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AIR HEATERS AND ECONOMIZERS FOR MARINE SERVICE.

By T. B. STILLMAN.*

The fundamental purpose of air heaters and economizers is to recover heat from gases leaving boilers which it would not be feasible to recover with the boilers alone. With increasing steam pressures and temperatures, the commercial desirability of using air heaters or economizers is correspondingly increased. In a similar manner, increased fuel costs will frequently justify the use of such additional equipment when relatively cheap fuel may not. Like other supplementary equipment which may be used aboard ship, which is not primarily essential for its operation, air heaters and economizers should only be used when their presence is justified on (*a*) merchant ships, by a reduction in fuel costs which will more than pay for the increased carrying and operating

* Engineering Department, Babcock & Wilcox Company, New York, N. Y.

TABLE 6

EFFECT OF DIFFERENT ACID LOTS FROM ONE MANUFACTURER

Sample Heat No.	*Acid Lot Used*	—Inches Penetration per Month— *1st 48 Hours*	*2nd 48 Hours*	*3rd 48 Hours*	*Total Penetration*
1	1	.00098	.00083	.00098	.00279
1	2	.00058	.00056	.00114	.00228
1	3	.00066	.00076	.00102	.00244
1	4	.00085	.00073	.00105	.00263
2	1	.00087	.00120	.00189	.00396
2	2	.00075	.00080	.00156	.00311
2	3	.00062	.00099	.00151	.00312
2	4	.00083	.00104	.00161	.00348

SUMMARY.

Investigation of the factors influencing the corrosion values secured in the testing of a particular stainless steel in boiling nitric acid has led to the following conclusions.

The amount of nitric acid used in relation to the surface area of steel exposed has a major effect in determination of the values secured. This is due to the fact that the presence of impurity in the acid introduced by solution of the sample greatly accelerates the corroding action. Some standard relation between area of samples and liquid volume must be used to secure comparable results and it is proposed that this relation be one and one-half square inches of exposed area to each 100 milliliters of concentrated acid.

The initial acid composition should be 67 per cent concentrated acid or over as weaker concentrations give low values.

Previous exposure of the acid to air is of no importance.

Periodic acid changes must be made during progress of the test to limit the amount of impurity in the acid resulting from sample solution. The 48-hour periods usually used are satisfactory.

Considerable variation in test results on a particular sample may occur due to the use of acids from different manufacturers and slight variations occur due to the use of different lots from the same manufacturer. The presence of traces of certain impurities such as hydrochloric and sulphuric acids or salts of iron, nickel, chromium, and other metals may cause variations out of all proportion to the amount present.

Whenever a rigid weight loss specification must be met and values slightly exceed the maximum allowable the use of another acid may place the result well within specifications.

PIPE COVERING MATERIALS FOR HIGH TEMPERATURES.

By Ralph R. Gurley, Lieutenant, U. S. N., and
W. P. Sinclair, Asst. Mech. Engr.

For many years the standard Navy pipe covering material has been 85 per cent magnesia. The ease with which this material can be applied in pipe covering form, its low heat conductivity, its relatively low cost, and its comparative lightness in weight have all been factors favoring its retention as the standard covering. The temperature range to which this material is adaptable, however, is limited. At temperatures in excess of 500 degrees F., it calcines and decomposes. Therefore, when the Navy began to contemplate the use of steam with temperatures in excess of 500 degrees F., it became necessary to investigate and to adopt other types of heat insulating materials for pipe coverings. These materials are not only required to have highly efficient insulating properties, but also thermal and physical properties which do not deteriorate on subjection to the higher temperature ranges.

The materials which have been approved and are now used in the Service as pipe coverings for temperatures above 500 degrees F. are grouped into the following categories:

(1) Sectional and segmental molded pipe covering.
(2) Felted mineral wools.
(3) Aluminum foil, (limited approval).
(4) Insulating cements.

