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Moisture Penetration Evaluation of Polystyrene Bead Foam as an Encapsulant for Electronic Packages

By G. D. Swanson

MASTER

Published June 1980

Topical Report

D. J. Fossey, Project Leader

Prepared for the United States Department of Energy Under Contract Number DE-AC04-76-DP00613.

Bendix Kansas City Division

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CONTENTS

ILLUSTRATIONS

TABLES

SUMMARY

One task in evaluating polystyrene bead foam (PSBF) as an encapsulant for electronic packages is measuring high-pressure moisture penetration resistance. Because no standard techniques or equipment were known, a test fixture was built and a procedure was developed for the required measurement.

One slab for each allowable fusion time and temperature for each PSBF density from 0.2 to 0.6 g/cm^3 was evaluated. Each condition withstanding the required 1724 kPa water pressure for 24 hours was submitted to extended testing for at least 96 hours. Replicates for the same conditions also proved to be impervious.

The higher densities of PSBF were less porous. Higher fusion temperatures and longer fusion times for a given density also increased resistance to moisture penetration. Only the 0.6 g/cm^3 PSBF was impervious and only for three of the eight fusion conditions evaluated. The adequate conditions were 115 and 125°C for 60 minutes and 125°C for 40 minutes.

DISCUSSION

SCOPE AND PURPOSE

The purpose of this project is to characterize the various properties of polystyrene bead foam (PSBF) at densities of 0.1 to 0.6 g/cm^3. These data are necessary to recommend the correct foam density, the appropriate bead fusion conditions, and other critical encapsulation process requirements. The goal of the project is to provide adequate environmental protection for electronic packages encapsulated with PSBF.

One candidate system requires protection from moisture penetration under 1724 kPa water pressure for 24 hours. Therefore, this task was undertaken to develop the necessary measurement techniques and to acquire necessary data for assuring adequate electronic package protection from such severe moisture exposure.

PRIOR WORK

Physical, mechanical, and chemical properties have been reported for PSBF.[1] Thermomechanical interactions when potting electronic assemblies in PSBF also have been reported.[2] In addition, two other tasks in the present PSBF evaluation have been completed.[3,4] However, no previous work is known which has investigated moisture penetration through PSBF. No standardized testing procedures or testing equipment were discovered in literature searches.

ACTIVITY

The moisture tests may be grouped into two categories. The first category included testing a thumb tack and a dummy electronic package to measure moisture (either liquid or vapor) intrusion into an encapsulated unit. The thumb tack tests were to provide preliminary information and to prove the adequacy of the chosen moisture sensor for encapsulation measurements; the dummy package tests were to provide functional information. The second category involved testing flat slabs to measure any direct vapor or liquid penetration through a thickness of PSBF.

Moisture Intrusion Tests

The paramount preliminary requirement for both moisture intrusion tests was to acquire moisture sensors of small size which could be potted in PSBF at 125°C. The sensor chosen, the Mini-Mod A from Panametrics, is sensitive to moisture levels down to parts per million and has fast response. Miniature in size and bakable to 400°C, this sensor easily can withstand PSBF encapsulation at its maximum 125°C.

A protective mounting for this transducer was designed by Bendix Kansas City. As received, the Mini-Mod A chips had to be bonded to transistor headers, and fine wire leads were thermocompression bonded in place. Protective covers were prepared to keep the PSBF from touching the sensor surface and the miniature electrical lead wires during encapsulation. Figure 1 shows a Mini-Mod A chip mounted to a transistor header with the lead wires bonded in place and a sensor with the protective cover installed.

After mounting the sensor chips on the headers, each sensor was calibrated to read relative humidity. Calibration was done in a closed bell jar with the appropriate solution of sulfuric acid and water in a pan at the bottom.

Figure 2 shows the calibration curves for the sensors used. The data points are the average meter readings of the four sensors calibrated, and the error bars show the total data scatter. Manufacturers data show that these sensors become nonlinear on a semilog plot below 1 percent relative humidity for ambient temperature.

The extended delay in receiving the moisture sensors caused a plan revision. The thumb tack tests were done without moisture sensors. The flab slab tests revealed that lower PSBF densities fused at lower temperatures would not be adequate moisture barriers. Therefore, the slab testing was expanded in scope, and the dummy unit moisture intrusion testing was cancelled.

