

must get over the fear of somebody stealing his secrets or improving on his methods. Little can be accomplished otherwise. Education should primarily consist in an effort to produce an attitude of mind rather than to instill definite knowledge. It should aim to cultivate the inventive faculty, which is most needed to-day. But inventive chemists seldom have either time or inclination for developing the commercial aspects of a discovery. It is for the manufacturer and his staff to put the discovery to practical and profitable application.

RECOIL.—I.

By Brigadier-General J. P. FARLEY, U.S.A.

THIS subject is one which has engaged the careful attention of ordnance people for some time past.

The simple relation $MV = mv$, expressed in terms of weights or masses, with velocities corresponding to a direct force and reaction, is no longer employed to determine free recoil of a piece of ordnance.

If the energy of recoil is sought for, at that instant when projectile and gun part company, and no consideration is given to the action and reaction of the powder gas after the projectile has passed from the bore, then and then only may the velocity of gun recoil be ascertained by the equating of motions, that of the mass moving forward and of that moving backward.

In this case, the muzzle velocity of the projectile must be determined instrumentally and the mean weight or mass of the powder, which is progressively being consumed from powder seat to muzzle, must be ascertained.

For this reason at the present day we are provided

the bore serving as a fulcrum, may best be appreciated by the accompanying plate, and is revealed through the medium of the photograph, but cannot be seen with the naked eye. The hemisphere of gas behind the projectile of a seacoast gun is here seen to follow up, and adds about 20 feet velocity or one per cent increase to the muzzle velocity of projectile.

The rationale of lesser recoil where smokeless powders are used, as compared with that due to the use of black powder for the same muzzle velocity and energy of projectile under the two conditions, is thought to be fully explained by the foregoing observations, and is now usually taken at about 1 to 1.18 in favor of the smokeless powder—a matter of some significance for all-day hunting or shooting. Tests where the firer is blindfolded, and is in ignorance of the powder being used, prevented discrimination in favor of one powder over the other.

The ratio of recoil energy as measured by the dynamometer is as 1 to 1.13 instead of as above 1 to 1.18—a difference accounted for by the extra weight of attached spindle, which increases the recoiling mass by about 60 per cent, reduces the velocity of recoil proportionately and the energy of recoil in the relation of the square of the velocity.

This now brings us to a consideration of certain views quite generally entertained and expressed by the smokeless powder manufacturers. Many of them claimed (in words we will thus formulate) that they possessed a powder which would give a low pressure long sustained, against a more sudden and less sustained pressure of the black powders in ordinary use, and therefore, that the time in which the shoulder of the firer must absorb a given energy of recoil would