Most of the molded pipe coverings are composed of large percentages of diatomaceous silica and magnesium or calcium carbonate bonded together with small percentages of asbestos fibers. One very efficient material of this type, in addition to the above constituents, contains bloated flakes of mica. The molded pipe coverings are furnished to the Navy in standard pipe sizes and standard thicknesses, made in cylindrical sections 36 inches long, split in half lengthwise. General Specifications for Machinery prescribe the thicknesses to be employed for different pipe sizes and temperatures. Double layers of pipe covering are specified for high temperature conditions (over 500 degrees F.) on standard pipes from 4 to 10 inches in diameter. Where double layers are specified, it is customary for the manufacturer to supply an inner layer of high temperature material, and an outer layer of 85 per cent magnesia. This reacts to the manufacturer's advantage, because 85 per cent magnesia is cheaper than diatomaceous earth. It is advantageous to the Navy because the combination cover weighs less than a complete high temperature cover. The high temperature materials, with two exceptions, are not as good insulators as 85 per cent magnesia; hence, in general, the combination cover gives better heat insulation than a complete high temperature covering would give for the same thickness of cover.

Mineral wools consist of rock fibers made from a dolomite rock composed of calcium and magnesium oxides and silicates. The rock is melted and blown in a steam spray. The resulting fibers are similar in appearance to spun glass and are equally brittle. This type of material has very little tensile strength. It is made up in the form of a blanket and is secured to a wire screen outside cover in much the same manner as the filler is secured inside the ticking of a mattress. Narrow strips of screen wire, running the length of the section of pipe covering on its inner side, are secured to the outer screen cover by wires passing through the rock wool blanket. The covering is wrapped around the pipe in a single layer and the abutting edges of the outer wire screen are secured by lacing or some type of clip. It is imperative, in using this type of cover, that it be fitted snugly to the pipe to prevent damage from vibration.

Aluminum foil was used in Germany for high temperature insulation before it was introduced in this country. The heat insulating value of an aluminum foil cover will vary widely with the manner of application of the foil and with the degree of expertness with which the application is made. In its most effective form aluminum foil is applied without crumpling. The successive layers are made of individual sections of foil separated from each other by bands of heat resisting material 3/8 inch thick and about an inch wide.

These bands are built up around the pipe as the successive layers of foil are applied and eventually support the sheet metal protecting cover.

The cost of application of aluminum foil in this manner is too great to be practical. For its insulating value in practical installations, it depends in part on the reluctance of a bright surface to absorb and radiate heat and in part on the opposition to convection currents presented by the small air cells formed between adjoining layers of crinkled foil. Aluminum foil 0.0032 inch thick, embossed with diamond shaped figures, is crinkled by hand and partially straightened out. It is then wrapped lightly around the pipe so that each successive layer occupies a space of about 3/8 inch and makes only point contacts with the next inner layer. Any number of layers may be applied, depending on the protection desired and on the allowable bulk of installation. The entire foil covering must be protected by a sheet metal housing to prevent damage to the fragile foil. This housing is supported directly from the pipe by small sheet metal " towers."

The big advantage of aluminum foil pipe coverings over other types lies in the reduction in weight which can be effected. This advantage is much reduced, if not entirely lost, with small sizes of pipe because of the increased percentage of the total weight of the installation represented by the "towers" and the sheet metal protector. With this type of insulation, higher cover temperatures are encountered than in the case of the molded and rock wool materials, because of the reluctance of the metal cover to radiate the heat transmitted to it.

Insulating cements are made up of widely variant materials. As a result they vary markedly in their specific weights, their insulating qualities, and other physical characteristics. In general, this type of heat insulating material may be divided into the following groups, according to the basic constituent:

(*a*) Asbestos cements.
(*b*) Diatomaceous earth cements.
(*c*) Mineral and slag wool cements.