Moisture Penetration Tests

Moisture penetration of flat slabs required a pressurization chamber sealed to one side of the fused PSBF slab, a porous mechanical support, and moisture measurement instrumentation. Because no appropriate apparatus was available, the chamber shown in Figure 3 was designed and built. The chamber was designed for 6895 kPa to give a safety factor of 4. It was large enough inside to hold an assembled unit for moisture testing. A calibrated pressure gage and an 1862 kPa safety relief valve were mounted in the top of the chamber. The chamber, made of stainless steel to prevent rusting and corrosion, is mounted in a cradle so it can be easily upended for changing PSBF slabs.

The meter (Figure 3) monitors relative humidity continuously on one channel or can be switched between up to six channels. The two-pen strip chart recorder records the relative humidity meter reading and the weight of water that penetrates the PSBF slab. Unattended, 24-hour testing can be done, with a permanent record of when moisture penetrates the slabs.

The details of the top and bottom chamber closure are shown in Figure 4. The top plate includes the pressure inlet port, a 0 to 2068 kPa pressure gage, and an 1862 kPa pressure release valve

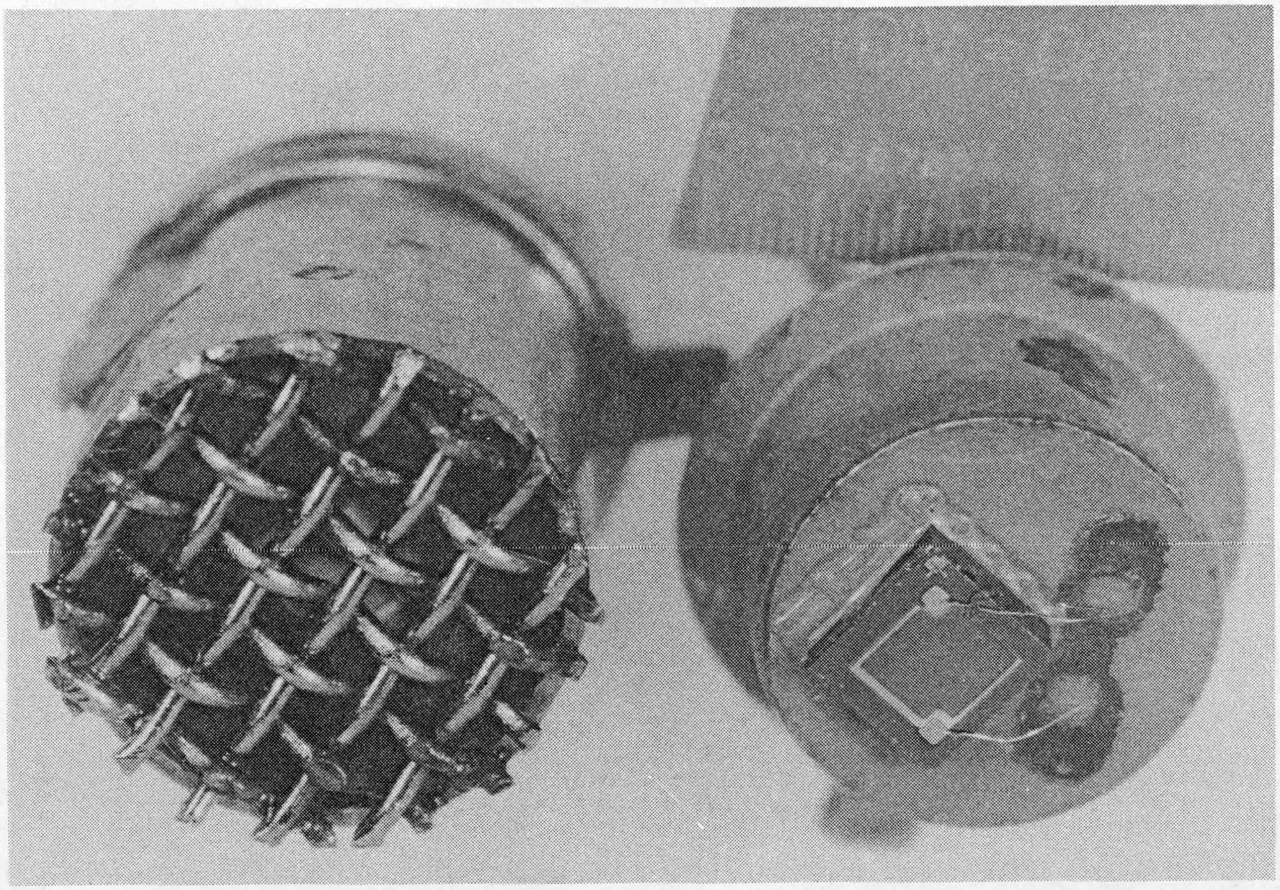

Figure 1. Mini-Mod Moisture Sensor Chip Mounted On Transistor Base

for added safety. The 0.4 g/cm^3 PSBF slab is shown sealed into a stainless steel ring. The mechanical support on the bottom of the PSBF slab is provided by a ceramic frit disc mounted in a stainless steel holder having an array of perforation holes. A closed container attaches to the bottom. This container has moisture vapor sensors mounted on the walls and a water collection pan mounted on a load cell at the center.

Slabs of PSBF with densities of 0.2, 0.3, 0.4, 0.5, and 0.6 g/cm^3 were tested for moisture penetration. The 0.1 g/cm^3 material could not be fused without distortion. The PSBF slabs tested were discs, 1.27 or 2.54 cm thick and 12.70 cm in diameter. These slabs were sealed into a stainless steel support ring using RTV. The slab and ring were then mounted onto a stainless steel pressure chamber. A porous ceramic frit disc supported the PSBF slab and allowed water to escape through the bottom into a collection pan mounted on a load cell. The pan had a capacity of 75 g.

