# PURDUE UNIV., THERMOPHYSICAL PROPERTIES LAB.

# THERMAL CONDUCTIVE TESTING BY LASER DIFFUSIVITY

## TEMP-COAT®
## LIQUID LATEX BARRIER INSULATION

THE ACCOMPANYING TEST DATA FROM THERMOPHYSICAL PROPERTIES RESEARCH LAB, REPRESENTS A JOINT EFFORT BETWEEN McDONNELL DOUGLAS CORPORATION (NOW BOEING). THERMSHIELD INTERNATIONAL CORP. AND SPAN-WORLD DISTRIBUTION, A DIVISION OF SOUTHERN PROFESSIONAL LEASING, INC., THE MANUFACTURERS OF TEMP-COAT ®.

THE THERMOPHYSICAL PROPERTY RESEARCH LAB. LOCATED AT PURDUE UNIVERSITY, IS THE LEADING THERMOPHYSICAL LAB IN THE WORLD. THE TEST, ASTM E-1461-92 WAS USED IN ORDER TO COMPARE TEMPCOAT® TO HIGH QUALITY AIRCRAFT INSULATION AND TO DETERMINE IT'S VALUES FOR INTERIOR USE IN COMPARISON TO THE WELL ESTABLISHED EXTERIOR SURFACE THERMAL VALUES OF THE PRODUCT DETERMINED BY COMPARATIVE TESTING.

THIS LAB AND THE SPECIFIC TEST METHOD WAS USED TO DETERMINE THERMAL VALUES BECAUSE THE STANDARD TESTS FOR THERMAL CONDUCTIVITY, ASTM E-1225-87 AND ASTM C-177-76 ARE DESIGNED FOR MASS THERMAL PRODUCTS. THESE TESTS WILL NOT RESPOND TO OR ADEQUATELY DOCUMENT A THIN BARRIER FORMS OF INSULATION.

ATTACHED YOU WILL ALSO FIND SEVERAL LETTERS AND COMMENTS PERTINENT TO THE THERMAL NATURE OF TEMP-COATS AND A VERIFICATION OF THE TEST RESULTS BY MR JIM FREDERIC, ASST. DIRECTOR OF ENGINEERING FOR CLEMSON UNIVERSITY.

THE THERMAL CONDUCTIVE COMPARATIVE VALUES OF TEMP-COAT®, AS STATED, HAVE ALSO BEEN REVIEWED BY THE U S NAVY, THE COAST GUARD, ALL OF THE MAJOR SHIPYARDS, BOEING PASSENGER AIRCRAFT DIV., NUMEROUS INTERNATIONAL GOVERNMENTS AND FIRMS AND NUMEROUS PRIVATE CORPORATIONS SUCH AS EXXON, SHELL & MOTIVA COMPANIES, CITGO, CONOCO, PROCTOR & GAMBLE. THE PRODUCT IS BEING UTILIZED BY THESE ORGANIZATIONS AND MANY OTHERS FOLLOWING THEIR TESTS AND IN DEPTH INVESTIGATIONS. TEMP-COAT® HAS BEEN SOLD AS A THERMAL BARRIER INSULATION SINCE 1989.

THANK YOU FOR YOUR INTEREST.

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THERMOPHYSICAL PROPERTIES
RESEARCH LABORATORY

TPRL 1625

# Thermophysical Properties of Air-Filled Beads in a Binder and a Blanket Material
(ASTM E-1461-92 and ASTM E-1269)

TEMP-COAT® by Span-World Distribution

A Report to McDonnell Douglas

by

H. Groot, J. Ferrier and D.L. Taylor

January 1996

Purdue University Research Park
2595 Yeager Road
West Lafayette, IN 47906

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SPAN-WORLD
DISTRIBUTION
Engineering Tomorrow's Environment

October 15, 1999

Mr. Richard Healing
Director
Naval Safety & Survivability
Bldg. 36, Washington Navy Yard
720 Kennon St., S.E.
Washington, DC 20374-5028

