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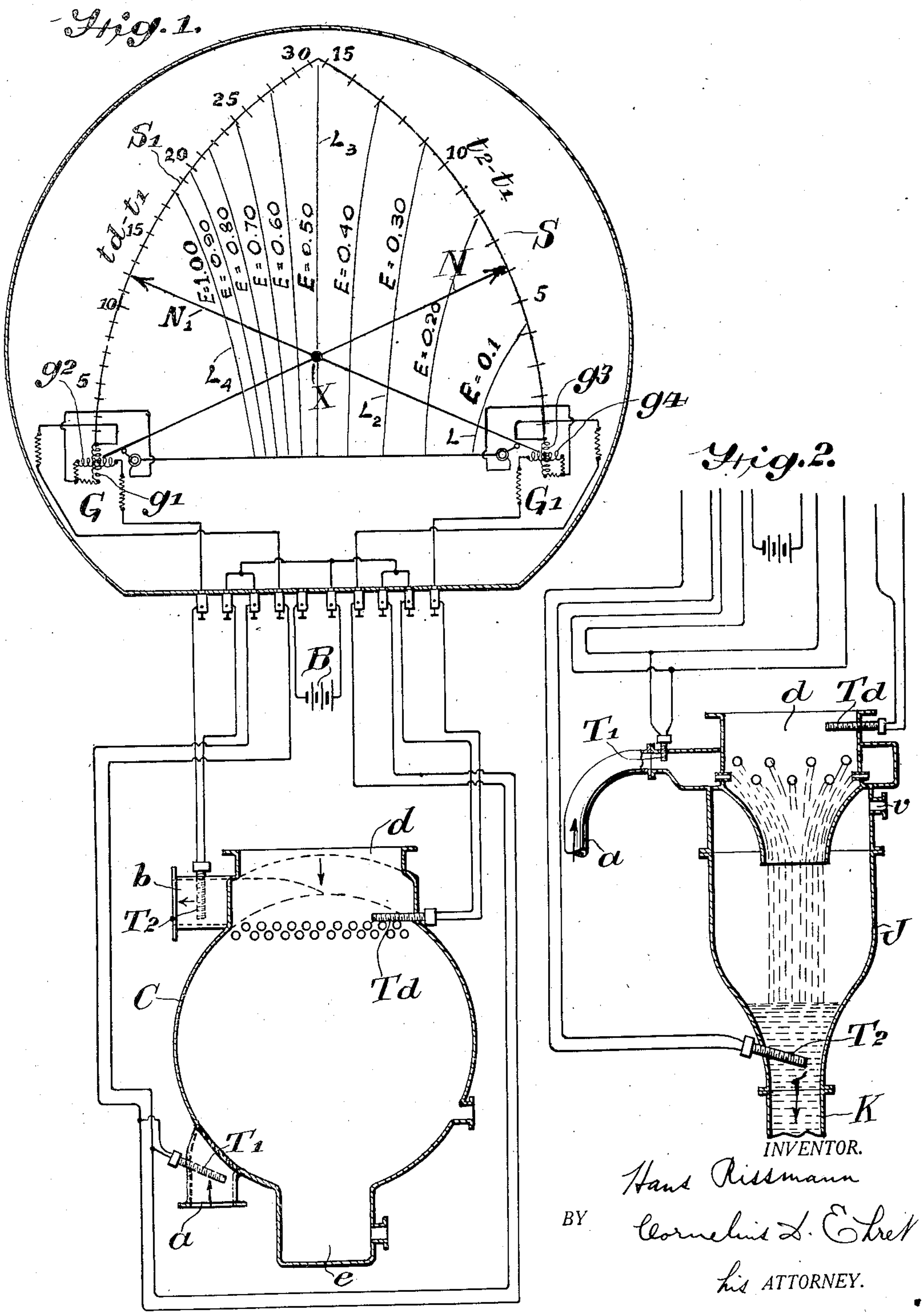

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DETERMINATION OF EFFICIENCY OF CONDENSING PLANTS.

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My invention relates to the determination of the efficiency of heat-exchange apparatus or plants, and more particularly of apparatus or condensers for condensing steam exhausted from the engines or turbines of a steam power plant.

