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TITLE

The effect of elevated temperature on certain properties of "Fiberfrax" insulating material.

By

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OBJECT

To carry out a limited investigation on the changes in thermal conductivity and resilience of "Fiberfrax" insulation after exposure to elevated temperatures.

SUMMARY

Descriptive data on the material is quoted from the Carborundum Company literature. The effect of prior heating to elevated temperatures was determined by measuring the temperature drop through the material when the hot face was maintained at about 190°F. The thermal insulating property was slightly impaired. Embrittlement of the material also occurred.

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INTRODUCTION

The Ordnance Materials Research Office requested that an evaluation be made of an insulating fiber known as "Fiberfrax" made by the Carborundum Company of Perth Amboy, New Jersey. Certain claims have been made for the material, which indicate possible ordnance applications. A complete description of the material, quoted from Carborundum literature, is presented in Appendix A.

The chemical composition of Fiberfrax is approximately 50% Al_2O_3 and 50% SiO_2. The material is of refractory nature and chemically stable. The claim is made that the properties are unimpaired up to 2300°F and melting does not occur below 3000°F. The material is claimed to have good thermal and electrical insulating properties up to elevated temperatures.

Four pieces of Fiberfrax, 8½ x 11 inches were received at Watertown Arsenal Laboratory. Two of these were in the form of "blankets" about 3/8 inch thick, one was a batt about 1/8 inch thick and the other a batt less than 1/16 inch thick. Fiberfrax is also available as a bulk fiber. The material has the appearance of cotton, but with a lower sheen, harder texture and generally shorter fibers.

A limited study of the effect of elevated temperatures on the thermal and mechanical properties of the material was desired. Preliminary checking of ASTM method C177-45 for determining the thermal conductivity of insulating materials showed that the method was not suitable for the small amount of Fiberfrax available. Therefore, a simple semi-quantitative test of the insulation was devised. All tests made were in the vicinity of room temperature.

TEST PROCEDURE, RESULTS AND DISCUSSION

The blankets of Fiberfrax were cut into pieces $5\frac{1}{2}$ x $8\frac{1}{2}$ inches. These pieces were placed in a wooden frame resembling a picture frame and fastened to the outside of a large steel tank holding a steam heated water solution maintained at about 190°F. A chromel-alumel thermocouple of #28 gauge wire was placed in the center of one face of the insultion and in contact with the wall of the tank. Another similar thermocouple was placed on the surface of the insulation exposed to the open air. By measuring the temperature of these two thermocouples, the temperature drop across the insulation was determined.

The temperature drop across the Fiberfrax at a mean temperature of about 140°F was determined on the material in the as-received condition and again after heating to 2000°F for thirty minutes and air cooling. Successive determinations were made after heating the same pieces of Fiberfrax to 2100, 2200, 2300 and 2400°F, each for thirty minutes. Finally a determination was made after heating to 2300°F for 65 hours. The data were taken after allowing at least four hours heating time on the side of the tank in order to attain equilibrium conditions. At least ten readings were then taken over a period of about one hour. These were averaged. The largest probable error was calculated to be 0.3°F. A summary of the results obtained is as follows:

Treatment	Temperature Hot Face	Temperature Cold Face	Temperature Difference	Relative Thermal Resistance
As Received	197.2°F	86.4°F	142.9°F	1.000
2000°F 30 min.	190.8	85.1	137.7	.953
2100 "	191.3	90.2	133.5	.915
2200 "	192.9	91.4	133.7	.917
2300 "	188.8	87.8	132.8	.909
2400 "	186.0	88.2	128.8	.874
2300 65 hours	185.7	88.9	128.7	.871

The data indicate that at the completion of the heating cycles the insulating properties were decreased by about 13%. A decrease in weight of the batts of from three to five percent was found. The material was kept in a desiccator over-night before each weighing. No visible differences were noted upon microscopic examination after heating; however, considerable bleaching occurred.

The physical properties of the insulation suffered from the heating. Considerable shrinking and sagging were noted, even at 2000°F. After all the tests were completed, the insulation had shrunk to a piece 6 1/8 x 8 inches with a total thickness of about 3/4 inch. The sagging had caused a mechanical interlocking so that the pieces of the blanket could no longer be separated. The most disturbing consequence of the high temperature was the brittleness induced in the material. As received, the batts could be bent 180° without any breaking or tearing. After heating to 2000°F and cooling to room temperature, such a bend caused some separation of the fibers on the outside of the bend. After heating to 2200°F, such a bend caused a complete separation of fibers, and considerable breakage. After heating to 2400°F, any bending caused breakage of the fibers. The material crumbled easily after being heated to 2400°F.

