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DEVELOPMENT OF IMPROVED INSULATION MATERIALS

Semiannual Report, September 1, 1978—February 28, 1979

By
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May 8, 1979

Work Performed Under Contract No. EM-78-C-04-4295

Dow Corning Corporation
Midland, Michigan

MASTER

U.S. Department of Energy

Solar Energy

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SEMIANNUAL REPORT

ON

DEVELOPMENT OF IMPROVED INSULATION MATERIALS

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Period Covered:

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ABSTRACT

The laboratory development of an improved insulation material has led to the development of three types of low density silicone foam (Type IA, IB and II) and a composite foam (Type IA silicone foam/rigid polyurethane foam) that could be used in a flat plate solar collector. Type IA and IB foam are both crosslinked with $\equiv\text{SiOSi}\equiv$ bond, the former being cured at room temperature using a platinum catalyst, whereas the latter being cured at 150°C using a rhodium catalyst. Type II foam is a room temperature vulcanized foam, crosslinked with $\text{=NCOS(CH}_2)_3\text{Si}\equiv$ linkage. The density of Type IA and II foam has been reduced down to 2-3 lbs/ft³ range whereas the lowest density of Type IB attained was 6 lbs/ft³. Both IA and II low density silicone foam have a thermal insulation property comparable to those of commercially available insulation materials. TGA show that both Type IA and Type II foams gives only 1-2% weight loss at 200°C . At higher temperature, however, Type IA foam shows less weight loss than Type II foam. A composite foam, where Type IA foam was used to protect a thermally less stable rigid polyurethane foam, was evaluated and found to be an effective insulation material for a flat plate solar collector.

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I. INTRODUCTION

Insulation materials used in flat plate solar collectors minimize heat loss through the back side of the collector once solar energy has been captured. The insulation must provide minimal heat loss under normal operating temperatures, show good thermal stability at high temperature, and good weatherability, provide long service life and be cost effective. Earlier insulation materials (i.e. home fiberglass insulation, polyurethane foam) used in flat plate collectors were found to outgas at high stagnation temperatures (e.g. 400°F) and weather poorly.^{1, 2} Condensation of the condensible decomposition products produced during outgassing collect on the glass cover plate of the collector, reduces the amount of sunlight to the absorber plate, and thus reduce the overall collector efficiency.

Many of the deficiencies in present insulations could be eliminated with a silicone insulation. Silicone elastomers are noted for their excellent high temperature stability and weatherability. These properties are also inherent in a new fire resistant elastomeric silicone foam³, Dow Corning® 3-6548 RTV Foam. However, the density (17 lbs./ft³) and thermal conductivity value [0.542 BTU-in/ft² hr. °F¹¹] of Dow Corning® 3-6548 RTV foam makes it economically unattractive for use in flat plate solar collectors.

The objective of this present contract effort was to develop silicone foam insulation that offers good insulating properties, resistance to outgassing and moisture retention, thermal stability and flame resistance, and which is cost effective.

This work has been divided into two major tasks: (1) laboratory development work and (2) cost effectiveness calculations. This report summarizes the first six months of effort devoted toward developing a low density silicone foam for insulation.

II. RESULTS AND DISCUSSION

The laboratory development work to develop silicone foam insulation has been divided into two areas of study. First, demonstrate that silicone foams can be used as a protective high temperature barrier between the absorber plate and conventional insulating materials (e.g. rigid polyurethane foam) to minimize the problems of outgassing and the thermal degradation associated with polyurethane foam at stagnation temperatures. This type of dual insulation has been designated as a composite foam. The second area of study is to develop low density silicone foam (1-3 lbs/ft³) which will be used as the only insulating material for the solar energy collector.

