82s. per ton the economy in power production is most marked.

The use of suction-gas engines, however, is limited by other reasons than the question of economy; some of these are—the difficulties of direct driving, and the unsatisfactory nature of belt driving; the tarnishing of electrical instruments and other brass work from the gas fumes; the difficulty of disposal of scrubber water, and the appreciable time required in blowing up the gas before starting. In addition, it is difficult to run on a light load for any considerable period, owing to the cooling of the fuel in the producer; also, should a heavy load be applied suddenly, the speed of the engine tends to drop, as the fuel cannot be made incandescent quickly enough to supply the necessary gas.

As regards steam, its great advantage is its reliability, but unless large units are being installed, so that superheated steam and turbines can be used, the fuel costs are high in comparison with the Diesel.

For a medium-sized engine, say, up to about 150-b.h.p., the consumption of good steam coal per p.h.p.-hour under actual working conditions of electricity supply would not be less than 2½ lb. Such coal now costs here 26s. 6d. per ton at railway, which gives a cost of .35d. per p.h.p.-hour, or an equivalent of .47d. per kilowatt-hour.

Beyond the question of fuel costs, the capital expenditure must be considered. With a Diesel engine a considerable saving is made in the cost of buildings by the fact that no boiler-house, chimney shaft or economizer is required. In addition, a large quantity of water is not required for feed and condensing purposes, though a certain amount is required for jacket circulation.

Cost of Machinery.—As regards the capital cost of the machinery, it can generally be taken that the Diesel engine will cost as much as the steam engine and the necessary boiler.

The cost of two 150-b.h.p. Diesel engines, and all requisite accessories, erected in 1914, was £2,762; the water cooler for dealing with 36 gallons per minute was £195, and the softener, of 200 gallons per hour-size, was £63.

The cost of these engines was very low, and the cost of an exactly similar engine which was added in April, 1915, was £1,739.

After carefully weighing up all the various points, the writer decided to recommend the adoption of Diesel engines, and two sets of 150-b.h.p. each, coupled to direct-current dynamos of 100 kilowatts, were installed.

The following fuel guarantees were given with the tender, and have been easily fulfilled on the test and in actual working:—

Full load	.44 lb. per b.h.p.-hour	.68 lb. per kw.-hour.
¾ "	.47 " "	.70 " "
½ "	.54 " "	.83 " "
¼ "	.70 " "	1.18 " "

The engine was also guaranteed to run satisfactorily on an overload of 10 per cent. for two hours.

Before describing the practical points in connection with Diesel engines, the general theoretical principles involved may be considered.

Theoretical Principles.—The economical working of the Diesel engine is due to the fact that the heat value of the fuel is utilized to a greater extent than in any other prime mover.

Thus the Diesel engines consume per b.h.p.-hour about 7,500 B.t.u.

Gas engines consume per b.h.p.-hour about 9,000 to 12,000 B.t.u.

Steam engines consume per b.h.p.-hour about 16,000 to 28,000 B.t.u.

This high efficiency is due in the first place theoretically to the fact that the range between the high temperature of the ignited fuel and the low temperature of the exhaust is very great.

The efficiency formula for the Carnot perfect engine cycle is—

$$\frac{\text{work done}}{\text{heat expanded}} = \frac{T_1 - T_2}{T_1}$$

T_1 being the initial absolute temperature of the gas, and T_2 being the final absolute temperature of the gas.

Practically, also, the Diesel works with such high compression that the clearance space is very small, so that there is very little surface for cooling the gases when they are at their highest temperature—*i.e.*, on ignition of the fuel.

There are no losses from boiler or producer plant, and less loss in cooling or condensing water; also fuel is only being consumed during actual running, there being no stand-by losses as in steam or producer gas. In addition, any class of liquid fuel can be used, from petroleum to tar oils; that generally in use is the thick, heavy residual oil which is left after the lighter oils—petrol and petroleum—have been distilled off from the original crude oil. This fuel oil has a specific gravity of about .92-.95, and a heat value of about 18,000 B.t.u per lb. It has a high-flash point of about 200 deg. Fahr., so that there is little risk of fire in storage or use.

Owing to the present high price of fuel oil, the use of tar oils is likely to come prominently forward in the near future. These tar oils are the heavy oils (creosote and anthracene) which are obtained in the fractionation of coal tar after the lighter oils (benzol, phenol, etc.) have been distilled off. They are also a by-product from coke ovens, which it is becoming increasingly remunerative to recover. The specific gravity is from 1.0 to 1.10, and the heat value is about 15,800 B.t.u. per lb. They cannot, however, except at high loads, be used without an auxiliary, which takes the form of a pump which delivers a very small quantity of easily burning oil, such as paraffin, into the cylinder to start the ignition of the tar oil. More frequent attention to the valves is also required, as they are more liable to clog and stick up than if a cleaner fuel oil were used.

The outstanding and distinguishing feature of the Diesel engine is that ignition is not obtained by any external agency, such as sparking plugs, lamps, etc., but by high compression generating sufficient heat to ignite the fuel mixture. The majority of Diesel engines in England, and especially the smaller sizes, are single acting and of the four-cycle type.

On the first and outgoing stroke of the piston air is drawn into the cylinder through the air valve. On the second and return stroke all valves are closed and the air within the cylinder is highly compressed, usually to about 450 to 500 lb. per square inch, with an accompanying increase of temperature to about 1,000 deg. Fahr. On the third stroke the fuel valve opens, and the fuel which has been accumulated in the passages of the fuel valve is blown through a pulverizer into the cylinder by compressed air, stored at a pressure greater than that in the cylinder. This process mixes the injection air and the oil intimately, so that when it reaches the cylinder it is in the form of a spray. Directly this spray enters into the highly compressed and heated air it automatically