CERAMIC INSULATION

FINAL REPORT

by

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DIVISION OF PLANNING AND PROGRAMMING
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ABSTRACT

Ceramic Insulation was evaluated for permeability and thermal conductivity to verify the claims of the product's manufacturer of it being a vapor barrier (less than 1 perm-inch) and possessing a 23.3 per inch R value. The test results yielded a permeability of 33.1±6.6 perm-inches and a thermal conductivity equivalent of 0.324 or R value of 3.08±0.31 per inch.

The recommendation of this report is that this product is not economical as a thermal insulation and should not be considered in construction of public facilities unless there is a specific requirement for a non-toxic fireproof insulation.
Each year a wide variety of new products are introduced to the consumer. The range of their worth is enormous. Some may have an incalculable value while others may not come close to fulfilling their promised performance. Other products which may be of great benefit under some conditions may fail miserably in a different environment.

From time to time such products come to our attention which are potentially beneficial to the Alaska Department of Transportation and Public Facilities. We evaluate these products to establish their performance under the conditions expected in Alaska and make our recommendations based on the test results. The findings may yield anything from a hearty endorsement to an outright rejection of a particular product.

The cost of heating the state's facilities is a major portion of the operating budget. Heating degree days in Alaska range from 8,000 in Southeast to 12,000 in Southcentral, 15,000 in the Interior and 20,000 in the high Arctic. This compares to 9,000 to 10,000 in the coldest parts of the Lower 48. "Ceramic Insulation," with its advertised R value of 23.3 per inch, has an obvious potential benefit to the state of Alaska. While most experts have voiced skepticism of the manufacturer's claim, any item which might reduce the operating expenses of the state warrants the Research Section's investigation.

John Rezek, P.E.
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<table>
<thead>
<tr>
<th>TABLE OF CONTENTS</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>Introduction</td>
<td>1</td>
</tr>
<tr>
<td>Permeance of Ceramic Insulation</td>
<td>3</td>
</tr>
<tr>
<td>Thermal Properties</td>
<td>10</td>
</tr>
<tr>
<td>Conclusions</td>
<td>17</td>
</tr>
<tr>
<td>Implementation</td>
<td>19</td>
</tr>
<tr>
<td>Calculations and Data</td>
<td>20</td>
</tr>
</tbody>
</table>
CERAMIC INSULATION

INTRODUCTION

Ceramic Insulation, (sold under the brand names "Ceram-A-Guard" and "Ceram-A-Shield"), as it is called by its manufacturer, is actually expanded perlite particles covered with a thin silicate membrane. Uncoated expanded perlite insulation has been marketed for many years. The thermal resistance of perlite is given as $R = 2.70$ per inch by the American Society of Heating, Refrigeration and Air Conditioning Engineers (ASHRAE) and as $R \ 2$ or $R \ 4$ per inch as measured by the American Society for Testing and Materials (ASTM) standard test methods C518* and C236**, respectively. Perlite insulation has primarily been used in very high temperature applications since it is non toxic, totally fireproof, and has a low heat capacity.

The manufacturer of Ceramic Insulation claims that the silicate coating on the perlite acts as a mirror to infrared electromagnetic radiation reflecting energy and thus retarding heat conduction through the insulation. They report it to have an equivalent $R$ value of 23.3 per inch when used as a loose fill attic insulation. Furthermore, they claim the insulation acts as a vapor barrier.

Initial review of the manufacturer's literature on Ceramic Insulation entitled "Answers to the Most Frequently Asked Questions about Ceram-A-Guard" raised more questions than it answered. The text, by the inventor Daniel K. Dunn, is filled with discussion about absorption spectroscopy, infrared radiation, resonance, electromagnetic waves, etc. and quotes attributed to Newton and Einstein, which he uses to back up the theory of

*Standard test method for steady-state thermal transmission properties by means of the heat flow meter.

