has suggested a very beautiful hypothesis, according to which the amount of graphite separated in any given instance is proportional to the time consumed by the pig iron in passing through a limited range of temperature, probably near the point of solidification. Adopting this hypothesis, may we not further imagine that the other ingredients, affecting the melting point of the compound, affect also the limits of this range of temperature; but that, these things being equal (as they almost are in the case before us), the conditions of casting and cooling may decide the quality of the product, by determining not merely, as Dr. Drown suggests, the amount, but also the form and distribution of the segregated graphite?

THE REFRIGERATION MACHINE AS A HEATER.

BY GEORGE RICHMOND.

Although the isentropic transfer of heat is usually impossible, yet we can approach as nearly to it as we desire, and the results based on the assumption of sources of heat of unlimited extent can be realized as nearly as practical construction can bring us to the limiting condition. Thus if we have an infinite supply of heat at T^0 we can transfer a finite quantity at T^1 very near to T^0 without sensible increase of entropy, and the practical limit of such a process is only reached when the value of the energy saved from dissipation is less than that required by the mechanism to effect the contact. On this understanding, the following discussion considers only the limiting case.

Suppose we have a quantity of heat Q_1 at temperature T_1 (absolute). By simple transfer (using the ordinary irreversible processes of conduction or radiation) to a lower temperature T_2 the quantity of heat remains unchanged, but the entropy is increased.

$$Q_1 \left(\frac{1}{T_2} - \frac{1}{T_1} \right) \quad (1)$$

and the available energy between T_1 and T_2 is entirely dissipated.

But if this heat Q_1 is passed through a heat engine in accordance with the second law of heat, we have an isentropic transfer of heat to T_2 , amounting to

Richmond:

$$Q_1 \frac{T_2}{T_1}$$

of work, of which the heat

$$\frac{Q_1}{T_1} (T_1 - T_2)$$

T_3 (lower than T_2) the temp
highest unlimited source of
 engine, and let the work (3)
 et a transfer of heat from T_3

Refrigeration Machine as a Heat Engine

available energy unchanged. We assume that this large amount of loss can be used in a heat engine to give a benefit. The engine works between T_1 and T_3 . In fact, it is a heat engine between T_2 and T_3 , and its efficiency is

$$\left(\frac{T_1 - T_3}{T_2 - T_3} \right) \frac{T_2 - T_3}{T_2} = \frac{Q_1}{T_1}$$

the same as that of working the

the object of the combination

and that of the low temperature engine

$$\frac{Q_1}{T_1} \frac{(T_1 - T_4)(T_2 - T_3)}{T_2 - T_4} = \frac{300 \times 40}{760 \times 100} Q_1 = \frac{3}{19} Q_1.$$

Here the work available for running the refrigerating machine is increased sixty per cent. If the steam engine had been able to utilize the heat down to t_3 , the work done would be

$$\frac{Q_1}{T_1} (T_1 - T_3) = \frac{6}{19} Q_1$$

the additional work due to the heat from the refrigerating machine giving an increase of fifty per cent. upon this. If this heat were really available, it might well be worth the expense of putting in a low temperature engine to utilize it. But this result could not be practically realized with advantage, for even if we admit that T_3 , the refrigerator of the low temperature engine being unlimited, would remain constant, yet the economical working of the refrigeration machine requires that the temperature of its condenser, T_2 , should be kept as low as possible; that is, as near to T_3 as practicable. Hence the factor $(T_2 - T_3)$ in (9) vanishes, and with it vanishes the possibility of employing the heat transferred by the refrigeration machine to assist it. We are confirmed in this conclusion if we observe the effect upon the efficiency of the refrigeration machine, which results from changing T_2 to T_3 . The

production is increased from $\frac{T_4}{T_2 - T_4} w$ to $\frac{T_4}{T_3 - T_4} w$, where w is the same amount of work employed in each case. In the example considered the production is increased in the ratio $\frac{T_2 - T_4}{T_3 - T_4} = \frac{100}{60} = 1.66$,

or sixty-six per cent. While, therefore, it is possible to utilize the heat transferred to the condenser of the refrigerating machine, if the temperature is sensibly raised, to restore the loss caused by such rise of temperature, it is better to provide ample surface and active circulation to effect the transfer at the lowest possible temperature.

