of the external air, the inner surface being exposed towards a highly heated enclosure will be less affected. It is to be observed that the temperature of the external surface of the regenerator cannot at any time be greater than that of the air escaping through the pipe *i*, and that the temperature of the internal surface can never be less than that of the air issuing from this surface, on its passage into the working cylinder, or rather, heating chamber.

The preparation necessary for starting the engine consists in "keeping up a slow fire in the furnaces, for about two hours, until the various parts contained within the brick work shall have become moderately heated, and then charging the receiver with air by means of a hand-pump," until the gauge shows a pressure of about 8 pounds above that of the external air. The upper valve, *g*, is then opened by a starting bar, and the compressed air flows into the working cylinder, and begins the work of raising the piston.

We are now prepared to enquire into the

THEORY OF THE MOTIVE POWER OF THE ENGINE.

I will first state a few principals which it is important should be kept in view.

1. The expansive force of the heated air under the working piston must be somewhat less than that of the compressed air in the receiver; otherwise the air in the receiver would have no tendency to flow from it into the heating chamber. The difference may not amount to more than a few ounces; it depends upon the obstructions to the free flow of the air and the relative size of the aperture of communication and heating chamber.

When the air is flowing from the supply cylinder into the receiver, its elastic force must exceed that of the air in the receiver; for the additional reason, beside that just stated, that the vales in the supply piston would close if no such difference of pressure existed.

In seeking to determine the power of the engine, I shall however disregard the inequality of pressure and suppose the expansive force of the air to be the same in the working and supply cylinders as in the receiver, so long as the communications between them are open.

3. Since the two connected pistons are of unequal size, and the elastic force of the air pressing upon them the same or nearly the same, the entire upward pressure exceeds the downward pressure, and the two pistons are urged up with a force equal to the difference of these pressures. This statement is here made with respect to the actual pressures subsisting when the communications are open. We shall see hereafter that it might also be made in regard to the mean effective pressures throughout the stroke.

4. In the engines of the Ericsson the cut off is introduced at the $\frac{5}{8}$ stroke, and therefore the space underneath the working piston into which the air is admitted from the receiver, before the cut off valve is closed, is equal in volume to the interior of the supply cylinder. It will soon be seen that this is in accordance with a general principle, the adoption of which is essential to the most efficient operation of the present form of engine.

5. When the engine has reached its permanent working state, the quantity of air admitted into the working cylinder, each upward stroke of the piston, cannot exceed the quantity forced into the receiver, from the supply cylinder, during the same interval. In fact it must be less, by reason of the waste from *leakage* and *clearance*.

Now it will be perceived that if this quantity of air, after being admitted into the working cylinder, as just supposed, retained the same temperature, its elastic force would be the same as that of the external air (15 lbs. say, per square inch) since the same quantity originally filled the supply cylinder, at this pressure. But if we suppose the temperature to be elevated 480°, or thereabouts, by the heat derived from the regenerator and the heating chamber, its elastic force would be doubled, or amount to 30 lbs., per square inch. To realize this supposition the compressed air in the receiver must therefore have an expansive force of over 30 lbs., or 15 lbs., above the atmospheric pressure. If the working temperature in the lower cylinder were 384° above the temperature of the external air instead of 480°, then the pressure in that cylinder, and of necessity therefore in the receiver, would be 12 lbs., above the atmospheric pressure, (i. e. $\frac{384}{480}$ths of 15 lbs.) It will be seen then that the working pressure in the receiver and the working temperature in the principal cylinder are necessarily connected together—that the one determines the other.

It is here supposed that there is no leakage or clearance, but the fact is otherwise; and therefore the quantity of air admitted into the working cylinder, each ascending stroke, is less than that which is expelled from the supply cylinder into the receiver. If we suppose the pressure in the receiver to be 8 lbs., above the atmospheric pressure, and that the leakage and clearance, at this pressure amounts to $\frac{1}{4}$, then $\frac{3}{4}$ of the air furnished by the supply cylinder will enter the working cylinder, and its elastic force, for the $\frac{5}{8}$ stroke would be reduced to $11\frac{1}{4}$lbs. ($\frac{3}{4}$ of 15 lbs.) by the expansion, if the temperature remained unchanged, but the 480° of additional heat will augment this to $22\frac{1}{2}$ lbs., or 15lbs., + $7\frac{1}{2}$ lbs. Now 8 lbs. above the atmospheric, is the actual working pressure of the engines, we may conclude therefore, that if the working temperature is 480° above the atmospheric temperature or a little less, the waste from leakage and clearance, during the double stroke, must amount to nearly $\frac{1}{4}$. The actual working temperature is undoubtedly less than this, but how much I have not been able to ascertain with certainty. The actual leakage is therefore less than $\frac{1}{4}$, but its exact amount cannot at present be determined. According to the newspaper accounts the working temperature, on the trial trip, was about 450°, or 418° above the temperature of the air (taken at 32°.) This would make the waste, from leakage and clearance, about $\frac{1}{5}$. It undoubtedly lies between $\frac{1}{4}$ and $\frac{1}{5}$.

Working at a given temperature, and with a given cut off, the leakage will determine the working pressure. To show this suppose the elevation of temperature to be 480°, and the leakage $\frac{1}{4}$ at a pressure of 8 lbs., shown by the receiver-guage; then at 12 lbs. pressure the leakage, if we disregard the clearance which is comparatively small, would be $\frac{3}{8}$ths, and the elastic force of the air in the working cylinder would be reduced from $7\frac{1}{2}$ lbs. to $3\frac{3}{4}$ lbs. If the communications remained the same, so great a difference of pressure between the receiver and the cylinder could not be realized; an additional quantity of air would flow out of the receiver, and this would go on for each successive stroke until the pressure in the receiver was reduced to 8 lbs. or thereabouts, when the pressure in the cylinder would be $7\frac{1}{2}$ lbs., and the engine would be nearly in its permanent working condition.

From this cause, (viz., the leakage,) mainly, as it would seem, the expected pressure of 12 lbs. has not been obtained in the working of the engines of the Ericsson. This is in fact the reason assigned by the builders of the engines, for the fact that no higher pressure than 8 lbs. has yet been realized.

There is another mode of presenting the theory of the motive power of the caloric engine. Suppose that the constant pressure in the receiver is 15 lbs. + 15 lbs. On this supposition air will begin to pass from the supply cylinder into the receiver, at the end of the $\frac{1}{2}$ stroke, or thereabouts, and will continue to flow to the end of the stroke, at a pressure a little above this. At the end of the $\frac{1}{2}$ stroke of the supply piston the body of air which