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ACCELEROMETER AND STRAIN GAGE EVALUATION*

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ABSTRACT

This document describes the method developed by Sandia National Laboratories (SNL) to evaluate transducers used in the design certification testing of nuclear material shipping packages. This testing project was performed by SNL for the Office of Civilian Radioactive Waste Management (OCRWM). This evaluation is based on the results of tests conducted to measure ruggedness, failure frequency, repeatability, and manufacturers' calibration data under both field and laboratory conditions. The results of these tests are provided and discussed. The transducers were selected for testing by surveying cask contractors and testing facilities. Important insights relating to operational characteristics of accelerometer types were gained during field testing.

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QUALITY ASSURANCE

This work was performed under a quality level of QL-3. The applicable level-three requirements of the Sandia National Laboratories' Transportation Systems Development Division Quality Assurance Program Plan were implemented for all of this activity.

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EXECUTIVE SUMMARY

Sandia National Laboratories (SNL) has completed an extensive testing project to evaluate transducers used in the design certification testing of nuclear material shipping packages for the Office of Civilian Radioactive Waste Management (OCRWM) Cask Systems Development Program. This testing project compared results of experiments obtained from transducers in laboratory and field tests. A large number of tests were conducted to investigate scatter in test data and the repeatability of results.

Two types of accelerometers and two types of strain gages were evaluated. Accelerometers were evaluated using calibration, shock, and impact testing. Only the calibration testing is directly comparable to factory specifications. Strain gages were evaluated using static loading and impact testing. This range of tests provided well-characterized laboratory tests for both the accelerometers and the strain gages and closely modeled the environment the transducers are subjected to in the testing of radioactive material shipping packages.

The results indicated little difference between the measurements obtained by transducers manufactured by different companies. However, results showed that a high confidence should not be placed in a single transducer to give reliable results. Even in well-controlled tests, the results were subject to considerable scatter. This emphasizes the importance of having redundant instrumentation in test programs. Tests also revealed that the results from any single transducer give only an estimate of the actual results. The standard deviation of the peak accelerations obtained in the shock impulse tests was 3.4% of the average value. For the static crush plastic tests, the standard deviation of the axial strains was approximately 8% of the average value. For the end-impact tests, the 1,000-Hz filtered peak accelerations had a standard deviation of 15% of their average value, and the 10,000-Hz filtered peak acceleration data had a standard deviation of 21% of the average. The results showed that test data were not, in general, more accurate than $\pm 10\%$ of the measured result. It is very likely that the majority of these deviations are due to changes in the quantities being measured, rather than transducer response. Part of the reason for this is that transducers give results only for the location at which they are located on the test specimen, and the local response at this point may not be representative of the quantity being measured at nearby locations. Also, because problems with the instrumentation or connections to or within the data acquisition system can produce questionable measurements, a data acquisition system must be used with diagnostics or other methods capable of isolating problems. Because the goal of this project was to compare transducers, readings where the deviation was suspected of being caused by other sources were not included in the evaluations.

This report can be used as a tool for instrumentation workers to aid in the selection of transducer types and numbers. It also can provide better understanding of the process by which published data are derived concerning design certification testing of nuclear material shipping packages.

1.0 INTRODUCTION

The Nuclear Waste Policy Act (NWSA) of 1982 (U.S. Congress, 1982) and its amendment in 1987 (the Amendments Act) (U.S. Congress, 1987) mandates the U.S. Department of Energy (DOE) to establish and operate a comprehensive, integrated system for the disposal of spent nuclear fuel and high-level radioactive waste. Under the NWSA, the Office of Civilian Radioactive Waste Management (OCRWM) was established within the DOE to fulfill this responsibility. A key component of the disposal program is the development and operation of a transportation system to move the waste from present locations to disposal facilities. A fleet of casks capable of transporting the waste by truck, rail, or barge is being developed.

Section 5061 of the Amendment Act specifies that each cask must be certified by the U.S. Nuclear Regulatory Commission (NRC). To meet these requirements, OCRWM is undertaking a program to design, test, certify, and fabricate a variety of cask systems. Design verification tests will be performed by the cask contractors to demonstrate design safety and to aid in cask certification by the NRC. During design verification testing of Type B shipping packagings, designers verify analytical calculations with instrumentation data. Many packagings are tested with transducers that measure structural response. Two types of transducers, accelerometers and strain gages, are considered here. Accelerometers measure acceleration and strain gages measure surface strain at the mounted location.

This document describes the method developed by Sandia National Laboratories (SNL) to evaluate various accelerometers and strain gages. This evaluation is based on the results of tests conducted to measure ruggedness, failure frequency, repeatability, and manufacturers' calibration data under both field and laboratory conditions. The results of these tests are provided and discussed. The transducers were selected for testing by surveying cask contractors and testing facilities. Important insights relating to operational characteristics of accelerometer types were gained during field testing.

Chapter 2.0 of this document describes the calibration and shock impulse testing of the accelerometers and static testing of strain gages under laboratory conditions. Chapter 2.0 also describes the impact testing for accelerometers and strain gages performed under field conditions. Chapter 3.0 describes the test results of accelerometer calibration and shock tests, strain gage static tests, and end-impact tests for both accelerometers and strain gages. Chapter 4.0 discusses the results of the field and laboratory tests, which demonstrate that there is little difference in the performance of the transducers evaluated.

Appendix A lists the survey participants who suggested accelerometers and strain gages for study and includes a copy of the survey form. Dimensional inspection data from the static test are provided in Appendix B, and end-impact dimensional inspection data are provided in Appendix C. Strain gage and accelerometer multiplots from end-impact tests are provided in Appendices D and E, respectively.

2.0 DESCRIPTION OF THE TEST PROGRAM

The transducers that were evaluated were selected based on a survey of OCRWM cask contractors and various testing laboratories. The survey requested data concerning the types of test transducers in use currently or in the future. The responses to this survey led to the selection of Endevco 7270 series and Bruel and Kjaer (B&K) 8309 accelerometers, and Micro-Measurements and BLH strain gages. A list of surveyed companies and a sample of the survey questionnaire are provided in Appendix A.

This evaluation of selected accelerometers and strain gages was comprised of laboratory and end-impact tests. The accelerometers were evaluated using calibration, shock, and impact testing. The strain gages were evaluated using static loading and impact testing. This range of tests provided well-characterized laboratory tests for both the accelerometers and the strain gages. The end-impact tests closely modeled the environment transducers encountered during the testing of radioactive material shipping packages. Multiple tests of each type were performed to determine the repeatability of the test results. Detailed descriptions of the tests performed for this evaluation are provided in the following sections.

2.1 Accelerometer Laboratory Testing

Accelerometers convert mechanical energy that is proportional to the input acceleration into electrical energy. Endevco 7270A-20K accelerometers are piezoresistive and B&K 8309 accelerometers are piezoelectric. The selected piezoresistive accelerometer uses a single, monolithic silicon chip sensing element. This element is a four-arm resistive strain gage assembly that is arranged in a full Wheatstone bridge circuit to monitor the resistance change. The sensing element has a mass mounted at the end of a cantilevered beam. When subjected to an acceleration, the mass deflects, bending the beam. This bending causes a strain in the strain gage assembly that changes its resistance. The bridge circuit requires an input voltage and measures the change in output voltage proportional to the change in resistance.

The piezoelectric accelerometer is a self-generating device that produces a change in the electrical charge due to an applied strain by an internal mass on a piezoelectric ceramic. The induced strain changes the electrical charge across the piezoelectric sensing element. This change is proportional to the applied acceleration.

In addition to the test accelerometers, two types of reference accelerometers, Kistler 805 and Endevco 2270M9, were used. The Kistler 805 is calibrated as a primary standard accelerometer and the Endevco 2270 is an accelerometer that Endevco suggests using as a primary standard for comparison calibration of other accelerometers. The tested accelerometers were divided into three sets. In each set, there were four Endevco 7270 accelerometers, three B&K 8309 accelerometers, and one Endevco 2270 reference accelerometer. Sets 1 and 3 used the same Kistler 805 reference accelerometer, and Set 2 had a different Kistler 805 reference. Table 2-1 shows the set that was used in each test.

TABLE 2-1. ACCELEROMETER UTILIZATION CHART											
SET NUMBER	SHOCK IMPULSE SERIES	END-IMPACT TEST NUMBER									
		1	2	3	4	5	6	7	8	9	10
1	X	X		X				X			
2	X		X			X			X		X
3	X			X			X			X	

2.1.1 Calibration Testing

Calibration testing of the accelerometers was performed in two controlled laboratory environments. Three important characteristics of accelerometers--sensitivity, amplitude linearity and frequency response--were calibrated by the manufacturer. Data acquisition systems require amplitude linearity and also require the sensitivity to relate acceleration to electrical output (Walter, 1978). Performance over the required range of frequencies was verified by frequency response calibration. The accelerometers that were evaluated by SNL were procured with manufacturer calibration certificates.

In addition, each of the accelerometers was subjected to a series of calibrations at the SNL calibration laboratory. The SNL calibration laboratory provides calibrations traceable to DOE's primary standards. These calibrations were performed in conjunction with the factory calibrations to provide a baseline to compare the post-test calibrations.

Three types of calibrations were performed on the Endevco 7270 accelerometers at SNL: shock, centrifuge, and frequency. The frequency calibration was performed at ambient temperature and at -20°F. Cold temperature calibration was performed to determine the response of the accelerometers in cold environments. The Code of Federal Regulations (10 CFR 71) requires evaluation of Type B nuclear material packages at this temperature (NRC, 1989). The B&K 8309 accelerometers were calibrated using shock and frequency techniques only; the nature of piezoelectric accelerometers precluded their use in measuring a steady acceleration field, as generated in the centrifuge calibration technique.

The shock calibration technique used was the drop-ball method. In this comparative calibration, the accelerometer was shocked five times at varying amplitude levels. A reference accelerometer calibrated by the

SNL Primary Standards Laboratory was mounted on the same fixture as the accelerometer to be calibrated. The reference accelerometer's output was used to determine the acceleration level experienced by the accelerometer to be calibrated, and the sensitivity was determined by dividing its output by the acceleration determined by the reference accelerometer. Sandia's calibration laboratory has determined that deviations in the sensitivity within 8% of the value obtained by the frequency calibration are acceptable. If the deviation is larger than this, the accelerometer was rejected.

Centrifuge calibration was used to determine amplitude linearity. The output of the accelerometer at specified acceleration levels divided by the input acceleration produced the accelerometer sensitivity. The acceleration level was determined from the rotation rate of the centrifuge and the distance between the position of the mounted accelerometer and the axis of rotation. Readings were taken at 1,000 g increments, from -5,000 to +5,000 g. The accelerometer output was plotted against the applied acceleration level and a least-squares straight-line fit was determined. The accelerometer sensitivity is the slope of this line. Amplitude linearity is expressed as a percent deviation from the straight-line fit. Sandia's calibration laboratory has determined that deviations of less than $\pm 3\%$ of accelerometer range provide acceptable amplitude linearity.

The frequency response of an accelerometer was determined by the deviation in sensitivity with respect to frequency. Accelerometers that were tested were considered by Sandia's calibration laboratory to have flat frequency response when the variation in sensitivity versus frequency deviated no greater than 5% from the base sensitivity (at 100 Hz) over their frequency range. If the accelerometer data fell within this frequency band, the accelerometer was considered to have an acceptable linear response in the frequency domain. The frequency response of the accelerometers were determined by shaker calibration. The accelerometer was subjected to a constant acceleration level over a broad range of frequencies, from 50 to 10,000 Hz, for this calibration. The transducer sensitivity was determined from the ratio of the accelerometer output at the specified frequency to the acceleration level. In this type of calibration, the acceleration level was constant at approximately 30 g while the frequency was changed. The accelerometer sensitivity was referenced to the output at 100 Hz.

This calibration process was performed again for each set of test evaluation accelerometers after their shock test series and after each of the end-impact tests in which they were used. The primary standard accelerometers were re-calibrated after the shock tests.

2.1.2 Shock Impulse Testing

Cask impact testing produces a shock input to accelerometers and the accelerometers, in turn, produce an electrical output representative of the input. Therefore, shock testing on each accelerometer was performed under controlled conditions. The tests consisted of a series of shocks to each of the three sets of accelerometers. Four Endevco 7270 accelerometers, three B&K 8309 accelerometers, and two reference accelerometers

calibrated as primary standards were mounted on a common test fixture. This fixture was a 5.5-in.-square by 1.0-in.-thick plate of 7075-T651 aluminum. Figure 2-1 shows a photograph of the test fixture and the location of the accelerometers. The fixture was mounted on a 10,000-g vertical shock frame manufactured by Minnesota Testing Systems (MTS) (Figures 2-2 and 2-3). The shock frame provided a haversine pulse, with a pulse width ranging from 0.5 to 2.5 ms, depending on the acceleration level. An idealized haversine shock pulse is shown in Figure 2-4. The fixture was shocked three times at each of three levels: 1,000, 5,000, and 10,000 g. These acceleration levels were chosen to utilize the accelerometers in ranges that envelope the response experienced in typical cask impact testing. The characteristics of the shock pulse were controlled by selecting the impact velocity and the stiffness of the impacting surface. The output of the accelerometers was recorded using digital storage oscilloscopes, one channel for each accelerometer. This procedure was repeated for each of the remaining two sets.

2.2 Strain Gage Laboratory Testing

In general, the response of the strain gages can be affected by installation practices. Typically, because strain gages are permanently installed, they are not calibrated on large structures. Instead, reliance is placed on established manufacturer's specifications and installation techniques. The manufacturer publishes properties of the strain gages based on lot sampling and proven lot tolerances. In typical cask testing, the strain gages are wired in a quarter-bridge configuration, where the strain gage is the only active element. [Strain gage circuits are described in detail by Window (1983) and Dally (1978).] After installation, the resistance across the strain gage and the resistance between the strain gage and the test specimen are measured to verify the electrical circuit. The person who installs the gage verifies that the gage is properly bonded to the test article, based on his or her judgment and experience.

Static tests were first performed at SNL on the strain gages to evaluate their performance during low-loading rates. These tests provided a verification of the acceptability of the installation procedures. A series of ten tests were conducted on ten individual aluminum cylinders fabricated from aluminum 6061-0 tubing. The cylinders were 24 in. in length, with inner and outer diameters of 3.58 and 5.42 in., respectively. The biaxial Micro-Measurement CEA-13-125UT-350 and BLH FAET-12D-35-S13EG gages were installed to measure strains in both the axial and hoop direction. Strain gages of each type were installed at 45-degree intervals around the outer circumference at positions located 6, 12, and 18 in. from the bottom, as shown in Figure 2-5. Each specimen had 12 biaxial Micro-Measurement gages and 12 biaxial BLH gages, but only ten of the BLH gages in the hoop direction were monitored because of data acquisition channel availability. The gage designation, location, and direction are listed in Table 2-2. Before testing, each specimen was sent to the SNL inspection laboratory, where detailed measurements of radius and length were taken at the locations shown in Figure 2-6. This provided baseline measurement information for comparison with the subsequent dimensional inspection.

Figure 2-1. Shock Impulse Test Fixture With the Mounted Accelerometers

Figure 2-2. Shock Test Fixture Mounted on a 10,000-g MTS Vertical Shock Frame

Figure 2-3. Close-Up View of the Shock Test Fixture Mounted on a 10,000-g MTS Vertical Shock Frame

Figure 2-4. Idealized Haversine Shock Pulse

The axial compression test was conducted using a calibrated MTS compression/tension test machine with a 220,000-lb capacity. Figures 2-7 and 2-8 show the machine and test setup. The static crush test of each unit consisted of two parts. During the first portion of the test, a load control test was performed. The load was cycled four times to 40,000 lb, which is approximately 70% of the elastic limit of the material. The purpose of the load control test was to determine the hysteretic behavior of the strain gages. The loading rate for these tests was 8,000 lb/s, which corresponds to a strain rate of 6.15×10^{-5} in./in./s. After the load control test, the test machine was operated in a displacement control mode and the specimen was loaded through the elastic range, extending to approximately 2% strain. The displacement rate for this portion of the test was 0.0125 in./s, which corresponds to a strain rate of 5.21×10^{-4} in./in./s. Strain, load, and displacement data were recorded during each test using digital transient recorders. After the tests were completed, each specimen was returned to the inspection laboratory and all of the measurements were repeated to determine the magnitude of the permanent deformation.

Figure 2-5. Static Crush Test Unit

**TABLE 2-2. LOCATION AND DIRECTION OF STRAIN GAGES
FOR THE STATIC CRUSH TESTS**

<u>GAGE DESIGNATION</u>	<u>TYPE/CATALOG NUMBER</u>	<u>LOCATION</u>		<u>DIRECTION</u>
		<u>DEGREE</u>	<u>In.</u>	
SG1	CEA-13-125UT-350	0	6.0	Axial
SG2	CEA-13-125UT-350	0	6.0	Hoop
SG3	CEA-13-125UT-350	0	12.0	Axial
SG4	CEA-13-125UT-350	0	12.0	Hoop
SG5	CEA-13-125UT-350	0	18.0	Axial
SG6	CEA-13-125UT-350	0	18.0	Hoop
SG7	FAET-12D-35-S13EG	45	6.0	Axial
SG8	FAET-12D-35-S13EG	45	6.0	Hoop
SG9	FAET-12D-35-S13EG	45	12.0	Axial
SG10	FAET-12D-35-S13EG	45	12.0	Hoop
SG11	FAET-12D-35-S13EG	45	18.0	Axial
SG12	FAET-12D-35-S13EG	45	18.0	Hoop
SG13	CEA-13-125UT-350	90	6.0	Axial
SG14	CEA-13-125UT-350	90	6.0	Hoop
SG15	CEA-13-125UT-350	90	12.0	Axial
SG16	CEA-13-125UT-350	90	12.0	Hoop
SG17	CEA-13-125UT-350	90	18.0	Axial
SG18	CEA-13-125UT-350	90	18.0	Hoop
SG19	FAET-12D-35-S13EG	135	6.0	Axial
SG20	FAET-12D-35-S13EG	135	6.0	Hoop
SG21	FAET-12D-35-S13EG	135	12.0	Axial
SG22	FAET-12D-35-S13EG	135	12.0	Hoop
SG23	FAET-12D-35-S13EG	135	18.0	Axial
SG24	FAET-12D-35-S13EG	135	18.0	Hoop
SG25	CEA-13-125UT-350	180	6.0	Axial
SG26	CEA-13-125UT-350	180	6.0	Hoop
SG27	CEA-13-125UT-350	180	12.0	Axial
SG28	CEA-13-125UT-350	180	12.0	Hoop
SG29	CEA-13-125UT-350	180	18.0	Axial
SG30	CEA-13-125UT-350	180	18.0	Hoop
SG31	FAET-12D-35-S13E	225	6.0	Axial
SG32	FAET-12D-35-S13EG	225	6.0	Hoop
SG33	FAET-12D-35-S13EG	225	12.0	Axial
SG34	FAET-12D-35-S13EG	225	12.0	Hoop
SG35	FAET-12D-35-S13EG	225	18.0	Axial
SG36	FAET-12D-35-S13EG	225	18.0	Hoop
SG37	CEA-13-125UT-350	270	6.0	Axial
SG38	CEA-13-125UT-350	270	6.0	Hoop
SG39	CEA-13-125UT-350	270	12.0	Axial
SG40	CEA-13-125UT-350	270	12.0	Hoop
SG41	CEA-13-125UT-350	270	18.0	Axial
SG42	CEA-13-125UT-350	270	18.0	Hoop
SG43	FAET-12D-35-S13EG	315	6.0	Axial
SG44	FAET-12D-35-S13EG	315	6.0	Hoop
SG45	FAET-12D-35-S13EG	315	12.0	Axial
SG46	FAET-12D-35-S13EG	315	12.0	Hoop
SG47	FAET-12D-35-S13EG	315	18.0	Axial
SG48	FAET-12D-35-S13EG	315	18.0	Hoop

INSPECTION POINT	MEASURE	LOCATION OF MEASUREMENT
1	RADIUS	L1(1.25) 2.710 36°
2	RADIUS	L1(1.25) 2.710 81°
3	RADIUS	L1(1.25) 2.710 126°
4	RADIUS	L1(1.25) 2.710 171°
5	RADIUS	L1(1.25) 2.710 216°
6	RADIUS	L1(1.25) 2.710 261°
7	RADIUS	L1(1.25) 2.710 306°
8	RADIUS	L1(1.25) 2.710 351°
9	RADIUS	L2(2.00) 2.710 36°
10	RADIUS	L2(2.00) 2.710 81°
11	RADIUS	L2(2.00) 2.710 126°
12	RADIUS	L2(2.00) 2.710 171°
13	RADIUS	L2(2.00) 2.710 216°
14	RADIUS	L2(2.00) 2.710 261°
15	RADIUS	L2(2.00) 2.710 306°
16	RADIUS	L2(2.00) 2.710 351°
17	RADIUS	L3(4.00) 2.710 36°
18	RADIUS	L3(4.00) 2.710 81°
19	RADIUS	L3(4.00) 2.710 126°
20	RADIUS	L3(4.00) 2.710 171°
21	RADIUS	L3(4.00) 2.710 216°
22	RADIUS	L3(4.00) 2.710 261°
23	RADIUS	L3(4.00) 2.710 306°
24	RADIUS	L3(4.00) 2.710 351°

INSPECTION POINT	MEASURE	LOCATION OF MEASUREMENT
25	RADIUS	L4(6.00) 2.710 36°
26	RADIUS	L4(6.00) 2.710 81°
27	RADIUS	L4(6.00) 2.710 126°
28	RADIUS	L4(6.00) 2.710 171°
29	RADIUS	L4(6.00) 2.710 216°
30	RADIUS	L4(6.00) 2.710 261°
31	RADIUS	L4(6.00) 2.710 306°
32	RADIUS	L4(6.00) 2.710 351°
33	RADIUS	L5(8.00) 2.710 36°
34	RADIUS	L5(8.00) 2.710 81°
35	RADIUS	L5(8.00) 2.710 126°
36	RADIUS	L5(8.00) 2.710 171°
37	RADIUS	L5(8.00) 2.710 216°
38	RADIUS	L5(8.00) 2.710 261°
39	RADIUS	L5(8.00) 2.710 306°
40	RADIUS	L5(8.00) 2.710 351°
41	RADIUS	L6(10.00) 2.710 36°
42	RADIUS	L6(10.00) 2.710 81°
43	RADIUS	L6(10.00) 2.710 126°
44	RADIUS	L6(10.00) 2.710 171°
45	RADIUS	L6(10.00) 2.710 216°
46	RADIUS	L6(10.00) 2.710 261°
47	RADIUS	L6(10.00) 2.710 306°
48	RADIUS	L6(10.00) 2.710 351°

INSPECTION POINT	MEASURE	LOCATION OF MEASUREMENT
49	RADIUS	L7(12.00) 2.710 36°
50	RADIUS	L7(12.00) 2.710 81°
51	RADIUS	L7(12.00) 2.710 126°
52	RADIUS	L7(12.00) 2.710 171°
53	RADIUS	L7(12.00) 2.710 216°
54	RADIUS	L7(12.00) 2.710 261°
55	RADIUS	L7(12.00) 2.710 306°
56	RADIUS	L7(12.00) 2.710 351°
57	RADIUS	L8(14.00) 2.710 36°
58	RADIUS	L8(14.00) 2.710 81°
59	RADIUS	L8(14.00) 2.710 126°
60	RADIUS	L8(14.00) 2.710 171°
61	RADIUS	L8(14.00) 2.710 216°
62	RADIUS	L8(14.00) 2.710 261°
63	RADIUS	L8(14.00) 2.710 306°
64	RADIUS	L8(14.00) 2.710 351°
65	RADIUS	L9(16.00) 2.710 36°
66	RADIUS	L9(16.00) 2.710 81°
67	RADIUS	L9(16.00) 2.710 126°
68	RADIUS	L9(16.00) 2.710 171°
69	RADIUS	L9(16.00) 2.710 216°
70	RADIUS	L9(16.00) 2.710 261°
71	RADIUS	L9(16.00) 2.710 306°
72	RADIUS	L9(16.00) 2.710 351°

INSPECTION POINT	MEASURE	LOCATION OF MEASUREMENT
73	RADIUS	L10(18.00) 2.710 36°
74	RADIUS	L10(18.00) 2.710 81°
75	RADIUS	L10(18.00) 2.710 126°
76	RADIUS	L10(18.00) 2.710 171°
77	RADIUS	L10(18.00) 2.710 216°
78	RADIUS	L10(18.00) 2.710 261°
79	RADIUS	L10(18.00) 2.710 306°
80	RADIUS	L10(18.00) 2.710 351°
81	RADIUS	L11(20.00) 2.710 36°
82	RADIUS	L11(20.00) 2.710 81°
83	RADIUS	L11(20.00) 2.710 126°
84	RADIUS	L11(20.00) 2.710 171°
85	RADIUS	L11(20.00) 2.710 216°
86	RADIUS	L11(20.00) 2.710 261°
87	RADIUS	L11(20.00) 2.710 306°
88	RADIUS	L11(20.00) 2.710 351°
89	RADIUS	L12(22.00) 2.710 36°
90	RADIUS	L12(22.00) 2.710 81°
91	RADIUS	L12(22.00) 2.710 126°
92	RADIUS	L12(22.00) 2.710 171°
93	RADIUS	L12(22.00) 2.710 216°
94	RADIUS	L12(22.00) 2.710 261°
95	RADIUS	L12(22.00) 2.710 306°
96	RADIUS	L12(22.00) 2.710 351°

INSPECTION POINT	MEASURE	LOCATION OF MEASUREMENT
97	RADIUS	L13(23.875) 2.710 36°
98	RADIUS	L13(23.875) 2.710 81°
99	RADIUS	L13(23.875) 2.710 126°
100	RADIUS	L13(23.875) 2.710 171°
101	RADIUS	L13(23.875) 2.710 216°
102	RADIUS	L13(23.875) 2.710 261°
103	RADIUS	L13(23.875) 2.710 306°
104	RADIUS	L13(23.875) 2.710 351°
105	LENGTH	L14(24.00) N/A 36°
106	LENGTH	L14(24.00) N/A 81°
107	LENGTH	L14(24.00) N/A 126°
108	LENGTH	L14(24.00) N/A 171°
109	LENGTH	L14(24.00) N/A 216°
110	LENGTH	L14(24.00) N/A 261°
111	LENGTH	L14(24.00) N/A 306°
112	LENGTH	L14(24.00) N/A 351°

Figure 2-6. Locations of the Static Crush Test Dimensional Inspection

Figure 2-7. Calibrated MTS Compression/Tension Test Machine with a 220,000-lb Capacity, and the Test Setup

Figure 2-8. Static Test Unit Positioned in the MTS Test Machine

2.3 End-Impact Testing

The tests described above were well-defined, and therefore useful in characterizing the response of the transducers. However, they did not subject the transducers to environments that are representative of cask testing. To evaluate the transducers in an environment similar to cask testing, a set of impact tests was conducted. Both accelerometers and strain gages were installed on a test unit to evaluate their behavior during impact testing. The structural code benchmark unit selected as the test unit is described in "Structural Code Benchmarking: Impact Response Resulting from the Regulatory Nine-Meter Drop" (Glass, 1989). This test unit was selected to provide an economical experiment that would produce varying strain levels and accelerations with rapid amplitude changes.

The test cylinders were fabricated from aluminum 6061-0 tubing. They were 45 in. in length, with inner and outer diameters of 3.58 and 5.42 in., respectively. This was the same material and diameters used for the static crush tests. As shown in Figure 2-9 and 2-10, the tests consisted of a series of ten guided drops of ten individual test units onto an unyielding target located at the 2,500-ft aerial cable facility in the Coyote Test Field at SNL (Uncapher, 1983). The lowest point on the guided units was positioned 32 ft, 4 in. above the target, so the impact velocity was 44 ft/s. The additional height above the regulatory 30-ft test was required to compensate for guide wire friction.

The test units were instrumented with four Micro-Measurement biaxial CEA-13-125UT-350 strain gages, two Micro-Measurement uniaxial CEA-13-125-UW-350 strain gages, four biaxial BLH FAET-12D-35-S13EG strain gages, and two uniaxial BLH FAE-12S-35-S13EG strain gages. These gages were located at 90-degree intervals around the outer circumference of the cylinder and at positions that were 1, 3, and 6 in. from the impacting end to measure axial and hoop strain. The accelerometers were installed on the top surface of the test unit. The locations, designations, and directions of the accelerometers and strain gages are listed in Table 2-3. The locations of the accelerometers and strain gages are shown in Figures 2-11 and 2-12. The accelerometers were divided into three sets, each set containing four Endevco 7270 accelerometers and three B&K 8309 accelerometers. Table 2-1 shows the set used in each of the ten drop tests. Each set of accelerometers was calibrated before the first test, between successive tests, and after the final test. Before testing, detailed radius and length measurements of each specimen at the locations shown in Figure 2-13 were taken at the SNL Inspection Laboratory.

Accelerations and strains were recorded using an analog tape machine. Photometric coverage of the impact test was provided by three cameras operating at 2,000 frames/s and three cameras operating at 400 frames/s.

