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Compression Testing of Alumina Fiber Insulation

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Abstract

A series of tests were conducted to measure the response of alumina fiber insulation to compression loading. The alumina fiber insulation is a candidate gasket material for the Space Shuttle Government Furnished Equipment (GFE) Tile Overlay Repair. Tests were conducted at room temperature and 2300°F. The alumina fiber insulation is a fibrous insulation blanket which was supplied to Langley in two forms, a nominal 3 lb/ft^3 version and a nominal 9 lb/ft^3 version. The 3 lb/ft^3 material was tested as sheets 0.15 and 0.25 inches thick and the 9 lb/ft^3 material in sheets 1 inch thick. The material showed very non-linear compression behavior with the compressive resistance of the material increasing as the material was compressed. The 3 lb/ft^3 0.15-inch thick material required 4.1 psi to reach the nominal installation thickness of 0.045 inches and retain a load of 2.1 lbs during unloading. Testing at 2300°F resulted in a stiffer more board-like material. The 3 lb/ft^3 0.15-inch thick material retained 1 psi of compressive resistance after a 10 minute hold at 2300°F and 0.045 inches thickness.

Test Objectives

Saffil®, a registered trademark of Saffil Limited Ltd. Liab. Co., a form of fibrous alumina insulation (95 to 97 percent alumina and 3 to 5 percent silica), has been chosen by the GFE Tile Overlay Repair Team as a potential gasket material between the carbon-silicon carbide composite overlay sheet and the tile surface (fig. 1). The primary purpose of the material is to block the flow of hot gasses under the overlay repair sheet. The alumina fiber insulation also provides some resistance to the insertion of the augers that secure the tile overlay sheet. The design teams need to know how much force is generated as the augers are tightened and how much spring back force the alumina fiber insulation will provide both after installation and after the material has undergone heating during descent. The purpose of this work is to measure the compression behavior of Alumina Fiber insulation at both room temperature (RT) and 2300°F (HT).

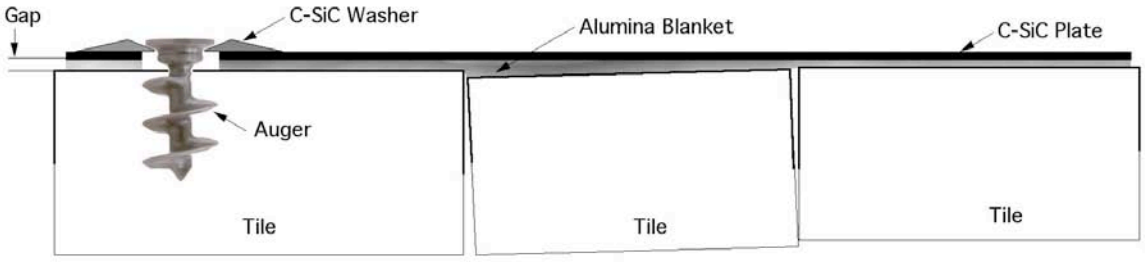

Figure 1. schematic of tile overlay showing alumina fiber gasket and tile-overlay gaps. Not to scale.

Test Materials

Test materials, supplied by NASA JSC, consisted of two types of alumina fiber insulation blanket, a 3 lb/ft^3 and a 9 lb/ft^3 material. The 3 lb/ft^3 material was supplied as a thick mat about 2 inches thick and the 9 lb/ft^3 material was supplied in 6 x 6 inch squares about 1 inch thick.

Test Procedures

Coupon Preparation

Coupons were prepared from 3 lb/ft^3 material by cutting 4 and 3.5-inch diameter pucks with an arch punch on a polyester cutting board. The punch cut through the material with firm pressure; no hammering was required. To form the 3 lb/ft^3 material coupons the puck was divided into sections about 0.5-inch thick and plies were peeled off until the mass was in the range to form the nominal 0.25 and 0.15 inch coupons. The target mass for the 0.25 inch thick 4-inch diameter coupon was 2.251 to 2.697 grams. The target mass is calculated as shown in equation 1, where M is the target mass in grams, A is the cross-sectional area in in^2, D is the nominal density in lb/ft^3 and T is the nominal thickness of the materials in inches and 0.2625 is the unit conversion factor:

$$M = 0.2625ADT \qquad \text{[equation 1]}$$

The 3.5-inch diameter coupons for the high temperature tests had a target mass of 1.724 to 2.064 grams. The 0.15-inch thick 3.5 inch diameter coupons had a target mass of 1.029 to 1.222 grams.

The 9 lb/ft^3 material was received as fifteen 6 x 6 inch blocks about 1 inch thick. The original plan was to cut two 3.5-inch diameter coupons from each block. It was very difficult to get two of the coupons from each block. Therefore, only six 3.5-inch diameter coupons were cut for the HT testing and the coupons for the RT testing were reduced in size to 3-inch diameter. These were kept at the as-received thickness. The target mass for the 3-inch coupons was 15.196 to 18.202 grams. The target mass for the 3.5-inch coupons was 20.684 to 24.775 grams.

After cutting, the coupons were placed in individually marked plastic bags. Coupons were labeled 3P-01 though 3P-27, 3T-01 to 3T-27 for the 3 lb/ft^3 materials and 9P-01 through 9P-27 and 9 lb/ft^3 material. Two extra coupons in addition to the 20 RT and 5 HT coupons were cut from each material for 5-cycle RT testing and extended hold testing.

Coupon Characterization

Each coupon was weighed to the nearest 0.001 grams. Each coupon was measured in diameter to the nearest 0.01 inches. The thickness of the coupon was measured to the nearest 0.01 inches as the first step of the mechanical testing. The thickness of the coupon after testing was measured to the nearest 0.01 inches as the last step of the mechanical testing. Data for the measurements were recorded in an a spreadsheet. Each coupon was photographed before and after testing. The photos for all the test specimens are in Appendix B.

Test Set-up

The Alumina insulation was compressed in a mechanical test machine between flat platens to a compressive stress of 12.5 ±0.2 psi then decompressed to the original thickness. The 3 lb/ft^3 material was compressed and decompressed at a rate of 0.25 inches per minute (0.00417 in/sec). The 9 lb/ft^3 material was compressed and decompressed at a rate of 0.50 inches per minute (0.00833 in/sec). The test machine ran a program that lowered the ram at a constant rate until a load, equivalent to a stress of 12.5 psi on the coupon, was reached. The ram then reversed direction until it returned to the initial position. Data was recorded at a 20 hertz rate for elapsed time, ram displacement, and load. The 5-cycle test was run by having the machine run to the average minimum displacement of the first twenty runs for each material type, unloading to the initial thickness then repeating for four additional cycles.

The compressions platens used for the RT tests are shown in figure 2 and consist of two 4-inch diameter stainless steel platens. The lower platen is fixed and the upper platen incorporates a hemispherical bearing surface.

The test equipment requiring calibration for testing is listed in table 1. and the calibration certificates are listed in Appendix C.

Table 1. List of Calibrated Test Equipment Used

Item	Serial Number	Calibration Date	Calibration Due	Test Used For
Instron 8562 Test Machine, Stoke	HO816	2/09/2006	8/9/2007	High Temperature
Instron 22.48 kip load cell	UK544	2/07/2006	8/7/2007	High Temperature
Ircon Optical Pyrometer	21405	3/28/2006	3/28/2007	High Temperature
MTS 858 Test Machine, Stroke	0418736	3/21/2006	9/21/2007	Room Temperature
MTS, 1000 lb load cell	V99523	3/27/2006	9/27/2007	Room Temperature
Balance, Sartorius B 120 S	38030148	6/03/2005	7/28/2008	All
Fowler Caliper, 6-inch	364833	3/16/2006	3/16/2007	All

Test Procedure Room Temperature

Adjustment of Zero Point

The upper and lower platens were installed on the test machine. The ram was adjusted to its zero position. The upper crosshead of the test machine was lowered until the upper platen was resting on the lower platen. This resulted in a load of about 150 lbs. The upper crosshead was then locked in place. Verification of zero was checked after each test run by lowering the upper platen onto the lower platen applying a load of 150 lbs and determining that the ram extension was at 0.000±0.002 inches. The ram returned to 0.0000 inches after each test.

Zeroing of Load Cell

The upper platen was raised to the initial position and the load checked to verify that it was at 0 ±.03 lbs. If the load was not at zero the cell was electronically adjusted to zero.

Adjustment of Starting Position

The test coupon was placed on the lower platen and the ram was raised or lowered until the lower surface of the upper platen was by visual inspection just touching the upper surface of the coupon. The position of the ram was recorded. This measurement also served as the initial thickness measurement of the coupon.

Figure 2. Room temperate compression platens and load cell.

Test Sequence.

Figures 3 through 10 show the ram position at the start of each run, at the top of the sample, at the minimum thickness position and at the return to start position after the test. Figures 3 through 6 show the 3 lb/ft^3 material and figures 7 though 10 show the 9 lb/ft^3 material.

Figure 3. Platens at open start position.

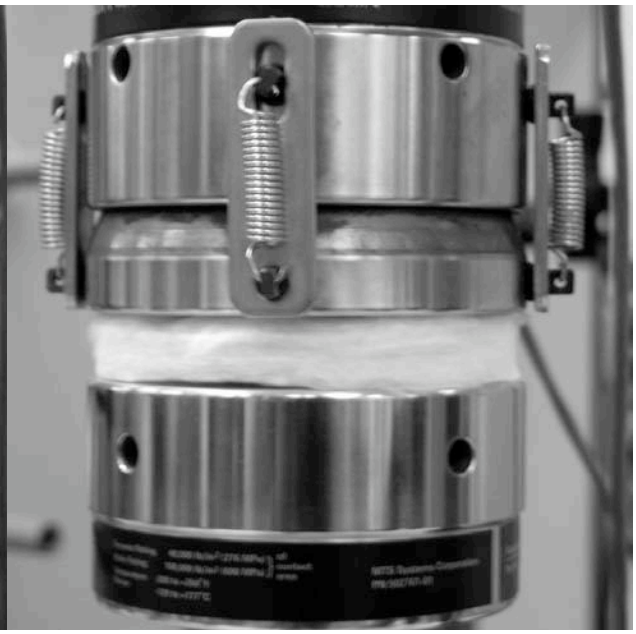

Figure 4. Platens at top of coupon start position.

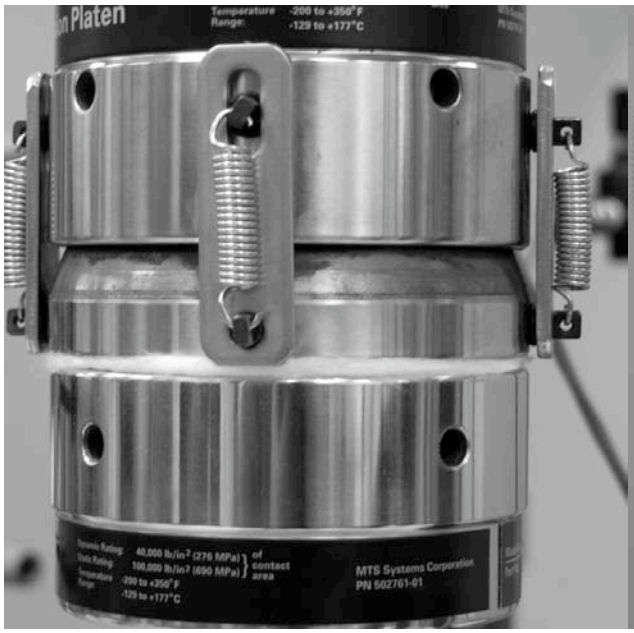

Figure 5. Platens at minimum displacement position.

Figure 6. Platens at open end position.

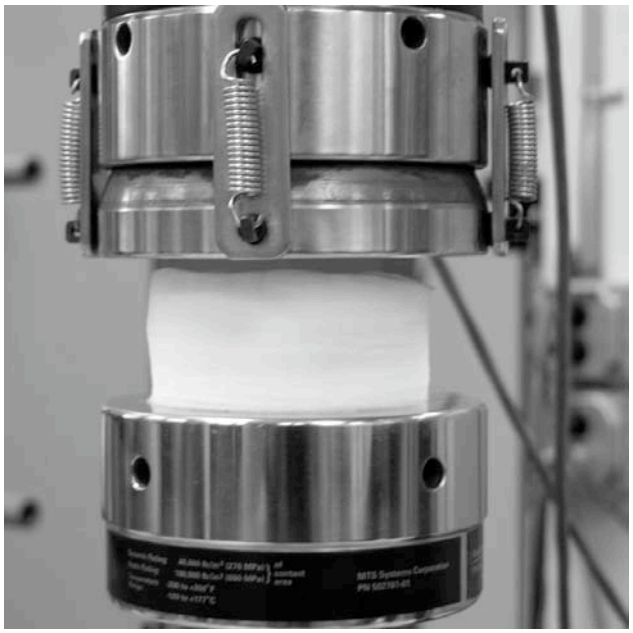

Figure 7. Platens at open start position.

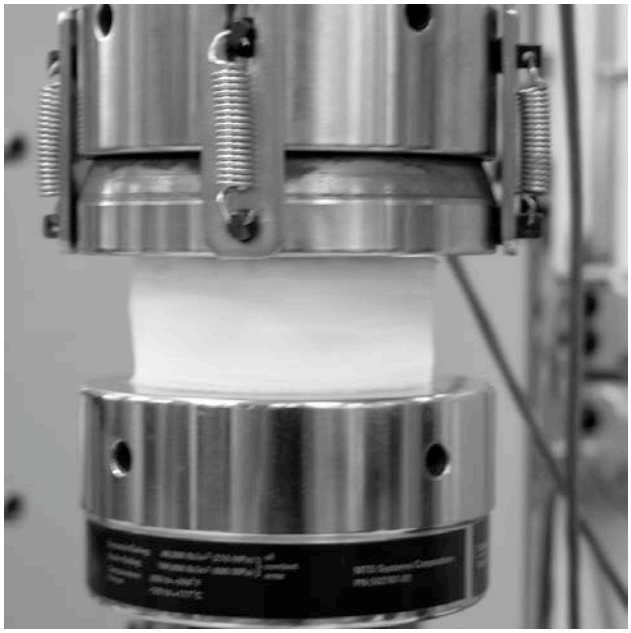

Figure 8. Platens at top of coupon start position.

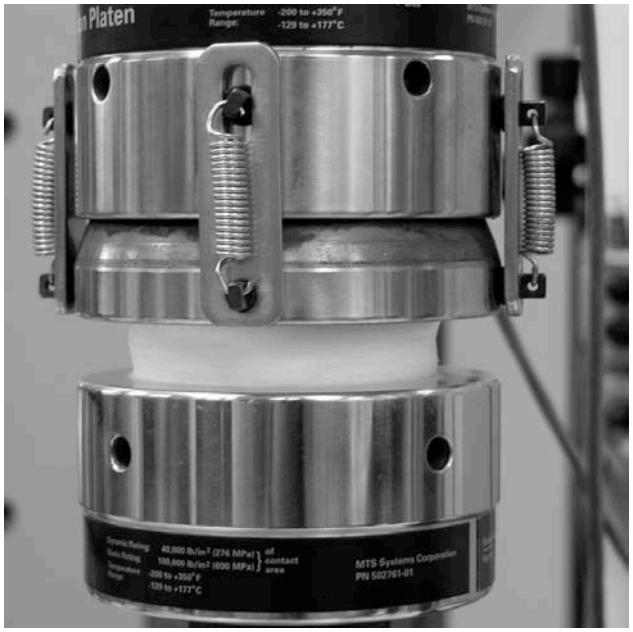

Figure 9. Platens at minimum displacement position.

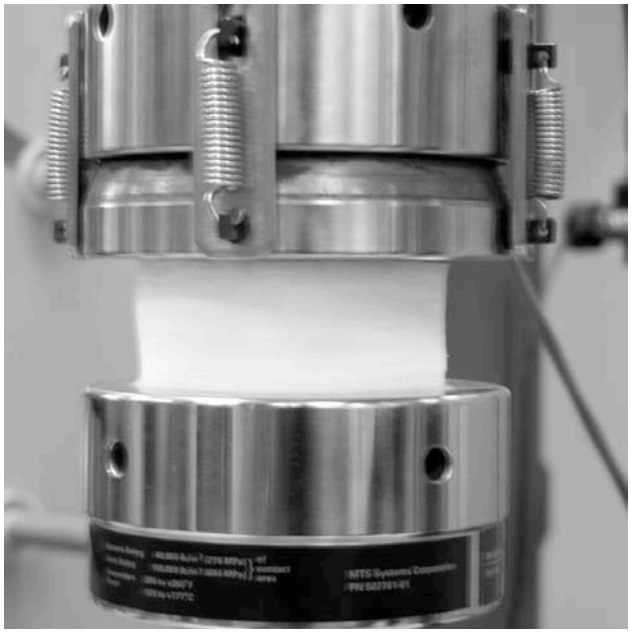

Figure 10. Platens at open end position.

Test Procedure High Temperature

The compression platen and graphite furnace used for the HT tests are shown in figure 11. Both upper and lower platens are 3.5-inch diameter at the top face and mounted on 2-inch diameter load rods. The platens are made from high strength fine grained graphite. The graphite platens were held together and attached to the test machine with 50 mm diameter graphite bolts.

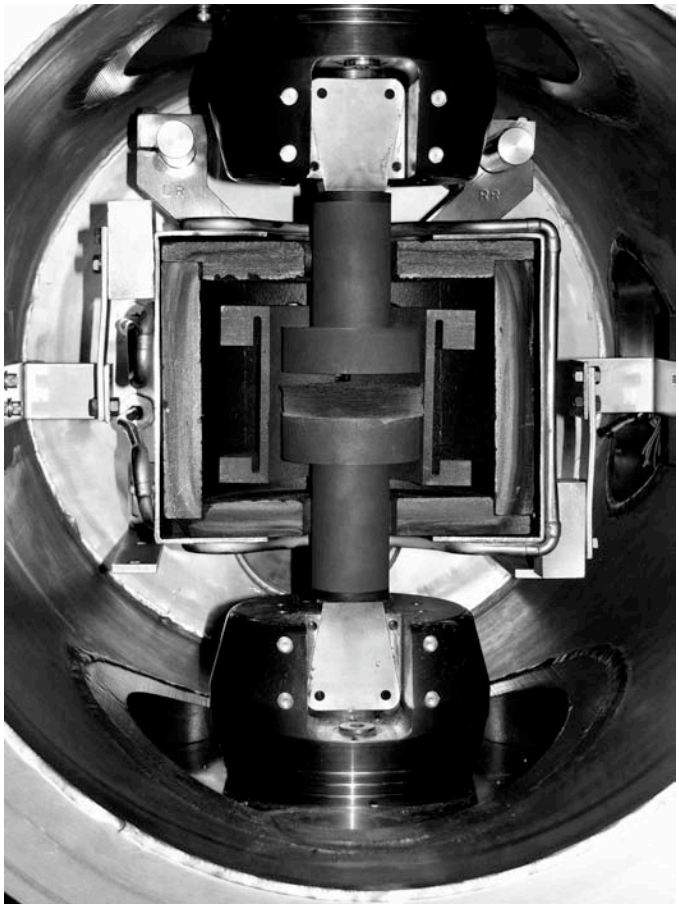

Figure 11. High temperature compression load train in graphite furnace.

Adjustment of Zero Point

The upper and lower platens were installed on the test machine. The ram was raised until a load of about 150 pounds was obtained. The position of the ram was recorded as the zero point on the test sheet. The zero position was re-established whenever the rams were removed and prior to testing each material set.

Characterization of Coupon with No Load

Prior to high temperature testing one coupon each of the 3 and 9 lb/ft^3 materials were heated to 2300°F with the platens well separated to see the if the sample thickness changed due to the heat treatment alone. The thickness of the sample was measured by adjusting the platens to just touch the top surface before and after the run. The coupon thicknesses did not change during this test.

Adjustment of Starting Position

The test coupon was placed on the lower platen and the ram was raised or lowered until the lower surface of the upper platen was by visual inspection just touching the upper surface of the coupon. The position of the ram was recorded. This measurement minus the zero point measurement also served as the initial thickness measurement of the coupon. The starting position was recorded on the spreadsheet. The ram was then lowered by 0.062 inches. The 0.062 inch adjustment to accommodate thermal expansion of the graphite fixturing and furnace frame during furnace heat up. The exact amount of the adjustment was determined by heating the furnace to temperature without a test coupon and noting the difference in ram position between closing the platens with 150 lbs of force at room temperature and at 2300°F.

Heating of Coupon

Once the test fixture was inserted, the test chamber was closed. It was then verified that the load train was off and load limits were off. The chamber is then evacuated to a vacuum of 0.100 torr or lower, and then backfilled with argon gas to 50 torr or greater. This cycle was repeated three times. The chamber was then brought back to 0.5 psig with argon gas and allowed to vent through a gas bubbler. The inert gas flow rate was adjusted to give a steady stream of bubbles. The furnace was then heated at a rate of 50°F per minute to the final test temperature of 2300°F ±50°F. The furnace temperature was controlled using Type B thermocouples. The final temperature was adjusted using a two color infrared pyrometer focused onto the alumina fiber coupon edge. The 2300°F furnace temperature was held for 15 minutes prior to testing. If the temperature required adjustment furnace temperature was held an additional 5 minutes after the final adjustment.

Zeroing of Load Cell

Once the test chamber was at temperature the load cell was electronically zeroed. Because of the significant noise in the test system and the possibility that there was a small amount of load on the alumina fiber insulation at the beginning of the run, the zero of the data set was calculated from the average load value for the last 30 seconds of the test run when there was no load on the alumina fiber insulation.

Running the test

1. Start the testing program
2. Enter new specimen name.
3. Start run.
4. Run will end automatically.
5. Record maximum load and minimum displacement in the spreadsheet.

Test profile

After holding at temperature for 15 minutes the ram was raised (compressing the coupon) at 0.5 inches per minute (0.00833 in/sec) until the minimum displacement was reached. The minimum displacement was the average minimum displacement for the room temperature tests. It was held at this displacement for 10 minutes before the ram was lowered at 0.5 inches per minute to the original position. The 0.150-inch thick alumina fiber insulation was compressed to 0.031 inches, the 0.25-inch alumina fiber insulation to 0.050 inches and the 1-inch alumina fiber insulation to 0.590 inches. An additional set of tests were run were one coupon each of the 0.15-inch thick alumina fiber insulation which were compressed to 0.035, 0.040, 0.045, 0.050, and 0.055 inches.

Cooling the Furnace

After the mechanical testing was completed the furnace was cooled back to room temperature under flowing argon by turning off furnace power.

Measurement of Final Coupon Thickness

After the furnace was cooled and opened, the ram was adjusted until the top of the coupon just touched the lower surface of the upper platen. This was the final thickness value and was recorded into the spreadsheet.

Test Results and Discussion

Test Results Room Temperature

The results for sample preparation and data recorded during the room temperature tests are shown in tables 2 though 4.

The coupon masses for the 3 lb/ft^3 materials were calculated based on a 3.5 or 4 inch diameter. The true diameter of the coupons was usually slightly larger than this value. In some cases this caused the areal density to be lower than the specified 0.117 ±0.01 (footnote 1) for the 0.15 inch thick material. The 9 lb/ft^3 material was not adjusted for thickness and some of these were also outside of a 9 percent error band. Tables 3 and 4 show the out of specification coupons. The data for these coupons are shown but the data were not used to calculate any of the summary values or statistics.

The average thickness for the starting coupons was 0.357, 0.558 and 1.314 inches for the 0.15 and 0.25 inch 3 lb/ft^3 and 9 lb/ft^3 materials respectively. The coupons were thicker than the nominal 0.15, 0.25 and 1.00 inch thickness. Some of this is due to the cutting process which increased the material thickness and some resulted from the as received material being thicker than nominal. After the coupons were compressed to 12.5 psi and released, the average thicknesses were 0.266, 0.422 and 1.225 inches for the 0.15 and 0.25 inch 3 lb/ft^3 and 9 lb/ft^3 materials respectively. For all materials, the standard deviations for the thicknesses decreased after testing. The thickness of the materials at the maximum stress level of 12.5 psi was 0.031, 0.050 and 0.590 inches for the 0.15 and 0.25 inch 3 lb/ft^3 and 9 lb/ft^3 materials respectively.

The load versus displacement was recorded for each run. The compressive resistance was calculated by dividing the measured load by the area of the coupons. The typical displacement versus compressive resistance plots are shown in figures 12 through 14 for the 0.15 and 0.25 inch 3 lb/ft^3 and 9 lb/ft^3 materials respectively. Modulus calculations are not recommended for compression curves of the type measured in these tests, so no modulus data will be reported.

The plots of compressive resistances versus thickness (figs. 12, 13 and 14) show that in all cases the material increased in stiffness as they were loaded. The 3 lb/ft^3 material had a steeper curve than the 9 lb/ft^3 material. The 3 lb/ft^3 material required a larger percent of its thickness to begin loading and the stiffness increased much faster than the 9 lb/ft^3 material. In all cases there were also a hystereses in the curves between the initial loading and unloading of the coupons.

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[1] Overlay Assembly Drawing (15 x 25 inch) Note 8., Drawing SED33118645, approved 8/17/05, NASA JSC.

Table 2. 3 lb/ft^3 alumina fiber insulation, 0.25-inch thick, 4.00-inch Diameter Compression Test Results.

Coupon Number	Thickness start, inch	Thickness end, inch	Load target, lbs	Stress error, psi	Displacement minimum, inch	Coupon mass, grams	Mass error, percent
3P-01	0.532	0.406	161.03	0.03	0.051	2.537	0.03
3P-02	0.517	0.425	161.03	0.49	0.048	2.482	-2.14
3P-03	0.624	0.423	158.65	0.08	0.048	2.397	-4.07
3P-04	0.610	0.453	160.63	0.07	0.052	2.442	-3.48
3P-05	0.478	0.355	160.24	0.03	0.052	2.518	-0.23
3P-06	0.787	0.548	157.87	-0.06	0.052	2.450	-1.46
3P-07	0.584	0.439	159.05	0.03	0.051	2.500	-0.20
3P-08	0.507	0.365	161.03	0.01	0.050	2.530	-0.24
3P-09	0.546	0.384	158.65	0.04	0.049	2.501	0.09
3P-10	0.570	0.407	162.23	0.02	0.051	2.530	-0.98
3P-11	0.634	0.496	159.45	0.02	0.052	2.486	-1.00
3P-12	0.551	0.433	165.03	0.05	0.048	2.460	-5.36
3P-13	0.447	0.362	157.47	-0.04	0.053	2.515	1.40
3P-14	0.477	0.344	158.65	1.08	0.049	2.510	0.45
3P-15	0.561	0.455	157.47	-0.01	0.050	2.466	-0.57
3P-16	0.661	0.514	161.43	-0.02	0.052	2.551	0.34
3P-17	0.427	0.362	159.45	-0.01	0.052	2.534	0.91
3P-18	0.554	0.426	158.26	-0.04	0.048	2.433	-2.39
3P-19	0.476	0.365	154.34	0.02	0.049	2.443	0.50
3P-20	0.629	0.474	157.47	-0.03	0.050	2.564	3.38
Average	0.558	0.422			0.050		
StDev	0.085	0.057			0.002		
95% CI	±0.041	±0.027			±0.001		

Table 3. 3 lb/ft^3 alumina fiber insulation, 0.15-inch thick, 3.50-inch Diameter Compression Test Results.

Coupon Number	Thickness start, inch	Thickness end, inch	Load target, lbs	Stress error, psi	Displacement minimum, inch	Coupon mass, grams	Mass error, percent
3T-01	0.409	0.320	125.51	0.09	0.028	1.094	-6.87
3T-02	0.298	0.262	124.44	-0.02	0.031	1.163	-0.16
3T-03	0.329	0.257	124.65	0.05	0.032	1.049	-10.09*
3T-04	0.299	0.234	123.91	0.03	0.030	1.038	-10.50*
3T-05	0.293	0.223	121.19	0.03	0.033	1.169	3.05
3T-06	0.460	0.318	123.36	0.00	0.032	1.185	2.63
3T-07	0.463	0.326	132.98	0.10	0.028	1.105	-11.23*
3T-08	0.263	0.191	120.47	-0.06	0.033	1.192	5.71
3T-09	0.334	0.252	121.61	-0.04	0.031	1.095	-3.80
3T-10	0.432	0.319	123.16	0.01	0.031	1.129	-2.06
3T-11	0.397	0.279	123.83	0.05	0.031	1.128	-2.68
3T-12	0.371	0.295	118.84	-0.05	0.032	1.160	4.29
3T-13	0.390	0.264	122.01	-0.02	0.031	1.105	-3.24
3T-14	0.342	0.248	122.53	-0.06	0.033	1.203	4.89
3T-15	0.370	0.290	125.70	0.06	0.029	1.124	-4.47
3T-16	0.407	0.323	124.25	0.11	0.030	1.053	-9.45*
3T-17	0.292	0.214	125.82	-0.05	0.032	1.218	3.42
3T-18	0.262	0.207	125.61	-0.01	0.031	1.168	-0.65
3T-19	0.408	0.282	123.78	-0.08	0.034	1.201	3.66
3T-20	0.387	0.300	124.18	0.07	0.029	1.112	-4.33
Average	0.357	0.266			0.031		
StDev	0.061	0.041			0.002		
95% CI	±0.034	±0.023			±0.001		

* in mass error column indicates coupons with greater than 9 percent error.

Table 4. 9 lb/ft^3 alumina fiber insulation, 1.00-inch thick, 3.00-inch Diameter Compression Test Results.

Coupon Number	Thickness start, inch	Thickness end, inch	Load target, lbs	Stress error, psi	Displacement minimum, inch	Target mass, grams	Mass error, percent
9P-07	1.366	1.228	90.13	-0.13	0.577	16.085	-5.58
9P-08	1.285	1.21	90.43	0.01	0.569	15.736	-7.93
9P-09	1.290	1.201	89.54	-0.01	0.561	15.320	-9.47*
9P-10	1.247	1.194	90.73	-0.02	0.587	16.231	-5.35
9P-11	1.295	1.208	90.73	0.00	0.618	17.002	-0.85
9P-12	1.254	1.198	91.03	-0.02	0.603	16.743	-2.68
9P-13	1.315	1.245	90.73	-0.02	0.575	15.970	-6.87
9P-14	1.371	1.278	90.13	-0.03	0.584	16.079	-5.61
9P-15	1.378	1.226	91.33	0.00	0.611	16.993	-1.55
9P-16	1.337	1.248	90.43	-0.02	0.596	16.327	-4.47
9P-17	1.277	1.205	91.33	0.01	0.605	16.672	-3.41
9P-18	1.286	1.212	90.43	0.74	0.592	16.395	-4.07
9P-19	1.283	1.191	90.43	0.00	0.575	16.053	-6.07
9P-20	1.350	1.262	90.13	0.01	0.574	16.002	-6.06
9P-21	1.328	1.217	89.54	0.78	0.56	15.674	-7.38
9P-22	1.264	1.211	90.43	0.00	0.539	14.666	-14.19*
9P-23	1.276	1.189	89.83	0.00	0.606	16.615	-2.14
9P-24	1.369	1.292	89.24	-0.01	0.609	16.646	-1.31
9P-25	1.313	1.214	90.43	0.00	0.585	16.007	-6.34
9P-26	1.267	1.192	89.54	0.01	0.517	14.975	-11.51*
Average	1.314	1.225			0.590		
StDev	0.043	0.031			0.017		
95% CI	±0.023	±0.016			±0.009		

* in mass error column indicates coupons with greater than 9 percent error.

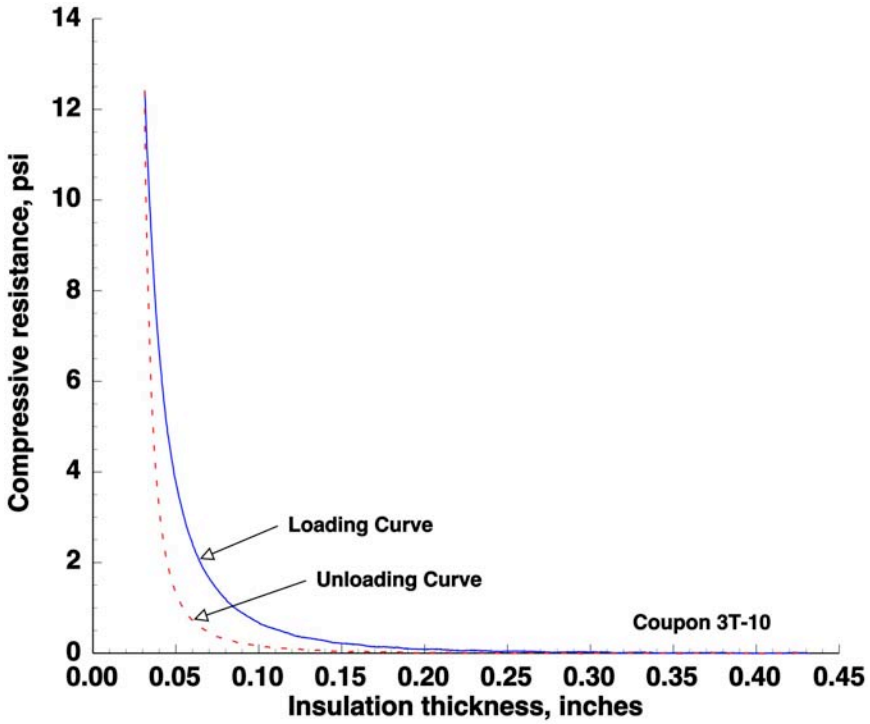


Figure 12. Compressive resistance versus insulation thickness for 3 lb/ft^3 alumina fiber insulation, 0.15-inch nominal thickness, coupon 3T-10.

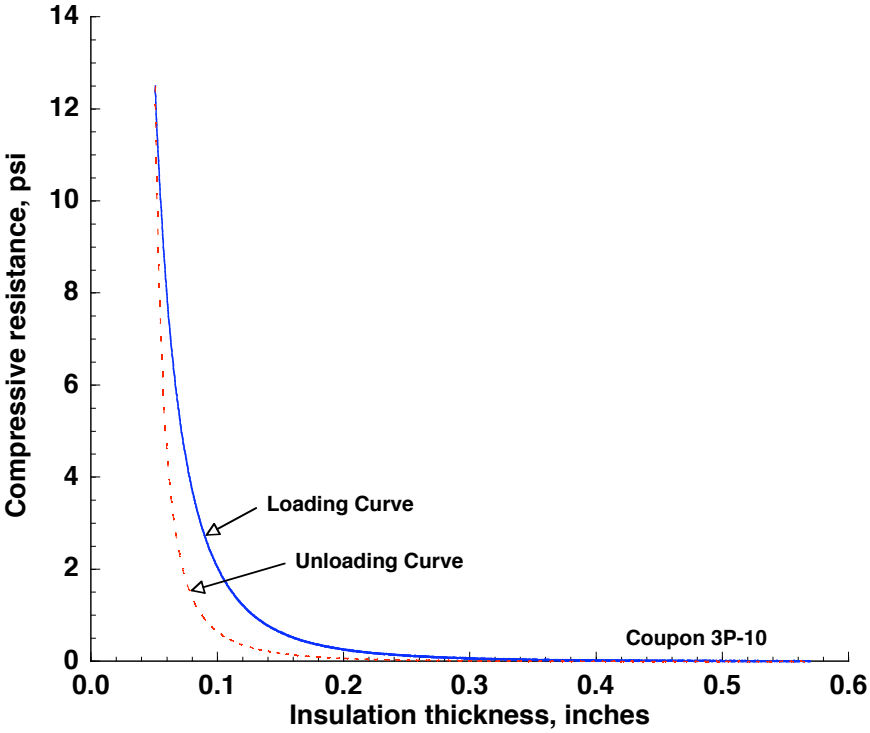


Figure 13. Compressive resistance versus insulation thickness for 3 lb/ft^3 alumina fiber insulation, 0.25-inch nominal thickness, coupon 3P-10

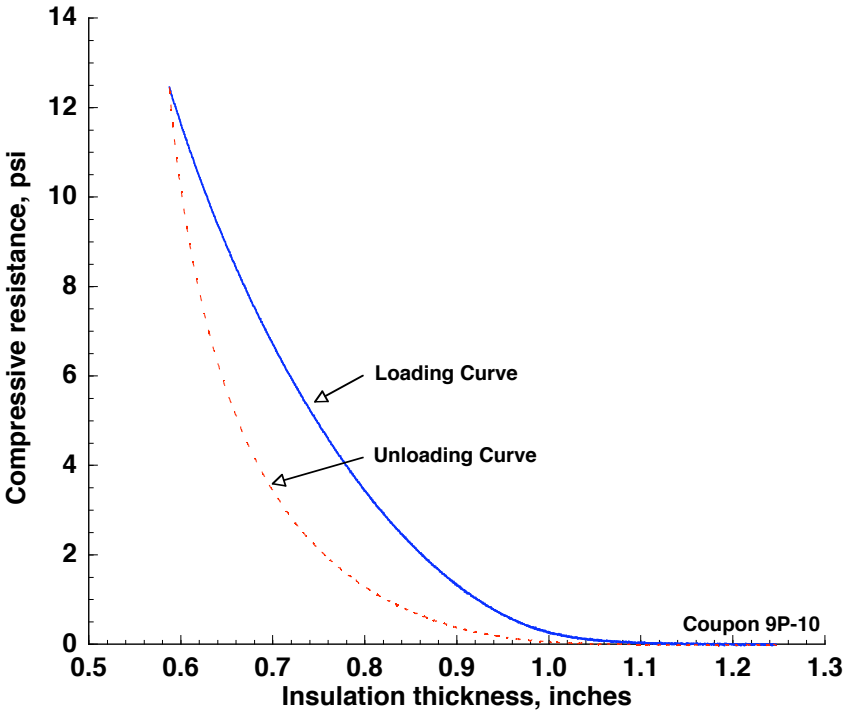


Figure 14. Compressive resistance versus insulation thickness for 9 lb/ft^3 alumina fiber insulation, 1.00-inch nominal thickness, coupon 9P-10.

Figures 15, 16 and 17 show all the valid curves superimposed on top of each other for the 0.15 and 0.25 inch 3 lb/ft^3 and 9 lb/ft^3 materials respectively. The 3 lb/ft^3 materials showed fairly consistent curves. The 9 lb/ft^3 material had a larger amount of scatter between the curves but the same overall shapes and behavior. It can also be seen that a couple of coupons exceeded the 12.5 psi maximum stress level anticipated. The overshoots in load appear random and may have been due to data buffer dumps occurring at the same time the machine reached maximum load, slowing the machine response slightly. The behavior of the coupons with the overshoots was consistent with the other coupons tested so the data for these were included in the summary data.

The areal density of the coupons was plotted versus the starting thickness, ending thickness and minimum thickness for each material. No correlations were found for starting or ending thickness and areal density, this data has not been plotted. Correlations were found for starting versus ending thickness values for all materials and between the areal density and minimum thickness for the 0.15-inch 3 lb/ft^3 and 9 lb/ft^3 materials. Figures 18, 19 and 20 show the relationship between minimum thickness at 12.5 psi and the areal density. Note: no correlation is shown in figure 18 for the 0.25-inch 3 lb/ft^3 material but the plot is shown for completeness. The slopes for the the 0.15-inch 3 lb/ft^3 and 9 lb/ft^3 materials were around 0.3 inches of difference in minimum thickness per 1 g/in^2 density change. The starting thickness versus ending thickness correlations are shown in figures 21, 22, and 23. The slopes were all about 0.6 inches of ending thickness for each 1 inch of starting thickness.

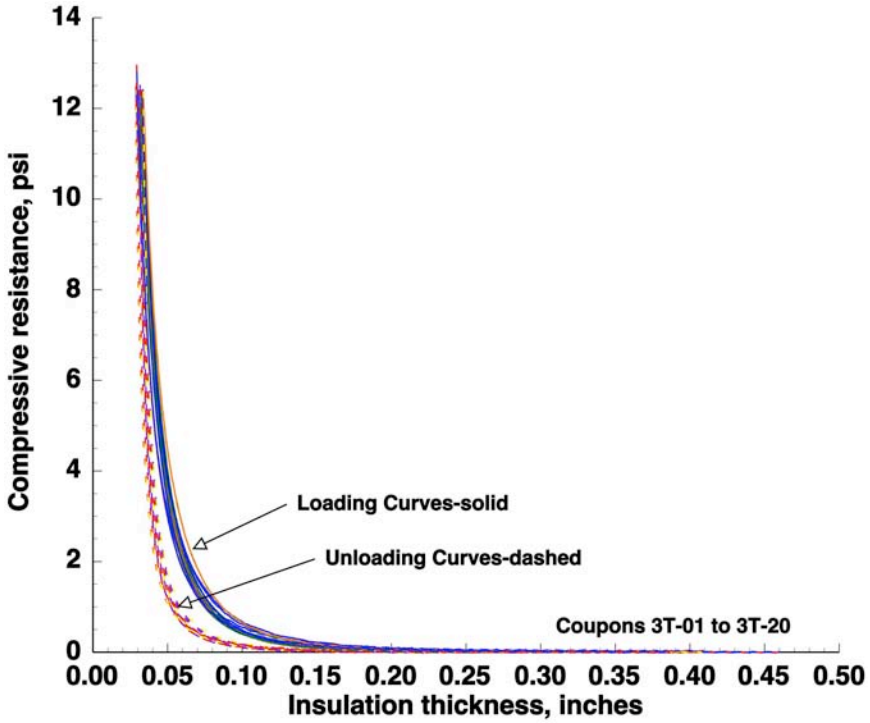


Figure 15. Compressive resistance versus insulation thickness for 3 lb/ft^3 alumina fiber insulation, 0.15-inch nominal thickness, coupons 3T-01 to 3T-20.

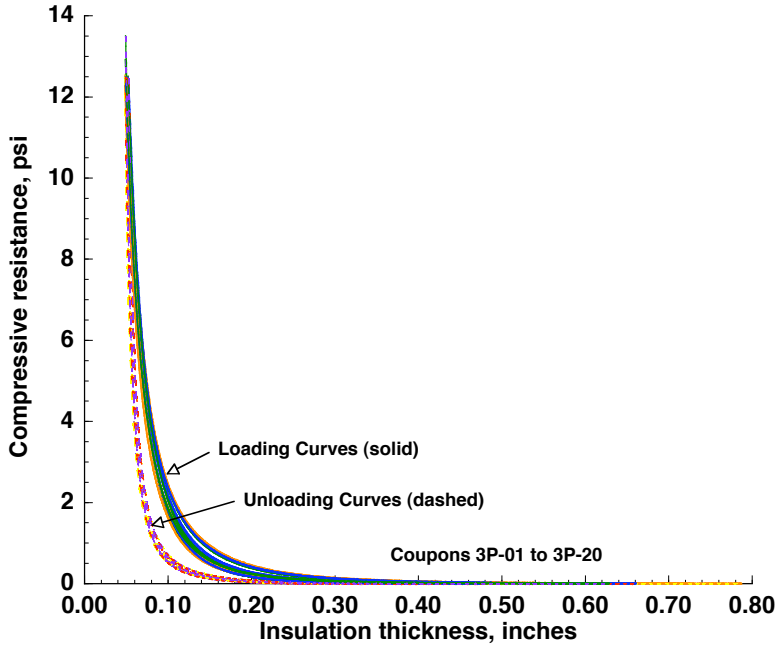


Figure 16. Compressive resistance versus insulation thickness for 3 lb/ft3 alumina fiber insulation, 0.25-inch nominal thickness, coupons 3P-01 to 3P-20.

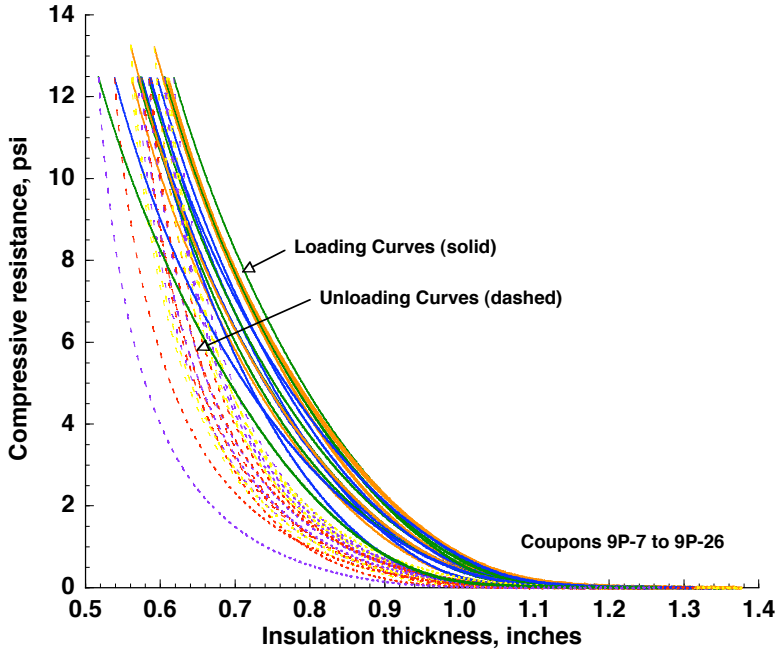


Figure 17. Compressive resistance versus insulation thickness for 9 lb/ft3 alumina fiber insulation, 1.00-inch nominal thickness, coupons 9P-07 to 3P-26.

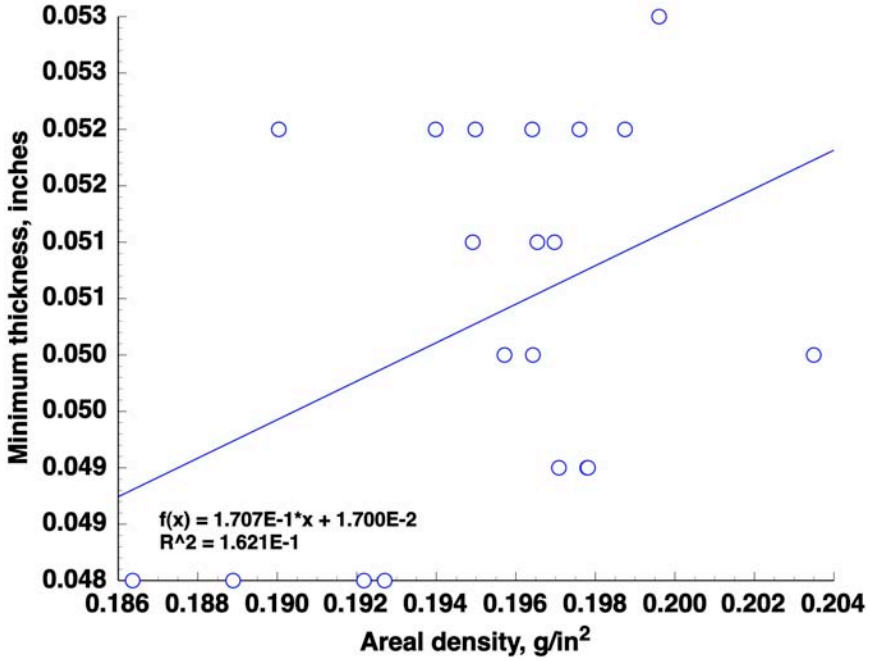


Figure 18. Minimum thickness versus areal density correlation for 3 lb/ft^3 alumina fiber insulation, 0.25-inch nominal thickness

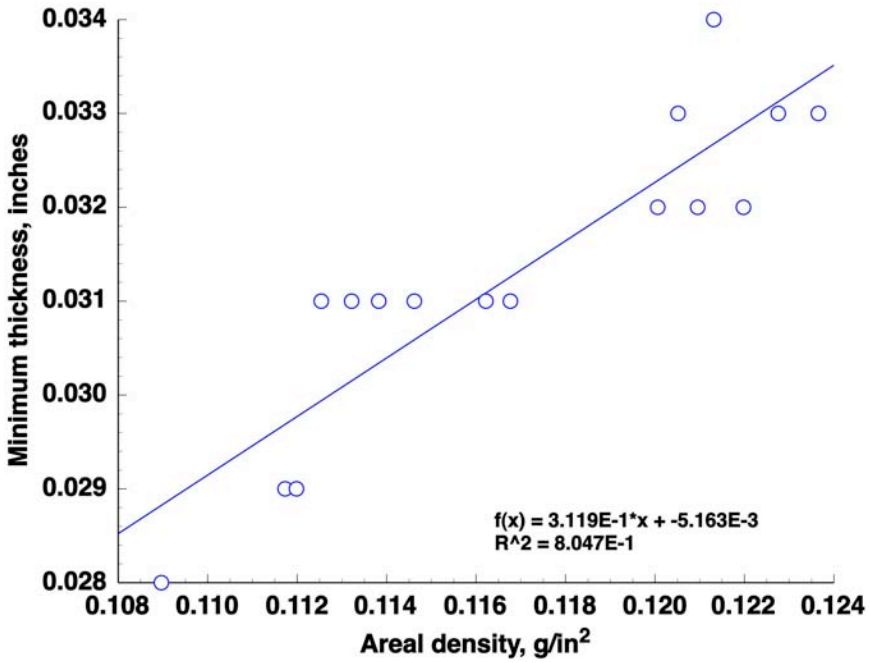


Figure 19. Minimum thickness versus areal density correlation for 3 lb/ft^3 alumina fiber insulation, 0.15-inch nominal thickness.

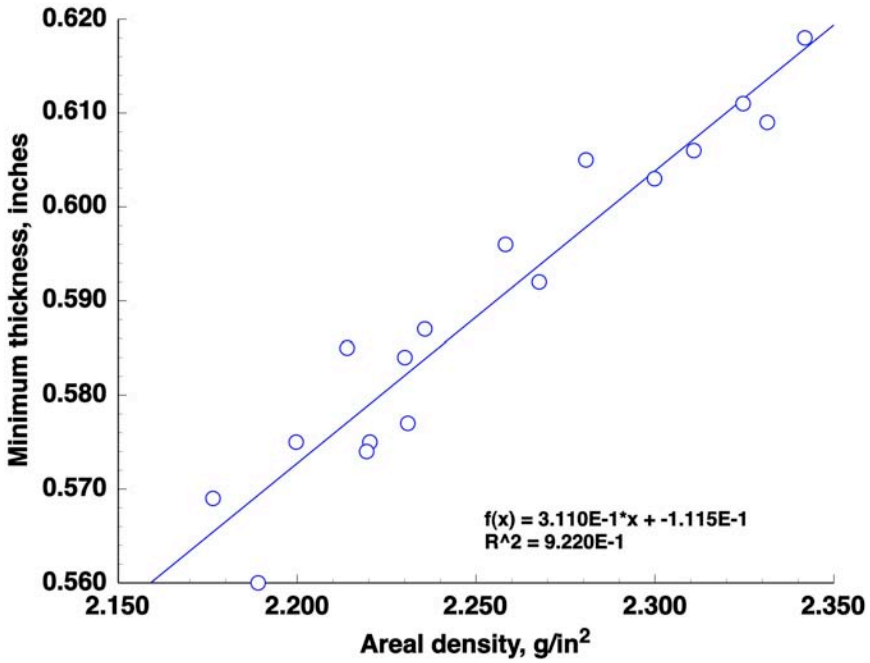


Figure 20. Minimum thickness versus areal density correlation for 9 lb/ft^3 alumina fiber insulation, 1.00-inch nominal thickness.

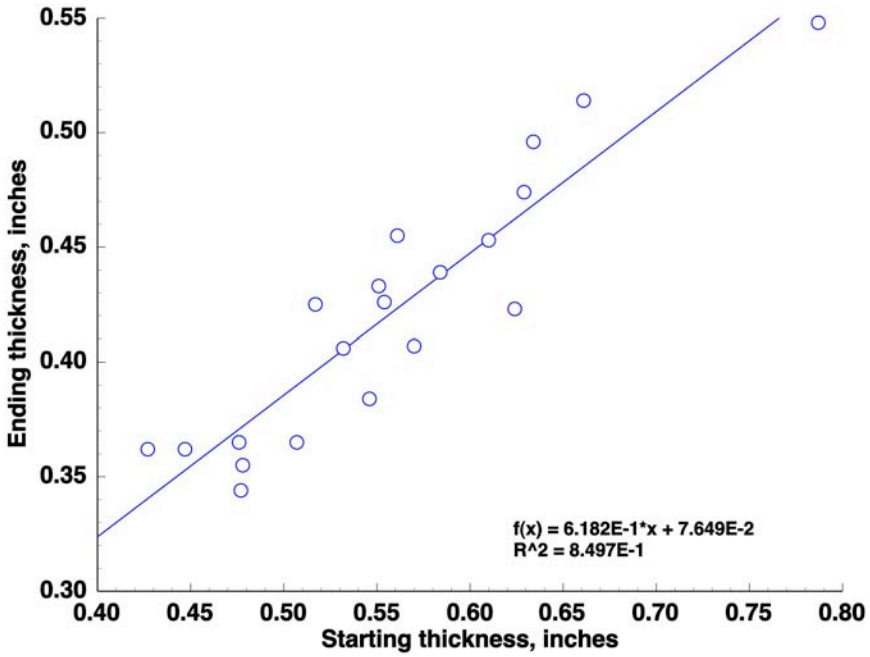


Figure 21. Ending thickness versus stating thickness correlation for 3 lb/ft^3 alumina fiber insulation, 0.25-inch nominal thickness.

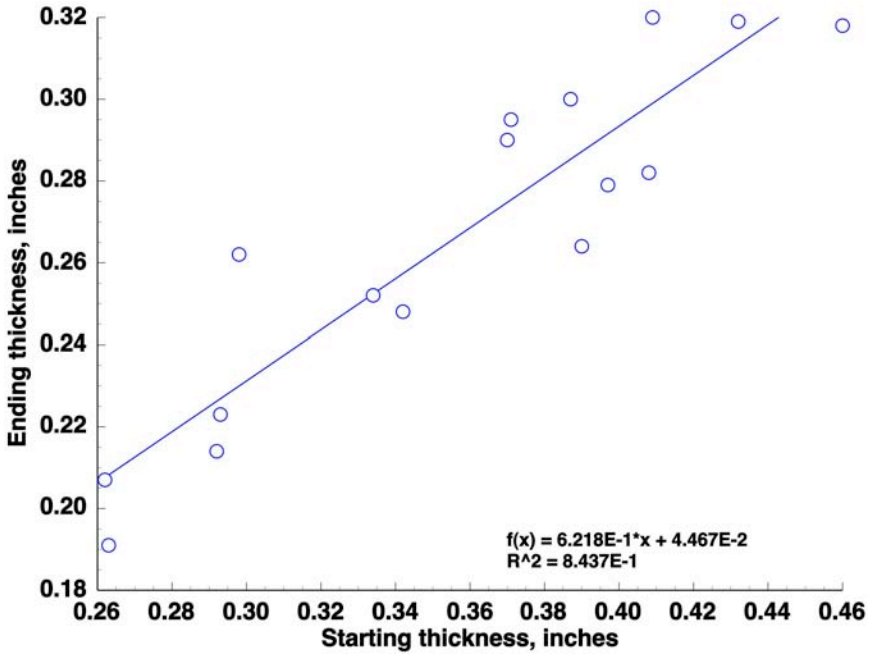


Figure 22. Ending thickness versus stating thickness correlation for 3 lb/ft^3 alumina fiber insulation, 0.15-inch nominal thickness.

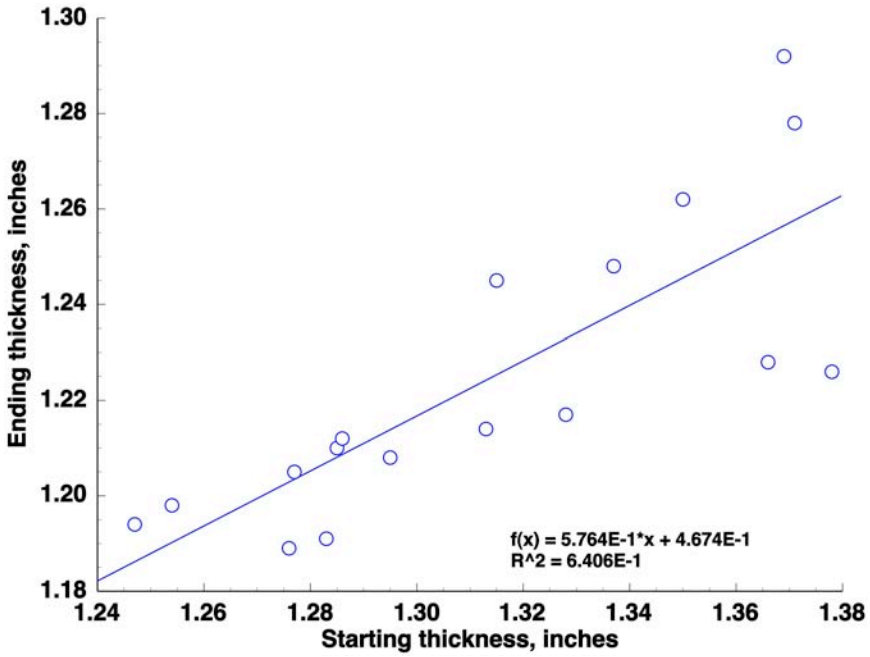


Figure 23. Ending thickness versus stating thickness correlation for 9 lb/ft^3 alumina fiber insulation, 1.00-inch nominal thickness.

Cyclic Testing

In order to determine if the compression of the material changed the behavior one coupon of each material was cycled five times and the results recorded. The plots of the compressive resistance versus insulation thickness for the 3 lb/ft^3 and 9 lb/ft^3 materials are shown in figures 24, 25, and 26. The 3 lb/ft^3 material became more compressed with each resulting cycle. The loading curves showed a larger change than the unloading curves. A similar behavior was seen in the 9 lb/ft^3 material (fig. 26). The coupons were cycled to the average thickness of the other coupons tested. This resulted in maximum stresses at the minimum thickness that were lower than 12.5 psi for all coupons, 11.14, 11.40 and 9.69 for the 0.15 and 0.25 inch 3 lb/ft^3 and 9 lb/ft^3 materials respectively. The final thickness of the coupons was also significantly smaller than the average of the other coupons after a single cycle; 0.193 inches versus 0.266, 0.323 inches versus 0.422 inches and 1.074 inches versus 1.225 inches for the 0.15 and 0.25 inch 3 lb/ft^3 and 9 lb/ft^3 materials respectively. A expanded scale version of each graph is shown in figures 27, 28 and 29.

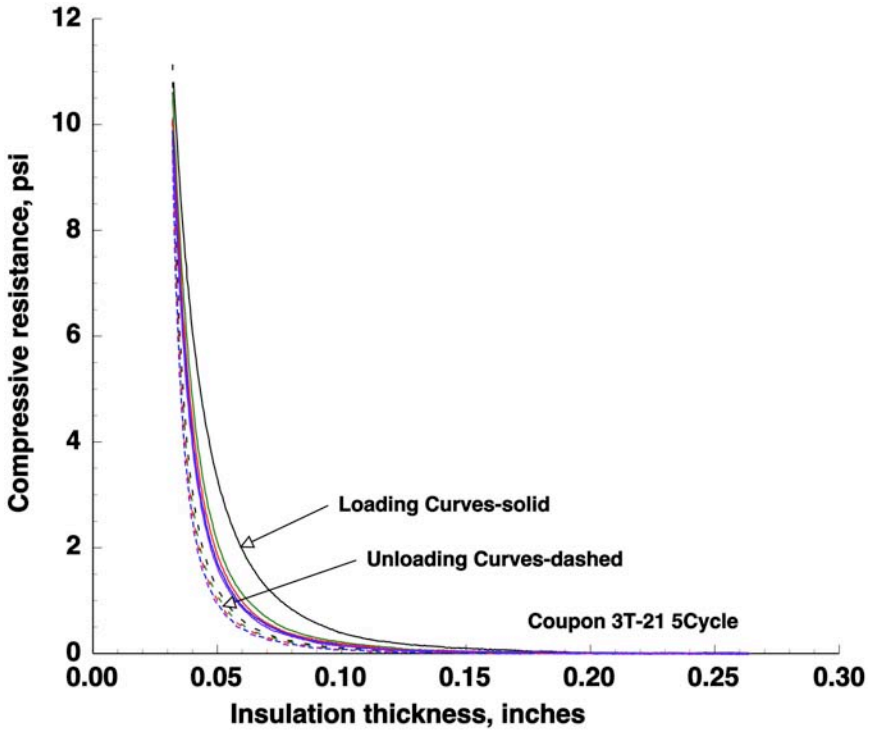


Figure 24. Five-cycle data for compressive resistance versus insulation thickness for 3 lb/ft3 alumina fiber insulation, 0.15-inch nominal thickness, coupon 3T-21

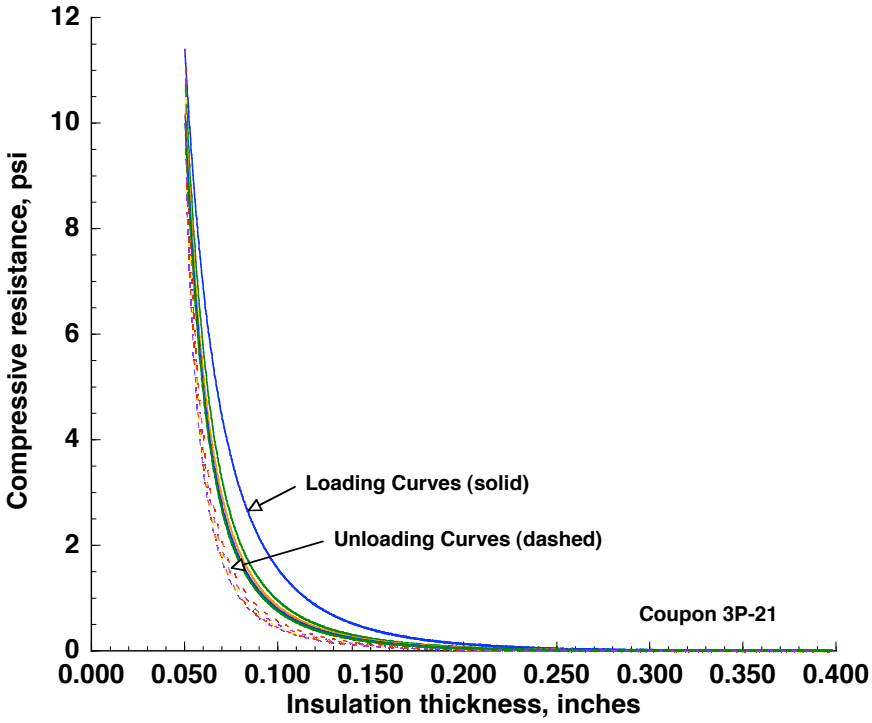


Figure 25. Five-cycle data for compressive resistance versus insulation thickness for 3 lb/ft^3 alumina fiber insulation, 0.25-inch nominal thickness, coupon 3P-21.

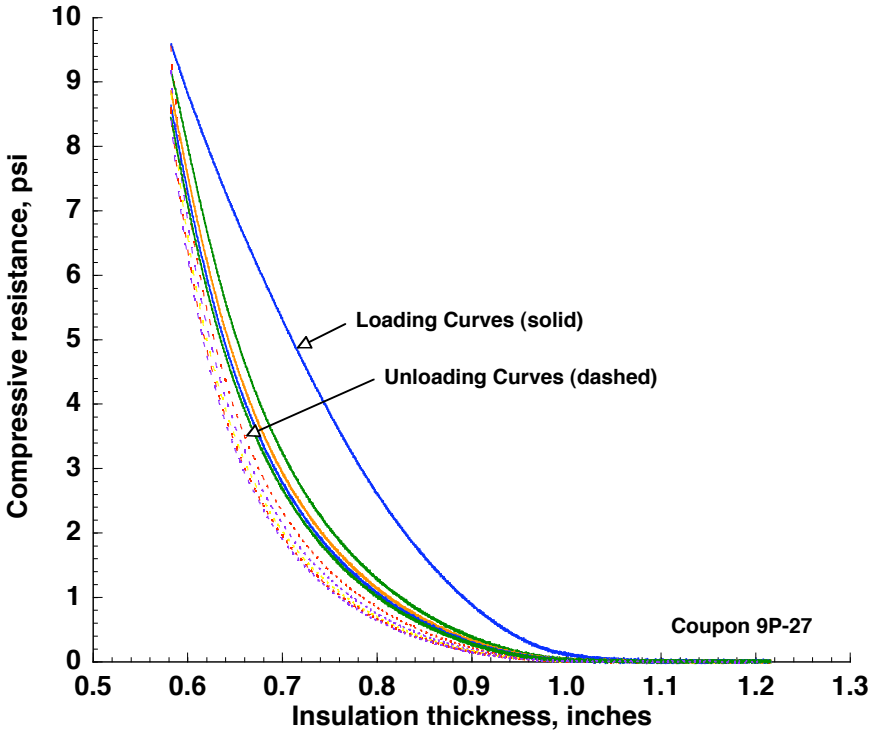


Figure 26. Five-cycle data for compressive resistance versus insulation thickness for 9 lb/ft^3 alumina fiber insulation, 1.00-inch nominal thickness, coupon 3P-27.

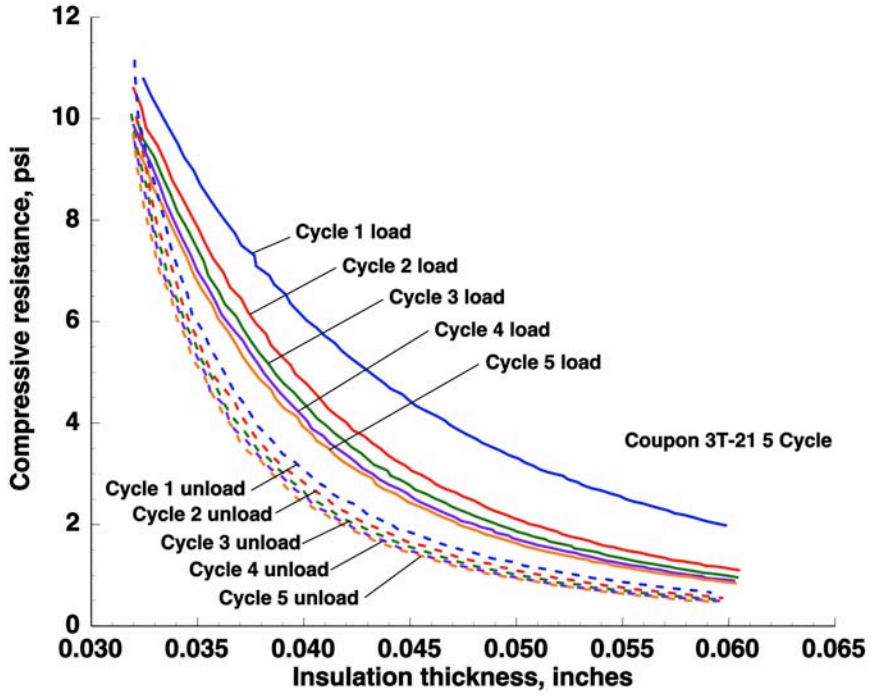


Figure 27. Enlarged view of five-cycle data for compressive resistance versus insulation thickness for 3 lb/ft^3 alumina fiber insulation, 0.15-inch nominal thickness, coupon 3T-21.