**Standard test method for thermal conductance and transmittance of built-sections by means of the Guarded Hot Box.
why the Ceramic Insulation works. His theory is basically that "radiation is the primary mode of heat transfer. Conduction and convection come into play only as they interfere with the primary mode. If the molecules did not absorb the radiant energy, they would not heat up to develop a difference in temperature to promote molecular and mass motion." By coating the perlite particles with a ceramic glaze which is reflective to electromagnetic waves from the upper end of the visible spectrum to the lower end of the x-ray band, the radiant energy is allegedly reflected and therefore cannot be conducted through the insulation. This theory is further complicated by the statement that this only applies "when these particles are placed in the presence of full atmospheric exposure" such as in a vented attic where "the coating is given the opportunity to resist, with full resonance, any infrared frequencies found in a living home."

On the matter of Ceramic Insulation being a vapor barrier, the text is even more confusing. Mr. Dunn readily admits that the material is hygroscopic, absorbing up to 3½ times its weight of water, and that air will freely pass through the material. However, he says this happens only "while in the conduction mode of heat transfer. Ceramic insulation, while in the infrared radiant mode of heat transfer will resist or deflect moisture found in the home. When heat cannot go through a substance such as ceramic insulation, then the heat cannot carry the moisture out of the home."

Much of the author's commentary on electromagnetic radiation and heat transfer is misleading, irrelevant or incorrect. Therefore, it was decided that rather than getting bogged down in a statement-by-statement critique of the text, we would simply examine the properties of the insulation material itself. The manufacturer acknowledges the failure of "Ceram-A-Guard" to perform as advertised when using standard conductivity test methods, thus he devised non-standard tests to establish an equivalent R value for the material. We chose to duplicate his test methods with some modification to allow better control of the test parameters. Since Mr. Dunn did no lab test to back up his vapor barrier claims, we devised a permeability test using ASTM C355 Test Method as a guide.
PERMEANCE OF CERAMIC INSULATION

The effectiveness of a material as a vapor barrier is determined by its water vapor permeability. ASTM defines a vapor barrier as: "those materials or systems which adequately retard the transmission of water vapor under certain conditions." For practical purposes in residential type construction, "it is assumed that permeance of an adequate barrier will not exceed one perm (1 grain of water/hr. x ft² x in. Hg)." In cold climates where the dew point of water vapor is likely to be within the insulation and where the vapor pressure is very high, the permeance of the vapor barrier must be very low. Six mil polyethylene, for example, has a permeance of 0.06 perms. At the other extreme, still air has a permeability of 120 perm-inches and unprotected mineral wool insulation a permeability of 116 perm-inches. The term permeance (perm) is the ratio of the rate of water vapor transmission between two specified surfaces, to the vapor pressure difference between the two surfaces. It is usually expressed when describing the vapor transmission properties of membranes, paint or materials of specific thickness such as brick or sheathing. Permeability is permeance per inch of material, and is generally reserved to describe water vapor transmission through variable thickness materials such as insulation.

To measure the permeability of Ceramic Insulation the ASTM C355-73, Standard Test Method for Water Vapor Transmission of Thick Materials was used. The test apparatus consisted of an 8 inch diameter No. 100 standard soil testing sieve fitted to a matching pan. The Ceramic Insulation was poured into the sieve to a uniform depth of 1 inch and the pan filled with distilled water to within one-half inch of the sieve. The combination of sieve and pan was placed on a stir/hot plate as shown in Figure 1. The water temperature was maintained at 90°F ± 0.5°F and was stirred with a magnetic pellet to keep the temperature uniform throughout. The joint between the pan and sieve was sealed with petroleum jelly to prevent extraneous vapor loss. Air was circulated across the apparatus at 130 fpm using a 15" diameter electric fan. No effort was made to control the room
humidity or temperature, however, they were recorded as part of the data set. The pan/sieve combination with contents was weighted on a Sauter R 3000 electronic gram scale to the nearest 0.1 gm, initially, and periodically (approximately every 24 hours thereafter) for 7 days. Care was taken to prevent the water from touching the specimen when the unit was weighed.