Dear Mr. Healing:

We have received the report prepared by Thermophysical Properties Research Laboratory / Purdue University (TPRL), the premier lab in the world in the field of thermal properties. The test there were conducted jointly on behalf of Span-World/ThermShield and McDonnell Douglas. Although the confidentiality agreement Span-World/ThermShield entered into with McDonnell precludes mass distribution of the actual test, we can tell you the results. The conclusion reached is that TEMP-COAT$^{TM}$ is as effective an insulation as the “blankets” of insulation placed between the outer and inner shells of aircraft bodies by the aircraft manufacturers. A side note: in house studies at McDonnell Douglas indicated TEMP-COAT$^{TM}$ was as good as or better than that same aircraft blanket insulation in reducing noise, except for the highest dB lever, above the range of human hearing.

Table 5 of the TPRL Report shows that k is not a function of thickness of the blankets used in aircraft insulation, and that a standard blanket of insulation has a k of 0.00096 at 392°F (200°C), while the TEMP-COAT$^{TM}$ sample had a k of 0.00090 at the same temperature. TPRL’s calculations take into consideration factors other than k, because true thermoconductivity calculations must also take into consideration conductivity and diffusivity.

The engineers at TPRL explained that contrary to common knowledge, k and R are quite variable, and are certainly not constant. An illustration of this was a reflective space blanket held two feet in front of a blazing fire. Very little heat passes through it, since it is reflected away. On the other hand, that same reflective space blanket, when placed in direct contact with a hot surface, will transfer the heat directly through to your hand and burn quite badly. How can a substance have two (or more) k and R calculation? Quite easily, since there are countless examples of the same illustration above. For example, with 12 inches of ice, Eskimos heat their igloos from 30°F below zero to 40°F above zero using only candles as a heat source. What would this indicate the k and R values to be for the ice in an igloo’s walls? Those guys ask good questions, and make it clear they know their stuff. I guess that is why McDonnell picked them for the studies.

We wanted to let you know how this was progressing. We can answer any questions you might have from a technical standpoint, since one of our people was at TPRL when the tests were done, using laser diffusivity and other tests that only TPRL is qualified and able to conduct.

Sincerely,

Morris I. Meyer

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CLEMSON
UNIVERSITY

September 23, 1998

Mr. Tad Crunkleton
Universal Coatings, Inc.
2430 Vantage Lane
Denver, N. C. 28037

Dear Ted:

We have revered the information sent to us comparing the thermal-properties of the TempCoat sample and the blanket sample. Some of the data has "considerable scatter" as the report states) which makes any evaluation a judgment call at the best.

It is still our opinion,. However, .that the Tempcoat material is comparable to the fiber blanket. The data in Figures 1. 2, and 4 for your sample is very consistent and suggests acceptable performance as a thermal barrier at the temperatures tested.

Please remember that this opinion reflects our evaluation as ceramic engineers and is not the opinion of Clemson.University. Call if you have any questions and thank you for allowing us to participate in your project..

With best regards,

Jim Frederic

Jim Frederic
Assistant Director

CENTER FOR ENGINEERING CERAMIC MANUFACTURING
Co1lege of Engineering & Science: 100 Clemson Research Blvd. Anderson. SC; 79625

