An Apparatus for the Study of the Radiation from Covered and Uncovered Steam Pipes.

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"The measurement of the efficiency of materials in preventing loss of heat from bodies involves the determination of the constant K in the expression:

$$K = \frac{DH}{A\,(t_2 - t_1)}$$

Where D = thickness of the specimen.

H = Amount of heat per sec. flowing through A.

A = Area of specimen.

t_1 = Temperature of cooler side of specimen.

t_2 = Temperature of hotter side of specimen.

"The determination of H, t_1, and t_2 are attended with considerable difficulty if accurate work is attempted, and for much engineering work the relative efficiency of two coverings for heated surfaces is all that is required. For the testing of the relative efficiency of two such substances as are commonly used for covering steam pipes, or for determining the relation between the heat loss from a covered pipe and that from an uncovered pipe, the following method has been found suitable:

"The apparatus consists of two short pieces of steam pipe which may be heated electrically from within by means of a current bearing coil of wire immersed in oil. If sufficient electrical energy be supplied, the pipe becomes gradually heated to some temperature at which the amount of heat energy lost to the surroundings is just equal to the electrical energy supplied to the heating coil. By measuring the electrical energy with an ammeter and voltmeter we may find at once the amount of heat lost from the pipe by radiation, convection, and conduction. At some temperature the heat loss would be such as to require some other rate of energy supply to keep the temperature of the pipe constant, and the electrical suppiy would, therefore, have to be varied. Again, if the bare pipe be heated to some convenient reference temperature (200°C is usually selected for testing steam pipe covers) and the current adjusted

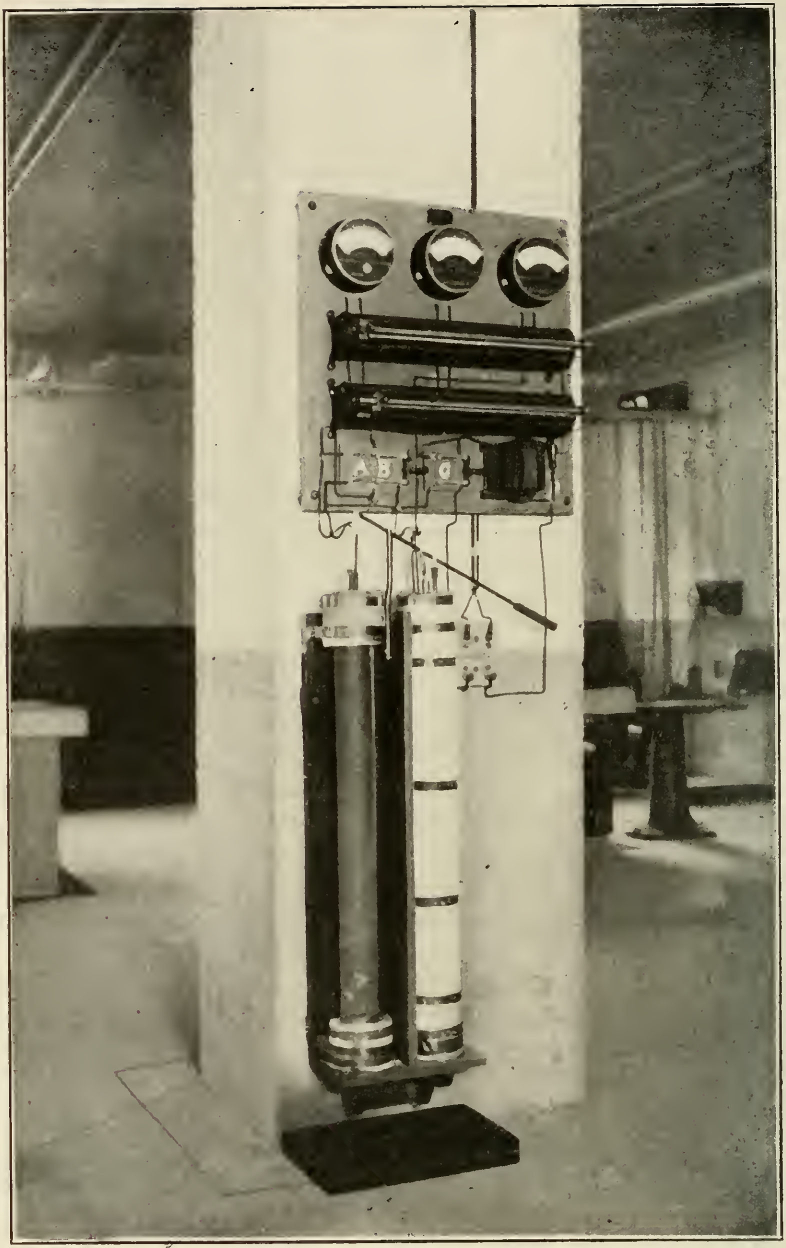

Fig. 1.

until a condition of temperature equilibrium is obtained—that is, the electrical input just compensates for the thermal output—and a second, and exactly similar pipe, be covered with a 'non-conducting' cover and heated in the same manner, it will be found that much less electrical energy is needed to keep the covered pipe hot than is required by the bare pipe. The difference represents the saving due to the use of the covering."—Laboratory Notes, Massachusetts Institute of Technology.

