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Heat Insulating Material
for
Electrically Heated Apparatus

HEAT INSULATING MATERIALS FOR ELECTRICALLY HEATED APPARATUS. [1]

BY J. C. Woodson [2]

INTRODUCTION

Heat and heat processes enter into practically every form of manufacture and the industry is indeed scarce that does not somewhere in its organization, utilize this form of energy to fashion or perfect its product. This has been true of industry since its inception, yet only within the last two decades has there been any real effort to conserve or reduce the heat lost in these processes. Even today, there is very limited data available on the subject of heat insulating material, except for certain specific temperatures and under conditions which do not necessarily hold for other conditions.

While the attempt will be made in this paper to be as general as possible on this subject, attention is called to the fact that most of the data and curves given refer to heat insulating material used in connection with electrically heated apparatus. It is vital and absolutely necessary to conserve all the heat possible with such apparatus, which also requires careful attention to other characteristics of insulating material ordinarily considered unimportant. The rapid and

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almost phenomenal increase in the commercial use of electrically heated apparatus, ovens, furnaces and machines, indicates that all other forms of heat and heat treatment will sooner or later be supplanted, to a large extent, by electric heat. This change is now and will continue to be, dependent, to a greater or less degree, upon the available heat insulating mediums and the ability of engineers and manufacturers to apply them properly.

TEMPERATURE RANGES CONSIDERED.

Low temperatures, such as 80° F. (27°C.) or lower will be considered only briefly, and for convenience we will divide our temperature ranges into the 5 divisions shown in Table 1.

TABLE 1.

Division	Range	Application
1	0° to 200° F. -18° to 93° C.	Refrigeration, cooling, water heating, drying, presses, air heating, various liquids.
2	200° to 350° F. 93° to 177° C.	Steam pipes, drying, color enamel, presses, baking.
3	350° to 600° F. 177° to 315° C.	Japanning, core baking, bread baking, presses, appliances, liquids.
4	600° to 1,000° F. 315° to 538° C.	Tempering, annealing, solder, babbitt, tin melting.
5	1,000° to 2,000° F. 538° to 1,093° C.	Heat treating, drawing, forging, melting, enameling.

To cover these five ranges, there are numerous commercial grades of insulating material of various trade names and ratings; a great many for divisions one and two and tapering off to only two or three reliable grades for division five. Practically all of these commercial grades can be located in three classes by fundamental composition as stated in Table 11.

TABLE 11.

CLASS	DIVISION	COMPOSITION
A	1	Hair, wool, felt, wood pulp, animal and vegetable fiber, asbestos paper, cork.
B	2,3,4	Asbestos, magnesia, sponge, earths, mineral wool.
C	4,5	Diatomaceous earth, mineral wool, earths, silicates.

From this Table, it is evident that there is no clear or definite dividing line between either the temperature division or the classes by composition, as there is a certain amount of overlapping. Certain combinations of these fundamental ingredients also produce distinct grades of insulation, entirely different from any of the component parts. Also, certain ingredients are used in one class as insulating material, and in another class as a mechanical binder or strengthener of the true insulation, such as asbestos in Classes B and C and mineral wool in class C.

There are numerous qualities desired in heat insulating materials and different applications require different qualities, but in general a good heat insulating material should have the following characteristics.

1. Low heat conductivity.
2. Low specific heat.
3. Low specific gravity.
4. Non-inflammable.
5. Strong and durable mechanically.

Low conductivity to reduce radiation losses; low specific heat to save as much power in heating up period as possible and make apparatus faster; low specific gravity to keep down unnecessary weight and save heating up power as No. 2; non-inflammable as most insulations are subjected to periodic or locally high temperatures; No. 5, for length of life and reliability.

Other attributes to be desired are:

6. Electrical non-conduction.
7. Have no chemical action on metals.
8. Easily shaped or formed.
9. Permanent in setting (no shifting or settling.)
10. Impervious to action of liquids, (water, acids, oil) [3]

Practically all commercial insulations have most of these qualities in some degree, the two last being the ones most often left out. In the writer's experience, No. 10 is not attained by any present day insulations; though several grades will stand drenching in water and after being thoroughly dried prove to be practically as good as ever. However, while still wet, this insulation is almost useless.[3]

An evacuated space is the best thermal insulator of conducted heat known, while gases under certain conditions are probably next. Air is a good insulator if it can be entrapped in small enough spaces to prevent convection currents, and to this fact and arrangement most present day heat insulators owe their value as such. This minute honey-combing of the structure places multitudes of confined dead air spaces in series opposing the heat flow, with only minute point contact of the material fibers or crystals for direct conduction.

[3] Weidlein, Chem. and Met. Eng., 24,295,(1921)

Heat transfer by radiation through insulating material is problematical, as these radiations are stopped by the insulation and the heat carried by conduction; or with some insulations the rays are to a certain extent refracted so that the penetration is relatively shallow. At temperatures beginning with 300°C this characteristic is important.

The law of heat flow through resisting materials is analagous to Ohm's law for electrical circuits, expressed as $I=E/R$ where I is the current, R the resistance and E the voltage pressure or difference between two points. Likewise the amount of heat flowing between two points of different temperatures can be expressed as

$$W=\frac{Td}{R} \qquad (1)$$

where W is watts flowing as heat, Td is temperature difference and R is the thermal resistance of the path of flow. This means that the rate of heat flow is directly proportional to the resistance of the path or material composing the thermal circuit.

From the above, it follows at

$$R=\frac{Td}{W} \qquad (2)$$

In formulas 1 and 2, Td is expressed in °C. R is the total thermal resistance of the circuit. Therefore

$$R = \frac{L}{A} . r = \frac{L}{A} . \frac{1}{c} \qquad (3)$$

Where

R= total resistance of circuit in thermal ohms

L= length of circuit in inches

A= area of path in sq. in.

r= specific resistance of circuit in thermal ohms per inch cube

c= thermal conductivity in watts per inch cube per c° (r= 1/c)

By substituting in formula No. 1, we have

$$W = \frac{A}{L} . \frac{Td}{r} = \frac{A}{L} .c. Td \text{ (4)} \qquad (4)$$

Where W is watts flowing per unit of time. Tables 111, 1V, and V, give the values of r for a number of building and insulating materials.

The above simple formulae are little recognized and seldom used, due to the many awkward and arbitrary units ordinarily used by engineers, so that while the rule remains simple, the means of applying and using it are often complicated and involved, In this country, the usual unit used is the

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4 C.P. Randolph, Trans. Am. Electrochem. Soc. 21,545 (1912)

British thermal unit, and the method of expressing heat flow is given by the equation

$$Q= KAt \left(\frac{T_1 - T_2}{th} \right) \qquad (5)$$

Where Q is the quantity of heat flowing through a path of area A in time "t" the length of the path is "th" with a temperature difference of $T_1 - T_2$. K is the coefficient of thermal conductivity of the material of the circuit. These units are ordinarily expressed as follows:

Q = B. t. u. transmitted

A = sq. ft.

t = hours

th = inches

$T_1 - T_2$ = F°

K = B. t.u. per sq. ft., per inch of thickness, per hr., per °F. temperature difference.