Figure 2-9. Impact Test Setup at the 2,500-ft Aerial Cable Facility at SNL

Figure 2-10. Close-Up View of the Impact Test Unit

**TABLE 2-3. LOCATIONS, DESIGNATIONS, AND DIRECTIONS
OF END-IMPACT TEST STRAIN GAGES
AND ACCELEROMETERS**

<u>GAGE DESIGNATION</u>	<u>TYPE/CATALOG NUMBER</u>	<u>LOCATION</u>		<u>DIRECTION</u>
		<u>DEGREE</u>	<u>In.</u>	
SG1	CEA-13-125UT-350	0	1.0	AXIAL
SG2	CEA-13-125UT-350	0	1.0	HOOP
SG3	CEA-13-125UT-350	0	3.0	AXIAL
SG4	CEA-13-125UT-350	0	3.0	HOOP
SG5	CEA-13-125UW-350	0	6.0	AXIAL
SG6	FAET-12D-35-S13EG	90	1.0	AXIAL
SG7	FAET-12D-35-S13EG	90	1.0	HOOP
SG8	FAET-12D-35-S13EG	90	3.0	AXIAL
SG9	FAET-12D-35-S13EG	90	3.0	HOOP
SG10	FAE-12S-35-S13EG	90	6.0	AXIAL
SG11	CEA-13-125UT-350	180	1.0	AXIAL
SG12	CEA-13-125UT-350	180	1.0	HOOP
SG13	CEA-13-125UT-350	180	3.0	AXIAL
SG14	CEA-13-125UT-350	180	3.0	HOOP
SG15	CEA-13-125UW-350	180	6.0	AXIAL
SG16	FAET-12D-35-S13EG	270	1.0	AXIAL
SG17	FAET-12D-35-S13EG	270	1.0	HOOP
SG18	FAET-12D-35-S13EG	270	3.0	AXIAL
SG19	FAET-12D-35-S13EG	270	3.0	HOOP
SG20	FAE-12S-35-S13EG	270	6.0	AXIAL
<u>ACCELEROMETER DESIGNATION</u>	<u>TYPE/CATALOG NUMBER</u>	<u>LOCATION</u>		<u>DIRECTION</u>
		<u>DEGREE</u>	<u>In.</u>	
A1	7270A-20K	0	45.0	AXIAL
A2	7270A-20K	90	45.0	AXIAL
A3	7270A-20K	180	45.0	AXIAL
A4	7270A-20K	270	45.0	AXIAL
A5	8309	45	45.0	AXIAL
A6	8309	157	45.0	AXIAL
A7	8309	292	45.0	AXIAL

Figure 2-11. View of Strain Gages on Impact Test Units

Figure 2-12. Close-Up View of Accelerometers on the Impact Test Unit

Figure 2-13. Locations of the End-Impact Test Dimensional Inspection

3.0 TEST RESULTS

3.1 Accelerometer Calibration Testing

Table 3-1 lists the results of the calibration tests performed on the three sets of accelerometers used in the shock impulse tests. Table 3-1 includes the results of the manufacturer shock and frequency calibrations as well as SNL pre-test and post-test calibrations. The SNL pre-test and post-test calibrations included centrifuge, shock, and frequency at ambient temperature (70°F) and -20°F. Table 3-2 lists the results of the SNL calibrations after each of the end-impact tests, and the pre-test calibrations for each set used in the end-impact testing. These are the same as the post-test calibrations from the shock impulse testing. Similar types of calibrations, such as pre-test and post-test shock, were compared to detect any changes in the transducer sensitivity. Large deviations (greater than 10%) may indicate functional problems. Tables 3-1 and 3-2 show the results of these calibrations.

Accelerometer A2 in Set 2 was replaced after the shock impulse tests and A3 in Set 3 was replaced before Test 6 because they failed the SNL calibrations. Test results indicated that the SNL shock calibration resulted in a lower sensitivity for the piezoresistive accelerometers. The frequency calibration at -20°F also reflected a different sensitivity due to the change in temperature. These changes were within the manufacturer's specification for sensitivity change versus temperature. The standard deviation of the sensitivities determined from all calibrations performed on any specific accelerometer was less than 3% of the average sensitivity. This is consistent with manufacturer and SNL centrifuge and frequency calibrations. For the piezoresistive accelerometers, the standard deviation of the sensitivities was within 1%. Therefore, there was good agreement between the various calibration techniques.

3.2 Accelerometer Shock Tests

Accelerometer shock pulses were recorded at sample rates of 200,000 samples/s for Sets 1 and 3 and at 500,000 samples/s for Set 2. Due to the short shock pulse width, the difference in the sample rates of the two sets did not affect the data. These pulses were adjusted to a baseline of zero and were digitally filtered at cutoff frequencies of 10,000 Hz for Sets 1 and 3 and 25,000 Hz for Set 2. The digital filter approximated a low-pass, constant-phase response with a 48-dB/octave rolloff. This procedure is referred to as fairing the data. The following pulse parameters were determined from the faired data:

- the maximum faired amplitude (MFA) of the signal;
- the rise time (TR) of the pulse, defined as the time between 10% of MFA and 90% of MFA on the leading edge;
- the time to peak (TP), defined as the time between 10% of MFA on the leading edge and MFA;

TABLE 3-1. ACCELEROMETER CALIBRATION DATA FROM SHOCK IMPULSE TESTS

SET 1 GAGE DESIGNATION	ENDEVCO				SNL PRE-TEST				SNL POST-TEST			
	SHOCK				CENT	SHOCK	FREQ	FREQ-20°	CENT	SHOCK	FREQ	FREQ-20°
	1 kg	5 kg	10 kg	FREQ								
A1	0.759	0.762	0.770	0.764	0.769	0.718	0.770	0.812	0.777	0.731	0.765	0.806
A2	0.727	0.716	0.724	0.717	0.714	0.673	0.728	0.763	0.725	0.689	0.720	0.759
A3	0.808	0.811	0.817	0.813	0.818	0.763	0.820	0.867	0.723	0.772	0.815	0.857
A4	0.711	0.710	0.715	0.711	0.718	0.669	0.718	0.756	0.705	0.683	0.713	0.749
B&K												
A5	(1)			0.043	(2)	0.0442	0.0444	0.0442	(2)	0.0485	0.0448	0.0430
A6	(1)			0.043	(2)	0.0452	0.0453	0.0455	(2)	0.0458	0.0449	0.0436
A7	(1)			0.043	(2)	0.0445	0.0443	0.0439	(2)	0.0451	0.0450	0.0430
SNL PRIMARY STD.												
A8	SHOCK				(2)	(3)	0.353	(4)	(2)	0.337	0.343	(4)
	1 kg	5 kg	10 kg	15 kg								
	0.328	0.324	0.319	0.325								
A9	ENDEVCO				(2)	(3)	0.746	(4)	(2)	0.714	0.747	(4)
	SHOCK											
	2.6 kg	9.7 kg	21.8 kg	FREQ								
A1, A2, A3, A4 A5, A6, A7 A8 A9	ENDEVCO 7270A-20K				CENT = CENTRIFUGE	V/I/g	pC/g	FREQ = FREQUENCY RESPONSE	FREQ-20° = FREQUENCY RESPONSE AT -20°F	kg = 1000g's		
	B&K 8309											
	KISTLER 805											
	ENDEVCO 2270M9											

- (1) Shock calibration certificates were not provided by B&K.
- (2) Centrifuge calibration was not performed on piezoelectric accelerometers.
- (3) This test was not performed.
- (4) A8 and A9 were used as reference accelerometers for shock impulse tests. Frequency calibrations at -20°F were not performed.

TABLE 3-1. ACCELEROMETER CALIBRATION DATA FROM SHOCK IMPULSE TESTS (CONTINUED)

SET 2 GAGE DESIGNATION	ENDEVCO				SNL PRE-TEST				SNL POST-TEST			
	SHOCK				CENT	SHOCK	FREQ	FREQ-20°	CENT	SHOCK	FREQ	FREQ-20°
	1 kg	5 kg	10 kg	15 kg								
A1	0.825	0.820	0.827	0.820	0.822	0.768	0.826	0.873	0.830	0.789	0.825	0.864
A2	0.794	0.791	0.797	0.782	0.799	0.738	0.799	0.843	(5)	0.751	0.796	FAILED
A3	0.702	0.700	0.705	0.703	0.715	0.657	0.709	0.747	0.711	0.664	0.709	0.741
A4	0.723	0.725	0.732	0.724	0.734	0.679	0.730	0.770	0.729	0.690	0.731	0.762
B&K												
A5	(1)	(1)	(1)	0.044	(2)	0.0454	0.0458	0.0450	(2)	0.0463	0.0466	0.0442
A6	(1)	(1)	(1)	0.041	(2)	0.0424	0.0427	0.0421	(2)	0.0431	0.0429	0.0411
A7	(1)	(1)	(1)	0.043	(2)	0.0443	0.0445	0.0443	(2)	0.0451	0.0450	0.0435
SNL PRIMARY STD.												
SHOCK												
1 kg 5 kg 10 kg 15 kg												
A8	0.278	0.276	0.273	0.280	(2)	(3)	0.279	(4)	(2)	0.282	0.275	(4)
ENDEVCO												
SHOCK												
2.6 kg 10 kg 19 kg FREQ												
A9	0.761	0.758	0.767	0.761	(2)	0.757	0.767	(4)	(2)	0.753	0.760	(4)
CALIBRATION FOLLOWING CABLE REPAIR												
B&K												
A5	(1)	(1)	(1)	0.046	(2)	0.0469	0.0468	0.0444				
A6	(1)	(1)	(1)	0.041	(2)	0.0437	0.0427	0.0411				
A7	(1)	(1)	(1)	0.042	(2)	0.0459	0.0447	0.0442				

- (1) Shock calibration certificates were not provided by B&K.
(2) Centrifuge calibration was not performed on piezoelectric accelerometers.
(3) This test was not performed.
(4) A8 and A9 were used as reference accelerometers for shock impulse tests. Frequency calibrations at -20°F were not performed.
(5) Failed the frequency response test at -20°F calibration; centrifuge calibration was not performed.

TABLE 3-1. ACCELEROMETER CALIBRATION DATA FROM SHOCK IMPULSE TESTS (CONCLUDED)

SET 3 GAGE DESIGNATION	ENDEVCO			SNL PRE-TEST			SNL POST-TEST		
	SHOCK			CENT	SHOCK	FREQ	CENT	SHOCK	FREQ
	1 kg	5 kg	10 kg						
A1	0.793	0.796	0.803	0.801	0.805	0.750	0.807	0.851	0.843
A2		(5)		0.687	0.640	0.691	0.734	0.690	0.724
A3		(5)		0.732	0.682	0.730	0.771	0.728	0.766
A4		(5)		0.580	0.538	0.579	0.614	0.584	0.609
	B&K								
A5		(1)		0.045	(2)	0.0464	0.0466	0.0451	0.0449
A6		(1)		0.042	(2)	0.0434	0.0437	0.0430	0.0422
A7		(1)		0.044	(2)	0.0451	0.0453	0.0444	0.0440
	SNL PRIMARY STD.								
	SHOCK								
	1 kg	5 kg	10 kg	15 kg					
A8	0.328	0.324	0.319	0.325	(2)	(3)	0.353	(4)	(4)
	ENDEVCO								
	2.5 kg	10 kg	21 kg	FREQ					
A9	0.740	0.746	0.750	0.742	(2)	0.749	0.745	(4)	(4)

- (1) Shock calibration certificates were not provided by B&K.
(2) Centrifuge calibration was not performed on piezoelectric accelerometers.
(3) This test was not performed.
(4) A8 and A9 were used as reference accelerometers for shock impulse tests. Frequency calibrations at -20°F were not performed.
(5) Was originally purchased for another program which did not require Endevco calibration certificates.

TABLE 3-2. ACCELEROMETER CALIBRATION DATA FROM END-IMPACT TESTS

SET 1 GAGE DESIGNATION	SNL PRE-TEST 1			SNL POST-TEST 1			SNL POST-TEST 4			SNL POST-TEST 7		
	CENT	SHOCK	FREQ	CENT	SHOCK	FREQ	CENT	SHOCK	FREQ	CENT	SHOCK	FREQ
A1	0.777	0.731	0.765	0.769	0.745	0.767	0.764	0.753	0.766	0.770	0.746	0.771
A2	0.725	0.689	0.720	0.722	0.697	0.720	0.717	0.705	0.721	0.722	0.694	0.722
A3	0.723	0.772	0.815	0.816	0.790	0.816	0.813	0.800	0.815	0.814	0.790	0.816
A4	0.705	0.683	0.713	0.712	0.691	0.715	0.711	0.695	0.713	0.714	0.690	0.714
A5	(1)	0.0485	0.0448	(1)	0.0445	0.0442	(1)	0.0451	0.0437	(1)	0.0436	0.0431
A6	(1)	0.0458	0.0449	(1)	0.0453	0.0452	(1)	0.0460	0.0446	(1)	0.0443	0.0473
A7	(1)	0.0451	0.0450	(1)	0.0446	0.0440	(1)	0.0451	0.0447	(1)	(2)	(2)
A1, A2, A3, A4			ENDEVCO 7270A-20K			V/V/G			CENT = CENTRIFUGE			
A5, A6, A7			B&K 8309			pC/G			FREQ = FREQUENCY RESPONSE			
									FREQ-20° = FREQUENCY RESPONSE AT -20°F			

- (1) Centrifuge calibration was not performed on piezoelectric accelerometers.
(2) Failed shock calibration. Frequency response calibration was not performed.

TABLE 3-2. ACCELEROMETER CALIBRATION DATA FROM END-IMPACT TESTS (CONTINUED)

SET 2 GAGE DESIGNATION	SNL PRE-TEST 2			SNL POST-TEST 2			SNL POST-TEST 5			SNL POST-TEST 8		
	CENT	SHOCK	FREQ	CENT	SHOCK	FREQ	CENT	SHOCK	FREQ	CENT	SHOCK	FREQ
A1	0.830	0.789	0.826	0.864	0.821	0.797	0.821	0.808	0.822	0.825	0.773	0.822
A2	0.703	0.662	0.704	0.735	0.700	0.671	0.702	0.683	0.704	0.696	0.651	0.709
A3	0.711	0.664	0.709	0.741	0.705	0.684	0.707	0.689	0.705	0.705	0.660	0.705
A4	0.729	0.690	0.731	0.762	0.728	0.703	0.731	0.712	0.729	0.726	0.685	0.728
A5	(1)	0.0463	0.0466	0.0442	(1)	0.0454	0.0456	0.0462	0.0456	(1)	0.0450	0.0456
A6	(1)	0.0431	0.0429	0.0411	(1)	0.0425	0.0421	0.0425	0.0425	(1)	0.0419	0.0429
A7	(1)	0.0451	0.0450	0.0435	(1)	0.0443	0.0444	0.0451	0.0446	(1)	0.0440	0.0443
ENDEVCO												
	1 kg	5 kg	10 kg	FREQ								
A2	0.688	0.688	0.692	(2)								
SNL POST-TEST 10												
	CENT	SHOCK	FREQ	FREQ-20°								
A1	0.819	0.799	0.822	0.867								
A2	0.696	0.671	0.737	FAILED								
A3	0.709	0.683	0.707	0.743								
A4	0.728	0.707	0.729	0.765								
A5	(1)	0.0446	0.0446	0.0438								
A6	(1)	0.0417	0.0418	0.0407								
A7	(1)	0.0437	0.0434	0.0429								

(1) Centrifuge calibration was not performed on piezoelectric accelerometers.

(2) A calibration certificate was not provided.

TABLE 3-2. ACCELEROMETER CALIBRATION DATA FROM END-IMPACT TESTS (CONCLUDED)

SET 3 GAGE DESIGNATION	SNL PRE-TEST 3			SNL POST-TEST 3			SNL POST-TEST 6			SNL POST-TEST 9			
	CENT	SHOCK	FREQ	CENT	SHOCK	FREQ	CENT	SHOCK	FREQ	CENT	SHOCK	FREQ	
	FREQ-20°												
A1	0.807	0.763	0.804	0.800	0.780	0.802	0.800	0.779	0.802	0.805	0.777	0.803	0.844
A2	0.690	0.656	0.688	0.693	0.663	0.688	0.684	0.671	0.689	0.683	0.666	0.689	0.721
A3	0.728	0.696	0.730	0.723	0.709	0.733	0.539	0.532	0.543	0.544	0.529	0.544	0.559
A4	0.584	0.546	0.578	0.586	0.576	0.576	0.564	0.564	0.576	0.577	0.556	0.576	0.605
A5	(2)	0.0467	0.0465	(2)	0.0466	0.0465	(2)	0.0472	0.0466	(2)	0.0455	0.0463	0.0456
A6	(2)	0.0438	0.0441	(2)	0.0433	0.0423	(2)	0.0440	0.0430	(2)	0.0426	0.0435	0.0422
A7	(2)	0.0459	0.0453	(2)	0.0455	0.0448	(2)	0.0461	0.0452	(2)	0.0443	0.0445	0.0431
ENDEVCO													
	1 kg	5 kg	10 kg	FREQ									
A3	0.539	0.538	0.541	-									
SNL PRE-TEST 6													
	CENT	SHOCK	FREQ	FREQ-20°									
A3	0.542	0.514	0.544	0.560									

(1) A3 was replaced for Test 6. Centrifuge post-test calibration exceeded the allowed 3% deviation.

(2) Centrifuge calibration was not performed on piezoelectric accelerometers.

- the total time (TT) of the shock pulse, defined as the time between 10% of MFA on the leading edge and 10% of MFA on the trailing edge; and
- the fall time (TF) of the pulse, defined as the time between 90% of MFA and 10% of MFA on the trailing edge.

These values were determined by scanning the filtered digital data to determine the peak value, or MFA, and the time of this value. The data were then processed to find the points corresponding to 10 and 90% of this value on both sides of the peak. Table 3-3 gives a compilation of the pulse parameters from all the tests. Amplitude, TR, TP, TT, and TF data are grouped to compare similar amplitude ranges. In Set 1 for Tests 1, 2, and 3 conducted at 1,000 g, the amplitude of A2 was consistently higher than the amplitudes of the other transducers. For Tests 4, 5, and 6 conducted at 5,000 g, the amplitude of A2 was similar to amplitudes of the other transducers. A consistently higher amplitude was recorded for Tests 7, 8, and 9. Figures 3-1, 3-2, and 3-3 show representative plots of a shock pulse from the 1,000-, 5,000-, and 10,000-g tests, respectively. The 5,000- and 10,000-g plots have oscillations following the major pulse that may be due to test fixture vibration. The highest amplitude pulse produced the sharpest rise time.

The shock impulse tests were conducted on a frame that provided the initial velocity by releasing an elastomeric spring. The pulse duration was adjusted by varying the number and thickness of felt pads placed on the impact surface. This procedure led to tests that were not exactly reproducible. For this reason, a better comparison between results was made with normalized data. To do this, the accelerations from each test were normalized with respect to the reference accelerometer, A9. Table 3-4 gives the normalized peak accelerations from each test, and the averages and standard deviations. Figure 3-4 shows the distribution of these results. As shown, the data were quite consistent with a standard deviation of 3%.

In addition to determining the pulse parameters for each shock input, the shock pulse was digitally integrated to determine the change in velocity. This integration indicated how well the accelerometer's signal returned to zero or oscillated near zero. Table 3-5 gives the values for change in velocity at the end of the pulse and at 12 ms after the end of the pulse (5 ms after the pulse for Set 2). The comparison in Table 3-5 shows large deviations in the piezoelectric accelerometers, indicating a slower return to zero.

3.3 Strain Gage Static Tests

A typical load history from the elastic portion of the static tests is shown in Figure 3-5. The test unit was loaded four times to 40,000 lb. Figure 3-6 shows the corresponding deflections for the four cycles. (The deflection measurement is the change in position of the loading head of the MTS machine and, therefore, includes the flexibility of the machine). Figure 3-7 shows a typical strain gage result for this test. The strain gage did not appear to exhibit hysteresis in its measurement. For this test all of the strain gages had similar behavior. Table 3-6

TABLE 3-3. ACCELEROMETER OUTPUT PULSE PARAMETERS FROM SHOCK IMPULSE TESTS

SET 1

GAGE DESIGNATION	TEST 1					TEST 2				
	MFA (g)	TT (ms)	TR (ms)	TF (ms)	TP (ms)	MFA (g)	TT (ms)	TR (ms)	TF (ms)	TP (ms)
A1	991	2.30	0.97	0.97	1.15	974	2.31	0.95	0.99	1.16
A2	1042	2.15	0.99	0.87	1.18	1029	2.22	0.99	0.95	1.18
A3	930	2.29	0.91	0.98	1.17	918	2.39	0.92	1.09	1.18
A4	928	2.31	0.94	1.01	1.17	897	2.40	0.95	1.08	1.19
A5	947	2.31	0.95	1.00	1.17	916	2.31	0.95	1.00	1.18
A6	980	2.30	0.96	0.98	1.15	968	2.30	0.96	0.97	1.17
A7	985	2.14	0.97	0.85	1.18	977	2.22	0.99	0.93	1.19
A8	855	2.31	0.91	0.99	1.18	836	2.31	0.94	0.99	1.19
A9	981	2.33	0.93	1.02	1.20	974	2.40	0.92	1.10	1.20

GAGE DESIGNATION	TEST 3					TEST 4				
	MFA (g)	TT (ms)	TR (ms)	TF (ms)	TP (ms)	MFA (g)	TT (ms)	TR (ms)	TF (ms)	TP (ms)
A1	1001	2.30	0.96	1.00	1.17	4963	1.30	0.60	0.51	0.70
A2	1079	2.18	1.01	0.96	1.20	4895	1.29	0.57	0.51	0.71
A3	932	2.29	0.92	0.98	1.19	4702	1.27	0.58	0.49	0.71
A4	924	2.36	0.91	1.05	1.20	4808	1.31	0.58	0.53	0.70
A5	942	2.27	0.97	0.97	1.19	4814	1.29	0.59	0.51	0.70
A6	994	2.30	0.97	0.99	1.18	4850*	1.45*	0.65*	0.55*	0.70*
A7	1020	2.21	0.95	0.95	1.21	4861	1.30	0.58	0.51	0.70
A8	855	2.25	0.91	0.94	1.03	4419	1.29	0.59	0.51	0.71
A9	1002	2.31	0.94	1.01	1.22	4800	1.32	0.58	0.53	0.72

*Pulse parameters were measured from data plots.

**TABLE 3-3. ACCELEROMETER OUTPUT PULSE PARAMETERS FROM SHOCK IMPULSE TESTS
(CONTINUED)**

SET 1										
GAGE DESIGNATION	TEST 5					TEST 6				
	MFA (g)	TT (ms)	TR (ms)	TF (ms)	TP (ms)	MFA (g)	TT (ms)	TR (ms)	TF (ms)	TP (ms)
A1	5186	1.26	0.59	0.51	0.70	5275	1.25	0.58	0.52	0.68
A2	5066	1.27	0.56	0.51	0.66	5183	1.18	0.55	0.43	0.65
A3	4915	1.30	0.58	0.54	0.67	5055	1.24	0.58	0.51	0.66
A4	4996	1.27	0.59	0.51	0.68	5106	1.23	0.57	0.49	0.68
A5	4998	1.26	0.58	0.50	0.68	5110	1.23	0.57	0.49	0.68
A6	5154	1.79	0.59	1.04	0.70	5246	1.26	0.58	0.52	0.68
A7	5031	1.28	0.57	0.51	0.68	5136	1.26	0.56	0.52	0.66
A8	4610	1.25	0.58	0.50	0.68	4721	1.23	0.57	0.50	0.68
A9	4995	1.28	0.57	0.52	0.66	5138	1.27	0.57	0.52	0.66

GAGE DESIGNATION	TEST 7					TEST 8				
	MFA (g)	TT (ms)	TR (ms)	TF (ms)	TP (ms)	MFA (g)	TT (ms)	TR (ms)	TF (ms)	TP (ms)
A1	9490	0.69	0.34	0.25	0.41	9842	0.68	0.33	0.25	0.38
A2	10051	0.54	0.26	0.23	0.28	10288	0.54	0.25	0.23	0.28
A3	9397	0.68	0.34	0.24	0.40	9719	0.66	0.34	0.22	0.39
A4	9738	0.68	0.35	0.25	0.39	10092	0.66	0.34	0.23	0.38
A5	9644	0.68	0.34	0.25	0.39	10008	0.66	0.34	0.24	0.38
A6	9613	0.70	0.34	0.26	0.40	9997	0.67	0.34	0.24	0.38
A7	9765	0.68	0.35	0.25	0.39	10066	0.56	0.25	0.23	0.29
A8	8932	0.68	0.34	0.24	0.40	9201	0.66	0.34	0.23	0.38
A9	9545	0.69	0.34	0.25	0.39	9858	0.66	0.34	0.24	0.38

**TABLE 3-3. ACCELEROMETER OUTPUT PULSE PARAMETERS FROM SHOCK IMPULSE TESTS
(CONTINUED)**

SET 1						
GAGE DESIGNATION	MFA (g)	TEST 9				
		TT (ms)	TR (ms)	TF (ms)	TP (ms)	
A1	10027	0.58	0.33	0.26	0.37	
A2	10442	0.52	0.24	0.22	0.27	
A3	9813	0.65	0.33	0.22	0.37	
A4	10202	0.65	0.34	0.23	0.38	
A5	10132	0.83	0.33	0.41	0.37	
A6	10167	0.69	0.33	0.27	0.37	
A7	10242	0.54	0.24	0.23	0.28	
A8	9313	0.65	0.33	0.23	0.37	
A9	9995	0.64	0.33	0.22	0.38	

**TABLE 3-3. ACCELEROMETER OUTPUT PULSE PARAMETERS FROM SHOCK IMPULSE TESTS
(CONTINUED)**

SET 2											
GAGE DESIGNATION	TEST 1					TEST 2					
	MFA (g)	TT (ms)	TR (ms)	TF (ms)	TP (ms)	MFA (g)	TT (ms)	TR (ms)	TF (ms)	TP (ms)	
A1	1236	1.95	0.91	0.87	1.01	1148	2.01	0.87	0.87	0.97	
A2	1188	1.95	0.87	0.86	0.98	1149	1.98	0.86	0.82	0.96	
A3	1145	1.93	0.86	0.80	0.94	1151	1.95	0.84	0.84	0.96	
A4	1154	1.79	0.87	0.67	1.02	1189	1.91	0.90	0.87	0.98	
A5	1154	1.98	0.86	0.85	0.95	1119	2.01	0.86	0.84	1.00	
A6	1170	2.06	0.85	0.92	0.95	1148	2.06	0.87	0.90	1.00	
A7	1150	1.99	0.85	0.85	0.99	1124	2.03	0.86	0.88	0.98	
A8	1145	1.97	0.86	0.85	0.95	1103	2.00	0.86	0.85	1.00	
A9	1162	1.98	0.87	0.85	1.00	1124	1.99	0.86	0.85	0.99	
GAGE DESIGNATION	TEST 3					TEST 4					
	MFA (g)	TT (ms)	TR (ms)	TF (ms)	TP (ms)	MFA (g)	TT (ms)	TR (ms)	TF (ms)	TP (ms)	
A1	1153	2.01	0.90	0.86	1.10	5154	1.08	0.60	0.37	0.65	
A2	1188	2.00	0.91	0.90	1.01	5051	1.10	0.55	0.42	0.65	
A3	1146	1.95	0.87	0.85	0.94	5056	1.17	0.57	0.47	0.66	
A4	1153	1.93	0.90	0.84	0.97	5208	1.17	0.57	0.47	0.65	
A5	1120	2.01	0.87	0.86	0.97	4866	-*	0.55	-*	0.65	
A6	1138	2.07	0.87	0.91	0.97	4925	1.54	0.55	0.81	0.62	
A7	1113	2.05	0.87	0.90	1.01	4852	2.00	0.55	1.28	0.63	
A8	1101	1.99	0.86	0.86	0.96	4630	1.03	0.45	0.42	0.55	
A9	1120	1.99	0.88	0.85	1.02	4929	1.01	0.40	0.45	0.49	

*Slow pulse decay.

**TABLE 3-3. ACCELEROMETER OUTPUT PULSE PARAMETERS FROM SHOCK IMPULSE TESTS
(CONTINUED)**

SET 2

GAGE DESIGNATION	TEST 5					TEST 6				
	MFA (g)	TT (ms)	TR (ms)	TF (ms)	TP (ms)	MFA (g)	TT (ms)	TR (ms)	TF (ms)	TP (ms)
A1	5008	0.96	0.53	0.25	0.63	5412	0.80	0.41	0.27	0.47
A2	5253	1.05	0.55	0.34	0.57	5324	0.98	0.55	0.31	0.60
A3	5125	1.11	0.55	0.41	0.66	5387	1.10	0.54	0.41	0.64
A4	4821	1.05	0.50	0.32	0.61	5051	1.10	0.56	0.40	0.64
A5	5254	1.86	0.56	1.17	0.63	5100	2.24	0.54	1.54	0.64
A6	4686	1.35	0.54	0.64	0.65	5244	1.53	0.54	0.82	0.63
A7	5000	1.54	0.54	0.83	0.64	5004	1.39	0.54	0.68	0.64
A8	5010	1.03	0.43	0.45	0.53	5065	1.03	0.42	0.45	0.53
A9	5072	0.96	0.37	0.42	0.46	5125	0.98	0.38	0.43	0.48

GAGE DESIGNATION	TEST 7					TEST 8				
	MFA (g)	TT (ms)	TR (ms)	TF (ms)	TP (ms)	MFA (g)	TT (ms)	TR (ms)	TF (ms)	TP (ms)
A1	11459	0.47	0.20	0.20	0.26	11515	0.49	0.19	0.22	0.21
A2	11976	0.43	0.20	0.17	0.23	12087	0.42	0.18	0.17	0.23
A3	11622	0.47	0.20	0.20	0.25	11385	0.46	0.19	0.19	0.24
A4	11644	0.43	0.20	0.17	0.23	11935	0.40	0.19	0.16	0.22
A5	11476	0.54	0.20	0.28	0.24	11493	0.53	0.20	0.26	0.23
A6	11589	1.39	0.19	1.12	0.25	11463	0.71	0.19	0.44	0.25
A7	11787	0.48	0.19	0.22	0.23	11671	0.43	0.18	0.17	0.23
A8	10279	0.47	0.18	0.19	0.24	10303	0.47	0.17	0.19	0.23
A9	11308	0.43	0.17	0.17	0.23	11475	0.40	0.17	0.14	0.18

TABLE 3-3. ACCELEROMETER OUTPUT PULSE PARAMETERS FROM SHOCK IMPULSE TESTS
(CONTINUED)

<u>GAGE DESIGNATION</u>	<u>SET 2</u>				
	<u>TEST 9</u>				<u>TP (ms)</u>
	<u>MFA (g)</u>	<u>TT (ms)</u>	<u>TR (ms)</u>	<u>TF (ms)</u>	
A1	11509	0.46	0.19	0.19	0.21
A2	11969	0.43	0.18	0.18	0.23
A3	11257	0.47	0.19	0.20	0.21
A4	11675	0.41	0.19	0.16	0.22
A5	11564	0.53	0.20	0.26	0.22
A6	11513	0.44	0.18	0.17	0.22
A7	11630	0.43	0.18	0.17	0.23
A8	10328	0.45	0.17	0.17	0.23
A9	11472	0.39	0.17	0.14	0.18

TABLE 3-3. ACCELEROMETER OUTPUT PULSE PARAMETERS FROM SHOCK IMPULSE TESTS
(CONTINUED)

SET 3										
GAGE DESIGNATION	TEST 1					TEST 2				
	MFA (g)	TT (ms)	TR (ms)	TF (ms)	TP (ms)	MFA (g)	TT (ms)	TR (ms)	TF (ms)	TP (ms)
A1	1163	2.16	0.92	0.95	1.07	1173	2.11	0.92	0.90	1.05
A2	1095	2.19	0.92	0.95	1.08	1108	2.08	0.89	0.87	1.04
A3	1103	2.20	0.90	0.99	1.04	1100	2.07	0.87	0.87	1.13
A4	1105	2.17	0.90	0.94	1.10	1134	2.09	0.89	0.88	1.09
A5	1144	2.34	0.89	1.13	1.03	1137	2.09	0.88	0.89	1.08
A6	1160	2.34	0.92	1.13	1.08	1139	2.09	0.89	0.88	1.04
A7	1129	2.29	0.90	1.07	1.08	1135	2.09	0.89	0.88	1.05
A8	997	2.13	0.89	0.92	1.03	1023	2.11	0.88	0.90	1.00
A9	1094	2.18	0.89	0.95	1.03	*	*	*	*	*
GAGE DESIGNATION	TEST 3					TEST 4				
	MFA (g)	TT (ms)	TR (ms)	TF (ms)	TP (ms)	MFA (g)	TT (ms)	TR (ms)	TF (ms)	TP (ms)
A1	1154	2.11	0.91	0.90	1.03	5549	1.18	0.54	0.46	0.63
A2	1116	2.07	0.89	0.88	1.07	5430	1.18	0.54	0.46	0.58
A3	1108	2.06	0.87	0.87	1.10	5423	1.19	0.54	0.48	0.64
A4	1132	2.06	0.89	0.86	1.03	5485	1.17	0.53	0.46	0.65
A5	1137	2.10	0.89	0.89	1.03	5439	1.16	0.53	0.45	0.65
A6	1142	2.08	0.89	0.88	1.04	5518	1.17	0.53	0.45	0.63
A7	1143	2.09	0.89	0.89	1.08	5458	1.19	0.54	0.47	0.63
A8	1033	2.09	0.88	0.89	1.11	5024	1.19	0.53	0.48	0.65
A9	1152	2.12	0.88	0.92	1.09	5486	1.19	0.54	0.47	0.62

*No acquired data.

