MAT-CS

MATERIALS CHARACTERIZATION SERVICES, LLC

February 14, 2018

Joe Riccelli
Innovative Designs
124 Cherry St, Suite 1
Pittsburgh, PA 15223-2243

Subject: Pressure versus Temperature Analysis
MAT-CS Job Number: 180095

Dear Joe,

Please find enclosed the final report for the Pressure versus Temperature analysis of your foam samples, as detailed in the following table.

Date received:	December 1, 2017, February 5, 2018
Results faxed/emailed:	February 12, 2018
Results emailed to:	joer@idigear.com
Number of samples:	2
Analysis Request:	Determine if vacuum is present inside cells of foam samples
Priority Surcharge	none

We will maintain copies of the report and data files for three years.

Thank you for using the analytical services of the MAT-CS. We appreciate your business and welcome any suggestions you may have for improving the quality and efficiency of our service. Please do not hesitate to call us if you have any questions regarding this report.

Sincerely,

Scott Baumann
Owner

MAT-CS

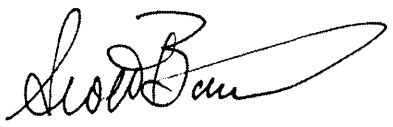
MATERIALS CHARACTERIZATION SERVICES, LLC

PRESSURE VERSUS TEMPERATURE ANALYSIS REPORT
MAT-CS Job# 180095

Prepared for:

Joe Riccelli
Innovative Designs

Prepared by:



Scott Baumann
Owner
Phone: 800-685-2088
Email: sbaumann@mat-cs.com

PRESSURE VS TEMPERATURE ANALYSIS REPORT

Purpose:

The purpose of the analysis was to determine if vacuum was present inside the cells of two foam samples.

Experimental (Initial):

An initial, preliminary investigation pressure versus temperature was performed on one foam sample provided by Joe Riccelli of Innovative Designs called "Insultex". The analysis was performed at Oneida Research Services in Englewood, Colorado. ORS has been providing outgassing and vacuum analysis of hermetically sealed packaging for over 40 years and is a world leader in this area, analyzing thousands of samples per year. The lab is ISO-9000 and accredited and DLA authorized (accreditations are attached).

A large flat piece of the foam was folded to form an oblong "ball" of material (see Figure 1 in Appendix 1). The mass of material was measured to be 9.6 grams.

The sample was placed in a stainless steel chamber with a volume of approximately 1.0 liters and hermetically sealed. For this test the chamber contained air at ambient pressure as the starting condition. The chamber was heated to a temperature of 188C. The foam was allowed to melt while the pressure inside the chamber was monitored over a period of 200 minutes.

After the experiment was completed the foam inside the chamber had clearly melted (Figure 2).

Results (Initial):

The results are summarized below in Charts 1 and 2.