TABLE 111.

Material	Density lb. per cu.ft.	Spec. Heat	K B.t.u. per Sq. ft. etc.	R Thermal ohms per cu.in.	At Temp. °F.	Authority
r	0.08	0.240	0.175	1560.0	77	Van Dusen
r-cel asbestos	8.8	0.281	0.500	546.0	77	Van Dusen
lsa wood	7.5		0.350	780.0	77	Van Dusen
bot quilt	13.0		0.321	851.0	77	Van Dusen
lorox	4.0		0.221	1235.0	77	Van Dusen
rk board	6.9	0.44	0.279	979.0	77	Van Dusen
tton wool	7.0	0.362	0.291	938.0	77	Van Dusen
press wood	29.0		0.666	410.0	77	Van Dusen
derdown	6.77		0.1345	2030.0	212	Randolph
derdown	0.134		0.438	623.0	212	Randolph
brofelt	11.3		0.329	830.0	77	Van Dusen
mco thermalite	17.0	0.20	0.272	1013.0	93	General Ins.and Mfg.Co.
ound cork	9. 4	0.48	0.296	923.0	77	Van Dusen
ir felt	17.0	0.40	0.246	1110.0	77	Van Dusen
rd maple (wood)	44.0		1.124	242.3	77	Van Dusen
sulite	11.9		0.296	923.0	77	Van Dusen
pok	0.88		0.237	1151.0	77	Van Dusen
ystone hair felt	13.0	0.40	0.271	1008.0	77	Van Dusen
nofelt	11.3		0.300	910.0	77	Van Dusen
th Board	12.5	0.32	0.379	721.0	77	Van Dusen
hogany wood	10.3	0.50	0.304	898.0	150	Armstrong Cork and Insulation Co.
npareil corkboard	34.0		0.916	298.0	77	Van Dusen
k wood	38.0	0.57	1,000	273.0	77	Van Dusen
lp board			0.458	596.0	77	Van Dusen
manit (charred silk)			0.274	996.0	300	Stott
eep's wool	6.9		0.246	1110.0	300	Van Dusen
r-paper roofing	55.0		0.708	386.0	300	Van Dusen
cuum			0.041	6666.0	300	Van Dusen
rginia Pine	34.0		0.958	285.0	300	Van Dusen
ite pine	32.0	0.67	0.792	345.0	300	Van Dusen
ol felt	21.0	0.39	0.363	752.5	300	Van Dusen

TABLE IV

Material	Density Lb.per cu.ft.	Spec. Heat	K B.t.u. per sq.ft. etc.	R Thermal Ohms per cu. in.	At Temp. °F	Authority
Air-cel asbestos	8.8	0.292	0.500	546.0	77	Van Dusen
Air-cel asbestos	15.3		0.693	399.0	0 to 392	Randolph
Asbestos felt	30 to 40		0.549	497.0	400	Franklin Mfg.C
Asbestos fiber	12.5 to 18.7		0.608 to 0.497	449.0 to 548.0	932	Randolph
Asbestos fire felt	37.3		1.093	249.0	370	McMillan
Asbestos lumber	123.0		2.710	100.5		Van Dusen
Asbestos Mill board	61.0		0.833	328.0		Van Dusen
Asbestos paper	50 to 70	0.300	1.250	218.5	150	Marks
Asbestos sponge felted			0.509	537.0	400	Stott
Asbestos sponge felted	34.4		0.329	830.0	392	Randolph
Carey Carocel			0.540	506.0	370	McMillan
Carey Duplex			0.636	429.0	370	McMillan
Carey 85% Magnesia	18.0		0.546	500.0	370	McMillan
Carey 85% magnesia	15 to 24	0.312	0.500	546.0	300	Wiedlien
Carey 85% magnesia	13 to 24	0.312	0.585	467.0	600	Wiedlien
Carey serrated			0.682	401.0	370	McMillan
Celite powder	10.6	0.239	0.309	883.0	77	Van Dusen
Diatomaceous earth and asbestos	20.7		0.497	549.0	0 to 750	Randolph
85% magnesia	13.5		0.455	600.0	0 to 750	Randolph
Fire felt roll	43.0		0.624	438.0	77	Van Dusen
Fire felt sheets	26.0		0.583	468.0	77	Van Dusen
Fullers earth	33.0		0.708	336.0	77	Van Dusen
Gypsum plaster	56.0	0.26	2.250	121.4	77	Van Dusen
Insulex	20.0		0.916	298.0	77	Van Dusen
J.M.Asbestocel		0.281	0.549	497.0	400	McMillan
J.M. Asbestos sponge felted	12.0 42.0		0.468	583.0	370	McMillan
J.M. 85% magnesia	13 to 16	0.312	0.507	538.0	370	McMillan
J.M. 85% magnesia	16.8		0.444	615.0	470	J.M.Co.
J.M.fine corrugated asbestos	15.6		0.538	507.0	470	J.M.Co.
J.M.Indented			0.666	409.0	370	McMillan
J.M.moulded asbestos			0.778	351.0	370	McMillan
J.M.vitrobestos	21.6		1.087	251.0	370	McMillan
X & M air-cel asbestos	12.5		0.680	402.0	370	Stott
Laminated cork		0.48	0.433	631.0	400	Stott
Mineral wool	12.5	0.198	0.275	993.0	77	Van Dusen
Mineral wool	26.6	0.198	0.479	570.0	932	Randolph
Nonpareil H.P.	23.56	0.20	0.470	581.0	370	McMillan
Nonpareil H.P.block	27.0	0.20	0.543	502.5	370	McMillan
Plastic 85% magnesia			0.587	465.0	370	McMillan
Poplox	1.43		0.384	713.0	572	Randolph
Poplox	5.80		0.463	589.0	932	Randolph
Rock cork			0.350	780.0	77	Van Dusen
Sallmo wool felt			0.510	536.0	370	McMillan

TABLE IV (Continued)

Material	Denisty lb. per cu.ft.	Spec. Heat	K B.t.u. per sq.ft. etc.	R Thermal Ohms per cu.in.	At temp. °F	Authority
Silica	103.0		1.775	153.8	932	Randolph
Solid cork		0.45	0.418	653.0	400	Stott
Thermo fiber	10.0	0.20	0.320	853.0	200	F.D.Farnum and Co.
35% magnesia	29.9		0.569	480.0	0 to 750	Randolph
Vitrified Monarch block	40 to 45		0.842	324.0	400	Franklin Mfg.Co