TABLE 3-3. ACCELEROMETER OUTPUT PULSE PARAMETERS FROM SHOCK IMPULSE TESTS
(CONTINUED)

SET 3										
GAGE DESIGNATION	TEST 5				TEST 6					
	MFA (g)	TT (ms)	TR (ms)	TF (ms)	TP (ms)	MFA (g)	TT (ms)	TR (ms)	TF (ms)	TP (ms)
A1	5581	1.17	0.52	0.46	0.63	5714	1.15	0.52	0.44	0.63
A2	5570	1.13	0.53	0.43	0.63	5612	1.17	0.53	0.46	0.63
A3	(1)	(1)	(1)	(1)	(1)	5597	1.19	0.54	0.48	0.64
A4	5460	1.16	0.52	0.45	0.63	5667	1.16	0.53	0.45	0.64
A5	5462	1.14	0.53	0.43	0.63	5752	1.19	0.53	0.48	0.64
A6	5589	1.15	0.52	0.44	0.63	6646	(2)	0.54	(2)	0.63
A7	5580	1.19	0.53	0.48	0.63	5873	(2)	0.55	(2)	0.64
A8	5042	1.18	0.53	0.47	0.63	5092	1.17	0.53	0.45	0.66
A9	5605	1.18	0.53	0.48	0.63	5626	1.18	0.54	0.47	0.63

GAGE DESIGNATION	TEST 7				TEST 8					
	MFA (g)	TT (ms)	TR (ms)	TF (ms)	TP (ms)	MFA (g)	TT (ms)	TR (ms)	TF (ms)	TP (ms)
A1	5718	1.16	0.52	0.46	0.61	9655	0.67	0.33	0.24	0.37
A2	5710	1.13	0.52	0.45	0.62	10453	0.55	0.25	0.24	0.28
A3	5640	1.17	0.52	0.47	0.63	9848	0.67	0.33	0.24	0.38
A4	5698	1.14	0.52	0.44	0.63	10178	0.67	0.34	0.25	0.38
A5	5827	1.18	0.53	0.47	0.63	10099	0.68	0.33	0.25	0.38
A6	6093	1.24	0.52	0.53	0.62	10797	0.87	0.35	0.44	0.40
A7	6107	1.47	0.54	0.78	0.63	10249	0.64	0.26	0.30	0.29
A8	5077	1.12	0.52	0.41	0.62	9070	0.66	0.33	0.23	0.38
A9	5709	1.16	0.52	0.47	0.62	9900	0.68	0.34	0.26	0.38

(1) No acquired data.

(2) Slow pulse decay.

**TABLE 3-3. ACCELEROMETER OUTPUT PULSE PARAMETERS FROM SHOCK IMPULSE TESTS
(CONCLUDED)**

SET 3										
GAGE DESIGNATION	TEST 9					TEST 10				
	MFA (g)	TT (ms)	TR (ms)	TF (ms)	TP (ms)	MFA (g)	TT (ms)	TR (ms)	TF (ms)	TP (ms)
A1	10026	0.67	0.33	0.24	0.38	10243	0.66	0.32	0.24	0.37
A2	10436	0.53	0.25	0.23	0.27	10605	0.52	0.24	0.23	0.27
A3	9925	0.67	0.33	0.24	0.37	10213	0.64	0.32	0.23	0.36
A4	10202	0.66	0.34	0.24	0.38	10447	0.64	0.33	0.23	0.37
A5	10249	0.68	0.33	0.25	0.38	10492	0.65	0.33	0.23	0.37
A6	11727	0.79	0.25	0.46	0.29	11232	0.73	0.25	0.40	0.29
A7	10374	0.81	0.25	0.46	0.29	10721	0.72	0.24	0.39	0.28
A8	9219	0.66	0.33	0.24	0.37	9438	0.64	0.32	0.22	0.36
A9	9944	0.64	0.33	0.21	0.38	10227	0.54	0.23	0.22	0.28

Figure 3-1. Representative Plot of a Shock Pulse From the 1,000-g Shock Impulse Test

Figure 3-2. Representative Plot of a Shock Pulse From the 5,000-g Shock Impulse Test

Figure 3-3. Representative Plot of a Shock Pulse From the 10,000-g Shock Impulse Test

lists the maximum strain for each gage at the first and fourth load peaks. The average peak strain for the axial gages in the first cycle was 310 microstrains ($\mu\epsilon$), with a standard deviation of 33, and the average peak strain on the fourth cycle was 302 $\mu\epsilon$, with a standard deviation of 29. These numbers compared with a theoretical value of 308 for the 40,000-lb load and a modulus of elasticity of 10^7 psi. Figure 3-8 shows a plot of the distribution of these strains for the first and fourth cycles from all of the axial gages (240 points from each cycle). In the hoop direction, the average of the peak strains for the first cycle was 102 $\mu\epsilon$, with a standard deviation of 13, and the average for the fourth cycle was 99 $\mu\epsilon$, with a standard deviation of 8. Figure 3-9 shows a plot of the distribution of these strains for the first and fourth cycles. The distribution centers between 95 and 105 $\mu\epsilon$.

The results of the elastic portion of the test showed that even in this well-characterized test there was some scatter in the data. The standard deviation of the strain gages was approximately 10% of the average value. Generally for strains as low as those recorded in this test, a large portion of the scatter can result from the data acquisition system. A strain of 300 $\mu\epsilon$ corresponds to a voltage signal of only 1.5 mV; frequently, noise may be as large as 1 mV. The largest level of noise in this test series was 0.95 mV, but most channels had less than 0.2 mV of peak-to-peak noise. If it is known that the maximum

TABLE 3-4. NORMALIZED ACCELERATIONS FROM SHOCK IMPULSE TESTS
(NORMALIZED WITH RESPECT TO A9)

SET 1									
TEST NO.	A1	A2	A3	A4	A5	A6	A7	A8	A9
1	1.010	1.062	0.948	0.946	0.965	0.999	1.004	0.872	1
2	1.000	1.056	0.943	0.921	0.940	0.994	1.003	0.858	1
3	0.999	1.077	0.930	0.992	0.940	0.992	1.018	0.853	1
4	1.034	1.020	0.980	1.002	1.003	1.010	1.013	0.921	1
5	1.038	1.014	0.984	1.000	1.001	1.032	1.007	0.923	1
6	1.027	1.009	0.984	0.994	0.995	1.021	1.000	0.919	1
7	0.994	1.053	0.984	1.020	1.010	1.007	1.023	0.936	1
8	0.998	1.044	0.986	1.024	1.015	1.014	1.021	0.993	1
9	1.003	1.045	0.982	1.021	1.014	1.017	1.025	0.932	1

SET 2									
TEST NO.	A1	A2	A3	A4	A5	A6	A7	A8	A9
1	1.064	1.022	0.985	0.993	0.993	1.007	0.990	0.985	1
2	1.021	1.022	1.024	1.058	0.996	1.021	1.000	0.981	1
3	1.029	1.061	0.023	1.029	1.000	1.016	0.994	0.983	1
4	1.046	1.025	1.026	1.057	0.987	0.999	0.984	0.980	1
5	0.987	1.036	1.010	0.951	1.036	0.924	0.986	0.988	1
6	1.056	1.039	1.051	0.986	0.995	1.023	0.976	0.988	1
7	1.013	1.059	1.028	1.030	1.015	1.025	1.042	0.909	1
8	1.003	1.053	0.992	1.040	1.002	0.999	1.017	0.898	1
9	1.003	1.043	0.981	1.018	1.008	1.004	1.014	0.900	1

TABLE 3-4. NORMALIZED ACCELERATIONS FROM SHOCK IMPULSE TESTS
(NORMALIZED WITH RESPECT TO A9) (CONCLUDED)

TEST NO.	SET 3								
	A1	A2	A3	A4	A5	A6	A7	A8	A9
1	1.063	1.001	1.008	1.010	1.046	1.060	1.032	0.911	1
2	1.066	1.007	1.000	1.031	1.034	1.035	1.032	0.930	1
3	1.002	0.969	0.962	0.983	0.987	0.991	0.992	0.897	1
4	1.011	0.990	0.989	1.000	0.991	1.006	0.995	0.916	1
5	0.996	0.994	(1)	0.974	0.974	0.997	0.996	0.900	1
6	1.016	0.998	0.995	1.007	1.021	1.181	1.044	0.905	1
7	1.002	1.000	0.988	0.998	1.021	1.067	1.070	0.889	1
8	0.975	1.056	0.995	1.028	1.020	1.091	1.035	0.916	1
9	1.008	1.049	0.998	1.026	1.031	1.179	1.043	0.927	1
10	1.002	1.037	0.999	1.022	1.026	1.098	1.048	0.923	1
AVG	1.0167	1.0300	0.9916	1.0031	1.0023	1.0289	1.0144	0.9240	
STD	0.0239	0.0264	0.0261	0.0344	0.0250	0.0530	0.0224	0.0373	
MIN	0.9752	0.9687	0.9301	0.9209	0.9401	0.9238	0.9763	0.8532	
MAX	1.0663	1.0768	1.0511	1.0578	1.0457	1.1813	1.0697	0.9882	
TOTAL	AVG	1.0125	STD	0.0344	MAX	1.1813	MIN	0.9209	

The totals are for A1 to A7 only.

(1) No acquired data

Figure 3-4. Distribution of Normalized MFA Accelerations From Shock Pulse Tests

strains are of such low magnitude, this problem can be alleviated by selecting strain gages with higher output, i.e., semiconductor type gages. However, this type of gage may be larger, more expensive, and more difficult to install.

A typical load history for the inelastic portion of the static tests is shown in Figure 3-10. Following the initial rise, a nearly linear loading was applied up to 140,000 lb. Figure 3-11 shows the corresponding deflection was approximately 0.5 in. A typical strain gage response is shown in Figure 3-12. The serrations in the strain response were likely caused by dynamic strain-aging of the test specimen, also known as the Portevin-LeChatelier effect (Dieter, 1976). In this portion of the testing, the flexibility of the test machine was not as significant as in the elastic range because once the specimen yielded, the stiffness of the machine was much higher than the stiffness of the specimen. Since these specimens were loaded past the yield point, the data from these tests could be used to determine the yield strength of the material. For materials that do not exhibit a sharp yield point, such as aluminum, the reported yield strength is determined from a 0.002-strain offset. For each of the test specimens, an external extensometer with a 2-in. gage length was attached near the midpoint. The output of this extensometer, i.e., strain, was plotted versus load on an X-Y recorder during each test, except for Test 1. An example of these plots is shown in Figure 3-13. The effect of dynamic strain-aging

TABLE 3-5. SHOCK IMPULSE TEST VELOCITY CHANGE DETERMINED FROM THE INTEGRATION OF ACCELERATION

TEST NO.	ACC. LEVEL	SET 1								
		A1	A2	A3	A4	A5	A6	A7	A8	A9
1	1K	V1 38	37	37	37	37	38	37	35	38
		V2 35	29	'9	30	33	29	19	27	36
2	1K	V1 38	37	36	37	37	38	35	34	38
		V2 36	31	31	31	29	30	19	28	35
3	1K	V1 38	37	36	37	37	38	37	34	38
		V2 36	31	30	31	31	31	29	26	36
4	5K	V1 110	112	108	108	110	100	110	98	112
		V2 108	98	96	96	550	2400	460	48	104
5	5K	V1 112	110	106	106	110	110	110	98	110
		V2 108	94	88	92	750	700	500	54	104
6	5K	V1 110	106	106	106	110	110	110	100	110
		V2 106	92	86	88	470	640	500	58	104
7	10K	V1 110	106	104	106	110	110	105	100	106
		V2 104	92	90	102	600	450	260	80	100
8	10K	V1 110	108	104	104	110	110	100	100	106
		V2 106	92	92	82	750	880	670	50	102
9	10K	V1 104	104	102	104	110	100	110	100	108
		V2 98	80	78	84	700	1000	900	50	102

V1 - Velocity at end of impact pulse.

V2 - Velocity at 12 ms after pulse for Sets 1 and 3 and 5 ms after pulse for Set 2.

TABLE 3-5. SHOCK IMPULSE TEST VELOCITY CHANGE DETERMINED FROM THE INTEGRATION OF ACCELERATION (CONTINUED)

SET 2										
TEST NO.	ACC. LEVEL	A1	A2	A3	A4	A5	A6	A7	A8	A9
1	1K	V1	38	38	38	38	40	38	37	38
		V2	37	38	37	36	38	39	37	37
2	1K	V1	38	38	38	38	39	38	37	38
		V2	37	38	37	36	37	39	35	37
3	1K	V1	38	38	38	38	39	38	36	37
		V2	37	38	37	36	38	40	35	37
4	5K	V1	94	96	96	100	110	110	89	93
		V2	94	94	96	350	130	165	82	92
5	5K	V1	94	94	94	96	98	98	90	94
		V2	94	92	94	166	100	150	86	92
6	5K	V1	94	94	94	95	100	100	92	94
		V2	94	92	92	200	124	124	88	92
7	10K	V1	90	92	94	98	95	96	86	90
		V2	80	90	88	300	330	166	86	90
8	10K	V1	90	90	90	90	95	94	87	89
		V2	80	88	74	300	190	116	82	87
9	10K	V1	89	90	88	95	100	100	85	88
		V2	81	92	86	260	156	130	83	87

V1 - Velocity at end of impact pulse.

V2 - Velocity at 12 ms after pulse for Sets 1 and 3 and 5 ms after pulse for Set 2.

TABLE 3-5. SHOCK IMPULSE TEST VELOCITY CHANGE DETERMINED FROM THE INTEGRATION OF ACCELERATION (CONCLUDED)

SET 3										
TEST NO.	ACC. LEVEL	A1	A2	A3	A4	A5	A6	A7	A8	A9
1	1K	V1	41	42	41	47	47	45	35	40
		V2	40	39	37	40	42	40	28	37
2	1K	V1	40	39	39	40	38	40	37	—
		V2	37	29	32	32	28	32	29	—
3	1K	V1	40	37	38	40	39	40	36	41
		V2	38	26	29	30	33	31	32	28
4	5K	V1	112	110	110	108	111	112	101	112
		V2	106	90	90	48	88	94	45	106
5	5K	V1	112	(1)	110	108	110	112	100	112
		V2	108	92	(1)	94	58	80	50	108
6	5K	V1	110	114	108	116	120	120	100	114
		V2	104	102	106	102	94	900	430	96
7	5K	V1	110	112	110	124	120	120	98	114
		V2	106	104	108	108	108	168	190	62
8	10K	V1	112	112	108	110	120	120	96	108
		V2	106	102	106	102	92	380	270	80
9	10K	V1	114	108	104	110	120	120	96	106
		V2	110	108	100	100	112	480	440	80
10	10K	V1	108	110	106	110	120	120	96	106
		V2	102	104	106	102	114	310	310	68

(1) - No acquired data.

V1 - Velocity at end of impact pulse.

V2 - Velocity at 12 ms after pulse for Sets 1 and 3 and 5 ms after pulse for Set 2.

Figure 3-5. Typical Elastic Load History From Static Crush Tests

Figure 3-6. Elastic Deflection History From Static Crush Tests

Figure 3-7. Typical Elastic Axial Strain Gage Plot From Static Crush Tests

can also be seen in Figure 3-13. These plots were used to determine the 0.002-strain offset yield point, as well as the elastic limit, or limit of proportionality, of the material. Table 3-7 lists the yield strength and elastic limit obtained from each test. The yields ranged from 5,300 to 6,400 psi and the elastic limits ranged from 3,700 to 4,750 psi.

In general, an important use of strain gages in test programs is to determine the peak and permanent strains at the gage location. Table 3-8 lists the peak and permanent strains recorded for each gage in the inelastic portion of the static crush test. The method used for checking the permanent strain was to measure the resistance of the gage before and after the test. The difference in resistance is proportional to the permanent strain; the constant of proportionality is the gage factor times the initial resistance. These measurements were made for each gage, and the calculated permanent strain was then compared with the measured value. The results of this comparison are shown in Table 3-9. This method located recorded strain gage errors that may have resulted from the cabling or data acquisition system. If the calculated strain from the change in resistance did not correspond with the measured permanent strain, the error was likely in the cabling or data acquisition system and not in the strain gage itself.

TABLE 3-6. PEAK ELASTIC STRAIN () AT THE FIRST AND FOURTH PEAKS
FROM STATIC CRUSH TESTS

GAGE DESIGNATION	TEST 1		TEST 2		TEST 3		TEST 4		TEST 5		TEST 6		TEST 7		TEST 8		TEST 9		TEST 10	
	PK1	PK4	PK1	PK4	PK1	PK4	PK1	PK4	PK1	PK4	PK1	PK4	PK1	PK4	PK1	PK4	PK1	PK4	PK1	PK4
SG 1	-330	-323	-333	-320	-310	-310	-335	-335	-310	-305	-308	-310	-325	-310	-330	-320	-305	-305	-315	-300
SG 2	105	105	103	100	104	105	108	103	93	93	95	105	108	98	105	103	95	98	103	95
SG 3	-318	-310	-320	-300	-295	-300	-330	-305	-303	-293	-260	-295	-310	-290	-315	-305	-300	-290	-315	-290
SG 4	125	121	100	100	103	103	103	100	100	95	88	100	105	100	115	103	98	95	100	93
SG 5	-320	-310	-325	-308	-315	-318	-308	-300	-305	-300	-240	-300	-330	-315	-335	-315	-310	-295	-328	-290
SG 6	114	113	105	100	103	105	95	95	95	95	70	95	103	98	113	105	95	93	108	95
SG 7	-340	-338	-283	-275	-295	-298	-293	-295	-370	-340	-293	-313	-340	-320	-350	-333	-295	-293	-285	-298
SG 8	114	111	105	98	95	96	108	108	123	114	89	100	104	99	108	103	98	93	93	93
SG 9	-330	-320	-280	-270	-278	-278	-315	-300	-330	-320	-275	-315	-323	-305	-338	-320	-305	-298	-285	-290
SG 10	111	110	94	94	100	100	108	95	105	105	91	93	107	95	103	100	100	99	94	95
SG 11	-330	-315	-305	-290	-310	-310	-310	-300	-345	-325	-265	-310	-333	-305	-338	-325	-325	-300	-283	-283
SG 12	105	100	108	94	96	96	100	98	130	110	88	108	103	94	100	99	113	103	98	95
SG 13	-350	-345	-278	-300	-330	-330	-315	-345	-410	-360	-345	-355	-345	-335	-365	-345	-330	-330	-290	-325
SG 14	103	103	90	90	104	103	103	105	138	133	115	120	113	100	113	113	109	110	90	95
SG 15	-320	-315	-255	-255	-295	-295	-300	-295	-350	-335	-320	-325	-310	-295	-325	-315	-310	-303	-258	-285
SG 16	118	108	90	85	103	103	103	100	103	113	113	109	105	98	105	105	100	100	90	95
SG 17	-318	-313	-283	-275	-300	-300	-265	-285	-340	-328	-327	-310	-305	-290	-318	-315	-305	-300	-250	-285
SG 18	115	114	91	88	98	98	98	95	118	113	118	114	110	98	105	103	88	95	83	93
SG 19	-305	-308	-245	-225	-305	-300	-325	-295	-345	-333	-320	-295	-308	-300	-310	-305	-310	-305	-285	-290
SG 20	109	103	93	93	108	108	105	100	118	119	105	95	104	104	103	103	100	100	90	95
SG 21	-295	-300	-260	-265	-300	-298	-290	-285	-338	-325	-340	-300	-310	-300	-313	-310	-300	-300	-250	-290
SG 22	103	103	79	81	100	100	110	98	129	114	115	100	90	95	100	103	88	98	80	93
SG 23	-295	-308	-290	-285	-305	-305	-290	-295	-325	-325	-405	-320	-315	-310	-310	-315	-305	-310	-245	-295
SG 24	103	104	98	93	100	100	100	98	128	110	148	105	95	95	100	98	100	100	80	95
SG 25	-275	-280	-308	-300	-295	-295	-315	-295	-315	-300	-355	-290	-380	-380	-290	-290	-285	-285	-285	-300
SG 26	81	88	99	90	93	93	98	95	90	93	148	103	108	103	100	95	100	100	88	94

TABLE 3-6. PEAK ELASTIC STRAIN () AT THE FIRST AND FOURTH PEAKS
FROM STATIC CRUSH TESTS (CONCLUDED)

GAGE DESIGNATION	TEST 1		TEST 2		TEST 3		TEST 4		TEST 5		TEST 6		TEST 7		TEST 8		TEST 9		TEST 10	
	PK1	PK4	PK1	PK4	PK1	PK4	PK1	PK4	PK1	PK4	PK1	PK4	PK1	PK4	PK1	PK4	PK1	PK4	PK1	PK4
SG 27	-265	-278	-290	-285	-290	-285	-310	-295	-323	-300	-345	-285	-275	-285	-265	-275	-288	-285	-273	-290
SG 28	91	91	94	93	103	104	108	98	103	98	130	93	105	103	91	89	93	95	88	98
SG 29	-265	-280	-310	-298	-305	-305	-320	-300	-310	-305	-430	-305	-285	-290	-275	-285	-290	-295	-268	-295
SG 30	100	93	105	100	108	105	98	98	110	104	175	105	95	85	94	94	90	91	88	96
SG 31	-275	-280	-333	-315	-305	-305	-338	-295	-260	-270	-340	-275	-285	-290	-260	-265	-285	-295	-315	-305
SG 32	95	98	115	106	98	98	110	100	90	90	139	93	90	93	89	90	98	100	100	103
SG 33	-265	-280	-350	-320	-300	-300	-345	-310	-270	-270	-395	-290	-305	-300	-275	-275	-290	-290	-313	-305
SG 34	85	90	106	100	100	103	110	94	96	90	113	88	93	95	93	89	89	89	101	100
SG 35	-265	-280	-318	-310	-308	-308	-315	-300	-275	-275	-380	-295	-280	-300	-290	-289	-290	-290	-310	-305
SG 36	73	79	108	105	98	98	103	98	100	95	105	93	95	100	95	98	88	93	100	98
SG 37	-270	-275	-365	-330	-295	-300	-330	-305	-240	-240	-350	-290	-308	-305	-300	-305	-295	-300	-338	-310
SG 38	93	90	146	121	104	103	108	105	80	88	90	90	95	95	83	85	98	100	113	105
SG 39	-280	-285	-350	-330	-290	-295	-325	-315	-255	-260	-330	-280	-293	-298	-278	-275	-295	-300	-343	-305
SG 40	80	88	110	110	95	95	120	105	80	83	98	93	93	98	84	86	100	100	110	100
SG 41	-285	-285	-350	-330	-310	-315	-338	-305	-270	-275	-350	-295	-290	-290	-285	-280	-298	-293	-300	-310
SG 42	88	94	120	105	100	100	105	95	85	87	123	98	100	100	94	93	100	98	114	100
SG 43	-360	-365	-440	-390	-268	-270	-390	-365	-290	-305	-335	-315	-325	-330	-300	-290	-325	-310	-375	-340
SG 44	100	95	149	123	96	99	113	100	88	90	128	110	95	93	98	94	100	100	108	100
SG 45	-305	-305	-365	-330	-300	-305	-330	-310	-263	-270	-315	-300	-128	-130	-300	-295	-305	-300	-350	-335
SG 47	-305	-305	-355	-325	-290	-295	-360	-320	-285	-280	-273	-290	-300	-295	-308	-290	-305	-295	-365	-305

= Microstrain.

PK = Peak.

Figure 3-8. Elastic Axial Strain Distribution From Static Crush Tests

Figure 3-9. Elastic Hoop Strain Distribution From Static Crush Tests

Figure 3-10. Plastic Load History From Static Crush Tests

Figure 3-11. Plastic Deflection History From Static Crush Tests

Figure 3-12. Plastic Axial Strain Gage Plot From Static Crush Tests

Figure 3-13. Load Versus Extensometer Strain Plot From Static Crush Tests

**TABLE 3-7. MATERIAL YIELD STRESS AND ELASTIC LIMIT
DETERMINED FROM STATIC CRUSH TESTS**

<u>TEST NUMBER</u>	<u>YIELD STRESS (psi)</u>	<u>ELASTIC LIMIT (psi)</u>
2	5768	4398
3	5311	3721
4	5633	4229
5	5954	4567
6	5464	4060
7	6106	4736
8	6208	4736
9	6259	4736
10	6394	4736
Avg.	5900	4435
σ	377	366

Figure 3-14 shows the distribution of the permanent axial strains from all of the reduced strain gage data. The average value was 17,358 $\mu\epsilon$, with a standard deviation of 1,377. These values did not include the results from six gages determined to be highly suspect. Five of these gages had measured permanent axial strains that differed from the value determined by the change in resistance by more than 5,000 $\mu\epsilon$. The sixth gage measured a permanent strain approximately 10,000 $\mu\epsilon$ lower than the average. The average value determined from the change of resistance was 17,339 $\mu\epsilon$, with a standard deviation of 1,364. The average value from the extensometer was 18,512 $\mu\epsilon$, with a standard deviation of 528. The average value determined from dimensional inspection was 18,411 $\mu\epsilon$, with a standard deviation of 178. All of the dimensional inspection data are given in Appendix B. The distribution of the permanent hoop strains from the reduced data is shown in Figure 3-15. The average value was 7,892 $\mu\epsilon$, with a standard deviation of 2,451 $\mu\epsilon$. This large standard deviation was due to variations in the tests. This is shown by the dimensional inspection which indicated large variations in permanent deformations that corresponded to these strains. The average value from the dimensional inspection data was 8,540 $\mu\epsilon$, with a standard deviation of 1,509.

The average measured strains in both the axial and hoop directions were smaller than the values determined by the dimensional inspections. For the axial direction, the average value of the Micro-Measurement gages from the reduced data was 17,103 $\mu\epsilon$, with a standard deviation of 1,198, and the calculated permanent strain average was 17,186 $\mu\epsilon$, with a standard deviation of 1,147. The average value of the BLH gages was 17,613 $\mu\epsilon$, with a standard deviation of 1,500, and the average calculated permanent strain was 17,494 $\mu\epsilon$, with a standard deviation of 1,537. If the true permanent strain was 18,411 $\mu\epsilon$, then the BLH gages gave a closer result, but with more scatter. Both sets were within one standard deviation (7%) of the result determined from dimensional inspection. One BLH gage in this test series appeared to give faulty

TABLE 3-8. PLASTIC PEAK AND PERMANENT STRAIN ($\mu\epsilon$) FROM STATIC CRUSH TESTS

GAGE DESIGNATION	TEST 1		TEST 2		TEST 3		TEST 4		TEST 5	
	PEAK	PERM	PEAK	PERM	PEAK	PERM	PEAK	PERM	PEAK	PERM
SG 1	-18400	-17200	-17900	-16700	-18833	-17666	-18500	-17333	-19666	-18333
SG 2	11300	10800	5450	5100	9500	9000	7500	7100	8400	8000
SG 3	-18800	-17600	-20833	-19666	-17400	-16200	-18600	-17300	-18333	-17166
SG 4	13000	12400	5200	4800	10125	9625	5650	5250	9650	9200
SG 5	-19700	-18500	-18400	-17000	-17500	-16400	-22500	-21333	-19875	-18625
SG 6	12600	12100	6550	6180	7750	7350	5000	4620	7500	7050
SG 7	-22000	-20625	-20250	-19000	-19200	-18100	-16500	-15300	-19875	-18625
SG 8	7300	6850	14000	13500	6300	5950	13083	12667	10300	9800
SG 9	-19400	-18200	-16300	-15200	-19100	-17900	-21000	-19833	-18875	-17750
SG 10	7600	7150	6900	6500	9400	8900	8700	8300	4875	4500
SG 11	-18100	-16700	-19400	-18200	-22666	-21333	-20333	-19166	-20250	-19000
SG 12	7100	6700	6550	6125	7000	6600	8200	7800	15000	14500
SG 13	-19333	-18000	-19800	-18666	-18000	-17000	-17000	-15800	-19166	-18000
SG 14	4650	4300	8075	7650	7600	7200	9700	9300	11100	10600
SG 15	-18800	-17500	-15000	-13800	-18000	-16800	-19100	-17900	-18166	-17000
SG 16	10900	10500	4175	3850	9300	8800	5900	5500	3875	3525
SG 17	-18200	-16900	-19300	-18100	-18400	-17200	-17100	-15900	-41250	-38500
SG 18	11200	10700	5300	4910	9800	9400	8450	8050	11100	10600
SG 19	-19200	-17900	-16500	-15400	-18700	-17500	-22166	-20833	-17000	-15700
SG 20	10700	10300	12400	11800	12600	12100	9400	9000	12400	11800
SG 21	-18400	-17200	-17200	-16000	-21333	-20166	-15000	-13800	-17000	-15700
SG 22	7450	7000	4975	4600	9900	9500	12900	12400	10900	10400
SG 23	-21000	-19666	-17700	-16500	-18000	-16700	-17500	-16300	-18000	-16700
SG 24	6950	6550	11600	11200	9300	8900	9800	9400	10600	10200

$\mu\epsilon$ = Microstrain.
PERM = Permanent.

