DESTRUCTIVE EXAMINATION OF SHIPPING PACKAGE 9975-00600

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Nomenclature

ASTM – American Society for Testing and Materials

DSA – Documented Safety Analysis

FT-IR – Fourier Transform Infrared Spectroscopy

ID – Inside Diameter

KAC – K-Area Complex

OD – Outside Diameter

PCV - Primary Containment Vessel

RH – Relative Humidity

SAT – Satisfactory

SCV – Secondary Containment Vessel

SEM – Scanning Electron Microscope

SPA – Surveillance Program Authority

SRNL – Savannah River National Laboratory

SRS – Savannah River Site

UNSAT – Unsatisfactory

WME – Wood Moisture Equivalent

Destructive Examination of Shipping Package 9975-00600

Introduction

The Savannah River Site (SRS) stores packages containing plutonium (Pu) materials in the K-Area Complex (KAC). The Pu materials are packaged per the DOE 3013 Standard and stored within Model 9975 shipping packages in KAC.

The KAC facility DSA (Document Safety Analysis) [1] credits the Model 9975 package to perform several safety functions, including criticality, impact resistance, containment, and fire resistance to ensure the plutonium materials remain in a safe configuration during normal and accident conditions. The Model 9975 package is expected to perform its safety function for at least 12 years from initial packaging. The DSA recognizes the degradation potential for the materials of package construction over time in the KAC storage environment and requires an assessment of materials performance to validate the assumptions of the analysis and ultimately predict service life.

As part of the comprehensive Model 9975 package surveillance program [2-3], destructive examination of package 9975-00600 was performed following field surveillance in accordance with Reference [4]. Field surveillance of the Model 9975 package in KAC included nondestructive examination of the drum, fiberboard, lead shield and containment vessels [5]. Results of the field surveillance are provided in Attachment 1.

Summary

Destructive and non-destructive examinations have been performed on specified components of shipping package 9975-00600. For those attributes that were also measured during the field surveillance, no significant changes were observed. Three conditions were identified that do not meet inspection criteria. These conditions are subject to additional investigation and disposition by the Surveillance Program Authority. The conditions include:

- The lead shield was covered with a white corrosion layer.
- The lead shield height dimension exceeded drawing requirements.
- Fiberboard thermal conductivity in the axial direction exceeded the specified range.

The Surveillance Program Authority was notified of these conditions. All other observations and test results met identified criteria, or were collected for information and trending purposes.

Package History

Package 9975-00600 was originally fabricated at Accurate Machine Products Corporation in July 2001. The package contained plutonium oxide material from Rocky Flats packaged in accordance with DOE-STD-3013. Rocky Flats loaded this package on October 29, 2001, and shipped it to KAC on July 30, 2002. The package has been used for shipment only once. It has been stored in KAC for approximately 5 years, until June 22, 2007. Routine field surveillance was performed on June 28, 2007. SRNL received the package on July 17, 2007 and performed destructive examination activities between August 22 and September 20, 2007.

Discussion

The results of the field surveillance [6] were reviewed. No unsatisfactory conditions were noted. The only condition noted was the presence of a dust-like film on the shield interior wall and a small amount of debris at the bottom. This condition was not noted during the destructive examination.

As the package was opened, and components removed, each component was marked to identify its orientation within the package. For components that were removed during the field surveillance, their orientation at the time of this examination probably bears no relation to their orientation while stored in KAC. However, the bottom fiberboard subassembly and lead shield would likely have remained in the same orientation they occupied in KAC.

Examination activities are documented through photographs, data sheets, and other documents. This documentation is maintained in a laboratory notebook [7]. The following examination activities were performed:

Fiberboard physical properties:

The weight and dimensions of the top and bottom fiberboard subassemblies were measured. The weight of the top subassembly was 11.496 kg (25.34 lb). During the field surveillance, the measured weight of the top subassembly was 25.4 lb. These two measurements are in agreement within their respective levels of precision, indicating no significant change in weight occurred between the two measurements. Weight and dimension data are recorded in Table 1.

The air shield was cut and peeled back at four locations to permit accurate measurement of the top fiberboard subassembly dimensions. In order to calculate the density of each subassembly, nominal dimensions were assumed for the aluminum bearing plate and air shield. The calculated densities (0.25 g/cc top subassembly, 0.29 g/cc bottom subassembly) exceed the minimum value for the criticality control function, 0.20 g/cc [4]. The volume and density were calculated using the following equations (refer to the Table 1 sketch for dimension nomenclature).

Top subassembly fiberboard volume,

$$V_U = (UD1)^2 (UH1) (\pi/4) + [(UD1) - 2 (UR2)]^2 (UH2) (\pi/4) - (UD2)^2 (UH3) (\pi/4) - 59.96 \text{ inch}^3$$

Top subassembly fiberboard weight, W_U = upper assembly weight – 9.773 lb

Top subassembly fiberboard density, $\rho_U = W_U / V_U$

Bottom subassembly fiberboard volume,

$$V_L = (LD1)^2 (LH1) (\pi/4) - [(LD2) + 2 (LR1)]^2 (LH3) (\pi/4) - (LD2)^2 (LH2) (\pi/4) - 59.96 \text{ inch}^3$$

Bottom subassembly fiberboard weight, W_L = bottom subassembly weight – 4.827 lb

Bottom subassembly fiberboard density, $\rho_L = W_L / V_L$

Fiberboard dimensions measured during field surveillance are summarized in Attachment 1, and are consistent with drawing requirements and destructive examination measurements. For each of the five dimensions measured in both the field surveillance and destructive examination, the change in value is small between the two measurements. No significant observations were found with the fiberboard physical measurements.

Fiberboard visual appearance:

Following removal of both the top and bottom fiberboard subassemblies from the outer drum, both were inspected visually. Several regions on the ID surface of the fiberboard contained white deposits from rubbing against the lead shield. The lower fiberboard assembly contained several dark spots on the OD surface (Figure 1), which appear consistent with dried patches of the glue used to laminate the assembly.

Fiberboard moisture content:

The moisture content of the fiberboard is expected to vary with changes in the ambient humidity. Change in the fiberboard moisture content will lead to change in density, mechanical properties and thermal properties. Measuring the relative moisture content of the top and bottom subassemblies provides a reference point to potentially correlate laboratory test results with behavior in KAC.

A GE Protimeter Surveymaster moisture probe was used to measure the relative moisture content of the top and bottom fiberboard subassemblies. This probe identifies the wood moisture equivalent (WME), or the weight % of moisture that would produce the same electrical conductivity in wood. Moisture measurements of both the upper and lower subassemblies were made soon after opening the drum. Moisture content data are presented in Figure 2.

Moisture measurements were compared to those taken on packages 9975-02234 and 9975-00826 during previous destructive examinations [8,9]. The readings on 9975-00600 were similar to those on 9975-00826, and lower than those on 9975-02234. Of the three packages, 9975-00600 had the largest difference in moisture content between the ID and OD surfaces. For the current package typical ID values were 8.0 to 9.8 %WME, while typical OD values were 11.2 to 13.5 %WME.

Fiberboard thermal and mechanical properties:

Samples of fiberboard were removed from the bottom fiberboard subassembly to measure compressive strength, specific heat capacity and thermal conductivity. The source location(s) of these samples is illustrated in Figure 3. The thermal conductivity sample from the bottom center of the subassembly is oriented for heat flow in the axial direction (perpendicular to the glue joints). The thermal conductivity sample from the side is oriented for heat flow in the radial direction (parallel to the glue joints). Testing on each sample was performed at a nominal (mean) temperature of approximately 25ºC (77ºF), with no environmental conditioning. Physical data on the fiberboard samples are recorded in Table 2.

The compression test data are shown in Figures 4 and 5, along with select baseline data. For both the perpendicular and parallel orientations, the compression strength of the 9975-00600 samples is similar to the baseline samples conditioned at 77ºF and 70% RH. A series of photographs showing typical compression behavior under parallel loading is shown in Figure 6.

Three samples were prepared from the side of the lower assembly for measuring the specific heat capacity of the fiberboard. The specific heat capacity was calculated in accordance with ASTM C351 at a mean temperature of 25ºC (~77ºF). This ASTM Standard specifies test temperatures that would produce a mean test temperature of 60ºC, but allows alternate test temperatures to be substituted as needed. Data were collected for a sample target temperature of 45ºC, and a water temperature of ~5ºC. The sample moisture content was 12.1 – 13.6 % WME (wood moisture equivalent). Each sample was tested two times, and all results were averaged. The average value was 1875 J/kg-K. Multiplying this value by the density of the lower subassembly (293 kg/m^3) gives a heat capacity of 549,000 J/m^3-K (8.19 Btu/ft^3-F). This meets the required minimum value of 3 Btu/ft^3-F. The specific heat capacity value is somewhat higher than typical baseline laboratory data, but an increased specific heat capacity is expected for fiberboard with a higher than average moisture content.

