Gas Engine Construction

A PRACTICAL TREATISE DESCRIBING THE THEORY AND PRINCIPLES OF THE ACTION OF GAS ENGINES OF VARIOUS TYPES

AND THE

DESIGN AND CONSTRUCTION

OF A HALF HORSE POWER

GAS ENGINE

WITH ILLUSTRATIONS OF THE WORK IN ACTUAL PROGRESS, TOGETHER WITH DIMENSIONED WORKING DRAWINGS GIVING CLEARLY THE SIZES OF THE VARIOUS DETAILS

FOR THE STUDENT,
THE SCIENTIFIC INVESTIGATOR
AND THE AMATEUR MECHANIC

BY

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PREFACE.

The use of the gas engine as a convenient and reliable source of power is rapidly extending, and the present widespread interest in horseless vehicles is bringing the small gas engine into special prominence as a means to their propulsion.

There are many good books on the gas engine, its theory, design, and various forms. There are books on various mechanical processes, turning, planing, filing, etc.; books, too, on how to make model boats, engines, locomotives and a host of mechanical toys, but no really practical book telling how to make one good machine and to make it well. It is with the above points in view that the authors have endeavored to give the amateur in this book: first, a broad and thorough knowledge of the principles of various forms of gas engines; second, a full and concise description of the making of a regular gas engine by practical shop methods, avoiding the makeshifts and bungling so prevalent in the toy machine books; third, a set of modified rules for designing similar engines, followed by a guide list of books and periodicals useful to the student.

In preparing this work for the amateur the authors have departed somewhat from the conventional method so long in vogue, of illustrating the book with a few pen drawings and then calling on the reader's imagination to spread these drawings over a long and minute specification of the necessary procedure.

We felt that to give drawings of the different parts and follow this with a lengthy description of each process was not the best method to employ in dealing with the construction of this engine.

Photographs were therefore taken of each important operation as it was performed in building the original engine, and cuts were made directly from these photos.

As must be supposed some of the pictures were made under very unfavorable circumstances, with poor light, etc., but it was necessary to make them at that particular time or not at all. We think this mode of illustration will be appreciated by the amateur builder.

The great convenience of the angle plate as a lathe accessory is too little known, and so we have dwelt upon its uses more extensively than would be necessary in a book addressed only to expert machinists.

To any who may think it is necessary to have a complete machine shop at one's disposal in order to construct one of these engines, we need only say that this original engine was built, and all the photos of the work made at Schroon Lake, in the heart of the Adirondacks.

We are indebted for the originals of the rules of designing to the Treatise on the Gas Engine published by the Colliery Engineer Co., and also to the excellent little Gas Engine Handbook, by E. W. Roberts.

The authors will feel well repaid for the year's work spent on this book if it advances the standard of amateur workmanship and aids the reader and student to find in the construction of the model gas engine a useful, practical and pleasant mechanical exercise.

HENRY V. A. PARSELL, JR.
ARTHUR J. WEED.

June, 1900.

PREFACE TO THE SECOND EDITION.

The authors gladly take the opportunity here afforded to thank their readers for the many kind words of appreciation of this work which they have sent us from time to time. We thank them also for their pertinent suggestions, which are always welcome.

In this new edition we have embodied the good things that these suggestions and our experience have shown advisable, and also have corrected the few errors which had crept in undiscovered until the book was published.

The principal additions are those showing the vertical adaptation of this type of construction, the making of cast iron piston rings and the new electric igniter. We are indebted to the kindness of Mr. E. J. Stoddard, the well-known gas engine expert, for the formula for weight of fly-wheel which we give in this edition.

With best wishes of success to our amateur friends, we remain,

Very cordially,

HENRY V. A. PARSELL,
ARTHUR J. WEED.

Dedicated

TO

HENRY V. PARSELL, Sr.

WHOSE KINDNESS AND GENEROSITY

HAVE BEEN OF GREAT ASSISTANCE TO THE AUTHORS

IN THE PREPARATION OF THIS WORK

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CHAPTER I.

HOW THE GAS ENGINE WORKS.

Every one knows that when a metal rod is heated it becomes longer—as a matter of fact, it also gets a little broader and a little thicker.

So it ensues that an iron bar is larger when warm than when cold. But, notwithstanding its increase in size, it will be found on trial that it weighs just the same hot as when cold. Hence comes the paradox that an iron bar of a certain size will weigh the same as one a little smaller, the key to this lying in their difference of temperature. Now, to explain this increase in size without increase in weight scientists have found that the heat which anything has is due to the vibrating motion of the tiny atoms of which it is composed; when cold the vibrations are somewhat less than when hot, so the hotter the body is the more room the atoms will take up by their movements and the larger it will be to us, our sense being far from delicate enough to detect anything more than the increase in size of the entire collection of atoms, that is, of the whole body.

Now air or any gas expands when heated very much the same as the metal explained above, but, not being a solid body, we only consider the increase in volume of a gas, and not its increase in length, breadth or thickness.

To get work done by the expansion of air or any gas we must make it push on something; so, to do this, we put the air in a cylinder which is closed at one end and provided with a sliding piston at the other. The next thing is to get heat into the air; an obvious way is to put fire around the closed end of the cylinder; the flame will heat the cylinder, which, in its turn, will heat the air, and the hotter the air gets the harder will its vibrating atoms beat against the inside of the cylinder, until there is pressure enough to overcome the friction of the piston and the pressure of the atmosphere, and the piston will move toward the open end of the cylinder. As this is done the pressure will become less and less in the cylinder, for the same amount of air is inside and at the same heat, but it now has more room. So now we have arrived at a point where the pressure of the hot air is so low that it will not push the piston along any farther, and we want to get the piston back and begin over again. This might be done by taking away the fire and running cold water over the end of the cylinder, thus cooling the air, which would contract to its original volume, and the pressure of the outside air would force the piston back.

The kind of engines known as "hot-air" or "caloric" engines are worked somewhat on this principle, only, instead of applying fire and cold water alternately to the end of the cylinder they are arranged at each end of a closed cylinder, to which the cylinder containing the power piston is connected by a short tube of ample diameter.

Fig. 1 shows such an arrangement. *A* is the "working cylinder" having under it the flame *F*, and at the upper end the water-jacket *E*, which consists of a hollow space around the cylinder filled with running water supplied by a pump worked from the beam, but not shown in the figure. *B* is the power cylinder, with its piston *D* connected to the crank *H*. Operated from this same crank through the beam *G*, and connecting rods *J* and *K*, is the plunger *C*. This plunger moves freely up and down in the cylinder *A*, and its

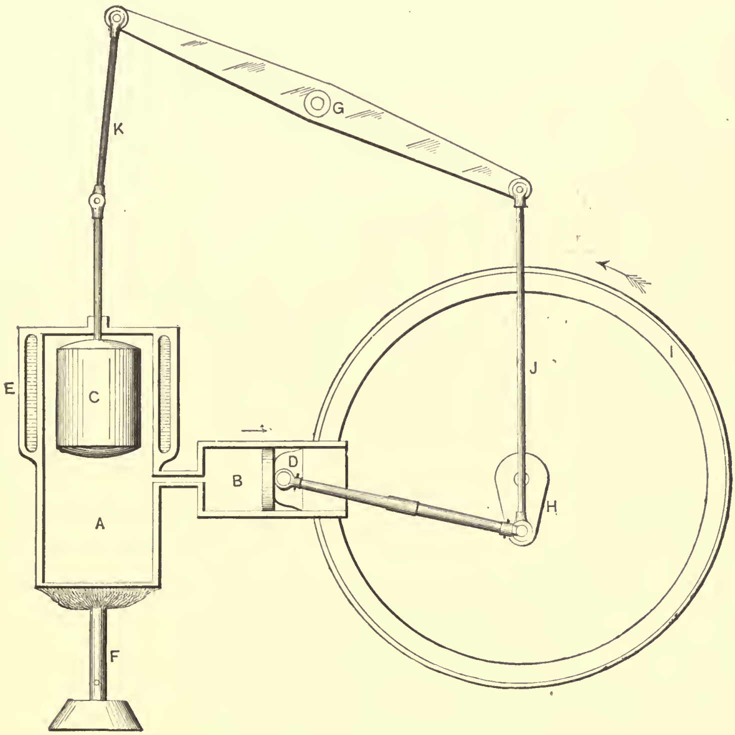


FIG. 1.—HOT AIR ENGINE.

use is to cause the air in *A* and *B* to be alternately heated and cooled so as to work the engine. A description of the action during one revolution will make things clear.

As will be seen, the plunger *C* is at the top of its stroke; this keeps the enclosed air down in the hot end of the cylinder, and as it expands it pushes the piston *D* outward, as shown by the arrow above cylinder *B*. When *D* gets near the outer end of its stroke the crank *H* will be rising and, consequently, the plunger *C* will move down, forcing the hot air up to the part of the cylinder kept cool by the water-jacket. At this time the piston *D* is beginning the inward stroke (motion of the parts being kept up by the fly-wheel *I*), and the air in the upper part of *A* gives up its heat to the running water and, by cooling, contracts. The pressure in *B* being thus diminished, the piston *D* is forced in by the pressure of the outer atmosphere. When at the inner end of the stroke of *D*, the plunger *C* will rise and shift the air down to the hot end of the cylinder so as to expand it again, and thus a continuous action of the machine is maintained.

These caloric engines, while running very nicely, are too cumbrous when used for large powers and would require a large amount of water to cool the air. Their principal use is for pumping water, and thus by their own work make available the water which otherwise might be wasted.

Now, the simplest of ways to bring heat to air in a cylinder is to mix in with the air a little gas or oil vapor, just enough being put in to be completely burned by the amount of air in the cylinder, and then start the combustion of the mixture by a spark. Instantly the whole charge in the cylinder is filled with a blaze and the pressure will rise from that of the atmosphere, 15 pounds per square inch, to 75 or 80 pounds per square inch, and the piston will move outward with great force. This sudden rise of pressure is due to the rapid heating of the whole body of air by the burning of the inflammable gas mixed with it. There is, in fact, a veritable explosion, but since, in an actual engine, the piston travels out under control of the crank and fly-wheel, the explosion is not perceived except as a strong, rapid push on the piston. This, then, is the principle of action of a gas engine and, from the nature of the motive force, gives rise to the names "explosion engine" and "internal combustion engine" by which it is also frequently called. The second name, "internal combustion engine," is the most general, and scientifically correct, as it refers to any engine driven by gas, gasoline or petroleum mixed with air in a cylinder and there consumed.

Historically considered, the internal combustion engine may be said to have originated with the invention of gunpowder, for the action in every rifle or cannon is that of a rapid chemical combination or combustion which evolves a great quantity of gaseous matter, the confinement of which in the gun barrel produces a great pressure on the projectile —or freely moving piston—and propels it with a high velocity.

A gunpowder engine was built by the Abbé de Hautefeuille in 1678. It was the same in principle as modern gas engines, except that no air inlet was needed, the ignition of the powder setting free the oxygen in its composition in a quantity sufficient for its own combustion, the same as in the case of the gun cited above.

Over a hundred years elapsed before the first actual gas engine was patented in England by John Barber, in 1791. In France the first patents were issued to Philippe Lebon in 1799 and 1801. His engine was very ingenious and included a frictional electric machine to ignite the explosive charge. The assassination of Lebon, in 1804, put an end to the perfecting of his invention.

In 1833 a double acting engine having pumps to separately compress the gas and air and inject them into the power cylinder was brought out by Wright, but the rapid introduction of steam power at the same period diverted public attention from this motor.

Various patents were taken out between this time and

1860, when the Lenoir engine appeared and created considerable enthusiasm for the gas engine by its smooth and regular operation. It was a double-acting engine of the first class as described in the next chapter. Its lack of economy, as compared with steam, soon caused its disappearance from extended service. The first of the modern types of highly efficient engines was brought out by Otto in 1878. This marks the practical introduction of the principle which has given rise to what is now a large industry, with almost countless modifications of details as designed by the many inventors who have been engaged during the past twenty years in this work.

Chapter II.

THE FOUR CLASSES OF ENGINES.

THE CROWN GAS PUMP. THE BRAYTON ENGINE. THE OTTO CYCLE. GOVERNING OF THE OTTO ENGINE. TWO, THREE AND FOUR CYLINDER ENGINES. DOUBLE ACTING ONE AND TWO CYLINDER ENGINES. TWO CYCLE ENGINES OF ONE AND TWO CYLINDERS. THE DIESEL ENGINE. DESCRIPTION OF THE MODEL ENGINE.

CHAPTER II.

THE FOUR CLASSES OF ENGINES.

The modes of utilizing the principle of explosion can be conveniently divided into four classes, which are here given with explanations of their actions.

CLASS I. The piston, traveling outward, see Fig. 2,

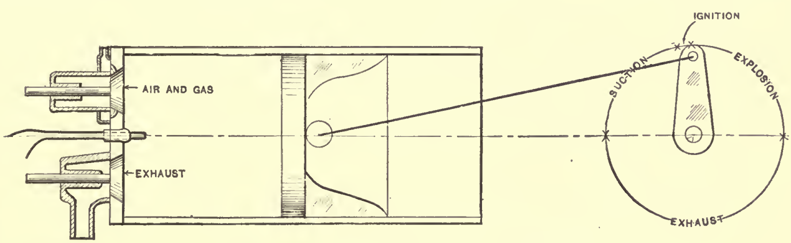


FIG. 2.—DIAGRAM OF CLASS I.

draws in a mixed charge of gas and air until it reaches about half of its full stroke. At this point the inlet valves are closed, and a spark is used to ignite the mixture whose combustion and expansion now drive the piston forcibly out to the end of its stroke. The exhaust valve then opens, and the products of combustion pass out during the entire return stroke.

It is obvious, that since the volume of the explosive mixture is but half the total contents of the cylinder, and that the force of the explosion acts on the piston during but half a stroke, therefore, this class of engine must be very cumbersome compared with more efficient types. This objection

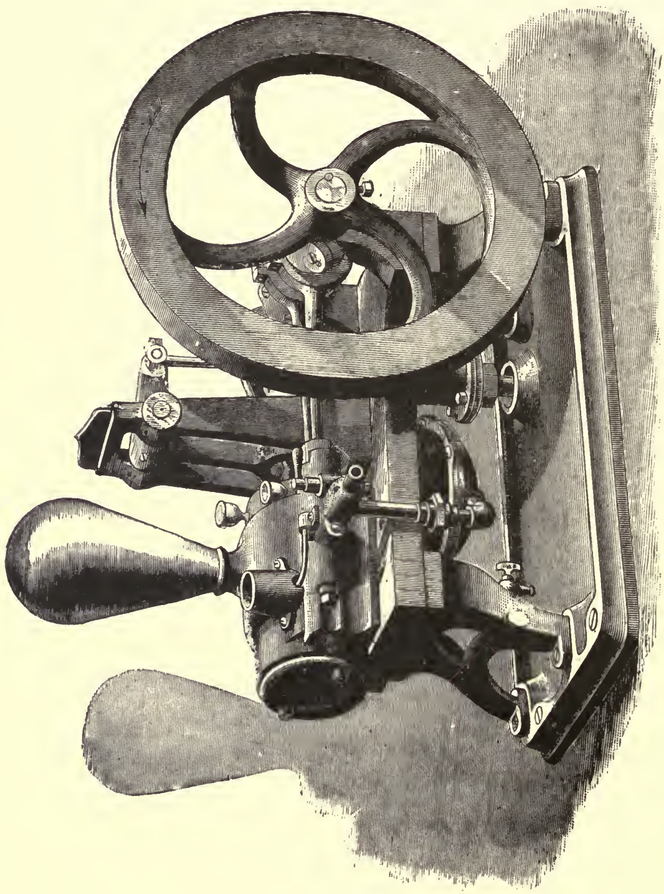


FIG. 3.—ENGINE OF CLASS I.

was met by making the engine double-acting, that is, by using a piston and piston rod like those in a steam-engine, and admitting the mixture at both ends of the cylinder alternately, but even when made in this way the engine used about six times as much gas per horse power as a good modern engine.

Despite the inefficiency of engines of Class 1, their simplicity, when single acting, has continued them in use for small domestic work where the cost of running, being so little, is not considered.

The Crown gas pump, Fig. 3, is a good example of this class. The piston-rod operates the pump piston through the bell crank seen to the right of the air chamber, the pump cylinder is vertical and hangs below the engine bed. The water from the pump is used to keep the cylinder cool by passing through a hollow, annular space cast in it.

The admission and the flame ignition are controlled by two cylindrical valves operated by eccentrics. There is no governor, as the load is always present.

CLASS 2. Two cylinders are used, as shown in the diagram, Fig. 4, one being an air pump *P*, the other the working or power cylinder *C*. The cylinders are both of the same diameter and are connected by an intermediate chamber, the receiver *R*. The stroke of the piston of the air-pump is but half that of the piston of the power cylinder, this ratio being preserved by the positions of the points of attachment of their connecting rods to the working beam *B* with respect to the fulcrum of the beam at *D*.

The operation is as follows:—the air-pump piston, ascending, draws in a charge of gas and air. On its down stroke the charge is forced into the receiver, through which it passes into the cylinder *C* by a valve *V* and a plate of wire gauze *G*. On entering the cylinder the mixture is at once ignited by the small flame *F*, which is maintained by a jet of the mixture, which is allowed to flow through a by-pass around the valve *V*. The expansion of the burning mixture as it flows into *C*, forces out the piston until the end of the stroke is reached, when the exhaust valve opens and the descending piston forces out the burnt gases, the air-pump, at the same time, drawing in a fresh charge.

The object of the plate of wire gauze *G* is to prevent the

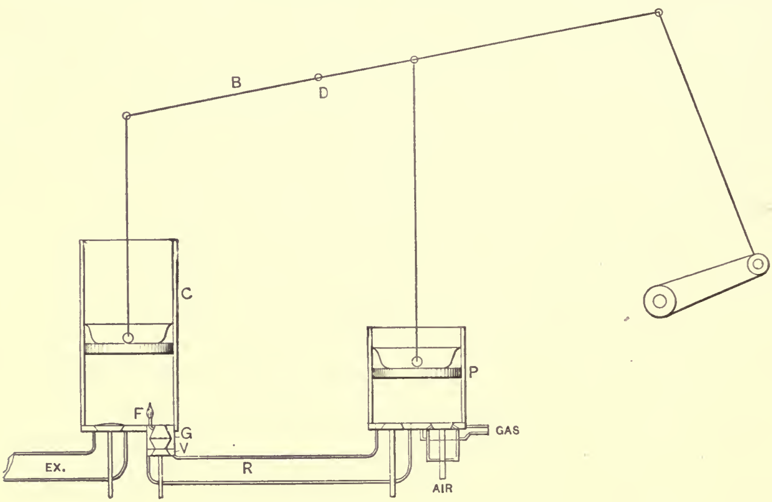


FIG. 4.—DIAGRAM OF CLASS II.

flame in *C* from igniting the inflammable mixture in *R*. This it does in the same way that the gauze in a miner's safety lamp prevents its flame from exploding the dangerous vapors so often present in mines. Engines of this type, though fifty per cent. more efficient than those of Class 1, are not now in use.

CLASS 3. This being the class of engine most largely used, as well as the kind whose construction is the principal subject of this book, we will describe its operation more particularly.

The cylinder and valves, shown in Fig. 5, are about the same as shown for Class 1, but the piston, in drawing in a charge, goes the full length of its stroke and so gets a whole cylinder full of mixture—twice as much as in Class 1. Now the piston moves in and compresses the charge into the rear part of the cylinder, called the combustion chamber, which has a volume equal to about one-third of the volume of the cylinder when the piston is at the outer end of its stroke.

The igniter now operates, while the crank is passing the dead center, and suddenly the pressure rises, reaching perhaps as much as 250 pounds per square inch. The piston

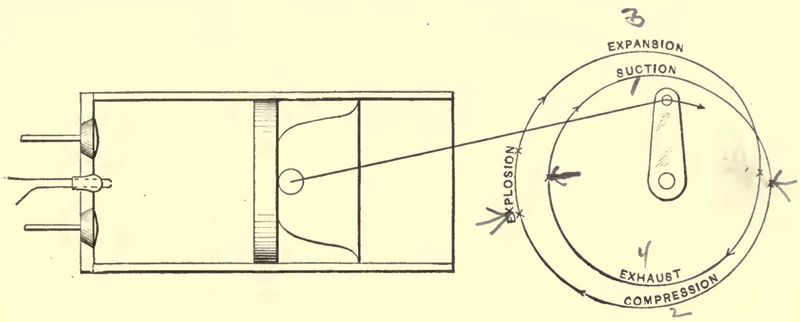


FIG. 5.—DIAGRAM OF CLASS III.

has now started on its forward journey and the gases under pressure push it along, at the same time expanding and losing their pressure. At the outer end of the stroke the pressure will have fallen to about 40 pounds. Now the exhaust valve is opened and the burnt charge passes out during the in-stroke of the piston.

The curves around the crank in Fig. 5 show the action at different parts of the revolution; first—the suction during half a turn; second—compression for another half turn, the ignition now spreads its flame through the mixture; third—the expansion of the hot gases; fourth—their exhaust, beginning just a little before the end of the second out-stroke, so that there will be no back-pressure on the piston during its return.

From the above it will be seen that there is but one impulse—one explosion—to every four strokes of the piston. On this account, engines working in this way are called four-cycle engines.

This cycle of operations was first proposed by a French scientist, Beau de Rochas, in 1870. It was not embodied in a practical machine until Otto built his first compression gas engine in 1876. From this circumstance the cycle camc to be known as the Otto cycle, although the honor of its invention belongs to Beau de Rochas.

The greater efficiency of this class of engine over those of Class 1 is due to several reasons:—

First.—A greater amount of the explosive mixture—the charge—can be drawn into a cylinder of given dimensions, and consequently more power can be obtained from an engine of certain size.

Second —The higher the pressure of the charge at the moment of ignition, the more rapid is the spread of the flame through the mixture, and, therefore, it follows that the explosive pressure is much higher than if there had been no previous compression.

Third.—The area of the cylinder walls which enclose the charge at the moment of its ignition is relatively less than in Class 1, hence the burning gases cannot lose as much heat, and consequently pressure, through the cylinder.

Fourth.—From the above it follows that the average pressure during the power stroke of the piston is much higher, and, therefore, more power can be obtained from the gas.

As an example of this class we will illustrate the Otto gasoline engine with electric igniter. Attached to the massive bed *B*, Fig. 6, is the cylinder *A* surrounded by a water jacket. At the rear of *A* is bolted the combustion chamber *C*, also water-jacketed by a continuation of that on the cylinder.

The casting *C* carries the mixing chamber *D*, exhaust

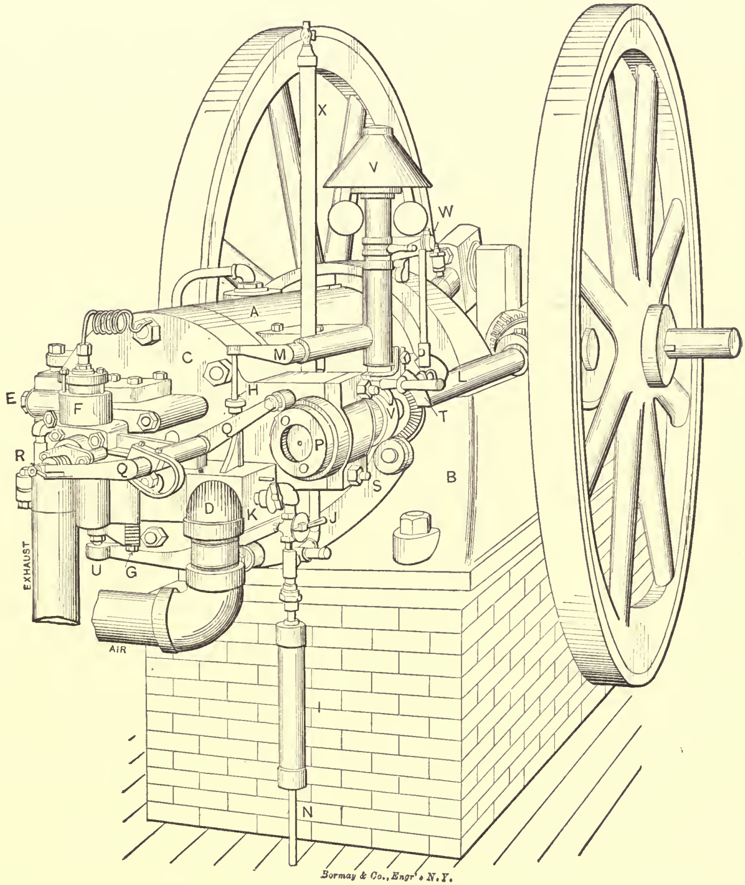


FIG. 6.—SINGLE CYLINDER, SINGLE ACTING, FOUR CYCLE GASOLINE ENGINE OF CLASS III.

valve and casing *E*, and the igniter *F*, together with the levers, springs, etc., which operate them. The shaft at the side of the cylinder is geared so as to make one revolution while the crank shaft makes two, thus operating the valves at the proper times during the cycle.

The air taken into the cylinder is first warmed by drawing it through a chamber attached to the exhaust muffler. This warming is to assist the air in vaporizing the gasoline and mingling with it to form a combustible mixture. The warm air then passes through the horizontal pipe marked "*AIR*" to the chamber *D*. At this same time the liquid gasoline, which is supplied by a small tank through the pipe *N* and filter *I*, and controlled by the cock *J* and needle valve *K*, is admitted to *D* by the valve stem *H* being depressed by the arm *M* moved by a cam at *L*.

The entering gasoline is sprayed by the needle valve *K* against the perforated metal plate *O* shown in Fig. 7, and is at once vaporized and carried off into the cylinder through the inlet valve *G*, which lifts automatically under the powerful suction of the outgoing piston.

At the outer end of the stroke of the piston, as it comes to rest, the valves *G* and *H* are closed by their springs, so that during the compression stroke there can be no escape of the charge from the cylinder.

When the inner dead center is reached and the compression is at its highest, then a sudden incline on the cam *P*, Fig. 6, lifts one end of arm *Q*, depressing its other end and thereby giving a slight rotation to the shaft *R*, and causing the electrode on its inner end, see Fig. 7, to jump out of contact with the fixed electrode *F*, and thus producing a spark by breaking a circuit. The electrodes remain separated until near the close of the compression stroke, when the cam brings them gently into contact, which is made firm by the springs attached to and acting on the lever *Q*, Fig. 6.

When the working stroke of the piston is about finished, the cam *V*, Fig. 6, depresses the lever *S*, whose other end *U* rises and lifts the exhaust valve during the second in-stroke of the piston and allows the burnt charge to pass out down the pipe shown.

In order that the starting of the engine may be made easy, the handle *T* is moved to the right; this throws in an aux-

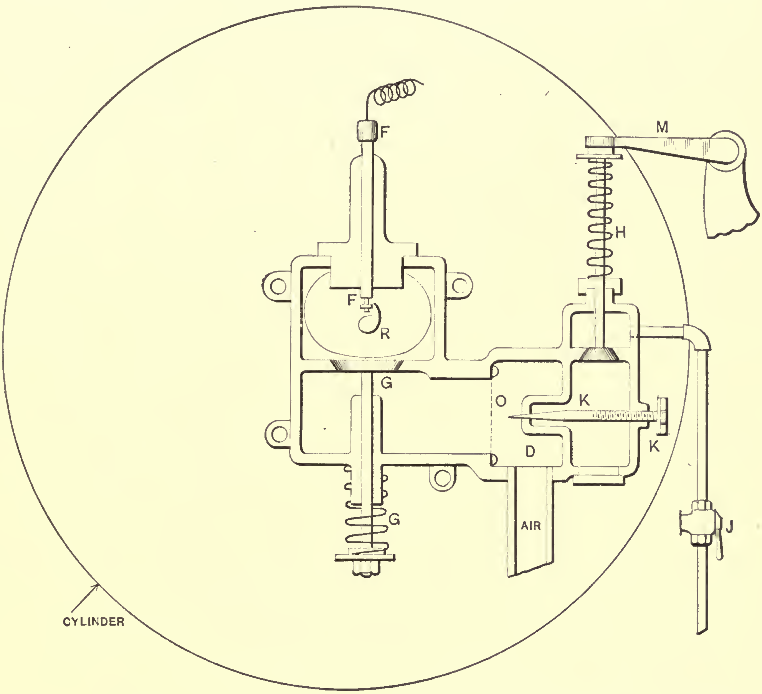


FIG. 7.—INLET VALVES OF GASOLINE ENGINE.

iliary cam which opens the exhaust valve during a part of the compression stroke, thus allowing a portion of the charge to escape, so that it is not so hard to turn the wheels.

The governor *V*, through the medium of the L-shaped lever *W*, Fig. 8, moves the roller *L*, which slides freely on the stud *N*, along the cylinder *C* on the side shaft. This cylinder has a projecting cam *D*, which, when the governor is at its mid-position, comes under the roller *L* and thereby rotates the rock-shaft *M* and admits the gasoline as above described.

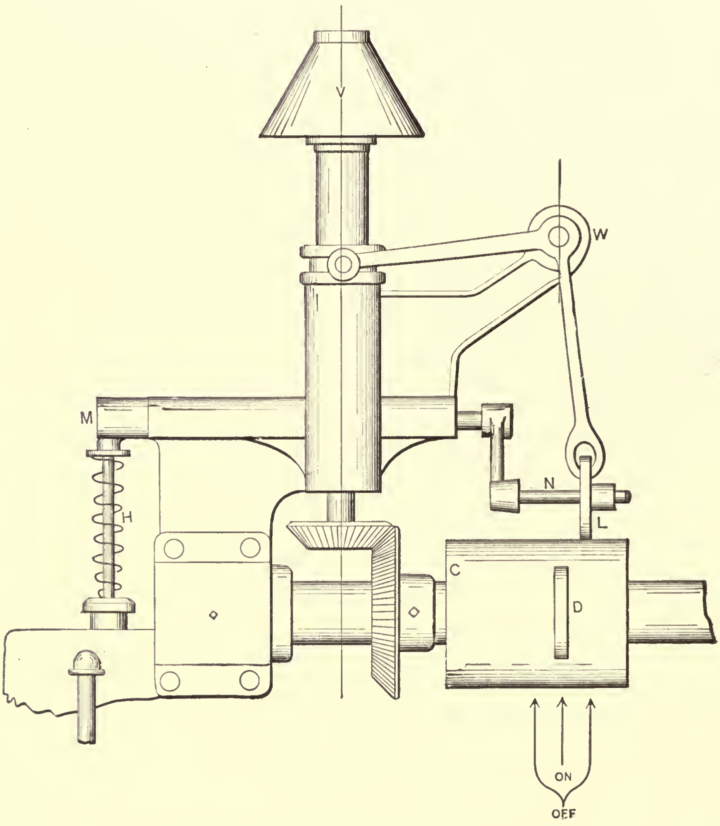


FIG. 8.—OTTO TYPE OF GOVERNOR.

When the speed of the engine rises, on loads less than the full capacity of the engine, the governor moves the roller to the left, so that it is not lifted by the cam *D*, and the charge of fuel is thereby omitted.

When the engine is stopped, either from lack of fuel or too heavy an overload, the roller *L* is carried to the right of cam *D*, so that, should the oil cock *J* (Fig. 6) be carelessly left open, there could be no escape of gasoline into the air supply pipe.

The fact that there is but one explosion to every two

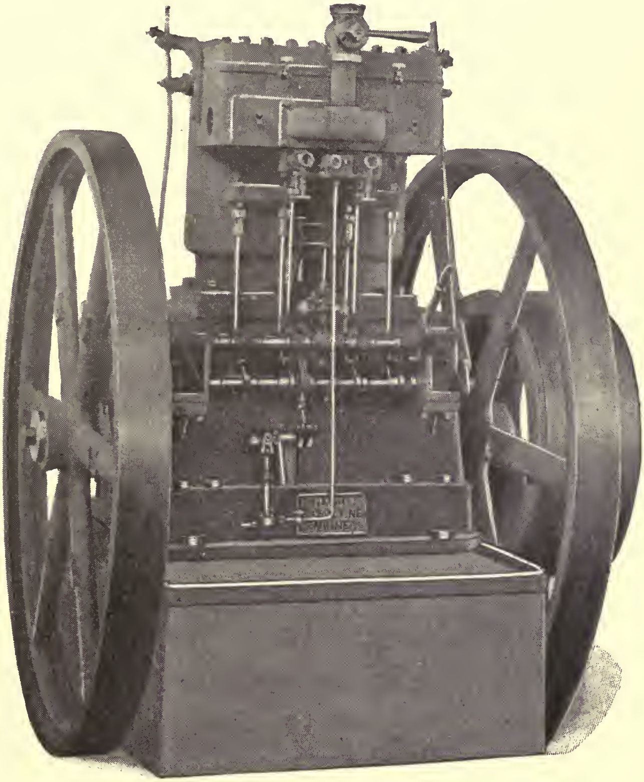


FIG. 9.—TWO CYLINDER, SINGLE ACTING, FOUR CYCLE ENGINE OF CLASS III.

revolutions has led to many combinations, more or less ingenious and practicable, whereby the force exerted by the engine may be rendered more uniform, like that of a good steam engine.

An obvious method is to multiply the number of cylin-

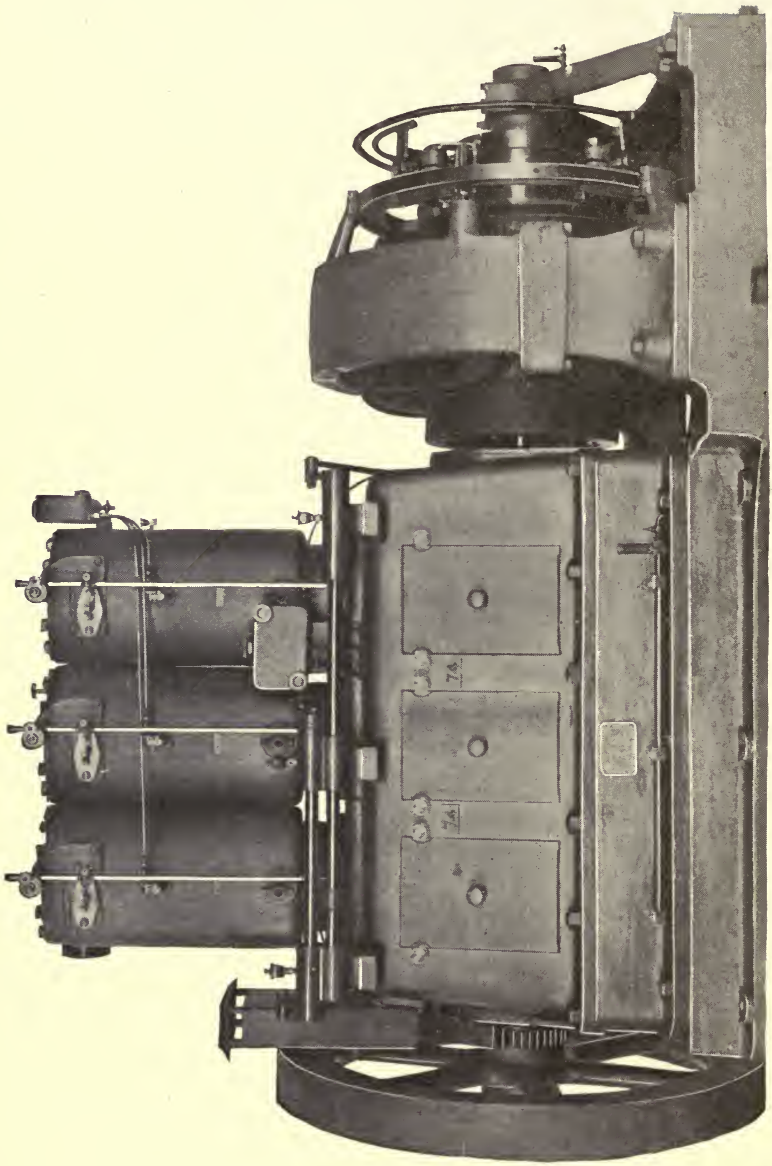


Fig. 10.—Three Cylinder, Single Acting, Four Cycle Engine of Class III, Direct Connected to Generator.

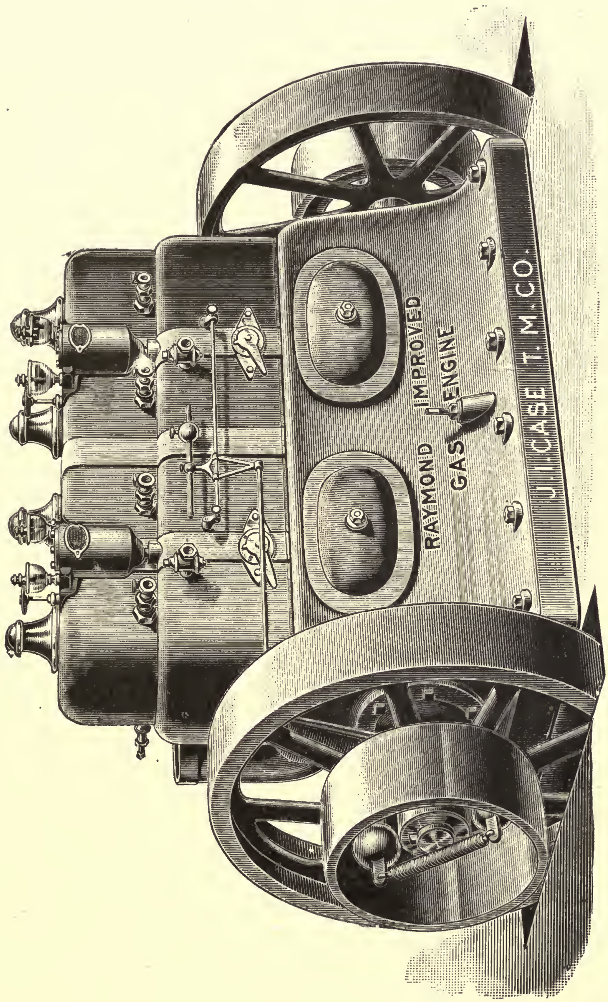


Fig. 11.—Four Cylinder, Single Acting, Four Cycle Engine of Class III.

ders. Two cylinders working alternately will give one impulse to each revolution of the shaft. A modern engine of this kind is shown in Fig. 9.

The next step, the use of three cylinders, gives one impulse to every two-thirds of a revolution. This type is illustrated in Fig. 10.

The use of four cylinders, shown in Fig. 11, is as far as this type of stationary engine goes, as it gives two impulses

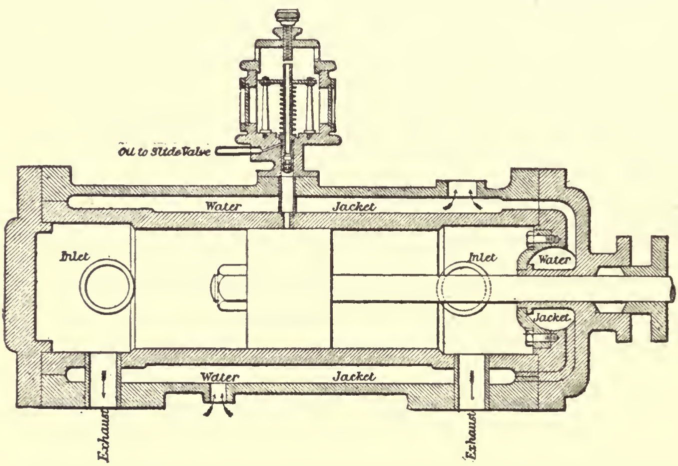


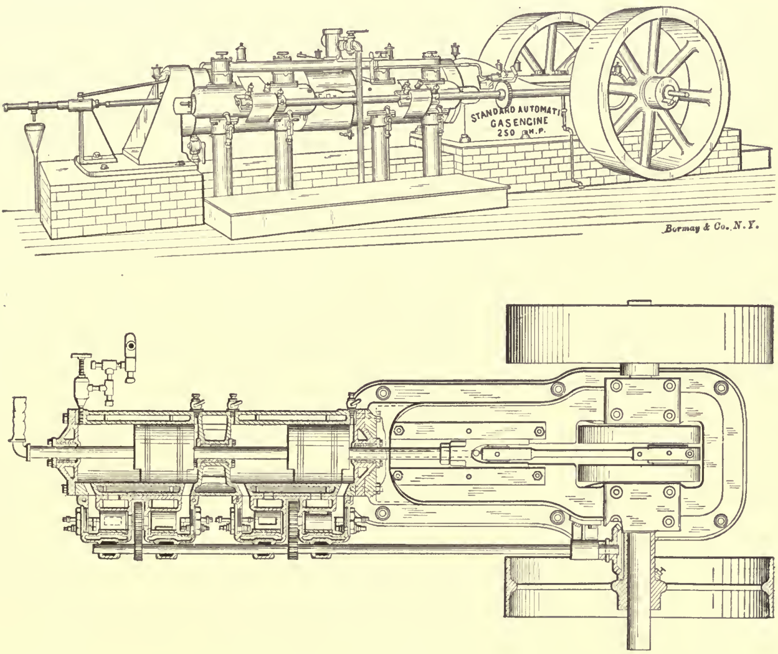
FIG. 12.—DIAGRAM OF DOUBLE ACTING, FOUR CYCLE CYLINDER OF CLASS III.

to each revolution, but experimental engines have been built for automobiles with more than four cylinders.

In all the above forms the cylinders are "single acting," that is, they force the piston in but one direction by the action of the explosion. Now, if we make each cylinder double acting by closing both ends, and drive the piston both forward and backward by explosions alternately in opposite ends of the cylinder, we will accomplish in the one cylinder what before it took two to do, and the engine may thus be made more simple.

A sectional view of a single cylinder engine of this type is shown in Fig. 12.

It will be noticed that the water-jacket is continued into a chamber in the cylinder head, surrounding the piston rod, so as to protect the packing around the rod from the heat of the explosions.



FIGS. 13 AND 14.—TWO CYLINDER, DOUBLE ACTING, FOUR CYCLE ENGINE OF CLASS III.

Figs. 13 and 14 show a double acting double cylinder tandem engine. In this the pistons and rod are hollow and have a water circulation through them.

In designing multiple cylinder and other combined forms, there are many details of apportioning the explosions among the cylinders and of balancing the pistons, which we cannot, in a work of this kind, enter into.

An important type of engines of this third class is known as the "two-cycle."

In two-cycle engines the front end of the cylinder is prolonged into a closed chamber containing the connecting rod and crank. To illustrate its action we will select a simple form shown in Fig. 15.

On the up stroke of the piston *A*, gas and air are drawn through the valve *D* into the crank chamber *O*. The down stroke of the piston now compresses this mixture until at the close of the down stroke the upper end of the piston

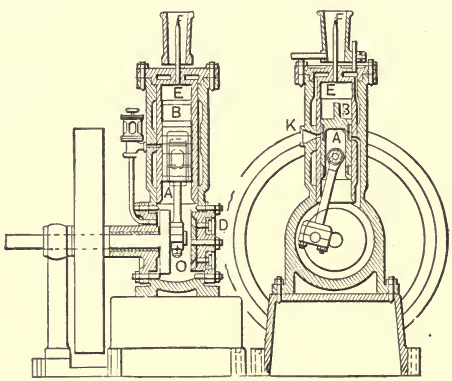


FIG. 15.—DIAGRAM OF SINGLE CYLINDER, TWO CYCLE ENGINE OF CLASS III.

uncovers a passage (seen at the extreme right) leading from the crank chamber *O* into the cylinder *E*. The compressed mixture rushes up this passage, strikes the plate *B*, which is cast on the piston, is deflected by *B* to the upper part of the cylinder and forces the residue of the previous combustion out through the exhaust port *K*, which opens opposite the charge inlet passage.

The up stroke of the piston now compresses the charge in *E* and at the same time draws in a fresh charge to the crank chamber.

At the upper end of the stroke ignition takes place and the working stroke ensues, compressing the new charge in the lower chamber ready for admission as soon as the piston opens the exhaust and inlet ports again.

In this way we get all the advantages of the compression used in the cycle of Beau de Rochas, and have an impulse at every revolution.

The name "two cycle" is derived from the fact that the cycle of operations (admission, compression, explosion with expansion and exhaust) is completed in two strokes of the piston.

The absence of cam-actuated valves will be remarked as giving extreme simplicity to this type.

In Fig. 16 is shown a motor of this type. The only external reciprocating part is the vertical rod at the right, which operates the igniter. On the passage connecting the crank chamber and cylinder is seen a valve whereby the speed can be varied by hand.

When required, this valve can be operated by a governor, so as to control the speed of the engine automatically.

Like the four-cycle type, this form of engine can also be arranged in a large variety of combinations. We will show but a single example, in Fig. 17. Here the cranks and connecting rods are open, but cylinder heads, piston rods and cross-heads are provided, so that the admission and compression take place in the lower end of the cylinder, the ignition and expansion following in the upper end as before.

This particular model, then, gives two impulses to each revolution and accomplishes with its two cylinders what the four-cycle form shown in Fig. 11, on p. 31, does with four.

Class 4.—This is represented at present by the motor of but a single inventor, Herr Rudolph Diesel.

A sectional cut is shown in Fig. 18, in which *A* is the cylinder, *B* the piston, and *C* the compression space, which is about 6 or 7 per cent. of the cylinder volume when the piston is at the lower end of its stroke.

Instead of the trunk piston so common in gas engines, there is a shorter piston provided with the piston-rod *D*,

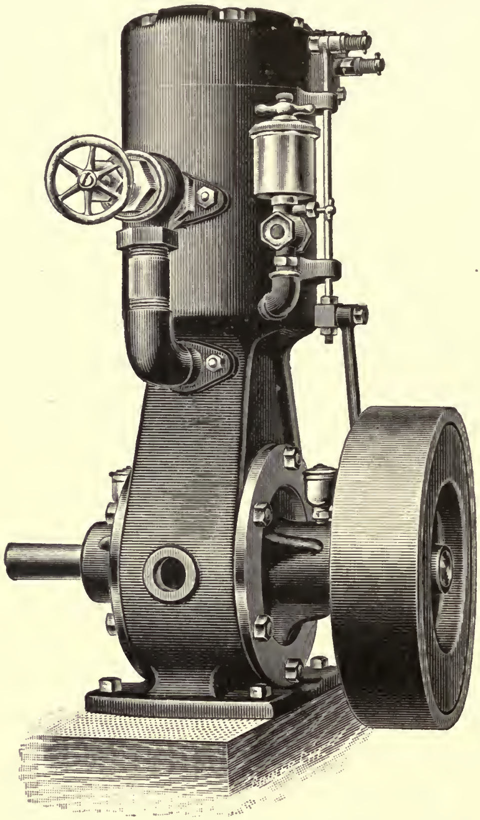


FIG. 16.—SINGLE CYLINDER, TWO CYCLE ENGINE OF CLASS III.

cross-head *K* and connecting rod *N*, which by the crank pin *U* turns the crank shaft *S*.

At *P* is an air pump operated from a point on the connecting rod *N* by a link and the lever *y*.

The cylinder *A* is surrounded by a water jacket *J*, which is continued into the cylinder head and to the air pump *p*. A heavy frame *O* supports the cylinder and is bolted to the bed plate *P*, which also contains the crank shaft bearings.

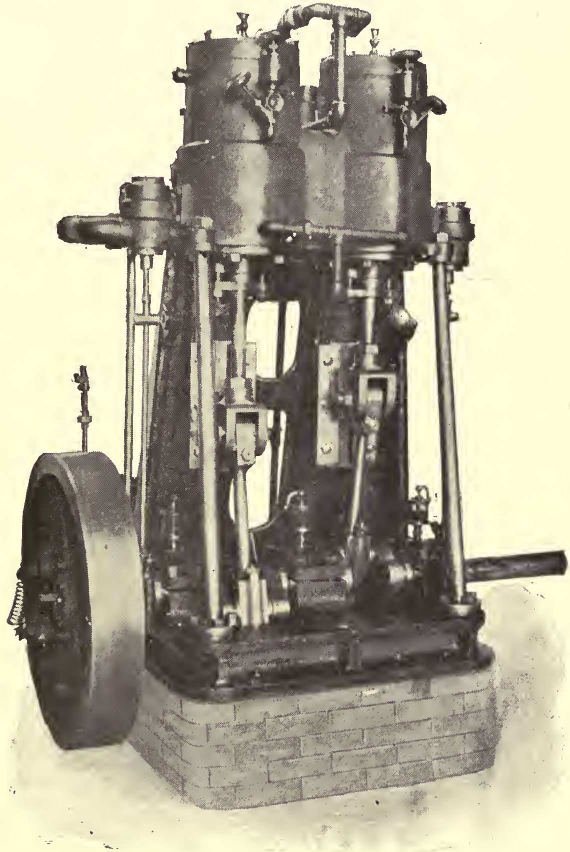


FIG. 17.—DOUBLE CYLINDER, TWO CYCLE ENGINE OF CLASS III.