TABLE V

Material	Density Lb. per cu. ft.	Spec. Heat	K B.t.u. per Sq.ft. etc.	r Thermal ohms per cu. in.	At Temp. °F	Authority
Alundum brick	127 to 149		7.26 to 4.03	37.5 to 67.7	1112	Randolph
Bauxite brick	119.0		9.41	29.0	1832	Randolph
Carborundum	129.0		40.8	6.69	2072	Randolph
Chromite brick	189.0	0.174	7.19 to 19.5	38.0 to 14.0	2072	Randolph
Concrete	170 to 180	0.20	6.38	42.8		McMillan
Feldspar			16.05	17.0	212	Randolph
Fire brick	111 to 178	0.253	10.1 to 13.4	27.0 22.0	2072	Randolph
Gas retort brick			11.03	24.7		Marks
Glass	150 to 170	0.18	7.00	39.0		McMillan
Glass			4.33	63.0	78	Randolph
Graphite brick	113.0		71.9	3.9		Randolph
Infusorial earth	43.0		0.583	468.0	77	Van Dusen
Insulbrix	36.0	0.19	0.84	325.0	1000	Quigley Fur. Spec.Co.
Iron	480.0	0.118	420.0	0.65		Marks
Lime stone	170.0	0.217	15.0	18.2		McMillan
Magnesia brick	125.0	0.324	17.05	16.0	2072	Randolph
Nonpareil brick	27.0	0.20	1.10	248.0	1600	Armstrong Cork Co.
Nonpareil brick	25.8	0.295	0.477	572.0	470	McMillan
Retort brick	116.0		10.95	24.9	2072	Randolph
Sand	110.0	0.195	2.70	101.0		McMillan
Silica brick	98.5	0.29	5.81	47.0	1832	Randolph
Silo-cel brick	30.0	0.225	0.67	407.0	470	McMillan
Silo-cel brick	31.0	0.2089	0.745	366.0	1600	Celite Prod. Co.
Silo-cel powder	12 to 15	0.2089	0.300	910.0	77	Celite Prod. Co.
White building brick	118.0		10.90	25.0	1832	Randolph

Many of the materials given in the Tables 111, 1V and V are not heat insulating materials in the ordinary sense of the term, but are given only for purposes of comparison. The authorities given refer to the value of K. K is expressed as B. t.u. per hour, per square foot, per inch of thickness, per °F. difference.

For flat surfaces of sufficient area so that the end or edge effect is relatively small, this formula can be used as given, though only approximately correct. McMillan gives this formula as

$$Q = \frac{ts - ta}{\frac{X}{k} + \frac{1}{a}} \qquad (6)$$

Where

Q = B. t.u. per sq.ft. per hr. transmitted

ts= temperature of hot surface, °F.

ta= temperature of surrounding air °F.

x= thickness of insulation in inches

a= surface transmission factor (1/a = surface resistance)

k= conductivity of material

This takes into account, not only the absolute mean conductivity of the insulation, but also the resistance that is offered by the surface of the material to the transmission of heat. This factor 1/a varies between wide limits, and has been determined for only a few materials, so that for ordinary calculations 0.5 is taken as the value of 1/a for still air conditions and a good grade of insulating material at medium temperature.

From formula No.5 it is evident that the factor $\frac{T_1 -- T_2}{th}$ is the determining variable, and expresses the rate of temperature drop with distance through the material, and its limiting value or dT/dth is the "temperature gradient" of any point in the path of flow, assuming that K is a true constant for the full thickness of the materials.

For cylindrical surfaces such as steam pipes, tanks, boilers, etc., it can be shown that the heat loss is equal to

$$Q = \frac{K (T_1 - T_2)}{R \log_e \frac{R_2}{R_1}} \qquad (7)$$

Where

R_1 is inside radius of covering in inches

R_2 is radius of outside of covering (or insulation) in inches.

R is outside radius of pipe in inches (usually taken equal to R_1 in above equation)

Q is rate of heat flow per in. B.t.u. per sq. ft. per hr.

T_1 is temperature of inside of pipe in °F.

T_2 is temperature of outside of insulation °F.

This is the formula generally used for all cylindrical surfaces and Table IV gives the value of K for a number of different insulations commonly used for such surfaces. T_2 is ordinarily taken as the temperature on the outside surface of the covering or even room temperature, whereas it actually refers to the temperature of the outside of the insulation, which for steam pipes would be under the canvas sheathing.

In the above formulae, numbers 4, 5, 7, etc, two assumptions are made which are not strictly correct; first, that K is constant in value throughout the thickness of the insulation, and second, that the value of K varies inversely with the thickness. The value of K varies with the temperature as shown in Fig. 1, so that it presents a curve between T_1 and T_2. It is a matter of common knowledge that the insulating value does not increase directly with the thickness, but so far no general law has been worked out. Stott[5] attempted this and states that for 85 per cent. magnesia, the law is

$$\frac{K_1}{K_2} = \frac{{}^{2}th_2}{{}^{2}th_1} \qquad (8)$$

[5] Power, 1902

Where K_1 and K_2 are the coefficients of conductivity and th_1 and th_2 are the thickness, while for every other material a different constant is required. These have not been accurately determined as yet. Fig. 2 shows this general relation for 85 per cent magnesia on flat surfaces. Stott's law will not hold for flat surfaces as it takes into account the increased radiating surface on a pipe or cylinder.

From the above, it will be seen that these two conditions tend to counteract each other, so that the result is a curve that will vary for each temperature and each insulating material. Common practice is to follow the inverse square root law for cylinders, and use a multiplier for flat surfaces, such as ovens, which really depend more upon the mechanical construction of the oven than upon the characteristics of the insulation. This multipler for formula No. 5 varies from 1.2 to 2.5, depending on conditions.

For many applications, such as medium temperature ovens and high temperature furnaces, it is customary to construct the walls of layers of different materials having different internal resistances. The heat loss from such a flat wall can be calculated by the following formula; using the notation and form of formula No.5 we have

$$Q = At \frac{T_1 - T_2}{\frac{th_1}{k_1} + \frac{th_2}{k_2} + \frac{thn}{kn}} \qquad (9)$$

where th is the thickness of the various layers and K the conductivity; or more accurately this is given by McMillan as

$$Q = \frac{ts - ta}{\frac{X_1}{K_1} + \frac{X_2}{K_2} + \frac{X_3}{K_3} + \dots + \frac{1}{a}} \qquad (10)$$

using the same notations as formula No. 6. For cylindrical surfaces this becomes

$$Q = \frac{ts - ta}{\frac{r_s \log_e r_2/r_1}{k_1} + \frac{r_s \log_e r_3/r_2}{k_2} + \dots + \frac{1}{a}} \qquad (11)$$

in which r_s is radius of outside surface of insulation r_1 is outside radius of cylinder and r_2 equals r_1 plus thickness of first layer of insulation, r_3 equals r_2 plus thickness of second layer, etc.