The thermal conductivity of the fiberboard was measured with a Lasercomp Inc. Fox 300 thermal conductivity instrument at a mean temperature of 25ºC (77ºF). For the sample with axial heat flow (perpendicular to the fiberboard layers), the measured thermal conductivity is 0.0646 W/m-K (0.0373 Btu/hr-ft-ºF). This value falls outside the acceptance range identified for destructive examinations (0.025 – 0.035 Btu/hr-ft-ºF [4]). It was noted that a region of fiberboard immediately above the axial sample was significantly lighter in color (Figure 7). A second axial sample was removed from this region and tested. The measured thermal conductivity for this second sample is 0.0604 W/m-K (0.0349 Btu/hr-ft-ºF), which falls within the identified range. For the sample with radial heat flow (parallel to the fiberboard layers), the measured thermal conductivity is 0.1060 W/m-K (0.0612 Btu/hr-ft-ºF). This value falls within the identified range of 0.053 – 0.067 Btu/hr-ft-ºF [4]. The thermal conductivity values are consistent with typical baseline laboratory data.

Lead shield visual examination:

The entire surface of the lead shield was visually examined. It was found to be free from significant deformation and physical damage, but the side was covered with a white corrosion product. From the prior examination of the shield from package 9975-02234, the corrosion product was identified as basic lead carbonate (hydrocerrusite), $Pb_3(CO_3)_2(OH)_2$.

Due to the presence of corrosion on the shield, additional testing was performed. The thickness of the corrosion layer was measured in a number of locations with an Elcometer 345FN coating thickness gage. This gage uses an eddy current technique. The gage was calibrated using shims ranging in thickness from 22.9 microns (0.00090") to 981 microns (0.0386") on the lead container. Measurements were made at a number of locations with a range of apparent layer thicknesses. Measurements ranged from 1.3 to 3 mils thick, and are summarized in Figure 8. These nondestructive measurements were made by SRNL / Materials NDE & Consultation Group.

Lead Shield Dimensions:

Several lead shield dimensions were measured (Table 3) and all but one are consistent with drawing requirements. The overall height of the shield was 24.716 inch, while the drawing specifies a maximum height of 24.7 inch.

The radial thickness was measured near the top of the shield, and was calculated from dimensional data taken near the bottom of the shield. The calculated thickness from near the bottom (0.542 inch) is slightly less than the measured thickness near the top (0.547 inch). While lead is known to creep at ambient temperatures, these data suggest that no significant creep deformation has occurred thus far.

O-ring examination and testing:

Prior surveillance testing of the four O-rings from this package included visual examination, dimensional and hardness measurements. Three of these O-rings (SCV outer, PCV outer and PCV inner) received additional testing. All three were submitted for FT-IR spectroscopy to confirm material composition, and the two outer O-rings received optical and SEM microscopic examination of the cross section. The dimensions and weight of the SCV outer and PCV outer O-rings were recorded to calculate their density. The PCV inner O-ring was tensile tested, including a hold point at 50% strain to visually examine the O-ring.

FT-IR spectroscopy generically identified the composition of each O-ring as consistent with a Viton® type fluoroelastomer (Figure 9). Viton® A produces a spectrum nearly identical to Viton® GLT, the base polymer for the specified O-ring compound (Parker Seals V0835-75) and the two are difficult to distinguish by FT-IR analysis alone. Additional test techniques (e.g. dynamic mechanical analysis, DMA) would be required to uniquely verify the GLT composition. These results are similar to those from previous destructive examination packages [8,9] and are consistent with baseline data [10].

Visual (Figure 10) and SEM (Figure 11) examination of the cross sections identified a distribution of very small particles throughout each O-ring. Each O-ring had a faint but distinct transition between the inner and outer regions of the cross section, with the center region being slightly lighter in appearance. X-ray analysis on the SEM identified no significant variation in element distribution across this transition. Aside from carbon and fluorine (which are the primary constituents of Viton®) the SEM identified aluminum, silicon, calcium, oxygen, and zinc. These elements are present in small amounts, and are generally associated with the particles. Though the actual compound is proprietary, the elements detected are consistent with Viton®-type fluoroelastomer compounds, which typically contain MgO, CaO, $Ca(OH)_2$, ZnO or lead compounds as acid acceptors and heat stabilizers [11]. Aluminum is generally not added to fluoroelastomer recipes, but may be present as a trace contaminant.

Weight and dimension data for the two outer O-rings are presented in Table 4. The average minor diameter for each O-ring is within the specified tolerances for new O-rings, but the major inside diameter for each O-ring (calculated from the length measured after the O-ring was cut) is greater than specified for new O-rings. This is consistent with a permanent stretch due to the lid diameter. Leak testing during the field surveillance was successful.

The PCV inner O-ring was tensile tested in accordance with ASTM D1414, using a cut (single strand) sample. The test was interrupted at 50% strain to visually examine the O-ring for signs of cracking or other degradation. None were observed. The stress-strain curve for the PCV inner O-ring is shown in Figure 12 along with that from a new O-ring tested during the previous destructive examination. The O-ring from package 9975-00600 displayed a greater tensile strength and significantly greater elongation than the new O-ring. The tensile strength of this O-ring (1.6 ksi) equals the minimum value specified in AMS-R-83485 for new O-rings, while the elongation (348%) significantly exceeds the minimum value (120%) specified in AMS-R-83485 [10]. While Parker Seals does not change the formulation of these O-rings, there are batch variations.

General:

A general visual examination was performed on all metallic components. Aside from the corrosion of the lead shield (discussed above) no significant damage or degradation was observed. Several components were observed to have unexpected markings. Several numbers were written on the top of the air shield (Figure 13), and various markings were engraved, stamped, scratched or written on the containment vessels and shield lid (Figure 14). Most of these markings appear to be identification numbers used during manufacture, prior to association of the parts with a final package number.

The distance from the drum flange to the top of the air shield was measured, and ranged from 0.897 to 0.943 inch. The average value was 0.912 inch. The drum drawing [12] identifies a reference value for this dimension as 0.8 inch, and notes that it may vary over time due to variations in fiberboard properties. Maintenance requirements, consistent with fire and drop test qualifications for the 9975 package, require this dimension be no greater than 1 inch. The measured values meet this requirement.

The data from the examination activities described above are compared with field surveillance data in Attachment 1. Several conditions were observed that do not meet specified criteria. The Surveillance Program Authority (SPA) was notified of these conditions, and will direct further investigation and analysis as appropriate. They are summarized as follows:

- The lead shield was covered with a white corrosion layer.
- The shield height exceeds the drawing maximum.
- Thermal conductivity of the fiberboard in the axial direction exceeds the specified range.

All other observations and examination results are consistent with expectations. All findings will be reviewed by NMM for potential impact on the continued storage of other packages in KAC.

Measurement Uncertainties:

Numerous measurements were made with a variety of instruments during the destructive examination of package 9975-00600. Some of the measurements were specifically compared to inspection criteria, while others were taken for information / trending purposes. All measurements which are compared to inspection criteria were made with calibrated instruments, or were verified against calibrated instruments. The uncertainties associated with measurements and calculated results required to meet inspection criteria are discussed below.

Weight – The weight of each fiberboard subassembly was measured to the nearest 2 grams. The balance used was M&TE, and was verified with weights. Measurement repeatability of weights similar to that of the fiberboard over a period of time is 6 grams. Calibration data for the balance shows an accuracy of 0.2 lb (90 g) at 100 lb. Adding the observed variability of 6 g gives a conservative uncertainty of 96 g for the measured weights less than 100 lb.

Calipers – Three different calipers were used to measure component dimensions. All three calipers were verified against length standards, with the length characterized to better than 0.001 inch. The 6 inch caliper was accurate to 0.002 inch or better, while the larger calipers were accurate to 0.001 inch or better. In addition, operator bias can affect measurement accuracy through the contact load applied when making a measurement. A degree of give exhibited by the fiberboard will lead to different results as the contact load changes. The larger calipers are judged to be more susceptible to this bias. Metallic components are significantly more rigid than the fiberboard, but operator bias may also exist for those components. While not characterized explicitly, it is judged that the total uncertainty (instrument uncertainty plus operator bias) in calipers results is no greater than +/- 0.003 inch for the 6 inch calipers, and +/- 0.005 inch for the larger calipers when measuring fiberboard. It is further judged that total uncertainty in calipers results is no greater than +/- 0.003 inch for all calipers when measuring metallic components.

Manual calipers – Dimension ID2 on the lead shield was captured with a manual swing calipers, which was then locked in that position and measured with a 24-inch calipers. It is judged that the accuracy of capturing this dimension with the manual calipers is within +/- 0.002 inch, and the measurement of that dimension is then within +/- 0.002 inch, for a (conservatively) combined accuracy of +/- 0.004 inch.

Thermal conductivity instrument – The specifications for the Fox300 thermal conductivity instrument include a stated accuracy of ~1%. Measurement of the thermal conductivity of a calibration standard was accurate to within 1.1%. Prior test reports of fiberboard samples from an independent laboratory, using the same model instrument, identified an overall 3% uncertainty. An uncertainty of 3% will be conservatively assumed for the current measurements.

Heat capacity – The specific heat capacity is derived from temperature and weight measurements, using calibrated instruments. The thermocouple and balance precisions are high. The greatest contribution to error in the specific heat capacity is considered to be consistency of operator technique. The total uncertainty is reflected in the range of results for multiple trials. The heat capacity is measured twice on each of three samples. The range of variation for each sample was +/- 12% or less. Previous variation up to 15% has been observed [9]. Using 15% as a bounding value, the uncertainty on the average of 3 samples is 8.6% or less.