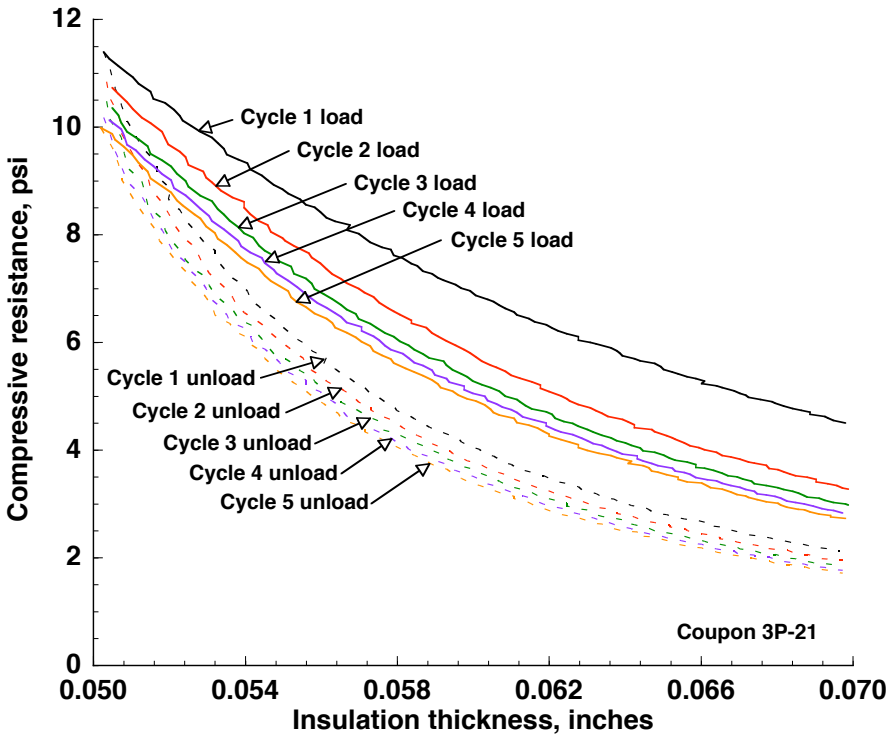


Figure 28. Enlarged view of five-cycle data for compressive resistance versus insulation thickness for 3 lb/ft^3 alumina fiber insulation, 0.25-inch nominal thickness, coupon 3P-21.

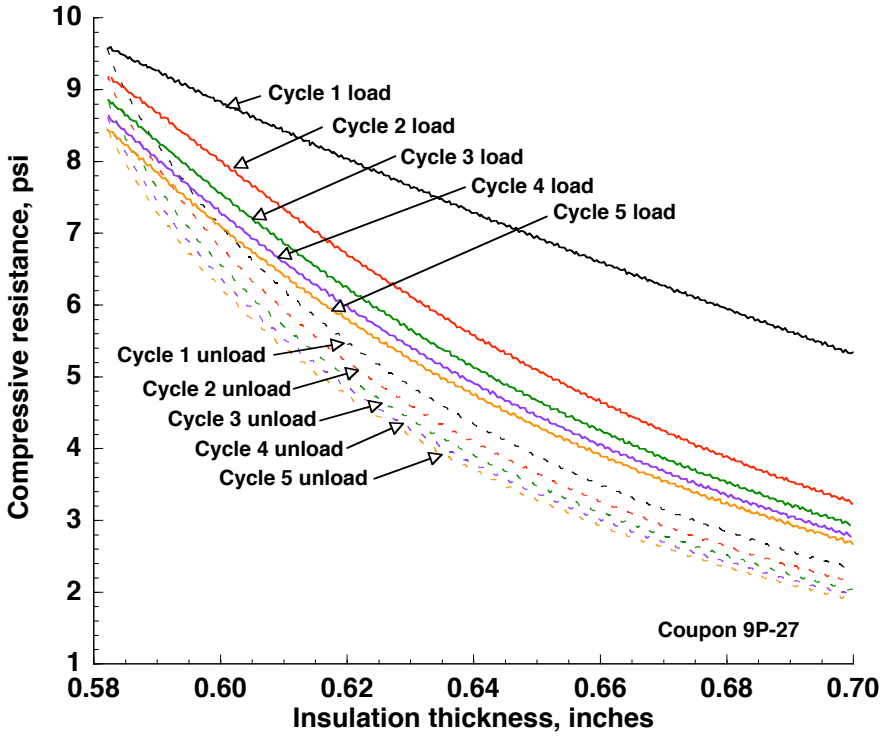


Figure 29. Five-cycle data for compressive resistance versus insulation thickness for 9 lb/ft^3 alumina fiber insulation, 1.00-inch nominal thickness, coupon 9P-27.

Compressive Resistance Calculations

The compressive resistance of the materials was calculated at specific thickness on both the loading and unloading curves. Only the curves for materials that fell within the areal density specifications were used in the calculation. Summaries of this data are shown in tables 5, 6 and 7 for the 0.15 and 0.25 inch 3 lb/ft^3 and 9 lb/ft^3 materials respectively.

Table 5. 3 lb/ft^3 alumina fiber insulation, 0.15-inch thick, RT Compression Resistance Summary Values.

Blanket thickness, inch	Loading compressive resistance, psi	Standard deviation, psi	95% CI of the mean	Unloading compressive resistance, psi	Standard deviation, psi	95% CI of the mean	No. of coupons
0.035	9.70	1.21	±0.64	6.80	1.77	±0.94	16
0.040	6.73	0.85	±0.45	3.43	0.71	±0.38	16
0.045	4.88	0.62	±0.33	2.06	0.38	±0.2	16
0.050	3.66	0.46	±0.25	1.40	0.24	±0.12	16
0.055	2.81	0.36	±0.19	0.99	0.16	±0.08	16
0.060	2.24	0.30	±0.16	0.73	0.11	±0.06	16
0.070	1.46	0.21	±0.11	0.44	0.07	±0.04	16
0.080	0.98	0.15	±0.08	0.29	0.05	±0.03	16
0.100	0.50	0.10	±0.05	0.14	0.03	±0.02	16
0.120	0.28	0.07	±0.03	0.08	0.02	±0.01	16
0.140	0.17	0.05	±0.03	0.04	0.01	±0.01	16
0.160	0.11	0.04	±0.02	0.03	0.01	±0.01	16
0.180	0.07	0.03	±0.02	0.01	0.01	±0.01	16
0.200	0.04	0.03	±0.01	0.01	0.01	±0.00	16

Table 6. 3 lb/ft^3 alumina fiber insulation, 0.25-inch thick, RT Compression Resistance Summary Values.

Blanket thickness, inch	Loading compressive resistance, psi	Standard deviation, psi	95% CI of the mean	Unloading compressive resistance, psi	Standard deviation, psi	95% CI of the mean	No. of coupons
0.052	11.02	0.71	±0.46	8.80	1.34	±0.88	15
0.055	10.00	0.77	±0.51	7.14	1.33	±0.64	20
0.060	7.80	0.62	±0.41	4.52	0.72	±0.35	20
0.065	6.33	0.53	±0.35	3.12	0.44	±0.21	20
0.070	5.20	0.45	±0.3	2.25	0.30	±0.14	20
0.080	3.62	0.35	±0.23	1.34	0.16	±0.08	20
0.090	2.64	0.29	±0.19	0.88	0.11	±0.05	20
0.100	1.99	0.26	±0.17	0.62	0.07	±0.04	20
0.150	0.62	0.16	±0.10	0.16	0.03	±0.02	20
0.200	0.25	0.09	±0.06	0.06	0.02	±0.01	20
0.247	0.12	0.05	±0.04	0.03	0.02	±0.01	20

Table 7. 9 lb/ft^3 alumina fiber insulation, 1-inch thick, RT Compression Resistance Summary Values.

Blanket thickness, inch	Loading compressive resistance, psi	Standard deviation, psi	95% CI of the mean	Unloading compressive resistance, psi	Standard deviation, psi	95% CI of the mean	No. of coupons
0.60	11.36	0.69	0.46	9.39	1.33	0.70	12
0.65	9.14	0.86	0.45	6.08	1.13	0.59	17
0.70	6.99	0.75	0.39	3.75	0.66	0.35	17
0.75	5.26	0.65	0.34	2.39	0.44	0.23	17
0.80	3.83	0.57	0.30	1.52	0.30	0.16	17
0.85	2.66	0.49	0.26	0.94	0.22	0.12	17
0.90	1.74	0.40	0.21	0.54	0.15	0.08	17
0.95	1.04	0.29	0.15	0.29	0.10	0.05	17
1.00	0.56	0.20	0.11	0.15	0.06	0.04	17

Long Hold Time Test Results

The 0.25-inch 3 lb/ft^3 and the 1.00-inch 9 lb/ft^3 materials were run at room temperature to duplicate the high temperature 10 minute hold used for the high temperature testing. These tests showed only a small drop in compressive resistance during the 10 minute hold (figures 30 and Appendix A). The decision was made to test the effect of much longer holds on the compressive resistance. A coupon of the 3 lb/ft^3 alumina fiber insulation, 0.15-inch nominal thickness material was compressed to thickness required to generate 12.5 psi of compressive resistance and held for 67 hours (figure 31). The coupons rapidly fell to below 10 psi from the initial 12.5 psi loading and slowly lost additional load over time. The final compressive resistance was 9.0 psi.

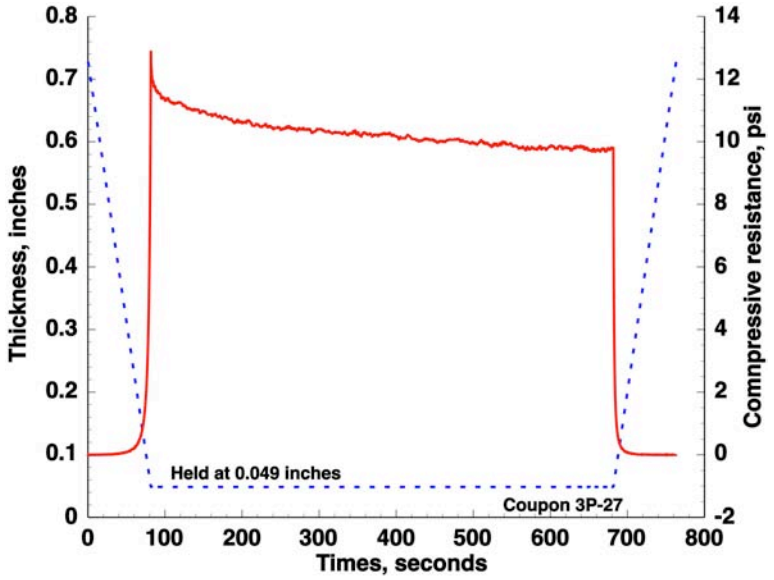


Figure 30, Long term hold data for compressive resistance versus insulation thickness for 3 lb/ft^3 alumina fiber insulation, 0.25-inch nominal thickness material held at a minimum displacement of 0.049 inches for 10 minutes.

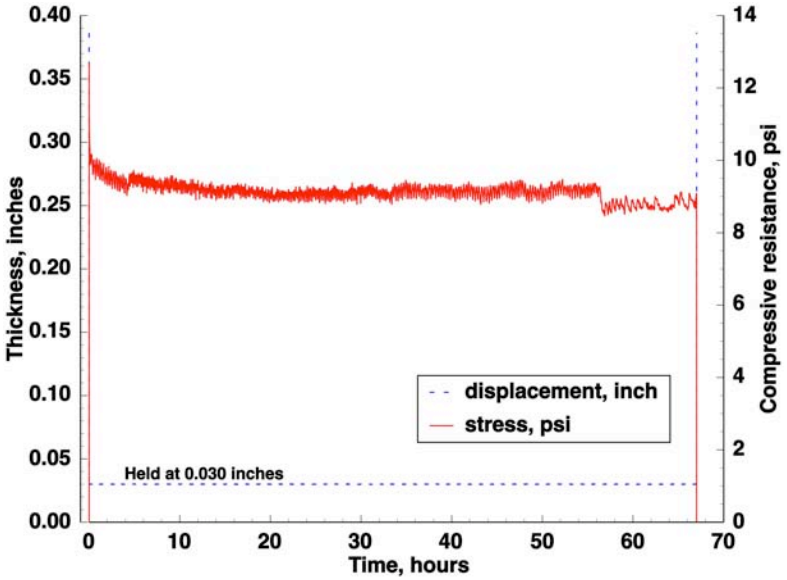


Figure 31. Long term hold data for compressive resistance versus insulation thickness for 3 lb/ft^3 alumina fiber insulation, 0.15-inch nominal thickness material held at a minimum displacement of 0.030 inches for 67 hours.

High Temperature Test Results

Figures 32, 33 and 34 show typical loading curves for the materials tested. The large amount of noise is due to two factors: first the load cell in the test stand has a maximum capacity of 11,000 lbs and the measurements are on the order of 100 lbs; and second there is a large amount of interference in the signal due to the 60 Hz furnace power. The test stand data acquisition does not allow for filtering of data below 100 Hz so the noise could not be removed during the test. A 2 second running average was applied post test to the data and is seen as the embedded line.

The compressive resistance of the coupons fell rapidly after the initiation of the hold segment to around 3 psi and slowly decreased to about 2 psi for the 3 lb/ft^3 materials. The 9 lb/ft^3 materials had a more gradual drop in load but still ended up around 2 psi. After completion of testing the materials retained much of the reduced thickness induced during testing and became more board like. The results are listed in tables 8, 9 and 10. The post test thickness is approximate due to the difficulty of visually determining the thickness for the 3 lb/ft^3 materials.

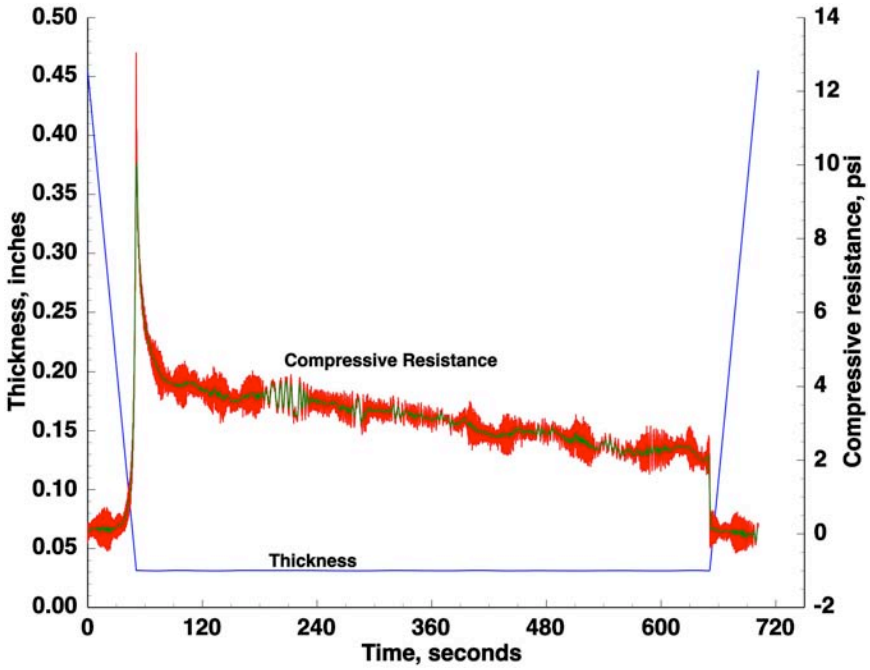


Figure 32. 2300°F data for compressive resistance versus insulation thickness for 3 lb/ft^3 alumina fiber insulation, 0.15-inch nominal thickness, coupon 3T-24.

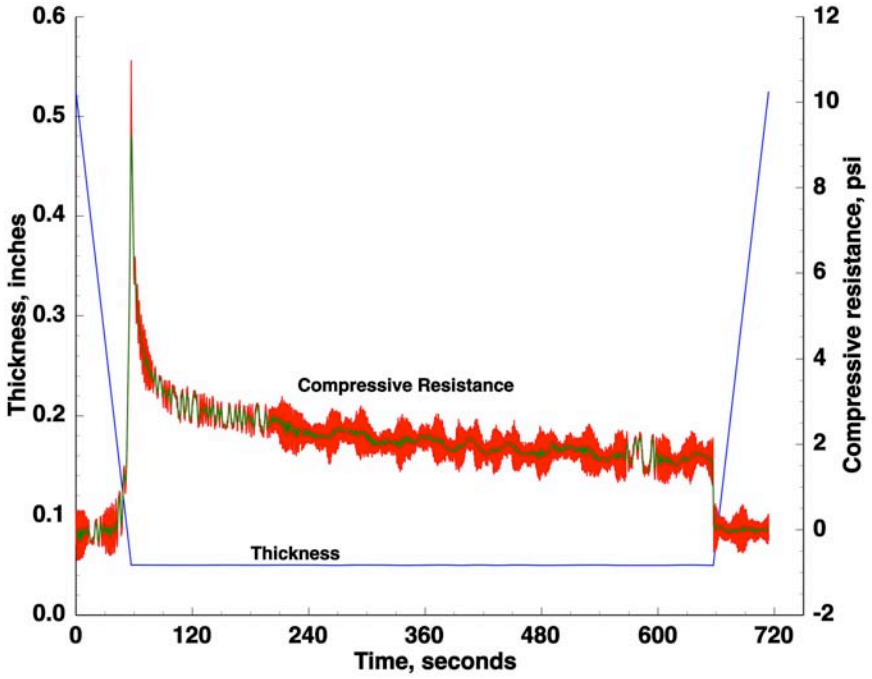


Figure 33. 2300°F data for compressive resistance versus insulation thickness for 3 lb/ft^3 alumina fiber insulation, 0.25-inch nominal thickness, coupon 3P-24.

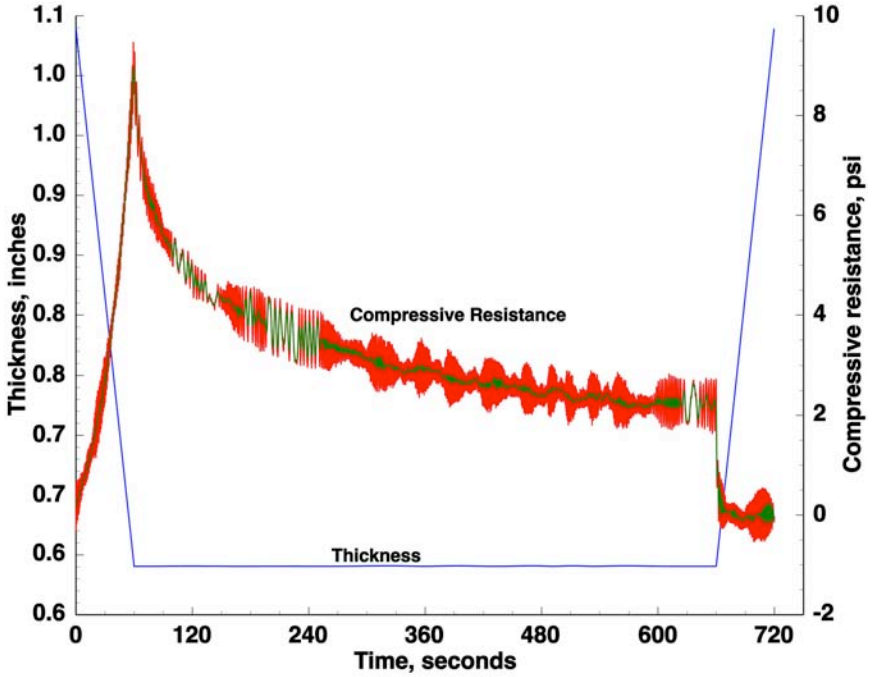


Figure 34. 2300°F data for compressive resistance versus insulation thickness for 9 lb/ft^3 alumina fiber insulation, 1.00-inch nominal thickness, coupon 9P-03.

Table 8. 3 lb/ft^3 alumina fiber insulation, 0.15-inch thick, HT Compression Resistance Summary Values.

Coupon Number	Thickness start, inch	Approximate thickness end, inch	Target minimum displacement, inches	Residual compressive resistance, psi
3T-22	0.389	0.069	0.031	2.07
3T-23	0.464	0.068	0.031	1.46
3T-24	0.455	0.075	0.031	2.19
3T-25	0.291	0.044	0.031	1.77
3T-26	0.378	0.047	0.031	2.09
Average	0.395	0.060		1.92
StDev	0.070	0.014		0.30
95% CI	0.097	0.020		0.42
3T-27	0.309	0.079	0.035	1.14
3T-28	0.365	0.050	0.040	1.06
3T-29	0.461	0.070	0.045	0.89
3T-30	0.475	0.087	0.050	0.40
3T-31	0.496	0.118	0.055	0.49

Table 9. 3 lb/ft^3 alumina fiber insulation, 0.25-inch thick, HT Compression Resistance Summary Values.

Coupon Number	Thickness start, inch	Approximate thickness end, inch	Target minimum displacement, inches	Residual compressive resistance, psi
3P-22	0.511	0.073	0.050	1.52
3P-23	0.567	0.061	0.050	1.38
3P-24	0.425	0.080	0.050	1.71
3P-25	0.501	0.068	0.050	1.66
3P-26	0.645	0.100*	0.050	3.80*
Average	0.530	0.071		1.57
StDev	0.082	0.008		0.15
95% CI	0.111	0.015		0.27

* 1 minute hold, not in average values

Table 10. 9 lb/ft^3 alumina fiber insulation, 1.00-inch thick, HT Compression Resistance Summary Values.

Coupon Number	Thickness start, inch*	Thickness end, inch	Target minimum displacement, inches	Residual compressive resistance, psi
9P-01	1.107	0.696	0.590	1.97
9P-02	1.108	0.697	0.593	1.98
9P-03	1.107	0.695	0.591	2.24
9P-04	1.101	0.679	0.591	2.14
9P-05	1.106	0.690	0.591	2.33
Average		0.691		2.13
StDev		0.007		0.16
95% CI		0.010		0.21

* Maximum separation of platens

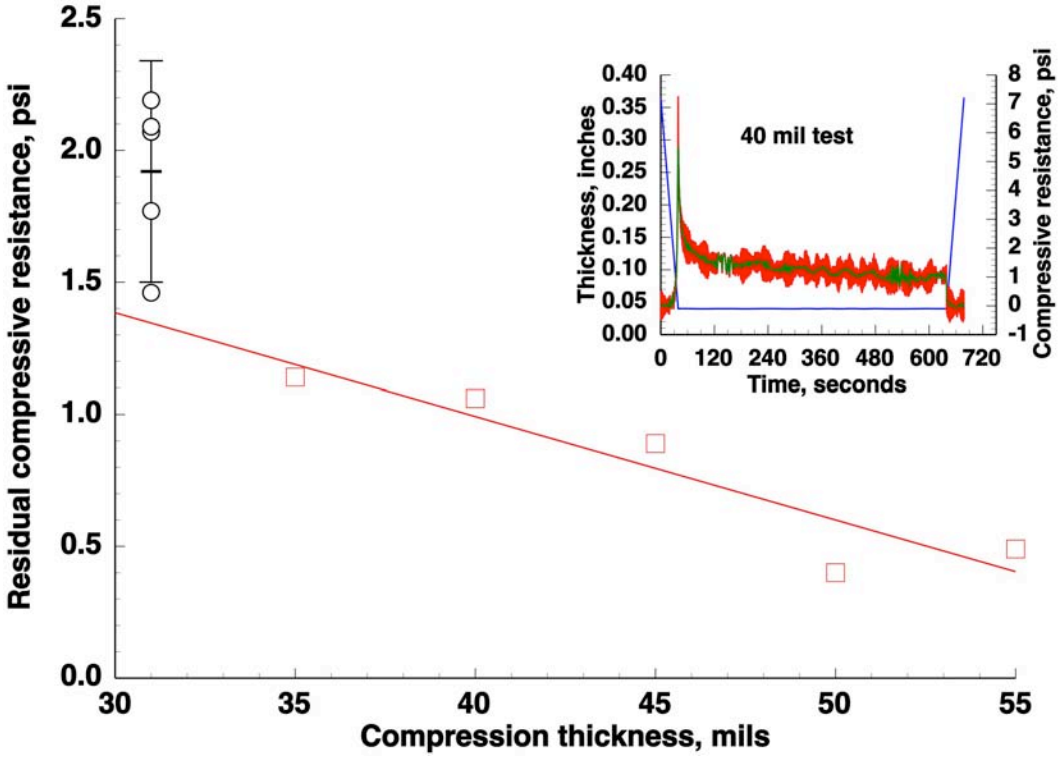


Figure 35. 2300°F data for compressive resistance versus insulation thickness for 3 lb/ft^3 alumina fiber insulation, 0.15-inch nominal thickness material tested at various minimum displacements. Bars show mean and 95% confidence interval for the data at 31 mils.

Since the alumina fiber insulation will not be compressed to 12.5 psi during the actual installation of the overlay plate a series of runs was conducted to test the residual compliance of the 0.15 inch alumina fiber insulation material after compression to lower loads. The initial thickness for the 0.15-inch alumina fiber insulation was 0.031 inches, this was increased in steps to 0.055 inches. Figure 35 shows the results of these tests. The average residual compressive resistance at the end of 0.031 inch tests was 1.9 psi. This value decreased to 1.1 psi at 0.035 inches and to 0.5 psi at 0.055 inches. The alumina fiber insulation material appears to retain a small amount of pre-load, around 1 psi, even after heating to 2300°F at the nominal installation thickness of 0.045 inches. 1 psi is about half the residual load measured during the room temperature unloading tests at 0.045 inches.

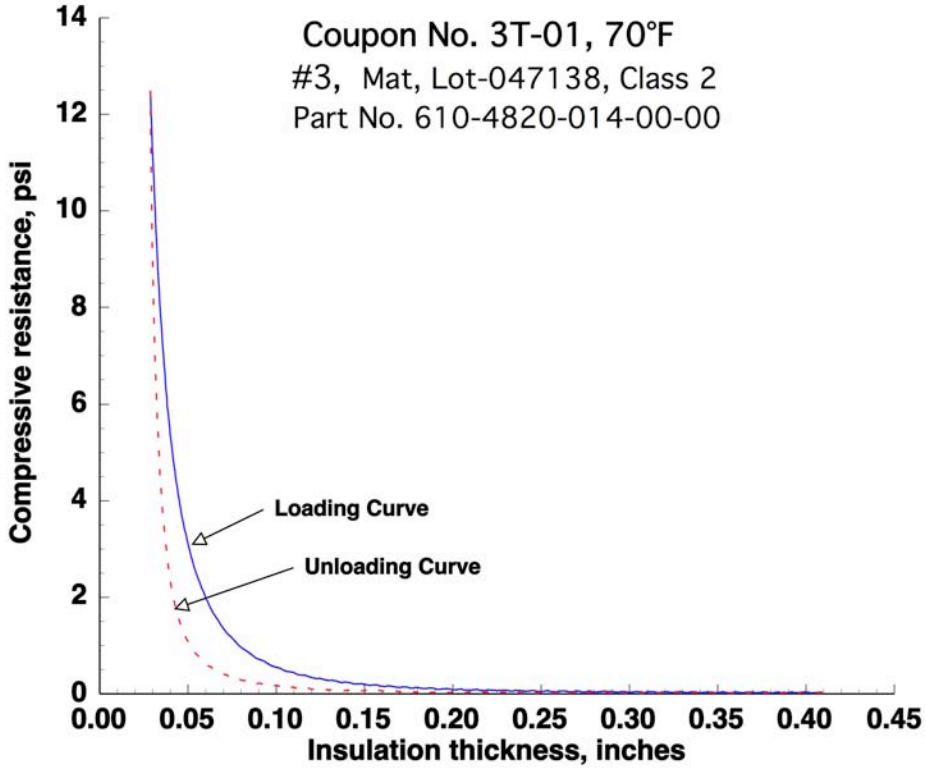
Conclusions

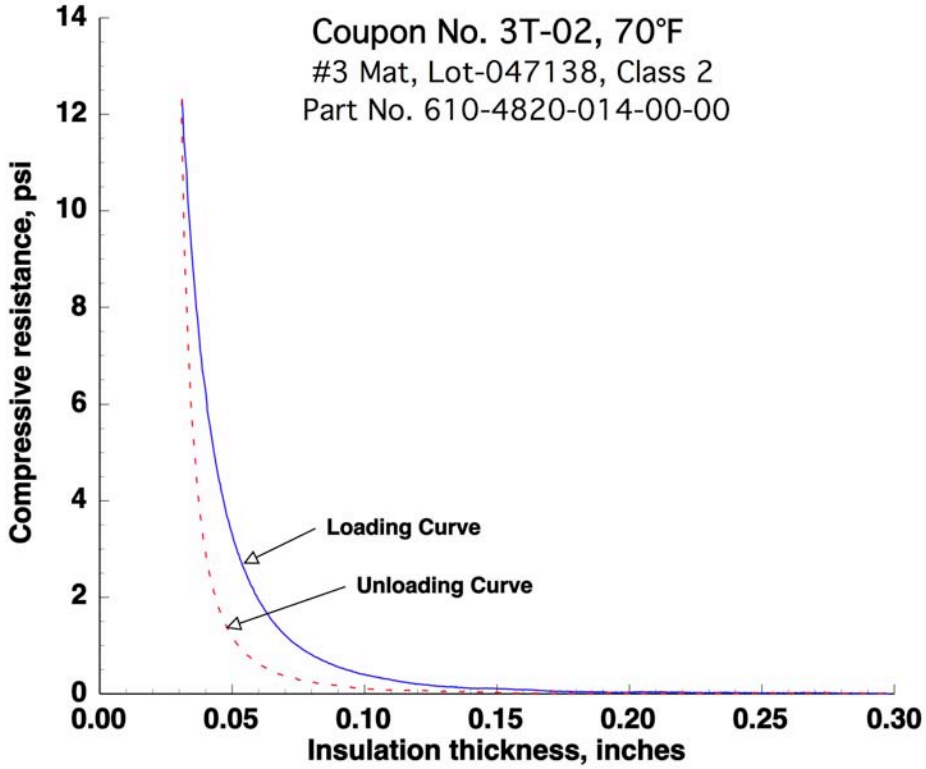
The room temperature compression of the alumina fiber insulation blanket insulation was consistent with the type of performance typical for blanket type insulations. The compressive resistance versus compression thickness was very non-linear with the stiffness increasing rapidly as the material became highly compressed. The key data for the alumina fiber insulation system was the unloading resistance at 0.045 inches for both room temperature and 2300°F. The compressive resistance at room temperature was 2.1 psi. When the material was held for 10 minutes at 2300°F, a residual compressive resistance of 1.0 psi was measured. The alumina fiber insulation insulation became more board-like after temperature exposure but retained a small of amount of compressive resistance which will provide some pre-load to the augers securing the overlay repair plate.

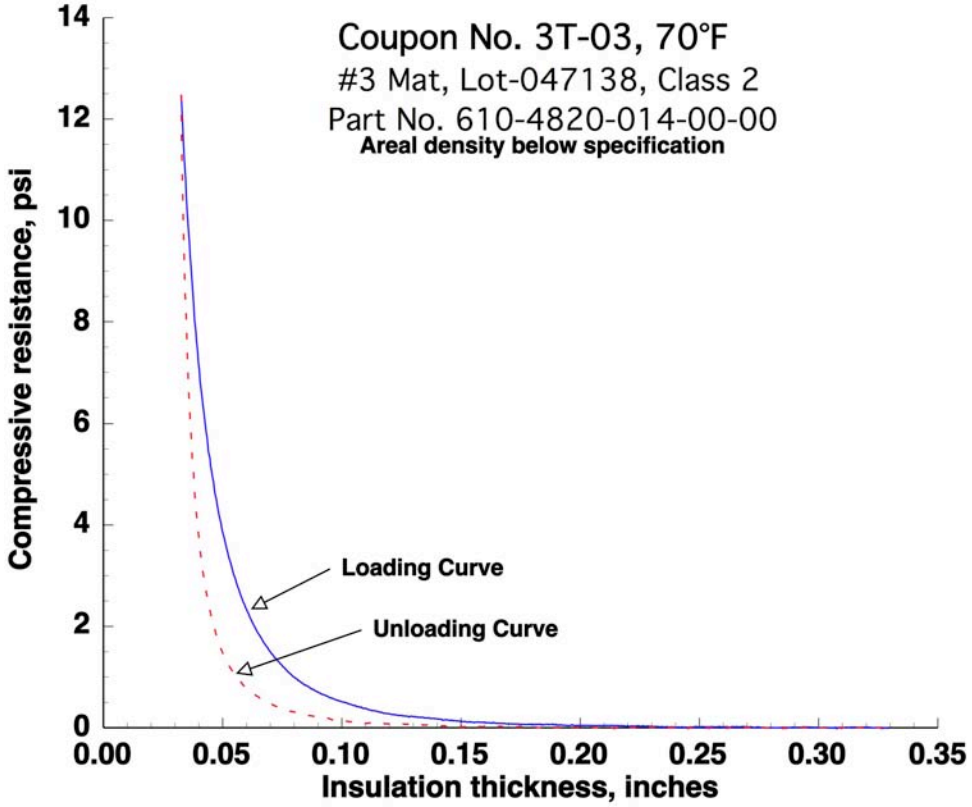
Appendix A

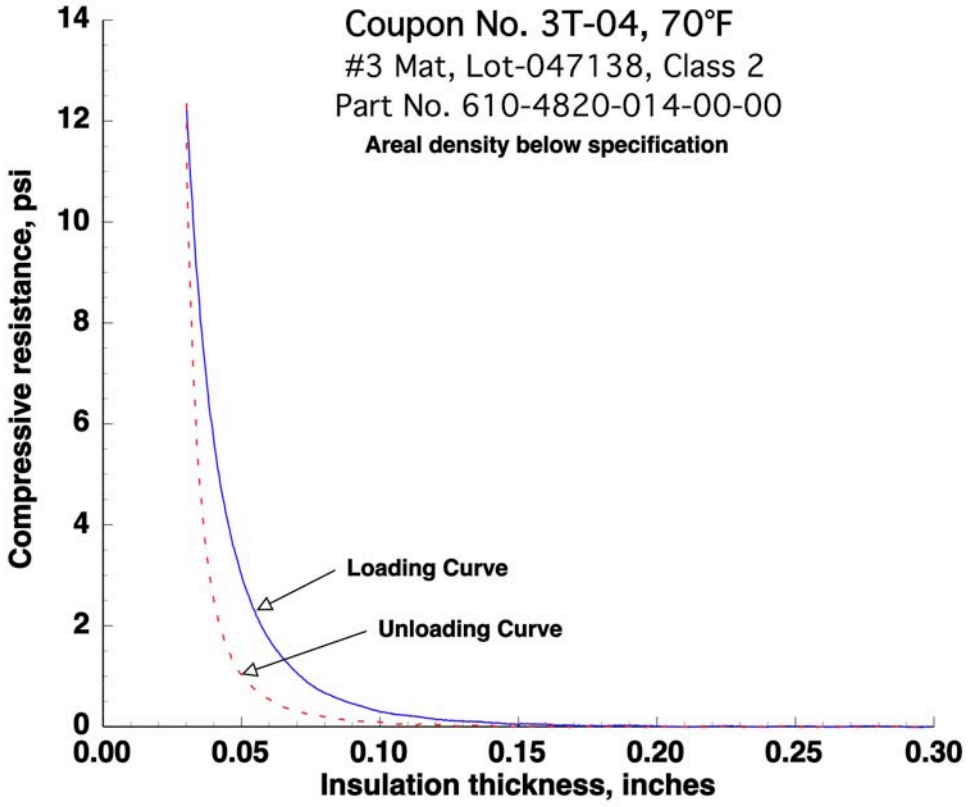
Alumina Fiber Insulation Compressive Resistance versus Insulation Thickness Graphs

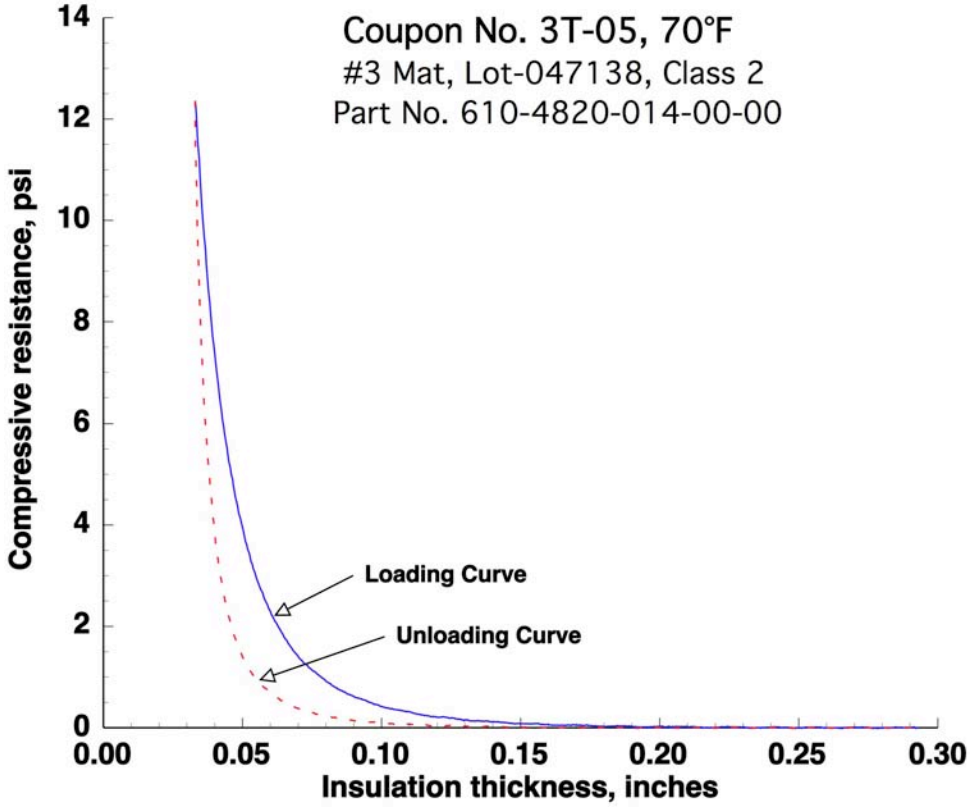
Alumina Fiber Blanket Insulation 0.15-inch 3 lb/ft^3 Materials Room Temperature Tests

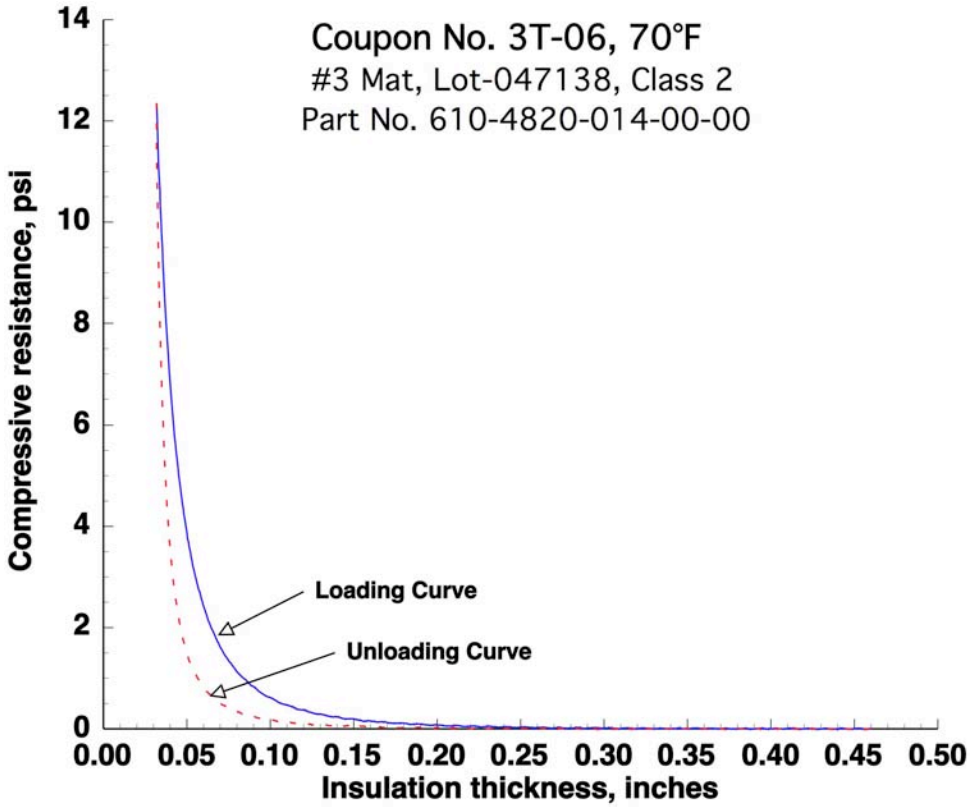


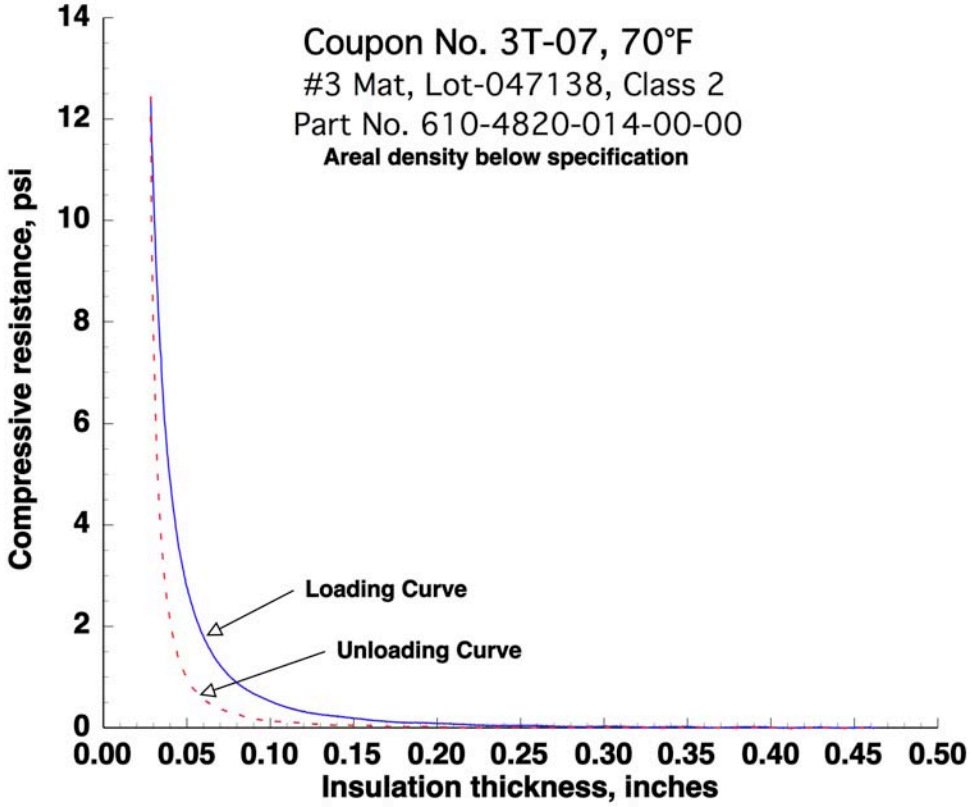


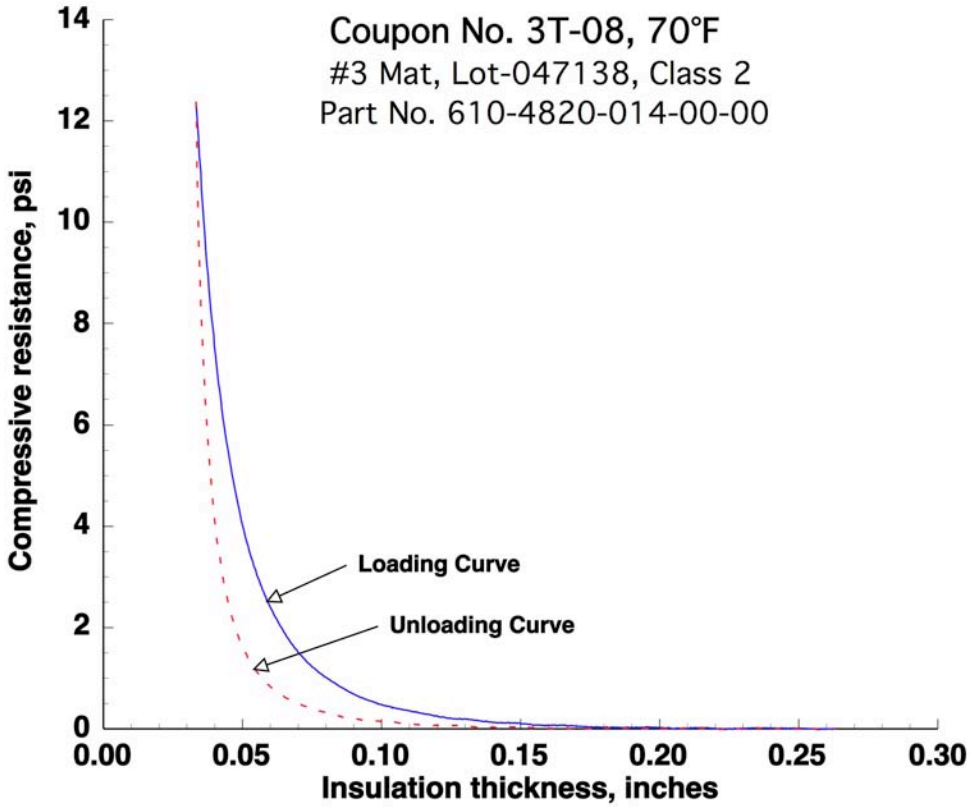

Coupon No. 3T-03, 70°F
#3 Mat, Lot-047138, Class 2
Part No. 610-4820-014-00-00
Areal density below specification
Compressive resistance, psi
Insulation thickness, inches
Loading Curve
Unloading Curve
0
2
4
6
8
10
12
14
0.00
0.05
0.10
0.15
0.20
0.25
0.30
0.35

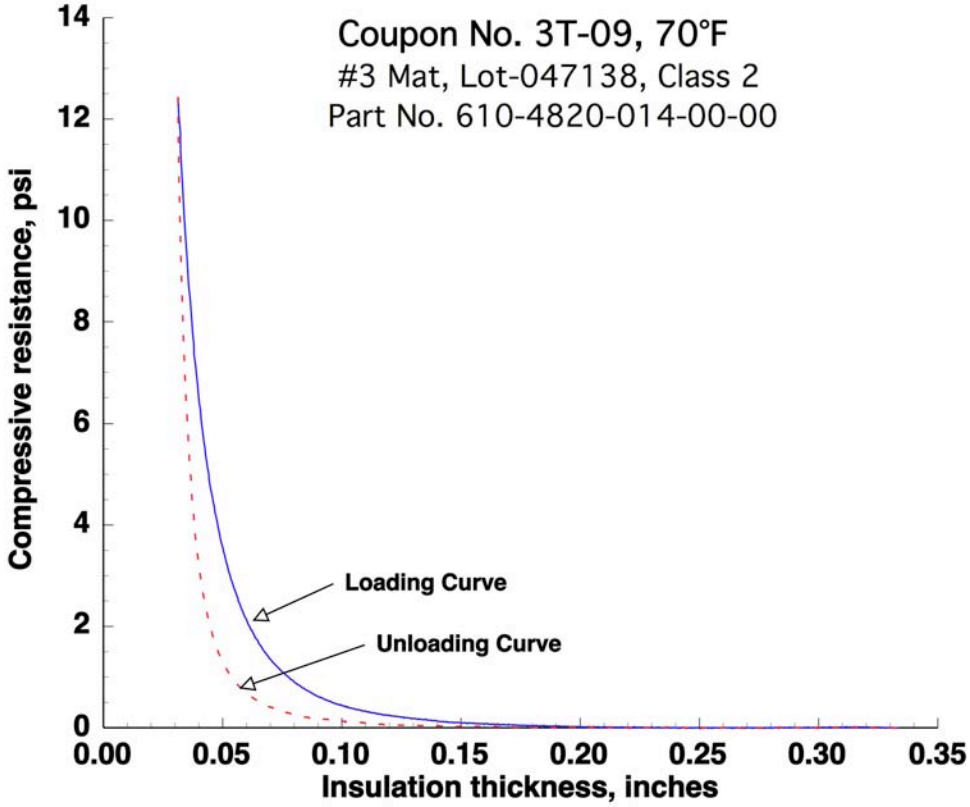

Coupon No. 3T-04, 70°F
#3 Mat, Lot-047138, Class 2
Part No. 610-4820-014-00-00
Areal density below specification
Compressive resistance, psi
Insulation thickness, inches
Loading Curve
Unloading Curve
0
2
4
6
8
10
12
14
0.00
0.05
0.10
0.15
0.20
0.25
0.30

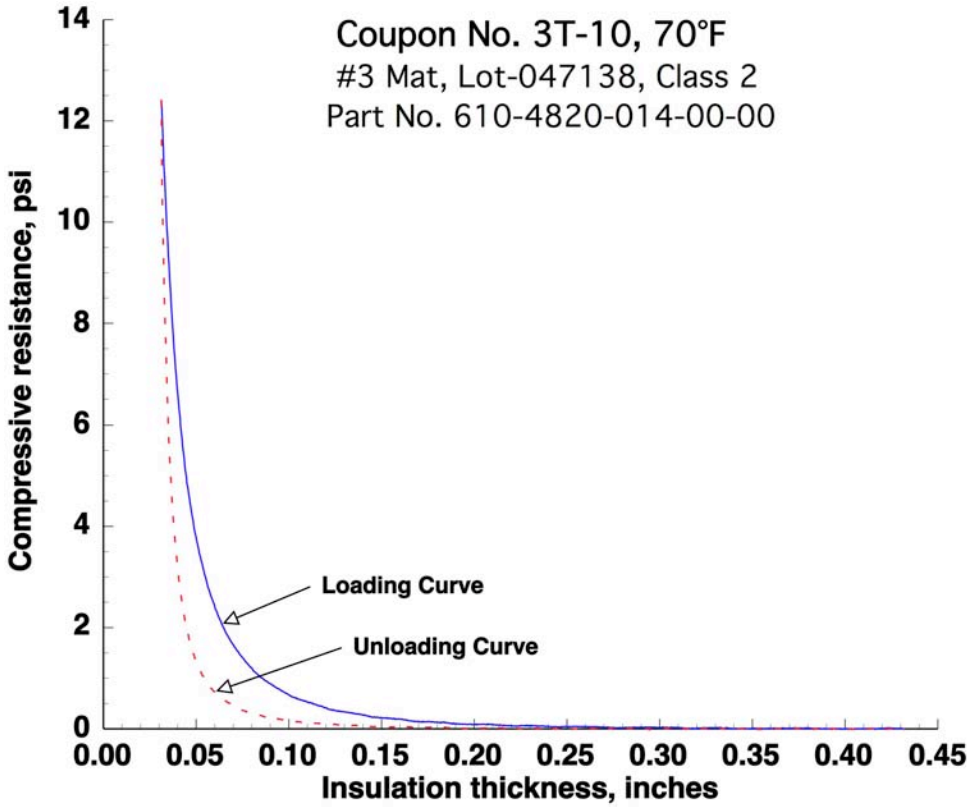

Coupon No. 3T-05, 70°F
#3 Mat, Lot-047138, Class 2
Part No. 610-4820-014-00-00
Compressive resistance, psi
Insulation thickness, inches
Loading Curve
Unloading Curve
0
2
4
6
8
10
12
14
0.00
0.05
0.10
0.15
0.20
0.25
0.30

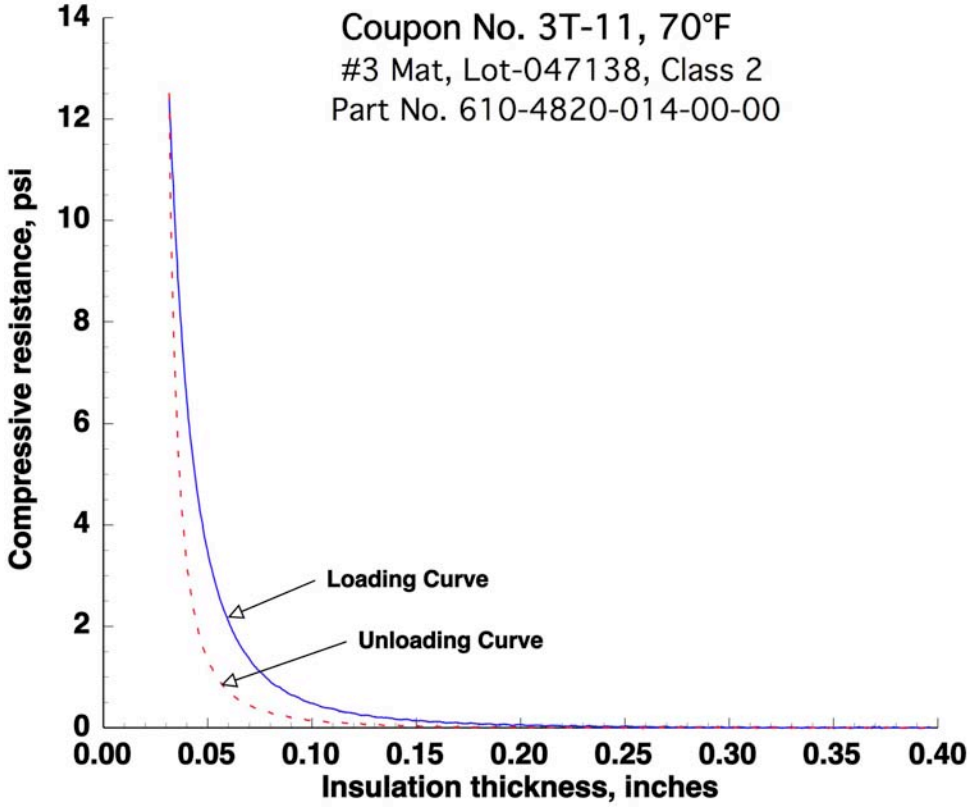

Coupon No. 3T-06, 70°F
#3 Mat, Lot-047138, Class 2
Part No. 610-4820-014-00-00
Compressive resistance, psi
Insulation thickness, inches
Loading Curve
Unloading Curve
0
2
4
6
8
10
12
14
0.00
0.05
0.10
0.15
0.20
0.25
0.30
0.35
0.40
0.45
0.50

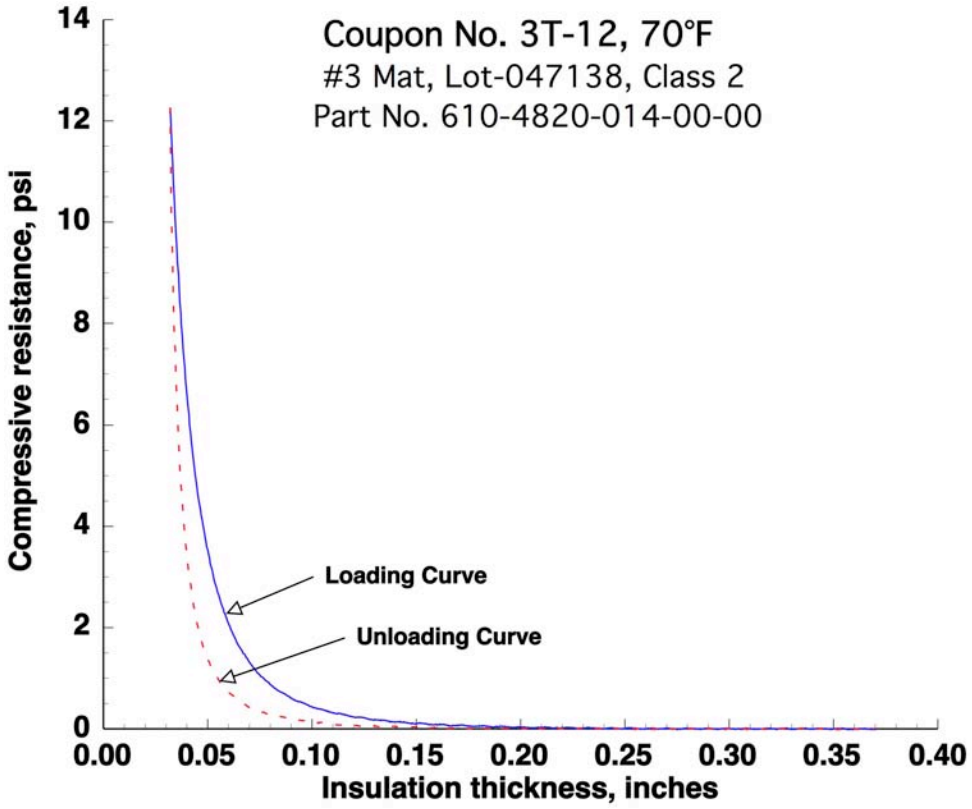

Coupon No. 3T-07, 70°F
#3 Mat, Lot-047138, Class 2
Part No. 610-4820-014-00-00
Areal density below specification
Compressive resistance, psi
Insulation thickness, inches
Loading Curve
Unloading Curve
0
2
4
6
8
10
12
14
0.00
0.05
0.10
0.15
0.20
0.25
0.30
0.35
0.40
0.45
0.50

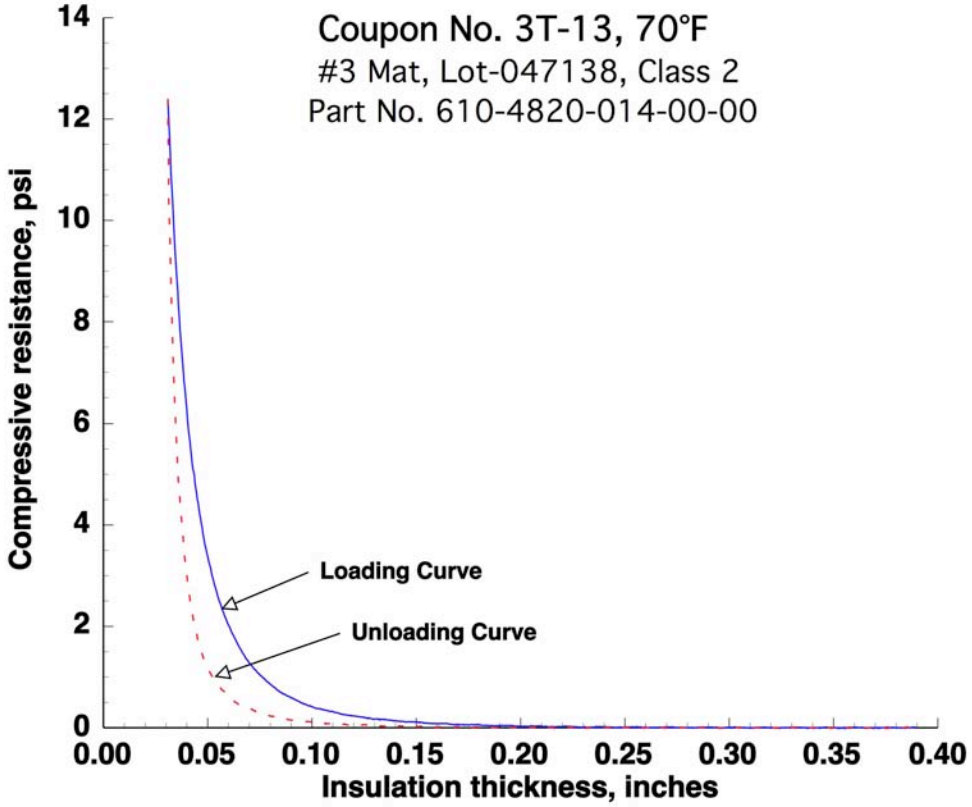

Coupon No. 3T-08, 70°F
#3 Mat, Lot-047138, Class 2
Part No. 610-4820-014-00-00
Compressive resistance, psi
Insulation thickness, inches
Loading Curve
Unloading Curve
0
2
4
6
8
10
12
14
0.00
0.05
0.10
0.15
0.20
0.25
0.30

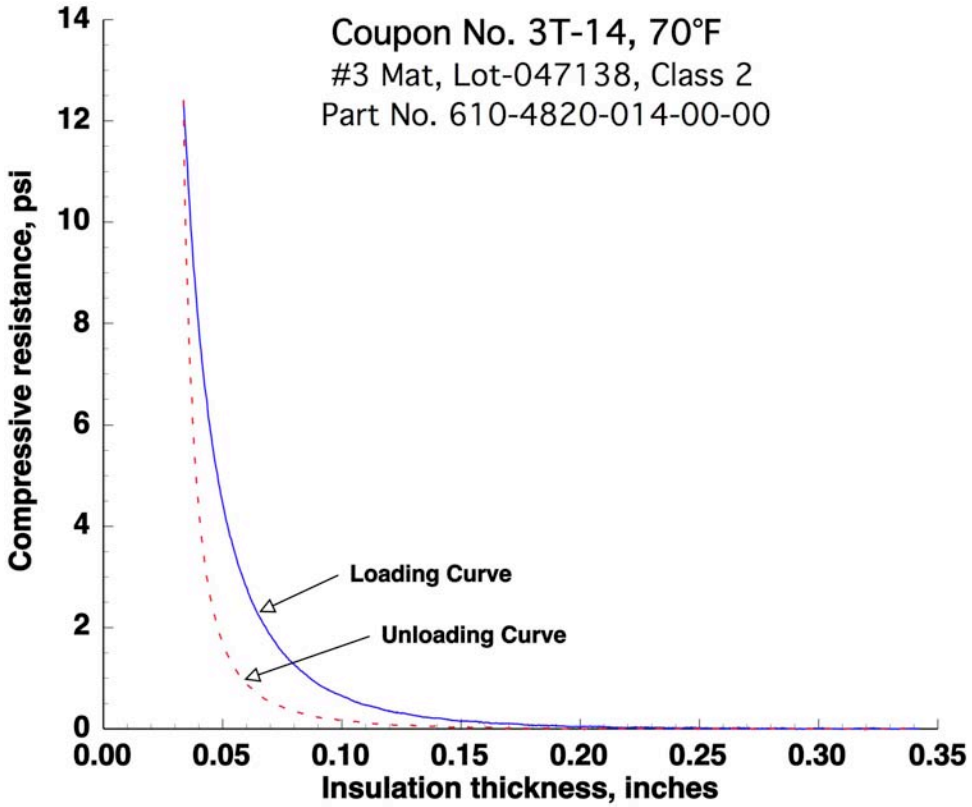

Coupon No. 3T-09, 70°F
#3 Mat, Lot-047138, Class 2
Part No. 610-4820-014-00-00
Compressive resistance, psi
Insulation thickness, inches
Loading Curve
Unloading Curve
0
2
4
6
8
10
12
14
0.00
0.05
0.10
0.15
0.20
0.25
0.30
0.35

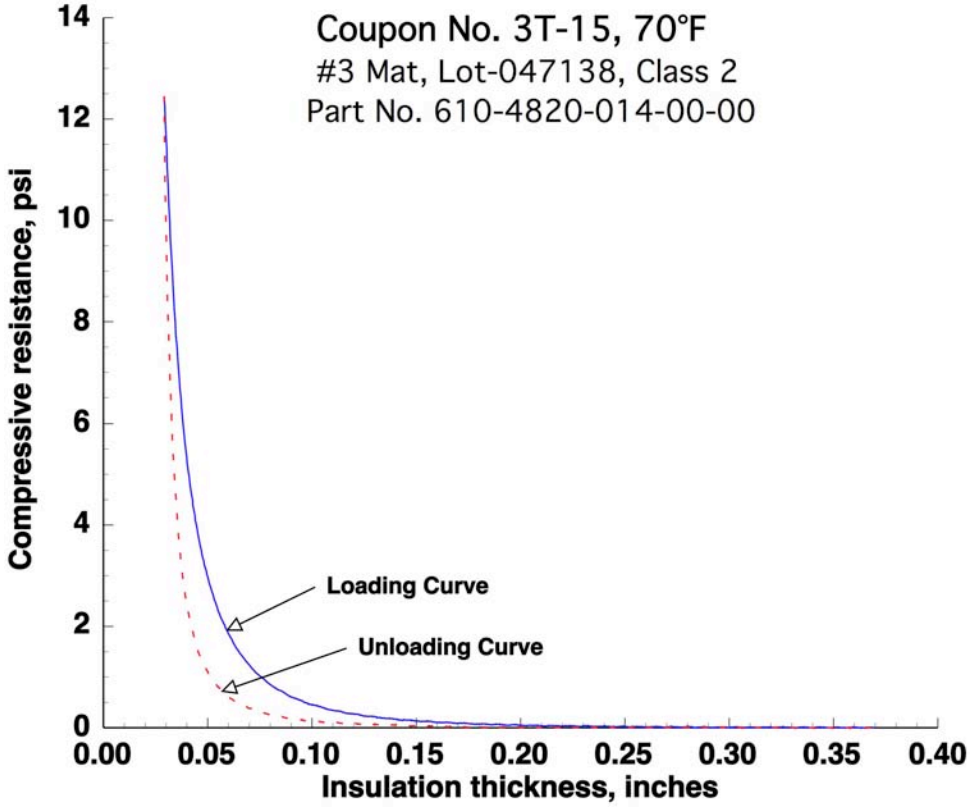

Coupon No. 3T-10, 70°F
#3 Mat, Lot-047138, Class 2
Part No. 610-4820-014-00-00
Compressive resistance, psi
Insulation thickness, inches
Loading Curve
Unloading Curve
0
2
4
6
8
10
12
14
0.00
0.05
0.10
0.15
0.20
0.25
0.30
0.35
0.40
0.45

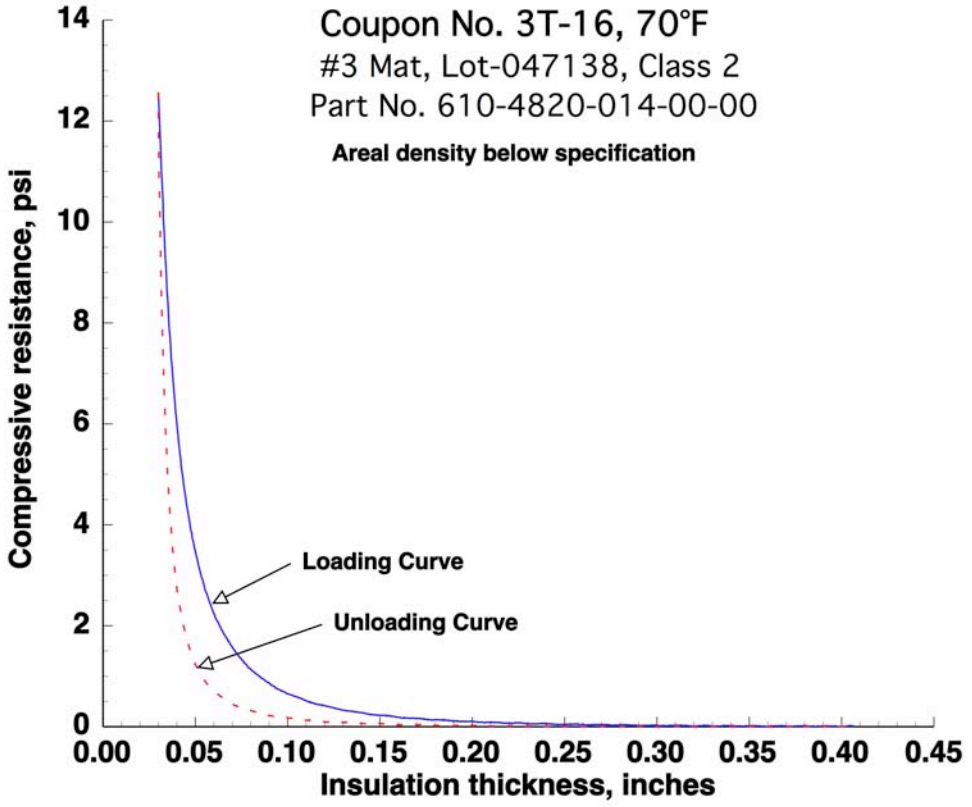

Coupon No. 3T-11, 70°F
#3 Mat, Lot-047138, Class 2
Part No. 610-4820-014-00-00
Compressive resistance, psi
14
12
10
8
6
4
2
0
Loading Curve
Unloading Curve
0.00
0.05
0.10
0.15
0.20
0.25
0.30
0.35
0.40
Insulation thickness, inches