It is the object of my invention to determine the efficiency of steam condensing plants and the like continuously or from time to time, whereby, to maintain high efficiency under varying conditions, the operator of a plant may suitably control or regulate the auxiliaries suitably to control the rate of flow of cooling water through the condenser, and to control the ejectors or other air pumps which remove air from the condenser to maintain desired vacuum theirin, in accordance with changes of load upon the plant.

In accordance with my invention, the efficiency of the condensing plant or the like is determined by taking into consideration not only the temperature of the saturated steam or vapor entering the condenser and the temperature of the cooling water adjacent its discharge, but also the temperature of the cooling water as it enters the condenser; and more particularly, the efficiency is indicated by the ratio of the change of temperature of the cooling water in the condenser to the difference between the temperature of the steam entering the condenser and the temperature of the cooling water at or adjacent its entry into the condenser.

Further in accordance with my invention, the efficiency may be directly read upon the chart or scale of an indicating instrument comprising two galvanometers whose deflecting pointers or needles intersect, the deflections of one of the galvanometers being dependent upon or proportional to the difference between the temperatures of the cooling water at the inlet and discharge from the condenser, and the deflections of the other galvanometer being dependent upon or proportional to the difference between the temperature of the steam entering the condenser and the temperature of the cooling water as it enters the condenser.

My invention resides in a system of the character hereinafter described and claimed.

For an understanding of my invention, and for an illustration of several of the various forms it may take, reference is to be had to the accompanying drawings, in which:

Fig. 1 is an illustration of my system as applied to a surface condenser.

Fig. 2 is a fragmentary view of a similar system as applied to a jet condenser.

Under ideal conditions, or under conditions leaving out of consideration certain variables, unity or perfect efficiency is attained when the temperature of the entering saturated steam is equal to the temperature of the cooling water adjacent its discharge from the condenser.

However, due to practical considerations, such as variations in load upon the plant, involving varying quantities of cooling water, and such as variations of temperature of entering cooling water, I have found that the determination of efficiency should take into account not only the temperature of the saturated steam entering the condenser, but also the temperatures of the cooling water as it enters and leaves the condenser.

The efficiency E may be expressed as follows:

$$E = \frac{\dfrac{J - td}{td - t^1}}{\dfrac{J - td}{t^2 - t^1}} = \frac{t^2 - t^1}{td - t^1}$$

in which:

J = heat of steam or vapor to be condensed.

td = the temperature or liquid heat of the steam or vapor to be condensed.

t^1 = the temperature of the cooling water adjacent its entry into the condenser.

t^2 = the temperature of the cooling water adjacent its discharge from the condenser, all of which may be expressed in the metric system.

Accordingly, the determination of the efficiency of the condensing plant is the determination of the quotient of the difference between the temperatures of the cooling water as it leaves and enters the condenser divided by the difference between the temperature of the steam in the steam space of the condenser and the temperature of the cooling water adjacent its entry into the condenser. This quotient is the ratio of the same quantities, and this ratio indicates the efficiency of the plant and may be determined by a system or apparatus of the character hereinafter described.

Three temperature-responsive devices, as resistance thermometers, thermo-couples or equivalents, are subjected, respectively, to the temperature of the entering cooling water, the temperature of the cooling water adjacent the discharge from the condenser, and to the temperature of the steam in the steam space of the condenser. A galvanometer such as a D'Arsonval or permanent magnet field galvanometer, having two coils disposed at right angles to each other and movable as a unit in the field, has its coils related, respectively, to the temperature-responsive devices subjected to the temperatures of the entering and discharging cooling water; and another similar galvanometer has its coils related, respectively, to the temperature-responsive devices subjected to the temperatures of the entering cooling water and of the steam in the steam space of the condenser. The pointers or needles of these galvanometers, movable with their coil systems, sweep across a chart or scale, and at their intersection there is given upon the scale the then efficiency as expressed by the aforesaid ratio.

Referring to Fig. 1, C is a surface condenser whose cooling water inlet is at *a* and whose cooling water outlet or discharge is at *b*. The steam or vapor to be condensed enters at the steam inlet *d* and the condensate is collected in and withdrawn from the hot well *e*.