Where measurement results are used in subsequent calculations, the uncertainty values identified above are assumed to be random. A standard error propagation formula for random errors is used to calculate the final result uncertainty. In some cases, the calculated uncertainty may be less than the potential error from rounding off the result, and the higher variation associated with round-off is reported as the uncertainty. These calculations are documented in the Laboratory Notebook [7]. Calculation results and their uncertainties are summarized as follows:

- Top fiberboard subassembly volume = 28494 +/- 26 cm^3
- Top fiberboard subassembly density = 0.248 +/- 0.003 g/ cm^3
- Bottom fiberboard subassembly volume = 85535 +/- 70 cm^3
- Bottom fiberboard subassembly density = 0.293 +/- 0.001 g/ cm^3
- Shield radial thickness at bottom = 0.542 +/- 0.003 inch
- Thermal conductivity (radial) = 0.0612 +/- 0.002 Btu/hr-ft-ºF
- Thermal conductivity (axial) = 0.0373 +/- 0.001 Btu/hr-ft-ºF
- Heat capacity = 8.2 +/- 0.71 Btu/ft^3-ºF

References

[1] WSRC-SA-2002-00005, Rev. 1, "K-Area Material Storage Facility Documented Safety Analysis", June 2004

[2] SFS-ENG-99-0085, "Summary and Guide to 9975 Container Qualification Program"

[3] WSRC-TR-2001-0286, Rev. 3, "Savannah River Site Surveillance Program for Storage of Pu Materials in KAMS", December 2006

[4] WSRC-TR-2005-00135, "Task Technical and Quality Assurance Plan for Destructive Examination of a 9975 Package from Field Surveillance Activities", W. L. Daugherty, April 2005

[5] WSRC-TR-2004-00197, "Inspection Activities and Acceptance Criteria for Field Surveillance of Model 9975 Package O-Rings and Celotex® Materials", W. L. Daugherty, April 2004

[6] SOP-CSS-207-K, Attachment 2 "9975 Surveillance Data Sheet" for surveillance WSRC-SRV-2007-004

[7] WSRC-NB-2006-00060, Laboratory Notebook "9975 Shipping Package Celotex Testing"

[8] WSRC-TR-2005-00273, Rev. 1, "Destructive Examination of Shipping Package 9975-02234", W. L. Daugherty, September 2005.

[9] WSRC-TR-2006-00162, "Destructive Examination of Shipping Package 9975-00826", W. L. Daugherty, May 2006.

[10] WSRC-TR-2004-00162, "Baseline Characterization of Model 9975 Shipping Package O-Rings", T. E. Skidmore, March 2004

[11] Rubber Technology Handbook, W. Hofmann, Hanser Publishers, New York, 1989, page 122

[12] Drawing R-R2-F-0025, Rev. 2, "9975 Drum with Flange Closure Subassembly & Details"

Table 1. Fiberboard physical measurements and calculated density

Top Subassembly						
Weight	11.496 kg					R-R2-F-0019 Rev 5
	0/180 deg.		90/270 deg.		Avg.	Nominal value (inch)
UD1 (in)	17.600		17.626		17.613	17.7
UD2 (in)	8.614		8.614		8.614	8.55
	0 deg.	90 deg.	180 deg.	270 deg.	Avg.	
UR1 (in)	3.042	3.040	3.040	3.044	3.042	3.075
UR2 (in)	1.528	1.511	1.500	1.510	1.512	1.5
UH1 (in)	7.161	7.158	7.146	7.160	7.156	7.1
UH2 (in)	2.095	2.084	2.089	2.083	2.088	2.1
UH3 (in)	5.038	5.046	5.046	5.038	5.041	5.0

Top subassembly calculated density = 0.248 g/cc

Bottom Subassembly						
Weight	27.254 kg					R-R2-F-0019 Rev 5
	0/180 deg.		90/270 deg.		Avg.	Nominal value (inch)
LD1 (in)	18.070		18.072		18.071	18.1
LD2 (in)	8.522		8.510		8.516	8.45
	0 deg.	90 deg.	180 deg.	270 deg.	Avg.	
LR1 (in)	3.187	3.235	3.262	3.242	3.232	3.275
LR2 (in)	1.538	1.520	1.521	1.534	1.528	1.55
LH1 (in)	26.605	26.561	26.548	26.581	26.574	26.7
LH2 (in)	20.676	20.683	20.665	20.651	20.677	20.4
LH3 (in)	2.035	2.032	2.035	2.029	2.033	2.0

Bottom subassembly calculated density = 0.293 g/cc

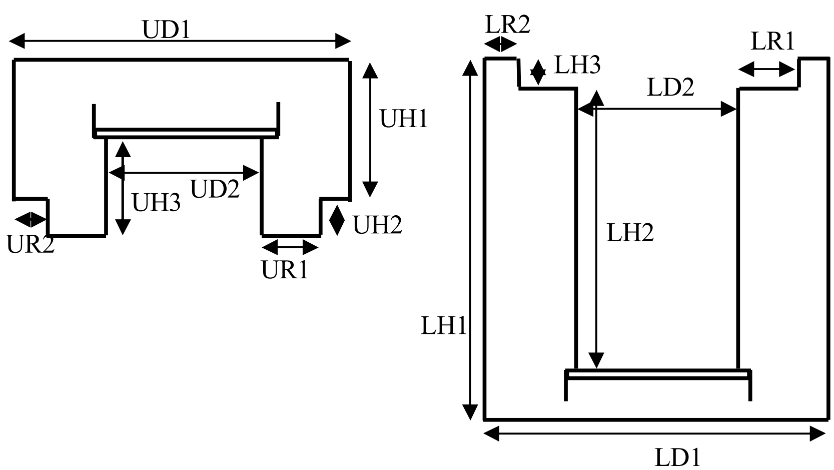


Table 2. Physical data for fiberboard test specimens

Compression Test Sample	Moisture Content (%WME)	Weight (g)	Length (inch)	Width (inch)	Height (inch)	Density (g/cc)
Compression Test Samples						
Side 1 (parallel)	10.5	38.259	2.012	2.024	1.975	0.301
Side 2 (parallel)	10.3	38.429	2.018	2.006	1.967	0.303
Side 3 (perpendicular)	10.4	38.165	2.013	2.017	1.959	0.300
Side 4 (perpendicular)	10.5	39.117	2.018	2.020	1.965	0.303
Base 1 (parallel)	11.9	39.002	1.986	1.990	1.999	0.290
Base 2 (parallel)	13.0	39.400	1.989	1.995	2.001	0.295
Base 3 (perpendicular)	11.5	38.729	1.981	1.993	1.997	0.293
Base 4 (perpendicular)	11.8	38.908	1.968	1.994	1.999	0.298
Thermal Conductivity Samples						
Side (radial)	10.6	440	9.272	7.004	1.418	0.291
Base (axial)	12.4	481	9.674	7.009	1.431	0.302

Table 3. Lead shield dimensions

Dimension	0/180 deg. (inch)		90/270 deg. (inch)		Avg. (inch)	Requirement (inch)
OD (in)	8.330		8.337		8.334	8.252 – 8.35
ID1 (in)	7.238		7.276		7.257	7.25 – 7.26
ID2 (in)	7.252		7.250		7.251	7.24 – 7.26
	0 deg.	90 deg.	180 deg.	270 deg.		
R (in)	0.562	0.542	0.549	0.535	0.547	0.506 min
H (in)	24.690	24.703	24.750	24.722	24.716	24.592 – 24.7

(OD – ID2) / 2 = 0.542 inch

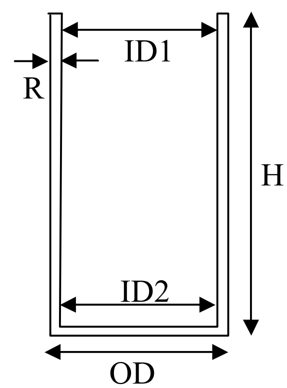


Table 4. O-ring physical data

	PCV Outer O-Ring		SCV Outer O-Ring	
	Radial	Axial	Radial	Axial
Minor Dia. 0 deg	0.1370 inch	0.1410 inch	0.1365 inch	0.1410 inch
Minor Dia. 45 deg	0.1340 inch	0.1405 inch	0.1380 inch	0.1380 inch
Minor Dia. 90 deg	0.1325 inch	0.1380 inch	0.1380 inch	0.1370 inch
Minor Dia. 135 deg	0.1335 inch	0.1400 inch	0.1420 inch	0.1330 inch
Minor Dia. 180 deg	0.1370 inch	0.1395 inch	0.1385 inch	0.1380 inch
Minor Dia. 225 deg	0.1330 inch	0.1395 inch	0.1400 inch	0.1380 inch
Minor Dia. 270 deg	0.1325 inch	0.1390 inch	0.1345 inch	0.1405 inch
Minor Dia. 315 deg	0.1325 inch	0.1400 inch	0.1415 inch	0.1390 inch
Avg. Minor Dia.	0.1368 inch		0.1384 inch	
Minor Dia. (new)	0.138 +/- 0.006 inch		0.138 +/- 0.006 inch	
Length (after cut)	14 5/32 inch		17 7/32 inch	
Calculated Major Dia.	4.51 inch avg. / 4.37 inch inside		5.48 inch avg. / 5.34 inch inside	
Major Inside Dia. (new)	4.234 +/- 0.030 inch		5.234 +/- 0.035 inch	
Weight	6.2384 g		7.3025 g	
Calculated Volume	0.2081 inch^3 (3.411 cm^3)		0.2588 inch^3 (4.242 cm^3)	
Calculated Density	1.83 g/cm^3		1.72 g/cm^3	