The engine works on a four-stroke cycle like the Otto, but its small compression space and absence of an igniter make its action so different as to place it in a separate class.

In order to understand the action in this engine it must be remembered that when work is performed on a gas, as by compressing it in a cylinder, the temperature of the gas is raised. So that by compressing a body of air in a cylinder with sufficient force and quickness, so as not to lose much by radiation, we can raise its temperature very considerably. The same principle is shown in the familiar experiment of warming an iron bar by placing it on an anvil and rapidly hammering it.

In the Diesel engine the first down stroke of the piston draws in a charge of air alone, both in the cylinder *A* and in the air pump *p*. On the up-stroke the air in the cylinder is compress d to the pressure of 500 pounds per square inch, and has, in consequence, the temperature of 1200° F. The air in *p* is brought to a considerably higher pressure, ai d, at the end of the up stroke, this air is used to blow into the compression space *C* a small quantity of oil, which is ignited by the high temperature of the air in said space.

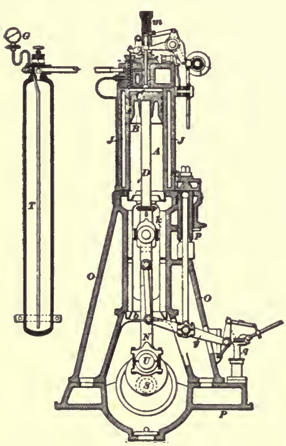


FIG. 18.—DIAGRAM OF ENGINE OF CLASS IV.

This injection and combustion of the oil fuel continues during one-tenth of the down stroke, and the expansion of this hot gaseous mass then continues to the lower end of the stroke, when the exhaust valve opens and remains so during the second up stroke. The tank *T* and pressure gauge *G* are used in starting the engine. At *q* is a mechanical device for forcing lubricating oil to the piston *B*.

As the reader will, by this time, have a good, general idea of gas engine operation, we will, in the next chapter, give a little description of the simplified type of engine whose construction is the subject of this book.

Chapter III.

DESIGN OF A SMALL GAS ENGINE.

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DESIGN OF A SMALL GAS ENGINE.

The engine which this book particularly describes was designed to meet the requirements of the amateur needing a small power, and who wishes to build his own engine.

The facilities of the amateur for engine construction are necessarily limited. Few of them possess a planer or shaper, and many are not equipped with a screw-cutting engine lathe. It is from this point of view that the design and construction of the parts of the engine have been carefully worked out.

The first engine constructed from this design was, with the exception of the fly wheels and bed plate, built on a 10-inch Reed bench lathe, having a plain hand slide rest.

The engine can be just as well built on a lathe swinging only 8 inches, as may be seen from the photo-engravings of the different lathe operations.

The largest pieces which are to be turned are the cylinder collars, and they measure but 6 inches across the lugs.

As will be seen on examining the half-tone cuts, Figs 50 and 53, the 10-inch lathe is large for the work. The fly wheels are something the amateur will require to have done for him. These can be procured, turned and finished at a nominal price. The bed plate is to be filed up on the level projections, where the main bearings and cylinder supports rest, or this can be supplied planed up.

All the other parts of the engine are designed to be built up without the necessity of planing.

The surfacing of the bottoms of the main bearings and cylinder supports is arranged for by the use of the angle plate which is attached to the face plate of the lathe, as will be seen in the chapter describing these operations.

The entire thrust of the engine is transferred from the piston to the fly wheels through the connecting rod, and the corresponding back thrust between the cylinder and the bearings is taken by the two steel side rods, thus relieving the cylinder supports, bed plate and bearings of any strain. The force of the engine is delivered and received in the same straight line.

The most difficult thing for an amateur to accomplish in engine work is the boring out of a cylinder casting. This is a practical impossibility on a lathe having only a slide rest with hand feed.

In this design of engine the cylinder is composed of a drawn steel tube, which requires no boring out, as it is drawn smooth on the inner side. The piston shell is another piece of steel tubing, which, being thinner and lighter than a casting, reduces the weight of the reciprocating parts very materially.

Another very difficult piece of work for the amateur engine builder is the turning and finishing of a crank shaft. This is entirely obviated by placing the fly wheels inside the bearings and bed plate, and connecting them together by the crank pin. In this construction the force exerted in the cylinder is delivered directly to the fly wheels without first passing through the shaft and exerting a torsional strain therein. The only torsional strains on the shaft are those which drive the valve gearing on one side of the engine, and on the other end of the shaft the pulley placed there to

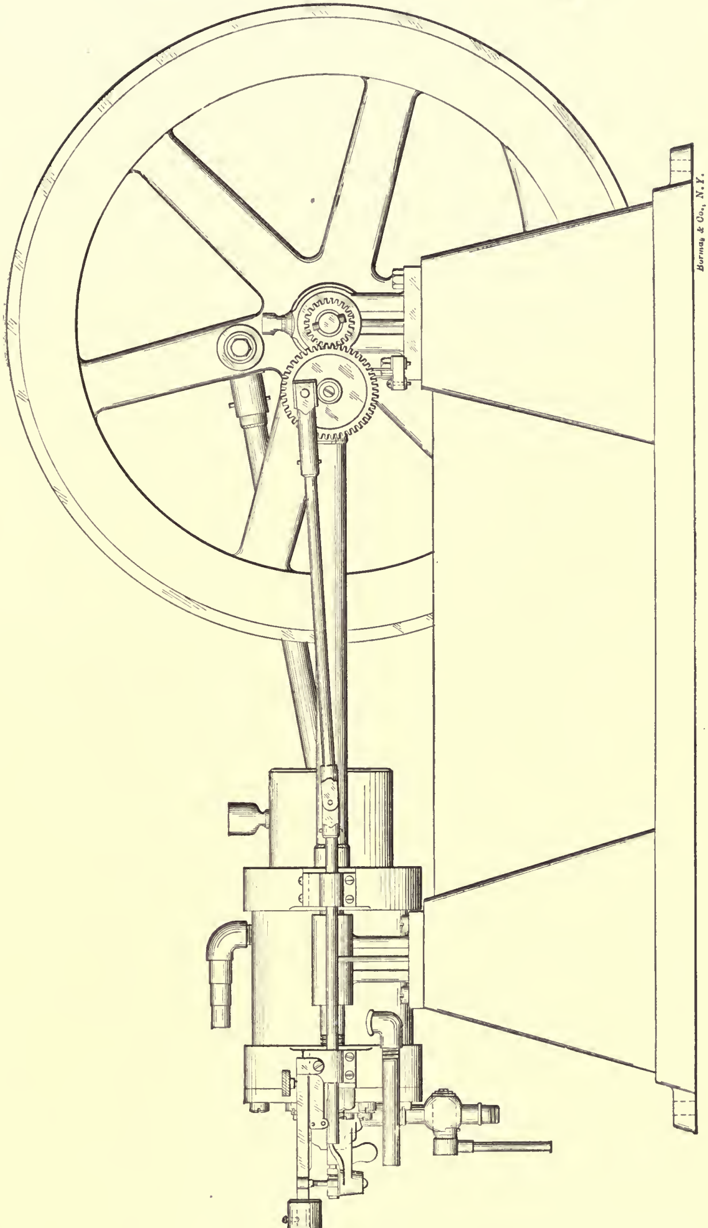

FIG. 19.—SIDE ELEVATION OF FINISHED ENGINE.

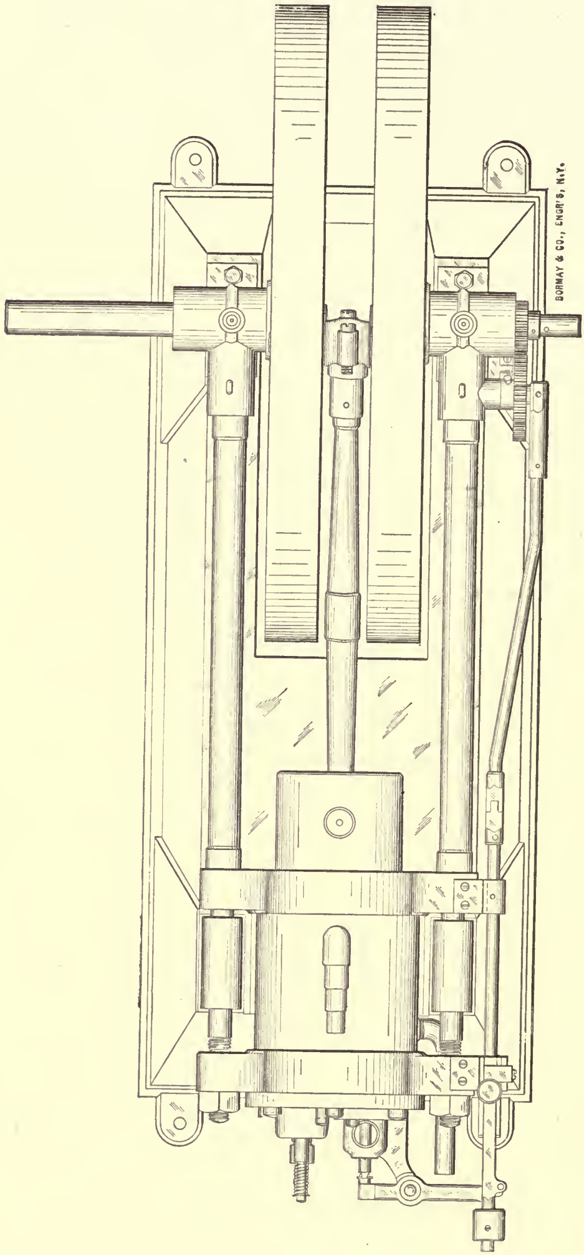

Fig. 20.—Plan of Finished Engine.

belt to the machine it is desired to drive. This pulley is not shown in the cuts of the finished engine.

Gas engines having fly wheels placed outside the bearings require a shaft of extra strength, and the fly wheels must be very firmly keyed to the shaft. In this engine a $\frac{3}{16}$-inch round steel pin passing through the hub of the wheel and the shaft is all that is required.

The engine is of the third class described in the preceding chapter, one cylinder, single acting, four-cycle type.

The valve gearing, therefore, which operates the exhaust valve, makes one stroke to every two strokes of the engine. This is accomplished by placing a 1-inch gear wheel on the engine shaft and a 2-inch gear on the gear stud set on the main bearing, as shown in Fig. 19. In the web of this gear wheel is placed a steel crank pin, to which is attached one end of the connecting rod, which gives the necessary reciprocating motion to the valve rod.

The gear wheels of the valve gearing are set in such a position in relation to each other that the valve rod comes in contact with the lever of the exhaust valve and opens the valve just as the piston is coming to rest at the end of the impulse stroke, and the valve closes just as the piston starts forward again on the admission stroke.

The inlet valve is entirely automatic. opening when the piston travels forward on its admission stroke, and is closed by the spring on the end of the valve stem when the piston has reached the end of the forward stroke.

Its action is simply as an air-pump valve, the cylinder and piston being the pump on the admission stroke.

The gas supply is graduated by the stopcock, shown on the inlet valve in Figs. 19 and 21.

The ignition of the charge is accomplished by an electric spark. This is made by the use of an induction coil placed

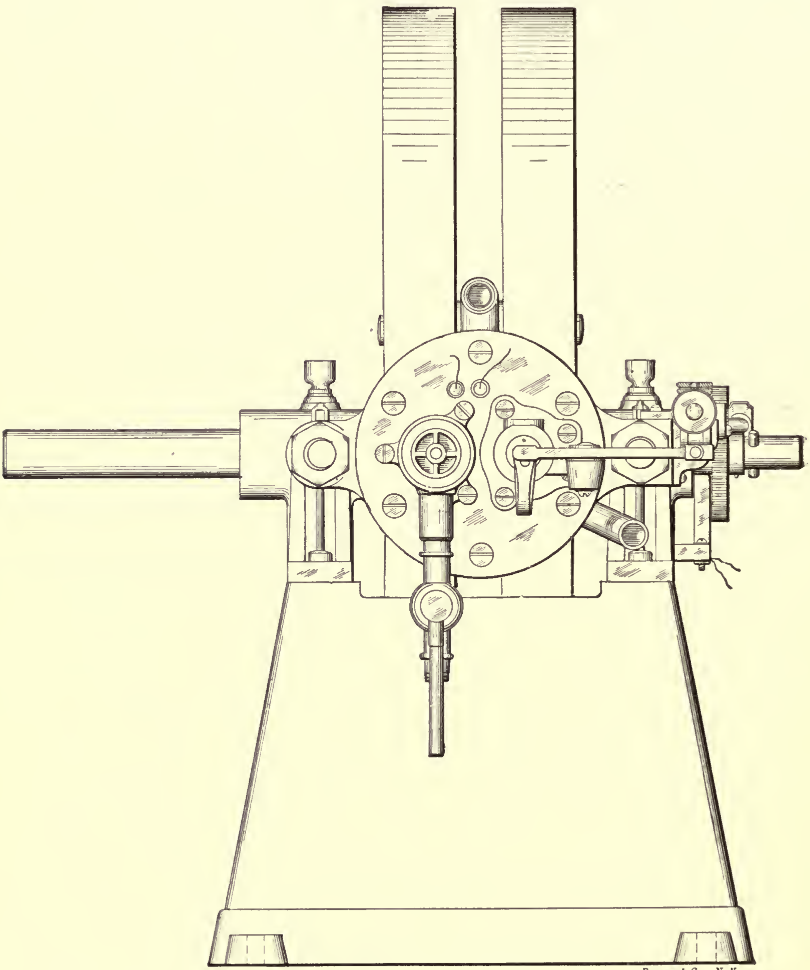

FIG. 21.—END ELEVATION OF FINISHED ENGINE.

in any convenient location near the engine. One wire leading from the battery to the coil connects with the contact springs pl ced behind the 2-inch gear wheel of the valve gearing. These contacts are brought together, and the current passes through the coil once in every two revolutions of the engine. The contacts are pressed together by a fiber pin placed in the hub of the 2-inch gear wheel.

The igniter is placed in the cylinder head, just above the valves. This is shown in Fig. 21.

The brass contact springs are seen in the same cut, standing behind the 2-inch gear wheel. Two small wires are shown projecting from the screws on the lower end of the contacts.

The detailed descriptions of these parts and connections are to be found in Chapter XX.

The governing of the speed of the engine is accomplished by an inertia governor. This is an original design, is easy to construct, and will be found very effective in operation. Detailed description and drawings will be found in Chapter XIX, clearly showing its construction and operation.

Chapter IV.

PATTERNS.

PATTERN WORK. DRAFT. GLUE. FINISH OF PATTERNS. CYLINDER COLLAR. LATHE WORK. PISTON PATTERN. PACKING RING. CYLINDER HEAD.

CHAPTER IV.

PATTERNS.

In dealing with this work we shall not go into the subject of complicated patterns, with core prints and core boxes, by which means the holes can be cast in some of the parts and only need boring out to finish. A study of any good book on pattern-making will give these points.

General

Our aim is to show the amateur how this work can be done in its simplest form.

The best material to use for those patterns which are to be turned, will be white pine. This should be selected of close grained lumber and thoroughly dry. The bed plate pattern, however, is best made of mahogany, which can be procured of any dealer in scroll-sawing material. This wood works very nicely also in the patterns which have to be built up.

All patterns require draft. That is, they must taper slightly in one direction, to allow being removed from the mould of sand.

This draft must not be less than one-half inch for every foot in height for a nice, smooth pattern.

An allowance must also be made for shrinkage of the metal in casting. That is, the pattern for a particular casting should have about one-eighth inch added to it for every foot in length and breadth of the finished size.

Another allowance must be made for the metal necessary to be removed in turning and finishing any part of the castings.

This will make your patterns a little larger than the finished parts.

Use the best quality of glue in fastening the various parts of the patterns together, and, where possible without danger of splitting, use also small nails or screws.

The patterns should be smoothed up with fine sandpaper when finished, and all uneven places and depressions filled with putty or beeswax.

In sandpapering the patterns, be careful not to take off the corners, or otherwise disfigure them. After they have been smoothed up give each one a coat of shellac with a good soft brush, and set them aside to dry.

After they are thoroughly dry, it may be found that on those parts of the patterns where the end grain of the wood is exposed they are rough. This should be sandpapered down again, and the pattern given another coat of shellac. It will be found advisable to give each pattern three coats of shellac, rubbing down all unevenness with fine sandpaper.

When sandpapering any flat surfaces, the sandpaper can be folded over a small, flat block of wood, which will prevent it from spoiling the surfaces or the sharp corners of the patterns.

We will first take up the pattern for the cylinder collars. These are both cast from the same pattern.

Cylinder Collars

It will be noticed, in Fig. 22, that the lugs are of different shape, that on one side being rounded on the end, and the other being square.

In making up this pattern the collar can be turned from a piece of pine.

An excellent way to hold this piece while turning is to fasten a piece of hard wood to the face plate of the lathe by screws passing through from the back of the face plate into the wood.

A tool having a rounded point can then be set in the slide rest of the lathe and the face of the hardwood piece turned off true. A piece of pine about $1\frac{1}{2}$ inches thick, and large enough to be turned down to the proper size, can then be glued to the face of the hardwood block and clamped there until the glue hardens. When this is ready, the slide rest should be set at a slight angle to turn down the outside of the pattern, and give it a smaller diameter toward the tail stock of the lathe. This is for draft in moulding the pattern. While the irregular projections of the piece of pine are being turned down, it will be advisable to place the tail stock center of the lathe against the work to help support it.

After the outside of the pattern is turned to size, set the slide rest at a slight angle in the opposite direction for turning out the inside of the pattern, the result being that it will have draft on both the outside and inside toward the tail stock of the lathe, and, when moulded, will leave the sand without destroying the mould.

After the piece has been finished with fine sandpaper while revolving in the lathe, it is ready to be cut away from the hardwood.

Set the slide rest squarely with the lathe bed, and place a cut-off tool in the slide rest. With this the pattern can be cut off the right depth, after which the superfluous wood and glue can be turned off from the face of the hardwood block, and it will be ready for a similar piece.

A piece of pine large enough to make one of the lugs, is now placed in the chuck of the lathe and turned down to the proper size, not omitting the draft, and a piece the right length cut off.

Two triangular pieces of wood the same height as the lug are now to be whittled out with their sides hollowed to fit against the collar and the lug. The outer sides are then hollowed to form a fillet between the collar and the lug. The other lug, being square ended, is cut out the proper size and fitted to the opposite side of the collar, after which fillets are fitted on either side of it.

The cut, from a photograph of this pattern, shows clearly

FIG. 22.—PATTERN FOR CYLINDER COLLARS.

the mode of construction. In this case, however, the collar was turned from pieces of mahogany glued up with the grain of the alternate layers at right angles. This is shown by the dark and light bands which surround this part of the pattern.

After the lugs have been fitted, the several parts can be glued together.

In fitting these parts together, be careful and get the lugs diametrically opposite each other. If this is not done, it will look very badly when the holes are put through the lugs for the side rods.

After the glue is hard the parts are finished and shellacked, as described.

All the cuts in this chapter show the general appearance of the different patterns. For the actual dimensions, the reader is referred to the detail drawings in the chapters treating on the machine work of the different parts.

The piston pattern is built up from several pieces. These

FIG. 23.—PISTON PATTERNS.

comprise the back or end of the piston, the two lugs or bosses which are bored and reamed to fit the piston pin and the two standards which connect the back and bosses.

Piston

The back is formed of a piece of wood, which may be glued to the hardwood block on the face plate.

In this case, however, we must consider the draft of the pattern in another way.

On referring to the cut of the patterns (Fig. 23) it shows a built up pattern of wood and, also, a metal pattern made in two parts.

That half of the metal pattern which is lying flat represents what the pattern would look like when the lower half of it is in one part of the mould and represents the direction of the draft of the upper part. From this it will be seen that when the disc forming the back of the piston is turned up in the lathe the slide rest must be set at a slight angle to make disc thinner on the edge than in the center.

On the back of the piston pattern is a smaller disc. This is what is called a "chuck piece" and is only used to hold the piston while the casting is being turned off. The jaws of the chuck are gripped on this piece during that operation, after which the chuck piece is turned off, leaving the back of the piston flat. This can be seen by referring to Figs. 23 and 56.

The back of the piston and chuck piece can be turned from the same piece of wood, after which they are cut from the hardwood block by a cutting off tool, or a saw can be used.

This piece can now be held in the jaws of the chuck by the chuck piece and the front faced off and beveled for draft.

The two bosses are turned from a piece of wood held in the chuck and then cut off the right length. It will be seen that the inner ends of the bosses are rounded, to give the proper draft.

The standards are now built up of pieces glued to the back at the lower end and the bosses set on at the other. Be careful to get these parts on a line with the center of the back.

Two small braces are placed between the standards, as shown, and glued into place, after which a small piece is placed across the tops of the standards. This piece helps to keep the pattern in shape, and is also a support for the casting when turning it down to fit the steel tube which forms the piston shell.

When the glue is hard the pattern is held in the chuck by the chuck piece, and the outside of the standards turned off. This operation gives draft to the outside of the standard, and the inside must be rounded up by hand.

This looks like a difficult piece of work at first sight, but

FIG. 24.—PISTON PACKING RING.

if these directions are followed, little trouble will be found in making it.

The piston packing ring is a very simple piece, and requires no explanation. The sizes can be had from the detail drawings, and it can be turned up from a piece of wood glued to the hardwood block and cut off after finishing.

The cylinder head is also a simple pattern. This requires draft on the edge only. It may be turned upon a half-inch mandrel or arbor.

Cylinder Head

Drill a half-inch hole in the center of a piece large enough to turn down for the pattern, and finish as shown in the cut, leaving a small projection on one side which is to be turned to fit inside the cylinder when the casting is finished.

After the pattern is finished and sandpapered smooth, drive out the mandrel and insert in the half-inch hole a small

FIG. 25.—CYLINDER HEAD PATTERN.

chuck piece projecting about three-quarters of an inch from the face of this pattern. This piece must be tapered slightly to give it draft lengthwise.

This chuck piece is to hold the head while the casting is faced off on the inside and the edge turned down to size.

The cut shows the projection on the inside face of the pattern, and the chuck piece on the outside face tilts the pattern forward.

Chapter V.

PATTERNS—CONTINUED.

MAIN BEARINGS. FILLETS. CYLINDER SUPPORTS. CONNECTING ROD HEAD. PISTON END OF CONNECTING ROD.

CHAPTER V.

PATTERNS—CONTINUED.

The patterns for the main bearings are built up from a number of pieces, and care is required to get them in proper alignment and of equal dimensions.

Main Bearings

The draft is each way from the center band which is turned around the hub of the bearing. It will be seen from the cuts and detail drawings that these patterns are alike, with the exception that they are right and left patterns.

The only variation from this being that on the pattern belonging to the valve gearing side of the engine a small projection is set on the side rod boss to support the gear stud.

The first operation will be to turn up the hubs or main parts of the bearings.

A piece of wood large enough to turn out both hubs should be placed in the chuck with the outer end supported by the back center.

A round-point tool is best to use for these pieces of the patterns in forming the ring around the bearing. Have the slide rest set to give the piece draft each way from this center ring, and be sure that they are both of equal size and shape.

Next make the bases, giving them draft sidewise from the center on top, bottom and ends, and allowing for facing off the bottom.

Bore a half-inch hole through the center of the bases, and also into the bearing hubs, the center of the hole being exactly at the center of the ring formed on the boss.

Turn out and finish two wood pins one-half inch in diameter, and of sufficient length to form the center of the standard between the base and the bearing.

Glue these pins into the half-inch holes bored in the bases and bearings, and be sure that the two patterns at this stage are exactly the same height. The remainder of the standards

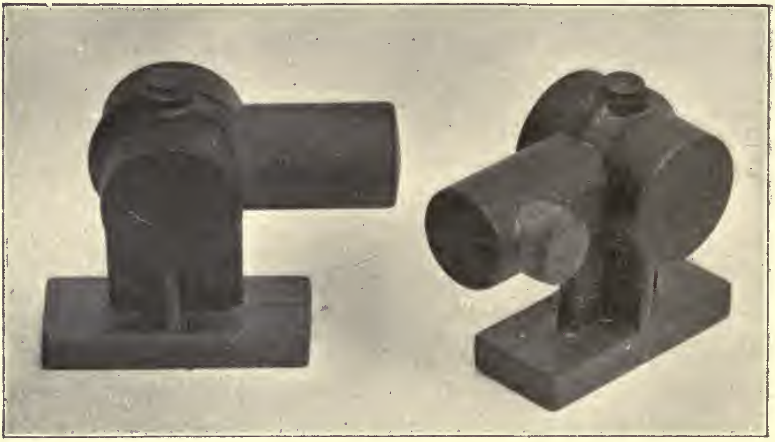

FIG. 26.—PATTERNS FOR MAIN BEARINGS.

are formed by glueing on pieces of one-eighth inch mahogany on the sides and one-quarter inch pieces on the ends. The half-tones show this construction plainly. Next turn out two pieces of wood to form the bosses for the side rods.

The only draft necessary to allow is on the outer ends, which should be slightly rounded.

These pieces are now to be fitted and glued to the bearing, as shown.

Great care should be exercised to have these bosses exactly parallel to the bases of the patterns, otherwise the bearing will have a bad appearance when cast and finished.

For the oil cups, two small projections are turned out and set on the top of the bearings, and the projection to support the gear stud is glued to the side of the proper pattern.

Around the bottom of the standard, where it is attached to the base, a rounded finish is made by using a little beeswax and rubbing it into shape with a piece of hardwood or metal having a ball-shaped end about $\frac{3}{16}$ inch in diameter.

FIG. 27.—CYLINDER SUPPORT PATTERN.

This is what is called putting on a fillet, and should always be done in pattern work where two surfaces meet at, or nearly at, a right angle.

The patterns are then ready to be shellacked and finished.

The cylinder supports are both cast from one pattern.

Cylinder Supports

The base and standard of this pattern are constructed exactly like the main bearing patterns, and the draft should be made the same. The cylindrical parts, through which the side rod passes, must be rounded slightly on the ends for draft, and in the finished pattern the center of this part must be on an exact line with the center of the boss on the main bearing.

Great care should also be taken to have this part and the base parallel.

The cut shows clearly the construction of the pattern.

Connecting Rod Ends

The pattern for the outer or crank-pin end of the connecting rod can be made in either of two ways. The half-tone shows both styles of pattern.

FIG. 28.—PATTERN OF OUTER END OF CONNECTING ROD.

In the wood pattern, where the whole head is cast in one piece, it is intended to be cut apart with the hack-saw and the two pieces fitted and screwed together, after which it is bored and reamed for the crank-pin. In this case the draft would be up and down, as the pattern lies in the cut.

Where the pattern is made in two parts, however, the draft is upwards on both pieces and the stem must be tapered slightly.

To make the solid pattern the center piece is first turned to size after which it is cut apart with a saw or split with a chisel, and after the two halves are trued up a piece of $\frac{1}{8}$ inch mahogany is set in between them and glued. The stem is next turned and fitted on, after which the lugs are set on through which the screws pass to hold the finished parts together. As the pattern from which the half-tone was made was built up of different colored woods, it is easy to see how the parts are fitted together, and further explanation is unnecessary.

FIG. 29.—PATTERN OF INNER END OF CONNECTING ROD.

In making up the pattern in two pieces the center piece is first turned to size and shape, after which it is cut apart, but in this case it should be cut just a little to one side of the center. This is to allow for the facing off of one of the pieces. On the other piece a thin strip of wood is glued to make up the allowance for facing off that piece.

The stem is next turned to shape and fitted on to one of the halves, and the lugs for the screws are made and put on, but in this case there will be four pieces to fit instead of two, and in fitting them the two patterns should be held together to see that these lugs correspond in their relative positions.

The pattern for the inner or piston pin end of the connecting rod is made exactly like the one first described, except that it has no lugs for screws. This piece when cast is left solid and is not cut apart to give adjustment for wear.

The center or bearing is first turned to shape and the stem then made and fitted. The pattern is moulded as it lies in the cut and the draft is, therefore, from the center up and down.

The end of the stem must be rounded for this purpose.

Chapter VI.

PATTERNS—CONCLUDED.

BED PLATE. FLY-WHEELS. VALVE ROD GEARING. INLET VALVE. EXHAUST VALVE. EXHAUST VALVE LEVER. GOVERNOR. STARTING HANDLE.

CHAPTER VI.

PATTERNS—CONCLUDED.

The bed-plate pattern is the largest pattern which is to be made; but, as everything is in straight lines, we think little difficulty will be encountered in constructing it. The bed plate is in reality a box open at the bottom and with a section removed from the top and one end. The cut clearly shows the construction of the pattern. The dimensions are all given in the detail drawings.

Bed Plate

The pattern is best made of mahogany. The sides and cylinder end should be one-eighth inch thick, the top and the end which is cut away for the fly-wheels should be one-quarter inch thick. Around the entire base, strips one-quarter inch thick and one inch wide are glued on, and on each side two pieces of mahogany one-eighth inch thick are glued, to reinforce the pattern under the main bearings and cylinder supports. The exact measurements of these pieces will be found from the detail drawings.

At each corner of the top, pieces of one-quarter inch mahogany are placed, on which the main bearings and cylinder supports are to rest.

Four lugs are attached to the bottom of the pattern, by which the finished bed plate is screwed or bolted to the foundation.

The four corners of the pattern should be rounded nicely,

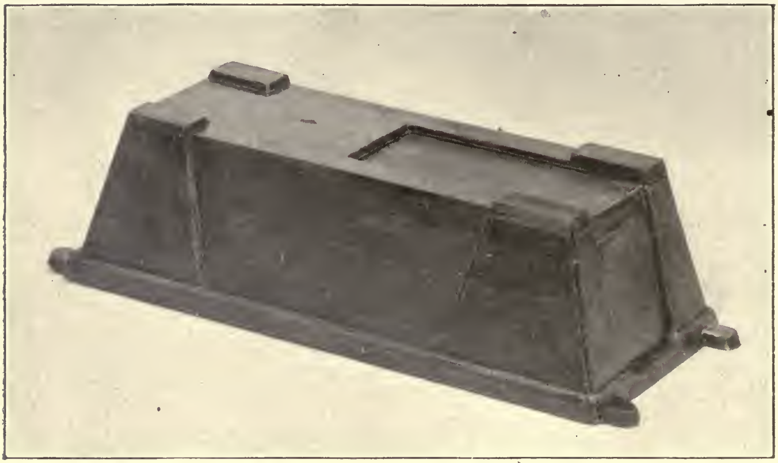

FIG. 30.—BED PLATE PATTERN WITH SUPPORT IN POSITION FOR MOULDING.

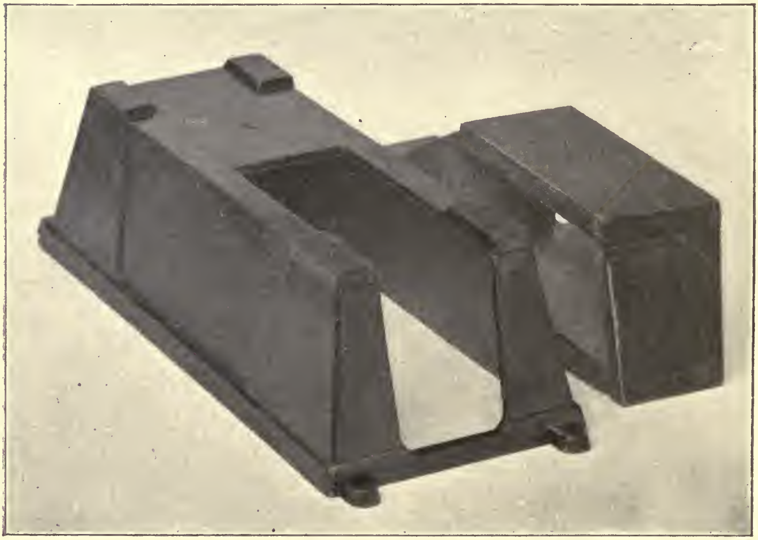

FIG. 31.—BED PLATE PATTERN WITH SUPPORT REMOVED.

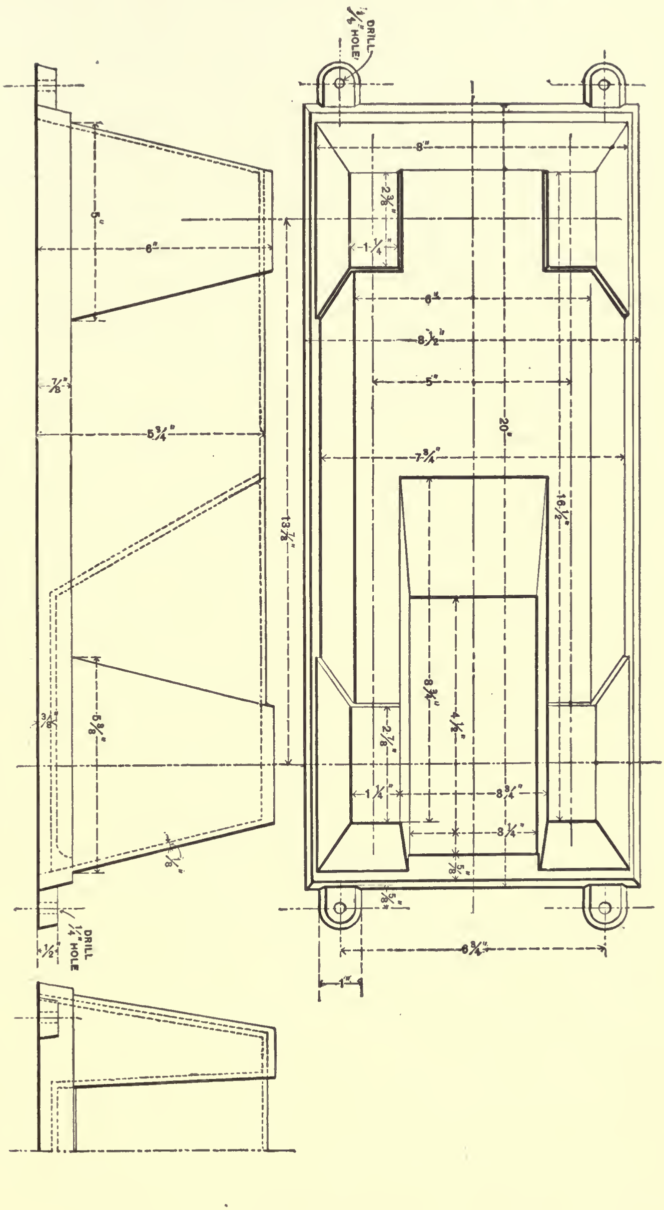

FIG. 32.—BED PLATE.

and also the inner corners of the reinforcing pieces on each side. On the inside, at each of the corners, also where the top and sides join, a fillet must be placed.

These can be purchased at the machinists' supply stores, of leather cut in a triangular shape, which, when glued into place, form a nice, rounded, smooth corner. Strips of straight-grained wood can be glued into the corners, and then hollowed out with a gouge, if the ready-made fillets cannot be procured.

The slant of the sides gives draft to the outside and inside of the pattern, in addition to adding to the appearance of the finished engine.

In the detail drawing is shown a casing for the two fly-wheels, which is cast with the bed plate.

This can be omitted, if desired, and the pattern left as shown in the half-tones. In the latter case, a box or support must be fitted into the bed plate to fill up the cut-away portion of the pattern, while it is being moulded in the position shown. This support is removed when the mould is turned over, and the sand is then packed into the inside of the pattern and the other half of the moulding flask filled.

We advise the use of this open pattern, as it is easier to construct, and the castings come out in better shape.

If it is desired to have the lower part of the wheels encased, a sheet-metal casing can be fitted inside the bed plate after the fly-wheels are in position.

Fly-Wheel

The fly-wheel pattern can be made from one piece of wood, or two or more pieces may be glued together with their grains at right angles for strength.

A hole can be bored through the center of the wood and a mandrel driven through, on which the pattern can be turned up.

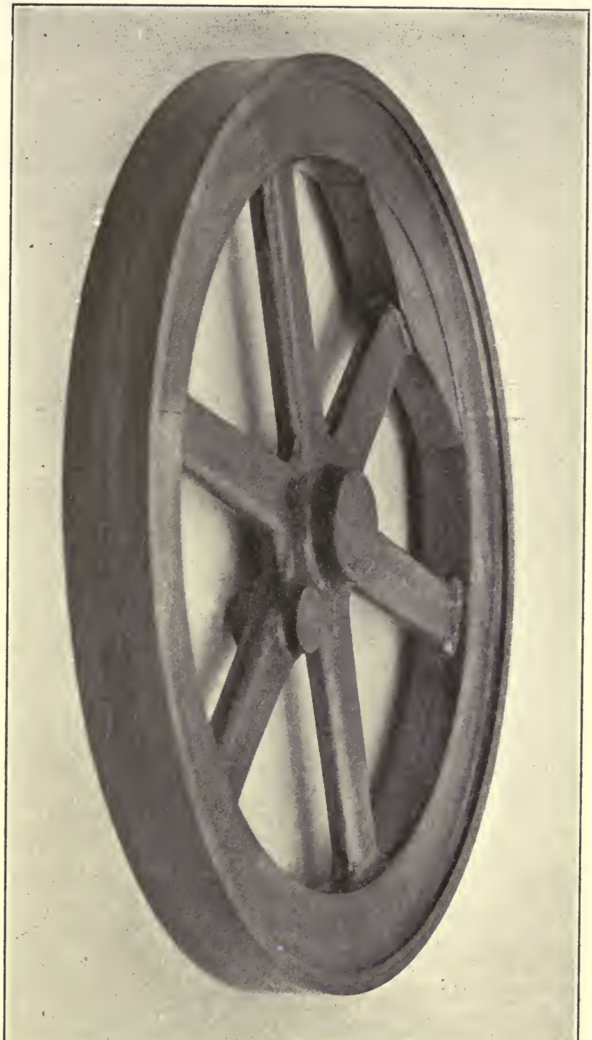

FIG. 33.—FLY WHEEL PATTERN.

After the pattern is turned to shape it can be removed from the mandrel and the arms marked out, after which the wood is to be cut away between them and the edges of the arms rounded.

One of the arms of the fly-wheel is enlarged a short distance from the hub and a boss glued on which forms the crank.

After the arms are marked out and finished, a piece of wood of the size and shape shown in the detail drawings must be glued on the pattern inside the rim as a counterweight to the crank-pin and connecting rod.

Fig. 34.—Valve Rod Bearing Pattern.

To make this pattern a lathe having a swing of 14 inches is required. When the builder of the engine has no lathe swinging this size the wheel can be furnished complete, turned and bored, at a nominal price.

This pattern can be carved out from one piece or built up from several pieces.

The detail drawings indicate the shape and size clearly.

Valve Rod Bearing

Two castings are required for bearings, one on either cylinder collar. The bearing on the front collar does not require a boss to attach the governor. It is best, however, to make only one pattern and have both pieces cast with the boss on. If one is spoiled in drilling for the governor screw the boss can be filed away from it and it can then be used as the front bearing, and the second one finished to hold the governor.

The cut shows the pattern as originally made, but the reader will find the detail drawings of this piece modified to fit the governor.

Inlet Valve

Three patterns are required for the inlet valve. The valve body is turned up of a single piece of pine and is given draft for its entire length. It is moulded in the position shown in Fig. 35, and should, therefore, be made with the slide rest set at a slight angle.

The projection at the top of the pattern is left for a chuck piece, by which the casting is held in the jaws of the chuck, while the outside and inside are

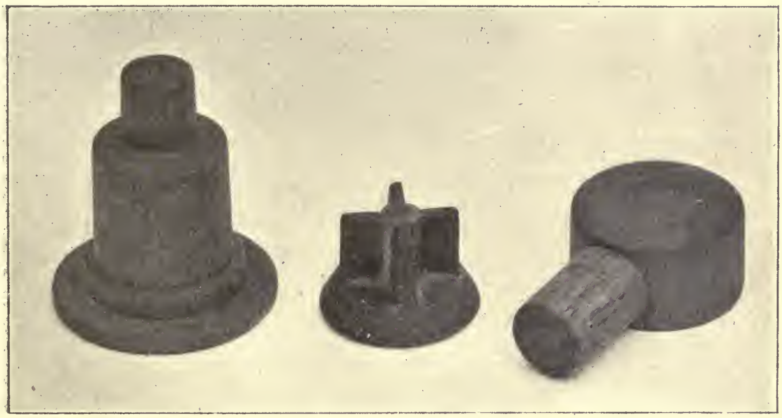

FIG. 35.—INLET VALVE PATTERNS.

turned, bored and finished, after which it is turned down to a small hub to act as a bearing for the guide pin, as shown in the detail drawings.

The valve pattern is best made by building it up, as shown in the cut. It is moulded in the position shown.

The valve disk of this pattern was turned from a piece of $\frac{1}{4}$ inch mahogany. A hole was drilled through the piece $\frac{1}{4}$ inch in diameter and a mandrel driven into it. After it was turned down to size, the mandrel was removed and a small hub of pine turned down to a diameter of $\frac{5}{16}$ inch to form a hub for the valve stem, but the end was turned down to $\frac{1}{4}$ inch to fit the hole in the valve disk. After this hub was cut off it was glued in place. The four wings were made of $\frac{1}{8}$-inch mahogany, and after tapering them for draft, they were glued into position.

A fillet of wax is required where the wings and the valve disk join.

The gas ring, which, when finished, forms an annular gas space around the inlet valve, was moulded from the pattern shown in the right of the cut. It was found, however, after the ring was completed and put in place, that connecting the stop cock and piping to the ring had a tendency to loosen it on the inlet valve. To overcome this, the lugs shown in the detail drawings, Fig. 108, were added.

Through these lugs screws are to be inserted to fasten the ring to the cylinder head.

The main parts of the ring and stem are clearly shown in the cut.

After the round disk forming the ring has been turned up in the lathe and cut off the proper length, a hole of the diameter of the stem is bored in one side and the stem glued in. The lugs are next glued around the bottom of the ring, as shown in the detail drawings.

Exhaust Valve

In Fig. 36 is shown two patterns of the exhaust valve casing. The wood pattern is shown in nearly the position in which it is to be moulded, and the draft of the parts must be made to conform to this. The different grainings of the parts of the wood pattern show clearly its construction.

The body of the valve should be turned first. It will be noticed on inspection of the metal pattern in the cut that the lower portion below the irregular shaped flange is slightly larger than the main part of the body.

In turning this piece into shape, a square shoulder is left, and after the irregular flange is bored to fit the body of the valve, it is slid down against the shoulder and glued there.

The shape of the flange is shown in the detail drawings.

From the side of the valve body an arm extends out, ter-

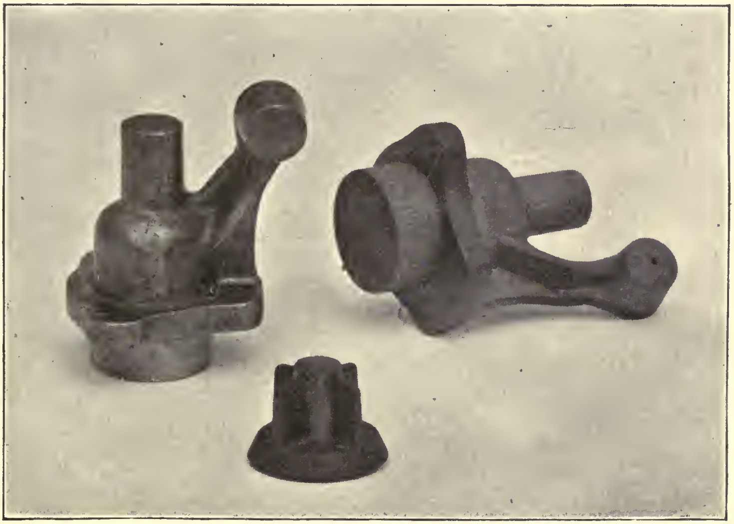

FIG. 36.—EXHAUST VALVE PATTERNS.

minating in a boss, which forms a bearing for the exhaust lever pin.

As will be seen, there is an offset in this arm to bring the top of the boss in line with the center of the valve body.

A rib is attached to the lower side of the arm to strengthen it, as shown.

A boss, shown in the detail drawings, Fig. 113, is fitted and glued to the upper side of the valve body for the exhaust pipe.

The projection on the end of the pattern of the body is for a chuck piece by which the valve body is held in the chuck while being bored and finished. This piece is afterward cut away and does not, therefore, appear on the detail drawings of the finished valve.

The valve pattern is made up exactly like the inlet valve, except that it is very little smaller, as shown in the drawings.

Exhaust Valve Lever The pattern of the exhaust valve lever is so simple that a special cut of the pattern will not be necessary.

The detail drawings of this piece, Fig. 115, will show its construction clearly.

Governor The governor patterns are very simple, and only two will be required, the governor lever and the weight.

The lever is shown in the detail drawings in Fig. 124.

The weight is a round piece and can be turned from a piece of brass rod of the size shown in the drawings.

The parallel pieces of brass which hold the steel roller are best made from sawed brass.

If this cannot be procured, however, they may be cast from a pattern.

Starting Handle The pattern for the starting handle will be a single piece. The details of this pattern are shown in Fig. 131 of the detail drawings.

Piston Lubricator A pattern can be made for this piece or it may be turned from a piece of solid rod. The details are shown in Fig. 47.

These directions will enable the amateur to construct any patterns required for this work, provided they have the necessary tools; if, however, they find their facilities are not adequate, it will be found much cheaper to procure a set of the complete castings than to have the pattern made especially for one engine.

Angle Plate

Fig 37 shows the pattern of the angle plate. It is moulded in the position shown, and the slots in the back are made a trifle wider at the upper side, as the pattern lies in this position, thus giving

FIG. 37.—ANGLE PLATE PATTERN.

the necessary draft to enable it to be removed from the mould.

The shelf of the angle plate is also made with a slight draft toward the front.

The two small brackets placed under the shelf give it strength and rigidity.

Dimensions of the different parts will be found in the detail drawings in the chapter following this.

Chapter VII.

SPECIAL TOOLS.

ANGLE PLATE. PIN. WASHERS. BUSHINGS. COLLAR. PATTERN. TURNING TOOLS FOR FLY-WHEELS. BORING TOOLS. CUTTERS. CENTERING TOOLS.

CHAPTER VII.

SPECIAL TOOLS.

In this chapter we shall describe a few tools and appliances which will be found of great advantage to the amateur mechanic. Most of these can be made very readily.

The angle plate is a very important adjunct to the lathe, with which most amateurs are not familiar. With a correct angle plate fitted to the lathe, irregular pieces may be firmly and accurately held and finished.

To insure good work, the back of the angle plate, which fits against the face plate of the lathe, and the top of the horizontal shelf must be planed up at right angles to each other.

The face of the angle plate, also the front and bottom of the horizontal shelf, may be planed up, but these are not so essential.

In the drawing, Fig. 38, is shown the angle plate attached to the face plate of the lathe and one of the cylinder supports clamped in position for facing off the bottom.

Two long slots are cast in the back of the angle plate, through which are inserted the two bolts for clamping the angle plate to the face plate of the lathe.

The two slots in the face plate, at right angles to the slots in the angle plate, give a large range of adjustment in bringing work of different heights in line with the lathe centers.

Figs. 57, 59, and 60 best show the angle plate in position.

In the construction of this engine the angle plate is fitted with a soft steel pin $\frac{1}{2}$ inch in diameter, having a head $\frac{5}{8}$-inch diameter at one end and a hole $\frac{1}{4}$-inch diameter drilled and tapped in the opposite end.

A $\frac{1}{2}$-inch hole should be drilled and reamed in the shelf of the angle plate at the position shown in the detailed drawings.

