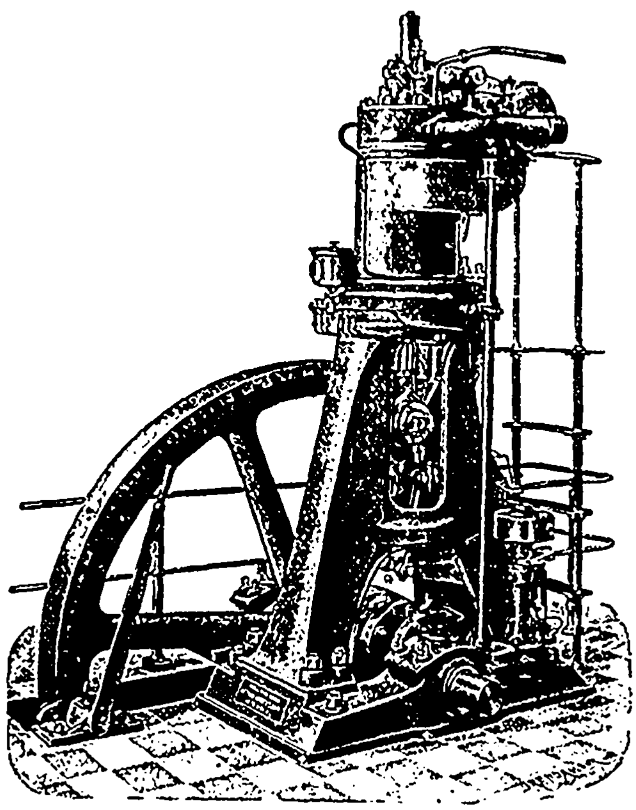
ditions, are far above their points of condensation. Ammonia vapors, especially, seem to have the properties best suited to the theoretical process. But great difficulties in handling them were encountered in practice. In the endeavor to replace them he was naturally lead to experiment with air. Up to this time he had necessarily applied his heat from without, and was subjected to the losses and limitations due to the metal walls



20 H. P. DIESEL MOTOR—GERMAN TYPE.

through w'ich it had to pass. He was then subject to the same losses which had defeated Ericsson, and was compelled to make the step which made his motor an internal combustion engine. Starting out, then, with the intention of improving the caloric process of the steam engine, he reached, in a round-about way, means similar to those employed in gas and oil engines. But this similarity is strictly limited to the fact of internal combustion, the method of combustion being radically different. Further, finding that to begin his compression isothermally led him into pressure which must, in our present practice, be considered excessive, he abandoned that part of the Carnot cycle, and made his compression adiabatic throughout, thus reducing the necessary pressures from over 100 atmospheres to between 30 and 40. When, as in the history of the steam engine, these higher pressures become practically feasible, a return to the original complete process may become advisable. Diesel's fundamental invention is then really a process of converting heat into work; this of course has been supplemented by other inventions naturally growing out of the persistent and logical development of a practical machine to operate on this process. It was Diesel's first intention to build a motor with three cylinders, embodying compound compression and compound expansion, and one of this type has been built at Augsburg, and is to be thoroughly tested on producer gas. But the development of the single cylinder type has been so satisfactory, and the demand for them has become so great, that at present the German shops are busy to their fullest extent, building their simpler form. As this form has reached an absolute efficiency of 30 per cent., and is in every way a simple and practical machine, there is at present no reason for developing the compound motor. The cut here given represents the first of these 20 h.p. motors, built by the Nuremberg Machine Works. This motor was exhibited at the Electrical Exposition in New York city, held in May, 1898. In appearance it resembles a vertical marine engine. A strong base plate supports the main journals of the crank shaft, outboard bearings being provided for the shaft extensions which carry the fly-wheel and pulley. Bolted to the base plate is a stout A. frame, containing the guides. In the rear leg of this frame a small air pump is supported. On the top of the frame is placed a cylinder open at the bottom. Its top is closed by a head cast in one piece, in which are contained one suction valve for air, one discharge valve for spent gases, and a needle valve for the fuel. The admission to the casing of this fuel valve is controlled by a stop valve, which can be instantly closed to shut off the supply of fuel. Besides this, there is a starting valve used only in starting the engine. Cylinder and air pumps are water jacketed. This water jacket was not used in the earlier experimental engines, but is found advantageous in keeping the temperature of the working parts uniform. As the temperature of combustion is so much lower than that of the explosion type of engines, a much smaller amount of water suffices for this. In the earlier German engines the main shaft and crank are bored for water cooling. This, however, grew out of the practice of Krupp's Steel Works of boring all small shafts produced. The practice has been discarded in England and in America as unnecessary. The air pump is driven by a set of levers attached to the main cross-head. Conveniently placed to one side is an air vessel known as the starting tank, connected by copper pipe to the air pump, and to the fuel valve casing.

The operation is as follows: On one down stroke the main cylinder is completely filled with pure air; the next up stroke compresses this to about 35 atmospheres, creating a temperature more than sufficient to ignite the fuel. At the beginning of the next down stroke the fuel valve opens, and the petroleum atomized by passing through a spool of fine netting (wire), is injected during a predetermined part of the stroke into this red-hot air, resulting in combustion controlled as to pressure and temperature. This injection is made possible by the air in the starting tank, which is kept by the small air pump at a pressure some 5 to 10 atmospheres greater than that in the main cylinder. A small quantity of the air enters with the fuel charge, which it atomizes as described. When the motor is running at full load a very small quantity of injected air suffices, and the pressure in the air tank steadily rises. At half-load, with less fuel injected, more air passes in. For this reason, the starting tank is made large enough to equalize these differences, and a small safety valve is provided on the air pump. The petroleum is pumped into the fuel valve casing by a small oil pump, bolted to the base plate. This pump is arranged to pump a fixed maximum quantity of petroleum. A by-pass is provided so that this whole quantity, or any portion of it, can be returned to the supply tank. The governor controls the action of this by-pass valve, closing it just long enough to compel the exact quantity of the fuel required to pass into the fuel valve casing. As this requires only the movement of a small light wedge, the regulation is accomplished with great exactness. In this regulation resides a great advantage for the Diesel motor. The full charge of air being always supplied for complete combustion, it matters not whether the governor permits one or fifty drops of petroleum to enter the working cylinder at each motor stroke; the combustion is always complete. Thus variations in excess of air over that theoretically necessary, from 26 to 116 per cent., have been measured, and the analysis of the spent gases shows no trace of unburnt carbon or hydrogen. It is hard to conceive a more perfect combustion than that which takes place when fuel is sprayed, finely powdered or atomized into red-hot air, just beginning to expand. To stop the motor it is only necessary to close the valve which admits the petroleum into the fuel valve casing. The valve gear consists of a series of cams placed on a shaft and journaled on brackets cast on the cylinder.

In starting the motor a hand lever is pulled to one side, throwing all these cams, except the exhaust valve cam, out of gear, and throwing a special cam into gear with the starting valve. A few strokes of the petroleum pump by a hand lever inject a small quantity of petroleum into the fuel valve casing. The fly-wheel is thrown over by a lever a trifle beyond the upper dead point. The fuel throttle valve is opened, and by a turn of the hand wheel communication is established between the air tank and the starting valve. A single charge of highly compressed cold air enters the cylinder, sufficient to give two revolutions of the fly-wheel at moderate speed. At the close of the first revolution the starting valve cam is automatically thrown out of, and the other cams into, gear, and thus on the second revolution a full charge of air is drawn in and compressed, and in less than thirty seconds the motor is running at full speed.

Mr. Diesel makes a sharp distinction between the tempera-