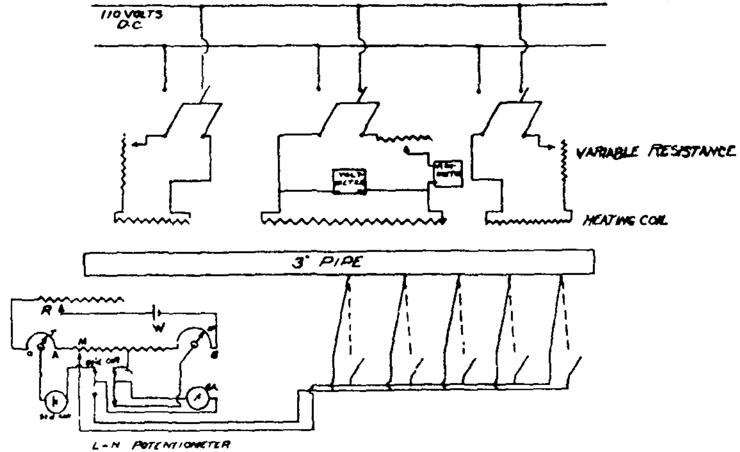
Although varying greatly among themselves in heat conductivity and weight, they are generally higher than the molded pipe covering in both respects.

The suitability of the material for patchwork, where other materials can not be employed, justifies its use at a sacrifice of heat protection and weight, within certain limits.

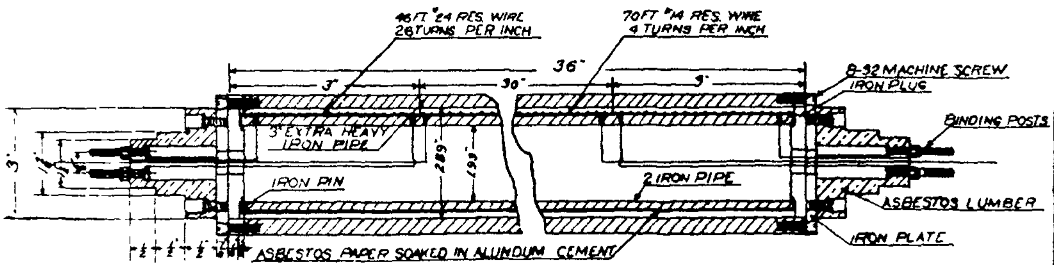
From among these four categories of high temperature pipe insulating materials, the Navy selects by means of "approval tests" the materials which best meet the Service requirements. Materials which pass the specified tests are placed on the Bureau of Engineering Approved List of Insulating Materials. Approval is based on tests conducted at the U. S. Naval Engineering Experiment Station at Annapolis. The approval test consists of a thorough investigation of the suitability of the material for use as a pipe covering on board ship. Tests are conducted to determine shrinkage and loss of weight under heats as high as 1500 degrees F.; resistance to erosion and vibration; tendency to absorb and retain moisture; and change in hardness after heating to 1200 degrees F. These tests are all designed to insure that the covering will have a satisfactory structure to meet all conditions of service. They have only a general bearing on insulating qualities. The true value of the material as a heat insulator is dependent on its heat conductivity and is determined on the Pipe Test Apparatus.

The Pipe Test Apparatus, Figure 2, which was built at this Station in 1925, consists of a 36-inch section of 3-inch standard wrought iron pipe, to which the covering under test is applied. Inside of this pipe there are three heating coils wound around an insulated 2-inch steel pipe of the same length. Two of the coils are so wound that each covers a 3-inch end section of the 2-inch pipe. The third coil covers the 30-inch middle section. The 2-inch pipe, on which the coils are mounted, is centered in the 3-inch pipe and the ends of the 3-inch pipe are closed with insulating discs.

A variable resistance connected in series with each coil affords means of regulating the heat supplied to each coil. The power input to each coil is adjusted until the temperature of the pipe over the end coils is the same as that over the central coil. Hence, corrections for end losses are eliminated and the heat supplied to the central coil is dissipated radially through the central 30-inch section of the covering. Iron constantan-thermocouples are used for measuring the temperatures of the inner and outer



WIRING DIAGRAM OF TESTING APPARATUS



APPARATUS FOR TESTING HEAT INSULATING PIPE COVERING MATERIAL

UNITED STATES NAVAL ENGINEERING EXPERIMENT STATION
ANNAPOLIS, MD.