The pin should fit snugly in this hole to prevent it from

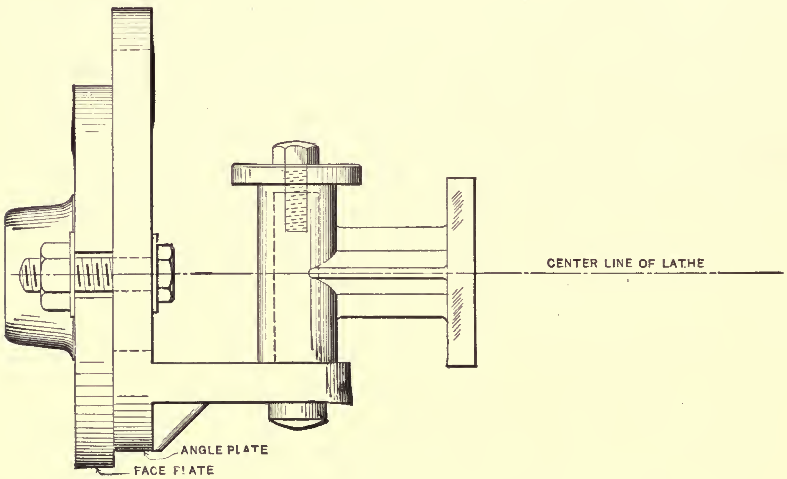

FIG. 38.—ANGLE PLATE AND FACE PLATE.

falling out when the work is being placed in position.

A large washer, with a $\frac{1}{4}$-inch hole in the center, should be made by which the work is clamped on the steel pin. This is shown in Fig. 38.

A collar made from a piece of heavy brass tubing of the dimensions shown in Fig. 39 will be found of great assistance in this work. Its use is shown in Fig. 107.

Two small washers must also be prepared to form bushings for the angle plate pin when it is desired to mount the main bearings, connecting rod head, etc., on the angle plate. These can be made from common $\frac{3}{8}$-inch iron washers or turned from a piece of brass rod. They should be held in

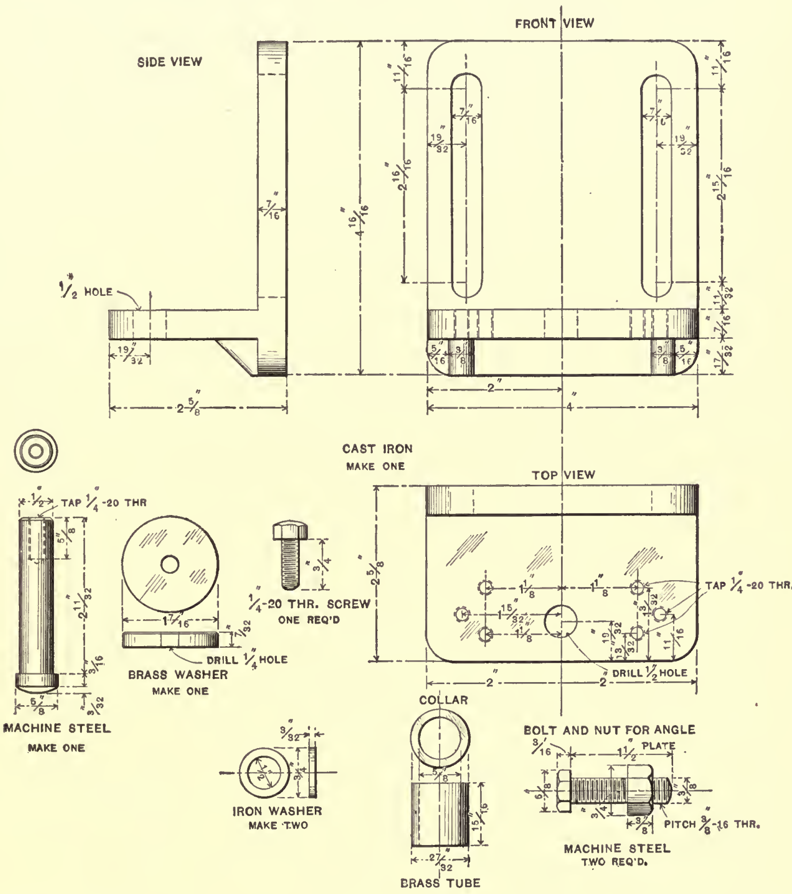

FIG. 39.—ANGLE PLATE.

the chuck and bored out to $\frac{1}{2}$-inch inside diameter, after which they can be driven on a mandrel and the outside turned down to $\frac{3}{4}$-inch in diameter to fit the bore of the main bearings, etc.

The holes drilled and tapped in the shelf of the angle plate are used to clamp work which the steel pin will not hold. They can be placed wherever convenient and should all be drilled and tapped for the same size of screw.

If it is intended to turn the fly-wheels, it is absolutely necessary to have the holes for the crank pin bored at exactly the same distance from the holes for the shaft.

This is best accomplished as shown in Fig. 40. A hole is

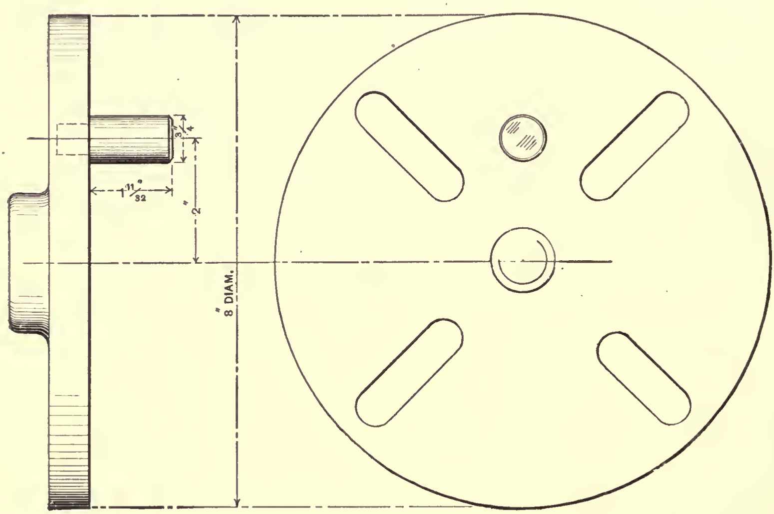

FIG. 40.—FACE PLATE AND PIN.

drilled in the face plate of the lathe exactly 2 inches from the center line of the lathe spindle. A pin of steel is turned to $\frac{3}{4}$ inch diameter to fit the bore of the fly-wheel, and one-end is then turned down to fit the hole drilled in the face plate.

After both wheels have been turned and bored, they are separately mounted on this pin, the holes for the crank pin are then bored and reamed.

This is fully described in the chapter on the fly-wheels.

For turning and facing the rims of the fly-wheels, a tool shown in Fig. 41 will be found to answer admirably. This is a piece of tool steel of the size to fit the tool post of the lathe, bent into the form shown.

With this tool the rim and also the face of the wheel next

FIG. 41.—TOOL FOR TURNING FLY WHEEL.

the face plate can be turned while the wheel is mounted on the face plate for boring.

A very convenient boring tool and one easily made by

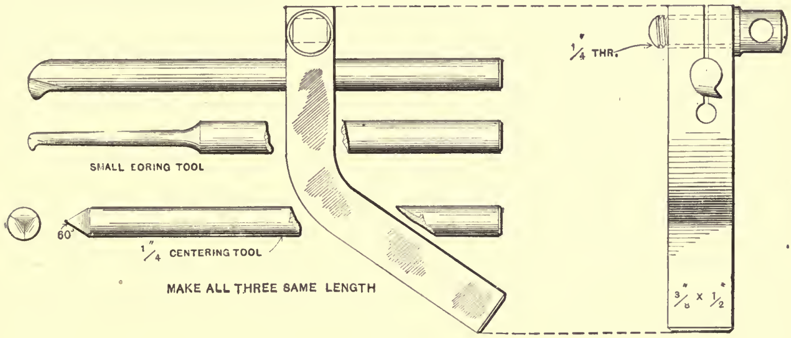

FIG. 42.—BORING TOOL.

anyone is shown in Fig. 42. This shows a piece of machine steel or iron of a size to fit the tool post of the lathe. A hole is drilled at the outer end from the top and tapped for a ¼-inch screw.

Just back of the tapped hole and at right angles to it is drilled and reamed a ¼-inch hole for the boring tools. A short distance back of this hole is drilled a smaller one. A hack saw is now used to split the tool holder from the end to the small hole back of the boring tool. The upper part

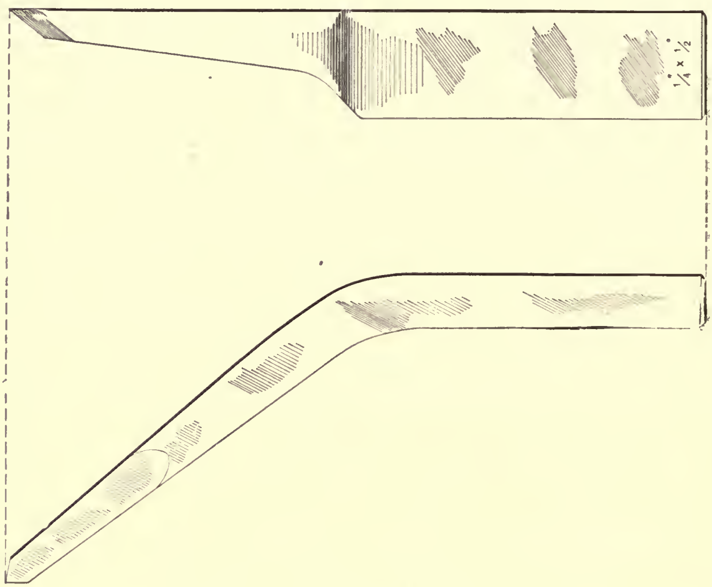

FIG. 43.—CENTERING TOOL.

of the hole tapped for a screw is now drilled out to ¼-inch to form a clearance hole and a screw fitted to clamp the tool in position. The screw can be made with a head, as shown in the cut, or an ordinary screw can be used with a slotted head.

Various cutters made from ¼-inch drill rod, can be fitted to this holder, and the cutting ends formed for any purpose desired.

In the cut a smaller boring tool is shown removed from the holder.

Another very necessary tool for this work is a centering tool. This can be made from a piece of $\frac{1}{4}$-inch drill rod and fitted to the boring tool holder or can be a separate tool, as shown in Fig. 43. This consists of a piece of tool steel to fit the tool post of the lathe, one end of which is drawn out to a small point and sharpened, as shown. After being drawn out, the tool is given a bend, as shown in the cut.

The centering tool for the boring tool holder is made by filing a piece of $\frac{1}{4}$-inch steel rod to a point of about 60° while it is revolving in the lathe, after which it is filed on three sides to form a triangular pyramid.

In Fig. 42 is shown the construction of the point.

Chapter VIII.

CYLINDER.

WATER JACKET SHELL. MANDREL. SQUARING UP ENDS OF TUBES. STEEL CYLINDER TUBE. LOCATION OF LUBRICATOR. CYLINDER COLLARS. JIG FOR LOCATING HOLES IN LUGS. THE JIG IN USE. WATER SUPPLY PIPES.

CHAPTER VIII.

CYLINDER, ETC.

It is advisable to begin operations with the cylinder and water jacket.

The brass tube forming the water jacket shell must be faced off perfectly true at each end, as on this depends the accurate spacing of the cylinder collars and consequently the alignment of the cylinder.

As an arbor, or mandrel, a piece of hard wood may be used. The mandrel shown in Fig. 44 was a piece of maple

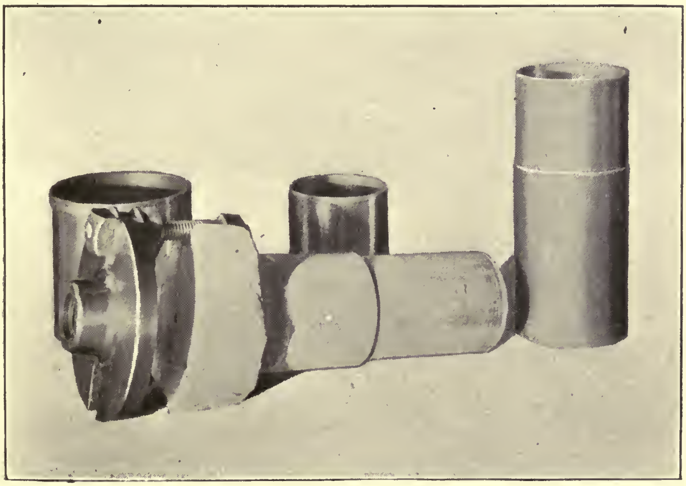

Fig. 44.—Tubing for Water Jacket, Cylinder and Piston Shell, with Hard Wood Mandrel.

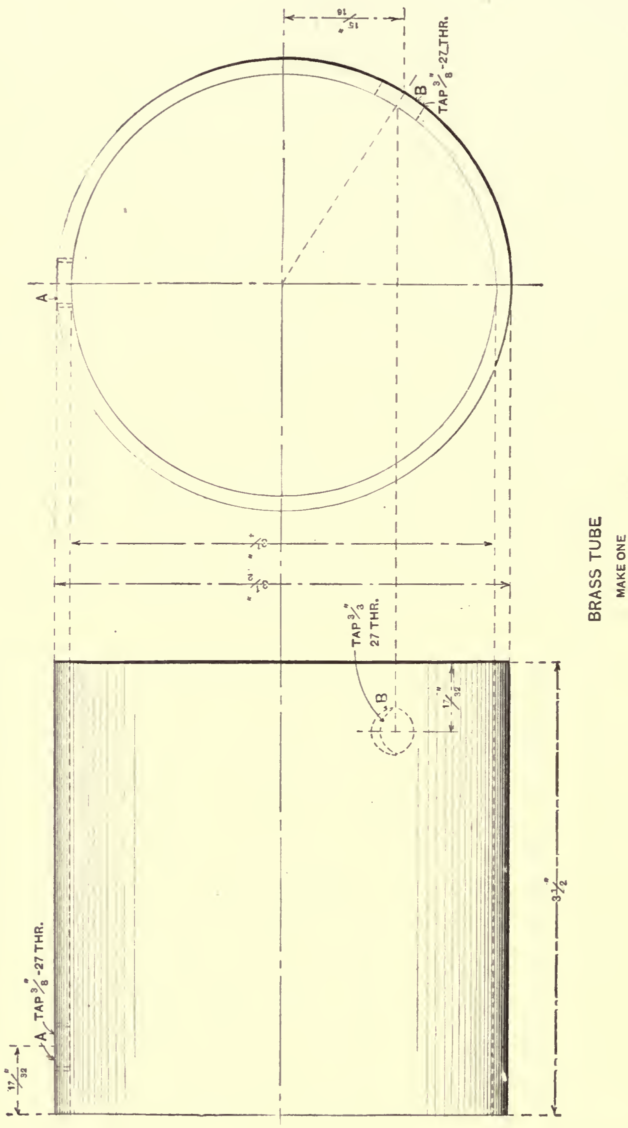

Fig. 45.—Water Jacket.

stove wood. This was mounted between the centers of the lathe and driven by a bolt which passed through one of the slots of the face plate and fitted into a groove chiseled into the wood. The cut shows the arrangement clearly.

Set the slide rest and turn down the wooden mandrel until the brass tube can be forced on by hand. When the tube is in position on the mandrel face up each end, using a right and left side tool in the tool post alternately.

Take light cuts, else the tube may move on the mandrel. The length of the finished piece should be $3\frac{1}{2}$ inches, as shown in Fig. 45.

Set a round nose tool in the tool post and take a cut across the outside of the tube to true it up with the inside, after which it may be filed up smooth and polished with emery cloth or, better still, fine sand paper.

Remove the jacket tube and turn down the mandrel again until the steel cylinder tube can be forced on. Face up both ends using the side tools as before.

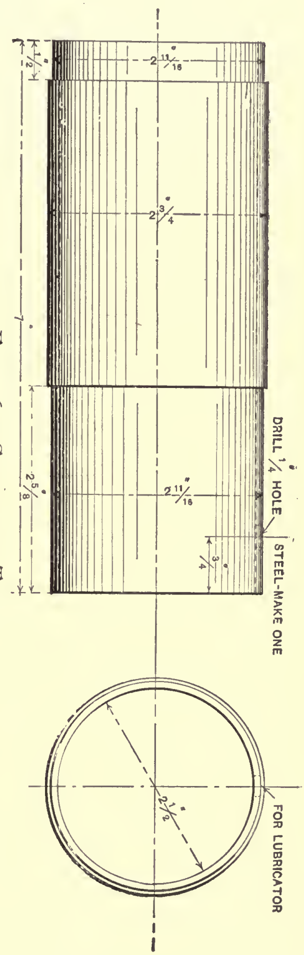

FIG. 46.—CYLINDER TUBE.

On the end of the cylinder tube, which is to be next the cylinder head, turn down the outside of the tube for a distance of $\frac{1}{2}$ inch.

Leave a space of $3\frac{7}{8}$ inches full size and turn down the remainder, or front end, of the tube to the same diameter as the ½ inch on back of tube, as shown in Fig. 46. This leaves the outside ends of the cylinder tube true with the inside, and when the cylinder collars are bored out to fit onto the ends of the shell the cylinder will be in line.

Fig. 44 shows the cylinder tube after the ends have been turned down to size.

On the front of the cylinder, at the position shown in Fig.

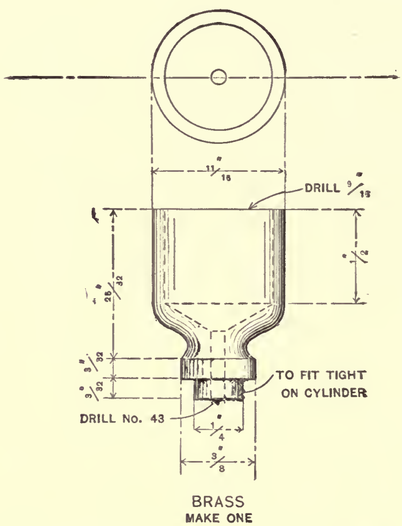

FIG. 47.—LUBRICATOR FOR CYLINDER.

46, a hole is drilled for the lubricator which supplies oil to the piston and piston pin.

The cylinder collars are chucked as shown in Fig. 48.* Should the outside of the casting not run true when the jaws of the chuck are closed on it the jaws may be loosened

*The two photos for Figs. 48 and 50 were spoiled and a finished collar was removed from the engine to make the cuts shown. The holes for side rods and cylinder head screws are to be seen.

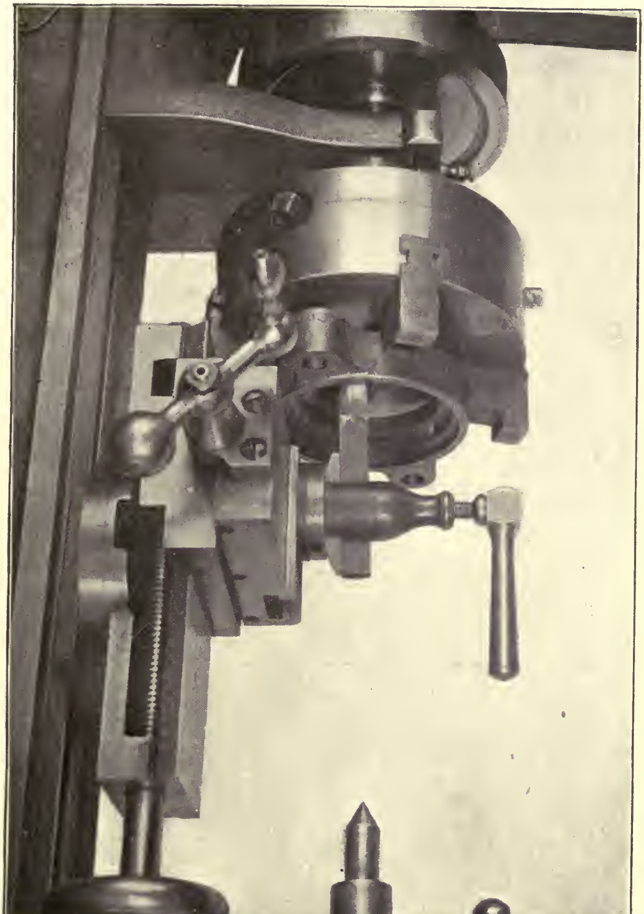

Fig. 48.—Boring Cylinder Collar to Fit Cylinder and Water Jacket Tules.

and a piece of paper or cardboard placed under one or two of them to obviate it. Do not place the casting against the jaws of the chuck on the back, but leave about ⅛-inch space between for clearance for the point of the tool when boring out to fit cylinder tube. A small round point tool can be used to bore out the casting to fit the cylinder tube

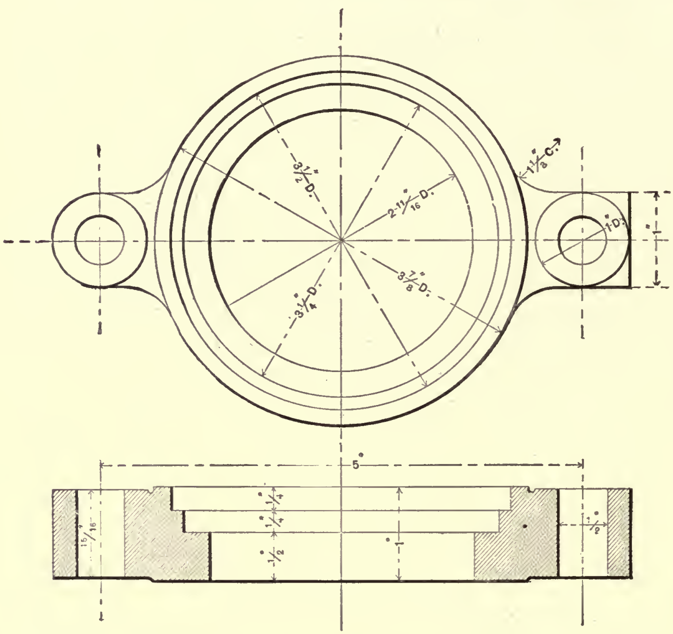

FIG. 49.—CYLINDER COLLAR.

and also to fit the brass jacket tube; but, in the latter case, a sharp point tool must be used afterwards to cut out the square corners.

The exact dimensions will be seen in Fig. 49. Both tubes should be a very snug fit in the collar.

After the casting is bored to fit the tubes, and while still in position in the chuck, face off the edge of the casting. The lugs on the side of the casting need not be faced on

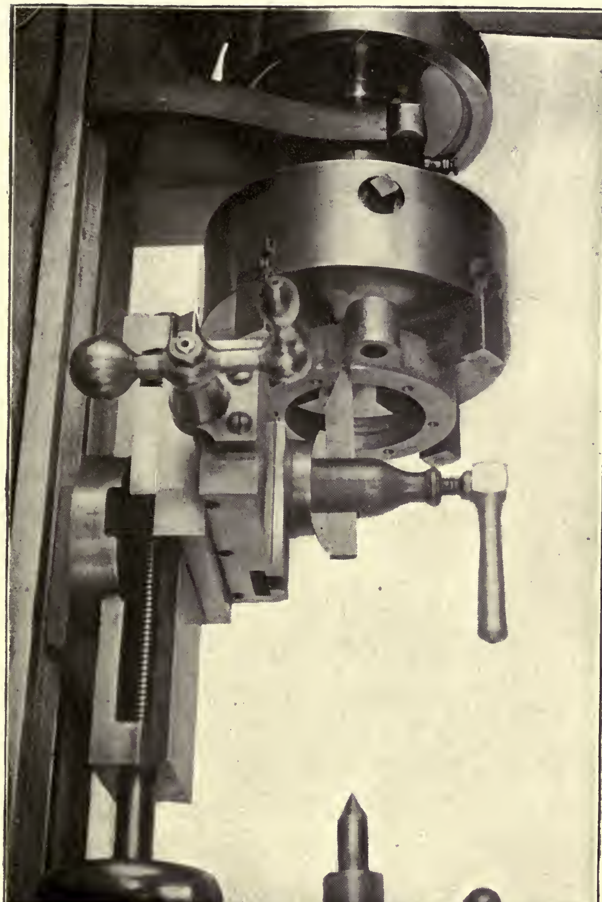

FIG. 50.—FACING OUTER SIDE OF CYLINDER COLLAR.

this side, but must be on the opposite side in the next operation.

After finishing the castings as described remove them from the chuck and replace again with the faced edge against the chuck jaws. Face up the side of the casting and the lugs, as shown in Fig. 50. The small round point tool is best adapted for this work. In facing across the lugs very light cuts should be taken to prevent the casting from jarring loose in the chuck jaws.

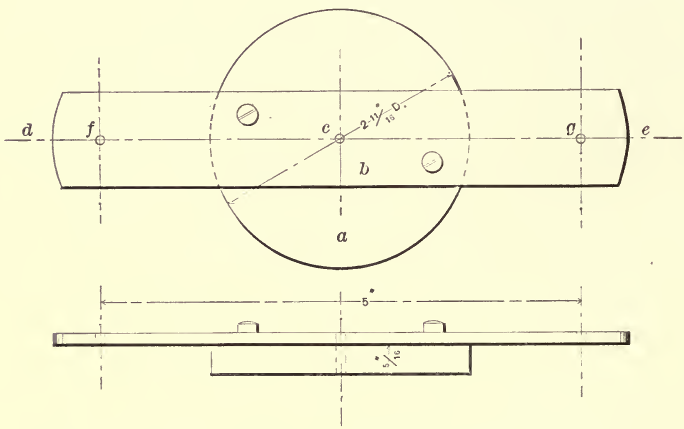

FIG. 51.—JIG FOR HOLES IN CYLINDER COLLAR LUGS.

A special jig must now be prepared to locate the holes in the lugs of the cylinder collars.

This is shown in Fig. 51, in which *b* is a piece of flat steel or iron $\frac{1}{8}$ inch by $\frac{1}{2}$ inch and 6 inches in length. Any convenient width or thickness of metal will do.

Mark with a scriber a line through the center from *d* to *e*, and on this line, midway between the two ends, centerpunch the point *c*. With the dividers lay off from this point the points *f* and *g* $2\frac{1}{2}$ inches distant, as shown. Drill a small hole at each of the three points with about a No. 42 drill.

FIG. 52.—DRILLING CYLINDER COLLAR FOR SIDE RODS. DRILLING JIG IN POSITION ON COLLAR.

The piece *a* is cast with a small chuck piece on the back, by which it is held in the chuck jaws while being turned down to size.

Place this casting in the chuck and turn down the edge until it will just fit into the cylinder collar. Face off the front and, while it is revolving in the chuck, with a sharp pointed hand tool or the centering tool shown in Fig. 43, make an indentation in the center.

Remove from the chuck and drill a hole at the indentation with the same size drill used at *c*.

A pin made of wire the same size as the drill used can now be placed through the two parts *a* and *b* to hold them in position while two screws are inserted, as shown in the cut, to fasten them permanently.

In using the jig, place the round piece *a* in the hole bored in the cylinder collar, with the holes *f* and *g* in the center of the lugs. Clamp in position and drill the lugs, through the holes *f* and *g*, with the same size drill as before.

Fig. 52 shows the jig in use. It is best, in using this jig to have a good large drill pad fitted to the tail stock of the lathe and the faced off part of the cylinder collar held firmly against the pad to insure the hole passing through straight. In the cut shown the tail stock bears against the back of the lug on the cylinder collar. After both lugs have been drilled remove the jig and drill the lugs with a ½-inch drill, which will follow the holes made by the small drill.

Before the cylinder parts are put together two holes must be drilled and tapped in the brass jacket tube for a ¼-inch pipe, as shown in Fig. 45. The water is to enter at the bottom and flow out at the top of the jacket, thus keeping it full.

To assemble the cylinder parts it will be necessary to have the side rods completed, the details of which are to be found in another chapter.

Chapter IX.

PISTON.

THE CASTING. STEEL SHELL. TURNING PISTON CASTING. CUTTING OFF THE CHUCK PIECE. FACING UP THE BACK. DRILLING, BORING AND REAMING FOR PISTON PIN. PISTON PIN. FASTENING PISTON SHELL. LUBRICATING TUBE FOR PISTON PIN. PACKING RING.

CHAPTER IX.

PISTON.

The piston is formed of an outer shell of steel tubing and a casting which forms the head and the wrist pin bearing.

The shell must be squared up at each end, which can be done on the wood arbor on which the cylinder tube was turned. Fig. 53 shows the shell on the wood mandrel and a side tool in the tool post of the lathe to square up the end.

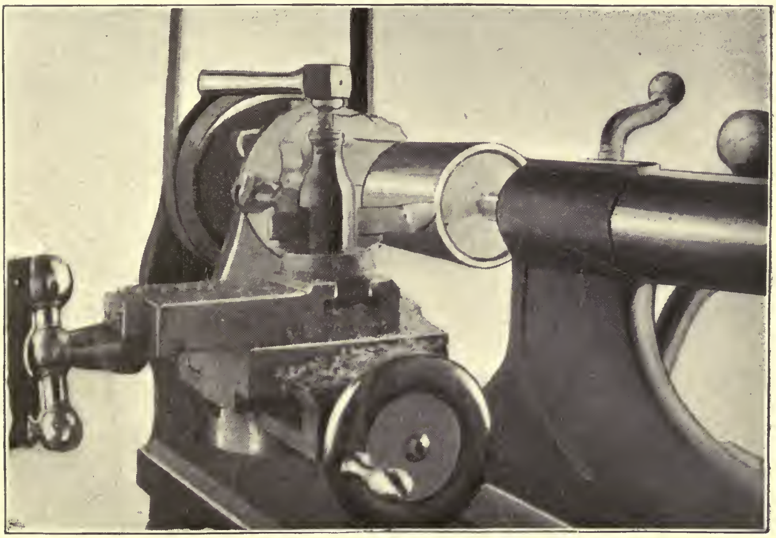

FIG. 53.—FACING UP ENDS OF STEEL PISTON SHELL.

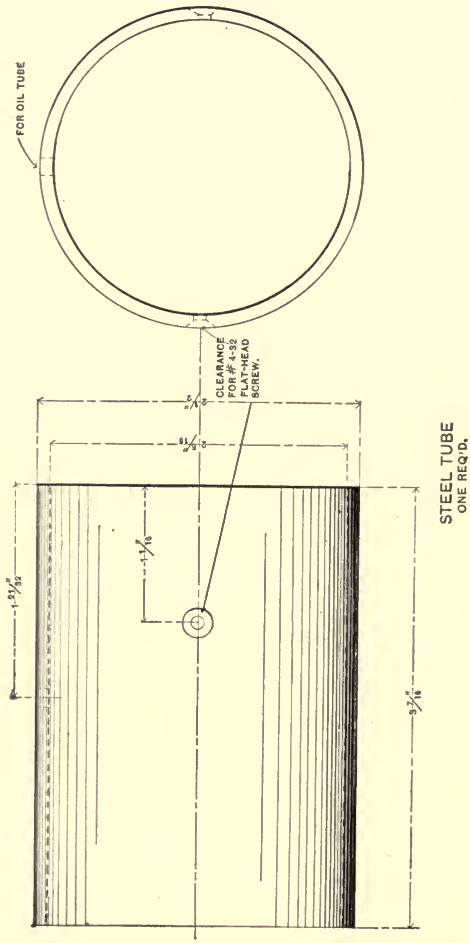

FIG. 54.—PISTON SHELL.

The length of the piston shell, when squared up, should be $3\frac{7}{16}$ inches.

The next operation will be to properly set the piston casting in the lathe. A chuck piece is cast on the back which is gripped in the jaws of the chuck. When the casting is in the chuck, the two bosses cast on the front through which the piston pin is to pass should be on a line with the center of the lathe.

When they are brought to this position the centering tool should be used to mark on the distance piece cast on the front of the bosses a center, which can be drilled by using a chuck in the tail stock, and into which the tail stock center is afterwards placed to support the casting while it is being turned.

Fig. 55 shows the casting held in the chuck with the tail-stock center in place and a cut being taken across the sides. The casting should be turned down until the shell can be placed on tight. A small shoulder is left on the back to act as a stop for the shell, but its diameter must not exceed the outside diameter of the shell.

When the casting has been turned to the proper size, remove it from the chuck, and after the shell has been placed on the casting it is inserted in the chuck, as shown in Fig. 56. The chuck jaws are inserted into the end of the tube and expanded by turning the chuck wrench backward. When the shell runs true in the lathe an indentation may be marked in the end of the casting and drilled for a center, into which the tail stock center is placed to support the end while being turned.

Fig. 56 shows the piston and shell in the lathe with a tool in the slide rest.

The back of the piston must now be faced up true and the chuck piece cut off.

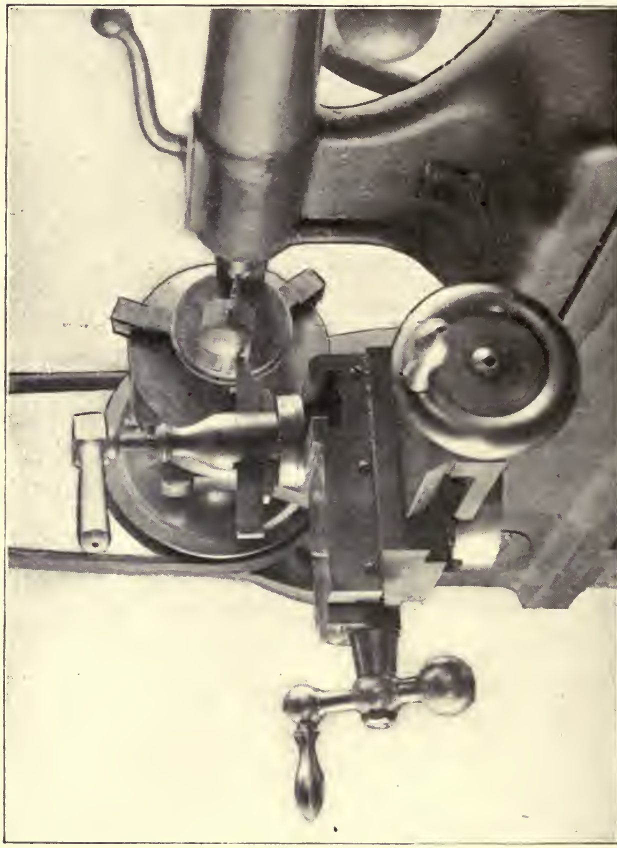

FIG. 55.—TURNING PISTON CASTING TO FIT STEEL TUBE.

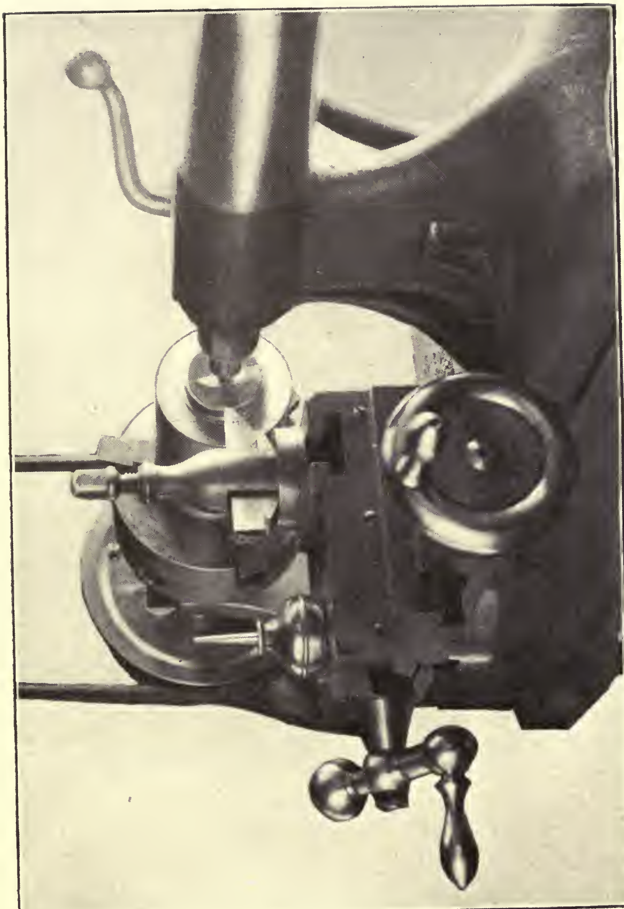

Fig. 56.—Removing Chuck Piece from Piston Casting.

Remove the parts from the lathe and separate the shell and piston casting.

The casting is to be mounted on the angle plate, as shown in Fig. 57, to be drilled, bored, and reamed for the piston pin.

It must be set at the proper height to drill the hole through the center of the two piston pin bosses, and the

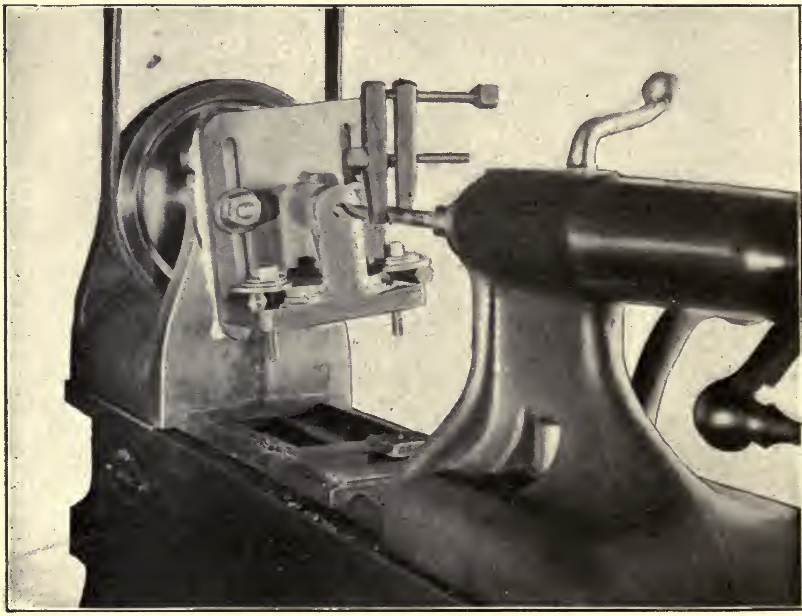

FIG. 57.—DRILLING PISTON CASTING FOR PISTON PIN.

bosses must be squared up by using a straight edge to true them up with the lathe bed, or a steel square can be used to square them up by the back of the angle plate.

Fig. 57 shows clearly the method of clamping the casting on the angle plate.

When lined up and in the proper position, start the lathe, and with the centering tool mark an indentation at the center of revolution of the casting. Start a $\frac{7}{16}$-inch drill at this indentation with the end of the drill against the back center. Fig. 57 shows the drill started and a clamp used to keep the drill from revolving. The clamp is held in the left hand

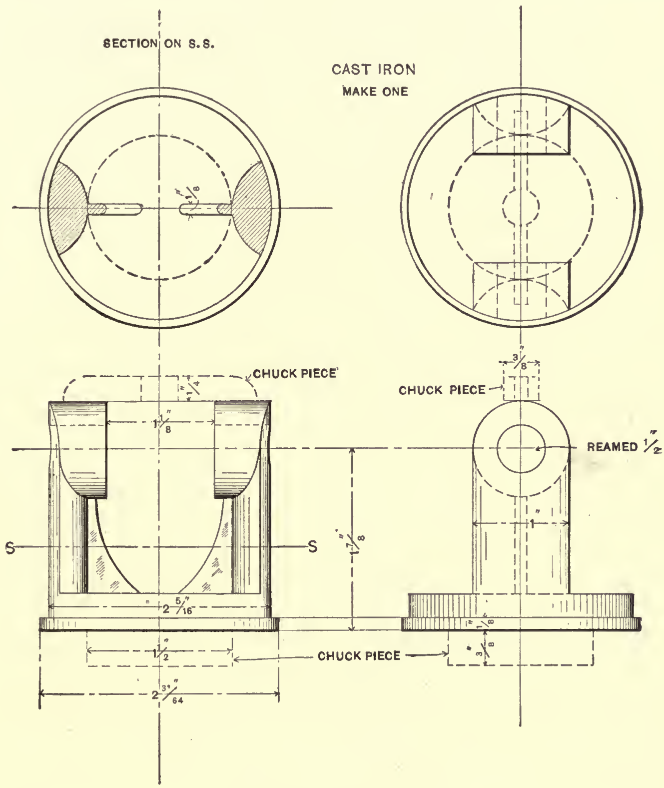

FIG. 58.—PISTON.

while the drill is fed by the right hand turning the tail stock screw.

When the drill has cut through the first boss of the casting, a boring tool can be placed in the tool post and the hole bored out to fit the end of a $\frac{1}{2}$-inch reamer. Pass the reamer through the hole with the lathe running at its slowest speed.

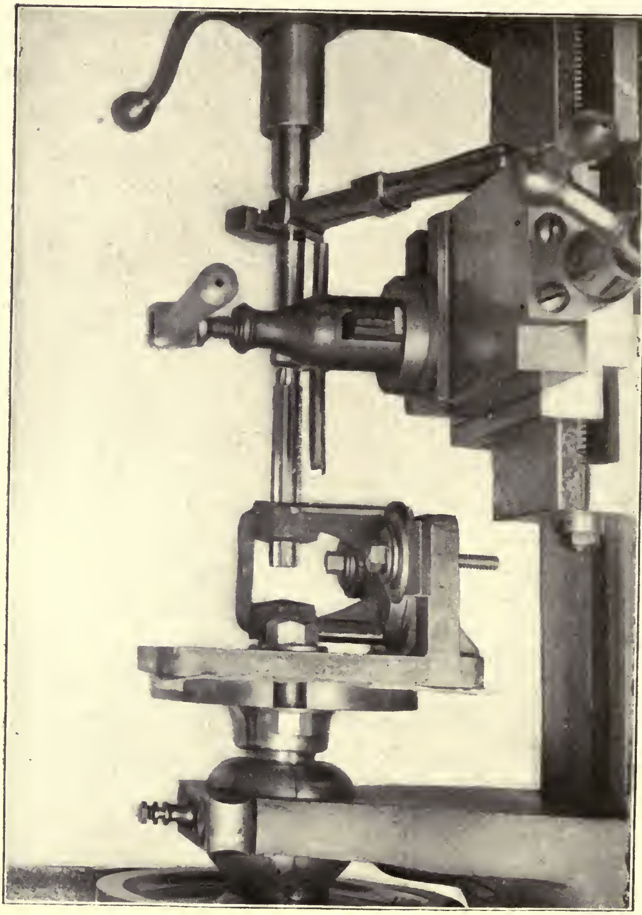

FIG. 59.—BORING AND REAMING PISTON FOR PISTON PIN.

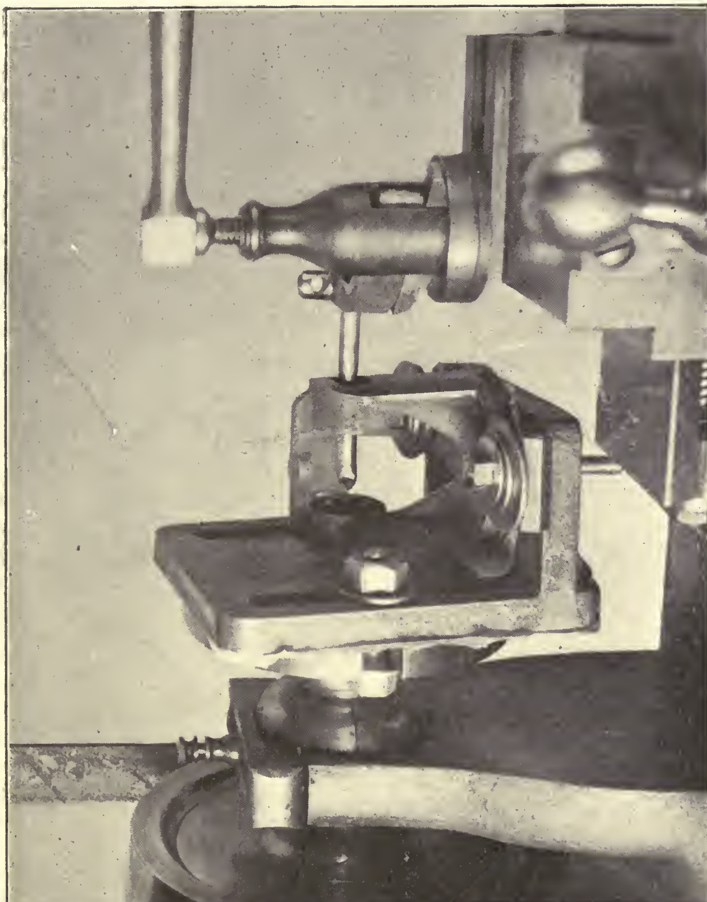

FIG. 60.—BORING HOLE IN REAR BOSS OF PISTON CASTING FOR PISTON PIN.

Fig. 59 shows the reamer in position and prevented from turning by the small wrench. The boring tool is still in the tool post.

The hole in the second boss must now be drilled. Start the drill in the center by passing it through the finished hole in the front boss, then bore and ream as before.

Fig. 60 shows the boring tool extended to reach the back boss.

The casting can now be removed from the lathe and the distance piece cut off even with the end of the bosses.

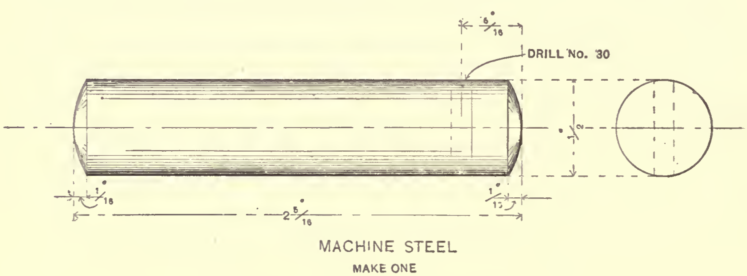

Fig. 61.—Piston Pin.

Through the holes in the two bosses, fit a piece of ½-inch steel rod, the ends of which must not project on the outside surface and interfere with placing in position the piston shell.

In Fig. 72 is shown the piston casting with the piston pin fitted.

Drill through one of the bosses and the piston pin and insert a small pin to prevent the piston pin from rotating in the holes.

Place the shell in position and insert two No. 4 flat-head machine screws through the shell on opposite sides and screwed into the piston casting to hold the shell in place.

Be sure that the screw holes in the shell are countersunk deep enough so that there will be no danger of the screw heads rubbing on the inside of the cylinder.

A small hole should be drilled in the top of the piston shell directly over the center of the piston pin and a small piece of brass tubing driven down into it, which almost reaches the oil hole in the connecting rod end. This hole

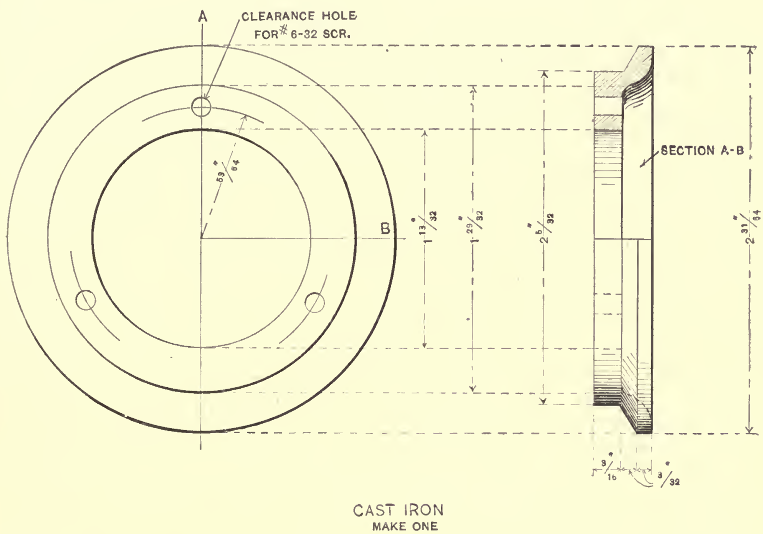

FIG. 62.—PISTON PACKING RING.

will be seen in the detail drawing of the piston shell. The tube receives oil from the lubricator on the end of the cylinder as it passes beneath and delivers it to the piston pin.

When the connecting rod is finished the shell must be removed and the piston pin unpinned and slid out sufficiently to allow of placing the connecting rod on the pin. The piston parts are then placed together as before.

To make a tight fit, without an excess of friction, a packing ring is introduced into the cylinder and screwed to the back of the piston.

This ring and the back of the piston form a V-shaped groove, into which a packing of asbestos is placed. The shape of the groove causes the asbestos to press against the inside of the cylinder when the screws fastening the ring and piston together are tightened.