Figure 1: Permeability Test Apparatus
The collected data was as follows:

<table>
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<tr>
<th>Date</th>
<th>Time</th>
<th>Weight* (gms)</th>
<th>Air Temp. (°F)</th>
<th>Humidity (%)</th>
<th>Dew Point** (°F)</th>
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<tr>
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<td>1530</td>
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<td>1962.2</td>
<td>79.2</td>
<td>18</td>
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</tr>
<tr>
<td>6/01</td>
<td>1530</td>
<td>1944.2</td>
<td>80.2</td>
<td>17</td>
<td>31.4</td>
</tr>
</tbody>
</table>

Average: 78.6°  18%  31.4°

*Combined weight of sieve, pan, water and insulation.
**From psychrometric chart (Figure 2).

Figure 3 is a plot of the measured weights versus time for the duration of the test. Since the rate of weight loss (water vapor transmission) was fairly constant for the entire 168 hours of the test, the total weight loss of 145 grams can be used in the calculations. Moisture absorbed by the insulation and thus included in the measured weights, was not included in the calculation, but is considered in the estimated accuracy of the test.
Figure 2
The permeability of the insulation is determined as follows:

Permeability = G x T / t x A x \Delta P

Where for the ceramic insulation:

G = Weight change in grains = 145 gms \_ 15.43 grns/gm = 2237.35 grns.
T = Sample thickness = 1.0 in.
t = Time in hours during which G occurred = 168 hrs.
A = Test area ft^2 = \pi (8/12 ft)^2 / 4 = 0.35 ft^2
\Delta P = Vapor pressure difference, in. Hg = S(R_1 - R_2)
S = Saturation vapor pressure at test temp., in. Hg = 1.40 in. Hg*
R_1 = Relative humidity at source = assumed 100%
R_2 = Relative humidity at sink = 18.0%

*from Figure 4.

The calculation is:

Permeability = 2237.35 grns x 1 in./168 hrs. x 0.35 ft^2 x 1.40(1.00-0.18)
= 33.1 perm-inches

Based on the parameters established by the ASTM Standards, this Figure is accurate to about ±20%.
Reproduced from part 18 1978 Annual Book of ASTM Standards

\[ \Delta P = S(R_1 - R_2) \]

\[ \Delta P = 1.4(1.00 - 0.18) \]

\[ = 1.15 \text{ (in. Hg.)} \]
THERMAL PROPERTIES

The manufacturer bases his equivalent R value of 23.3 primarily on a direct comparison test, which he devised, between a known standard and the Ceramic Insulation. He also used two other methods; the Delta-T Method, where the insulation performance is measured by comparison of surface temperatures on either side of the insulation, and by use of an infrared thermosscanner. He did not offer any figures on these latter two methods, however, stating only that the results compared favorably with the first method. For this reason, we chose to duplicate only the direct comparison test method.

The exact construction of the manufacturer's test device is unknown other than as shown in Figure 5. Apparently two such test boxes were built, one for the standard insulation, the other for the Ceramic Insulation. The standard was only described as: "a 12 inch x 12 inch x 1 inch high density fiberboard certified by the National Bureau of Standards." Instrumentation of each box "consisted of a laboratory thermostat controlling the wire wound (electrical resistance type) radiant heat source, line voltage and amperage monitors, total elapsed time indicators, monometers," (I believe they meant manometers), "and temperature measuring and recording equipment. The thermostats were set at 75°F and the sides and bottom of the heated chambers are instrumented with heat flow meters to form a calorimeter." Power levels, on-time, and temperatures and pressures of ambient air on both sides of the sample were apparently monitored throughout the test period. The samples were tested twice, once on each test box, and the power consumption of the two tests averaged. The average power consumption for the two insulations was then compared to determine an equivalent R value. The manufacturer found the power consumption to maintain steady-state conditions with the Ceramic Insulation was less than one eighth that required with the standard sample. The standard sample had an R of 2.95 thus 8 x 2.95 = 23.6 is the equivalent R value of the Ceramic Insulation. The discrepancy between this figure and the R 23.3 claimed in the product literature is not explained.
MANUFACTURER'S TEST APPARATUS