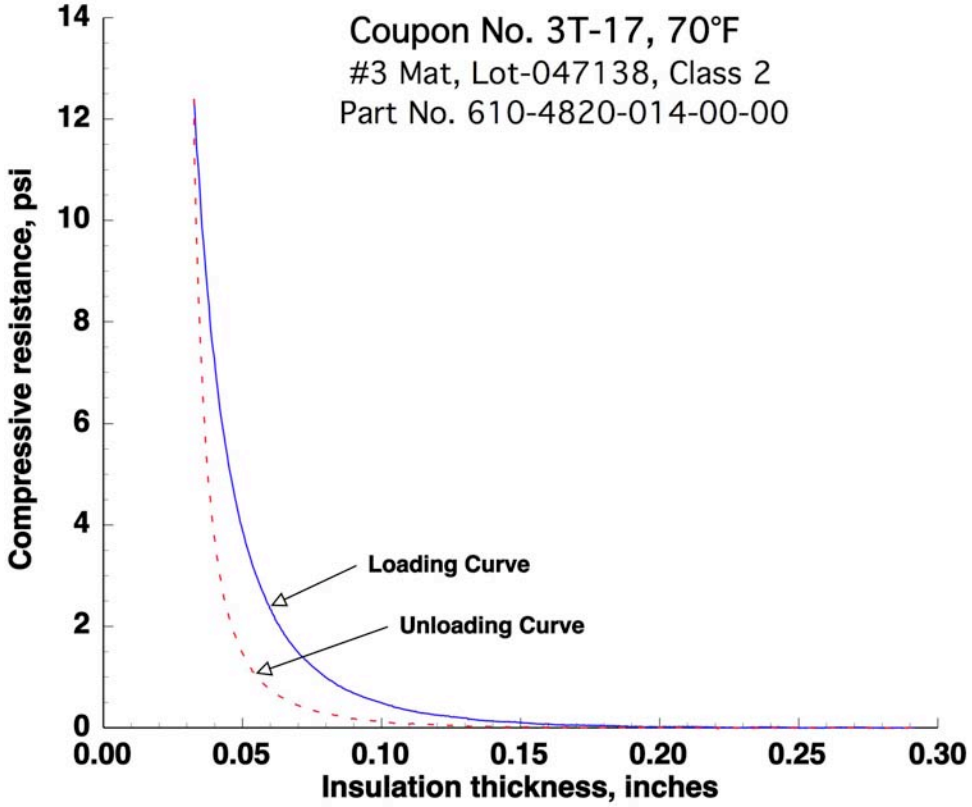

Coupon No. 3T-12, 70°F
#3 Mat, Lot-047138, Class 2
Part No. 610-4820-014-00-00
Compressive resistance, psi
14
12
10
8
6
4
2
0
Loading Curve
Unloading Curve
0.00
0.05
0.10
0.15
0.20
0.25
0.30
0.35
0.40
Insulation thickness, inches

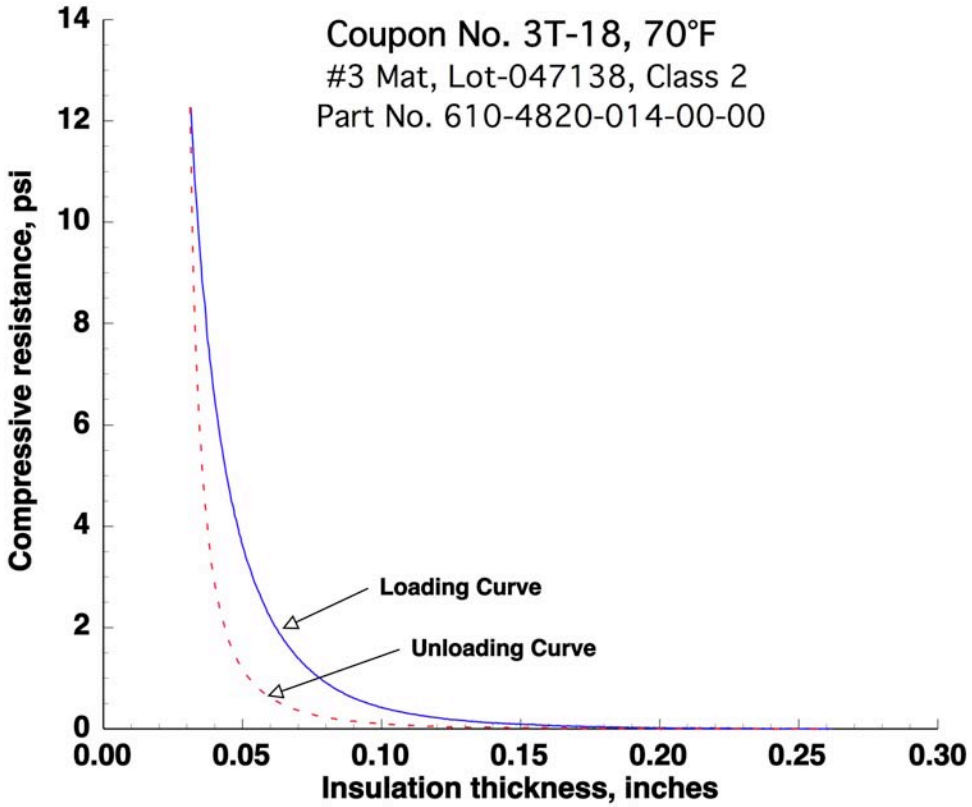

Coupon No. 3T-13, 70°F
#3 Mat, Lot-047138, Class 2
Part No. 610-4820-014-00-00
Compressive resistance, psi
Insulation thickness, inches
Loading Curve
Unloading Curve
0
2
4
6
8
10
12
14
0.00
0.05
0.10
0.15
0.20
0.25
0.30
0.35
0.40

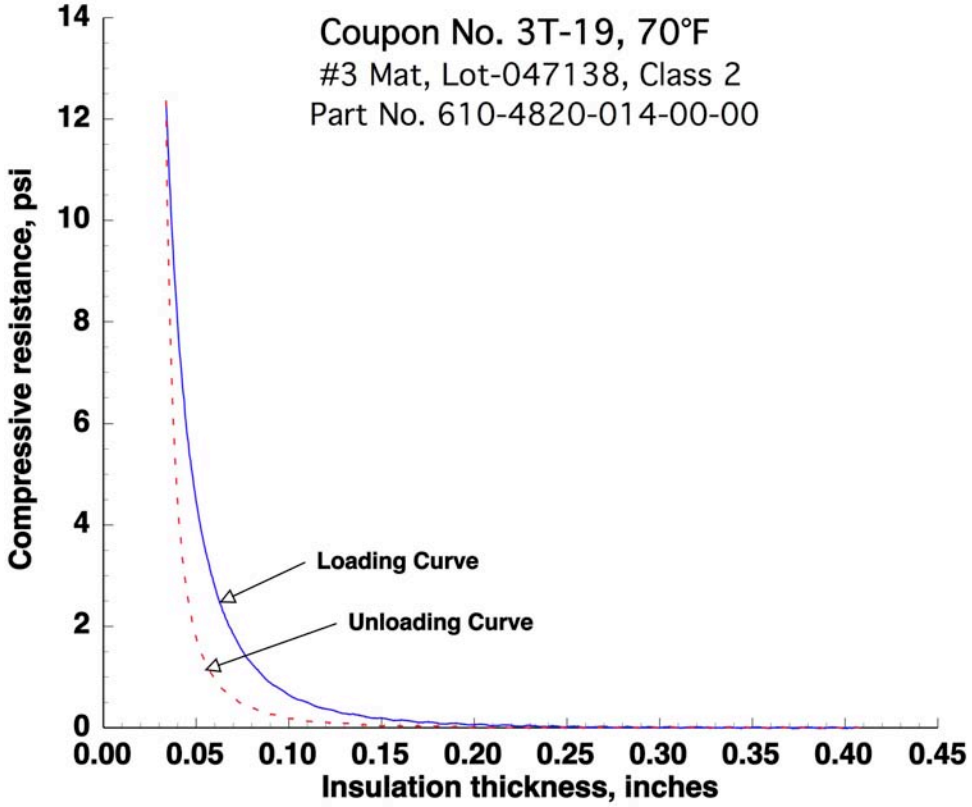

Coupon No. 3T-14, 70°F
#3 Mat, Lot-047138, Class 2
Part No. 610-4820-014-00-00
Compressive resistance, psi
Insulation thickness, inches
Loading Curve
Unloading Curve
0
2
4
6
8
10
12
14
0.00
0.05
0.10
0.15
0.20
0.25
0.30
0.35

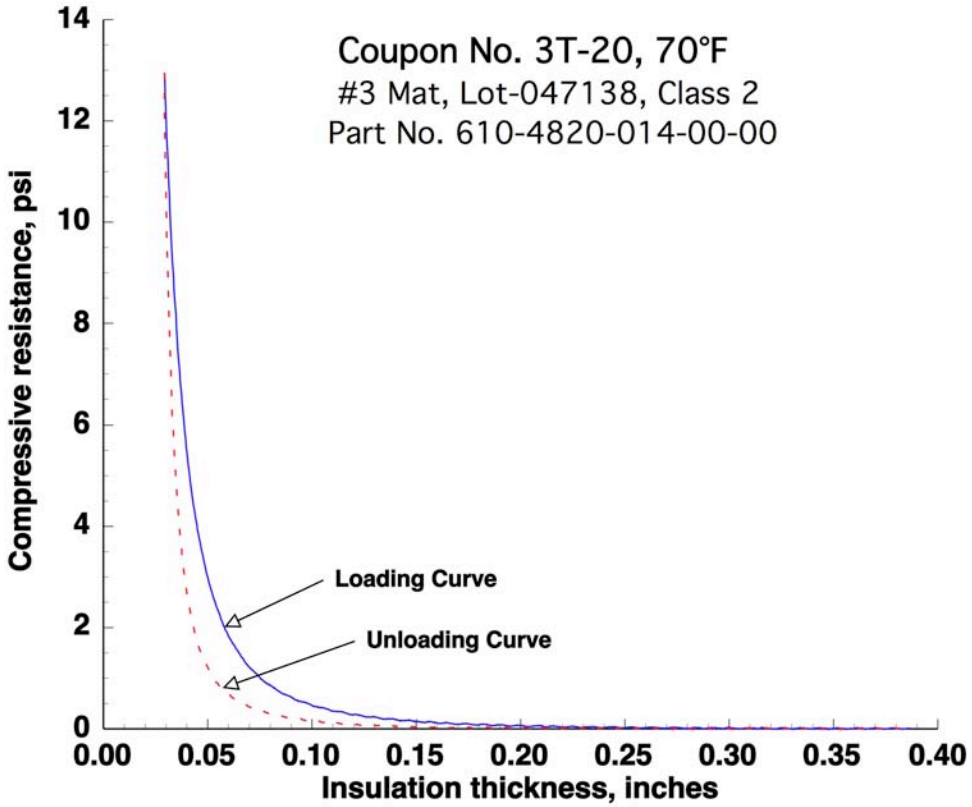

Coupon No. 3T-15, 70°F
#3 Mat, Lot-047138, Class 2
Part No. 610-4820-014-00-00
Compressive resistance, psi
Insulation thickness, inches
Loading Curve
Unloading Curve
0
2
4
6
8
10
12
14
0.00
0.05
0.10
0.15
0.20
0.25
0.30
0.35
0.40

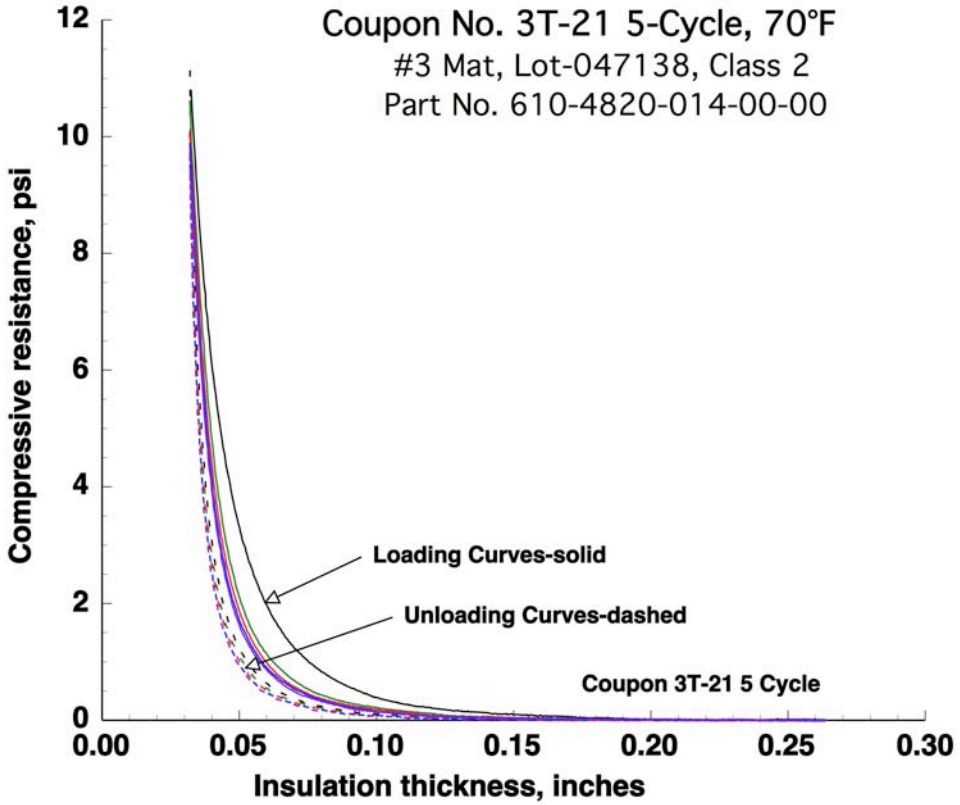

Coupon No. 3T-16, 70°F
#3 Mat, Lot-047138, Class 2
Part No. 610-4820-014-00-00
Areal density below specification
Compressive resistance, psi
Insulation thickness, inches
Loading Curve
Unloading Curve
0
2
4
6
8
10
12
14
0.00
0.05
0.10
0.15
0.20
0.25
0.30
0.35
0.40
0.45

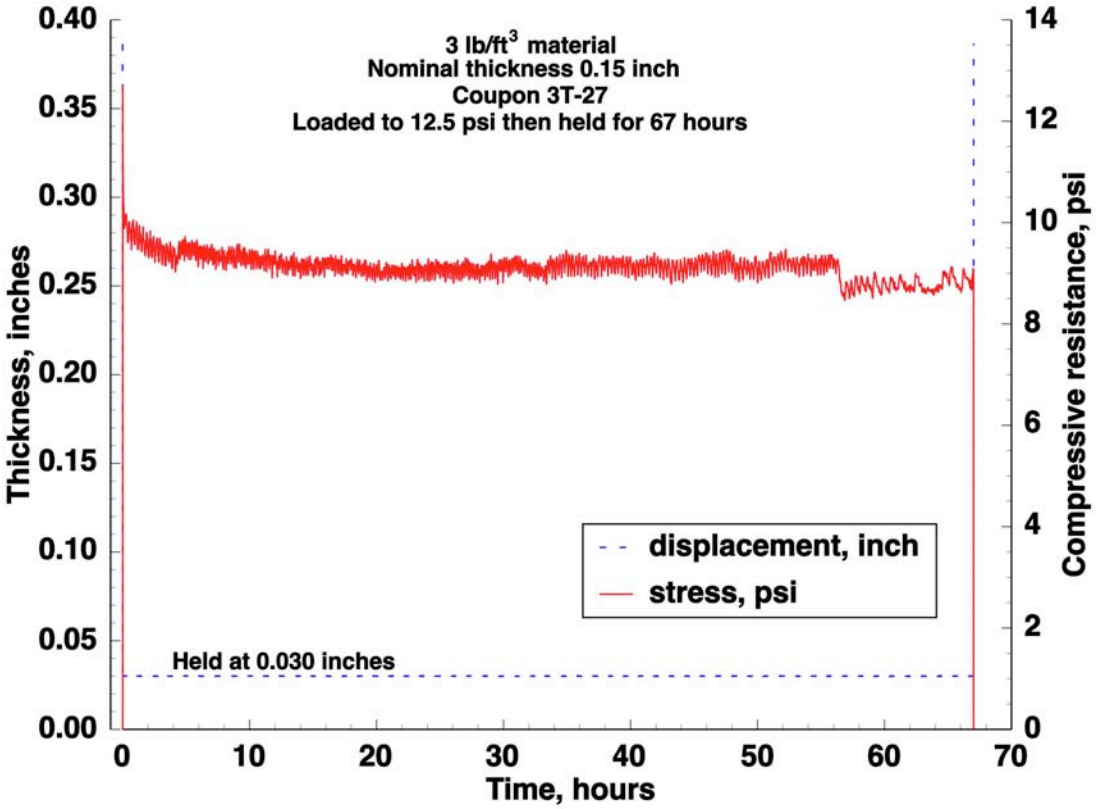

Coupon No. 3T-17, 70°F
#3 Mat, Lot-047138, Class 2
Part No. 610-4820-014-00-00
Compressive resistance, psi
Insulation thickness, inches
Loading Curve
Unloading Curve
0
2
4
6
8
10
12
14
0.00
0.05
0.10
0.15
0.20
0.25
0.30


Coupon No. 3T-18, 70°F
#3 Mat, Lot-047138, Class 2
Part No. 610-4820-014-00-00
Compressive resistance, psi
Insulation thickness, inches
Loading Curve
Unloading Curve
0
2
4
6
8
10
12
14
0.00
0.05
0.10
0.15
0.20
0.25
0.30

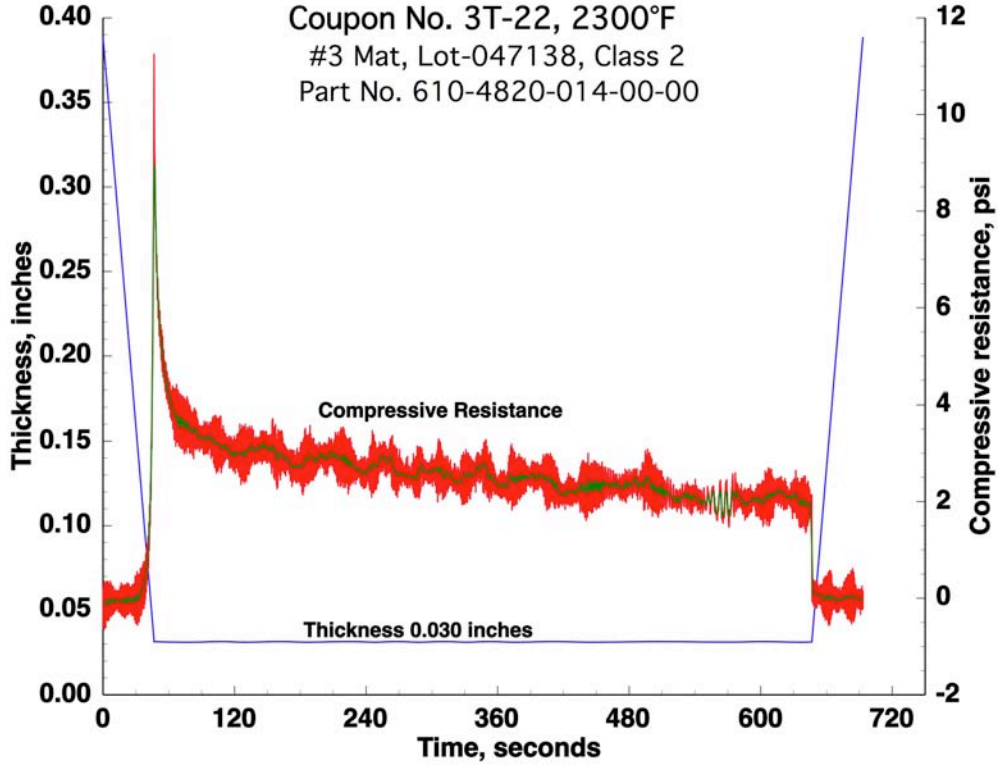

Coupon No. 3T-19, 70°F
#3 Mat, Lot-047138, Class 2
Part No. 610-4820-014-00-00
Compressive resistance, psi
Insulation thickness, inches
Loading Curve
Unloading Curve
0
2
4
6
8
10
12
14
0.00
0.05
0.10
0.15
0.20
0.25
0.30
0.35
0.40
0.45

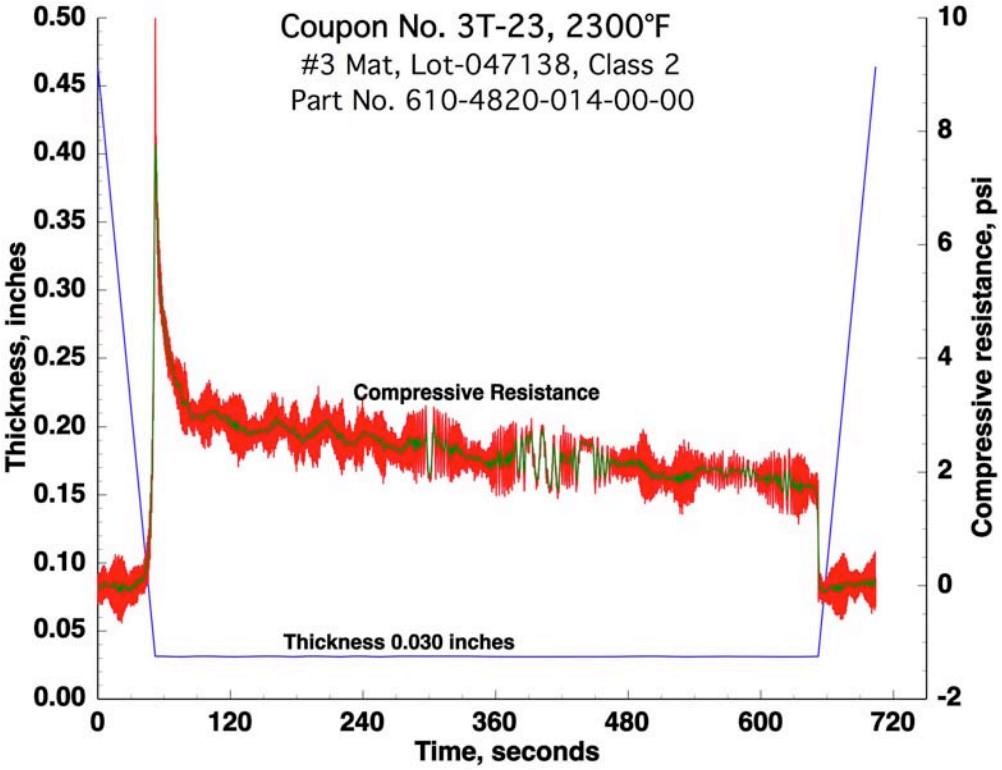

Coupon No. 3T-20, 70°F
#3 Mat, Lot-047138, Class 2
Part No. 610-4820-014-00-00
Compressive resistance, psi
Insulation thickness, inches
Loading Curve
Unloading Curve
0
2
4
6
8
10
12
14
0.00
0.05
0.10
0.15
0.20
0.25
0.30
0.35
0.40

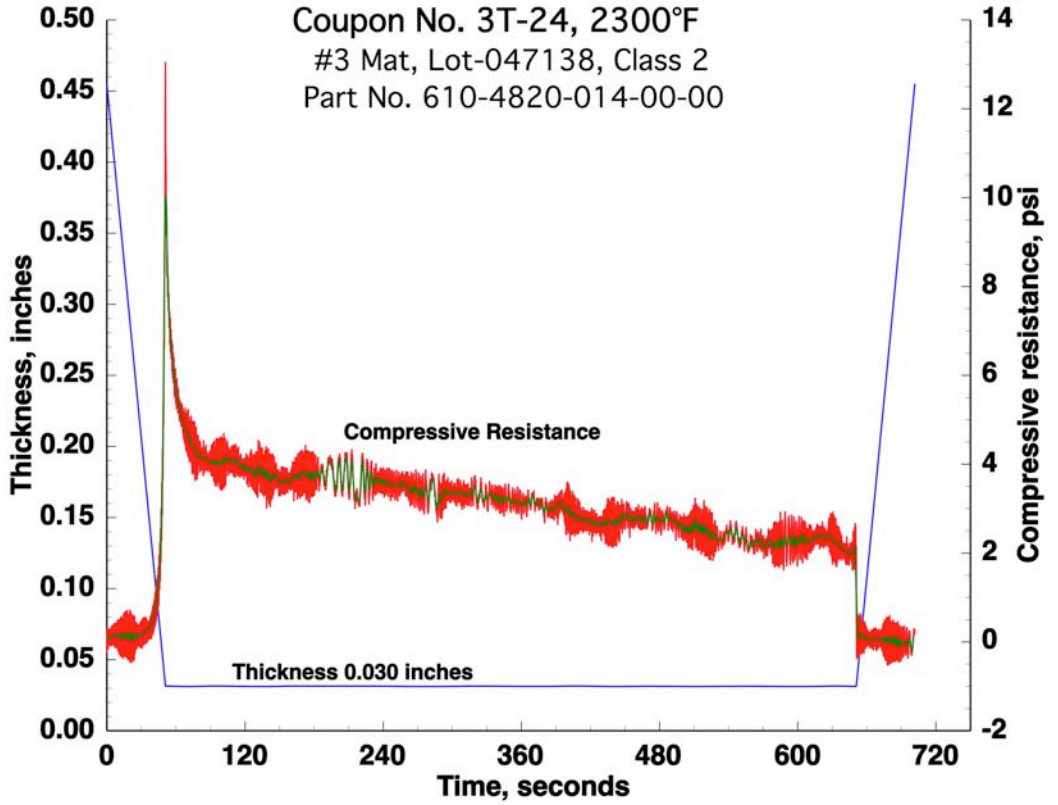

Coupon No. 3T-21 5-Cycle, 70°F
#3 Mat, Lot-047138, Class 2
Part No. 610-4820-014-00-00
Compressive resistance, psi
Insulation thickness, inches
Loading Curves-solid
Unloading Curves-dashed
Coupon 3T-21 5 Cycle
0
2
4
6
8
10
12
0.00
0.05
0.10
0.15
0.20
0.25
0.30

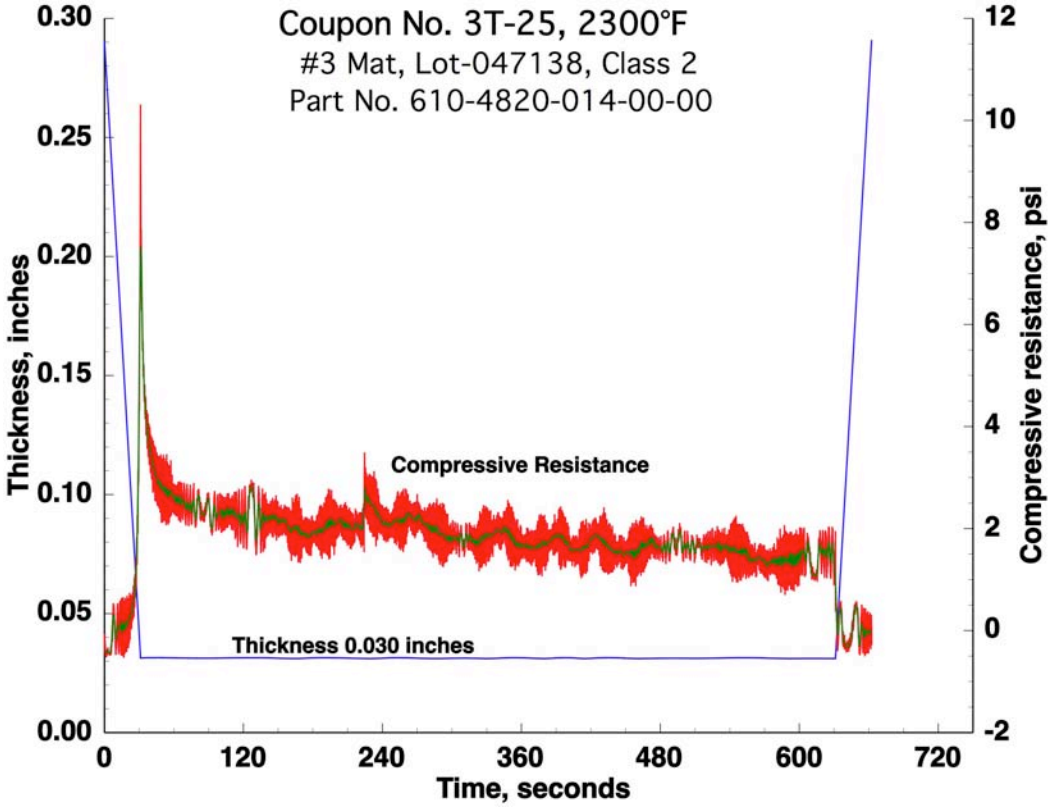

3 lb/ft3 material
Nominal thickness 0.15 inch
Coupon 3T-27
Loaded to 12.5 psi then held for 67 hours
Thickness, inches
Compressive resistance, psi
Time, hours
displacement, inch
stress, psi
Held at 0.030 inches
0.00
0.05
0.10
0.15
0.20
0.25
0.30
0.35
0.40
0
2
4
6
8
10
12
14
0
10
20
30
40
50
60
70

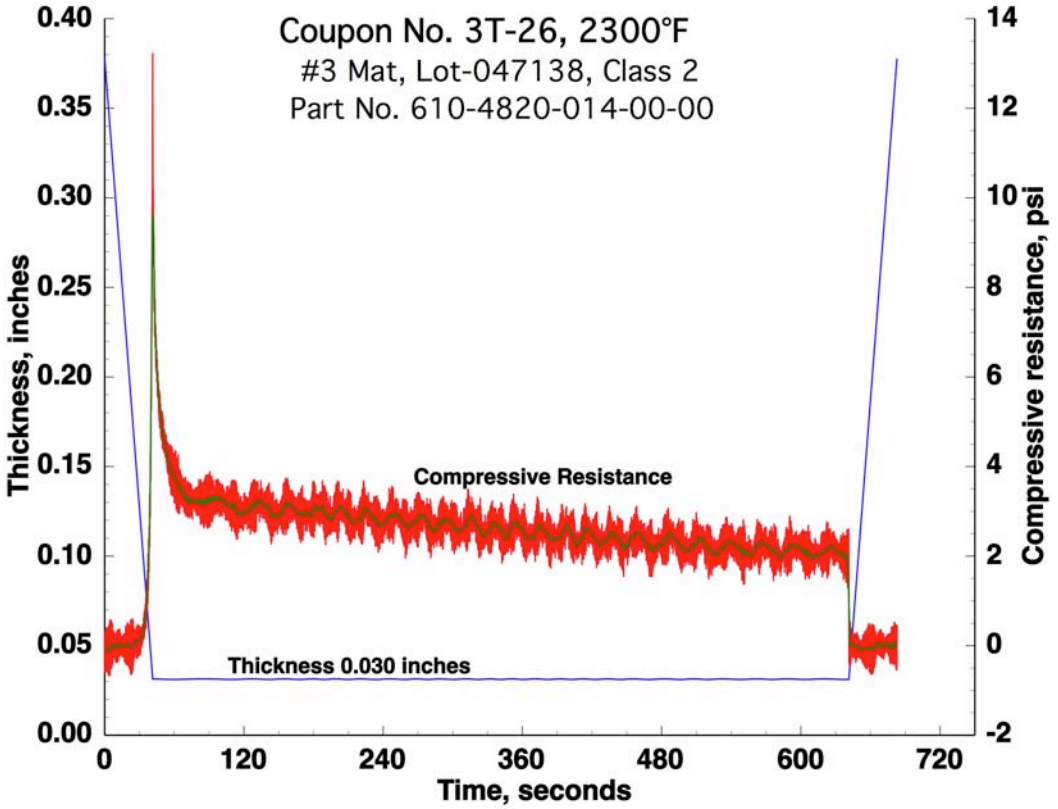
Alumina Fiber Blanket Insulation 0.15-inch 3 lb/ft^3 Materials 2300°F Tests

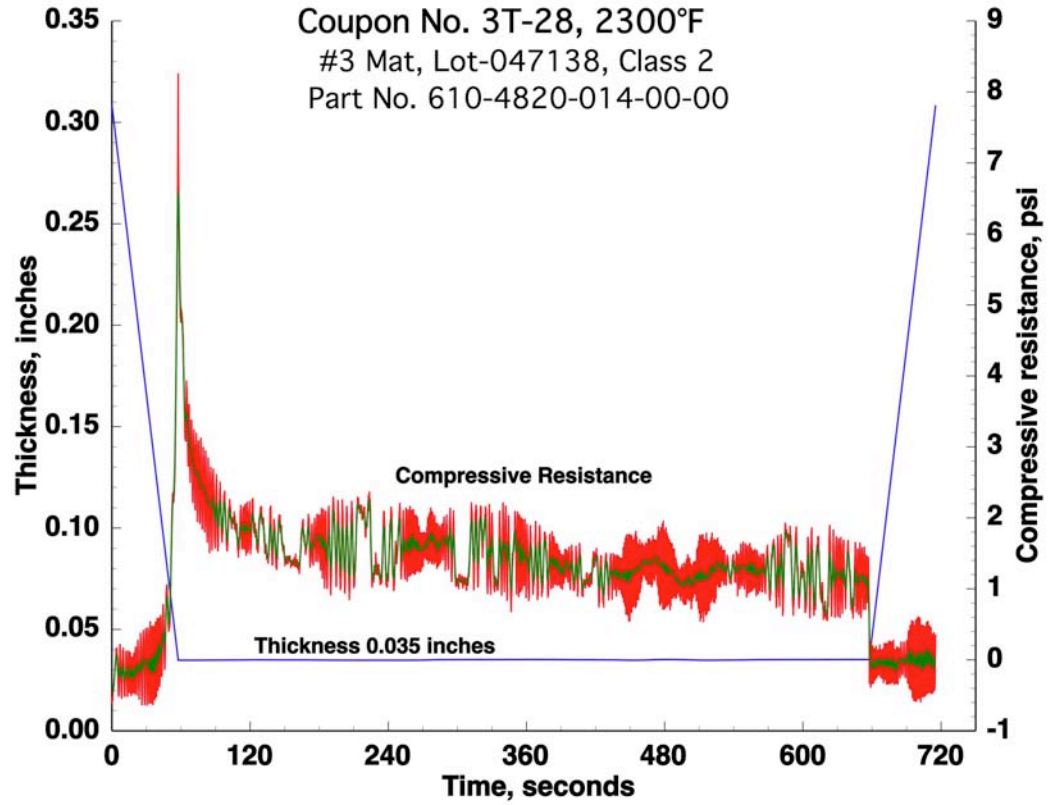


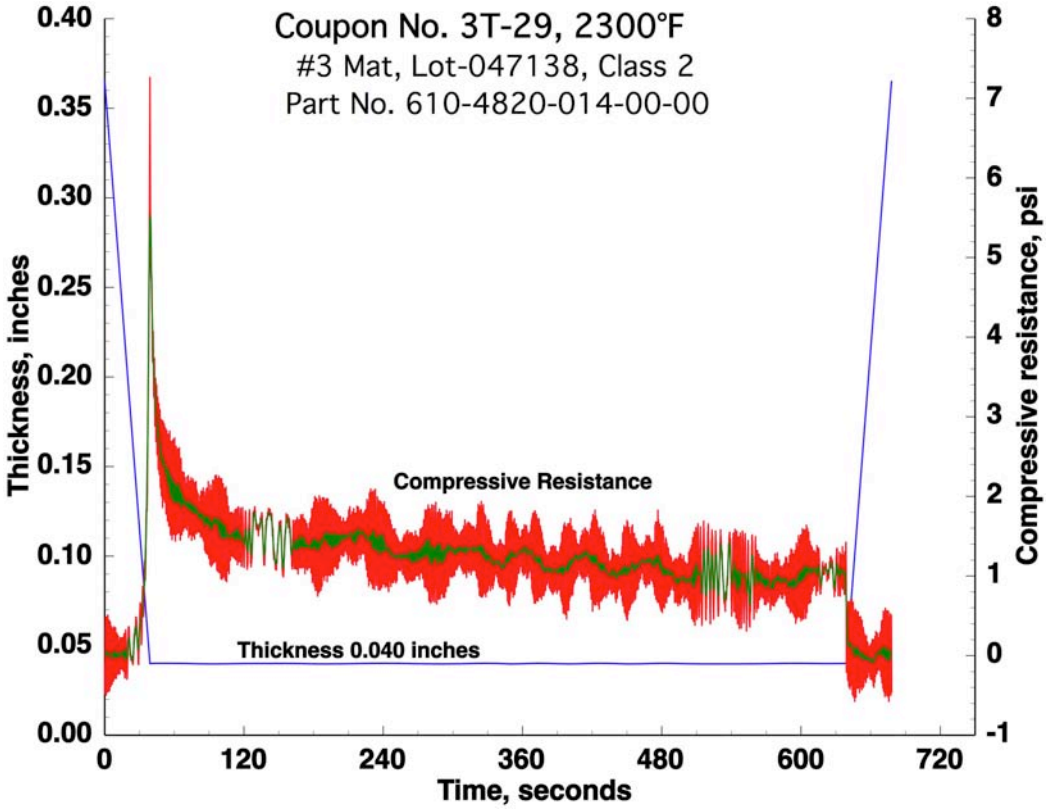


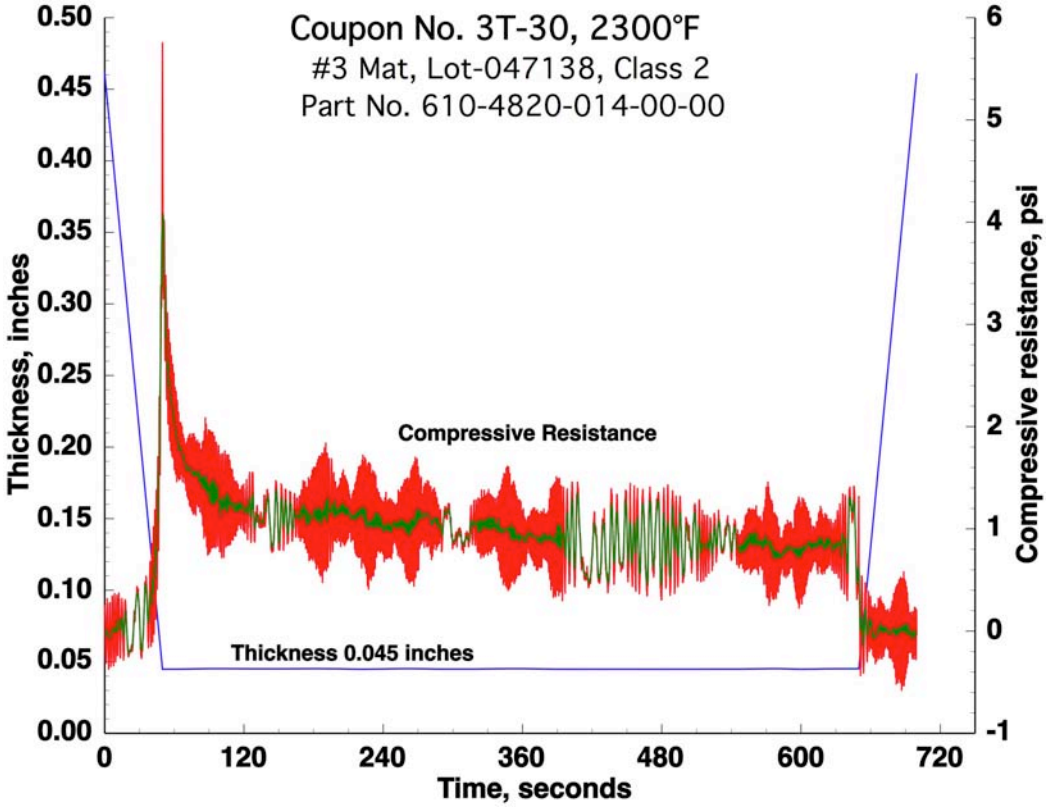

Coupon No. 3T-24, 2300°F
#3 Mat, Lot-047138, Class 2
Part No. 610-4820-014-00-00
Thickness, inches
Compressive resistance, psi
Compressive Resistance
Thickness 0.030 inches
Time, seconds
0.00
0.05
0.10
0.15
0.20
0.25
0.30
0.35
0.40
0.45
0.50
-2
0
2
4
6
8
10
12
14
0
120
240
360
480
600
720

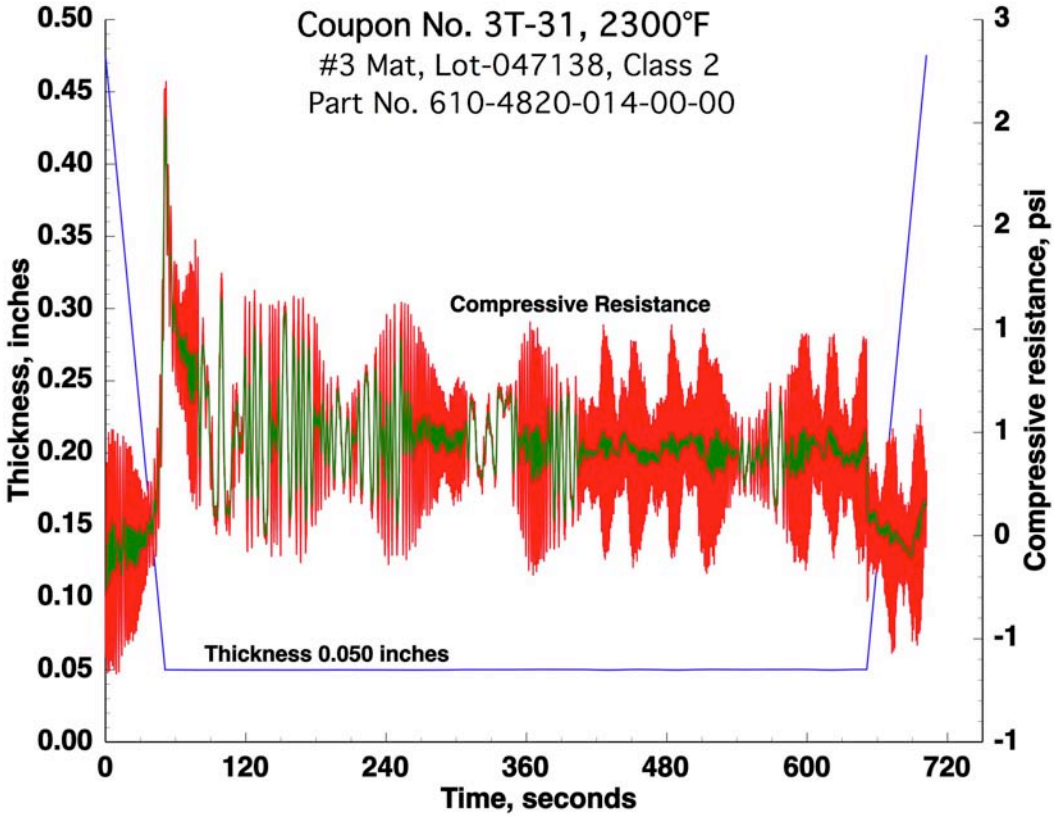

Coupon No. 3T-25, 2300°F
#3 Mat, Lot-047138, Class 2
Part No. 610-4820-014-00-00
Thickness, inches
Compressive resistance, psi
Compressive Resistance
Thickness 0.030 inches
Time, seconds
0.00
0.05
0.10
0.15
0.20
0.25
0.30
-2
0
2
4
6
8
10
12
0
120
240
360
480
600
720

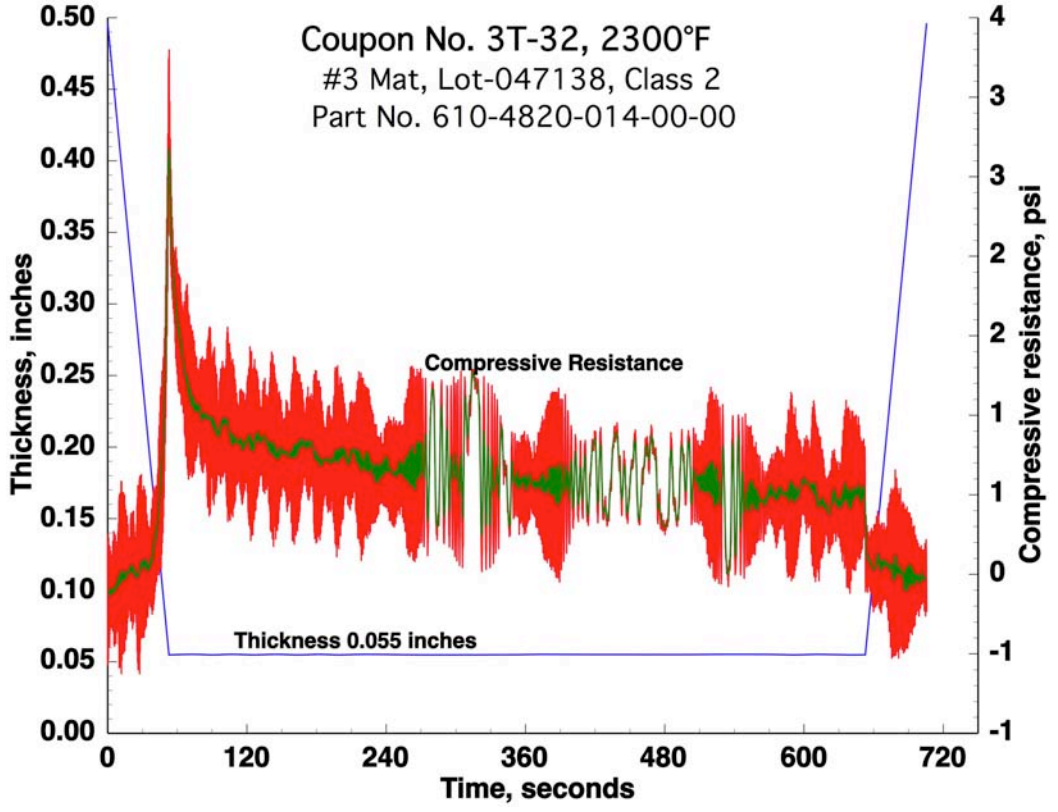

Coupon No. 3T-26, 2300°F
#3 Mat, Lot-047138, Class 2
Part No. 610-4820-014-00-00
Thickness, inches
Compressive resistance, psi
Compressive Resistance
Thickness 0.030 inches
Time, seconds
0.00
0.05
0.10
0.15
0.20
0.25
0.30
0.35
0.40
-2
0
2
4
6
8
10
12
14
0
120
240
360
480
600
720


Coupon No. 3T-28, 2300°F
#3 Mat, Lot-047138, Class 2
Part No. 610-4820-014-00-00
Thickness, inches
Compressive resistance, psi
Compressive Resistance
Thickness 0.035 inches
Time, seconds
0.00
0.05
0.10
0.15
0.20
0.25
0.30
0.35
-1
0
1
2
3
4
5
6
7
8
9
0
120
240
360
480
600
720

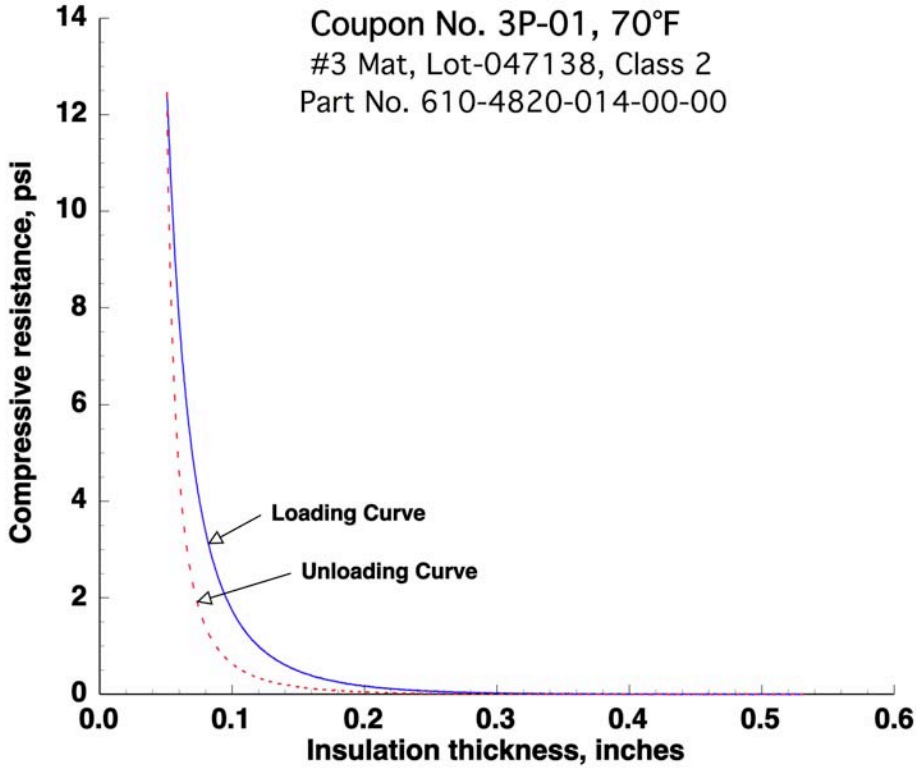

Coupon No. 3T-29, 2300°F
#3 Mat, Lot-047138, Class 2
Part No. 610-4820-014-00-00
Thickness, inches
Compressive resistance, psi
Compressive Resistance
Thickness 0.040 inches
Time, seconds
0.00
0.05
0.10
0.15
0.20
0.25
0.30
0.35
0.40
-1
0
1
2
3
4
5
6
7
8
0
120
240
360
480
600
720

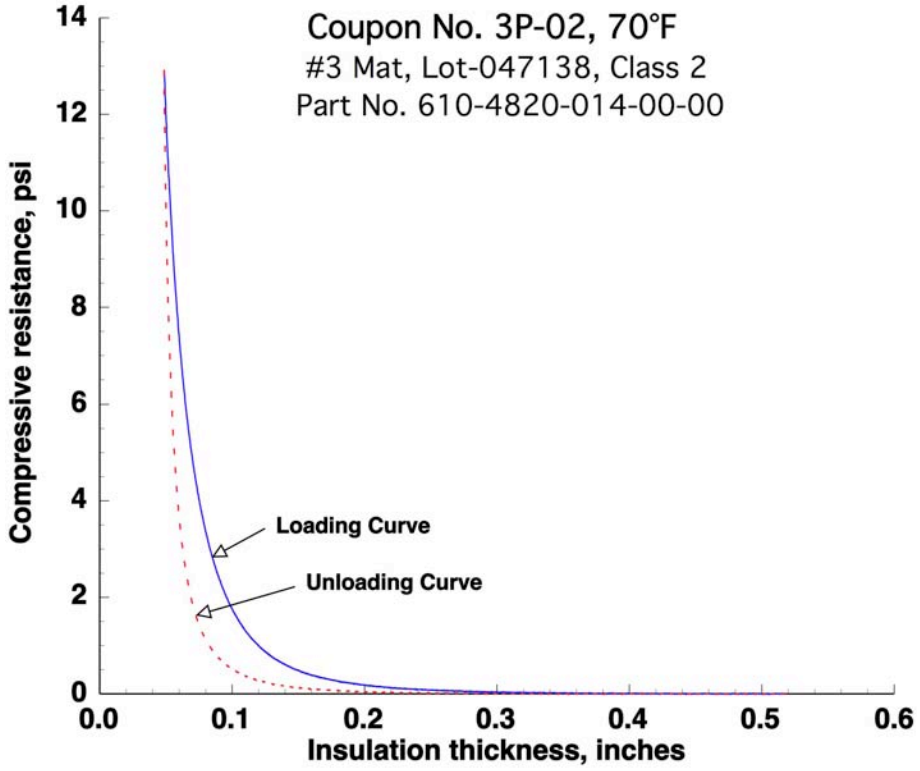

Coupon No. 3T-30, 2300°F
#3 Mat, Lot-047138, Class 2
Part No. 610-4820-014-00-00
Thickness, inches
Compressive resistance, psi
Compressive Resistance
Thickness 0.045 inches
Time, seconds
0.00
0.05
0.10
0.15
0.20
0.25
0.30
0.35
0.40
0.45
0.50
-1
0
1
2
3
4
5
6
0
120
240
360
480
600
720

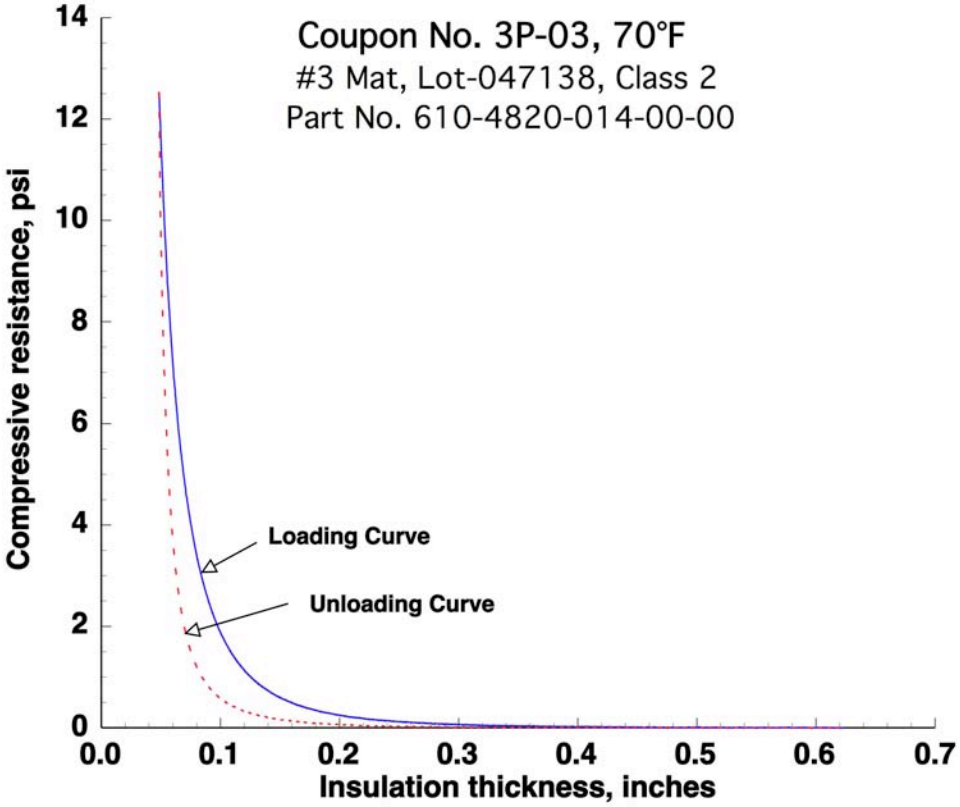

Coupon No. 3T-31, 2300°F
#3 Mat, Lot-047138, Class 2
Part No. 610-4820-014-00-00
Compressive Resistance
Thickness 0.050 inches
Thickness, inches
Compressive resistance, psi
Time, seconds
0.00
0.05
0.10
0.15
0.20
0.25
0.30
0.35
0.40
0.45
0.50
-1
0
1
1
2
2
3
0
120
240
360
480
600
720

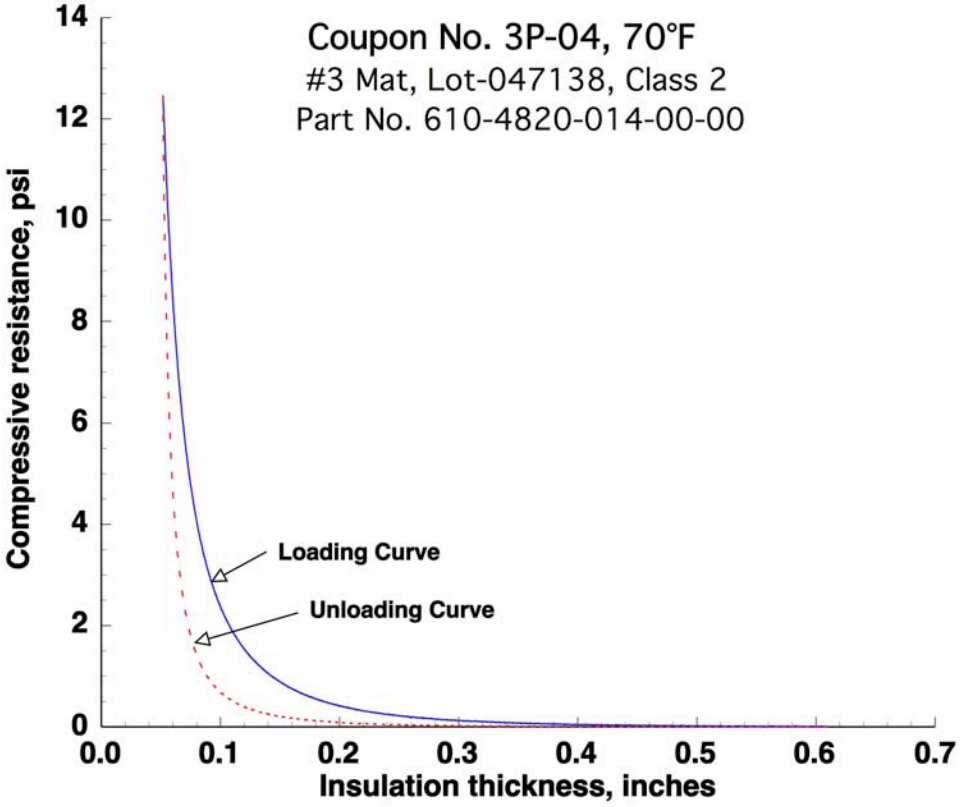

Coupon No. 3T-32, 2300°F
#3 Mat, Lot-047138, Class 2
Part No. 610-4820-014-00-00
Compressive Resistance
Thickness 0.055 inches
Thickness, inches
Compressive resistance, psi
Time, seconds
0.00
0.05
0.10
0.15
0.20
0.25
0.30
0.35
0.40
0.45
0.50
-1
0
1
1
2
2
3
3
4
0
120
240
360
480
600
720

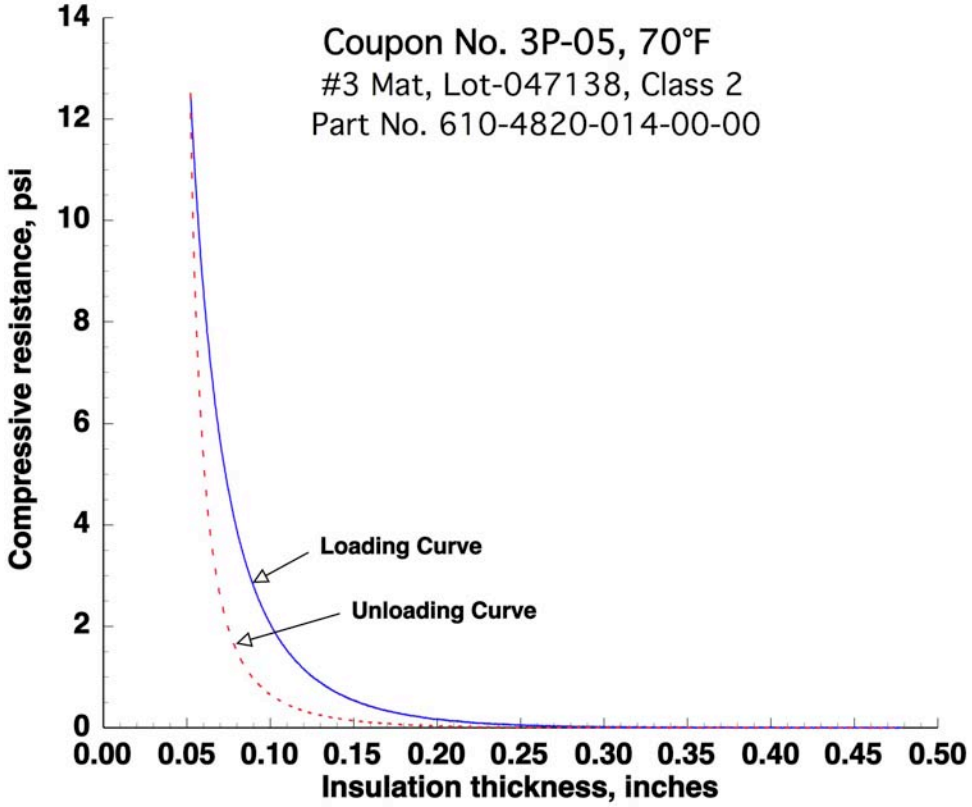
Alumina Fiber Blanket Insulation 0.25-inch 3 lb/ft^3 Material Room Temperature Tests

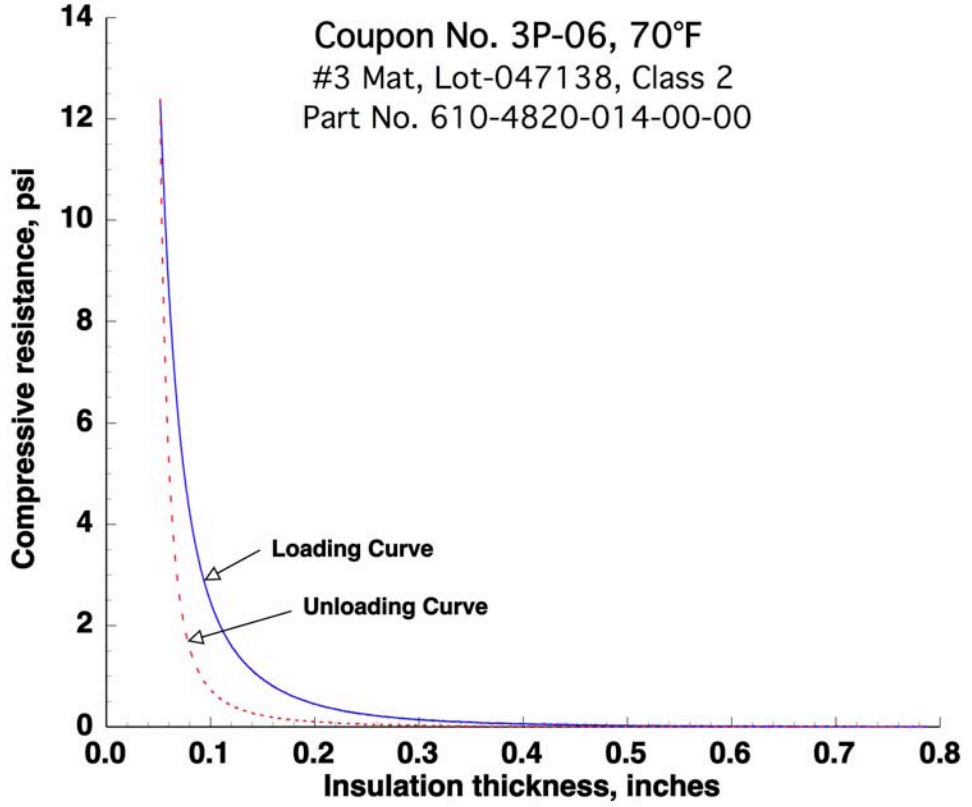


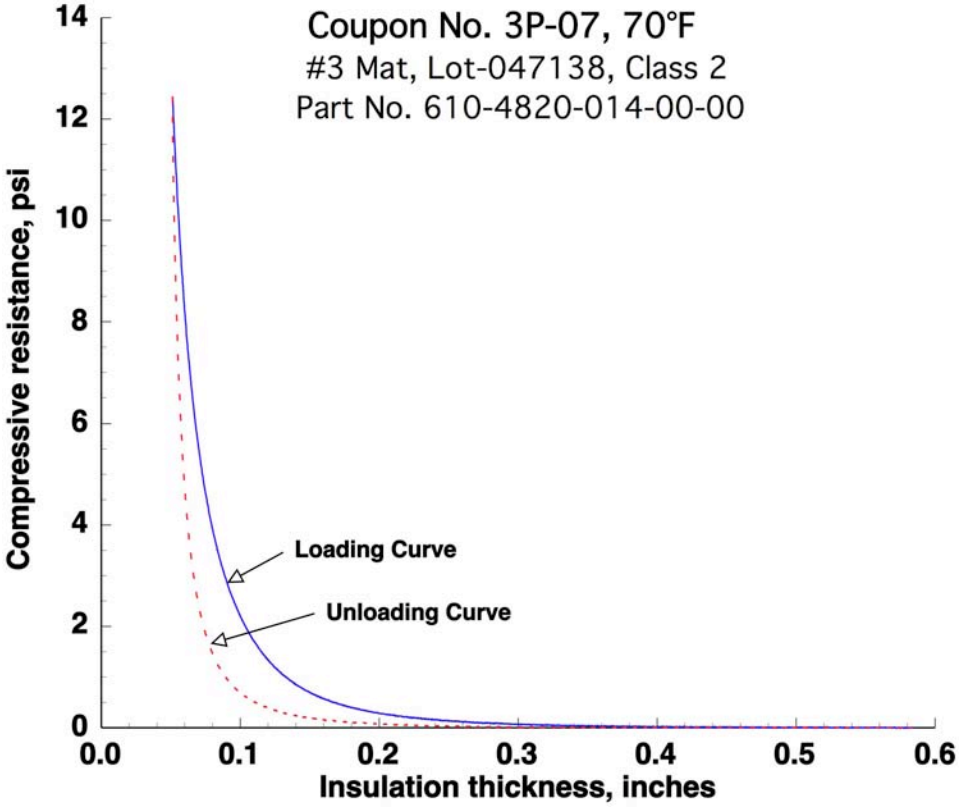


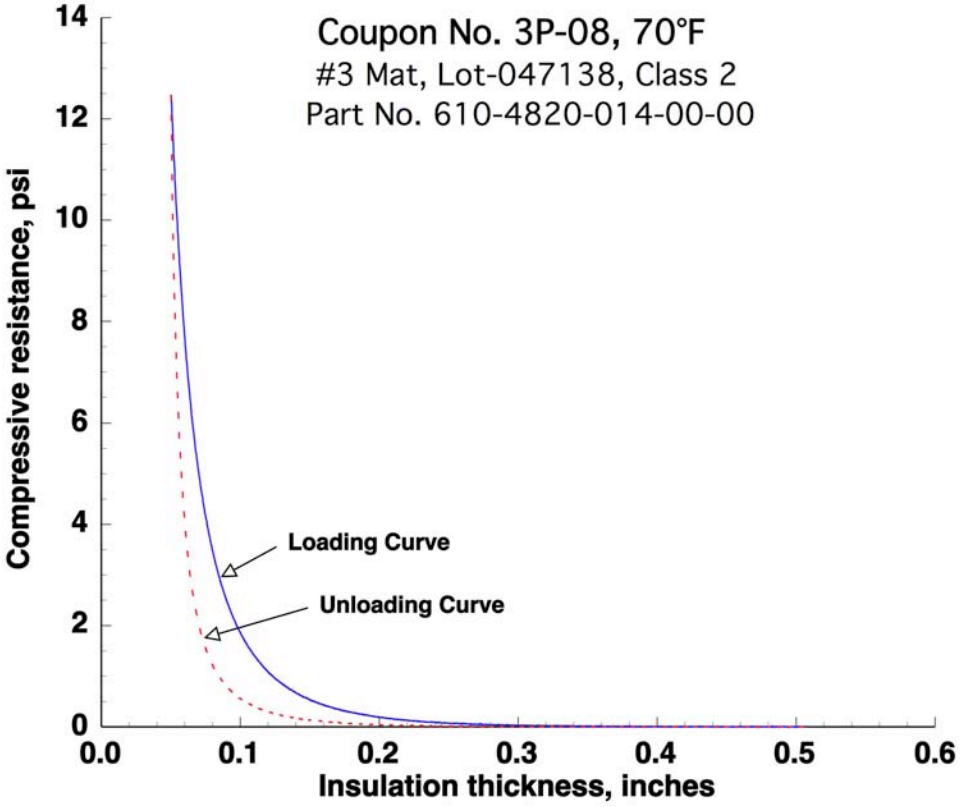

Coupon No. 3P-03, 70°F
#3 Mat, Lot-047138, Class 2
Part No. 610-4820-014-00-00
Compressive resistance, psi
Insulation thickness, inches
Loading Curve
Unloading Curve
0
2
4
6
8
10
12
14
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7