APPENDIX A

INFORMATION AND DATA OBTAINED FROM CARBORUNDUM COMPANY LITERATURE CONCERNING FIBERFRAX

WHAT "FIBERFRAX" FIBER IS

Fiberfrax fiber is a new man-made ceramic fiber that offers industry an unusual and interesting combination of properties.

This new material is an aluminum-silicate fiber, made by melting aluminum oxide and silica in an electric furnace, then subjecting a molten stream of the material to an air blast. The stream is blown into a fluffy mass of fibers which is collected with special equipment.

PHYSICAL PROPERTIES

As blown, Fiberfrax fiber is a white, cotton-like mass made up of random arrangements of extremely fine fibers. The individual fibers are up to three inches in length, and have an average diameter of about four microns, or about one-fourth that of fine silk, one-twenty-fifth that of a human hair. Range in diameters is from 10 microns down to less than 1 micron.

Weight, as blown, is two pounds per cubic foot. The material can readily be compressed; a pressure of two pounds per square inch compresses it to a density of 12 pounds per cubic foot.

The material is resilient, which property is retained even after being subjected to high temperatures for long periods. Individual fibers appear to have sufficient strength and hardness to satisfy many application requirements.

As manufactured at present, there is a percentage of very fine shot found in the mass of fibers. With certain manufacturing techniques that are being improved rapidly, shot content is continually being reduced. The data given here, however, pertains to the mass as blown, including the pellets.

THERMAL PROPERTIES

High refractoriness is one of the outstanding characteristics of Fiberfrax ceramic fiber. It does not lose any of its properties to any appreciable degree at temperatures up to 2300 F, and it will not melt under

3000 F. These temperatures are far higher than mineral wools and glass fibers will stand. Unlike asbestos, these fibers do not disintegrate at elevated temperatures sustained for lengthy time periods.

The K factor (insulating value) for Fiberfrax fiber at the optimum density of six pounds per cubic foot, is shown by Figure 1. This is about the same as for rock or glass wools within the range of temperatures that these other materials will stand. It should be noted particularly that the curve is based on mean temperature which is the average of hot and cold face temperatures. This means, for example, that with a hot face of 2300 F and a cold face of 200 F, the mean temperature is 1250 F.

CHEMICAL STABILITY OF "FIBERFRAX" FIBER

The chemical composition of Fiberfrax fiber is approximately 50% alumina (aluminum oxide) and 50% silica. Like other ceramic materials, it is highly resistant to most acids. The following table shows the stability of Fiberfrax fiber in various acid solutions:

	% loss in weight when leached for 1 hour	
	Normal	Concentrated
Hydrochloric acid	0.34	0.28
Sulphuric acid	0.31	0.85
Phosphoric acid	0.28	0.50
Nitric acid	0.25	0.20
Acetic acid	0.16	0.27

"FIBERFRAX" FIBER AS A FILTER

The high efficiency of Fiberfrax fiber as a filter results from the extreme fineness, range of diameters, and the random arrangement. Filtering properties are retained even when the fiber is processed into paper.

A simple cigarette test, in which both cotton and Fiberfrax fiber are used as filters, will demonstrate the effectiveness of this new ceramic material. If the cotton is placed ahead of the Fiberfrax fiber, smoke will stain the cotton, but will stain the fiber even more. If the position is reversed, and the Fiberfrax filter placed ahead of the cotton, then smoke will stain the fiber heavily and the cotton will show no stain at all.

A Fiberfrax filter can handle either liquid or gaseous filtrates, regardless of temperature. It can also be purified or cleaned by baking or burning, since temperatures below about 2300 F do not affect its filtering characteristics. It can handle most acids because of its excellent chemical stability.

