Primary Causes of Loss or Lowness of Useful Effect.

1. Generation of heat during compression, which passes away by radiation, &c., without producing any useful effect; this loss of heat represents exactly the same loss in work.

2. During compression, the temperature of the air being increased, its bulk is increased. During compression from atmospheric pressure to 45 lb. above, its bulk is increased so much by the increase in temperature that what should be 2 cubic feet becomes 3 cubic feet in the air-cylinder; but on leaving it, with reduction again of the temperature, the bulk is again reduced to 2 cubic feet, so that the work of compression is performed on a larger bulk of air than work is obtained from.

3. Inability to get much expansion out of the compressed air at the motor. The compressed air on arriving at the motor, at the point it is to be utilised, is at or near the temperature of the atmosphere, and always holds some moisture in suspension. On expanding in the cylinder of the motor its temperature will fall to such an extent that the moisture will freeze, and ice is formed in the exhaust-passage of the engine.

Secondary Causes of Loss.

(1.) Resistance to air in passing through suction-valves. (2.) Resistance to air in passing through delivery-valves. (3.) Clearance-losses in cylinder. (4.) Leakage past the piston. (5.) Losses from friction of mechanism. (6.) Losses in air-mains from leakages. (7.) Losses from friction in air-mains of insufficient diameter.

Means of diminishing the Loss of Power.

There have been several methods adopted for diminishing the loss of power in compressing air, and the writer will first try to describe, or consider, those adopted for diminishing primary losses, the more important ones. These losses have been to some extent obviated by surrounding the air-compressors—the cylinders—with cold water, so that the surface of the cylinder shall not be heated during compression. This reduces the pressure of the air, and consequently less work has to be done upon it in order to compress it, and hence also less heat is generated in the act of compression. By this means the temperature is not raised so high, and thus less heat—*i.e.*, less work—is lost by radiation during the whole operation. It is necessary to cool the cylinders for other reasons, such as the lubrication of the cylinder and the packing of the piston-rod and valves. Also, when the cylinder is very hot, the air which enters from the atmosphere is at once heated and expanded before the inlet-valve has closed, and thus the air compressed by each stroke will fill a smaller volume when it has cooled in the receiver and pipes. This smaller volume at equal temperature and pressure represents a proportionately smaller quantity of work.

Again, we may adopt stage compression with intermediate cooling, such as the West two-stage compressor. In this the air may be compressed to 35 lb. in the low-pressure cylinder, then passed through the intermediate cooler to the high-pressure cylinder for further compression. For pressures of four atmospheres and upwards, the extra first cost, &c., of a stage compressor will pay for itself in a short time, because the loss which arises from heating of the air increases rapidly as the pressure increases.

We cannot afford to use the air without expansion, hence some means must be adopted to use the air expansively without being encumbered with the freezing difficulty. Several methods have been devised of heating the air before it reaches the motor, so as to obtain the necessary expansion and avoid the freezing. When the compressed air comes to be used to drive an engine the air has already cooled down nearly to its former temperature. When it is expanded in the cylinder down to atmospheric pressure its temperature falls very low, and thus its pressure upon the piston falls much more rapidly than it would do if the temperature remained constant. When the air is exhausted its temperature is usually much below the freezing temperature of water, and therefore the moisture in the air is frozen upon the exhaust-valves, and causes much trouble by choking them with ice. The writer considers that the best means to adopt to diminish the loss from this cause would be to provide air-receivers of a large size, both near the air-compressor on the surface and near the engines underground where the air is used; these, together with the air-mains of ample dimensions, would give sufficient time to deposit any moisture held in suspension, and with large and straight exhaust-passages no trouble need be experienced from ice, because if there is no water, or moisture, it is not likely there will be ice.

Diminishing Secondary Losses.

These losses may occur by the suction-valves not being large enough, or the springs upon them being too strong. The negative suction-pressure sometimes amounts to 2 lb. or 3 lb. per square inch—a serious loss of power. Valves actuated mechanically are to be preferred, but these are more suitable for large-size compressors, and are often found to be too great a refinement for small ones. West and Jenkins have a good mechanically actuated valve, and Reidler's and Fowler's are also good valves.

Delivery-valves should be nicely adjusted, capacious and easy, and quick in action. They should open immediately the piston-pressure equals the receiver-pressure, and should close again immediately it becomes less. In badly constructed compressors the delivery-pressure in the cylinders is frequently several pounds below the receiver-pressure; extra work is then required to deliver the air against this resistance. If the delivery-valves do not close immediately the piston-pressure becomes less than the receiver-pressure, then the engine loses the work it has performed. To guard against this the air-compressing cylinder should be frequently indicated, to see that the valves are in good and proper working-order.

Clearance-losses are often very troublesome. The simplest method of reducing clearance-loss, so far as the writer knows, is by means of by-pass grooves in the end of the cylinder, which allow the high-pressure air to pass to the other side of the piston, where it will be a distinct gain. The