TABLE 3-8. PLASTIC PEAK AND PERMANENT STRAIN ($\mu\epsilon$) FROM STATIC CRUSH TESTS
(CONTINUED)

GAGE DESIGNATION	TEST 1		TEST 2		TEST 3		TEST 4		TEST 5	
	PEAK	PERM	PEAK	PERM	PEAK	PERM	PEAK	PERM	PEAK	PERM
SG 25	-17000	-15800	-18600	-17300	-14200	-13000	-17400	-16200	-18333	-17166
SG 26	7000	6600	13000	12600	8400	8000	9100	8700	4700	4325
SG 27	-18700	-17300	-18900	-17700	-17100	-16000	-6800	-6350	-20833	-19600
SG 28	9300	8800	7500	7100	10500	10100	8750	8300	7150	6800
SG 29	-18800	-17600	-17800	-16600	-17800	-16600	-19500	-18300	-20333	-19000
SG 30	11400	11000	10000	9600	13500	13000	6750	6350	12167	11667
SG 31	-20000	-18600	-15250	-14125	-19900	-18700	-18800	-17600	-18000	-16833
SG 32	11200	10700	9700	9350	7050	6700	7250	6800	6400	6000
SG 33	-19375	-18125	-22000	-20666	-18000	-16833	-20333	-19166	-17100	-16000
SG 34	8100	7650	5200	4820	9650	9220	5000	4600	9600	9150
SG 35	-18400	-17200	-16500	-15300	-20833	-19666	-14100	-13000	-16200	-15000
SG 36	5550	5200	9800	9300	8500	8050	7200	6800	13000	12400
SG 37	-19500	-18200	-19875	-18750	-16600	-15500	-17700	-16500	-17400	-16200
SG 38	4900	4550	9100	8650	11200	10700	5850	5450	3600	3250
SG 39	-19400	-18000	-18000	-16800	-15900	-14700	-19100	-17600	-16700	-15500
SG 40	2383	2066	6200	5850	6900	6500	14000	13500	3100	2775
SG 41	-18700	-17500	-18400	-17200	-21833	-20500	-19900	-18700	-18666	-17500
SG 42	8600	8200	8750	8350	7200	6800	11000	10500	7200	6800
SG 43	-19333	-18000	-19500	-18000	-19333	-18000	-21000	-19833	-19666	-18500
SG 44	7900	7500	11600	11200	6100	5700	11600	11200	8200	7750
SG 45	-18600	-16800	-19200	-18000	-21000	-19833	-18500	-17166	-17000	-15800
SG 47	-20000	-18833	-20000	-18666	-17000	-15800	*	*	-18666	-17500
LOAD										
(lb)	154000		149000		144000		147000		150000	
DISPLACEMENT										
(in.)	0.5		0.5		0.5		0.5		0.5	

*No acquired data.

$\mu\epsilon$ = Microstrain.

PERM = Permanent.

TABLE 3-8. PLASTIC PEAK AND PERMANENT STRAIN ($\mu\epsilon$) FROM STATIC CRUSH TESTS
(CONTINUED)

GAGE DESIGNATION	TEST 6		TEST 7		TEST 8		TEST 9		TEST 10	
	PEAK	PERM	PEAK	PERM	PEAK	PERM	PEAK	PERM	PEAK	PERM
SG 1	-20125	-19000	-18333	-17000	-19000	-17667	-18333	-17167	-19000	-17667
SG 2	8700	8250	6700	6350	6900	6550	3575	3175	8050	7600
SG 3	-18400	-17300	-17400	-16200	-16800	-15600	-17000	-15800	-17800	-16500
SG 4	8650	8200	10200	9600	10700	10300	7600	7200	8150	7700
SG 5	-18500	-17000	-17100	-15900	-18100	-16800	-19600	-18400	-17800	-16500
SG 6	8000	7600	8400	7900	10300	9800	10400	10000	7950	7500
SG 7	-20100	-18900	-19666	-18333	-21333	-20000	-20000	-18833	-19300	-18000
SG 8	7800	7400	5400	4983	7050	6600	7050	6650	8350	7900
SG 9	-17400	-16200	-18000	-16900	-19500	-18200	-18000	-16833	-18600	-17300
SG 10	7600	7200	10000	9600	6450	6050	6800	6400	7700	7300
SG 11	-19500	-18300	-19666	-18500	-19100	-17800	-20500	-19333	-18100	-16800
SG 12	10900	10400	6100	5720	4825	4475	10400	10000	7750	7300
SG 13	-16800	-15600	-19333	-18166	-16800	-15600	-17100	-15800	-18667	-17500
SG 14	10700	10200	5900	5450	10200	9700	12100	11600	8350	7950
SG 15	-27000	-25333	-16750	-15500	-18600	-17400	-19400	-18200	-17500	-16300
SG 16	7100	6750	5900	5500	6650	6250	6650	6250	7800	7350
SG 17	-18375	-17125	-17375	-16250	-17200	-15900	-18100	-16800	-18200	-17000
SG 18	10600	10200	7500	7100	8700	8250	5500	5150	7850	7400
SG 19	-18900	-17700	-19400	-18100	-18800	-17600	-18400	-17100	-19300	-18000
SG 20	4800	4480	7350	6900	6000	5650	5200	4820	8500	8100
SG 21	-18100	-16900	-19333	-18000	-19500	-18333	-17400	-16100	-18200	-17000
SG 22	9300	8800	2316	2133	6700	6300	7700	7300	7850	7450
SG 23	-19833	-18666	-18333	-17166	-19833	-18666	-20167	-18833	-18667	-17333
SG 24	9600	9200	7200	6800	6500	6100	11100	10600	7750	7350

$\mu\epsilon$ = Microstrain.
PERM = Permanent.

TABLE 3-8. PLASTIC PEAK AND PERMANENT STRAIN ($\mu\epsilon$) FROM STATIC CRUSH TESTS
(CONCLUDED)

GAGE DESIGNATION	TEST 6		TEST 7		TEST 8		TEST 9		TEST 10	
	PEAK	PERM	PEAK	PERM	PEAK	PERM	PEAK	PERM	PEAK	PERM
SG 25	-19900	-18700	-16700	-15500	-19167	-18000	-16800	-15600	-19200	-18000
SG 26	13400	12800	14600	14000	10900	10400	11100	10600	8075	7650
SG 27	-19500	-18200	-17500	-16300	-18800	-17500	-17300	-16100	-18400	-17100
SG 28	5750	5350	15800	15400	8100	7700	6700	6320	8100	7700
SG 29	-18500	-17300	-18200	-17000	-18300	-17000	-19600	-18350	-17900	-16700
SG 30	8650	8300	8600	8200	9700	9200	5750	5350	7900	7450
SG 31	-24875	-23375	-18200	-17000	-17500	-16400	-17400	-16100	-19600	-18300
SG 32	6350	6050	8000	7500	8400	8000	9600	9100	8450	8000
SG 33	-20800	-19666	-21833	-20500	-17800	-16600	-19000	-17700	-18500	-17200
SG 34	5500	5150	7200	6800	9600	9100	4900	4520	7975	7550
SG 35	-18600	-17400	-18333	-17000	-29333	-27333	-20000	-18667	-18200	-17000
SG 36	5350	5000	6900	6500	6000	5600	7950	7550	8000	7600
SG 37	-19400	-18200	-19000	-17800	-18600	-17400	-16700	-15500	-19000	-17700
SG 38	3650	3300	4600	4300	4800	4450	9900	9500	8410	8000
SG 39	-18000	-16800	-18100	-16800	-18500	-17300	-17000	-15700	-18400	-17200
SG 40	6100	5750	4950	4600	4800	4400	7500	7100	8100	7650
SG 41	-17400	-16200	-17200	-16000	-18100	-16900	-18200	-17000	-17600	-16400
SG 42	8700	8200	11000	10500	11500	11000	12500	12000	8850	8400
SG 43	-18333	-17166	-17000	-15800	-16400	-15200	-19167	-17833	-19667	-18333
SG 44	9600	9100	5950	5600	9500	9000	10400	10000	8350	7900
SG 45	*	*	-7500	-6700	-18333	-17166	-17600	-16300	-18667	-17333
SG 47	*	*	-17000	-15800	-18200	-17000	-20167	-18833	-18600	-17300
LOAD (lb)	*		152000		153000		155000		159000	
DISPLACEMENT (in.)	*		0.5		0.5		0.5		0.5	

*No acquired data.

$\mu\epsilon$ = Microstrain.

PERM = Permanent.

TABLE 3-9. MEASURED AND CALCULATED PERMANENT STRAIN ($\mu\epsilon$) FROM STATIC CRUSH TESTS

GAGE DESIGNATION	TEST 1		TEST 2		TEST 3		TEST 4		TEST 5	
	MEAS	CALC	MEAS	CALC	MEAS	CALC	MEAS	CALC	MEAS	CALC
SG 1	-17200	-16745	-16700	-16586	-17666	-17766	-17333	-17395	-18333	-18482
SG 2	10800	10759	5100	5179	9000	9113	7100	7093	8000	8043
SG 3	-17600	-17196	-19666	-19662	-16200	-16361	-17300	-17421	-17166	-17236
SG 4	12400	12379	4800	4898	9625	9675	5250	5233	9200	9314
SG 5	-18500	-18046	-17000	-17077	-16400	-16506	-21333	-21346	-18625	-18641
SG 6	12100	12178	6180	6250	7350	7400	4620	4577	7050	7066
SG 7	-20625	-20084	-19000	-18902	-18100	-18184	-15300	-15285	-18625	-18593
SG 8	6850	6798	13500	13666	5950	5855	12667	12723	9800	9711
SG 9	-18200	-17762	-15200	-15144	-17900	-18114	-19833	-19831	-17750	-17720
SG 10	7150	7037	6500	6446	8900	8944	8300	8262	4500	4448
SG 11	-16700	-16298	-18200	-18072	-21333	-21309	-19166	-19071	-19000	-18917
SG 12	6700	6559	6125	6193	6600	6517	7800	7657	14500	14624
SG 13	-18000	-17580	-18666	-18575	-17000	-17037	-15800	-15910	-18000	-17925
SG 14	4300	4215	7650	7815	7200	7133	9300	9368	10600	10693
SG 15	-17500	-17183	-13800	-13842	-16800	-16944	-17900	-17912	-17000	-17010
SG 16	10500	10438	3850	3934	8800	8832	5500	5527	3525	3520
SG 17	-16900	-16599	-18100	-18084	-17200	-17382	-15900	-16042	-38500	-17753
SG 18	10700	10679	4910	5045	9400	9475	8050	8137	10600	10800
SG 19	-17900	-17340	-15400	-15186	-17500	-17551	-20833	-20718	-15700	-15735
SG 20	10300	10359	11800	12034	12100	12062	9000	8909	11800	11935
SG 21	-17200	-16678	-16000	-15848	-20166	-20042	-13800	-13835	-15700	-15721
SG 22	7000	6784	4600	4645	9500	9388	12400	12428	10400	10584
SG 23	-19666	-19184	-16500	-16341	-16700	-16904	-16300	-16312	-16700	-16707
SG 24	6550	6418	11200	11260	8900	8811	9400	9346	10200	10176

MEAS = Measured from data plots.

CALC = Calculated from strain gage resistance.

$\mu\epsilon$ = Microstrain.

TABLE 3-9. MEASURED AND CALCULATED PERMANENT STRAIN ($\mu\epsilon$) FROM STATIC CRUSH TESTS
(CONTINUED)

GAGE DESIGNATION	TEST 1		TEST 2		TEST 3		TEST 4		TEST 5	
	MEAS	CALC	MEAS	CALC	MEAS	CALC	MEAS	CALC	MEAS	CALC
SG 25	-15800	-15459	-17300	-17249	-13000	-13258	-16200	-16241	-17166	-17315
SG 26	6600	6638	12600	12874	8000	8016	8700	8752	4325	4336
SG 27	-17300	-17103	-17700	-17673	-16000	-16188	-6350	-17633	-19600	-19662
SG 28	8800	8792	7100	7280	10100	10171	8300	8351	6800	6762
SG 29	-17600	-17196	-16600	-16546	-16600	-16745	-18300	-18402	-19000	-19039
SG 30	11000	10907	9600	9783	13000	13128	6350	6276	11667	11763
SG 31	-18600	-18030	-14125	-13990	-18700	-18649	-17600	-17424	-16833	-16749
SG 32	10700	10654	9350	9374	6700	6418	6800	6784	6000	5925
SG 33	-18125	-17410	-20666	-20690	-16833	-16918	-19166	-18987	-16000	-15848
SG 34	7650	7516	4820	4856	9220	9106	4600	4546	9150	9036
SG 35	-17200	-16678	-15300	-15172	-19666	-19662	-13000	-13005	-15000	-14821
SG 36	5200	5053	9300	9416	8050	7966	6800	6756	12400	12470
SG 37	-18200	-17408	-18750	-18628	-15500	-15724	-16500	-16546	-16200	-16201
SG 38	4550	4537	8650	8779	10700	10866	5450	5420	3250	3158
SG 39	-18000	-17594	-16800	-16798	-14700	-14982	-17800	-17978	-15500	-15631
SG 40	2066	2048	5850	5928	6500	6490	13500	13770	2775	2703
SG 41	-17500	-17580	-17200	-17594	-20500	-21120	-18700	-19132	-17500	-17938
SG 42	8200	8163	8350	8498	6800	6785	10500	10666	6800	6825
SG 43	-18000	-17720	-18000	-17607	-18000	-17917	-19833	-19592	-18500	-18269
SG 44	7500	7516	11200	11288	5700	5503	11200	11217	7750	7741
SG 45	-16800	-16551	-18000	-17790	-19833	-19690	-17166	-17058	-15800	-15707
SG 47	-18833	-18410	-18666	-18311	-15800	-15707	*	-21816	-17500	-17227

*No acquired data.

MEAS = Measured from data plots.

CALC = Calculated from strain gage resistance.

$\mu\epsilon$ = Microstrain.

TABLE 3-9. MEASURED AND CALCULATED PERMANENT STRAIN ($\mu\epsilon$) FROM STATIC CRUSH TESTS
(CONTINUED)

GAGE DESIGNATION	TEST 6		TEST 7		TEST 8		TEST 9		TEST 10	
	MEAS	CALC	MEAS	CALC	MEAS	CALC	MEAS	CALC	MEAS	CALC
SG 1	-19000	-19065	-17000	-17024	-17667	-17594	-17167	-17010	-17667	-18021
SG 2	8250	8297	6350	6477	6550	6691	3175	3265	7600	7614
SG 3	-17300	-17302	-16200	-16255	-15600	-15684	-15800	-15830	-16500	-16800
SG 4	8200	8217	9600	9957	10300	10532	7200	7374	7700	7695
SG 5	-17000	-17355	-15900	-15897	-16800	-16798	-18400	-18363	-16500	-16746
SG 6	7600	7574	7900	8070	9800	10090	10000	10171	7500	7521
SG 7	-18900	-18916	-18333	-18353	-20000	-19859	-18833	-18607	-18000	-18030
SG 8	7400	7248	4983	4940	6600	6671	6650	6629	7900	7797
SG 9	-16200	-16270	-16900	-18156	-18200	-18001	-16833	-16678	-17300	-17340
SG 10	7200	7051	9600	9641	6050	6207	6400	6446	7300	7150
SG 11	-18300	-18072	-18500	-18410	-17800	-17650	-19333	-19043	-16800	-16791
SG 12	10400	10429	5720	5700	4475	4518	10000	10134	7300	7108
SG 13	-15600	-15645	-18166	-18137	-15600	-15525	-15800	-15830	-17500	-17699
SG 14	10200	10545	5450	5540	9700	9943	11600	11910	7950	7909
SG 15	-25333	-18668	-15500	-15499	-17400	-16944	-18200	-18124	-16300	-16598
SG 16	6750	8806	5500	5594	6250	6397	6250	6343	7350	7387
SG 17	-17125	-17222	-16250	-16400	-15900	-15830	-16800	-16851	-17000	-17350
SG 18	10200	10345	7100	7267	8250	8418	5150	5219	7400	7427
SG 19	-17700	-17607	-18100	-17861	-17600	-17312	-17100	-17143	-18000	-17889
SG 20	4480	4279	6900	6897	5650	5574	4820	4799	8100	7952
SG 21	-16900	-16904	-18000	-17875	-18333	-18015	-16100	-16003	-17000	-16538
SG 22	8800	8852	2133	4236	6300	6362	7300	7347	7450	7332
SG 23	-18666	-18522	-17166	-17044	-18666	-18395	-18833	-18677	-17333	-18649
SG 24	9200	9162	6800	6826	6100	5771	10600	10739	7350	6685

MEAS = Measured from data plots.

CALC = Calculated from strain gage resistance.

$\mu\epsilon$ = Microstrain.

TABLE 3-9. MEASURED AND CALCULATED PERMANENT STRAIN ($\mu\epsilon$) FROM STATIC CRUSH TESTS
(CONCLUDED)

GAGE DESIGNATION	TEST 6		TEST 7		TEST 8		TEST 9		TEST 10	
	MEAS	CALC	MEAS	CALC	MEAS	CALC	MEAS	CALC	MEAS	CALC
SG 25	-18700	-18721	-15500	-15472	-18000	-17885	-15600	-15525	-18000	-17368
SG 26	12800	13155	14000	14413	10400	10692	10600	10773	7650	7829
SG 27	-18200	-18376	-16300	-16626	-17500	-17448	-16100	-16056	-17100	-17143
SG 28	5350	5380	15400	15791	7700	7882	6320	6450	7700	8123
SG 29	-17300	-17514	-17000	-16851	-17000	-16957	-18350	-18217	-16700	-17659
SG 30	8300	11348	8200	8310	9200	9408	5350	5420	7450	6852
SG 31	-23375	-17692	-17000	-16763	-16400	-16228	-16100	-15989	-18300	-18213
SG 32	6050	8318	7500	7291	8000	7980	9100	9219	8000	7896
SG 33	-19666	-19353	-20500	-20338	-16600	-16383	-17700	-17495	-17200	-17115
SG 34	5150	5024	6800	6798	9100	9233	4520	4532	7550	7305
SG 35	-17400	-17340	-17000	-16861	-27333	-18006	-18667	-18508	-17000	-16890
SG 36	5000	4842	6500	6488	5600	5574	7550	7586	7600	7403
SG 37	-18200	-18416	-17800	-17514	-17400	-16122	-15500	-15433	-17700	-18021
SG 38	3300	3265	4300	4309	4450	4510	9500	9609	8000	8003
SG 39	-16800	-16971	-16800	-16838	-17300	-17236	-15700	-15645	-17200	-17404
SG 40	5750	5701	4600	4644	4400	4496	7100	7307	7650	7708
SG 41	-16200	-16772	-16000	-16347	-16900	-17143	-17000	-17421	-16400	-17055
SG 42	8200	7829	10500	10679	11000	11188	12000	12285	8400	8431
SG 43	-17166	-16791	-15800	-15637	-15200	-15032	-17833	-17607	-18333	-18184
SG 44	9100	9064	5600	5503	9000	9134	10000	10063	7900	7769
SG 45	*	-17762	-6700	-6460	-17166	-16875	-16300	-16186	-17333	-17270
SG 47	*	-14046	-15800	-15581	-17000	-16707	-18833	-18367	-17300	-17157

*No acquired data.

MEAS = Measured from data plots.

CALC = Calculated from strain gage resistance.

$\mu\epsilon$ = Microstrain.

Figure 3-14. Plastic Axial Strain Distribution From Static Crush Tests

Figure 3-15. Plastic Hoop Strain Distribution From Static Crush Tests

readings either because the gage was defective or because the bond between the gage and the specimen was incomplete.

In general, the BLH gages showed a higher instance of required reinstallation due to questionable bonding. A total of 21 BLH gages were replaced on the ten test specimens.

3.4 End-Impact Tests

The two types of instrumentation results from the end-impact tests were acceleration-time histories and strain-time histories. Figure 3-16 shows a typical plot of filtered accelerometer data with a cutoff frequency of 10,000 Hz. The filter used for this data was a digital Butterworth filter (Stearns, 1988). Figure 3-17 shows a plot of this same data filtered at 1,000 Hz, which was below the lowest natural frequency (approximately 2,400 Hz) of the test specimen and thus represented the rigid-body acceleration. Table 3-10 gives the values for peak accelerations from the 10,000-Hz plot and the 1,000-Hz plot for each accelerometer for all ten tests. Variations in amplitude between the 10,000-Hz filtered data and the 1,000-Hz filtered data were the result of removing the vibratory response of the test article from the higher filtered frequency. Table 3-2 gives the calibration information for the accelerometers.

A typical strain-time history for an axial strain gage located at 1 in. from the bottom of the specimen is shown in Figure 3-18. A permanent strain offset due to plastic deformation was measured. Table 3-11 gives the values of peak and permanent strain for all of the gages for the ten tests, and Table 3-12 compares the permanent strain values obtained from the data to those calculated by the change in resistance of the strain gage. For strain gages 1 and 2, the large difference between measured and calculated permanent strains for some of the tests was because the measured strains only included primary impact and the calculated strains included the effect of secondary impact, which produced additional permanent deformation in some of the test articles.

For these tests it was more difficult to make comparisons between transducers on the same test specimen because the specimen's impact on the unyielding target was not perfectly flat. This caused the strains and accelerations on the initial impacting side to be higher than those on the side away from initial impact. This behavior was also seen in the dimensional inspection permanent axial deformations. Figure 3-19 illustrates the average distribution of permanent axial strains at 1 in. from the impacting end, the permanent deformations, the peak 10,000-Hz accelerations, and the peak 1,000-Hz accelerations around the test specimen. Figure 3-19 shows that the maximum accelerations corresponded to the maximum strains and maximum permanent deformations. For most of the tests, the initial impact occurred at approximately 150 degrees, which was near accelerometer A6 and between strain gages 6 and 11 at 1 in., strain gages 8 and 13 at 3 in., and strain gages 10 and 15 at 6 in. (See the dimensional inspection data in Appendix C.) For the accelerations the effect of the angled impact was less pronounced for the 1,000-Hz filtered data because these data were more representative of the rigid body motion of the test article. For the strain gages the

Figure 3-16. Typical Accelerometer Filtered at 10,000 Hz From End-Impact Tests

Figure 3-17. Typical Accelerometer Filtered at 1,000 Hz From End-Impact Tests

TABLE 3-10. ACCELEROMETER DATA (g) FROM END-IMPACT TESTS

TEST NO.	SET	FILTER CUTOFF FREQ.	GAGE DESIGNATION						
			A1	A2	A3	A4	A5	A6	A7
1	1	1K 10K	1900 2350	3030 3800	2700 4000	2425 3050	2725 3800	2625 4250	2700 3200
2	2	1K 10K	1875 2750	2725 3250	2775 3050	2725 3800	2500 3400	3300 6600	2550 3800
3	3	1K 10K	2000 2550	2550 4050	1125 4050	2600 3400	2750 3650	2550 4400	2375 3700
4	1	1K 10K	1450 1950	2650 3500	2675 3550	2625 3400	2775 3600	2650 3650	2350 3600
5	2	1K 10K	1675 2000	2700 4200	2700 4550	2675 3700	2725 3700	2600 4800	2800 3700
6	3	1K 10K	1325 1650	2350 3050	2500 3100	2425 3000	2400 2950	2550 3150	2800 3500
7	1	1K 10K	2025 2400	2525 3725	2550 3800	2550 3200	2675 3550	2575 3900	2500 3050
8	2	1K 10K	2025 2300	2500 3300	2575 3875	2525 3000	2350 2950	2475 3750	2350 2950
9	3	1K 10K	1900 2250	2400 3400	2425 4100	2450 3150	2600 3500	2425 4100	2375 3000
10	2	1K 10K	2025 2550	2475 3350	2475 3600	2550 3500	2600 3550	2375 3400	2600 3550

Figure 3-18. Typical Strain-Time History for an Axial Gage From End-Impact Tests. The axial gage was located 1 in. from the impact end.

effect of the off-angle impact was less pronounced for the gages higher on the specimen. This is predicted by the Saint-Venant principle that states, "For bodies extended in two or three dimensions, such as disks, spheres, or the semi-infinite solid, the stress or strain due to loading on a small part of the body may be expected to diminish with distance due to 'geometrical divergence', whether or not the resultant is zero" (Timoshenko, 1970).

This result can also be observed by comparing the magnitude of the permanent strains from the strain gages at different locations. A larger range was present in the strains at 1 in. from the impact end than at 6 in. from the end. Figure 3-20 shows a representative multiplot of the strain histories for axial gages located at 1 in. from the impact end. Figure 3-21 shows a similar plot for the gages at 6 in. from the end for Test 1. Maximum strains were measured at locations nearest to the impact. Multiplots for all tests are included in Appendix D.

TABLE 3-11. PLASTIC PEAK AND PERMANENT STRAIN ($\mu\epsilon$) FROM END-IMPACT TESTS

GAGE DESIGNATION	TEST 1		TEST 2		TEST 3		TEST 4		TEST 5	
	PEAK	PERM	PEAK	PERM	PEAK	PERM	PEAK	PERM	PEAK	PERM
SG 1	-2600	-2125	-970	-500	-3700	-3125	-5850	-5200	-2383	-1933
SG 2	1267	1088	810	660	1817	1633	2925	2700	1550	1383
SG 3	-6600	6300	-7500	-6600	-7050	-6200	-7850	-7000	-6850	-6000
SG 4	3450	3100	4425	3975	4175	3850	4350	3950	5400	5000
SG 5	-7250	-6300	-7200	-6250	-8150	-7200	-9800	-8700	-7600	-6650
SG 6	-21000	-19833	-18700	-17600	-24333	-23000	-20167	-19000	-16600	-15500
SG 7	8200	7750	3900	3600	4850	4550	4750	4425	7800	7450
SG 8	-15833	-14700	-15600	-14400	-15600	-14500	-14400	-13200	-14700	-13400
SG 9	10600	10100	7750	7300	7150	6750	7850	7350	8850	8450
SG 10	-13600	-12400	-14900	-13700	-14400	-13200	-17000	-15800	-11900	-10800
SG 11	-15400	-14200	-16000	-14800	-17200	-16000	-12300	-11300	-17500	-16400
SG 12	767	467	7550	7250	3600	3300	5150	4800	3500	3250
SG 13	-12400	-11300	-12400	-11200	-14000	-12700	-10700	-9600	-14000	-12700
SG 14	4700	4250	5950	5400	8250	7650	11500	10900	6750	6250
SG 15	-12667	-11500	-12500	-11200	-14600	-13300	-13100	-12000	-12600	-11400
SG 16	-14583	-13500	-15800	-14600	-13800	-12700	-13300	-12300	-17300	-16100
SG 17	5050	4775	5650	5300	5000	4700	6100	5800	5050	4750
SG 18	-13333	-12250	-11300	-10200	-12100	-11000	-13200	-12000	-13400	-12200
SG 19	6750	6300	3175	2850	4200	3850	7600	7150	5050	4700
SG 20	-10100	-9100	-8700	-7700	-9900	-8800	-11000	-10000	-11400	-10200

$\mu\epsilon$ = Microstrain.
PERM = Permanent.

TABLE 3-11. PLASTIC PEAK AND PERMANENT STRAIN ($\mu\epsilon$) FROM END-IMPACT TESTS
(CONCLUDED)

GAGE DESIGNATION	TEST 6		TEST 7		TEST 8		TEST 9		TEST 10	
	PEAK	PERM	PEAK	PERM	PEAK	PERM	PEAK	PERM	PEAK	PERM
SG 1	-1866	-1417	-6900	-6150	-255	-45	-460	-205	570	10
SG 2	670	510	3175	2975	260	150	465	335	290	140
SG 3	-5500	-4700	-7950	-7000	-5150	-4400	-4900	-4100	-4100	-3350
SG 4	2233	1867	1783	1550	3975	3575	3875	3500	2775	2375
SG 5	-7000	-6050	-7600	-6650	-5150	-4900	-6850	-5950	-4700	-3800
SG 6	-12600	-11500	-27500	-26250	-16400	-15200	-16700	-15500	-12100	-10900
SG 7	1850	1583	6000	5650	5500	5100	7050	6700	3700	3275
SG 8	-17600	-16400	-15600	-14400	-14300	-13100	-15700	-14500	-14400	-13200
SG 9	5150	7800	7600	7200	7000	6600	4475	4150	5250	4900
SG 10	-17300	-16100	-12200	-11100	-12000	-10800	-14000	-12900	-10700	-9700
SG 11	-22333	-21167	-17500	-16300	-21167	-20000	-22667	-21500	-15200	-14100
SG 12	10900	10600	350	165	2400	2100	6150	5800	4250	3900
SG 13	-16200	-14800	-12000	-10800	-15000	-13600	-16700	-15300	-18300	-16800
SG 14	7550	6950	9700	9150	8900	8200	10600	10000	6250	5650
SG 15	-17100	-15800	-12700	-11500	-16000	-14700	-15900	-14600	-15200	-13900
SG 16	-14700	-13600	-11500	-10500	-17400	-16200	-16900	-15700	-22833	-21500
SG 17	5650	5250	2067	1783	6400	6000	5350	5050	5250	4850
SG 18	-9100	-8100	-13300	-12100	-13600	-12500	-14300	-13100	-16900	-15600
SG 19	3800	3475	3275	2900	5550	5150	5000	4650	11500	11100
SG 20	-7750	-6800	-9700	-8700	10200	-9100	-11400	-10300	-12700	-11600

$\mu\epsilon$ = Microstrain.
PERM = Permanent.

