by ordinary tides are safe, and so are all those low enough to be attractive to fiddler crabs.

Areas covered by the monthly high tides are safe, except in midsummer if it has been dry enough to kill out the young fish and has then rained enough to fill the low places. The danger points are such as I pointed out in SCIENCE and more at length, recently, in Special Bulletin T of the New Jersey Agricultural College Experiment Station.

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'LATENT HEAT' AND THE VAPOR-ENGINE CYCLE.

THE discussion, some time since published in SCIENCE, relating to the vapor-engines, so-called, and the 'latent heat fallacy' led to inquiries from various sources regarding the exact distribution of the work of thermodynamic transformation in the case of the steam, and other vapor-engines. The following may perhaps make clearer the relation between the action of sensible and of 'latent' heat in such cycles. The discussion of this problem has been one of the annual topics in the classes of the writer for years past.

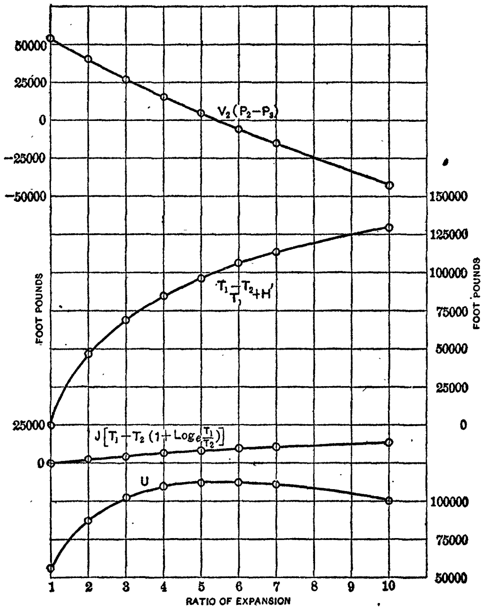
The usual standard form of engine-cycle, in all departments of applied thermodynamics and with the steam, and other vapor-engines employed in the industries, is that known as the Rankine cycle with incomplete expansion, as in the figure. It consists of a line of constant maximum pressure, an adiabatic expansion-line, as nearly as practicable, a line of constant volume, a line of constant minimum pressure, and the cycle is closed by a line of constant volume. Assuming unit-weight of the working substance to be carried through such a cycle, it is easy, by the adoption of one of Rankine's beautifully ingenious mathematical devices, to obtain the following expression for work of one cycle in which p, T and u are the pressures, the temperatures, absolute, and the specific volume of the charge; H is the latent heat of vaporization and J is Joule's factor. The subscripts indicate, respectively, values of p and T on the expansion line and of p on the back-pressure line:

$$ABCDE = AFG + ABCFA + CDEG$$
$$= (\text{I.}) + (\text{II.}) + (\text{III.})$$

$$U = J[T_1 - T_2(1 + \log_e T_1/T_2)] + H_1(T_1 - T_2)/T_1 + (p_2 - p_3)u_2.$$

The three parts into which the measure of net work, U, divides itself are obviously a function of temperature which measures the effect of the thermodynamic application of sensible heat, a function of temperature and 'latent' heat which is instantly recognized as the measure of the Carnot efficiency of the 'perfect engine,' and a function of the terminal and back pressures and specific volume of the charge at the minimum temperature of the expansion-line. This latter is obviously, also, the work between the terminal and back-pressures, the rectangle, $CDEG$. The intermediate term is the work obtainable from the same quantity of fluid between the same two temperatures, T_1 and T_2, in the Carnot cycle, $ABCFA$, and it is thus evident that the first term must measure the remaining area of the Rankine cycle, the triangle, AFG; which is as evidently the work alike of the compression in the Carnot cycle and that of expansion of unit weight of a mixture of steam and its liquid between the state of liquid at maximum temperature at A and that of mixed vapor and liquid at the lower limit of expansion pressure and temperature, p_2 and T_2.

Noting the proportions of the areas thus measured, it is seen that, with any fixed value of the latent heat of vaporization, the last-named quantity has a lower relative measure as the ratio of expansion and the temperature-range decrease, and, *vice versa*, that the quantity of work performed within the same temperature-range is in all cases greater in the Rankine than in the perfect engine cycle by this amount; that the work in either cycle is proportional, in some direct measure, to the quantity of the heat of vaporization; that the heat entering the fluid during vaporization is *all* converted into work and that none is employed to change temperature and thus to become stored as sensible heat. Observing, also, that the Carnot cycle is that of maximum efficiency, it follows that the work measured by the first term, and by AFG, is obtained at a comparative loss of efficiency and that, therefore, the work gained in the Rankine cycle, per unit of working fluid, is secured at a loss of power per unit of heat supplied. It is still further to be seen that the greater, as well



WORK IN RANKINE CYCLES.

as the more economical, work-production is effected by the conversion of the so-called 'latent' heat of vaporization directly into mechanical energy or into work. It follows, still further, that the larger the quantity of 'latent' heat, the greater the work of a given weight of fluid and the lower the weight of water or other liquid per unit of power. Water has thus a double advantage in low expenditure per horse-power at a given temperature-range and efficiency of cycle, and in small, usually insignificant, cost.

These relations and the variations, especially, of relative magnitudes of the three terms with varying expansion-ratios from a given initial pressure, with, as is usual, constant back-pressure, in the ideal case, is well exhibited by the accompanying figure. This set of curves includes those of total work, of values of the several terms, and of relations of rate of variation, for such a case, in which the steam-pressure is about 7.5 atmospheres, the back-pressure one seventh that tension, and the ratio of expansion, ranging from unity upward, in an engine which would be ordinarily rated at about 200 horse-power, at 85 revolutions per minute with $r = 4$.

It is seen that the total work, U, increases rapidly from $r = 1$ to $r = 4$, passes a maximum at about 5 and rather rapidly falls off again, after the expansion-line begins to intersect the back-pressure line (curve A).

The work of sensible heat (curve B) increases slowly throughout the range exhibited, and substantially in proportion to r, and is, throughout the whole range, small in comparison with the work of 'latent heat' (curve C).

The work of the rectangular area below terminal pressure (curve D) is similarly variable, but becomes negative at the point of junction of the expansion line with the back-pressure line. Throughout the whole usual range of expansion in the real engine, this quantity is small in comparison with that measuring the second term.

The value of the second term, on B, is thus the principal element of the total work of the cycle and is larger, relatively, as the diagram approximates the form of the Carnot, rather than the Rankine cycle. The deduction at once follows that 'latent' heat, and latent heat only, so far as practicable, should be utilized in the thermodynamic transformations of the vapor-engines.* The 'latent heat fallacy' is thus clearly disposed of.

A similar investigation would show that, in the gas-engines, the 'latent' heat of isothermal expansion, rather than the sensible heat producing change of temperature, should be utilized in thermodynamic transformations and the production of power.

The final conclusion is thus obvious that maximum efficiency of thermodynamic engines can only be secured by the utilization, solely, of 'latent' heat.

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ON BACUBIRITO, THE GREAT METEORITE OF SINALOA, MEXICO.

FOR more than a century the meteorites of Mexico have attracted attention and record.

* 'Manual of the Steam-Engine,' Vol. I., §112, pp. 437–438.