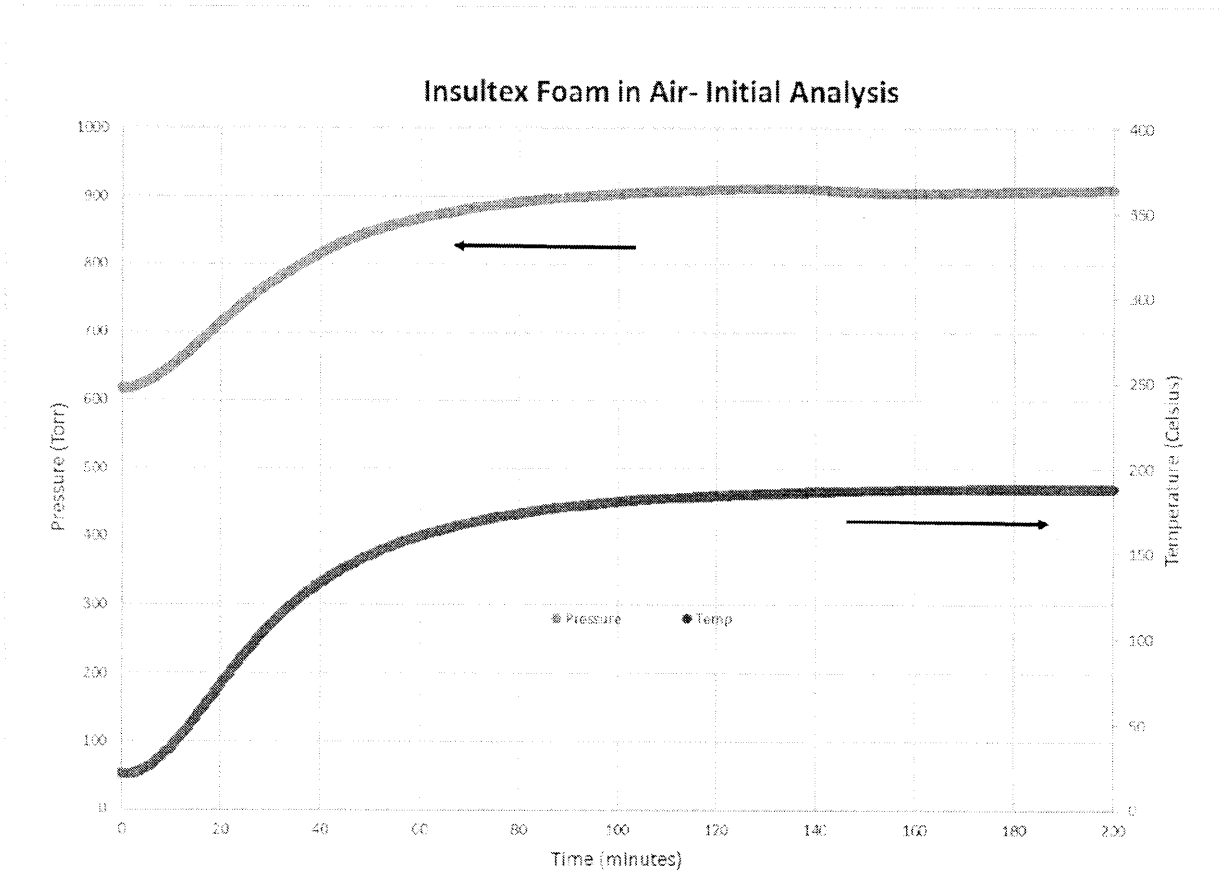


Chart 1: Chamber pressure versus temperature

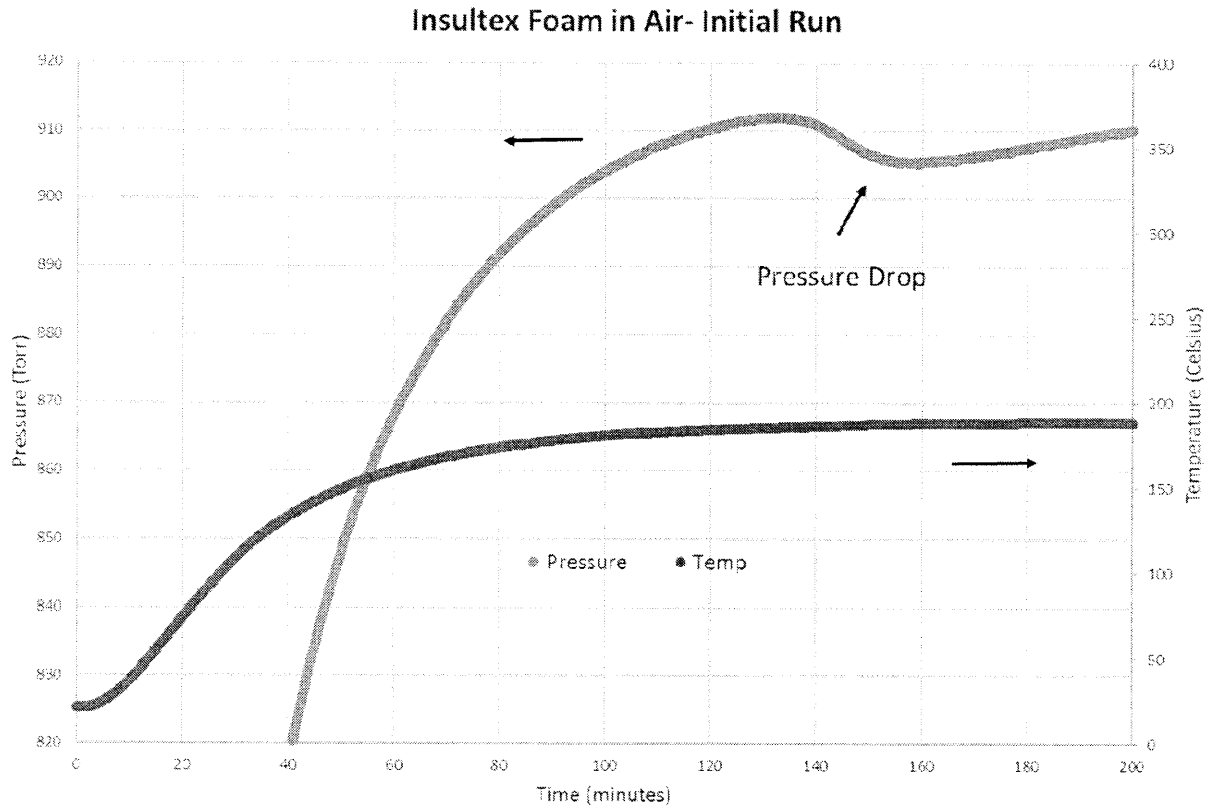


Chart 2: Chamber pressure versus temperature (expanded pressure scale)

In Charts 1 and 2 the temperature of the chamber is plotted versus the right axis, while the chamber pressure is plotted versus the left axis. The supporting data for Charts 1 and 2 are provided in the attached spreadsheet. Chart 2 has an expanded Y-axis to show the significant pressure drop starting at approximately 140 minutes of heating time.

The pressure drop shown in Chart2 was significant, since the only apparent cause for such a drop in pressure was from the melting of the foam and a subsequent exposure of vacuum from the cells in the foam.

At this point it was determined that it was likely that vacuum was present in the cells of the Insultex foam, and a 2nd round of experiments was needed to quantify the amount of vacuum present in the Insultex foam. In particular, a comparison to a control sample

and an empty chamber with no foam was needed, as well as a determination of the actual volume occupied by the foam.

Experimental (Final):

For the second round or analyses, two foam samples were analyzed for pressure versus temperature at Oneida Research Services in Englewood, Colorado:

- The original foam sample provided by Joe Riccelli of Innovative Designs called "Insultex" abbreviated as "Ins".

- A generic foam sample purchased on Amazon, called "Amazon", abbreviated as "Amz". Supporting information for this sample is provided in Appendix 2

Each sample was cut into small squares, then weighed, so that a total of approximately 10.5g of each sample was analyzed. The nominal volume of the Amazon sample appeared to be approximately 2X that of the Insultex sample, suggesting a difference in the densities of the two materials.