A. Composite Foam

Rigid polyurethane foam is an excellent thermal insulator because of its low thermal conductivity value [0.12-0.14 BTU-in/ft² hr. °F at 75°F]. However, at 340°F stagnation temperature, polyurethane foam is reported to outgass.⁵ Installation of a high temperature insulating barrier (i.e. silicone foam) between the hot surface and polyurethane foam (PU) is expected to reduce the temperature encountered by PU foam and thus eliminate problems of outgassing associated with thermal degradation. In a conventional flat plate collector, the silicone foam can be placed between the absorber plate and PU foam as shown in Figure I.

The effectiveness of silicone foam as a high temperature protective barrier for PU foams was demonstrated using a conventional laboratory oven, shown in Figure II. The oven was modified such that 200°C (392°F) stagnation temperatures could be simulated in a manner similar to stagnation temperatures generated in a flat plate collector. A multi-point strip chart recorder was used to record the surface temperature of silicone foam and silicone-PU foam interface temperature as a function of time after the power of the oven was turned on. A typical result is shown in Figure III. These results indicate that silicone foam can be used effectively to prevent the PU foam from reaching the reported 340°F outgassing temperature.⁵

The type of silicone foam employed in the composite foam is Type IA foam, which will be described later.

Since the thermal conductivity of foam is known to be dependent on the foam density,^{6, 7} the effects of Type IA silicone foam density on the silicone-PU foam interface temperature were studied. The densities of the Type IA silicone foams employed were 6, 10 and 15.4 lbs/ft³. The foam thicknesses were 1, 2, and 3 inches. Results are summarized in Figure IV. It can be seen that even a one inch Type IA silicone foam is sufficient to protect the PU foam from reaching the reported stagnation temperature.

The thermal conductivity of Type IA silicone foam, when measured perpendicular to the foam rise, was found to be lower than that obtained parallel to the foam rise. This is illustrated in Figure V. To maximize the efficiency of insulation, therefore, the silicone foam should be installed such that heat transfer is perpendicular to the direction of foam rise.

B. Development of Low Density Silicone Foams

Two types of low density silicone foam were investigated which have been designated as Type I and Type II foams. Both are flexible foams. These are summarized below.

1. Type I Low Density Silicone Foam

The basic reaction which takes place during the formation of Type I foam is shown below:

The formation of siloxane bonds is responsible for the elastomer network formation, whereas the generation of hydrogen gas creates the foam structure during cure. The reaction takes place at room temperature if a platinum catalyst is employed. The resulting foam is designated as Type IA foam.

If a rhodium catalyst is employed, the reaction will not take place unless heated.⁸ This permits the formulation of a one-component, liquid foam product which is stable at room temperature, but will readily foam and cure when sufficiently heated (e.g. 150°C). The resulting foam is designated as Type IB foam. Type IB silicone foams, which have densities ranging from 7 to 20 lbs./ft³, have unusual cell structures. The cells elongate along the same axis in which the foam rises, and the cells are almost 100% open in the direction of expansion and closed in a perpendicular direction. Because of the effect of cell orientation on the thermal conductivity of foam, as described in the previous section, the rhodium catalyzed foam should be prefabricated and installed in the solar energy collector such that the cell orientation is parallel to the glass cover plate. (Note: Type IB is the same type as the prefabricated foam described in the contract proposal).

Type IA silicone foams, with densities ranging from 5 to 20 lbs/ft³, had been prepared and their thermal conductivity determined. Typical results are shown below:

<u>Density (lbs/ft³)</u>	<u>K-factor (BTU-in/ft² hr. °F)</u>
17	.542 ¹¹
5	.27

Because of the dramatic decrease in K-factor due to a decrease in density, our effort under the contract has been concentrated on the development of both Type IA and IB lower density foams; aiming at about 1-3 lbs/ft³. It is hoped that the low density foams not only give K-factors lower than 0.27, but also reduces the cost per unit volume such that it becomes competitive with other commercial foams in the solar energy collector application. Results are summarized below.