Figure 1. Dark regions on the OD surface of the lower fiberboard assembly

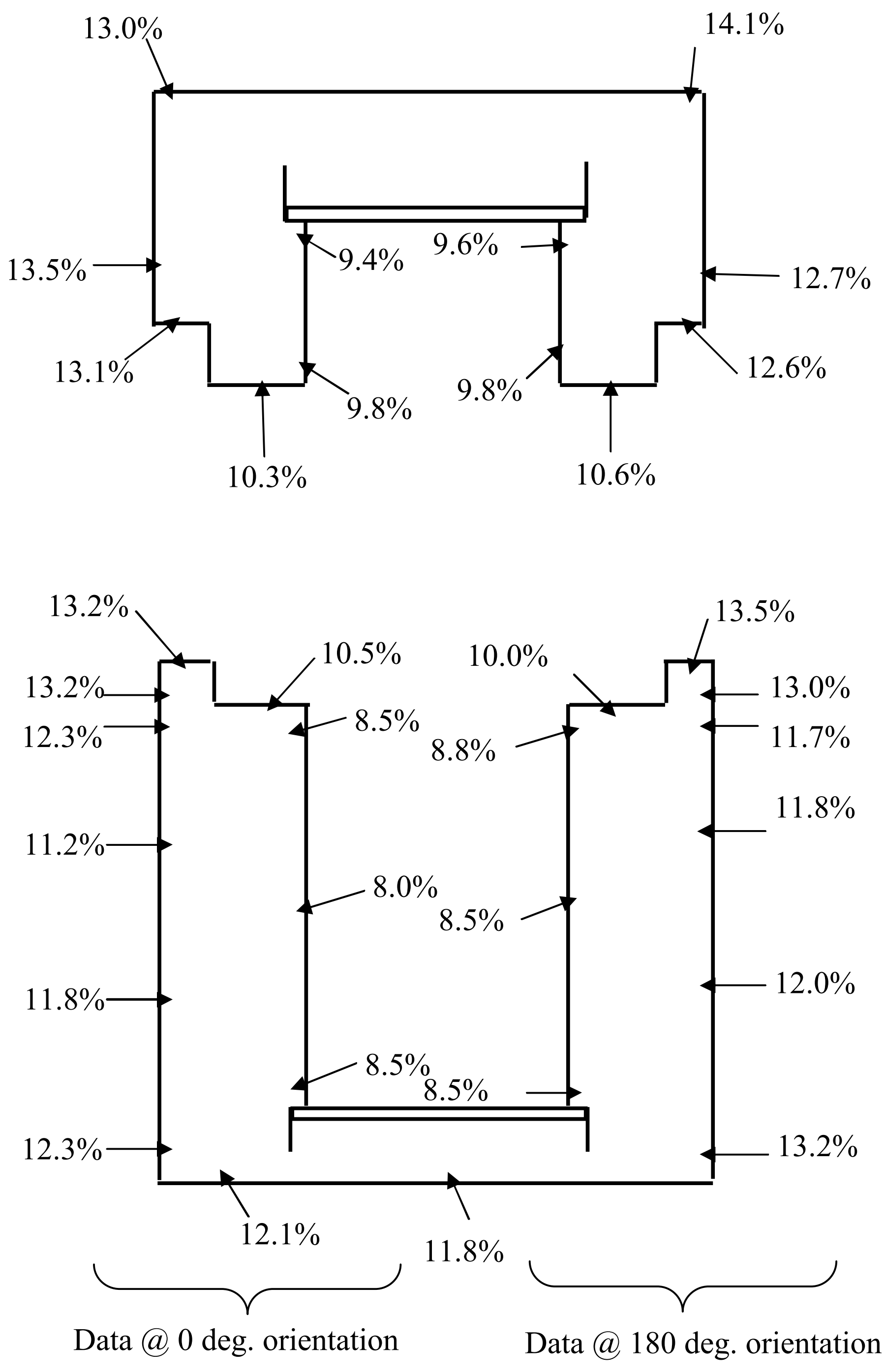


Figure 2. Fiberboard moisture content data. All values are % wood moisture equivalent.

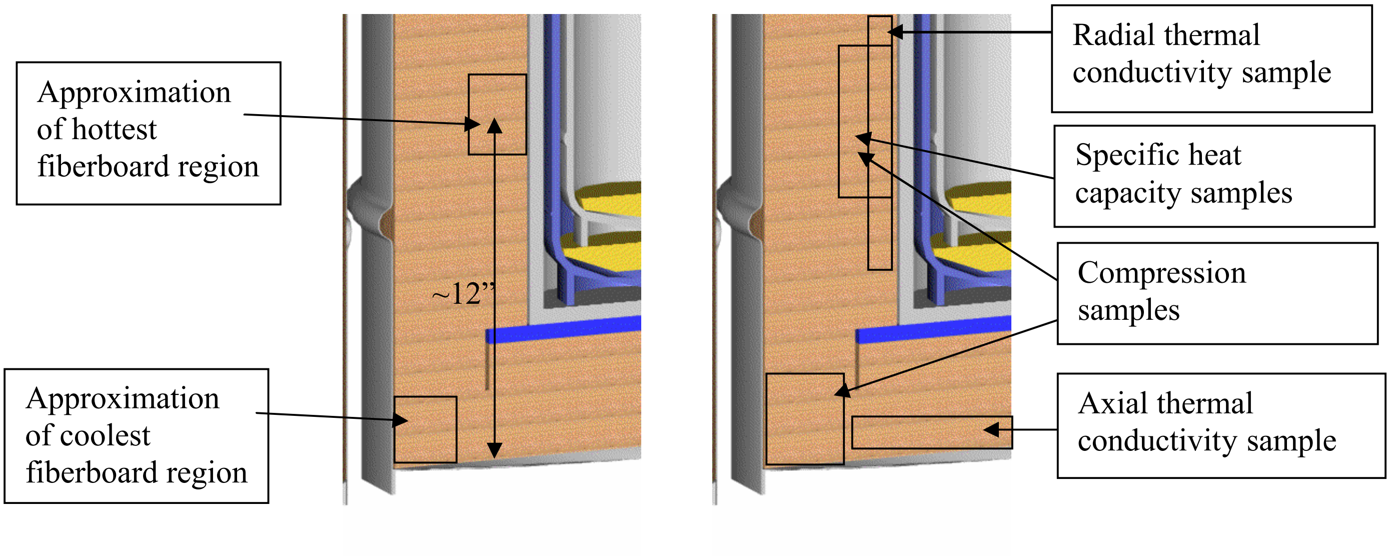


Figure 3. Illustration of fiberboard regions of the bottom subassembly to be tested. Multiple samples (where used) were removed from the illustrated locations at different circumferential positions. Not to scale.