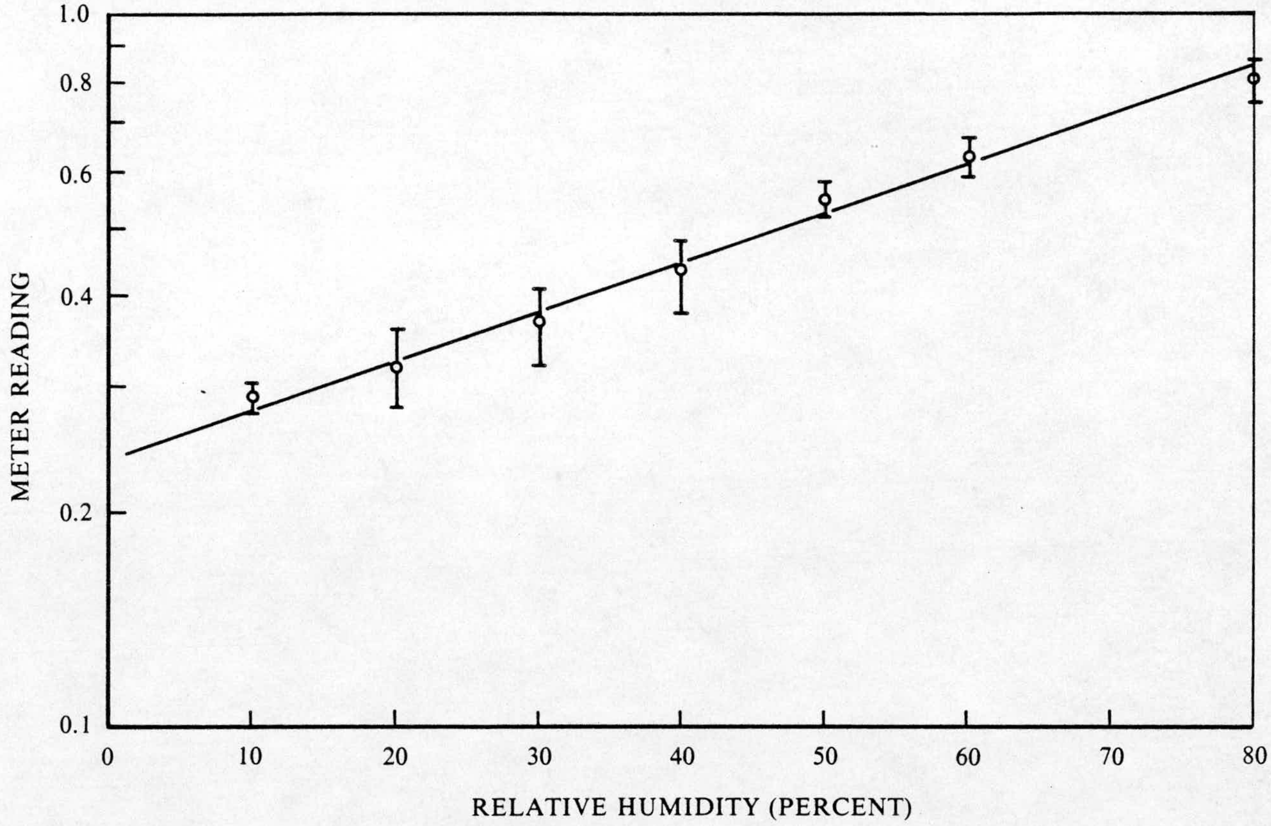

Figure 2. Moisture Calibration Chart

Table 1 shows preliminary data for 2.54-cm-thick slabs. All of these allowed water penetration well below 1724 kPa in much less than 24 hours. Table 2 shows the data for moisture penetration tests on 1.27-cm-thick slabs of PSBF foam. Slabs of 0.1 g/cm^3 density cannot be fused at 107°C without distortion. A fusion temperature of 115°C is too high for 0.2 and 0.3 g/cm^3 densities, resulting in distorted test specimens. For 0.4 g/cm^3 density, 115°C is useable, but 125°C is too high. A fusion temperature of 125°C for 60 minutes may be too severe for 0.5 g/cm^3 as seen by the lower resistance to moisture penetration as compared to 60 minutes fusion at 115°C. Added external pressure is required to achieve densities greater than 0.6 g/cm^3. Table 2 shows that only three fusion conditions met the goal of resisting penetration by water under 1724 kPa for 24 hours, as evidenced by 0 g of collected water. All these slabs were tested for extended periods of 96 or 120 hours, and all were still impervious upon test termination. No relative humidity increase was seen in the enclosed moisture collection container; such an increase was evident before water collection in the weight pan for all slabs which were penetrated.

