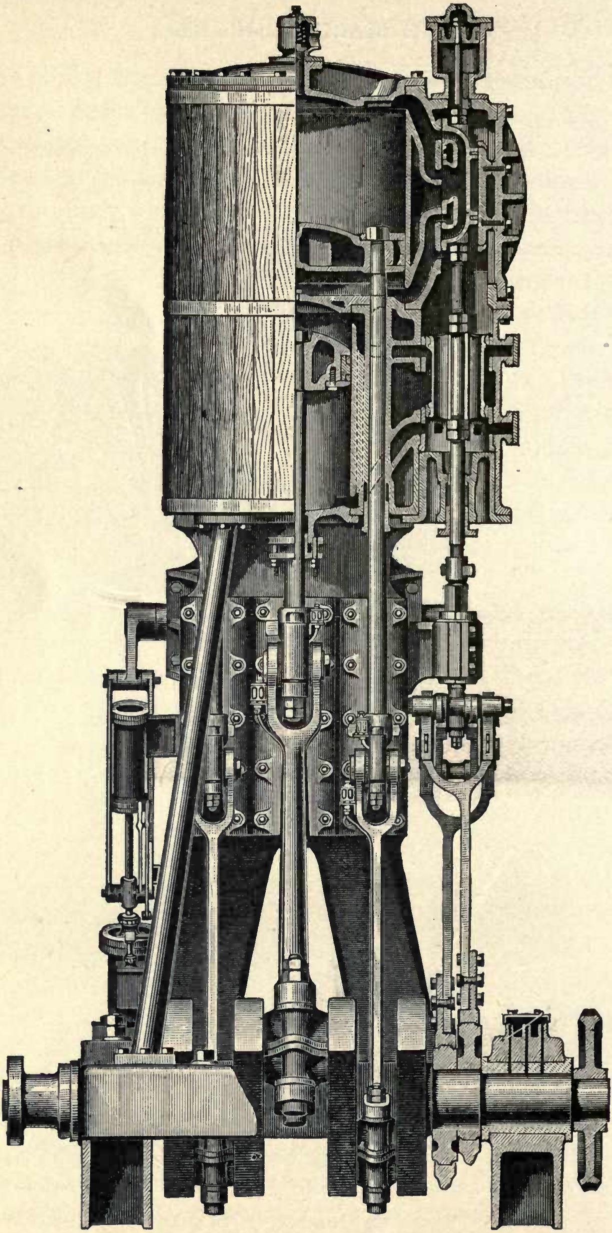


Fig. 279. WELLS' COMPOUND MARINE ENGINE. Front view. (Seen from starboard side.)

THE MARINE ENGINE.

There is only one crank, both pistons being attached to the same piston rod, the high pressure cylinder being placed above the low pressure.

These engines require a little more attention by the engineer, while operating, as for instance, if the boat is hauling alongside a dock, or a vessel to be towed, as they are liable to stop at the bottom center when stopping, and would have to be turned nearly one-half a revolution by hand before being able to start. This, however, is easily avoided by reversing when on the last stroke, thus cushioning the pistons, and preventing them from descending all the way.

The economy is a little beyond the fore and aft compound engine with cranks at right angles, because one crank does not distribute the load as evenly as the two at right angles.

The Wells balanced engine is represented in Figs. 279 and 280, the force of the steam applied to the high pressure piston descending upon one side of the shaft is balanced by the force of the steam applied to the low pressure piston ascending upon the other side, leaving only the weight of the crank shaft and its connections to be carried by the main bearing boxes.

In practice steam is admitted to both cylinders simultaneously; during the first stroke, the steam pressures upon the middle cylinder head are exerted against each other; the force acting upward in the high pressure cylinder becomes the support of the force acting downward in the low pressure cylinder. In the return stroke the pressures are exerted upon the top and bottom cylinder heads in opposite directions, giving a balance of pressures within the cylinders.

Unbalanced weight in motion (momentum) being the main element that tends to destroy an engine, makes it apparent that balanced weights, balanced steam pressures,

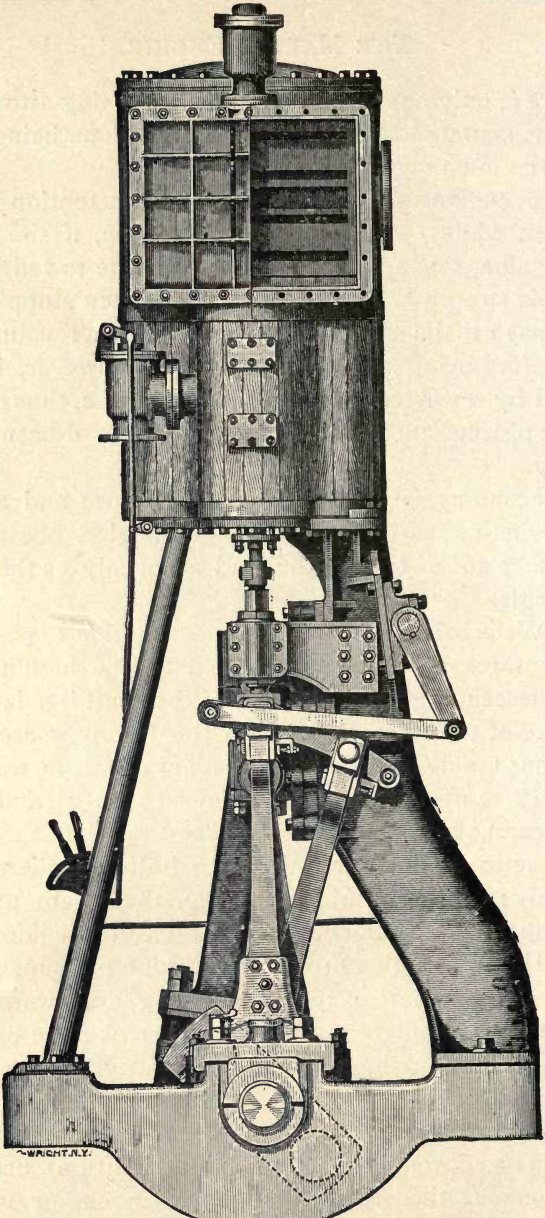


Fig. 280. WELLS' COMPOUND MARINE ENGINE. SIDE VIEW.
(Seen from the bow.)

THE MARINE ENGINE.

and balanced motions are the qualifications necessary to produce a durable engine, all of which this design possesses, hence, the advantages claimed for this engine are:

1. Owing to the compact form of cylinders and steam chests the steam has little distance to travel.

2. Steam from the boiler being admitted between the high pressure cylinder and the low pressure steam chest, creates and maintains a high temperature in both.

3. The cranks being set at 180°, no receiver is required, as the exhaust steam passes direct from high to low pressure piston, giving a continuous force, and preventing undue expansion.

4. The balance of forces permits much higher piston speed with greatly reduced compression, and also gives less cylinder condensation.

5. An equal steam pressure applied to opposite sides of the crank shaft and exerted in opposite directions in the same plane relieves the main bearings of friction due to steam pressures and also of the thrust of the connecting rods, leaving only the friction in the main boxes, due to the weight of the shaft and the moving parts of the engine.