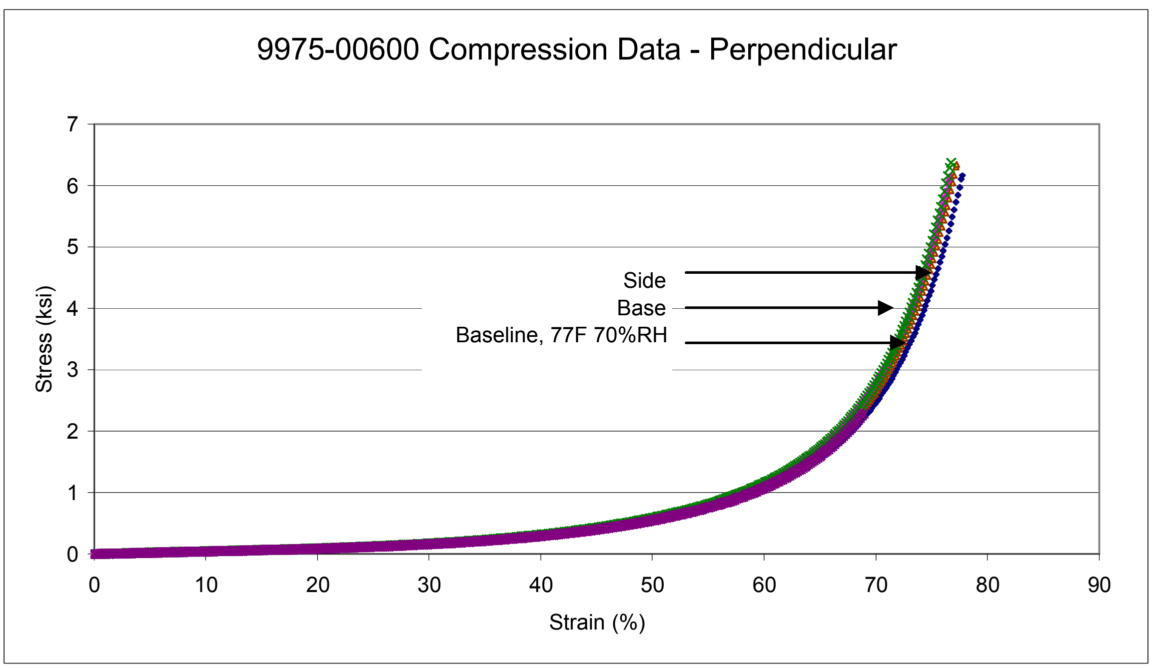
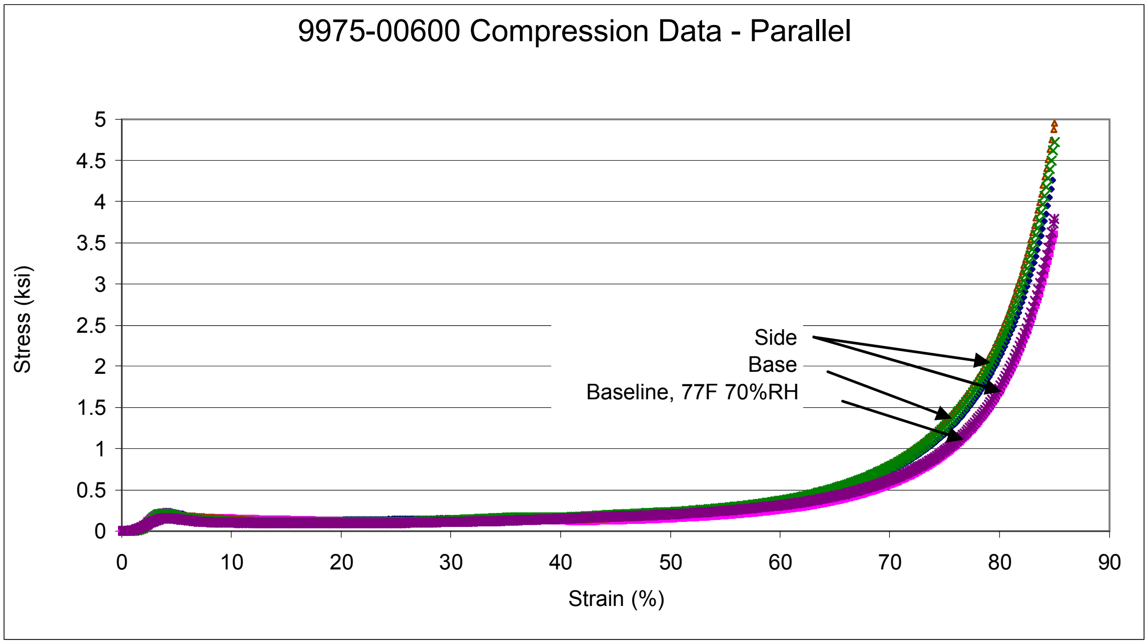
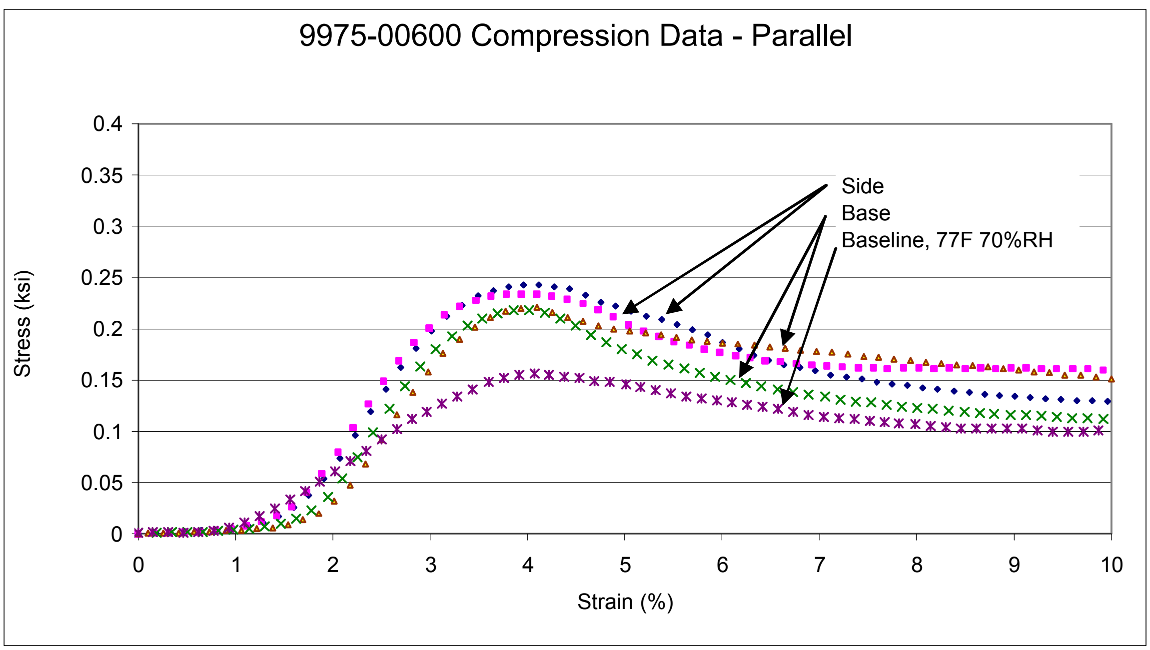


Figure 4. Fiberboard compression test data, compared with typical baseline (77°F, 70% RH) data, in the perpendicular orientation (i.e. load applied perpendicular to the fiberboard layers).

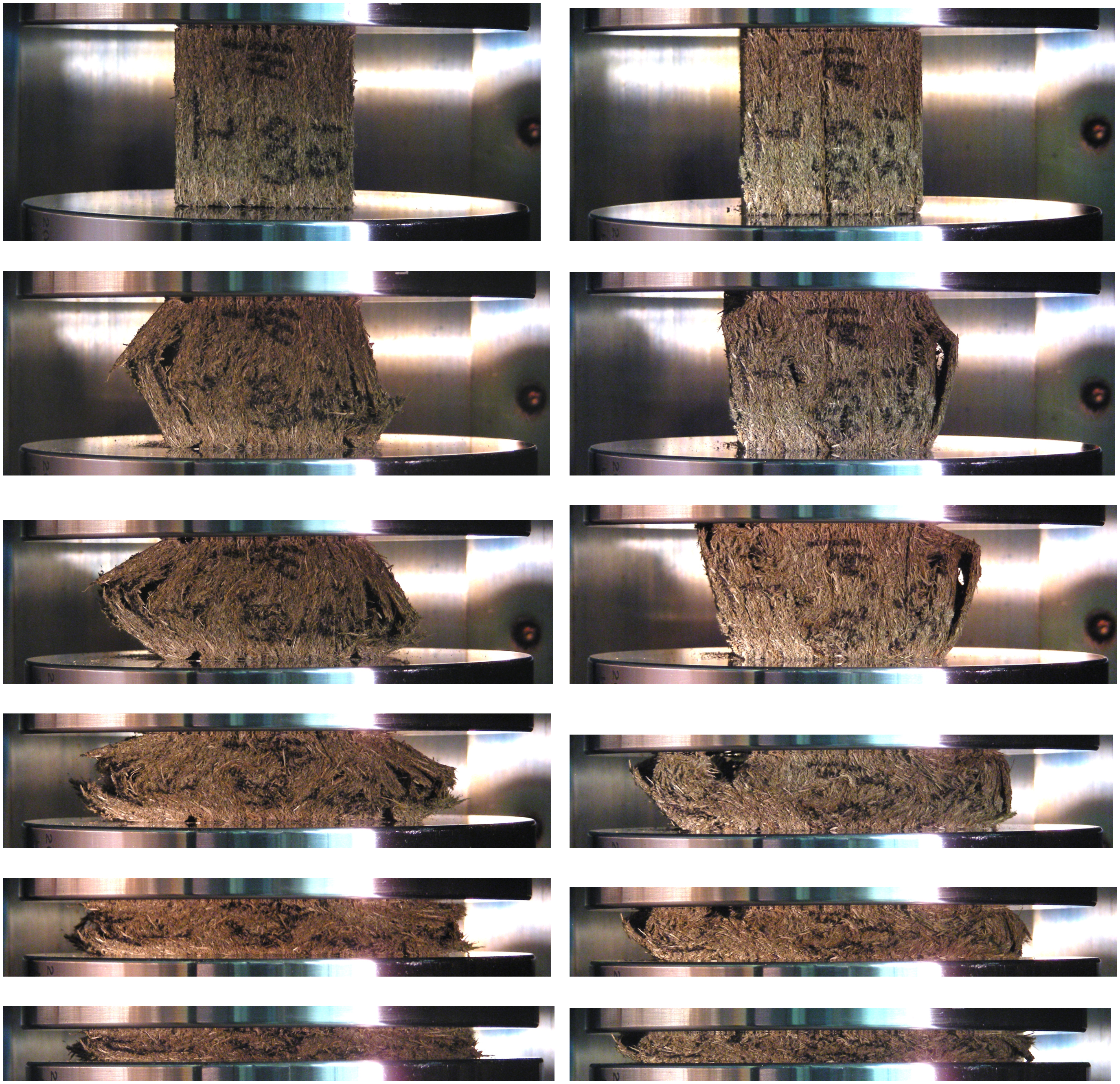


(a)



(b)

Figure 5. Fiberboard compression test data, compared with typical baseline (77°F, 70% RH) data, in the parallel orientation (i.e. load applied parallel to the fiberboard layers). The full curves are shown in (a), while the initial buckling region is expanded in (b).