Each sample was placed in a stainless steel chamber with a volume of approximately 1.0 liters and hermetically sealed. The squares were stacked vertically to allow for uniform melting, and to minimize trapped gas between the sheets of foam. The chamber was then purged with Argon through a valving system then sealed and heated to a temperature of 175C. Argon was selected in order to avoid any potential chemical reaction with foam in the remote possibility that some chemical reaction was occurring between the foam and the air in the initial experiment that was causing the observed pressure drop. The foam was melted while the pressure inside the chamber was monitored over a period of at least 1,000 minutes. A control analysis where the chamber was only filled with Ar (with no foam) was also performed.

After the experiment was completed the foam inside the chamber had clearly melted and significantly decreased in size. The mass of each sample after the analysis was also measured.

In addition, the density of each sample was analyzed by gas pycnometry.at Micromeritics Instrument Corporation in Norcross, Georgia. Micromeritics is both a manufacturer of gas pycnometers as well as a provider of pycnometry analysis services. They have been in business for over 50 years, are recognized as leaders in their field, and are ISO-17025 accredited for gas pycnometry analysis (accreditations are attached).

Gas pycnometry analysis was necessary to determine the actual volume of foam that was analyzed in each test. Gas pycnometry uses a slight overpressure of gas in a sealed chamber to determine the exact volume of a material. By measuring the amount

of gas required to increase the chamber pressure by a known amount the exact volume of the sample can be determined. Since foam samples can be compressed by high pressures a special pynometry methodology designed specifically for foam samples was employed, and the pressure increase during the pycnometry measurement was limited to 5psig, or roughly 40%. By combining the volumetric measurement with a measurement of the sample mass a very accurate density for the material can be obtained.

Representative photos taken from the foam samples during the experiment are shown in Figures 3-11 in Appendix 1.

Results:

The results are summarized below in Charts 3 and 4 and in Table 1.