TABLE 3-12. PERMANENT MEASURED VERSUS CALCULATED STRAIN ($\mu\epsilon$) FROM END-IMPACT TESTS

GAGE DESIGNATION	TEST 1		TEST 2		TEST 3		TEST 4		TEST 5	
	MEAS.	CALC.	MEAS.	CALC.	MEAS.	CALC.	MEAS.	CALC.	MEAS.	CALC.
SG 1	-2125	-10500	-500	-740	-3125	-10180	-5200	-4690	-1933	-4190
SG 2	1088	1870	660	340	1633	3080	2700	3330	1383	2110
SG 3	-6300	-6140	-6600	-6690	-6200	-6310	-7000	-6240	-6000	-6100
SG 4	3100	3100	3975	4190	3850	3890	3950	4870	5000	5120
SG 5	-6300	-6340	-6250	-6350	-7200	-7270	-8700	-8050	-6650	-6700
SG 6	-19833	-19590	-17600	-17420	-23000	-22770	-19000	-17960	-15500	-15430
SG 7	7750	7770	3600	3500	4550	4500	4425	5170	7450	7470
SG 8	-14700	-14490	-14400	-14280	-14500	-14380	-13200	-12330	-13400	-13360
SG 9	10100	9960	7300	7350	6750	6770	7350	8150	8450	8440
SG 10	-12400	-12290	-13700	-13660	-13200	-13290	-15800	-14880	-10800	-10770
SG 11	-14200	-14290	-14800	-14820	-16000	-16190	-11300	-10740	-16400	-16470
SG 12	467	450	7250	7400	3300	3370	4800	5660	3250	3270
SG 13	-11300	-11370	-11200	-11200	-12700	-12830	-9600	-8980	-12700	-12750
SG 14	4250	4270	5400	5520	7650	7770	10900	11830	6250	6330
SG 15	-11500	-11560	-11200	-11310	-13300	-13360	-12000	-11350	-11400	-11520
SG 16	-13500	-13330	-14600	-14560	-12700	-12620	-12300	-11460	-16100	-15920
SG 17	4775	4770	5300	5330	4700	4660	5800	6600	4750	4700
SG 18	-12250	-12240	-10200	-10220	-11000	-11000	-12000	-11150	-12200	-12200
SG 19	6300	6290	2850	2880	3850	3840	7150	7990	4700	4700
SG 20	-9100	-8820	-7700	-7760	-8800	-8780	-10000	-9060	-10200	-10290

MEAS = Measured from data plots.

CALC = Calculated from strain gage resistance.

$\mu\epsilon$ = Microstrain.

TABLE 3-12. PERMANENT MEASURED VERSUS CALCULATED STRAIN ($\mu\epsilon$) FROM END-IMPACT TESTS
(CONCLUDED)

GAGE DESIGNATION	TEST 6		TEST 7		TEST 8		TEST 9		TEST 10	
	MEAS.	CALC.	MEAS.	CALC.	MEAS.	CALC.	MEAS.	CALC.	MEAS.	CALC.
SG 1	-1417	-1450	-6150	-6310	-45	-4450	-205	-11830	10	-8540
SG 2	510	410	2975	3040	150	-330	335	1280	140	2290
SG 3	-4700	-4800	-7000	-7210	-4400	-4380	-4100	-4120	-3350	-3310
SG 4	1867	1960	1550	1570	3575	3590	3500	3530	2375	2380
SG 5	-6050	-6110	-6650	-6830	-4900	-5010	-5950	-6020	-3800	-3820
SG 6	-11500	-11550	-26250	-25940	-15200	-15130	-15500	-15440	-10900	-10480
SG 7	1583	1460	5650	5590	5100	5020	6700	6590	3275	3000
SG 8	-16400	-16370	-14400	-14380	-13100	-12980	-14500	-14400	-13200	-12410
SG 9	7800	7870	7200	7130	6600	6540	4150	4100	4900	4610
SG 10	-16100	-15211	-11100	-10970	-10800	-10080	-12900	-12780	-9700	-9610
SG 11	-21167	-23490	-16300	-16400	-20000	-20020	-21500	-21450	-14100	-14250
SG 12	10600	10670	165	150	2100	2140	5800	5890	3900	3970
SG 13	-14800	-14770	-10800	-10910	-13600	-13700	-15300	-15350	-16800	-16890
SG 14	6950	7080	9150	9210	8200	8310	12300	10090	5650	5780
SG 15	-15800	-15900	-11500	-12400	-14700	-14670	-14600	-14710	-13900	-13910
SG 16	-13600	-16020	-10500	-10870	-16200	-15970	-15700	-16650	-21500	-20040
SG 17	5250	5020	1783	1750	6000	5940	5050	5020	4850	4510
SG 18	-8100	-8260	-12100	-12100	-12500	-12510	-13100	-13000	-15600	-14600
SG 19	3475	3590	2900	2870	5150	5120	4650	4550	11100	11230
SG 20	-6800	-6850	-8700	-8660	-9100	-9100	-10300	-10230	-11600	-11470

MEAS = Measured from data plots.

CALC = Calculated from strain gage resistance.

$\mu\epsilon$ = Microstrain.

Figure 3-19. End-Impact Test Distribution of Permanent Axial Deformations

Figure 3-20. End-Impact Test Multiplot of Strain Histories for Axial Gages SG 1, SG 6, SG 11, and SG 16 Located at 1 in. From the Impact End

Figure 3-21. End-Impact Test Multiplot of Strain Histories for Axial Gages SG 5, SG 10, SG 15, and SG 20 Located at 6 in. From the Impact End

Except for the slight change in magnitude from the off-axis impact, the output of the Endevco accelerometers for each test was very consistent. Figure 3-22 shows a multiplot of the 10,000-Hz filtered time histories for these four accelerometers from Test 8. All of the signals were in very close agreement. For all of the tests the magnitude of the signal for accelerometer A1, which was not always the same transducer, was lower than expected. This result was likely due to a problem not associated with the accelerometer, such as cabling or data acquisition. Figure 3-23 shows a multiplot of the time histories for the B&K accelerometers for Test 8. Comparison of Figures 3-22 and 3-23 shows that the transducers had very similar output other than the sign difference caused by an inversion of the signal for the piezoelectric accelerometers in the charge amplifiers. In general, both types of accelerometers gave good results during the initial impact pulse. However, the B&Ks had more nonrepresentative large amplitude signals later in the time history, such as the pulse shown for accelerometer A6 at approximately 2 ms in Figure 3-23. Multiplots of the accelerometer outputs filtered at 10,000 Hz for all the tests are included in Appendix E.

An important purpose of the drop test was to determine the ruggedness of the accelerometers. During the drop test sequence, only three accelerometers failed: A7 from Set 1 failed shock calibration following Test 7, A2 from Set 2 failed frequency calibration at -20°F following Test 10, and A3 from Set 3 failed centrifuge calibration following Test 3. Also, A2 from Set 2 failed frequency calibration at -20°F following the shock impulse tests. This was a different accelerometer than the one that failed after Test 10. The loading history for a typical piezoresistive accelerometer that survived to the end of the test series was the following:

- manufacturer shock calibration at 1,000, 5,000, and 10,000 g;
- manufacturer frequency calibration;
- SNL calibration, consisting of centrifuge calibration, shock calibration using five shock pulses, frequency calibration at ambient temperature, and frequency calibration at -20°F;
- three 1,000-g shock impulse tests;
- three 5,000-g shock impulse tests;
- three 10,000-g shock impulse tests; and
- three sequences of a drop test and SNL calibration without the -20°F frequency calibration.

The total history of a typical piezoresistive accelerometer that survived to the end of the test series was 40 shocks above 1000 g, eight frequency calibrations, and five centrifuge calibrations. The loading history for the piezoelectric accelerometers was similar, except that the centrifuge calibrations were not performed.

Figure 3-22. End-Impact Test Multiplot of 10,000-Hz Filtered Time Histories for Accelerometers A1, A2, A3, and A4

Figure 3-23. End-Impact Test Multiplot of 10,000-Hz Filtered Time Histories for B&K Accelerometers A5, A6, and A7

4.0 CONCLUSIONS

The results of this test program showed no major difference in the measurements obtained by transducers manufactured by different companies. One minor difference was the slower pulse decay for the B&K 8309 accelerometers, which did not significantly affect the initial filtered or unfiltered peak accelerations in the end-impact tests. The area where this difference was most pronounced was in integrating the accelerations to obtain change in velocity. In general, the method of integrating accelerations to obtain change in velocity is frequently performed to validate accelerometer data. The slower pulse decay can also affect tests where multiple shocks are separated by only a few milliseconds, such as in slapdown cask tests or during secondary impact of the cask. Another minor difference in transducers was that the lead wires for the B&K accelerometers required more care in handling than those of the Endevco accelerometers.

The strain gage data indicates that the BLH strain gages measured higher average strain, which was closer to the value determined from dimensional inspection. Also, the BLH strain gages measured larger deviation between readings than the Micro-Measurement gages. It is uncertain if the difference was due to differences in the gages or the result of the testing. The BLH gages had a higher instance of required reapplication than the Micro-Measurement gages when following the instructions provided by the manufacturer.

The purpose of this project was to compare the results from different types of transducers. For the comparison to be significant, a large number of tests with several transducers were conducted. This allowed for the examination of scatter in test data, which is seldom available in test programs. Several conclusions may be drawn from the data. The most important of these is that a high confidence should not be placed in a single transducer to give reliable results. This emphasizes the importance of having redundant instrumentation in test programs. In addition, problems with the instrumentation or connections to or within the data acquisition system can make the results questionable. Errors within the data acquisition system can be reduced or identified if the system has methods capable of isolating problems, such as diagnostics. Another important conclusion drawn from these studies is that the choice of a transducer must be appropriate for the application, e.g., acceleration range or strain range.

The standard deviation of the peak accelerations for the normalized shock impulse tests was 3.4% of the average value. For the static crush plastic tests, the standard deviation of the axial strains was approximately 8% of the average value. For the end-impact tests, the 1,000-Hz filtered peak accelerations had a standard deviation of 15% of their average value, and the 10,000-Hz filtered peak acceleration data had a standard deviation of 21% of the average. Table 4-1 summarizes these results. The results showed that test data were not, in general, more accurate than $\pm 10\%$ of the measured result. It is very likely that the majority of these deviations are due to changes in the quantities

being measured, rather than transducer response. This is because the transducers only measure the response at the location where they are attached, which may not be the same as the response at a nearby location.

TABLE 4-1. STANDARD DEVIATIONS FOR THE NORMALIZED SHOCK IMPULSE TESTS, STATIC CRUSH PLASTIC TESTS, AND END-IMPACT TESTS

<u>Test Sequence</u>	<u>Measure</u>	<u>Mean</u>	<u>σ</u>	<u>%</u>
Shock Impulse	Normalized MFA Acceleration	1.01	0.034	3.40
Static Crush	Permanent Axial Deformation	17,354 $\mu\epsilon$	1,379 $\mu\epsilon$	7.95
End Impact	Peak 1,000 Hz Filtered Acceleration	2,454 g	360 g	14.7
End Impact	Peak 10,000 Hz Filtered Acceleration	3,426 g	716 g	20.9

5.0 REFERENCES

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APPENDIX A
TRANSDUCER SURVEY

SURVEY PARTICIPANTS

GENERAL ATOMICS
NUCLEAR ASSURANCE CORPORATION
WESTINGHOUSE
BABCOCK AND WILCOX
NUCLEAR PACKAGING
WYLIE LABORATORIES
FRANKLIN RESEARCH CENTER
OAK RIDGE NATIONAL LABORATORIES
SANDIA NATIONAL LABORATORIES

TRANSDUCER EVALUATION SURVEY

In order to conduct a comprehensive evaluation, several private industry test companies and national laboratories have been surveyed to provide transducer recommendations. The chart at the bottom of this page lists transducers currently included in the evaluation. Would you please circle the Y at the right of any transducer you plan to use. If you plan to use transducers not included on the list, please supply manufacturer and model numbers on the blank lines. Thank you.

<u>Transducer Type</u>	<u>Manufacturer</u>	<u>Model</u>	<u>Yes</u>
Strain Gage	BLH Electronics	FAE/FAET 350 Ohm	Y
Strain Gage	Measurements Group, Micro Measurements Div.	CEA UW/UT 350 Ohm	Y
_____	_____	_____	_____
_____	_____	_____	_____
Accelerometer	Bruel & Kjaer	8309 series	
Accelerometer	Evdevco	7270A series	
_____	_____	_____	_____
_____	_____	_____	_____

APPENDIX B

STATIC TEST DIMENSIONAL INSPECTION DATA

**CYLINDER
DIMENSIONAL INSPECTION DATA**

STATIC CRUSH, TEST 1

<u>MEASUREMENT DESIGNATION</u>	<u>PRE-TEST</u>	<u>POST-TEST</u>	<u>MEASUREMENT CHANGE</u>
L1-36	2.709	2.729	0.020
L1-81	2.710	2.727	0.017
L1-126	2.710	2.724	0.014
L1-171	2.711	2.726	0.015
L1-216	2.711	2.730	0.019
L1-261	2.711	2.731	0.020
L1-306	2.710	2.727	0.017
L1-351	2.710	2.727	0.017
L2-36	2.709	2.734	0.025
L2-81	2.710	2.733	0.023
L2-126	2.710	2.731	0.021
L2-171	2.711	2.734	0.023
L2-216	2.711	2.736	0.025
L2-261	2.710	2.738	0.028
L2-306	2.710	2.736	0.026
L2-351	2.710	2.735	0.025
L3-36	2.709	2.733	0.024
L3-81	2.710	2.732	0.022
L3-126	2.710	2.731	0.021
L3-171	2.711	2.733	0.022
L3-216	2.711	2.736	0.025
L3-261	2.710	2.738	0.028
L3-306	2.710	2.736	0.026
L3-351	2.710	2.735	0.025
L4-36	2.710	2.732	0.022
L4-81	2.710	2.731	0.021
L4-126	2.710	2.731	0.021
L4-171	2.711	2.733	0.022
L4-216	2.710	2.735	0.025
L4-261	2.709	2.736	0.027
L4-306	2.710	2.736	0.026
L4-351	2.710	2.735	0.025
L5-36	2.710	2.732	0.022
L5-81	2.710	2.730	0.020
L5-126	2.710	2.731	0.021
L5-171	2.711	2.733	0.022
L5-216	2.710	2.735	0.025
L5-261	2.710	2.736	0.026
L5-306	2.710	2.735	0.025
L5-351	2.710	2.734	0.024
L6-36	2.710	2.733	0.023
L6-81	2.710	2.730	0.020
L6-126	2.710	2.731	0.021
L6-171	2.710	2.733	0.023

**CYLINDER
DIMENSIONAL INSPECTION DATA**

STATIC CRUSH, TEST 1

<u>MEASUREMENT DESIGNATION</u>	<u>PRE-TEST</u>	<u>POST-TEST</u>	<u>MEASUREMENT CHANGE</u>
L6-216	2.710	2.735	0.025
L6-261	2.710	2.735	0.025
L6-306	2.710	2.735	0.025
L6-351	2.710	2.733	0.023
L7-36	2.710	2.732	0.022
L7-81	2.710	2.729	0.019
L7-126	2.710	2.732	0.022
L7-171	2.711	2.734	0.023
L7-216	2.710	2.735	0.025
L7-261	2.710	2.735	0.025
L7-306	2.710	2.734	0.024
L7-351	2.710	2.733	0.023
L8-36	2.710	2.732	0.022
L8-81	2.710	2.731	0.021
L8-126	2.710	2.732	0.022
L8-171	2.711	2.734	0.023
L8-216	2.710	2.735	0.025
L8-261	2.710	2.735	0.025
L8-306	2.710	2.735	0.025
L8-351	2.710	2.733	0.023
L9-36	2.710	2.733	0.023
L9-81	2.710	2.731	0.021
L9-126	2.710	2.732	0.022
L9-171	2.711	2.734	0.023
L9-216	2.710	2.735	0.025
L9-261	2.709	2.735	0.026
L9-306	2.710	2.735	0.025
L9-351	2.710	2.733	0.023
L10-36	2.710	2.733	0.023
L10-81	2.710	2.733	0.023
L10-126	2.710	2.733	0.023
L10-171	2.710	2.734	0.024
L10-216	2.710	2.734	0.024
L10-261	2.710	2.734	0.024
L10-306	2.710	2.735	0.025
L10-351	2.710	2.733	0.023
L11-36	2.710	2.734	0.024
L11-81	2.710	2.734	0.024
L11-126	2.710	2.733	0.023
L11-171	2.711	2.734	0.023
L11-216	2.709	2.733	0.024
L11-261	2.709	2.735	0.026
L11-306	2.710	2.735	0.025
L11-351	2.710	2.734	0.024

**CYLINDER
DIMENSIONAL INSPECTION DATA**

STATIC CRUSH, TEST 1

<u>MEASUREMENT DESIGNATION</u>	<u>PRE-TEST</u>	<u>POST-TEST</u>	<u>MEASUREMENT CHANGE</u>
L12-36	2.710	2.732	0.022
L12-81	2.710	2.733	0.023
L12-126	2.710	2.732	0.022
L12-171	2.710	2.733	0.023
L12-216	2.709	2.731	0.022
L12-261	2.709	2.735	0.026
L12-306	2.710	2.735	0.025
L12-351	2.710	2.734	0.024
L13-36	2.710	2.724	0.014
L13-81	2.710	2.723	0.013
L13-126	2.710	2.723	0.013
L13-171	2.710	2.726	0.016
L13-216	2.709	2.723	0.014
L13-261	2.709	2.725	0.016
L13-306	2.709	2.728	0.019
L13-351	2.710	2.726	0.016
L14-36	24.010	23.569	-0.441
L14-81	24.010	23.567	-0.443
L14-126	24.012	23.567	-0.445
L14-171	24.014	23.567	-0.447
L14-216	24.015	23.568	-0.447
L14-261	24.015	23.569	-0.446
L14-306	24.013	23.570	-0.443
L14-351	24.013	23.570	-0.443

**CYLINDER
DIMENSIONAL INSPECTION DATA**

STATIC CRUSH, TEST 2

<u>MEASUREMENT DESIGNATION</u>	<u>PRE-TEST</u>	<u>POST-TEST</u>	<u>MEASUREMENT CHANGE</u>
L1-36	2.705	2.726	0.021
L1-81	2.710	2.731	0.021
L1-126	2.713	2.735	0.022
L1-171	2.713	2.732	0.019
L1-216	2.710	2.725	0.015
L1-261	2.705	2.721	0.016
L1-306	2.702	2.721	0.019
L1-351	2.702	2.725	0.023
L2-36	2.705	2.734	0.029
L2-81	2.710	2.739	0.029
L2-126	2.713	2.742	0.029
L2-171	2.713	2.738	0.025
L2-216	2.710	2.732	0.022
L2-261	2.705	2.730	0.025
L2-306	2.703	2.728	0.025
L2-351	2.703	2.731	0.028
L3-36	2.706	2.735	0.029
L3-81	2.710	2.740	0.030
L3-126	2.712	2.740	0.028
L3-171	2.712	2.738	0.026
L3-216	2.710	2.734	0.024
L3-261	2.706	2.730	0.024
L3-306	2.703	2.729	0.026
L3-351	2.703	2.732	0.029
L4-36	2.706	2.735	0.029
L4-81	2.710	2.739	0.029
L4-126	2.712	2.739	0.027
L4-171	2.711	2.737	0.026
L4-216	2.710	2.733	0.023
L4-261	2.706	2.731	0.025
L4-306	2.704	2.728	0.024
L4-351	2.704	2.730	0.026
L5-36	2.707	2.735	0.028
L5-81	2.710	2.738	0.028
L5-126	2.711	2.738	0.027
L5-171	2.711	2.736	0.025
L5-216	2.709	2.733	0.024
L5-261	2.706	2.730	0.024
L5-306	2.705	2.729	0.024
L5-351	*	2.730	*
L6-36	2.707	2.734	0.027
L6-81	2.710	2.735	0.025
L6-126	2.711	2.738	0.027
L6-171	2.710	2.734	0.024

*No data.

**CYLINDER
DIMENSIONAL INSPECTION DATA**

STATIC CRUSH, TEST 2

<u>MEASUREMENT DESIGNATION</u>	<u>PRE-TEST</u>	<u>POST-TEST</u>	<u>MEASUREMENT CHANGE</u>
L6-216	2.709	2.731	0.022
L6-261	2.706	2.730	0.024
L6-306	2.705	2.729	0.024
L6-351	2.706	2.730	0.024
L7-36	2.707	2.733	0.026
L7-81	2.709	2.735	0.026
L7-126	2.710	2.737	0.027
L7-171	2.710	2.734	0.024
L7-216	2.709	2.731	0.022
L7-261	2.707	2.729	0.022
L7-306	2.706	2.729	0.023
L7-351	2.706	2.731	0.025
L8-36	2.708	2.733	0.025
L8-81	2.709	2.734	0.025
L8-126	2.710	2.735	0.025
L8-171	2.710	2.734	0.024
L8-216	2.709	2.731	0.022
L8-261	2.707	2.729	0.022
L8-306	2.706	2.728	0.022
L8-351	2.707	2.731	0.024
L9-36	2.708	2.732	0.024
L9-81	2.709	2.733	0.024
L9-126	2.709	2.735	0.026
L9-171	2.709	2.733	0.024
L9-216	2.709	2.731	0.022
L9-261	2.708	2.729	0.021
L9-306	2.707	2.730	0.023
L9-351	2.707	2.731	0.024
L10-36	2.709	2.733	0.024
L10-81	2.709	2.734	0.025
L10-126	2.709	2.734	0.025
L10-171	2.709	2.733	0.024
L10-216	2.708	2.731	0.023
L10-261	2.708	2.731	0.023
L10-306	2.708	2.731	0.023
L10-351	2.708	2.731	0.023
L11-36	2.709	2.734	0.025
L11-81	2.709	2.735	0.026
L11-126	2.708	2.734	0.026
L11-171	2.708	2.733	0.025
L11-216	2.708	2.732	0.024
L11-261	2.708	2.732	0.024
L11-306	2.708	2.732	0.024
L11-351	2.709	2.732	0.023

**CYLINDER
DIMENSIONAL INSPECTION DATA**

STATIC CRUSH, TEST 2

<u>MEASUREMENT DESIGNATION</u>	<u>PRE-TEST</u>	<u>POST-TEST</u>	<u>MEASUREMENT CHANGE</u>
L12-36	2.709	2.734	0.025
L12-81	2.709	2.734	0.025
L12-126	2.708	2.732	0.024
L12-171	2.708	2.730	0.022
L12-216	2.708	2.731	0.023
L12-261	2.709	2.732	0.023
L12-306	2.709	2.732	0.023
L12-351	2.709	2.732	0.023
L13-36	2.709	2.725	0.016
L13-81	2.708	2.727	0.019
L13-126	2.708	2.728	0.020
L13-171	2.707	2.723	0.016
L13-216	2.708	2.723	0.015
L13-261	2.709	2.725	0.016
L13-306	2.709	2.725	0.016
L13-351	2.709	2.724	0.015
L14-36	24.014	23.573	-0.441
L14-81	24.015	23.573	-0.442
L14-126	24.015	23.573	-0.442
L14-171	24.014	23.573	-0.441
L14-216	24.014	23.573	-0.441
L14-261	24.013	23.573	-0.440
L14-306	24.013	23.572	-0.441
L14-351	24.014	23.572	-0.442

**CYLINDER
DIMENSIONAL INSPECTION DATA**

STATIC CRUSH, TEST 3

<u>MEASUREMENT DESIGNATION</u>	<u>PRE-TEST</u>	<u>POST-TEST</u>	<u>MEASUREMENT CHANGE</u>
L1-36	2.716	2.730	0.014
L1-81	2.715	2.725	0.010
L1-126	2.709	2.724	0.015
L1-171	2.703	2.723	0.020
L1-216	2.701	2.722	0.021
L1-261	2.703	2.728	0.025
L1-306	2.709	2.738	0.029
L1-351	2.714	2.738	0.024
L2-36	2.715	2.736	0.021
L2-81	2.714	2.730	0.016
L2-126	2.709	2.729	0.020
L2-171	2.703	2.728	0.025
L2-216	2.701	2.729	0.028
L2-261	2.703	2.735	0.032
L2-306	2.709	2.743	0.034
L2-351	2.713	2.743	0.030
L3-36	2.714	2.736	0.022
L3-81	2.714	2.732	0.018
L3-126	2.709	2.729	0.020
L3-171	2.704	2.729	0.025
L3-216	2.703	2.734	0.031
L3-261	2.704	2.738	0.034
L3-306	2.709	2.743	0.034
L3-351	2.713	2.742	0.029
L4-36	2.713	2.736	0.023
L4-81	2.713	2.731	0.018
L4-126	2.709	2.729	0.020
L4-171	2.705	2.730	0.025
L4-216	2.704	2.734	0.030
L4-261	2.705	2.738	0.033
L4-306	2.709	2.742	0.033
L4-351	2.712	2.740	0.028
L5-36	2.713	2.736	0.023
L5-81	2.713	2.732	0.019
L5-126	2.709	2.729	0.020
L5-171	2.706	2.730	0.024
L5-216	2.705	2.735	0.030
L5-261	2.705	2.739	0.034
L5-306	2.709	2.742	0.033
L5-351	2.712	2.740	0.028
L6-36	2.712	2.736	0.024
L6-81	2.712	2.732	0.020
L6-126	2.709	2.730	0.021
L6-171	2.707	2.732	0.025

**CYLINDER
DIMENSIONAL INSPECTION DATA**

STATIC CRUSH, TEST 3

<u>MEASUREMENT DESIGNATION</u>	<u>PRE-TEST</u>	<u>POST-TEST</u>	<u>MEASUREMENT CHANGE</u>
L6-216	2.706	2.736	0.030
L6-261	2.707	2.740	0.033
L6-306	2.709	2.742	0.033
L6-351	2.711	2.739	0.028
L7-36	2.712	2.736	0.024
L7-81	2.711	2.734	0.023
L7-126	2.709	2.733	0.024
L7-171	2.707	2.732	0.025
L7-216	2.707	2.736	0.029
L7-261	2.708	2.740	0.032
L7-306	2.709	2.742	0.033
L7-351	2.711	2.738	0.027
L8-36	2.711	2.736	0.025
L8-81	2.711	2.736	0.025
L8-126	2.709	2.735	0.026
L8-171	2.708	2.734	0.026
L8-216	2.708	2.736	0.028
L8-261	2.709	2.740	0.031
L8-306	2.710	2.740	0.030
L8-351	2.711	2.738	0.027
L9-36	2.711	2.737	0.026
L9-81	2.710	2.738	0.028
L9-126	2.709	2.735	0.026
L9-171	2.708	2.735	0.027
L9-216	2.708	2.736	0.028
L9-261	2.709	2.738	0.029
L9-306	2.710	2.739	0.029
L9-351	2.710	2.738	0.028
L10-36	2.710	2.738	0.028
L10-81	2.710	2.738	0.028
L10-126	2.710	2.737	0.027
L10-171	2.709	2.735	0.026
L10-216	2.709	2.736	0.027
L10-261	2.710	2.737	0.027
L10-306	2.710	2.736	0.026
L10-351	2.710	2.738	0.028
L11-36	2.710	2.739	0.029
L11-81	2.709	2.738	0.029
L11-126	2.710	2.737	0.027
L11-171	2.710	2.736	0.026
L11-216	2.709	2.737	0.028
L11-261	2.711	2.737	0.026
L11-306	2.711	2.738	0.027
L11-351	2.709	2.738	0.029

**CYLINDER
DIMENSIONAL INSPECTION DATA**

STATIC CRUSH, TEST 3

<u>MEASUREMENT DESIGNATION</u>	<u>PRE-TEST</u>	<u>POST-TEST</u>	<u>MEASUREMENT CHANGE</u>
L12-36	2.708	2.740	0.032
L12-81	2.708	2.738	0.030
L12-126	2.710	2.737	0.027
L12-171	2.710	2.737	0.027
L12-216	2.710	2.738	0.028
L12-261	2.711	2.739	0.028
L12-306	2.711	2.736	0.025
L12-351	2.708	2.737	0.029
L13-36	2.707	2.731	0.024
L13-81	2.708	2.730	0.022
L13-126	2.709	2.728	0.019
L13-171	2.710	2.729	0.019
L13-216	2.711	2.731	0.020
L13-261	2.711	2.729	0.018
L13-306	2.711	2.729	0.018
L13-351	2.709	2.729	0.020
L14-36	23.992	23.543	-0.449
L14-81	23.992	23.543	-0.449
L14-126	23.992	23.544	-0.448
L14-171	23.992	23.544	-0.448
L14-216	23.993	23.544	-0.449
L14-261	23.993	23.544	-0.449
L14-306	23.992	23.544	-0.448
L14-351	23.992	23.544	-0.448