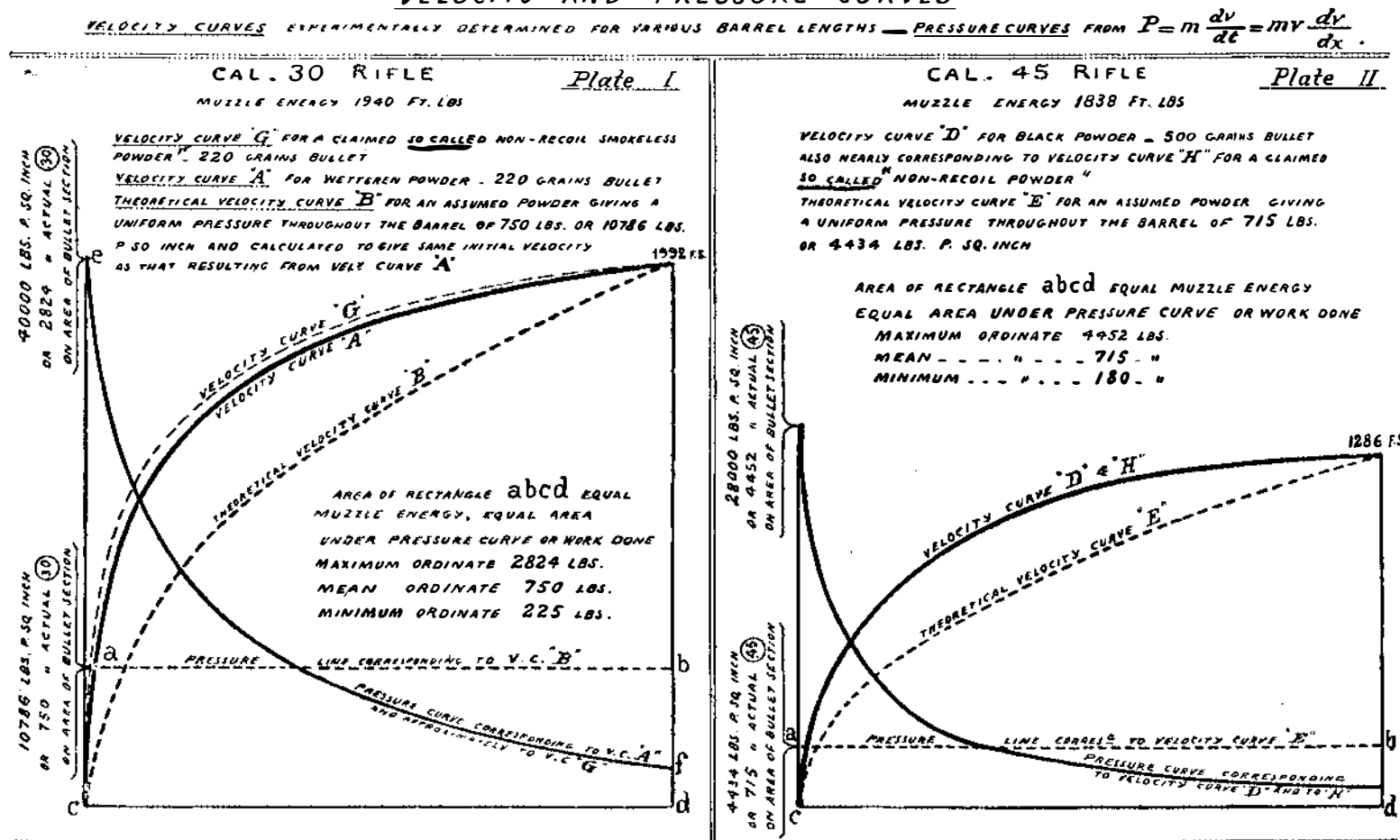
11. Both are parabolic curves, as they should be under the hypothesis of a uniformly acting force, or uniform pressure on the projectile in the bore. A comparison of A and G, D and H shows that in practice we are far from realizing this character of acceleration of the projectile in the bore, and therefore all claims for non-recoil powders are disproved, as they should be under the laws of physics.

But assuming that a powder has been found which will give a mean pressure in the bore, capable of imparting a required muzzle velocity, of service standard, to the projectile, the time of motion for a mean velocity of projectile through the bore being but 0.0017 of a second in the 0.45 caliber carbine under normal conditions, this element of time would increase by not more than 0.0003 of a second for the theoretically perfect powder. What can be said of the action of the gun in this fractional reduction of so small an element?

Can the senses appreciate it? And will the gun really get back against the shoulder any more fully in this restricted increment of time than it would where the time were not increased by say twenty per cent? What really does take place in this matter of recoil under normal conditions?

It has been found by exact experiment, which the writer himself has conducted, that the arm here discussed, the 0.45 caliber service rifle, moves to the rear about one-quarter of an inch before the ball leaves the muzzle, and that after that instant, under the hypothesis of equal muzzle projectile velocities for the perfect and the imperfect powders (as they relate to recoil) the velocity of recoil of the gun will be the same in either case. Will the butt set up

VELOCITY AND PRESSURE CURVES



with a formula accurately expressed, which will give for any special powder and gun the maximum velocity of free gun recoil.

This formula is thus expressed:

$$W_1 V_1 = wv + Ap. \quad (1)$$

W_1 = weight of gun in pounds.

V_1 = velocity of gun recoil, to be determined.

w = weight of projectile, in pounds.

v = velocity of projectile, measured at the muzzle.

p = weight of powder charge, in pounds.

A = a coefficient experimentally determined for each weight of gun and character of powder.

In order that the application of the formula may be the better understood, a special case is taken, that of the 0.45 caliber service carbine, and smokeless and black powder charges were so prepared in point of weight as to impart to a 500-grain rifle bullet 1,279 feet second. This arm was suspended in a manner to permit of absolutely free motion.