6. The principle of balance also embraces another most important advantage in its control of the momentum forces stored in its moving parts, which in this case are concentrated in the crank shaft for useful effect, as they work in unison with the steam forces.

7. The forces being balanced, the pressures upon the crank pin can never exceed the resistance of the load.

8. It entirely relieves the hull of all strains, jar and vibration. By this control the forces are entirely absorbed in motion, and no strains communicated to the engine frame, bed plate, or hull.

As shown in the illustration, the low pressure cylinder is placed above the high pressure, the low pressure piston rods passing down on both sides of the high pressure cylin-

THE MARINE ENGINE.

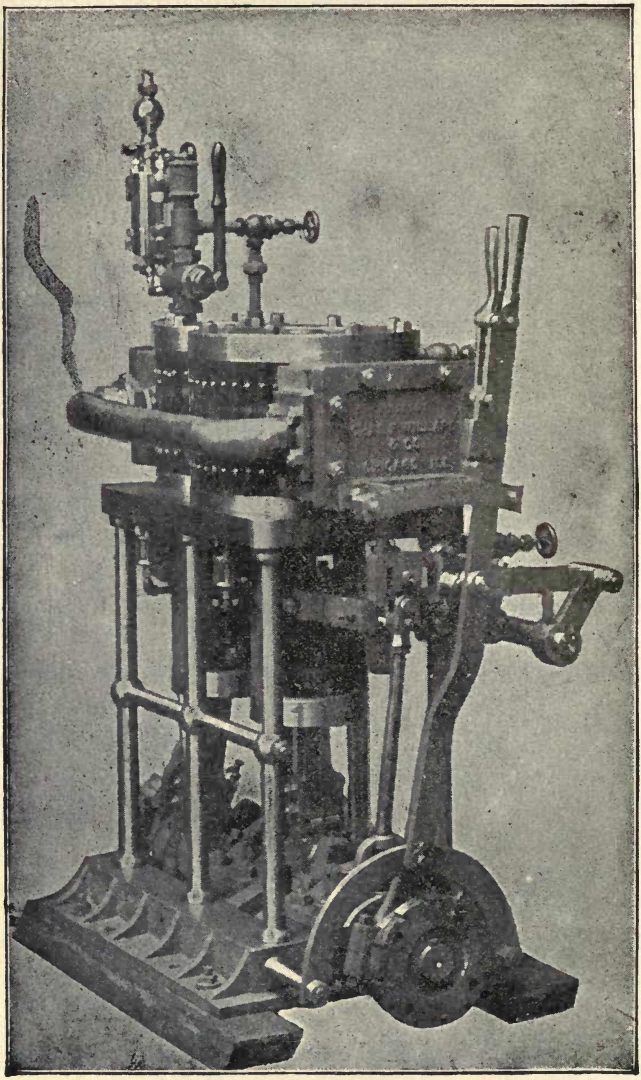


Fig. 281. COMPOUND MARINE ENGINE.
"Fore and aft compound."

THE MARINE ENGINE.

der. These are connected to cranks opposite the high pressure crank, all the three cranks forming one piece. Both valves are operated by the same eccentric, the high pressure valve being a piston valve, the low pressure a double ported balanced slide valve. When the cranks are standing at their horizontal position, the weight of the high pressure ports counterbalances the weight of the low pressure ports.

This engine is also built for stationary purposes with automatic cut-off. The two illustrations given are so clear and distinct as to almost explain the working of the engine.

Fig. 281 is an illustration of a compound marine engine. The fore and aft compound engine, as the above is named, is, as previously stated, the most popular marine engine at the present date. It is more economical than the simple engine, and besides, possesses the advantage of having two cranks; with two cranks placed at right angles to each other there are no dead centres, and the engine may readily be started from any position.

A single crank engine receives only two impulses each revolution, while a double crank engine with cranks at right angles receives four impulses each revolution, hence a more equal distribution of the load.

If another crank be added, as in a triple expansion engine, the shaft receives six impulses every revolution, thus distributing the load still more evenly, and coming nearer to a continuous rotary motion.

The Marshall valve gear, Fig. 283, consists of a single eccentric, *I*, which either has to be set directly opposite the crank, *Q*, or in the same direction with the crank, according to the design of the valve and valve gear.

The eccentric operates a lever, *K*, which also forms one-half of the eccentric strap, *J*, the extreme end of this lever is attached to the valve rod, *O*, by means of a pivot, *N*, and thus to the valve stem, *P*.

NOTE.—Wells' Engine Co., 136 Liberty St., N. Y. City.

THE MARINE ENGINE.

The fulcrum of this lever is at *M*, about which it is swung vertically by the throw of the eccentric, the amount of travel thus imparted to the valve being equal to the lap and lead for both ports.

The travel necessary to open the port is imparted to the valve by the up and down motion of the fulcrum *M*, due to the horizontal throw of the eccentric, which causes the vibrating link *H*, pivoted to *K* at *M*, to swing, and thus raise and lower the fulcrum.

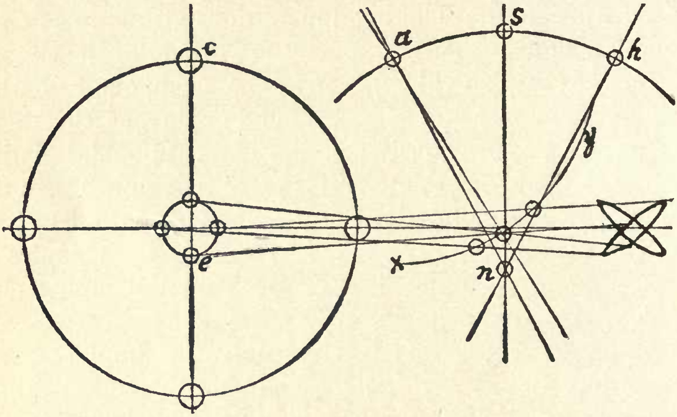


Fig. 282. DIAGRAM OF MARSHALL VALVE MOTION.

The upper end of the vibrating link *H* is pivoted to the tumbling link *G*, which can be swung about the pin *L* by means of the reversing gear, which consists of reach rod *F*, tumbling crank *E*, worm wheel *D*, worm *C*, reversing shaft *B*, and finally of the hand wheel *A*, by means of which the engineer can reverse, stop, or let the engine turn ahead.

It must be understood that when the tumbling link *G* is at its midway position, no vertical motion is given to the fulcrum *M*, and if it is thrown over into its opposite position the motion is reversed to that indicated in Fig. 283.

The Marshall valve gear may be used to operate an ordinary flat slide valve or piston valve as required.

THE MARINE ENGINE.