The ring is held in the chuck jaws, as shown in Fig. 63, while the face, front, shoulder, and bevel face are finished

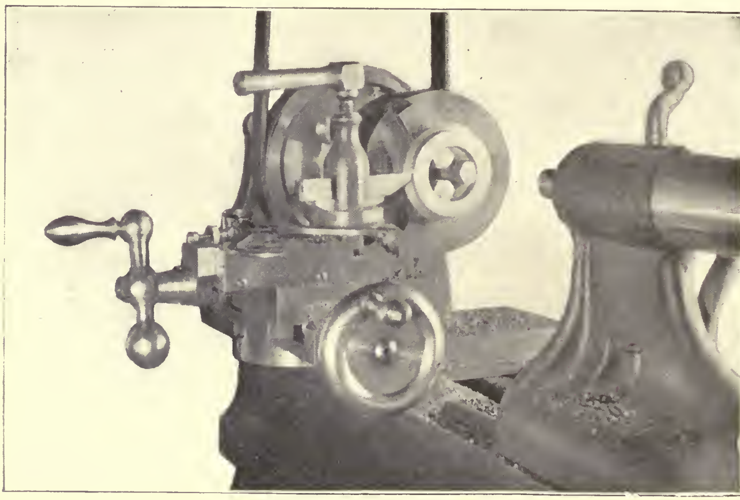

FIG. 63.—FINISHING INSIDE OF PISTON PACKING RING.

and the ring turned down to the proper diameter to fit the bore of the cylinder tube easily.

The ring is then reversed in the chuck and held by the shoulder, as shown in Fig. 64.

The back of the ring is then finished and faced off, as shown.

When the piston and ring are finished, three clearance holes are drilled in the ring for No. 6 machine screws, by which the ring is secured to the piston.

Place the piston and ring in the cylinder and mark through the clearance hole in the ring, the position of one of the screws in the piston.

Remove the piston from the cylinder and drill and tap a

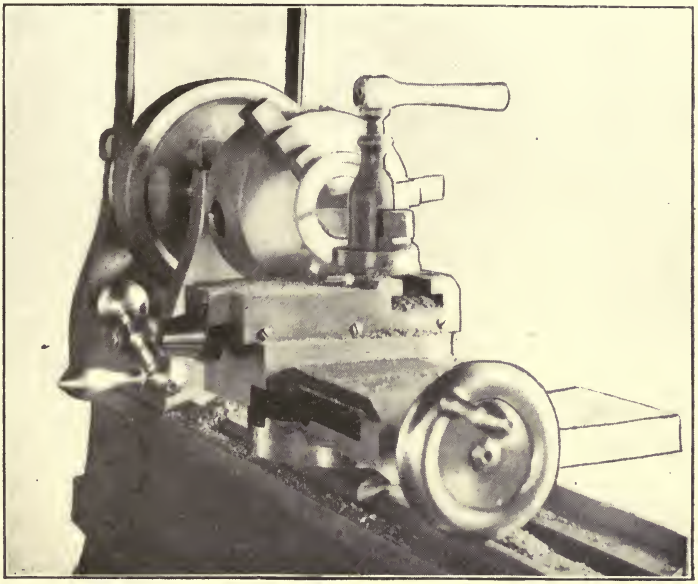

FIG. 64.—FINISHING OUTSIDE OF PISTON PACKING RING.

hole for a No. 6 screw. Replace the piston and ring in the cylinder and fasten together by one screw, when they can be removed from the cylinder and the remaining two screw holes drilled and tapped.

Several who have built engines from these designs have asked for a more permanent packing than the asbestos wicking. We show here a design which can be utilized in all future engines or applied to those already built.

These parts consist of two cast-iron rings cut apart and sprung into the cylinder. These rings take the place of the asbestos packing and are held in place by a follower ring which corresponds to the packing ring already described.

The piston rings should both be turned from one end of a cast-iron ring while the other end is held in the jaws of the chuck.

The casting for the rings should therefore be an inch long at least.

In making up the pattern have the outside diameter $2\frac{11}{16}$ inches and the inside diameter $2\frac{1}{16}$ inches.

Hold one end of the cast ring in a three-jaw chuck and bore out the inside to a finished diameter of $2\frac{11}{32}$ inches. It will be seen on referring to Fig. 64 A that the rings are $\frac{5}{32}$

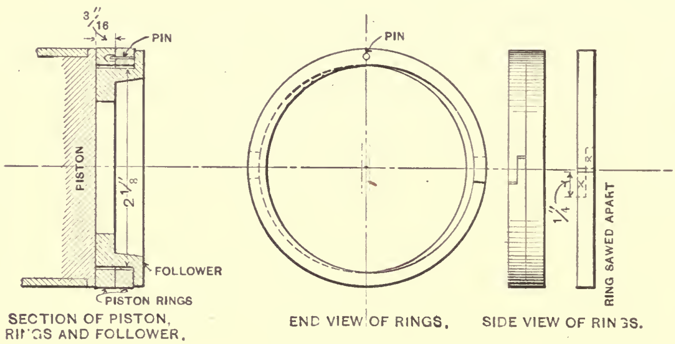

FIG. 64 A.

inch thick on one side and thinner on the other. To accomplish this open the chuck jaws, after the inside of the ring casting is bored out, and place a piece of metal about $\frac{1}{32}$ inch thick under one of the jaws. This will force the casting to one side, and the result will be that, when finished, the ring will be thickest on one side and gradually taper to the thinnest part of the ring directly opposite.

The outside of the casting is now to be turned down to a diameter of $2\frac{37}{64}$ inches and long enough to cut off both rings. Turn as smooth as possible and polish with emery cloth.

Face up the end of the casting true and then with a good, sharp cut-off tool in the slide rest cut off a ring $\frac{3}{16}$ inch long. Face up the end of the casting again and cut off the second ring.

The rings are now to be sawed through at their thinnest point, as shown in the view at the extreme right in Fig. 64 A. In order to spring the rings sufficiently to place them in the cylinder, the portions inclosed in the dotted lines, and marked X, must be cut away. This must be done very carefully, using a small flat file. The rings can now be sprung together to place in the cylinder, and the joint will have the appearance shown in the side view.

When placed in the cylinder the joints of the rings should be at opposite sides of the cylinder. To maintain them in their relative positions, a small pin is inserted in one of the rings and one end allowed to project into a larger hole drilled into the other ring, as shown in the sectional view.

The follower is very similar in shape to the packing ring described in this chapter. When finished it should be turned down to a diameter of $2\frac{1}{8}$ inches where the rings fit over it. It should not touch the inside of the rings at any point. The follower is held against the piston in the same manner as the packing ring, by three No. 6-32 screws.

The instructions given for turning, finishing and fitting the packing ring are applicable to this piece.

Chapter X.

CONNECTING ROD.

CHUCKING PISTON PIN END. FITTING IN STEEL CENTER.
CRANK PIN END. CUTTING APART AND FITTING.
CHUCKING. DRILLING, BORING AND REAMING
DRILLING FOR STEEL CENTER. TURNING
AND FITTING STEEL CENTER.
TAPERING PIN.

CHAPTER X.

CONNECTING ROD.

The connecting rod is built up of four separate pieces aside from the two fillister head screws required to bolt together the crank-pin end.

The brass ends should be finished first, as the holes into which the steel rod is to be driven should be bored before the ends of the rod are turned down.

The piston pin end is chucked by the cylindrical part, as shown in Fig. 65.

Center the casting with a tool in the slide rest and drill the hole with about a $\frac{7}{16}$-inch drill.

Set a boring tool in the slide rest, bore out to scant $\frac{1}{2}$ inch and finish with a $\frac{1}{2}$-inch reamer.

Fig. 65 shows the boring tool in operation and the reamer at hand to gauge size of hole.

In chucking be sure that the boss of the casting, into which the steel rod is to fit, is parallel with the face of the chuck.

After reaming the hole for piston pin, face off the outside of the casting.

In boring the boss to fit on steel rod, fasten the casting to the angle plate, as shown in Fig. 66, by using the $\frac{1}{2}$-inch pin of angle plate and clamping down by means of washers, etc., which build up to the height of the pin.

Face off the end of the boss and center it with a tool in the slide rest.

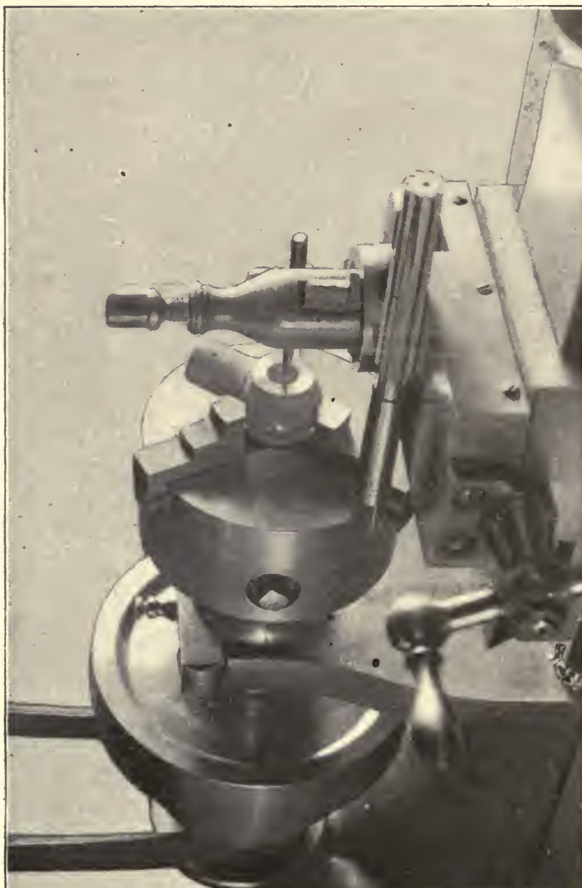

Fig. 65.—Boring Connecting Rod End to Fit Piston Pin.

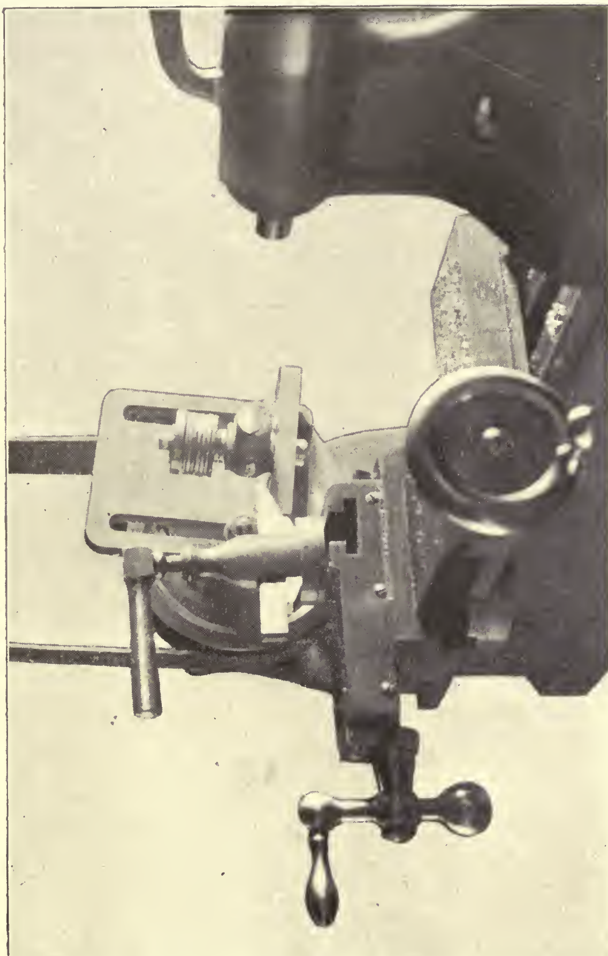

FIG. 66.—PISTON END OF CONNECTING ROD IN POSITION FOR BORING TO FIT ROD.

Drill, bore and ream the hole to $\frac{3}{8}$-inch diameter and $\frac{7}{8}$-inch deep.

Finish the outside of the boss while in this position.

If the crank pin end of the rod is cast in one piece it must first be center-punched and drilled, as shown in Fig. 67, using a No. 4 twist drill. Center-punch a hole for the drill to start in, and directly opposite that a hole for the back center of the lathe to rest in while the casting is being drilled.

Care must be exercised to prevent drilling through too far and either damaging the drill or the back center. A hole can be drilled with much more certainty of going straight through in this manner against the center than to attempt holding the uneven surface of the casting against a flat surface.

Examine the depth of the hole frequently, and when it is found that the drill is almost through remove the back center and finish by forcing the tail stock of the lathe against the casting.

In drilling brass with a twist drill the work should always be held firmly against the tail stock when the drill is about to come through, as the tendency at that time is for the drill to catch and the work to travel up the spiral groove. Woe be to the fingers which are attempting to hold an angular piece of brass when this happens and the said piece catches and begins to travel around at the same rate as the drill!

After both holes are drilled cut the casting apart with a hack saw through the center of the bearing. The two pieces must now be filed and fitted together.

The holes in the outer piece are to be enlarged to $\frac{1}{4}$-inch and the holes in the inner piece tapped with a 14-20 tap. The two pieces are now to be fastened together with cap screws and bored out to fit the crank pin.

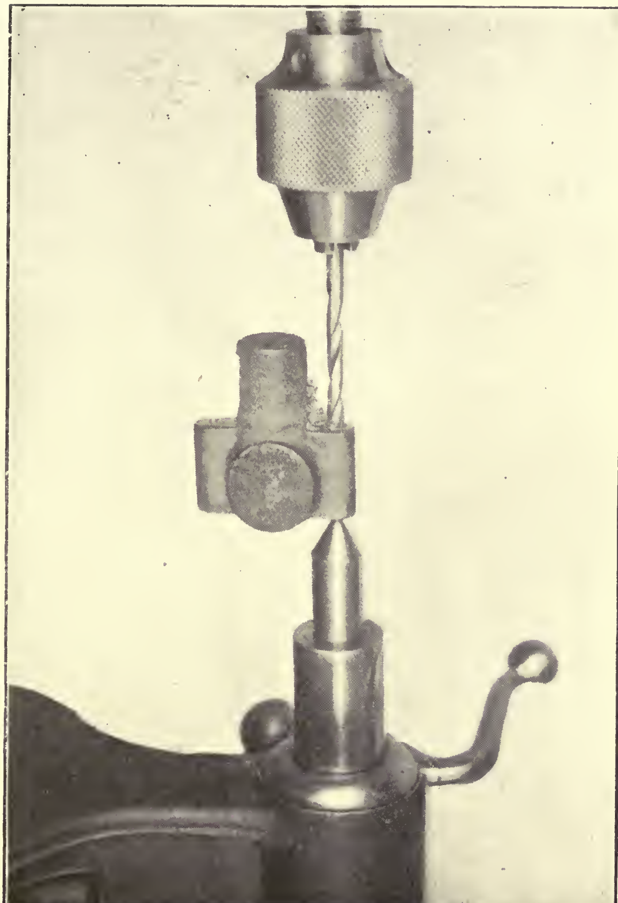

FIG. 67.—DRILLING CONNECTING ROD HEAD FOR SCREWS.

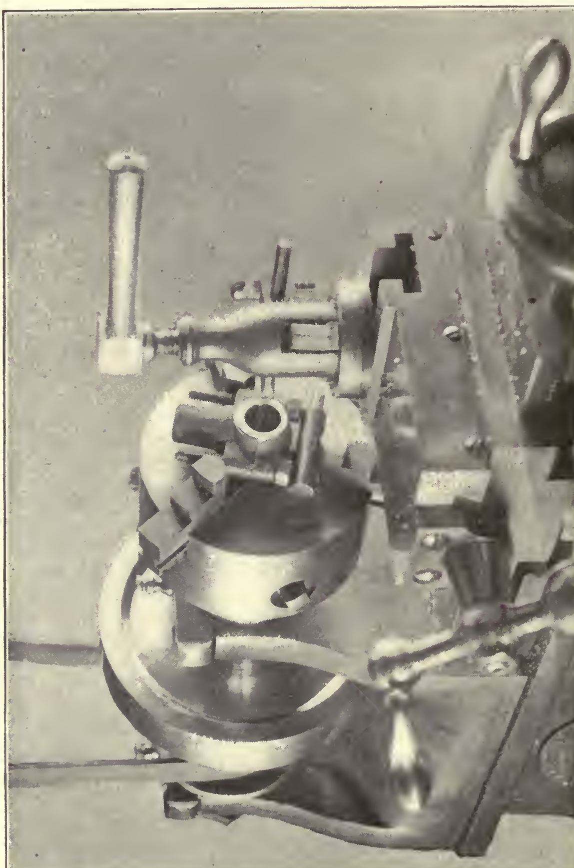

Fig. 68.—Boring Connecting Rod Head to Fit Crank Pin.

In chucking this end of the connecting rod some little ingenuity may be necessary to hold it in a three-jawed chuck.

Fig. 68 shows the parts chucked with a small piece of brass rod used as a packing piece to fill out the lower side. In this case a notch had to be filed in the piece of rod to make it the proper thickness.

When in position face off and center with a tool in the slide-rest. Drill, bore and ream out to $\frac{3}{4}$-inch size.

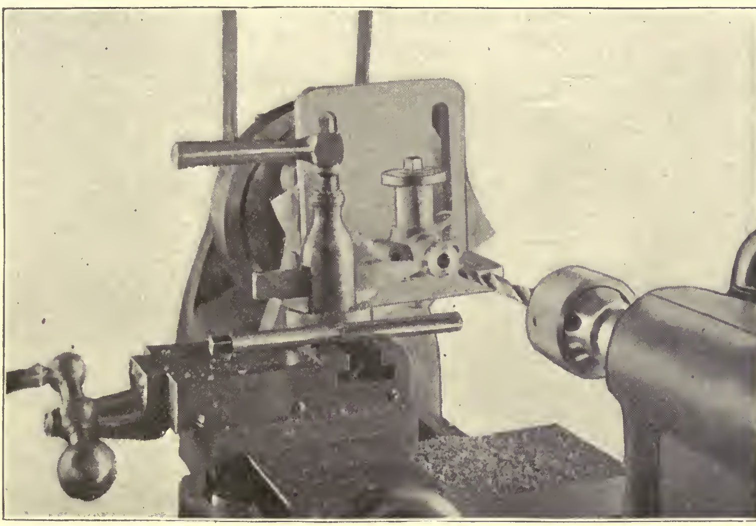

FIG. 69.—DRILLING AND REAMING CONNECTING ROD HEAD TO FIT ROD.

The parts can be removed from the chuck and clamped to the angle plate for boring out boss for steel rod. Fig. 69 shows the operation. The $\frac{1}{2}$-inch pin of the angle plate must be bushed to fit the $\frac{3}{4}$-inch hole, and the parts clamped in position. As will be seen, this operation is identical with the one described for the piston pin end of the connecting rod. The only difference shown is in method of clamping to the angle plate. In this cut a piece of brass tubing is used, instead of washers, to build up the casting to the height of the angle plate pin.

Drill, bore and ream a $\frac{3}{8}$-inch hole in boss of casting, $\frac{7}{8}$-inch deep.

The two rod ends must be faced up true with the holes for crank pin and piston pin. This is done on an arbor or mandrel, as shown in Fig. 70. This mandrel is made from

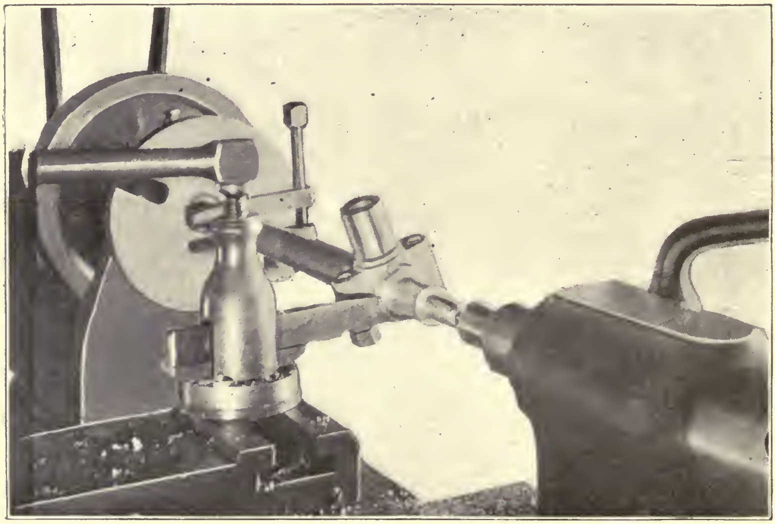

FIG. 70.—TURNING AND FINISHING CONNECTING ROD HEAD.

any piece of iron or steel which is found suitable. In this cut it will be seen that the end of the arbor next the back center has been turned down to $\frac{1}{2}$-inch diameter to fit the piston pin end of the rod and the next section is turned to $\frac{3}{4}$-inch diameter. The crank pin end of the rod is in position ready for facing up. This is best done by using right and left side tools on the alternate sides of the parts. The most important thing in connection with this operation is to leave both faces at an equal distance from the sides of the finished boss.

The arbor should be turned a little full in size and then filed slightly tapering toward the tail stock to allow the rod ends to be driven on tight enough to retain their position while being faced.

Referring to Fig. 71 it will be seen that the center section of the connecting rod is turned from a piece of $\frac{5}{8}$-inch machinery steel, $9\frac{15}{16}$ inches long.

Center the ends carefully and drill them for about $\frac{3}{16}$-inch with small drill, after which use a center reamer.

Place in the lathe, between the centers, and turn down each end to a full $\frac{3}{8}$-inch for a distance of $\frac{7}{8}$-inch, squaring up the shoulders with a sharp side tool.

Leave a collar $\frac{3}{16}$-inch wide at each shoulder and turn down behind each collar a neck of the rod $\frac{1}{2}$-inch in diameter.

Swivel the slide rest, or, if an engine lathe is used, set over the tail stock until a cut started at the neck of the rod would just run out at the center. In a light lathe two or more cuts will have to be made to straighten this across.

Stop the tool $\frac{1}{2}$-inch from the center of the rod.

Turn the rod around, cut the other end in the same manner. This will leave a portion of the rod, in the center, of the original diameter and 1 inch in length, with a slight shoulder at each end, which adds very much to its appearance.

File up with a smooth file and finish with fine emery cloth.

In assembling the parts of the connecting rod it is important that the holes for crank pin and piston pin should be in line.

This is best accomplished as shown in Fig. 72.

In this cut the piston pin end of the rod has been drilled through the brass boss and steel rod and a small pin made

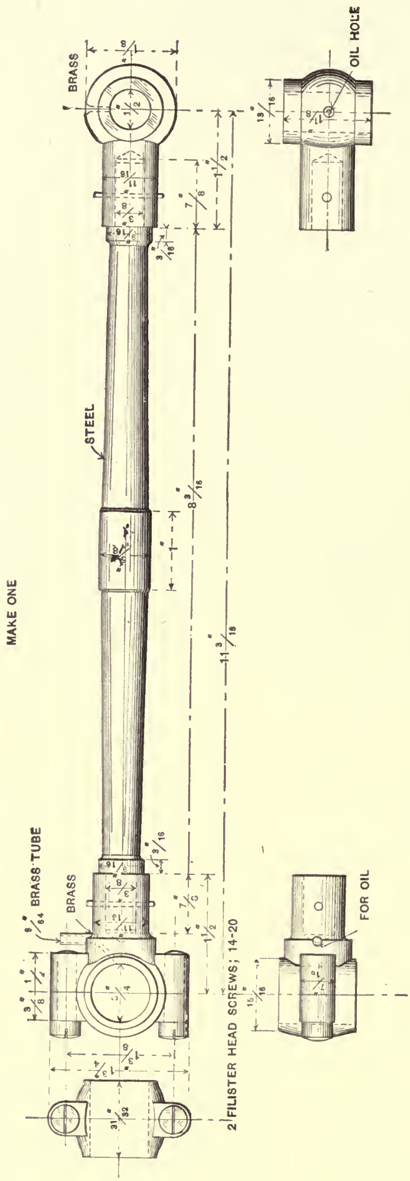

Fig. 71.—Connecting Rod and Ends.

of steel wire driven through. A $\frac{1}{2}$-inch reamer was then placed in the hole for the piston pin and a piece of $\frac{3}{4}$-inch rod in the crank pin hole. In sighting across the reamer and rod, if they are exactly parallel, the rod is in line. If not parallel, the free end of the rod must be turned until the holes are exactly in line, after which the remaining end is drilled and a pin inserted. It will be found advisable to ream these pin holes with a small five-sided brooch or reamer and use taper pins to fit them.

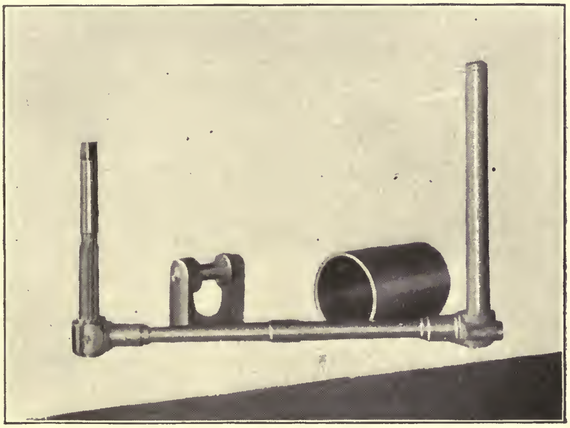

FIG. 72.—PUTTING CONNECTING ROD ENDS IN LINE.

Chapter XI.

BEARINGS.

CHUCKING THE CASTINGS. DRILLING, BORING AND REAMING FOR SHAFT. ATTACHING TO ANGLE PLATE. LINING UP THE PLATE. INSERTING PIN BUSHINGS. CENTERING AND BORING FOR SIDE RODS. TURNING TO FACE OFF BASE. CYLINDER SUPPORTS. CHUCKING AND BORING. FACING BASE. DRILLING FOR SCREWS. HUB FOR GEAR STUD. DRILLING. OIL CUPS.

CHAPTER XI.

BEARINGS, ETC.

The castings for the main bearings should first be chucked to bore out for the shaft, as shown in Fig. 73.

With a round point tool in the slide rest face off the end of the bearing, then make an indentation in the end of the bearing with the centering tool while the piece of work is revolving.

This should be made quite deep and must run true.

With a $\frac{5}{8}$-inch drill (either flat or twist drill will do) held against the back center of the lathe, as shown in Fig. 73, start the drill through the casting where the indentation is made.

Before the hole is drilled entirely through it will probably be noticed that the drill is wabbling more or less, and when the hole is drilled it will run unevenly. This must now be trued up by using a boring tool in the slide rest.

Bore out by taking light cuts until the end of the reamer will enter the hole, then ream to size, which, in this engine, will be $\frac{3}{4}$ inch.

After both bearings have been bored and reamed for the shaft they must be drilled and bored for the side rods.

For this operation the angle plate is used.

Place the angle plate on the face plate, with a piece of newspaper between, and insert the bolts. Place the steel pin in position in the angle plate shelf and place on the pin

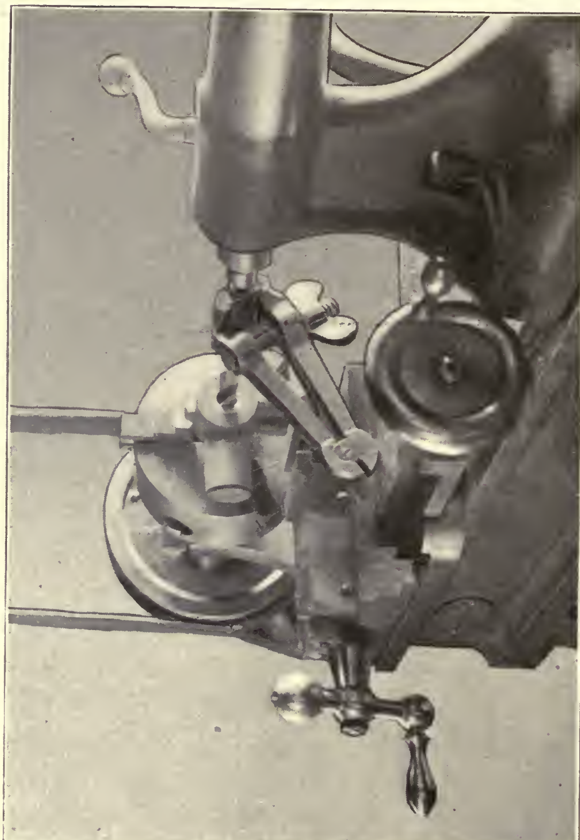

FIG. 73.—DRILLING MAIN BEARING FOR SHAFT.

one of the bushings. A small piece of newspaper should be previously put on over the pin. It may be well to state that the purpose in placing a piece of paper on the angle plate shelf, and between it and the face plate, is that the two smooth surfaces of the metal will not adhere as well under a given

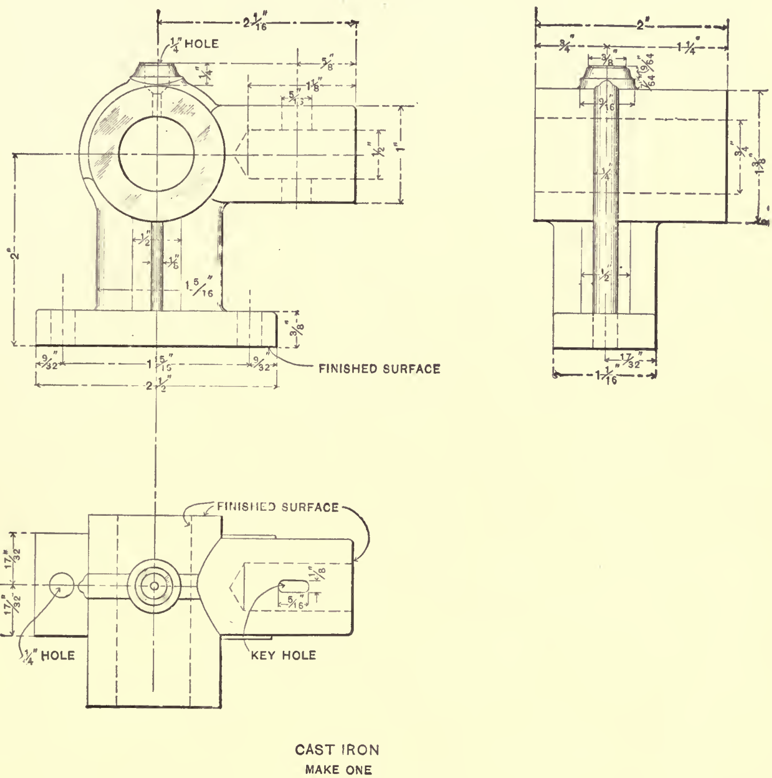

FIG. 74.—BEARINGS.

pressure when put together surface to surface as they will if a thin piece of soft paper is inserted between. This is a good wrinkle to remember in clamping up work.

After the first bushing is in place set the bearing on over it and then place the second bushing over the pin and down into the top of the hole in the bearing. Build up on top of the casting with washers until they exceed the height of the pin, when a large washer with small hole to fit the $\frac{1}{4}$-inch cap screw is placed across the top and the bearing clamped

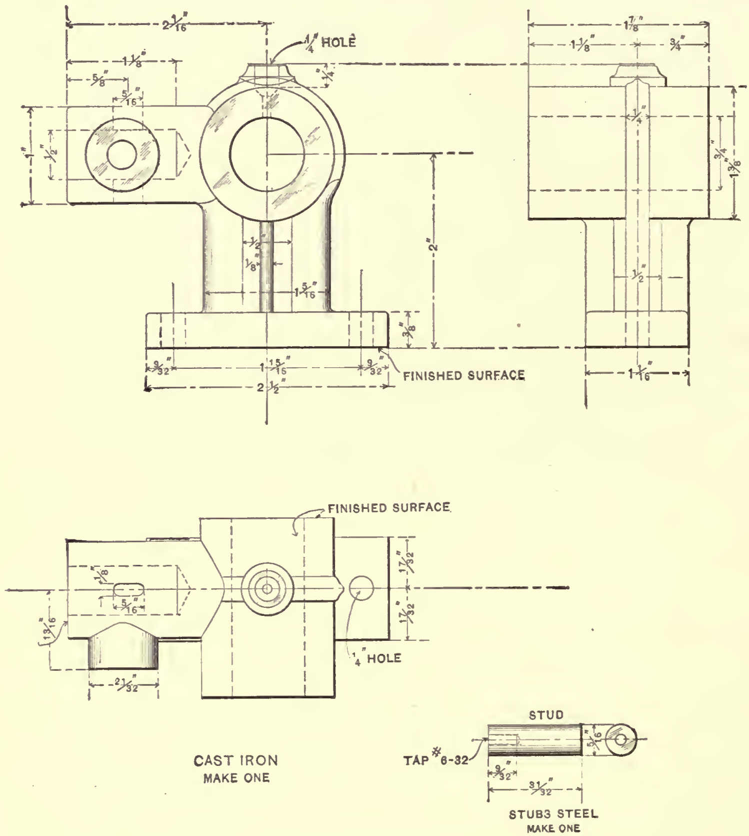

FIG. 75.—BEARINGS.

down on the shelf of the angle plate. The plate must now be adjusted up or down on the face plate until the center of the boss for the side rod is in line with the back center. The boss of the bearing should also be in line with the lathe bed and run true when the lathe spindle revolves.

Fig. 76 shows the bearing in position on the angle plate. Center the end of the boss by using the centering tool in the slide rest, or a hand tool.

Drill into the end of the boss with about a $\frac{7}{16}$-inch drill to a depth of $1\frac{1}{2}$ inches. Set a boring tool in the slide rest and bore out the hole until the end of a $\frac{1}{2}$-inch reamer will enter. Ream to size with the lathe revolving at very slow speed.

Fig. 76 shows the boring tool in operation and the reamer on the slide rest ready to use for gauging the diameter of the hole.

The ends of the boss of each bearing must be faced off at an equal distance from the hole for the shaft. An easy way to determine this is to face off the first bearing and measure with a pair of dividers the distance from the end of the boss to the back of the angle plate. Keep the dividers set at the same measurement until the boss of the second bearing is ready to be faced, when the dividers can be used to gauge the length of it.

After finishing the second bearing the cap screw in the angle plate pin can be loosened and the bearing swung around until the foot of the bearing is in position to face off.

Fig. 77* shows the bearing in position.

A $\frac{1}{2}$-inch reamer is placed in the hole of the boss, by which it is lined up. If one side of a steel square is now held against the side of the reamer the other side of the square should be in line with the lathe bed.

This will bring the hole in the boss and the bottom of the bearing parallel when the base has been faced off.

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* It will be noted that in this cut the screw holes in the base have been bored. This photo had to be retaken, and the bearing was removed from the finished engine for that purpose, the first plate having been spoiled.

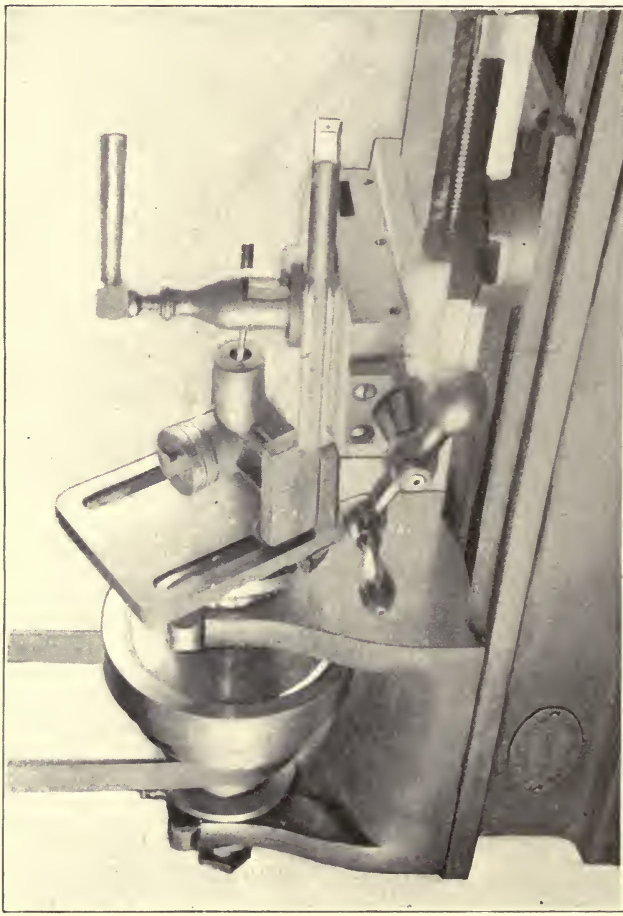


Fig. 76.—Boring Main Bearing for Side Rod.

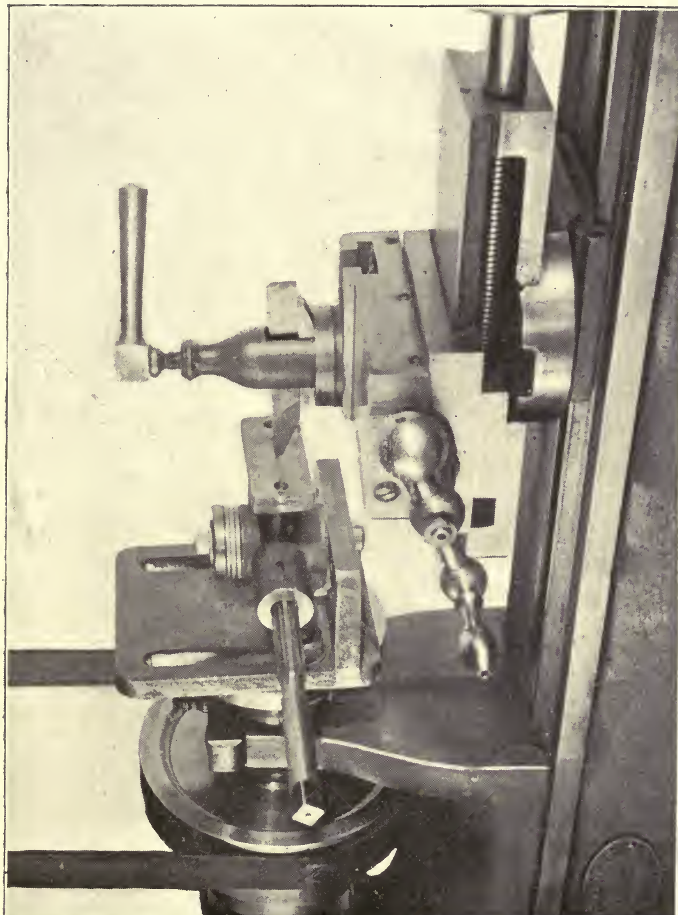


FIG. 77.—SETTING MAIN BEARING ON ANGLE PLATE TO FACE OFF BOTTOM.

Set a round point tool in the slide rest to face across the bottom of the bearing.

After the cut is made across the bottom the operator should run the slide rest toward him by using the cross-feed only, and remove the bearing from the angle plate. Place the second bearing in position and feed the slide rest toward the work by the cross-feed only. If cut across in this way the bearings will be of exactly the same height from the bottom to the shaft.

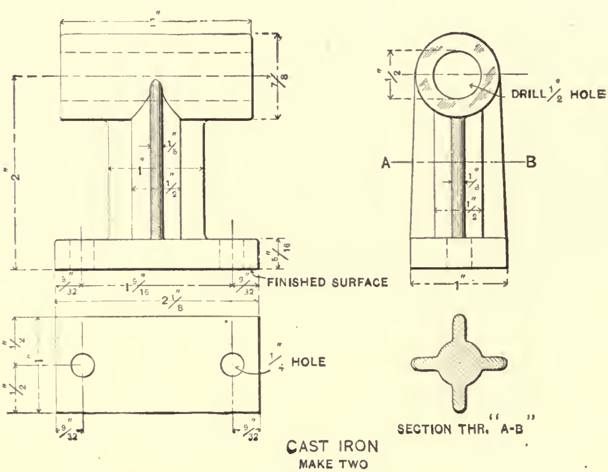


FIG. 78.—SUPPORTS.

The supports for the cylinder are to be done in the same manner as the main bearings, being first chucked by their cylindrical parts and drilled, bored and reamed to ½ inch, after which they are placed on the angle plate pin and the bottom faced off.

It will be found advisable to do the drilling, boring and reaming of the cylinder supports before the angle plate is placed in position, as they can then be faced off on the bottom by placing on the angle plate pin as soon as the bearings

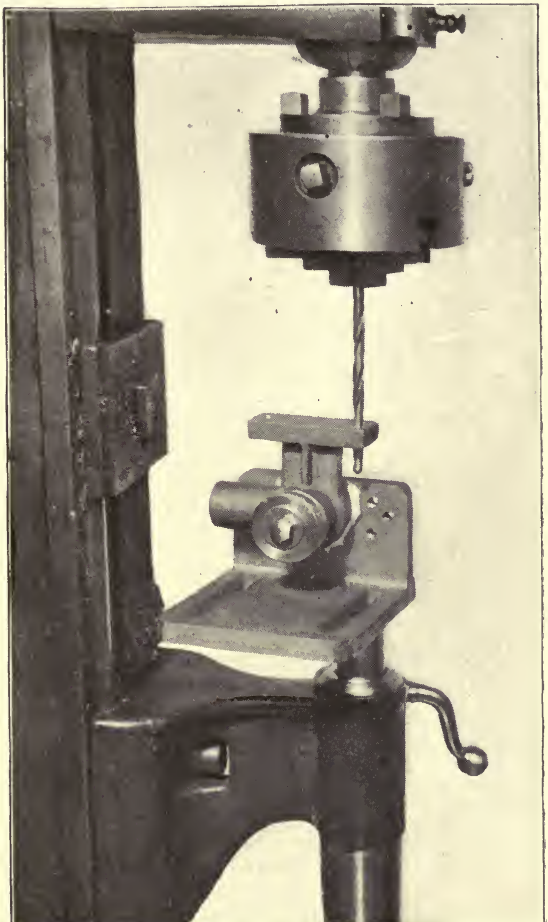


FIG. 79.—DRILLING BASE OF MAIN BEARING FOR CAP SCREWS.

are faced off and a cut taken across them while the tool is adjusted for the bearings.

This will bring all four pieces exactly the same height from the bottoms to the center of the holes.

After the bearings and supports have been faced the holes

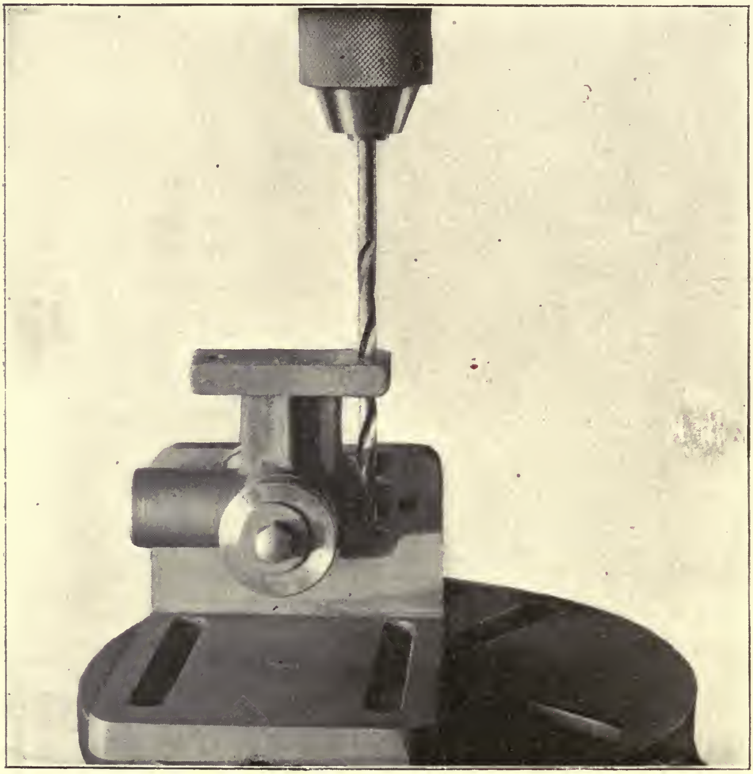


FIG. 80.—DRILLING MAIN BEARING ON DRILL PRESS.

are to be drilled in the bottom, by which they are to be fastened to the bed plate. The position of the screws and cap screws are laid off on the bottom of the castings with a pair of dividers. The positions laid off are then center-punched. In drilling the bearings for cap screws use a $\frac{1}{4}$-inch

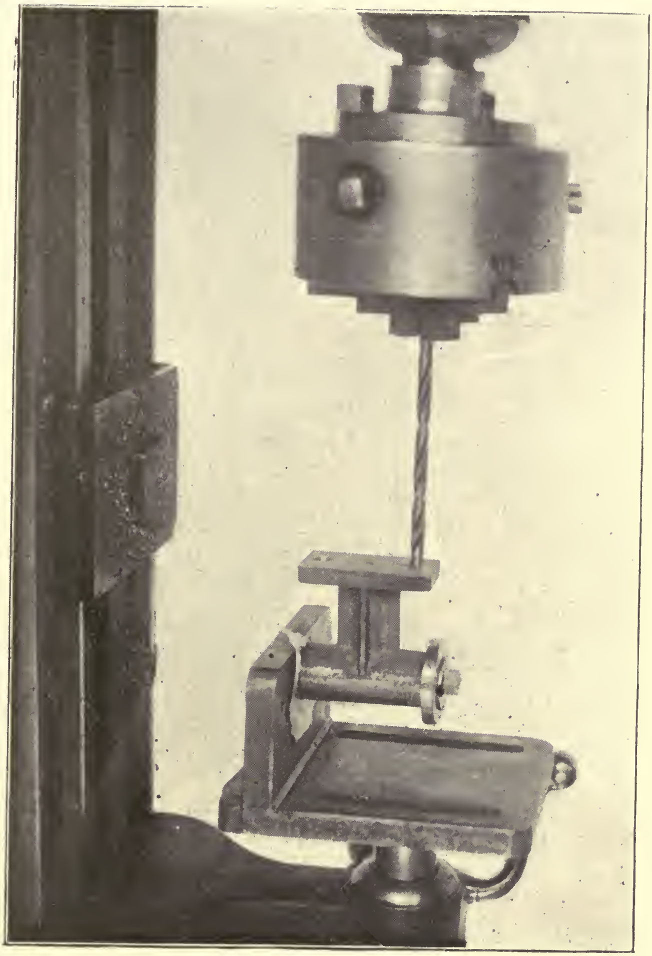


FIG. 81.—DRILLING CYLINDER SUPPORTS FOR SCREWS.

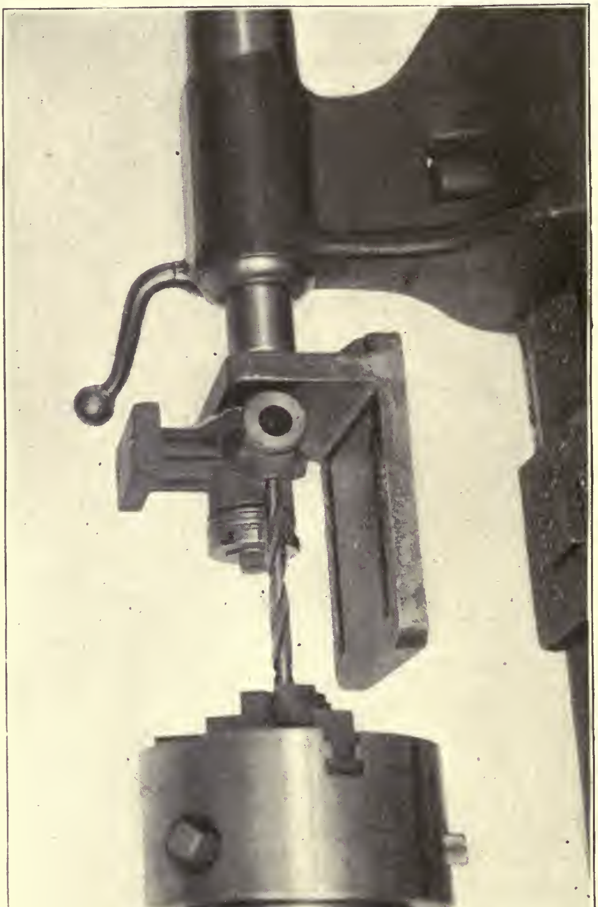


FIG. 82.—DRILLING MAIN BEARING FOR GEAR STUD.

drill and hold the bearings on the angle plate pin, as shown in Fig. 79.

Fig. 80 shows the same operation as it would be done on an upright drill press.

The cylinder supports are also to be drilled for screws. Lay off the holes in their proper location, then center-punch them and drill when clamped on the angle plate pin, as shown in Fig. 81.