APPROVED
OFFICER IN CHARGE

SCALE
DATE
DRAWN BY LWH
TRACED BY RBP
CHECKED BY WPS

3	9	3198

FIGURE 2

surfaces of the covering. The power input to the central heating coil is computed from voltmeter and ammeter readings. The heat loss through the cover is expressed in B.t.u.'s per hour per square foot per degree Fahrenheit temperature difference (pipe to room). A heat loss curve for the material under test is developed by making runs at several different pipe temperatures, *viz.*, 400, 600, 800 and 1000 degrees F. The heat loss curve represents the B.t.u.'s lost per square foot of pipe surface per hour per degree F. temperature difference (pipe to room) for the particular thickness of material under test at any temperature difference over the range of the curve. It does not give any information regarding the heat losses to be expected when using other thicknesses of the same material on the same or different pipes. But, from the results of this test, the conductivity of the material can be determined mathematically. Using this conductivity, the losses to be expected from all sizes of pipes and all thicknesses of cover at any pipe temperature may be calculated.

The conductivity of the pipe covering material is determined by formula from the results of the heat loss test, as follows:

$$h = \frac{k\ (T_1 - T_2)}{r_1 \log_e \frac{r_2}{r_1}} \qquad . \quad . \quad . \qquad (1)$$

h = heat loss, B.t.u.'s per square foot pipe surface per degree F. temperature difference (pipe to room).

k = heat conductivity of material.

T_1 = pipe temperature, degrees F.

T_2 = cover temperature, degrees F.

r_1 = inside radius of cover (3.3 inches on Pipe Test Apparatus).

r_2 = outside radius of cover (6.3 inches on Pipe Test Apparatus).

The conductivity of insulating cements is determined in the Flat Plate Testing Apparatus, Figure 3, on a molded disc of the materials. This apparatus consists essentially of a round heater plate, 8 inches in diameter, to each side of which is applied a similar shaped, 1-inch thick disc of the material to be tested. To the outer surface of each test disc there is applied a similar disc of

