the case, misfires and prematures are liable to occur occasionally, and the designer must minimize their possibilities for evil. These considerations, as well as the capacity for caring for heavily swinging railway loads, have caused our adoption of tandem double acting cylinders for railway work.

It is sometimes argued that cylinders so arranged are inaccessible. If, as is the practice of the Westinghouse Company, ample space is arranged between the cylinders, and if the inlet and exhaust valves are not located in the heads, but in the cylinder body entirely above the floor level, such a gas engine is as accessible as a tandem compound Corliss engine or as a Corliss engine driving an air compressor.

The speed of a gas engine must be adapted to the kind of generator to which it is to be directly connected. In a general way, its speed will usually somewhat exceed that of a Corliss engine of the same cylinder dimensions. In my experience, the speed of large steam engines is limited by **the inertia and consequent wear and tear of the valve gear rather than by the inertia of the reciprocating parts themselves,** which is absorbed by the compression. Inasmuch as in a four cycle gas engine the valve gear only moves at half the speed of the engine, somewhat higher speeds are permissible than would be the case with a steam engine having the same dimensions of cylinders.

The speed regulation adopted for large Westinghouse gas engines is specially suitable for generator driving in that no conditions of changeable load or variable friction of valve gear affect the regulator. Our gas engine regulator governs the speed by means of a relay cylinder, and, therefore, produces results similar in type to those obtained with the relay governor used by The Westinghouse Machine Company on steam turbines. The advantage of such a relay governor with the gas engine is that the varying friction of valves with different qualities of gas does not affect the sensitiveness of the governor. Without a relay cylinder the only way in which this result can be accomplished on large gas engines is by some form of a drop cut-off controlling the gas. This is objectionable on a gas engine, as any slight change in the speed of the dash pot very seriously affects the mixture of gas and air, with corresponding bad effect upon the regulation. Such small changes in speed of dash pots are frequent in a Corliss engine, where they cause no bad results. The Westinghouse arrangement employs no releasing gear of any kind, but secures all the advantages of regulation without its use.

The question is frequently asked as to whether large gas engines will drive A. C. generators successfully in electrical synchronism or "parallel." This has been done for several years past in Germany with entire success, and it has also been done in a number of instances very successfully by our company. We have at the present time orders for several such plants on our books, one of which is to drive an electric railway from Warren, Pa., to Jamestown, N. Y., which we expect will be in operation some time during the autumn.

It is sufficient for our purpose to observe here that the cyclic variation, i e., the degree of departure from absolutely uniform rotation, is sufficiently small to conform with the design of generators now built for steam driving.

The European designer of gas engines has allowed himself an amount of complication in valve gear which would not be permissible under American operating conditions. The successful American machine must be as nearly "Fool Proof" as is the large Corliss engine. If it is not, it will fail to be a success from the purchaser's point of view—no matter what thermal efficiency may be claimed by the builders—as a consequence of such complication as the European engineers have been prone to adopt. In the designing of valve gear for large gas engines, wide range of quality of gases must be considered. In this respect the design of the gas engine is very different from that of a steam engine, inasmuch as the steam used has practically constant characteristics, differing only in such minor points as pressure and superheat. With the different kinds of gas to be met with, however, the proportions of air and gas, and sometimes of compression, are radically different, and no gear can hope to be a universal success which does not provide for meeting the widely varying conditions to be encountered in the market.

We are frequently asked, "What is the overload capacity of your gas engine?" A clear understanding on the part of the purchaser of the limitations in this direction is very desirable, from the point of view both of the buyer and the seller. A gas engine and producer is thermally very much more efficient than a steam engine and boiler. It is, perhaps, not amiss to say that, with a well designed producer and gas engine plant, a horse-power can be delivered with one-half the cost of fuel that is possible with a well designed steam engine plant. The power of the gas engine, however, is limited by **the total volume of explosive mixture which can be drawn into the cylinders** during the suction stroke, compressed and finally ignited. This condition sets a limit which does not allow of a large temporary increase of the power, such as obtained with the Westinghouse steam turbine by the automatic operation of the secondary admission valve. Such overload capacity is, of course, convenient for the purchaser, but it is unobtainable on a gas engine, unless the engine is largely under-rated, and the purchaser should consider that this is one of the prices that he pays for the enormously increased output obtained with the gas engine per pound of coal. **The overload capacity is, therefore, simply the amount which the builder rates his machine below its ultimate capacity.** It has been our practice to rate our gas engines in such a way that they would have a safe overload capacity of ten per cent. Our machines are ordinarily good for somewhat more than this, but conservative engineering requires that there be a margin of power in order that overloads may not materially reduce the speed. The above remarks on overload furnish a general guide which may be of service in selecting suitable generator capacity for a gas engine. For ordinary cases the overload capacity of the generator and that of the gas engine should be about equal, although the gas engine will indefinitely carry its overload while the generator will not, in all cases, unless it is bought with that understanding.

The mechanical efficiency of a large gas engine is very much greater with a four cycle than with a two stroke cycle, this being one of the arguments against the two cycle engine. It is no uncommon thing to see two cycle engines which do not realize as brake horse power more than sixty per cent. of the work actually done by the combustion in the cylinders. The efficiency of a four cycle engine varies considerably, but it may be said in a general way that a well designed engine will deliver about eighty-five per cent. of the gas indicated horse-power in the form of brake horse-power. This fifteen per cent. of power lost is not exclusively composed of frictional resistance of journals, cross-head slides, etc., as is the case in a steam engine. The four cycle engine has, of course, to draw in its own mixture of air and gas and compress the same, and its functions, therefore, combine those of a pump, a compressor and a motor. It is the pumping and compressing work which causes the mechanical efficiency of the gas engine to be somewhat lower than that of a steam engine. The actual friction of the working parts need be no greater than with a well constructed Corliss engine, viz., 90-95 per cent. In order to keep down the friction and increase the reliability of the machines, it is the practice of the Westinghouse Company to design large gas engines with provisions for attaching a continuous return oiling system. The large amount of oil put through the journals increases the safety, requires less attendance and keying up, and washes out dust if the engine is required to operate in an atmosphere which is not clean.

The thermodynamic efficiency of the gas engine varies so much with different kinds of gas that it is hard to say just what the average value would be. It is probably not far from the truth, however, that its thermal efficiency is about twenty-five per cent., though in favorable cases gas engines have obtained efficiencies well over thirty per cent.*

$$\text{* (Efficiency} = \frac{\text{Heat equivalent of work done.}}{\text{Heat input}}$$