Fig. 282 shows a diagram which more plainly indicates the operation of this valve gear.

c indicates the position of the crank, *e* the eccentric, *a* the point about which the vibrating link swings to describe the

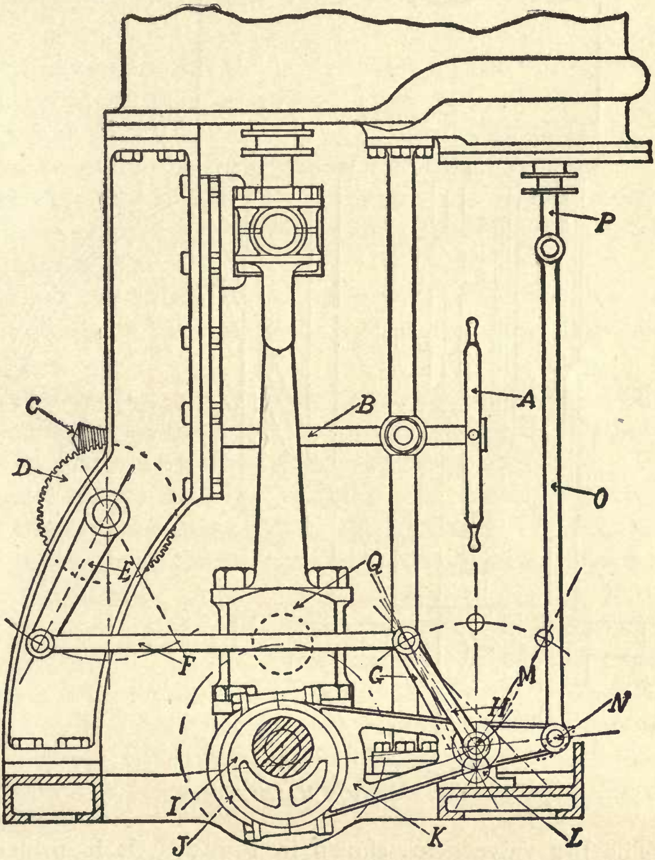


Fig. 283. MARSHALL VALVE GEAR.

arc *x*, *y*, and *n* the pin about which the tumbling link is turned. If *a* be moved into the position *s*, it will be understood that *x* and *y* will both be at the same height.

THE MARINE ENGINE.

If *a* be swung into position *h*, *y* will be below the centre line and *x* above, and the engine is reversed. It will be observed that the point of *k*, which is attached to the valve rod, describes an ellipse.

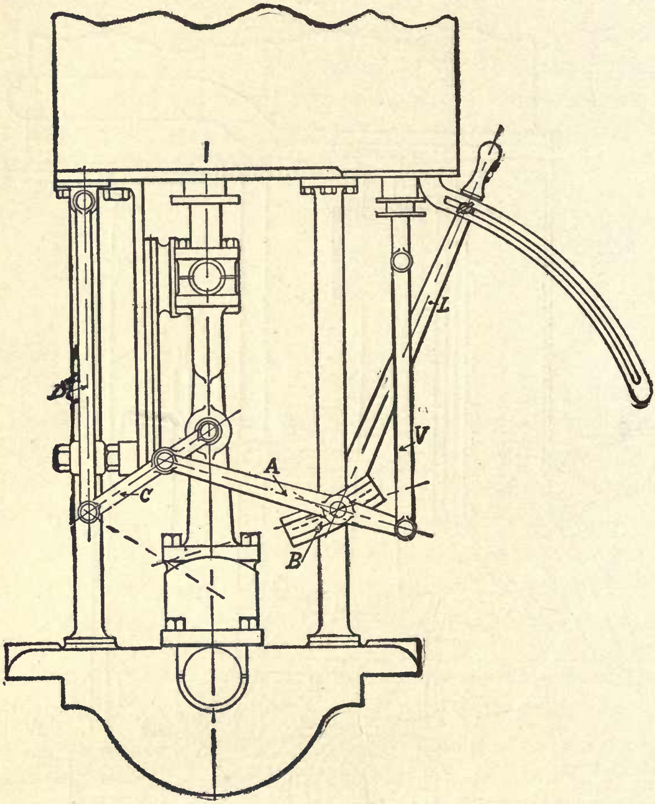


Fig. 284. JOY VALVE GEAR.

The Joy valve gear, shown in Fig. 284, is in principle identical with the Marshall valve gear.

The lever *A*, Fig. 284, operates the valve rod *V* in the same manner as lever *K* in Fig. 283; instead of the vibrating link a block *B*, provided with a curved slot is used, in which the pin forming the fulcrum of the lever *A* slides.

THE MARINE ENGINE.

The motion is imparted to the lever *A* directly from the connecting rod by means of the connecting link *C*, one end of which is pivoted to the connecting rod, the other end to the suspension link *D*.

The vertical motion of the connecting link moves the valve an amount equal to its lap and lead, while the horizontal motion causes the ports to open their full opening, by moving the fulcrum up and down in the inclined slot. By means of the reversing lever *L* the incline of the block *B* can be altered, or reversed, to reverse the engine.

In Figs. 285 and 286 is shown, as a practical example, a triple expansion engine fitted to yacht "Penelope," St. Augustine, Fla.

The valves of this engine are driven by cranks on a separate shaft, which receives its motion from the main shaft by gears.

The valves are of the piston type, the high pressure valve taking steam on the upper end, from whence it also passes to the lower port through the body of the valve. The exhaust passes into the chamber surrounding the valve, and through the channel shown in the section in Fig. 285, which also forms the intermediate receiver, to the intermediate valve chest.

The intermediate valve takes steam on its inner edges, exhausting on the ends, the exhaust of the upper port passing partly through the valve and partly through the space formed between the intermediate and low pressure valve chests, the combined volume of these form the low pressure receiver, from whence it passes to the low pressure cylinder.

The reversing gear of this engine is different from the Stephenson link motion. One end of the shaft from which the valves receive their motion is provided with a tripple thread of very long pitch, upon which a nut is mounted with grooves to fit these threads.