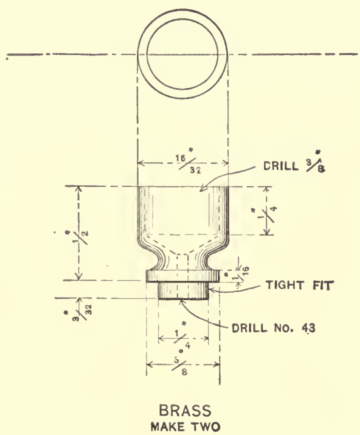


FIG. 83.—SMALL LUBRICATOR FOR BEARINGS.

One of the main bearings has a small hub cast on the boss for the gear stud.

Lay off, with the dividers, a point on this hub $1\frac{1}{2}$ inches from the center of the hole for the shaft. Center-punch this point and drill a $\frac{5}{16}$ inch hole for the stud. To drill the hole the bearing should be clamped to the angle plate and drilled, as shown in Fig. 82.

Oil cups are to be placed on the bearings. Center-punch the bearing directly over the shaft. Use a $\frac{1}{4}$-inch drill, placing the base of bearing against the the tail stock of the lathe.

Drill the bearings to a depth of about $\frac{1}{4}$ inch, after which the holes are to be continued through to the shaft with a smaller drill—No. 42 will do for this.

The oil cups can be turned up by hand from a piece of $\frac{1}{2}$-inch brass rod.

Chapter XII.

SIDE RODS.

CENTERING. LENGTH. SHOULDERS. TURNING. FITTING. FILING. FINISHING. THREADING. TESTING ACCURACY OF PREVIOUS WORK. DRILLING AND FILING FOR KEYS.

CHAPTER XII.

SIDE RODS.

The side rods are made of soft steel bars $\frac{3}{4}$ inch in diameter and $16\frac{3}{8}$ inches long.

In turning these rods on a plain lathe with a slide rest, care must be exercised to have the slide rest set squarely on the lathe bed, and that the tool travels parallel with the rod to be turned.

Use a sharp side tool to turn down the ends and finish the shoulders.

After the slide rest is set and the first cut taken, caliper the work at each end of the cut. If it is found that the two diameters are not exactly the same, the slide rest must be loosened and reset. If the difference is very slight, a light tap on the proper side of the slide rest with a mallet will be found to correct the fault.

Be sure to clean out the corners of the shoulders at each end of the rod, to allow the bearings and cylinder lugs to come square up.

The ends of the rods which fit into the boss of the bearing must be slightly tapered at the ends to correspond with the taper of the end of the reamer. This may be done with a file while the rod is revolving in the lathe, but care must be used that only just sufficient material is removed to make the rod a tight fit into the boss.

In finishing the center portion of the side rods be sure

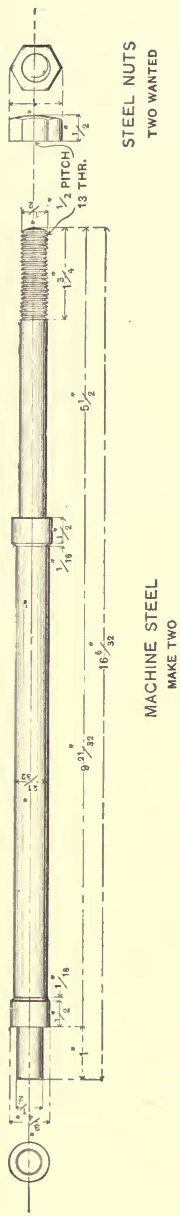


Fig. 84.– Side Rods.

that the distance between the shoulders is exactly the same, otherwise the cylinder and shaft will be cramped when the parts are put together and fastened.

If a plain side rest is used in turning these rods, it may be necessary to set it in two different positions on the lathe bed, as the travel of the tool post may not be sufficient to turn the lengths of cut required at one setting. In this case, when the slide rest is moved, be sure there are no chips or cuttings under the base of the rest, as they would tend to prevent accurate work.

In Fig. 85 is shown a side tool in the slide rest finishing the long cut on the cylinder end of one of the rods. It will be noticed that the metal is cut from the work in long spiral coils, one of which is seen at the point of the tool.

The rod is turned down along the center between the two shoulders, but at each end of the cut a collar is left the original diameter of the rod, which adds very much to the appearance when finished.

After being turned to size, the center part should be filed as smooth as possible and polished with emery cloth.

Fig. 85 shows one rod finished and ready for threading.

Should the builder possess an engine lathe, the rods can be threaded easily

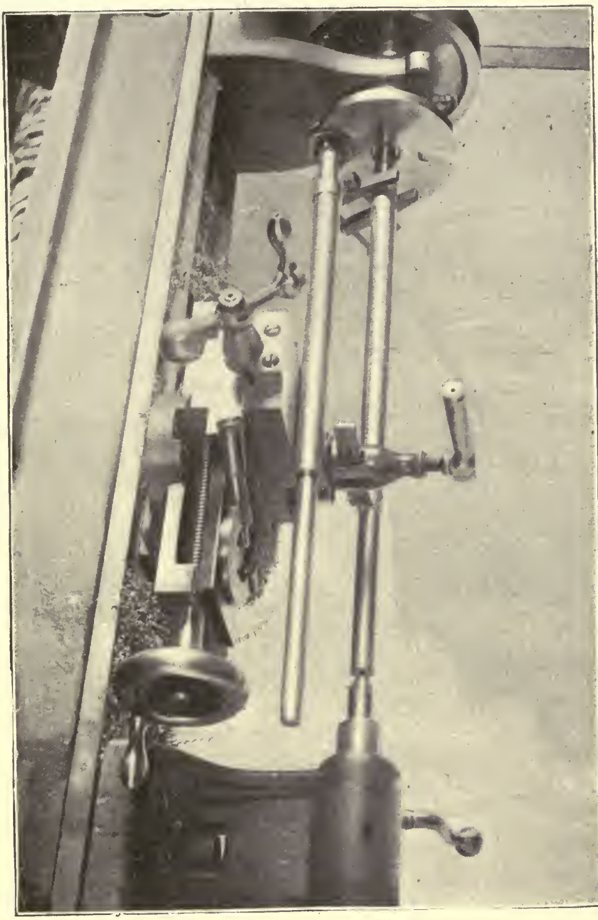


FIG. 85.—TURNING AND FINISHING SIDE RODS.

and accurately, but the cuts taken with the threading tool must be very light, as otherwise the work will spring, being so long and of small diameter.

If done by hand with a ½-inch die, the thread must be started very carefully to prevent the die from running in on one side, as it will sometimes cut away the material to quite an extent, thus weakening the rod at that point, and furthermore, the nut will not bear squarely on the cylinder collar.

At this point the accuracy of the work may be tested, as

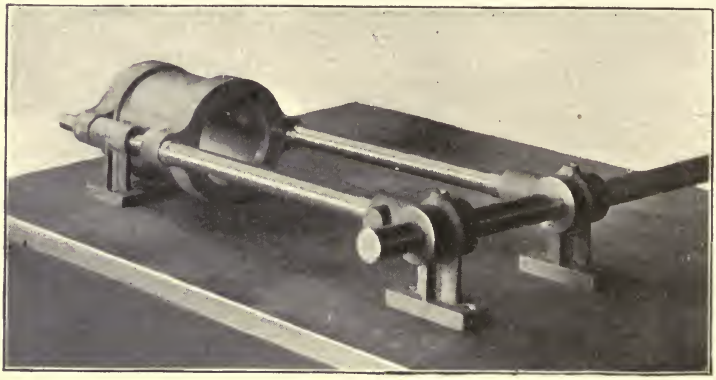


FIG. 86.—CYLINDER COLLARS, SIDE RODS AND MAIN BEARINGS ASSEMBLED TO TEST ACCURACY OF WORK.

shown in Fig. 86. This shows the cylinder collars, brass jacket shell, cylinder supports, side rods, and bearings placed in position, which should be done on a perfectly level surface. When these parts are assembled in their proper positions and a solid shaft placed through the bearings, if the lathe work has been accurately done, the shaft can be easily rotated between the fingers.

The rods are secured to the bearings by keys driven through the boss and the rod, as shown in Fig. 88.

Center-punch the top of the boss ⅝ inch from its outer end

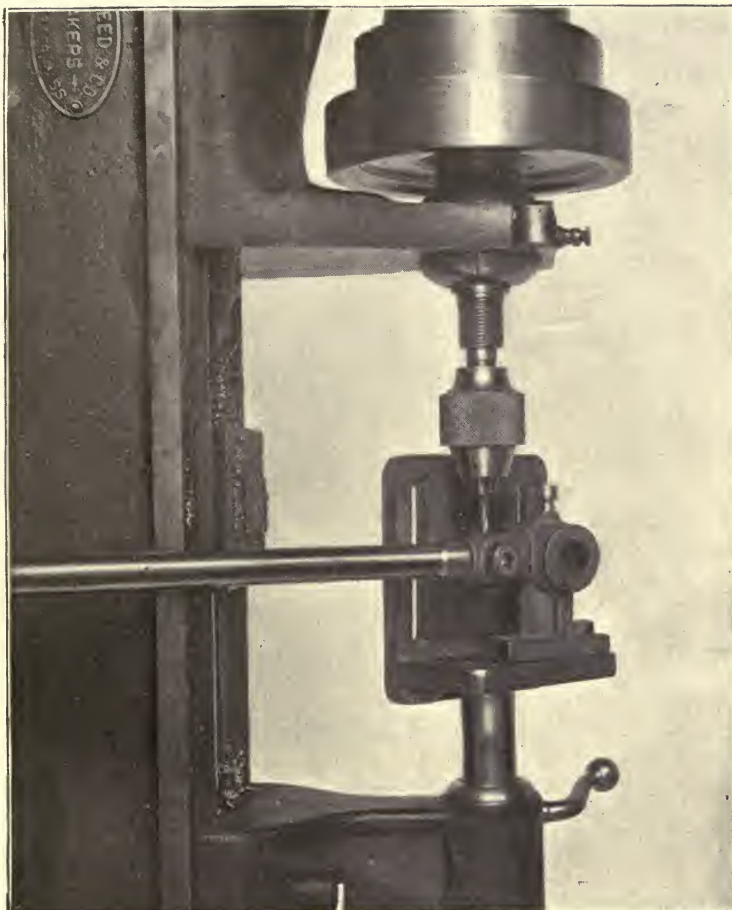


FIG. 87.—DRILLING MAIN BEARING AND SIDE ROD FOR KEY.

and lay off with the dividers another point $\frac{5}{32}$ inch from the first center-punch mark toward the shaft, which also center-punch.

Fasten the bearing to the angle plate by a $\frac{1}{4}$-inch cap screw, as shown in Fig. 87.

Drill directly through the boss and side rod at both center-punch marks with a $\frac{1}{8}$-inch drill.

In drilling this in the lathe, do not let any of the weight of the angle plate, etc., hang on the drill, as it will, in that case, run out of place, and the two holes will not be parallel. Also see that the side rod remains in position until the drill

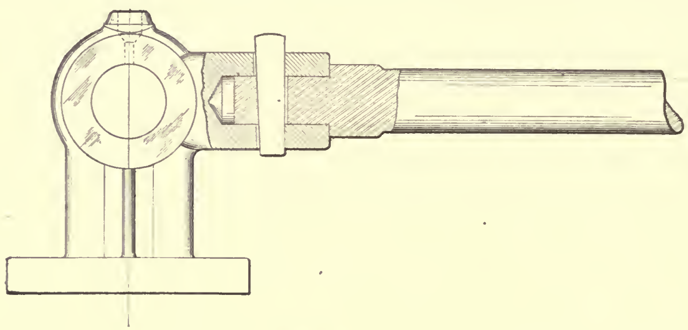


FIG. 88.—SIDE ROD AND MAIN BEARING KEYED TOGETHER.

has passed through. When finished there will be two parallel holes $\frac{1}{32}$ inch apart. Remove the rod and, using a small round file, cut away the metal between the two holes in the rod; they will then form a slot $\frac{1}{8}$ inch by $\frac{9}{32}$ inch. File away the rod about $\frac{1}{32}$ inch more *toward the shoulder*.

The holes in the bearings must now be filed into a slot, after which the slot is filed another $\frac{1}{32}$ inch *toward the shaft*.

When the parts are put together now, a taper key $\frac{1}{8}$ inch thick driven through the slots will draw the rod into the bearing, as shown in the cross section in Fig. 88. The key should be made of steel.

Chapter XIII.

BED PLATE.

FILING. PLANING. LINING UP. AN IMPROVED FORM.

CHAPTER XIII.

BED PLATE.

The bed plate casting requires very little work, yet to the amateur this little may present some difficulties.

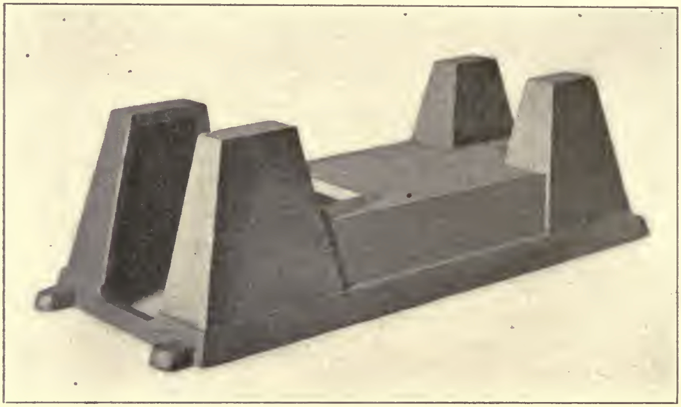
The four points on which the engine proper rests require to be perfectly level.

The only way in which this can be done with perfect accuracy is on a planer or a milling machine. The four surfaces can be filed down if the operator has sufficient patience, but it would be preferable to take the piece to a machine shop or procure the casting already planed.

If it is decided to work the casting down by filing, it will be first necessary to ascertain how the parts line up in the rough, which stand the highest and, in consequence, require the most filing.

In determining this, set the bed plate on a sufficient elevation and use the two pieces of straight steel rods before turning them for side rods, or the two pieces of $\frac{3}{4}$ inch steel shaft may be used; place one across the tops of the raised surfaces where the main bearings are to stand and the other across the surfaces where the supports for the cylinder are to be placed. If the eye is brought to the same level and sighted across the tops of the two rods, it will be readily seen which surface is the highest.

Now change the position of the rods, resting one end of each one on a main bearing surface and the other end of each on a cylinder support surface. Sight across the rods as now placed and it will be apparent which surfaces require the most filing. Continue using the steel rods at intervals to test the accuracy of the work while filing the bearing surfaces.



IMPROVED FORM OF BED PLATE.

This form of bed plate gives the engine a neater appearance when completed, but as the pattern work is much more difficult we should not advise the amateur to attempt it.

Chapter XIV.

FLY-WHEELS AND SHAFT.

SIMPLE ARRANGEMENT OF FACE PLATE FOR TURNING. BOLTING TO FACE PLATE. CENTERING, BORING AND REAMING FOR SHAFT. FACING HUBS. BORING CRANK PIN HOLES. SHAFT. DIMENSIONS. FITTING GEAR WHEEL TO SHAFT. DRILLING AND PINNING FLY-WHEELS TO SHAFT. EXTENDING DRILL. CRANK PIN.

CHAPTER XIV.

FLY-WHEELS AND SHAFT.

To turn and finish the fly-wheels of an engine this size, a lathe swinging 18 inches is required. This is the only part of the work an amateur with a small lathe will be unable to accomplish. These, however, may be obtained already finished.

In turning up the wheels, the best and cheapest arrangement for the purpose is shown in Fig. 89. The face plate in this case was about 8 inches in diameter. A piece of hardwood board was cut off the same length and width as the diameter of the face plate, and after the corners had been cut off, it formed an octagon, as shown. This was fastened to the face plate by four wood screws, with washers under the heads, which passed through the slots in the face plate. The front of the hardwood board was then faced off true and a recess cut out at the center for the fly-wheel hub. Two ½ inch holes were bored through the wood at opposite slots in the face plate, through which were inserted the two bolts for holding the fly-wheel. The bolt heads can be seen in the cuts. The bolts came through between two of the arms on opposite sides of the wheel, and washers were placed across the front of the arms and the wheel bolted to the face plate thereby, as shown in Fig. 90. Tighten the nuts just sufficiently to hold the wheel from slipping while the lathe is revolved slowly to ascertain if the wheel runs true. If the

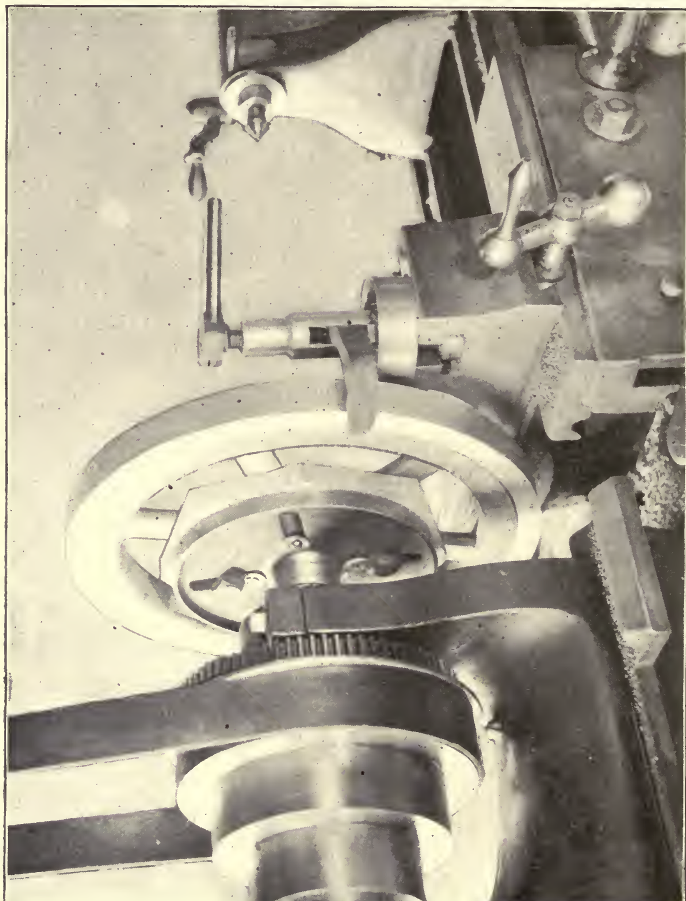


Fig. 89.—Facing Outer Side of Fly-Wheel with Bent Tool.

wheel is not in proper position, a light blow with a hammer is sufficient to move it in the desired direction.

When the wheel runs sufficiently true, tighten up the nuts and it is ready to face up.

With the wheel held in this manner, it is possible to turn up and finish the entire rim and the hub, with the exception

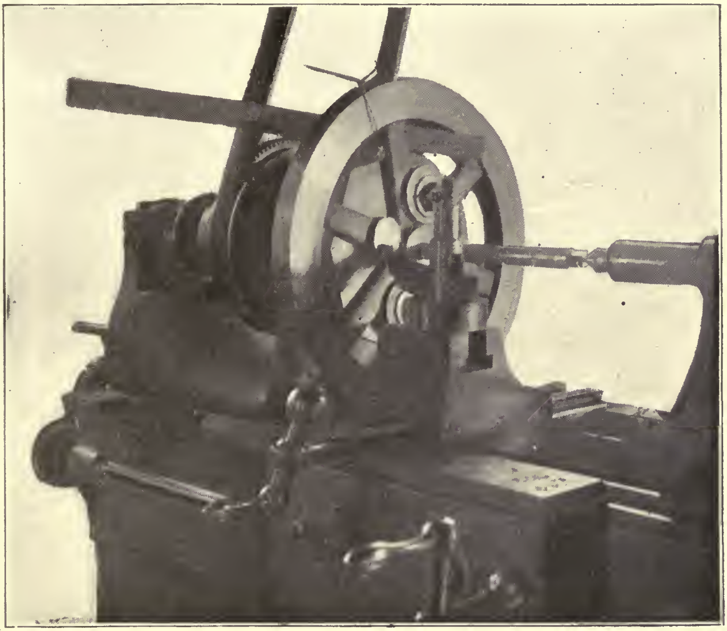


FIG. 90.—FLY-WHEEL BOLTED TO FACE PLATE.

of facing the side of the hub next the face plate. The side of the rim next the carriage can be operated on with a plain round point tool.

The face of the wheel may require a tool with its point bent at a right angle; this depends on how far the tool post comes toward the front of the lathe. The side of the rim next the lathe head will, however, require a special tool

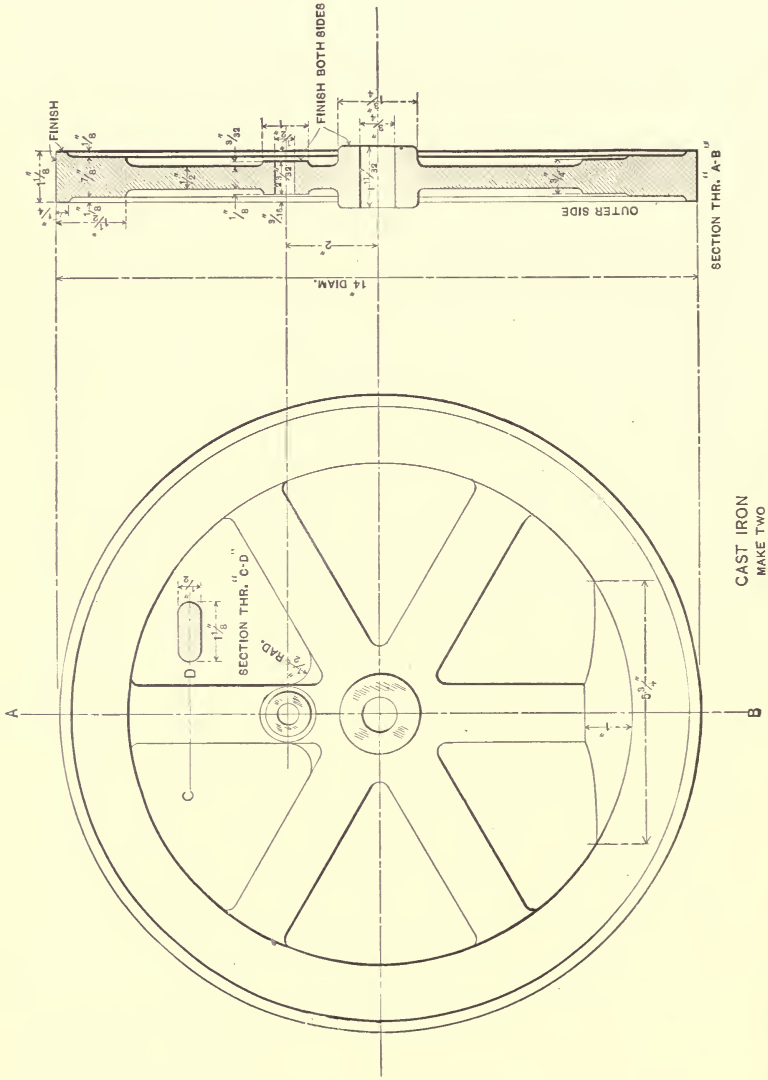


FIG. 91.—FLY-WHEEL.

bent as shown in operation in Fig. 89 and described in Chapter 7.

This tool is bent around in a semicircle and the point turned toward the carriage.

This plan of turning the wheel will be found preferable to boring for shaft first and then placing on a mandrel to turn

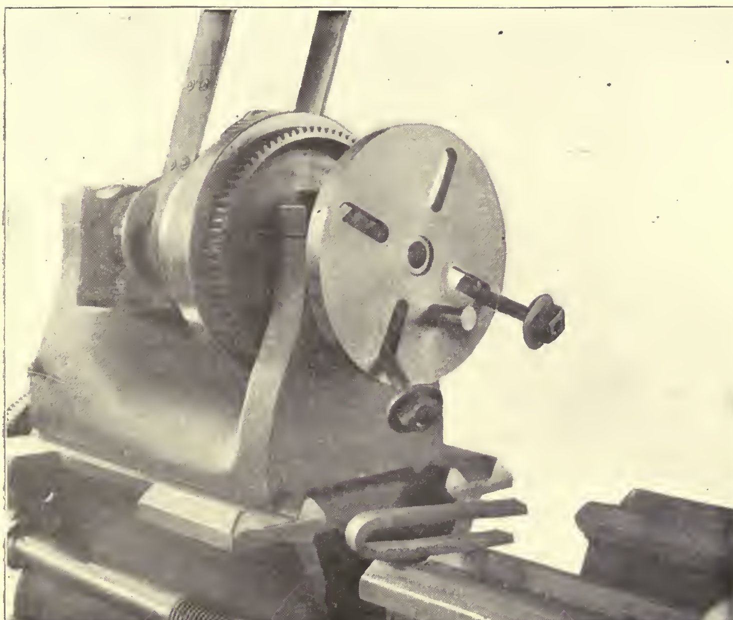


FIG. 92.—PIN FITTED TO FACE PLATE.

the rim, as it is held more securely in this manner and will not chatter if the lathe head is in order.

In finishing the hub while in this position, first face off the side and center the hole with the proper lathe tools. Drill, bore, and ream to size of shaft, which in this case is $\frac{3}{4}$ inch.

The wheel can now be removed and the opposite face of the hub finished by placing the wheel on a mandrel between the lathe centers.

When both wheels have been finished thus far they are ready for the crank pin holes. These must be drilled very accurately in reference to their distance from and alignment to the holes bored for the shaft.

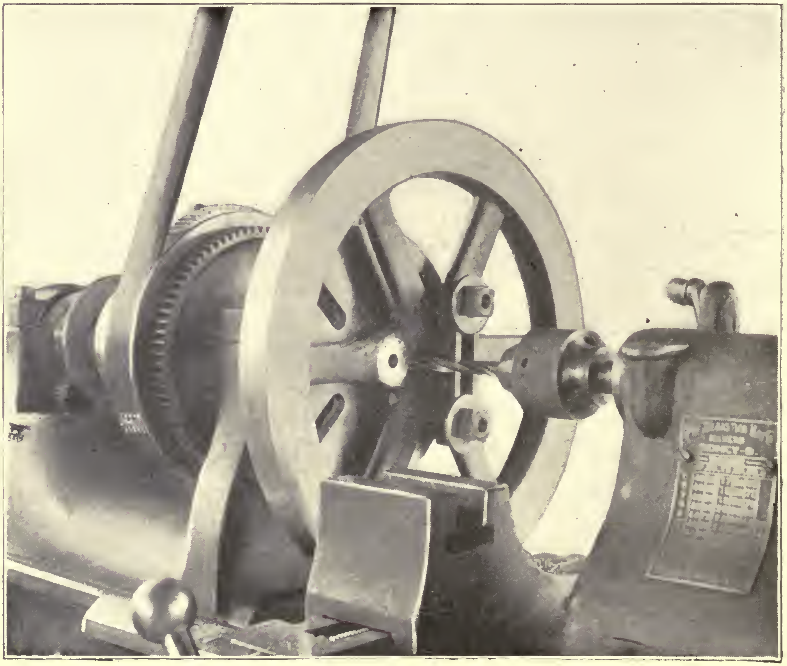


FIG. 93.—DRILLING FLY-WHEEL FOR CRANK PIN.

To do this accurately a soft steel pin of the exact diameter of the shaft should be inserted in the face plate at a distance from the center exactly corresponding to one-half the throw of the crank. In this size of engine the distance will be 2 inches.

In Fig. 92 will be seen the pin inserted in the face plate, with bolts protruding from two of the slots with which to clamp the wheel to the face plate. In this cut a piece of U-shaped iron is shown lying on the front of the lathe bed, through which the bolts pass, as shown in Fig. 93. This clamps the wheel by the hub alone and will hold it more accurately than if the two bolts clamped the arms of the wheel, as there would then be a tendency to spring the stud on the face plate if one bolt were tighter than the other.

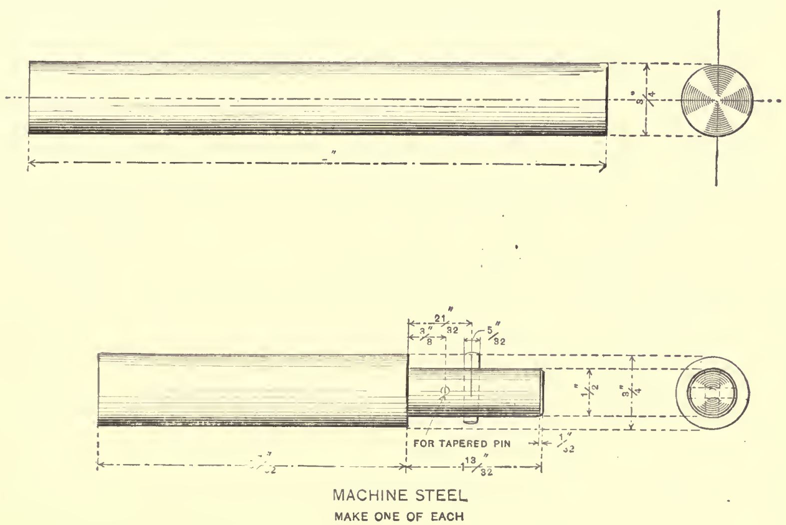


FIG. 94.—FLY-WHEEL SHAFTS.

This brings the crank pin boss directly over the hollow spindle of the lathe head, where it can be drilled, bored and reamed the proper size, ½ inch, and the hole will be in line with the hole for the shaft.

A space ⅞ inch in diameter should be faced off around this hole, while the wheel is in this position, for the shoulder of the crank pin to fit against.

The crank shaft is made in two pieces. The shaft on the valve gear side of the engine should be $4\frac{5}{8}$ inches long and the outer end should be turned down to a diameter of $\frac{1}{2}$ inch for a distance of $1\frac{13}{32}$ inch.

This is done in order to fit on the 1 inch gear wheel used to drive the valve mechanism.

The gear wheel should be chucked and bored out to fit the shaft, after which the hub is turned and finished.

To attach the 1 inch gear to crank shaft, drill through the hub and shaft for a steel pin, using about a No. 42 twist drill. The hole may be tapered with a five-sided brooch and a taper pin filed up for it in the lathe.

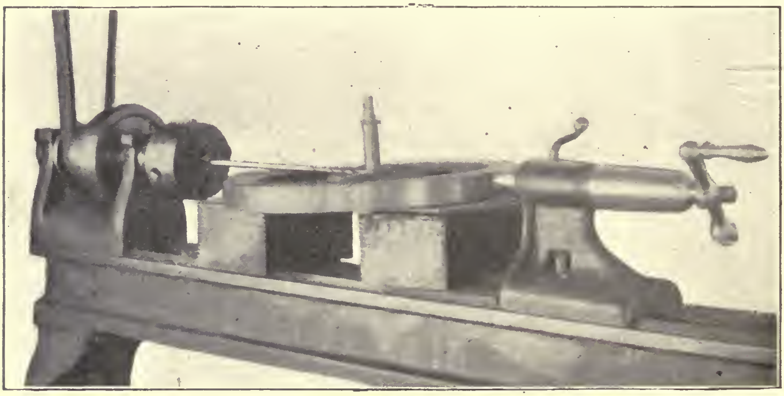


FIG. 95.—DRILLING FLY-WHEEL AND SHAFT FOR PIN.

On the turned down portion of the shaft, $\frac{3}{4}$ inch from the end, drill a hole through the shaft, using a No. 19 twist drill. A steel pin $\frac{3}{4}$ inch long should be driven through this hole. It is intended to form a clutch for the starting handle. This portion of the crank shaft is shown in the detail drawings.

The other portion of the crank shaft is 7 inches in length and full diameter for its entire length.

The operation of drilling the fly-wheel and shaft for the purpose of fastening them securely together is shown in Fig.

95. The drill is extended by using a piece of brass rod. To make the extension, drill into the end of the rod with a drill about one size smaller than the one to be used, or a No. 20, for a distance of about 1 inch. Hold the No. 19 drill securely between two pieces of hardwood or fiber in the vise and drive the brass extension onto it.

Fig. 95 shows clearly the wheel blocked up to the proper height and fed against the drill by the tail stock. Use steel wire for pins, and make a driving fit.

An engine built on this plan, with the fly-wheel between the bearings, does not require the wheel to be as firmly keyed to the shaft as one having the wheels outside the bearings. In this case the thrust of the explosion of the gas is delivered directly to the fly-wheels by the connecting rod, without exerting a torsional strain on the shaft, as would be the case were the wheels outside the bearings.

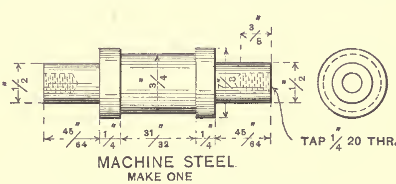


FIG. 96.—CRANK PIN.

The crank pin is shown in detail in Fig. 96, which gives all dimensions. This should be turned from a piece of machinery steel.

After the bearing part of the pin has been turned to size, finish with a smooth file and polish evenly with fine emery cloth.

In turning up the pin be sure to have the two shoulders faced up true to fit against the crank pin bosses on the fly-wheels.

After the crank pin is finished to size, drill into each end with a No. 4 twist drill to the depth of about 1 inch and tap the holes with $\frac{1}{4}$ inch—20 tap.

This is for the cap screws which, with a washer under each, clamp the fly-wheels securely to the pin.

The complete crank shaft is now ready to assemble with the other parts. To do this, place the wheels and shaft in position on the bed plate and insert the ends of the shaft into the main bearings, which are slid on from either side and fastened into position by the cap screws in their bases. The cylinder and supports can then be slid onto the ends of the side rods and secured in their proper places.

Chapter XV.

CYLINDER HEAD.

CHUCK PIECE. TURNING AND FACING. TURNING OUTSIDE. DRILLING FOR SCREWS. TRANSFERRING HOLES TO CYLINDER. LOCATING POSITIONS OF INLET AND EXHAUST VALVES. BORING FOR EXHAUST VALVE. BORING FOR INLET VALVE.

CHAPTER XV.

THE CYLINDER HEAD.

The cylinder head has a chuck piece cast on the outside, which is held in the chuck jaws and the inside of the head turned first.

The shoulder should be turned down to make a snug fit into the cylinder tube. Fig 97 shows the head in the lathe and a diamond point tool in the slide rest to cut out the sharp corner of the shoulder. The calipers should be set to the proper size and tried as shown.

Turn down the edge of the head to a diameter of $3\frac{13}{16}$ inches.

Remove from the chuck and reverse the head, chucking it by the outside edge or the shoulder on the inside. Cut off the chuck piece and face off outside, as shown in Fig. 98.

The outside should be faced off very smooth and true. Mark slight indentation in center of head while it is revolving in the lathe.

When finished, remove from the chuck and, with the dividers, set at $1\frac{9}{16}$ inches, using the indentation as a center, mark out a circle on which to space holes for the cap screws.

Without changing the setting of the dividers lay off on this circle six points, which may be center-punched for drilling.

Drill these holes with a No. 4 twist drill and, when the

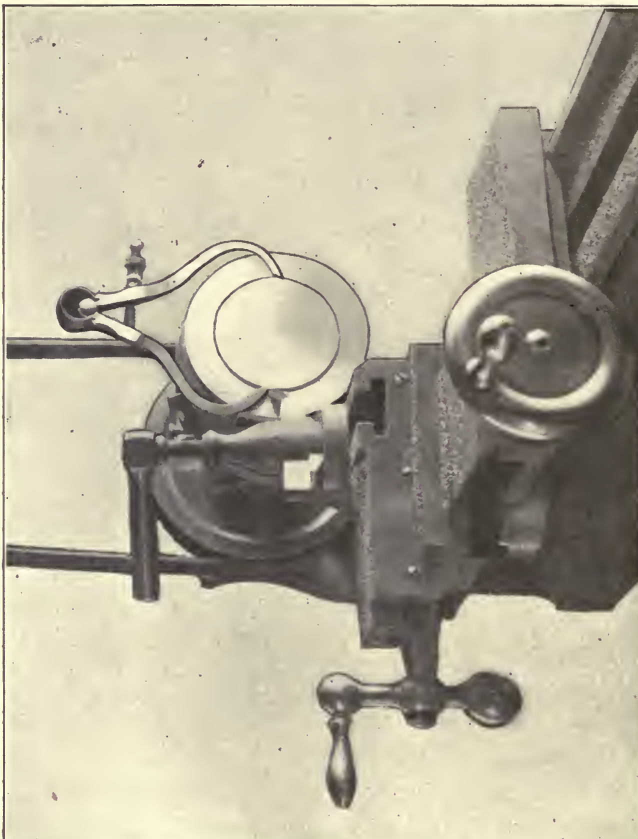


Fig. 97.—Turning Cylinder Head.

holes have been transferred to the cylinder, they can be enlarged to $\frac{1}{4}$ inch.

To transfer the holes to the cylinder place the head in position, and if the shoulder has been made a tight fit in the cylinder tube it will remain in position while the holes are being drilled in the cylinder collar, the holes in the head being used as guide holes for the drill. Should the shoulder

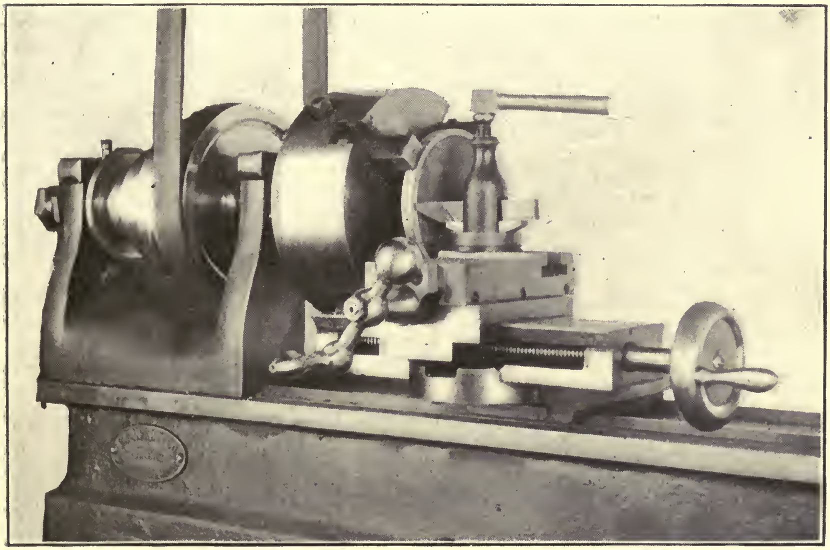


FIG. 98.—FACING OUTSIDE OF CYLINDER HEAD.

of the cylinder head fit loosely in the cylinder tube it will be necessary to hold the head in place until one hole has been drilled in the cylinder collar. This hole can now be tapped $\frac{1}{4}$ inch, 20 threads, the corresponding hole in the head enlarged to $\frac{1}{4}$ inch, and the head can then be fastened on with a cap screw until the remaining five holes have been drilled in the cylinder collar.

In placing the cylinder head in position be sure to have the holes come in the positions shown in Fig. 99: two holes on the vertical diameter and two spaces on the horizontal diameter.

The latter are required for the inlet and exhaust valves.

Across the center of the inside of the head, on the horizontal diameter, a line can be scribed and the center of the head located by a small center-punch mark.

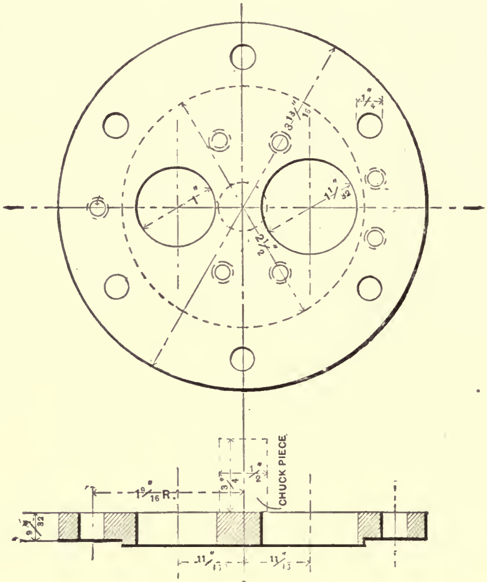


FIG. 99.—CYLINDER HEAD.

The location of the inlet and exhaust valves can now be laid out on this line.

They are to be marked by a center-punch mark $\frac{11}{16}$ inch each side of the center point, as shown in Fig. 99. The holes in the head are bored as shown in Figs. 100 and 101.

The cylinder head must be clamped on the face plate with distance pieces between to make a clearance space for

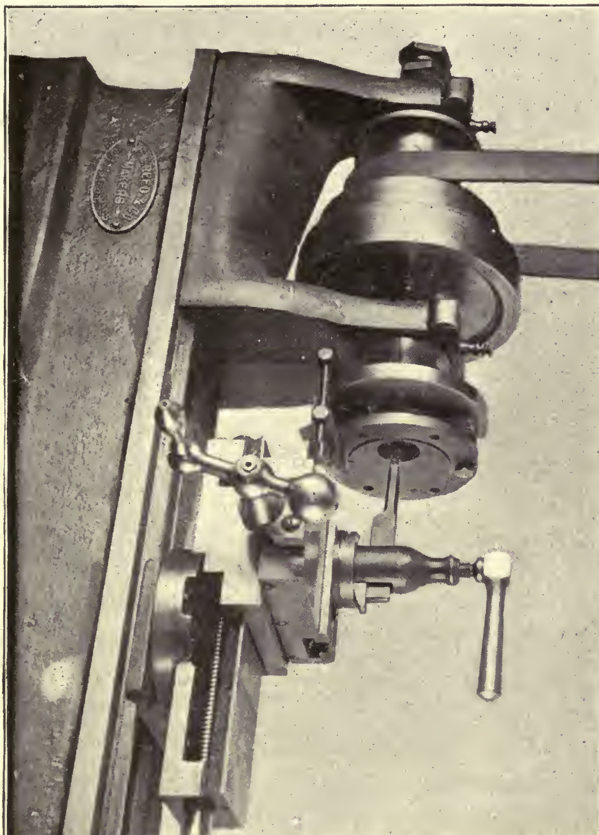


Fig. 100.—Boring Cylinder Head for Exhaust Valve.

FIG. 101.—BORING CYLINDER HEAD FOR INLET VALVE.

the drill and boring tool when cutting through the cylinder head.

In the cuts shown three pieces of $\frac{3}{8}$-inch hexagonal brass rod were used. A small bolt was passed through one of the cap screw holes in the cylinder head, and the opposite side was held by a small adjustable clamp, as shown.

To locate the head at the proper position on the face plate, bring the back center up and place the point on the center punch mark of the center of the hole to be bored. The head can be firmly held against the face plate in this manner while the clamps or bolts are secured in place.

When the head is clamped in position, start a drill at the center punch mark and, after drilling through, use a boring tool in the slide rest to finish the hole and true it up.

Fig. 100 shows the boring tool in position and the hole for the exhaust valve finished.

The diameter of this hole should be $1\frac{1}{32}$ inch.

The cylinder head is now to be loosened and clamped in position to drill and bore the hole for the inlet valve.

In Fig. 101 it will be seen that a bolt passes through the hole drilled for the exhaust valve with washers covering the hole, and the clamp is used on the opposite side of the head.

This hole is to be bored and finished to 1 inch diameter.

Chapter XVI.

THE INLET VALVE.

THE CASING. BORING AND FINISHING. DRILLING HOLE FOR VALVE STEM. FINISHING OUTSIDE. TURNING DOWN CHUCK PIECE. DRILLING GAS INLET HOLES. DRILLING AIR PASSAGES. THE VALVE. TURNING AND FITTING TO VALVE SEAT. FITTING STEEL STEM. GRINDING. DRILLING STEM FOR PIN. SPRING. GAS INLET RING. BORING AND RECESSING. DRILLING FOR STOP COCK. FILING GROOVES. FINISHING OUTSIDE OF RING. ASSEMBLING THE PARTS.

CHAPTER XVI.

INLET VALVE.

The inlet valve castings comprise the valve casing, gas inlet ring, and valve.

The valve casing is first chucked in the lathe by the extension on the back, as shown in Fig. 102.

The casing is centered with a hand tool or otherwise and drilled with about a $\frac{1}{2}$-inch drill for a depth of $3\frac{1}{2}$ inch.

A boring tool is set in the tool post of the lathe and the hole bored out to $\frac{5}{8}$ inch diameter for a depth of $3\frac{1}{2}$ inches.

This must be done very carefully with a light cut to finish smoothly.

The outer end is now to be faced off and the valve seat beveled to an angle of 30°.

The next operation requires some care: it is to center and drill the hole for the guide stem of the valve. Fig. 102 shows this operation clearly.

The centering tool is placed in position in the tool post with the point on a line with the center of the work.

The tool is now fed into the hole of the valve casing until it reaches the bottom.

While the lathe head is revolving, it is fed to the center of the casting, and if the point of the tool is exactly on a line with the center of the work, it will mark an indentation like a center-punch mark. Should it be found that the tool does not mark at the center, it must be reset until it makes the indented cut exactly in the center.

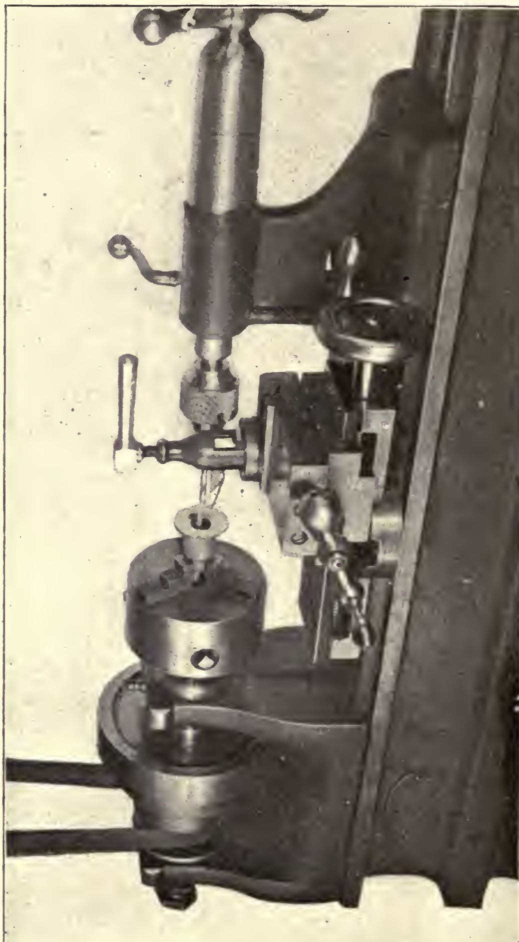


FIG. 102.—CENTERING AND DRILLING INLET VALVE CASING FOR VALVE STEM.

Be very careful that the body of the tool does not touch the finished valve seat when marking the center. When the center is marked sufficiently deep, a $\frac{3}{16}$-inch twist drill is held in a chuck in the tail stock of the lathe and the hole drilled through where the indentation is made.

In Fig. 102 the center marking tool is shown in the slide rest, but fed back out of the way, and the drill is in position for use. When the guide hole has been drilled, the casing can be removed from the chuck and the outside finished. Fig. 103 shows this operation. A short piece of machine steel or iron, slightly larger in diameter than the hole in the valve casing, is gripped in the chuck and the end turned down until the casting can be forced on by hand.

The outside of the body of the casing is now turned down to a diameter of $\frac{13}{16}$ inch, and the collar on the valve seat end is turned down to make a driving fit into the smaller of the two holes bored in the cylinder head.

A shoulder must be left on this, as shown in the detail drawings, to prevent the valve from being forced through the hole in the cylinder head when the engine is working.

The outer end of the valve casing, which has been drilled for the valve stem, is turned down to a diameter of $\frac{5}{16}$ inch and the end of the casing cut off, leaving the stem a length of $\frac{9}{16}$ inch, as shown in the detail drawings. In Fig. 103 the the casing is shown on the mandrel and finished, with the exception of turning off the superfluous length.

The lathe tool is in position for this last operation. The casing is removed from the mandrel when finished.

