other compressor types, is always a small matter in this machine.

The Angle-Compound compressor may be connected by any usual method to the motor unit which may be located at either end of the compressor. It may be direct connected, by mounting a motor or water wheel on its crank shaft. A wide range in the size of the band wheel is permissible, to accommodate various sizes and speeds of motor pulleys. A change of form, type or size of driving means may be made more easily and cheaply than with any other design.

Refinement in every detail, making for increased efficiency and durability, has been achieved for this design, as shown in the detailed description in the following pages.

The intercooler used is of extra size, effective in action, durable and convenient to repair. The use of the outside walls of the cylinder water jackets for cooling the air is a valuable addition of water cooled area that would otherwise be wasted.

The lubrication system is superior to the usual forms. A self-contained gravity system for working parts, a force feed system for cylinders and valves and compression grease cups on the valve motion, make a combination that insures perfect lubrication at all speed, eliminates oil drip or splash on outside parts and requires no drip pans.

With increased speed, the question of adequate and reliable lubrication becomes of greatest importance. The well-known splash system for supplying oil to the working parts, while simple and reliable, is not suited to fast-running engines and compressors. The oil used in this system is contained in the main frame, from which the most conscientious manufacturer is unable to remove every vestige of moulding or core sand and the gritty scale on the surface of the castings which is eventually dissolved by the oil. Even if all grit were removed in the manufacture of the machine, the erecting man or operator cannot be relied upon to thoroughly clean out all cinders and grit accumulated in transit or during erection. The constant and violent agitation of the oil by the moving parts keeps grit or foreign substance in the oil in suspension and delivers it repeatedly through the bearings, where, even if the grit is not harsh enough to cause heating, it produces unnecessary wear.

The oil reservoir in the Angle-Compound compressor is in the bottom of the horizontal frame, but the oil level is maintained at such a height that the moving parts do not touch it. Any gritty matter, therefore, remains undisturbed at the bottom. On the outside of the frame is attached a small plunger pump, operated from the valve gear, with all of its working parts submerged in the oil. This pump forces the oil into an elevated reservoir, whence it is distributed through piping to the bearings. Adjustable sight feed connections are provided, through which the oil flows in generous streams. The pump has a capacity largely in excess of requirements so that positive lubrication is assured. The excess oil is returned to the bottom of the horizontal frame through an overflow.

A separate system of lubrication is provided for the air cylinders in the form of a positive multiple feed oil pump actuated by connections to the air valve gear. This pump has sight feeds, so that the flow of oil is at all times under the observation of the operator.

The outboard bearing supporting the end of the crank shaft is independently lubricated by a supply of oil contained in a well underneath the bearing, to which it is delivered by ring oilers.

That compactness and accessibility can be brought together in the same unit has been demonstrated in this machine. Notwithstanding its enclosed and neat appearance, all working parts are easy to inspect, adjust or remove.

A single crank pin takes the place of the usual two eccentrics used for driving the valve motion in duplex machines. No supporting brackets or intermediate rocker arms are required.

A balanced disc on the end of the crank shaft carries a crank pin, on which the connecting rods for the valve motion of both cylinders are hung. It is unnecessary to point out the obvious simplicity and the many advantages of this arrangement as compared with the usual two eccentrics and eccentric straps with their high rubbing speeds and inconvenience of adjustment.

Balancing of Reciprocating Forces.—The reciprocating parts of a high-speed steam engine or compressor offer problems in balancing extremely difficult of satisfactory solution. Opposing balancing weights attached to the crank produce uniform opposing centrifugal forces radially around the shaft, while the inertia forces set up by the motion of the reciprocating parts change constantly in intensity throughout a revolution in line with their motion. They are started from a point of rest at one end of the stroke accelerated to maximum speed about mid-stroke, retarded from this point and brought to rest at the end of the stroke. In accelerating the reciprocating parts force has to be applied to them from the crank, tending to oppose its rotation, and they become charged, so to speak, with potential energy due to their velocity. After their maximum velocity has been reached at mid-stroke, and retardation begins to take place, the energy absorbed during the first half of the stroke is given up during the latter half, producing a force tending to assist the crank in its rotation.

In compressors of slow or moderate rotative speed, say 150 r.p.m., the disturbing effects of these inertia forces are so small that they are readily absorbed by the mass of the entire machine, but as the inertia varies as the square of the speed, it will be seen that if it is attempted to run such a compressor at a speed of 225 r.p.m. the disturbing effects have been increased in the ratio of $\left(\frac{225}{150}\right)^2 = 2.25$

In other words, with a speed increase of 50 per cent., the disturbing forces produced by the reciprocating parts have increased 225 per cent.

The inertia of the reciprocating parts reaches a maximum at the ends of the stroke and is equal in value to the centrifugal force of a mass having the same weight as the combined weight of the piston rod, crosshead and connecting rod. As stated above, the effect at the ends of the stroke is equivalent to the centrifugal force of a revolving mass of the same weight as the reciprocating parts, and the horizontal vibrations may be entirely neutralized by attaching such an equivalent weight to the crank opposite the crank pin. If this be done, however, the opposing centrifugal force of the revolving weight will practically neutralize the inertia forces, but introduce a new set of vertical unbalanced forces, of equal intensity, tending to shake the shaft and engine up and down.

In horizontal single or duplex compressors it will be seen that good balancing is an impossibility, and the best that can be accomplished is a compromise, effected by attaching a centrifugal counter weight of less weight than that of the reciprocating parts, which will partially absorb their horizontal disturbing effects without