ELECTRICAL CHARACTERISTICS

The electrical properties of Fiberfrax fiber seem to be exceptional. Aluminum silicate is inherently an excellent insulator at all temperatures, and tests on paper made of Fiberfrax fiber indicate that not only is its high dielectric strength retained in paper form, but its electrical losses are some four times less than those of a good Kraft paper.

	a) 60 cycles	1.08
Dielectric Constant	b) 1000 cycles	1.08
	c) 10 kc	1.08
	a) 60 cycles	0.02
Power Factor (%)	b) 1000 cycles	0.02
	c) 10 kc	0.02
	a) 60 cycles	0.0002
Dielectric Loss Factor	b) 1000 cycles	0.0002
	c) 10 kc	0.0002
AIEE Insulation Class		C

AVAILABILITY

Present pilot-plant production of Fiberfrax fiber is adequate to supply all known experimental needs and to leave a substantial volume over for commercial applications.

At the current stage of development, Fiberfrax fiber is available only in the bulk form. Experimentally, it has been made into felted blanket rolls, firmly bonded batts, and papers. Work is under way to produce it in these forms commercially. It is anticipated that fiber will soon be available in a form suitable for spinning into yarns and fabrics possessing excellent dielectric properties and ability to withstand temperatures up to 2300°F.

AS A FILTERING MATERIAL

Fiberfrax fiber as now produced can compete directly with extremely fine glass fibers in applications such as filters. It has successfully and economically replaced diatomaceous earth in an oil-filtering application. Special Fiberfrax fiber compositions containing a minimum of neutron-trapping materials can be produced.

Because of its high resistance to most corrosive liquids and gases, it can be used as a filtering medium for acids, or as a diffusing medium. Because of its refractoriness, it has possible uses as a flame arrestor, or as a flame filter to remove ash, as in gas turbines.

AS A THERMAL INSULATION

Insulation tests show that Fiberfrax fiber, as compared to high-quality insulating brick, can make impressive savings. The following table shows comparative furnace efficiencies and weights in a test conducted with small furnaces at 2600 F.

LINING	lb / cu ft	Hrs to reach 2600 F	Average watts used to heat	Average watts required at equilibrium	Shell temp. °F	Lining wt. lbs.	Watt input % ratio cemented brick = 100
"FIBERFRAX" FIBER	6	3	7350	4168	410	37.2	69.8
"FIBERFRAX" FIBER	12	2 3/4	7677	3281	347	74.4	55.0
HIGH TEMPERATURE INSULATED BRICK - CEMENTED	44.2	6 1/3	7820	5969	448	[illegible]	100

The thermal properties have led to field tests of the material in blanket form as high-temperature insulation in combustion and exhaust systems of jet engines, where light weight and low thermal conductivity are distinct advantages.

Fiberfrax fiber might also have applications in fireproofing safes and containers; as a packing for expansion joints; as a cushion or support for materials being fired or heat treated at high temperatures; and in the form of paper, as fire curtains, fireproof records and similar applications.

AS A REPLACEMENT, STRENGTHENING OR REINFORCING MATERIAL

Fiberfrax fiber, since it is made from alumina and silica, both of which are plentiful, may find use as a replacement in whole or in part for natural asbestos - or for other fibers which require critical materials in their manufacture.

Fiberfrax fiber can be used in combination with many materials, with an improvement in over-all characteristics. As an example, it quite conceivably could be used to strengthen electrical insulators, to reinforce battery plates, or as a replacement for asbestos in brake linings. It has interesting possibilities as a filler in plastic molding compounds to increase dimensional stability and dielectric strength. It is expected that fibers offering advantages as a reinforcing agent for laminated plastics will soon be available. It might become the foundation for sprayed-on ceramic films or coatings, which would be baked at temperatures higher than non-ceramics can stand. Or it might be the base for sprayed or electrolytically deposited metals, particularly where a porous structure is desired. It would seem to have uses as a catalyst carrier or support for catalysts, particularly where corrosive liquids or gases are present or where high temperatures are involved.