(a) Sample B1 from base of assembly (b) Sample S1 from side of assembly

Figure 6. Photographs of samples during compression testing, parallel orientation

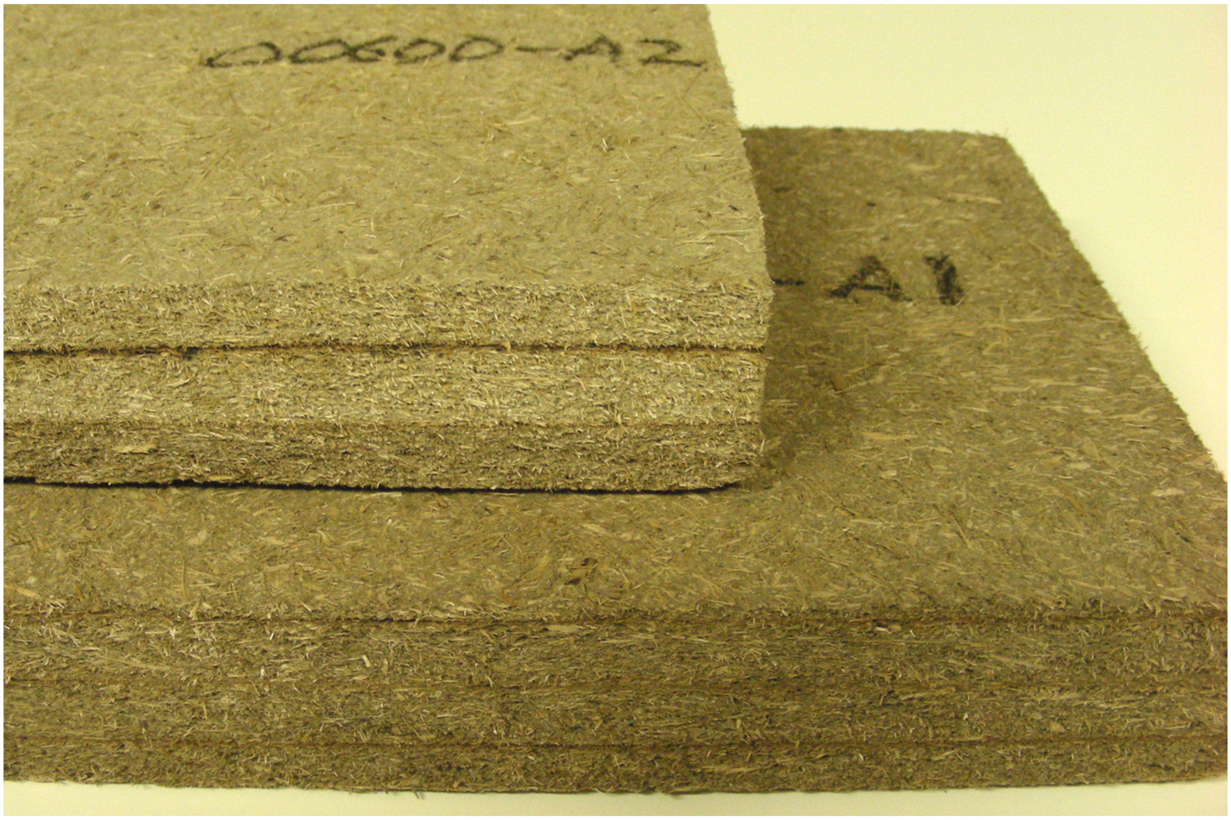
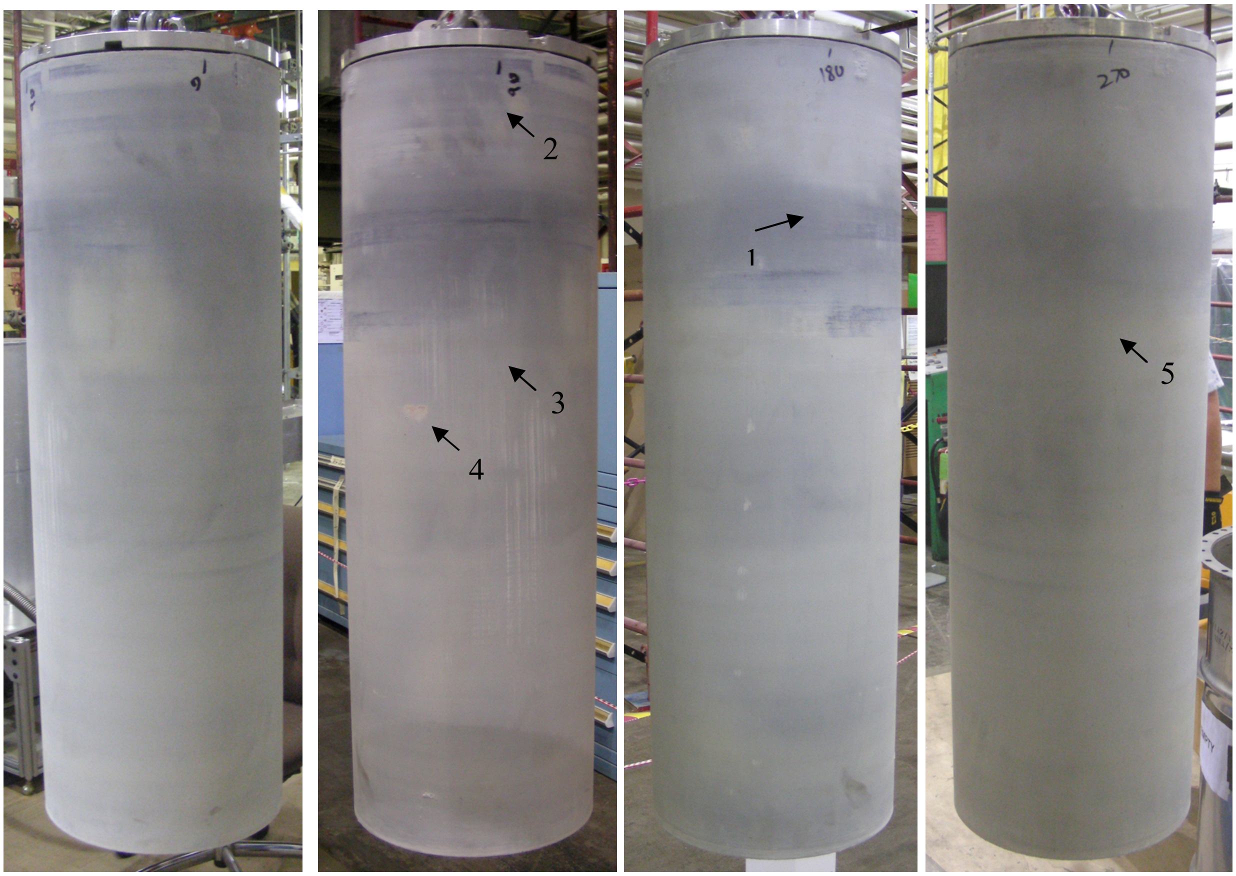
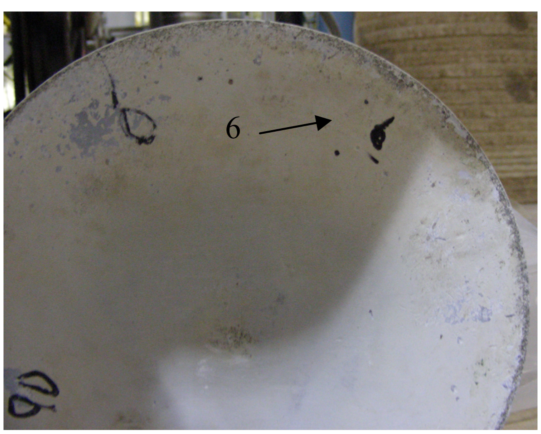


Figure 7. Two axial thermal conductivity samples, showing the difference in appearance of layers in the second sample (on top).





Location	Thickness (mil)	Location	Thickness (mil)
1	1.3	4	2.2
2	1.9	5	1.7
3	2.0	6	3.0

Figure 8. Lead shield with corrosion product. The arrows identify locations of corrosion thickness measurements, which are summarized in the chart.