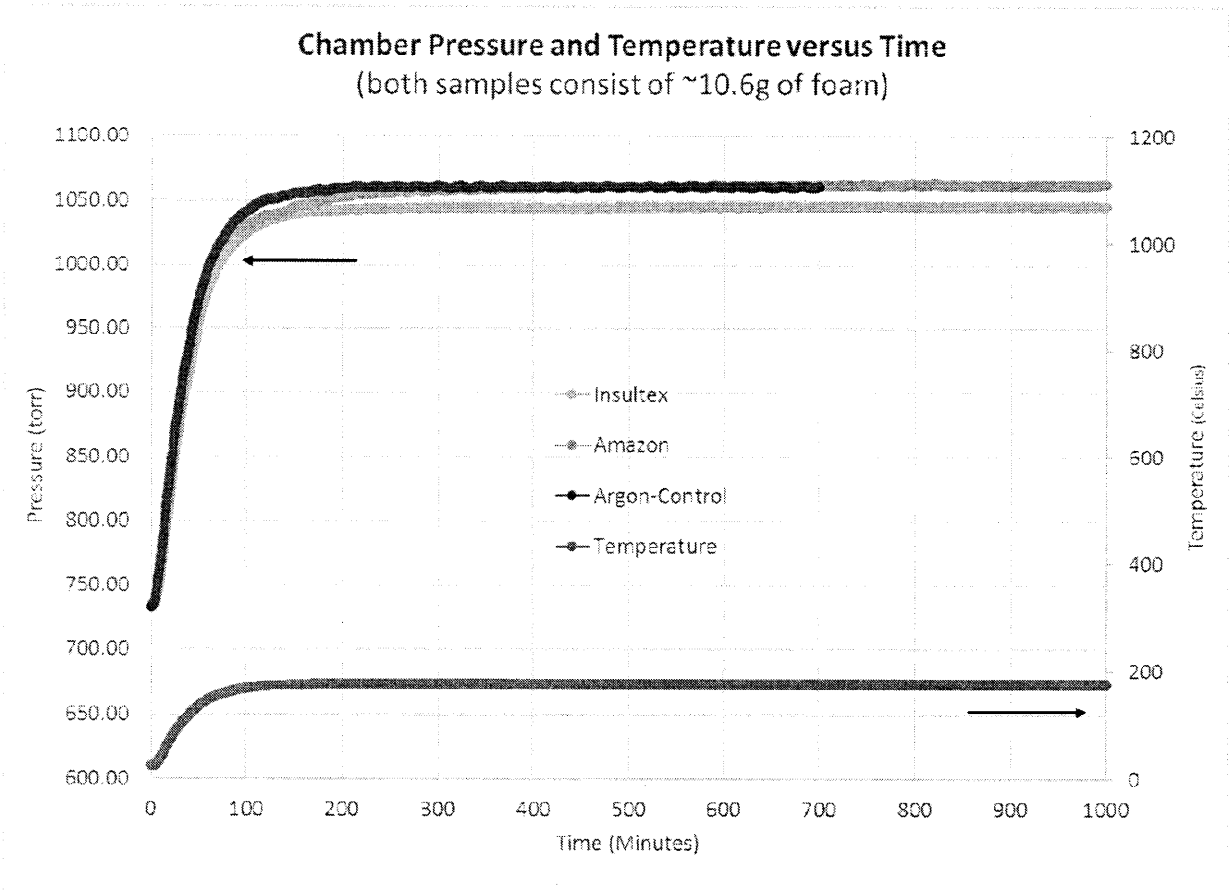


Chart 3: Chamber pressure versus temperature

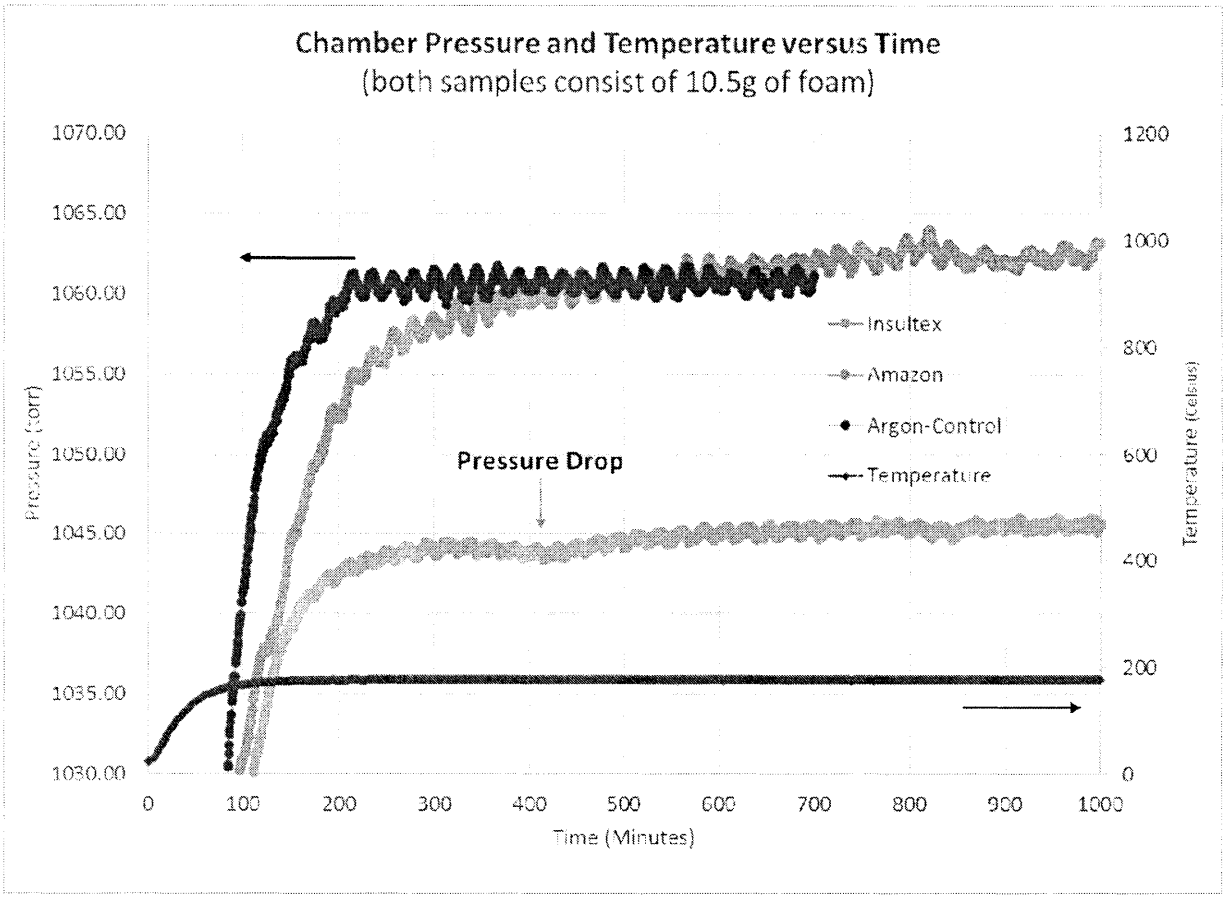


Chart 4: Chamber pressure versus temperature (expanded pressure scale showing pressure drop for Insultex sample)

In Charts 3 and 4 the temperature of the chamber is plotted versus the right axis, while the chamber pressure is plotted versus the left axis. Chart 4 has an expanded Y-axis to show the difference in pressure between the two samples. The results show identical final pressures for the Amazon sample and the empty chamber, but a significantly lower final pressure was obtained for the Insultex sample. This indicates that vacuum is present inside the cells of the Insultex sample, while no vacuum is present in the cells of the Amazon sample.

Furthermore, a pressure drop was again observed for the Insultex sample (albeit a smaller one than observed during the preliminary analysis). This smaller drop is likely due to cutting the samples into small squares rather than folding into a large ball. In the case of the ball a larger volume of vacuum can be trapped, resulting in a sudden decrease of pressure when the trapped vacuum was finally breached. In this case with

numerous sheets of foam rather than a ball, the gas in the chamber could more easily enter between the sheets and fill the evacuated cells as they broach.

The supporting data for Charts 3 and 4 are provided in the attached spreadsheet. It should be noted that each analysis had a slightly different starting pressure and some small differences in chamber temperature occurred during the runs, so corrections were made to the raw pressure values using the ideal gas law to correct for differences in the starting pressures and provide an accurate comparison between the samples on the charts.

The cyclical signal shown in the pressure profiles is likely due to the on/off cycling of the heater used to maintain the chamber temperature, resulting in slight variations in the chamber temperature and resultant pressure. The divergence between the Amazon pressure the Control pressure from 100-200 minutes is likely due to the melting of the foam inside the chamber which is an endothermic process. The absorption of heat by the foam in the process of melting slows the heating of the gas in the chamber. Once the foam is melted, the pressure in the chamber with the Amazon sample rises to the same level as the Control analysis.

Table 1

	Insultex	**Amazon**	**Control (no sample)**	**Measurement Uncertainty**
Starting mass (g)	10.554	10.687		+/- 0.0001g
Final mass (g)	10.479	10.787*		+/- 0.0001g
Final Pressure (Torr) (avg. from 600-700min)	1045.2	1061.7	1060.8	+/- 2 Torr **
Density g/cm^3 (gas pycnometry)	0.4187	0.2154		+/-0.002

*Some Al foil remained stuck to this sample after test, resulting in the slightly higher mass after melting.
** For comparative measurements in the 1000 Torr range

Table 1 shows that there was no significant change in mass of the samples after melting compared to before melting. The gas pycnometry results show the density of the starting Insultex foam is 0.4187g/cm^3 while the density of the starting Amazon foam.is 0.2154g/cm^3. The complete gas pycnometry results are attached in pdf form.

