a pin or catching of a valve has thus produced serious damage and made necessary, expensive repairs. Thus, briefly, we see that the fly-wheel engines are expensive in first cost, foundations, and repairs, and liable to serious accidents, but the most economical in running.

The more modern direct acting pumps present a marked contrast to the fly-wheel engines. They are horizontal in action, and the steam and water pistons are situated at the opposite ends of one and the same horizontal piston rod, the essential feature of this class. They thus present a much simpler and more compact form than the fly-wheel engines. The foundations required are much lighter and less expensive, and indeed the pumping engine and plant frequently cost only about one fifth of that of a rotative engine of the same capacity. The economy of running is, however, much less than that of the fly-wheel engine. The simple type of direct pumping engine is rather uneconomical, and various additions and improvements have been made to increase its effectiveness, but none have reached within much more than half of that of the fly-wheel engines.

A brief consideration of the more important improvements may well be given a place. One of the most important modifications consists in what is known as the "duplex" form. This is essentially two pumps placed side by side which work alternately, and by such alternation produce a much steadier and more continuous discharge. All horizontal pumps are of necessity double acting, and the alternation of the pumps is so arranged as to move the necessary mechanism for admission of the steam to each side of the steam piston, so that one pump works the other.

Another very important improvement is the compounding of the steam cylinders. Two cylinders are thus provided at the steam end of the piston rod, one worked by direct pressure and the other by the expansion of the steam exhausted from the first cylinder. About twenty-five per cent has been estimated to be gained in power by such compounding.

A third modification consists in the addition of a condenser, which by condensation of the steam produces a vacuum in the rear of the piston at the same time the steam is pressing on its front. This adds from twenty to fifty per cent of power. We thus have in the compound condensing duplex pumping engine the most modern type of this class of machinery.

The advantages and disadvantages of the direct acting may be, therefore, stated as follows: They are vastly cheaper in first cost, foundations, and repairs, than the fly-wheel engines. They give, however, only about half the efficiency for fuel used, as given by the rotative. They are, however, able to work at any length of stroke, and thus suffer but slightly from any stoppage of parts. They do not require extensive repairs. The difference between the rotative and direct acting engines consists in any given case, therefore, in the first cost, cost of foundations and repairs, liability of damage, and economy of operating.

The method of ascertaining the cost of operating consists in finding the "duty," so called, of the engine, or the work done per one hundred pounds of fuel in foot pounds. The duties thus assigned in tests are, however, never realized in ordinary use. By far the greater portion of pumping engines are necessarily built for a much larger capacity than they will be subjected to when in ordinary use. Such pumps must run to their full capacity to work economically, and when tested for duty, they are so run, but when in actual daily use their duties fall much below the recorded tests. This is true of all pumping engines, but especially of fly-wheel engines. A duty test thus does not generally show the ordinary efficiency, but the maximum possible efficiency at the full capacity of the pumping engine.

The question which class of engine is the best must necessarily depend on the character and constancy of the work to be done. The question which must be answered in every case is, which class will give a minimum cost of operating and interest on the investment combined. Cost of operating must include repairs as well as mere running expenses. The rotative engine gives a high duty, and consequently a low cost of