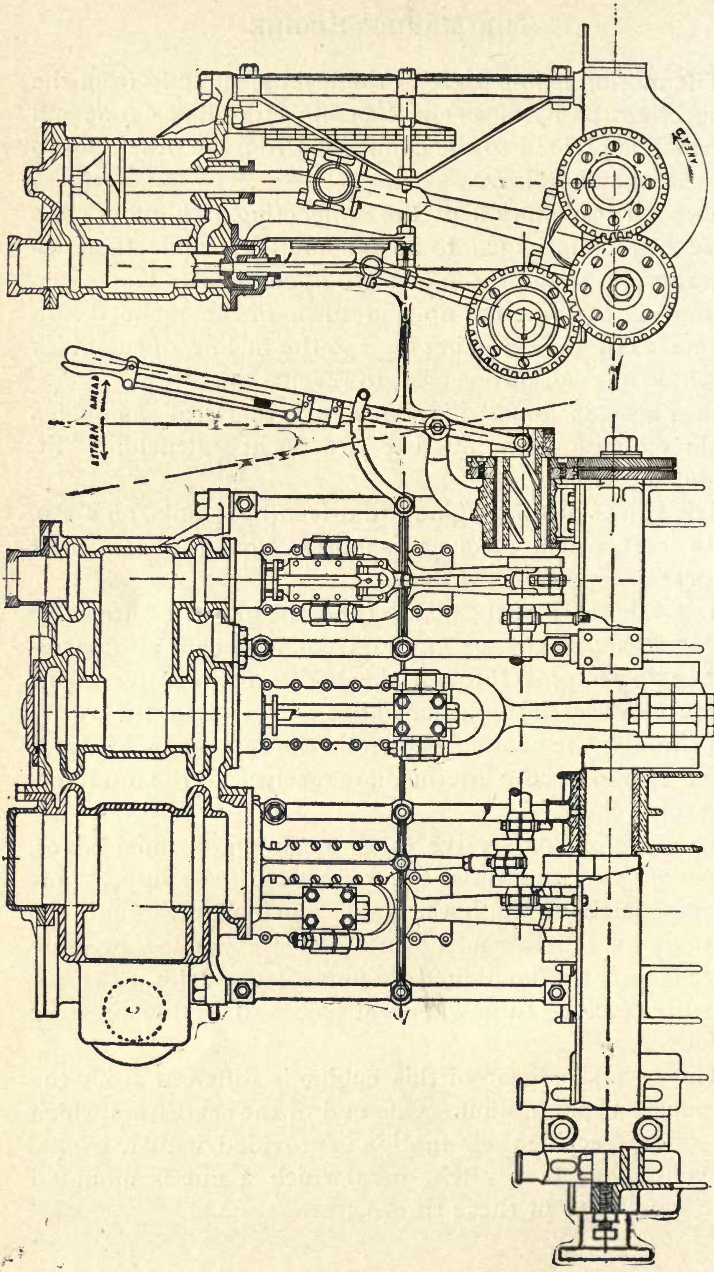


Fig. 286. Side View.

Fig. 285. TRIPLE EXPANSION MARINE ENGINE—Front View.

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The nut is circular in shape and provided with keys, which slide in keyways in a sleeve upon which the gear, which rotates the shaft, is mounted.

If the engine is running, the gears, driven by the main shaft will rotate the sleeve with nut and valve shaft as one piece. In throwing the hand lever, see Fig. 285, the nut is slid outward, and as it cannot rotate inside of the sleeve on account of its keys, the valve shaft has to rotate, changing the position of the cranks, which operate the valve rods, for the astern motion.

The principle is the same as if an eccentric should be mounted loose upon a shaft, and turned to direct the motion of the engine either astern or ahead, instead of using two eccentrics for each valve.

Fig. 285 shows this engine in front elevation, the valve chambers, which are in front of the cylinders, are shown in section.

The reversing gear is also shown in section, and part of the bed plate and valve shaft is broken away to show the main bearing in section and one of the cranks.

The thrust bearing at the extreme left is attached to the bed of the engine and consists of a single adjustable thrust collar.

Fig. 286 shows a side elevation of the high pressure side, showing the gear connection. The centre gear is simply used to transmit the motion from the crank shaft to the valve shaft, and to take up wear by moving it towards the other two gears, all of which are twist gears, to insure quiet and easy running.

The high pressure cylinder and valve chest are shown in section, to expose the piston and valve. The dimensions of this engine are: cylinder, 3.5″ x 5.3″ x 8.5″; stroke, 6″; number of revolutions, 550 per minute; steam pressure, 150 lbs.; horse power, 50. The floor space required, including thrust bearing, is 34″ x 15″, which is 10.2 square

THE MARINE ENGINE.

inches per horse power. The height above engine room floor, which is 1⅛ inch above centre of crank shaft, is 27 inches.

The reversing gear is a very important part of the marine engine. Some engines may run for weeks without being reversed or even stopped, but whenever reversing is required it has to be done quickly.

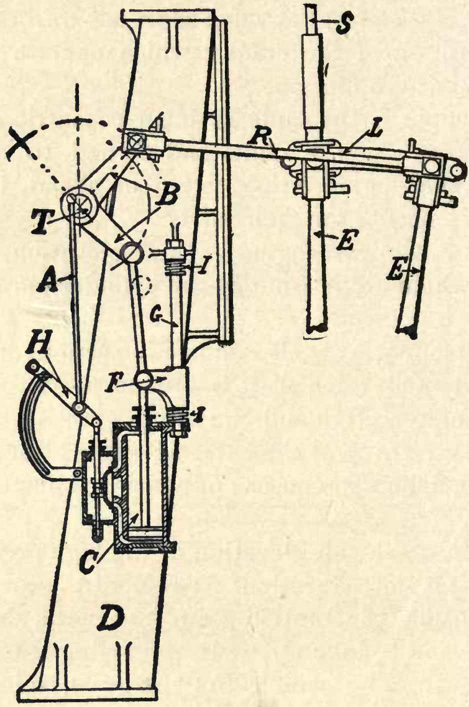

Fig. 287. STEAM REVERSING GEAR.

The Stephenson link motion consists of two eccentrics, with their respective straps and rods, connected to a curved link *L*, Fig. 287, by means of which either of the eccentrics can be made operative upon the valve stem *S*, one of the eccentric rods *E E* can be seen "thrown in."

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Several applications of the Stephenson link motion can be seen in Figs. 271, 278, 280 and 281. Other reversing gears are illustrated and described on pages 409, 410 and 412, and Figs. 282, 283, 284 and 285.

The reversing gear is operated in various ways, in smaller engines by a lever, as in Figs. 278, 281, 284 and 285, and in medium and larger sizes by means of a worm gear and hand wheel, as in Figs. 271 and 283, or by gear connection. In very large engines this method of reversing would require so much intermediate gearing that the reversing would be too slow an operation for the safety of the ship, and to overcome this various methods have been devised to operate the reversing gear by steam power.

A very largely used type of steam reversing gear is shown in Fig. 287, attached to the column *D* of a large compound engine, to operate a Stephenson link motion. The reach rod *R* connects the link *L* to the bell crank *B* upon the tumbling shaft *T* in the ordinary manner; to one arm of the bell crank *B* is pivoted the connecting rod of steam cylinder *C*, the valve of which is operated by means of hand lever *H*, turning about a pin on stay rod *A*. If the lever is pushed downward it will raise the valve, uncovering the lower steam port and admitting steam below the reversing piston, the piston being forced upward by steam pressure will turn bell crank *B*, and by means of reach rod *R* will draw the link over to the left.

But while the bell crank is rotating it also forces the stay rod *A* downward, one end being connected to it, and thus closes the valve, so the link will only move while the hand lever is rotated, and can be moved slowly or fast at will, and be stopped at any desired position by locking the pin upon which it is free to turn near the handle by means of the thumb screw, to the quadrant.

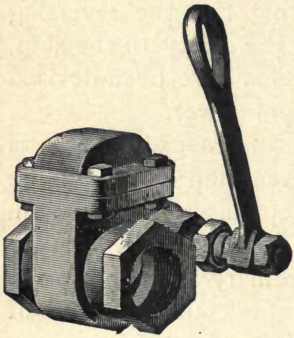
To prevent the piston of the reversing engine from striking the cylinder head, cushion springs *I* are mounted on the

THE MARINE ENGINE.

ends of the guide *G*, against which the crosshead *F* strikes, thus cushioning its motion.

There are several other types of steam reversing gear, some consisting of a small steam engine turning a worm wheel shaft.

Some reversing gears are provided with an oil cylinder, in which a piston operates, the oil acting as a cushion, and also locking the piston in its position. The valve of this cylinder is also operated by lever and bell crank.



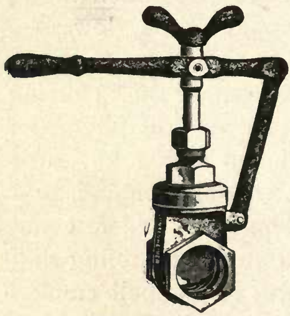


Fig. 288. THROTTLE VALVES. Fig. 289.