Application to Apparatus

The materials in Class A Table II are used successfully only for quite low temperature work, and due to this fact the heat loss is generally low regardless of insulation used. For this reason, little attention is paid to the proper selection and too often a few layers of asbestos paper is used, as this is easy to obtain almost anywhere. It has been shown that the heat loss from a bare bright tin pipe is less than from the same pipe covered with 7 layers of 0.025-inch (0.64 mm.) asbestos paper at approximately 180° F. (82°C.) in the pipe (Fig. 3)[6]. So it is obvious that it would be better economy to use some of the fibrous or spongy insulations given in Table III even though the first cost and cost of installation was higher than for the asbestos paper.

Class B, Table II, is by far the most important class, as most commercial and industrial applications fall within it. To meet this demand there are dozens of grades and brands of commercial insulations on the market. Table lV gives only a few representative grades of this class. Much care should be exercised in the selection of an insulation in this class, as many are good under certain conditions and poor under other conditions at the same temperatures. For instance some will stand

[6] University of Ill. Bulletin No. 117

soaking in water and when dried out are apparently as good as ever. Others disintegrate and fall to pieces under the action of water or any other liquid. Some grades will stand up and hold their place and position under continual jarring and vibration, others settle down and leak out of their retaining walls and leave an air space. So other considerations besides thermal characteristics are important, depending upon the particular application.[7]

In the application of these insulations to electrical apparatus, the largest per cent will go on tanks, boilers, etc., and on ovens, drying cabinets, etc. These are shown in figures 4 and 5. On the former the insulation is usually applied exactly as pipe covering, with an outer surface of canvas, while with ovens the insulation is ordinarily confined between two thin sheet metal walls. In building such ovens, care should be exercised so to construct them that there is a minimum of continuous through metal from inside to outside of the wall; that all joints are tight and well packed; and that the outer surface of the oven is one that does not radiate the conducted heat readily. Cases are on record of similar ovens in which one was finished in black iron and one in bright galvanized iron. At 500°F.(260°C.)

7 E.R. Weidlein, Chem. and Met.Eng. 24, 295, (1921)

the black oven showed a radiation loss 30 per cent greater than the galvanized oven. Other conditions may have contributed to this difference, but it is believed the different character of surface was the main cause, In ovens of several hundred square feet radiating surface, this is a feature to be watched closely.

As brought out previously, it is essential that the specific heat or heat absorbing power of an insulation be taken into considerations as well as its conductivity. Fig. 6 and 7 show curves of identical ovens, one with a commercial grade of mineral wool, the other with a commercial grade of aircel asbestos insulation. It will be noted that the former not only has a lower constant loss, but comes up to temperature more rapidly, thus storing less power to be lost when the oven is shut down at night.

Some of the insulating materials in Table V can be, and often are, used for temperatures as low as 300° F.(149°C.) but their real field lies in furnace work, where temperatures of 1,000 to 3,000°F. (538 to 1,650°C.) are encountered.

While these insulators will stand direct contact with the heating elements and temperatures of 2,000°F., it is better practice to line the inside of the furnace with a good grade of refractory fire brick, and place the insulating brick outside of these. As these insulating brick are not strong mechanically, a layer of building brick or red brick outside of them will protect them and insure permanent insulating value. Fig. 9 shows one of the large electrical furnaces insulated in this manner.

Due to the fact that the absolute mean conductivity of air is considerably lower than any present day commercial insulation, industrial plant engineers often try to increase the efficiency of furnaces and boiler settings by including air spaces in the walls. The results are invariably the opposite from those desired. This is due to the fact that even thin air spaces readily set up convection currents, and that the radiant heat leaps across the air space with little opposition, especially if the air space is close to the inside of the furnace.

Tests by the U.S.Bureau of Mines, proved that a wall of solid fire brick or building brick lost less heat than a similar wall with a 2-inch (51 mm.) air space enclosed in it.[8] Therefore, this practice is poor and should be abandoned entirely where medium and high temperatures are involved.

Conclusions.

While there are numerous grades of heat insulations on the market, there are none that can compare with electrical insulators. Of all the different grades, there are only a

8 Bureau of Mines Bulletin No. 8

few fundamentally different sorts, as some half dozen items will cover the raw materials successfully used. In all these materials the true insulation value lies almost entirely in the entrapped dead air spaces of their structure. The difference between grades then really goes back to the physical structure of the crystals or cells. This fact leads many engineers astray in the use, in furnace and oven walls, of air spaces, which actually increase rather than decrease the heat loss.

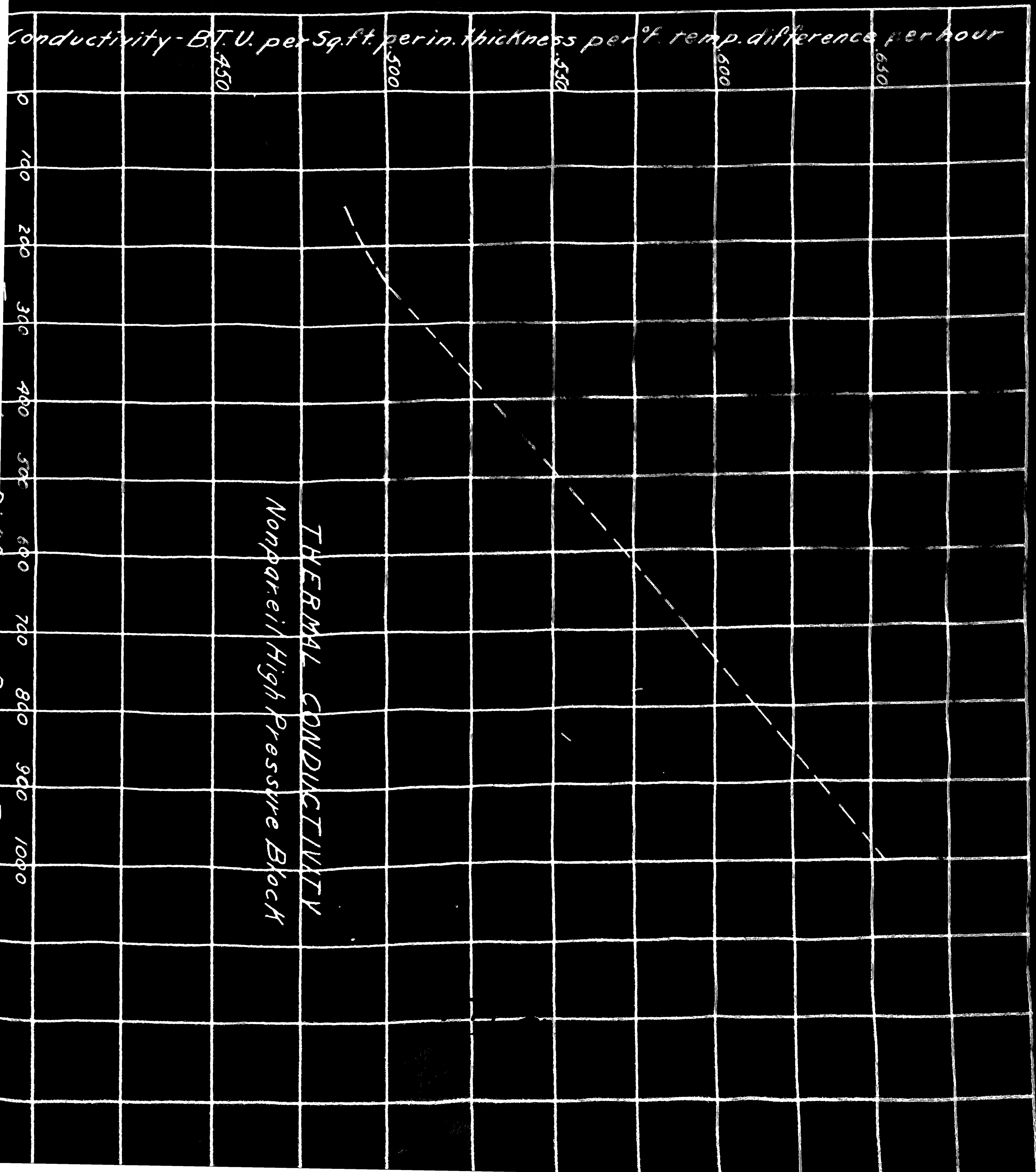
The application of poor insulation can have the same effect as the air spaces mentioned above, as shown by the University of Illinois in tests of asbestos paper on hot air pipes. See Fig. 2.