In the example illustrated, the temperature-responsive devices are resistance thermometers T^1, subjected to the temperature of the cooling water at or adjacent the inlet *a*; T^2 subjected to the temperatures of the cooling water at or adjacent its discharge *b*; and T*d* disposed in the steam space of the condenser, where the steam is saturated and is about to condense into water. A battery or common source of current B is connected in circuit with these several resistance thermometers, and the galvanometers G and G^1, the former having the crossed coils g^1 and g^2 in circuit, respectively, with the thermometer resistances T^1 and T^2, and opposing each other, and the latter having the crossed coils g^3 and g^4, in circuit, respectively, with the thermometer resistances T^1 and T*d*, and opposing each other.

Secured in fixed relation to and deflected by the coil system g^1, g^2 of galvanometer G is its pointer or needle N co-acting with the scale S, whose readings or markings are differences of temperature of the cooling water adjacent its entry and discharge from the condenser. Similarly, the pointer or needle N^1 of the galvanometer G^1 co-acts with the scale S^1, whose markings or readings are differences between the temperatures of the entering steam and of the entering cooling water.

By dividing the reading on the scale S^1 by the simultaneous reading on the scale S, there is obtained the quotient or ratio aforesaid, representing the efficiency of the condensing plant.

The two co-acting galvanometers G and G^1, each of the crossed coil or ohmmeter type, constitutes such a quotient or ratio meter utilizable by so positioning the galvanometer systems that their pointers N and N^1 sweep across each other or intersect, the point of intersection X varying from time to time with variations of the several temperatures involved. In the space between the two scales S and S^1 may be a chart or scale having a series of lines or markings L, L^1–L^4, etc., constituting readings of different magnitudes of efficiency, or of magnitudes of the aforesaid ratio or quotients. For example, when the intersection X of the pointers N and N^1 lies directly over the line L, anywhere along that line, the efficiency is, for example, 0.1 or ten per cent. Similarly, when the intersecting point X lies over any of the other lines L^1, etc., the corresponding efficiency is indicated. In the position of the pointers N, N^1 illustrated, the point X lies between the lines L^3 and L^4, and the efficiency is, for example, 0.5, or fifty per cent.

Referring to Fig. 2, J is a jet condenser into which the steam to be condensed enters at *d*, the condensing water enters at *a*, and the condensed steam and condensing water collect in the barometric column K, from which it is withdrawn in well known manner. The air pump or vacuum-producing means is connected at *v*. In this case again the galvanometers, scales and temperature-responsive devices are correlated as above described in connection with Fig. 1. The thermometer resistance T^1 is again subjected to the temperature of the entering cooling or condensing water; thermometer resistance T^2 is subjected to the temperature of the mixture of condensate and condensing water, and the thermometer resistance T*d* is subjected to the temperature of the entering steam to be condensed.

While in the case of a jet condenser the temperature of the condensate or condensed steam is not that of the temperature of the steam to be condensed entering at *d*, but rather takes approximately the same temperature as the outgoing cooling water, the efficiency may nevertheless be indicated by an instrument of the character described, particularly since the efficiency depends upon the same quotient or ratio as aforesaid, though the factor J—*td* does not enter into the relation, and since it does not appear in the final quotient or ratio of the equation hereinbefore given, the efficiency is with reasonable exactitude or accuracy indicated by the system of Fig. 1 or one equivalent thereto.

By a system or instrument of the character herein described, the operator of the power plant is continuously advised of the efficiency of the condensing plant, which is accordingly controllable by him, upon observation of the efficiency, by suitably regulating the condenser auxiliaries, as, for example, the cooling water pump, the vacuum-producing means or air pump, and the like.

What I claim is:

1. In a system of the character described, the combination with a condenser, of temperature-responsive devices subjected, respectively, to the temperature in the steam space of the condenser, to the temperature of the cooling water of said condenser adjacent the cooling water inlet, and to the temperature of the outgoing cooling water, an indicating instrument controlled by a pair of said temperature-responsive devices, and a second indicating instrument controlled by another pair of said temperature-responsive devices, said indicating instruments co-acting to effect an indication of the operation of the condenser.

2. In a system of the character described, the combination with a condenser, of temperature-responsive devices subjected, respectively, to the temperature in the steam space of the condenser, to the temperature of the cooling water of said condenser adjacent the cooling water inlet, and to the temperature of the outgoing cooling water, an indicating instrument controlled by a pair of said temperature-responsive devices, a second indicating instrument controlled by another pair of said temperature-responsive devices, said indicating instruments co-acting to effect an indication of the operation of the condenser, said indicating instruments having pointers crossing each other, and a scale to be read at the intersection of said pointers.