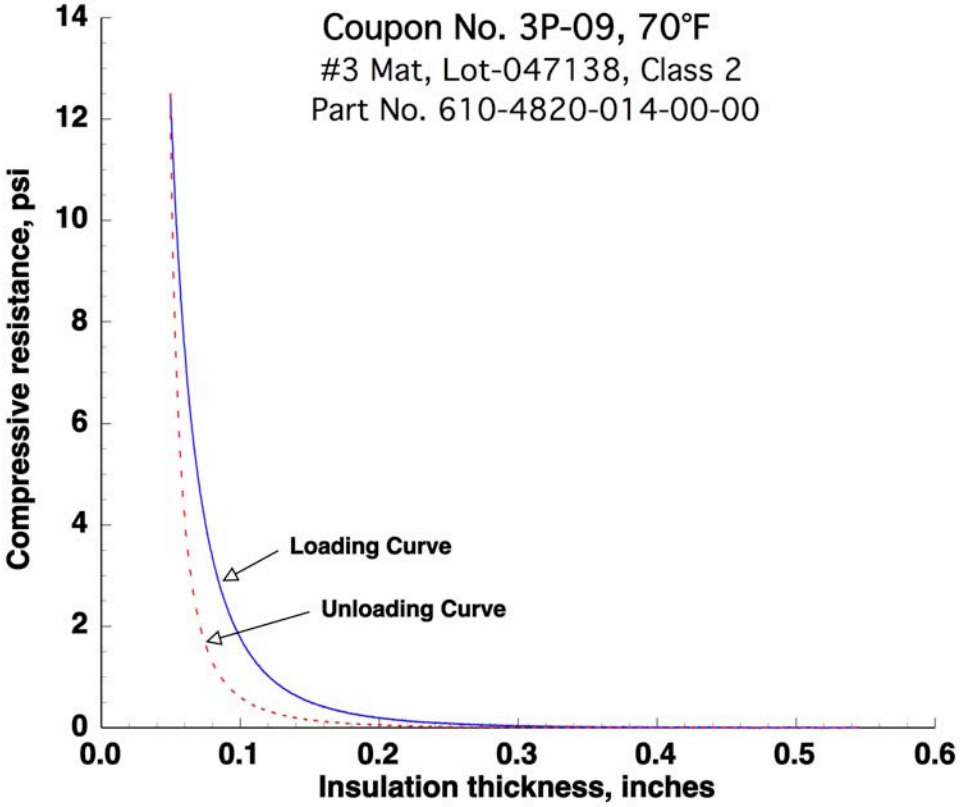

Coupon No. 3P-04, 70°F
#3 Mat, Lot-047138, Class 2
Part No. 610-4820-014-00-00
Compressive resistance, psi
Insulation thickness, inches
Loading Curve
Unloading Curve
0
2
4
6
8
10
12
14
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7

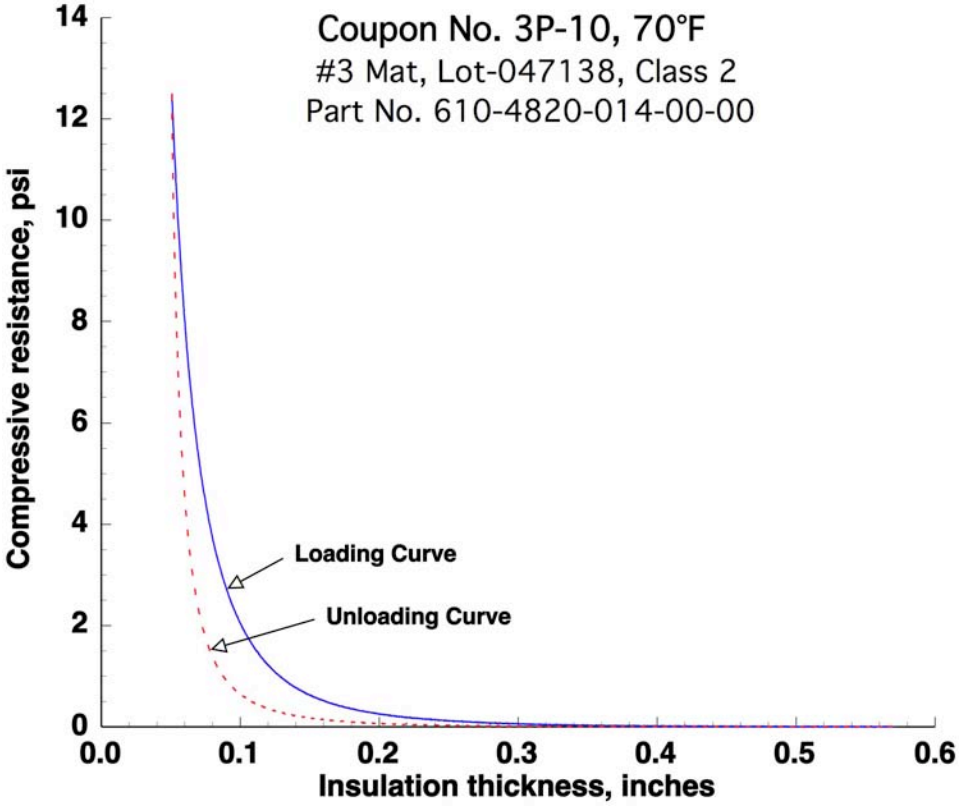

Coupon No. 3P-05, 70°F
#3 Mat, Lot-047138, Class 2
Part No. 610-4820-014-00-00
Compressive resistance, psi
Insulation thickness, inches
Loading Curve
Unloading Curve
0
2
4
6
8
10
12
14
0.00
0.05
0.10
0.15
0.20
0.25
0.30
0.35
0.40
0.45
0.50

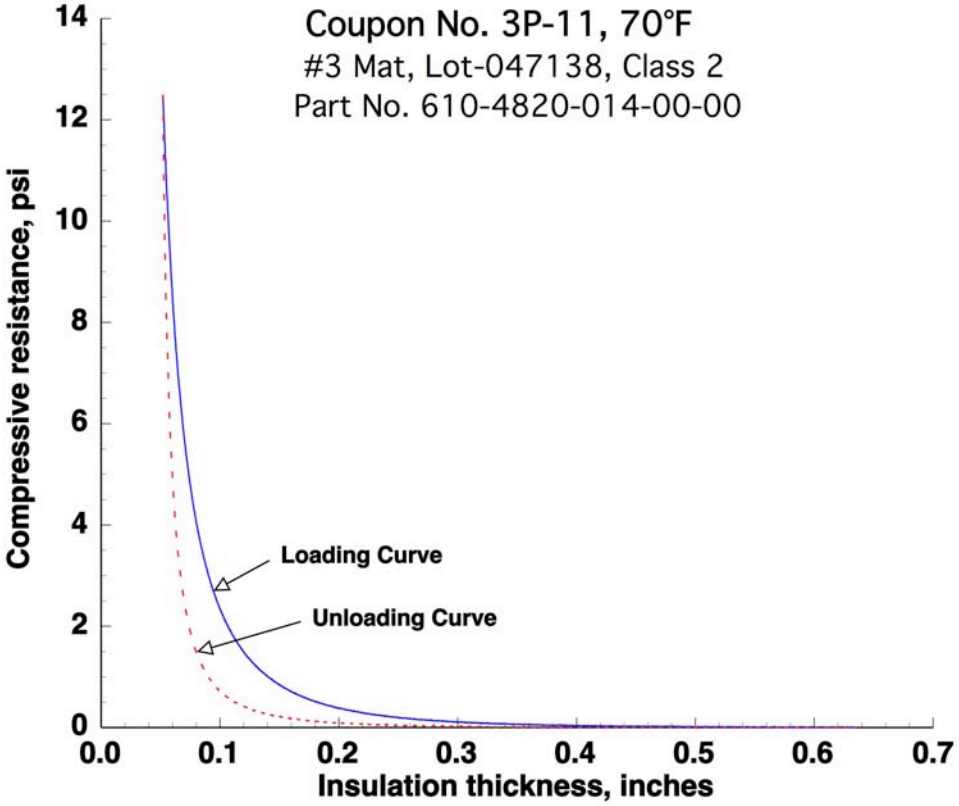

Coupon No. 3P-06, 70°F
#3 Mat, Lot-047138, Class 2
Part No. 610-4820-014-00-00
Compressive resistance, psi
Insulation thickness, inches
Loading Curve
Unloading Curve
0
2
4
6
8
10
12
14
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8

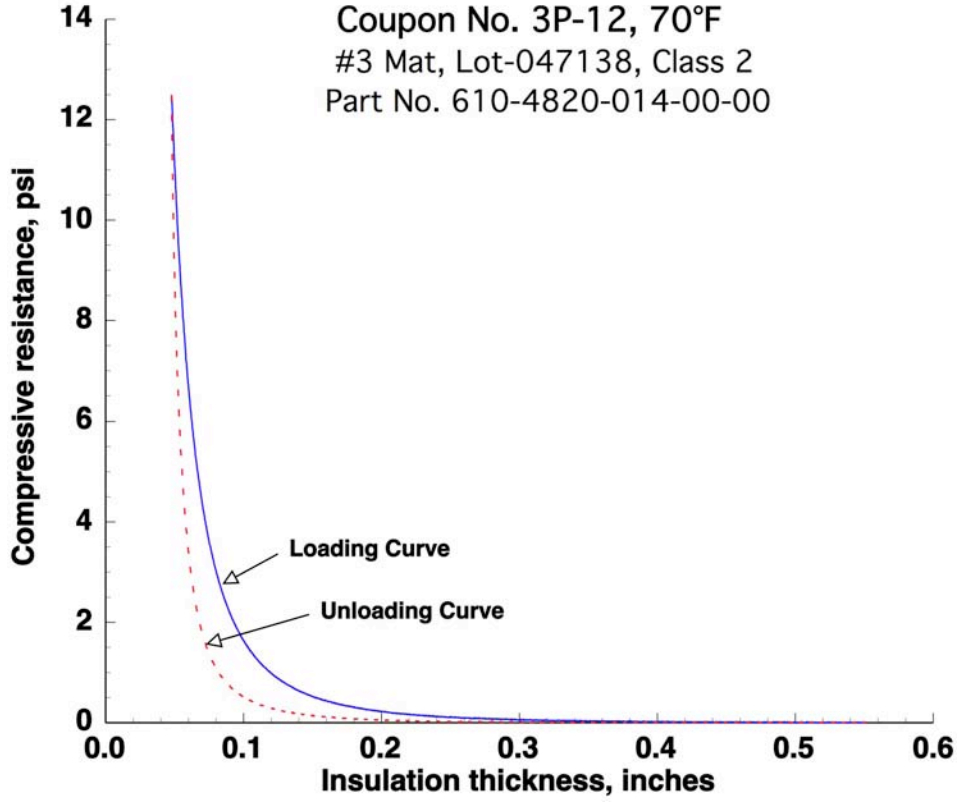

Coupon No. 3P-07, 70°F
#3 Mat, Lot-047138, Class 2
Part No. 610-4820-014-00-00
Compressive resistance, psi
Insulation thickness, inches
Loading Curve
Unloading Curve
0
2
4
6
8
10
12
14
0.0
0.1
0.2
0.3
0.4
0.5
0.6

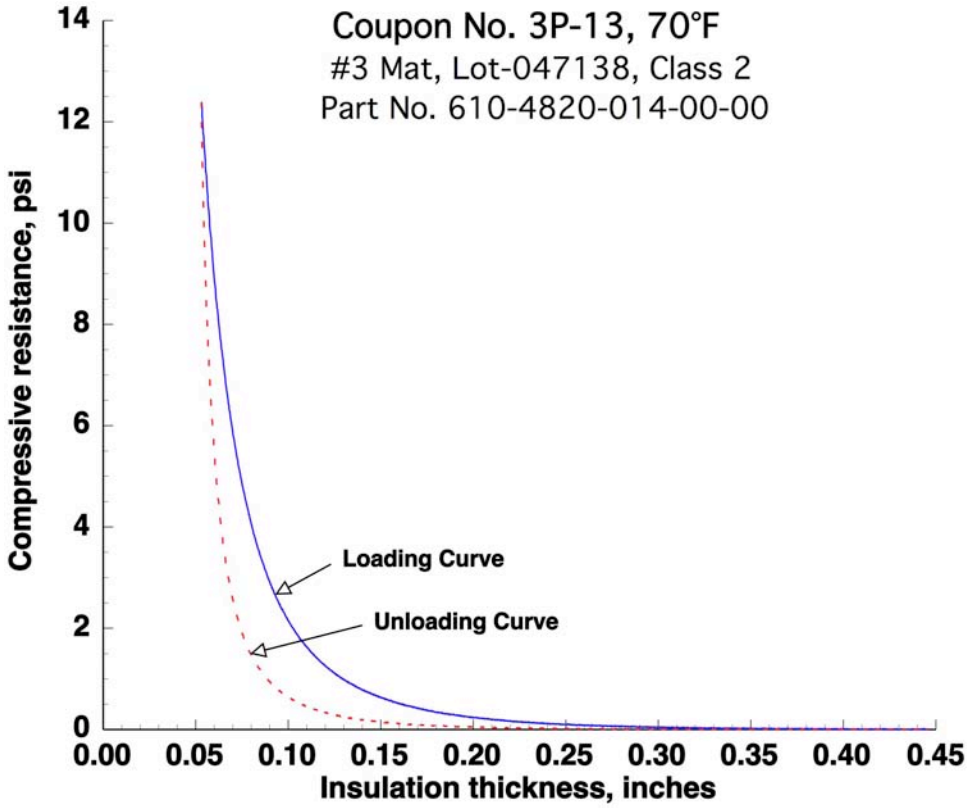

Coupon No. 3P-08, 70°F
#3 Mat, Lot-047138, Class 2
Part No. 610-4820-014-00-00
Compressive resistance, psi
Insulation thickness, inches
Loading Curve
Unloading Curve
0
2
4
6
8
10
12
14
0.0
0.1
0.2
0.3
0.4
0.5
0.6

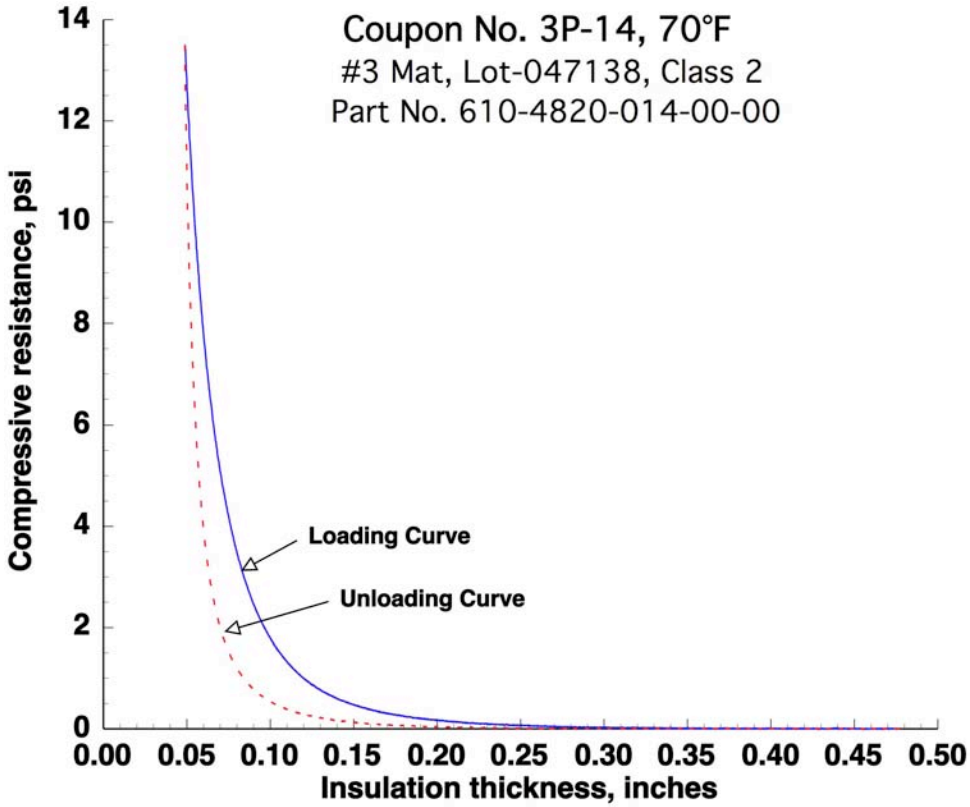

Coupon No. 3P-09, 70°F
#3 Mat, Lot-047138, Class 2
Part No. 610-4820-014-00-00
Compressive resistance, psi
Insulation thickness, inches
Loading Curve
Unloading Curve
0
2
4
6
8
10
12
14
0.0
0.1
0.2
0.3
0.4
0.5
0.6

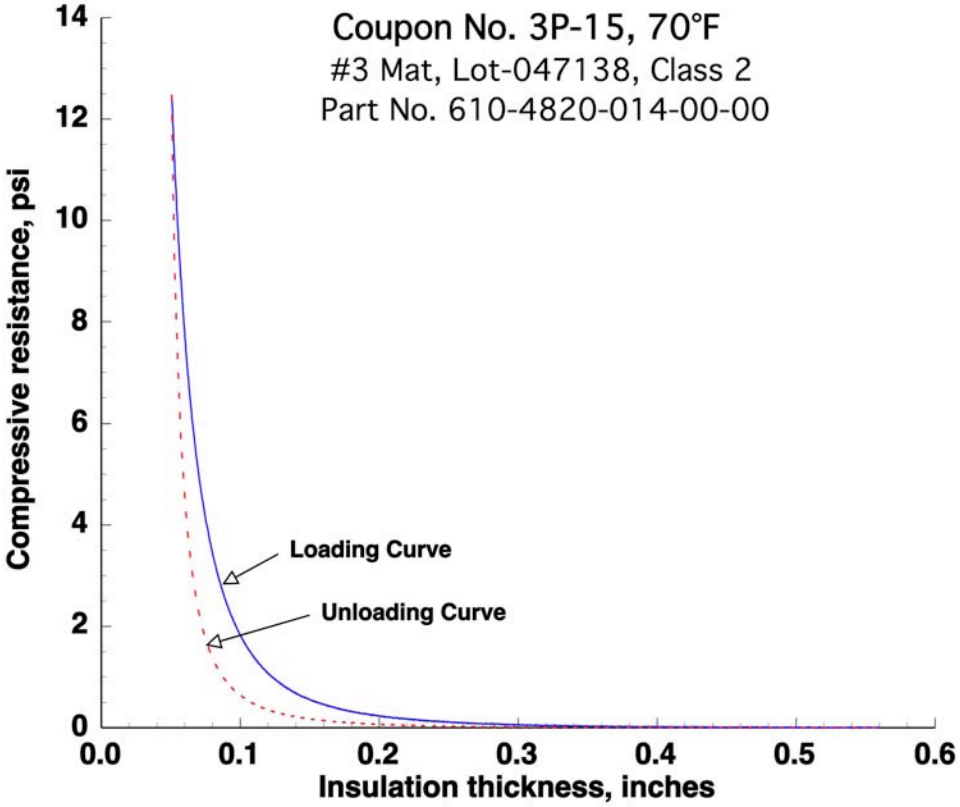

Coupon No. 3P-10, 70°F
#3 Mat, Lot-047138, Class 2
Part No. 610-4820-014-00-00
Compressive resistance, psi
Insulation thickness, inches
Loading Curve
Unloading Curve
0
2
4
6
8
10
12
14
0.0
0.1
0.2
0.3
0.4
0.5
0.6

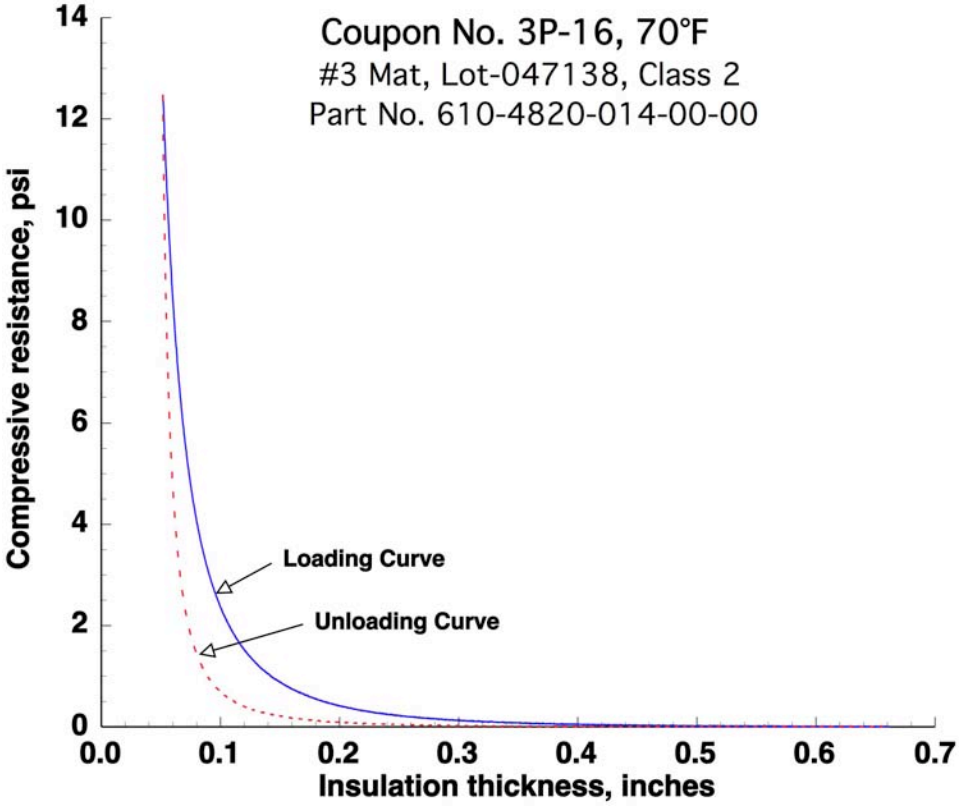

Coupon No. 3P-11, 70°F
#3 Mat, Lot-047138, Class 2
Part No. 610-4820-014-00-00
Compressive resistance, psi
Insulation thickness, inches
Loading Curve
Unloading Curve
0
2
4
6
8
10
12
14
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7

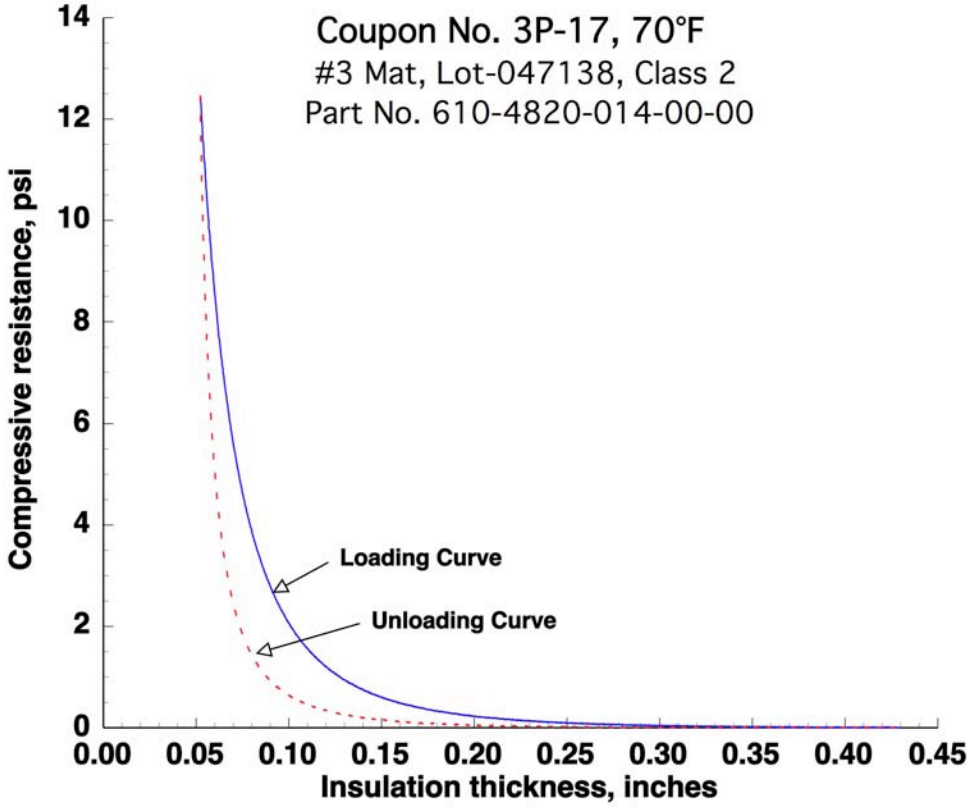

Coupon No. 3P-12, 70°F
#3 Mat, Lot-047138, Class 2
Part No. 610-4820-014-00-00
Compressive resistance, psi
Insulation thickness, inches
Loading Curve
Unloading Curve
0
2
4
6
8
10
12
14
0.0
0.1
0.2
0.3
0.4
0.5
0.6

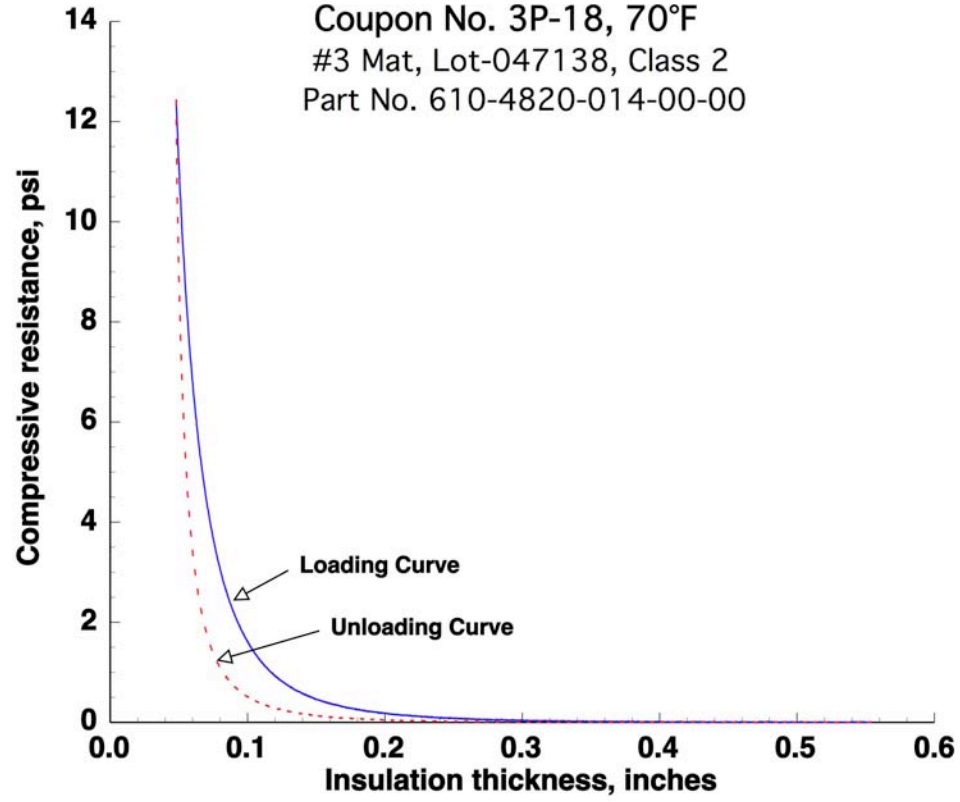

Coupon No. 3P-13, 70°F
#3 Mat, Lot-047138, Class 2
Part No. 610-4820-014-00-00
Compressive resistance, psi
Insulation thickness, inches
Loading Curve
Unloading Curve
0
2
4
6
8
10
12
14
0.00
0.05
0.10
0.15
0.20
0.25
0.30
0.35
0.40
0.45

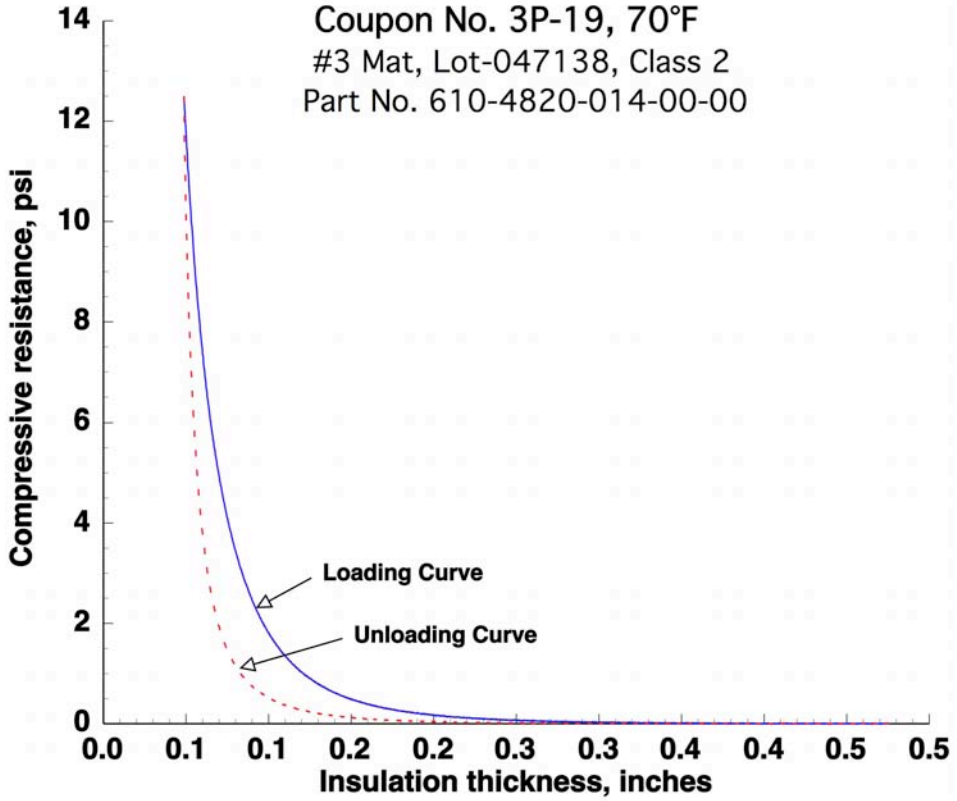

Coupon No. 3P-14, 70°F
#3 Mat, Lot-047138, Class 2
Part No. 610-4820-014-00-00
Compressive resistance, psi
Insulation thickness, inches
Loading Curve
Unloading Curve
0
2
4
6
8
10
12
14
0.00
0.05
0.10
0.15
0.20
0.25
0.30
0.35
0.40
0.45
0.50

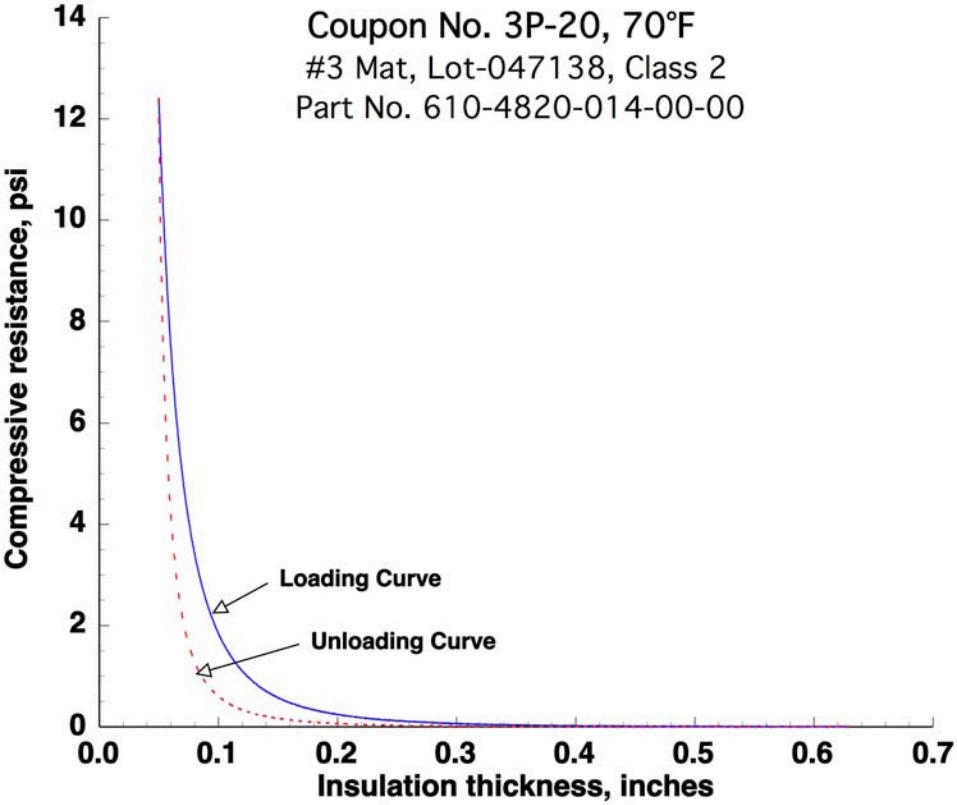

Coupon No. 3P-15, 70°F
#3 Mat, Lot-047138, Class 2
Part No. 610-4820-014-00-00
Compressive resistance, psi
Insulation thickness, inches
Loading Curve
Unloading Curve
0
2
4
6
8
10
12
14
0.0
0.1
0.2
0.3
0.4
0.5
0.6

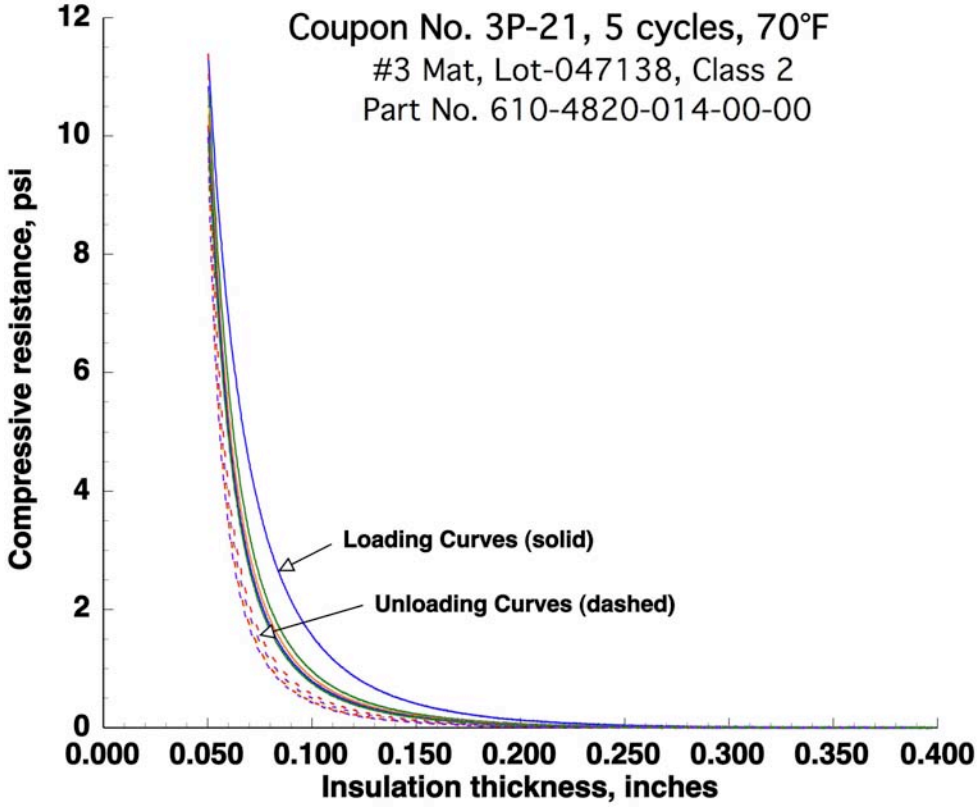

Coupon No. 3P-16, 70°F
#3 Mat, Lot-047138, Class 2
Part No. 610-4820-014-00-00
Compressive resistance, psi
Insulation thickness, inches
Loading Curve
Unloading Curve
0
2
4
6
8
10
12
14
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7

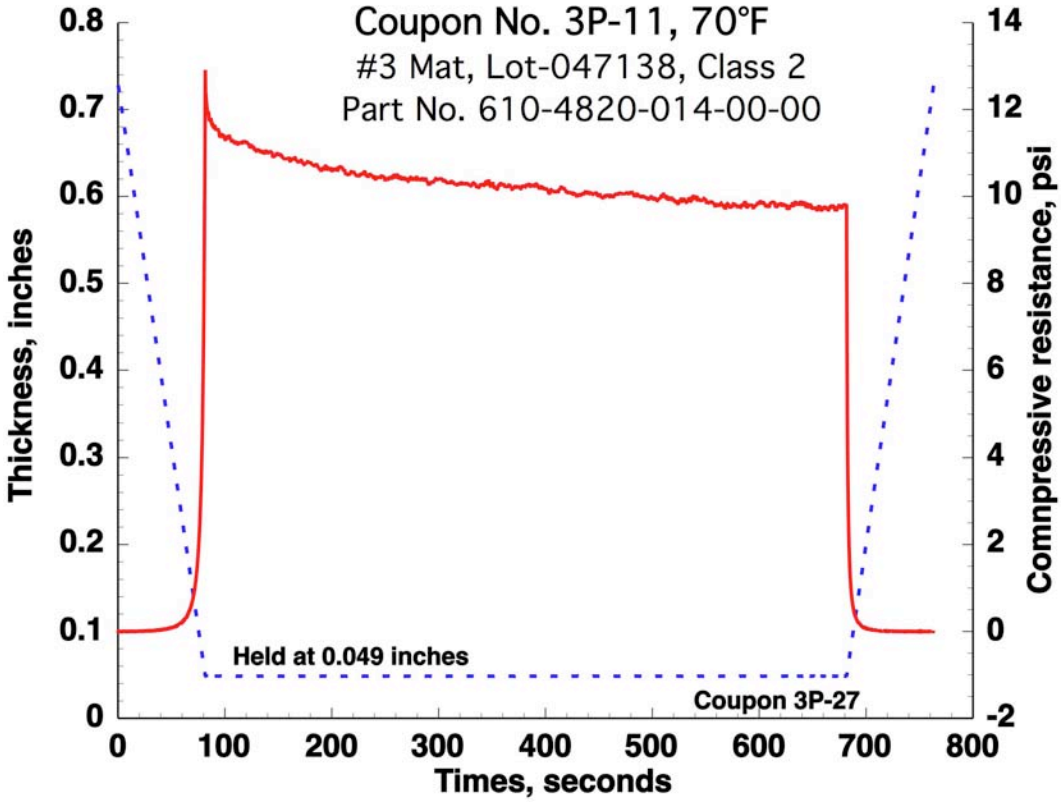

Coupon No. 3P-17, 70°F
#3 Mat, Lot-047138, Class 2
Part No. 610-4820-014-00-00
Compressive resistance, psi
Insulation thickness, inches
Loading Curve
Unloading Curve
0
2
4
6
8
10
12
14
0.00
0.05
0.10
0.15
0.20
0.25
0.30
0.35
0.40
0.45


Coupon No. 3P-18, 70°F
#3 Mat, Lot-047138, Class 2
Part No. 610-4820-014-00-00
Compressive resistance, psi
Insulation thickness, inches
Loading Curve
Unloading Curve
0
2
4
6
8
10
12
14
0.0
0.1
0.2
0.3
0.4
0.5
0.6

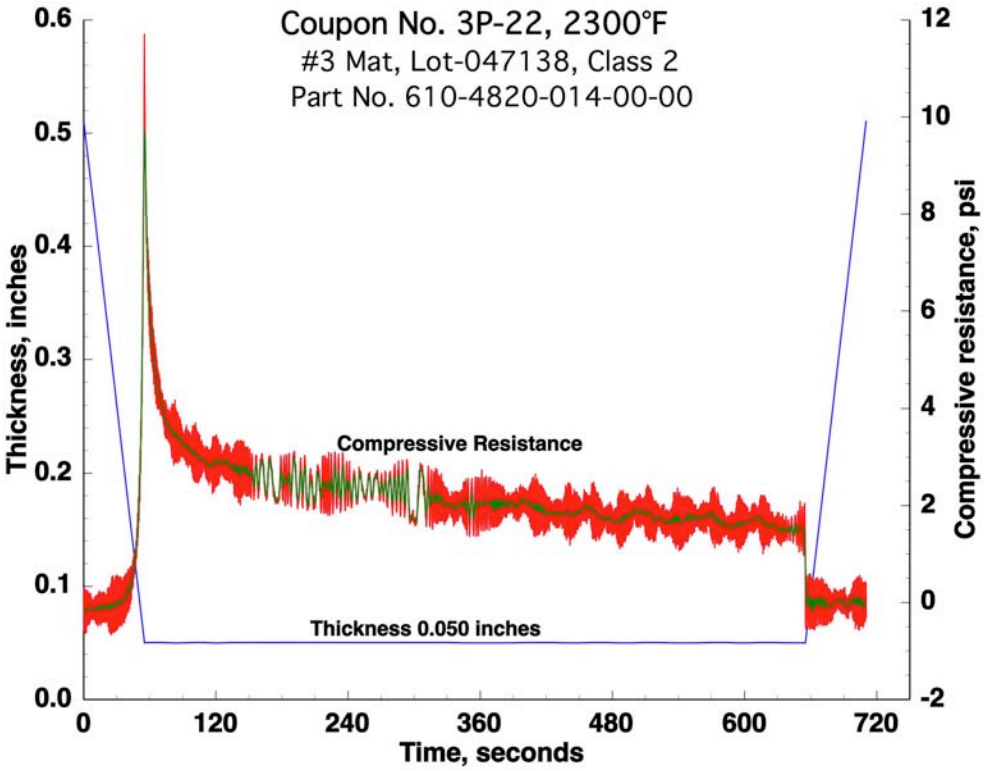

Coupon No. 3P-19, 70°F
#3 Mat, Lot-047138, Class 2
Part No. 610-4820-014-00-00
Compressive resistance, psi
Insulation thickness, inches
Loading Curve
Unloading Curve
0
2
4
6
8
10
12
14
0.0
0.1
0.1
0.2
0.2
0.3
0.3
0.4
0.4
0.5
0.5

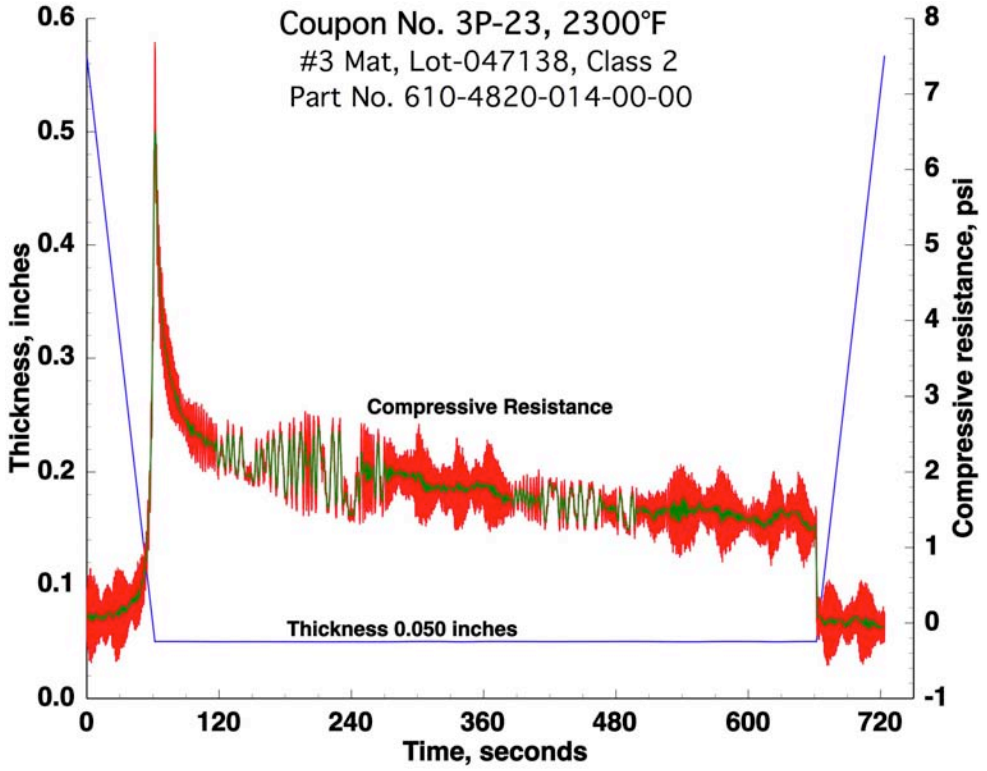

Coupon No. 3P-20, 70°F
#3 Mat, Lot-047138, Class 2
Part No. 610-4820-014-00-00
Compressive resistance, psi
Insulation thickness, inches
Loading Curve
Unloading Curve
0
2
4
6
8
10
12
14
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7

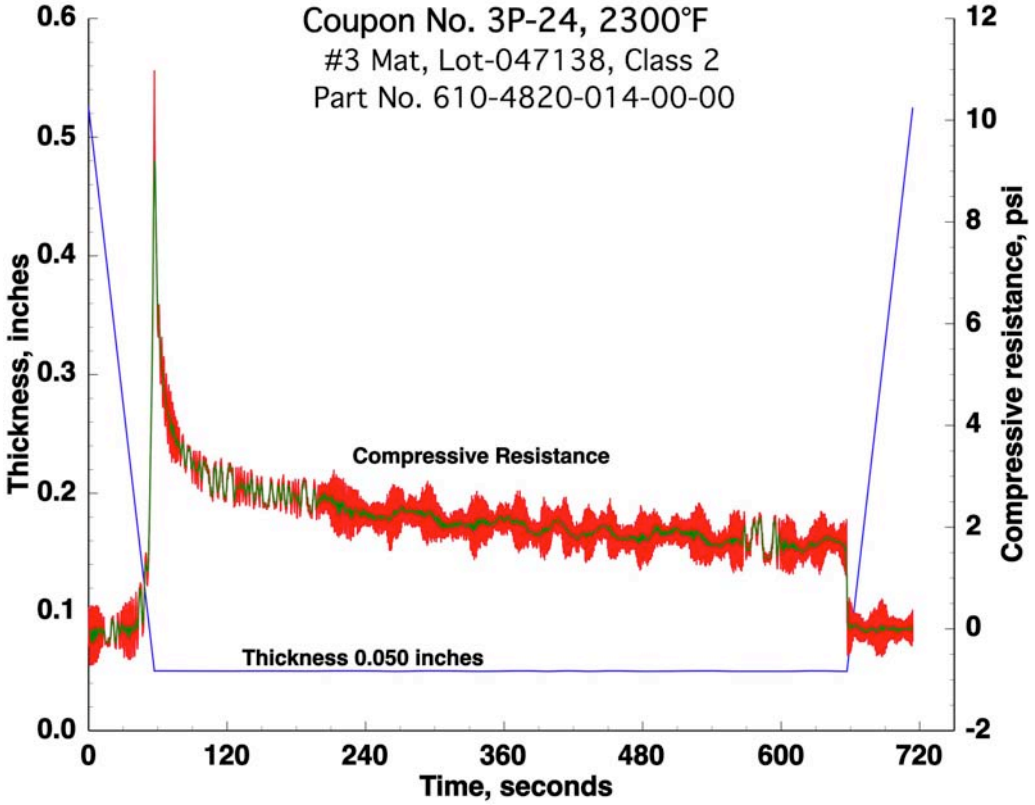

Coupon No. 3P-21, 5 cycles, 70°F
#3 Mat, Lot-047138, Class 2
Part No. 610-4820-014-00-00
Compressive resistance, psi
Insulation thickness, inches
Loading Curves (solid)
Unloading Curves (dashed)
0
2
4
6
8
10
12
0.000
0.050
0.100
0.150
0.200
0.250
0.300
0.350
0.400

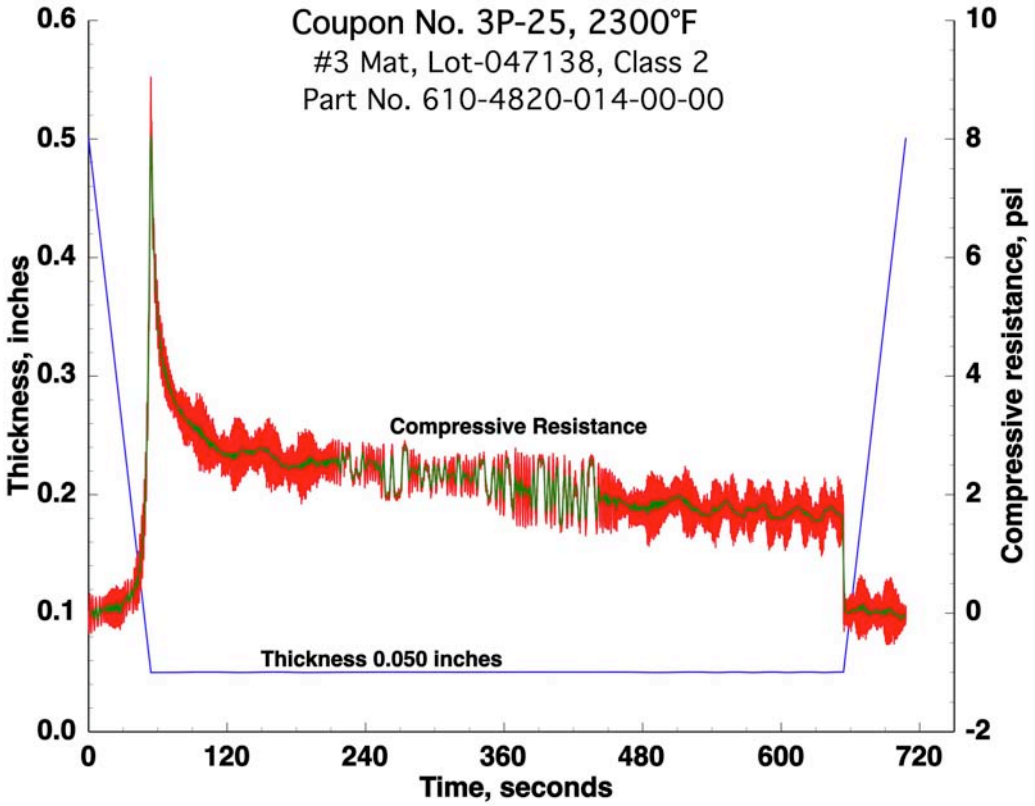

Coupon No. 3P-11, 70°F
#3 Mat, Lot-047138, Class 2
Part No. 610-4820-014-00-00
Thickness, inches
Comnpressive resistance, psi
Times, seconds
Held at 0.049 inches
Coupon 3P-27
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
-2
0
2
4
6
8
10
12
14
0
100
200
300
400
500
600
700
800

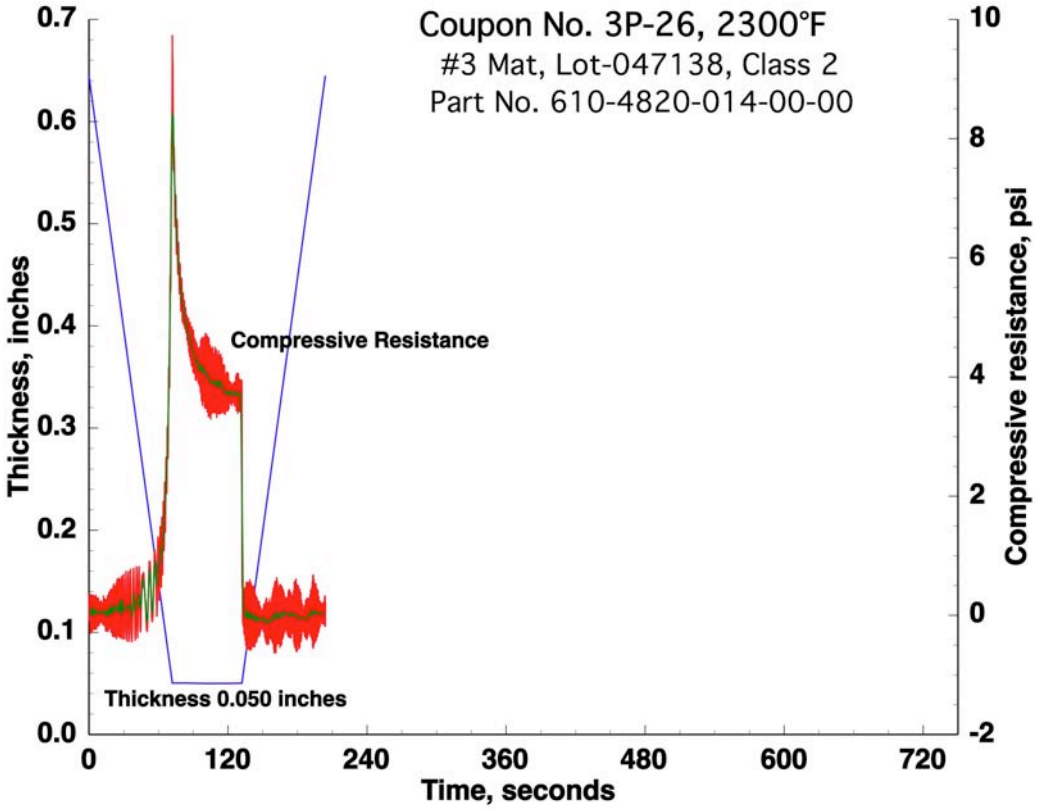
Alumina Fiber Blanket Insulation 0.25-inch 3 lb/ft^3 Material 2300°F Tests



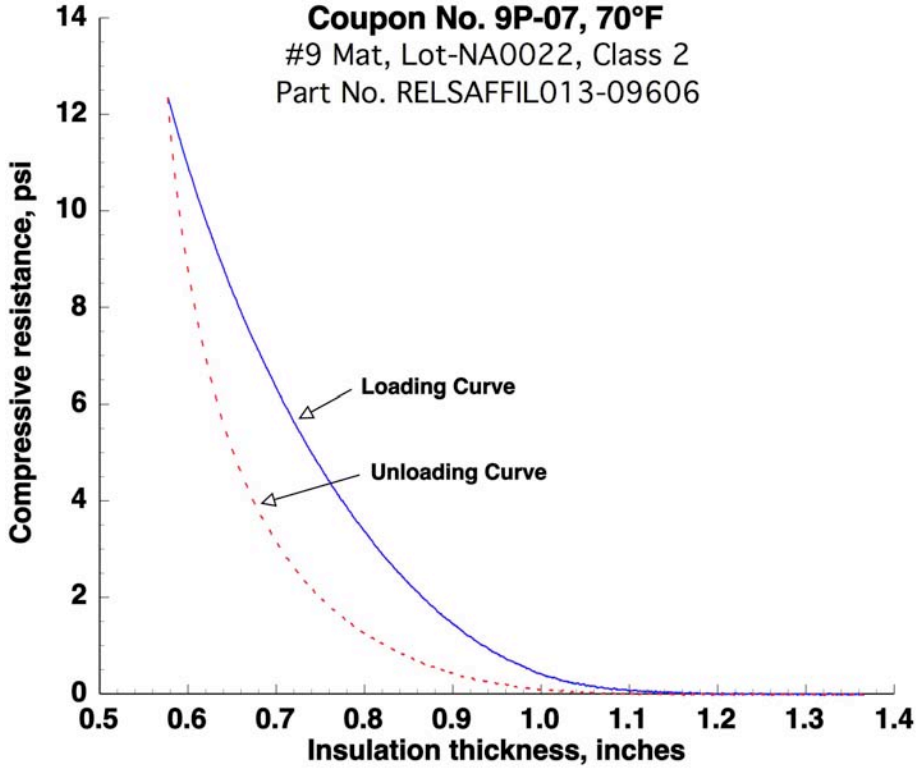


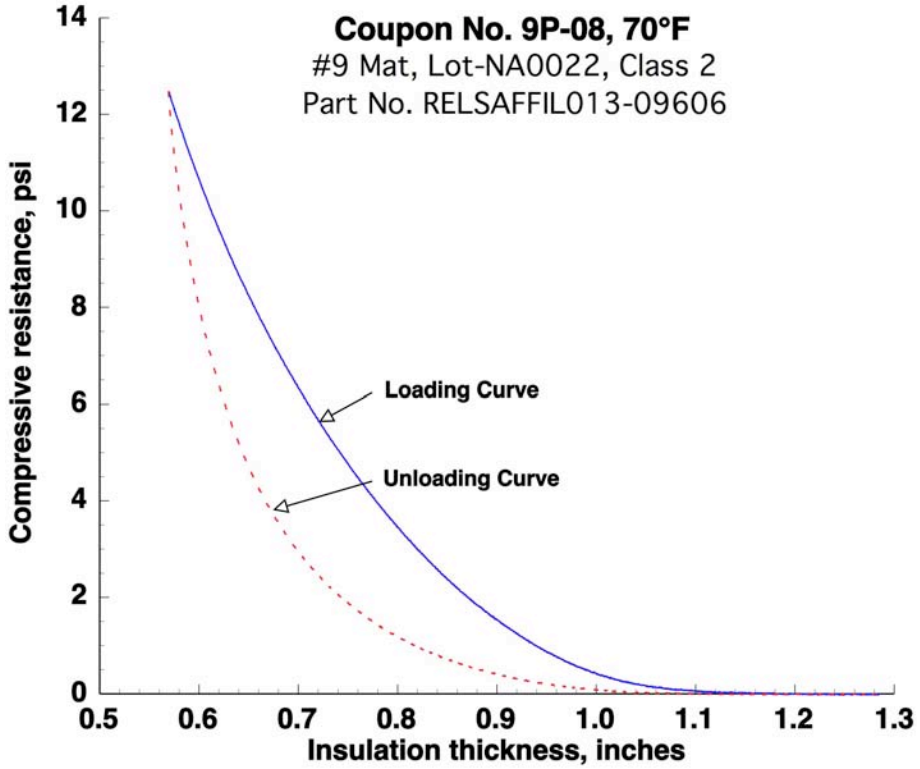

Coupon No. 3P-24, 2300°F
#3 Mat, Lot-047138, Class 2
Part No. 610-4820-014-00-00
Thickness, inches
Compressive resistance, psi
Compressive Resistance
Thickness 0.050 inches
Time, seconds
0.0
0.1
0.2
0.3
0.4
0.5
0.6
-2
0
2
4
6
8
10
12
0
120
240
360
480
600
720

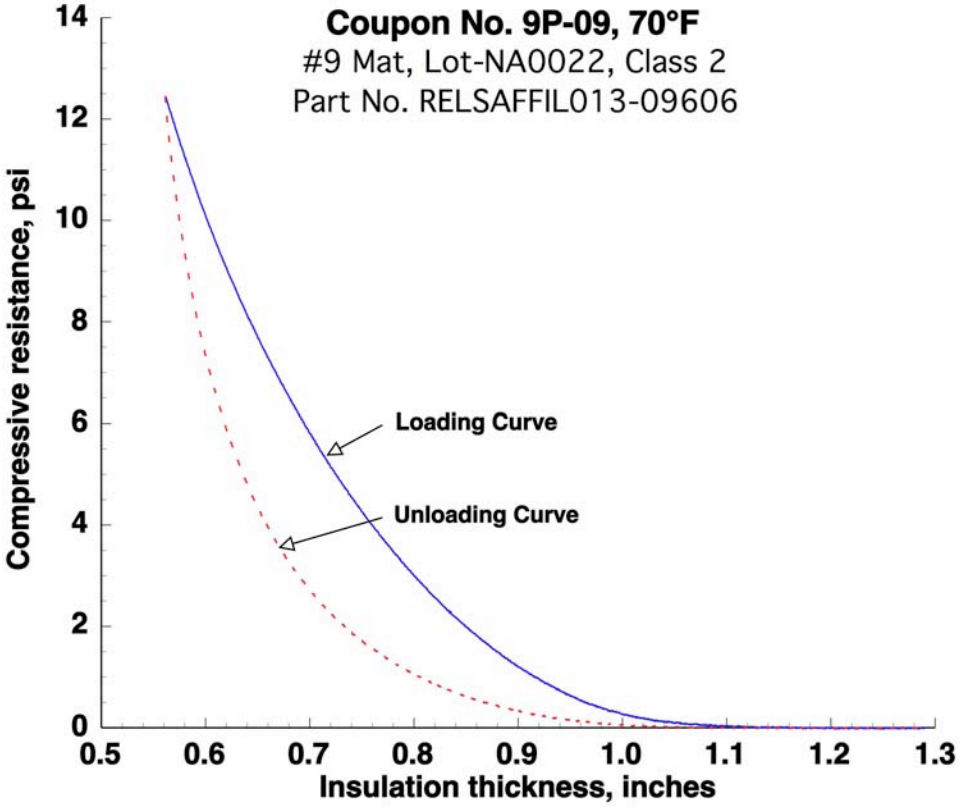

Coupon No. 3P-25, 2300°F
#3 Mat, Lot-047138, Class 2
Part No. 610-4820-014-00-00
Thickness, inches
Compressive resistance, psi
Compressive Resistance
Thickness 0.050 inches
Time, seconds
0.0
0.1
0.2
0.3
0.4
0.5
0.6
-2
0
2
4
6
8
10
0
120
240
360
480
600
720

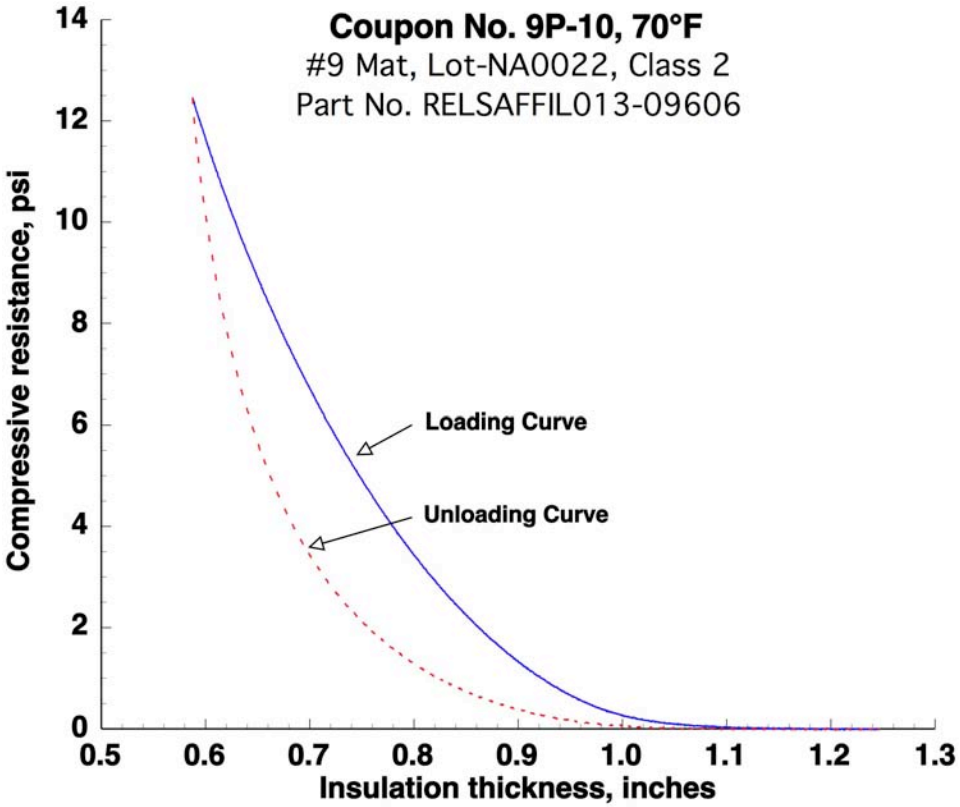

Coupon No. 3P-26, 2300°F
#3 Mat, Lot-047138, Class 2
Part No. 610-4820-014-00-00
Compressive Resistance
Thickness 0.050 inches
Thickness, inches
Compressive resistance, psi
Time, seconds
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
-2
0
2
4
6
8
10
0
120
240
360
480
600
720

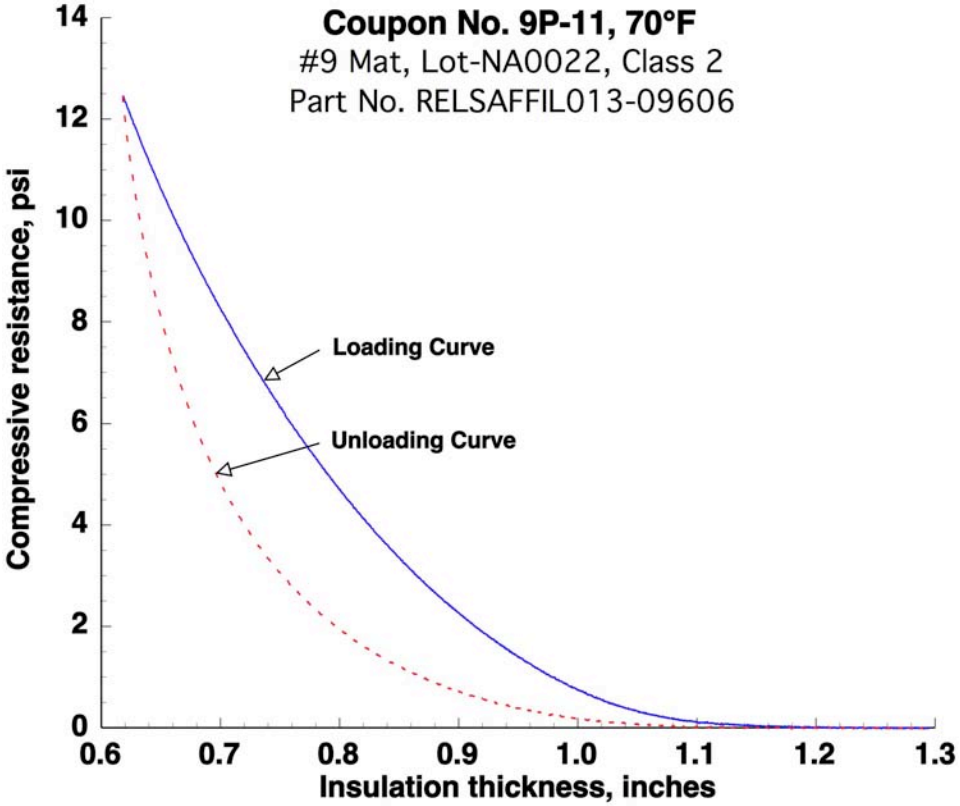
Alumina Fiber Blanket Insulation 1.00-inch 9 lb/ft^3 Material Room Temperature Tests