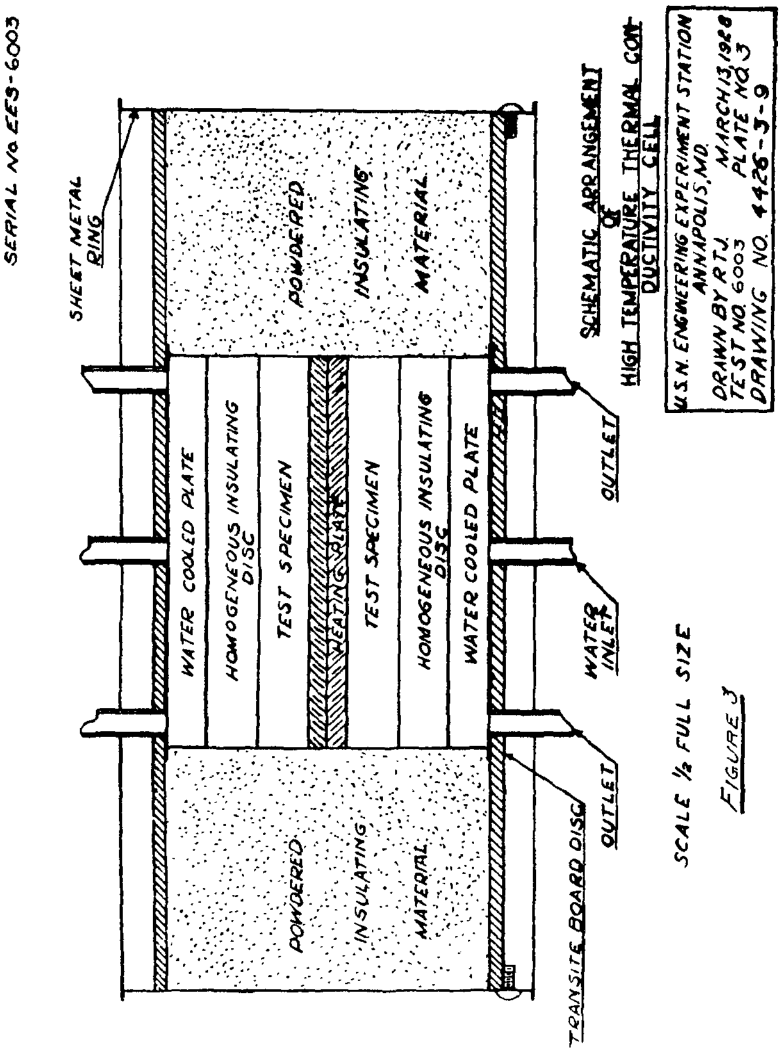

SERIAL No EES-6003
SHEET METAL RING
POWDERED INSULATING MATERIAL
WATER COOLED PLATE
HOMOGENEOUS INSULATING DISC
TEST SPECIMEN
HEATING PLATE
TEST SPECIMEN
HOMOGENEOUS INSULATING DISC
WATER COOLED PLATE
POWDERED INSULATING MATERIAL
TRANSITE BOARD DISC
OUTLET
WATER INLET
OUTLET
SCHEMATIC ARRANGEMENT OF HIGH TEMPERATURE THERMAL CONDUCTIVITY CELL
U.S.N. ENGINEERING EXPERIMENT STATION ANNAPOLIS, MD.
DRAWN BY R.T.J. MARCH 13, 1928
TEST NO. 6003 PLATE NO. 3
DRAWING NO. 4426-3-9
SCALE ½ FULL SIZE

FIGURE 3

homogenous insulating material. To the outer surface of each homogenous insulating disc there is applied a water cooled plate of the same diameter. The entire assemblage of heater plate, test pieces, homogenous material, and cooler plates is supported in a vertical pile in a sheet metal receptacle and packed with diatomaceous earth.

The method of eliminating end, or edge, losses is much the same as that employed in the pipe test apparatus. Electrical energy is supplied to the heater plate by two coils. One of these coils heats the central 6-inch diameter area of the plate and the other heats the outer 1-inch rim. Thermocouples indicate the temperature at different points across the face of the plate and at the outer face of the test discs. When the temperature across the face of the heater plate is constant at all points, it is assumed that all the heat supplied to the central heating coil is being dissipated through the test discs. In order to minimize the effect of losses through the edges of the test discs themselves, temperature measurements for calculation of conductivity are taken from only the central 4-inch diameter area of the plate and test discs. The input to the 4-inch central section of the 6-inch heating coil is measured by wattmeter.

The conductivity of the material is calculated as the B.t.u.'s per hour per square foot per inch thickness per degree F. of mean temperature (from face to face of the test discs). The conductivity curve of the material is determined by making runs at 500, 700, 900, 1100, 1300, 1500 and 1800 degrees F. The conductivity of the material under test is plotted against the mean temperature of the high and low temperature faces. For flat surfaces:

$$h = \frac{k\ (T_1 - T_2)}{x} \quad . \quad . \quad . \quad (2)$$

T_1 = temperature of inner face.
T_2 = temperature of outer face.
x = thickness of material, inches.

In testing high temperature molded coverings on the Pipe Test Apparatus, two layers of the high temperature material are used. Combination covers are not tested because the conductivity so determined would apply only to that particular set-up and would not be the conductivity of the high temperature covering alone. However, it is possible to compare heat losses through combination covers with those through homogeneous covers without further practical tests. The method of computation is beyond the scope of this article.