Sixty-eight grains of black powder, twenty-nine grains of smokeless powder were the charges requisite to give the muzzle projectile velocity specified.

The coefficients A for each powder were determined, and found to be for the smokeless powder 3,236, and for the black powder 2,258.

Substituting the above values in equation (1) the velocity of recoil V_1 became known, and from this, E_1 , the energy of recoil, $\frac{1}{2} M V_1^2$ was derived. The lesser energy, 17.06 foot pounds, for the smokeless as compared with that for the black powder, 19.84 foot pounds, is then to be attributed entirely to the less weight of powder charge moving forward in a semi-burned condition, and to the lesser gas action on the projectile after it has left the bore of the gun. This after action of gas on the projectile, with its corresponding reactionary effect on the gun, the bottom of

be greater, the effect would be less like that of a blow, and the shock correspondingly ameliorated.

This reasoning is entirely correct, but it is a question rather more of degree than of kind when we put it into practice.

Most certainly, if we have an abnormally long barrel and an extremely slow-burning charge, and yet one which will develop in the projectile a muzzle velocity the same as that of an instantaneously acting powder like that of a high explosive or detonating charge, it would seem reasonable to think that that powder by which the highest acceleration of velocity is produced in the projectile in its passage through the bore should give the greatest sensation of shock, since correspondingly sudden changes would be produced in the velocity of recoil of the rifle resting in contact with the shoulder of the firer.

The action of such a powder would be characterized by a relatively high pressure suddenly developed, and then falling off rapidly toward the muzzle. On the other hand, the least possible sensation of shock should be produced by a powder giving pressures so regulated as to cause the projectile velocity to be uniformly accelerated from seat to muzzle.

This is of course aside from the question of maximum recoil energy as usually computed, or the total work of recoil as measured by the dynamometer, in which the factor of time does not enter.

Let us now take an extreme case, and assume that the powder manufacturer has arrived at what may be called a theoretically perfect powder, one whose maximum and mean pressure in the bore is the same. What should be the acceleration of the projectile from seat to muzzle under this uniform force?

The query is best answered by an examination of velocity curve B, Plate I, and velocity curve E, Plate

hard against the shoulder for this one-quarter inch motion? We think not; and so the theory of shock effect being less in smokeless powders than in black powders, and operating to disturb the aim of the firer, must for the practical conditions of service rifle be given over, as disproved; and the time element, as we have considered it in the matter of gain of time, to reduce shock, is too small to be reckoned with even if it were found; but not being found, and only theoretically considered, it is out of the question altogether. It is not to be understood, however, that if an abnormally long barrel were employed, and a theoretically perfect powder used, so as to flatten out the parabolic velocity curve to which reference has before been made, some amelioration of shock would not follow. Our purpose here is to get at practical conditions, and to explode exaggerated claims based upon theoretically correct premises—a process the more dangerous because alluring. This returns the question to its original status, and enables us to state that for sound theoretical reasons, confirmed by practical tests, the best that can be hoped for smokeless powders in the way of recoil is a saving of some sixteen per cent as compared with that of black powder; and so let us hear nothing more of non-recoil powders.

(To be continued.)

The rubber industry of Guatemala should be of far greater importance than is at present the case. There are in the republic large tracts of land suitable for the growing of rubber; but, owing to the impossibility of sufficiently policing the country, the rubber is frequently stolen from the trees, and the unfortunate proprietors actually have to buy back what really belongs to them from the thieves or their intermediaries. The

exports do not vary much; they amounted last year to 4,423 quintals, about the average for the last five years.

THE DIESEL ENGINE.

By A. W. OPPENHEIMER.

In 1893 Mr. Rudolf Diesel began experimenting with a view to finding a more efficient prime mover than existing oil, gas, or steam engines.

Mr. Diesel succeeded in doing this after four years of hard work, by building an internal combustion engine on the following novel principles:

1. Attaining the temperature necessary for the combustion of the fuel by mechanical compression of air, previous to, and quite independent of, the introduction of the fuel into the cylinder.

2. Substituting a single adiabatic compression for the combination of isothermal and adiabatic compressions in the Carnot cycle, for the following reason:

By a single adiabatic compression, the required temperature is reached at a pressure of 30 to 40 atmospheres. On the other hand, with a four to one isothermal, followed by an adiabatic compression, the same temperature is reached at a pressure of 200 atmospheres, which pressure would give rise to practical difficulties.