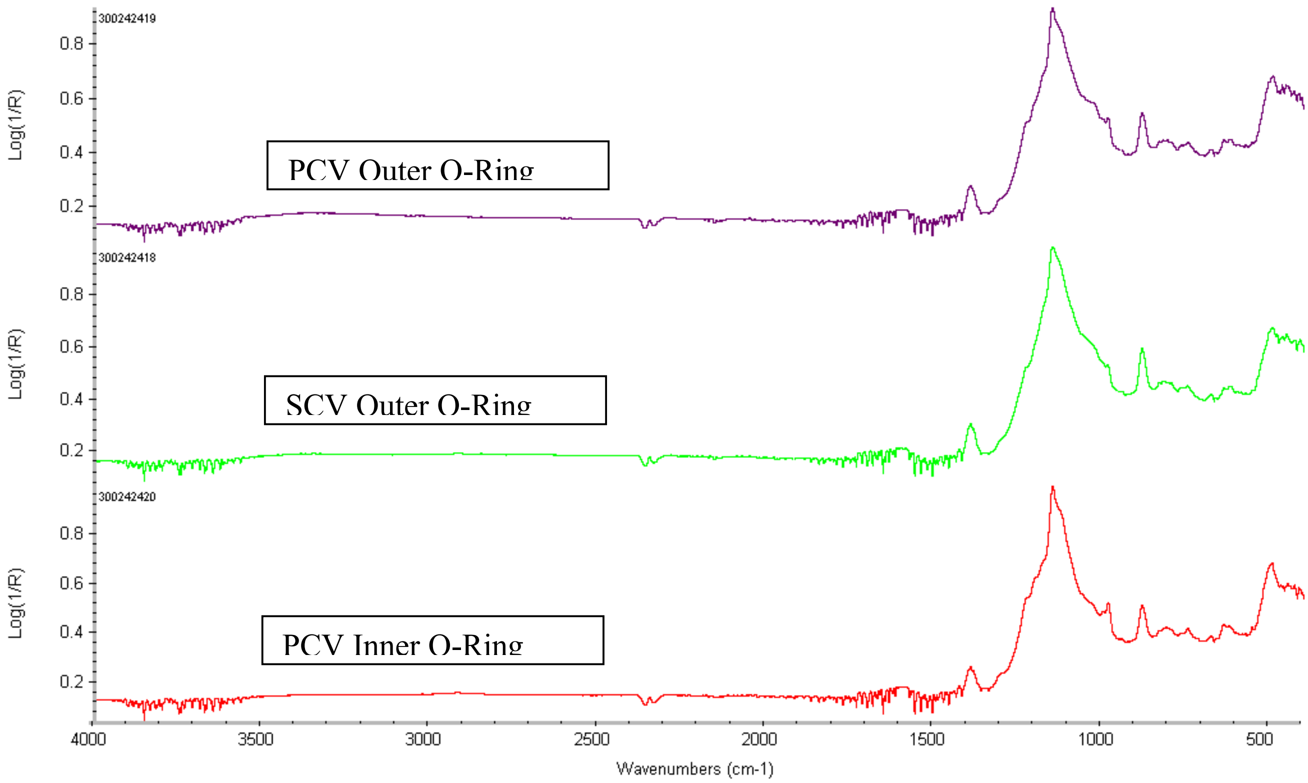
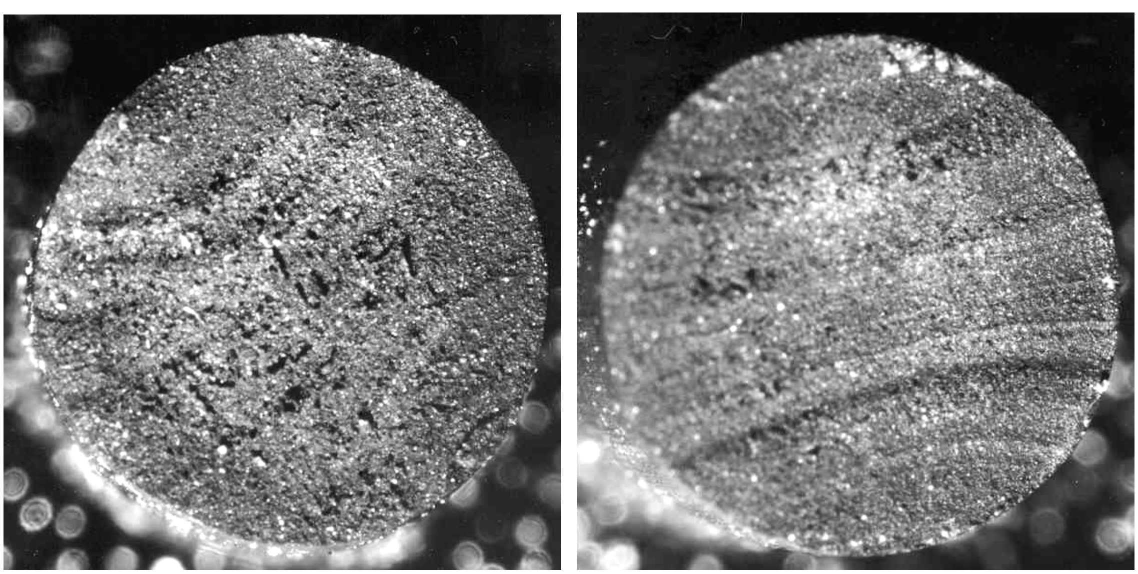
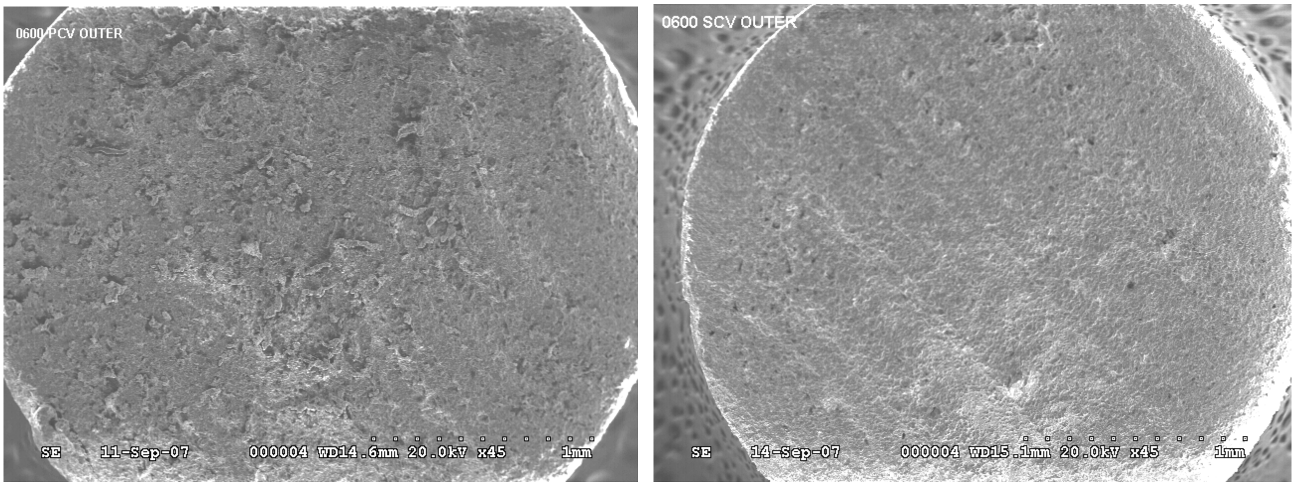


Figure 9. FT-IR spectra for the three tested O-rings. Each spectrum is consistent with a Viton® type fluoroelastomer.



(a) (b)

Figure 10. Visual cross section of the (a) PCV outer and (b) SCV outer O-rings.



(a) (b)

Figure 11. SEM cross section of the (a) PCV outer and (b) SCV outer O-rings.

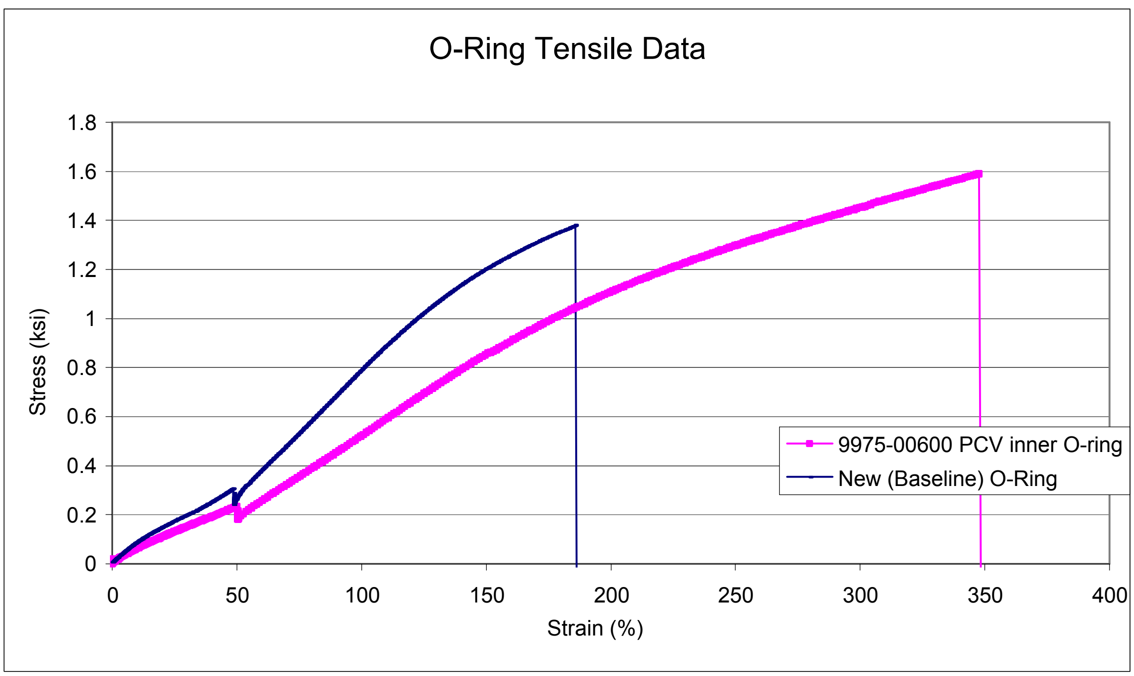


Figure 12. Tensile data for PCV inner O-ring and a new O-ring.