**CYLINDER
DIMENSIONAL INSPECTION DATA**

STATIC CRUSH, TEST 4

<u>MEASUREMENT DESIGNATION</u>	<u>PRE-TEST</u>	<u>POST-TEST</u>	<u>MEASUREMENT CHANGE</u>
L1-36	2.710	2.729	0.019
L1-81	2.715	2.734	0.019
L1-126	2.718	2.739	0.021
L1-171	2.715	2.735	0.020
L1-216	2.708	2.726	0.018
L1-261	2.702	2.720	0.018
L1-306	2.702	2.722	0.020
L1-351	2.704	2.726	0.022
L2-36	2.709	2.736	0.027
L2-81	2.715	2.740	0.025
L2-126	2.717	2.743	0.026
L2-171	2.714	2.740	0.026
L2-216	2.708	2.733	0.025
L2-261	2.702	2.727	0.025
L2-306	2.703	2.727	0.024
L2-351	2.704	2.731	0.027
L3-36	2.709	2.736	0.027
L3-81	2.714	2.740	0.026
L3-126	2.716	2.743	0.027
L3-171	2.714	2.739	0.025
L3-216	2.708	2.734	0.026
L3-261	2.703	2.728	0.025
L3-306	2.703	2.728	0.025
L3-351	2.705	2.731	0.026
L4-36	2.709	2.733	0.024
L4-81	2.713	2.738	0.025
L4-126	2.716	2.740	0.024
L4-171	2.714	2.738	0.024
L4-216	2.708	2.735	0.027
L4-261	2.704	2.728	0.024
L4-306	2.704	2.728	0.024
L4-351	2.706	2.730	0.024
L5-36	2.709	2.733	0.024
L5-81	2.712	2.737	0.025
L5-126	2.715	2.739	0.024
L5-171	2.713	2.738	0.025
L5-216	2.708	2.735	0.027
L5-261	2.705	2.729	0.024
L5-306	2.705	2.729	0.024
L5-351	2.706	2.732	0.026
L6-36	2.709	2.733	0.024
L6-81	2.712	2.736	0.024
L6-126	2.714	2.738	0.024
L6-171	2.712	2.738	0.026

**CYLINDER
DIMENSIONAL INSPECTION DATA**

STATIC CRUSH, TEST 4

<u>MEASUREMENT DESIGNATION</u>	<u>PRE-TEST</u>	<u>POST-TEST</u>	<u>MEASUREMENT CHANGE</u>
L6-216	2.709	2.736	0.027
L6-261	2.705	2.729	0.024
L6-306	2.706	2.729	0.023
L6-351	2.706	2.733	0.027
L7-36	2.708	2.732	0.024
L7-81	2.711	2.734	0.023
L7-126	2.713	2.737	0.024
L7-171	2.711	2.738	0.027
L7-216	2.709	2.736	0.027
L7-261	2.706	2.730	0.024
L7-306	2.705	2.729	0.024
L7-351	2.707	2.733	0.026
L8-36	2.709	2.731	0.022
L8-81	2.711	2.734	0.023
L8-126	2.712	2.736	0.024
L8-171	2.711	2.737	0.026
L8-216	2.709	2.734	0.025
L8-261	2.707	2.730	0.023
L8-306	2.706	2.729	0.023
L8-351	2.708	2.731	0.023
L9-36	2.709	2.732	0.023
L9-81	2.710	2.734	0.024
L9-126	2.711	2.734	0.023
L9-171	2.710	2.737	0.027
L9-216	2.709	2.735	0.026
L9-261	2.707	2.731	0.024
L9-306	2.707	2.730	0.023
L9-351	2.708	2.733	0.025
L10-36	2.709	2.732	0.023
L10-81	2.710	2.734	0.024
L10-126	2.711	2.734	0.023
L10-171	2.710	2.735	0.025
L10-216	2.709	2.736	0.027
L10-261	2.708	2.732	0.024
L10-306	2.708	2.732	0.024
L10-351	2.709	2.733	0.024
L11-36	2.709	2.734	0.025
L11-81	2.709	2.734	0.025
L11-126	2.710	2.735	0.025
L11-171	2.709	2.734	0.025
L11-216	2.709	2.734	0.025
L11-261	2.708	2.733	0.025
L11-306	2.709	2.733	0.024
L11-351	2.709	2.734	0.025

**CYLINDER
DIMENSIONAL INSPECTION DATA**

STATIC CRUSH, TEST 4

<u>MEASUREMENT DESIGNATION</u>	<u>PRE-TEST</u>	<u>POST-TEST</u>	<u>MEASUREMENT CHANGE</u>
L12-36	2.709	2.733	0.024
L12-81	2.709	2.733	0.024
L12-126	2.709	2.733	0.024
L12-171	2.709	2.733	0.024
L12-216	2.709	2.734	0.025
L12-261	2.709	2.731	0.022
L12-306	2.709	2.733	0.024
L12-351	2.709	2.734	0.025
L13-36	2.709	2.723	0.014
L13-81	2.709	2.723	0.014
L13-126	2.709	2.723	0.014
L13-171	2.709	2.723	0.014
L13-216	2.709	2.722	0.013
L13-261	2.709	2.723	0.014
L13-306	2.709	2.723	0.014
L13-351	2.709	2.723	0.014
L14-36	24.007	23.563	-0.444
L14-81	24.007	23.563	-0.444
L14-126	24.008	23.563	-0.445
L14-171	24.007	23.564	-0.443
L14-216	24.006	23.565	-0.441
L14-261	24.007	23.565	-0.442
L14-306	24.008	23.565	-0.443
L14-351	24.008	23.564	-0.444

**CYLINDER
DIMENSIONAL INSPECTION DATA**

STATIC CRUSH, TEST 5

<u>MEASUREMENT DESIGNATION</u>	<u>PRE-TEST</u>	<u>POST-TEST</u>	<u>MEASUREMENT CHANGE</u>
L1-36	2.714	2.730	0.016
L1-81	2.702	2.715	0.013
L1-126	2.694	2.709	0.015
L1-171	2.694	2.710	0.016
L1-216	2.702	2.719	0.017
L1-261	2.714	2.730	0.016
L1-306	2.723	2.740	0.017
L1-351	2.722	2.740	0.018
L2-36	2.714	2.736	0.022
L2-81	2.703	2.723	0.020
L2-126	2.696	2.716	0.020
L2-171	2.696	2.717	0.021
L2-216	2.703	2.728	0.025
L2-261	2.713	2.738	0.025
L2-306	2.722	2.746	0.024
L2-351	2.721	2.745	0.024
L3-36	2.714	2.736	0.022
L3-81	2.704	2.724	0.020
L3-126	2.698	2.718	0.020
L3-171	2.698	2.720	0.022
L3-216	2.703	2.729	0.026
L3-261	2.713	2.739	0.026
L3-306	2.720	2.745	0.025
L3-351	2.719	2.745	0.026
L4-36	2.713	2.735	0.022
L4-81	2.705	2.725	0.020
L4-126	2.700	2.720	0.020
L4-171	2.700	2.721	0.021
L4-216	2.705	2.730	0.025
L4-261	2.712	2.739	0.027
L4-306	2.719	2.743	0.024
L4-351	2.718	2.743	0.025
L5-36	2.712	2.734	0.022
L5-81	2.706	2.725	0.019
L5-126	2.701	2.721	0.020
L5-171	2.701	2.723	0.022
L5-216	2.706	2.729	0.023
L5-261	2.712	2.737	0.025
L5-306	2.719	2.743	0.024
L5-351	2.717	2.742	0.025
L6-36	2.711	2.734	0.023
L6-81	2.707	2.727	0.020
L6-126	2.703	2.723	0.020
L6-171	2.701	2.724	0.023

**CYLINDER
DIMENSIONAL INSPECTION DATA**

STATIC CRUSH, TEST 5

<u>MEASUREMENT DESIGNATION</u>	<u>PRE-TEST</u>	<u>POST-TEST</u>	<u>MEASUREMENT CHANGE</u>
L6-216	2.707	2.729	0.022
L6-261	2.711	2.736	0.025
L6-306	2.716	2.742	0.026
L6-351	2.715	2.740	0.025
L7-36	2.711	2.733	0.022
L7-81	2.708	2.728	0.020
L7-126	2.705	2.726	0.021
L7-171	2.704	2.726	0.022
L7-216	2.707	2.729	0.022
L7-261	2.710	2.736	0.026
L7-306	2.714	2.740	0.026
L7-351	2.713	2.739	0.026
L8-36	2.711	2.734	0.023
L8-81	2.709	2.730	0.021
L8-126	2.706	2.727	0.021
L8-171	2.706	2.728	0.022
L8-216	2.708	2.730	0.022
L8-261	2.710	2.737	0.027
L8-306	2.711	2.739	0.028
L8-351	2.712	2.739	0.027
L9-36	2.710	2.735	0.025
L9-81	2.708	2.732	0.024
L9-126	2.708	2.730	0.022
L9-171	2.708	2.730	0.022
L9-216	2.709	2.732	0.023
L9-261	2.709	2.736	0.027
L9-306	2.711	2.739	0.028
L9-351	2.711	2.738	0.027
L10-36	2.709	2.735	0.026
L10-81	2.709	2.732	0.023
L10-126	2.710	2.731	0.021
L10-171	2.710	2.732	0.022
L10-216	2.709	2.733	0.024
L10-261	2.708	2.735	0.027
L10-306	2.709	2.737	0.028
L10-351	2.709	2.737	0.028
L11-36	2.708	2.736	0.028
L11-81	2.710	2.733	0.023
L11-126	2.710	2.733	0.023
L11-171	2.710	2.733	0.023
L11-216	2.710	2.733	0.023
L11-261	2.709	2.735	0.026
L11-306	2.708	2.736	0.028
L11-351	2.708	2.736	0.028

**CYLINDER
DIMENSIONAL INSPECTION DATA**

STATIC CRUSH, TEST 5

<u>MEASUREMENT DESIGNATION</u>	<u>PRE-TEST</u>	<u>POST-TEST</u>	<u>MEASUREMENT CHANGE</u>
L12-36	2.708	2.734	0.026
L12-81	2.710	2.734	0.024
L12-126	2.712	2.734	0.022
L12-171	2.711	2.735	0.024
L12-216	2.711	2.733	0.022
L12-261	2.708	2.735	0.027
L12-306	2.707	2.735	0.028
L12-351	2.706	2.735	0.029
L13-36	2.707	2.725	0.018
L13-81	2.710	2.725	0.015
L13-126	2.714	2.725	0.011
L13-171	2.712	2.725	0.013
L13-216	2.712	2.725	0.013
L13-261	2.708	2.725	0.017
L13-306	2.705	2.725	0.020
L13-351	2.704	2.725	0.021
L14-36	24.005	23.563	-0.442
L14-81	24.006	23.565	-0.441
L14-126	24.010	23.568	-0.442
L14-171	24.012	23.569	-0.443
L14-216	24.011	23.569	-0.442
L14-261	24.010	23.567	-0.443
L14-306	24.007	23.565	-0.442
L14-351	24.005	23.564	-0.441

**CYLINDER
DIMENSIONAL INSPECTION DATA**

STATIC CRUSH, TEST 6

<u>MEASUREMENT DESIGNATION</u>	<u>PRE-TEST</u>	<u>POST-TEST</u>	<u>MEASUREMENT CHANGE</u>
L1-36	2.707	2.716	0.009
L1-81	2.707	2.720	0.013
L1-126	2.708	2.728	0.020
L1-171	2.708	2.738	0.030
L1-216	2.710	2.737	0.027
L1-261	2.710	2.732	0.022
L1-306	2.709	2.729	0.020
L1-351	2.708	2.720	0.012
L2-36	2.707	2.725	0.018
L2-81	2.707	2.728	0.021
L2-126	2.708	2.734	0.026
L2-171	2.709	2.742	0.033
L2-216	2.710	2.744	0.034
L2-261	2.710	2.741	0.031
L2-306	2.709	2.735	0.026
L2-351	2.708	2.729	0.021
L3-36	2.707	2.727	0.020
L3-81	2.707	2.730	0.023
L3-126	2.708	2.734	0.026
L3-171	2.709	2.740	0.031
L3-216	2.710	2.743	0.033
L3-261	2.710	2.740	0.030
L3-306	2.709	2.736	0.027
L3-351	2.708	2.729	0.021
L4-36	2.707	2.727	0.020
L4-81	2.707	2.730	0.023
L4-126	2.708	2.734	0.026
L4-171	2.710	2.739	0.029
L4-216	2.710	2.741	0.031
L4-261	2.710	2.740	0.030
L4-306	2.709	2.735	0.026
L4-351	2.708	2.730	0.022
L5-36	2.708	2.729	0.021
L5-81	2.708	2.730	0.022
L5-126	2.708	2.734	0.026
L5-171	2.710	2.738	0.028
L5-216	2.710	2.740	0.030
L5-261	2.710	2.740	0.030
L5-306	2.709	2.735	0.026
L5-351	2.709	2.731	0.022
L6-36	2.708	2.730	0.022
L6-81	2.708	2.730	0.022
L6-126	2.709	2.733	0.024
L6-171	2.710	2.736	0.026

**CYLINDER
DIMENSIONAL INSPECTION DATA**

STATIC CRUSH, TEST 6

<u>MEASUREMENT DESIGNATION</u>	<u>PRE-TEST</u>	<u>POST-TEST</u>	<u>MEASUREMENT CHANGE</u>
L6-216	2.710	2.739	0.029
L6-261	2.710	2.739	0.029
L6-306	2.709	2.735	0.026
L6-351	2.709	2.732	0.023
L7-36	2.708	2.731	0.023
L7-81	2.708	2.731	0.023
L7-126	2.709	2.732	0.023
L7-171	2.710	2.734	0.024
L7-216	2.710	2.737	0.027
L7-261	2.710	2.737	0.027
L7-306	2.709	2.736	0.027
L7-351	2.709	2.733	0.024
L8-36	2.708	2.731	0.023
L8-81	2.708	2.731	0.023
L8-126	2.709	2.733	0.024
L8-171	2.710	2.734	0.024
L8-216	2.710	2.736	0.026
L8-261	2.709	2.737	0.028
L8-306	2.709	2.735	0.026
L8-351	2.709	2.734	0.025
L9-36	2.709	2.733	0.024
L9-81	2.709	2.732	0.023
L9-126	2.709	2.732	0.023
L9-171	2.710	2.734	0.024
L9-216	2.710	2.735	0.025
L9-261	2.710	2.736	0.026
L9-306	2.709	2.735	0.026
L9-351	2.709	2.735	0.026
L10-36	2.709	2.735	0.026
L10-81	2.709	2.734	0.025
L10-126	2.710	2.734	0.024
L10-171	2.710	2.735	0.025
L10-216	2.709	2.735	0.026
L10-261	2.709	2.736	0.027
L10-306	2.709	2.736	0.027
L10-351	2.709	2.736	0.027
L11-36	2.709	2.736	0.027
L11-81	2.709	2.736	0.027
L11-126	2.710	2.734	0.024
L11-171	2.710	2.735	0.025
L11-216	2.709	2.738	0.029
L11-261	2.709	2.737	0.028
L11-306	2.709	2.737	0.028
L11-351	2.709	2.736	0.027

**CYLINDER
DIMENSIONAL INSPECTION DATA**

STATIC CRUSH, TEST 6

<u>MEASUREMENT DESIGNATION</u>	<u>PRE-TEST</u>	<u>POST-TEST</u>	<u>MEASUREMENT CHANGE</u>
L12-36	2.710	2.735	0.025
L12-81	2.709	2.734	0.025
L12-126	2.710	2.733	0.023
L12-171	2.710	2.735	0.025
L12-216	2.709	2.734	0.025
L12-261	2.709	2.736	0.027
L12-306	2.709	2.733	0.024
L12-351	2.709	2.735	0.026
L13-36	2.710	2.725	0.015
L13-81	2.710	2.723	0.013
L13-126	2.710	2.723	0.013
L13-171	2.710	2.725	0.015
L13-216	2.709	2.725	0.016
L13-261	2.709	2.723	0.014
L13-306	2.709	2.723	0.014
L13-351	2.709	2.725	0.016
L14-36	23.989	23.547	-0.442
L14-81	23.990	23.548	-0.442
L14-126	23.990	23.548	-0.442
L14-171	23.990	23.546	-0.444
L14-216	23.990	23.544	-0.446
L14-261	23.989	23.543	-0.446
L14-306	23.989	23.543	-0.446
L14-351	23.990	23.545	-0.445

**CYLINDER
DIMENSIONAL INSPECTION DATA**

STATIC CRUSH, TEST 7

<u>MEASUREMENT DESIGNATION</u>	<u>PRE-TEST</u>	<u>POST-TEST</u>	<u>MEASUREMENT CHANGE</u>
L1-36	2.707	2.729	0.022
L1-81	2.704	2.725	0.021
L1-126	2.704	2.721	0.017
L1-171	2.705	2.719	0.014
L1-216	2.708	2.717	0.009
L1-261	2.711	2.719	0.008
L1-306	2.712	2.726	0.014
L1-351	2.711	2.731	0.020
L2-36	2.707	2.735	0.028
L2-81	2.704	2.732	0.028
L2-126	2.704	2.729	0.025
L2-171	2.705	2.729	0.024
L2-216	2.708	2.725	0.017
L2-261	2.711	2.726	0.015
L2-306	2.711	2.731	0.020
L2-351	2.710	2.736	0.026
L3-36	2.707	2.734	0.027
L3-81	2.705	2.733	0.028
L3-126	2.705	2.730	0.025
L3-171	2.706	2.729	0.023
L3-216	2.708	2.726	0.018
L3-261	2.710	2.727	0.017
L3-306	2.710	2.731	0.021
L3-351	2.710	2.735	0.025
L4-36	2.707	2.734	0.027
L4-81	2.705	2.734	0.029
L4-126	2.705	2.732	0.027
L4-171	2.706	2.729	0.023
L4-216	2.708	2.727	0.019
L4-261	2.710	2.727	0.017
L4-306	2.710	2.731	0.021
L4-351	2.709	2.733	0.024
L5-36	2.707	2.734	0.027
L5-81	2.706	2.734	0.028
L5-126	2.706	2.733	0.027
L5-171	2.706	2.729	0.023
L5-216	2.708	2.727	0.019
L5-261	2.709	2.729	0.020
L5-306	2.709	2.731	0.022
L5-351	2.709	2.733	0.024
L6-36	2.707	2.731	0.024
L6-81	2.706	2.734	0.028
L6-126	2.706	2.733	0.027
L6-171	2.707	2.730	0.023

**CYLINDER
DIMENSIONAL INSPECTION DATA**

STATIC CRUSH, TEST 7

<u>MEASUREMENT DESIGNATION</u>	<u>PRE-TEST</u>	<u>POST-TEST</u>	<u>MEASUREMENT CHANGE</u>
L6-216	2.708	2.729	0.021
L6-261	2.709	2.730	0.021
L6-306	2.709	2.731	0.022
L6-351	2.708	2.733	0.025
L7-36	2.707	2.731	0.024
L7-81	2.707	2.734	0.027
L7-126	2.707	2.732	0.025
L7-171	2.707	2.730	0.023
L7-216	2.708	2.729	0.021
L7-261	2.708	2.730	0.022
L7-306	2.708	2.731	0.023
L7-351	2.708	2.731	0.023
L8-36	2.707	2.731	0.024
L8-81	2.707	2.732	0.025
L8-126	2.707	2.731	0.024
L8-171	2.707	2.729	0.022
L8-216	2.708	2.730	0.022
L8-261	2.708	2.731	0.023
L8-306	2.707	2.731	0.024
L8-351	2.708	2.731	0.023
L9-36	2.707	2.730	0.023
L9-81	2.708	2.731	0.023
L9-126	2.707	2.730	0.023
L9-171	2.708	2.729	0.021
L9-216	2.708	2.730	0.022
L9-261	2.708	2.731	0.023
L9-306	2.707	2.731	0.024
L9-351	2.707	2.730	0.023
L10-36	2.707	2.729	0.022
L10-81	2.708	2.730	0.022
L10-126	2.708	2.729	0.021
L10-171	2.708	2.729	0.021
L10-216	2.707	2.729	0.022
L10-261	2.707	2.731	0.024
L10-306	2.707	2.731	0.024
L10-351	2.707	2.729	0.022
L11-36	2.707	2.730	0.023
L11-81	2.708	2.730	0.022
L11-126	2.708	2.730	0.022
L11-171	2.708	2.730	0.022
L11-216	2.707	2.731	0.024
L11-261	2.707	2.731	0.024
L11-306	2.706	2.731	0.025
L11-351	2.706	2.730	0.024

**CYLINDER
DIMENSIONAL INSPECTION DATA**

STATIC CRUSH, TEST 7

<u>MEASUREMENT DESIGNATION</u>	<u>PRE-TEST</u>	<u>POST-TEST</u>	<u>MEASUREMENT CHANGE</u>
L12-36	2.707	2.730	0.023
L12-81	2.708	2.730	0.022
L12-126	2.709	2.730	0.021
L12-171	2.708	2.730	0.022
L12-216	2.707	2.731	0.024
L12-261	2.707	2.731	0.024
L12-306	2.706	2.731	0.025
L12-351	2.706	2.730	0.024
L13-36	2.707	2.723	0.016
L13-81	2.709	2.723	0.014
L13-126	2.709	2.723	0.014
L13-171	2.708	2.724	0.016
L13-216	2.707	2.723	0.016
L13-261	2.706	2.723	0.017
L13-306	2.705	2.724	0.019
L13-351	2.705	2.724	0.019
L14-36	24.011	23.574	-0.437
L14-81	24.011	23.574	-0.437
L14-126	24.011	23.574	-0.437
L14-171	24.011	23.574	-0.437
L14-216	24.011	23.575	-0.436
L14-261	24.012	23.575	-0.437
L14-306	24.012	23.575	-0.437
L14-351	24.012	23.575	-0.437

**CYLINDER
DIMENSIONAL INSPECTION DATA**

STATIC CRUSH, TEST 8

<u>MEASUREMENT DESIGNATION</u>	<u>PRE-TEST</u>	<u>POST-TEST</u>	<u>MEASUREMENT CHANGE</u>
L1-36	2.718	2.728	0.010
L1-81	2.715	2.728	0.013
L1-126	2.707	2.722	0.015
L1-171	2.700	2.716	0.016
L1-216	2.700	2.718	0.018
L1-261	2.702	2.723	0.021
L1-306	2.707	2.727	0.020
L1-351	2.712	2.727	0.015
L2-36	2.717	2.735	0.018
L2-81	2.714	2.733	0.019
L2-126	2.707	2.727	0.020
L2-171	2.701	2.725	0.024
L2-216	2.700	2.725	0.025
L2-261	2.702	2.729	0.027
L2-306	2.706	2.733	0.027
L2-351	2.712	2.735	0.023
L3-36	2.716	2.736	0.020
L3-81	2.714	2.733	0.019
L3-126	2.707	2.728	0.021
L3-171	2.702	2.727	0.025
L3-216	2.702	2.728	0.026
L3-261	2.703	2.731	0.028
L3-306	2.706	2.733	0.027
L3-351	2.711	2.736	0.025
L4-36	2.715	2.735	0.020
L4-81	2.713	2.732	0.019
L4-126	2.707	2.728	0.021
L4-171	2.703	2.728	0.025
L4-216	2.703	2.730	0.027
L4-261	2.704	2.731	0.027
L4-306	2.707	2.733	0.026
L4-351	2.711	2.736	0.025
L5-36	2.714	2.735	0.021
L5-81	2.712	2.733	0.021
L5-126	2.708	2.729	0.021
L5-171	2.704	2.729	0.025
L5-216	2.703	2.732	0.029
L5-261	2.704	2.733	0.029
L5-306	2.707	2.733	0.026
L5-351	2.710	2.735	0.025
L6-36	2.713	2.734	0.021
L6-81	2.712	2.732	0.020
L6-126	2.708	2.729	0.021
L6-171	2.705	2.729	0.024

**CYLINDER
DIMENSIONAL INSPECTION DATA**

STATIC CRUSH, TEST 8

<u>MEASUREMENT DESIGNATION</u>	<u>PRE-TEST</u>	<u>POST-TEST</u>	<u>MEASUREMENT CHANGE</u>
L6-216	2.705	2.732	0.027
L6-261	2.705	2.733	0.028
L6-306	2.707	2.733	0.026
L6-351	2.710	2.734	0.024
L7-36	2.713	2.732	0.019
L7-81	2.711	2.732	0.021
L7-126	2.708	2.729	0.021
L7-171	2.706	2.729	0.023
L7-216	2.706	2.732	0.026
L7-261	2.706	2.733	0.027
L7-306	2.707	2.732	0.025
L7-351	2.710	2.732	0.022
L8-36	2.712	2.730	0.018
L8-81	2.711	2.730	0.019
L8-126	2.709	2.729	0.020
L8-171	2.707	2.729	0.022
L8-216	2.706	2.732	0.026
L8-261	2.707	2.733	0.026
L8-306	2.708	2.731	0.023
L8-351	2.710	2.730	0.020
L9-36	2.711	2.730	0.019
L9-81	2.710	2.730	0.020
L9-126	2.709	2.729	0.020
L9-171	2.708	2.730	0.022
L9-216	2.708	2.732	0.024
L9-261	2.707	2.732	0.025
L9-306	2.708	2.731	0.023
L9-351	2.709	2.730	0.021
L10-36	2.710	2.730	0.020
L10-81	2.710	2.730	0.020
L10-126	2.709	2.730	0.021
L10-171	2.709	2.732	0.023
L10-216	2.709	2.732	0.023
L10-261	2.708	2.732	0.024
L10-306	2.709	2.731	0.022
L10-351	2.709	2.730	0.021
L11-36	2.710	2.730	0.020
L11-81	2.709	2.731	0.022
L11-126	2.709	2.732	0.023
L11-171	2.710	2.733	0.023
L11-216	2.709	2.733	0.024
L11-261	2.709	2.732	0.023
L11-306	2.709	2.732	0.023
L11-351	2.709	2.731	0.022

**CYLINDER
DIMENSIONAL INSPECTION DATA**

STATIC CRUSH, TEST 8

<u>MEASUREMENT DESIGNATION</u>	<u>PRE-TEST</u>	<u>POST-TEST</u>	<u>MEASUREMENT CHANGE</u>
L12-36	2.710	2.730	0.020
L12-81	2.709	2.731	0.022
L12-126	2.710	2.732	0.022
L12-171	2.710	2.733	0.023
L12-216	2.710	2.731	0.021
L12-261	2.709	2.732	0.023
L12-306	2.709	2.732	0.023
L12-351	2.709	2.731	0.022
L13-36	2.709	2.722	0.013
L13-81	2.708	2.721	0.013
L13-126	2.710	2.722	0.012
L13-171	2.710	2.725	0.015
L13-216	2.710	2.723	0.013
L13-261	2.709	2.722	0.013
L13-306	2.709	2.724	0.015
L13-351	2.709	2.722	0.013
L14-36	24.012	23.579	-0.433
L14-81	24.012	23.579	-0.433
L14-126	24.012	23.579	-0.433
L14-171	24.013	23.579	-0.434
L14-216	24.013	23.579	-0.434
L14-261	24.013	23.580	-0.433
L14-306	24.012	23.580	-0.432
L14-351	24.012	23.580	-0.432

**CYLINDER
DIMENSIONAL INSPECTION DATA**

STATIC CRUSH, TEST 9

<u>MEASUREMENT DESIGNATION</u>	<u>PRE-TEST</u>	<u>POST-TEST</u>	<u>MEASUREMENT CHANGE</u>
L1-36	2.702	2.721	0.019
L1-81	2.704	2.725	0.021
L1-126	2.708	2.729	0.021
L1-171	2.711	2.729	0.018
L1-216	2.712	2.727	0.015
L1-261	2.710	2.721	0.011
L1-306	2.707	2.720	0.013
L1-351	2.703	2.720	0.017
L2-36	2.703	2.731	0.028
L2-81	2.705	2.734	0.029
L2-126	2.708	2.737	0.029
L2-171	2.711	2.737	0.026
L2-216	2.712	2.734	0.022
L2-261	2.710	2.730	0.020
L2-306	2.707	2.728	0.021
L2-351	2.703	2.728	0.025
L3-36	2.704	2.731	0.027
L3-81	2.706	2.734	0.028
L3-126	2.709	2.737	0.028
L3-171	2.711	2.738	0.027
L3-216	2.712	2.734	0.022
L3-261	2.710	2.731	0.021
L3-306	2.707	2.729	0.022
L3-351	2.704	2.729	0.025
L4-36	2.704	2.730	0.026
L4-81	2.706	2.733	0.027
L4-126	2.709	2.736	0.027
L4-171	2.711	2.737	0.026
L4-216	2.711	2.733	0.022
L4-261	2.710	2.732	0.022
L4-306	2.708	2.728	0.020
L4-351	2.705	2.729	0.024
L5-36	2.705	2.730	0.025
L5-81	2.706	2.732	0.026
L5-126	2.709	2.735	0.026
L5-171	2.710	2.735	0.025
L5-216	2.711	2.734	0.023
L5-261	2.710	2.732	0.022
L5-306	2.708	2.730	0.022
L5-351	2.705	2.730	0.025
L6-36	2.705	2.731	0.026
L6-81	2.707	2.733	0.026
L6-126	2.709	2.735	0.026
L6-171	2.710	2.735	0.025

**CYLINDER
DIMENSIONAL INSPECTION DATA**

STATIC CRUSH, TEST 9

<u>MEASUREMENT DESIGNATION</u>	<u>PRE-TEST</u>	<u>POST-TEST</u>	<u>MEASUREMENT CHANGE</u>
L6-216	2.711	2.733	0.022
L6-261	2.710	2.732	0.022
L6-306	2.708	2.731	0.023
L6-351	2.706	2.731	0.025
L7-36	2.706	2.732	0.026
L7-81	2.707	2.732	0.025
L7-126	2.709	2.733	0.024
L7-171	2.710	2.733	0.023
L7-216	2.710	2.732	0.022
L7-261	2.709	2.732	0.023
L7-306	2.708	2.733	0.025
L7-351	2.706	2.733	0.027
L8-36	2.707	2.732	0.025
L8-81	2.708	2.732	0.024
L8-126	2.709	2.733	0.024
L8-171	2.710	2.733	0.023
L8-216	2.710	2.732	0.022
L8-261	2.709	2.732	0.023
L8-306	2.708	2.733	0.025
L8-351	2.706	2.733	0.027
L9-36	2.707	2.733	0.026
L9-81	2.708	2.732	0.024
L9-126	2.709	2.734	0.025
L9-171	2.709	2.733	0.024
L9-216	2.710	2.732	0.022
L9-261	2.709	2.734	0.025
L9-306	2.709	2.735	0.026
L9-351	2.707	2.734	0.027
L10-36	2.708	2.733	0.025
L10-81	2.709	2.733	0.024
L10-126	2.709	2.734	0.025
L10-171	2.709	2.734	0.025
L10-216	2.709	2.733	0.024
L10-261	2.709	2.734	0.025
L10-306	2.710	2.735	0.025
L10-351	2.708	2.735	0.027
L11-36	2.708	2.735	0.027
L11-81	2.709	2.734	0.025
L11-126	2.709	2.734	0.025
L11-171	2.709	2.735	0.026
L11-216	2.709	2.735	0.026
L11-261	2.709	2.734	0.025
L11-306	2.710	2.735	0.025
L11-351	2.708	2.735	0.027