The throttle valve of a marine engine is an important adjunct. It must be quick to operate, consequently the ordinary globe valve with the screwed spindle is unsuitable.

In Fig. 288 is shown a throttle valve for small engines. It is operated by a hand lever, the disc sliding on the seat. The valve shown in Fig. 289 is often used for medium sized engines, the construction of it is plainly illustrated. Both these valves are manufactured by the Lunkenheimer Co. of Cincinnati, O.

It is not always necessarily a gate valve, for there are many quick opening devices used for throttling. A largely

NOTE.—The throttle valves of very large engines are operated by steam, as the enormous size of the valve would make hand operation impossible. The mechanism to operate such valves works on the same principle as the steam reversing gear.

THE MARINE ENGINE.

used throttling device, is similar to the air by-pass on boiler furnace doors, which only needs a fraction of a turn to open or close it. A double beat valve is often used in connection with steam operation, on account of being balanced.

In Fig. 290 is illustrated the crank shaft of a triple expansion marine engine. The shaft consists of three sections, each forged in one solid piece with the crank.

All marine engines previously described, are the propelling power of the ship, but there are also engines for handling the cargo, steering, and on some steamers electric light engines, as well as refrigerating machines.

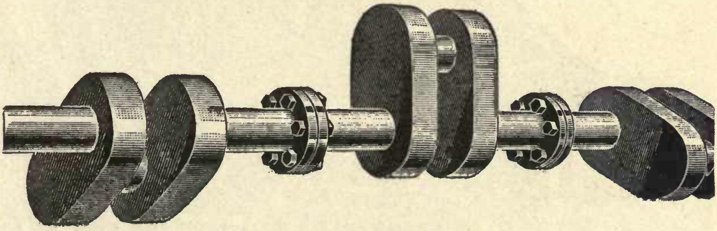


Fig. 290. CRANK SHAFT.

The electric light engines and those used to drive the refrigerating machines, do not differ from the common stationary engines, but as small floor space and lightness of the engines is a very important factor on shipboard, the long stroke, slow speed engine is entirely out of question.

Fig. 291 represents a towing machine; these are used on board of steam barges, and seagoing tugboats. If the boat has a vessel in tow, the hawser is wound partly upon the drum, and if subjected to sudden strains, as in a heavy sea, the drum will commence to revolve, paying out the hawser, and thus releasing it of part of its strain.

The revolving of the drum, by means of bevelgearing, see Fig. 291, further opens the regulating valve, admitting more steam to the cylinders, until the steam pressure upon the pistons balances the strain upon the hawser.

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As soon as the hawser begins to slack up again, the engine will begin to revolve, hauling in the amount of hawser, paid out before.

Fig. 292 shows a steam steering engine. The pilot wheel is connected with the regulating valve of the engine by means of a sprocket chain and screw.

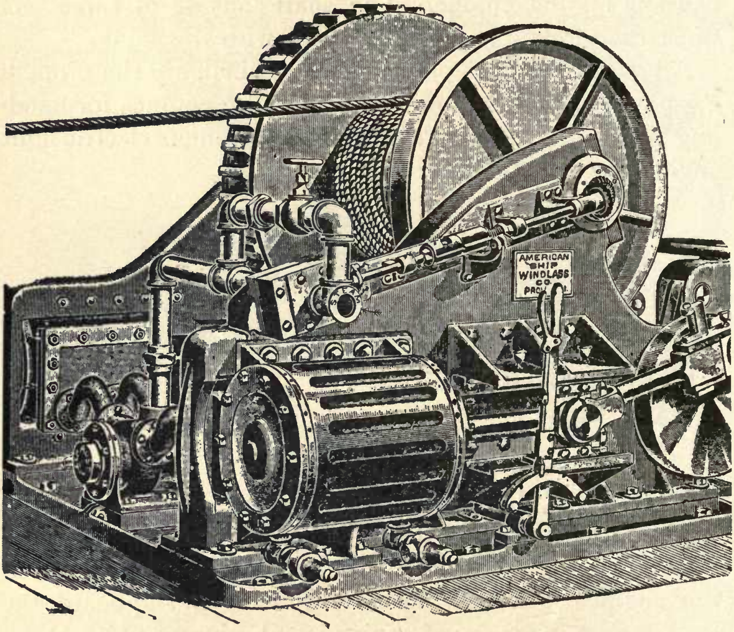

Fig. 291. STEAM TOWING MACHINE.

When the pilot wheel is revolved, the screw, also being revolved, will draw or push the regulating valve, to open a port, which will admit steam to run the engine in the direction necessary to turn the rudder the way desired, but the nut in which the screw works, is attached to the drum shaft, which transmits the motion of the engine by cable or chain to the rudder, and when the drum revolves, thus also turning the nut, the screw, which is attached to the

THE MARINE ENGINE.

stem of the regulating valve is forced in the opposite direction, thus shutting off the steam.

It will be understood, that the engine only revolves, while the wheel is turned, thus the rudder can be turned

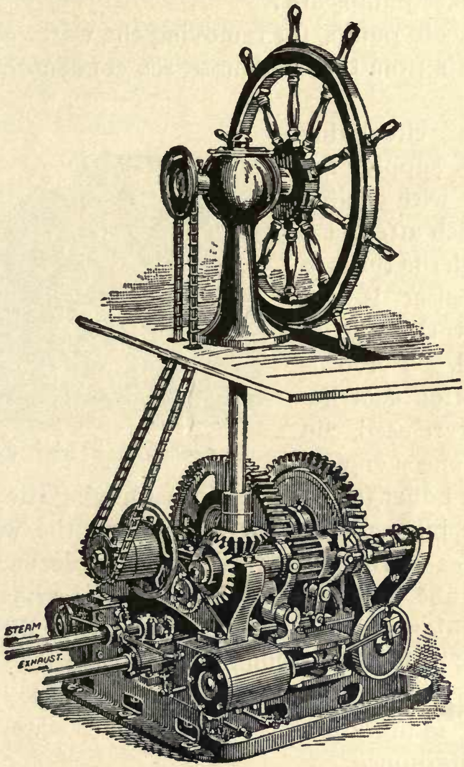

Fig. 292. STEAM STEERING ENGINE.

any desired amount. The action of the steering engine, with its mechanism is somewhat similar to the steam reversing gear.

The gear connection between the pilot wheel and the drum shaft, shown in Fig. 292 is for the purpose of operating the rudder directly by the pilot wheel if desired.

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Steam winches do not differ much from the stationary and portable second motion hoisting engines.

Besides the engines, there are numerous steam pumps on board of ship, each of which serves for a special purpose. These pumps are:

1. The air pump, for removing the water of condensation and air from the condenser, see condensers, page 360. Fig. 253.

2. The circulating pump, to supply the condenser with cooling water, which after passing through the tubes in the condenser is discharged at the side of the vessel. For this purpose often centrifugal pumps are used, run by a high speed engine.

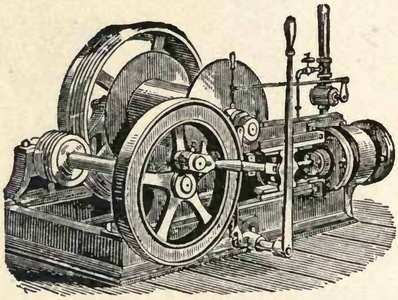


Fig. 293. STEAM WINCH.