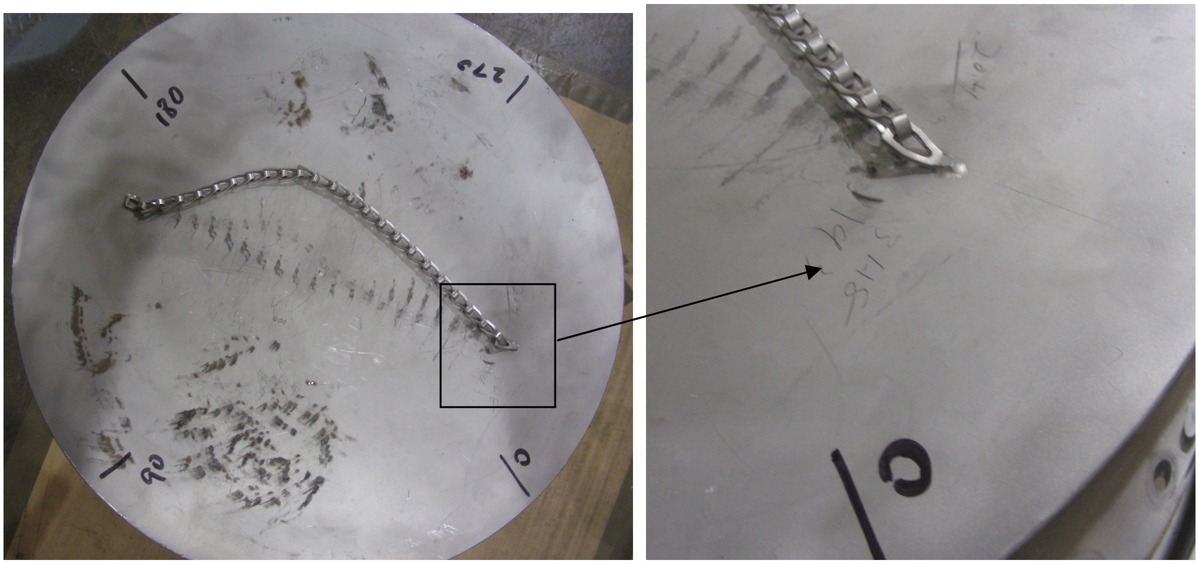


Figure 13. Top fiberboard subassembly, with detail showing writing on air shield.

(a) (b)

(c) (d)

Figure 14. Markings (at arrows) on various components in addition to the package ID: (a) SCV exterior side, (b) PCV lid bottom, (c) PCV lid top, (d) shield lid.

Attachment 1 9975-00600 Field Surveillance Results, with Comparison to Destructive Examination Results

Section I

Drum Exterior Examination

Item	Field Surveillance Result	Destructive Exam. Result
Drum vent plugs are specified and are in place as required	SAT	SAT
Drum surface is not dented beyond 0.25 inch	SAT	SAT
Drum Dents adjacent to the air shield are not deeper than 0.125 inch	SAT	SAT
Drum surface is free from corrosion, swelling/bulging and other physical damage	SAT	SAT

Section II

Temperature Measurements

[These data not repeated in this report.]

Section III

Celotex® Inspection

Upper Celotex® Assembly Weight: 25.4 lb (field surv.) 11.496 kg / 25.34 lb (destructive exam)

Visual:

Item	Field Surveillance Result	Destructive Exam. Result
Inspect all exposed Celotex® surfaces for significant damage and ensure layers are well bonded	SAT	SAT
Upper Celotex® came out smoothly, without interference	SAT	SAT
All visible Celotex® surfaces are free from staining and variation in coloration	SAT	SAT
Celotex® is free from significant swelling (e.g. gap exists against drum), shrinkage and other significant physical damage	SAT	SAT
Lead shield interior is free from significant deformation and physical damage	SAT	SAT
Lead shield Go/No Go gauge went smoothly into the lead shield and reached all the way to the bottom of the lead shield	SAT	NA

Attachment 1 9975-00600 Field Surveillance Results, with Comparison to Destructive Examination Results

Celotex® Dimensions (all results reported in inches)

	Dimensions	0°	90°	180°	270°	Field Surveillance Average	Destructive Exam. Average
1	Upper Assembly OD	17.689	17.689			17.689	17.613
2	Upper Assembly lower step OD	14.708	14.707			14.708	14.698
3	Upper Assembly ID	8.586	8.590			8.588	8.614
4	Upper Assembly inside height	5.024	5.004	5.020	5.008	5.014	5.041
5	Lower Assembly step height	2.037	2.021	2.044	2.031	2.033	2.088
6	Lower Assembly height from lower step to top of lead shield	3.979	4.056	4.077	4.039	4.038	NA

Dimension	Result	Criteria	Field Surveillance Result	Destructive Exam. Result
Dimension #6 average	4.038	$\leq$ 4.65 "	SAT	NA
Dimension #1 average – Dimension #3 average	9.101	$\geq$ 8 3/16"	SAT	8.999 / SAT

Section IV

O-Ring Inspection

Test	SAT/UNSAT
O-ring seal test performed on SCV	SAT
SCV O-rings were removed intact	SAT
SCV O-rings have no excess accumulation of grease	SAT
O-ring seal test performed on PCV	SAT
PCV O-rings were removed intact	SAT
PCV O-rings have no excess accumulation of grease	SAT

Attachment 1 9975-00600 Field Surveillance Results, with Comparison to Destructive Examination Results

(all dimensional results reported in inches)

Action	0°	90°	180°	270°	Time	Destructive Exam. Average Result
Loosen SCV lid					0511	NA
Outer SCV O-Ring						
Measure OD (while on plug)	6.315	6.310			0517/0520	NA
Measure radial thickness	0.1255	0.1295	0.1235	0.1300	0526/0528	0.1386
Measure vertical thickness	0.1365				0911	0.1381
Inner SCV O-Ring						
Measure OD (while on plug)	6.190	6.191			0521/0523	NA
Measure radial thickness	0.1275	0.1280	0.1290	0.1285	0523/0526	NA
Measure vertical thickness	0.1375				0526	NA
Loosen PCV lid					0958	NA
Outer PCV O-Ring						
Measure OD (while on plug)	5.229	5.234			1001/1003	NA
Measure radial thickness	0.1260	0.1280	0.1260	0.1380	1011/1012	0.1340
Measure vertical thickness	0.1400				1013	0.1397
Inner PCV O-Ring						
Measure OD (while on plug)	5.137	5.131			1004/1005	NA
Measure radial thickness	0.1265	0.1285	0.1295	0.1280	1013/1014	NA
Measure vertical thickness	0.1395				1014	NA

Field Surveillance Comments:

Observed dust-like film on interior wall of lead shield & small amount of debris at bottom. Not radioactive.

Attachment 1 9975-00600 Field Surveillance Results, with Comparison to Destructive Examination Results

SRNL Receipt Examination of O-Rings

VISUAL EXAMINATION

PCV	PCV Outer	PCV Inner
Grease present	yes	yes
Color (normal or explain)	Normal	Normal
Cross-sectional shape	round	round
Nicks, Scratches, Cracks	none	none
Other Damage (Note extent/size)	none	none
Picture (Note if taken)		

SCV	SCV Outer	SCV Inner
Grease (type, amount)	yes	yes
Color (normal or explain)	Normal	Normal
Cross-sectional shape	round	round
Nicks, Scratches, Cracks	none	none
Other Damage (Note extent/size)	none	none
Picture (Note if taken)		

THICKNESS (all results reported in inches)

PCV	PCV Outer		PCV Inner	
	Axial	Radial	Axial	Radial
Thickness 1 (in)	0.1410	0.1370	0.1410	0.1365
Thickness 2 (in)	0.1380	0.1325	0.1370	0.1380
Thickness 3 (in)	0.1395	0.1370	0.1380	0.1385
Thickness 4 (in)	0.1390	0.1325	0.1405	0.1345
Average	0.1394	0.1347	0.1391	0.1369
Destructive Exam Average	0.1397	0.1340		

SCV	SCV Outer		SCV Inner	
	Axial	Radial	Axial	Radial
Thickness 1 (in)	0.1410	0.1365	0.1360	0.1335
Thickness 2 (in)	0.1370	0.1380	0.1325	0.1405
Thickness 3 (in)	0.1380	0.1420	0.1335	0.1380
Thickness 4 (in)	0.1405	0.1345	0.1365	0.1350
Average	0.1391	0.1377	0.1346	.01367
Destructive Exam Average	0.1381	0.1386		

Attachment 1 9975-00600 Field Surveillance Results, with Comparison to Destructive Examination Results

SRNL Receipt Examination of O-Rings (Continued)

HARDNESS

	PCV O-Rings		SCV O-Rings	
	Outer	Inner	Outer	Inner
Hardness 1, M-Scale	79.9	80	79	82
Hardness 2, M-Scale	79	79	78	82
Hardness 3, M-Scale	80	79.5	79.5	80.5
Hardness 4, M-Scale	79.5	79	79	80.5
Hardness 5, M-Scale	79	81.5	78	82
Average	79.4	79.8	78.7	81.4

CONTINUATION:
NA

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K. A. Dunn, 773-41A
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J. W. Mcevoy, 735-B
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