In Figure 1 are delineated the bands of conductivity curves of the four different categories of pipe covering materials as deter-

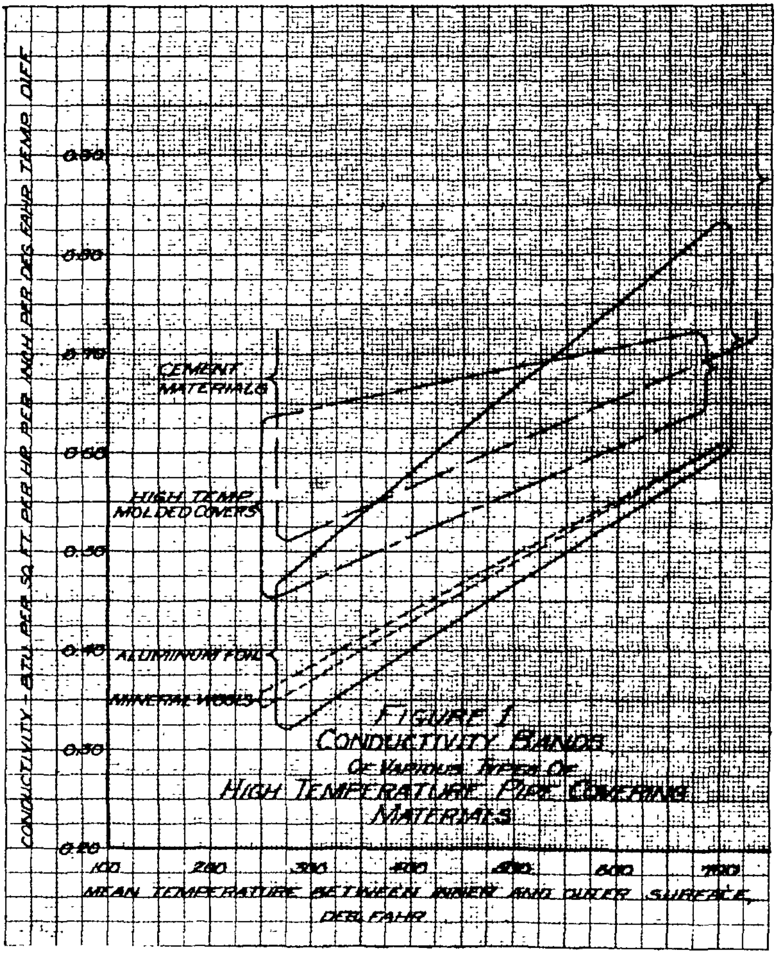


FIGURE 1
CONDUCTIVITY BANDS OF VARIOUS TYPES OF HIGH TEMPERATURE PIPE COVERING MATERIALS

mined on the 3-inch Pipe Test Apparatus and the Flat Plate Testing Apparatus at the Engineering Experiment Station. These results studied in conjunction with the physical tests for structural strength, moisture absorption, resistance to change under heat, etc., constitute the basis for approval or disapproval of heat insulating materials submitted for use in the Naval Service.

PRESSURE DROP THROUGH A 10½-INCH BORE, BUREAU DESIGN, GLOBE VALVE.

By Mason S. Noyes, Member.*

The cost of maintaining steam stop valves, on vessels of the fleet, in satisfactory operating condition became so excessively high about six years ago, that the Bureau of Engineering decided to investigate the design of the valves then in service, with the view of developing an improved design, as free as possible from all features contributory to the difficulties experienced.

The task of developing the new design was assigned to the mechanical drafting section of the Bureau. A careful and thorough study of the problem was made, including an investigation of the best commercial practice. The Bureau was greatly aided in its work by the lively interest and cooperation of several leading valve manufacturers, who made many valuable suggestions.

The principal requirements for the new design were:

(1) A compact and rigid body of a shape that would expand uniformly in all directions and not distort at the operating pressure and temperature, or due to the force applied through the stem when closing the valve.

(2) A disk of rigid construction to prevent warping, positively guided throughout its travel to assure proper seating.

(3) A high lift for the disk to assure ample steam passage.

(4) A steam flow through the valve as free as practicable from abrupt changes in direction.

(5) Some form of differential gear for operating the larger valves, in order to assure sufficient seating force for tightness.

The work on the design culminated several years later in a series of valves for 300 pounds per square inch, gage, maximum working steam pressure and 750 degrees F. total temperature,

* Design Division, Bureau of Engineering