Although it is thus evident that this complex cycle cannot be made use of to increase the efficiency either of the steam (or other heat) engine or its reverse, the refrigeration machine, there yet remain two cases in which the indications of practical utility are sufficient to merit consideration.

(1.) Where the object in view is to obtain low temperature heat from a high temperature source.

(2.) Where the object is to extend the cycle of operation beyond the temperatures readily controlled by the ordinary form of heat engine.

It is obvious that the impossibility of practically realizing completely either portion of this complex cycle will prevent our obtaining results equal to those indicated. But it may be noticed that in the present case the losses arising from defects are not the same as in the case where the object sought is the conversion of heat into work. Thus, for example, the loss arising from the incompleteness of the cycle by reason of which we fail to convert the available heat energy into work, is not a total loss to us, but remains as heat, and so much of such available heat as is converted into work will effect, under favorable conditions, the transfer to the condenser of the reverse engine of a much greater amount than the converted heat, even though the reverse cycle be itself imperfect. This is evident from the fact that the heat so transferred is the sum of the heat equivalent of the work (which is reconverted into heat) and whatever refrigerating effect may be produced.

Hence, a refrigerating machine may be employed as a heating machine, and the simplest explanation of this fact is that it utilizes the available energy of high temperature heat (which is dissipated in the usual mode of heating) to effect the transfer of another quantity of heat from surrounding objects.

The obstacles to an increased range of temperature in the heat engine, and consequent increased efficiency are due almost entirely to mechanical difficulties. It is conceivable that a means of practically effecting the transfer of heat considered from a temperature beyond the control of the present form of heat engine, to one within its range may be found which will not involve the mechanical difficulties of the present heat engine. The effect of this would be to render the efficiency of an engine working between T_2 and T_3 equal to that working between T_1 and T_3 , and the possibility of accomplishing this gives an interest to the second case.

As a matter of fact, we have an example of a transfer of heat approximately at least, in accordance with the cycle considered in the closed distillation process which practically combines an

engine and its reverse. In this apparatus the heat received by the condenser is the sum of that taken from the refrigerator and that part of the heat supplied by the still, which corresponds to the available energy of the steam engine, while that portion, also supplied by the still, which corresponds to the rejected heat of the engine, appears in the absorber. The moving parts in this mechanism are insignificant and, but slightly, if at all affected by the range of the cycle, being merely a pump to effect the transfer of the agents used from the absorber to the still. Moreover, since the losses arising from the difficulties of adapting the mechanism of the heat engine to the cycle of maximum efficiency, together with those arising from the dissipation of energy in running the same are absent we may expect a greater practical efficiency. A still greater efficiency may be looked for from the fact that the range of the cycle is not limited by the same conditions which are imposed by the ordinary form of heat engine. The only apparatus of this description with which we are practically acquainted is the ammonia distillation machine. It is possible that in very cold climates a combination of this with a single low temperature engine would be simpler than that of a high and low temperature engine, although as shown the theoretic efficiency of each combination would be the same. But for extending the cycle in the other direction where the option of employing two heat engines is less practicable, we are at present unacquainted with suitable agents.

MEASURE OF LIQUID RESISTANCE BY ALTERNATIVE CURRENTS.—Two methods have been employed for the exact measurement of the resistance of liquids; one, based upon the use of electrometers with an elimination of the influence of the polarization of the electrodes; the other, consists in weakening the polarization so that it may be disregarded while augmenting at the same time the useful surface of the electrodes, and having recourse to alternative currents of the shortest possible duration. This method has been often employed abroad, especially by F. Kohlrausch. Bouty and Fousseureau have compared the results by the two methods, using a small Deprez motor with a velocity of 100 turns per second, directing the currents to a Wheatstone bridge, in which the galvanometer was replaced by an excellent Ader telephone. They find the precision of the measurements with electrometers much the most satisfactory. It seems, indeed, very difficult to apply with any success the method of alternative currents to liquors which are greatly diluted, or which present great resistance.—*L'Electricien*, Aug. 15, 1885.