3. The boiler feed pumps, for supplying the boilers.

4. The bilge pumps, for discharging the water, which accumulates in the hold of the vessel, by leakage, through the stern tube, or from pipes, used to cool a hot bearing.

5. The donkey pumps, used to discharge different compartments, if the vessel should spring "aleak."

6. The fire pump, to be used in case of fire.

7. The sanitary pump, which supplies water to the different sanitariums.

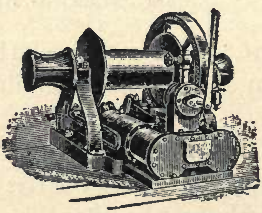


Fig. 294. STEAM WINCH.

THE TURBINIA STEAMSHIP.

The subject of the steam turbine has been elsewhere treated upon, but as applied to marine propulsion the claimed merits of the system may be thus summarized: (1) Greatly increased speed, owing to diminution of weight and smaller steam consumption; (2) increased carrying power of vessel; (3) increased economy in coal consumption; (4) increased facilities for navigating shallow waters; (5) increased stability of vessel; (6) reduced weight of machinery; (7) reduced cost of attendance on machinery; (8) reduced size and weight of screw propellers and shafting; (9) absence of vibration; (10) lowered center of gravity of machinery, and reduced risk in time of war.

The first ship fitted with turbine engines has been the Turbinia. She is 100 ft. in length, 9 ft, beam, 3 ft. draught amidships, and 44½ tons displacement. She has three screw shafts, each directly driven by a compound steam turbine of the parallel flow type. The three turbines are in series, and the steam is expanded—at full power—from a pressure of 170 lb. absolute, at which it reaches the motor, to a pressure of 1 lb. absolute, at which it is condensed.

The shafts are slightly inclined, and each carries three screws, making nine in all. The screws have a diameter of 18 in., and when running at full speed they make 2,200 revolutions per minute. Steam is supplied from a water tube boiler, and the draught is forced by a fan, mounted on a prolongation of the low pressure motor shaft, the advantage of this arrangement being that the draught is increased as the demand for steam increases, and also that the power to drive the fan is obtained directly from the main engines.

Up to the present the maximum mean speed attained has been 32¾ knots per hour as the mean of two consecutive runs on the measured mile; the indicated horse power realized is 2,100, and the consumption of feed water

THE TURBINIA STEAMSHIP.

per indicated horse power hour 14½ lb., and the speed the fastest of any vessel irrespective of size. The weight of the main engines is 3 tons 13 cwt. Total weight of machinery, including turbines and auxiliary engines, condenser and boiler, the propellers and shafts, the tanks and the water in boiler and hot well, 22 tons. Thus nearly 100 horse power is developed per ton of machinery, and nearly 50 horse power per ton of displacement of boat.

ENGINES OF THE S. S. "CAMPANIA."

As an example, Figs. 295 and 296, of modern marine engineering, the engines of the Cunard line steamship "Campania" are given. The dimensions of the "Campania" are as follows: Length over all 620 feet, breadth 65 feet, depth 43 feet, with a draft of 26 feet. The gross tonnage is 13,000.

The ship is fitted with two triple expansion engines of 15,000 horse power each, and by their aid has made a speed of upwards of 27 miles an hour.

The dimensions of the engines are as follows: two high pressure cylinders of 37 inches diameter each, one intermediate 79 inches, and two low pressure 98 inches diameter, with a common stroke of 69 inches. The two high pressure cylinders are mounted on top of the two low pressure cylinders at each end of the engine, the intermediate being in the middle.

The high pressure cylinders have piston valves, and the intermediate and low pressure cylinders have double ported slide valves.

The engines are provided with combined steam and hydraulic starting and reversing gear, and also with an emergency governing gear for automatically stopping the engines in case they exceed a certain speed.

The height from base of the engine to top of cylinders is 47 feet.

Marine Engines.

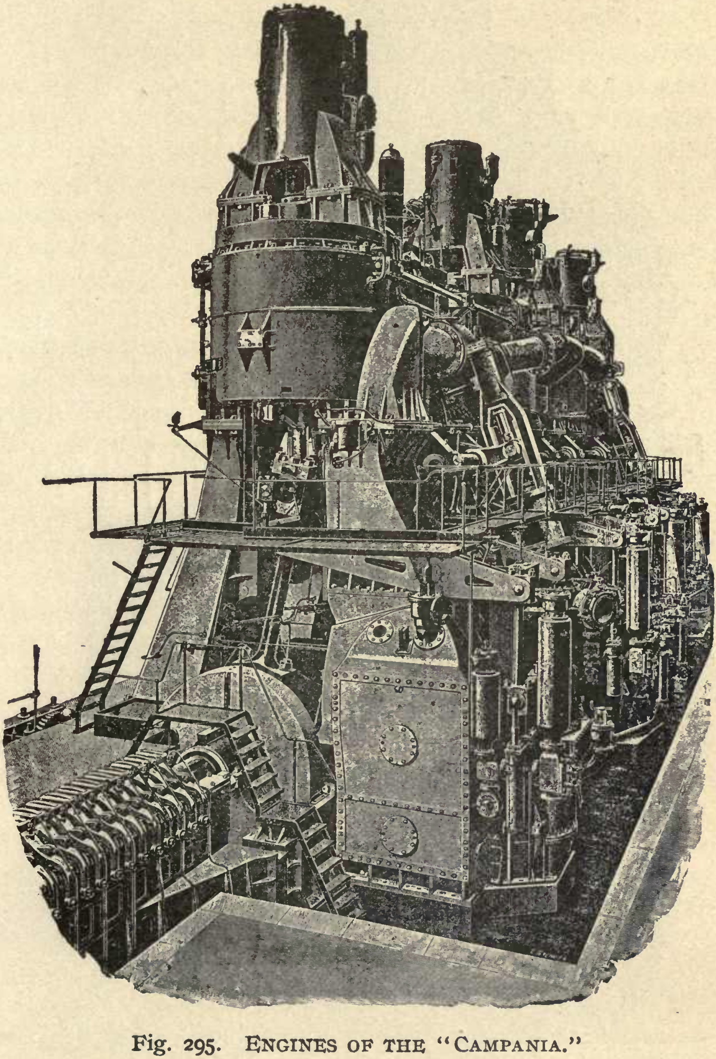


Fig. 295. Engines of the "Campania."
Rear view two engines placed end to end.