Bulb Thermometer
Ice & Water Tray
Vented Spacer
Sample Shelf
Heated Cavity
3" Fiberglass

Reproduced from: "Answers to the Most Frequently Asked Questions about CERAM-A-GUARD"

Figure 5
A - Relative Humidity Indicator  B - Thermocouple (Water Temperature)
C - Thermocouple (Air Temperature)  D - Thermostat (68° ± 2°F)
E - 60 watt Watt Light Bulb  F - 6-Watt Fan
G - Standard Top: 2" Dow Styrofoam ...or Test Top: 2" Ceramic Insulation
H - 4-Walls: 2 Layers of 2" Dow Styrofoam 1/2" Sheetrock Lining on
   Interior Side
I - Floor: 2" Dow Styrofoam Sandwitched Between
   2 Sheets of 1/4" Plywood  J - Felt Seal  K - 1/2" Sheetrock

Figure 6
The test device we built to duplicate this method was similar but was built with walls and floor of 4 inch extruded polystyrene (Figure 6). The walls were lined with half-inch gypsum board and the floor with quarter-inch plywood to somewhat simulate the structural surfaces of a building. The standard top consisted of 2 inches extruded polystyrene on half-inch gypsum board rimmed with 3/4 inch x 2 inch pine. The test top was a "pan" built of half-inch gypsum board rimmed with 3/4 inch x 2 inch pine and filled flush with 2 inches of ceramic insulation (Figure 7). Heat for the box was provided primarily with a 60 watt light bulb. Air was circulated in the box with a small fan to maintain an even temperature. The thermostat, set to approximately 70°F, was shielded from the heat source to prevent infrared induced cycling. A beaker of water was placed in the box to provide humidity and thermal mass. Temperature monitoring was achieved by one thermocouple suspended in the air behind the baffle near the thermostat and another immersed in the water. The box interior is shown in Figure 8. Humidity within the box was indicated by means of a Weather Measure HMI-14 relative humidity indicator. Power consumption of the light bulb and fan was determined by use of a Fluke multimeter and a timer on that circuit. A second timer was used to measure the duration of the test. The test box was then placed into an environmental chamber (Figures 9 and 10) capable of holding temperatures to -100°F. The chamber was equipped with a fan which circulates the air within at a fairly high rate to minimize differential temperatures in the chamber. (The induced air flow across the surface of the sample also provides the condition described by the manufacturer to greatly enhance the performance of ceramic insulation.) The chamber temperature was set to -30°F and monitored by a thermocouple. A Digitec 2000 datalogger was used to read the temperatures inside and outside the test box, but was not used to record data. The timers and multimeter were not equipped with analog output, thus manual recording of that data was required.

After the test box temperatures reached equilibrium, data was recorded periodically for approximately 20½ hours for the standard top and 21½ hours for the ceramic sample top. (See data pages 21 and 22 respectively.) By comparing the box heat on time with the total test time
Figure 9: Cold Chamber and Test Monitoring Apparatus

Figure 10: Test Box within Cold Chamber
Figure 7: Test Box with Standard Top

Figure 8: Test Box Interior
and by using the measured voltage and current to calculate power consumption of the box, determination of the heat loss with each top was possible. (See Calculations, Page 19.)

Since the conditions were consistent during the two test runs, it was assumed that the heat loss rate from the lower portion of the box (referred to henceforth as "box") was the same for both tops. To determine that constant, the heat loss for the box and the standard top were calculated using ASHRAE R values for the materials of the box as constructed and the same temperature differential as the tests. The calculated heat loss from the box accounted for 91.02 Btu/hr or 71.01% of the total of 128.18 Btu/hr for the box plus standard top.

The actual power consumption of the box with standard top was 37.70 watts or 128.71 Btu/hr. By applying the box-to-top heat loss ratio of 71.01% to this figure, a heat loss constant for the box without top of 91.40 Btu/hr. is obtained. The power consumption for the box with Ceramic Insulation top was 44.13 watts or 150.69 Btu/hr. The heat loss through the top is then 150.69 - 91.40 or 59.29 Btu/hr. which translates, after accounting for the half-inch sheetrock pan, to an R value of 3.08 per inch for the Ceramic Insulation.