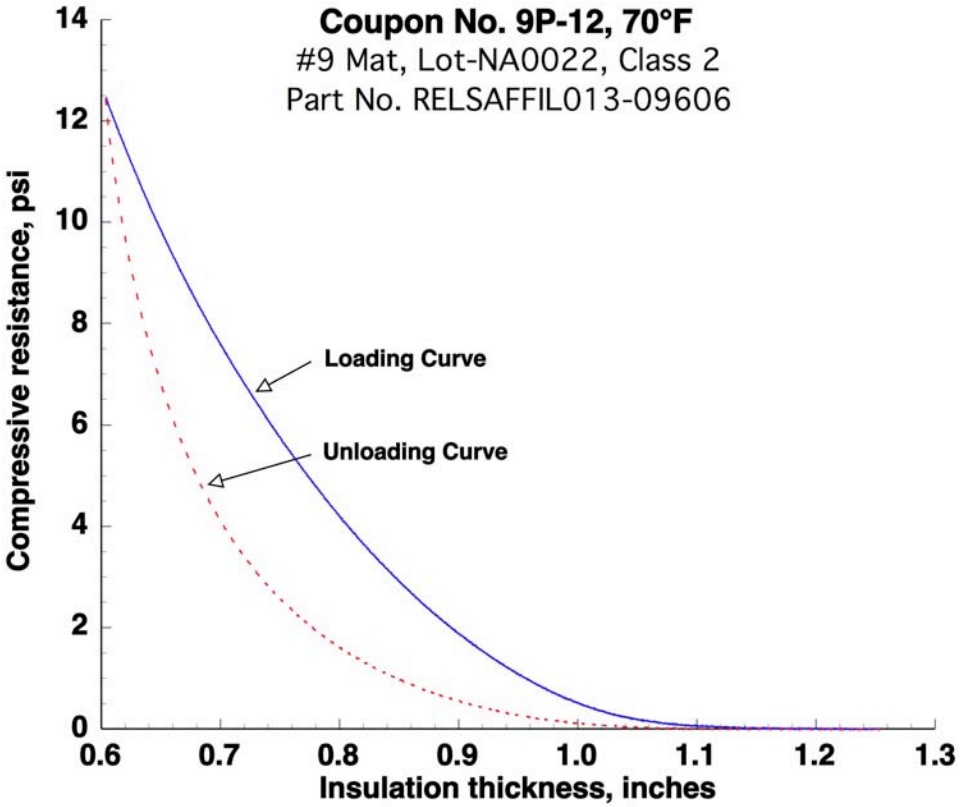


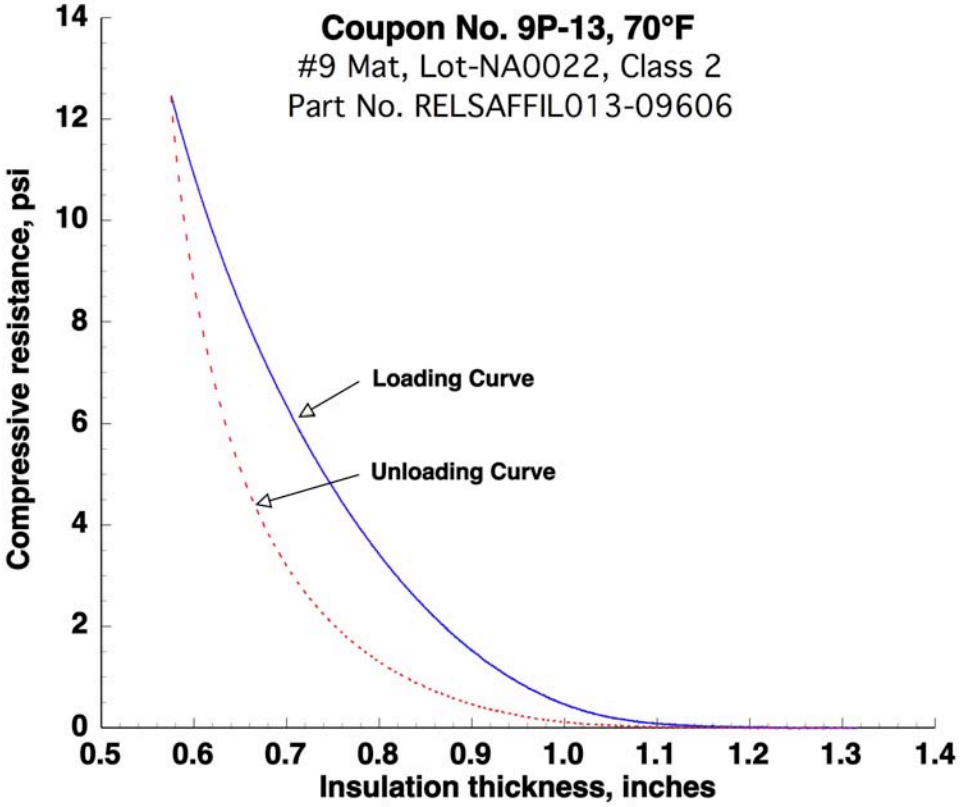


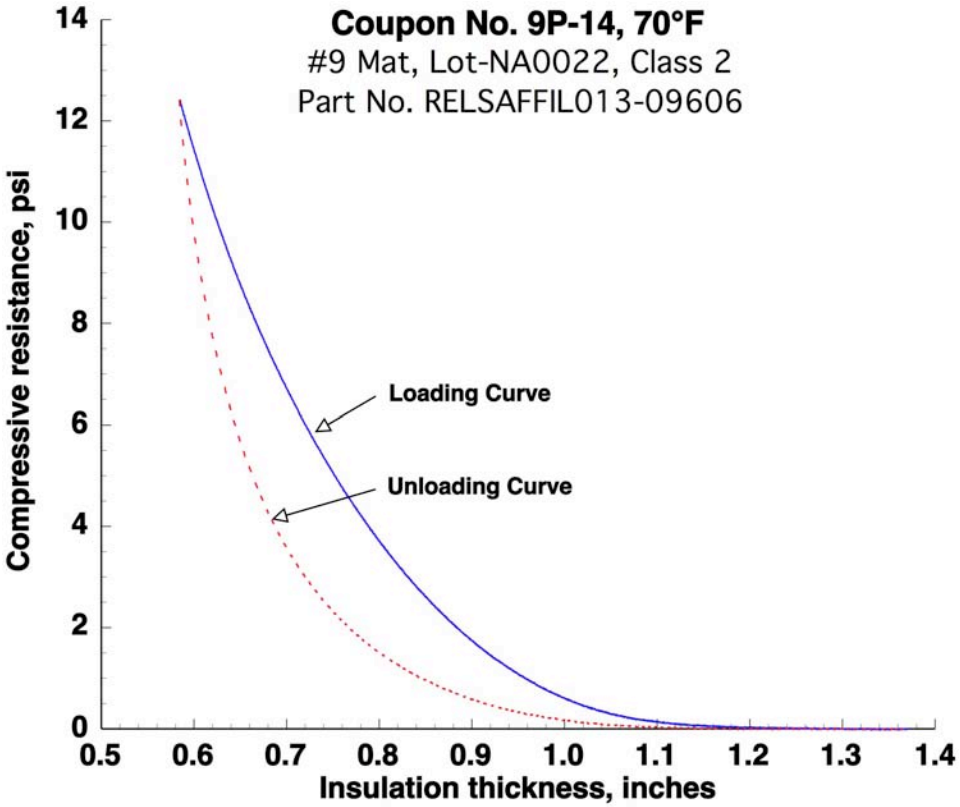

Coupon No. 9P-09, 70°F
#9 Mat, Lot-NA0022, Class 2
Part No. RELSAFFIL013-09606
Compressive resistance, psi
Insulation thickness, inches
Loading Curve
Unloading Curve
0
2
4
6
8
10
12
14
0.5
0.6
0.7
0.8
0.9
1.0
1.1
1.2
1.3

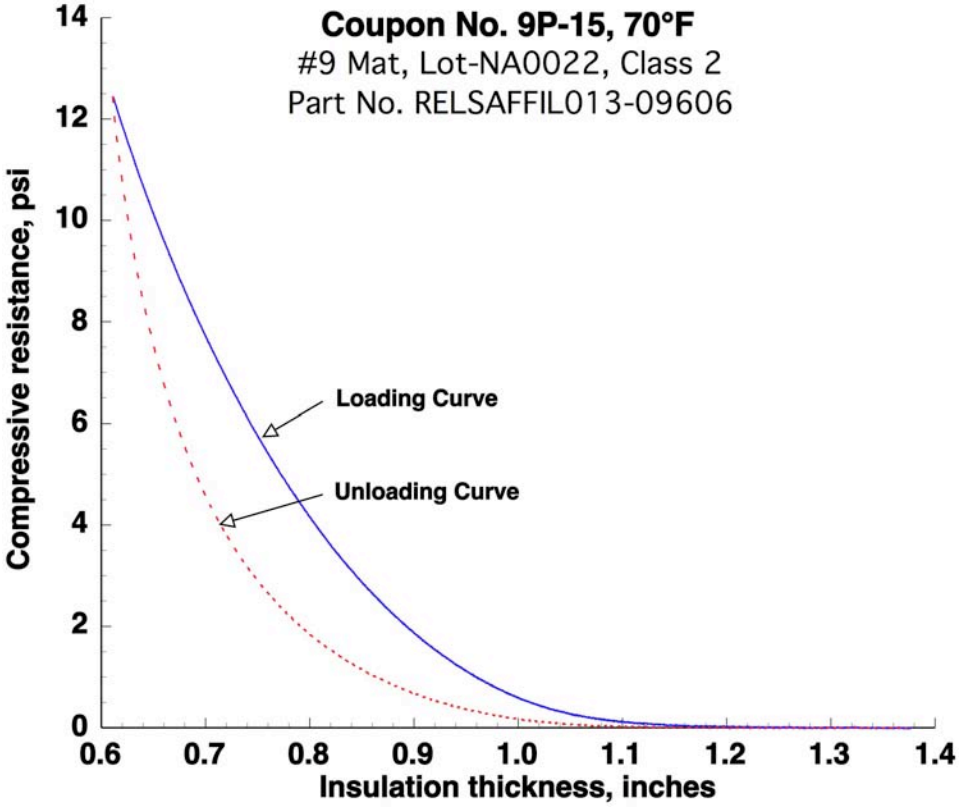

Coupon No. 9P-10, 70°F
#9 Mat, Lot-NA0022, Class 2
Part No. RELSAFFIL013-09606
Compressive resistance, psi
Insulation thickness, inches
Loading Curve
Unloading Curve
0
2
4
6
8
10
12
14
0.5
0.6
0.7
0.8
0.9
1.0
1.1
1.2
1.3

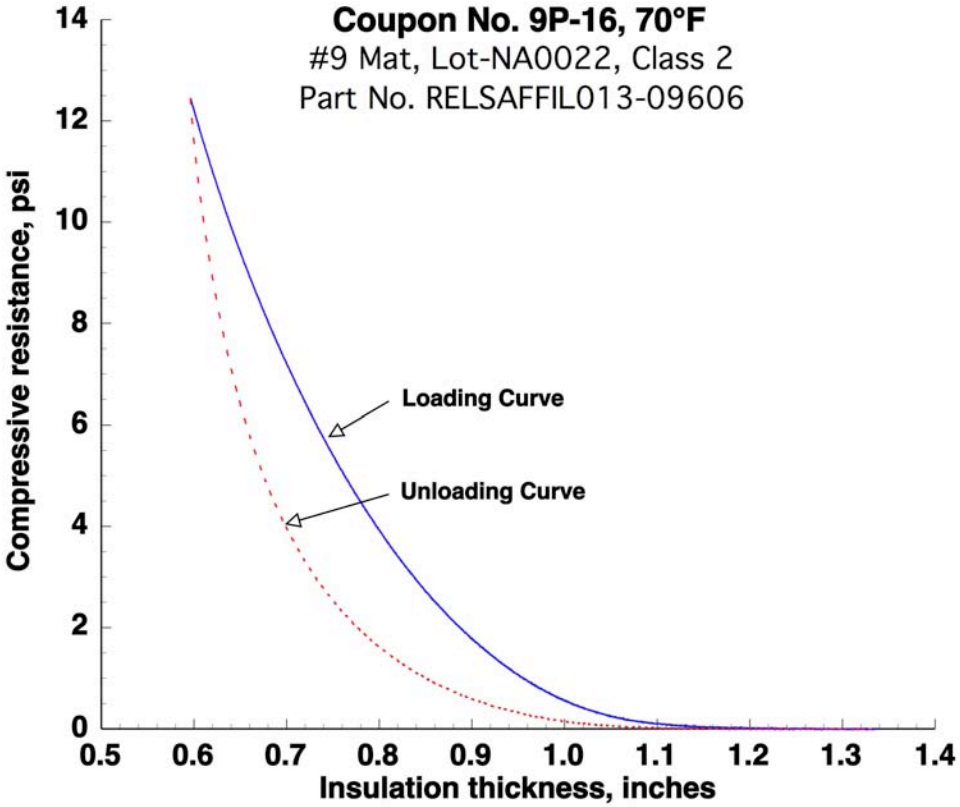

Coupon No. 9P-11, 70°F
#9 Mat, Lot-NA0022, Class 2
Part No. RELSAFFIL013-09606
Compressive resistance, psi
Insulation thickness, inches
Loading Curve
Unloading Curve
0
2
4
6
8
10
12
14
0.6
0.7
0.8
0.9
1.0
1.1
1.2
1.3

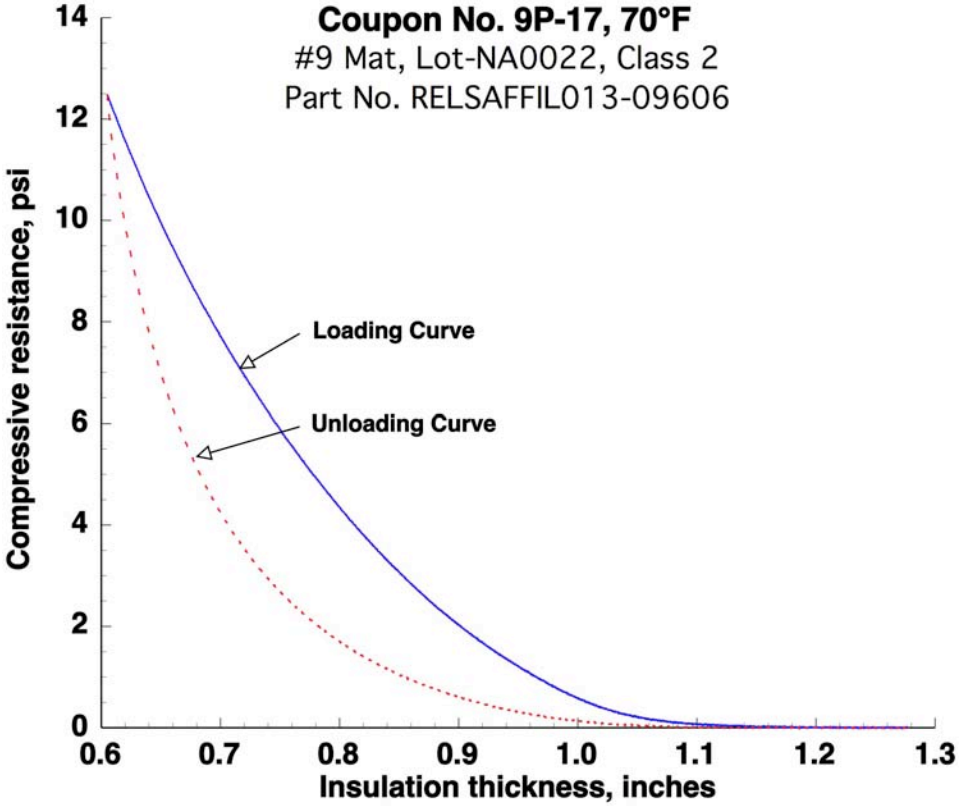

Coupon No. 9P-12, 70°F
#9 Mat, Lot-NA0022, Class 2
Part No. RELSAFFIL013-09606
Compressive resistance, psi
Insulation thickness, inches
Loading Curve
Unloading Curve
0
2
4
6
8
10
12
14
0.6
0.7
0.8
0.9
1.0
1.1
1.2
1.3

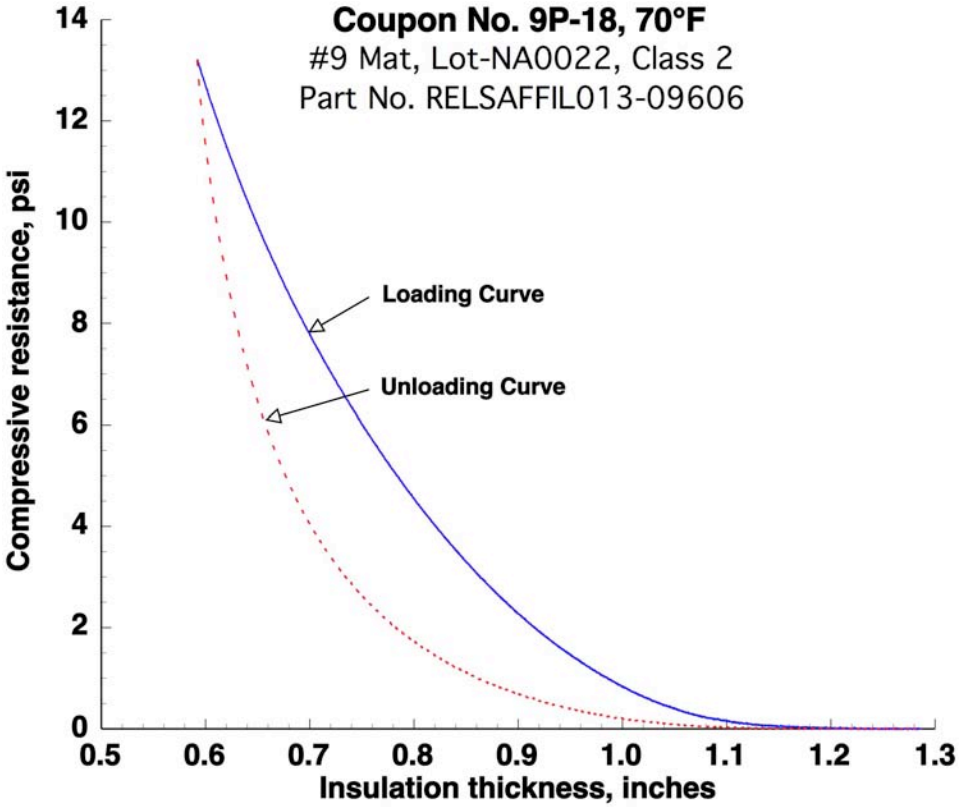

Coupon No. 9P-13, 70°F
#9 Mat, Lot-NA0022, Class 2
Part No. RELSAFFIL013-09606
Compressive resistance, psi
Insulation thickness, inches
Loading Curve
Unloading Curve
0
2
4
6
8
10
12
14
0.5
0.6
0.7
0.8
0.9
1.0
1.1
1.2
1.3
1.4

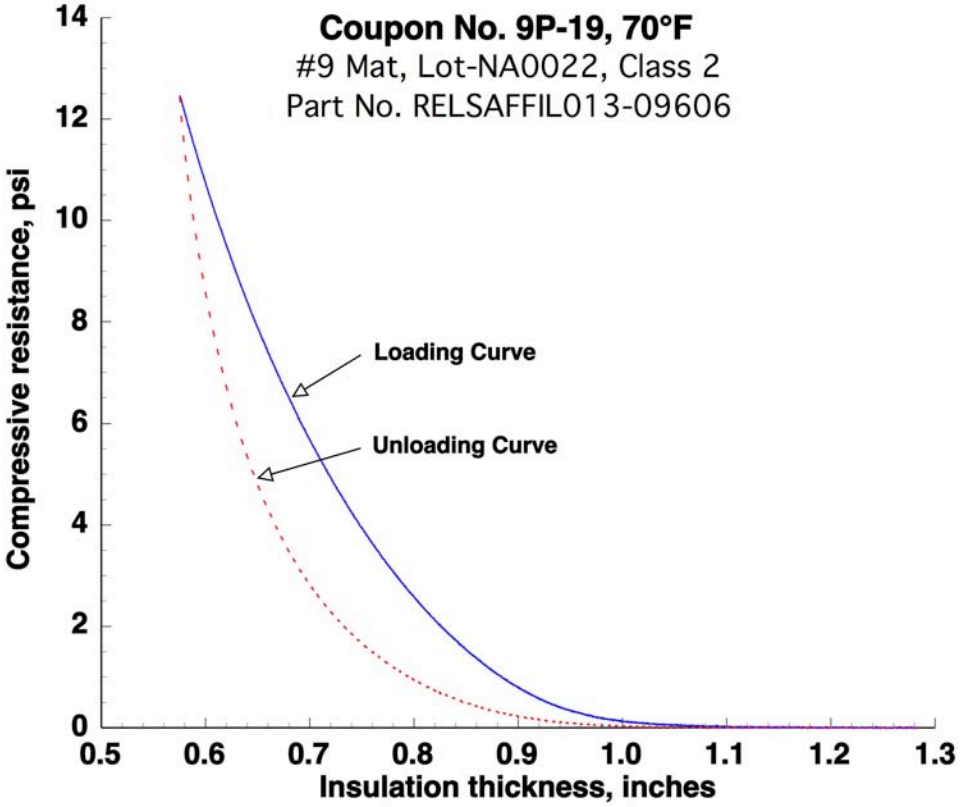

Coupon No. 9P-14, 70°F
#9 Mat, Lot-NA0022, Class 2
Part No. RELSAFFIL013-09606
Compressive resistance, psi
Insulation thickness, inches
Loading Curve
Unloading Curve
0
2
4
6
8
10
12
14
0.5
0.6
0.7
0.8
0.9
1.0
1.1
1.2
1.3
1.4

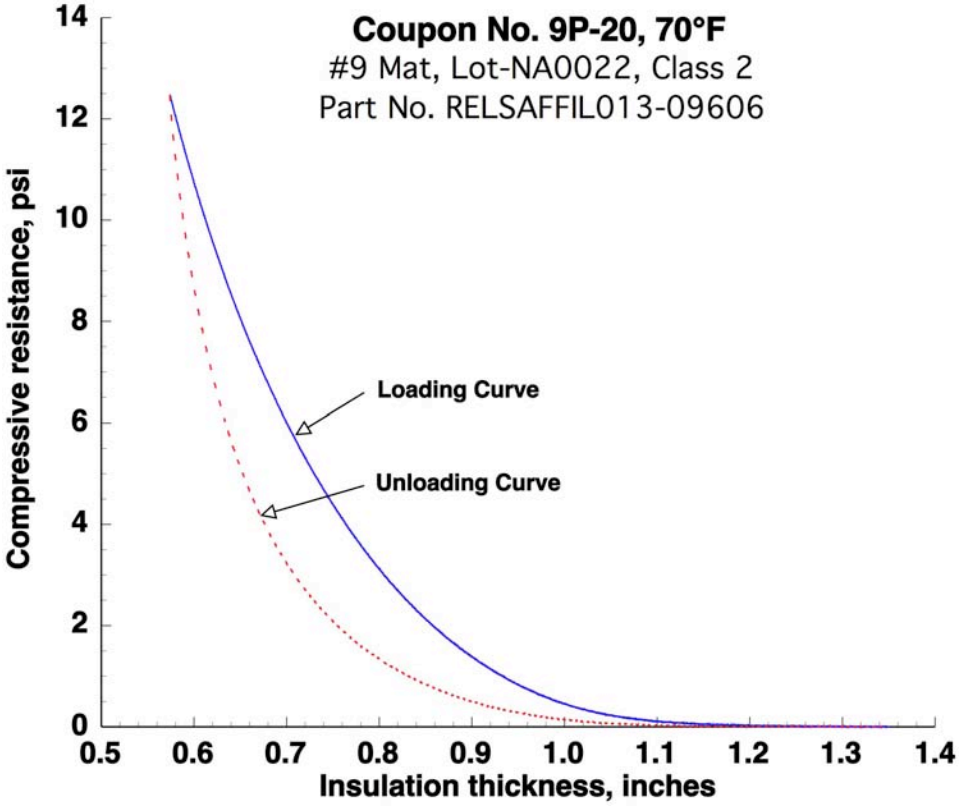

Coupon No. 9P-15, 70°F
#9 Mat, Lot-NA0022, Class 2
Part No. RELSAFFIL013-09606
Compressive resistance, psi
Insulation thickness, inches
Loading Curve
Unloading Curve
0
2
4
6
8
10
12
14
0.6
0.7
0.8
0.9
1.0
1.1
1.2
1.3
1.4

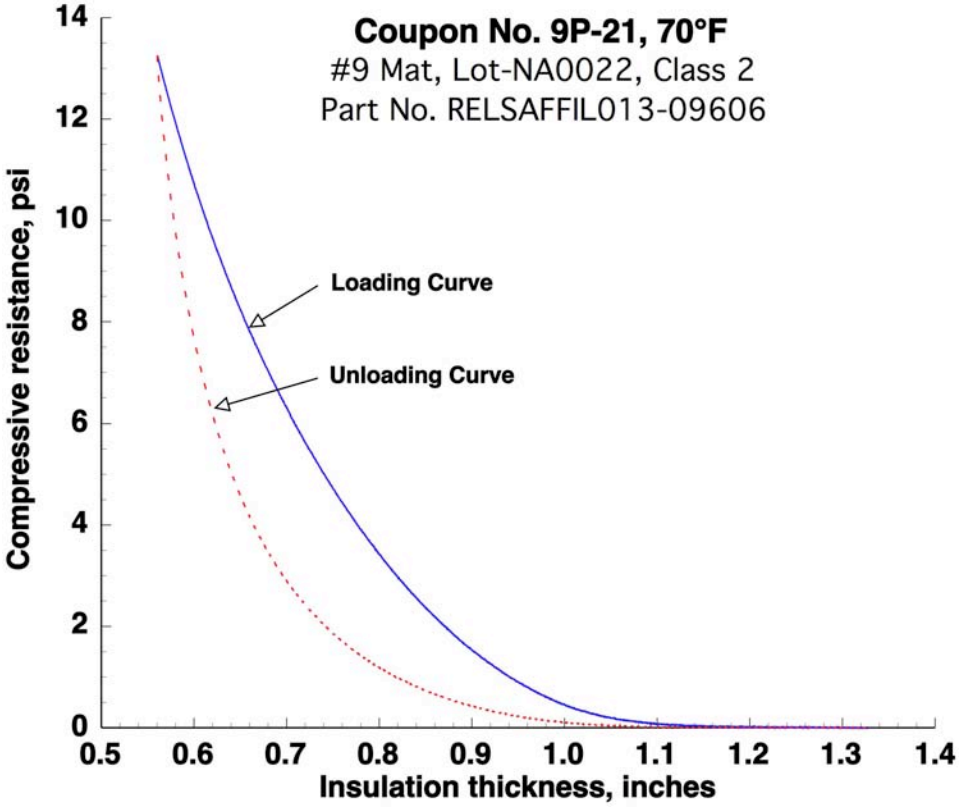

Coupon No. 9P-16, 70°F
#9 Mat, Lot-NA0022, Class 2
Part No. RELSAFFIL013-09606
Compressive resistance, psi
Insulation thickness, inches
Loading Curve
Unloading Curve
0
2
4
6
8
10
12
14
0.5
0.6
0.7
0.8
0.9
1.0
1.1
1.2
1.3
1.4

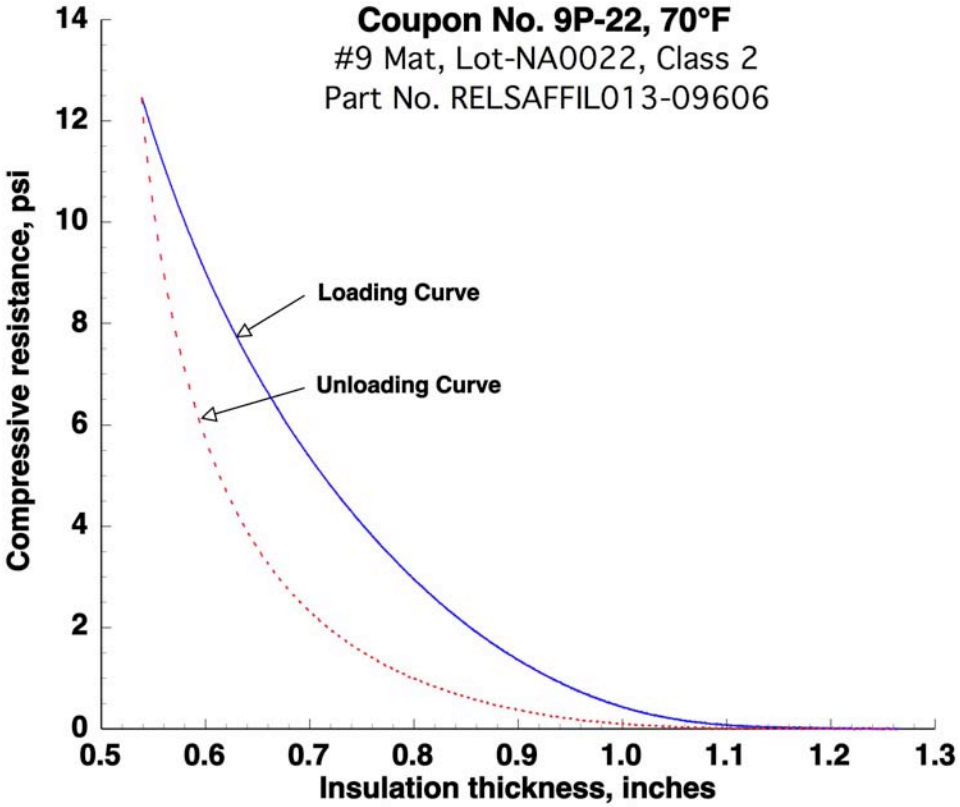

Coupon No. 9P-17, 70°F
#9 Mat, Lot-NA0022, Class 2
Part No. RELSAFFIL013-09606
Compressive resistance, psi
Insulation thickness, inches
Loading Curve
Unloading Curve
0
2
4
6
8
10
12
14
0.6
0.7
0.8
0.9
1.0
1.1
1.2
1.3

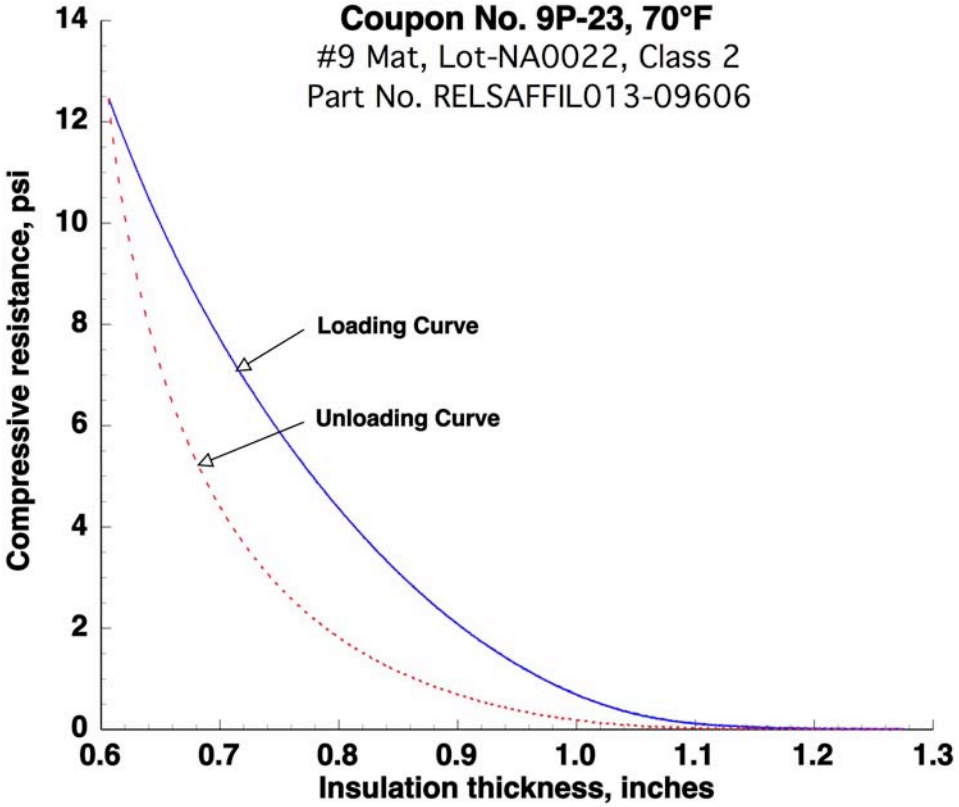

Coupon No. 9P-18, 70°F
#9 Mat, Lot-NA0022, Class 2
Part No. RELSAFFIL013-09606
Compressive resistance, psi
Insulation thickness, inches
Loading Curve
Unloading Curve
0
2
4
6
8
10
12
14
0.5
0.6
0.7
0.8
0.9
1.0
1.1
1.2
1.3

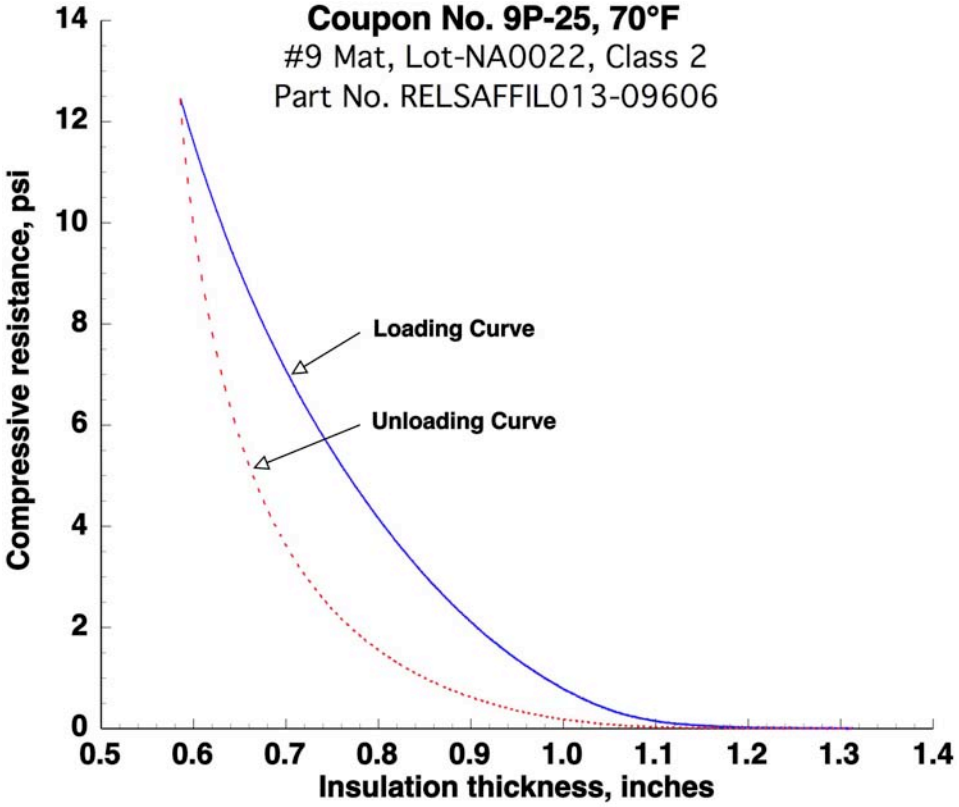

Coupon No. 9P-19, 70°F
#9 Mat, Lot-NA0022, Class 2
Part No. RELSAFFIL013-09606
Compressive resistance, psi
Insulation thickness, inches
Loading Curve
Unloading Curve
0
2
4
6
8
10
12
14
0.5
0.6
0.7
0.8
0.9
1.0
1.1
1.2
1.3

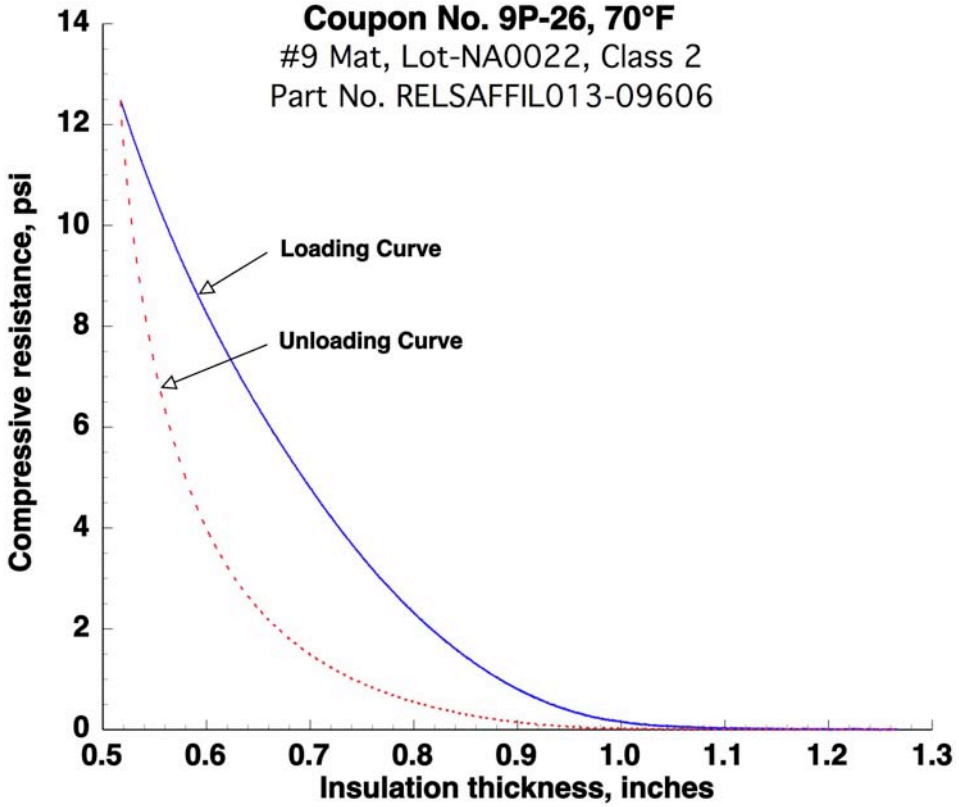

Coupon No. 9P-20, 70°F
#9 Mat, Lot-NA0022, Class 2
Part No. RELSAFFIL013-09606
Compressive resistance, psi
Insulation thickness, inches
Loading Curve
Unloading Curve
0
2
4
6
8
10
12
14
0.5
0.6
0.7
0.8
0.9
1.0
1.1
1.2
1.3
1.4

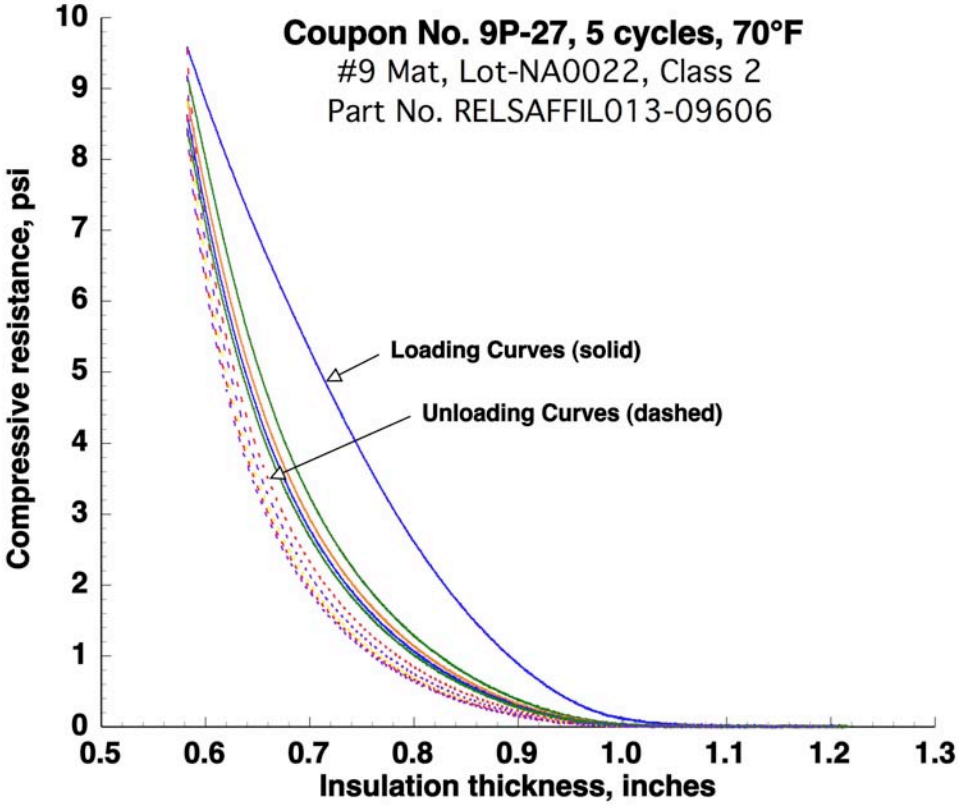

Coupon No. 9P-21, 70°F
#9 Mat, Lot-NA0022, Class 2
Part No. RELSAFFIL013-09606
Loading Curve
Unloading Curve
Compressive resistance, psi
Insulation thickness, inches
0
2
4
6
8
10
12
14
0.5
0.6
0.7
0.8
0.9
1.0
1.1
1.2
1.3
1.4

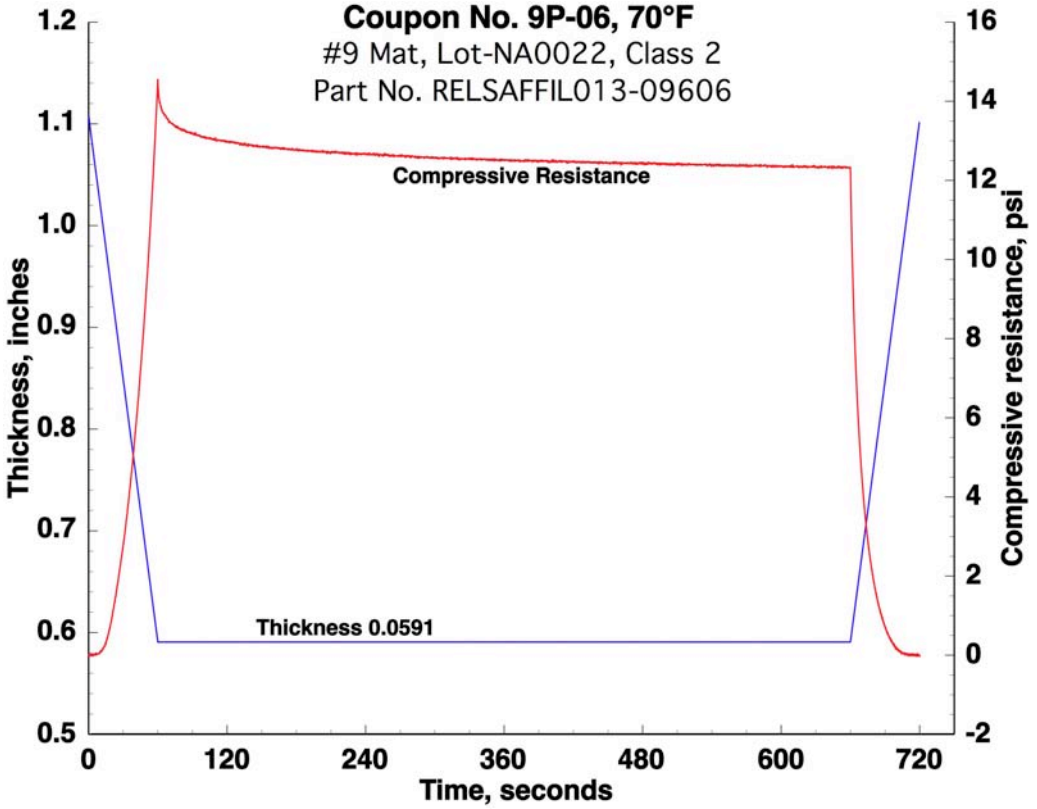

Coupon No. 9P-22, 70°F
#9 Mat, Lot-NA0022, Class 2
Part No. RELSAFFIL013-09606
Loading Curve
Unloading Curve
Compressive resistance, psi
Insulation thickness, inches
0
2
4
6
8
10
12
14
0.5
0.6
0.7
0.8
0.9
1.0
1.1
1.2
1.3


Coupon No. 9P-23, 70°F
#9 Mat, Lot-NA0022, Class 2
Part No. RELSAFFIL013-09606
Compressive resistance, psi
Insulation thickness, inches
Loading Curve
Unloading Curve
0
2
4
6
8
10
12
14
0.6
0.7
0.8
0.9
1.0
1.1
1.2
1.3

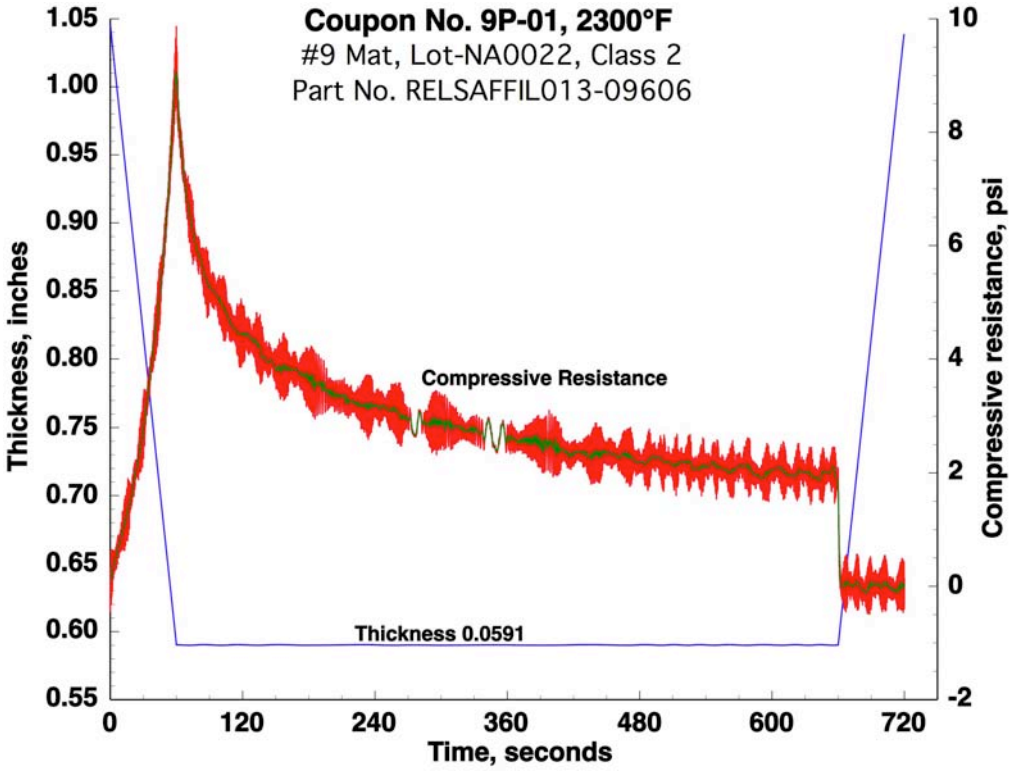

Coupon No. 9P-25, 70°F
#9 Mat, Lot-NA0022, Class 2
Part No. RELSAFFIL013-09606
Compressive resistance, psi
Insulation thickness, inches
Loading Curve
Unloading Curve
0
2
4
6
8
10
12
14
0.5
0.6
0.7
0.8
0.9
1.0
1.1
1.2
1.3
1.4

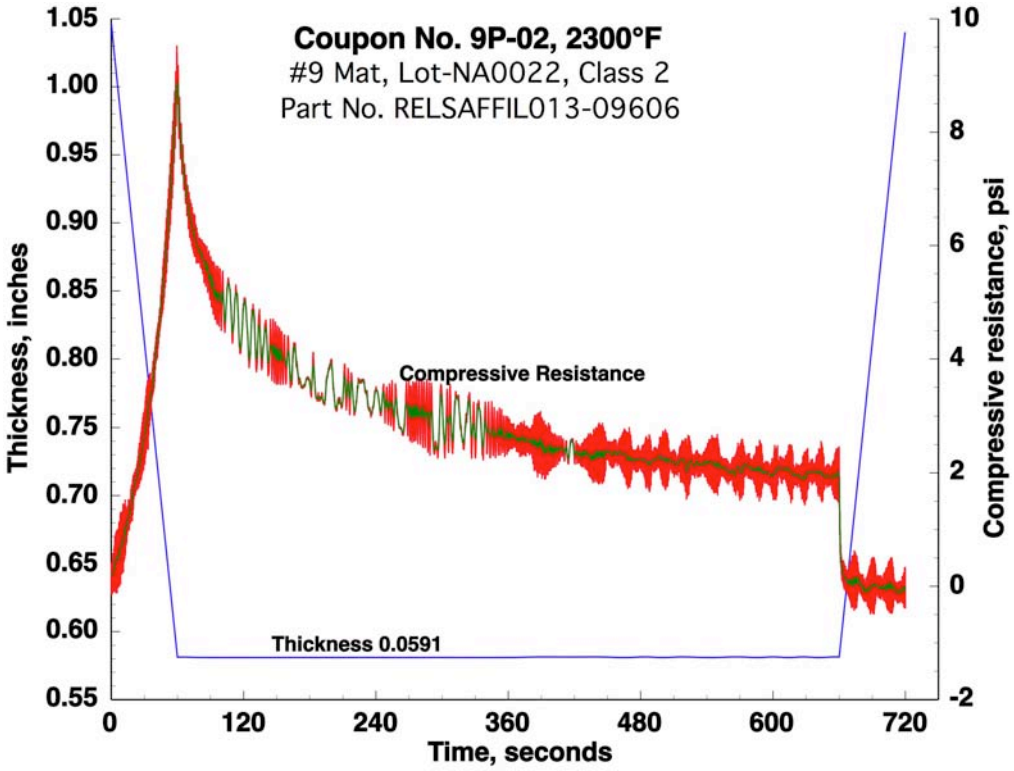

Coupon No. 9P-26, 70°F
#9 Mat, Lot-NA0022, Class 2
Part No. RELSAFFIL013-09606
Loading Curve
Unloading Curve
Compressive resistance, psi
Insulation thickness, inches
0
2
4
6
8
10
12
14
0.5
0.6
0.7
0.8
0.9
1.0
1.1
1.2
1.3

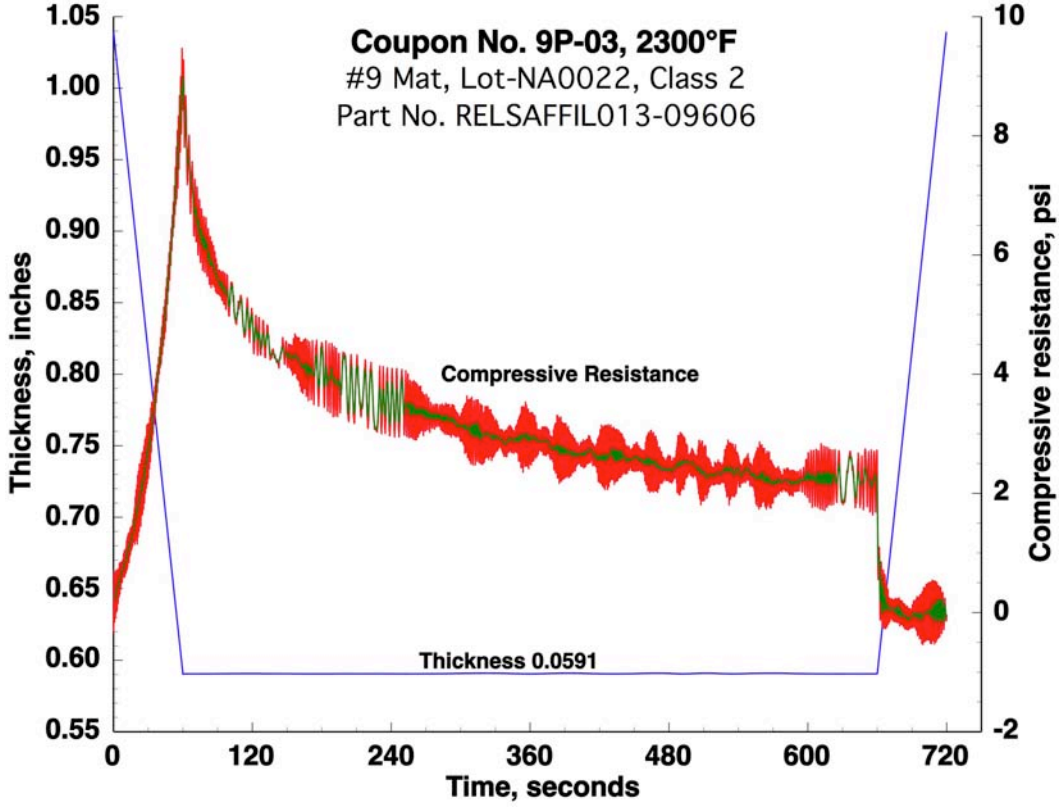

Coupon No. 9P-27, 5 cycles, 70°F
#9 Mat, Lot-NA0022, Class 2
Part No. RELSAFFIL013-09606
Loading Curves (solid)
Unloading Curves (dashed)
Compressive resistance, psi
Insulation thickness, inches
0
1
2
3
4
5
6
7
8
9
10
0.5
0.6
0.7
0.8
0.9
1.0
1.1
1.2
1.3

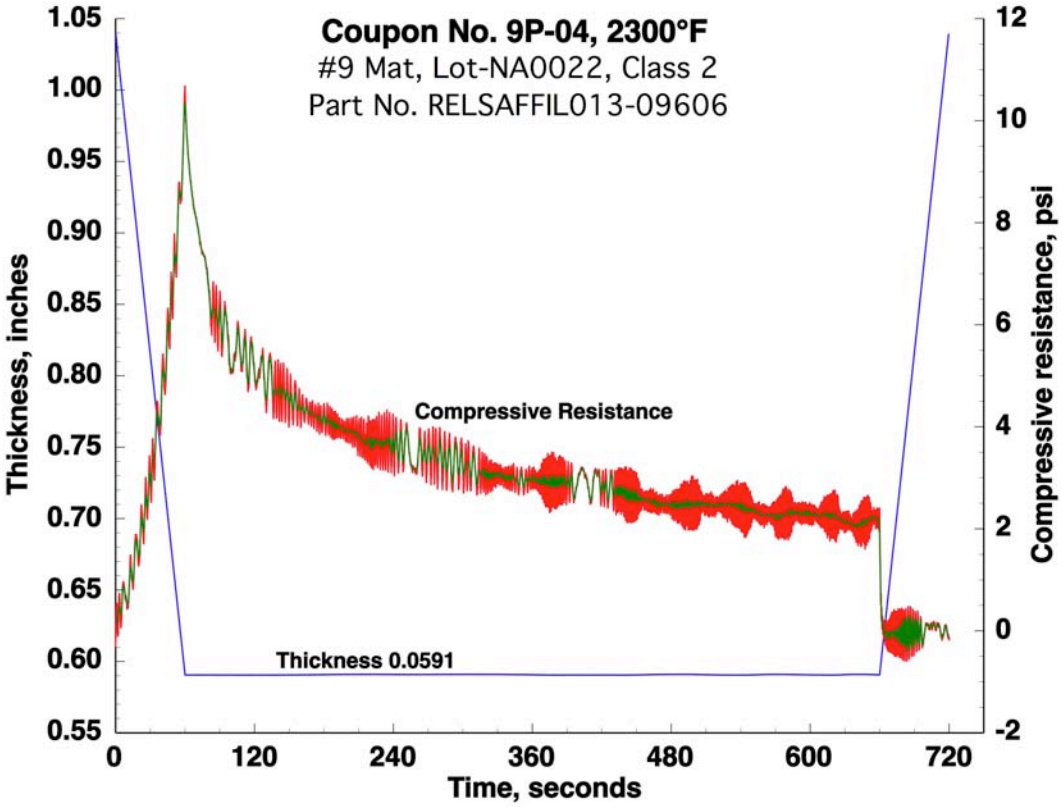

Coupon No. 9P-06, 70°F
#9 Mat, Lot-NA0022, Class 2
Part No. RELSAFFIL013-09606
Compressive Resistance
Thickness 0.0591
Thickness, inches
Compressive resistance, psi
Time, seconds
1.2
1.1
1.0
0.9
0.8
0.7
0.6
0.5
16
14
12
10
8
6
4
2
0
-2
0
120
240
360
480
600
720

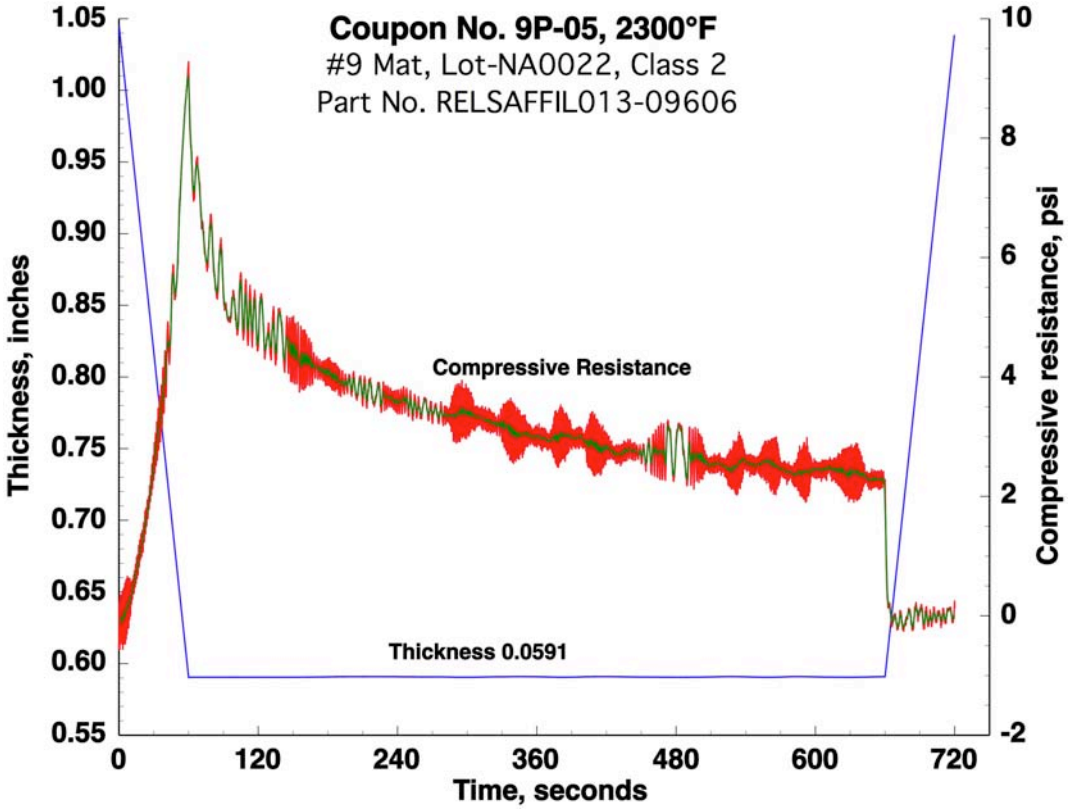
Alumina Fiber Blanket Insulation 1.00-inch 9 lb/ft^3 Material 2300°F Tests






Coupon No. 9P-03, 2300°F
#9 Mat, Lot-NA0022, Class 2
Part No. RELSAFFIL013-09606
Compressive Resistance
Thickness 0.0591
Thickness, inches
Compressive resistance, psi
Time, seconds
1.05
1.00
0.95
0.90
0.85
0.80
0.75
0.70
0.65
0.60
0.55
10
8
6
4
2
0
-2
0
120
240
360
480
600
720

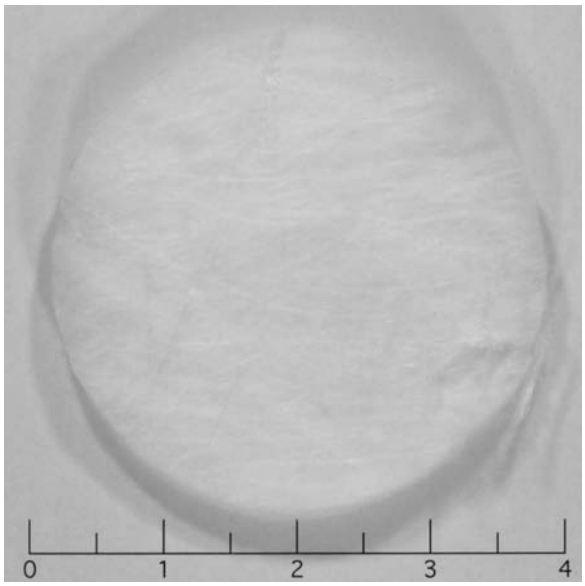

Coupon No. 9P-04, 2300°F
#9 Mat, Lot-NA0022, Class 2
Part No. RELSAFFIL013-09606
Compressive Resistance
Thickness 0.0591
Thickness, inches
Compressive resistance, psi
Time, seconds
1.05
1.00
0.95
0.90
0.85
0.80
0.75
0.70
0.65
0.60
0.55
12
10
8
6
4
2
0
-2
0
120
240
360
480
600
720


Coupon No. 9P-05, 2300°F
#9 Mat, Lot-NA0022, Class 2
Part No. RELSAFFIL013-09606
Compressive Resistance
Thickness 0.0591
Thickness, inches
Compressive resistance, psi
Time, seconds
1.05
1.00
0.95
0.90
0.85
0.80
0.75
0.70
0.65
0.60
0.55
10
8
6
4
2
0
-2
0
120
240
360
480
600
720

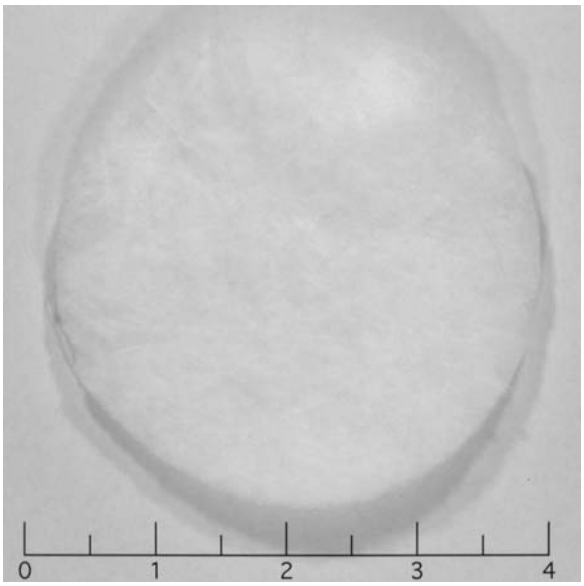
Appendix B

Alumina Fiber Insulation Photographs, Pre and Post Test

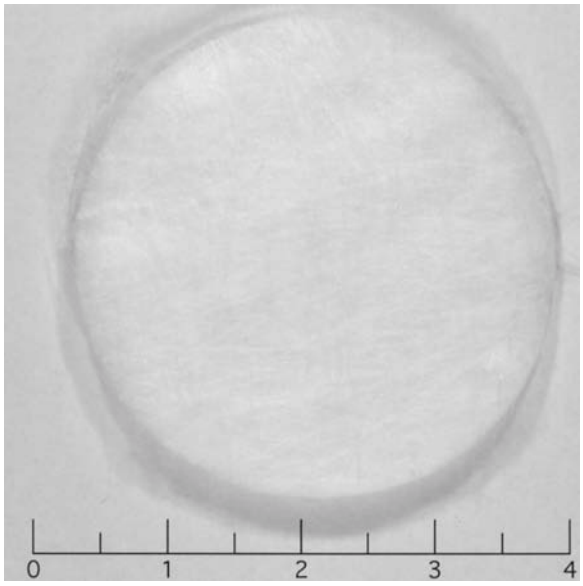
Alumina Fiber Insulation 0.15-inch 3 lb/ft^3 Pre and Post Test Pictures RT



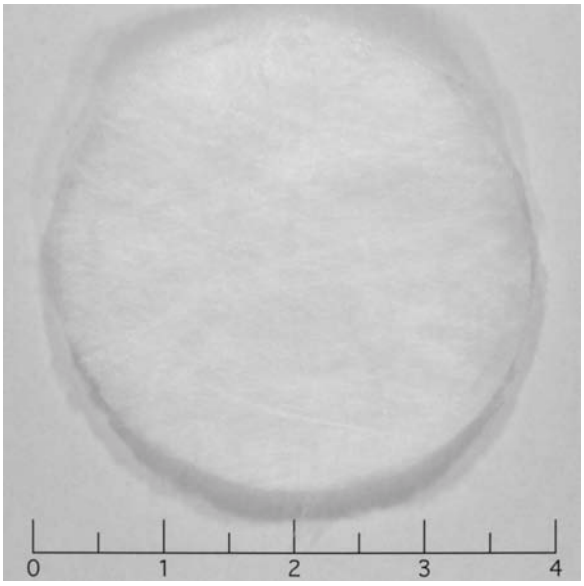
Coupon 3T-01, 70°F, Pre-Test, Scale in inches



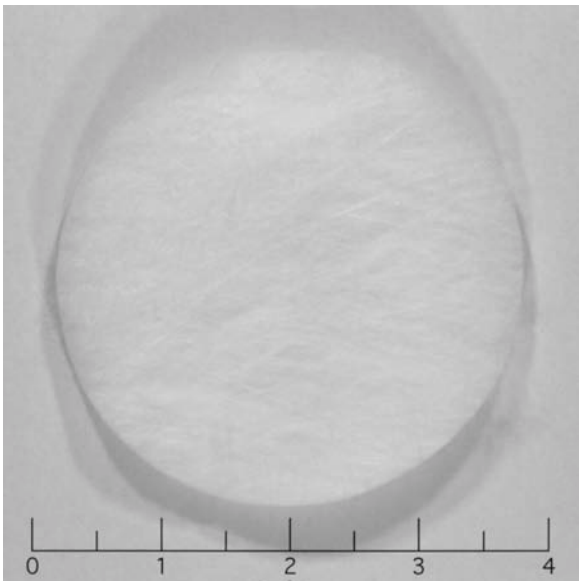
Coupon 3T-01, 70°F, Post-Test, Scale in inches



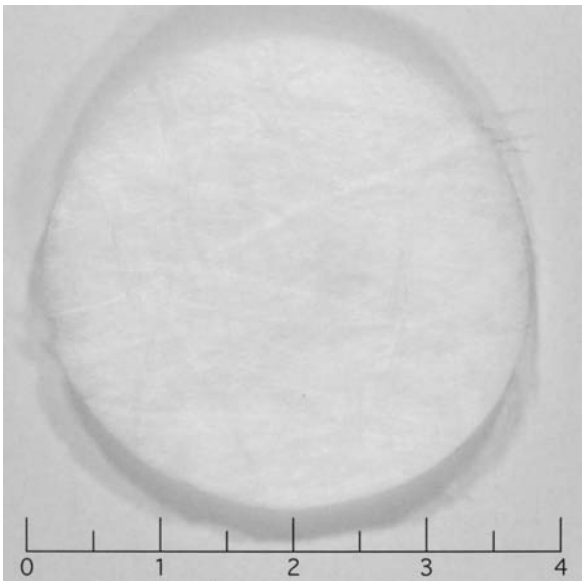
Coupon 3T-02, 70°F, Pre-Test, Scale in inches



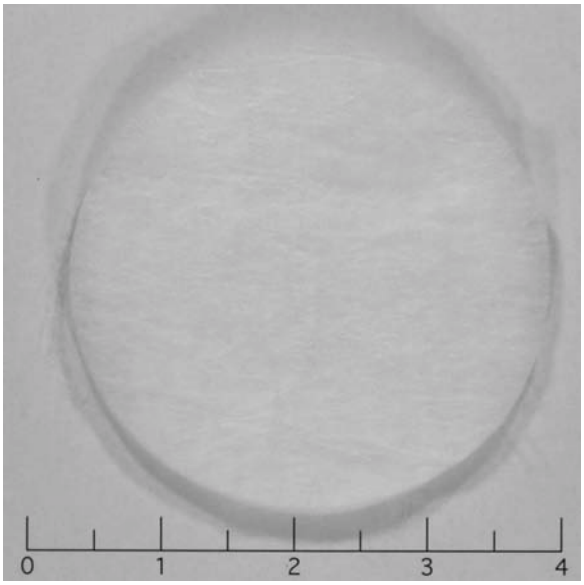
Coupon 3T-02, 70°F, Post-Test, Scale in inches



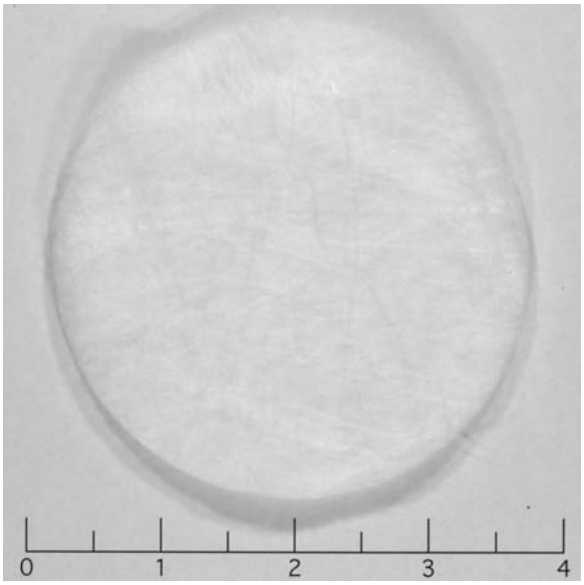
Coupon 3T-03, 70°F, Pre-Test, Scale in inches



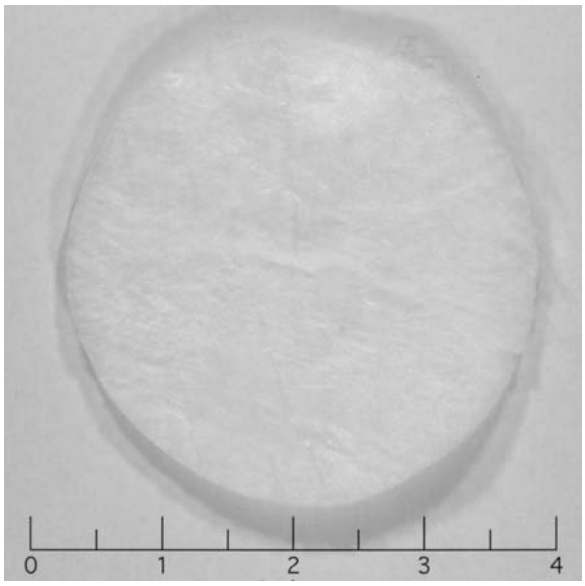
Coupon 3T-03, 70°F, Post-Test, Scale in inches