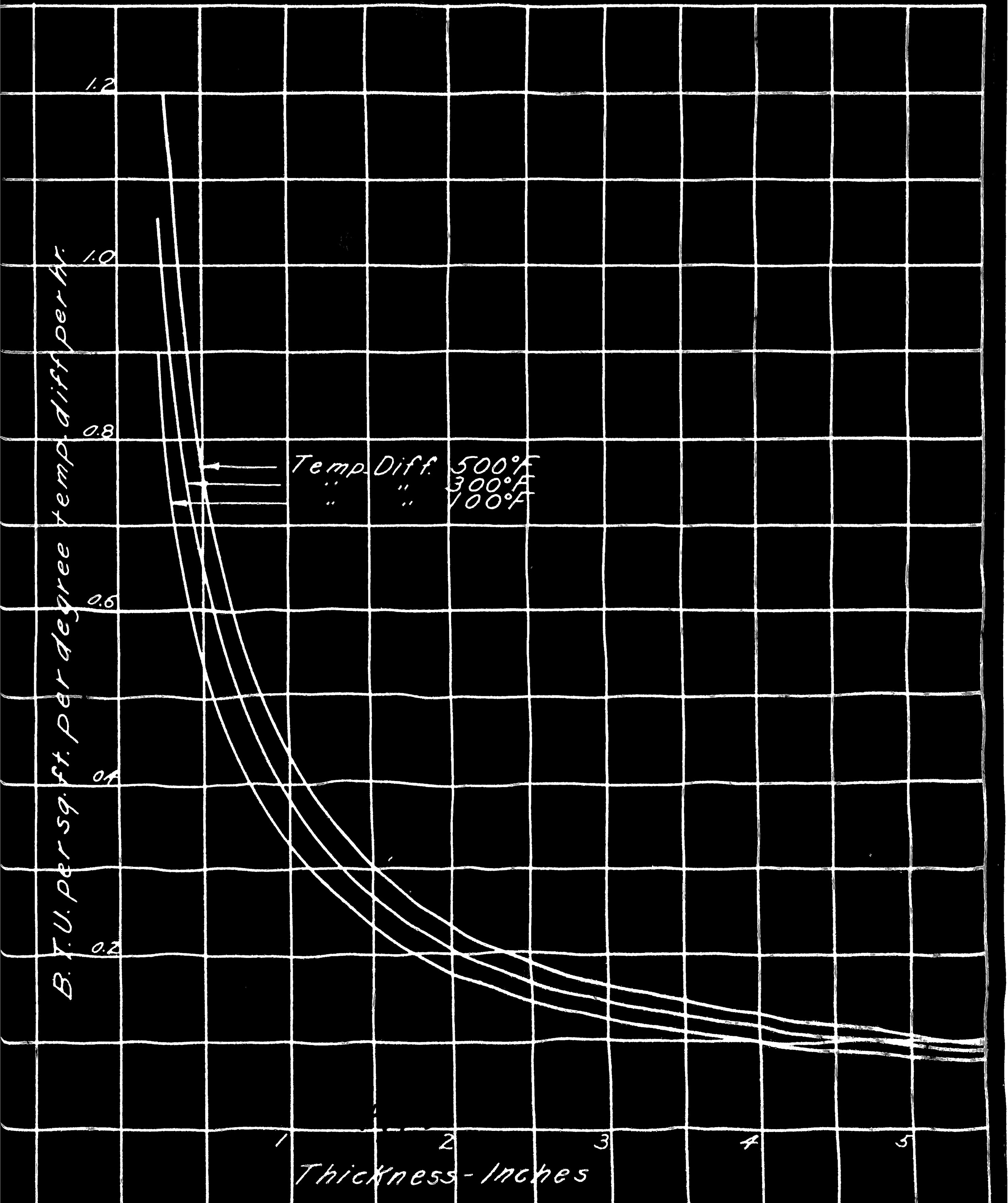
While the conductivity of an insulation is of primary importance, other thermal characteristics must be considered, such as specific heat and specific weight. The application also has to be considered with regard to the physical properties of the material.

The laws of heat flow are simple and follow closely those for electrical energy, but are little used or understood. This probably is due in part to the fact that there are few reliable data available on the subject, and of these the values given by different authors vary over wide limits.