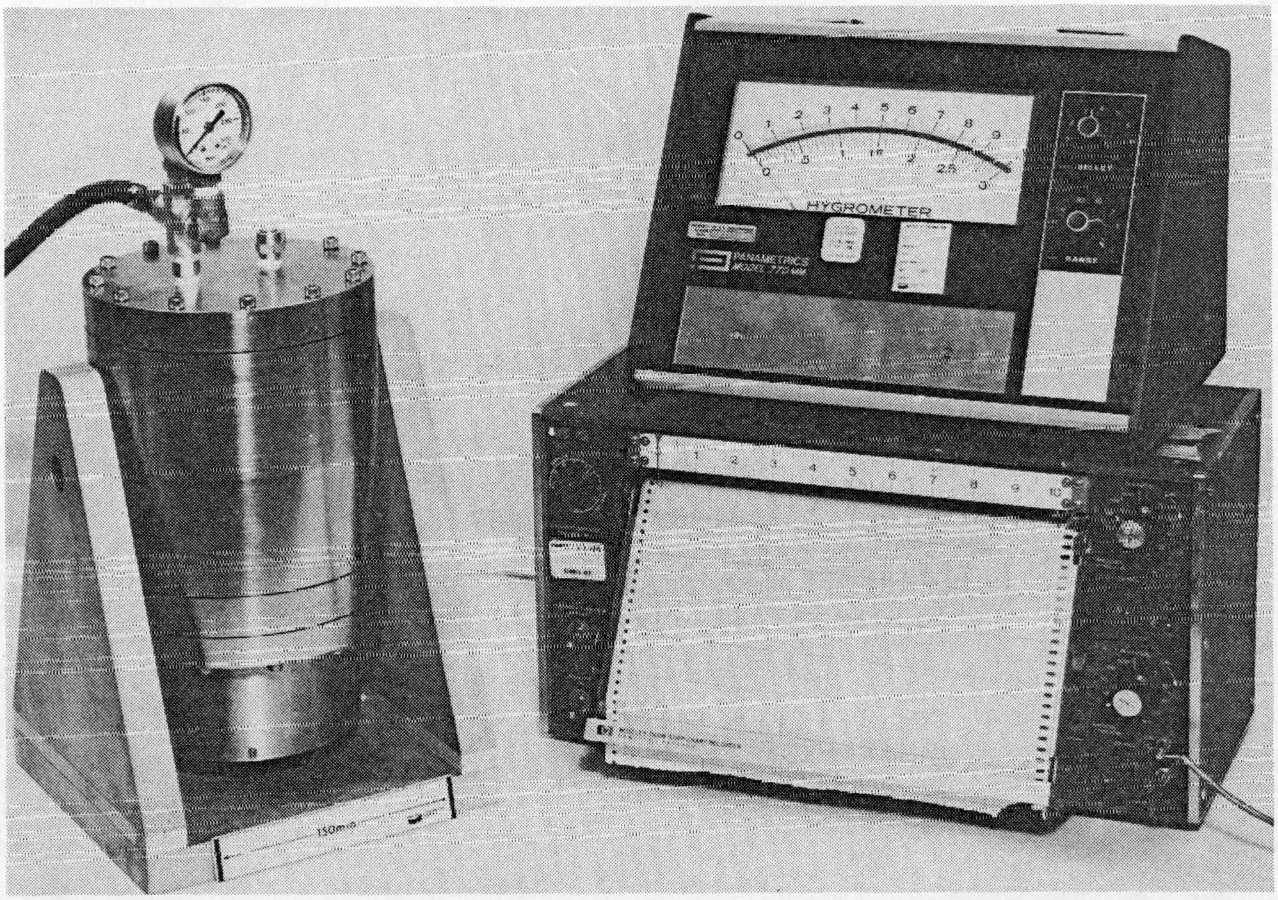

Figure 3. Test Chamber, Meter, and Strip Chart Recorder

Conclusions

The expected conclusions were confirmed by the test results. For the processing parameters evaluated, the higher densities of PSBF were less porous to water under pressure. In addition, the higher fusion temperatures for the PSBF processing for a given density increased resistance to moisture penetration, and longer times at fusion temperature resulted in PSBF with increased moisture penetration resistance.

ACCOMPLISHMENTS

A test fixture and related techniques have been developed and used to measure resistance to moisture penetration of flat PSBF slabs ranging in density from 0.2 to 0.6 g/cm^3 and fabricated at various fusion times and temperatures. Only three fusion conditions were identified as impervious to moisture penetration at 1724 kPa for the 96-hour test duration; all were 0.6 g/cm^3 density.