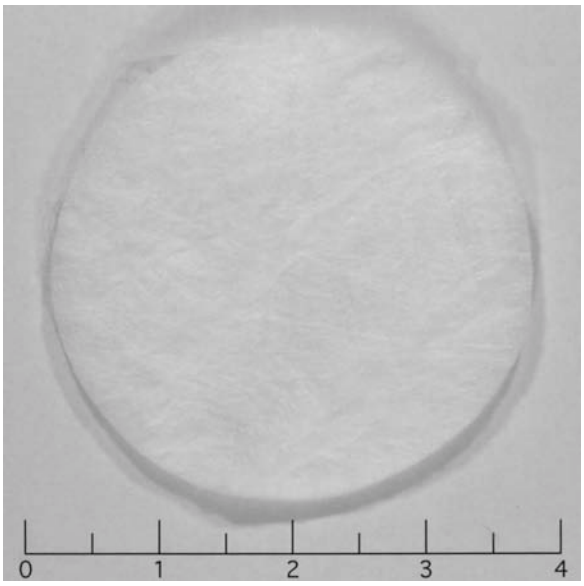
Coupon 3T-04, 70°F, Pre-Test, Scale in inches



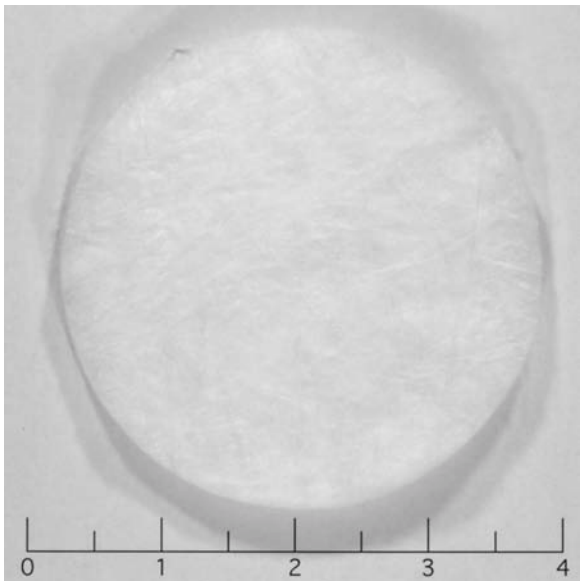
Coupon 3T-04, 70°F, Post-Test, Scale in inches



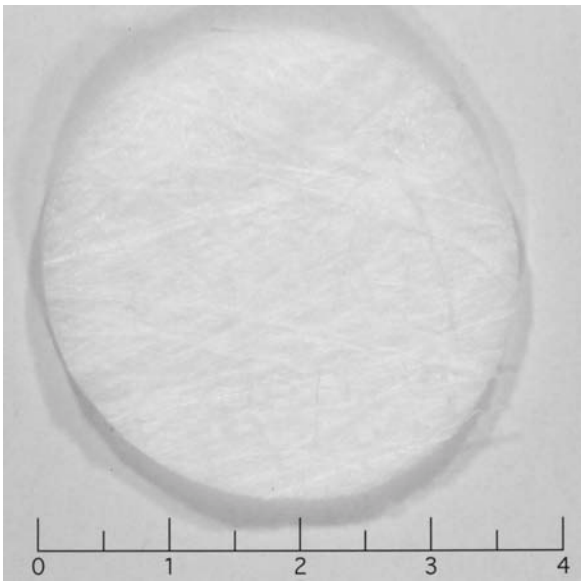
Coupon 3T-05, 70°F, Pre-Test, Scale in inches



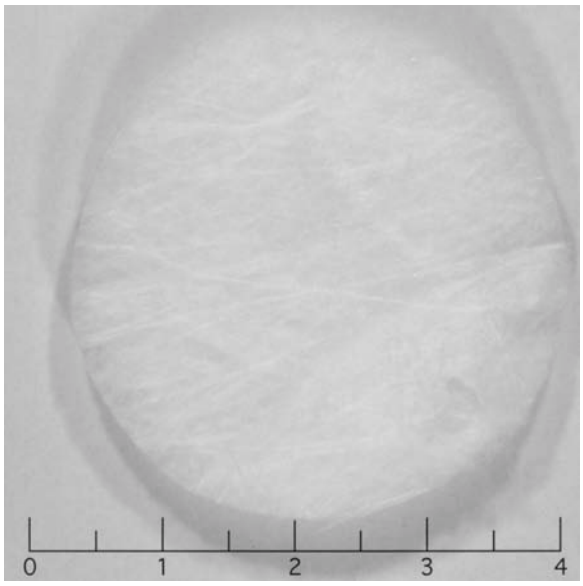
Coupon 3T-05, 70°F, Post-Test, Scale in inches



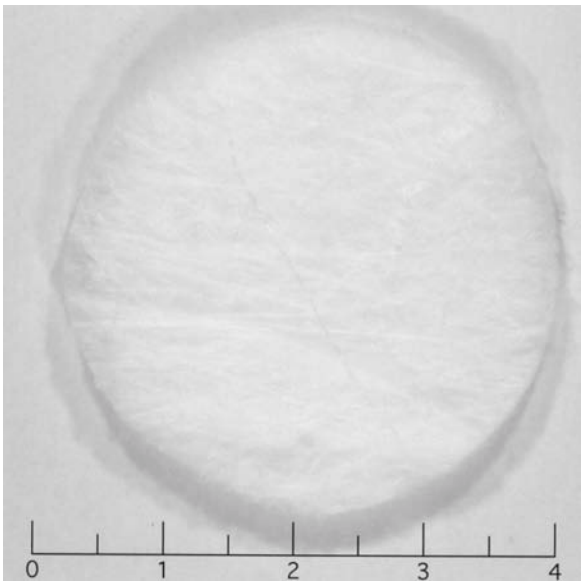
Coupon 3T-06, 70°F, Pre-Test, Scale in inches



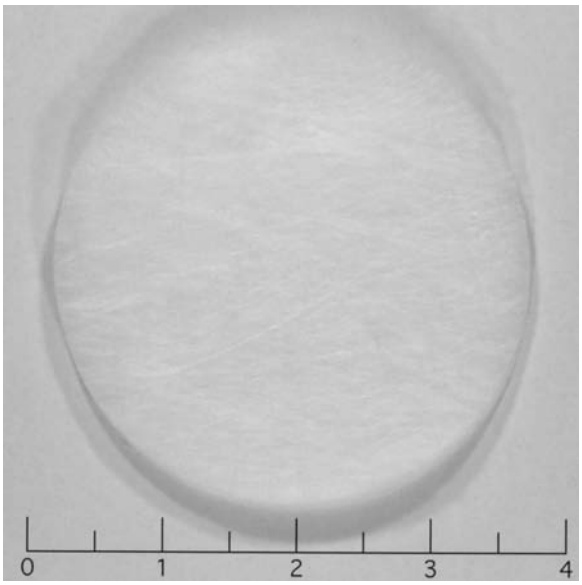
Coupon 3T-06, 70°F, Post-Test, Scale in inches



Coupon 3T-07, 70°F, Pre-Test, Scale in inches

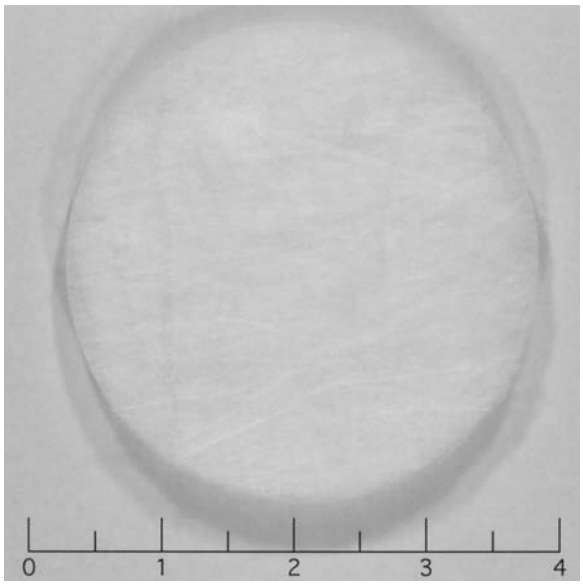


Coupon 3T-07, 70°F, Post-Test, Scale in inches

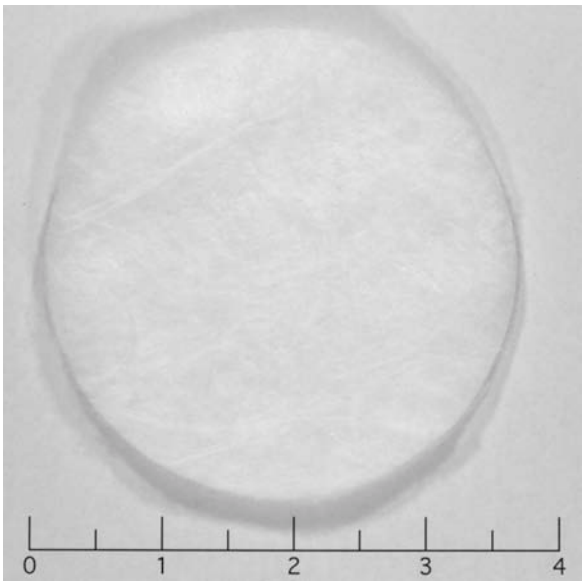


Coupon 3T-08, 70°F, Pre-Test, Scale in inches

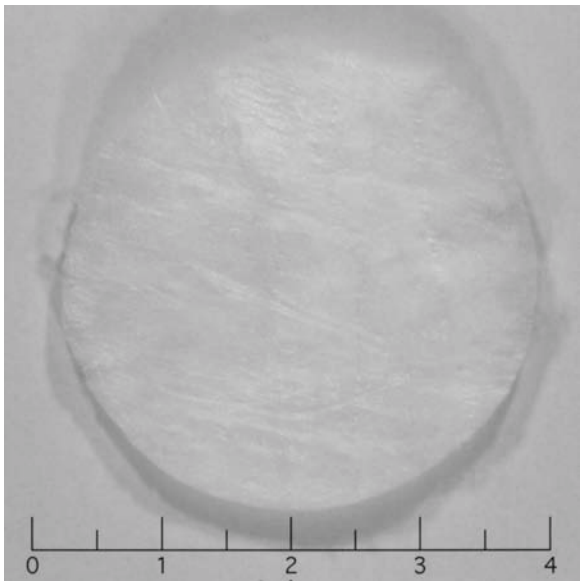
Coupon 3T-08, 70°F, Post-Test, Scale in inches



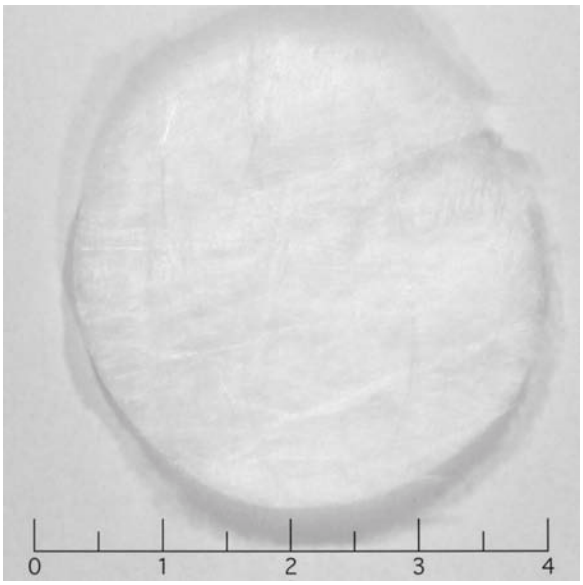
Coupon 3T-09, 70°F, Pre-Test, Scale in inches



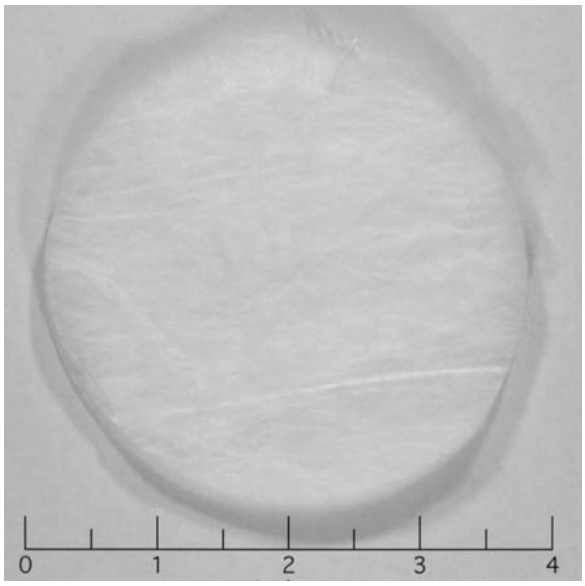
Coupon 3T-09, 70°F, Post-Test, Scale in inches



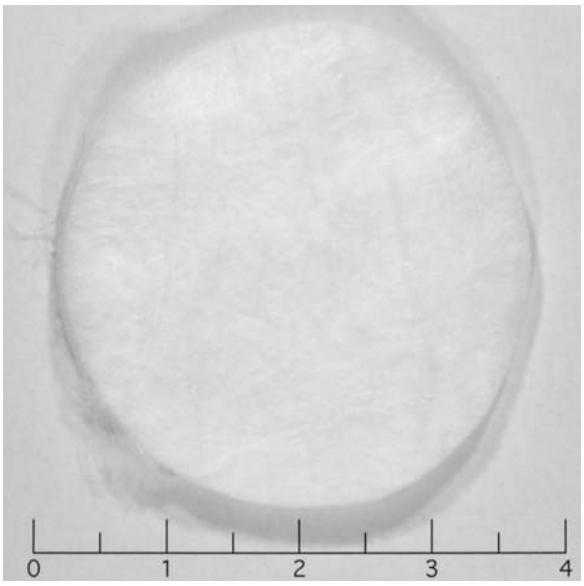
Coupon 3T-10, 70°F, Pre-Test, Scale in inches



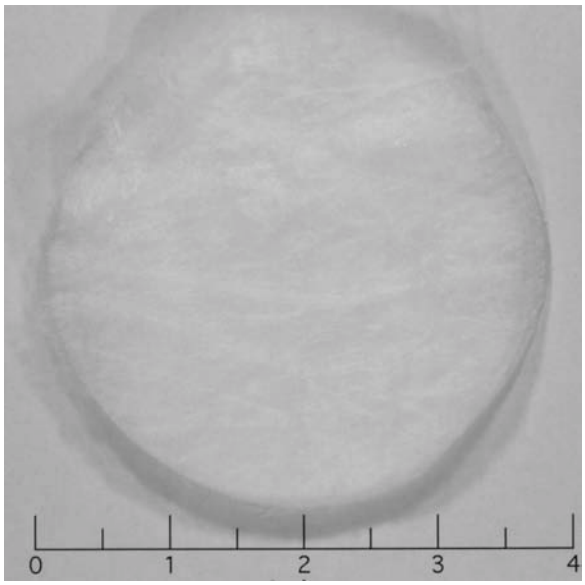
Coupon 3T-10, 70°F, Post-Test, Scale in inches



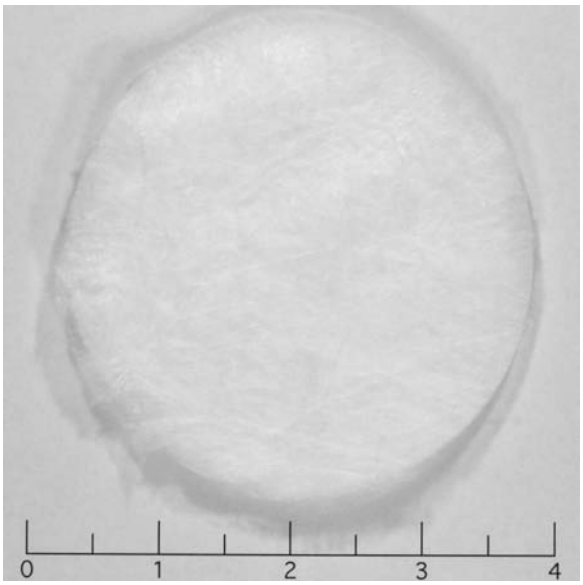
Coupon 3T-11, 70°F, Pre-Test, Scale in inches



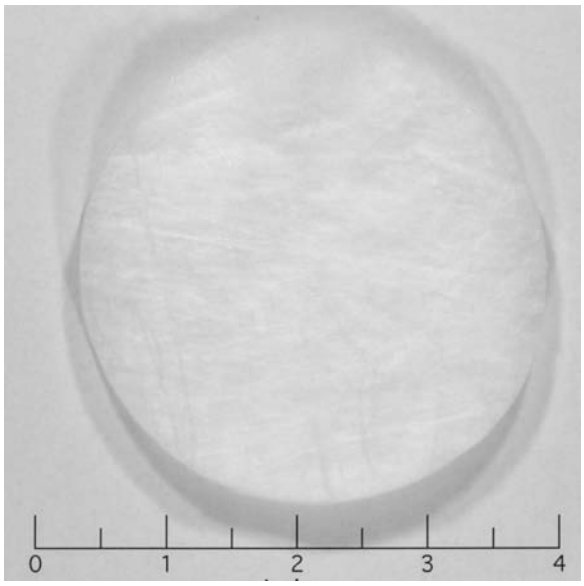
Coupon 3T-11, 70°F, Post-Test, Scale in inches



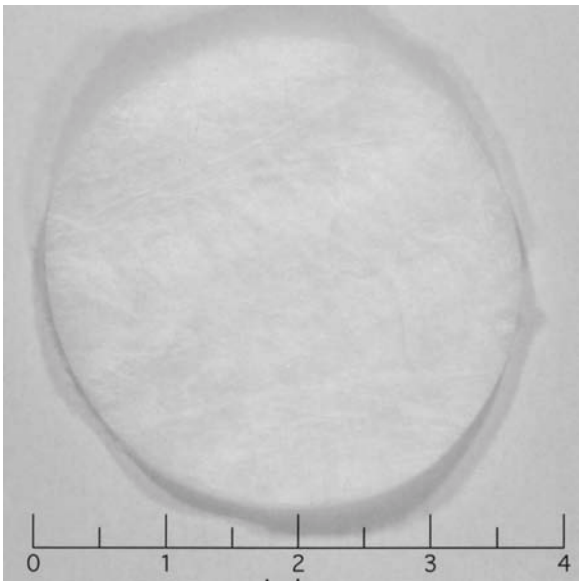
Coupon 3T-12, 70°F, Pre-Test, Scale in inches



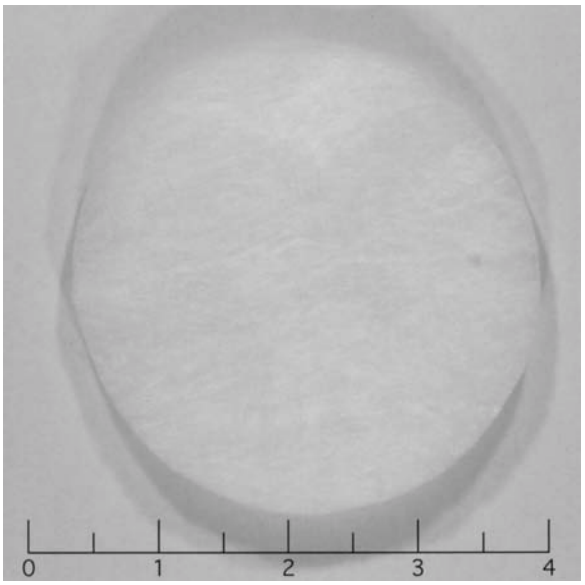
Coupon 3T-12, 70°F, Post-Test, Scale in inches



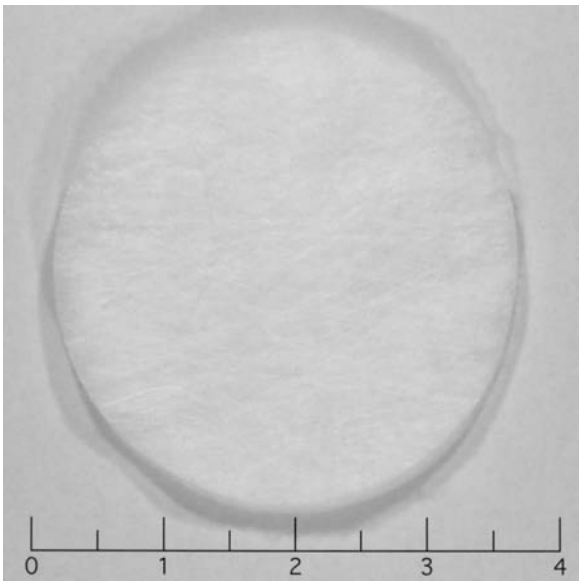
Coupon 3T-13, 70°F, Pre-Test, Scale in inches



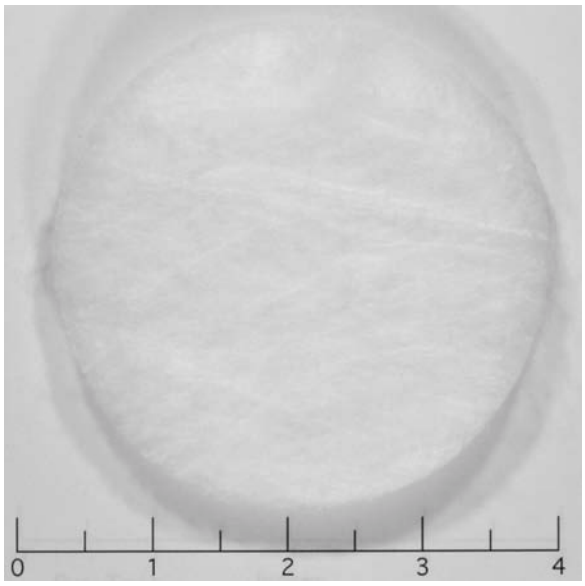
Coupon 3T-13, 70°F, Post-Test, Scale in inches



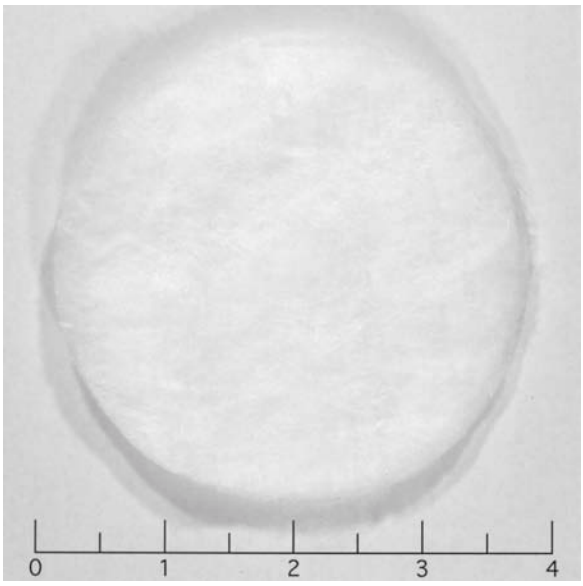
Coupon 3T-14, 70°F, Pre-Test, Scale in inches



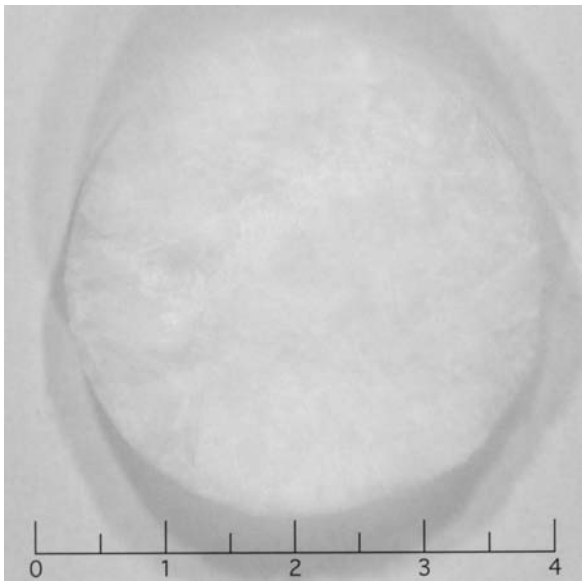
Coupon 3T-14, 70°F, Post-Test, Scale in inches



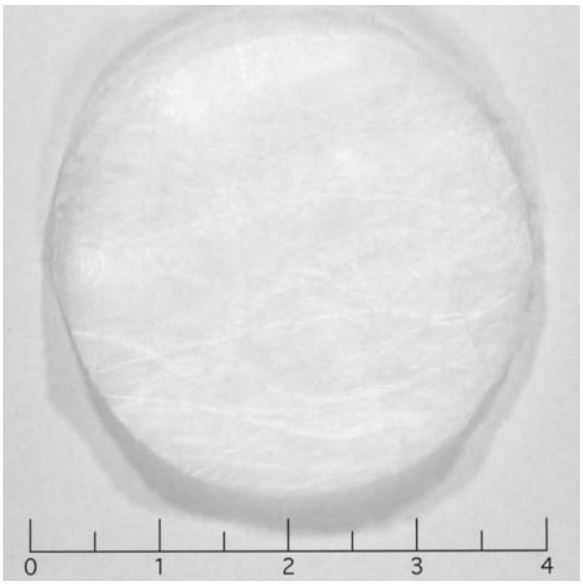
Coupon 3T-15, 70°F, Pre-Test, Scale in inches



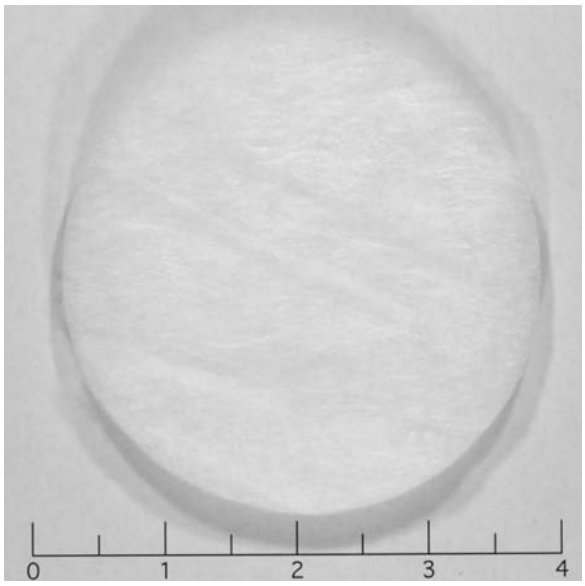
Coupon 3T-15, 70°F, Post-Test, Scale in inches



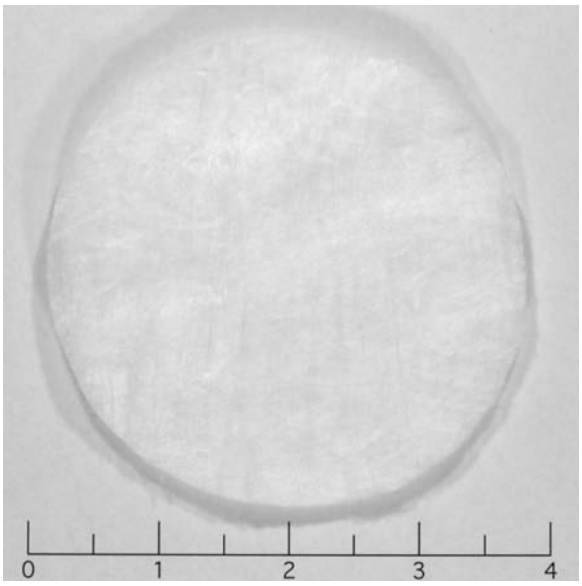
Coupon 3T-16, 70°F, Pre-Test, Scale in inches



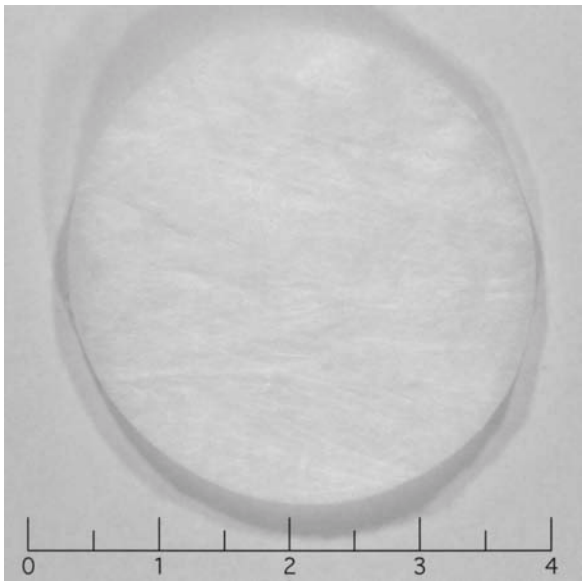
Coupon 3T-16, 70°F, Post-Test, Scale in inches



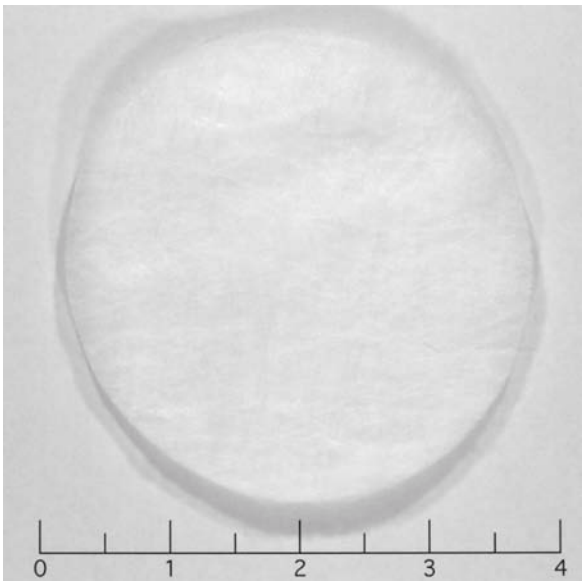
Coupon 3T-17, 70°F, Pre-Test, Scale in inches



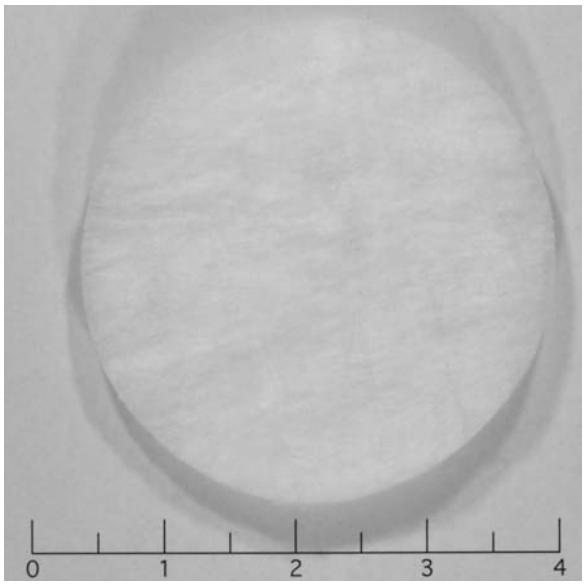
Coupon 3T-17, 70°F, Post-Test, Scale in inches



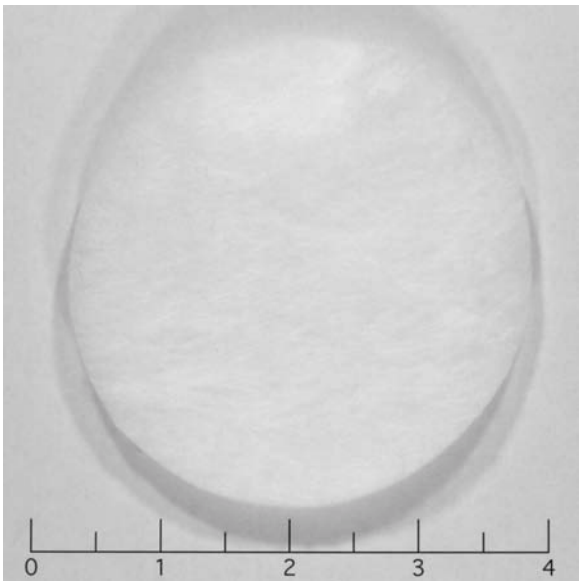
Coupon 3T-18, 70°F, Pre-Test, Scale in inches



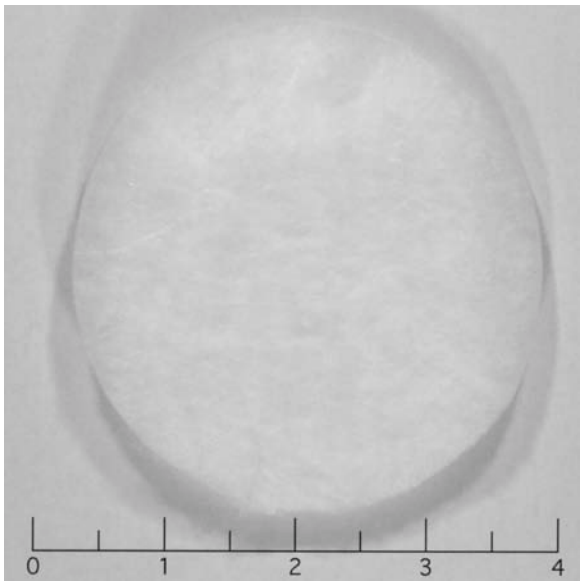
Coupon 3T-18, 70°F, Post-Test, Scale in inches



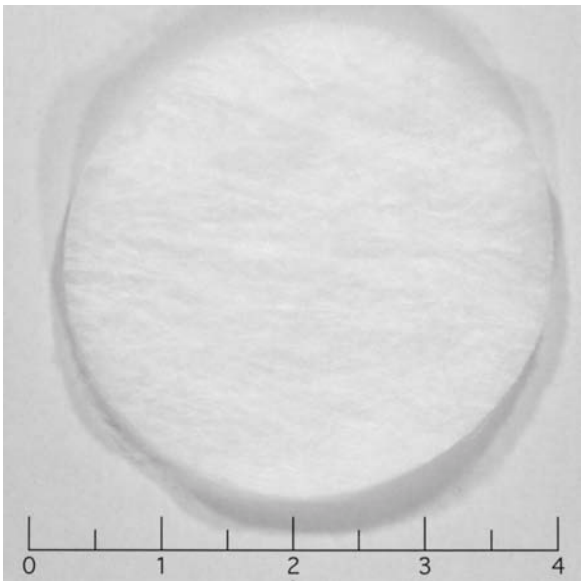
Coupon 3T-19, 70°F, Pre-Test, Scale in inches



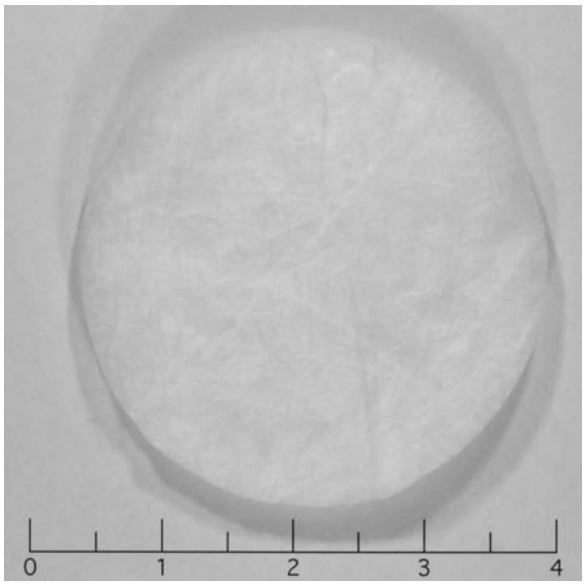
Coupon 3T-19, 70°F, Post-Test, Scale in inches



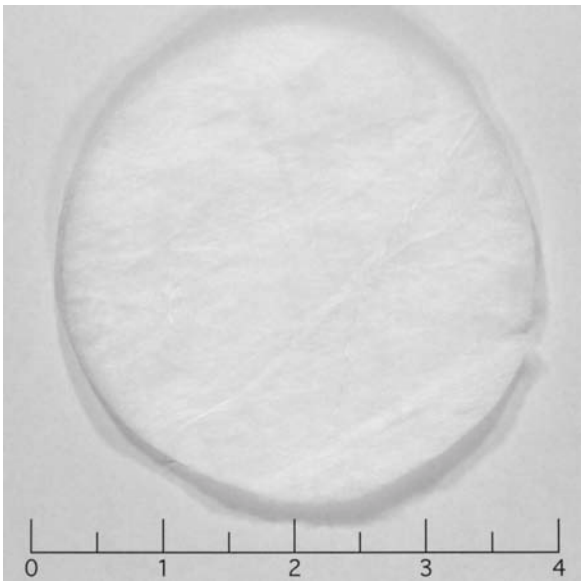
Coupon 3T-20, 70°F, Pre-Test, Scale in inches



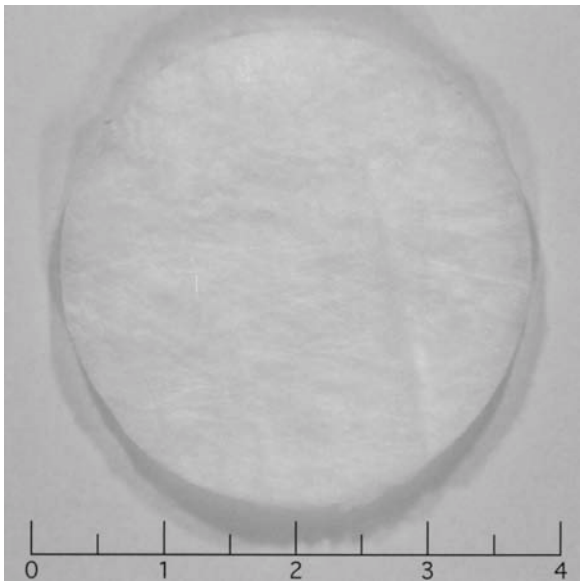
Coupon 3T-20, 70°F, Post-Test, Scale in inches



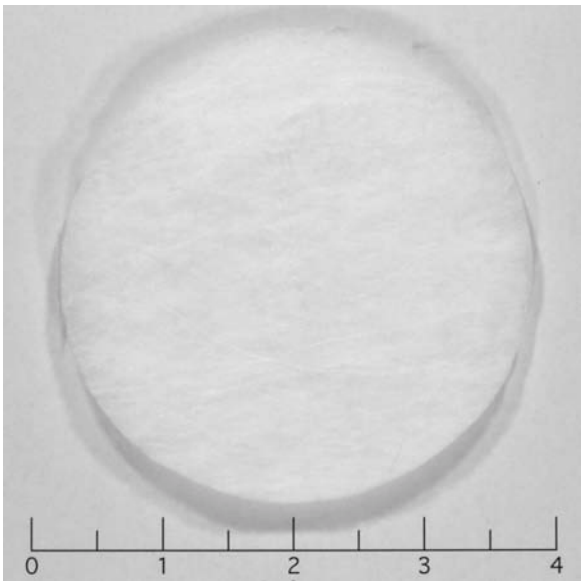
Coupon 3T-21, 70°F, Pre-Test, Scale in inches



Coupon 3T-21, 70°F, Post-Test, Scale in inches

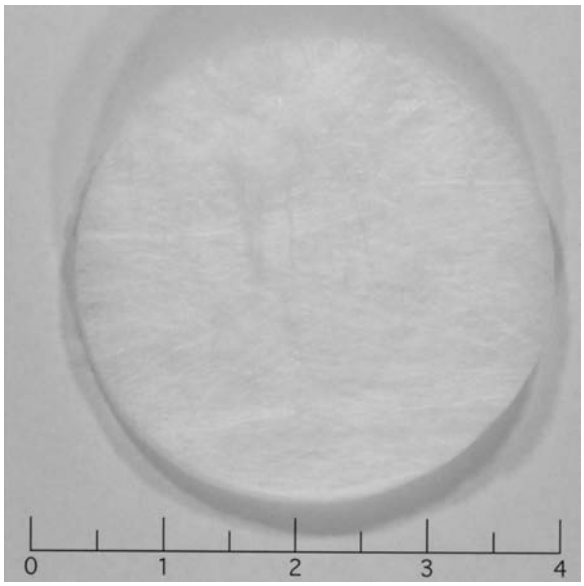


Coupon 3T-27, 70°F, Pre-Test, Scale in inches

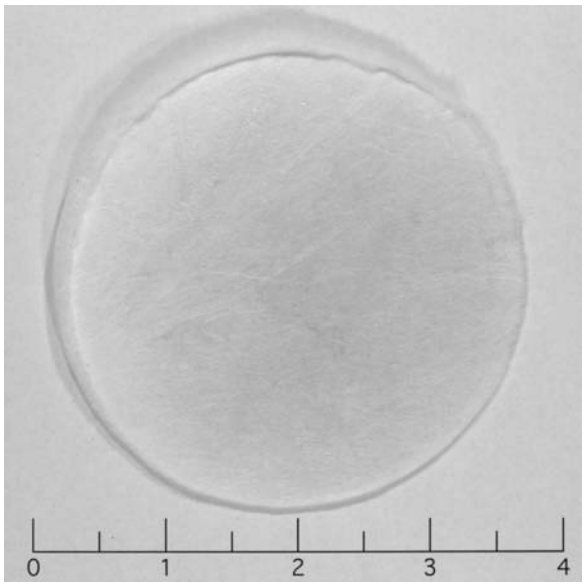


Coupon 3T-27, 70°F, Post-Test, Scale in inches

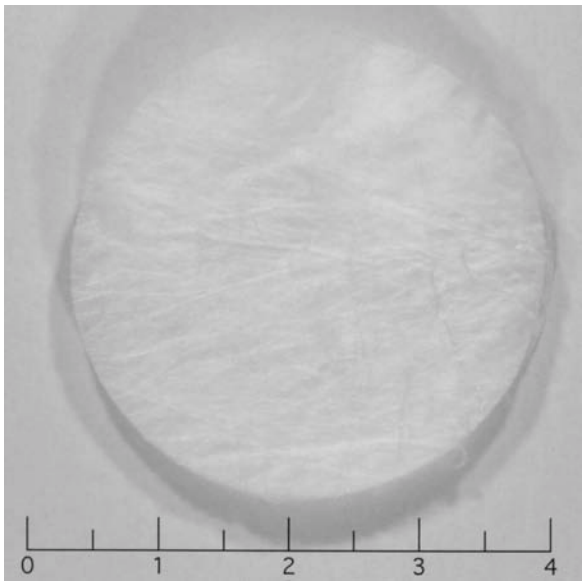
Alumina Fiber Insulation 0.15-inch 3 lb/ft^3 Pre and Post Test Pictures 2300°F



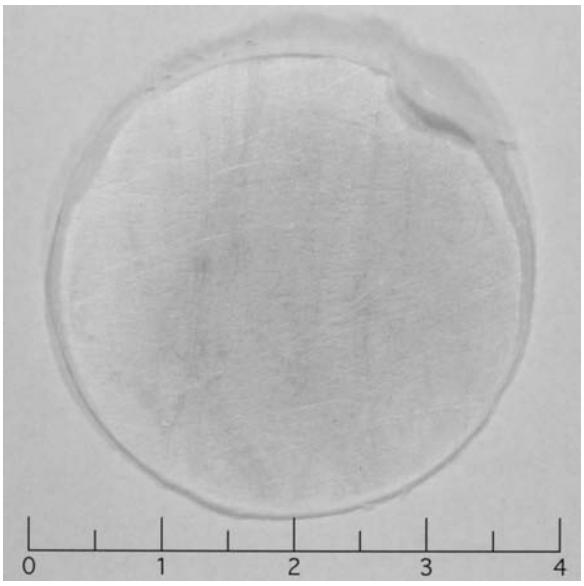
Coupon 3T-22, 2300°F, Pre-Test, Scale in inches



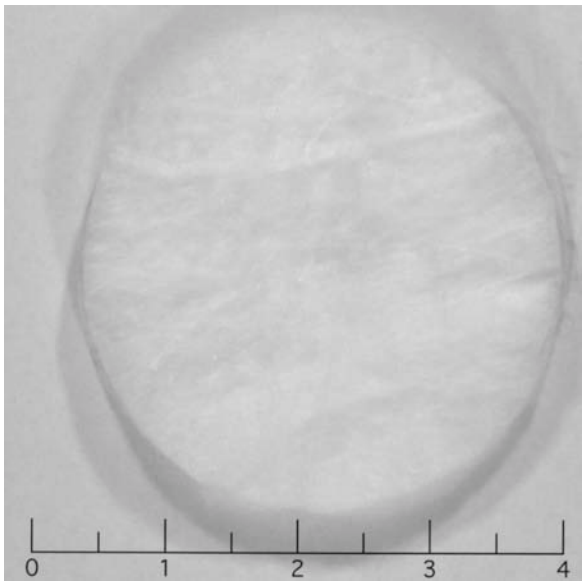
Coupon 3T-22, 2300°F, Post-Test, Scale in inches



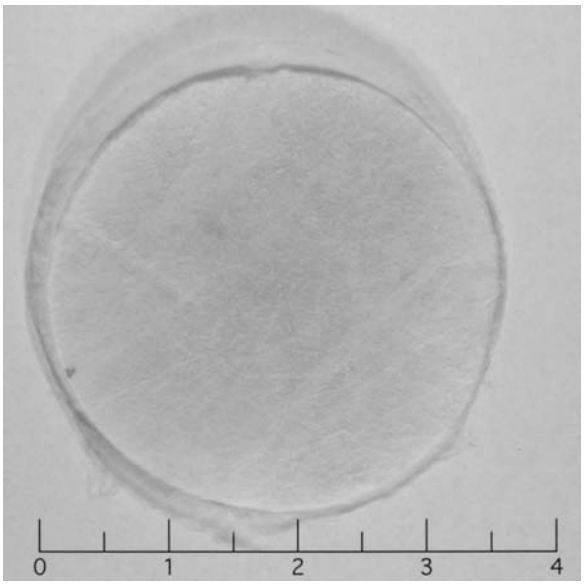
Coupon 3T-23, 2300°F, Pre-Test, Scale in inches



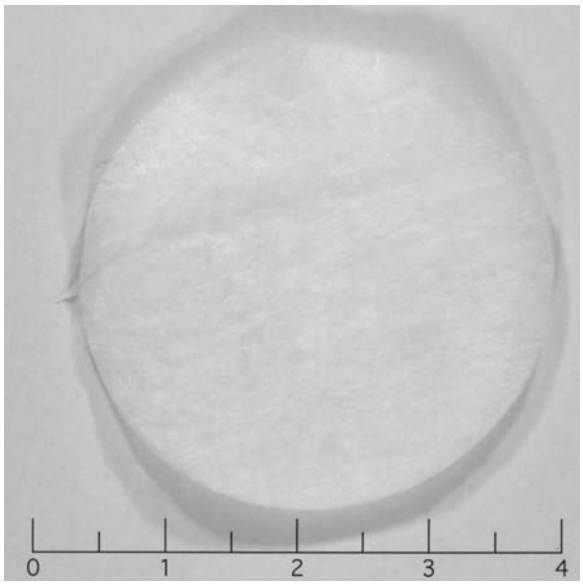
Coupon 3T-23, 2300°F, Post-Test, Scale in inches



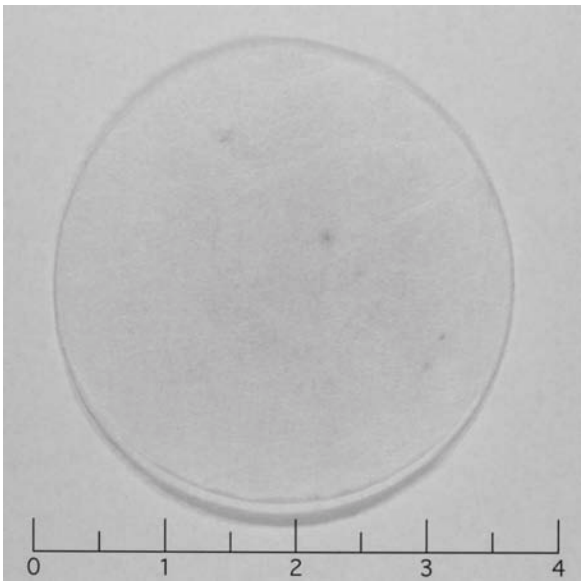
Coupon 3T-24, 2300°F, Pre-Test, Scale in inches



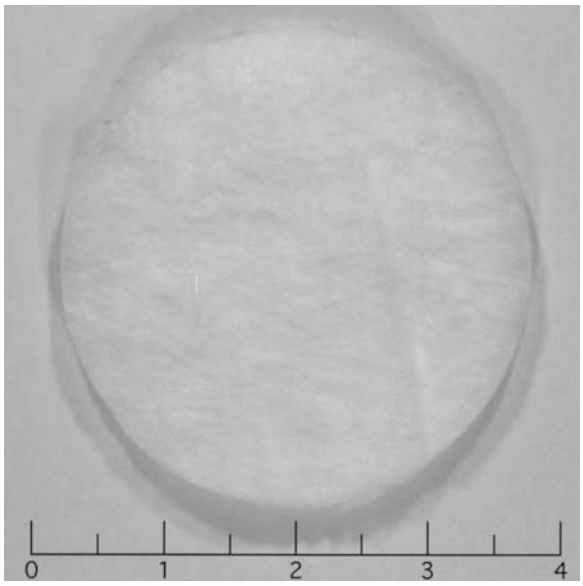
Coupon 3T-24, 2300°F, Post-Test, Scale in inches



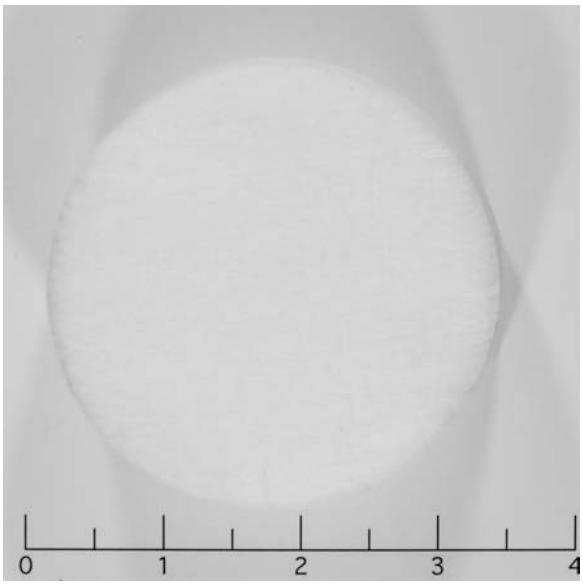
Coupon 3T-25, 2300°F, Pre-Test, Scale in inches



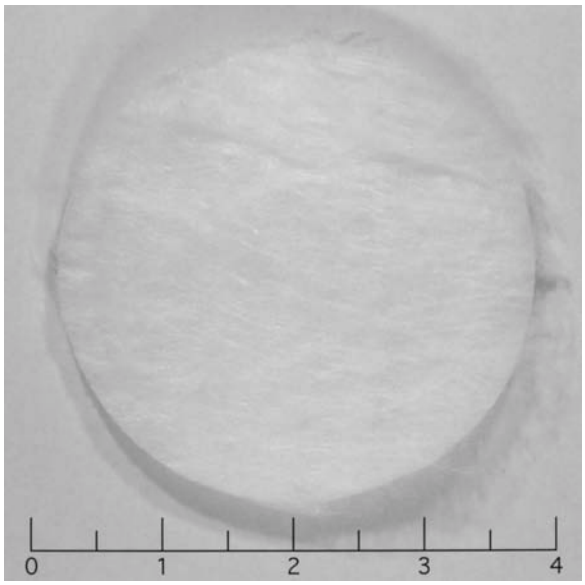
Coupon 3T-25, 2300°F, Post-Test, Scale in inches



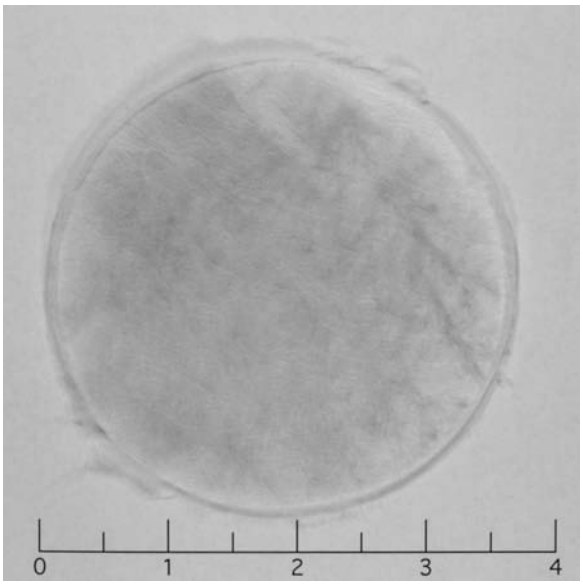
Coupon 3T-26, 2300°F, Pre-Test, Scale in inches



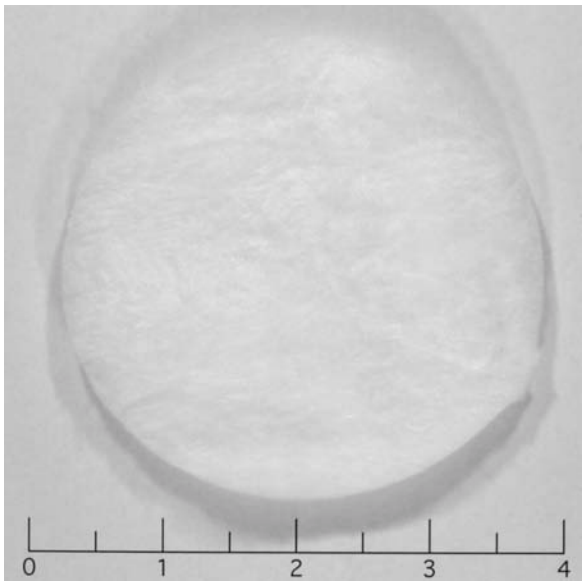
Coupon 3T-26, 2300°F, Post-Test, Scale in inches



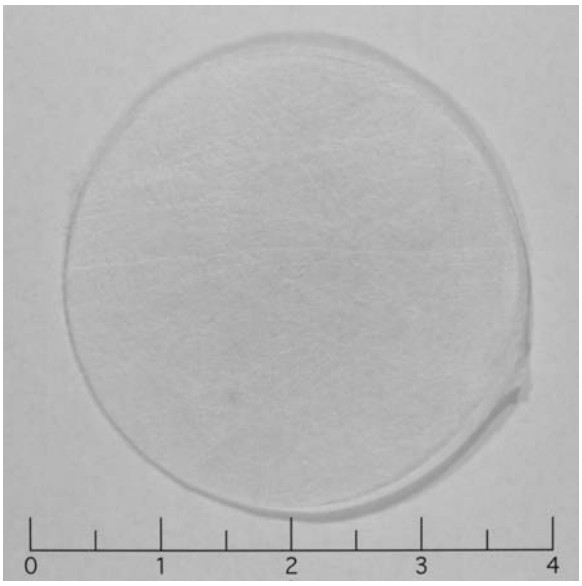
Coupon 3T-28, 2300°F, Pre-Test, Scale in inches



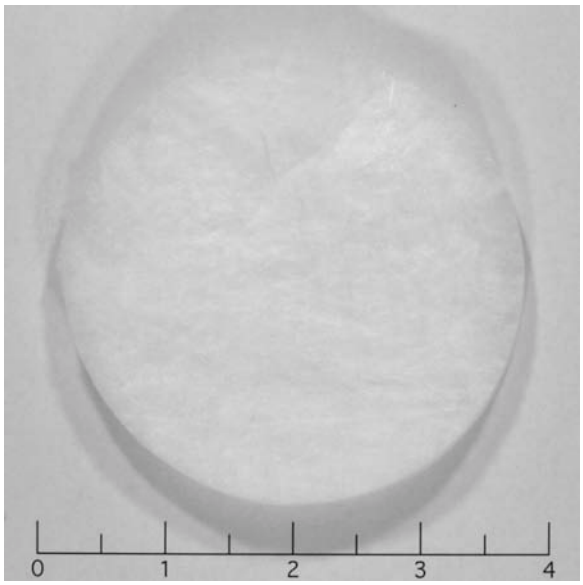
Coupon 3T-28, 2300°F, Post-Test, Scale in inches



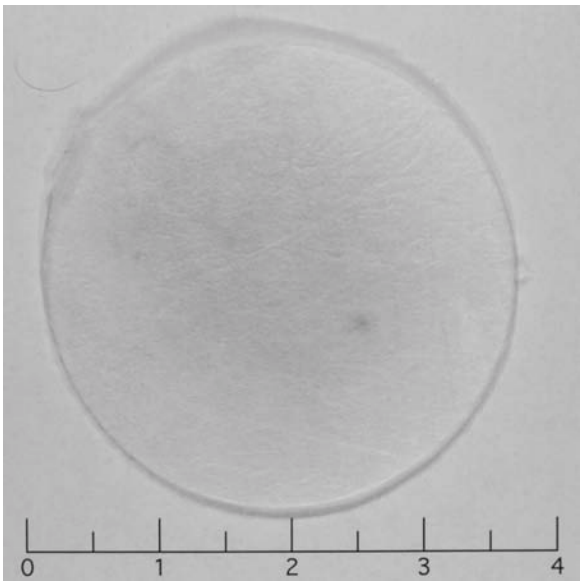
Coupon 3T-29, 2300°F, Pre-Test, Scale in inches



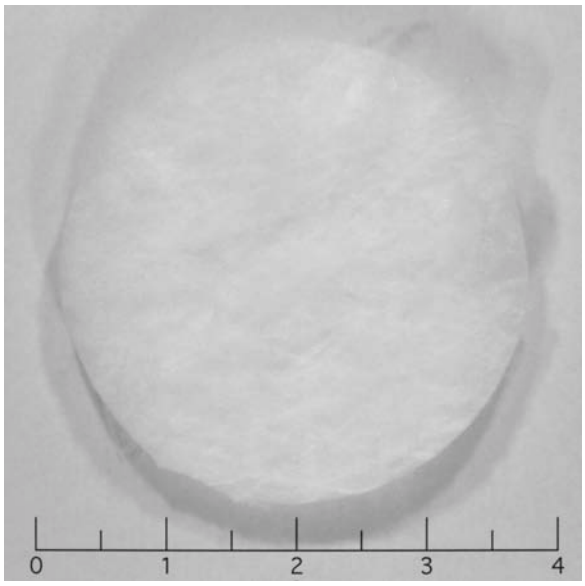
Coupon 3T-29, 2300°F, Post-Test, Scale in inches



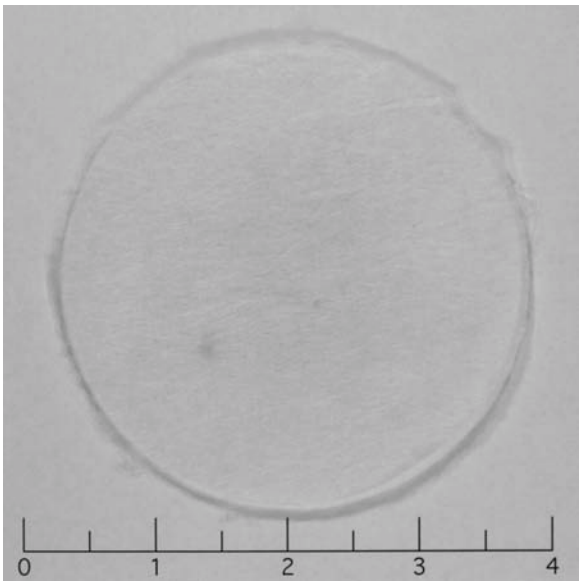
Coupon 3T-30, 2300°F, Pre-Test, Scale in inches



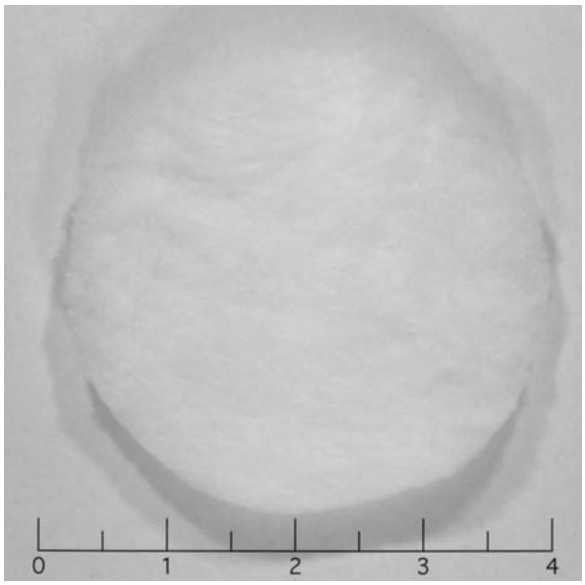
Coupon 3T-30, 2300°F, Post-Test, Scale in inches



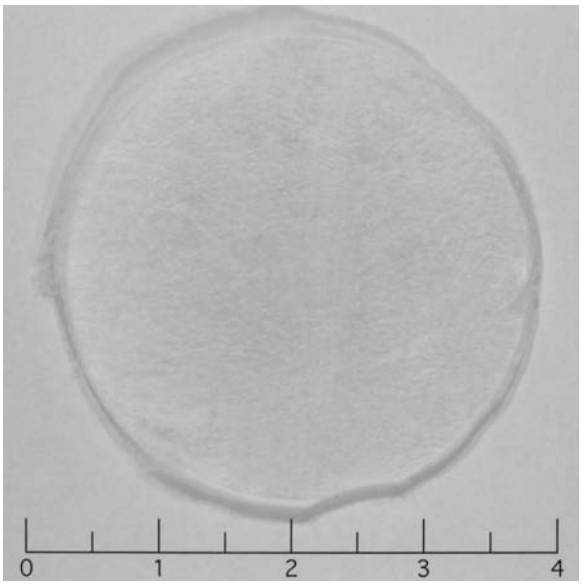
Coupon 3T-31, 2300°F, Pre-Test, Scale in inches



Coupon 3T-31, 2300°F, Post-Test, Scale in inches

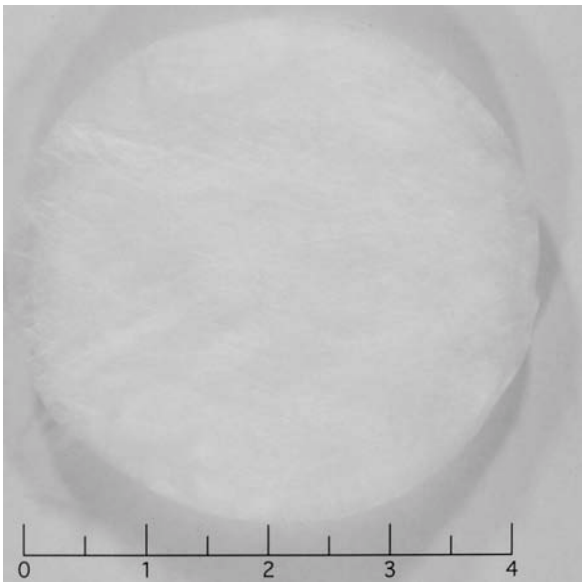


Coupon 3T-32, 2300°F, Pre-Test, Scale in inches

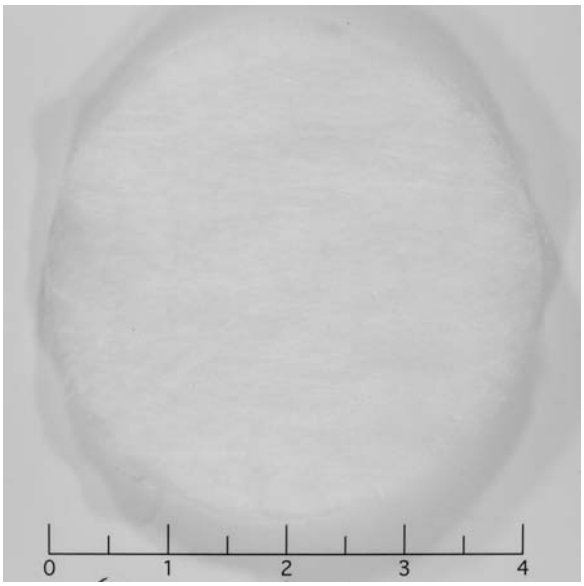


Coupon 3T-32, 2300°F, Post-Test, Scale in inches

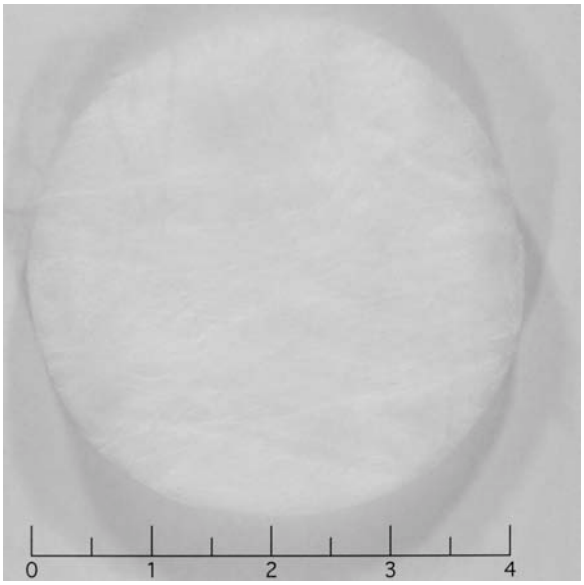
Alumina Fiber Insulation 0.25-inch 3 lb/ft^3 Pre and Post Test Pictures RT



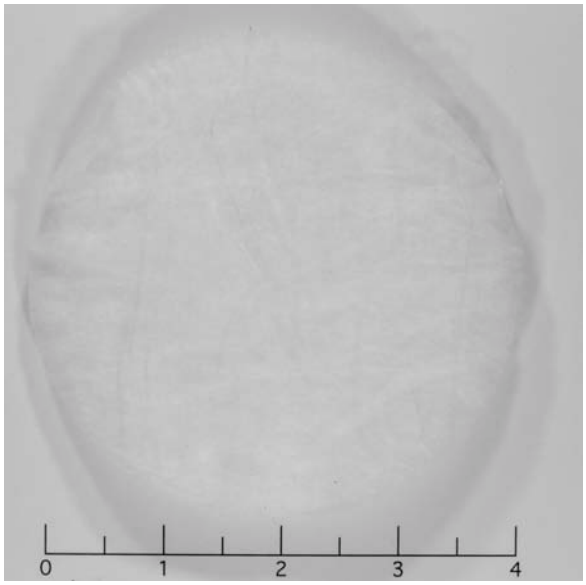
Coupon 3P-01, 70°F, Pre-Test, Scale in inches



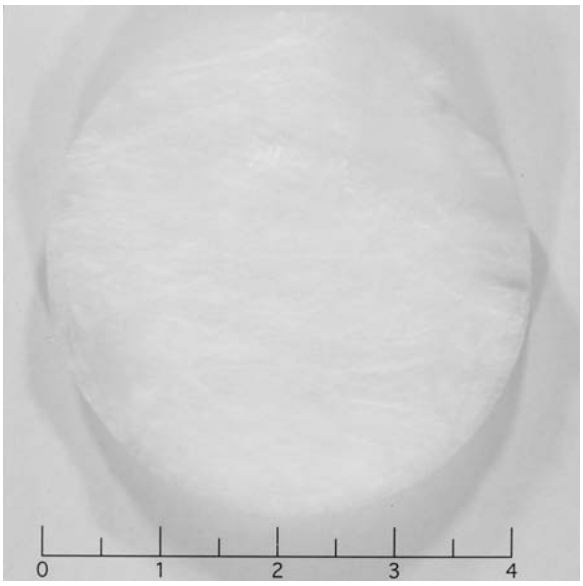
Coupon 3P-01, 70°F, Post-Test, Scale in inches



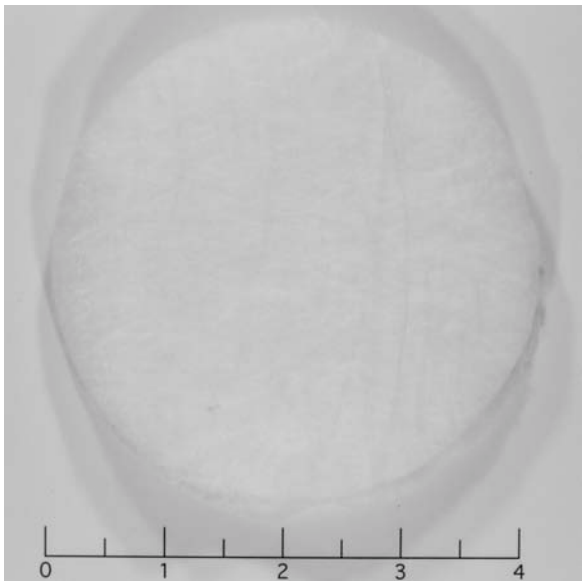
Coupon 3P-02, 70°F, Pre-Test, Scale in inches