3. Gradually introducing the fuel in a finely-divided state and thoroughly mixed with air, into the highly heated air, at such a rate that the temperature during combustion remains as nearly constant as possible.

4. Using a large and definite excess of air to insure the perfect combustion of the fuel.

Contrary to expectations, the first engine built on these principles showed that a water jacket was necessary. Although jacketing lowers the efficiency, it thickens up the diagram considerably; all sharp corners on the diagram are rounded off, so that in the whole cycle

for expansion. The connecting rod turns the solid crank-shaft, to which a flywheel, made in halves, is attached by means of two wrought-iron rings. The inner edge of the flywheel rim is provided with teeth, so that the engine can be brought into the starting position by a barring gear.

pump, which forces oil to the fuel valve, in quantities controlled by the governor, according to the load on the engine.

Mounted at the back of the cylinder is a water-jacketed air-pump, driven off the small end of the connecting rod by links, a rocking lever, and connecting rod.

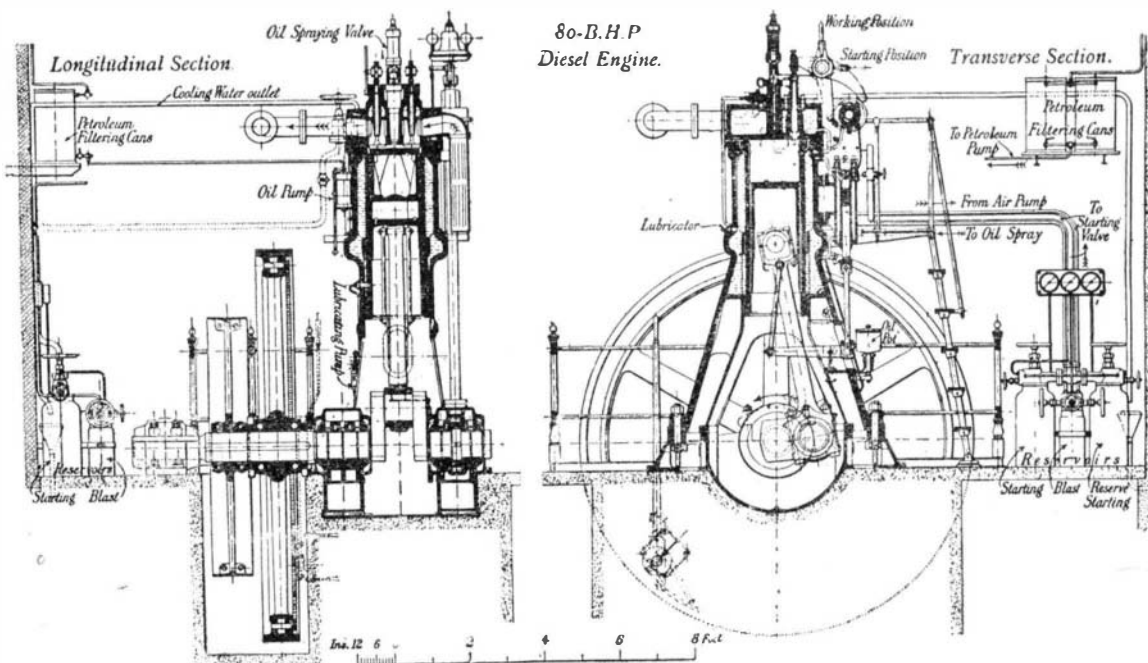


FIG. 2.—SECTIONS OF 80-BRAKE-HORSE-POWER DIESEL ENGINE.

The cylinder cover, which is well water-jacketed, is securely bolted to the frame, the joint being made with an asbestos ring. The cover carries the four main valves: the air-inlet valve, the fuel valve, the exhaust valve, and the starting valve. The three former are opened every two revolutions by means of rocking levers, actuated by cams keyed to a half-speed shaft.

This air-pump is of ample dimensions, and can be throttled so as to fill the cast steel reservoirs with air at any required pressure. The smaller reservoir is used for injecting the petroleum into the cylinder; one of the larger ones is used for starting the engine, the other being kept in reserve.