In accordance with the above plan, we are now using for a laboratory exercise for engineering students the apparatus shown in Fig. 1. Two pieces of ordinary three-inch gas pipe of equal length (40 inches), are closed by means of caps at both ends. They are mounted on an oaken support, and separated by a $\frac{7}{8}$-inch oak board, which prevents one pipe receiving heat from the other. Three short pipes are fitted into holes in the upper cap extending through about an inch; one (B. Fig. 2), of $\frac{5}{8}$-inch pipe, five inches long in the center, another (A), of $\frac{1}{4}$-inch pipe, five inches long, for the support of a thermometer, and a third (C), of $\frac{3}{8}$-inch pipe, nine inches long on the opposite side of the center from the second, for the lead wires of the heating coil.

The heating coils (G), made of No. 16 advance wire, are wound on a paper-insulated brass tube, which extends along the axis of the pipe. Each turn of the coil is separated from the neighboring coil by a hemp cord. The tube is held in position at the top by telescoping over the lower end of the pipe which pierces the middle of the cap. At the lower end it is held in position by a wooden frame (E), clamped rigidly around it by means of screws. This frame also holds firmly the lower end of the heating coil and the lower part of the paper insulation. A similar clamp holds the upper end of the coil and insulation.

The two pipes are covered alike at the ends by means of magnesia covering one inch thick (D and F), leaving 36 inches of each one bare. Brass collars having a flange extending out flush with the circumference of the covering are clamped to the pipes and prevent the end covering from slipping along the pipes. When a test is to be made, a piece of pipe covering of regulation length (36 in.) and suitable size, is placed on one of the pipes, thus completely covering it, while the other one has an equal length left bare.

The tube (Fig. 3), upon which the heating coil is wound, acts also as the cylinder for a pump, by means of which the oil is stirred. It is $\frac{7}{8}$ inch

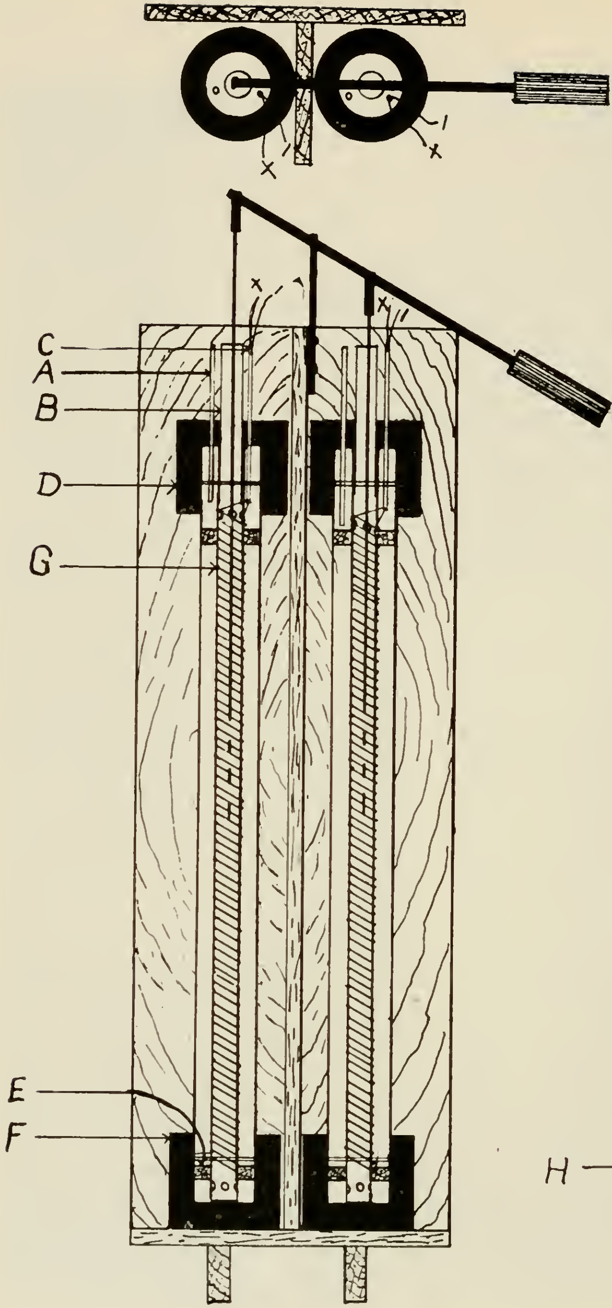

Fig. 2

Fig. 3

in diameter and has near the bottom a hollow wooden cylinder (H), upon which rests a small marble, which acts as a valve. The piston of the pump is made of a smaller tube, which is just large enough to slip easily inside the $\frac{7}{8}$-inch tube. The valve in it is of the same type as the one at the bottom of the tube. The piston rods extend through the central hole at the top of the heating pipe, and are attached to a lever which is pivoted to a support fastened to the oaken partition.