It was noted that the humidity in the box during the tests averaged 41.5% with the standard top and 37.0% with the ceramic top. Also approximately 50 ml of water evaporated during the standard test and 106 ml evaporated during the ceramic test. The moisture content of the "Ceram-A-Guard" increased by 13.4% (by weight) during the test and took 18 days in an ambient humidity of about 30% to return to its original moisture content.
CONCLUSIONS

The results of our tests differ in the extreme with the claims of the Ceramic Insulation's manufacturer with regard to R value and vapor transport characteristics of the material. A thorough re-analysis of our test procedure suggests our results are valid. The ASTM C355 procedure for measuring water vapor transmission includes means of calculating the accuracy of the results. This figure is a possible error of ±20% for our test or in other words the permeance of the Ceramic Insulation is 26.5 to 39.7 perm inches. Regardless of the error, the permeance of the insulation is much greater than 1 perm inch and therefore, by definition, the insulation is not a vapor barrier.

The errors associated with our comparative R value test are somewhat harder to assess. The test method itself was not an ASTM Standard, but was a reasonable reproduction of the manufacturer's method, though somewhat refined. The calculated theoretical heat loss for the box and standard top was only 2.7% less than the actual measured value at the same temperature difference. However, the calculations for the box/top heat loss ratio could easily be off by 10% or so since heat loss was approximated for each portion of the box (with top) assuming one dimensional heat flow. Using this assumed error of 10% in calculating the heat loss from the box, the comparative R value for the ceramic top is 2.77 to 3.39 per inch. Again, regardless of the error, the equivalent R value is much less than the manufacturer's claimed equivalent R value of 23.3 per inch and is still in the 2 to 4 range cited by ASTM for expanded perlite.

The cost of this product from a Seattle area distributor was $8.00 per 2 cubic foot bag F.O.B. Seattle. Parcel post* shipping would add approximately $5.90 per bag to Anchorage and $7.10 to Fairbanks. This brings the total to $15.10/bag in Fairbanks or $7.55/ft³. Fiberglass batt

*For any quantities less than a van load, parcel post is the cheapest shipping method available. For less than van quantity, the commodity bulk rate for insulation is $69.58/100 lb. to Anchorage and $90.09/100 lb. to Fairbanks. The van rate is $9,200 to Fairbanks so one would have to be shipping nearly 1,300 bags (about 96% of a van's volume) to beat the parcel post rate.
sulation, which has a similar R value (3.15/in), costs approximately $0.85/ft³ in Fairbanks or about one ninth the cost of Ceramic Insulation. Even if the manufacturer's claim of R 23.3 per inch were valid, the price would be higher per R than for fiberglass batts.

In conclusion, for building insulation, Ceramic Insulation exhibits no better insulative qualities than does regular expanded perlite. Since the product is hygroscopic and definitely is not itself a vapor barrier, it should never be used in a structure without a superior vapor barrier and preferably the insulation should not be enclosed, such as in a wall, where moisture can be trapped. No R value equivalent testing was performed with the material at high moisture content, but presumably the resistance to heat flow would be reduced. Structural damage could also occur from prolonged contact with moist insulation.

On the plus side, the Ceramic Insulation is for all practical purposes nonflammable. It may prove to have application in spite of its high cost, where very high temperatures must be contained. Whether it performs any differently at high temperatures than regular expanded perlite is not known.
IMPLEMENTATION

The conclusions of our evaluation of ceramic insulation clearly indicate that the product should not be used in state facilities except in very limited circumstances. Other than its extreme stability in very high temperatures and its ability to rapidly dissipate heat, the insulation does not offer any outstanding qualities which cannot be found in other common insulations. The R value is in the same range as fiberglass batts or cellulose, but its relatively high cost makes it uneconomical as a substitute. Though water does not damage it, its hygroscopic nature makes it unsuitable for use where moisture may accumulate.