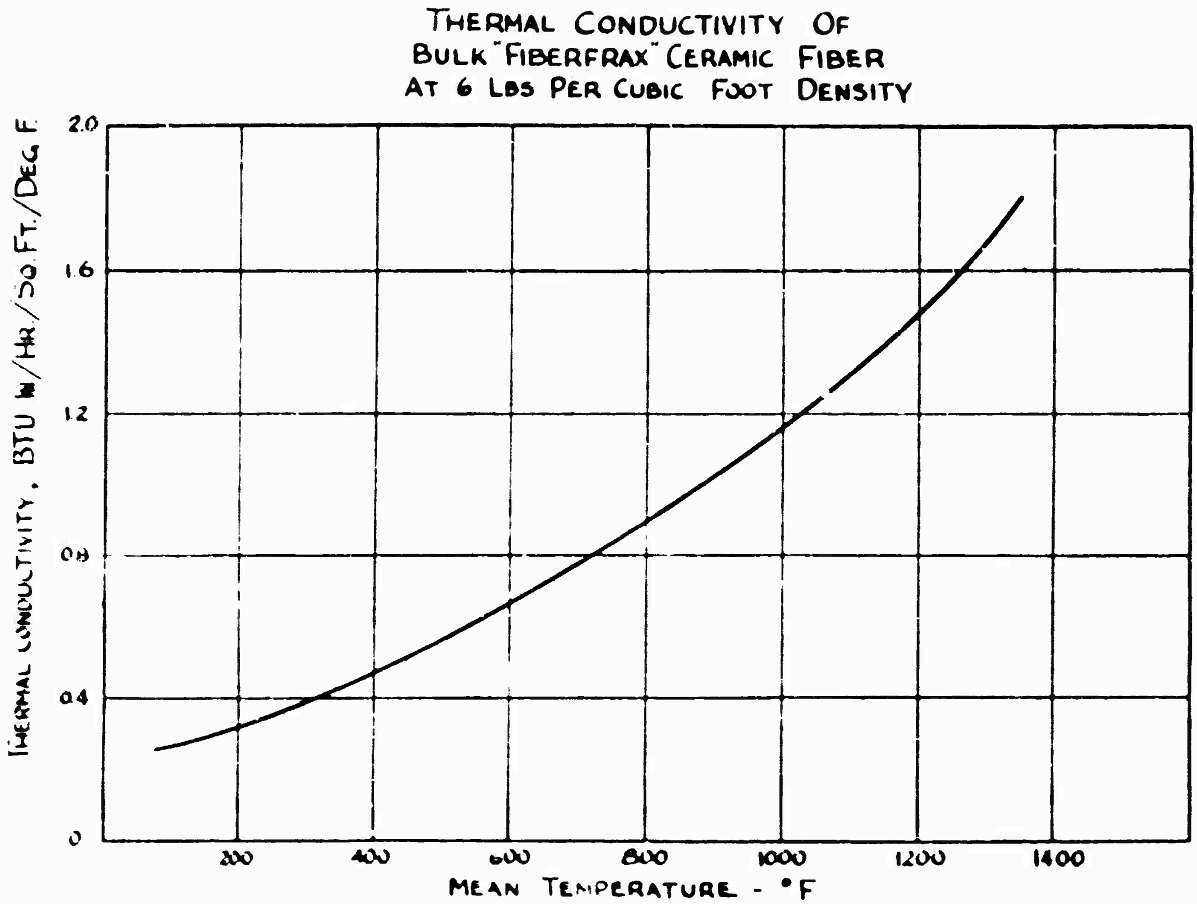
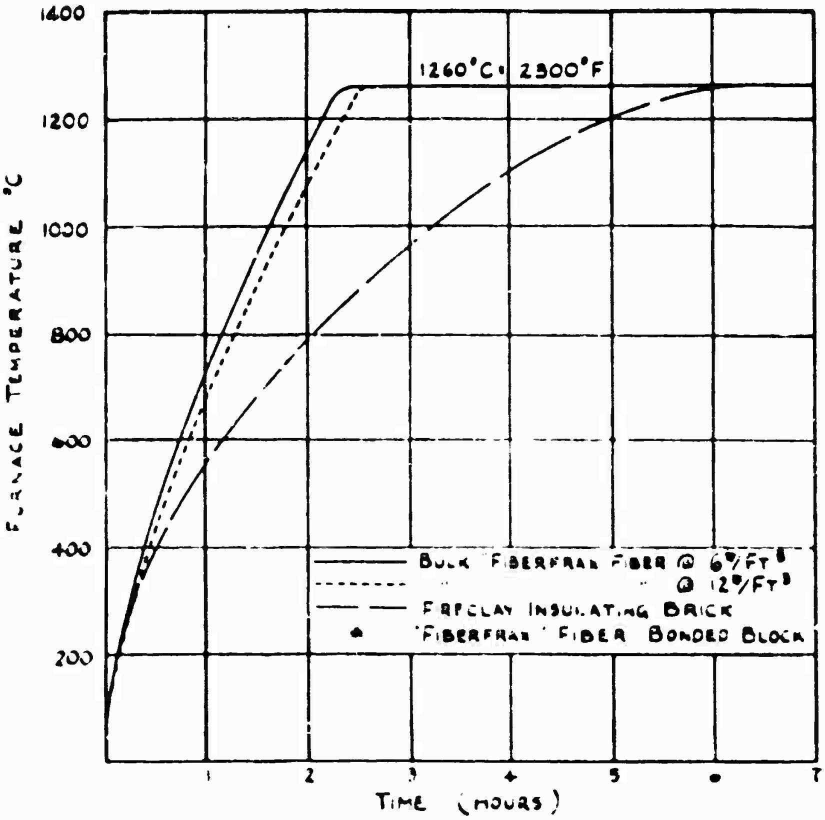