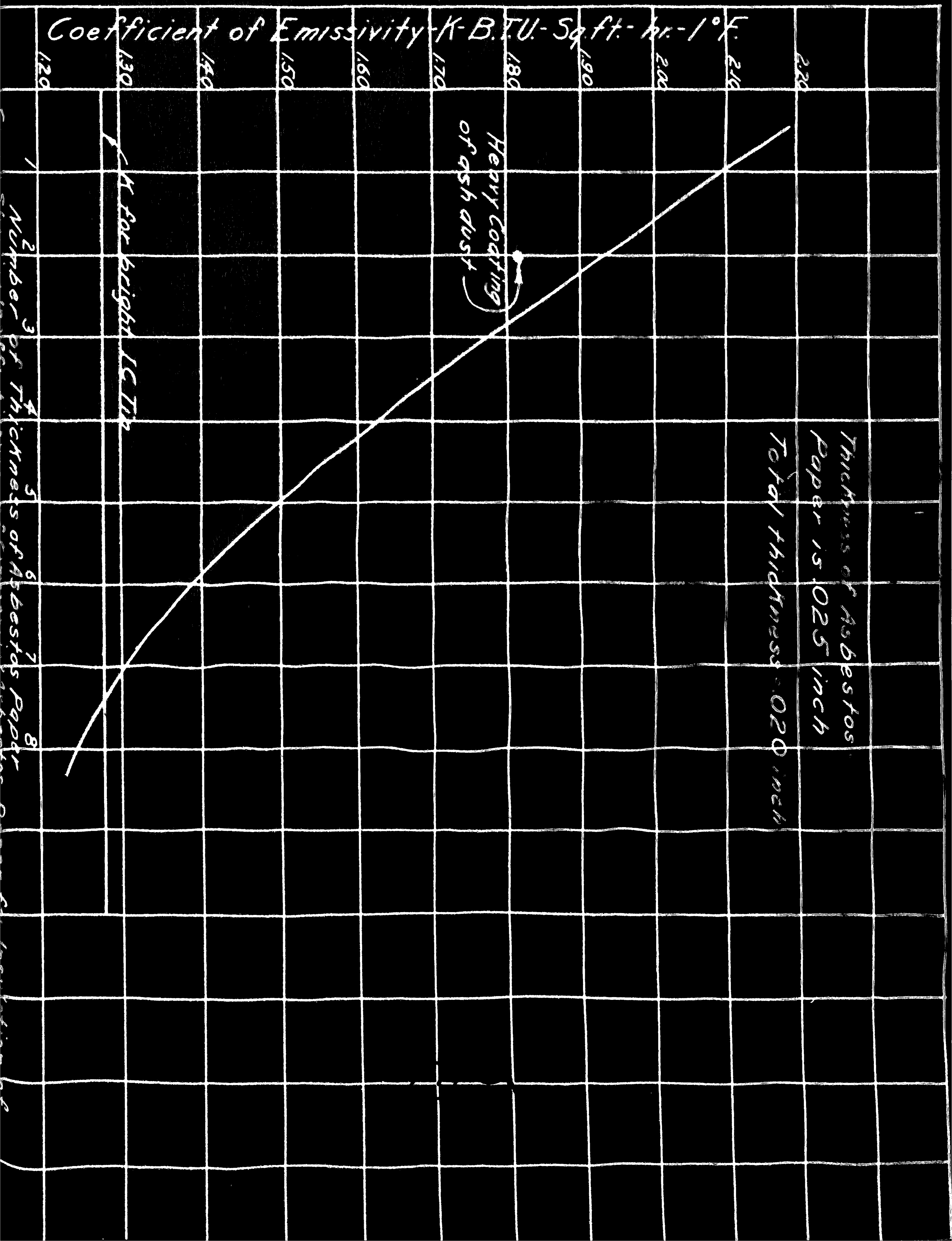
It is the writer's opinion that a great deal more research and development work should be done along the lines of heat insulation engineering, as we have about come to a stop and have accepted our present standards by saying "there is bound to be a certain amount of heat lost, and this is as good as we can do."

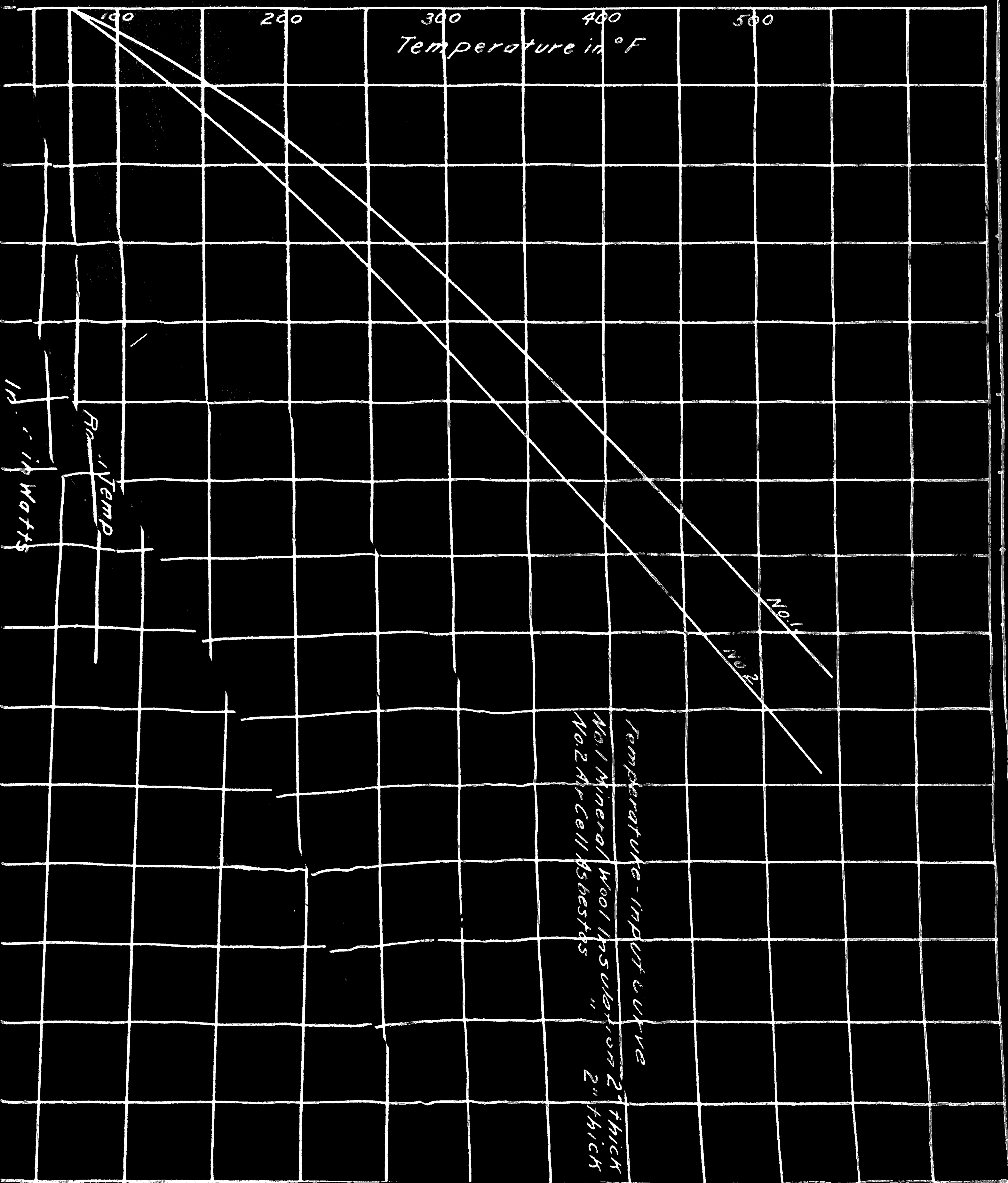
I believe that if there was a wider distribution of available data and a broader dissemination of the laws and character of heat flow and its prevention, it would help to conserve the national coal supply and result in better insulation methods being developed. The progress of electrically heated apparatus is dependent to a large extent upon the efficiency of its insulation, and warrants the keenest attention of electrical, chemical and mechanical engineers, as well as of heating and ventilating engineers.