**CYLINDER
DIMENSIONAL INSPECTION DATA**

STATIC CRUSH, TEST 9

<u>MEASUREMENT DESIGNATION</u>	<u>PRE-TEST</u>	<u>POST-TEST</u>	<u>MEASUREMENT CHANGE</u>
L12-36	2.709	2.735	0.026
L12-81	2.709	2.734	0.025
L12-126	2.709	2.733	0.024
L12-171	2.709	2.734	0.025
L12-216	2.709	2.736	0.027
L12-261	2.709	2.735	0.026
L12-306	2.710	2.733	0.023
L12-351	2.709	2.735	0.026
L13-36	2.709	2.728	0.019
L13-81	2.710	2.725	0.015
L13-126	2.710	2.723	0.013
L13-171	2.709	2.727	0.018
L13-216	2.709	2.730	0.021
L13-261	2.709	2.725	0.016
L13-306	2.710	2.725	0.015
L13-351	2.709	2.729	0.020
L14-36	24.013	23.573	-0.440
L14-81	24.014	23.573	-0.441
L14-126	24.014	23.573	-0.441
L14-171	24.013	23.573	-0.440
L14-216	24.013	23.572	-0.441
L14-261	24.013	23.572	-0.441
L14-306	24.013	23.572	-0.441
L14-351	24.013	23.572	-0.441

**CYLINDER
DIMENSIONAL INSPECTION DATA**

STATIC CRUSH, TEST 10

<u>MEASUREMENT DESIGNATION</u>	<u>PRE-TEST</u>	<u>POST-TEST</u>	<u>MEASUREMENT CHANGE</u>
L1-36	2.707	2.721	0.014
L1-81	2.705	2.718	0.013
L1-126	2.706	2.720	0.014
L1-171	2.707	2.727	0.020
L1-216	2.711	2.730	0.019
L1-261	2.714	2.731	0.017
L1-306	2.714	2.731	0.017
L1-351	2.711	2.728	0.017
L2-36	2.708	2.731	0.023
L2-81	2.705	2.727	0.022
L2-126	2.706	2.729	0.023
L2-171	2.707	2.733	0.026
L2-216	2.711	2.738	0.027
L2-261	2.714	2.739	0.025
L2-306	2.714	2.740	0.026
L2-351	2.711	2.737	0.026
L3-36	2.708	2.732	0.024
L3-81	2.706	2.729	0.023
L3-126	2.706	2.730	0.024
L3-171	2.707	2.733	0.026
L3-216	2.711	2.737	0.026
L3-261	2.713	2.739	0.026
L3-306	2.713	2.740	0.027
L3-351	2.711	2.737	0.026
L4-36	2.709	2.733	0.024
L4-81	2.708	2.730	0.022
L4-126	2.708	2.730	0.022
L4-171	2.708	2.730	0.022
L4-216	2.711	2.734	0.023
L4-261	2.713	2.736	0.023
L4-306	2.713	2.738	0.025
L4-351	2.711	2.737	0.026
L5-36	2.709	2.734	0.025
L5-81	2.708	2.731	0.023
L5-126	2.708	2.730	0.022
L5-171	2.708	2.730	0.022
L5-216	2.710	2.732	0.022
L5-261	2.712	2.735	0.023
L5-306	2.713	2.737	0.024
L5-351	2.710	2.737	0.027
L6-36	2.709	2.735	0.026
L6-81	2.709	2.732	0.023
L6-126	2.708	2.730	0.022
L6-171	2.708	2.730	0.022

**CYLINDER
DIMENSIONAL INSPECTION DATA**

STATIC CRUSH, TEST 10

<u>MEASUREMENT DESIGNATION</u>	<u>PRE-TEST</u>	<u>POST-TEST</u>	<u>MEASUREMENT CHANGE</u>
L6-216	2.710	2.732	0.022
L6-261	2.712	2.733	0.021
L6-306	2.712	2.736	0.024
L6-351	2.710	2.736	0.026
L7-36	2.709	2.735	0.026
L7-81	2.710	2.732	0.022
L7-126	2.708	2.730	0.022
L7-171	2.709	2.730	0.021
L7-216	2.710	2.732	0.022
L7-261	2.712	2.733	0.021
L7-306	2.712	2.735	0.023
L7-351	2.710	2.736	0.026
L8-36	2.709	2.735	0.026
L8-81	2.710	2.732	0.022
L8-126	2.709	2.730	0.021
L8-171	2.709	2.730	0.021
L8-216	2.710	2.732	0.022
L8-261	2.711	2.733	0.022
L8-306	2.711	2.735	0.024
L8-351	2.710	2.736	0.026
L9-36	2.710	2.734	0.024
L9-81	2.710	2.731	0.021
L9-126	2.710	2.730	0.020
L9-171	2.709	2.731	0.022
L9-216	2.710	2.733	0.023
L9-261	2.710	2.732	0.022
L9-306	2.711	2.734	0.023
L9-351	2.710	2.735	0.025
L10-36	2.710	2.733	0.023
L10-81	2.710	2.731	0.021
L10-126	2.709	2.730	0.021
L10-171	2.710	2.731	0.021
L10-216	2.710	2.733	0.023
L10-261	2.710	2.733	0.023
L10-306	2.710	2.733	0.023
L10-351	2.710	2.733	0.023
L11-36	2.710	2.733	0.023
L11-81	2.710	2.732	0.022
L11-126	2.710	2.731	0.021
L11-171	2.710	2.732	0.022
L11-216	2.710	2.734	0.024
L11-261	2.710	2.733	0.023
L11-306	2.710	2.733	0.023
L11-351	2.710	2.733	0.023

**CYLINDER
DIMENSIONAL INSPECTION DATA**

STATIC CRUSH, TEST 10

<u>MEASUREMENT DESIGNATION</u>	<u>PRE-TEST</u>	<u>POST-TEST</u>	<u>MEASUREMENT CHANGE</u>
L12-36	2.710	2.732	0.022
L12-81	2.710	2.731	0.021
L12-126	2.711	2.731	0.020
L12-171	2.710	2.733	0.023
L12-216	2.710	2.734	0.024
L12-261	2.710	2.733	0.023
L12-306	2.711	2.732	0.021
L12-351	2.710	2.732	0.022
L13-36	2.710	2.725	0.015
L13-81	2.710	2.725	0.015
L13-126	2.710	2.726	0.016
L13-171	2.710	2.724	0.014
L13-216	2.710	2.726	0.016
L13-261	2.710	2.725	0.015
L13-306	2.710	2.723	0.013
L13-351	2.709	2.725	0.016
L14-36	24.013	23.568	-0.445
L14-81	24.013	23.568	-0.445
L14-126	24.013	23.568	-0.445
L14-171	24.013	23.568	-0.445
L14-216	24.013	23.568	-0.445
L14-261	24.013	23.568	-0.445
L14-306	24.013	23.568	-0.445
L14-351	24.013	23.568	-0.445

**CYLINDER DIMENSIONAL MEASUREMENTS
MEAN AND STANDARD DEVIATION**

STATIC CRUSH TEST

<u>MEASUREMENT DESIGNATION</u>	<u>MEAN</u>		<u>NET CHANGE</u>	<u>STANDARD DEVIATION</u>	
	<u>PRE-TEST</u>	<u>POST-TEST</u>		<u>PRE-TEST</u>	<u>POST-TEST</u>
L1-36	2.710	2.726	0.016	0.005	0.005
L1-81	2.709	2.725	0.016	0.005	0.006
L1-126	2.708	2.725	0.017	0.006	0.008
L1-171	2.707	2.726	0.019	0.006	0.008
L1-216	2.707	2.725	0.018	0.004	0.006
L1-261	2.708	2.726	0.018	0.005	0.005
L1-306	2.710	2.728	0.018	0.006	0.006
L1-351	2.710	2.728	0.018	0.006	0.006
L2-36	2.709	2.733	0.024	0.004	0.003
L2-81	2.709	2.732	0.023	0.004	0.005
L2-126	2.708	2.732	0.024	0.005	0.007
L2-171	2.707	2.732	0.025	0.005	0.007
L2-216	2.707	2.732	0.025	0.004	0.006
L2-261	2.708	2.733	0.025	0.004	0.005
L2-306	2.709	2.735	0.026	0.005	0.006
L2-351	2.710	2.735	0.025	0.005	0.005
L3-36	2.709	2.734	0.025	0.004	0.003
L3-81	2.709	2.733	0.024	0.004	0.005
L3-126	2.708	2.732	0.024	0.004	0.007
L3-171	2.707	2.733	0.026	0.005	0.006
L3-216	2.708	2.734	0.026	0.004	0.005
L3-261	2.708	2.734	0.026	0.004	0.005
L3-306	2.709	2.735	0.026	0.005	0.006
L3-351	2.709	2.735	0.026	0.004	0.005
L4-36	2.709	2.733	0.024	0.003	0.003
L4-81	2.709	2.732	0.023	0.003	0.004
L4-126	2.708	2.732	0.024	0.004	0.006
L4-171	2.708	2.732	0.024	0.004	0.005
L4-216	2.708	2.733	0.025	0.003	0.004
L4-261	2.708	2.734	0.026	0.003	0.004
L4-306	2.709	2.734	0.025	0.004	0.005
L4-351	2.709	2.734	0.025	0.004	0.005
L5-36	2.709	2.733	0.024	0.003	0.002
L5-81	2.709	2.732	0.023	0.003	0.004
L5-126	2.709	2.732	0.023	0.003	0.005
L5-171	2.708	2.732	0.024	0.004	0.005
L5-216	2.708	2.733	0.025	0.002	0.003
L5-261	2.708	2.734	0.026	0.003	0.004
L5-306	2.709	2.734	0.025	0.004	0.005
*L5-351	2.710	2.735	0.025	0.003	0.004
L6-36	2.709	2.733	0.024	0.002	0.002
L6-81	2.709	2.732	0.023	0.002	0.003
L6-126	2.709	2.732	0.023	0.003	0.004

*Data based on 9 tests; Test 2 pre-test data not available.

**CYLINDER DIMENSIONAL MEASUREMENTS
MEAN AND STANDARD DEVIATION**

STATIC CRUSH TEST

<u>MEASUREMENT DESIGNATION</u>	<u>MEAN</u>			<u>STANDARD DEVIATION</u>	
	<u>PRE-TEST</u>	<u>POST-TEST</u>	<u>NET CHANGE</u>	<u>PRE-TEST</u>	<u>POST-TEST</u>
L6-171	2.708	2.732	0.024	0.003	0.004
L6-216	2.709	2.733	0.024	0.002	0.003
L6-261	2.709	2.734	0.025	0.002	0.004
L6-306	2.709	2.734	0.025	0.003	0.004
L6-351	2.709	2.734	0.025	0.003	0.003
L7-36	2.709	2.733	0.024	0.002	0.002
L7-81	2.709	2.732	0.023	0.002	0.002
L7-126	2.709	2.732	0.023	0.002	0.003
L7-171	2.709	2.732	0.023	0.002	0.003
L7-216	2.709	2.733	0.024	0.001	0.003
L7-261	2.709	2.734	0.025	0.002	0.003
L7-306	2.709	2.735	0.025	0.003	0.004
L7-351	2.709	2.734	0.025	0.002	0.003
L8-36	2.709	2.733	0.024	0.002	0.002
L8-81	2.709	2.732	0.023	0.001	0.002
L8-126	2.709	2.732	0.023	0.002	0.003
L8-171	2.709	2.732	0.023	0.002	0.003
L8-216	2.709	2.733	0.024	0.001	0.002
L8-261	2.709	2.734	0.025	0.001	0.003
L8-306	2.709	2.734	0.025	0.002	0.004
L8-351	2.709	2.734	0.025	0.002	0.003
L9-36	2.709	2.733	0.024	0.001	0.002
L9-81	2.709	2.732	0.023	0.001	0.002
L9-126	2.709	2.732	0.023	0.001	0.002
L9-171	2.709	2.733	0.024	0.001	0.002
L9-216	2.709	2.733	0.024	0.001	0.002
L9-261	2.709	2.733	0.024	0.001	0.003
L9-306	2.709	2.734	0.025	0.002	0.003
L9-351	2.709	2.734	0.025	0.001	0.003
L10-36	2.709	2.733	0.024	0.001	0.002
L10-81	2.709	2.733	0.024	0.001	0.002
L10-126	2.710	2.733	0.023	0.001	0.002
L10-171	2.709	2.733	0.024	0.001	0.002
L10-216	2.709	2.733	0.024	0.001	0.002
L10-261	2.709	2.734	0.025	0.001	0.002
L10-306	2.709	2.734	0.025	0.001	0.002
L10-351	2.709	2.734	0.025	0.001	0.003
L11-36	2.709	2.734	0.025	0.001	0.003
L11-81	2.709	2.734	0.025	0.001	0.002
L11-126	2.709	2.734	0.025	0.001	0.002
L11-171	2.710	2.734	0.024	0.001	0.002
L11-216	2.709	2.734	0.025	0.001	0.002

**CYLINDER DIMENSIONAL MEASUREMENTS
MEAN AND STANDARD DEVIATION**

STATIC CRUSH TEST

<u>MEASUREMENT DESIGNATION</u>	<u>MEAN</u>			<u>STANDARD DEVIATION</u>	
	<u>PRE-TEST</u>	<u>POST-TEST</u>	<u>NET CHANGE</u>	<u>PRE-TEST</u>	<u>POST-TEST</u>
L11-261	2.709	2.734	0.025	0.001	0.002
L11-306	2.709	2.734	0.025	0.001	0.002
L11-351	2.709	2.734	0.025	0.001	0.002
L12-36	2.709	2.734	0.025	0.001	0.003
L12-81	2.709	2.733	0.024	0.001	0.002
L12-126	2.710	2.733	0.023	0.001	0.002
L12-171	2.710	2.733	0.023	0.001	0.002
L12-216	2.709	2.733	0.024	0.001	0.002
L12-261	2.709	2.734	0.025	0.001	0.002
L12-306	2.709	2.733	0.024	0.002	0.002
L12-351	2.709	2.734	0.025	0.001	0.002
L13-36	2.709	2.725	0.016	0.001	0.003
L13-81	2.709	2.725	0.016	0.001	0.002
L13-126	2.710	2.724	0.014	0.002	0.002
L13-171	2.710	2.725	0.015	0.001	0.002
L13-216	2.709	2.725	0.016	0.001	0.003
L13-261	2.709	2.725	0.016	0.001	0.002
L13-306	2.709	2.725	0.016	0.002	0.002
L13-351	2.708	2.725	0.017	0.002	0.002
L14-36	24.007	23.565	-0.442	0.009	0.011
L14-81	24.007	23.565	-0.442	0.008	0.011
L14-126	24.008	23.566	-0.442	0.009	0.011
L14-171	24.008	23.566	-0.442	0.009	0.011
L14-216	24.008	23.566	-0.442	0.009	0.011
L14-261	24.008	23.566	-0.442	0.009	0.012
L14-306	24.007	23.565	-0.442	0.009	0.012
L14-351	24.007	23.565	-0.442	0.009	0.011

APPENDIX C

END IMPACT DIMENSIONAL INSPECTION DATA

**CYLINDER
DIMENSIONAL INSPECTION DATA**

END IMPACT, TEST 1

<u>MEASUREMENT DESIGNATION</u>	<u>PRE-TEST</u>	<u>POST-TEST</u>	<u>MEASUREMENT CHANGE</u>
L1-36	2.705	2.709	0.004
L1-81	2.705	2.709	0.004
L1-126	2.701	2.709	0.008
L1-171	2.698	2.709	0.011
L1-216	2.701	2.709	0.008
L1-261	2.703	2.708	0.005
L1-306	2.703	2.707	0.004
L1-351	2.704	2.707	0.003
L2-36	2.707	2.709	0.002
L2-81	2.706	2.710	0.004
L2-126	2.703	2.711	0.008
L2-171	2.701	2.709	0.008
L2-216	2.703	2.707	0.004
L2-261	2.706	2.705	-0.001
L2-306	2.706	2.703	-0.003
L2-351	2.707	2.704	-0.003
L3-36	2.708	2.715	0.007
L3-81	2.707	2.715	0.008
L3-126	2.705	2.711	0.006
L3-171	2.703	2.708	0.005
L3-216	2.706	2.706	0.000
L3-261	2.707	2.707	0.000
L3-306	2.708	2.707	-0.001
L3-351	2.708	2.712	0.004
L4-36	2.709	2.732	0.023
L4-81	2.708	2.715	0.007
L4-126	2.707	2.695	-0.012
L4-171	2.706	2.690	-0.016
L4-216	2.707	2.700	-0.007
L4-261	2.708	2.718	0.010
L4-306	2.709	2.724	0.015
L4-351	2.709	2.739	0.030
L5-36	2.709	2.732	0.023
L5-81	2.708	2.715	0.007
L5-126	2.707	2.695	-0.012
L5-171	2.707	2.689	-0.018
L5-216	2.707	2.699	-0.008
L5-261	2.708	2.718	0.010
L5-306	2.709	2.724	0.015
L5-351	2.709	2.740	0.031
L6-36	2.709	2.732	0.023
L6-81	2.708	2.715	0.007
L6-126	2.707	2.695	-0.012

**CYLINDER
DIMENSIONAL INSPECTION DATA**

END IMPACT, TEST 1

<u>MEASUREMENT DESIGNATION</u>	<u>PRE-TEST</u>	<u>POST-TEST</u>	<u>MEASUREMENT CHANGE</u>
L6-171	2.707	2.689	-0.018
L6-216	2.707	2.699	-0.008
L6-261	2.709	2.718	0.009
L6-306	2.709	2.737	0.028
L6-351	2.709	2.742	0.033
L7-36	2.709	2.733	0.024
L7-81	2.708	2.716	0.008
L7-126	2.708	2.694	-0.014
L7-171	2.708	2.691	-0.017
L7-216	2.708	2.699	-0.009
L7-261	2.709	2.718	0.009
L7-306	2.709	2.735	0.026
L7-351	2.709	2.740	0.031
L8-36	2.709	2.734	0.025
L8-81	2.709	2.716	0.007
L8-126	2.708	2.696	-0.012
L8-171	2.708	2.692	-0.016
L8-216	2.708	2.700	-0.008
L8-261	2.709	2.716	0.007
L8-306	2.709	2.734	0.025
L8-351	2.709	2.740	0.031
L9-36	2.709	2.733	0.024
L9-81	2.709	2.717	0.008
L9-126	2.708	2.700	-0.008
L9-171	2.708	2.696	-0.012
L9-216	2.708	2.701	-0.007
L9-261	2.709	2.713	0.004
L9-306	2.709	2.732	0.023
L9-351	2.709	2.738	0.029
L10-36	2.709	2.732	0.023
L10-81	2.709	2.718	0.009
L10-126	2.709	2.701	-0.008
L10-171	2.708	2.700	-0.008
L10-216	2.709	2.703	-0.006
L10-261	2.709	2.710	0.001
L10-306	2.710	2.730	0.020
L10-351	2.709	2.736	0.027
L11-36	2.709	2.731	0.022
L11-81	2.709	2.719	0.010
L11-126	2.709	2.705	-0.004
L11-171	2.709	2.702	-0.007
L11-216	2.709	2.704	-0.005
L11-261	2.709	2.709	0.000

**CYLINDER
DIMENSIONAL INSPECTION DATA**

END IMPACT, TEST 1

<u>MEASUREMENT DESIGNATION</u>	<u>PRE-TEST</u>	<u>POST-TEST</u>	<u>MEASUREMENT CHANGE</u>
L11-306	2.710	2.727	0.017
L11-351	2.710	2.733	0.023
L12-36	2.709	2.730	0.021
L12-81	2.709	2.721	0.012
L12-126	2.709	2.707	-0.002
L12-171	2.709	2.705	-0.004
L12-216	2.709	2.705	-0.004
L12-261	2.709	2.708	-0.001
L12-306	2.710	2.725	0.015
L12-351	2.710	2.731	0.021
L13-36	2.709	2.730	0.021
L13-81	2.709	2.720	0.011
L13-126	2.709	2.710	0.001
L13-171	2.709	2.707	-0.002
L13-216	2.709	2.706	-0.003
L13-261	2.710	2.708	-0.002
L13-306	2.710	2.723	0.013
L13-351	2.710	2.730	0.020
L14-36	2.709	2.729	0.020
L14-81	2.709	2.721	0.012
L14-126	2.709	2.712	0.003
L14-171	2.709	2.709	0.000
L14-216	2.709	2.707	-0.002
L14-261	2.710	2.707	-0.003
L14-306	2.710	2.720	0.010
L14-351	2.709	2.727	0.018
L15-36	2.709	2.728	0.019
L15-81	2.709	2.722	0.013
L15-126	2.710	2.715	0.005
L15-171	2.709	2.711	0.002
L15-216	2.709	2.709	0.000
L15-261	2.710	2.706	-0.004
L15-306	2.710	2.718	0.008
L15-351	2.709	2.724	0.015
L16-36	2.709	2.726	0.017
L16-81	2.709	2.724	0.015
L16-126	2.710	2.717	0.007
L16-171	2.709	2.713	0.004
L16-216	2.710	2.710	0.000
L16-261	2.710	2.703	-0.007
L16-306	2.710	2.715	0.005
L16-351	2.709	2.721	0.012
L17-36	2.709	2.726	0.017

**CYLINDER
DIMENSIONAL INSPECTION DATA**

END IMPACT, TEST 1

<u>MEASUREMENT DESIGNATION</u>	<u>PRE-TEST</u>	<u>POST-TEST</u>	<u>MEASUREMENT CHANGE</u>
L17-81	2.709	2.726	0.017
L17-126	2.710	2.720	0.010
L17-171	2.710	2.716	0.006
L17-216	2.710	2.710	0.000
L17-261	2.710	2.704	-0.006
L17-306	2.710	2.712	0.002
L17-351	2.709	2.715	0.006
L18-36	2.709	2.723	0.014
L18-81	2.709	2.727	0.018
L18-126	2.710	2.722	0.012
L18-171	2.710	2.719	0.009
L18-216	2.710	2.710	0.000
L18-261	2.710	2.703	-0.007
L18-306	2.710	2.710	0.000
L18-351	2.709	2.712	0.003
L19-36	2.709	2.722	0.013
L19-81	2.710	2.727	0.017
L19-126	2.710	2.724	0.014
L19-171	2.710	2.720	0.010
L19-216	2.710	2.709	-0.001
L19-261	2.710	2.702	-0.008
L19-306	2.710	2.706	-0.004
L19-351	2.710	2.710	0.000
L20-36	2.709	2.721	0.012
L20-81	2.710	2.726	0.016
L20-126	2.710	2.725	0.015
L20-171	2.710	2.721	0.011
L20-216	2.710	2.707	-0.003
L20-261	2.710	2.700	-0.010
L20-306	2.710	2.703	-0.007
L20-351	2.710	2.707	-0.003
L21-36	2.709	2.719	0.010
L21-81	2.710	2.726	0.016
L21-126	2.710	2.725	0.015
L21-171	2.710	2.721	0.011
L21-216	2.710	2.706	-0.004
L21-261	2.710	2.699	-0.011
L21-306	2.710	2.701	-0.009
L21-351	2.710	2.706	-0.004
L22-36	2.709	2.718	0.009
L22-81	2.710	2.723	0.013
L22-126	2.710	2.723	0.013
L22-171	2.710	2.720	0.010

**CYLINDER
DIMENSIONAL INSPECTION DATA**

END IMPACT, TEST 1

<u>MEASUREMENT DESIGNATION</u>	<u>PRE-TEST</u>	<u>POST-TEST</u>	<u>MEASUREMENT CHANGE</u>
L22-216	2.710	2.706	-0.004
L22-261	2.710	2.699	-0.011
L22-306	2.710	2.699	-0.011
L22-351	2.710	2.703	-0.007
L23-36	45.014	44.857	-0.157
L23-81	45.012	44.827	-0.185
L23-126	45.009	44.788	-0.221
L23-171	45.008	44.739	-0.269
L23-216	45.008	44.785	-0.223
L23-261	45.007	44.804	-0.203
L23-306	45.010	44.821	-0.189
L23-351	45.013	44.846	-0.167

**CYLINDER
DIMENSIONAL INSPECTION DATA**

END IMPACT, TEST 2

<u>MEASUREMENT DESIGNATION</u>	<u>PRE-TEST</u>	<u>POST-TEST</u>	<u>MEASUREMENT CHANGE</u>
L1-36	2.704	2.709	0.005
L1-81	2.705	2.710	0.005
L1-126	2.701	2.710	0.009
L1-171	2.700	2.710	0.010
L1-216	2.707	2.709	0.002
L1-261	2.710	2.709	-0.001
L1-306	2.707	2.709	0.002
L1-351	2.705	2.709	0.004
L2-36	2.706	2.709	0.003
L2-81	2.706	2.705	-0.001
L2-126	2.704	2.704	0.000
L2-171	2.703	2.705	0.002
L2-216	2.708	2.709	0.001
L2-261	2.710	2.699	-0.011
L2-306	2.709	2.696	-0.013
L2-351	2.707	2.711	0.004
L3-36	2.708	2.711	0.003
L3-81	2.707	2.709	0.002
L3-126	2.707	2.710	0.003
L3-171	2.705	2.711	0.006
L3-216	2.709	2.714	0.005
L3-261	2.710	2.692	-0.018
L3-306	2.710	2.683	-0.027
L3-351	2.708	2.715	0.007
L4-36	2.710	2.709	-0.001
L4-81	2.709	2.723	0.014
L4-126	2.708	2.737	0.029
L4-171	2.707	2.742	0.035
L4-216	2.710	2.731	0.021
L4-261	2.709	2.679	-0.030
L4-306	2.710	2.651	-0.059
L4-351	2.709	2.695	-0.014
L5-36	2.710	2.708	-0.002
L5-81	2.709	2.725	0.016
L5-126	2.708	2.739	0.031
L5-171	2.708	2.743	0.035
L5-216	2.710	2.731	0.021
L5-261	2.709	2.674	-0.035
L5-306	2.710	2.649	-0.061
L5-351	2.709	2.694	-0.015
L6-36	2.710	2.707	-0.003
L6-81	2.709	2.725	0.016
L6-126	2.708	2.740	0.032

**CYLINDER
DIMENSIONAL INSPECTION DATA**

END IMPACT, TEST 2

<u>MEASUREMENT DESIGNATION</u>	<u>PRE-TEST</u>	<u>POST-TEST</u>	<u>MEASUREMENT CHANGE</u>
L6-171	2.708	2.745	0.037
L6-216	2.710	2.732	0.022
L6-261	2.709	2.677	-0.032
L6-306	2.710	2.644	-0.066
L6-351	2.709	2.694	-0.015
L7-36	2.710	2.707	-0.003
L7-81	2.709	2.724	0.015
L7-126	2.709	2.740	0.031
L7-171	2.709	2.745	0.036
L7-216	2.710	2.733	0.023
L7-261	2.709	2.676	-0.033
L7-306	2.710	2.745	0.035
L7-351	2.709	2.695	-0.014
L8-36	2.710	2.708	-0.002
L8-81	2.709	2.723	0.014
L8-126	2.709	2.738	0.029
L8-171	2.709	2.746	0.037
L8-216	2.710	2.732	0.022
L8-261	2.709	2.675	-0.034
L8-306	2.710	2.646	-0.064
L8-351	2.709	2.698	-0.011
L9-36	2.710	2.709	-0.001
L9-81	2.709	2.720	0.011
L9-126	2.709	2.736	0.027
L9-171	2.709	2.744	0.035
L9-216	2.710	2.731	0.021
L9-261	2.709	2.675	-0.034
L9-306	2.710	2.647	-0.063
L9-351	2.709	2.701	-0.008
L10-36	2.710	2.710	0.000
L10-81	2.710	2.719	0.009
L10-126	2.710	2.734	0.024
L10-171	2.710	2.741	0.031
L10-216	2.710	2.731	0.021
L10-261	2.709	2.675	-0.034
L10-306	2.710	2.649	-0.061
L10-351	2.709	2.705	-0.004
L11-36	2.710	2.712	0.002
L11-81	2.710	2.718	0.008
L11-126	2.710	2.732	0.022
L11-171	2.710	2.740	0.030
L11-216	2.710	2.730	0.020
L11-261	2.709	2.675	-0.034

**CYLINDER
DIMENSIONAL INSPECTION DATA**

END IMPACT, TEST 2

<u>MEASUREMENT DESIGNATION</u>	<u>PRE-TEST</u>	<u>POST-TEST</u>	<u>MEASUREMENT CHANGE</u>
L11-306	2.710	2.649	-0.061
L11-351	2.710	2.707	-0.003
L12-36	2.710	2.713	0.003
L12-81	2.710	2.716	0.006
L12-126	2.710	2.731	0.021
L12-171	2.710	2.739	0.029
L12-216	2.710	2.729	0.019
L12-261	2.709	2.677	-0.032
L12-306	2.710	2.651	-0.059
L12-351	2.710	2.710	0.000
L13-36	2.710	2.715	0.005
L13-81	2.710	2.716	0.006
L13-126	2.710	2.730	0.020
L13-171	2.710	2.737	0.027
L13-216	2.710	2.729	0.019
L13-261	2.709	2.677	-0.032
L13-306	2.710	2.652	-0.058
L13-351	2.710	2.712	0.002
L14-36	2.710	2.716	0.006
L14-81	2.710	2.716	0.006
L14-126	2.710	2.728	0.018
L14-171	2.710	2.736	0.026
L14-216	2.710	2.727	0.017
L14-261	2.709	2.678	-0.031
L14-306	2.710	2.654	-0.056
L14-351	2.710	2.714	0.004
L15-36	2.710	2.718	0.008
L15-81	2.710	2.715	0.005
L15-126	2.710	2.724	0.014
L15-171	2.710	2.733	0.023
L15-216	2.710	2.726	0.016
L15-261	2.709	2.680	-0.029
L15-306	2.710	2.657	-0.053
L15-351	2.710	2.716	0.006
L16-36	2.710	2.719	0.009
L16-81	2.710	2.714	0.004
L16-126	2.710	2.722	0.012
L16-171	2.710	2.727	0.017
L16-216	2.710	2.725	0.015
L16-261	2.709	2.680	-0.029
L16-306	2.710	2.658	-0.052
L16-351	2.710	2.719	0.009
L17-36	2.710	2.720	0.010