a. Type IA Low Density Foam

In our work prior to this contract, some variables which affect the foam density and cell structure had been identified, e.g., mole ratio of $\equiv\text{SiH}$ to $\equiv\text{SiOH}$ and $\equiv\text{SiH}$ to

$\equiv\text{SiVi}$, type of $\equiv\text{SiH}$ compound, molecular weight of polymer, platinum catalyst concentration, filler concentration, etc. A similar approach was taken in our attempt to prepare a lower density RTV foam. Thus, Plackett-Burman screen experiments ^{12, 13} were carried out to identify the variables which give rise to densities lower than 5 lbs/ft³. The variables screened are listed below:

1. Molecular weight of Polymer I, $\text{HO}(\text{Me}_2\text{SiO})_x\text{H}$: average $x = 66$ vs. 459.
2. Type of silicone gum: $\text{HO}(\text{Me}_2\text{SiO})_x\text{H}$ vs.
 $\text{ViMe}_2\text{Si}(\text{OMe}_2\text{Si})_x(\text{OMeViSi})_y$
 OSiMe_2Vi
3. Loading level of silicone gum: 5.9 vs. 15.0 pph*
 (*pph = parts per 100 parts of polymer I)
4. Type of filler: Ground quartz (Min-U-Sil) vs.
 diatomaceous earth (Celite 315JM)
5. Loading level of filler: 5.9 vs. 30 pph
6. Mole Ratio of $\equiv\text{SiOH}$ in $\text{HO}(\text{Me}_2\text{Si})_{13}\text{H}$ to that in Polymer I: 9.8 vs. 39.2
7. Mole ratio of $\equiv\text{SiH}$ to $\Sigma\equiv\text{SiOH}$: 6.2 vs. 4.0
8. Type of $\equiv\text{SiVi}$ containing polymer:
 Polymer II - $\text{ViMe}\phi\text{Si}(\text{OMe}_2\text{Si})_x\text{OSiMe}\phi\text{Vi}$ vs.
 Polymer III - $\text{ViMe}\phi\text{Si}(\text{OMe}_2\text{Si})_x(\text{OMeViSi})_y\text{OSiMe}\phi\text{Vi}$
9. Number average molecular weight of $\equiv\text{SiVi}$ containing polymer: 10,200 vs. 21,600
10. Loading level of polymer II or III: 5.8 vs. 58 pph
11. Platinum catalyst concentration: 30 vs. 60 ppm
12. Initial reaction temperature: 23-25 vs. 38-40°C
13. Type of $\equiv\text{SiH}$ containing disiloxane: $(\text{HMe}_2\text{Si})_2\text{O}$
 vs. $(\text{HMe}_2\text{Si})_2\phi$
14. Loading level of $\equiv\text{SiH}$ containing disiloxane: 0.375 vs. 0.75 pph
15. Effect of $(\text{CF}_3\text{CH}_2\text{CH}_2\text{MeSiO})_4$: 0 vs. 3 pph.
16. Effect of Silicone resin: 0 vs. 5 pph
17. Effect of carbon black: 0 vs. 10 pph
18. Mole ratio of $\equiv\text{SiH}$ to hydrosilation inhibitor: 356 vs. 712

All failed to give densities lower than 5 lbs/ft³.

Subsequent investigations used methanol in the formulations which resulted in 1-3 lbs/ft³ Type IA silicone foams. This is attributed to an increase in the volume of hydrogen gas generated by the reaction shown below.