The product may have a limited use for insulating around high temperature building envelope penetrations where its incombustibility justifies its cost.
CALCULATIONS

Theoretical Heat Load for Test Box with Standard Top

Assume:

\[ \text{Dow Styrofoam, } R = 5.16/\text{in}^* \]
\[ \frac{1}{4}" \text{ Sheetrock, } R = 0.45* \]
\[ \frac{1}{8}" \text{ Plywood, } R = 0.31* \]

\[ A_{\text{sides}} = 4(2.17)(1.83) = 15.88 \text{ ft}^2 \]
\[ A_{\text{bottom}} = (1.83)(1.83) - 3.35 \text{ ft}^2 \]
\[ A_{\text{top}} = (2)(2) = 4 \text{ ft}^2 \]

\[ K_{\text{sides}} = \frac{1}{4}(5.16) + 0.45 = 0.0474 \]
\[ K_{\text{bottom}} = \frac{1}{4}(5.16) + 2(0.31) = 0.0470 \]
\[ K_{\text{top}} = \frac{1}{2}(5.16) + 0.45 = 0.0929 \]
\[ \Delta T = 100^\circ \text{F} \]

Then using the formula for heat loss:

\[ Q = kA\Delta t \]

\[ q_{\text{box}} = [(0.0474)(15.88) + (0.0470)(3.35)]100 = 91.02 \text{ Btu/hr} \]
\[ q_{\text{top}} = [(0.0929)(4)]100 = 37.16 \text{ Btu/hr} \]

\[ Q_{\text{total}} = 128.18 \text{ Btu/hr} \]
\[ q_{\text{box}} = 71.01\% \text{ of total heat load} \]

*Reference No. 2
Actual Heat Load for Test Box with Standard Top was:

\[ P = 66.15 \text{ watts or } 225.8 \text{ Btu/hr, } \Delta T = 98^\circ \text{F} \]

The power was on 57.00\% of the time (see data)

\[ 0.57 (225.8) = 128.71 \text{ Btu/hr} \]

Assuming the same heat load proportions for box vs. top as the theoretical, the box load constant @ 98\(^\circ\)F is:

\[ q_{\text{box}} = 0.7101 \times 128.71 = 91.40 \text{ Btu/hr} \]

The actual heat load for the test box with ceramic top was:

\[ P = 65.80 \text{ watts or } 224.67 \text{ Btu/hr, } \Delta T = 98^\circ \text{F} \]

The power was on 67.07\% of the time (see data)

\[ 0.6707 \times 224.67 = 150.69 \text{ Btu/hr} \]

Subtracting the box constant from the total gives us the loss through the top:

\[ 150.69 - 91.40 = 59.29 \text{ Btu/hr} \]

Therefore,

\[ q_{\text{ceramic top}} = K (4 \text{ ft}^2)(98.0^\circ \text{F}) = 59.29 \text{ Btu/hr} \]

Solving for \( K \):

\[ K = \frac{59.29}{(4)(98)} = 0.1513 \text{ or } R = 6.61 \]

\[ R_{\text{ceramic insulation}} = 6.61 - 0.45 = 6.16 / 2 \text{ in.} \]

\[ R/\text{in for ceramic insulation} = 3.08 \]
Date: 8/12/81
Test: Standard Top
Freezer Temperature -34.5°C (-30.0°F)

\[ V_{\text{Line}} = 119.2 \]
\[ P_{\text{Box}} = 66.16 \text{ Watts} \]

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<th>Lap Time (hr)</th>
<th>Accum Time (hr)</th>
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<th>Box Heat Off (hr)</th>
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**Start Test Hr 31.61**