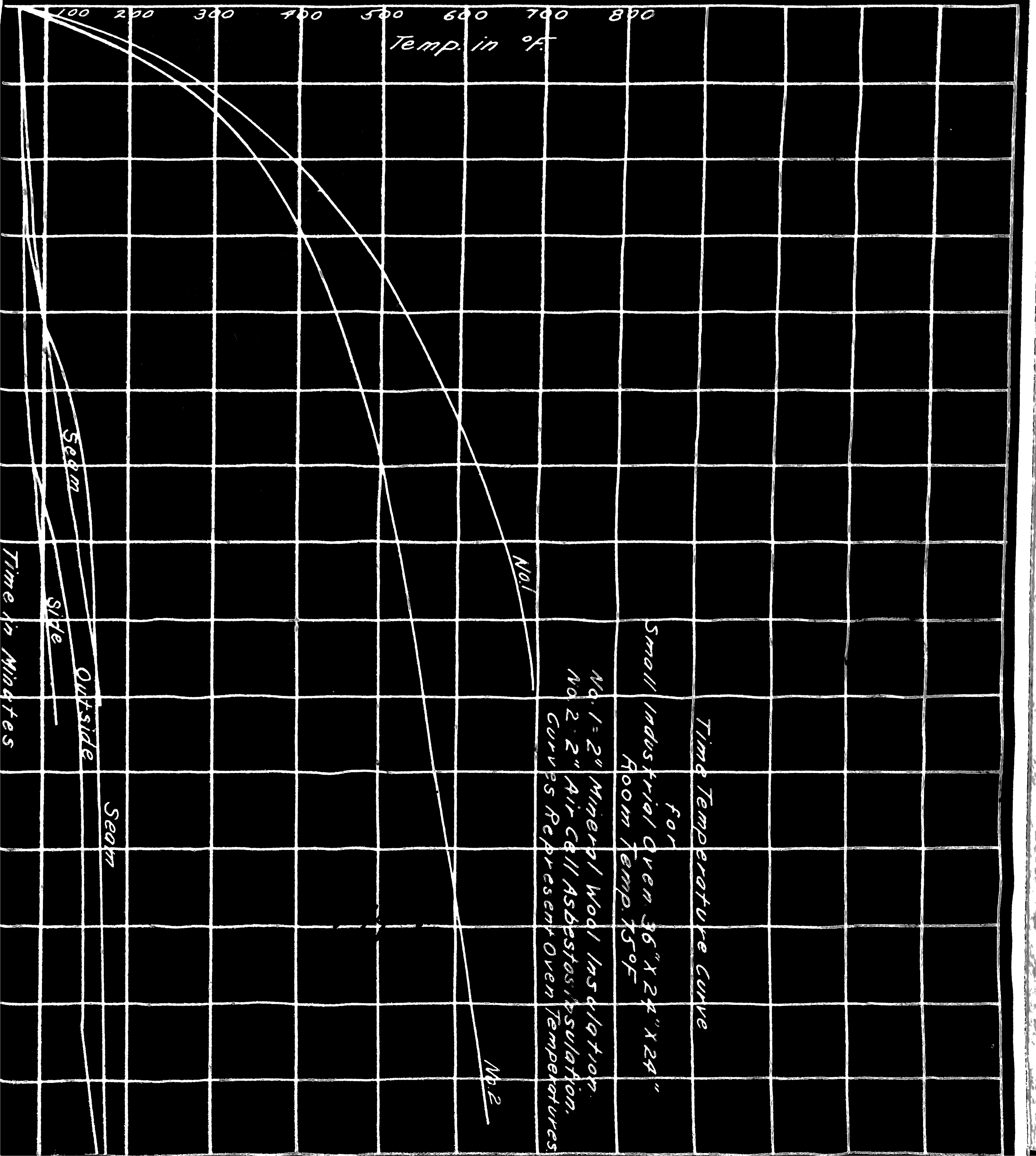

THERMAL CONDUCTIVITY
Nonpareil High Pressure Block



Variation of heat transmission for various thickness of material on flat surfaces.