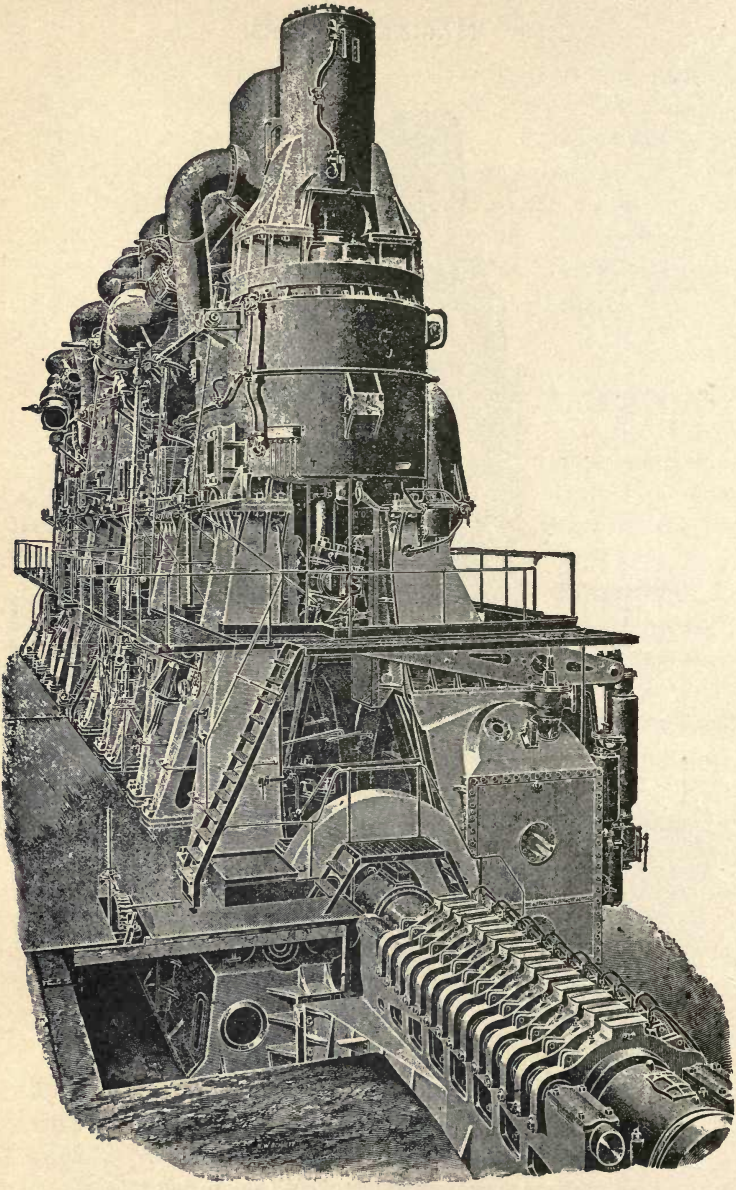


Fig. 296. ENGINES OF THE "CAMPANIA." Front View.

THE ARITHMETIC OF THE STEAM ENGINE.

The figures for the strength of the materials going into the construction of the engine are made with the utmost nicety in the designer's plans, but these are not necessary to be known generally, but, the power developed under varying conditions by an engine is a subject, often, of daily computation and it is of importance that the subject should be carefully studied. There are four factors which determine the power of an engine, viz.:

(*a*) The mean effective pressure on the piston
(*b*) The length of the stroke
(*c*) The area of the piston.
(*d*) The speed.

In other words, an engine of a given diameter and length of stroke, acting under a given mean effective pressure, will develop power in proportion to its speed, and if the speed is doubled, its power will also be doubled, and so to obtain a given power under a given mean effective pressure we need make an engine only half as large if we double its speed.

A horse power is equal to a weight of 33,000 pounds lifted one foot in one minute. Therefore, if an engine is said to have one horse power, it is capable of lifting 33,000 pounds one foot in one minute, or one pound 33,000 feet in a minute. Thus the power of an engine depends upon the amount of weight it can lift in a certain time.

The force, which enables an engine to raise a weight, or work against the frictionless resistance of machinery, is exerted upon the piston, by the pressure of the steam.

NOTE.—Some persons figure without thinking, i. e., they use formulas and rules without understanding the principles upon which they are used. This should not be encouraged, as the results are often dangerously misleading, and sometimes ludicrous, as in the case of the very young "graduate" who figured by an accepted formula that it would require (among other materials) *two tons of putty* to fasten in their sashes a few windows in an office extension for which the superintendent had asked the young "chappie" to make up an estimate.

ARITHMETIC OF THE STEAM ENGINE.

The space, through which this force acts, is the piston speed at which the engine is running.

And for the time is taken a unit, through which a certain amount of piston travel has acted.

Thus the pressure upon the piston, multiplied by the piston speed in a certain time, for which the minute has been accepted, gives the power upon the piston, and dividing this product by 33,000, gives the horse power.

The pressure upon the piston is equal to the steam pressure, multiplied by the piston area, which is the square of piston diameter multiplied by .7854.

The piston speed per minute is equal to the number of revolutions, multiplied by twice the length of the stroke.

The steam pressure, however, varies for different points of the stroke, as has been explained before, thus the mean average pressure must be used, instead of the whole boiler pressure.

Thus the horse power is figured by the following rule:

Multiply the square of the piston diameter by .7854, and the mean effective pressure.

The product multiply by twice the number of revolutions per minute, times the stroke in feet. Divide this product by 33,000, and the result will be the horse power.

For a compound engine, figure the high pressure and low pressure separate by the above rule, and add the results.

If the engine is a single cylinder, single acting engine, the piston stroke should be multiplied by the number of revolutions only, instead of the number of revolutions multiplied by 2, as the piston only makes one power stroke for each revolution.

NOTE.—There is a good deal of difference between a horse power and the power of a horse. The steam engine will, for each horse power, lift 33,000 pounds one foot high each minute of the 24 hours of the day. It is a good horse that can do it day by day for eight of the 24 hours. If the arrangement could be such that the power of the horses exerted on shore could be utilized in propelling one of the steamships from New York to Liverpool, 75,000 instead of 25,000 horses would be required for the purpose, and the "motive power" would weigh 75,000,000 pounds.

ARITHMETIC OF THE STEAM ENGINE.

The following example shows method of computing the power of a 16 x 42 engine, with 84 revolutions per minute and mean average pressure 40 pounds:

Cylinder diameter	= 16 inches.
Length of stroke	= 42 inches.
Number of revolutions,	84
Mean effective pressure by diagram	= 40 pounds.

16		
16		
—		
96	piston area, leaving off	
16	the two last decimals,	201.06
—		40
256		—
.7854		8042.40
—		
1024	which is the total pressure upon the piston	
1280		
2048		
1792		
—		
201.0624		

42 ins. = 3 ft. 6 in. × 2 = 7 ft.

84
7
—
588 feet of piston speed per minute.

8042.4
588
—
643392
643392
402120
—
33000)4728931.2(= 143.3 Horse power.

IFS.

If the "striking points" on the cylinder heads are not known to the engineer in charge then they should be learned and be marked on the guides so that it can be clearly seen at all times that the piston has sufficient clearance at the end of stroke—which clearance, other conditions being favorable, should be kept equal at each end. If clearances have to be made slightly different to regulate travel of rings over counterbore, it is of slight importance.

If engineers desire to get considerable useful information regarding the particular kind of engine they have in charge, and on other things which will be of benefit to them, they should write to the manufacturers of the engine, who nearly all have printed matter describing their engines in every detail, and some of them issue valuable pamphlets giving directions for setting up and operating the engines. In response to a polite request, stating the circumstances, they will receive the matter without cost and will be well repaid by the information they obtain from the same.