This is demonstrated by adding various amounts of methanol to a given foam formulation consisting of $\text{HO}(\text{Me}_2\text{SiO})_x\text{H}$, $\text{Me}_3\text{Si}(\text{MeHSiO})_x\text{SiMe}_3$, $\text{ViMe}\phi\text{Si}(\text{OMe}_2\text{Si})_x\text{OSiMe}\phi\text{Vi}$ and platinum catalyst, as shown in Figure VI. As the amount of methanol is increased, the hydrogen gas volume increases and the foam density decreases. The data also indicates that there is no point in increasing the methanol beyond 5 weight percent, since no further decrease in density is noted. It was decided, therefore, to fix the level of methanol at 5 weight percent and study the effects of other variables such as (1) molecular weight of $\text{HO}(\text{Me}_2\text{SiO})_x\text{H}$, (2) loading level of $\text{ViMe}\phi\text{Si}(\text{OMe}_2\text{Si})_x\text{OSiMe}\phi\text{Vi}$, (3) mole ratio of $\equiv\text{SiH}$ to $(\equiv\text{SiOH} + \equiv\text{SiVi})$ and (4) platinum catalyst concentration.

Table I shows the effect of the molecular weight of $\text{HO}(\text{Me}_2\text{SiO})_x\text{H}$ on the foam density. These results indicate that the average value of X should be less than 269; preferably around 30 in order to obtain 1-2 lbs/ft³ foam.

The effect of the loading level of $\text{ViMe}\phi\text{Si}(\text{OMe}_2\text{Si})_x\text{OSiMe}\phi\text{Vi}$, where average value of X is 160, on the foam density is shown in Figure VII. The lowest density was found at about 25 weight percent. The presence of this polymer gives rise to the following hydrosilation:

This reaction consumes the $\equiv\text{SiH}$ without giving off gas. It affects not only the structure of the elastomeric network in the cell walls, but also the cure rate; i.e. slows down the cure rate.

Figure VIII show the effect of mole ratio of $\equiv\text{SiH}$ to $(\equiv\text{SiOH} + \equiv\text{SiVi})$, R_1 , on the foam density. $R_1 = 2.4$ appears to be the optimum value.

The platinum catalyst concentration controls the rates of blowing agent generation and curing of the expanded polymer network. Both curing and gas generation must be properly balanced to obtain the lowest density foam. Figure IX shows the effect of varying catalyst concentration upon foam density and the time required to reach maximum foam rise.

At the low catalyst concentrations, foams in the 2 lbs/ft³ density range can be obtained. However, the foams are not cured properly (i.e. tacky surfaces) at this level, which indicates that the rates of gas generation and curing are not balanced. At higher catalyst concentrations (>120ppm), the curing and gas generations are properly balanced resulting in lower density foams with dry surfaces. In the second half of this contract, one of the Type IA low density foams, described above, will be scaled up and installed into a solar energy collector for field testing. Also planned in the second half is the optimization of formulations using Box-Behnken designed experiments.

b. Type IB Low Density Foam

To identify the variables which affect the density of Type IB foams, a 13-variable, 20-run Plackett-Burman screening experiment was carried out. The variables screened are show below:

1. Molecular weight of $\text{HO}(\text{Me}_2\text{SiO})_x\text{H}$ (Polymer I):
Average X = 66 vs. 459
2. Type of silicone gum: $\text{ViMe}_2\text{Si}(\text{OMe}_2\text{Si})_x(\text{OMeViSi})_y\text{OSiMe}_2\text{Vi}$ vs. $\text{HO}(\text{Me}_2\text{SiO})_x\text{H}$
3. Level of silicone gum: 0 vs. 5 pph (parts per 100 parts of Polymer I)
4. Type of filler: Celite 315-JM vs. 5 μ Min-U-Sil
5. Level of filler: 0 vs. 25 pph
6. Level of $\text{HO}(\text{Me}_2\text{SiO})_{13}\text{H}$: 6.52 vs. 13 pph
7. Type of $\equiv\text{SiH}$ compound: $\text{Me}_3\text{Si}(\text{OMeHSi})_x\text{OSiMe}_3$ vs. $\text{Me}_3\text{Si}(\text{OMe}_2\text{Si})_y(\text{MeHSi})_z\text{OSiMe}_3$, where average value of x, y, and z is 60, 30, and 30 respectively.
8. Mole ratio of $\equiv\text{SiH}$ to $\equiv\text{SiOH}$: 5.35 vs. 8.35
9. Level of $\text{Vi}\phi\text{MeSi}(\text{OMe}_2\text{Si})_x\text{OSiMe}\phi\text{Vi}$, average x = 287: 0 vs. 25 pph
10. Rhodium catalyst concentration : 35 vs. 75 ppm
11. Level of Krytox 143 Az(surfactant): 0 vs. 0.5 pph
12. Temperature: 175 vs. 200°C
13. Level of $\text{HMe}_2\text{Si}(\text{OMe}_2\text{Si})_x\text{OSiMe}_2\text{H}$, average x = 10: 0 vs. 5 pph