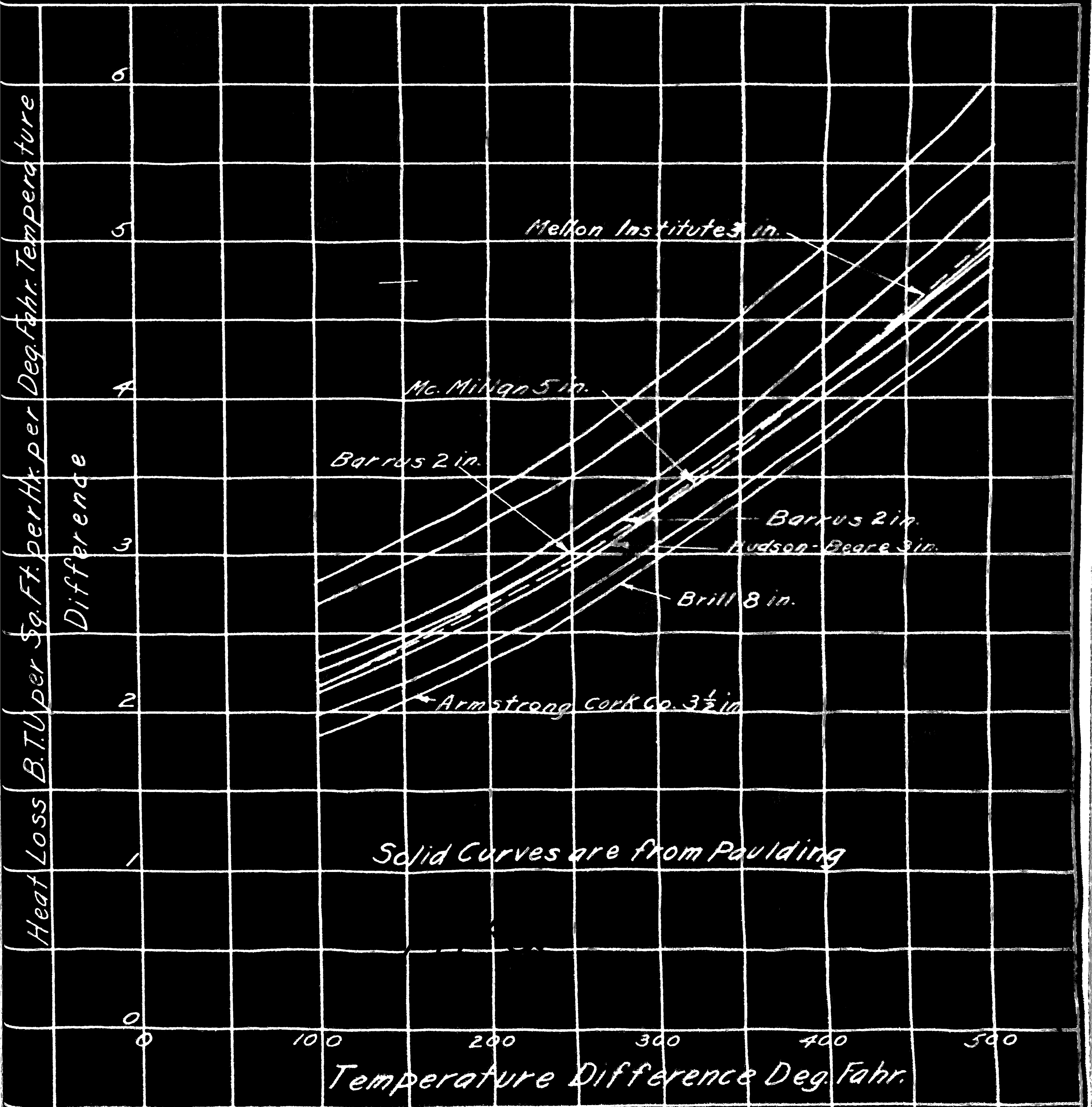

Coefficient of Emissivity-K-B.T.U.-Sq.ft.-hr.-1°F.
1.20
1.30
1.40
1.50
1.60
1.70
1.80
1.90
2.00
2.10
2.20
K for bright I.C. Tin
Heavy Coating of ash dust
1
2
3
4
5
6
7
8
Number of Thickness of Asbestos Paper
Thickness of Asbestos Paper is .025 inch
Total thickness .020 inch


100
200
300
400
500
Temperature in °F
In... in Watts
Ro... Temp
No.1
No.2
Temperature-input curve
No.1 Mineral Wool Insulation 2" thick
No.2 Air Cell Asbestos " 2" thick



Time Temperature Curve
for
Small Industrial Oven 36"x24"x24"
Room Temp. 75°F

No. 1 = 2" Mineral Wool Insulation.
No. 2 = 2" Air Cell Asbestos Insulation.
Curves Represent Oven Temperatures.



Heat Loss from Bare Pipe

Fig #4.

Fig #5.

C.S

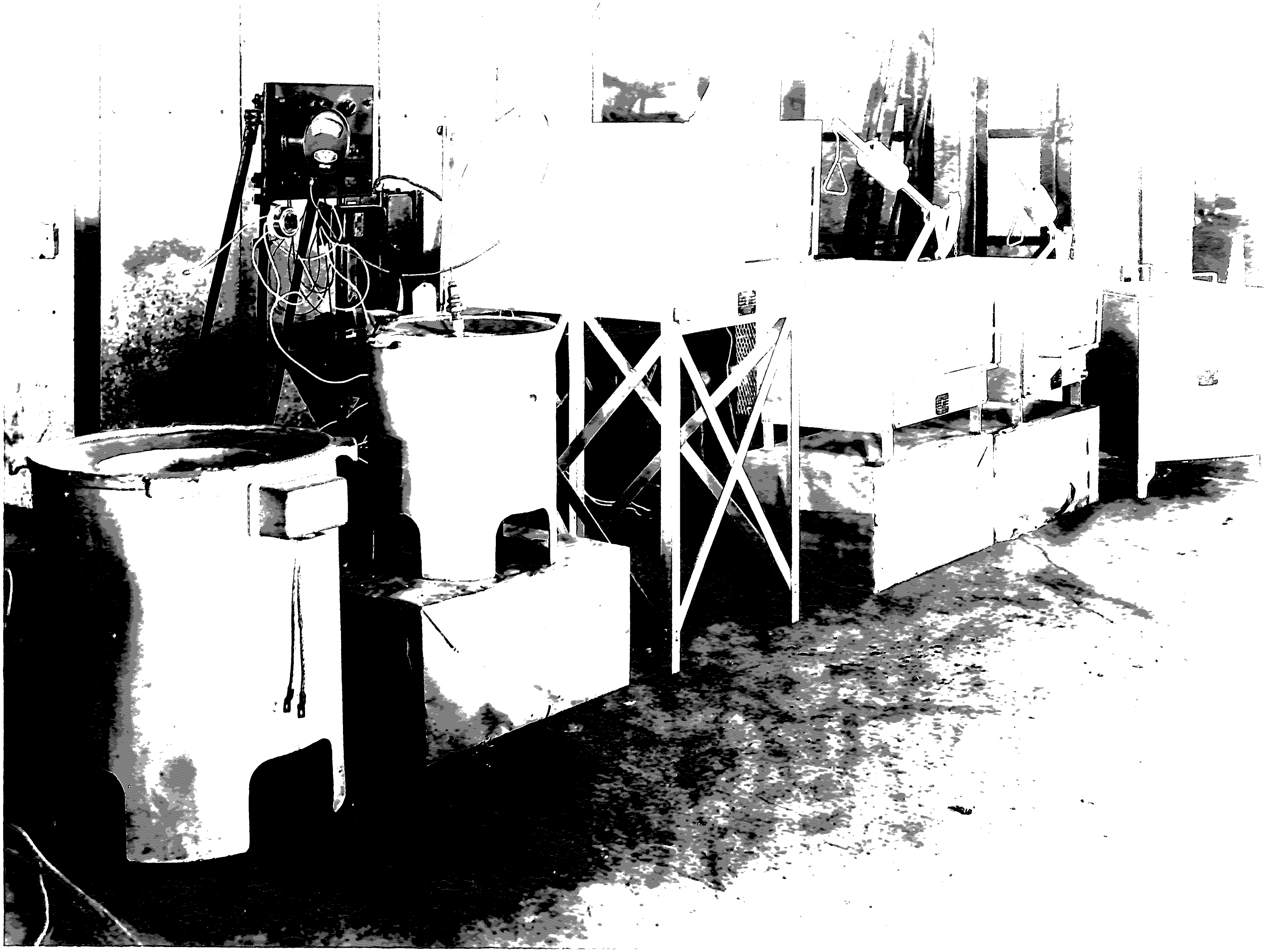


Fig #9.