Calculations:

As shown in Table 1, the difference in pressure between the empty Ar filled chamber and chamber with melted Insultex is 15.6 Torr.

The ideal gas law states that:

$$PV=nRT$$

Where:

- P = Pressure (torr)
- V = Volume (cc)
- n = number of moles
- R = the gas constant (8.31/JK-mol)
- T = Temperature (Kelvin)

In this case, n, R and T are constant, so the lower pressure attributed to the Insultex sample can be converted to an equivalent volume of vacuum added to the chamber using the equation.

$$V_{Insultex} = V_{Control} (P_{Insultex} / P_{Control})$$

The volume for the "Control" sample is the chamber volume of 1 liter (1000 cm^3), so using the values in Table 1 we obtain a $V_{Insultex}$ value of 0.985 cm^3. This indicates that the melting of the Insultex sample was the equivalent of adding a volume of 14.7cm^3 of vacuum to the chamber.

The manufacturer of the Insultex foam indicated that it is made from Low Density Polyethylene (LDPE) and LDPE is known to have a typical density of 0.91-0.94g/cm^3. Using this density range and the starting mass of 10.5g of LDPE we can calculate that the volume of the Insultex sample occupied by the LDPE is 11.1-11.5 cm^3. This means that the remaining volume of the Insultex foam is the closed cells.

Taking the total sample volume calculated from pycnometry of 25 cm^3 minus the volume occupied by the LDPE of 11.1-11.5 cm^3 leaves a volume of 13.5-13.9 cm^3 of closed cells which appear to be filled with vacuum.

Comparing the calculated volume of 14.7 cm^3 of vacuum added to the chamber by the melting of the Insultex foam to the calculated volume of ~14 cm^3 of empty space within the foam obtained from the gas pycnometry results indicates that 100% of the empty space within the Insultex foam contains vacuum, to within the uncertainty of these measurements.

Since no change in pressure was observed for the Amazon foam compared to the control chamber, one can conclude that there is no vacuum present in the Amazon sample.

Conclusions/Discussion:

The goal of this investigation was to determine if vacuum was present in the cells of the Insultex foam. This has been confirmed.

During the initial heating of the chamber the pressure increased, as one would expect for a sealed chamber with a fixed volume of gas. As the Insultex foam reached melting temperature a clear decrease in pressure was observed, apparently caused by the breaching of the closed cell in the Insultex foam, allowing the vacuum in the cells to decrease the pressure in the chamber.

In the final experiment, as the chamber continued to heat a continued divergence in the measured pressure compared to the chamber without foam was observed, confirming the presence of vacuum inside the Insultex foam. By comparison, the commercial "Amazon" packing foam purchased from the internet showed a final pressure identical to the chamber with no foam, indicating no vacuum was present.

Furthermore, the volume of vacuum calculated from the pressure difference observed between the melted Insultex foam and the control run of the empty chamber matches the empty space present within the Insultex foam as calculated using gas pycnometry and the known density of LDPE. Therefore, we conclude that the cells within the Insultex foam have nearly 100% vacuum within them, within the uncertainty of these measurements.

Appendix 1

Representative photos showing Insultex sample during preparation for final analysis and after final analysis

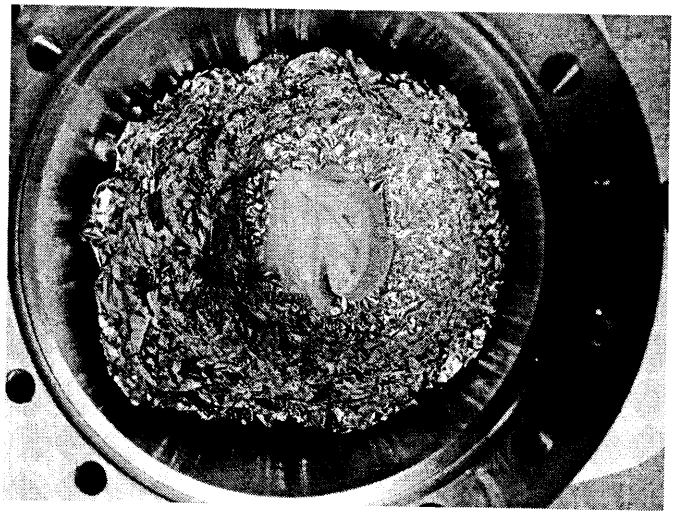


Figure 1: Preliminary analysis showing Insultex foam inside chamber before heating.

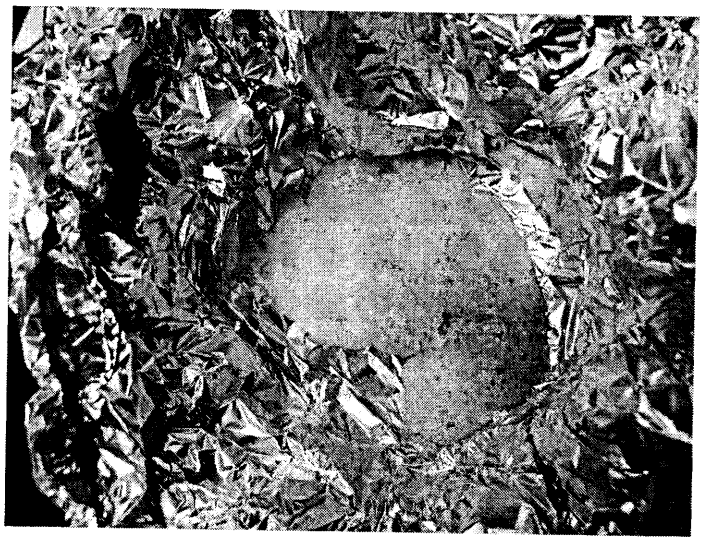


Figure 2: Melted Insultex foam after analysis.