The next procedure is to drill the casing for the gas inlet holes. These holes must be carefully center-punched in the center of the valve seat. Nine holes are required, and the size of the drill is No. 45. These holes must start at the center of the gas ring and come through to the outside of

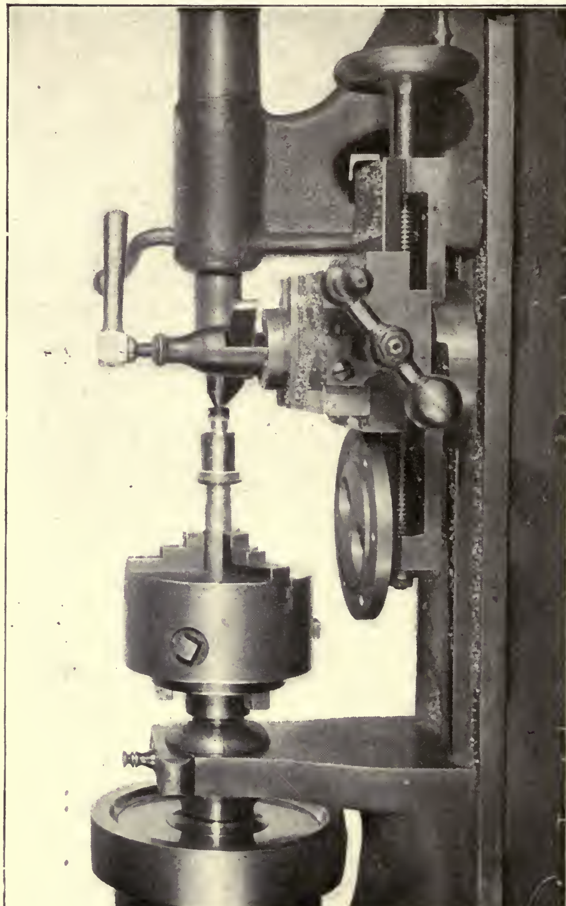


Fig. 103.—Turning and Finishing Inlet Valve Casing on a Mandrel.

the casing below the collar which is turned on the casing to fit the hole in the cylinder head, as shown in the detail drawings. The casing must be held in such a manner that the drill will run in the required direction.

The lower end of the valve casing must be drilled for air passages. Drill four equidistant holes with a $\frac{1}{8}$-inch drill as close to the lower guide stem as the drill can be held. Enlarge these holes with a small square file until four ribs $\frac{1}{16}$ inch wide are left to support the guide stem.

Fig. 104 shows the appearance of the casing when the holes are enlarged, as described.

The valve proper is a small casting having four thin wings to guide it in the casing, aside from the steel rod which passes through the guide stem of the casing.

The four wings are cast on one side of the circular valve, and on the opposite side is cast a small chuck piece by which it is held in the jaws of the chuck while being finished.

Fig. 105 shows the valve in the lathe.

First, the four wings are turned down until they fit easily into the hole bored in the casing.

The valve proper is then turned down to size and beveled to fit the bevel of the valve seat in the casing.

The hub where the four wings come together is next centered carefully and a hole drilled to the depth of $\frac{5}{16}$ inch. In Fig. 105 these operations are clearly shown. The valve casing is lying on the slide rest in position to show the interior, and the valve is turned to the proper size with the drill in position to make the hole for the steel valve stem.

The stem must be a good fit, and in drilling the hole for it *be sure* that the drill starts right, else the valve stem will not be concentric with the valve, and it will require a large amount of grinding to make the parts a good fit. The valve

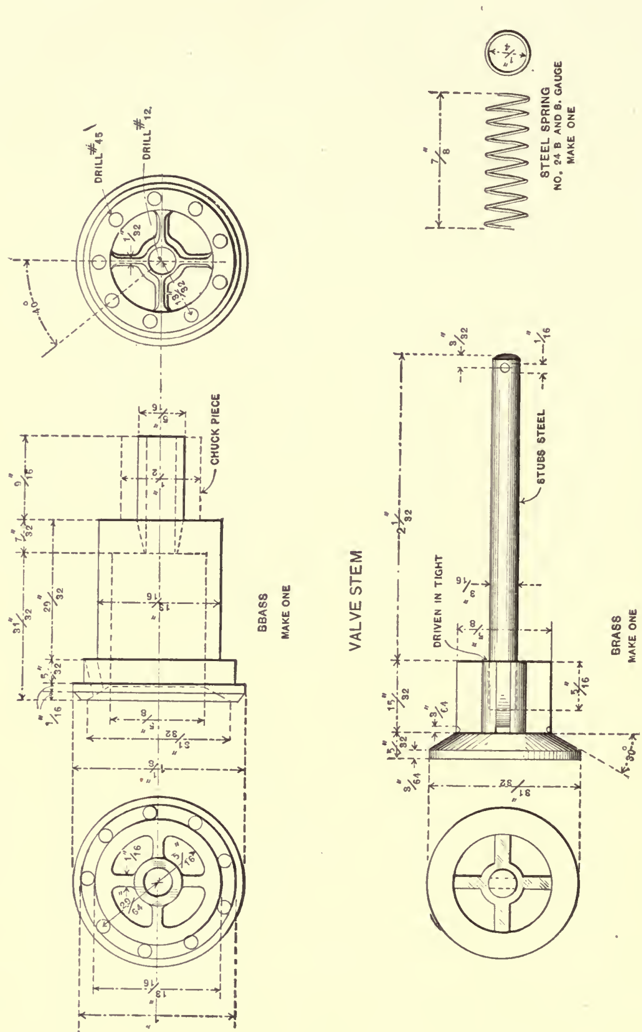


FIG. 104.—INLET VALVE.

can now be cut from the chuck piece with a cut-off tool held in the slide rest, and the stem inserted.

The next operation is to grind the valve on the valve seat. To do this, place the valve and stem in position in the casing and grip the lower end of the valve stem in the jaws of the chuck. Place a little fine emery, mixed with oil, on the valve seat and start the lathe head running at the fastest speed.

Press the casing against the valve while rotating.

Put on a little oil without emery, with the valve still rotating. Remove from the chuck and carefully wipe off all emery and oil, and test the valve by suction on the lower end of the casing. If not tight, repeat the grinding process until the desired result is obtained.

The stem must be drilled very near the end for a small pin, against which the washer and spring press to close the valve.

The spring is made of No. 24 steel wire and should be only of sufficient strength to close the valve by overcoming the friction of the stem and wings. This will allow the valve to open at once as soon as the piston begins its forward stroke without a pressure in the cylinder.

The gas inlet ring is held in the chuck, as shown in Fig. 106, but it must have clearance enough at the back to prevent the boring tool from cutting into the chuck when it passes through the ring.

Bore out the ring until it would make a tight driving fit on the valve casing. Next bore out a recess in the ring $\frac{1}{8}$ inch deep and $\frac{3}{8}$ inch in width, after which the front of the ring is faced up.

In this cut the ring is shown with the inside bored to fit the diameter of the casing, the recess turned out, and the ring faced up on the front.

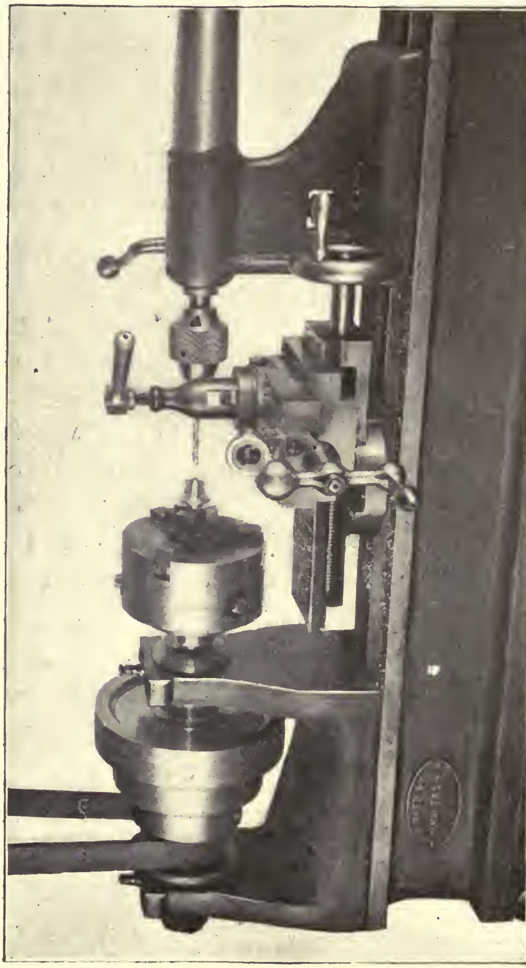


FIG. 105.—DRILLING INLET VALVE FOR VALVE STEM.

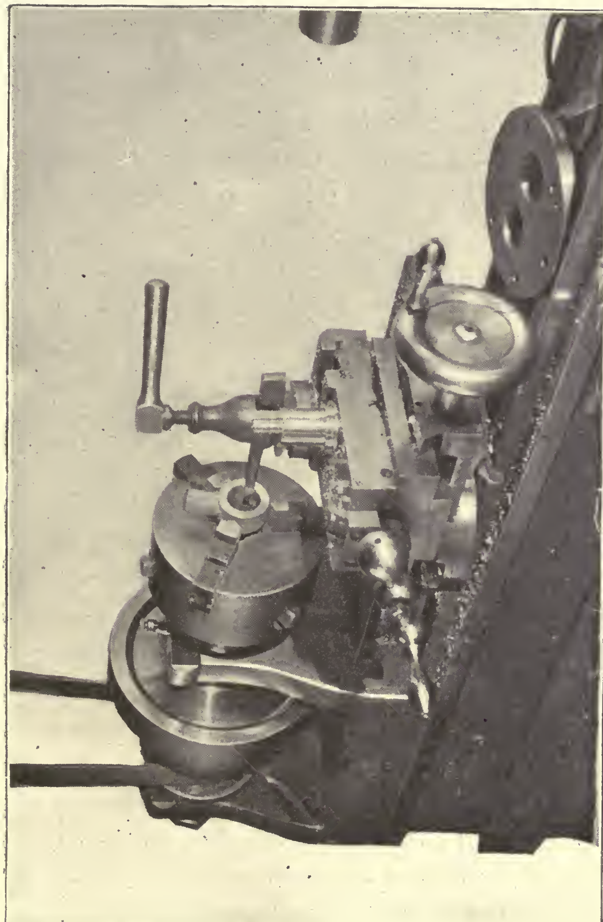


Fig. 106.—Boring and Recessing Gas Ring.

The ring can then be removed from the chuck and placed on the angle plate, as shown in Fig. 107, where the stem is to be drilled out and the outside finished. In this cut the operations have been finished, but the locations of the tools therein are sufficient without a lengthy description.

The ring in this case was clamped down around the pin of the angle plate and a piece of brass tubing was used to build up to the clamping washer on top. The hole should be $\frac{5}{16}$ inch in diameter and tapped out for a $\frac{1}{8}$-inch stopcock, iron pipe size.

On the side of the ring which was faced up when held in the chuck a number of half-round grooves are to be filed, as shown in the detail drawings.

These grooves are for the gas to pass through from the recess in the ring to the chamber formed between the hole in the cylinder head and the valve casing, which is clearly shown in the detail drawings.

Should the operator possess a screw-cutting lathe, this part which is grooved may be entirely cut away while the ring is in the chuck and a fine thread cut in the remaining ring. The casing can be threaded on the lower end to correspond, while in the position shown in Fig. 103.

The outside of the ring can be finished up by filing and polishing with emery cloth.

The gas-ring should have three lugs cast on the circumference, as shown in the detail drawings, Fig. 108. These were not placed on the parts photographed. Through these lugs holes are drilled for screws to attach the ring firmly to the cylinder head. It was found that adjusting the amount of gas admitted by opening and closing the stopcock below had a tendency to loosen the ring on the casing of the inlet valve.

The inlet valve should not be put into the cylinder head

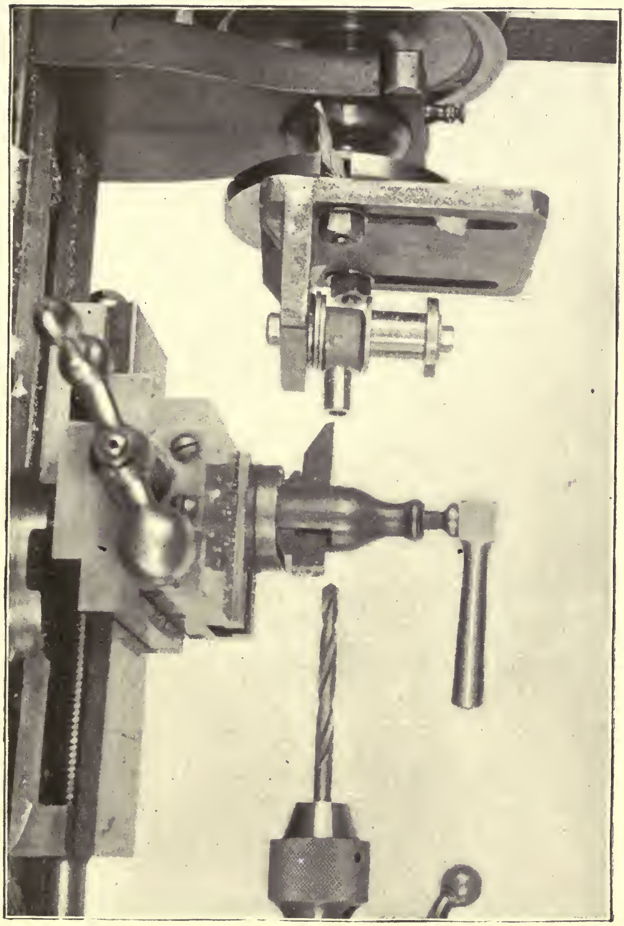


FIG. 107.—DRILLING AND FINISHING STEM OF GAS RING.

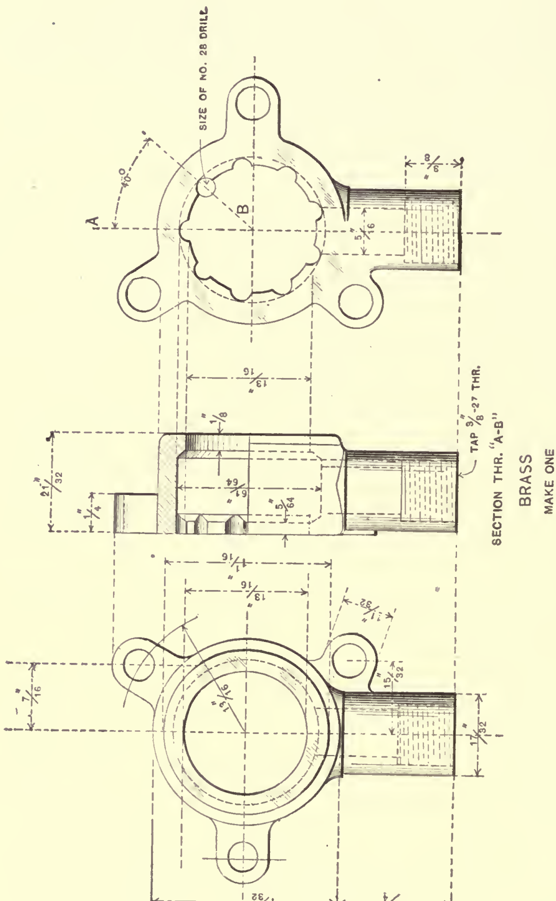


FIG. 108.—GAS RING.

until the exhaust valve and igniter have been finished and fitted.

In putting the inlet valve together in the cylinder head, first put a very little white lead on the collar of the valve casing to make a perfectly tight joint when the casing is forced into place.

It is best to force this part into place by pressure. This can be easily done in the vise, provided the parts are protected by blocks of wood. After the casing is in, place a very small amount of white lead around the hole in the cylinder head where the gas ring is to fit against it.

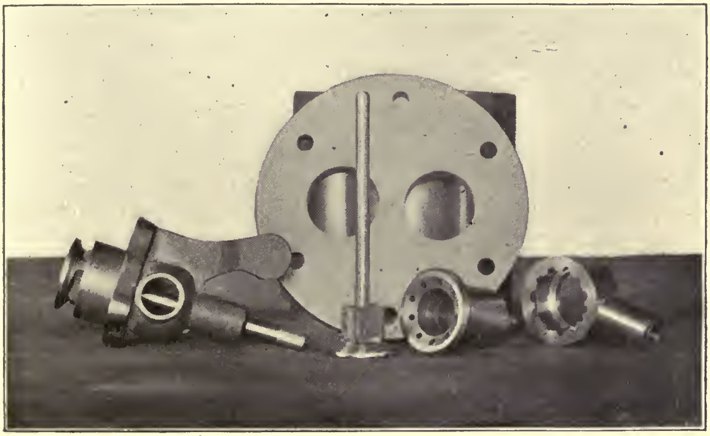


FIG. 109.—CYLINDER HEAD, INLET AND EXHAUST VALVE PARTS.

Now force the ring onto the casing and tight up against the cylinder head with the stem pointing downward. It may be advisable to screw in the stopcock before the ring is forced into position.

Fig. 109 shows the parts of the inlet valve, exhaust valve, and cylinder head before fitting and assembling.

Chapter XVII.

EXHAUST VALVE.

CHUCKING THE CASING. BORING AND FINISHING INSIDE. VALVE SEAT. CENTERING AND DRILLING HOLE FOR VALVE STEM. BORING FOR EXHAUST PIPE. THE VALVE. TURNING AND DRILLING. GRINDING. CUTTING OFF CHUCK PIECE.

DRILLING VALVE LEVER BRACKET. DRILLING FOR SCREW HOLES. THE SPRING. HARDENING AND TEMPERING. VALVE LEVER. DRILLING AND FITTING. HARDENED STEEL PIN. ATTACHING TO CYLINDER HEAD.

CHAPTER XVII.

EXHAUST VALVE.

The exhaust valve proper is composed of three pieces, the casing, valve and valve stem.

In the exhaust valve casing, as in the inlet valve casing, we shall suppose it has been cast solid.

The casing is first gripped in the jaws of the chuck by the extension of the valve stem guide on the back of the casting. Fig. 110 shows the casing chucked.

The body of the casing, up to the flange, is to be turned down to a diameter of $1\frac{1}{32}$ inches, to fit the hole bored in the cylinder head, and the flange must be faced up square with the body. Center and bore out the interior of the casing to a diameter of $\frac{3}{4}$ inch, as shown in the detail drawings.

Bevel the valve seat to an angle of 30°.

With the centering tool mark the bottom of the hole with an indentation in which to drill the hole for the valve stem guide. Use a $\frac{1}{4}$-inch drill for this hole and be sure that it starts true.

The next operation to the casing is to bore the hole for the exhaust pipe on the side of the body. This procedure is clearly shown in Fig. 111. The casing is mounted on the angle plate and the angle plate pin is inserted from below the shelf and prevented from coming up through by a washer and a piece of brass tubing.

The $\frac{1}{4}$-inch cap screw is now put down through the hole

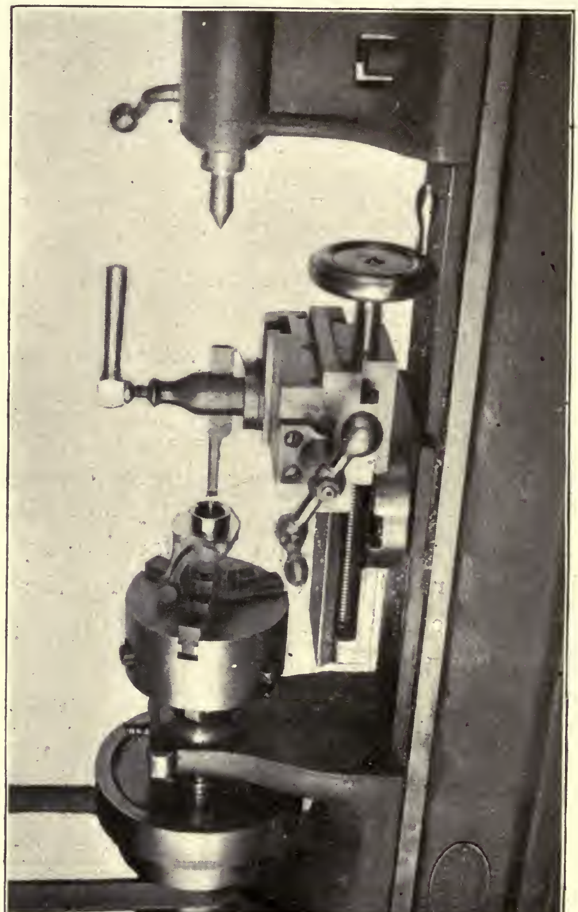


FIG. 110.—BORING EXHAUST VALVE CASING.

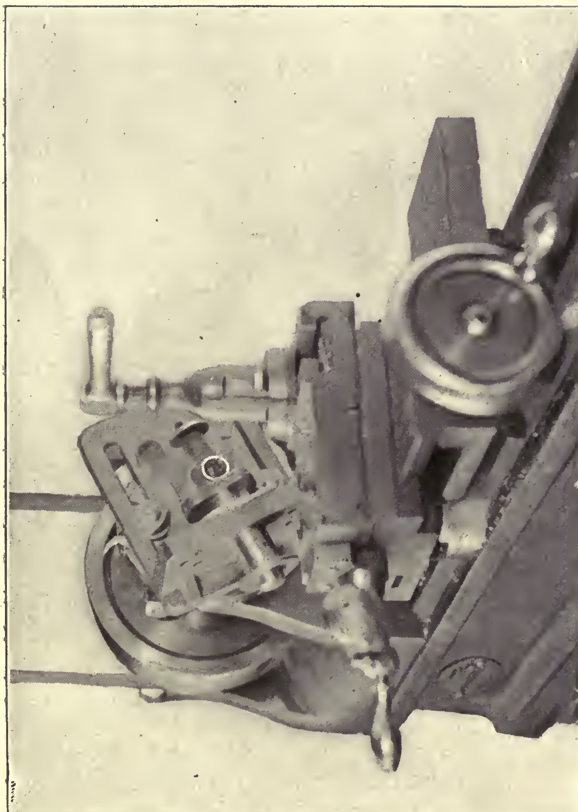


FIG. 111.—BORING EXHAUST VALVE CASING FOR EXHAUST PIPE.

forming the valve stem guide and thus clamps the valve casing down firmly onto the shelf of the angle plate.

The angle plate must now be set with the boss on the side of the casing on a line with the center of the lathe spindle.

Center the boss with the centering tool, and drill and bore to ½ inch to fit a piece of ½-inch brass tubing.

The valve is a casting of the same shape and style of the inlet valve, with the exception that it is a little larger.

The valve is turned and drilled in the same manner as shown in Fig. 105.

The valve stem is made of a piece of ¼-inch steel rod.

In Fig. 112 is shown another method of grinding the valve on its seat. This differs from the directions given for grinding the inlet valve, as in this case the valve is ground on the valve seat before being cut off from the chuck piece.

This method is not as accurate as that described for the inlet valve, as it does not allow for any variation which may come from either the hole drilled in the valve for the stem, or the hole in the casing for the guide being out of true. We consider the first method the more accurate, but a modification of both will be found as accurate, which is to drill the valve to receive the stem and force the stem into position by using the back center; but care must be exercised not to disturb the setting of the valve in the chuck. When the valve stem is in place the casing may be held in position by the hand, as shown in Fig. 112, *but without the back center.* The valve can then be accurately ground, with emery and oil, as described for the inlet valve.

In grinding the valve do not let the emery get down into the body of the casing to grind the wings and valve stem.

After the valve is ground in this manner a cut-off tool can be used in the slide rest to cut off the chuck piece on the

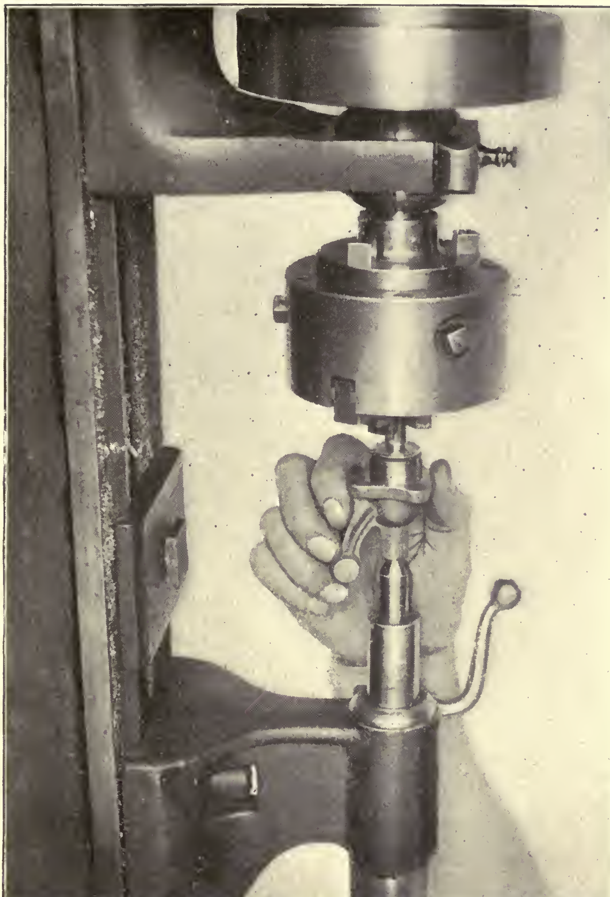


FIG. 112.—GRINDING EXHAUST VALVE AND VALVE SEAT.

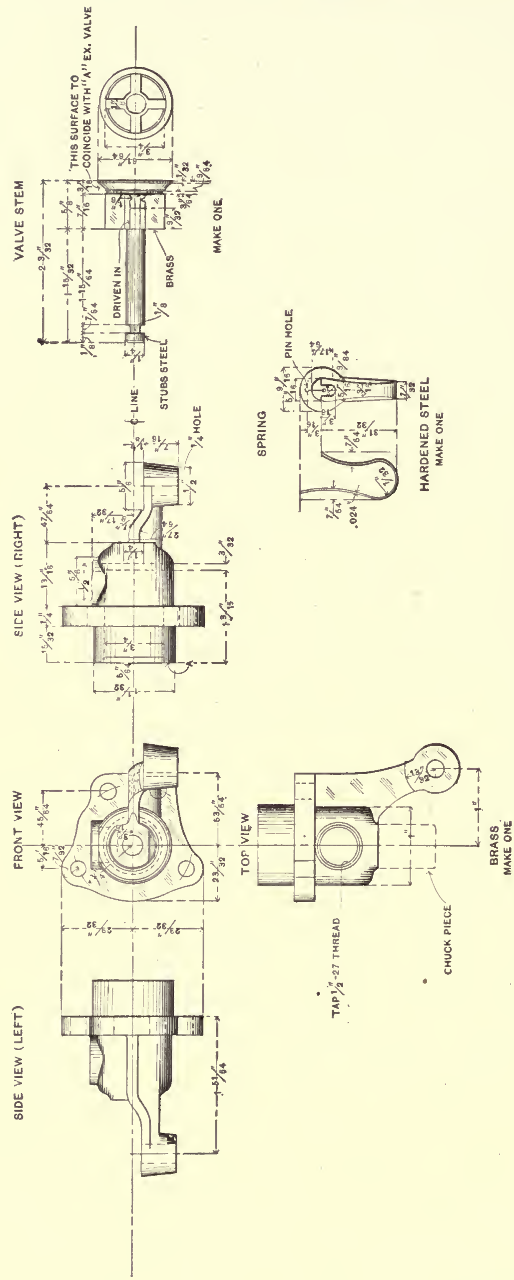


Fig. 113.—Exhaust Valve.

back of the valve. Fig. 109 shows the valve, valve stem and casing put together at this stage of the operation.

The chuck piece on the end of the casing can now be cut down to the size given in the detail drawings.

The boss on the end of the valve lever bracket is center-

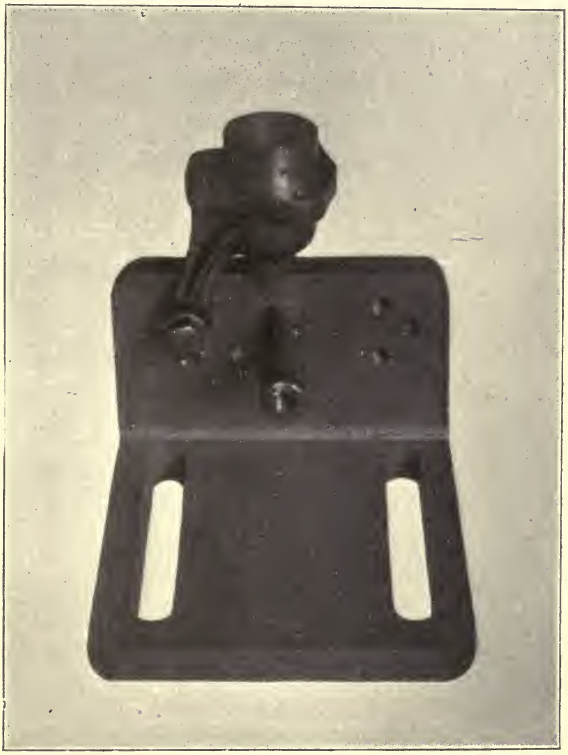


FIG. 114.—EXHAUST VALVE IN POSITION FOR DRILLING SCREW HOLES.

punched and a $\frac{1}{4}$ inch hole drilled and reamed in it. This is for the steel shaft of the valve lever.

The clearance holes for the screws by which the complete valve is secured to the cylinder head are next to be drilled. The holes are laid out and center-punched in the four projections of the flange of the casing. Fig. 114 shows how the casing is held for drilling, by clamping the bracket on the shelf of the angle plate with a $\frac{1}{4}$-inch cap screw passing through the hole for the valve lever shaft.

The end of the valve stem should be cut down to the dimensions shown in the drawings, but the groove for the spring should be first cut in the stem. The spring is cut from a piece of sheet steel the shape and size given in the detail drawings. The steel from an ordinary clock spring will be found to be about the right thickness. If the sheet steel is not soft enough to bend, it should be annealed by heating to a dull red and allowing it to cool slowly in the air. Bend the spring to the shape shown, after which it must be hardened and tempered.

Place some machine oil in a small cup or other dish sufficient to immerse the entire spring. First heat the spring evenly to a cherry red and plunge it into the bath of cold oil. The spring will then be hard and as brittle as a piece of glass, therefore do not attempt to bend it when it is removed from the oil. The spring must now be tempered. The best method of doing this is to have a piece of wire, long enough to hold in the hand, and hook one end of it into the hole in the end of the spring.

Lift the spring from the oil bath and, without shaking off the oil which will cling to it, place the spring in the flame until the oil catches fire. Hold up from the flame and let the oil burn off until the flame dies out, then plunge the spring into the oil bath again. Repeat this operation until the oil has been burned off three times, and if the material used was of good quality the spring will be of the proper temper.

This spring must be of sufficient strength to prevent the exhaust valve from opening by the suction of the piston.

The spring is kept in position by the small pin passing through it just above the hole cut for the valve stem.

The valve lever has a hole drilled through the center boss in which the ¼-inch steel pin must fit tight. Should it be found that the hole is a trifle large for a driving fit, the lever and pin must be drilled through from the side and a small pin driven in to fasten them together.

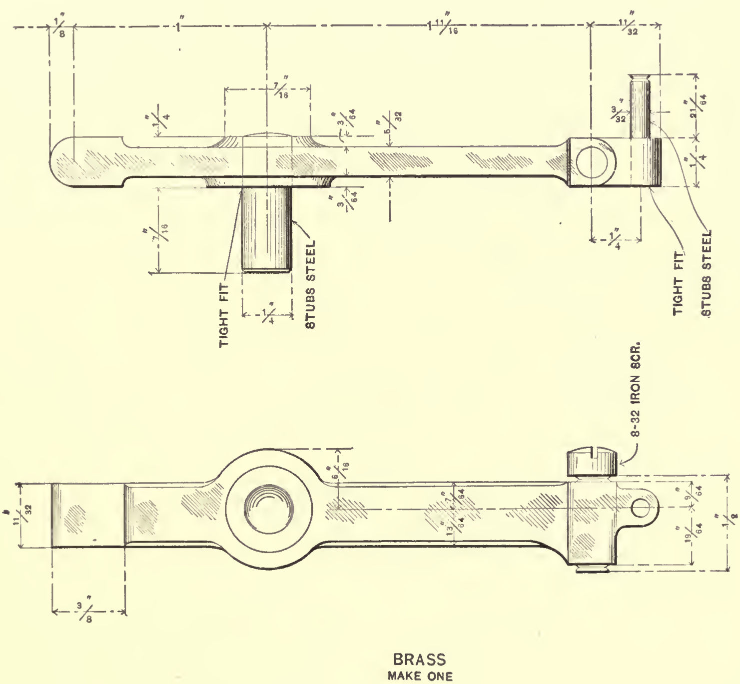


FIG. 115.—EXHAUST VALVE LEVER.

The pin extends down flush with the bottom of the boss on the bracket and has a hole drilled and tapped in the lower end for a No. 4-36 machine screw. A small washer about ⅜ inch in diameter, clamped onto the end of the pin by the screw, prevents it from being lifted out of the bracket.

In the outer end of the lever a hole is drilled and tapped for a No. 8-32 machine screw. This allows an adjustment in setting the valve rod gearing to open and close the valve at the proper time.

If the engine is to have a governor, a small hardened steel pin must be set into the end of the lever for the governor pin to catch in.

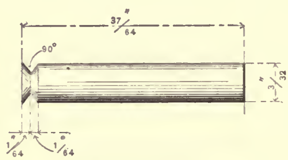


FIG. 116.—HARDENED STEEL PIN IN EXHAUST VALVE LEVER.

This mechanism will be described under the head of governor in another chapter.

When the exhaust valve is completed it should be placed on the cylinder head of the engine in such a position that the adjusting screw of the valve lever is on a line with the valve rod on the side of the cylinder.

As the flat steel spring shown in Fig. 113 is somewhat difficult to make, the builder can substitute a spring of steel piano wire No. 18 (Brown & Sharpe gauge) coiled, as shown in Fig. 116 A.

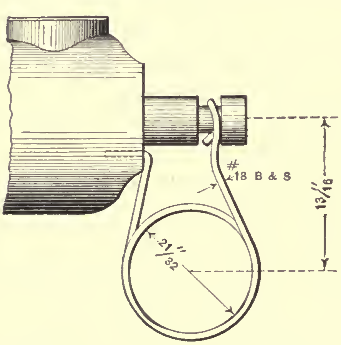


FIG. 116 A.—STEEL WIRE SPRING.

A piece about six inches in length is sufficient to make the spring. The wire must be coiled around a mandrel considerably smaller than the size of the loop shown in the cut, as piano wire is very elastic.

One end of the wire spring is bent into a loop to fit the groove turned in the valve stem. The other end of the spring is bent at a right angle and inserted in a small hole drilled in the casing of the valve, just below the valve stem, as shown in the cut. Do not make this bend too abrupt or the wire may break.

Chapter XVIII.

VALVE GEARING.

GEAR WHEELS. FINISHING GEARS. CRANK PIN FOR VALVE RODS. CONNECTING ROD. KNUCKLE JOINT. VALVE ROD GUIDES. DRILLING CYLINDER COLLARS FOR GUIDES. ADJUSTING THE VALVE ROD.

CHAPTER XVIII.

VALVE GEARING.

In an engine of this style the cycle is completed in two revolutions.

To accomplish this, the valve rod must be geared to open the exhaust valve once in two revolutions of the engine.

This is done by placing a gear wheel of 1 inch pitch diameter on the shaft of the engine and another gear of 2 inch pitch diameter on the gear stud of the main bearing.

The gears should be finished bright, and to do this neatly they should be held in the chuck, as shown in Fig. 117.

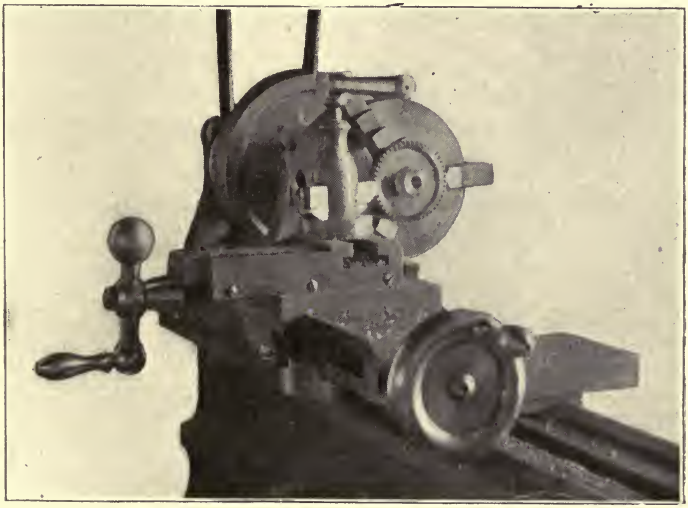


FIG. 117.—FACING GEAR WHEEL.

A small piece of narrow strip brass or spring steel is placed around the outside of the gear teeth. This protects the teeth from the jaws of the chuck and allows the hub and web of the gear to be finished.

After finishing one side, the gear can be turned over and the other side finished.

A steel crank pin is set into the larger gear wheel, the center of the hole for the crank pin being $\frac{17}{32}$ inch from the center of the hole in the hub. This gives the connecting rod and valve rod a stroke of $1\frac{1}{16}$ inches.

The crank pin is made a driving fit in the gear wheel.

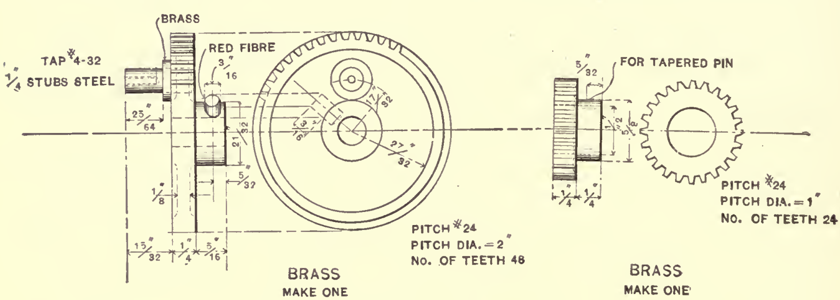


FIG. 118.—GEAR WHEELS.

The outer end is drilled and tapped for a No. 4-36 machine screw, by which a small washer is clamped on the end of the crank pin to keep the connecting rod in place.

The end of the connecting rod, where it is attached to the crank pin, is made from a piece of sawed brass $\frac{3}{8}$ by $\frac{9}{16}$ inch. in size and $2\frac{1}{8}$ inches long. One end is drilled with a $\frac{1}{4}$ inch hole for the crank pin and the other is drilled lengthwise with a $\frac{1}{4}$-inch drill for a depth of $1\frac{1}{4}$ inches. The outside of this end is turned down to a diameter of $\frac{3}{8}$ inch.

The connection between the valve rod and the connecting rod is by a knuckle joint.

The bearings for the valve rod are secured to the lugs on the side of the cylinder collars. The holes for the $\frac{1}{4}$-inch steel valve rod are first drilled in each guide and they are then fitted to the lugs by filing.

The screw holes are then drilled in the guides, and, after fitting, they are transferred to the cylinder collars.

The cylinder will need to be removed from the frame for drilling these holes.

The connecting rod must be offset to bring it in line with the valve rod. This is clearly shown in the detail drawings.

The dimensions of the different parts of the valve gearing are also shown.

The knuckle joint is made from two pieces of $\frac{3}{8}$-inch square brass rod. One piece is cut away in the center and the other cut away on each side to form the joint. In securing the knuckle joint to the valve rod, it is best to drill through both parts and use a small wire pin. This allows the parts to be disconnected easily.

The other end of the knuckle joint can be secured to the connecting rod by soldering.

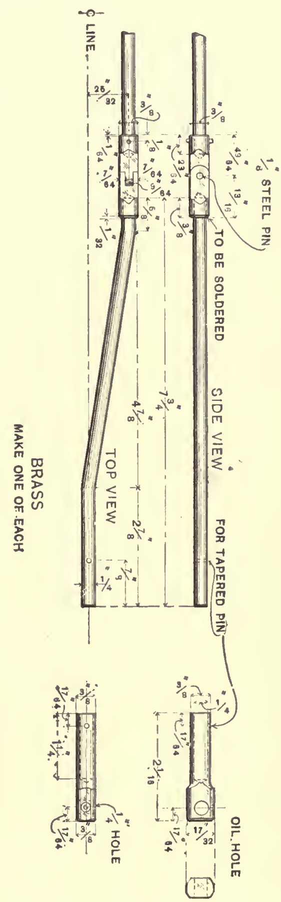


Fig. 119.—Connecting Rod Knuckle Joint and Connecting Rod End.

The crank pin end of the connecting rod should not be pinned permanently until the adjustment is found to be right, when the pin can be cut off flush with the sleeve and riveted in place.

To adjust the valve rod to open the exhaust valve at the proper time, it will be found necessary to uncouple the valve rod from the knuckle joint and remove the screw from the gear stud. The gear wheel can then be removed and

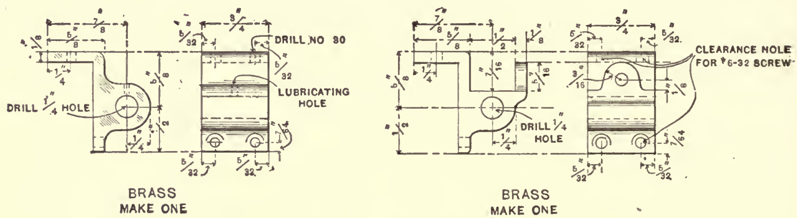


Fig. 120.—Bearings.

rotated forward or back as needed to operate the valve at the proper moment.

When the point is found, a scratch should be made across a tooth of the small gear and the space of the large one

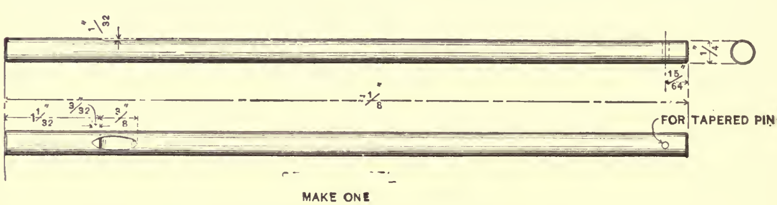


Fig. 121.—Valve Rod.

which engages with it. This is for the purpose of placing the gears together in their exact relative positions should it become necessary to again separate them.

Fig. 121 shows the steel valve rod. The indentation for the governor roller is clearly shown. The measurements given in this cut of the distance from the end of the rod to the indentation should not be strictly adhered to. This indentation should not be made until the governor is completed and in place, as described in Chapter XIX.

Chapter XIX.

GOVERNOR.

DESCRIPTION OF GOVERNOR. SPRING. GOVERNOR LEVER. WEIGHT. THUMB SCREW. NOTCH IN VALVE ROD. STEEL ROLLER. CLUTCH PINS.

CHAPTER XIX.

GOVERNOR.

The governor shown in connection with this engine was designed by the authors and will be found to work very satisfactorily. This governor belongs to the class called inertia governors.

The detail drawings show clearly the construction of the different parts and Figs. 122 and 123 are to show the operation of the governor. In the cuts *A* represents the valve rod and *B* is the end view of the exhaust valve lever. *C* is a small hardened steel pin having a groove turned around the top end. This pin fits into a hole drilled in the end of the exhaust valve lever.

D is the end of the bracket attached to the exhaust valve to support the lever. *E* is the valve rod bearing, through the lugs of which passes a screw forming the bearing for the moving parts of the governor.

F is the governor lever, having a weight *G* at its outer end. On the side of the lever is a projection, into which is fitted the hardened steel pin *H* having a notch formed on the side. This notch engages the groove formed in the pin *C*, if the speed of the engine is too great.

Along the underside of the governor lever is a flat steel spring *I*. This spring is attached to the lever just behind the pin *H* and extends forward far enough to allow the lower end of the thumb screw *J* to rest on its free end.

K is one of two parallel pieces of brass, between which the spring *I* is free to move. Between the outer ends of these pieces is placed a distance piece *L* and below this is a steel roller *M*, which turns freely on the small steel pin shown. On the upper side of the steel valve rod *A* is filed a small depression, clearly shown in Fig. 121. This depres-

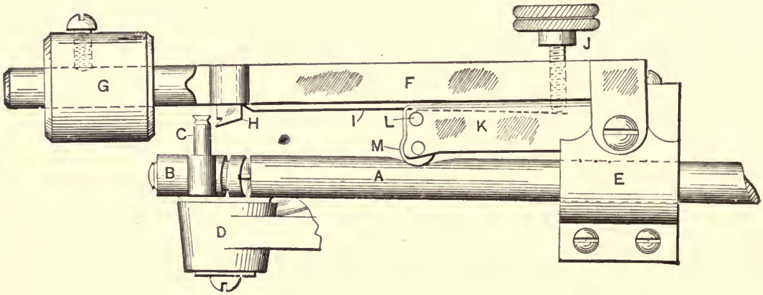


FIG. 122.—GOVERNOR.

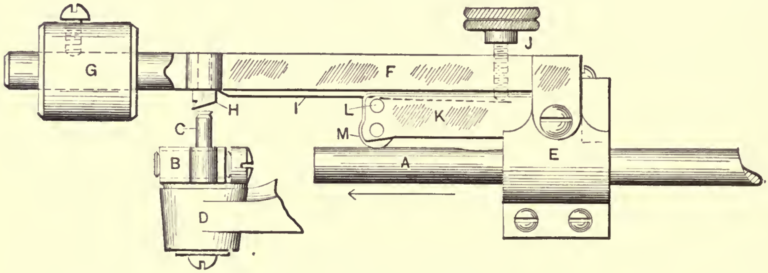


FIG. 123.—GOVERNOR.

sion should not be filed, however, until all the other parts of the governor have been completed and put in place.

The action of the governor is simple and effective. In Fig. 123 is shown the parts in their respective positions when the piston of the engine is traveling forward under the impulse of an explosion of the charge in the cylinder. The valve rod *A* will then be moving in the direction of the arrow shown below it. The exhaust valve is closed and the exhaust valve lever *B* is in the position shown.

The depression in the valve rod is seen just to the left of the valve rod bearing *E*. The hardened steel pin *H* is directly over the pin *C*.

On examining the relative positions of the parts in Fig. 122 it will be seen that the valve rod *A* has reached the end of its travel, the roller *M* has entered the depression filed in the top of the valve rod, and in consequence the lever F and weight *G* are lowered. The notch of the pin *H* is now lower than the top of the pin *C*.

As the weight of the lever *F* and weight *G* is carried by the spring *I*, resting on the distance pin *L*, it will be seen that if the spring is under sufficient tension the lever *F* will rise at once as the valve rod *A* moves forward and the roller *M* emerges from the depression. In this case the pin *H* will just clear the top of the pin *C* and the governor valve will close. If, however, the valve rod moves forward too swiftly, the spring *I* will bend before the weight *G* and lever *F* move upward, in which case the pin *H* will engage the pin *C*, thus holding the exhaust valve open.

In this instance, as the piston travels forward on the beginning of a new cycle, a fresh charge of gas and air will not be drawn into the cylinder and the engine will complete a cycle running free, without admission, compression or explosion, until the valve rod *A* again reaches the exhaust valve lever *B*, when the two pins *C* and *H* will be disengaged and be again in the position shown in Fig. 122. As the valve rod travels forward again, if the speed of the engine has decreased to normal, the pins will pass each other and the exhaust valve close. If the speed of the engine is too great, however, the pins will engage as before and the engine miss another cycle.

The tension of the spring can be changed while the engine is in motion by the thumb screw *J*.

Screwing the thumbscrew down will increase the speed of the engine. In adjusting the governor the weight *G* can be moved in or out on the lever until the proper position is reached.

In constructing the different parts of the governor little

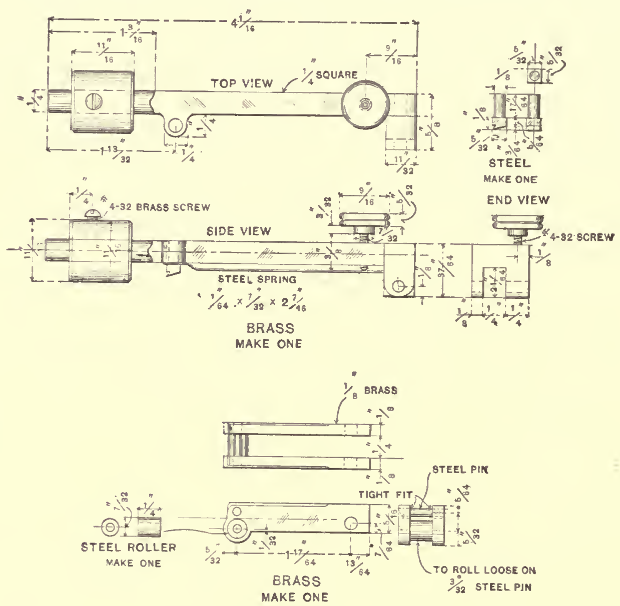


FIG. 124.—GOVERNOR.

difficulty will be found. The governor lever is filed up at the forward end and the back end can be turned down to fit the hole drilled in the weight. The two parallel pieces should be firmly clamped or soldered together until the three holes have been drilled through both pieces.