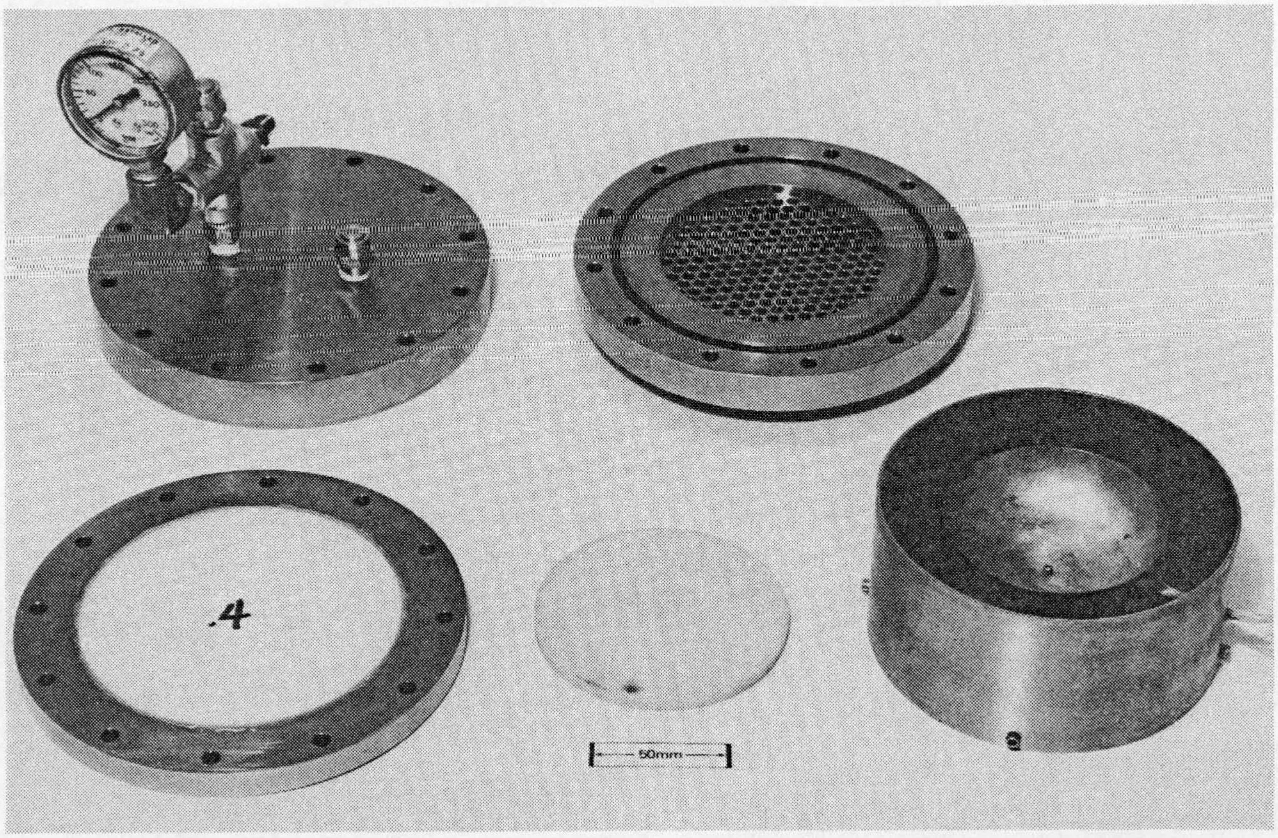

Figure 4. Piece Parts of Moisture Test Chamber

FUTURE WORK

Other tasks remain to be completed in the PSBF evaluation for potting electronic packages. Although no additional moisture testing is currently planned, the test fixture design is such that full-scale evaluation of the finished product can be performed if and when it becomes necessary.

Table 1. Preliminary Moisture Penetration of 2.54-cm-Thick PSBF Slabs

Density* (g/cm^3)	Penetration Time (s)	Collection Time (Min)	Pressure (kPa)
0.2	3	1.2	1.5
0.3	24	24	69
0.4	72	9	552
0.5	90	19	414
0.6	60	1.0	69
0.6L**	30	0.5	69

*All slabs were fused at 107°C for 20 minutes above 93°C.

**PSBF of lower pentane content.

Table 2. Moisture Penetration of 1.27-cm-Thick PSBF Slabs

Density (g/cm^3)	Oven Temperature (°C)	Time Above 93°C (Min)	Pressure (kPa)	Collection Time (Min)	Collected Water (g)
0.2	107	20	1.5	20.0	75
0.2*	107	20	1.5	180.0	75
0.3	107	20	69.0	0.5	75
0.4	107	20	552.0	23.0	75
0.4	115	60	1724.0	1440.0	36
0.5	107	20	1724.0	43.5	75
0.5	115	60	1724.0	1440.0	30
0.5	125	60	759.0	234.0	75
0.6	107	20	207.0	14.0	75
0.6**	107	20	69.0	1.0	75
0.6	115	20	828.0	249.0	75
0.6	115	40	1724.0	220.0	75
0.6	115	60	1724.0	7200.0	0
0.6*	115	60	1724.0	5760.0	0
0.6*	115	60	1724.0	5760.0	0
0.6	125	20	1172.0	23.4	75
0.6	125	40	1724.0	7200.0	0
0.6*	125	40	1724.0	5760.0	0
0.6*	125	40	1724.0	5760.0	0
0.6	125	60	1724.0	7200.0	0

*Repeat tests on additional slabs.
**PSBF of lower pentane content.

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