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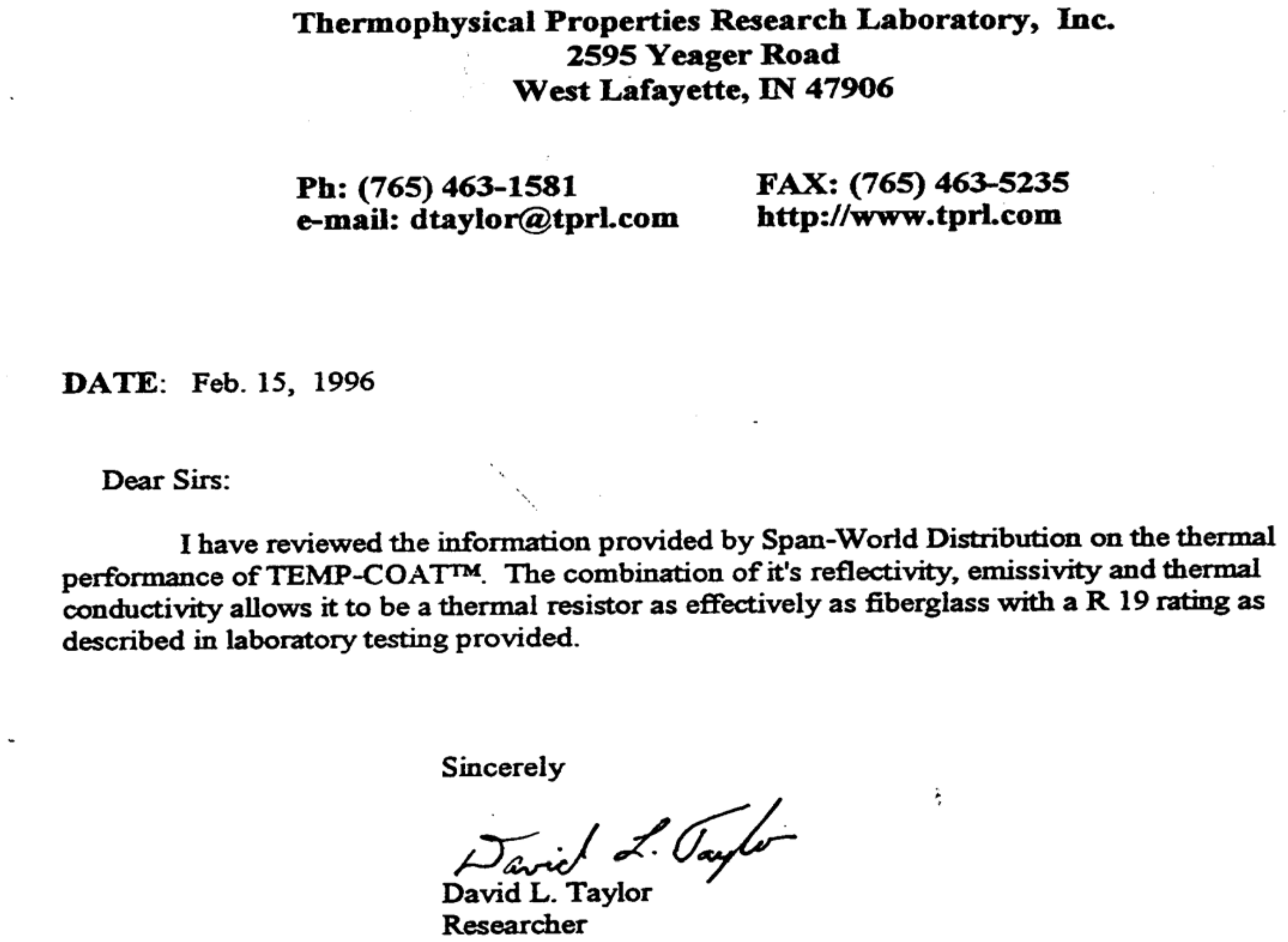

**Thermophysical Properties Research Laboratory, Inc.**
**2595 Yeager Road**
**West Lafayette, IN 47906**

**Ph: (765) 463-1581**
**e-mail: dtaylor@tprl.com**

**FAX: (765) 463-5235**
**http://www.tprl.com**

**DATE**: Feb. 15, 1996

Dear Sirs:

I have reviewed the information provided by Span-World Distribution on the thermal performance of TEMP-COAT™. The combination of it's reflectivity, emissivity and thermal conductivity allows it to be a thermal resistor as effectively as fiberglass with a R 19 rating as described in laboratory testing provided.

Sincerely

David L. Taylor

David L. Taylor
Researcher

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# Thermophysical Properties of Air Filled Beads in Binder
# And a Blanket Material

## INTRODUCTION

Two materials were submitted for thermophysical property testing. One material (TempCoat) was a binder material with air-filled beads in it that was tested using the laser flash diffusivity technique for determining thermal diffusivity (a).