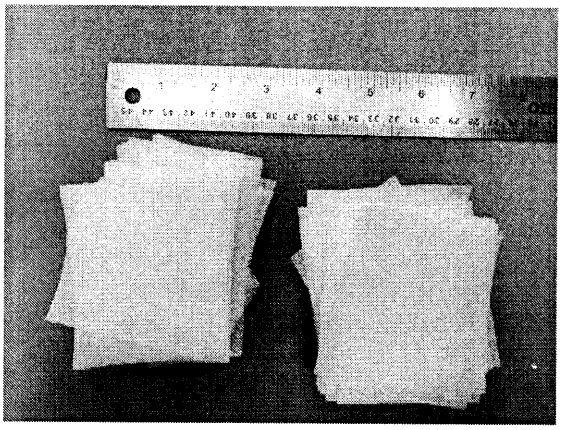


Figure 3: Insultex foam cut into ~3" squares

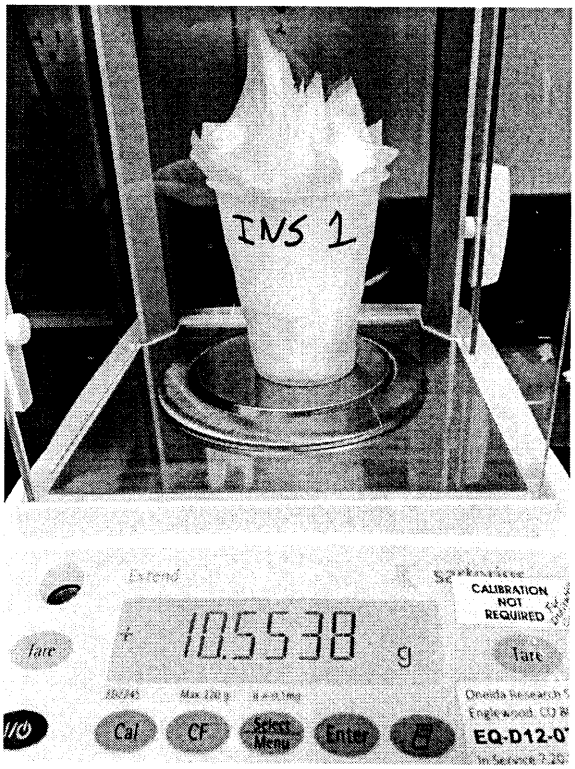


Figure 4: Insultex being weighed

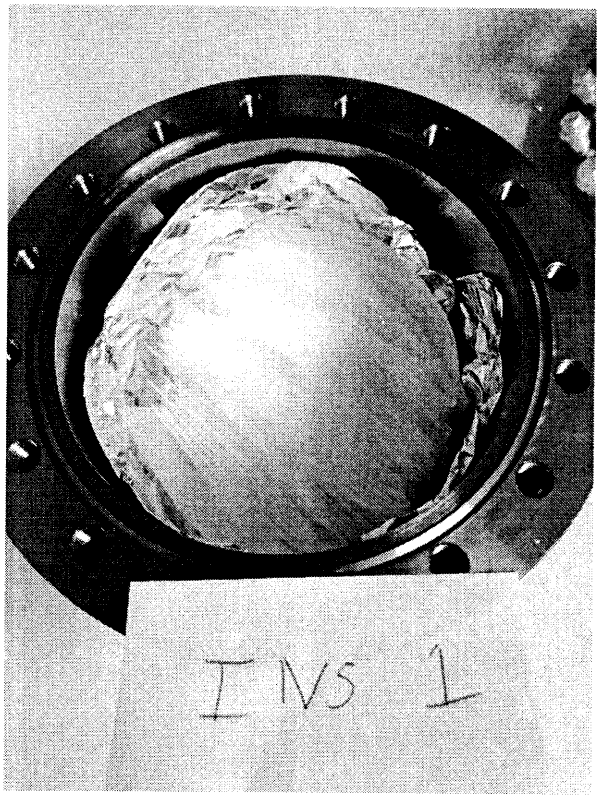


Figure 5: Insultex foam loaded into test chamber

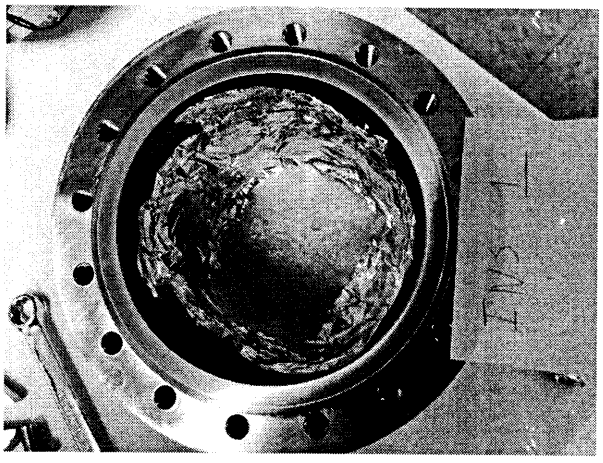


Figure 6: Melted Insultex foam after test

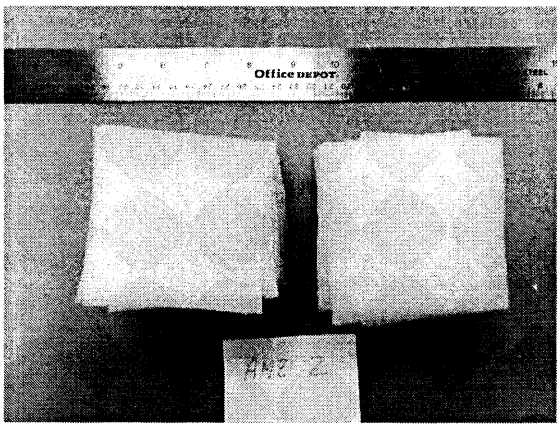