From the screening experiments, three significant variables were identified, i.e. X_1 = mole % vinyl in silicone gum, X_2 = amount of $\text{HO}(\text{Me}_2\text{SiO})_{13}\text{H}$ added to Polymer I and X_3 = mole ratio of $\equiv\text{SiH}$ to $\equiv\text{SiOH}$. Three-variable, 15-run Box-Behnken designed experiments were carried out. Polynomical equations relating these three variables to foam density were obtained by computer analysis and the response surfaces, plotted as a function of these three variables, were generated with a Hewlett Packard 98132 plotter. Results are shown in Figure X. The lowest density obtained from these experiments was 6 lbs/ft³.

2. Type II Low Density Silicone Foam

Prior to the start of this contract, research work at Dow Corning demonstrated that a room temperature cured silicone foam with a density of 5 lbs/ft³ could be made from polydimethylsiloxanes containing mercaptopropyl functional groups, toluene diisocyanate (TDI), water and an amine catalyst.⁹ This type of foam is designated as Type II silicone foam. The primary and secondary reactions involved in this type of foam are shown below.

Primary Reactions:

Secondary Reactions:

Secondary reactions (7) and (8) proceed more slowly than the primary reactions (4) through (6). Carbon dioxide generated from Reaction (5) is responsible for the foaming and the formation of $\text{=NCOS(CH}_2\text{)}_3\text{Si=}$ linkage is responsible for the crosslinking.

To reduce the density of Type II foam to less than 5 lbs/ft³ the effect of the following three variables on the density of foam was investigated:

- a. molecular weight of polymer , $\text{HS(CH}_2\text{)}_3\text{SiR}_2(\text{OMe}_2\text{Si})_x\text{OR}_2\text{Si(CH}_2\text{)}_3\text{SH}$,

where R is Me or MeO,

- b. amount of water, and
- c. mole ratios of NCO to -SH

The effect of polymer molecular weight on the foam density was studied using $\text{HS(CH}_2\text{)}_3\text{Me}_2\text{SiO(Me}_2\text{SiO)}_x\text{SiMe}_2(\text{CH}_2\text{)}_3\text{SH}$, where the average value of X is 30 and 229 respectively. These two polymers were blended to give an average value of X ranging from 55 to 100, as shown in Figure XI. As shown in Figure XI, the density of Type II foam decreases with polymer molecular weight. The lowest density foam (2.5 lbs/ft³) was obtained when the value of X was about 60.

The effect of the mole ratio of NCO to SH on foam density was studied using $\text{HS(CH}_2\text{)}_3\text{Me}_2\text{Si(OMe}_2\text{Si)}_x\text{OSiMe}_2(\text{CH}_2\text{)}_3\text{SH}$. Two types of amine catalyst were employed, i.e. Et₃N and Polycat®8 amine catalyst (Abbot Lab). Results are shown in Figure XIII. For a given catalyst the foam density decreases as the NCO/SH ratio increases. A foam with 1.1 lbs/ft³ density was obtained at a NCO/SH ratio of 11.5 when Polycat 8 amine catalyst was employed.

As shown in Type I foam, the volume of gas generated also affects the density of Type II foam. This was demonstrated by adjusting the amount of water. As shown in Figure XIII, when the water concentration is between 3 to 7 weight percent, the density of resulting foam is in the range of 2 -2.5 lbs/ft³.