THERMAL CONDUCTIVITY OF
BULK "FIBERFRAX" CERAMIC FIBER
AT 6 LBS PER CUBIC FOOT DENSITY
THERMAL CONDUCTIVITY, BTU IN/HR/SQ FT./DEG F.
2.0
1.6
1.2
0.8
0.4
0
200
400
600
800
1000
1200
1400
MEAN TEMPERATURE - °F

FIGURE 1

FURNACE HEAT UP TIME
(CONSTANT POWER INPUT)



* CURVE FOR "FIBERFRAX" FIBER BONDED BLOCK SAME AS 2#/FT³ BULK

FIGURE 2

THERMAL INSULATION DATA
"FIBERFRAX" CERAMIC FIBER BONDED BLOCK

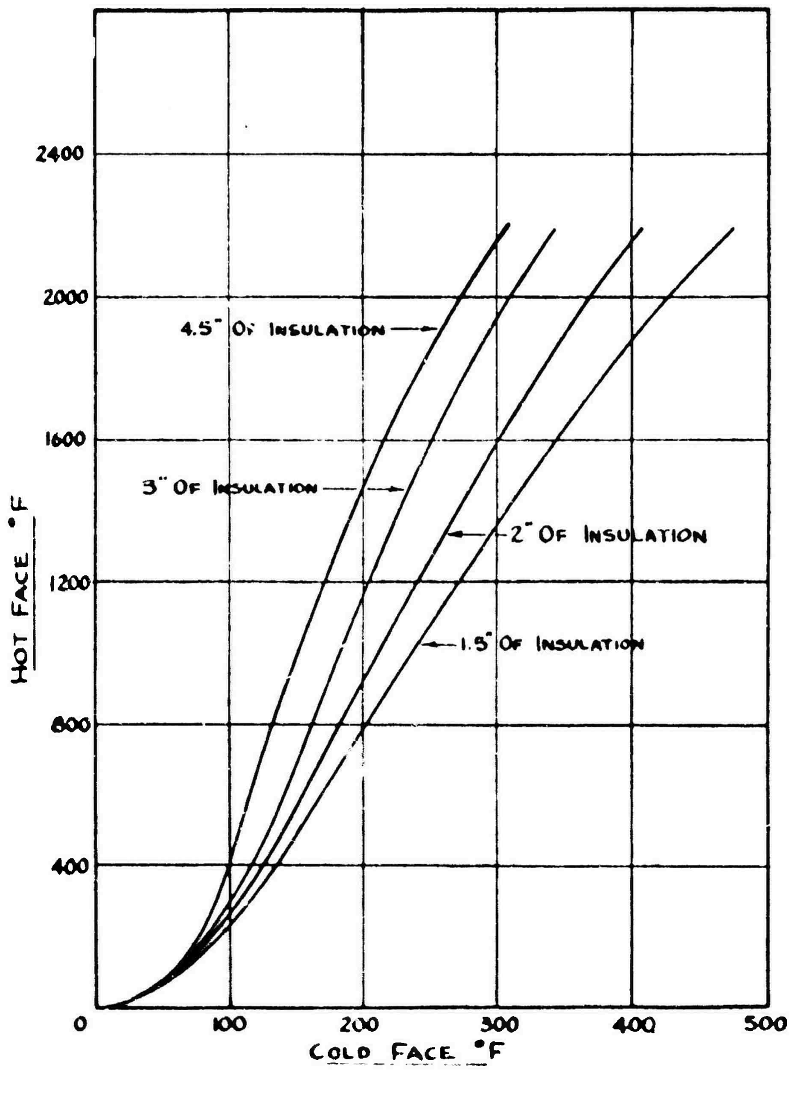


FIGURE 3

THERMAL CONDUCTIVITY OF "FIBERFRAX" CERAMIC FIBER BONDED BLOCK

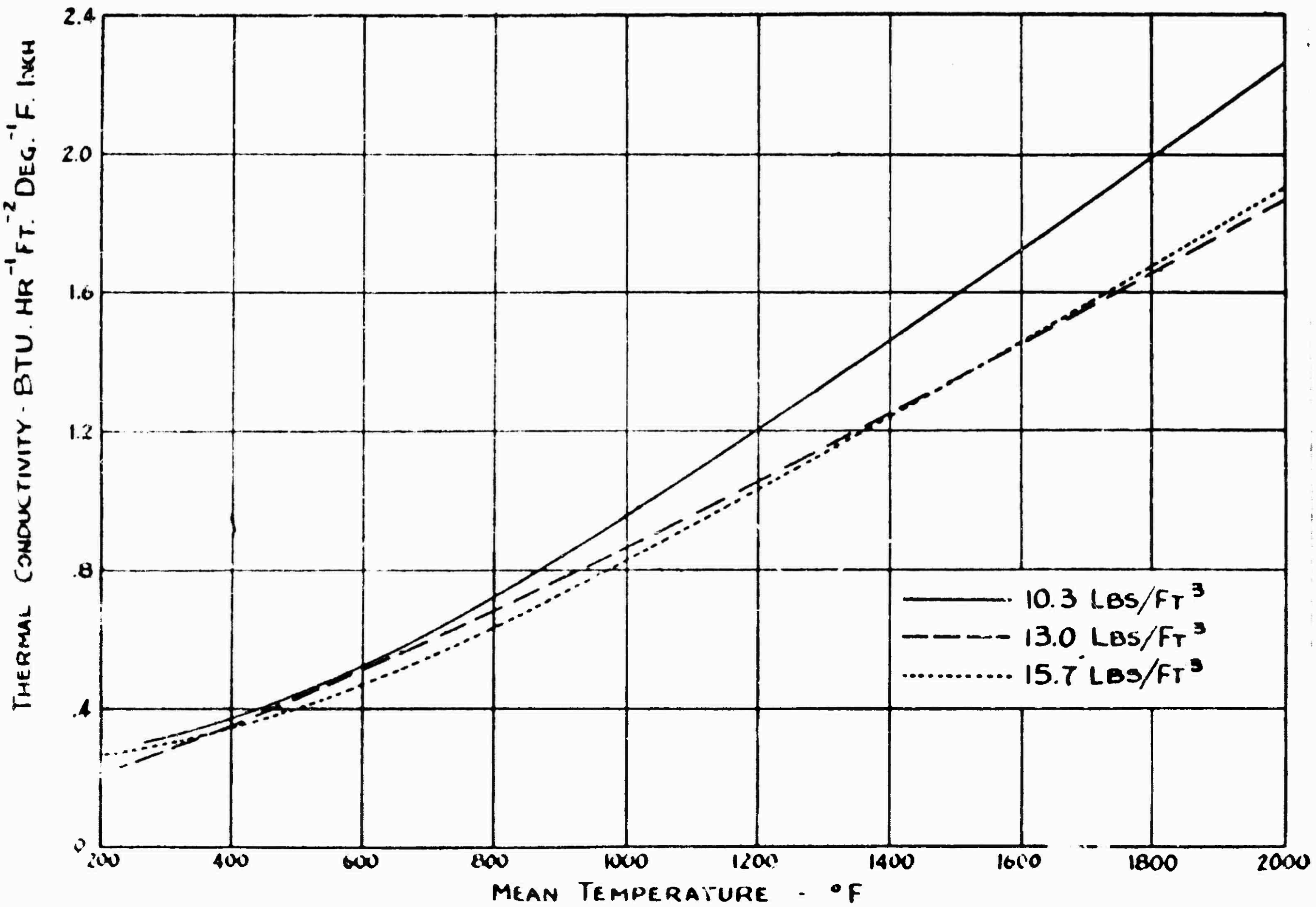


FIGURE 4