The screw which holds the governor in position on the valve rod bearing passes through two separate projections of the governor lever. This is to give the lever enough bearing on the screw to prevent any side motion of the lever.

The thumb screw can be turned from a piece of brass rod. When threading it, have the die open slightly and cut the thread a good full size, as it must fit tightly in the hole tapped for it in the governor lever to prevent the screw from turning by the jar of the engine when running.

A governor could be made of fewer pieces than this one, which would work on the centrifugal principle, the same as the ordinary steam engine governor, but we do not consider that as reliable as the one here shown unless it is driven by gearing it directly to the shaft.

If it is run with a belt the engine will "run away" if the belt breaks. It would require an extra attachment to prevent this.

Another great advantage in the governor here shown is that the speed of the engine can be varied at will by turning the adjusting thumb screw.

This can be done while the engine is in motion and will be found of great advantage in laboratory work where the speed of machines and models can be varied to suit the requirements.

The only part of this governor which is at all liable to break is the spring, and this would at once stop the engine, as the support of the governor lever would, in that case, be removed and there would be nothing to hold the catch pins apart.

Should the weight become loose and slip off the end of the lever the engine would "run away," but this could not happen under ordinary circumstances. When the proper position of the weight is found the set screw should be removed from the weight, and a scriber introduced through the screw hole to mark the point on the lever that the screw touches. A small indentation can be made with a drill at this point for the end of the screw to enter, which will prevent its sliding out of place.

If one wishes to leave the weight free to be moved along the lever and clamp it wherever desired, it is advisable to drill and tap a hole for a No. 4–36 machine screw in the end of the lever and fasten a brass washer in this manner. The washer should be about $\frac{5}{16}$ or $\frac{3}{8}$ inch in diameter.

Another effective way would be to drill a small hole through the lever near the end and drive in a small pin which would project on both sides. Either method will keep the weight on the lever and prevent a possible accident.

Chapter XX.

IGNITER.

PLATINUM POINTS. INSULATION. FIBER PROTECTORS. CEMENTING IGNITER TO TIPS. ATTACHING TO CYLINDER HEAD. BENDING PLATINUM POINTS. THE SPARK. ELECTRICAL CONNECTIONS. BATTERY. SPARK COIL. CONTACT POINTS. FIBER BLOCK. FIBER PIN IN GEAR WHEEL HUB. CHANGING THE MOMENT OF CONTACT.

CHAPTER XX.

IGNITER AND ELECTRICAL CONNECTIONS.

The igniter in this engine is composed of two brass wires threaded at the outer extremities for clamping the wires from the secondary terminals of a spark coil, and the inner ends are extended by pieces of platinum wire, which almost meet inside the cylinder head.

These wires must be insulated from the cylinder head and also from each other. The insulation in this case must be something capable of standing quite a high temperature.

Two lava gas tips, having a small round hole through the tip and the hole enlarged from the underside, will be found to answer the purpose admirably. The wires should be threaded on the outer end No. 2-56 and four brass nuts made and tapped the same size. The inner ends of the brass wires are drilled to correspond with the size of the platinum wire used.

A piece of $\frac{1}{4}$-inch fiber rod is drilled the size of the brass wire, after which the outside is turned down to fit into the enlarged hole of the lava tip. The piece is then cut off, leaving a small hub of the original diameter of the rod to project on the outside of the hole.

The platinum wire is inserted into the end of the threaded brass wire and the fiber bushing placed on. Now place a small quantity of sodium silicate, or water glass, as it is commonly called, into the hole of the lava tip and insert the parts of the igniter. Press the fiber bushing tightly into the enlarged hole of the gas tip and set in a warm, dry place until the sodium silicate is thoroughly hardened.

Never attempt to use white lead or other mineral cement for this purpose.

When the two igniters have been prepared and cemented, the holes in the cylinder head can be drilled and reamed to fit the bevel of the tips.

On the upper portion of the cylinder head, between the

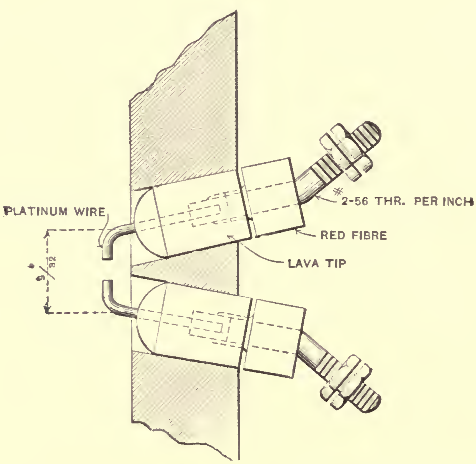


FIG. 125.—IGNITER, TWICE FULL SIZE.

inlet and exhaust valve, lay off and center-punch two points $\frac{9}{32}$ inch apart for the igniters.

Drill with a $\frac{1}{4}$-inch twist drill, holding the cylinder head against the tail stock in such a manner that the holes diverge toward the outside of the cylinder head to bring the points of the igniter as near each other as possible on the inside of the cylinder and as far apart as possible on the outside. This is to prevent the spark from jumping across between the outer ends of the igniter, which it has a great tendency to do when there is a compression in the cylinder, as that offers a great resistance to the spark.

In the detail drawing, Fig. 125, is shown the proper positions of the igniter parts.

Ream the holes with a taper reamer *from the inside* of the cylinder head to fit the taper of the lava tip.

When the cylinder head, valve and valve gearing have all been finished and assembled, the igniters can be put in place.

It is best not to put them in before as they may be injured in handling.

A little sodium silicate is first put into the holes of the cylinder head with a brush and the igniters firmly pressed into place from the inside. The head should be placed where it will not be disturbed for several hours to allow the cement to harden thoroughly.

The outer ends of the threaded wire of the igniters should be carefully bent away from each other to prevent the spark from jumping across where the brass nuts are attached, as that point would otherwise be the shortest distance between the igniters. When the igniters are in place in the cylinder head, the ends of the platinum wires should be bent toward each other until they almost touch. When they are in this position the spark passing between the points will be of a reddish color and hot, which is desirable for igniting the charge of gas and air in the cylinder.

In Fig. 126 is shown a diagram of the electrical connections required for this engine.

At *a* is shown the battery which should consist of two or three good cells capable of giving a high electro-motive force, and having considerable capacity for endurance.

The spark coil is shown at *b*. The wires from the battery connect to the binding posts on the base of the coil as shown.

From the binding posts of the secondary coil the wires pass to the two igniter points as shown.

The coil should be placed as near the engine as possible to keep the secondary wires from grounding or sparking across between each other. On one of the primary wires, between the battery and the coil, is introduced the contact *e*. This is formed of two pieces of spring brass fastened at the bottom to a block of fiber. The ends of the springs are bent at a right angle at the bottom and held down on the

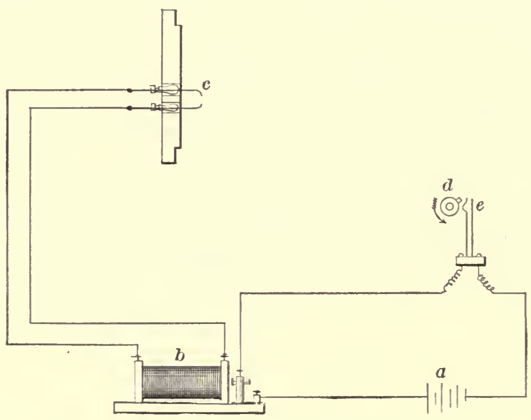


FIG. 126.—ELECTRICAL CONNECTIONS.

block of fiber by machine screws; the lower ends of which are also used to clamp the ends of the primary wire.

The upper ends of these springs are bent toward each other and, at the points where they touch when pressed together, small pieces of sheet platinum should be soldered.

At *d* is represented the hub of the 2-inch gear wheel which operates the exhaust valve rod.

The contact springs are held in position behind the web of the gear wheel and close to the hub. The hub travels in the direction shown by the arrow. These points should be in contact just as the piston reaches the end of the in-stroke and the charge of gas and air is compressed in the rear of the cylinder.

When the moving parts are in this position, the contact screw of the interrupter of the induction coil should be adjusted so that it just touches the spring. This is necessary in order that the vibrator shall act whenever the contact springs on the engine close the circuit.

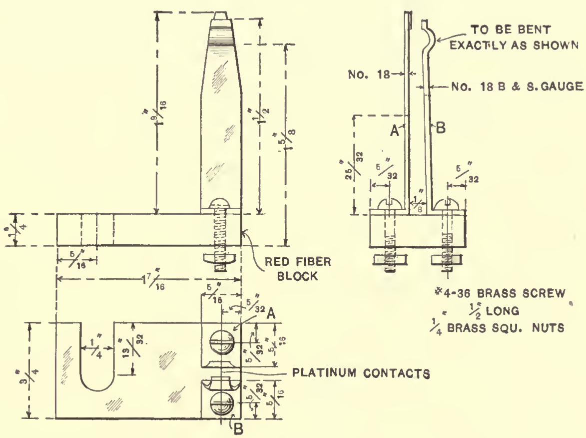


FIG. 127.—IGNITER CONTACTS AND FIBER BLOCK.

The pin shown projecting from the hub of the gear wheel is made from a piece of fiber rod $\frac{3}{16}$ inch in diameter.

After the valve gearing has been finished, and the gear wheels marked in their relative positions, rotate the fly-wheels of the engine by hand and locate the point in the cycle at which the explosion of the charge in the cylinder is to take place. This can be found by referring to the chapter treating on the cycle of the gas engine.

When the point is found and the piston placed in its proper position in reference to the explosion, mark the hub of the gear wheel where it must be drilled for the fiber pin.

The fiber block on which the brass contact springs are set is held in position by being clamped under the head of one of the cap screws of the bearing. A washer should be placed under the head of the screw.

The moment of contact can be varied slightly by tapping the fiber block on one or the other side to make the points touch at the exact instant.

In the cut of the complete engine, Fig. 130, these parts can be clearly seen.

Since the first edition of this work was published, the particular style of lava tip shown in this chapter has been so materially changed by the manufacturers that it has been found very difficult to make the igniters "spark tight" under compression. This led us to design a small spark plug which could be easily removed for examination and cleaning.

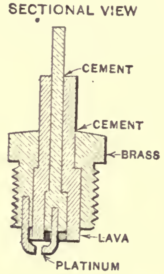


FIG. 127 A.—IMPROVED IGNITER.

The igniter pin is of brass surrounded by a lava bushing which extends outside the cylinder head far enough to prevent a leakage of the spark. The igniter pin terminates in a platinum point inside the cylinder. The second platinum point is set in the inner end of the screwed brass plug. The construction is clearly shown in Fig. 127 A.

With this spark plug the connections shown in Fig. 126 are to be slightly changed. At C one of the secondary wires is attached to the projecting end of the igniter pin, and the other wire is to be clamped under the head of one of the screws of the cylinder head or any convenient screw of the engine.

Chapter XXI.

ASSEMBLING.

CYLINDER PARTS. SHAFT, CRANK PIN AND FLY-WHEELS. INSERTING CRANK PIN. PUTTING CRANK SHAFT IN PLACE. PISTON AND CONNECTING ROD. FITTING FINISHED PARTS TO BED PLATE. DRILLING. DRILLING LUGS. ASSEMBLING ENGINE FRAME.

CHAPTER XXI.

ASSEMBLING.

No regular routine can be laid down for the builder of this engine to follow in assembling the different parts. Some of the parts cannot be assembled until certain other parts have been completed.

For instance, the cylinder parts cannot be permanently and correctly put together until the side rods and bearings have been completed and fitted.

In assembling the cylinder parts, put the side rods into the main bearings, which are held in line by inserting a piece of shaft through both of them. Fasten the rods into the bearings by driving in the steel keys.

Place the forward cylinder collar in its proper position on the side rods and insert into it, from the back, the front end of the cylinder tube.

Slide the cylinder supports on the side rods. Place the end of the brass jacket tube into its position in the front cylinder collar, after which the back cylinder collar is placed on the side rods and cylinder tube. The two nuts can now be screwed on the side rods by which the cylinder parts are securely clamped together. This should be done with the bearings and supports setting on a level surface.

Should it become necessary to remove the cylinder from the rods, its parts will be held firmly together if the boring of the cylinder collars and turning down of the tubing was accurately done.

When the shaft, crank pin, and fly-wheels are ready to be put together, the two pieces of shaft must be driven into their respective fly-wheels.

A wood mallet is best to use for this purpose, and the blows should be struck squarely on the end to prevent springing the shaft.

After the two parts have been drilled for steel pins, as shown in Fig. 95, and securely pinned, they should be attached by forcing the crank pin into place in both wheels, keeping the two pieces of shaft in line with each other. A large vise is the best thing to use for this purpose, but it must be large enough in the throat so that the jaws shall come to the crank pin boss.

If it is found necessary to drive the parts together, one fly-wheel can have the pin driven into it with a mallet, and then placing this wheel, with the crank pin boss supported from the under side, on a good, solid foundation, place the other wheel above with the shafts in line and strike with the mallet on the crank pin boss. Use caution when driving these parts together, and do not spring the crank pin by pressing the outer rims together before the crank pin is home in both wheels. Before screwing the two cap screws into the ends of the crank pin, test the complete shaft for alignment. If the two fly-wheels are exactly the same diameter and straight across the face, a steel rule or straight edge placed across the two wheels will show if the shaft is in line. If found out of line, take hold of the two rims of the fly-wheels opposite the crank pin and twist one of the wheels on the pin until the complete shaft lines up. Then insert the screws in the ends of the pin and clamp the washers down tight on the crank pin boss.

The completed crank shaft is then ready to mount in the bearings.

When the bed plate is ready for the engine proper, the cylinder side rods and bearings are fastened together, with the cylinder supports in place, and a piece of solid shaft passed through the bearings.

Place these parts on the bed plate in their proper position, as shown in Fig. 128.

With a scriber mark on the bed plate the position of the front holes in the main bearing through the holes already

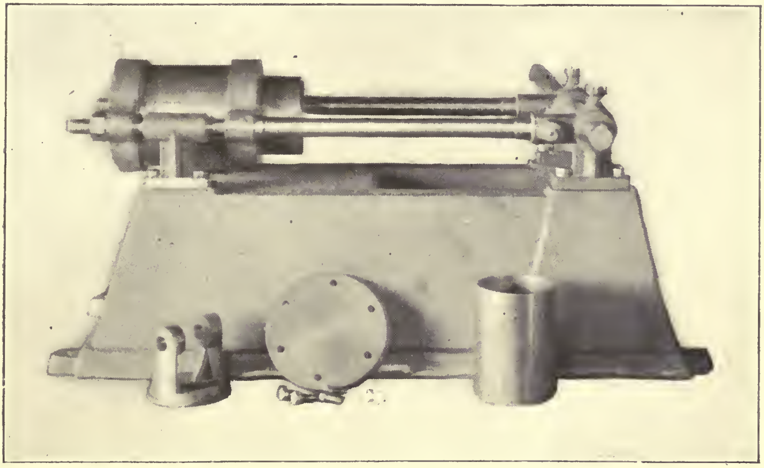


FIG. 128.—CYLINDER, SIDE RODS AND BEARINGS ASSEMBLED AND BOLTED TO BED PLATE.

drilled in their bases; also mark position of one hole of each cylinder support.

Lift the engine parts from the bed plate and center-punch the places marked.

Also center-punch the four lugs on the bottom of the bed plate. Drill the latter holes first with a $\frac{1}{4}$-inch drill. Use these holes to fasten the bed plate on a piece of hardwood board, which will cover the entire bottom of the bed plate.

This piece of board is for the back center of the lathe to rest against when drilling the holes in the top of the bed plate.

Drill the four screw holes marked with a No. 4 twist drill and tap them ¼-inch 20.

Replace the engine parts and fasten them down with ¼-inch cap screws, then the remaining holes can be marked. Remove the engine parts again and drill and tap the remaining holes, after which the piece of board can be removed from the bottom of the bed plate and the engine parts replaced and fastened down, as shown in Fig. 128.

In placing the frame of the engine in position on the bed plate, the most important thing to consider is the proper location of the main bearings in reference to the depression of the bed plate where the fly-wheels are to be placed.

If this is neglected it may be found on mounting the fly-wheels and shaft in the bearings that the wheels will rub on the bed plate.

In the size engine here described the centers of the bearings should be just 5 inches apart, as shown in detail drawings.

When the cylinder, supports, side rods, and main bearings are assembled and screwed to the bed plate, as in Fig. 128, the crank shaft and fly-wheels can be mounted into position. To do this unscrew the supports from the bed plate and remove the two nuts from the ends of the side rods. The cylinder and supports can then be slid from the rods. Next unscrew the main bearings from the bed plate and slide them on the shaft on their respective sides.

Replace the bearings on the bed plate with the fly-wheels between them and screw into place again. The cylinder and bearings can then be slid on the side rods and screwed to the bed plate.

In assembling the piston and connecting rod parts, the rod and piston pin are finished and placed in position in the piston casting before the shell of the piston is placed on the casting. In Fig. 128 the casting and shell are shown standing beside the bed plate of the partially finished engine. In Fig. 72 the casting is shown with the pin inserted. It will be seen that the ends of the pin are rounded to conform to the curve of the inside of the piston shell.

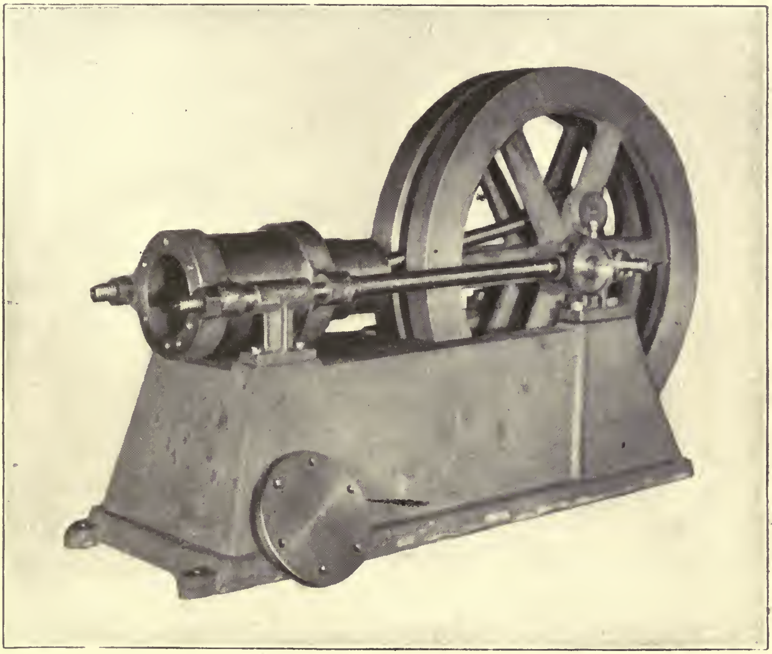


FIG. 129.—MAIN PARTS OF ENGINE ASSEMBLED.

The connecting rod is lined up and both ends pinned to the steel rod, after which the rod must be inserted between the lugs of the piston casting and the piston pin put through the two and pinned into place.

The shell is then slid on the casting and fastened there by the two screws. The piston is then ready for the fitting of the packing ring on the back of the casting. After this is fitted a piece of asbestos wicking can be wrapped around the groove of the packing ring and oiled, and a little graphite should be sprinkled on the oiled wicking. Slide the piston into the cylinder with the screws of the packing ring loose. After the piston and ring are inside the cylinder, tighten up the screws, which will set the packing against the cylinder shell.

The connecting rod can now be attached to the crank pin. The work will then have the appearance shown in Fig. 129.

The cylinder head should be finished next by boring it for the valves and igniter. After these parts are completed and the valves in place, the valve gearing should be assembled.

In placing the exhaust valve in position the end of the lever should come on a line with the center of the side rods, then, when the valve rod bearings are screwed on to the ends of the lugs of the cylinder collars, the valve rod will also line up with the side rods and have a very neat appearance.

It may be necessary to give the lever of the exhaust valve a slight offset to meet the end of the valve rod. This will depend upon how accurately the exhaust valve has been put in position.

The governor should be completed and put in position next.

Be sure that the catch pins come in line. The pin projecting from the lower side of the governor lever is made square to allow for any slight variation in the lining up of the pins.

In fitting the governor to the valve rod bearing the parts should not bind, as the governor lever must move up and down easily.

There should not be any lost motion, however, which would allow the governor lever to move from side to side, as a slight movement in this direction at the point where the lever attaches to the valve rod bearing would be multiplied to such an extent at the catch pins that they might miss each other. After the exhaust valve, valve rod and

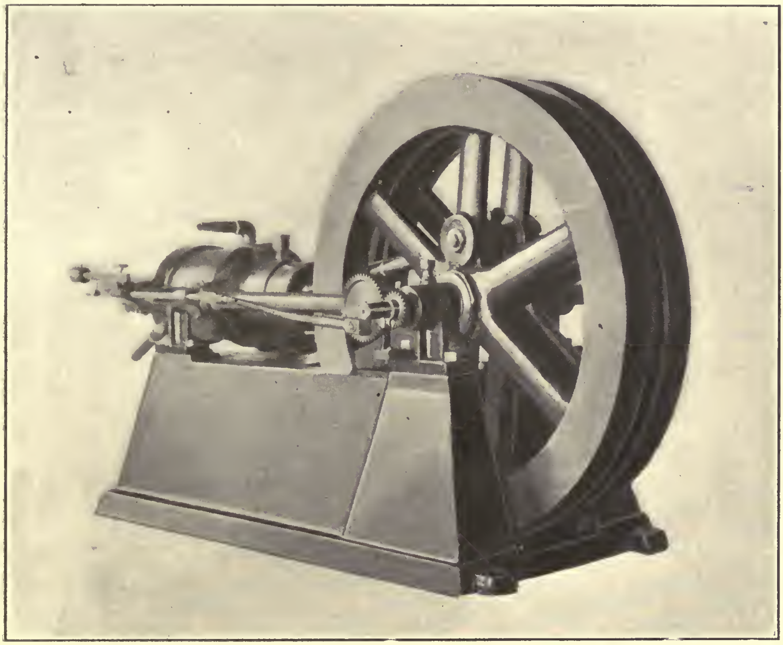


FIG. 130.—THE FINISHED ENGINE.

governor are in place the indentation in the top of the valve rod can be marked and afterwards filed.

In filing this indentation great care must be exercised to get it in exactly the right place and at the proper depth.

The starting handle should be fitted and the engine tried with it to see how the governor will work.

The governor weight can be moved to different positions on the lever, and the adjusting thumb screw used to vary the tension of the spring.

By running the engine with the starting handle it can be brought up to speed enough to test the working of the governor.

The igniter should be put in place last, after all the other parts are finished and in position, as the pieces composing this are so much more delicate than the others and are liable to be broken.

Directions for finishing up these parts will be found in Chapter XX.

The completed engine is shown in Fig. 130.

Chapter XXII.

REGULATING AND STARTING.

STARTING HANDLE. TESTING INLET VALVE. ADJUSTING EXHAUST VALVE. TESTING CONTACT SPRINGS. ADJUSTING AND TESTING IGNITER. ADJUSTING GOVERNOR. STARTING THE ENGINE. REGULATING THE AMOUNT OF GAS. PROPORTIONING THE CHARGE. GAS SUPPLIES FOR ISOLATED ENGINES. VAPORIZERS AND CARBURETERS.

CHAPTER XXII.

REGULATING AND STARTING.

After the machine work has been completed on the engine proper a starting handle must be made, the dimensions of which are given in the detail drawings, Fig. 131. This is made of a casting of iron and the handle is of wood, turning on a piece of $\frac{1}{4}$-inch steel rod. A washer and screw prevent the wood handle from sliding off the rod.

At the opposite end of the crank a two-jaw clutch is cast, and through this part of the casting a $\frac{1}{2}$ inch hole is to be drilled to enable the handle to be placed on the end of the crank shaft which has been turned down. The pin driven into this piece of the shaft, as described and shown in Chapter XIV., is to engage with the clutch of this handle, and by this means the engine can be turned easily by hand.

An examination of the shape of the clutch will show that so long as pressure is exerted by the hand turning the crank the clutch will engage with the pin on the shaft. As soon as the engine starts off of itself, however, the shaft and pin will travel faster than the handle and passing along the incline of the clutch will throw it out of gear. The handle is then slid off the end of the shaft. The fit of the handle on the shaft must be an easy one, that it may be removed without difficulty after the engine has started.

By the use of the starting handle the various parts of the engine can be tested; such as the inlet and exhaust valves, electrical connections and igniter, governor, etc.

When the piston is traveling forward on the admission stroke of the cycle the inlet valve should open and air will be drawn into the cylinder. This being a description of the testing of the valves the gas is not as yet turned on.

The spring of the inlet valve must be adjusted to let the valve open easily on this part of the stroke, but yet must be sufficiently strong to hold the valve closed if the piston is

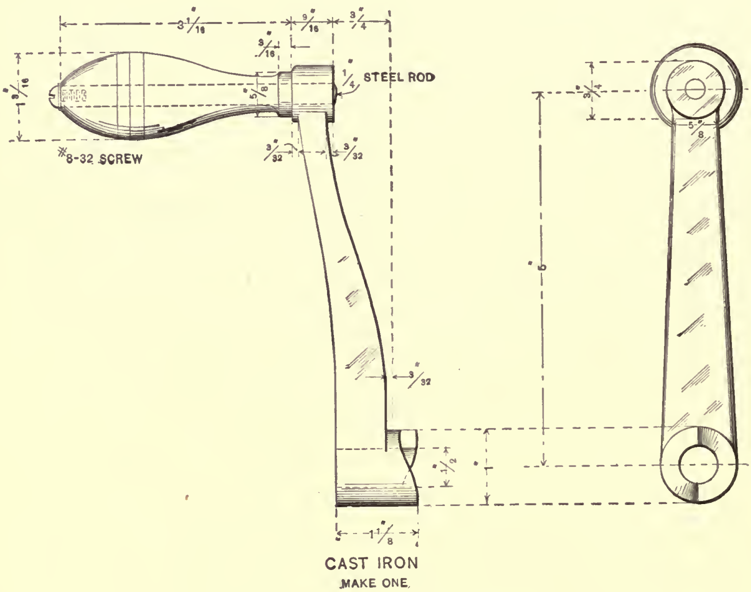


FIG. 131.—CRANK HANDLE.

traveling in this same forward direction and the exhaust valve is held open by the governor. This can be determined by turning the engine and holding the exhaust valve open, either by depressing the governor lever or holding back on the exhaust valve lever. The valves can be tested for leaks by turning the engine by the handle and stopping at the end of the compression stroke of the cycle.

The engine should be turned to see that the exhaust valve opens at the proper moment. It should begin to open just before the piston reaches the forward end of the cylinder on the expansion stroke of the cycle, and the valve should close just as the piston reaches the back end of the cylinder on the exhaust stroke.

If is found that the valve is not set exactly right it can be varied by sliding the 2-inch gear wheel from the gear stud and revolving it forward or back one tooth at a time until the proper position is reached. A variation can also be made by the adjusting screw on the end of the exhaust valve lever.

The electrical connections should also be tested to see that the contact occurs at just the right time. The spring contacts should touch each other just the instant the piston is coming to rest at the end of the compression stroke. The two platinum points of the igniter should be separated by only about $\frac{1}{32}$ inch. To see the spark the cylinder head can be removed and held in position on the foundation with the inside of the head in view. When the engine is then rotated, if the connections are all right according to the diagram in Chapter XX, the spark can be seen at every second revolution of the engine.

The two small pipes of the water jacket must be connected up with the water supply.

Where the engine is to be used near a water connection a piece of rubber hose can be used between the water faucet and the lower pipe of the jacket, and a waste pipe connected with the pipe in the top of the jacket and the waste water allowed to run away. The water should not be supplied too freely, as it is much better to allow the engine cylinder to remain quite warm than to keep it too cool by a large supply of water. Where running water is not convenient, a circulating tank must be used. This can be made from a small sized galvanized ash can or any other suitable reservoir. If the lower pipe of the water jacket is connected with the tank by a pipe entering near the bottom of the tank and the outlet of the jacket is connected by a pipe entering the tank near the top, a circulation of the water will be kept up and the cylinder will remain cool enough.

The reservoir should hold twelve or fifteen gallons for an engine of this size.

The water level in the tank must be higher than the point of entrance of the pipe from the top of the water jacket.

Should it be allowed to get below that level there will be no circulation and the cylinder will become overheated.

The tank should be placed near the engine and the pipes should have as few bends as possible. Use nothing smaller than ½-inch iron pipe for this purpose.

If all these different parts are found to be in proper order the gas may be turned on and the engine given one or more complete revolutions with the starting handle to get it into operation. It is well to set the governor for a low speed at the first trial to be sure that all parts of the engine are firmly fastened together. To set the governor, loosen up the speed regulating screw and turn the engine by hand until the governor works by catching the pin of the exhaust valve lever and holding the exhaust valve open.

After the engine has been started and allowed to run light at a low speed, to see that all its parts are in working order, the speed can be increased by screwing down the speed regulating screw on the governor lever.

It will be necessary to place a stop cock on the gas inlet pipe to regulate the amount of gas admitted to the engine. This stop cock should be placed on the gas ring of the inlet valve, as shown in the cut of the finished engine.

A little experimenting will be necessary to determine the best proportions of the charge of explosive mixture to admit to the cylinder. When the stop cock is once set where the best result is obtained under the prevailing conditions, the screw in the end of the plug of the stop cock should be tightened down to hold the stop cock in that position, and the turning on and off of the gas supply, at stopping and starting, should be done with a separate stop cock at any other convenient point on the supply pipe.

The exact proportions of the charge of gas and air will vary under different conditions. The gas in some towns will be found richer than in others. The richer the gas the smaller the quantity required in each charge and the poorer the quality of the gas the more of it will be required to obtain the same result in the engine.

It has been found that the best results are obtained with an average proportion of 1 part of gas to 12 parts of air.

This is based on the supposition that the gas is of A1 quality city coal gas. With an inferior quality it may be found necessary to increase the quantity of gas in the mixture to a proportion of 1 part of gas to 8 parts of air.

In practice the best results will be obtained with mixtures proportioned between these two extremes.

Where gas is not obtainable, the engine must be supplied with a carbureter, or vaporizer, to generate gas from gasoline, etc. In the following chapter will be found a design for a carbureter.

A vaporizer is not recommended by the writers for so small an engine. They are complicated and consequently get out of order easily. In the case of automobiles they are necessary, as they are much lighter than a carbureter, besides taking up so much less room. We should not advise an amateur to attempt the construction of a vaporizer.

Chapter XXIII.

ON CARBURETERS.

DESIGN FOR CHEAP CARBURETER. DESCRIPTION OF CARBURETER PARTS. SAFETY DEVICE. FITTING THE INSIDE OF CARBURETER. SPRING HOOPS. CAPILLARY PARTITIONS. CHARGING THE CARBURETER. CONNECTING WITH THE ENGINE. PRACTICAL WORKING OF THE CARBURETER. AMOUNT OF GASOLINE TO USE. ADVANTAGES OF THIS CARBURETER. CAUTIONS.

CHAPTER XXIII.

CARBURETERS.

Where coal or natural gas is not obtainable, it will be found necessary to furnish a substitute for supplying the engine with an explosive mixture.

Gasoline will be found to answer this purpose admirably, but some apparatus is necessary to convert the gasoline into a gas before it can be used for combustion in the gas engine cylinder.

A carbureter will be found to be the best adapted for this purpose, as the gasoline will be entirely enclosed and free from danger.

The carbureter shown in Fig. 132 is one designed by the authors several years ago, and has been found to do excellent work. There is nothing about it either to wear out or get out of order.

The body of the carbureter *A* may be a piece of brass tubing about 6 inches in diameter and 18 inches long. It can also be made up of heavy sheet tin or copper with a lock joint, the same as a stovepipe is put together. Another way is to use a piece of 6-inch iron pipe threaded at each end, on which two 6-inch caps can be screwed to close up the ends. This is a matter which the builder can decide for himself, as it will depend on his facilities which mode of construction he chooses. In the cut is shown a cap *B* on one end of the tube and a flange is attached to the opposite end, to which the head *C* is fastened by screws.

At *D* is a ½-inch stopcock. This is screwed into one end of a ½-inch elbow, which is screwed to a ½-inch close nipple tapped into the head *B*.

This stopcock is the inlet for the air which is to be carbureted and is connected to the elbow and placed in an upright position that gasoline may be poured into it when it is necessary to charge the carbureter.

In the opposite head is placed the stopcock *E*, which con-

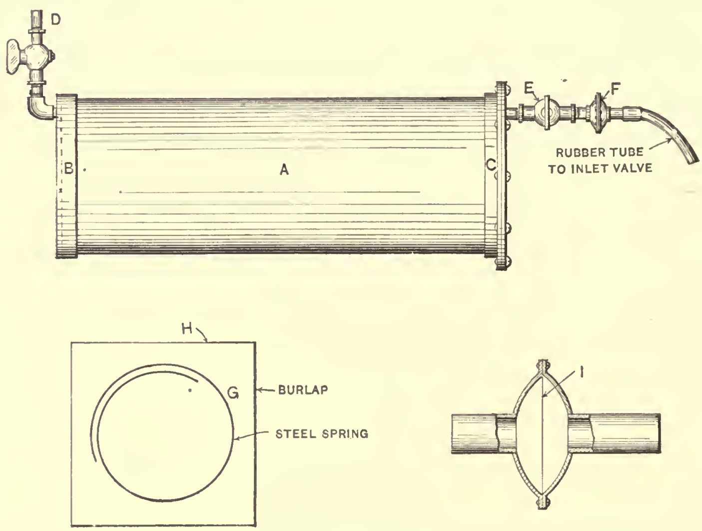


FIG. 132.—CARBURETER.

trols the outlet of the carbureted air or gas which passes through the rubber hose on its way to the inlet valve of the gas engine.

F represents a small safety device to prevent any possibility of the flame from the gas engine cylinder reaching the carbureter. This can be placed next the stopcock *E*, as shown in the cut, or in the tubing nearer the inlet valve.

A cross section of this device is shown in the lower part of the cut. *F* represents one of the two saucer shaped pieces of copper or other ductile metal. These are made of two sheet metal disks 2 inches in diameter and about $\frac{1}{64}$ inch thick. They are formed to shape by hammering with a ball pein hammer into a depression cut or hammered in a piece of hard wood. The edges should be left flat, as shown. In the center of these pieces a hole is punched and a piece of brass tubing driven through and soldered. *I* represents a piece of fine brass wire gauze which is cut into a disk the same diameter as the pieces *F*, and when placed in the position it is to occupy between the two saucer-shaped pieces *F* the edges of all three are soldered together. The material for this device can be procured in any tin shop.

We now come to the most important part—the fitting of the inside of carbureter.

Gasoline is a liquid which possesses the property of rapid evaporation when placed in intimate contact with air, and the more thoroughly the two can be brought into relation with each other the richer will be the gas produced. In this carbureter the desired result is obtained by passing the incoming air through a great number of thicknesses of burlap or other coarse cloth.

In the lower half of Fig. 132 *G* represents a piece of thin spring brass or spring steel about 20 inches in length for this diameter of carbureter and $\frac{3}{8}$ inch wide. It is bent around with the fingers until it forms a hoop about 5 inches in diameter, and while held in this position is laid down on a piece of burlap *H* about 9 inches square. Holding the spring together with the fingers of one hand, the corners of the burlap are folded over into the center of the spring, after which they are gathered into one hand and the spring thereby prevented from distending.

The carbureter should be previously set on one end with the upper end open. The spring and burlap are placed down into the end of the carbureter, and the spring is then allowed to expand slowly by letting the corners of the burlap slide through the fingers. The corners are carefully folded over into the center of the hoop and another hoop and piece of burlap prepared and placed in position above the first one. This is continued until the carbureter is filled. Each hoop should be pushed firmly against the one preceding it in order to get in as many as possible. The spring hoops are for the purpose of holding the burlap pieces snugly against the tube and preventing air from passing through the carbureter unless it shall pass through the burlap partitions.

In a carbureter 18 inches in length about forty or more of these hoops can be placed.

When the carbureter is placed in its normal position, as shown in the cut, the burlap-covered hoops will be standing on edge. If gasoline is now introduced through the stopcock by placing a funnel therein, it will flow along the bottom of the carbureter, and the burlap on each hoop will at once exert its capillary attraction and become saturated with gasoline.

If the rubber tube from the outlet *E* be now connected with the gas ring of the inlet valve of the engine, the forward motion of the piston in the cylinder will act as a pump, and a portion of the air drawn into the inlet valve will pass through the carbureter.

As each particle of air passing through the carbureter must of necessity pass through each of the burlap partitions, it is, therefore, brought in intimate contact with the gasoline with which the burlap is saturated. These particles of gasoline are absorbed by the air in its passage through the carbureter, and the combination forms a combustible gas.

A charge of one gallon of gasoline is all that should be placed in the carbureter at one time. This will fill it about half full, and the partitions of burlap will remain saturated as long as any gasoline is collected in the bottom of the carbureter.

If desired, a small plug could be screwed into one head of the carbureter about an inch from the bottom.

This could be carefully removed if it were suspected that the charge of gasoline was exhausted.

If no gasoline shows when the plug is loosened, the carbureter needs recharging.

A small stopcock would be a quicker test, but we should not advise using one because of the danger of accidental loss of gasoline.

The stopcocks *D* and *E* should be closed as soon as the engine is stopped and opened again before starting. The stopcock of the inlet valve should only be used to graduate the flow of gas, and when the proper opening has been found by experiment, the stopcock should be tightened up and remain in that position.

This carbureter possesses several advantages, as it is cheap, yet effective. There can be no waste of gasoline if the stopcocks and connections are tight.

The carbureter can be left charged for weeks and is as ready to supply gas at the end of that time as it would be if only freshly charged.

If made up of sheet metal, the heads may be soldered in. One head can be put in before the hoops are placed in position, and the other head after these are in place. In this case all joints must be securely soldered.

If the carbureter is made from a piece of pipe and the heads screwed on, white lead should be used in the threads to insure their being perfectly tight.

To the experimenter who is unaccustomed to the handling of gasoline a few words of advice and caution are desirable.

Gasoline at ordinary temperatures gives off a heavy and inflammable gas, so that if a bottle or can of this oil be left open one may see, by reason of its greater density, a thin stream of the vapor issuing from the opening and pouring down the sides on to the table and then to the floor. Should a burning match be in its path the gas will at once catch fire and the flame will run along up the stream to the can.

So every precaution must be taken when handling gasoline that no one is near by who is smoking, nor must any flame be burning. The room windows should be open, so that the ventilation will prevent the gas from accumulating on the room floor.

Should any of the liquid catch fire the flames may be smothered by throwing on them sand, earth, or flour. A fire in a closed room can be extinguished by the use of liquid ammonia.

Always keep your gasoline can tightly closed and in a cool, safe place.

Chapter XXIV.

ENGINE DETAILS AND THEIR DESIGN.

CLASSIFICATION OF PARTS. BED PLATE. CYLINDER DIMENSIONS. SPEED. LENGTH OF STROKE. WEIGHT OF FLY-WHEELS. COUNTER-WEIGHTS. MAIN SHAFT. BEARINGS. OILERS. CRANK PIN. CONNECTING ROD. PISTON PIN. PISTON. CYLINDER AND HEAD. INLET AND EXHAUST PORTS AND VALVES. SIDE RODS. GOVERNORS. IGNITERS. MUFFLERS.

CHAPTER XXIV.

ENGINE DETAILS AND THEIR DESIGN.

Forms and styles of engines for many different purposes vary so much that it is possible in this chapter only to give sundry hints and suggestions and to indicate, in a general way, some of the principles of design which apply especially to gas engine work. So that, while our object is to encourage the amateur and small motor builder all we can, we do not advise our readers to attempt the design and construction of engines of, say, three horse power or more without being farther informed in the subjects of machine design, strength of materials, etc.

In order to readily classify the various parts of an engine we can divide them into fixed and moving, and again, according to size and importance, into primary and secondary ;

- Fixed Parts
  - Primary
    - Bed plate.
    - Cylinder.
  - Secondary
    - Cylinder head.
    - Bearings.
    - Igniter.
    - Water jacket.
    - Piping.
    - Muffler.

- Moving parts
  - Primary
    - Piston.
    - Connecting rod.
    - Crank shaft.
    - Fly-wheels.
    - Valve shaft.
    - Valves.
  - Secondary
    - Valve levers.
    - Governor.
    - Cams.
    - Igniter lever.
    - Pulley.

The bed plate or supporting frame is a part which will vary so much, according to the use for which an engine is designed, that we will but point out what its general functions must be, and they are principally two in number: first, to resist the explosion which tends to separate the cylinder from the crank shaft; second, to keep the whole machine firmly fixed in place so as to resist the pull of the belt by which the power is transmitted, or the turning effort which will ensue when coupled to a shaft or dynamo.

In the model engine which is the subject of this book the first of the above requirements is filled by the two side rods, making direct connection from the cylinder to the main bearings; the second is met by the bed casting with its lugs, whereby it may be fastened to a floor or a small brick foundation.

The cylinder dimensions and speed for a given power of engine are quantities which vary so with the quality of the fuel used and its temperature, the point at which ignition takes place, and other items which cannot all be previously known, that it is most convenient to rate the engines at a nominal horse power which is about two-thirds their maximum horse power when working under the best conditions. For a four cycle engine the rule for finding the nominal horse power is :—

Multiply together the square of the cylinder diameter in inches, the length of the stroke in inches and the number of revolutions per minute and divide the product by 28,000.

For example, let the cylinder diameter be $2\frac{1}{2}$ inches, the stroke 4 inches and the revolutions 450 per minute.

$$\text{Then } \frac{(2\frac{1}{2})^2 \times 4 \times 450}{28{,}000} = .4018, \text{ say } \tfrac{4}{10} \text{ nominal horse power.}$$

In applying this rule to two cycle engines we use 14,000 as a divisor in place of 28,000.

The rule for the proper speeds of engines is a little more complex than the above, as it involves the use of a logarithmic table ; for a four-cycle engine it is :—

Divide 350 by the value of the nominal horse power raised to the $\frac{21}{100}$th power.

Example. Find the proper speed for our .4 nominal horse power engine ?

$$\text{Log. } 350 = 2.544068$$

$$\text{Log. } .4^{.21} = \bar{1}.60206 \times .21 = \bar{1}.916433$$

$$\text{Log. ans.} = 2.627635 = 424.3$$

or say 425 revolutions.—Answer.

For two cycle engines substitute the number 405 in place of 350.

The ratio between the length of the stroke and the cylinder diameter varies from equality in small engines to twice the diameter in large engines of foreign make. The usual American practice is to make the stroke one-fourth greater than the cylinder diameter in two cycle engines, and one-half greater in four cycle types.

The volume of the combustion chamber or compression space is usually one-third of the total cylinder volume measured when the crank is on the outer dead-center, though modern practice has often reduced it to $\frac{3}{10}$ and sometimes less. In estimating this the spaces over the valves and the passages from the valves to the cylinders must be included.

The fly-wheel of a gas engine, especially on the four-cycle type, must store in itself during the power-stroke the energy of the explosive impulse which is in excess of that which is given to whatever machinery the engine drives, and then gradually part with its store in moving the engine and its attached machinery through the exhaust, suction and compression strokes.

In engines which govern by the hit-and-miss method the fly-wheels of the engine must carry it along for four or six revolutions when the load is very light.

Hence it is seen that a gas engine fly-wheel must have considerable weight in its rim and be moving at a high speed so that the momentum shall diminish the fluctuations of its velocity to an amount which shall be so small that it will not be objectionable for the purpose for which the engine is to be used. The following rule for the weight of fly-wheels gives the weight proper to the kind of machinery the engine is to run.

To find weight of rim of fly-wheels multiply together the indicated horse power, the average number of idle strokes between explosions, and one of the constants from the following table; divide this figure by the product given by multiplying the cube of the number of revolutions by the square of the mean diameter* of the fly-wheel rim measured in inches.

---

* Mean diameter equals the sum of the outer and inner diameters divided by two.

TABLE OF FLY-WHEEL CONSTANTS.

For pumping and ordinary work,	556,416,000,000
" driving machine tools,	927,360,000,000
" " looms, etc.,	1,112,832,000,000
" " dynamos, etc.,	1,391,040,000,000
" " spinning machinery,	2,782,080,000,000

These constants are for four-cycle engines; for two-cycle engines take one-half these values. If it is desired to calculate the weight by using Brake Horse Power, then take ¾ or ⅜ of these values for four or two-cycle engines respectively.

As the above rule is in rather a cumbrous form, we will repeat it in a diagrammatic form which, though not as elegant as an algebraic formula, will perhaps make it easier for the amateur to use.

$$\text{Weight of rim in pounds} = \frac{\text{Indicated H.P.} \times \text{average idle strokes} \times \text{constant from table}}{(\text{Revolutions per minute})^3 \times (\text{Mean diameter of rim})^2}$$

An example will best show the calculation.

How heavy should the fly-wheel rims of our model engine be made for ordinary purposes?

Call the I. H. P. $\frac{4}{10}$.

The idle strokes when running at full power will be 3, viz., exhaust, suction and compression. If we wished good regulation at half load we would use the number 7 on account of getting an impulse once in 8 strokes, i. e., in 4 revolutions. Some designers take the number 4 as an average figure. We use 3 so as to get the wheel as small as is advisable for the amateur's convenience.

Multiplying together $\frac{4}{10}$, 3, and the first constant, 556,416,000,000, gives us the product 667,699,200,000. Reserve this until needed later.

The cube of the number of revolutions is 450×450×450 =91,125,000.

Mean diameter of rim is $\frac{11''+14''}{2}=\frac{25'}{2}=12\frac{1}{2}$ inches.

The square of $12\frac{1}{2}$ is $156\frac{1}{4}$, or, putting it decimally for convenience, 156.25.

The product of 91,125,000 times 156.25 equals 14,238,281,250.

Now divide our first product, 667,699,200,000, by this number, 14,238,281,250, and we get as our final result 46.89458, or say 47 pounds. Dividing this into two parts gives 23½ pounds for the rim of each fly-wheel.

The size of the wheel rim can easily be calculated by remembering that a cubic inch of cast iron weighs very close to a quarter of a pound, so to find the number of cubic inches in the rim we multiply the weight in pounds by 4, thus: $23\frac{1}{2}\times4=94$ cubic inches.

For convenience we may now assume the rim to be straightened out into a rectangular bar whose length equals 3.1416 times the mean diameter, or $3.1416\times12\frac{1}{2}$ inches = 39.27 inches. Call it $39\frac{1}{4}$ inches.

Now since the cubic contents of the rim are to be 94 cubic inches and we have its mean length $39\frac{1}{4}$ inches, it is obvious that the area of a section taken vertically across the rim will be equal to the contents divided by the length, or $94\div39\frac{1}{4}=2.395$, say $2\frac{3}{8}$ square inches. So for width and depth of rim we may choose any two numbers whose product equals $2\frac{3}{8}$. For practical purposes we might take $1\frac{1}{8}$ inches wide by $1\frac{7}{8}$ inches deep, which would give nearly the above section, or $2\frac{7}{64}$ square inches.

To save turning off the full depth of the rim it is the practice to form a shallow edge on each side of the rim, as will be seen from the detail drawing on page 166. After facing off the periphery and these edges, the sunken surface and the arms are finished by painting to match the bed plate, etc.

The fly-wheel arms should be well proportioned so as not to appear clumsy and yet be strong at the hub to take the thrust of the connecting rod.

In a single cylinder engine of this kind it will be found desirable to balance the rapidly moving piston and connecting rod by weights placed opposite the crank hubs on the fly-wheels. While no engine is ever perfectly balanced in this way, yet it is the nearest approximation that is simple and practical.

To find the weight of the counter-weights add together the weight of the crank pin with its cap screws, half the weight of the complete piston and pin, and $\frac{13}{16}$ of the weight of the connecting rod; multiply this sum by half the stroke and divide the product by the distance from the center of the fly-wheel to the center of gravity of the balance weight. Measure all the weights in pounds and the distances in inches.