3. Thermal Conductivity and Thermal Stability

a. Thermal Conductivity

The thermal conductivity of Type IA silicone foam has been shown to decrease linearly with foam density (Figure V). This relationship holds, however, down to the 5-6 lbs/ft³ range only. Below 5-6 lbs/ft³, the thermal conductivity remains more or less constant at 0.26-0.27 BTU-in/ft³ hr. °F for both Type IA and Type II foams. This is shown in Figure XIV. Included in the figure is the theoretical curve

calculated by the method described by McIntire.⁶ It can be seen that the agreement between the calculated and experimental data is excellent. As the density of foam is decreased to below 6 lbs/ft³, however, the experimental curve deviates from the linearity. This behavior has been observed for a number of organic foams and has been attributed to an increased radiant-heat transfer.⁷ This explanation also applies to our case because the other possible contributing mechanism -- convection heat transfer -- can be ignored since the cell diameter of both Type IA and Type II foam are smaller than 4 mm. Investigations by Skochdopole¹⁰ have shown that there is ordinarily no measureable convection in cells of diameters less than 4 mm.

b. Thermal Stability

The thermal stability of foam can be evaluated in terms of weight loss by TGA. Figure XV compares the TGA data for Type IA foam, Type II foam, and Dow Corning® 3-6548 Silicone RTV foam (also Type IA) respectively. At 200°C all three foams show 1-2% weight loss. However, as temperature is increased, the observed weight losses also increase, with Q3-6548 foam showing the smallest weight loss and Type II foam showing the greatest percent weight loss. The thermal stability of Type II foam obviously is poorer than Type IA foam, due to the presence of =NCOS- linkages, which are known to be thermally less stable than =SiOSi= linkages.

Another method for assessing the thermal stability of foam is to monitor the changes in strength properties (i.e. compression/deflection) during the heat aging. A substantial loss in compressive strength, as a function of extended periods of heat aging at high temperature, would indicate the lack of thermal stability. Figure XVI shows the change in compressive strength at 20% deflection (via ASTM D 1564-39) as a function of heat aging time at 200°C. As can be seen, no significant loss of compressive strength is observed. Compared to the initial values, the two lowest density foams show higher compression values after thermal aging, which indicates that these foams become more rigid.

Monitoring the changes in thermal conductivity values as a function of extended periods at high temperatures (i.e. 200°C) is another way of measuring the thermal stability. Heat aging of Type IA silicone foams at 200°C for several days has shown no change in thermal conductivity values (Figure XVII), indicating that the low density Type IA foam is thermally stable at 200°C for an extended period of time.

III. CONCLUSIONS

1. Three types of low density silicone foams were developed, i.e., Type IA, IB and II. Type IA and IB foam are both crosslinked with $\equiv\text{SiOSi}\equiv$ bond, the former being cured at room temperature using a platinum catalyst, whereas, the latter being cured at 150°C using a rhodium catalyst. Type II foam is a room temperature vulcanized foam, crosslinked with $=\text{NCOS}(\text{CH}_2)_3\text{Si}\equiv$ linkage. The density of Type IA and II silicone foam has been reduced down to 2-3 lbs/ft³ range. The lowest density of Type IB foam attained was 6 lbs/ft³.
2. The thermal conductivity of Type IA and II silicone foam was found to be comparable to those of most commercially available insulating material, i.e. about 0.26 BTU-in/ft² hr. °F.
3. TGA show that both Type IA and Type II foams give only 1-2% weight loss at 200°C . At higher temperatures, however, Type IA foams show less weight loss than Type II foams.
4. Type IA foam shows good to excellent retention of initial physical properties after heat aging at elevated temperatures (200°C) for extended time periods.
5. A composite foam, where a Type IA foam was used to protect thermally less stable insulation foam (rigid polyurethane foam) was evaluated and found to be an effective insulation material for a flat plate solar collector.