The other material was a fibrous blanket material in between sheet of plastic which was tested using the step heat method. Bulk density (d) values were calculated from the sample's geometries and masses. Specific heat (C) was measured using a differential scanning calorimeter and thermal conductivity ($\lambda$) values were calculated as a product of the above, ie $\lambda = aC_p d$.

Thermal diffusivity is determined using the laser flash diffusivity method In the flash method, the front face of a small disc-shaped sample is subjected to a short laser burst and the resulting rear face temperature rise is recorded and analyzed. A highly developed apparatus exists at TPRL and we have been involved in an extensive program to evaluate the technique and broaden its uses. The apparatus consists of a Korad K2 laser, a high vacuum system including a bell jar with windows for viewing the sample, a tantalum or stainless steel tube heater surrounding a sample holding assembly, a thermocouple or an i.r. detector, appropriate biasing circuit, amplifiers, A/D converters, crystal clocks and a microcomputer based digital data acquisition system capable of accurately taking data in the 40 microsecond and longer time domain. The computer controls the experiment, collect, the data, calculates the results and compares the raw data with the theoretical model.

Specific heat is measured using a standard Perkin-Elmer Model DSC-2 Differential Scanning Calorimeter with sapphire as the reference material. The standard and sample were subjected to the same heat flux as a blank and the differential powers required to heat the sample and standard at the same rate were determined using the

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digital data acquisition system. From the masses of the sapphire standard and sample differential power, and the known specific heat of sapphire, the specific heat of the sample is computed The experimental data are visually displayed as the experiment progresses. All measured quantities are directly traceable to NBS standards.

The step heating method involves subjecting one face of a specimen to a uniform heat flux and recording the temperature responses at various locations. A 600 Watt, quartz-iodide tungsten element bulk mounted within an aluminum parabolic reflector is the heat flux source. The reflector is cooled using both a water cooling system and force convection to an air stream. The source has been experimentally verified to be reasonably constant over 30 min and requires approximately 2 s to reach maximum output. The heat flux can be controlled between zero and maximum output using a Variac. The flux intensity was measured 30 cm from the heat source and found to vary less than 2% across a 5-cm diameter.

Temperature rise curves are measured at three or four locations spaced along the sample. The two outside locations (one on each end) are used as boundary conditions and interior position data are used as the basis for the diffusivity calculations. Diffusivity values are determined using these temperature response data, specimen dimensions and the method of parameter estimation. The inverse problem of solving the heat equation from temperature measurements has been addressed by Beck, who has discussed the problem in detail and who has developed the one-dimensional numerical analysis program that is used. in calculating the diffusivity values.

In the method, the sum of squares function S where

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$$S = \sum^{m} \sum^{n} [Y_v\,(a,x,h) - T_v\,(a,x,t)]^2$$

is minimized with respect to the thermal diffusivity. Thus the diffusivity value is obtained which produces the best possible agreement between the experimentally measured temperatures Y(ij) and the temperature T(ij) produced by a finite difference solution of the heat equation subjected to the measured temperatures. In the equation, i represents time and j refers to the number of thermocouples not on the boundary. In the analysis, a Crank-Nicolson finite difference solution of the heat equation is implemented.

In addition to accounting for interior temperature measurements and allowing for front and rear face temperatures to be a function of time, the parameter estimation technique also allows sequential calculation of the sensitivity of the experiment. Sensitivity analysis produces criteria for best locations for interior thermocouples and experiment times that produce theoretical optimum estimates of the diffusivity.

## RESULTS AND DISCUSSION

Diffusivity sample geometries, masses and bulk density values are given in Table 1. For the step heat measurement, two samples were cut out of a sheet of the blanket material and were squeezed down to a thickness of 0.120 cm. The samples had significantly different masses and there is a 12% difference in the resulting bulk densities.

