It is necessary to know: (a) The atmospheric pressure and temperature when the cards were taken; (b) the outlet temperature from high-pressure cylinder; (c) the accurate volume swept per stroke of the low-pressure piston; (d) receiver pressure. In addition to these details a card from the high-pressure air cylinder is required; and cards from the two steam cylinders.

Then the volumetric efficiency can be calculated by the ratio of the weight of air actually delivered by the compressor to the weight of the volume contained in the low-pressure cylinder at atmospheric pressure and temperature. And the mechanical efficiency would be calculated from the ratio between the theoretical work of isothermally compressing the weight of air delivered by the machine from atmospheric pressure to receiver pressure, and the actual work performed in the steam cylinders. Of course, any leakage during the period of high-pressure delivery would not be accounted for, but such a test should only be carried out when the delivery valves were known to be in perfect condition ,and under present conditions, no leakages at all are accounted for.

The use of compressed air is entirely distinct from its generation, and is, of course, attended with very serious losses of energy. The air available for use, after atmospheric temperature (assumed at 80 degrees Fahrenheit) had been reached, is shown in Fig. 6 by the area bounded by A.B.C.D. Of course, if the air were used at a point so near to the com-

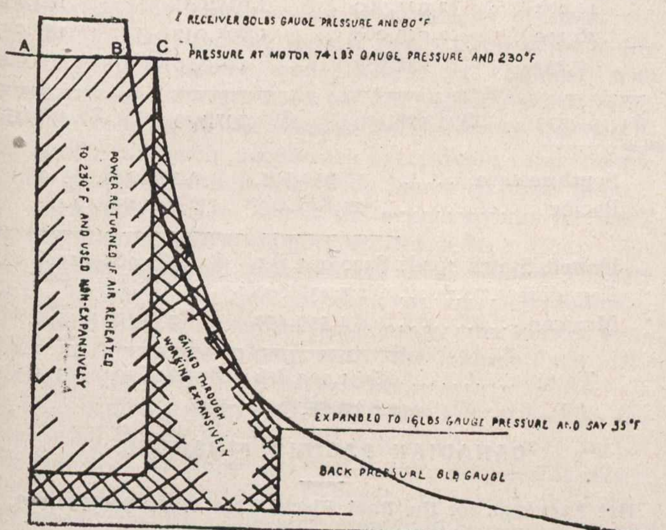

Fig. 7.

pressor that the temperature did not fall to atmospheric, then the amount of energy available would be increased in direct proportion to the higher absolute temperature, but as it is seldom that air can be used before it has fallen to atmospheric temperature, it is not of much practical advantage to consider any other condition. As air can only be slightly expanded if it is not raisel to a fairly high temperature, it is usually only employed practically at high pressure. Fig. 6 shows the proportion of the energy which is used if the air is employed non-expansively at the motor at 80 degrees Fahrenheit, at a pressure of 74 lbs. (allowing 6 lbs. drop for pipe friction) and a back pressure of 8 lbs. above atmosphere. The amount returned is "hatched in" with single lines. Even this comparatively small amount would be reduced by pipe leakages. If the air were expanded to a pressure at which a temperature of 35 degrees Fahrenheit might be reached (allowing for expansion on slightly other than adiabatic lines) it would have a terminal pressure of about 52 gauge. The amount of energy gained due to expansion is shown cross hatched; it will be noted that, as the air is expanded, a lower back pressure is possible. So that, unless the air is reheated, the maximum amount of energy which can be recovered is that shown by the two portions hatched in in Fig. 6. It must be remembered that the area A.B.C.D. represents the energy available for use, not the energy put into the air in the compressor cylinder; Figs. 3 and 6 must be combined in order to compare the energy recoverel wth that expended.

If reheating is adopted Fig. 7 shows what would be the return were the pressure at motor still 74 lbs. gauge and the temperature raised to 230 degrees Fahrenheit (the outlet temperature from compressor high-pressure cylinder). The increase in volume due to reheating is shown by the difference in the lengths of the lines A B and A C, being in direct proportion to the absolute temperatures. The same back pressure as before is assumed if the air is not used expansively, and under those conditions the area "hatched in" with single lines is the measure of the energy returned by the motor. As the temperature is high there should be no excuse for not using the air expansively, and, if it were expanded again until the temperature was in the neighborhood of 35 degrees Fahrenheit, a pressure of 16 lbs. above the atmosphere would be reached. The back pressure would be reduced owing to the lower terminal pressure, and that portion cross hatched in Fig. 7 would show the extra recovery due to using the air expansively when reheated to 230 degrees Fahrenheit. Again, Fig. 7 should be combined with Fig. 3, in order to compare the energy recovered with that put into the air in the compressor cylinder.

The lesson I have attempted to convey by Figs. 6 and 7 is a very bad one, being simply the value of reheating, and I think they show how imperative it is that air should, wherever possible, be reheated. Of course, there are difficulties in the way of reheating. The air must be reheated practically at the point where it is used, otherwise a great portion, if not the whole, of the gain from reheating would have disappeared when the air reached the point at which it was to be used. But, as difficulties only arise in order that engineers shall overcome them, surely there should be some attempt made to solve the difficulty of providing a reheater which can be installed at practically every working face, in such a manner as to avoid the CO_2 into the atmosphere. Air at 80 lbs. gauge needs, roughly, ⅛ of a B.T.U. to raise 1 cubic foot 1 degree Fahrenheit in temperature, so that if it were raised from 80 degrees Fahrenheit to 240 degrees Fahrenheit, 20 B.T.U. per lb. would have to be aded to each cubic foot. The addition of this heat would increase its bulk approximately 30 per cent., and if this heat were added with a thermal efficiency of 50 per cent. in the reheater, the increase would be gained at an outlay of not more than 10 per cent. of the heat originally required to produce the air. And the air could also be used expansively down to about 16 lbs. gauge pressure. A petroleum has a calorific value of about 20,000 B.T.U. per lb., and a gallon weighs about 8 lbs., one gallon would add (at 50 per cent. thermal efficiency) the necessary heat to about 4,000 cubic feet of air at 80 lbs. pressure and increase its bulk to about 5,200 cubic feet, an amount equal to nearly 40,000 cubic feet at atmospheric pressure, or sufficient to supply a 3¼ in. rock drill for about five hours' continuous running. But the combustion of one gallon of petroleum would turn about 30 lbs. of CO_2 free into the workings, unless it could be caught before passing to the atmosphere. Perhaps our chemical friends could tell us whether this could be managed. A solution of caustic potash will absorb CO_2, but I am unable to say whether it could be done in a manner which would prove commercially satisfactory. In any case, if a system could be designed by which the CO_2 could be cheaply absorbed, it would prove most profitable, as it would mean the installation of thousands of reheaters at working faces, with enormous increase in the efficiency of the compressed air system.

At the present time it would be almost indecent to leave the subject of compressed air without referring to the potential danger attendant on its use. Compressed air, when its compression is carefully attended to, is practically the safest known means of transmitting power, but under certain conditions it can, as we have recently seen in a most lamentable accident, become an actively dangerous medium. Repeated explosions have shown us that compressed air is not the innocuous mixture that it ought to be. Though we must all regret the fact ,it still remains that explosions in air compressors are becoming more prevalent. Briefly, the causes

(Contineud on Page 192.)