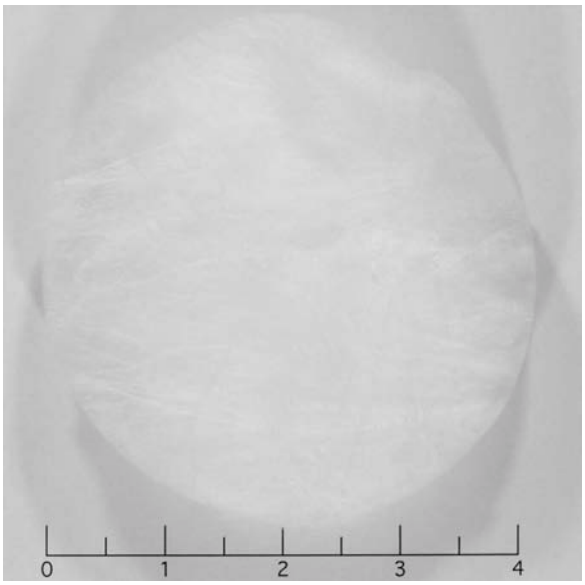
Coupon 3P-02, 70°F, Post-Test, Scale in inches



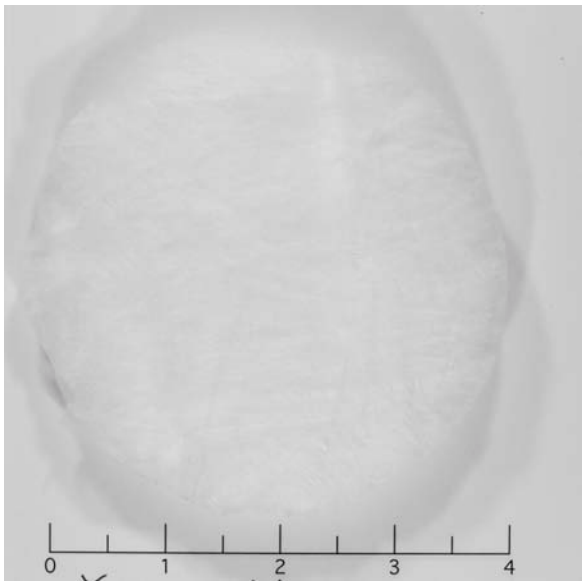
Coupon 3P-03, 70°F, Pre-Test, Scale in inches



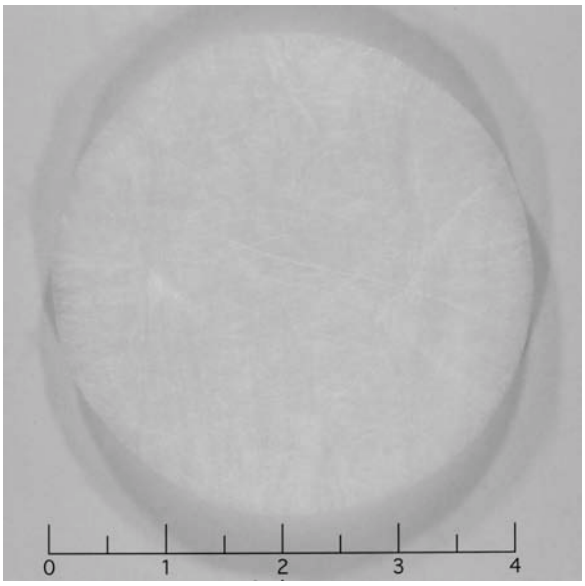
Coupon 3P-03, 70°F, Post-Test, Scale in inches



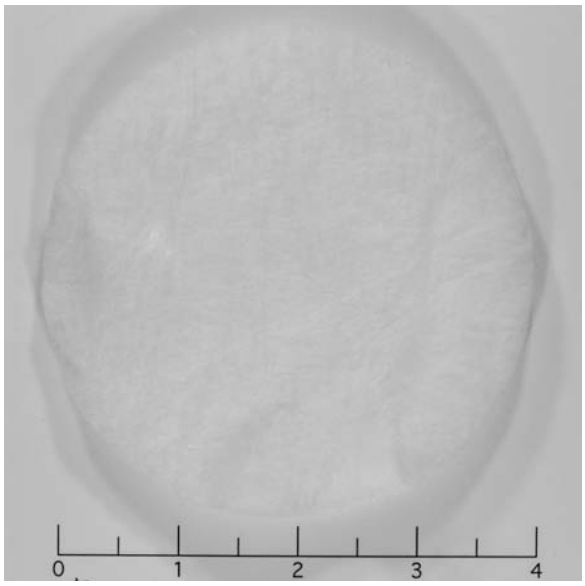
Coupon 3P-04, 70°F, Pre-Test, Scale in inches



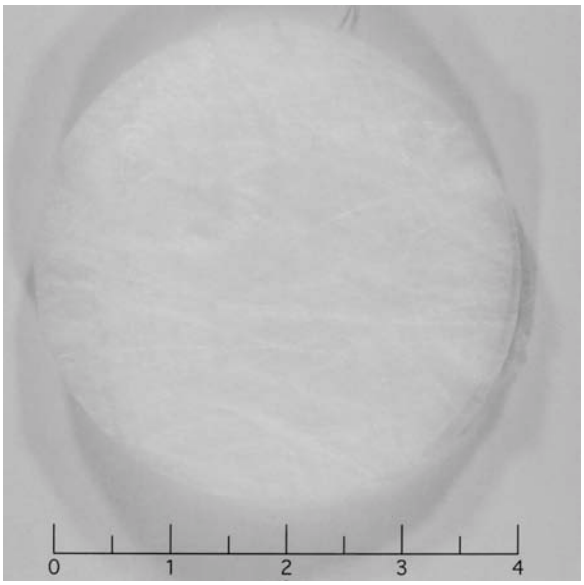
Coupon 3P-04, 70°F, Post-Test, Scale in inches



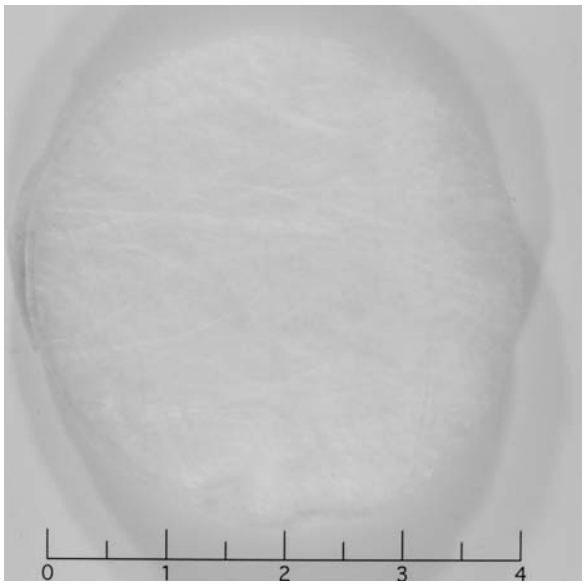
Coupon 3P-05, 70°F, Pre-Test, Scale in inches



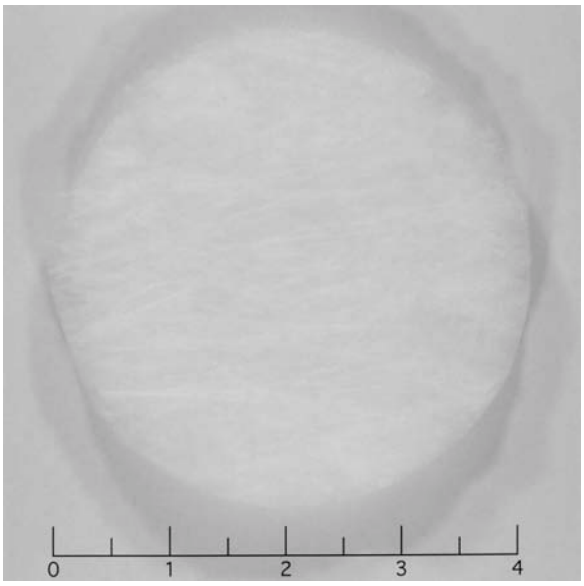
Coupon 3P-05, 70°F, Post-Test, Scale in inches



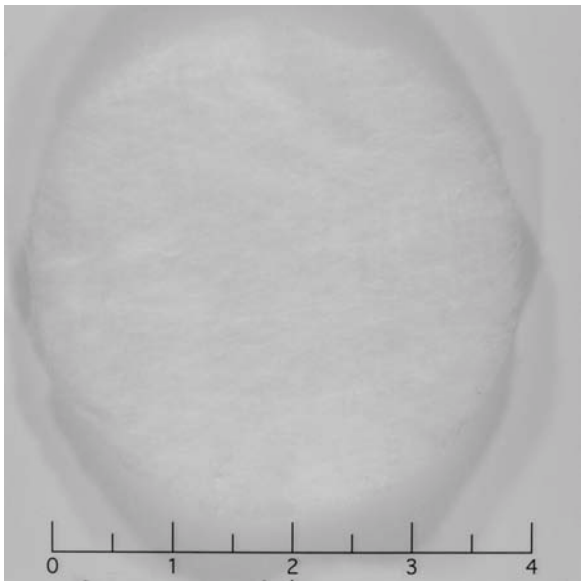
Coupon 3P-06, 70°F, Pre-Test, Scale in inches



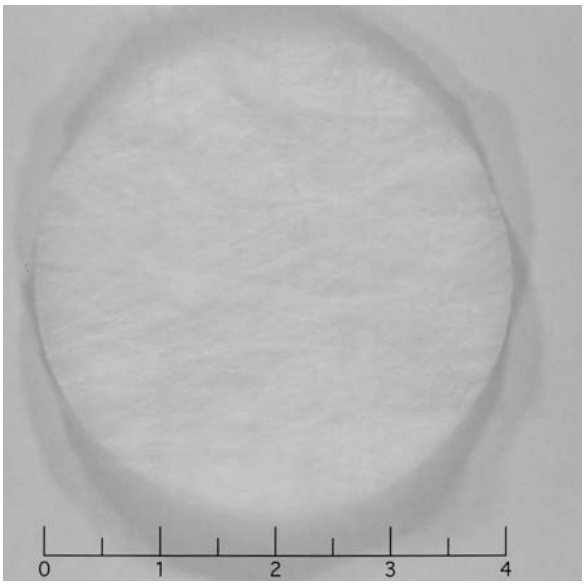
Coupon 3P-06, 70°F, Post-Test, Scale in inches



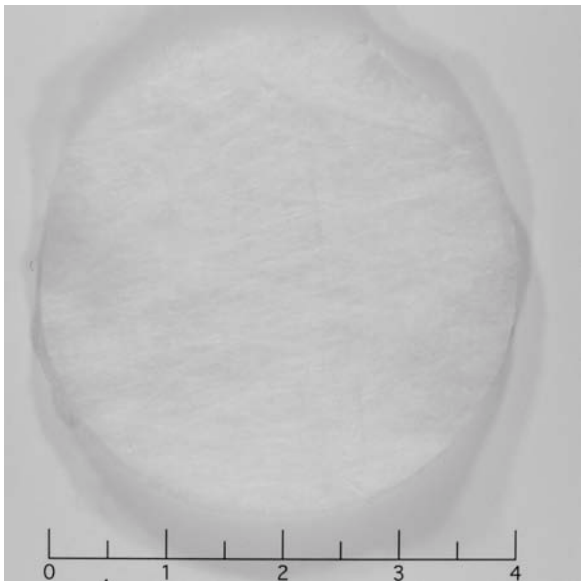
Coupon 3P-07, 70°F, Pre-Test, Scale in inches



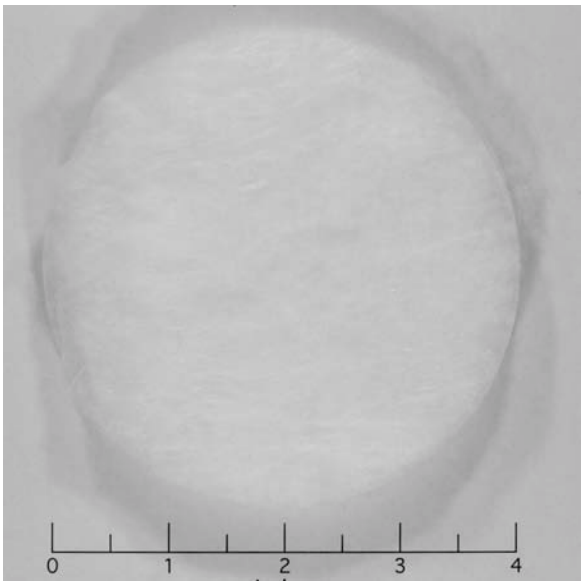
Coupon 3P-07, 70°F, Post-Test, Scale in inches



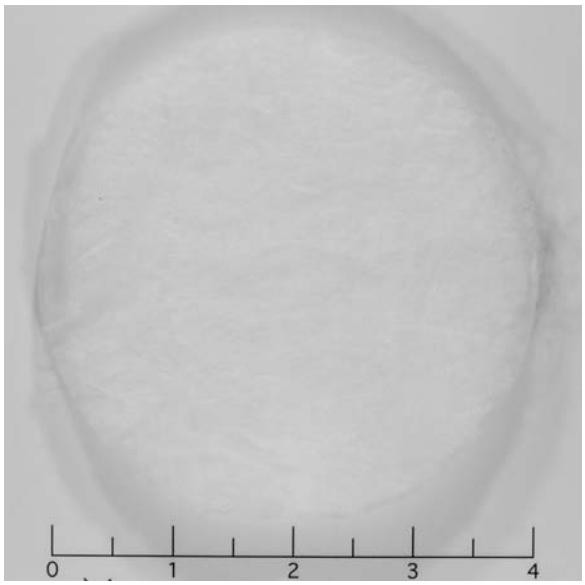
Coupon 3P-08, 70°F, Pre-Test, Scale in inches



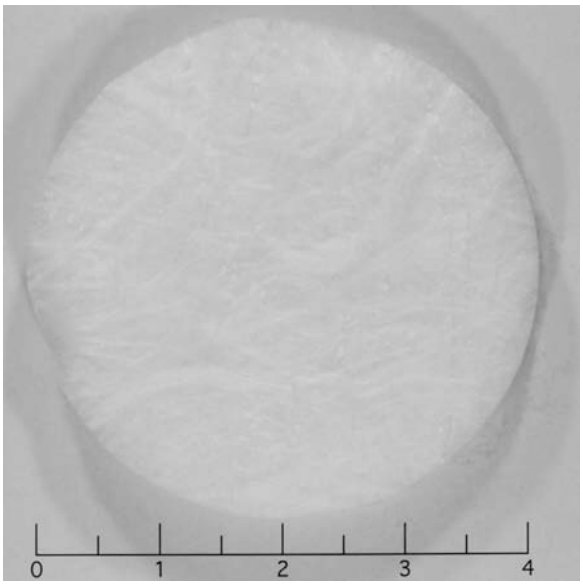
Coupon 3P-08, 70°F, Post-Test, Scale in inches



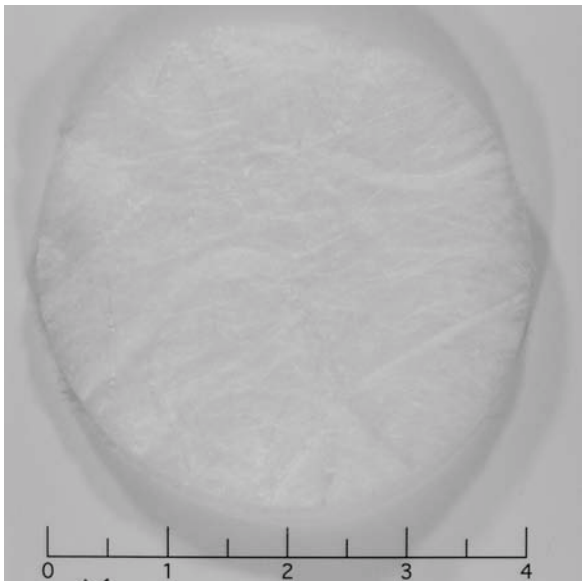
Coupon 3P-09, 70°F, Pre-Test, Scale in inches



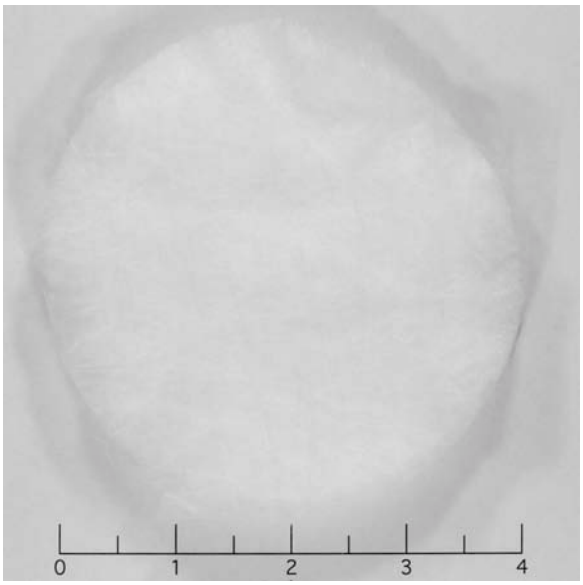
Coupon 3P-09, 70°F, Post-Test, Scale in inches



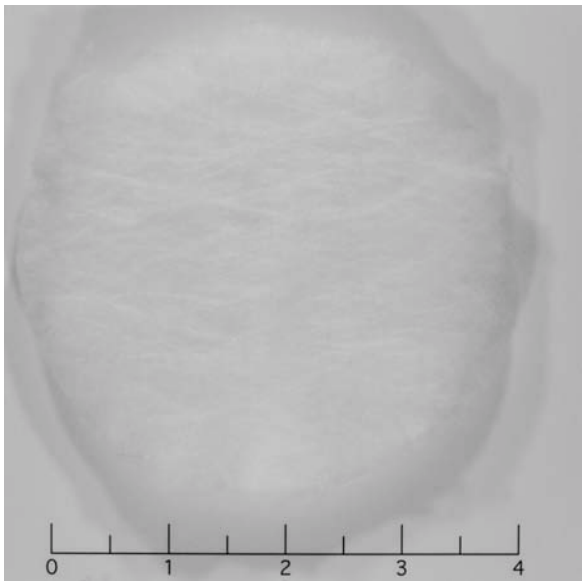
Coupon 3P-10, 70°F, Pre-Test, Scale in inches



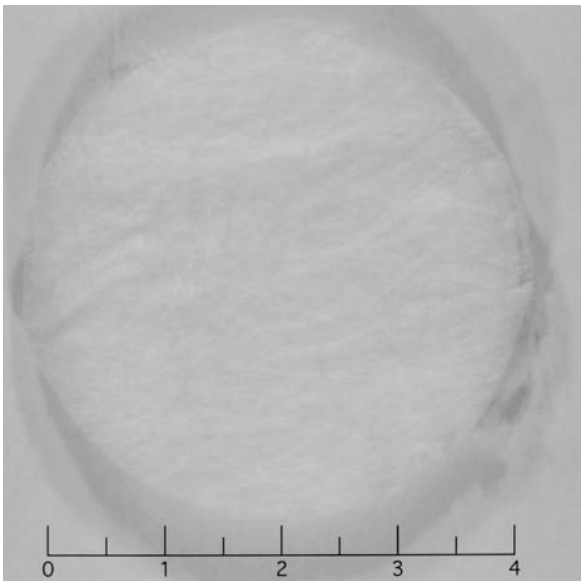
Coupon 3P-10, 70°F, Post-Test, Scale in inches



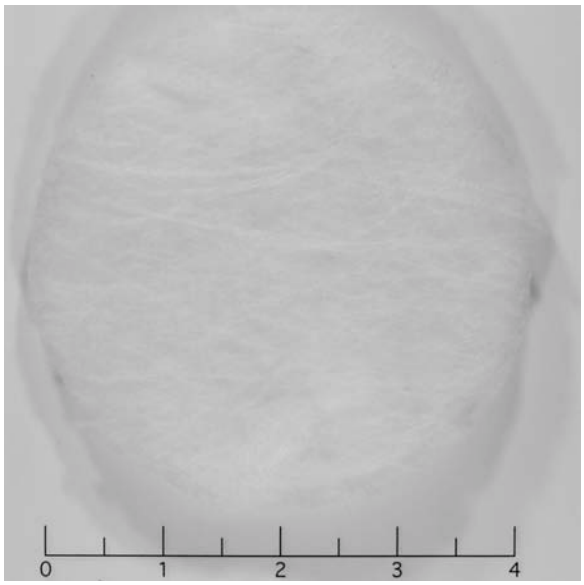
Coupon 3P-11, 70°F, Pre-Test, Scale in inches



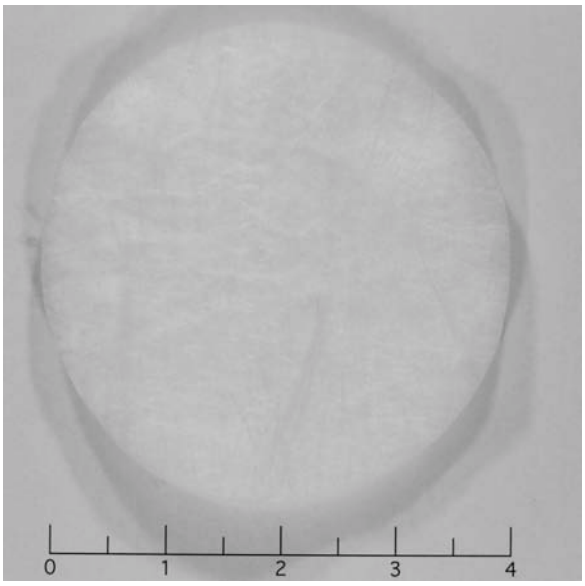
Coupon 3P-11, 70°F, Post-Test, Scale in inches



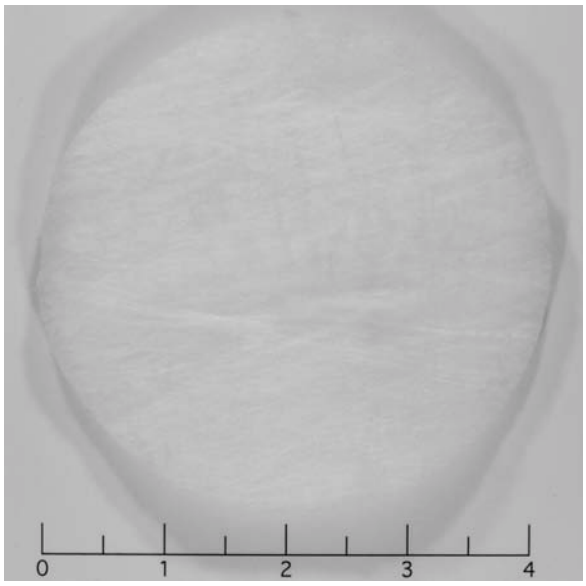
Coupon 3P-12, 70°F, Pre-Test, Scale in inches



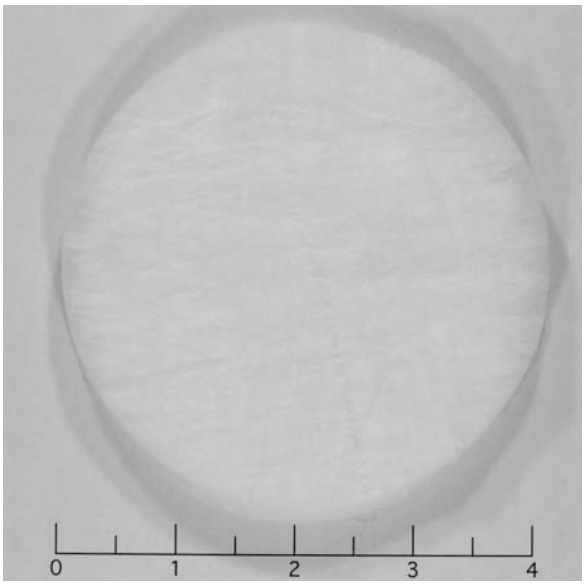
Coupon 3P-12, 70°F, Post-Test, Scale in inches



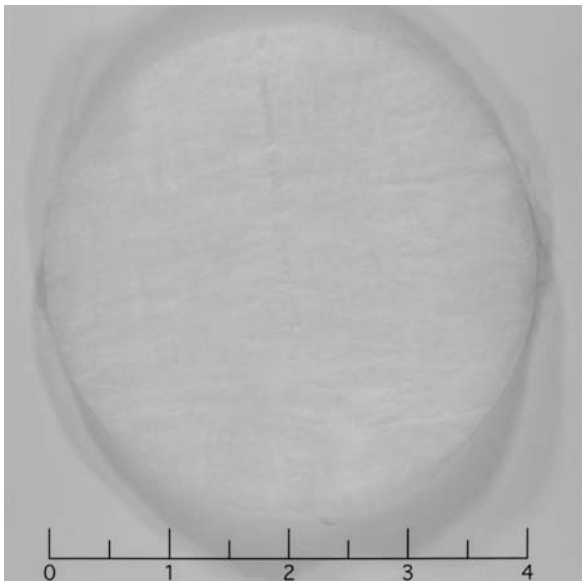
Coupon 3P-13, 70°F, Pre-Test, Scale in inches



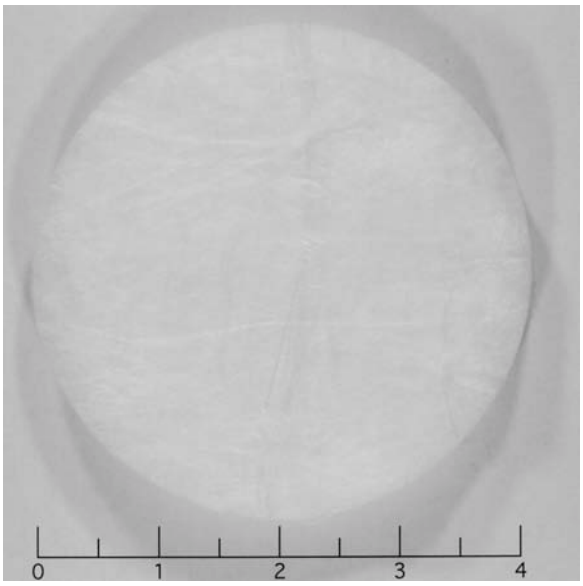
Coupon 3P-13, 70°F, Post-Test, Scale in inches



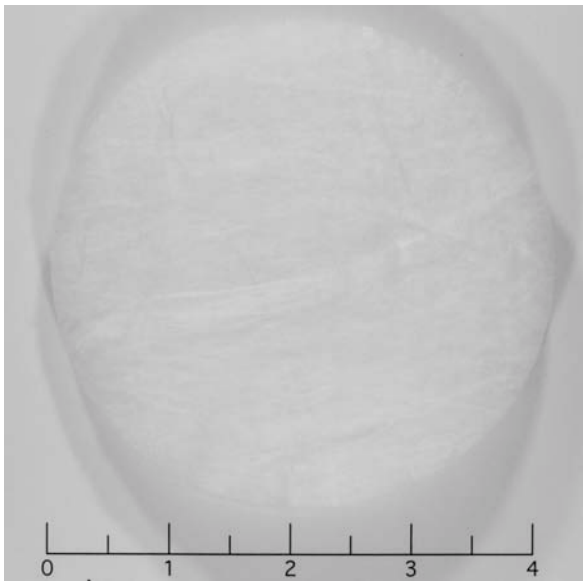
Coupon 3P-14, 70°F, Pre-Test, Scale in inches



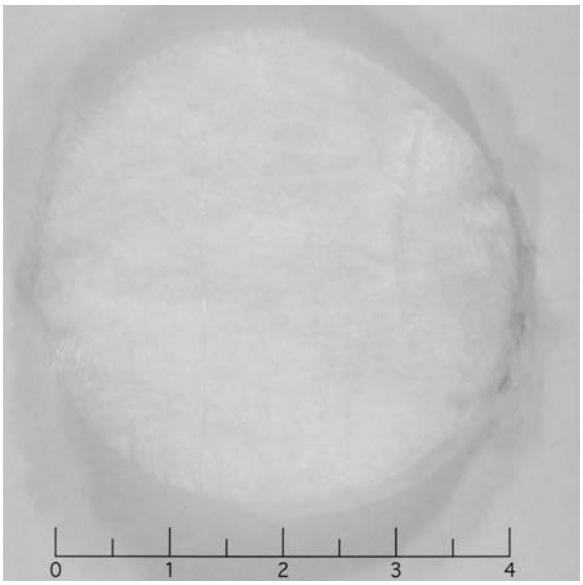
Coupon 3P-14, 70°F, Post-Test, Scale in inches



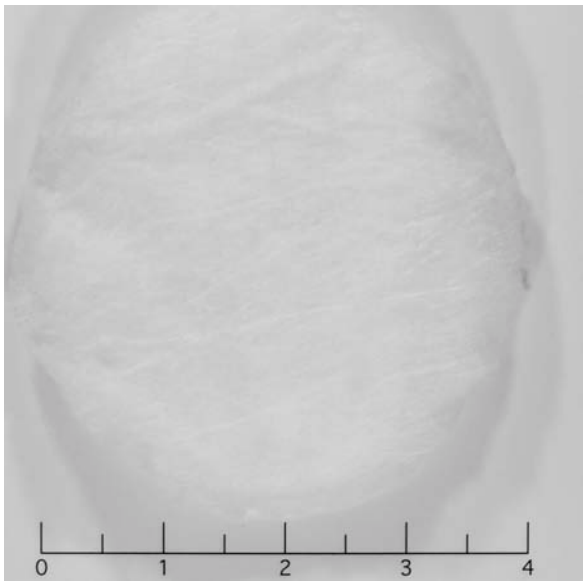
Coupon 3P-15, 70°F, Pre-Test, Scale in inches



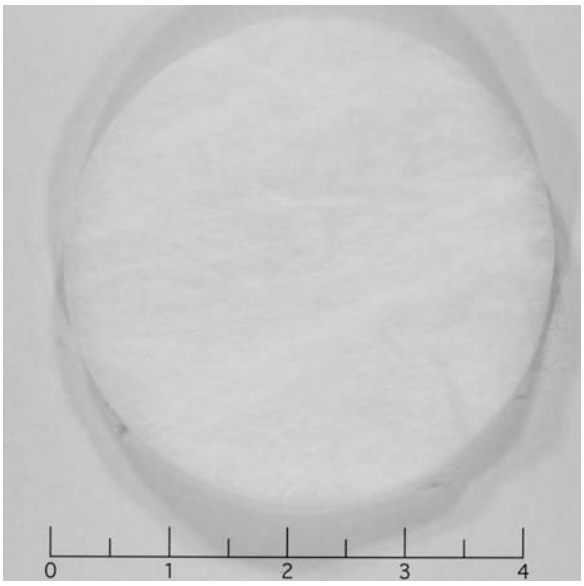
Coupon 3P-15, 70°F, Post-Test, Scale in inches



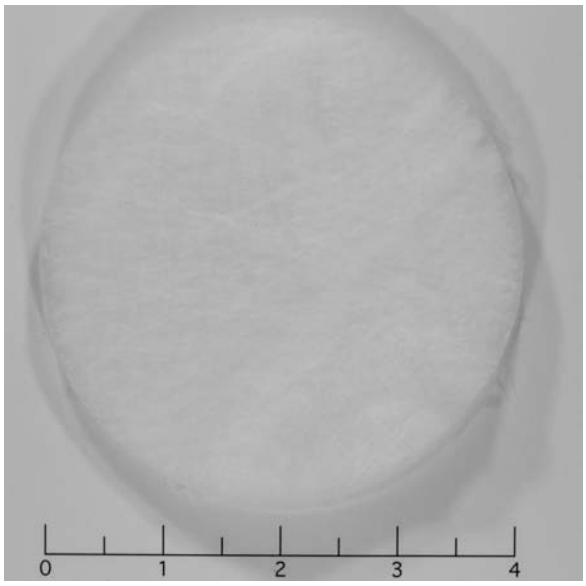
Coupon 3P-16, 70°F, Pre-Test, Scale in inches



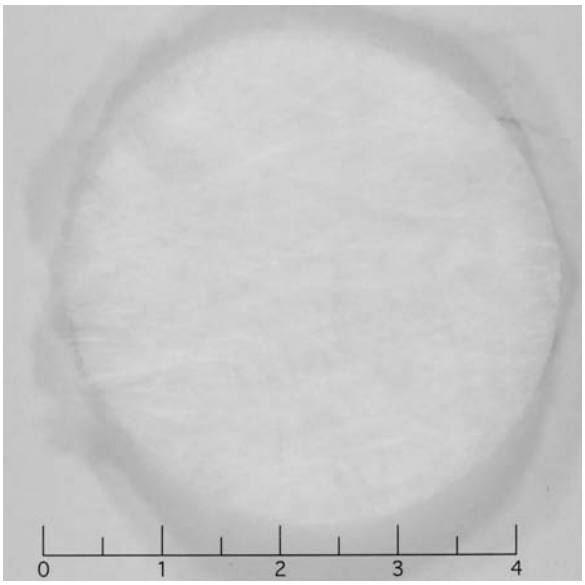
Coupon 3P-162, 70°F, Post-Test, Scale in inches



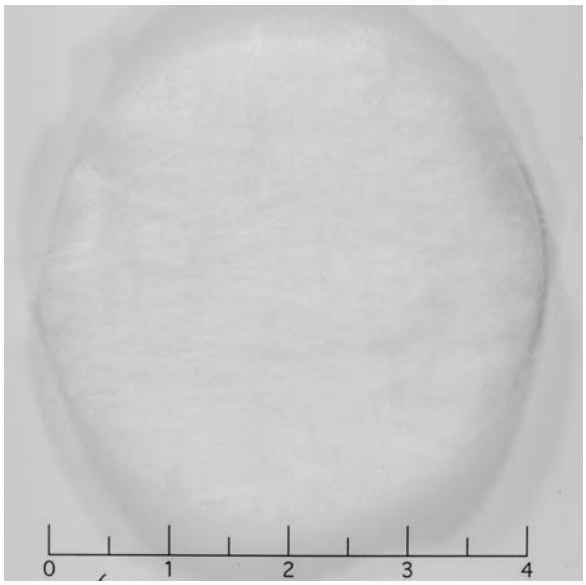
Coupon 3P-17, 70°F, Pre-Test, Scale in inches



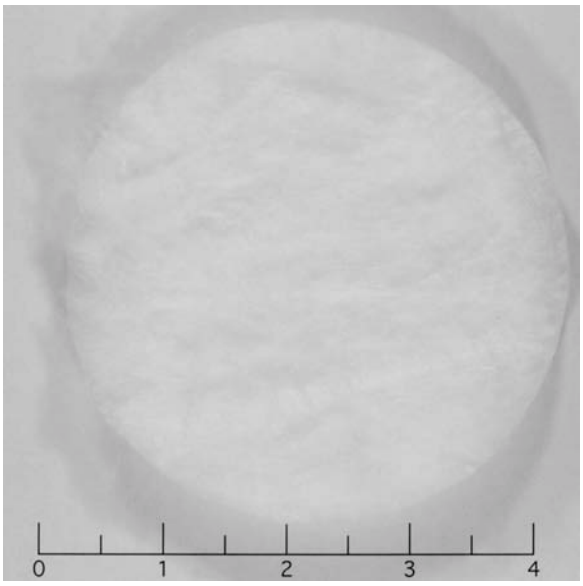
Coupon 3P-17, 70°F, Post-Test, Scale in inches



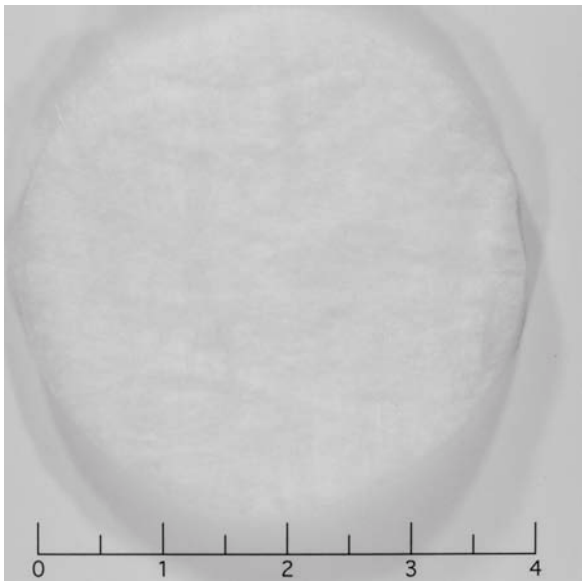
Coupon 3P-18, 70°F, Pre-Test, Scale in inches



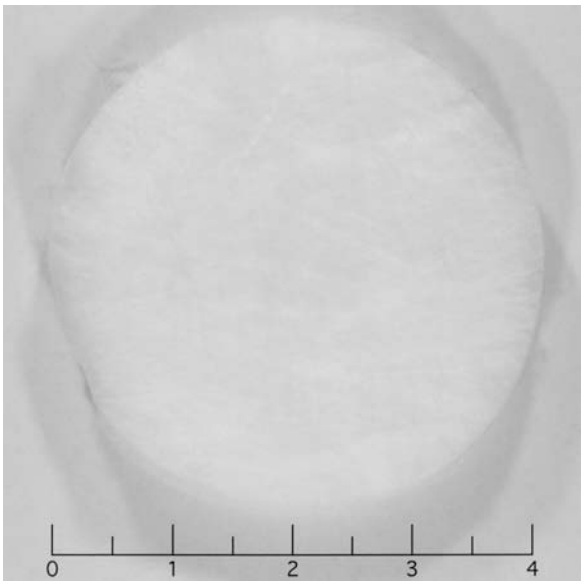
Coupon 3P-18, 70°F, Post-Test, Scale in inches



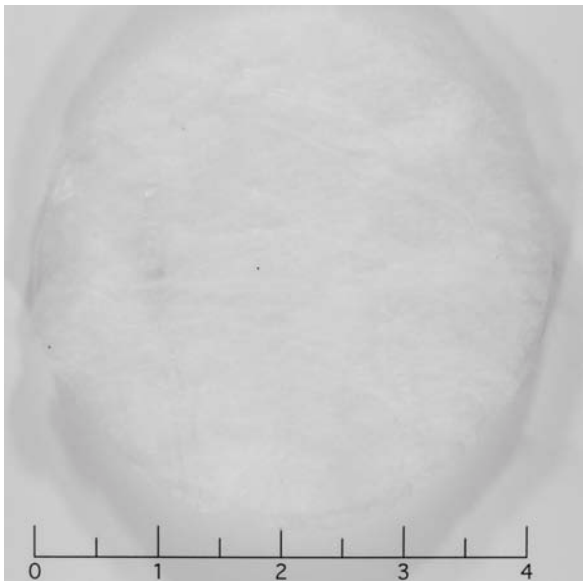
Coupon 3P-19, 70°F, Pre-Test, Scale in inches



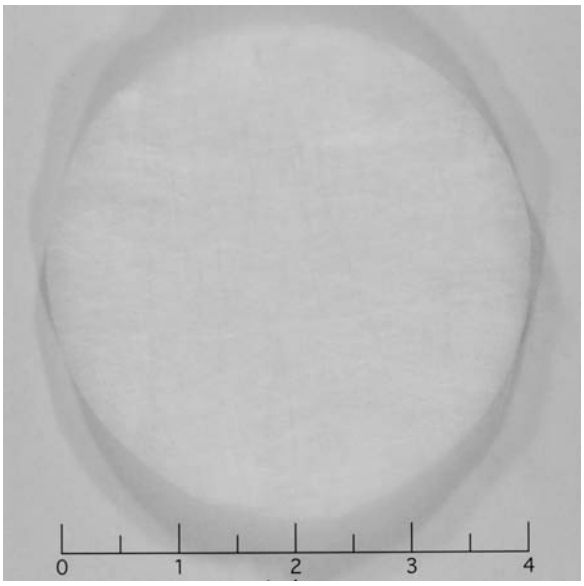
Coupon 3P-19, 70°F, Post-Test, Scale in inches



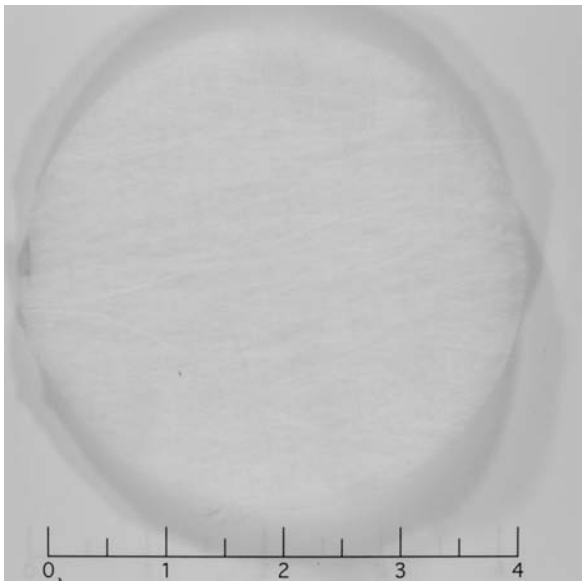
Coupon 3P-20, 70°F, Pre-Test, Scale in inches



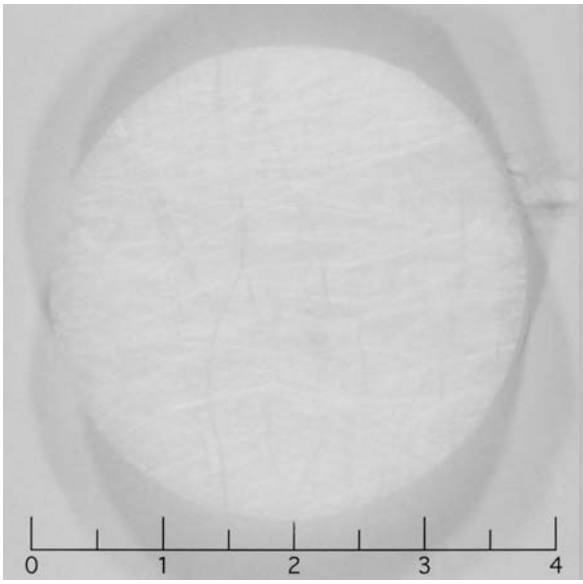
Coupon 3P-20, 70°F, Post-Test, Scale in inches



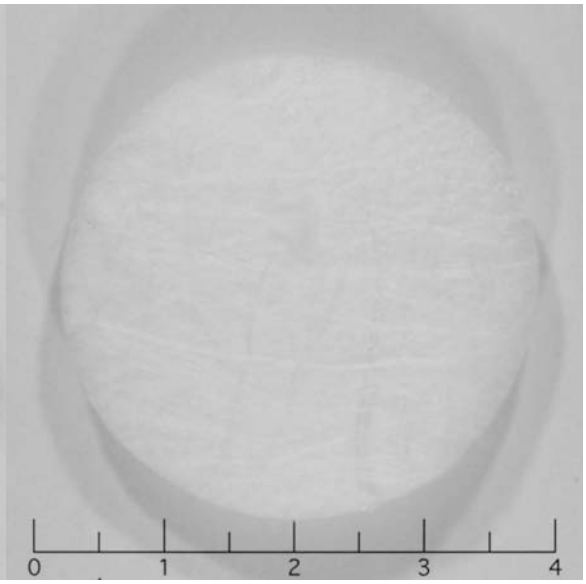
Coupon 3P-21, 70°F, Pre-Test, Scale in inches



Coupon 3P-21, 70°F, Post-Test, Scale in inches

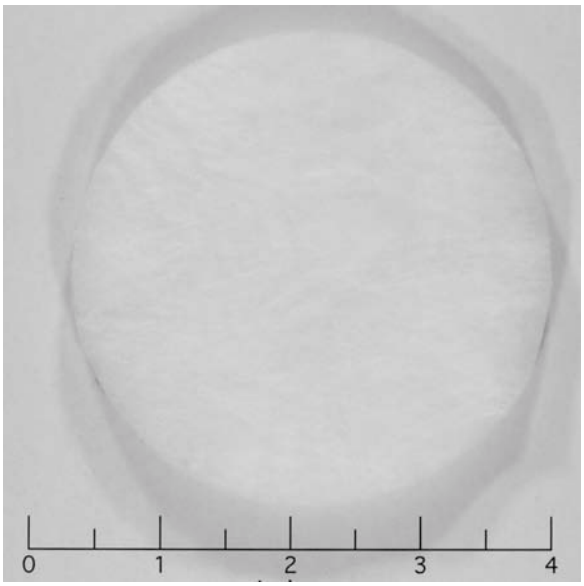


Coupon 3P-27, 70°F, Pre-Test, Scale in inches

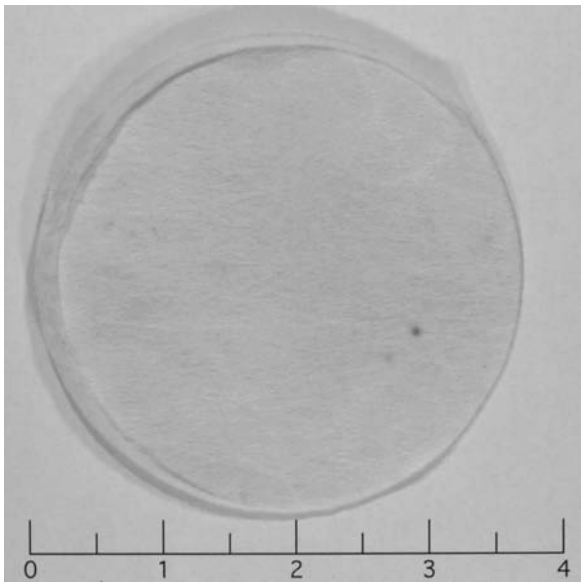


Coupon 3P-27, 70°F, Post-Test, Scale in inches

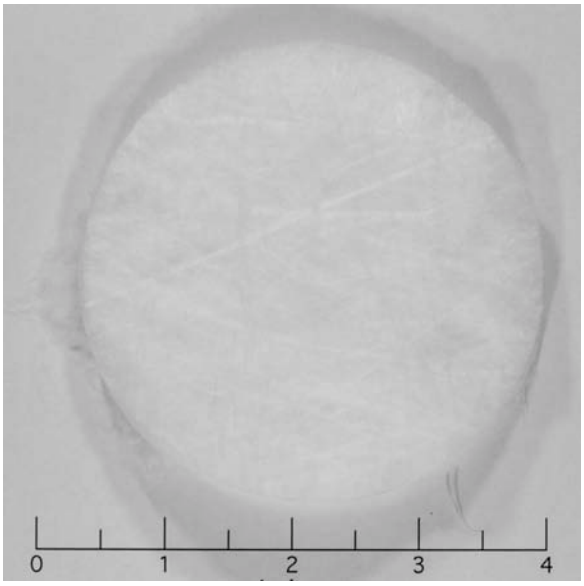
Alumina Fiber Insulation 0.25-inch 3 lb/ft^3 Pre and Post Test Pictures 2300°F



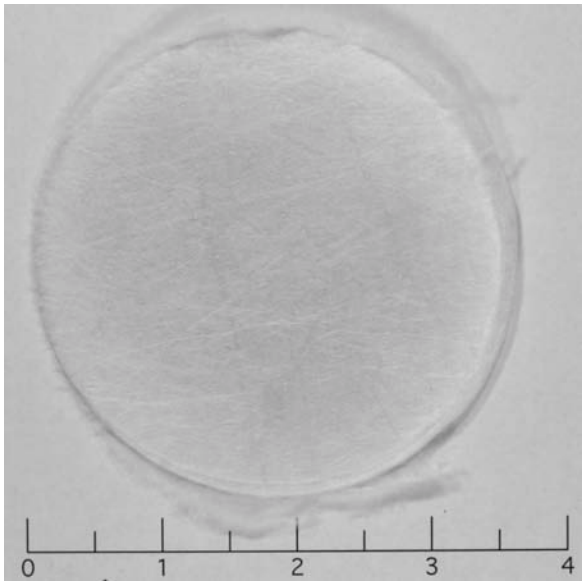
Coupon 3P-22, 2300°F, Pre-Test, Scale in inches



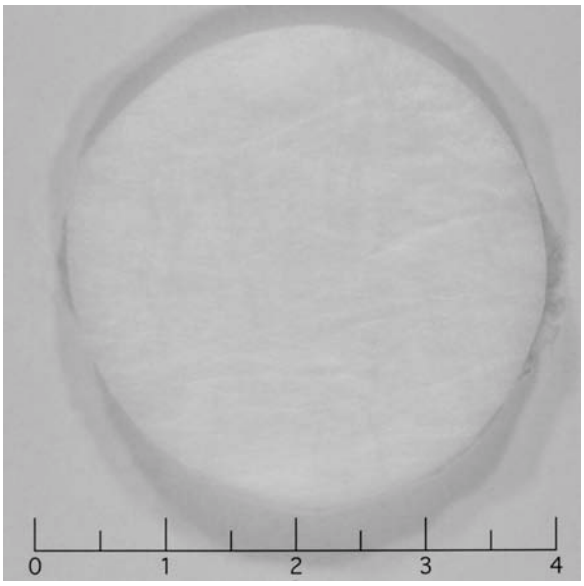
Coupon 3P-22, 2300°F, Post-Test, Scale in inches



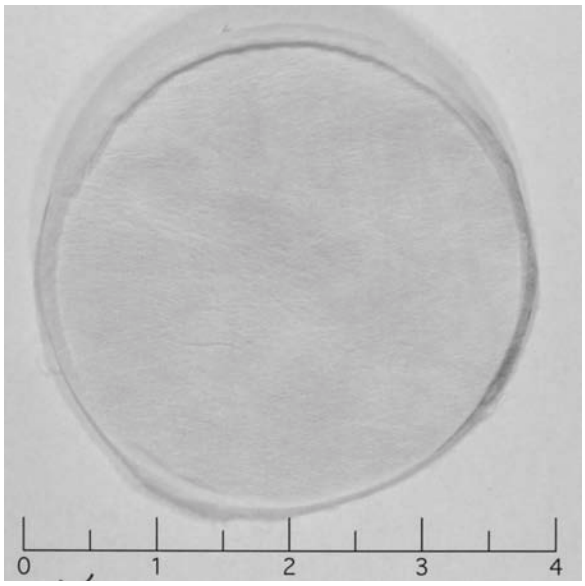
Coupon 3P-23, 2300°F, Pre-Test, Scale in inches



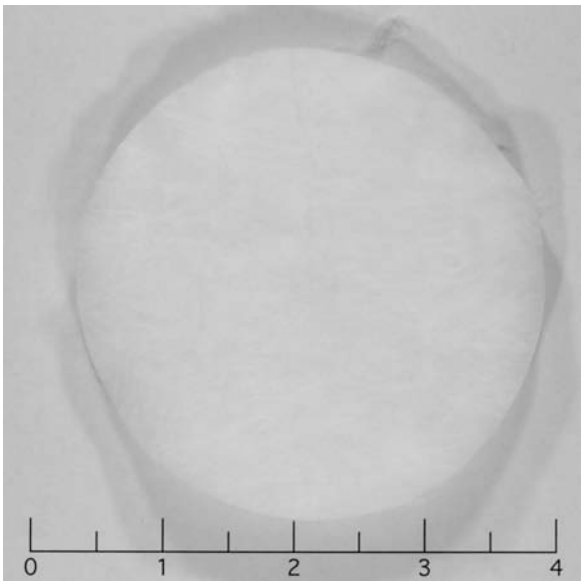
Coupon 3P-23, 2300°F, Post-Test, Scale in inches



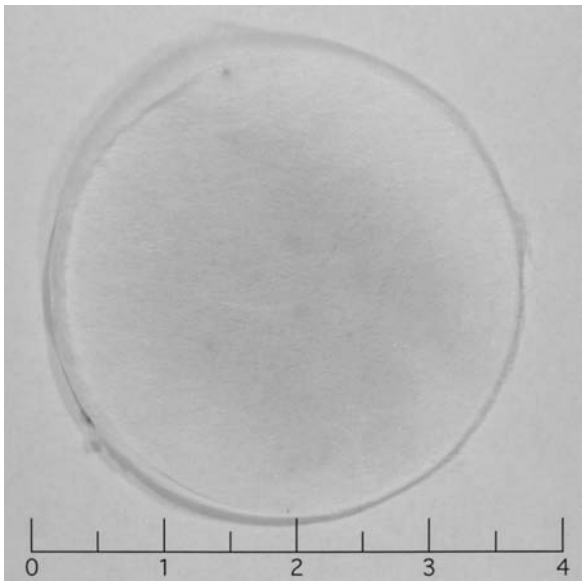
Coupon 3P-24, 2300°F, Pre-Test, Scale in inches



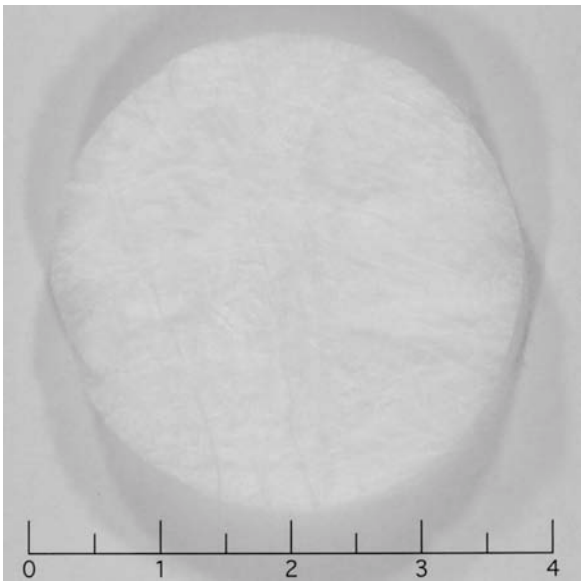
Coupon 3P-24, 2300°F, Post-Test, Scale in inches



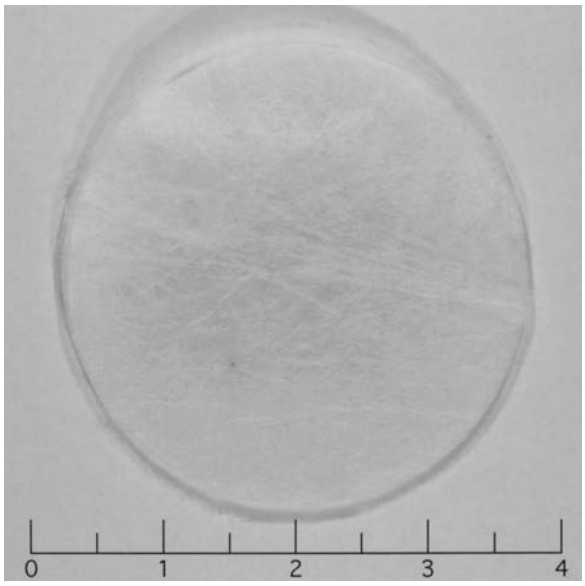
Coupon 3P-25, 2300°F, Pre-Test, Scale in inches



Coupon 3P-25, 2300°F, Post-Test, Scale in inches

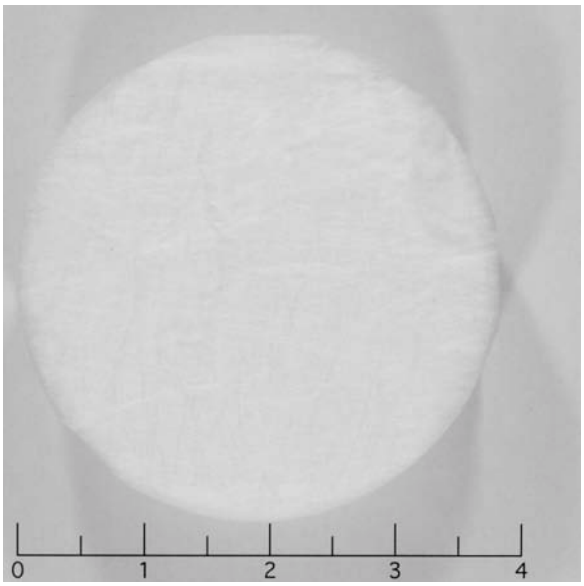


Coupon 3P-26, 2300°F, Pre-Test, Scale in inches

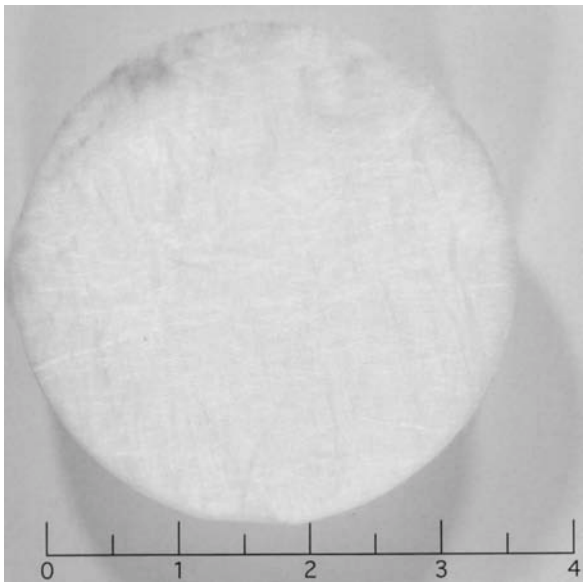


Coupon 3P-26, 2300°F, Post-Test, Scale in inches

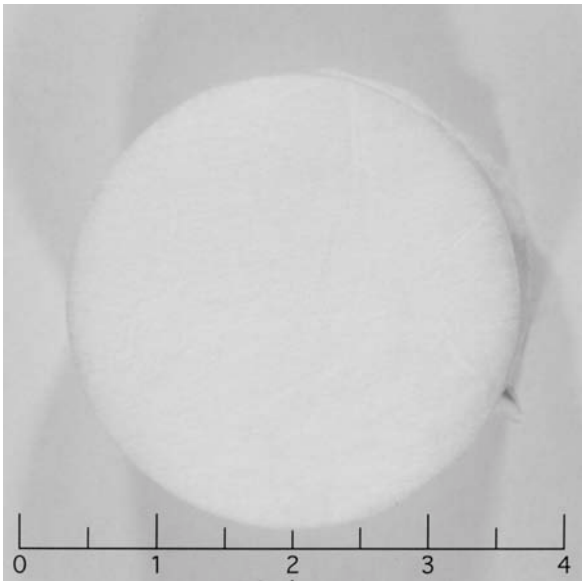
Alumina Fiber Insulation 1.00-inch 9 lb/ft^3 Pre and Post Test Pictures RT



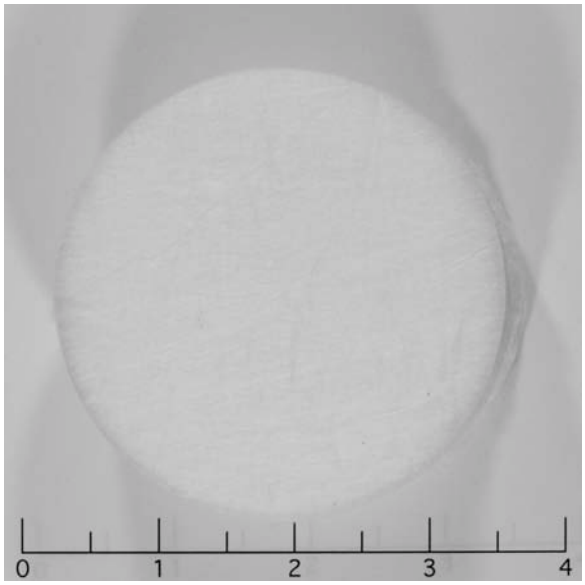
Coupon 9P-06, 70°F, Pre-Test, Scale in inches



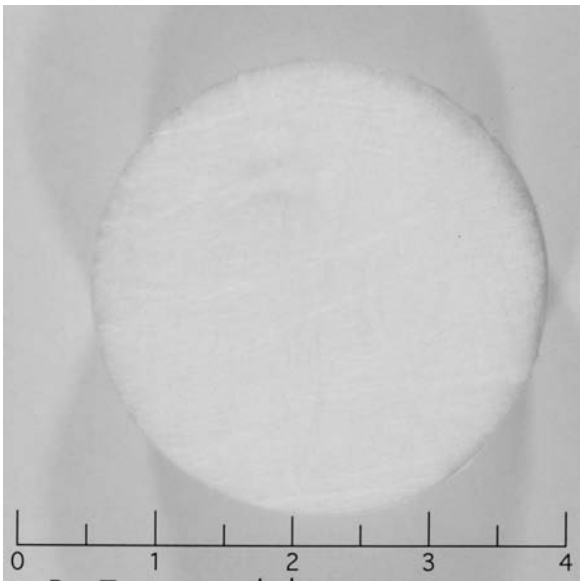
Coupon 9P-06, 70°F, Post-Test, Scale in inches



Coupon 9P-07, 70°F, Pre-Test, Scale in inches

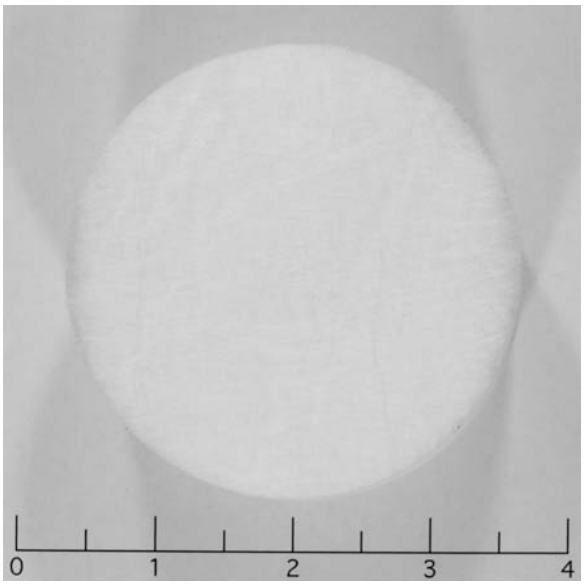


Coupon 9P-07, 70°F, Post-Test, Scale in inches

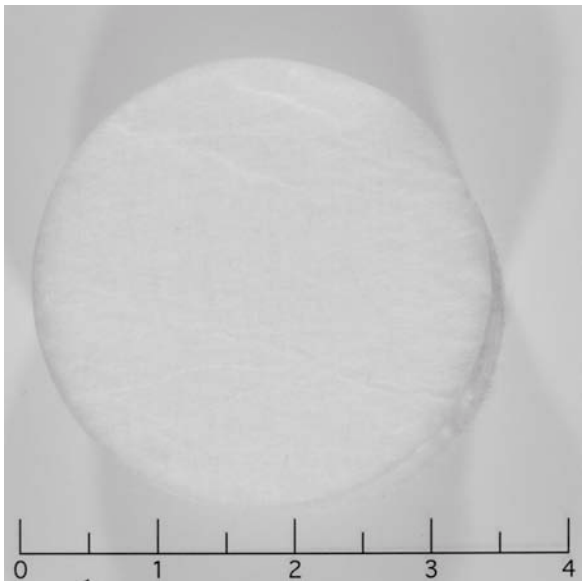


Coupon 9P-08, 70°F, Pre-Test, Scale in inches

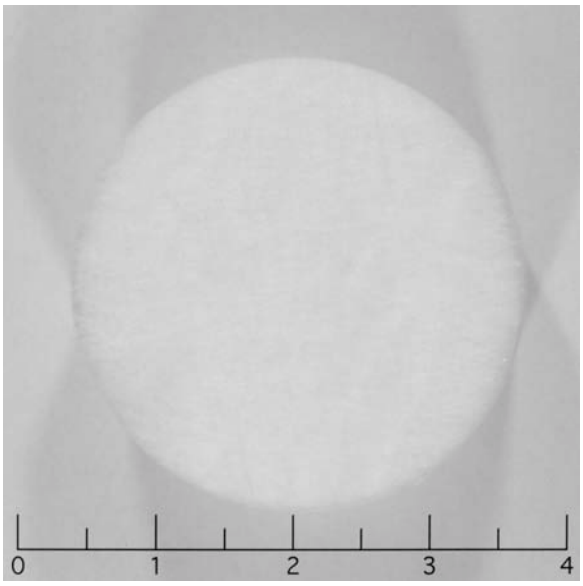
Coupon 9P-08, 70°F, Post-Test, Scale in inches



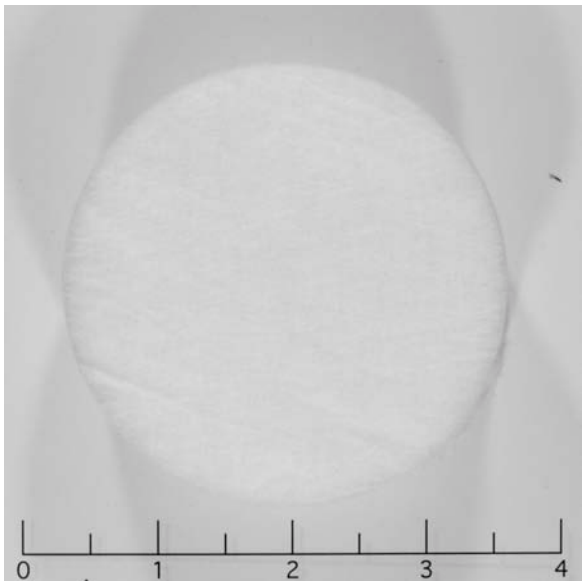
Coupon 9P-09, 70°F, Pre-Test, Scale in inches



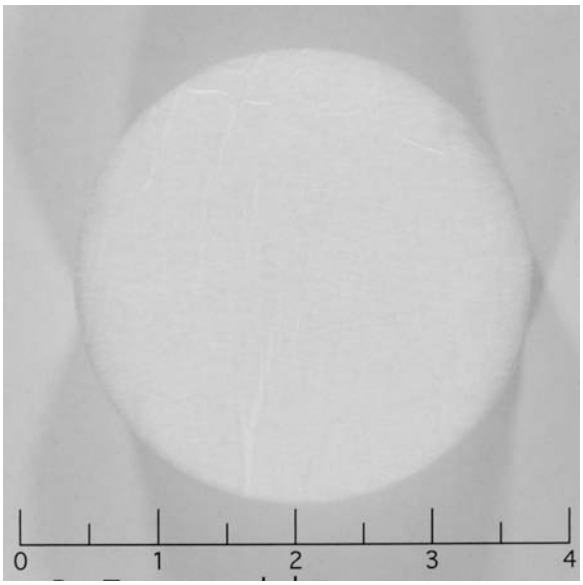
Coupon 9P-09, 70°F, Post-Test, Scale in inches



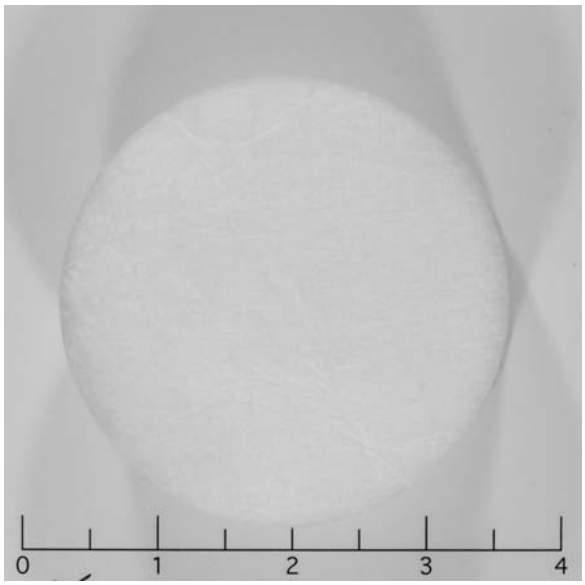
Coupon 9P-10, 70°F, Pre-Test, Scale in inches