Specific heat results are given in Table 2 and Figure 1. The thermal diffusivity values for the TempCoat are given in Table 3 and Figure 2. There is Negligible change over the temperature range. The step heat measurements for the blanket material were taken in air over a. period of several days. The data are presented in

Table 4 arid Figure 3. There is considerable. scatter in the data from the effects of Moisture content, uniformity of compaction and degradation of the plastic material by heat. A lease squares line, shown in Figure 3 was fitted through the data and values obtained from this line were used in the thermal conductivity calculations.

The thermal. conductivity calculations are presented in Table 5 and the results are shown,. in Figare 4. The 0.114 gm/cm$^3$ bulk density value was used in the blanket conductivity calculations. The accuracy of the TempCoat measurements are quite good. The accuracy of the blanket material are much worse, around 25%.

Further study would be required to determine the effects of moisture content the amount of compaction in the blanket material on the thermal conductivity.

TABLE 5

Thermal Conductivity Calculations

| Sample | Temp. | Density | Specific Heat | Diffusivity | Conduct. | Conduct. | Temp |
|---|---|---|---|---|---|---|---|
| (No.) | (C) | (gm cm$^{-3}$) | (W-s-gm$^{-1}$ K$^{-1}$) | (cm $^{2}$ sec $^{-1}$) | (W-cm$^{-1}$ K$^{-1}$) | (BTU *) | (F) |
| COAT | 23.0 | 0.432 | 1.0760 | 0.00151 | 0.00076 | 0.49 | 73.4 |
| | 50.0 | 0.432 | 1.1400 | 0.00151 | 0.00074 | 0.52 | 122.0 |
| | 100.0 | 0.432 | 1.2370 | 0.00150 | 0.00080 | 0.56 | 212.0 |
| | 150.0 | 0.432 | 1.3160 | 0.00150 | 0.00085 | 0.59 | 302.0 |
| | 200.0 | 0.432 | 1.4020 | 0.00149 | 0.00090 | 0.63 | 392.0 |
| | 250.0 | 0.432 | 1.5060 | 0.00150 | 0.00097 | 0.68 | 482.0 |
| Blanket | 23.0 | 0.114 | 1.0870 | 0.00544 | 0.00067 | 0.47 | 73.4 |
| | 50.0 | 0.114 | 1.1990 | 0.00554 | 0.00076 | 0.53 | 122.0 |
| | 75.0 | 0.114 | 1.2965 | 0.00563 | 0.00083 | 0.58 | 167.0 |
| | 100.0 | 0.114 | 1.3820 | 0.00572 | 0.00090 | 0.63 | 212.0 |
| | 125.0 | 0.114 | 1.4525 | 0.00581 | 0.00096 | 0.67 | 257.0 |
| | 150.0 | 0.114 | 1.5050 | 0.00590 | 0.00101 | 0.70 | 302.0 |
| | 175.0 | 0.114 | 1.5550 | 0.00599 | 0.00106 | 0.74 | 347.0 |
| | 200.0 | 0.114 | 1.5870 | 0.00608 | 0.00110 | 0.76 | 392.0 |

* (BTU in hr $^{-1}$ ft $^{-2}$ F $^{-1}$)

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## TABLE 1

### Sample Dimensions, Masses and Density Values

| Sample<br>(No.) | Thickness<br>(cm) | Diameter<br>(cm) | Mass<br>(gm) | Density<br>(gms $cm^{-3}$) |
|---|---|---|---|---|
| COAT | 0.2895 | 1.277 | 0.1601 | 0.432 |
| BLANKET | 0.1200 | 4.580 | 0.2255 | 0.114 |
| BLANKET 2 | 0.1200 | 4.620 | 0.2560 | 0.127 |