| 31.80       | 0.19          | 0.19            | 25.17            | --                | --               | --                | 18.6            | 19.6            | 42.5        |
| 47.23       | 15.43         | 15.62           | --               | 34.10             | 8.93             | 8.93              | 21.6            | 19.8            | 40.0        |
| 47.43       | 0.20          | --              | 34.10            | --                | --               | --                | 18.5            | 19.8            | 43.0        |
| 47.68       | 0.25          | --              | 34.35            | 0.25              | --               | --                | --              | --              | --          |
| 47.87       | 0.19          | --              | 34.35            | --                | --               | --                | 18.6            | 19.9            | 43.0        |
| 48.12       | 0.25          | 16.51           | --               | 34.60             | 0.25             | 9.43              | 21.7            | 20.0            | 40.0        |
| 50.00       | 1.88          | --              | 35.56            | --                | --               | --                | 18.5            | 19.8            | 43.5        |
| 50.23       | 0.23          | 18.62           | --               | 35.79             | 0.23             | 10.62             | 21.6            | 20.0            | 40.0        |
| 50.42       | 0.19          | --              | 35.79            | --                | --               | --                | 18.5            | 19.8            | --          |
| 50.65       | 0.23          | 19.04           | --               | 36.02             | 0.23             | 10.85             | --              | --              | --          |
| 51.98       | 1.33          | **20.37**       | --               | 36.78             | **11.61**        | **21.6**          | 20.0            | 40.5            | --          |

**Test Duration**

**Box Heat on 57.00% of test time**

Note: Test was begun after box temperatures and lap times stabilized. Test time was recorded from a box-heat-off to box-heat-off interval.
Date: 8/13/81  
Test: Ceramic Insulation Top  
Freezer Temperature -34.5°C (-30.0°F)  

\[ I_{\text{Total}} = 0.566 \]  
\[ I_{\text{Ext}} = 0.014 \]  
\[ I_{\text{Box}} = 0.552 \]  
\[ V_{\text{Line}} = 119.2 \]  
\[ P_{\text{Box}} = 65.80 \text{ Watts} \]

<table>
<thead>
<tr>
<th>Line on (hr)</th>
<th>Lap Time (hr)</th>
<th>Accum Time (hr)</th>
<th>Box Heat On (hr)</th>
<th>Box Heat Off (hr)</th>
<th>Lap Time On (hr)</th>
<th>Accum Time On (hr)</th>
<th>Box Air Temp (°C)</th>
<th>Box Water Temp (°C)</th>
<th>Box Humidity</th>
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<td>52.71</td>
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<td>0.47</td>
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<td>38.26</td>
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<td>21.5</td>
<td>20.1</td>
<td>41.0</td>
<td></td>
</tr>
</tbody>
</table>

Start Test Hr 55.01

| 70.71        | 15.70         | 15.70          | 48.63           | --               | --              | 18.2              | 20.1              | 39.0              |
| 71.05        | 0.34          | 16.04          | --              | 48.97            | 10.71           | 10.71             | 21.6              | 20.1              | 37.0        |
| 71.21        | 0.16          | --             | 48.97           | --               | --              | 18.2              | 20.0              | 39.0              |
| 73.54        | 2.49          | 18.53          | --              | 50.66            | 1.69            | 12.40             | 21.5              | 20.1              | 36.5        |
| 73.69        | 0.15          | --             | 50.66           | --               | --              | 18.2              | 20.0              | 38.5              |
| 74.03        | 0.34          | --             | 51.00           | --               | --              | 21.5              | 20.1              | 36.0              |
| 74.19        | 0.16          | --             | 51.00           | --               | --              | 18.2              | 19.9              | 38.0              |
| 74.55        | 1.01          | 19.54          | --              | 51.36            | 0.70            | 13.10             | 21.6              | 20.1              | 36.0        |
| 75.72        | 1.17          | --             | 52.03           | --               | --              | 18.2              | 20.0              | 38.0              |
| 76.06        | 0.34          | --             | 52.37           | 0.34             | --              | 21.5              | 20.1              | 36.0              |
| 76.22        | 0.16          | --             | 52.37           | --               | --              | 18.2              | 20.0              | 38.0              |
| 76.57        | 0.35          | 21.56*         | 52.72           | 0.35             | 14.46           | 21.6              | 20.1              | 36.0              |

* Test Duration  
** Box Heat on 67.07% of test time

Note: Test was begun after box temperatures and lap times stabilized. Test time was recorded from a box-heat-off to box-heat-off interval.