Figure 7: Amazon foam cut into ~3" squares

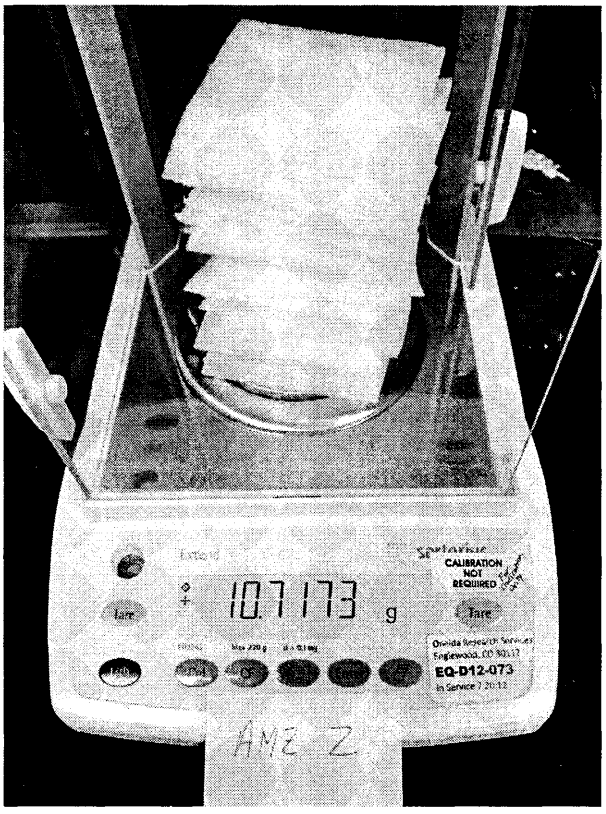


Figure 8: Amazon foam being weighed

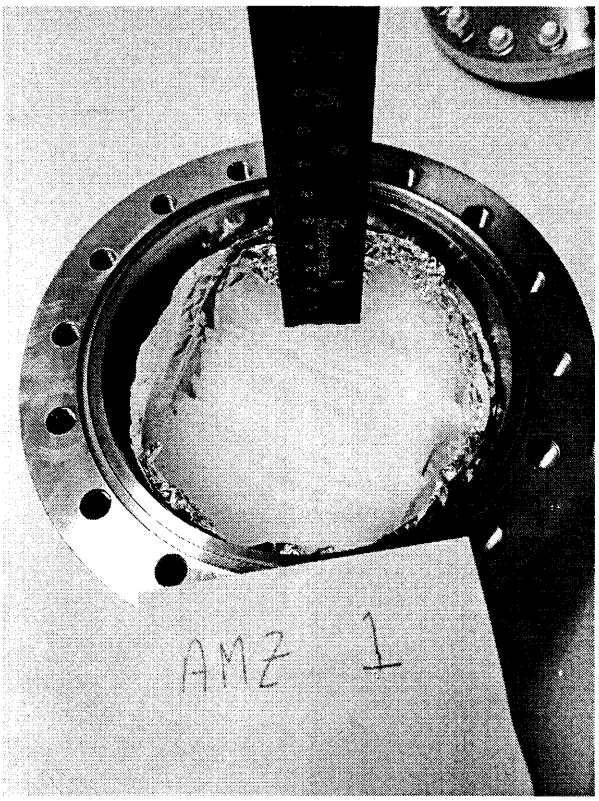


Figure 9: Amazon foam loaded into test chamber

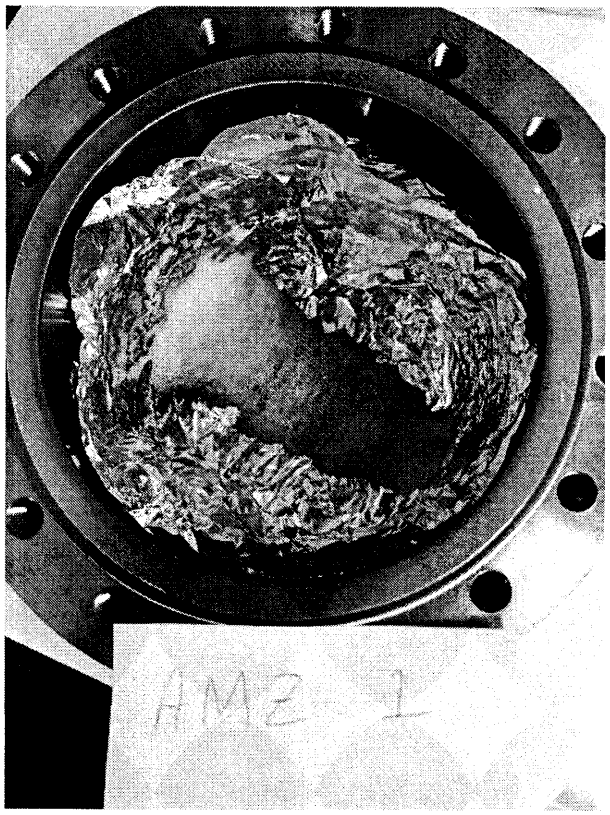


Figure 10: Melted Amazon foam after test

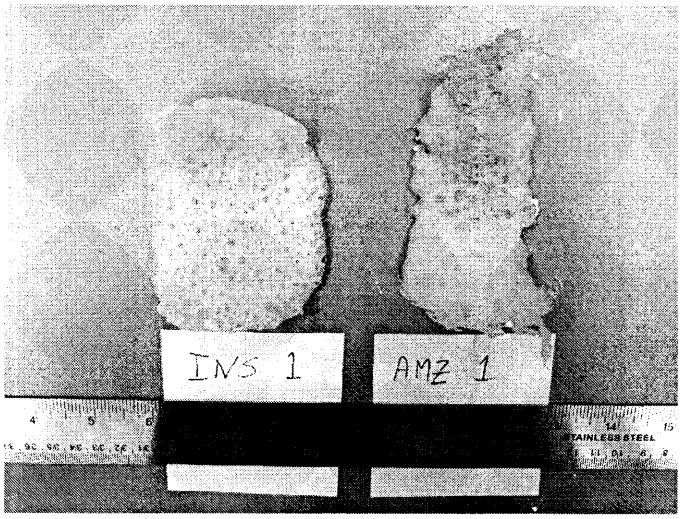
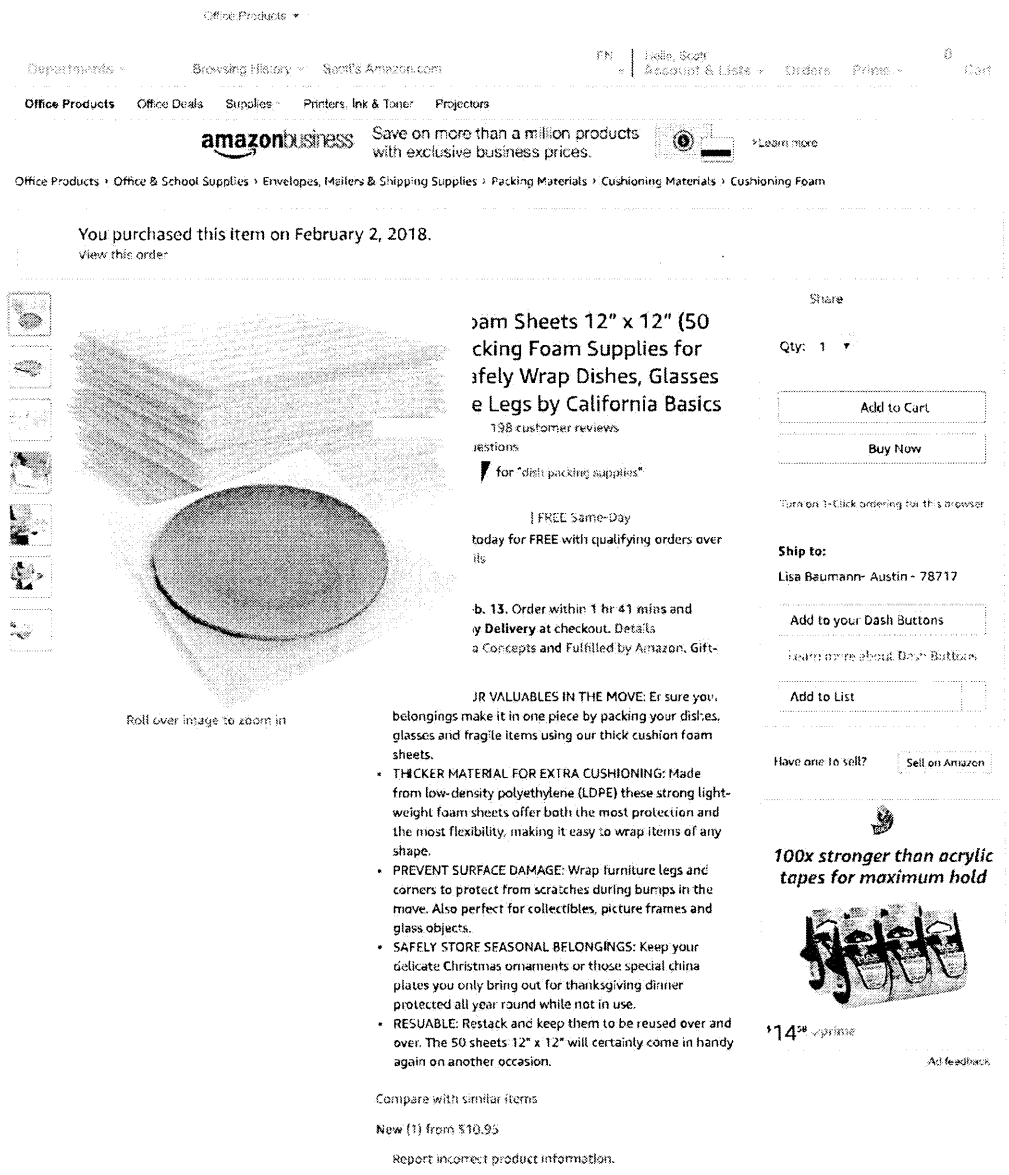


Figure 11: Melted Insultex and Amazon foam after test

Appendix 2

Amazon webpage showing ordering information for packing foam

2/13/2018 Amazon.com: Cushion Foam Sheets 12" x 12" (50 Count), Packing Foam Supplies for Moving, Safely Wrap Dishes, Glasses & Furniture Legs ...



https://www.amazon.com/gp/product/B01LXWVOTY/ref=oh_aui_detailpage_o05_s00?ie=UTF8&psc=1 1/9