## TABLE 2

### Specific Heat Results

| Temperature (C) | Specific Heat (W-s/gm-K) | Specific Heat (w-s/gm-K) |
|---|---|---|
| | Blanket | Coat |
| 23.0 | 1.0870 | 1.0760 |
| 30.0 | 1.1180 | 1.0930 |
| 40.0 | 1.1600 | 1.1170 |
| 50.0 | 1.1990 | 1.1400 |
| 60.0 | 1.2410 | 1.1630 |
| 70.0 | 1.2770 | 1.1860 |
| 80.0 | 1.3160 | 1.2050 |
| 90.0 | 1.3520 | 1.2220 |
| 100.0 | 1.3820 | 1.2370 |
| 110.0 | 1.4130 | 1.2520 |

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## TABLE 3

### Thermal Diffusivity Results

### (Tempcoat)

| Sample Description | Temperature (C) | Diffusivity ($cm^2\ sec^{-1}$) |
|---|---|---|
| COAT | 23.0 | 0.001510 |
| COAT | 50.0 | 0.001510 |
| COAT | 100.0 | 0.001500 |
| COAT | 150.0 | 0.001500 |
| COAT | 200.0 | 0.001490 |
| COAT | 250.0 | 0.001500 |

## TABLE 4

### Thermal Diffusivity Results
### (Blanket)

| Sample Description | Temperature ( C) | Diffusivity ($cm^2\ sec^{-1}$) |
|---|---|---|
| Blanket | 43.5 | 0.00538 |
| Blanket | 45.4 | 0.00484 |
| Blanket | 93.7 | 0.00550 |
| Blanket | 92.8 | 0.00606 |
| Blanket | 203.3 | 0.00626 |
| Blanket | 97.6 | 0.00602 |
| Blanket | 42.6 | 0.00587 |
| Blanket | 10.5 | 0.00505 |
| Blanket | 10.4 | 0.00585 |
| Blanket | 63.7 | 0.00559 |
| Blanket | 110.8 | 0.00562 |
| Blanket | 15.5 | 0.00590 |
| Blanket | 15.8 | 0.00504 |
| Blanket | 180.1 | 0.00575 |