IV. FUTURE WORK

1. Evaluate the 2.7 lbs/ft³ Type IA foam in a flat plate solar collector; as the primary insulation and as a composite foam.
2. Optimize the formulations of Type IA foam using design experimentation.
3. Continue physical property determinations.
4. Do cost effectiveness calculations.

V. ACKNOWLEDGEMENTS

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TABLE I

Effect of Molecular Weight of $\text{HO}(\text{Me}_2\text{SiO})_x\text{H}$ on Type IA Foam Density

<u>Formulation No.</u>	<u>A</u>	<u>B</u>	<u>C</u>
<u>Formulation (parts)</u>			
$\text{HO}(\text{SiMe}_2\text{O})_{35}\text{H}$	44.7	--	--
$\text{HO}(\text{SiMe}_2\text{O})_{270}\text{H}$	--	44.7	--
$\text{HO}(\text{SiMe}_2\text{O})_{460}\text{H}$	--	--	44.7
$\text{ViMe}\phi\text{Si}(\text{OSiMe}_2)_{160}\text{OSiMe}\phi\text{Vi}$	30	30	30
Pt Catalyst (ppm)	176	176	176
CH_3OH	5.0	5.0	5.0
$\text{Me}_3\text{SiO}(\text{MeHSiO})_{45}\text{SiMe}_3$	30.0	30.0	30.0
Initial Viscosity at 25°C (centipoise)	132	520	1,750
<u>Physical Properties</u>			
Density (lbs/ft ³)	1.5	6.4	4.8
Cell size (mm)	0.6	0.1-4	3-8

Figure I: Conventional Flat Plate Solar using Composite Foam as Insulation Material

FIGURE II: DIAGRAM OF HIGH TEMPERATURE OVEN
WITH COMPOSITE FOAM

FIGURE III: TEMPERATURE PROFILE OF COMPOSITE
FOAM

FIGURE IV: EFFECT OF SILICONE FOAM UPON SILICONE/
POLYURETHANE FOAM INTERFACE TEMPERATURE

FIGURE V: EFFECT OF DENSITY UPON THERMAL CONDUCTIVITY OF TYPE IA SILICONE FOAM

FIGURE VI : EFFECT OF CH_3OH CONCENTRATION UPON
DENSITY OF TYPEIA SILICONE FOAM

FIGURE VII: EFFECT OF VINYL ENDBLOCKED POLYMER UPON DENSITY OF TYPE IA SILICONE FOAM

FIGURE VIII: EFFECT OF CURING AGENT LEVEL UPON THE DENSITY OF TYPE IA SILICONE FOAM

FIGURE IX: EFFECT OF Pt CATALYST CONCENTRATION UPON DENSITY OF TYPE IASILICONE FOAM

FIGURE X : EFFECT OF FORMULATION VARIABLES ON THE DENSITY OF TYPE IB SILICONE FOAM

(density: lbs./ft³)

FIGURE XI: EFFECT OF POLYMER MOLECULAR WEIGHT
UPON DENSITY OF TYPE II SILICONE FOAM

FIGURE XII: EFFECT OF NCO/SH MOLE RATIO UPON DENSITY OF TYPE II FOAM

FIGURE XIII: EFFECT OF WATER CONCENTRATION UPON
DENSITY OF TYPE II SILICONE FOAM

FIGURE XIV: THERMAL CONDUCTIVITIES OF SILICONE FOAMS

FIGURE XV: THERMOGRAVIMETRIC ANALYSIS OF SILICONE FOAMS

FIGURE XVI: THERMAL STABILITY, EFFECT OF HEAT AGING UPON COMPRESSION/DEFLECTION OF TYPE IA SILICONE FOAM

Figure XVII: THERMAL STABILITY, EFFECT OF HEAT AGING UPON THERMAL CONDUCTIVITY OF TYPE IA SILICONE FOAMS.