The governor is mounted on the vertical intermediate shaft, and is of the ordinary loaded type.

The crankshaft bearings are bushed with white met-

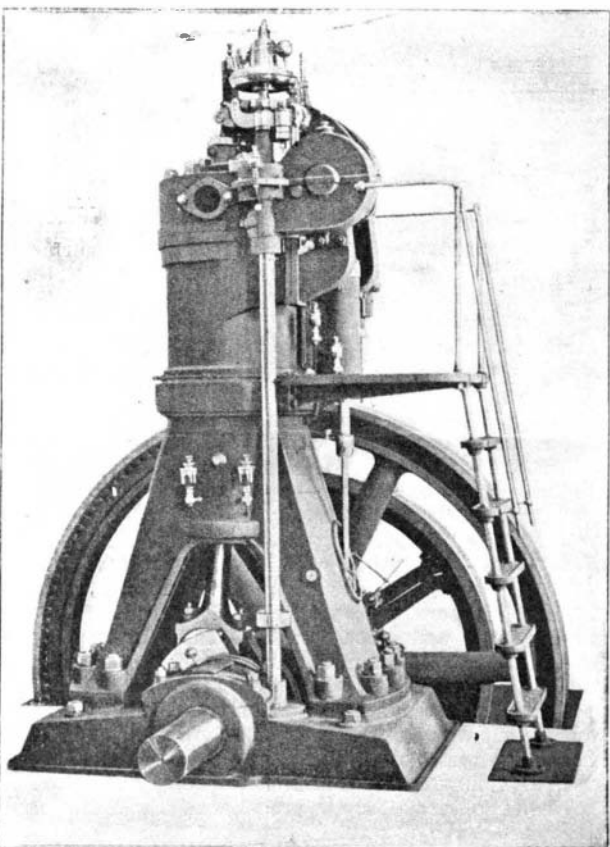


FIG. 1.—80-HORSE-POWER DIESEL ENGINE.

there is no sudden change in pressure, thus insuring steady running.

The greatest difficulty encountered in the first attempts was to design a suitable fuel-valve. At that time engineers thought that the only method of thoroughly pulverizing the fuel was to force it through successive layers of fine wire gauze, which were liable to clog. Later on, it was found that a number of fairly large but carefully arranged holes gave equally good results without clogging.

Even in the early engines, the combustion was found to be so perfect that crude and unrefined oils were consumed with ease.

Diesel engines have been running successfully on the Continent for the last six years, and so far back as 1899, Prof. Unwin, F.R.S., after careful examination, pronounced the engine to be entirely out of its experimental stage.

So much has been written about Mr. Diesel's experimental engines, that to refer to them here would be merely repetition; the author, therefore, proposes to describe the engine in its present stage, in which crude petroleum is used as fuel.

The task of developing the engine was undertaken abroad, chiefly by the Maschinenfabrik, Augsburg; Carls Frères, Ghent; and Sulzer Bros., Winterthur, who have succeeded in constructing a most efficient, trustworthy, and steady-running prime mover.

DESCRIPTION OF ENGINE.

The main details of a modern Diesel engine (Fig. 2) are:

A vertical cylinder liner, made of very hard, close-grained cast iron, fitted into a substantial frame, the space between the two serving as a water-jacket. The vertical frame is bolted to a stiff bed-plate in the ordinary way. The long open trunk piston carries six lap-jointed rings, and has only enough clearance to allow

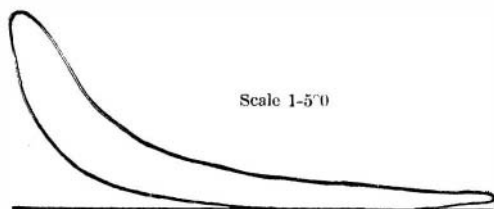


FIG. 3.—FULL LOAD DIAGRAM.

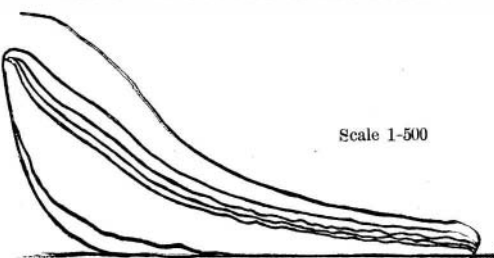


FIG. 4.—STARTING DIAGRAM.