Applying this rule to our model we have the weight of the crank pin and screws, about . .	.50	pound.
Half weight of piston, etc., ...	1.00	"
$\frac{13}{16}$ weight of connecting rod, $\frac{13}{16} \times 1.2$ lb . .	.97	"
	2.47	"
Multiply by half the stroke $= \frac{4}{2}''$ . . .	2	
Divide by distance of center of gravity . .	5")4.94	
	.99	"

Call the answer one pound, this will give one-half pound to be placed on each wheel and, using the weight of cast iron as in the fly-wheel calculation, will require 2 cubic inches of cast iron.

The size of main shaft in engines having the fly-wheels outside the bearings is usually taken at about one-third of the cylinder diameter. In our model engine we can safely take a little less. One-third of $2\frac{1}{2}$ inches is $\frac{5}{6}$ inch, so we take as a convenient stock size $\frac{3}{4}$ inch.

The length of the bearing of the shaft should be from 2

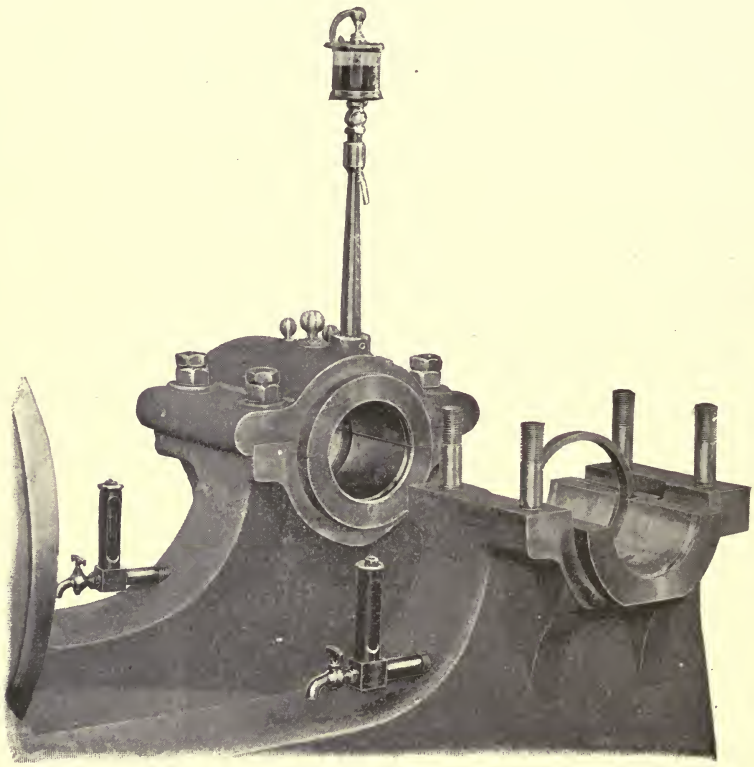


FIG. 134.—GAS ENGINE BEARINGS.

to $2\frac{1}{2}$ times the diameter of the shaft; we have used a little more than the latter figure to be sure of a good rigid bearing. In large, high-speed engines the bearings should have special arrangements to keep them well flooded with oil.

In Fig. 134 is shown an excellent design for this purpose.

Here are shown the cast iron housings containing the bearing brasses. Where the bearing cap is removed is seen a brass ring, which hangs loosely on the shaft and whose lower side dips into a reservoir of oil in the bearing pedestal and when in action carries a continuous stream to the top of the shaft. At the left of each pedestal is a draw-off cock and a gauge glass to show the height of oil in the reservoir. The oil cup standing on a pillar at the top is to oil the crank pin and will be described later.

The diameter of the crank pin should be one-fifth greater than that of the shaft, though in our model we have used the same size so as to save the amateur the cost of a reamer for the crank pin brasses alone.

The product of the length and diameter should be about equal to one-fifth the area of the piston.

The crank pin is also an important part to keep well oiled. For ordinary work a good screw-top oil cup will answer very well, but when an engine must make long, uninterrupted runs some other method must be used.

Fig. 135 shows another view of the same bearings given in the previous cut. A sight-feed lubricator is mounted on a neat, steel pillar and the oil from it is delivered by a tube to a wiper attached to the crank. Thus at each revolution a small quantity of oil is transferred to the interior of the crank and flows through the hole to the bearing surfaces.

This device could be applied to our model engine by drilling the crank pin as shown and also drilling one of the cap screws and arranging on its head a piece of thin tubing shaped like a stub pen so that it will catch the drop of oil and throw it into the hole in the pin.

The connecting rod should, in larger engines, be made larger at the crank pin end than at the piston end. Its mean diameter may be taken as $\frac{1}{4}$ of the cylinder diameter when it is twice the length of the stroke, and is proportionally larger up to one-third of the cylinder diameter, when it is three times the length of the stroke.

The length of the bearing surface of the piston pin should be the same as that of the crank pin, and the product of its length and diameter should equal one-tenth of the piston area.

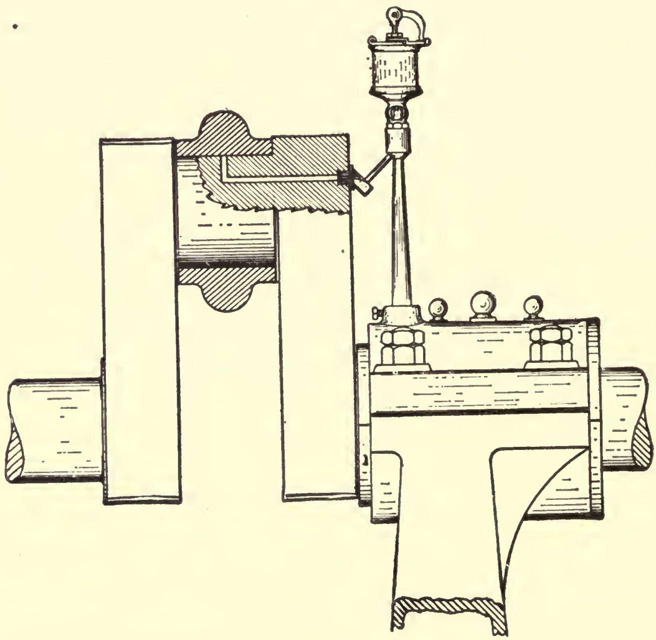


FIG. 135.—CRANK PIN OILER.

In our model, $\frac{1}{10}$ of the piston area, 4.91 square inches, is .49', or say $\frac{1}{2}$ square inch, the piston pin bearing is $\frac{1}{2}$ inch in diameter, its length is, therefore, 1 inch.

The length of the trunk piston should not be less than $1\frac{1}{3}$ times its diameter. In the model the piston length, $3\frac{7}{16}$ inches, is $\frac{1}{8}$ inch longer than $1\frac{1}{3} \times 2\frac{1}{2} = 3\frac{5}{16}$ inches, nearly.

Larger pistons for heavier service would be made of a single casting without the steel shell and, instead of the asbestos packing, will require three or four spring piston rings set in grooves turned in the body of the piston near the rear end. In designing cylinders of steel tubing of larger sizes than $2\frac{1}{2}$ inch diameter the wall of the cylinder should be taken proportionately thicker, but it will not be necessary to have a greater thickness than $\frac{1}{4}$ inch, as the tubing is not listed above 4 inches diameter. The depth of the water jacket is $\frac{1}{10}$ the cylinder diameter. It should extend along the cylinder to a point a little beyond where the piston exposes the cylinder wall to the hot gases. In larger engines the cylinder head should be cast hollow so as to be a continuation of the water jacket and it is also desirable to water-jacket the exhaust valve casing so that it will not become too hot and the valve stem cut into its guide.

The thickness of the cylinder head should be about $\frac{1}{10}$ of the cylinder diameter, this will make it strong enough to support the valves.

In these small engines the cylinder head is often fastened on with six iron screws, as in our model.

To find the size of the screw for this type of engine it will be sufficient to take it as $\frac{1}{10}$ the cylinder diameter when six screws are used. Should the construction of a different type be contemplated, involving higher pressures, the designer is recommended to study some of the recent works, mentioned in the next chapter, which treat the subject more fully.

The diameter of the inlet port should be $31\frac{1}{2}$ per cent. of the cylinder diameter, and the diameter of the exhaust port should be 35 per cent. of the same. The lift of the valves must be at least equal to one-quarter of their diameters, and they should have stems long enough to allow a little more, to compensate for any delay in action or rebound from the washer striking the valve stem guide.

The diameter of the threaded and keyed ends of the side rods may be taken as $\frac{1}{5}$ of the cylinder diameter and the maximum diameter of the rods at the shoulders is half as much again.

As to the governor, in a larger engine this may be enlarged proportionately and have a stiffer spring. There are other methods of governing which may be considered preferable under different conditions, they may be classified as follows:

Hit-or-miss.	1. Closing gas inlet. 2. Opening or closing exhaust. 3. Shutting off igniter. 4. Uncoupling valve shaft.
Variable impulse.	5. Throttling gas supply. 6. Throttling charge of gas and air. 7. Varying point of ignition.

The hit-or-miss methods give a complete and unvarying charge to the cylinder whenever required, but omit any impulse whatever at other times, so that at light loads the engine operates with irregularly timed impulses, at rather heavy loads there are a number of successive impulses with an occasional miss and at full loads there is an explosion at every stroke and the engine runs the steadiest.

With the variable impulse methods there is an explosion at every stroke, but its force is varied by the governor, as explained later. This results in a much more even running of the engine and with two or more cylinders is adequate to the exacting demands of electric lighting service.

The governor illustrated in Figs. 6 and 8 is a good example of method 1. As there explained, the valve remains closed, except when running at normal speed, then it is operated by the cam at the proper interval in the cycle.

The 2d method is partly illustrated by our model engine. Keeping the valve shut will retain the burnt gases which will be compressed on the instroke but will push the piston out again, so no power is lost except by the heat due to compressing the gases being carried off by the water jacket. Retaining the valve in an open position will simply allow the exhaust gases to be drawn in and out again as long as the valve stays open.

The 3d method is a wasteful one unless used in a specially devised engine, in which there can be no charge drawn in unless an explosion has occurred.

Method 4 is a very good one. The shaft is unclutched from the gear by the governor, so as to stop it when holding the exhaust valve open, thus doing away with the compression and expansion of the confined gases and diminishing as well the wear of the cams, valve gear, igniter, etc.

The 5th method is one in which a small variation in the proportions of gas and air in the charge will make a large difference in the power produced. It is not an economical method, as a given amount of gas will give its maximum force only when mixed with a definite amount of air. On this account the hit-and-miss methods have been so long in vogue, as they use an unvarying proportion of charge.

Method 6 unites both economy and good regulation. It keeps the gases of the charge mixed in their most suitable proportions and admits them in an amount dependent on the work to be done. This method has been applied to the largest engines.

The 7th method has made its appearance recently in connection with gasoline motor vehicles. It is not used with a governor to maintain a constant speed but to vary the speed by hand within wide limits, say from 150 or 200 to 1,500 revolutions per minute. It is only done with the electric mode of ignition by moving the circuit closing spring around the center of the larger gear.

We will now take up the subject of igniters. As the student has seen, it is necessary that the mixture of gas and air should have a combustion started in it at the proper

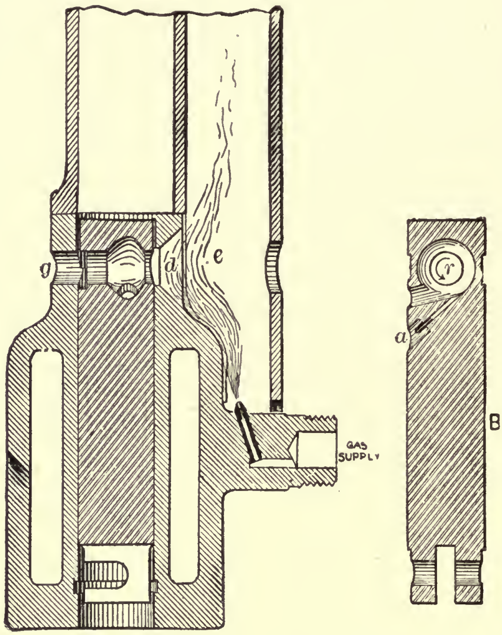


FIG. 136.—DIRECT FLAME IGNITER WITH VALVE.

moment of the cycle. The various methods of accomplishing this firing of the charge we may classify as follows:

- Flame.
  - Direct.
    - Valve.
    - Suction.
  - Indirect.
    - Tube.
    - Cone.
    - Rod.

- Spark.
  - Primary.
    - Strike.
    - Wipe.
  - Secondary.
    - Vibrator.
    - Toothed interruptor.

The direct flame method is used very little at present.

The valve form consists in having a chamber in a sliding valve as represented by the cavity *r* in valve *B*, Fig. 136. A small jet of gas admitted through *a* is ignited by the flame *c* at the port *d*. The valve is now moved so that one of the ports of its flame cavity is opposite an opening into the cylinder and the flame of the remaining gas and air burning in the cavity is communicated to the charge and explosion ensues.

The suction form of flame igniter is only applicable to engines of Class I. About the middle of the cylinder is an opening in the cylinder wall provided with a small steel shutter hanging loosely over its inner end. A flame impinges on its outer end. When the piston moves forward, drawing in the charge, it uncovers the ignition port, the flame is sucked in, the charge explodes and the impact closes the little steel shutter which prevents escape of the force of the expanding gases.

The hot tube is one of the best known methods of indirect flame ignition.

When first brought into use it was thought desirable to have its action under the control of a valve. Fig. 137 shows how this was accomplished. At *C* is the tube surrounded by flame from a Bunsen burner, which is attached at the lower rear part of the asbestos-lined chimney. At *A* is the combustion chamber of the cylinder; at *B* is what is called the timing valve, which is operated from a cam shaft through the bell crank *E* and the adjusting nut *F*. The spring *D* holds the valve to its seat against the force of the compression.

When the proper moment comes the valve is drawn back and the compressed mixture rushes in and part way up the tube, then the red heat of the tube fires the gases in it, the

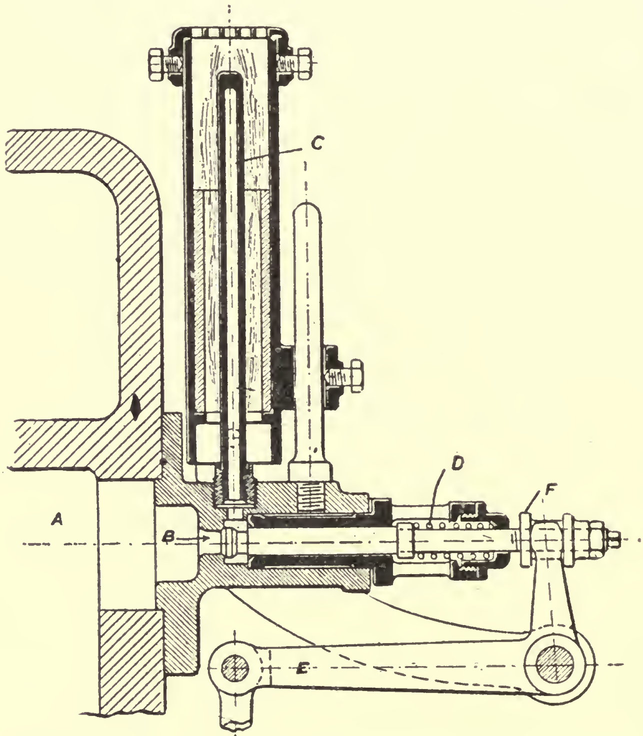


FIG. 137.—HOT TUBE IGNITER WITH TIMING VALVE.

flame rushes back to the cylinder and ignites the whole mass.

Further experience with hot tube igniters developed the fact that a timing valve was not always necessary. The regulation could be effected by varying the distance that the fresh charge must travel up the tube before reaching the igniting surface.

How this is done is illustrated in Fig. 138. Here *A* is the cylinder space, *B* the ignition port and *C* the Bunsen burner, which is fastened to the chimney by a swivel at *D*.

The chimney is capable of being moved up or down on the post so as to vary the place of redness of the tube. A

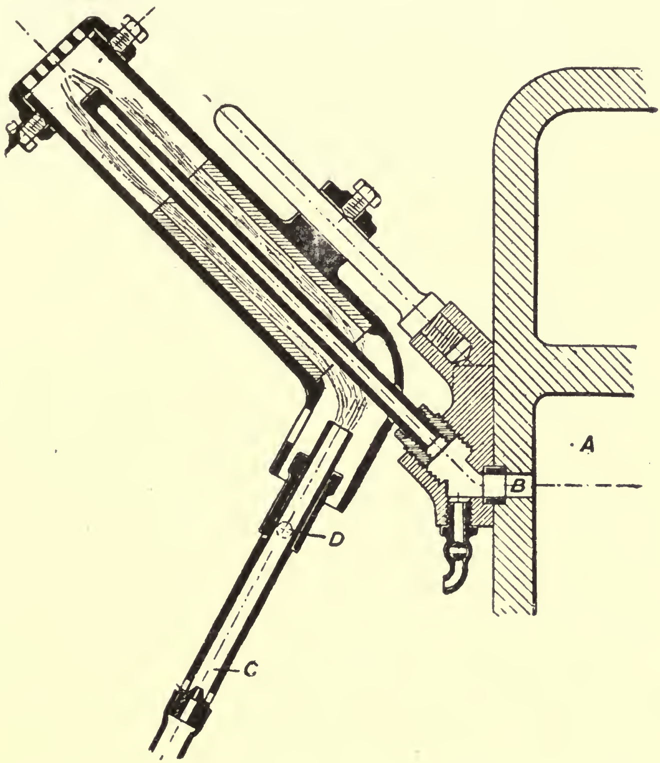


FIG. 138.—HOT TUBE IGNITER.

further small adjustment can be obtained by swiveling the burner tube, at *D*.

The principle of action is simply that the higher the flame is up the tube the farther the fresh charge will have to travel and compress the burnt gases ahead of it before it reaches the igniting port and the later the ignition will occur.

Iron tube is commonly used for these igniters, but as they burn out soon and break it is better to use a tube of nickel. Platinum or porcelain tubes are also used.

The cone and rod igniters are both adapted for use with petroleum engines.

It is a property of a compressed mixture of petroleum vapor and air that it ignites readily by contact with a body which is not quite at a red heat.

In actual engines a hollow casting is fastened to the rear of the cylinder and is unprovided with a water-jacket, but is guarded by a cast iron hood provided with a short chimney and damper above and a larger opening below.

Before starting the engine a large oil or gas burner is lighted and placed below the hood and the damper opened so that the flame will surround the hollow cone. When the cone is hot enough the engine is started, and as soon as it is running at full speed the burner is removed and extinguished. The damper is now closed enough to keep the cone at a proper temperature, for it will be receiving heat from the explosions within and losing heat by radiation and by the air current up through the hood

To aid in receiving heat from the hot gases in the cylinder the cone may have ribs cast on its interior, which project inwardly and by spraying the charge of petroleum upon them these ribs perform the triple function of vaporizer, heat conductor and igniter.

The rod method consists in having a small bar of nickel located within the cylinder over a port by which a flame can be introduced to heat the rod. The port is then closed and the engine operates the same as with the cone.

A spiral of platinum wire or a grating of the same have also been used in this way.

When the governing is by the hit-and-miss method these hot metal igniters will not work satisfactorily unless there is sufficient load on the engine to make the explosions frequent enough to keep the igniter from cooling too much.

The first of the electrical methods is practically the same as is used for gas lighting in private residences. The circuit breaker is connected in series with a battery and spark coil. When the circuit is completed the current passes and magnetizes the iron wire core of the coil. On breaking the circuit the instant collapse of the magnetic lines of force into the iron core creates, by the well-known phenomenon of induction, an electric pressure in the circuit greatly in excess of that due to the battery and prolongs the flow of current for a considerable distance through the air between the rapidly separating contacts.

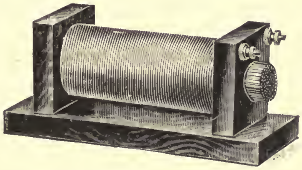


FIG. 139.—SPARK COIL.

On account of the rapid running of gas and gasoline engines the coils suitable for gas lighting are not well adapted to engine ignition as their long cores require an appreciable time to become fully magnetized.

To make the coil quicker in action a short form must be used. Fig. 139 shows a coil of this kind. A battery of low internal resistance should be employed.

The circuit breaker inside the cylinder is variously constructed by different makers, but all have practically the same parts—one stationary and insulated electrode and one movable electrode connected to some rotating or reciprocating part of the engine, so that it shall make and break contact with the fixed electrode at the proper time. An igniter using the "strike" method is described and illustrated on page 26 and Fig. 7. The sparking surfaces must be of platinum or a special hard alloy.

The electric circuit is from battery through the spark coil to the engine frame, thence from the insulated electrode back to the battery.

The wipe spark is electrically the same as the strike method but the contacts have a rubbing action instead of being merely pressed together.

In Fig. 140 is shown an arrangement of this kind. The insulated fixed electrode is shown with a spring point projecting upwards so as to engage a stirrup attached to the rear of the piston. This is done at the inner end of the stroke so that as the piston moves forward the spring will be compressed until its point is released, breaking the circuit and producing the spark.

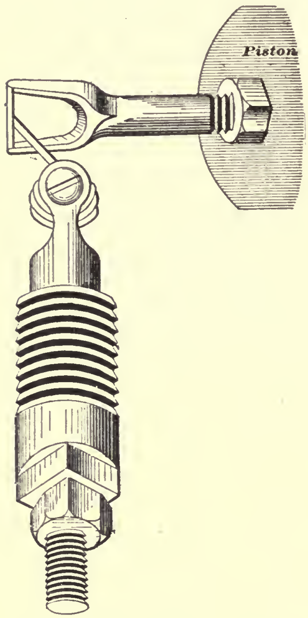


FIG. 140.—WIPE SPARK DEVICE.

This device has been selected as a lesson to the designer in what to avoid in this class of igniter. We will point out defects in this form and suggest changes in its arrangement. First, the coiled spring will not last long under the action of the hot gases. Second, the time of the spark will be delayed later than it should. Third, there is no means of regulating the time of the spark. Fourth, the spring or stirrup may get hot enough to act as an igniter like the nickel rod mentioned on page 278. Fifth, on a four cycle engine a switching device would be needed to turn off the current at alternate strokes.

All this could be avoided and better results secured by arranging a rotating electrode which should connect with a springy, insulated electrode once in each cycle, or by a little more ingenuity the spring could be entirely outside the cylinder.

The time of ignition could be adjusted by varying the relative angular position of the rotating electrode and its driving gear.

The fourth objection is one which needs attention as it has often been overlooked. The remedy is to keep the electrodes as cool as possible and this is conveniently done by placing them just within the inlet port so the fresh charge will blow past them at each admission. This point applies with equal force to all kinds of electric igniters. It is illustrated in Fig. 7, page 27, where the electrodes are seen in the port opening into the cylinder just over the inlet valve.

A very desirable point in engine design is to place opposite the igniter a screw plug which can be removed and the spark observed while turning the engine by hand, the gas of course being shut off.

The methods of ignition by a secondary or "jump" spark require less mechanism on the engine. The principle is that when a rapidly interrupted current is sent through the primary coil of a Ruhmkorff or induction coil, it will produce in its secondary coil a current of sufficient force to jump the space between the two fixed and insulated electrodes.

We will not describe the vibrator method here as it has been treated of in Chapters XX and XXII.

The toothed interrupter is simply a wheel on the valve cam shaft provided with one or more teeth which touch a contact spring, and the spring and teeth are connected so as to take the place of the vibrator on the coil.

This arrangement is used on automobile motors where the speeds are so high that the vibrator springs would not act quickly enough, and also by shifting the contact spring around the wheel the speed is changed as already explained under the head of governors.

One more ignition arrangement deserves mention. It is the one used in the Diesel motor and consist in compressing the air to so high a temperature as to ignite the fuel when introduced.

In closing we will speak of the silencing and disposal of the exhaust. The whole point is to get the exhaust down to atmospheric pressure gradually. This can be done by gradually increasing the size of the exhaust pipe, by placing expansion chambers or mufflers on the pipe, or by allowing it to escape through a number of small openings.

The rule for volume of muffler is to take $3\frac{1}{2}$ times the product of the square of the piston diameter multiplied by the stroke.

Applied to our model, $3.5 \times 2.5^2 \times 4 = 87\frac{1}{2}$ cubic inches, Answer.

This is about equivalent to $4\frac{1}{3}$ times the piston displacement, so a piece of $2\frac{1}{2}$ inch iron pipe, 18 inches long will be suitable. The ends should be provided with reducers for inlet and outlet of the exhaust. It is preferable when it can conveniently be done, to make the outlet pipe from the muffler a size larger than the inlet.

CHAPTER XXV.

VERTICAL ENGINE.

With a slight modification of some of the parts this engine can be constructed in the upright style as shown in Fig. 141. This may be found advisable where floor space is limited. The parts which require modification are the bed plate, bearings, side rods and contacts. Two entirely new parts will have to be added, consisting of a small bracket and spring which are required to keep the governor in an upright position. Several engines have already been built from this design and work very successfully.

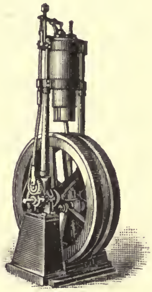


FIG. 141.—UPRIGHT STYLE GAS ENGINE.

Fig. 142 shows the design of the bed plate, the pattern of which is easier to construct than is that of the horizontal style.

It will be noticed that the top of the bed plate is made quite thick. This is to give a good long hole for the cap screws by which the bearings are held down. The same instructions given in Chapter VI. are to be followed in building up this pattern.

The only finish required on the casting is to plane or file off the two top surfaces on which the bearings are to rest.

As the bearings and side rods of this style of engine have to withstand a considerable side thrust at each impulse, they must necessarily be made correspondingly stronger.

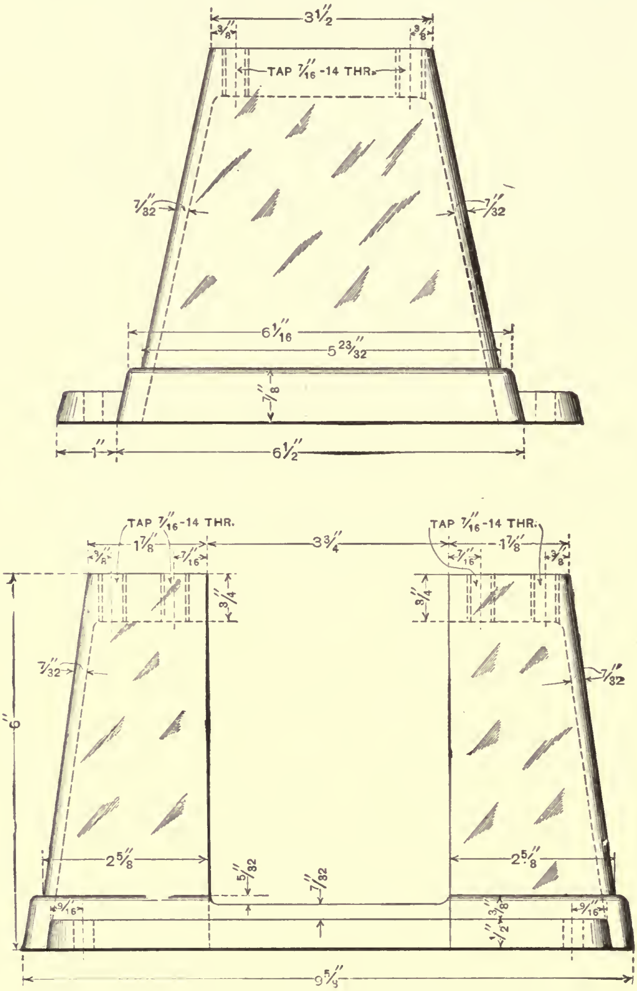


FIG. 142.—BED PLATE FOR UPRIGHT ENGINE.

Fig. 143 shows the sizes of the various parts of the bearings. It will be noticed that both bearings are exact duplicates, with the exception that the one which is located on the valve gearing side of the engine has a small hub or boss cast on to hold the gear stud, and also a small flat projection near the shaft, to which is screwed the fiber block holding the contacts.

To save unnecessary work only one pattern need be made.

The small boss for the gear stud and the projection for the fiber block can be attached to the pattern by small brads after it is finished and shellacked. The foundryman can then be instructed to make one casting with these parts in position, and the second casting after they have been removed.

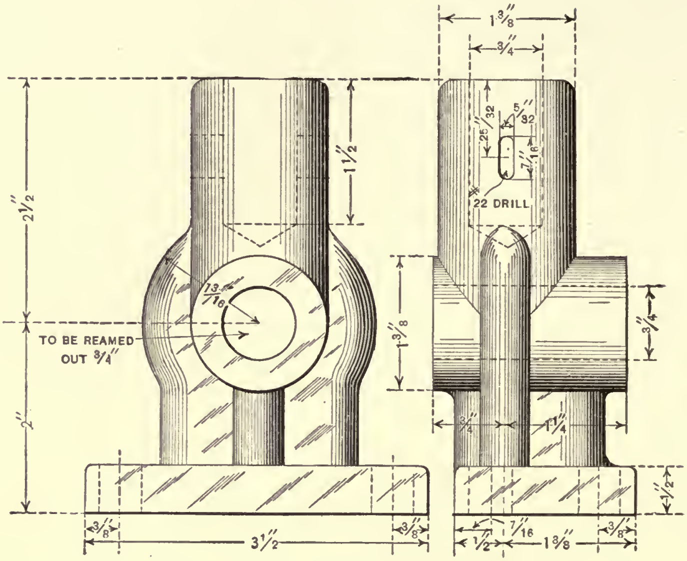
Another plan is to fasten these parts securely to the pattern and then remove them from one of the finished castings by filing or machining.

The dimensions given in Fig. 143 are finished sizes. When building up the pattern allowance should be made for finish on the bottom and top and for facing off both ends of the bearing, together with the necessary shrinkage of the casting.

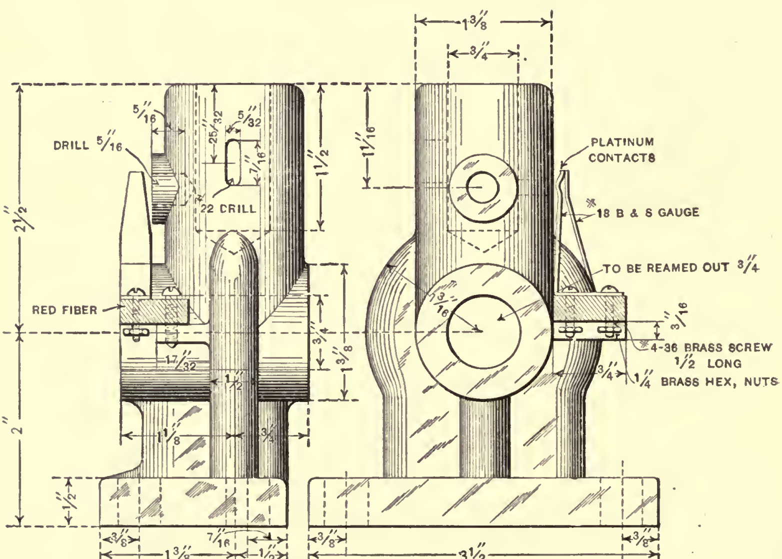
As the size for the finished hole for the shaft is to be $\frac{3}{4}$ inch, the pattern can be made to core out this hole to $\frac{5}{8}$ inch if desired. This will save considerable work in drilling out and boring the casting.

The mode of procedure in boring, facing and finishing these castings will be somewhat different from that of the horizontal bearings described in Chapter XI. because of their difference of arrangement and shape.

In the former case the casting was chucked by the hub of the bearing, and the hole for the shaft finished and reamed. This hole was then placed on the pin of the angle plate, and the boss drilled and reamed for the side rods, after which the casting was swung around on the pin and the bottom of the bearing faced off.



CAST IRON
MAKE ONE



CAST IRON
MAKE ONE

FIG. 143.—BEARINGS FOR UPRIGHT ENGINE.

In the case of the upright bearing, the side-rod boss and the base of the casting being diametrically opposite each other, there will not be sufficient space between the back of the angle plate and the pin to allow the casting to be thus placed. The first operation will be to catch the side-rod boss in the jaws of the chuck and face off the bottom of the casting.

See that the boss runs true in the chuck. In this operation the important thing to be observed is to have both castings faced off equally, so that the distance from the hub of the bearing, or the center of the hole to the bottom of the casting, will be the same in both cases. For the next operation remove the chuck from the lathe head and place the face plate in position. Put the finished surface of the bottom of the bearing against the face plate, first inserting a thickness of newspaper between (see page 137). Hold the casting in position temporarily by bringing up the back center of the lathe against the side-rod boss. The casting can now be bolted lightly to the face plate and the lathe revolved a few times by hand to see that the boss runs true. If not true a light tap with a small hammer will shift the position of the casting on the face plate, and a few trials will bring it to the proper position.

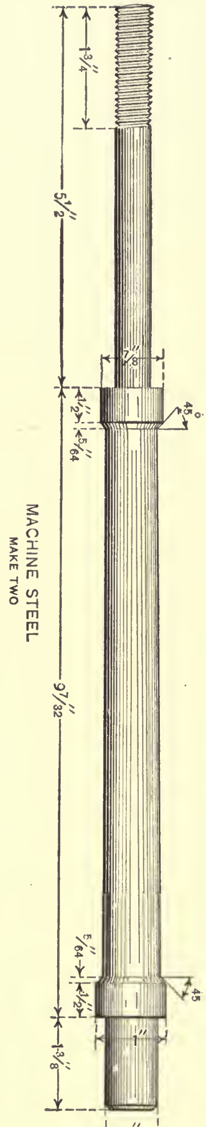


FIG. 144.—SIDE RODS FOR UPRIGHT ENGINE.

The bolts should then be tightened up to clamp the casting firmly to the face plate, while the hole for the side rods is drilled, bored and reamed and the end of the boss faced off.

After finishing the holes for the side rods the angle plate is attached to the face plate of the lathe and the bearing set upright on the shelf of the angle plate and clamped there. The angle plate is now to be adjusted to the proper height to bring the casting in position to bore and ream the hole for the shaft. One end of the bearing can be faced off at this time, and the opposite end is afterward faced by placing the bearing on a $\frac{3}{4}$-inch mandrel between the lathe centers. After the angle plate is set for one casting, it must not be loosened from the face plate until the second bearing has been finished, else the height of the hole for the shaft will not be exactly the same distance from the bottom of the bearing, and in consequence the holes will not "line up" properly. The only adjustment necessary for the second casting is to move it forward or back on the shelf of the angle plate until the hub of the bearing runs true when the lathe is revolved. In both cases the hub of the bearing must be parallel with the bed of the lathe.

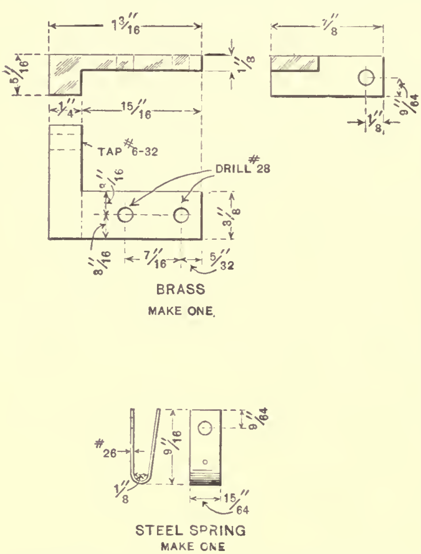


FIG. 145.—BRACKET AND SPRING FOR GOVERNOR.

We have not deemed it necessary to illustrate these operations, as they are almost identical with those of the horizontal type of bearing which is fully illustrated and described in Chapter XI., the only difference being in the manner of holding the castings, and this, we are sure, will be readily understood by the reader.

The contacts, as will be noted on referring to Fig. 143, must have a different bend at the bottom from those described on page 231. This is so clearly shown that farther description is unnecessary.

In the horizontal engine the side rods are turned from ¾-inch machinery steel and are of equal diameter at each end. In the vertical style the rods are turned from 1-inch machinery steel and the diameter is smaller at the top.

After the ends have been turned down to their proper sizes, the central portion is tapered as shown in Fig. 144. If the work is done in a screw-cutting lathe the tail stock of the lathe is set over far enough to give the proper taper. If done on a lathe with a plain slide rest, the latter must be given the proper angle with the bed of the lathe to give the required result.

The cylinder supports described in Chapter XI. will not be needed in this style of engine.

In order to adapt the same design of governor described in Chapter XIX. it will be necessary to add some attachment which will cause the governor roller to drop into the depression filed in the valve rod, corresponding to its drop by gravity in the horizontal type.

This is accomplished by the bracket and spring shown in Fig. 145. This bracket fits on the valve-rod bearing.

The screws which fasten the bearing to the cylinder collar also pass through the two holes in the thin portion of the bracket. The projection of the bracket is thus held just below the lower end of the governor lever, and the flat bent steel spring between them gives the proper tension to the governor mechanism.

The spring is held in place by the No. 6-32 screw tapped into the bracket at the place indicated in the cut. The tension of the spring can be varied by a slight opening or closing of the bend.

CHAPTER XXVI.

ANNOTATED BIBLIOGRAPHY OF THE PRINCIPAL GAS ENGINE BOOKS PUBLISHED IN THE ENGLISH LANGUAGE.

Allen, James T.

Digest of U. S. Automobile Patents from 1789 to July 1, 1899. 472 pl. 713 pp. Washington. 1900.

Classifies horseless vehicles according to their motive power being either springs, steam, gas, air or electricity. Also sections on gearing, traction engines, etc. Contains about 200 drawings, descriptions and claims of patents on gas-propelled carriages.

Beaumont, W. Worby.

Motor Vehicles and Motors; Their Design, Construction and Working by Steam, Oil and Electricity. 457 illus. 636 pp. Westminster and Philadelphia. 1900.

An exhaustive treatise on automobiles and motor cycles of the principal American and foreign builders. Its thirty-nine chapters are replete with details and descriptions.

Bramwell, Charles C.

The Construction of a Gasoline Motor Vehicle. 86 illus. 149 pp. New York. 1901.

The first part of this work describes the principles of operation of gasoline engines, methods of mixing the fuel and air, modes of ignition, relative efficiency of transmission devices, etc. The remainder of the book gives a description in detail of a gasoline engine and vehicle for it.

Clerk, Dugald.

THE GAS AND OIL ENGINE. 6th ed. 228 illus. 568 pp. London. 1896.

A historical sketch is followed by the classification and thermodynamics of the gas engine. Various types of engine are illustrated and explained. Oils and oil engines are separately treated. The book closes with chapters on gases and their analysis. A list of British gas and oil engine patents is appended.

Colliery Engineer Co. (The)

AN ELEMENTARY TREATISE ON THE GAS ENGINE. 341 illus. 712 pp. 5 vols. Scranton, Pa. 1899.

This valuable and practical work is prepared for the students of the International Correspondence Schools. Its scope may be seen from the following table of contents:

Vol. 1. Arithmetic, mensuration, algebra, trigonometry, logarithms, elementary mechanics.

Vol. 2. Pneumatics, gas, petroleum, heat; gas, gasoline, and oil engines.

Vol. 3. Geometrical and mechanical drawing. 43 pp.

Vol. 4. Gas engineers' tables, and formulæ. 33 pp.

Vol. 5. Answers to questions. 197 pp.

Diesel, Rudolph.

THEORY AND CONSTRUCTION OF A RATIONAL HEAT MOTOR. Translated from the German by Bryan Donkin. 85 pp. 3 pl. London and New York. 1894.

Contains the full, mathematical theory of Diesel's motor.

Diesel, Rudolph.

DIESEL'S RATIONAL HEAT MOTOR. A Lecture. Pamphlet. 36 pp. 3 pl. New York. 1897.

A description of the engine and tests made on it.

Donkin, Bryan, Jr.

A Text-book on Gas, Oil, and Air Engines; or Internal Combustion Motors Without Boiler. 136 illus. 419 pp. London. 1894.

Part 1. Gas Engines; contains a general description of their action and mechanism, and a classification of the different types. The history of the gas engine occupies four chapters. These are followed by descriptions of the various makes of English, French and German engines. This part closes with chapters on gas producers and on the theory, etc., of the engines.

Part 2. Petroleum Engines; contains an account of the discovery, utilization and properties of oil. Next is the history and working methods of oil engines, followed by descriptions of the different types.

Part 3. Air Engines; contains their theory in brief and descriptions of various makes.

Elliott, A. G. [Editor.]

Gas and Petroleum Engines. Translated from the French of Henri de Graffigny. 52 illus. 140 pp. London and New York. 1898.

After chapters on the history and the principles of operation of gas engines, various foreign makes of gas, gasoline, and kerosene engines are described and illustrated.

Fuel gas generators are treated of and the operation of engines by them.

The final chapter is on the care and maintenance of gas and oil engines.

Goldingham, A. H.

The Design and Construction of Oil Engines. 78 illus. 196 pp. New York and London. 1900.

A work on kerosene engines proper. Has chapters on designing and testing; on water tanks, mufflers, etc. Treats on the direct connection of engines to pumps, etc. Gives instructions for engine running and repairs. The book closes with a description of various oil engines.

Goodeve, T. M.

ON GAS ENGINES. 25 illus. 59 pp. London. 1889.

A clearly written little book, descriptive of the principles and operation of the Otto engine and comparing its efficiency with the Lenoir engine.

Grover, Frederick.

A PRACTICAL TREATISE ON MODERN GAS AND OIL ENGINES. 123 illus. 256 pp. London and Manchester. 1897.

A short historical introduction is followed by a chapter on the arrangement of the engine room. Next are chapters on four and two cycle engines of English, French and German builders and on self-starters. These are followed by the practical testing of engines and computation of their power and efficiency. The design of engines, producer gas and products of combustion complete the first part of the book.

The second part consists of four chapters on kerosene and gasoline engines and on testing them.

Hiscox, Gardner D.

GAS, GASOLINE AND OIL VAPOR ENGINES. Fourth edition. 270 illus. 361 pp. New York. 1901. Published by Norman W. Henley & Co., 132 Nassau Street, New York. Price $2.50.

After an introductory and historical chapter, the theory of the engine is clearly explained with the use of only the most elementary mathematics. Then the utilization of the heat of the fuel, the various losses and the efficiency are treated of. A chapter is on their economy when used to operate electric lighting plants. This is followed by one on the values of various gas and oil fuels. The next chapters treat of cylinder capacity, mufflers, governors, igniters, and lubricators.

After chapters on engine management, measurement of power, efficiency and testing, is one of 157 pages illustrating and explaining all of the prominent American types of engines and showing some of their applications.

The work ends with a chronological index of the gas engine patents in the U. S. Patent Office, and a directory of manufacturers of engines.

Hiscox, Gardner D.

Horseless Vehicles, Automobiles and Motor Cycles Operated by Steam, Hydro-Carbon, Electric and Pneumatic Motors. 316 illus. 459 pp. New York. 1900. Published by Norman W. Henley & Co., 132 Nassau Street, New York. Price $3.00.

In addition to a large amount of interesting matter, it contains chapters on horseless vehicles with explosive motors, electric ignition devices, atomizing carbureters, operating devices and speed gears, motive power and running gears, automobile bicycles and tricycles, gasoline motor carriages, etc. Contains also reference lists of automobile patents and manufacturers.

Humphrey, Herbert A.

Power-Gas and Large Gas Engines for Central Stations. 11 pl. 60 illus. 206 pp. Westminster. 1901.

A reprint of the Proceedings of a Meeting of the Institution of Mechanical Engineers.

This is a technical work on engines of 200 H. P. and upward.

Knight, John Henry.

Notes on Motor Carriages, with Hints for Purchasers and Users. 15 illus. 84 pp. London. 1896.

Explains the principles of gas engines and has a chapter on petroleum carriages.

Lee, William H.

American Automobile Annual. 103 illus. 275 pp. Chicago. 1900.

A descriptive pocket-book of the prominent types of horseless vehicles.

Lieckfeld, George.

A Practical Handbook on the Care and Management of Gas Engines. Translated by G. Richmond. 103 pp. Several illustrations. New York and London. 1896.

Treats of choosing and installing an engine; of testing the power of an engine. Then the attendance requisite to an engine is mentioned, how to stop and start, and the proper cleaning. A very useful chapter is on troubles and their remedies. The next one is on precautions necessary in engine running.

The final chapter is on gasoline and oil engines.

Lockert, Louis.

PETROLEUM MOTOR-CARS. 92 illus. 218 pp. New York. 1898.

Describes not only kerosene and gasoline motors, but also steam engines using oil fuels. Both foreign and American machines are shown. The two final chapters are on acetylene and its use in motors.

Longanecker, E. W.

THE PRACTICAL GAS ENGINEER. 2 illus. 119 pp.

A guide to the selection, setting up and operation of gas and gasoline engines. Treats in a comprehensive manner of engine troubles and their remedies.

Macgregor, William.

GAS ENGINES. 75 illus. 231 pp. London. 1885.

In the first part the various engines are taken in their historical sequence and described.

The rest of the book is occupied with the theory and data of gas engines.

The illustrations are on six folded plates in the rear of the volume.

Norris, William.

A PRACTICAL TREATISE ON THE "OTTO" CYCLE GAS ENGINE. 207 illus. 260 pp. London, 1896.

After describing the Otto engine as made by various English firms, there follow seventeen chapters, each one devoted to the calculation and design of a different part of the engine.

The final chapters are on fuel gas, engine testing, and private electric lighting plants.

Parsell, Henry V. A., and Weed, Arthur J.

GAS ENGINE CONSTRUCTION. 146 illus. 300 pp. New York. 1902. Second edition. Revised and Enlarged. Published by Norman W. Henley & Co., 132 Nassau Street, New York. Price $2.50.

A practical handbook for the amateur mechanic and experimenter. Full of original detail drawings and half-tones showing the mode of pattern making and of finishing and assembling the castings. With chapters on elementary gas engine theory and design.

Very suitable for a technical school manual in shop work.

Perry, Prof. John.

THE STEAM ENGINE AND GAS AND OIL ENGINES. London. 1899.

A book for students in the experimental and theoretical investigation of the action of these engines.

Roberts, E. W.

THE GAS-ENGINE HANDBOOK. 40 illus. 241 pp. Cincinnati, O. 1900.

An epitome of gas engine practice, Treats of the selection, operation and care of engines. Describes various details. Gives directions for designing and testing. Contains also several practical and useful tables. An appendix deals with two-cycle engines for boats and automobiles.

An excellent book for the designer and user.

Roberts, E. W.

HOW TO BUILD A THREE HORSE POWER LAUNCH ENGINE. 14 pl. 66 quarto pp. Cincinnati, O. 1901.

A work for those desiring to build a four-cycle launch engine of 3½ horse power, suitable for a boat 20 to 25 feet in length. Gives detail drawings and directions.

Roberts, E. W.

ON MARINE AND MOTOR LAUNCHES. 20 illus. 107 pp. New York. 1901.

Gives a description of the principles of operation of marine gasoline engines, and how to handle them. Contains chapters on the properties of gasoline and on choosing an engine.

Robinson, William.

GAS AND PETROLEUM ENGINES: A PRACTICAL TREATISE ON THE INTERNAL COMBUSTION ENGINE. 210 illus. 596 pp. London. 1890.

About one-third of the book is occupied with detailed descriptions of various engines, arranged both historically and by classes. A chapter is devoted to various modes of ignition.

Directions are given for the use of the indicator and dynamometer in power measurements. The thermodynamics of the gas engine are led up to in an elementary way, and give the theories and calculations of the compression and combustion of the charge. The various fuel-gas producers are also described.

Stoddard, E. J.

GAS ENGINE DESIGN. 14 illus. 31 pp. Detroit. 1900.

A concise treatise on the leading formulæ relating to the gas engine indicator diagram, and to the subjects of vibration, speed, valves, springs, proportions of mixture, sizes of parts, etc.

Wallis-Tayler, A. J.

MOTOR CARS OR POWER-CARRIAGES FOR COMMON ROADS. 76 illus. 200 pp. London. 1897.

Has a very good chapter on oil engines applied to vehicles, and shows various details of different makes.

Warwick, B. P.

THE GAS ENGINE. HOW TO MAKE AND USE IT. Lynn, Mass. 1897.

An elementary work describing various makes of engines and

giving briefly the construction of a two-cycle engine. Has directions for making a carbureter and an electric igniter.

Westinghouse Machine Co.

A New Industrial Situation. 12 illus. 24 pp. Pittsburg. 1900.

Treats of the economical distribution of power by means of gas conveyed in pipes from large gas-generating stations, and shows its utilization by Westinghouse gas engines in various installations.

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