Above the pipes is mounted a switchboard (Fig. 1), containing the necessary measuring instruments. The ammeter on the right side of the switchboard measures the current used in heating the covered pipe, and the one in the upper central part of the board measures the current used in heating the uncovered pipe. The two coils are in multiple circuit, and when switch C is closed current passes through both coils, the amount in each coil being regulated by the two rheostats. The upper rheostat controls the current in the covered pipe, and the lower one controls the current in the uncovered pipe. When the switch on the left side of the board is thrown, closing circuit A, the voltmeter is connected to the terminals of the coil in the unjacketed pipe, and when thrown, closing circuit B, it is connected to the terminals of the jacketed pipe. Switch B is in multiple circuit with an impedance coil, and may be used when a large circuit is needed in the heating coils.

Each of the heating coils has a resistance of about 6.5 ohms, the impedance coil a resistance of about 9.3 ohms, and each rheostat has a resistance of 7.5 ohms when all is used. At the outset of a measurement the resistance of the rheostats is thrown in, switch D is closed, then the sides of the rheostats moved until the current in the covered pipe is 8 amperes. The oil in the pipes is stirred by means of the pumps. When the temperature of about 100° C. is reached switch D is opened, and while the oil is vigorously stirred the current is regulated until the temperature of both pipes is kept at the same constant value. After the two pipes have kept at the same constant temperature for about ten minutes, the temperature of each oil bath, the voltage at the terminals of each coil, and the current in each coil, is read.

A record of the test is as follows:

Outside diameter of pipes, 3.5 in.

Length exposed, 36.0 in.

Temperature of surroundings, 23.1° C.

Uncovered Pipe.			Covered Pipe.		
Volts.	Amperes.	Temperature, Degrees C.	Volts.	Amperes.	Temperature, Degrees C.
38.5	5.5	98.8	24.0	4.1	98.9
38.5	5.5	99.0	23.5	4.1	98.6
38.5	5.4	98.7	24.0	4.2	98.9
39.0	5.5	98.8	23.0	4.2	98.9
39.0	5.5	98.8	24.0	4.1	99.0
39.0	5.5	99.0	24.0	4.2	99.0
39.0	5.5	99.0	23.5	4.1	99.0
38.0	5.5	98.8	23.0	4.1	99.0
38.5	5.5	98.9	24.0	4.1	99.0
38.3	5.4	98.9	24.0	4.1	99.0
Mean, 38.63	5.48	98.88	23.70	4.13	98.93

Average energy consumed by uncovered pipe, 211.69 watts.

Average energy consumed by covered pipe, 97.88 watts.

(211.69 — 97.88) ÷ 211.69 = 53% the efficiency of the pipe covering.

211.69 watts = 0.283 horse-power

97.88 watts = 0.131 horse-power.

Difference = 113.81 watts = 0.152 horse-power.

Area of radiating surface, 395.64 sq. in. = 2.74 sq. ft.

$113.81 \times 10^7 \div 4.2 \times 107 = 27.09$ cal. per second loss.

$= 0.107$ B. T. U. per second loss.

$0.107 \times 3600 \times 24 = 9240$ B. T. U. loss per 24 hours.

$0.107 \times 3600 \times 24 \times 365 = 337 \times 10^4$ B. T. U. loss per year.

$337 \times 10^4 \div 2.74 = 123 \times 10^4$ B. T. U. loss per sq. ft. per year.

"Problem: Compute the saving for the first year for 1,000 feet of three-inch pipe, assuming that the pipes are maintained at the temperature used in the above test, that coal develops 14,000 B. T. U. per pound and costs $6.00 per ton, and that the loss in the boiler, etc., is 50%. The pipe covers cost 25 cents per square foot, and interest and depreciation are 10%."

Loss on 1,000 square feet of pipe per year 123×10^7 B. T. U.

1 lb. coal gives up on combustion 14,000 B. T. U.

1 ton of coal gives up on combustion 28×10^6 B. T. U.

At 50% efficiency 14×10^6 B. T. U. are used in pipes at a cost of \$6.00.

Cost of covering per 1,000 square feet at 25 cents per square foot, is \$250.00; interest 10% = \$25.00.

Total \$275.00.

$123 \times 10^7 \div 14 \times 10^6 = 87.9$ tons of coal required.

$87.9 \times 6 =$ \$527.40 loss per 1,000 feet per year.

\$527.40 — \$275.00 = \$252.40 saving for the first year for a pipe covering of 53% efficiency.

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