The air-inlet, exhaust, and starting valves are of the ordinary mushroom type, and open downward. The fuel valve will be described later. The rocking levers for the fuel and starting valves can be turned on an eccentric axis. In one position of this, the starting lever is on its cam; while in the other position, the fuel lever is on its cam, and the starting lever out of action. Thus, according to the position of the eccentric,

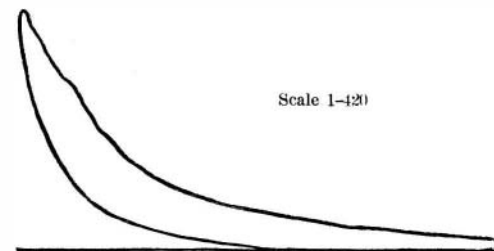


FIG. 5.—SMALL LOAD DIAGRAM SHOWING ISOTHERMAL COMBUSTION.



FIG. 8.—FLAME PLATE.

al, and are provided with ring lubricators. White metal is used to line all the bearings, except the cross-head bearing, which is made of phosphor-bronze to stand the heat.

The lubrication of the piston and small-end presents no difficulties. At the end of the down stroke, a force pump delivers gas-engine oil to the piston at six equi-

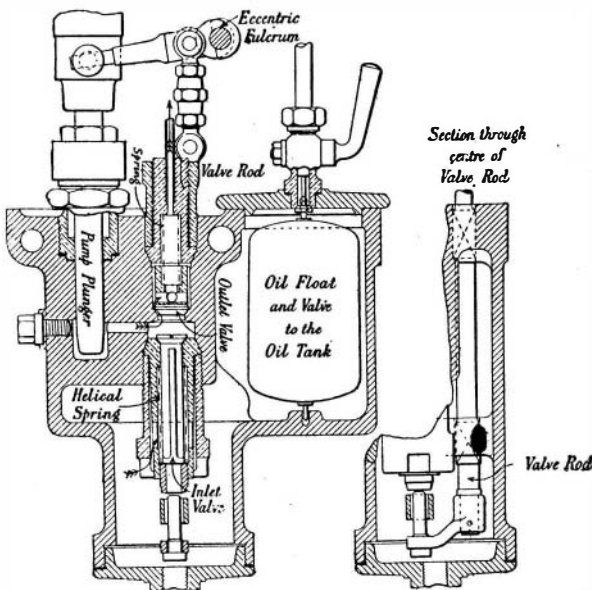


FIG. 6.—FUEL PUMP, SHOWING METHOD OF GOVERNING.

either the starting or the fuel valve opens, but it is impossible for the two to open together. I shall refer to this arrangement later, when describing the starting of the engine.

Driven off the end of the camshaft is the petroleum

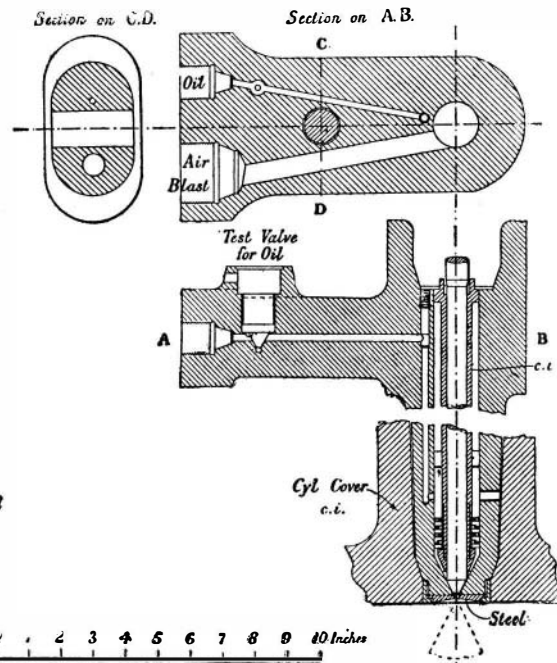


FIG. 7.—FUEL VALVE.

distant points in a horizontal plane, and on the up stroke this oil is distributed over the liner. This injection takes place between the first and second rings, so that no lubricating oil comes into direct contact with the flame. At the same time, the force pump delivers