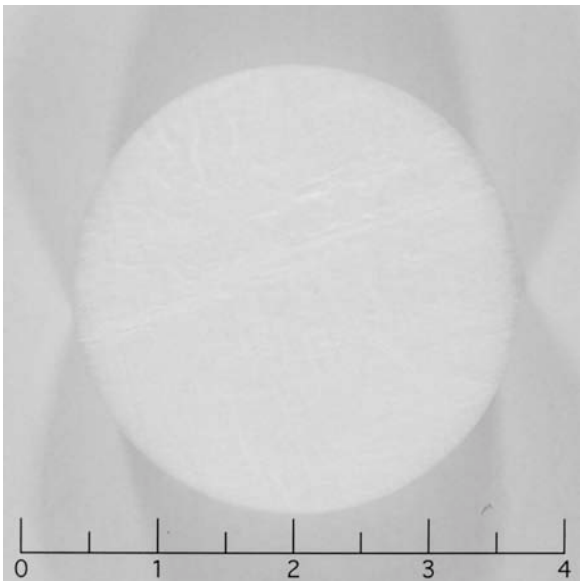
Coupon 9P-10, 70°F, Post-Test, Scale in inches



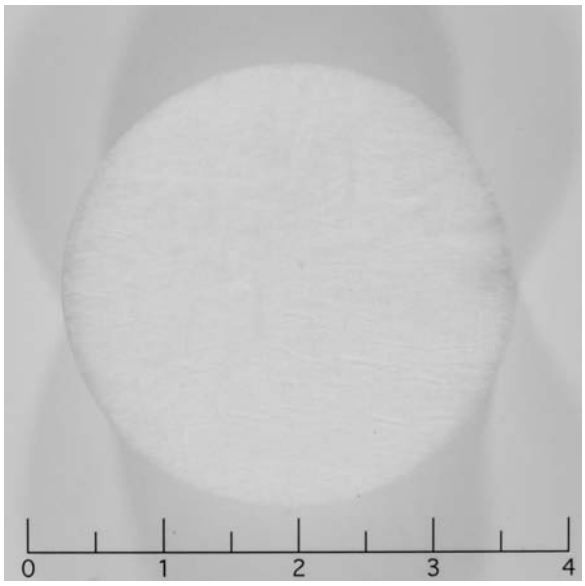
Coupon 9P-11, 70°F, Pre-Test, Scale in inches



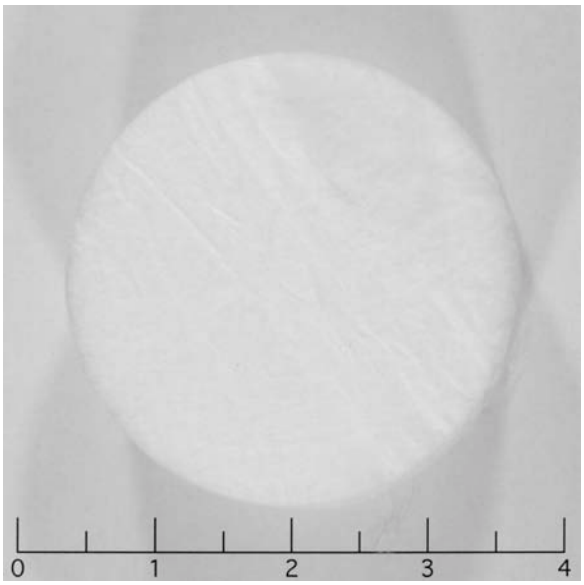
Coupon 9P-11, 70°F, Post-Test, Scale in inches



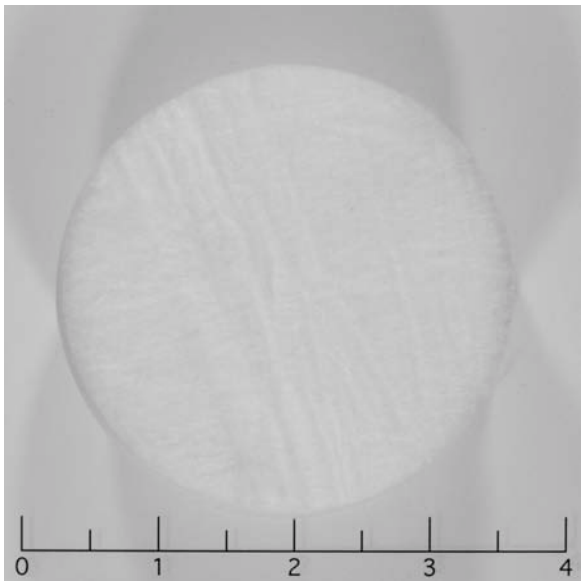
Coupon 9P-12, 70°F, Pre-Test, Scale in inches



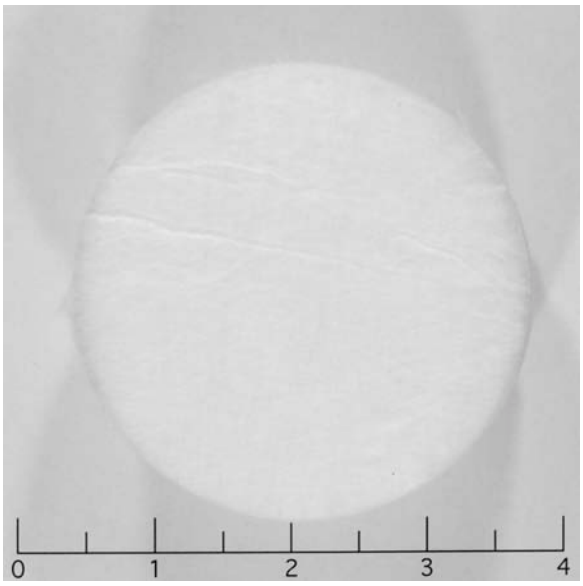
Coupon 9P-12, 70°F, Post-Test, Scale in inches



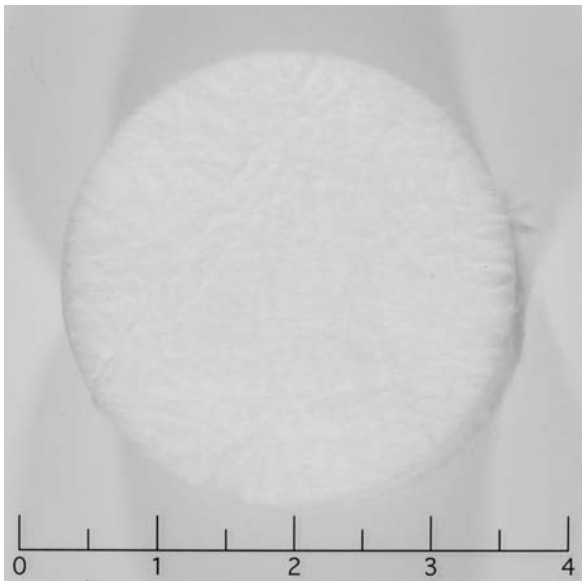
Coupon 9P-13, 70°F, Pre-Test, Scale in inches



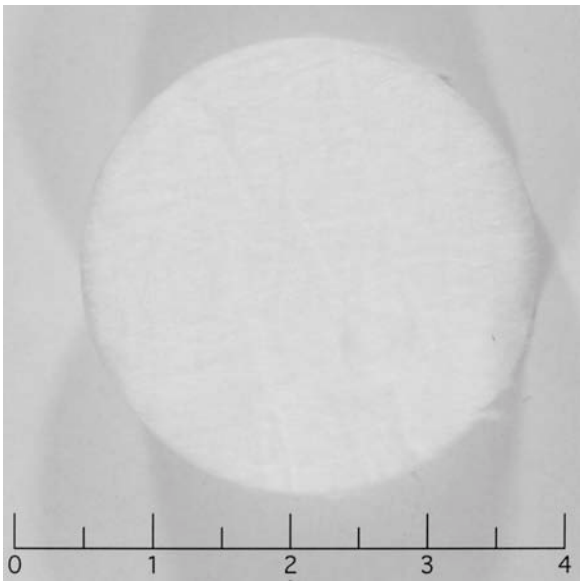
Coupon 9P-13, 70°F, Post-Test, Scale in inches



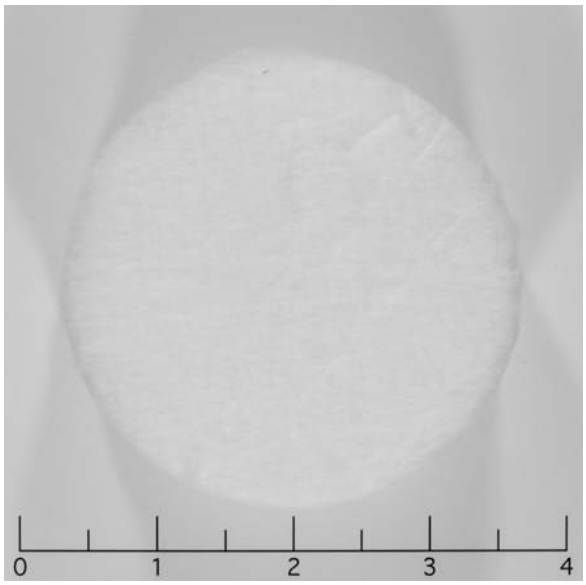
Coupon 9P-14, 70°F, Pre-Test, Scale in inches



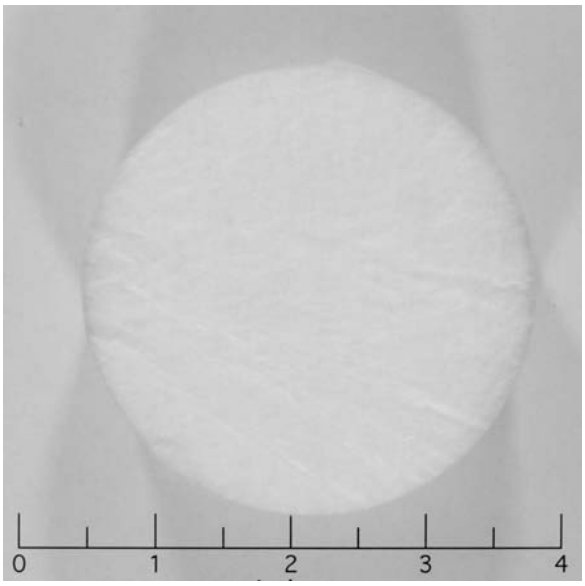
Coupon 9P-14, 70°F, Post-Test, Scale in inches



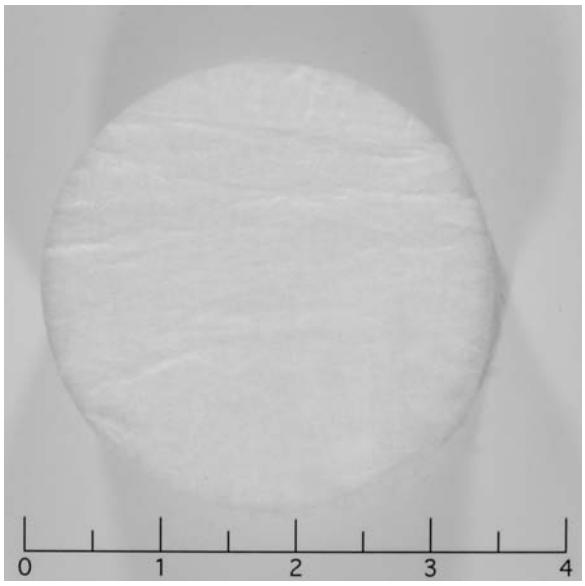
Coupon 9P-15, 70°F, Pre-Test, Scale in inches



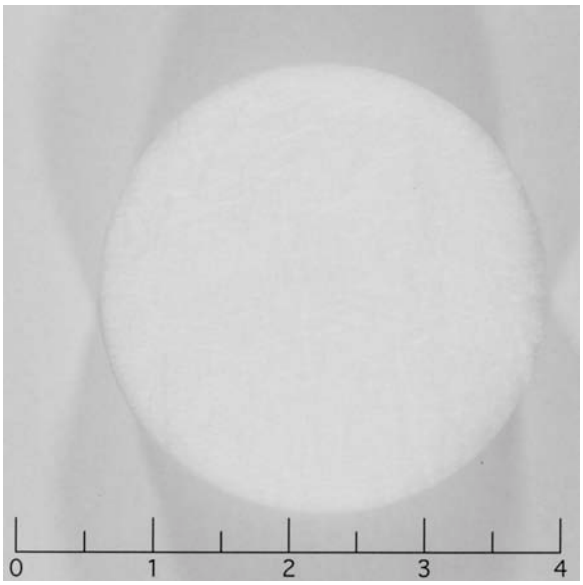
Coupon 9P-15, 70°F, Post-Test, Scale in inches



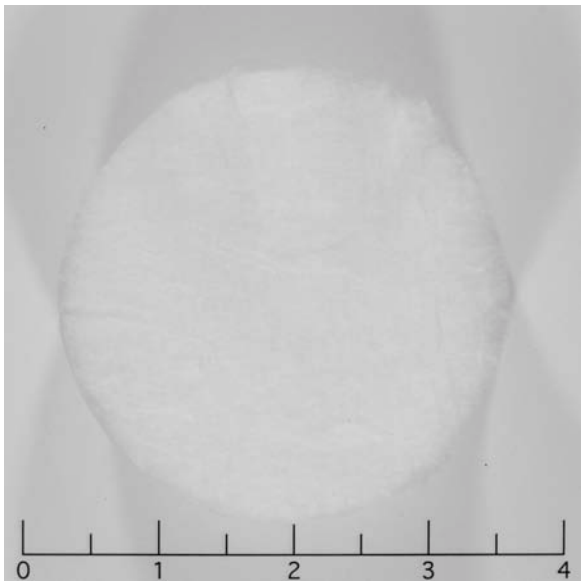
Coupon 9P-16, 70°F, Pre-Test, Scale in inches



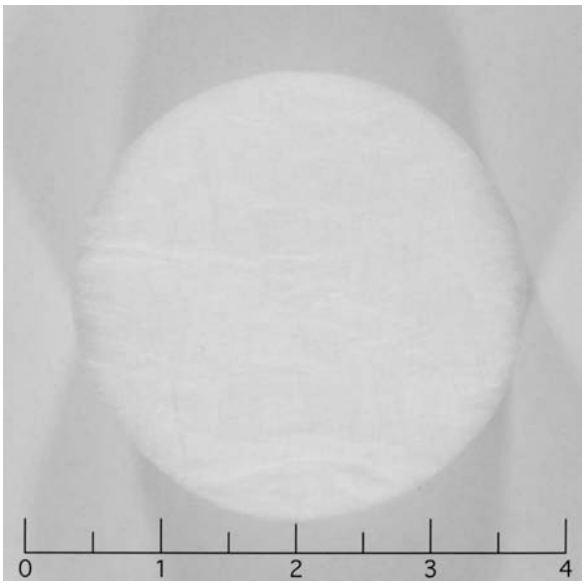
Coupon 9P-16, 70°F, Post-Test, Scale in inches



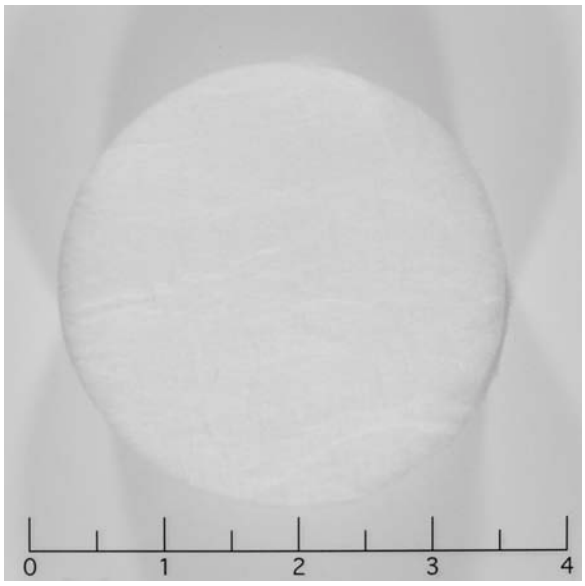
Coupon 9P-17, 70°F, Pre-Test, Scale in inches



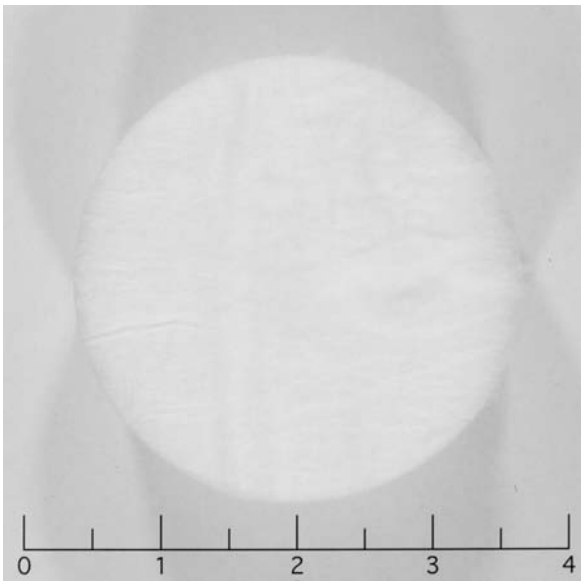
Coupon 9P-17, 70°F, Post-Test, Scale in inches



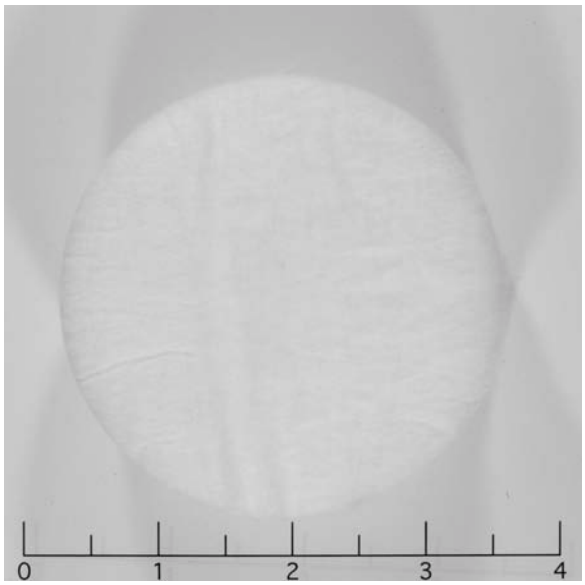
Coupon 9P-18, 70°F, Pre-Test, Scale in inches



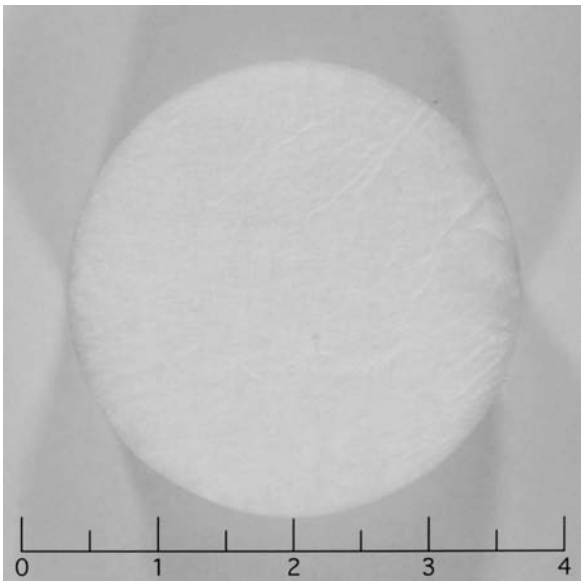
Coupon 9P-18, 70°F, Post-Test, Scale in inches



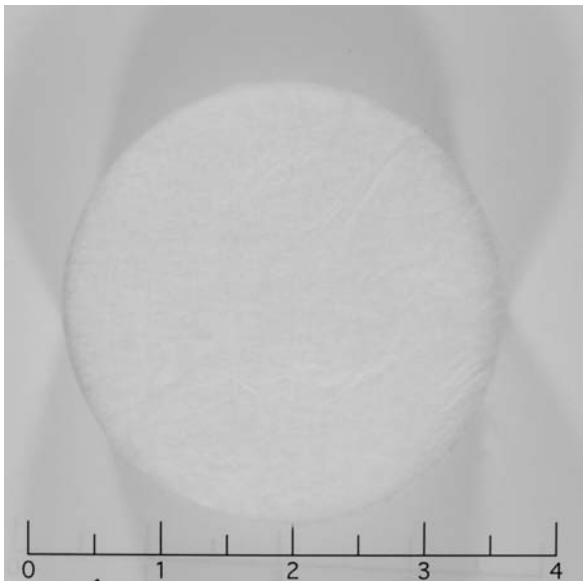
Coupon 9P-19, 70°F, Pre-Test, Scale in inches



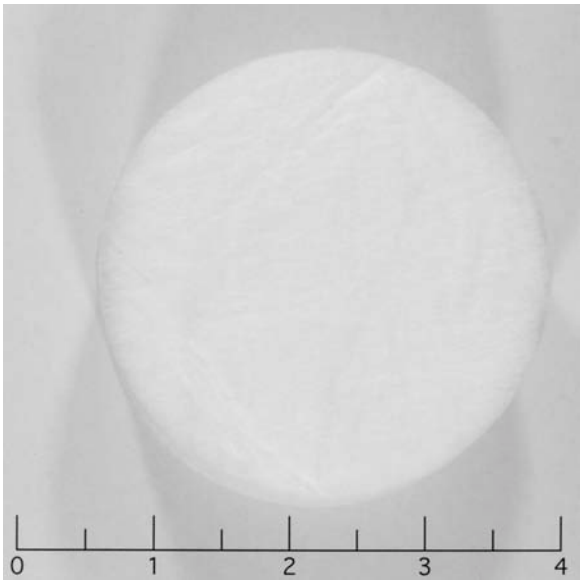
Coupon 9P-19, 70°F, Post-Test, Scale in inches



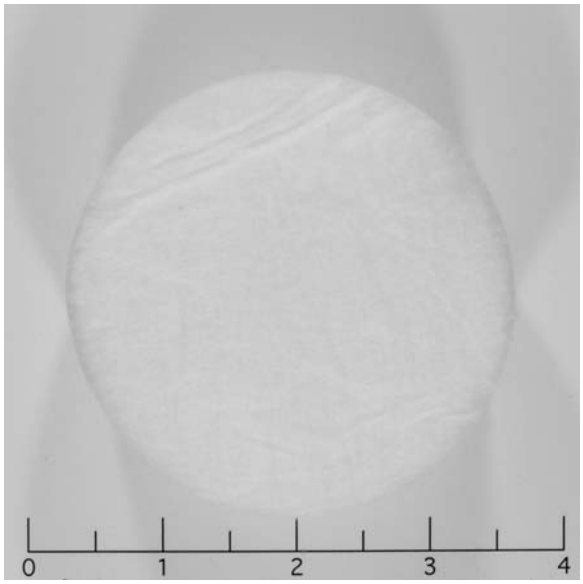
Coupon 9P-20, 70°F, Pre-Test, Scale in inches



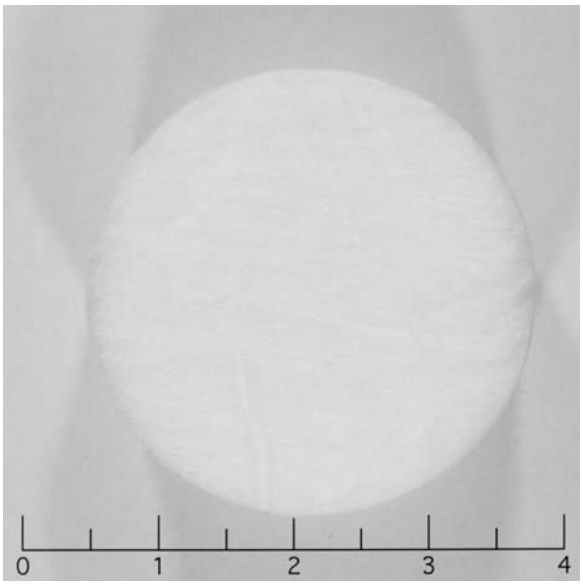
Coupon 9P-20, 70°F, Post-Test, Scale in inches



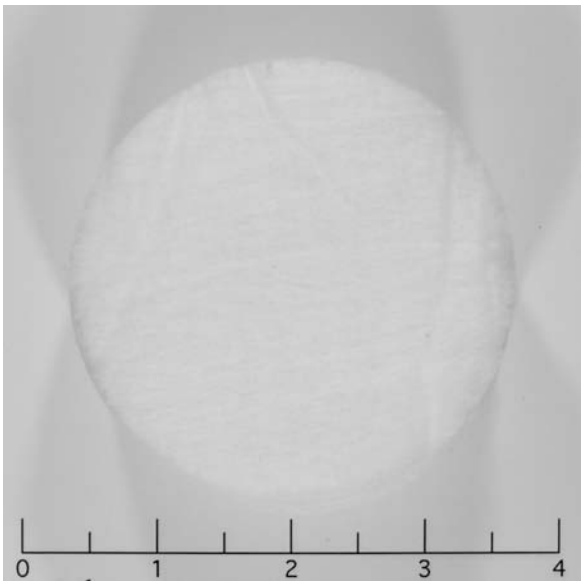
Coupon 9P-21, 70°F, Pre-Test, Scale in inches



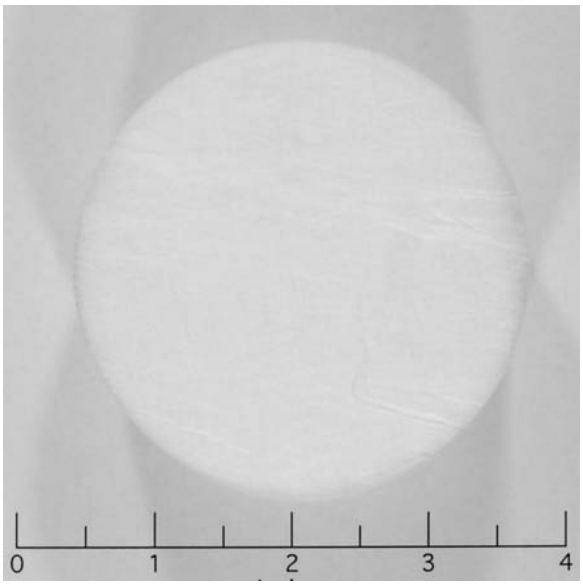
Coupon 9P-21, 70°F, Post-Test, Scale in inches



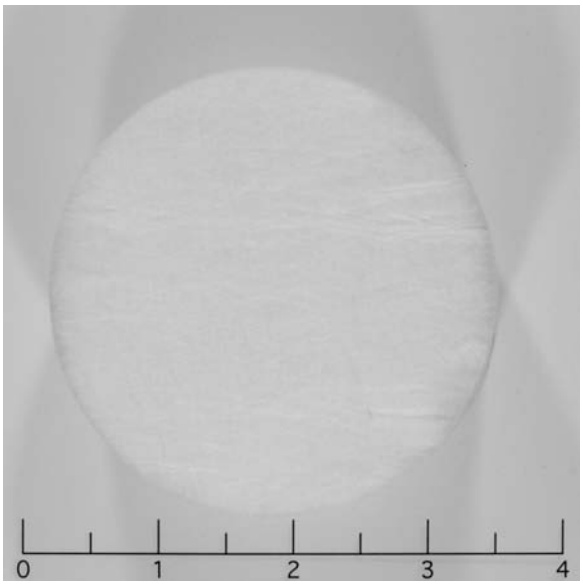
Coupon 9P-22, 70°F, Pre-Test, Scale in inches



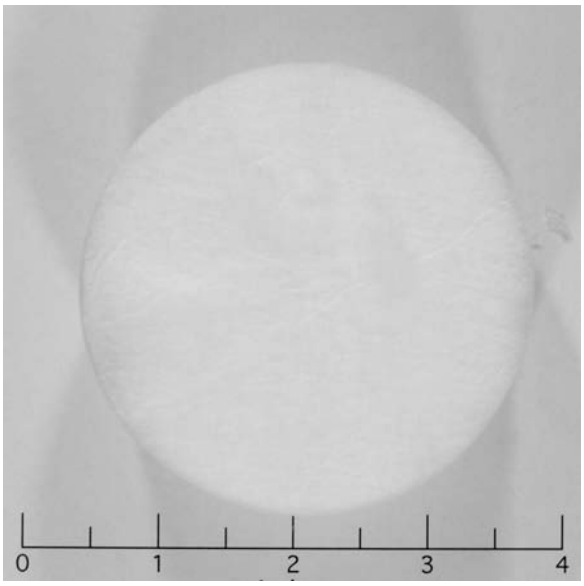
Coupon 9P-22, 70°F, Post-Test, Scale in inches



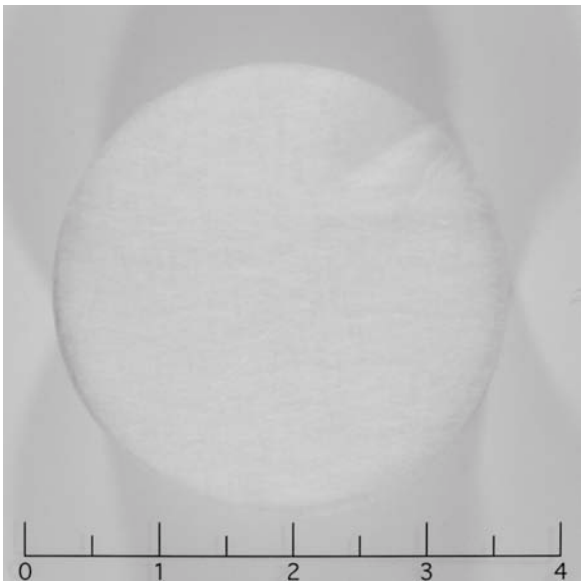
Coupon 9P-23, 70°F, Pre-Test, Scale in inches



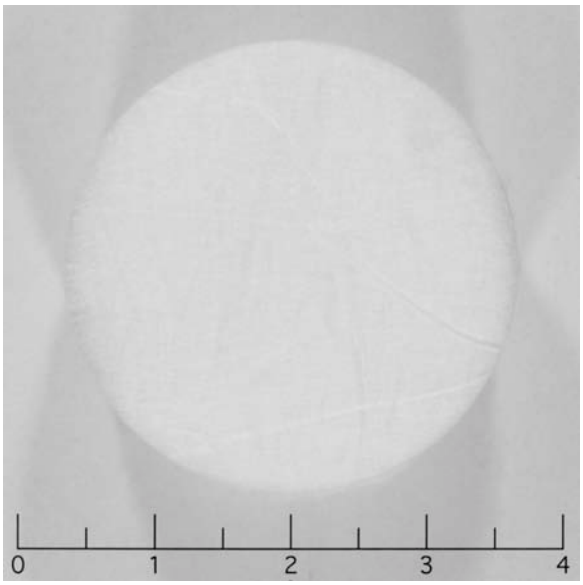
Coupon 9P-23, 70°F, Post-Test, Scale in inches



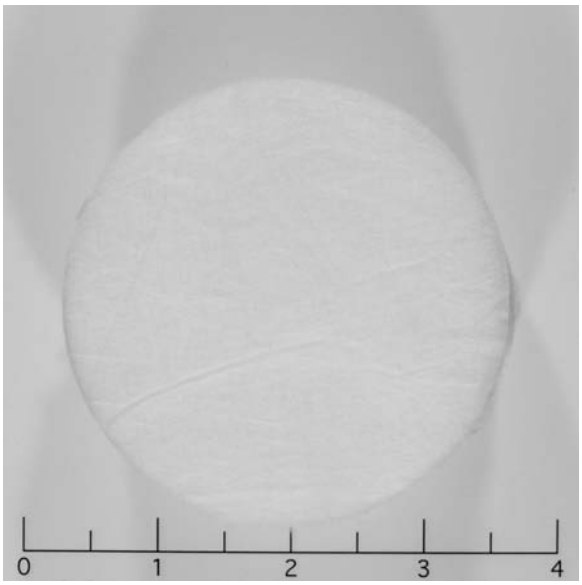
Coupon 9P-24, 70°F, Pre-Test, Scale in inches



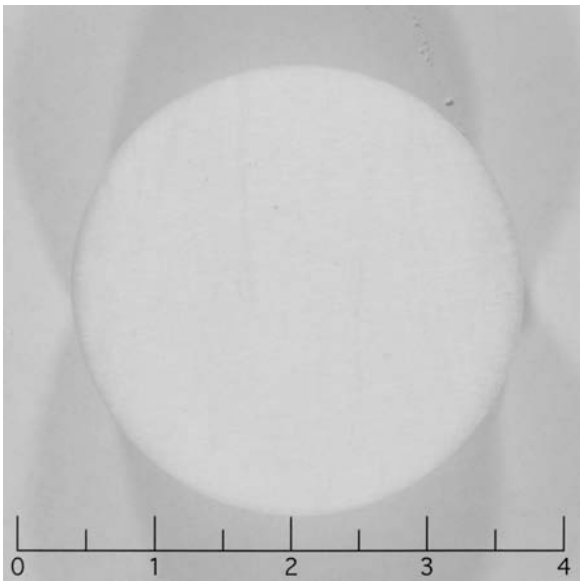
Coupon 9P-24, 70°F, Post-Test, Scale in inches



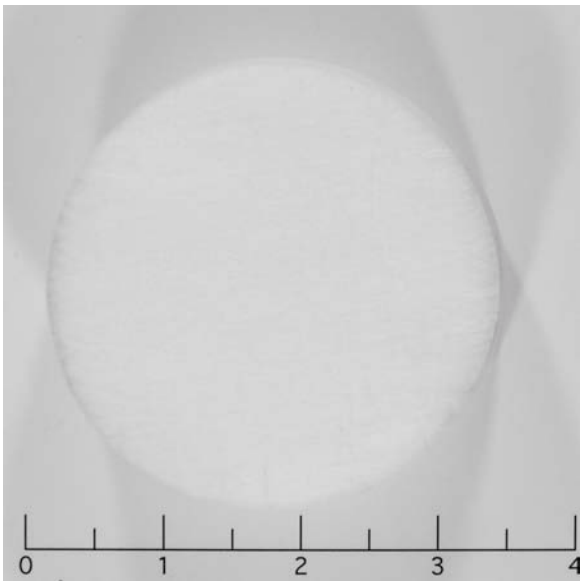
Coupon 9P-25, 70°F, Pre-Test, Scale in inches



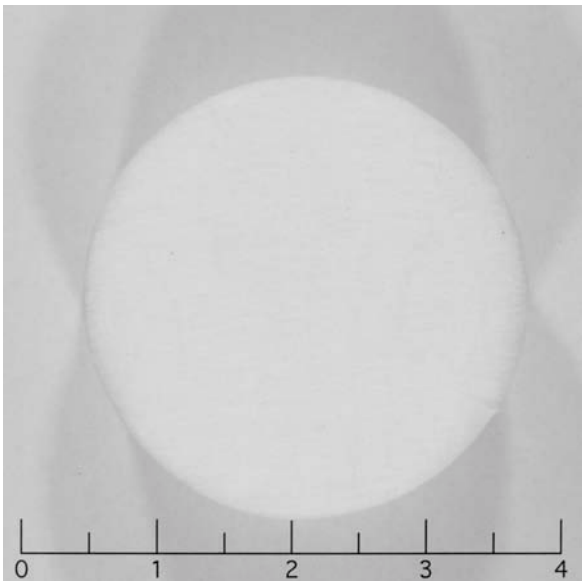
Coupon 9P-25, 70°F, Post-Test, Scale in inches



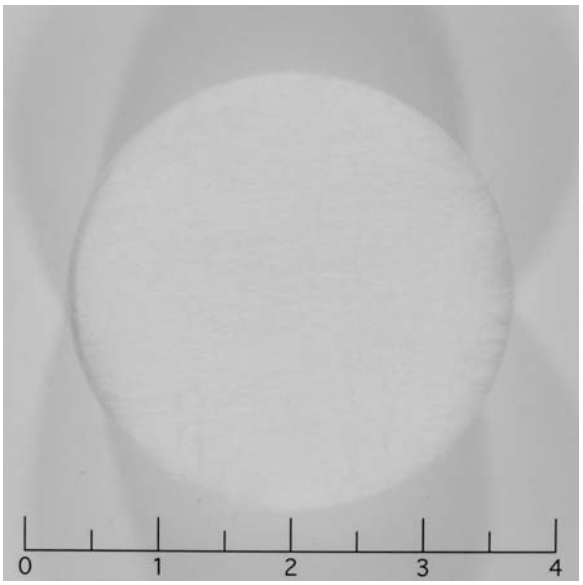
Coupon 9P-26, 70°F, Pre-Test, Scale in inches



Coupon 9P-26, 70°F, Post-Test, Scale in inches

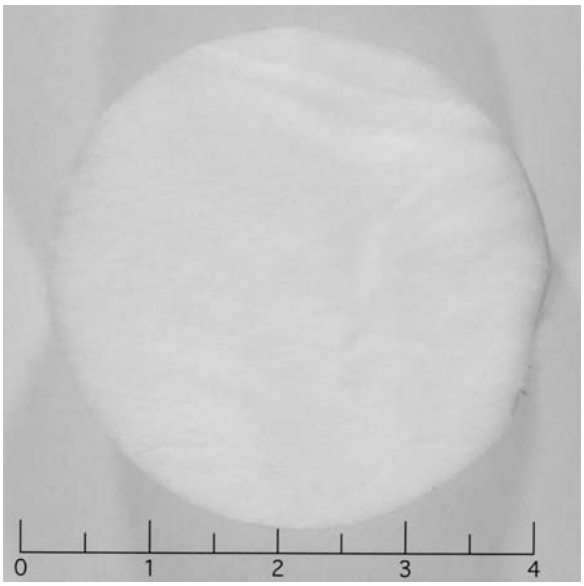


Coupon 9P-27, 70°F, Pre-Test, Scale in inches

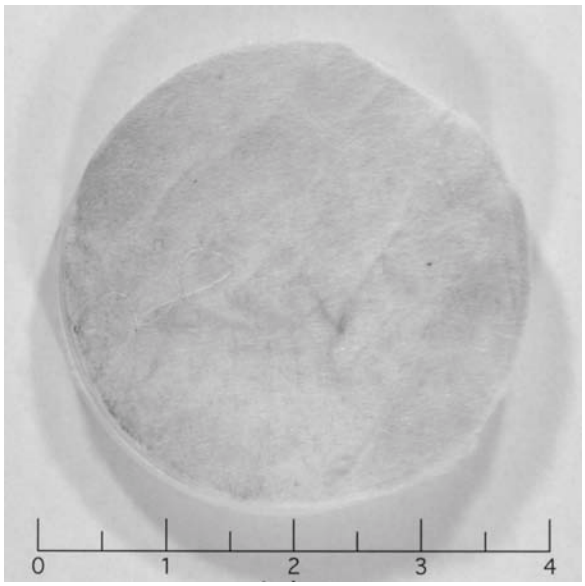


Coupon 9P-27, 70°F, Post-Test, Scale in inches

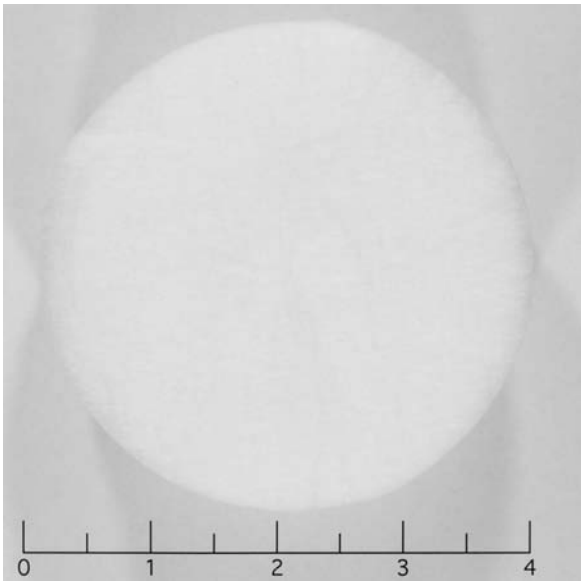
Alumina Fiber Insulation 1.00-inch 9 lb/ft^3 Pre and Post Test Pictures 2300°F



Coupon 9P-01, 2300°F, Pre-Test, Scale in inches

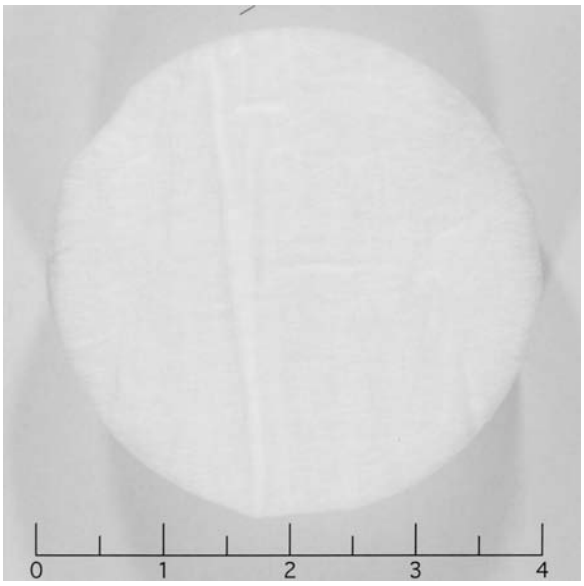


Coupon 9P-01, 2300°F, Post-Test, Scale in inches

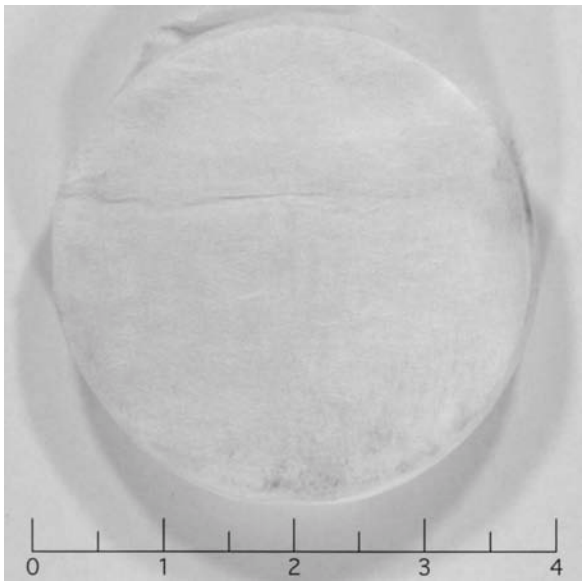


Coupon 9P-02, 2300°F, Pre-Test, Scale in inches

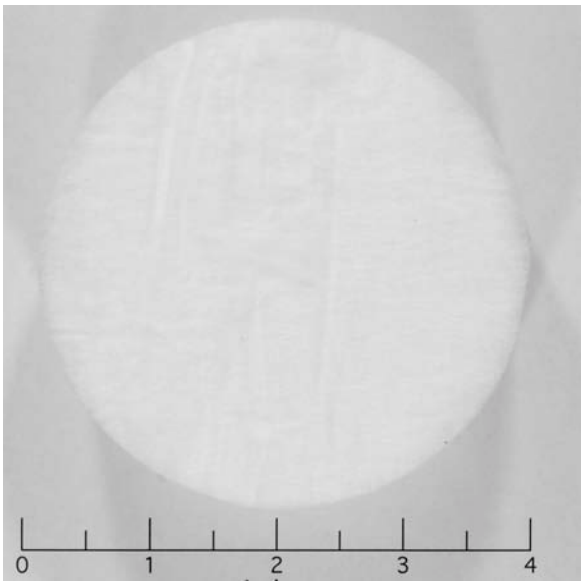
Coupon 9P-02, 2300°F, Post-Test, Scale in inches



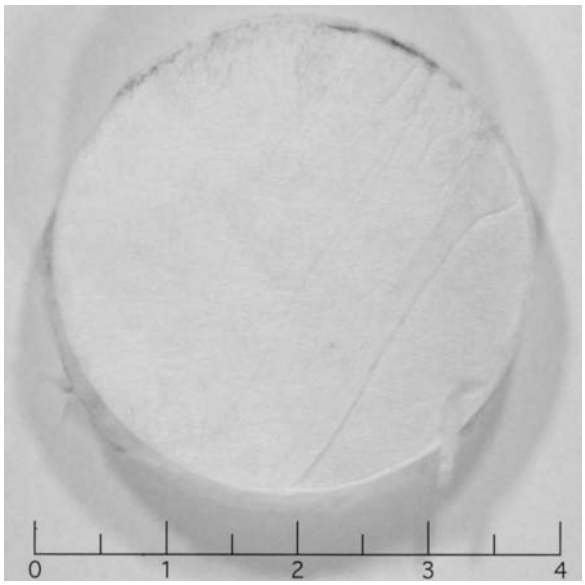
Coupon 9P-03, 2300°F, Pre-Test, Scale in inches



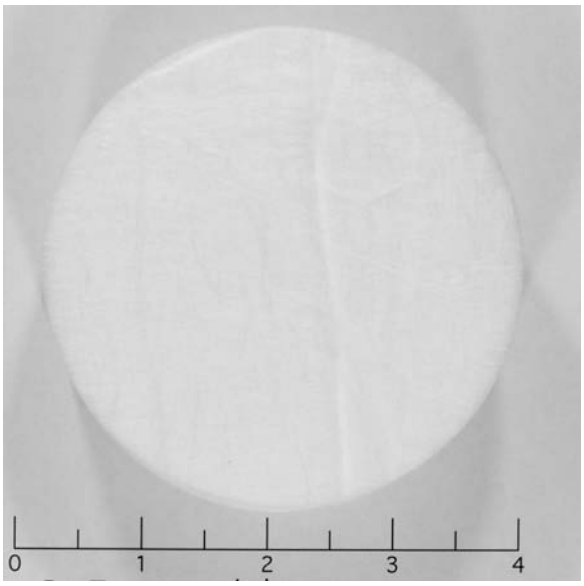
Coupon 9P-03, 2300°F, Post-Test, Scale in inches



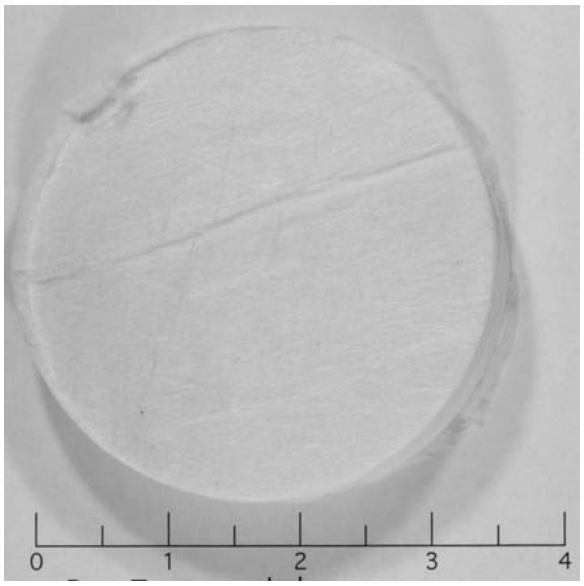
Coupon 9P-04, 2300°F, Pre-Test, Scale in inches



Coupon 9P-04, 2300°F, Post-Test, Scale in inches



Coupon 9P-05, 2300°F, Pre-Test, Scale in inches



Coupon 9P-05, 2300°F, Post-Test, Scale in inches

Appendix C

Calibration sheets for instruments used in report

Stroke Calibration Sheet

Test Stand: MTS 858 Table Top **Mode: Tension and Compression** **Calibration Procedure No: LMS-TD-5317**

EX Voltage: 10 Volts	NIST Traceable Standard ID: A038877			V / FS: 10 Volts					
Sensor Serial #:418736			Cal Range: 2.0 in. +/-			Conditioner Serial #: 411862		Post-amp: 2.485	
As Found (n/a)			Corrected (Run 1)			As Left (Run 2)			
Machine	Dial Gage	Error % Reading	Volt	Machine	Dial Gage	Error % Reading	Volt	Machine	Dial Gage	Error % Reading	Volt	Repeat Error %
		0.00		0.0000	0.0000	0.00		0.0000	0.0000	0.00		0.00
		0.00		-0.2000	-0.2004	0.20		-0.2000	-0.2002	0.10		0.10
		0.00		-0.4000	-0.4000	0.00		-0.4000	-0.4000	0.00		0.00
		0.00		-0.6000	-0.5998	-0.03		-0.6000	-0.5997	-0.05		0.02
		0.00		-0.8000	-0.7996	-0.05		-0.8000	-0.7995	-0.06		0.01
		0.00		-1.0000	-0.9990	-0.10		-1.0000	-0.9989	-0.11		0.01
		0.00		-1.2000	-1.1987	-0.11		-1.2000	-1.1985	-0.13		0.02
		0.00		-1.4000	-1.3985	-0.11		-1.4000	-1.3983	-0.12		0.01
		0.00		-1.6000	-1.5982	-0.11		-1.6000	-1.5982	-0.11		0.00
		0.00		-1.8000	-1.7989	-0.06		-1.8000	-1.7989	-0.06		0.00
		0.00		-2.0000	-1.9999	-0.01		-2.0000	-1.9999	-0.01		0.00
		0.00		-1.8000	-1.7981	-0.11		-1.8000	-1.7980	-0.11		0.01
		0.00		-1.6000	-1.5975	-0.16		-1.6000	-1.5974	-0.16		0.01
		0.00		-1.4000	-1.3976	-0.17		-1.4000	-1.3975	-0.18		0.01
		0.00		-1.2000	-1.1977	-0.19		-1.2000	-1.1977	-0.19		0.00
		0.00		-1.0000	-0.9981	-0.19		-1.0000	-0.9981	-0.19		0.00
		0.00		-0.8000	-0.7986	-0.18		-0.8000	-0.7986	-0.18		0.00
		0.00		-0.6000	-0.5989	-0.18		-0.6000	-0.5989	-0.18		0.00
		0.00		-0.4000	-0.3991	-0.23		-0.4000	-0.3992	-0.20		-0.03
		0.00		-0.2000	-0.1994	-0.30		-0.2000	-0.1994	-0.30		0.00
		0.00		0.0000	-0.0006	-0.03		0.0000	-0.0005	-0.03		-0.01
		0.00		0.0000	0.0000	0.00		0.0000	0.0000	0.00		0.00
		0.00		0.2000	0.2006	0.30		0.2000	0.2006	0.30		0.00
		0.00		0.4000	0.4005	0.12		0.4000	0.4005	0.12		0.00
		0.00		0.6000	0.6005	0.08		0.6000	0.6005	0.08		0.00
		0.00		0.8000	0.8007	0.09		0.8000	0.8006	0.07		0.01
		0.00		1.0000	1.0007	0.07		1.0000	1.0006	0.06		0.01
		0.00		1.2000	1.2006	0.05		1.2000	1.2005	0.04		0.01
		0.00		1.4000	1.4006	0.04		1.4000	1.4006	0.04		0.00
		0.00		1.6000	1.6006	0.04		1.6000	1.6005	0.03		0.01
		0.00		1.8000	1.8000	0.00		1.8000	1.7997	-0.02		0.02
		0.00		2.0000	1.9978	-0.11		2.0000	1.9976	-0.12		0.01
		0.00		1.8000	1.7996	-0.02		1.8000	1.7994	-0.03		0.01
		0.00		1.6000	1.6002	0.01		1.6000	1.6000	0.00		0.01
		0.00		1.4000	1.4002	0.01		1.4000	1.4000	0.00		0.01
		0.00		1.2000	1.2003	0.02		1.2000	1.1999	-0.01		0.03
		0.00		1.0000	1.0003	0.03		1.0000	1.0000	0.00		0.03
		0.00		0.8000	0.8002	0.02		0.8000	0.7999	-0.01		0.04
		0.00		0.6000	0.6001	0.02		0.6000	0.5997	-0.05		0.07
		0.00		0.4000	0.3999	-0.03		0.4000	0.3997	-0.08		0.05
		0.00		0.2000	0.2000	0.00		0.2000	0.1997	-0.15		0.15
		0.00		0.0000	0.0002	0.01		0.0000	0.0004	0.02		-0.01
					Cal by: C. Leggette			Cal Date: 3/21/06		Next Cal Due: 9/21/07		

Post-amp: 2.485, Excitation (peak): 10.000 V, Phase: 48.5 deg, DeltaK: 1.0000, Fine Zero: 0.000V

Load Calibration Sheet

Test Stand No: MTS 858 Tabletop Mode: Compression Calibration Procedure No: LMS-TD-5321

EX Voltage: 9.500V	NIST Traceable Standard ID: A031457 (cell), C67883 (ind)							V / FS: 10 Volts				
Sensor Serial #: 0416362				Cal Range: -1,000#				Conditioner Serial #: 0327253			SH REF VAL: 902.18 lbf	
As Found (n/a)				Corrected				As Left				
STD	Machine	Error % Reading	Volt	STD	Machine	Error % Reading	Volt	STD	Machine	Error % Reading	Volt	Repeat Error %
				0.0	0.0	0.00		0.0	-0.0	0.00		0.00
				-100.0	-99.9	0.10		-100.0	-99.9	0.10		0.00
				-200.0	-199.7	0.15		-200.0	-199.6	0.20		-0.05
				-300.0	-299.3	0.23		-300.0	-299.3	0.23		0.00
				-400.0	-398.7	0.33		-400.0	-398.7	0.33		0.00
				-500.0	-498.5	0.30		-500.0	-498.5	0.30		0.00
				-600.0	-597.8	0.37		-600.0	-597.9	0.35		0.02
				-700.0	-697.3	0.39		-700.0	-697.5	0.36		0.03
				-800.0	-797.1	0.36		-800.0	-797.3	0.34		0.02
				-900.0	-896.3	0.41		-900.0	-896.4	0.40		0.01
				-1000.0	-995.6	0.44		-1000.0	-995.8	0.42		0.02
				-900.0	-896.2	0.42		-900.0	-896.2	0.42		0.00
				-800.0	-796.7	0.41		-800.0	-796.9	0.39		0.02
				-700.0	-697.2	0.40		-700.0	-697.3	0.39		0.01
				-600.0	-597.9	0.35		-600.0	-597.9	0.35		0.00
				-500.0	-498.5	0.30		-500.0	-498.5	0.30		0.00
				-400.0	-398.8	0.30		-400.0	-398.9	0.28		0.02
				-300.0	-299.3	0.23		-300.0	-299.3	0.23		0.00
				-200.0	-199.9	0.05		-200.0	-199.9	0.05		0.00
				-100.0	-100.3	-0.30		-100.0	-100.3	-0.30		0.00
				0.3	0.0	0.03		0.4	-0.0	0.00		0.03
						Cal.By: C. Leggette		Cal Date: 3/27/06		Next Cal Due: 9/27/07		

Post Amp: 4.309, Excitation: 9.500V, DeltaK: 1.0054, Balance Option: 0.0000V, Fine Zero: -0.012V

Extensometer Calibration Sheet

Instron 8562 Stroke Calibration Mode: Compression Calibration Procedure No: LMS-TD-5317

EX Voltage:	NIST Traceable Standard ID: Mitutoyo Digital Indicator #A038877							V / FS: 10 Volts		mV Sensitivity:		
Instron Stroke Conditioner				Cal Range: -4.0" F.S.				Transducer serial no.		Shunt Cal:		
As Found				Corrected				As Left				
Machine	Std	Error % Range	Volt	STD	Machine	Error % Range	Volt	Machine	Std	Error % Range	Volt	Repeat Error %
0.0000	0.0000	0.0000				0.0000		0.0000	0.0000	0.0000		0.0000
0.3000	0.3034	-0.0850				0.0000		0.3000	0.3036	-0.0900		0.0900
0.6000	0.6021	-0.0525				0.0000		0.6000	0.6022	-0.0550		0.0550
0.9000	0.9029	-0.0725				0.0000		0.9000	0.9029	-0.0725		0.0725
1.2000	1.2046	-0.1150				0.0000		1.2000	1.2046	-0.1150		0.1150
1.5000	1.5029	-0.0725				0.0000		1.5000	1.5030	-0.0750		0.0750
1.8000	1.8051	-0.1275				0.0000		1.8000	1.8052	-0.1300		0.1300
2.1000	2.1043	-0.1075				0.0000		2.1000	2.1044	-0.1100		0.1100
2.4000	2.4030	-0.0750				0.0000		2.4000	2.4031	-0.0775		0.0775
2.7000	2.7058	-0.1450				0.0000		2.7000	2.7058	-0.1450		0.1450
2.8000	2.8058	-0.1450				0.0000		2.8000	2.8058	-0.1450		0.1450
2.7000	2.7060	-0.1500				0.0000		2.7000	2.7061	-0.1525		0.1525
2.4000	2.4035	-0.0875				0.0000		2.4000	2.4036	-0.0900		0.0900
2.1000	2.1047	-0.1175				0.0000		2.1000	2.1047	-0.1175		0.1175
1.8000	1.8054	-0.1350				0.0000		1.8000	1.8055	-0.1375		0.1375
1.5000	1.5027	-0.0675				0.0000		1.5000	1.5027	-0.0675		0.0675
1.2000	1.2044	-0.1100				0.0000		1.2000	1.2045	-0.1125		0.1125
0.9000	0.9028	-0.0700				0.0000		0.9000	0.9029	-0.0725		0.0725
0.6000	0.6018	-0.0450				0.0000		0.6000	0.6019	-0.0475		0.0475
0.3000	0.3031	-0.0775				0.0000		0.3000	0.3032	-0.0800		0.0800
0.0000	0.0003	-0.0075				0.0000		0.0000	0.0003	-0.0075		0.0075
Note:	R5=	R8=				Cal.By: C. Leggette		Cal Date: 2/9/06		Next Cal Due: 8/9/07		

Calibration Sheet

Test Stand No: Instron 8562 Mode: Compression Calibration Procedure No: LMS-TD-5320

EX Voltage:	NIST Traceable Standard ID: M98283, C67882							V / FS: 10 Volts		mV Sensitivity:		
Xducer/Controller SN:				Cal Range: -10,000 lbs						Sh Cal:		
As Found				Corrected (N/A)				As Left				
STD	Machine	Error % Reading	Volt	STD	Machine	Error % F.S.	Volt	STD	Machine	Error % Reading	Volt	Repeat Error %
0	0	0.00						0	0	0.00		0.00000
-1000	-1003	-0.30						1000	1003	-0.30		0.00000
-2000	-2003	-0.15						2000	2003	-0.15		0.00000
-3000	-3003	-0.10						3000	3003	-0.10		0.00000
-4000	-4005	-0.13						4000	4005	-0.13		0.00000
-5000	-5006	-0.12						5000	5007	-0.14		0.02000
-6000	-6006	-0.10						6000	6006	-0.10		0.00000
-7000	-7005	-0.07						7000	7005	-0.07		0.00000
-8000	-8009	-0.11						8000	8009	-0.11		0.00000
-9000	-9006	-0.07						9000	9008	-0.09		0.02222
-9950	-9952	-0.02						9983	9956	0.27		-0.29056
-9000	-9002	-0.02						9000	9004	-0.04		0.02222
-8000	-8000	0.00						8000	8002	-0.03		0.02500
-7000	-6994	0.09						7000	6996	0.06		0.02857
-6000	-5993	0.12						6000	5995	0.08		0.03333
-5000	-4992	0.16						5000	4995	0.10		0.06000
-4000	-3990	0.25						4000	3993	0.18		0.07500
-3000	-2990	0.33						3000	2992	0.27		0.06667
-2000	-1992	0.40						2000	1995	0.25		0.15000
-1000	-994	0.60						1000	997	0.30		0.30000
-1	3	-0.04						0	1	-0.01		-0.02100
Note: R5= R8=						Cal.By: C. Leggette		Cal Date: 2/7/06		Next Cal Due: 8/7/07		

Calibration Report

IRCON ISO 9001 Quality System Certified
Certificate No. QSC-3542

CERTIFICATE OF CALIBRATION FOR INFRARED THERMOMETER

Model: MR-OR05-24C-0-1/0-0-0
Serial # 21405
Condition as received: GOOD

Customer ID: RMA 13915
Calibration Date: 3/28/2006
Calibration DUE: 3/28/2007

INDICATED TEMPERATURE VS BLACKBODY STANDARD TEMPERATURE

Blackbody Temperature	Indicated Temperature		Correction Factor			Thermometer Output		
	Before	**After**	**Before**	**P/F**	**After**	**Before**	**P/F**	**After**
T_{TRUE} (°C)	T_{IND} (°C)		ΔT_{CORR} (°C)			Volts		
900	899	895	1	P	5	-0.014	P	-0.025
1200	1210	1204	-10	P	-4	2.050	P	2.030
1600	1616	1608	-16	P	-8	4.750	P	4.730
2000	2012	2001	-12	P	-1	7.390	P	7.350
2300	2309	2295	-9	P	5	9.400	P	9.310
0	0	0	0	0	0	0.000	0	0.000

NOTES: Indicated Temperature (T_{IND}) is temperature displayed on built-in meter of thermometer. $T_{TRUE} = T_{IND} + \Delta T_{CORR}$
Thermometer Output is measured at output terminals of thermometer. Nominal output range 0-10 V
"Before" and "After" indicate the readings as received and after calibration.

TEST PARAMETERS

1. This thermometer was calibrated against a Blackbody Source verified by standards traceable to the National Institute of Standards and Technology.
2. Calculated emissivity of the blackbody cavity is 1.000 - 0.005
3. Size of blackbody cavity >2 times calculated spot size of thermometer.
4. Probable uncertainty of the temperature values reported is estimated to be 5°C
5. Thermometer stabilized at rated line voltage for at least 1 hour before calibration.
6. Ambient temperature maintained for this calibration was 75°F
7. Thermometer accuracy: 1%FS or 6 deg.C whichever is greater.
8. Emissivity control of thermometer (if applicable) set to 1.0
9. Calibration self-check of thermometer (if applicable) adjusted per manufacturer's instructions.
10. Calibration system complies with the requirements of ISO 10012-1 and ISO Guide 25.
11. Calibration procedure used: S001, rev.E.
12. Traceable equipment used for calibration:
    Tool:S1067; Infrared Transfer Standard UX-10; Calibrated: 10/13/2005 844/264935-01
    Tool:S1157; FLUKE Multimeter Model 45; Calibrated: 8/25/2005

Calibrated by: _____ (Technician)

IRCON, INC.
7300 North Natchez Ave.
Niles, Illinois 60714 USA

Phone (847) 967-5151
Toll Free (800) 323-7660
Fax (847) 647-0948

CALIBRATION CERTIFICATE

MODERN MACHINE & TOOL CO. INC.
PRECISION ● ACCURACY ● DEPENDABILITY
11844 JEFFERSON AVE., NEWPORT NEWS, VA. 23606-2587

CUSTOMER: NASA - LANGLEY **CONTRACT NO.** NNL04AA01B

TEST INSTRUMENT	ANALYTICAL BALANCE				**REFERENCE STD.**	MM&T CO. MASS STANDARDS	
MFG.	SARTARIOUS	**MODEL**	B120S	**INV. NO.** A026332	**MFG.**	TROEMNER	**MODEL** CLASS "S"
SER.NO.	38030148	**RANGE**	0 - 120 g	**TEMP.** N/A	**RANGE**	1mg - 1kg	**SER. NO.** SET 192
DATE	6/3/05	**CAL. BY**	WALLS / SNIDER	**APPROVED** _____	**TEMP.OF STD.**	72°	**DUE DATE** 7/28/08
					MEAS. UNC. OF STD.	±0.01%	

INDICATION OF STANDARD (grams)		INDICATION OF TEST INSTR. (grams)	DEVIATION IN (grams)	PERCENT ERROR OF F.S.
0.000		0.0000	0.0000	0.0000%
0.001		0.0010	0.0000	0.0000%
0.003		0.0030	0.0000	0.0000%
0.005		0.0049	-0.0001	0.0001%
0.007		0.0070	0.0000	0.0000%
0.010		0.0099	-0.0001	0.0001%
0.030		0.0298	-0.0002	0.0003%
0.050		0.0500	0.0000	0.0000%
0.070		0.0699	-0.0001	0.0001%
0.100		0.1000	0.0000	0.0000%
0.300		0.2999	-0.0001	0.0001%
0.500		0.5000	0.0000	0.0000%
0.700		0.7000	0.0000	0.0000%
1.000		0.9998	-0.0002	0.0003%
3.000		2.9998	-0.0002	0.0003%
5.000		5.0001	0.0001	0.0001%
7.000		7.0001	0.0001	0.0001%
10.000		9.9999	-0.0001	0.0001%
30.000		29.9999	-0.0001	0.0001%
50.000		50.0006	0.0006	0.0009%
70.000		70.0007	0.0007	0.0010%
100.00		100.0000	0.0000	0.0000%
120.000		119.9997	-0.0003	0.0004%

TEST INSTRUMENT RECERTIFICATION
DATE: 6/3/06

STANDARDS USED TRACEABLE TO NIST
NIST CERTIFICATE NO. 822/268896-03
DATE OF REPORT 7/28/03 **PROCEDURE NO.** 7.6.2
CONFORMS TO MIL - STD45662A & ANSI / NCSL Z540-1-1994

AMB. ENV. COND.
TEMP N/A
HUMIDITY N/A

TEST INSTRUMENT READOUT
DIGITAL INDICATOR
MFG. SARTARIOUS
INV.NO. A026332
CALIB. DATE 6/3/05

ENGINEERING ● MANUFACTURING ● TESTING **MM&T FORM NO. M958**

Caliper Calibration Sheet

Fowler 6" Caliper — **Calibration Procedure No: LMS-TD-5314**

Serial No. 364833	NIST Traceable Standard ID: A022213, Gage Block Set											
Range: 0-4"					Acceptable tolerance: +/- 0.0020"							
As Found				Corrected				As Left				
Std	Caliper	Error % Range		STD	Machine	Error % Range	Volt	Machine	Std	Error % Range	Volt	Repeat Error %
0.0000	0.0000	0.0000				0.0000		0.0000	0.0000	0.0000		0.0000
0.2000	0.2005	-0.0005				0.0000		0.2000	0.2005	-0.0005		0.0005
0.4000	0.4000	0.0000				0.0000		0.4000	0.4000	0.0000		0.0000
0.6000	0.6005	-0.0005				0.0000		0.6000	0.6005	-0.0005		0.0005
0.8000	0.8005	-0.0005				0.0000		0.8000	0.8005	-0.0005		0.0005
1.0000	1.0000	0.0000				0.0000		1.0000	1.0000	0.0000		0.0000
2.0000	2.0000	0.0000				0.0000		2.0000	1.9995	0.0005		-0.0005
3.0000	2.9995	0.0005				0.0000		3.0000	2.9995	0.0005		-0.0005
4.0000	4.0000	0.0000				0.0000		4.0000	4.0005	-0.0005		0.0005
3.0000	2.9995	0.0005				0.0000		3.0000	2.9995	0.0005		-0.0005
2.0000	1.9995	0.0005				0.0000		2.0000	1.9995	0.0005		-0.0005
1.0000	0.9995	0.0005				0.0000		1.0000	0.9995	0.0005		-0.0005
0.8000	0.8005	-0.0005				0.0000		0.8000	0.8005	-0.0005		0.0005
0.6000	0.6005	-0.0005				0.0000		0.6000	0.6005	-0.0005		0.0005
0.4000	0.4000	0.0000				0.0000		0.4000	0.4005	-0.0005		0.0005
0.2000	0.2005	-0.0005				0.0000		0.2000	0.2005	-0.0005		0.0005
0.0000	0.0000	0.0000				0.0000		0.0000	0.0000	0.0000		0.0000
						Cal.By: C. Leggette		Cal Date: 3/16/06		Next Cal Due: 3/16/07		

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14. ABSTRACT

A series of tests were conducted to measure the response of alumina fiber insulation to compression loading. The alumina fiber insulation is a candidate gasket material for the Space Shuttle Government Furnished Equipment (GFE) Tile Overlay Repair. Tests were conducted at room temperature and 2300°F. The alumina fiber insulation is a fibrous insulation blanket which was supplied to Langley in two forms, a nominal 3 lb/ft3 version and a nominal 9 lb/ft3 version. The 3 lb/ft3 material was tested as sheets 0.15 and 0.25 inches thick and the 9 lb/ft3 material in sheets 1 inch thick. The material showed very non-linear compression behavior with the compressive resistance of the material increasing as the material was compressed. The 3 lb/ft3 0.15-inch thick material required 4.1 psi to reach the nominal installation thickness of 0.045 inches and retain a load of 2.1 lbs during unloading. Testing at 2300°F resulted in a stiffer more board-like material. The 3 lb/ft3 0.15-inch thick material retained 1 psi of compressive resistance after a 10 minute hold at 2300°F and 0.045 inches thickness.

15. SUBJECT TERMS
Saffil, Insulation, Compressive properties, Alumina, Aluminum Oxide

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