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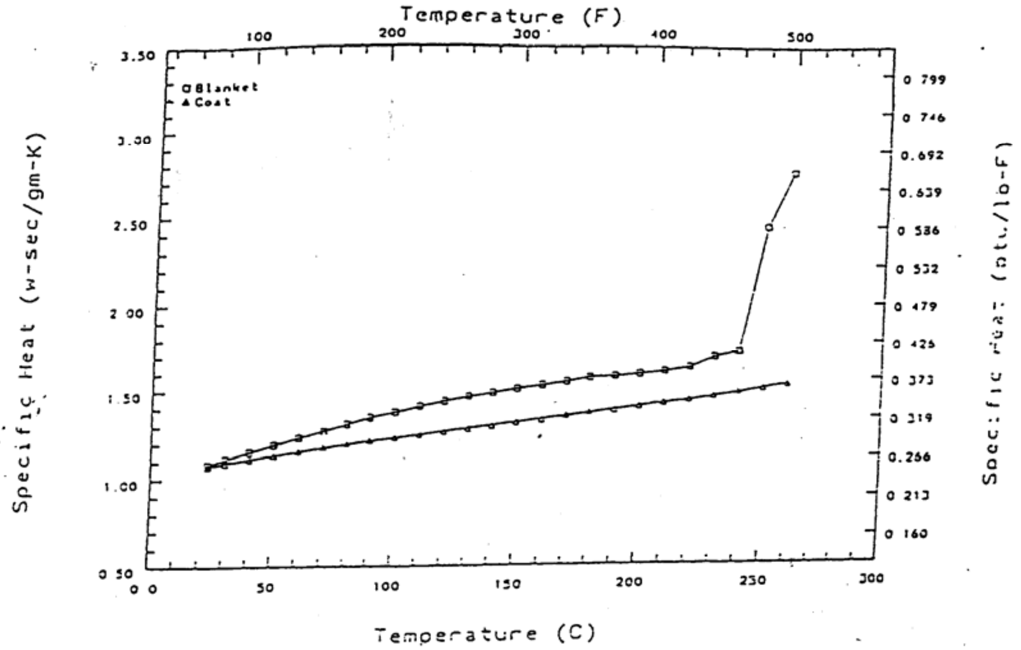
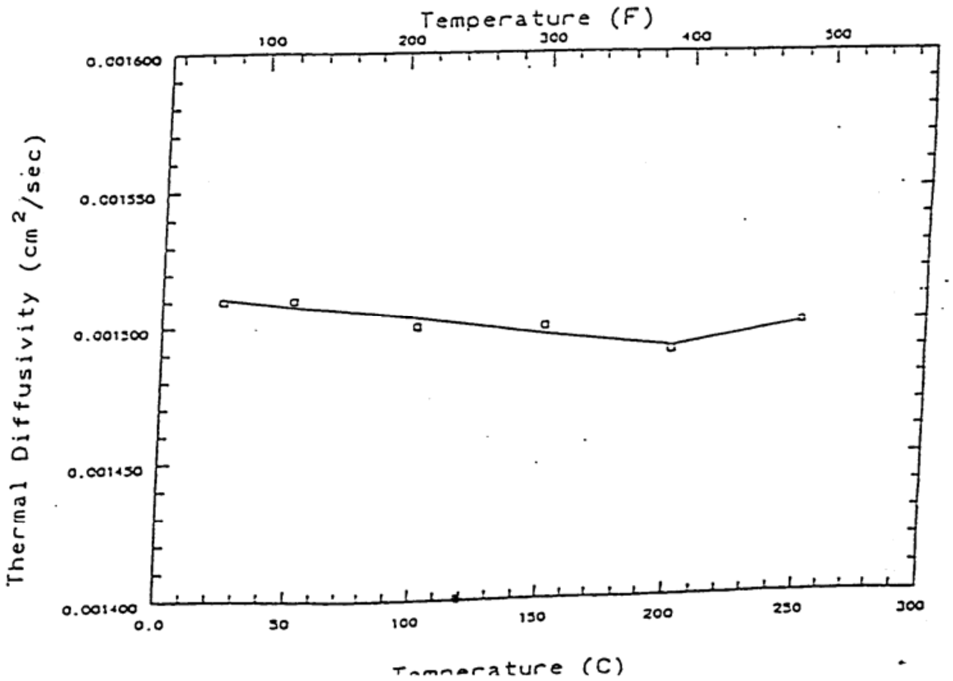


Figure 1. Specific Heat



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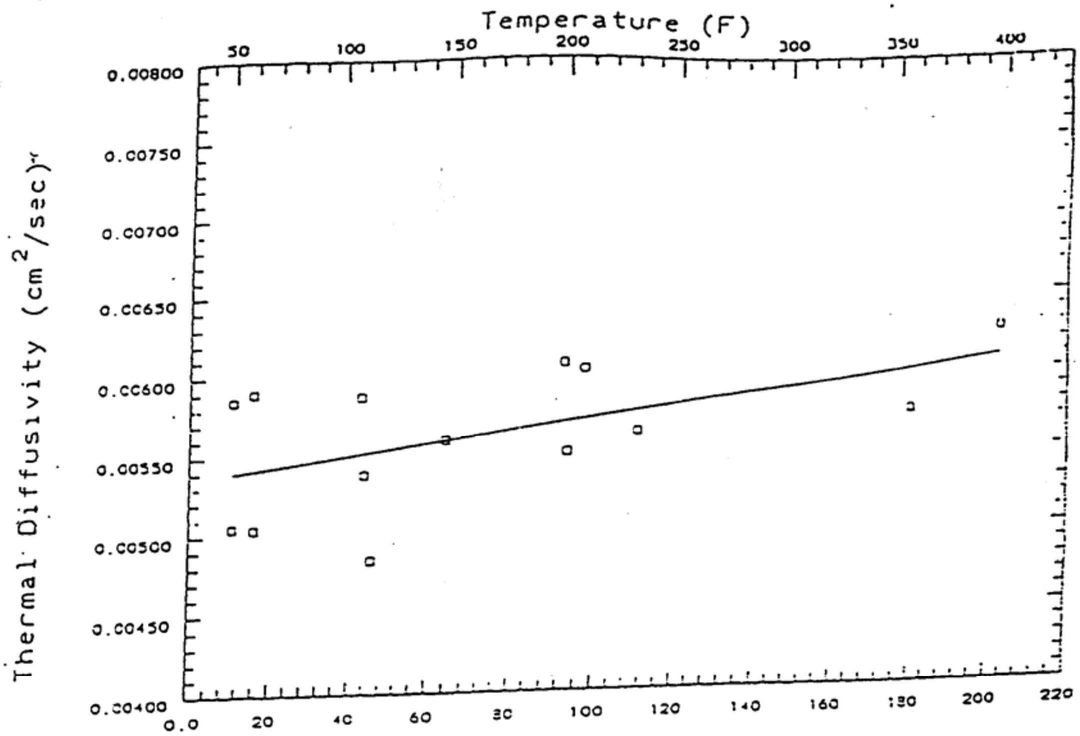