3. In a system of the character described, the combination with a condenser, of temperature-responsive devices subjected, respectively, to the temperature in the steam space of the condenser, to the temperature of the cooling water of said condenser adjacent the cooling water inlet, and to the temperature of the outgoing cooling water, an indicating instrument controlled by a pair of said temperature-responsive devices to effect deflections dependent upon the difference between the temperatures of the outgoing and entering cooling water, a second indicating instrument controlled by a different pair of said temperature-responsive devices to effect deflections dependent upon the difference between the temperatures of the steam and the entering cooling water, said instruments being correlated to indicate the ratio of said temperature differences.

4. In a system of the character described, the combination with a condenser, of temperature-responsive devices subjected, respectively, to the temperature in the steam space of the condenser, to the temperature of the cooling water of said condenser adjacent the cooling water inlet, and to the temperature of the outgoing cooling water, a galvanometer having crossed coils in circuit, respectively, with said first and second named temperature-responsive devices, to effect deflections dependent upon the difference between the temperatures to which said temperature-responsive devices are subjected, and a second galvanometer having crossed coils in circuit, respectively, with said second and third temperature-responsive devices to effect deflections dependent upon the difference between the temperatures to which said second and third temperature-responsive devices are subjected.

5. In a system of the character described, the combination with a condenser, of temperature-responsive devices subjected, respectively, to the temperature in the steam space of the condenser, to the temperature of the cooling water of said condenser adjacent the cooling water inlet, and to the temperature of the outgoing cooling water, a galvanometer having crossed coils in circuit, respectively, with said first and second named temperature-responsive devices, to effect deflections dependent upon the difference between the temperatures to which said temperature-responsive devices are subjected, a second galvanometer having crossed coils in circuit, respectively, with said second and third temperature-responsive devices to effect deflections dependent upon the difference between the temperatures to which said second and third temperature-responsive devices are subjected, said galvanometers having pointers crossing each other, and a scale to be read at the intersection of said pointers.

6. In a system of the character described, the combination with a condenser, of resistance thermometers subjected, respectively, to the temperature in the steam space of the condenser, to the temperature of the cooling water of said condenser adjacent the cooling water inlet, and to the temperature of the outgoing cooling water, an indicating instrument controlled jointly by the resistance thermometers subjected, respectively, to the temperatures of the entering and discharging cooling water, a second indicating instrument controlled jointly by the resistance thermometer subjected to the entering cooling water and the resistance thermometer subjected to the temperature in the steam space of the condenser, said instruments be-

ing correlated to indicate the ratio of the temperature differences between the entering and discharging cooling water and of the steam space and the entering cooling water.

7. In a system of the character described, the combination with a condenser, of temperature-responsive devices subjected, respectively, to the temperature in the steam space of the condenser, to the temperature of the cooling water of said condenser adjacent the cooling water inlet, and to the temperature of the outgoing cooling water, an indicating instrument controlled by the temperature-responsive devices subjected, respectively, to the temperature in the steam space of the condenser and the temperature of the cooling water adjacent the cooling water inlet, and a second indicating instrument controlled by the temperature-responsive devices subjected, respectively, to the temperature of the cooling water adjacent the cooling water inlet and the temperature of the outgoing cooling water, said indicating instruments co-acting to effect an indication of the operation of the condenser.

8. In a system of the character described, the combination with a condenser, of temperature-responsive devices subjected, respectively, to the temperature in the steam space of the condenser, to the temperature of the cooling water of said condenser adjacent the cooling water inlet, and to the temperature of the outgoing cooling water, an indicating instrument controlled by the temperature-responsive devices subjected, respectively, to the temperature in the steam space of the condenser and the temperature of the cooling water adjacent the cooling water inlet, a second indicating instrument controlled by the temperature-responsive devices subjected, respectively, to the temperature of the cooling water adjacent the cooling water inlet and the temperature of the outgoing cooling water, said indicating instruments co-acting to effect an indication of the operation of the condenser, and scales associated with said first and second indicating instruments, for giving readings, respectively, of the differences of the temperatures to which said instruments are responsive.

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