If the steam escapes from the plant by leakage, either from the boilers themselves, the piping or stop valves, or by passage through leaking valves and pistons in the engine cylinders, then the consumption of coal is greater

NOTE.—It would well repay the engineer in charge of a power plant, if a thorough examination was made for leakage at regular intervals of say once a month. It is an easy matter to determine the amount of leakage from the boilers and steam piping by observing the fall of water in the gauge glasses when the engine is stopped, and the usual steam pressure maintained. If there is no loss the full height of water should be maintained continuously or with practically no reduction. On the same occasion the valves and pistons of the engines should also be examined for leakage, which can easily be tried by the indicator cock test so far as this applies, and by the time method when the other is unavailable. With systematic attention to these matters loss of steam by leakage could not go unawares for a great length of time, and when found the proper remedy could be applied for its prevention.

A CHAPTER OF "IFS."

than it should be. Waste of steam by leakage may be expected in all steam plants, but it is too apt to be excessive when it should be trifling.

If for any unusual cause "the plant" needs beautifying a very neat effect is produced by bronzing the flanges of fittings after they have been painted black. For a few cents enough bronze powder and sizing can be purchased at most any paint shop—sufficient for "decorating" several hundred fittings.

If an engine is to be overhauled sufficient time should be allowed to make it practically as good as new. To do this very thorough inspection is required of every detail; simply raising a shaft that is known to be low, shimming up rods that are too short from constant keying, tightening piston rings without knowing whether they require it or not, and, in a word, superficially tinkering with this, that, or the other member, is of no benefit and it is only a waste of time to undertake it. It really requires a skilled mechanic to do this work properly, one who is familiar with machine work and knows where to look for defects and the relation that one defect has to the whole machine.

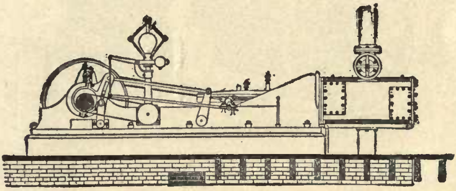
If the cylinder head leaks steam and needs packing anew the thinner the packing used the tighter the joint. Thick packing is more liable to blow out and the additional thickness unnecessarily increases the clearance in the cylinder.

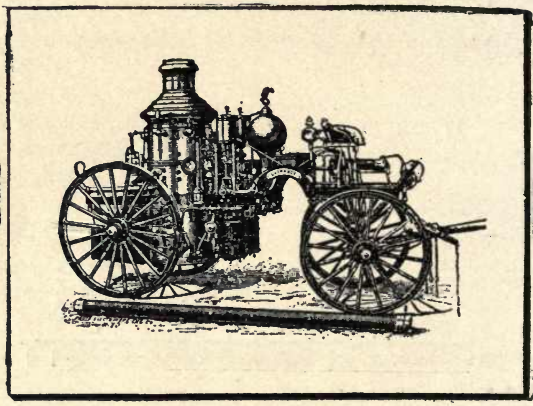
If the stuffing boxes have to be repacked none of the old packing should be used, as it has lost its elasticity and other merits.

If the sight feed glass in the lubricator fills with oil and it is so constructed that it cannot be cleaned out—now, if the oil is removed from the body of the cup and it is filled with water and started up in the usual way, the water will float the oil out without further trouble.

INDEX

To Hawkins' New Catechism of the Steam Engine.





CONTENTS.

The work has been carefully arranged according to the fundamental principles of the art of drawing, each theme being separately treated, and many examples given for practice. A list of the subjects are given below, all of which are plainly described and illustrated.

The practical instructions given in this volume are in helpful language, such as a teacher would use, and it is to be hoped that the book will serve, at least, as a stepping stone toward a thorough mastery of the draughtsman's art.

CONTENTS.

The Dynamo; Conductors and Non-Conductors; Symbols, abbreviations and definitions relating to electricity; Parts of the Dynamo; The Motor; The Care and Management of the Dynamo and Motor.

Electric Lighting; Wiring; The rules and requirements of the National Board of Underwriters in full; Electrical Measurements.

The Electric Railway; Line Work; Instruction and Cautions for Linemen and the Dynamo Room; Storage Batteries; Care and Management of the Street Car Motor; Electro Plating.

The Telephone and Telegraph; The Electric Elevator; Accidents and Emergencies, etc., etc.

The full one-third part of the whole work has been devoted to the explanation and illustrations of the dynamo, and particular directions relating to its care and management;—all the directions are given in the simplest and most kindly way to assist rather than confuse the learner. The names of the various parts of the machine are also given with pictorial illustrations of the same.

In the Catechism no less than 25 full page illustrations have been given of the various dynamo machines made in different parts of the country, and an equal number of part page illustrations.

CONTENTS.

This book embraces information not elsewhere obtainable.

It tells exactly what an engineer will have to go through in getting a license, with much kindly and helpful advice to the applicant for a license.

It contains the annual report of the superintendents of "Steam Boiler Inspection and Certification of Engineers" for the cities of New York and Brooklyn.

It contains various rules, regulations and laws of cities for the examination of boilers and the licensing of engineers.

It contains the laws and regulations of the United States for the examination and grading of all marine engineers.

It gives a short chapter on the "Key to Success" in obtaining knowledge necessary for advancement in engineering. This is very important.

The book gives the underlying principles of steam engineering in plain language, with sample questions and answers likely to be asked by the examiner.

It gives a few plain rules of arithmetic with examples of how to work the problems relating to the safety valve, strength of boilers and horse power of the Steam Engine and Steam Boiler.

The main subjects treated, upon which are given detailed information with questions and answers, are as follows:— The Steam Boiler, Boiler Braces, Incrustation and Scale, Firing of Steam Boilers, Water Circulation in Boilers, Construction and Strength of Boilers, The Steam Engine, Engine and Boiler Fittings, Pumps, The Injector, Electricity and Electric Machines, Steam Heating, Refrigeration, Valve Setting, etc., etc.

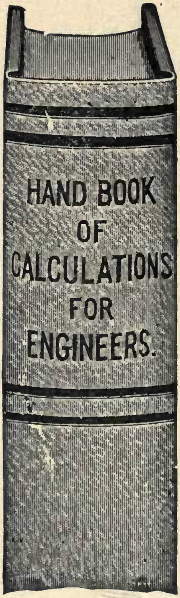
CONTENTS.

Materials; Evaporation; Fire Irons and Tools; Firing of Steam Boilers; Points relating to Fuels; Foaming; Chapter of Don'ts; Full descriptions of the Locomotive, Upright, Water Tube, Horizontal, and Marine Steam Boilers; Parts of a Boiler; Various Specifications for Construction of a Boiler; Riveting; Bracing; Various Repairs; Grate Bars; Boiler Cleaners; Boiler Scales; Boiler Tests; Scumming Chemical Terms; Inspection of Boilers; Mechanical Stokers; Pumping Machinery; Feed Water Heaters; Steam Heating; Plumbing; Safety Valve Rules.

And many hundreds of other valuable pointers for Steam Users, Superintendents, Engineers, etc.

No Engineer, Fireman or Steam User can afford to be without this valuable book, as it contains the pith and vital "points" of economical and safe steam production.

The plan followed in this work is the same as that so generally approved in "Calculations", it proceeds from the most simple rules and maxims to the highest problems; it is both a book of instruction and reference. The carefully prepared Index contains nearly one thousand references, thus making it almost a dictionary of terms.



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CONTENTS.

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