Figure 3· Thermal Diffusivity
(Blanket Sample)

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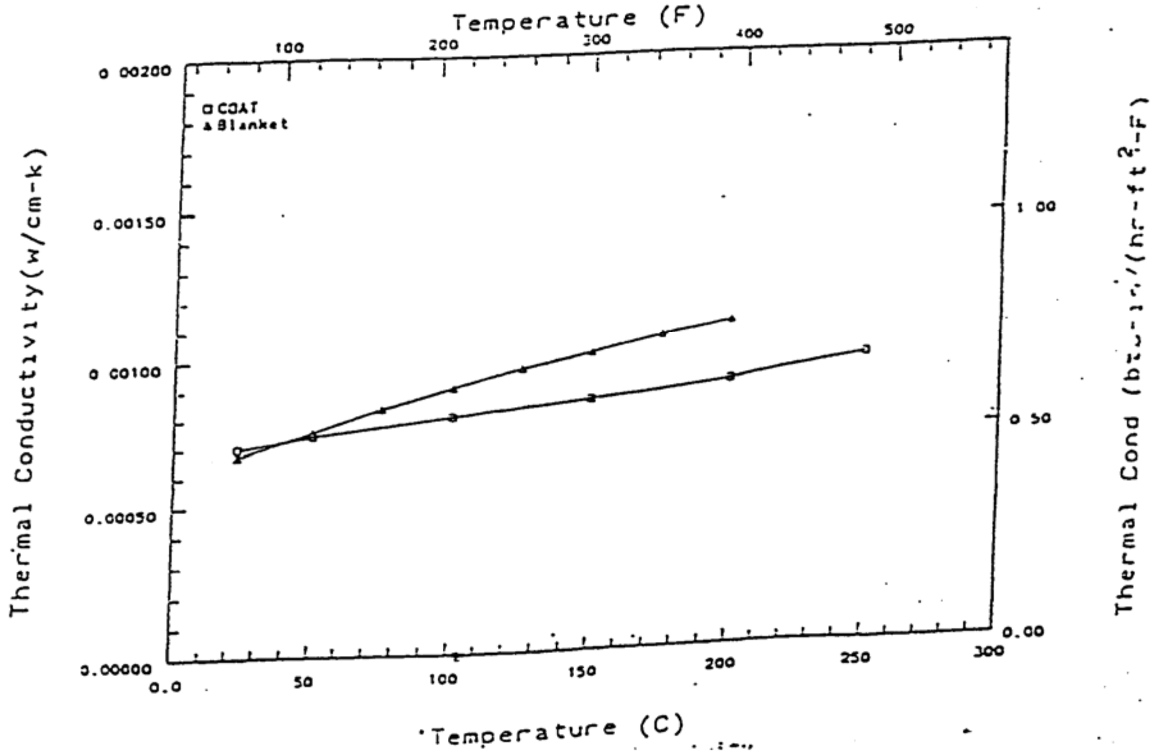

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