**CYLINDER
DIMENSIONAL INSPECTION DATA**

END IMPACT, TEST 2

<u>MEASUREMENT DESIGNATION</u>	<u>PRE-TEST</u>	<u>POST-TEST</u>	<u>MEASUREMENT CHANGE</u>
L17-81	2.710	2.712	0.002
L17-126	2.710	2.719	0.009
L17-171	2.710	2.724	0.014
L17-216	2.710	2.723	0.013
L17-261	2.709	2.682	-0.027
L17-306	2.710	2.659	-0.051
L17-351	2.710	2.721	0.011
L18-36	2.710	2.720	0.010
L18-81	2.710	2.711	0.001
L18-126	2.710	2.715	0.005
L18-171	2.710	2.722	0.012
L18-216	2.710	2.721	0.011
L18-261	2.708	2.681	-0.027
L18-306	2.710	2.660	-0.050
L18-351	2.710	2.722	0.012
L19-36	2.710	2.720	0.010
L19-81	2.710	2.711	0.001
L19-126	2.710	2.712	0.002
L19-171	2.710	2.719	0.009
L19-216	2.710	2.720	0.010
L19-261	2.708	2.680	-0.028
L19-306	2.710	2.660	-0.050
L19-351	2.710	2.721	0.011
L20-36	2.710	2.719	0.009
L20-81	2.710	2.709	-0.001
L20-126	2.710	2.707	-0.003
L20-171	2.710	2.714	0.004
L20-216	2.710	2.718	0.008
L20-261	2.709	2.677	-0.032
L20-306	2.710	2.660	-0.050
L20-351	2.710	2.724	0.014
L21-36	2.710	2.716	0.006
L21-81	2.710	2.711	0.001
L21-126	2.710	2.704	-0.006
L21-171	2.710	2.711	0.001
L21-216	2.710	2.717	0.007
L21-261	2.709	2.677	-0.032
L21-306	2.710	2.662	-0.048
L21-351	2.710	2.724	0.014
L22-36	2.710	2.717	0.007
L22-81	2.710	2.710	0.000
L22-126	2.710	2.703	-0.007
L22-171	2.710	2.709	-0.001

**CYLINDER
DIMENSIONAL INSPECTION DATA**

END IMPACT, TEST 2

<u>MEASUREMENT DESIGNATION</u>	<u>PRE-TEST</u>	<u>POST-TEST</u>	<u>MEASUREMENT CHANGE</u>
L22-216	2.710	2.716	0.006
L22-261	2.709	2.675	-0.034
L22-306	2.710	2.657	-0.053
L22-351	2.710	2.724	0.014
L23-36	44.977	44.747	-0.230
L23-81	44.976	44.773	-0.203
L23-126	44.975	44.795	-0.180
L23-171	44.974	44.814	-0.160
L23-216	44.973	44.826	-0.147
L23-261	44.973	44.791	-0.182
L23-306	44.974	44.735	-0.239
L23-351	44.976	44.715	-0.261

**CYLINDER
DIMENSIONAL INSPECTION DATA**

END IMPACT, TEST 3

<u>MEASUREMENT DESIGNATION</u>	<u>PRE-TEST</u>	<u>POST-TEST</u>	<u>MEASUREMENT CHANGE</u>
L1-36	2.698	2.709	0.011
L1-81	2.703	2.709	0.006
L1-126	2.711	2.709	-0.002
L1-171	2.710	2.708	-0.002
L1-216	2.703	2.708	0.005
L1-261	2.699	2.708	0.009
L1-306	2.699	2.709	0.010
L1-351	2.699	2.709	0.010
L2-36	2.704	2.707	0.003
L2-81	2.706	2.706	0.000
L2-126	2.711	2.707	-0.004
L2-171	2.710	2.708	-0.002
L2-216	2.704	2.710	0.006
L2-261	2.701	2.710	0.009
L2-306	2.701	2.710	0.009
L2-351	2.703	2.708	0.005
L3-36	2.705	2.710	0.005
L3-81	2.708	2.705	-0.003
L3-126	2.711	2.704	-0.007
L3-171	2.709	2.706	-0.003
L3-216	2.705	2.712	0.007
L3-261	2.703	2.717	0.014
L3-306	2.704	2.719	0.015
L3-351	2.704	2.716	0.012
L4-36	2.707	2.725	0.018
L4-81	2.709	2.700	-0.009
L4-126	2.710	2.686	-0.024
L4-171	2.709	2.689	-0.020
L4-216	2.707	2.709	0.002
L4-261	2.706	2.731	0.025
L4-306	2.706	2.748	0.042
L4-351	2.708	2.744	0.036
L5-36	2.708	2.724	0.016
L5-81	2.709	2.700	-0.009
L5-126	2.710	2.685	-0.025
L5-171	2.709	2.688	-0.021
L5-216	2.707	2.708	0.001
L5-261	2.706	2.732	0.026
L5-306	2.707	2.750	0.043
L5-351	2.708	2.746	0.038
L6-36	2.708	2.725	0.017
L6-81	2.709	2.700	-0.009
L6-126	2.710	2.685	-0.025

**CYLINDER
DIMENSIONAL INSPECTION DATA**

END IMPACT, TEST 3

<u>MEASUREMENT DESIGNATION</u>	<u>PRE-TEST</u>	<u>POST-TEST</u>	<u>MEASUREMENT CHANGE</u>
L6-171	2.709	2.688	-0.021
L6-216	2.708	2.708	0.000
L6-261	2.707	2.734	0.027
L6-306	2.707	2.751	0.044
L6-351	2.708	2.747	0.039
L7-36	2.709	2.726	0.017
L7-81	2.709	2.699	-0.010
L7-126	2.710	2.686	-0.024
L7-171	2.709	2.690	-0.019
L7-216	2.708	2.709	0.001
L7-261	2.707	2.734	0.027
L7-306	2.707	2.752	0.045
L7-351	2.708	2.748	0.040
L8-36	2.709	2.725	0.016
L8-81	2.709	2.698	-0.011
L8-126	2.710	2.687	-0.023
L8-171	2.709	2.692	-0.017
L8-216	2.708	2.710	0.002
L8-261	2.708	2.734	0.026
L8-306	2.707	2.750	0.043
L8-351	2.709	2.748	0.039
L9-36	2.709	2.724	0.015
L9-81	2.709	2.698	-0.011
L9-126	2.710	2.688	-0.022
L9-171	2.709	2.695	-0.014
L9-216	2.708	2.712	0.004
L9-261	2.708	2.732	0.024
L9-306	2.707	2.751	0.044
L9-351	2.709	2.747	0.038
L10-36	2.709	2.721	0.012
L10-81	2.709	2.698	-0.011
L10-126	2.710	2.692	-0.018
L10-171	2.709	2.699	-0.010
L10-216	2.709	2.714	0.005
L10-261	2.708	2.730	0.022
L10-306	2.708	2.747	0.039
L10-351	2.709	2.746	0.037
L11-36	2.710	2.720	0.010
L11-81	2.709	2.698	-0.011
L11-126	2.710	2.692	-0.018
L11-171	2.709	2.701	-0.008
L11-216	2.709	2.715	0.006
L11-261	2.708	2.730	0.022

**CYLINDER
DIMENSIONAL INSPECTION DATA**

END IMPACT, TEST 3

<u>MEASUREMENT DESIGNATION</u>	<u>PRE-TEST</u>	<u>POST-TEST</u>	<u>MEASUREMENT CHANGE</u>
L11-306	2.708	2.745	0.037
L11-351	2.709	2.743	0.034
L12-36	2.710	2.719	0.009
L12-81	2.709	2.699	-0.010
L12-126	2.710	2.694	-0.016
L12-171	2.709	2.704	-0.005
L12-216	2.709	2.717	0.008
L12-261	2.709	2.729	0.020
L12-306	2.708	2.744	0.036
L12-351	2.710	2.742	0.032
L13-36	2.710	2.718	0.008
L13-81	2.709	2.700	-0.009
L13-126	2.710	2.696	-0.014
L13-171	2.709	2.706	-0.003
L13-216	2.709	2.718	0.009
L13-261	2.709	2.728	0.019
L13-306	2.708	2.742	0.034
L13-351	2.710	2.739	0.029
L14-36	2.710	2.716	0.006
L14-81	2.709	2.701	-0.008
L14-126	2.710	2.699	-0.011
L14-171	2.709	2.708	-0.001
L14-216	2.709	2.720	0.011
L14-261	2.709	2.728	0.019
L14-306	2.709	2.740	0.031
L14-351	2.710	2.738	0.028
L15-36	2.710	2.714	0.004
L15-81	2.709	2.701	-0.008
L15-126	2.710	2.702	-0.008
L15-171	2.709	2.708	-0.001
L15-216	2.709	2.722	0.013
L15-261	2.709	2.727	0.018
L15-306	2.709	2.737	0.028
L15-351	2.710	2.737	0.027
L16-36	2.710	2.712	0.002
L16-81	2.710	2.704	-0.006
L16-126	2.710	2.703	-0.007
L16-171	2.709	2.714	0.005
L16-216	2.709	2.724	0.015
L16-261	2.709	2.728	0.019
L16-306	2.709	2.736	0.027
L16-351	2.710	2.731	0.021
L17-36	2.710	2.711	0.001

**CYLINDER
DIMENSIONAL INSPECTION DATA**

END IMPACT, TEST 3

<u>MEASUREMENT DESIGNATION</u>	<u>PRE-TEST</u>	<u>POST-TEST</u>	<u>MEASUREMENT CHANGE</u>
L17-81	2.710	2.704	-0.006
L17-126	2.710	2.704	-0.006
L17-171	2.709	2.715	0.006
L17-216	2.709	2.725	0.016
L17-261	2.709	2.728	0.019
L17-306	2.709	2.733	0.024
L17-351	2.710	2.730	0.020
L18-36	2.710	2.709	-0.001
L18-81	2.710	2.705	-0.005
L18-126	2.710	2.706	-0.004
L18-171	2.709	2.716	0.007
L18-216	2.709	2.726	0.017
L18-261	2.709	2.728	0.019
L18-306	2.709	2.730	0.021
L18-351	2.711	2.727	0.016
L19-36	2.710	2.707	-0.003
L19-81	2.710	2.705	-0.005
L19-126	2.710	2.707	-0.003
L19-171	2.709	2.716	0.007
L19-216	2.709	2.726	0.017
L19-261	2.710	2.728	0.018
L19-306	2.709	2.729	0.020
L19-351	2.711	2.725	0.014
L20-36	2.711	2.706	-0.005
L20-81	2.710	2.705	-0.005
L20-126	2.710	2.709	-0.001
L20-171	2.709	2.717	0.008
L20-216	2.709	2.725	0.016
L20-261	2.710	2.726	0.016
L20-306	2.709	2.725	0.016
L20-351	2.711	2.719	0.008
L21-36	2.711	2.704	-0.007
L21-81	2.710	2.704	-0.006
L21-126	2.710	2.710	0.000
L21-171	2.709	2.717	0.008
L21-216	2.710	2.724	0.014
L21-261	2.710	2.726	0.016
L21-306	2.709	2.722	0.013
L21-351	2.711	2.718	0.007
L22-36	2.711	2.706	-0.005
L22-81	2.710	2.704	-0.006
L22-126	2.710	2.708	-0.002
L22-171	2.709	2.715	0.006

**CYLINDER
DIMENSIONAL INSPECTION DATA**

END IMPACT, TEST 3

<u>MEASUREMENT DESIGNATION</u>	<u>PRE-TEST</u>	<u>POST-TEST</u>	<u>MEASUREMENT CHANGE</u>
L22-216	2.710	2.724	0.014
L22-261	2.710	2.730	0.020
L22-306	2.709	2.718	0.009
L22-351	2.711	2.714	0.003
L23-36	45.009	44.831	-0.178
L23-81	45.008	44.771	-0.237
L23-126	45.006	44.733	-0.273
L23-171	45.004	44.764	-0.240
L23-216	45.005	44.777	-0.228
L23-261	45.005	44.797	-0.208
L23-306	45.007	44.847	-0.160
L23-351	45.009	44.840	-0.169

**CYLINDER
DIMENSIONAL INSPECTION DATA**

END IMPACT, TEST 4

<u>MEASUREMENT DESIGNATION</u>	<u>PRE-TEST</u>	<u>POST-TEST</u>	<u>MEASUREMENT CHANGE</u>
L1-36	2.705	2.709	0.004
L1-81	2.697	2.708	0.011
L1-126	2.694	2.708	0.014
L1-171	2.702	2.708	0.006
L1-216	2.710	2.708	-0.002
L1-261	2.717	2.709	-0.008
L1-306	2.718	2.709	-0.009
L1-351	2.713	2.709	-0.004
L2-36	2.708	2.713	0.005
L2-81	2.700	2.713	0.013
L2-126	2.698	2.713	0.015
L2-171	2.704	2.707	0.003
L2-216	2.711	2.702	-0.009
L2-261	2.716	2.701	-0.015
L2-306	2.717	2.704	-0.013
L2-351	2.714	2.709	-0.005
L3-36	2.709	2.721	0.012
L3-81	2.704	2.721	0.017
L3-126	2.701	2.715	0.014
L3-171	2.706	2.706	0.000
L3-216	2.711	2.699	-0.012
L3-261	2.715	2.701	-0.014
L3-306	2.714	2.710	-0.004
L3-351	2.714	2.720	0.006
L4-36	2.710	2.742	0.032
L4-81	2.708	2.725	0.017
L4-126	2.706	2.707	0.001
L4-171	2.709	2.691	-0.018
L4-216	2.711	2.692	-0.019
L4-261	2.714	2.708	-0.006
L4-306	2.714	2.731	0.017
L4-351	2.713	2.744	0.031
L5-36	2.710	2.744	0.034
L5-81	2.708	2.725	0.017
L5-126	2.707	2.706	-0.001
L5-171	2.709	2.690	-0.019
L5-216	2.711	2.691	-0.020
L5-261	2.714	2.709	-0.005
L5-306	2.714	2.733	0.019
L5-351	2.713	2.745	0.032
L6-36	2.710	2.745	0.035
L6-81	2.709	2.726	0.017
L6-126	2.707	2.706	-0.001

**CYLINDER
DIMENSIONAL INSPECTION DATA**

END IMPACT, TEST 4

<u>MEASUREMENT DESIGNATION</u>	<u>PRE-TEST</u>	<u>POST-TEST</u>	<u>MEASUREMENT CHANGE</u>
L6-171	2.710	2.691	-0.019
L6-216	2.711	2.691	-0.020
L6-261	2.712	2.709	-0.003
L6-306	2.714	2.733	0.019
L6-351	2.713	2.747	0.034
L7-36	2.711	2.745	0.034
L7-81	2.709	2.726	0.017
L7-126	2.708	2.706	-0.002
L7-171	2.710	2.691	-0.019
L7-216	2.711	2.691	-0.020
L7-261	2.712	2.708	-0.004
L7-306	2.714	2.731	0.017
L7-351	2.713	2.748	0.035
L8-36	2.711	2.746	0.035
L8-81	2.709	2.726	0.017
L8-126	2.708	2.707	-0.001
L8-171	2.710	2.692	-0.018
L8-216	2.711	2.692	-0.019
L8-261	2.712	2.707	-0.005
L8-306	2.713	2.732	0.019
L8-351	2.713	2.748	0.035
L9-36	2.711	2.746	0.035
L9-81	2.710	2.727	0.017
L9-126	2.709	2.708	-0.001
L9-171	2.710	2.695	-0.015
L9-216	2.711	2.692	-0.019
L9-261	2.712	2.706	-0.006
L9-306	2.713	2.730	0.017
L9-351	2.712	2.746	0.034
L10-36	2.711	2.746	0.035
L10-81	2.710	2.727	0.017
L10-126	2.709	2.712	0.003
L10-171	2.710	2.697	-0.013
L10-216	2.712	2.693	-0.019
L10-261	2.712	2.703	-0.009
L10-306	2.713	2.728	0.015
L10-351	2.712	2.745	0.033
L11-36	2.711	2.745	0.034
L11-81	2.711	2.727	0.016
L11-126	2.709	2.712	0.003
L11-171	2.710	2.698	-0.012
L11-216	2.712	2.694	-0.018
L11-261	2.712	2.702	-0.010

**CYLINDER
DIMENSIONAL INSPECTION DATA**

END IMPACT, TEST 4

<u>MEASUREMENT DESIGNATION</u>	<u>PRE-TEST</u>	<u>POST-TEST</u>	<u>MEASUREMENT CHANGE</u>
L11-306	2.713	2.726	0.013
L11-351	2.712	2.744	0.032
L12-36	2.711	2.745	0.034
L12-81	2.711	2.729	0.018
L12-126	2.710	2.713	0.003
L12-171	2.710	2.700	-0.010
L12-216	2.712	2.695	-0.017
L12-261	2.711	2.701	-0.010
L12-306	2.712	2.725	0.013
L12-351	2.712	2.744	0.032
L13-36	2.711	2.744	0.033
L13-81	2.711	2.730	0.019
L13-126	2.710	2.715	0.005
L13-171	2.711	2.703	-0.008
L13-216	2.712	2.696	-0.016
L13-261	2.711	2.701	-0.010
L13-306	2.712	2.721	0.009
L13-351	2.712	2.742	0.030
L14-36	2.711	2.744	0.033
L14-81	2.711	2.731	0.020
L14-126	2.710	2.718	0.008
L14-171	2.711	2.703	-0.008
L14-216	2.712	2.697	-0.015
L14-261	2.711	2.700	-0.011
L14-306	2.712	2.721	0.009
L14-351	2.712	2.741	0.029
L15-36	2.711	2.743	0.032
L15-81	2.711	2.732	0.021
L15-126	2.711	2.719	0.008
L15-171	2.711	2.705	-0.006
L15-216	2.712	2.698	-0.014
L15-261	2.711	2.700	-0.011
L15-306	2.712	2.718	0.006
L15-351	2.712	2.740	0.028
L16-36	2.711	2.742	0.031
L16-81	2.711	2.730	0.019
L16-126	2.711	2.719	0.008
L16-171	2.711	2.707	-0.004
L16-216	2.712	2.697	-0.015
L16-261	2.711	2.699	-0.012
L16-306	2.712	2.718	0.006
L16-351	2.712	2.736	0.024
L17-36	2.711	2.741	0.030

**CYLINDER
DIMENSIONAL INSPECTION DATA**

END IMPACT, TEST 4

<u>MEASUREMENT DESIGNATION</u>	<u>PRE-TEST</u>	<u>POST-TEST</u>	<u>MEASUREMENT CHANGE</u>
L17-81	2.711	2.731	0.020
L17-126	2.711	2.720	0.009
L17-171	2.711	2.707	-0.004
L17-216	2.712	2.697	-0.015
L17-261	2.711	2.699	-0.012
L17-306	2.712	2.715	0.003
L17-351	2.712	2.735	0.023
L18-36	2.711	2.739	0.028
L18-81	2.711	2.731	0.020
L18-126	2.711	2.720	0.009
L18-171	2.711	2.708	-0.003
L18-216	2.712	2.696	-0.016
L18-261	2.711	2.698	-0.013
L18-306	2.711	2.714	0.003
L18-351	2.712	2.734	0.022
L19-36	2.711	2.737	0.026
L19-81	2.711	2.730	0.019
L19-126	2.711	2.720	0.009
L19-171	2.712	2.708	-0.004
L19-216	2.712	2.695	-0.017
L19-261	2.711	2.697	-0.014
L19-306	2.711	2.711	0.000
L19-351	2.712	2.731	0.019
L20-36	2.711	2.734	0.023
L20-81	2.711	2.730	0.019
L20-126	2.711	2.721	0.010
L20-171	2.712	2.707	-0.005
L20-216	2.712	2.692	-0.020
L20-261	2.711	2.694	-0.017
L20-306	2.711	2.709	-0.002
L20-351	2.711	2.725	0.014
L21-36	2.711	2.733	0.022
L21-81	2.711	2.731	0.020
L21-126	2.711	2.722	0.011
L21-171	2.712	2.707	-0.005
L21-216	2.712	2.691	-0.021
L21-261	2.710	2.693	-0.017
L21-306	2.711	2.708	-0.003
L21-351	2.711	2.725	0.014
L22-36	2.711	2.733	0.022
L22-81	2.711	2.727	0.016
L22-126	2.711	2.721	0.010
L22-171	2.712	2.705	-0.007

**CYLINDER
DIMENSIONAL INSPECTION DATA**

END IMPACT, TEST 4

<u>MEASUREMENT DESIGNATION</u>	<u>PRE-TEST</u>	<u>POST-TEST</u>	<u>MEASUREMENT CHANGE</u>
L22-216	2.712	2.690	-0.022
L22-261	2.710	2.690	-0.020
L22-306	2.711	2.704	-0.007
L22-351	2.711	2.725	0.014
L23-36	45.010	44.814	-0.196
L23-81	45.007	44.754	-0.253
L23-126	45.004	44.724	-0.280
L23-171	45.003	44.740	-0.263
L23-216	45.004	44.764	-0.240
L23-261	45.009	44.783	-0.226
L23-306	45.010	44.798	-0.212
L23-351	45.011	44.809	-0.202

**CYLINDER
DIMENSIONAL INSPECTION DATA**

END IMPACT, TEST 5

<u>MEASUREMENT DESIGNATION</u>	<u>PRE-TEST</u>	<u>POST-TEST</u>	<u>MEASUREMENT CHANGE</u>
L1-36	2.708	2.707	-0.001
L1-81	2.710	2.707	-0.003
L1-126	2.709	2.708	-0.001
L1-171	2.704	2.708	0.004
L1-216	2.701	2.709	0.008
L1-261	2.704	2.709	0.005
L1-306	2.708	2.708	0.000
L1-351	2.708	2.707	-0.001
L2-36	2.708	2.708	0.000
L2-81	2.710	2.705	-0.005
L2-126	2.710	2.704	-0.006
L2-171	2.707	2.703	-0.004
L2-216	2.704	2.705	0.001
L2-261	2.705	2.708	0.003
L2-306	2.708	2.709	0.001
L2-351	2.708	2.709	0.001
L3-36	2.708	2.718	0.010
L3-81	2.710	2.707	-0.003
L3-126	2.711	2.698	-0.013
L3-171	2.707	2.696	-0.011
L3-216	2.706	2.703	-0.003
L3-261	2.707	2.711	0.004
L3-306	2.708	2.718	0.010
L3-351	2.708	2.720	0.012
L4-36	2.708	2.740	0.032
L4-81	2.710	2.711	0.001
L4-126	2.711	2.681	-0.030
L4-171	2.708	2.672	-0.036
L4-216	2.709	2.689	-0.020
L4-261	2.709	2.717	0.008
L4-306	2.709	2.741	0.032
L4-351	2.708	2.753	0.045
L5-36	2.708	2.743	0.035
L5-81	2.710	2.712	0.002
L5-126	2.711	2.680	-0.031
L5-171	2.709	2.671	-0.038
L5-216	2.709	2.686	-0.023
L5-261	2.709	2.717	0.008
L5-306	2.709	2.743	0.034
L5-351	2.708	2.786	0.078
L6-36	2.708	2.743	0.035
L6-81	2.710	2.712	0.002

**CYLINDER
DIMENSIONAL INSPECTION DATA**

END IMPACT, TEST 5

<u>MEASUREMENT DESIGNATION</u>	<u>PRE-TEST</u>	<u>POST-TEST</u>	<u>MEASUREMENT CHANGE</u>
L6-126	2.711	2.680	-0.031
L6-171	2.709	2.670	-0.039
L6-216	2.709	2.685	-0.024
L6-261	2.709	2.717	0.008
L6-306	2.709	2.745	0.036
L6-351	2.708	2.757	0.049
L7-36	2.709	2.745	0.036
L7-81	2.710	2.712	0.002
L7-126	2.711	2.680	-0.031
L7-171	2.709	2.670	-0.039
L7-216	2.709	2.686	-0.023
L7-261	2.709	2.717	0.008
L7-306	2.710	2.743	0.033
L7-351	2.708	2.758	0.050
L8-36	2.709	2.745	0.036
L8-81	2.710	2.711	0.001
L8-126	2.711	2.680	-0.031
L8-171	2.709	2.670	-0.039
L8-216	2.710	2.687	-0.023
L8-261	2.710	2.715	0.005
L8-306	2.710	2.743	0.033
L8-351	2.708	2.758	0.050
L9-36	2.709	2.745	0.036
L9-81	2.710	2.711	0.001
L9-126	2.711	2.681	-0.030
L9-171	2.709	2.674	-0.035
L9-216	2.710	2.689	-0.021
L9-261	2.710	2.715	0.005
L9-306	2.710	2.741	0.031
L9-351	2.708	2.759	0.051
L10-36	2.709	2.744	0.035
L10-81	2.710	2.711	0.001
L10-126	2.711	2.682	-0.029
L10-171	2.709	2.677	-0.032
L10-216	2.710	2.691	-0.019
L10-261	2.710	2.712	0.002
L10-306	2.710	2.739	0.029
L10-351	2.709	2.755	0.046
L11-36	2.709	2.743	0.034
L11-81	2.710	2.711	0.001
L11-126	2.710	2.683	-0.027
L11-171	2.709	2.679	-0.030
L11-216	2.710	2.692	-0.018

**CYLINDER
DIMENSIONAL INSPECTION DATA**

END IMPACT, TEST 5

<u>MEASUREMENT DESIGNATION</u>	<u>PRE-TEST</u>	<u>POST-TEST</u>	<u>MEASUREMENT CHANGE</u>
L11-261	2.710	2.712	0.002
L11-306	2.710	2.737	0.027
L11-351	2.709	2.755	0.046
L12-36	2.709	2.742	0.033
L12-81	2.710	2.711	0.001
L12-126	2.710	2.685	-0.025
L12-171	2.709	2.681	-0.028
L12-216	2.710	2.694	-0.016
L12-261	2.710	2.712	0.002
L12-306	2.710	2.736	0.026
L12-351	2.709	2.755	0.046
L13-36	2.709	2.740	0.031
L13-81	2.710	2.711	0.001
L13-126	2.710	2.687	-0.023
L13-171	2.710	2.683	-0.027
L13-216	2.710	2.696	-0.014
L13-261	2.710	2.712	0.002
L13-306	2.710	2.734	0.024
L13-351	2.709	2.752	0.043
L14-36	2.709	2.740	0.031
L14-81	2.710	2.712	0.002
L14-126	2.710	2.689	-0.021
L14-171	2.710	2.686	-0.024
L14-216	2.710	2.698	-0.012
L14-261	2.710	2.713	0.003
L14-306	2.710	2.732	0.022
L14-351	2.709	2.752	0.043
L15-36	2.709	2.738	0.029
L15-81	2.710	2.712	0.002
L15-126	2.710	2.691	-0.019
L15-171	2.710	2.686	-0.024
L15-216	2.710	2.700	-0.010
L15-261	2.710	2.713	0.003
L15-306	2.710	2.730	0.020
L15-351	2.709	2.752	0.043
L16-36	2.709	2.735	0.026
L16-81	2.710	2.711	0.001
L16-126	2.710	2.693	-0.017
L16-171	2.710	2.689	-0.021
L16-216	2.710	2.701	-0.009
L16-261	2.710	2.713	0.003
L16-306	2.710	2.730	0.020
L16-351	2.709	2.745	0.036

**CYLINDER
DIMENSIONAL INSPECTION DATA**

END IMPACT, TEST 5

<u>MEASUREMENT DESIGNATION</u>	<u>PRE-TEST</u>	<u>POST-TEST</u>	<u>MEASUREMENT CHANGE</u>
L17-36	2.709	2.733	0.024
L17-81	2.710	2.714	0.004
L17-126	2.710	2.694	-0.016
L17-171	2.710	2.689	-0.021
L17-216	2.710	2.701	-0.009
L17-261	2.710	2.713	0.003
L17-306	2.710	2.728	0.018
L17-351	2.709	2.742	0.033
L18-36	2.709	2.732	0.023
L18-81	2.710	2.715	0.005
L18-126	2.710	2.696	-0.014
L18-171	2.710	2.690	-0.020
L18-216	2.710	2.701	-0.009
L18-261	2.711	2.713	0.002
L18-306	2.710	2.726	0.016
L18-351	2.709	2.740	0.031
L19-36	2.709	2.729	0.020
L19-81	2.710	2.715	0.005
L19-126	2.710	2.696	-0.014
L19-171	2.710	2.690	-0.020
L19-216	2.710	2.700	-0.010
L19-261	2.711	2.712	0.001
L19-306	2.710	2.723	0.013
L19-351	2.709	2.740	0.031
L20-36	2.709	2.729	0.020
L20-81	2.710	2.715	0.005
L20-126	2.710	2.696	-0.014
L20-171	2.710	2.694	-0.016
L20-216	2.710	2.698	-0.012
L20-261	2.711	2.712	0.001
L20-306	2.710	2.722	0.012
L20-351	2.709	2.739	0.030
L21-36	2.709	2.726	0.017
L21-81	2.710	2.715	0.005
L21-126	2.710	2.696	-0.014
L21-171	2.710	2.694	-0.016
L21-216	2.710	2.696	-0.014
L21-261	2.711	2.712	0.001
L21-306	2.710	2.722	0.012
L21-351	2.709	2.734	0.025
L22-36	2.709	2.725	0.016
L22-81	2.710	2.711	0.001
L22-126	2.710	2.696	-0.014

**CYLINDER
DIMENSIONAL INSPECTION DATA**

END IMPACT, TEST 5

<u>MEASUREMENT DESIGNATION</u>	<u>PRE-TEST</u>	<u>POST-TEST</u>	<u>MEASUREMENT CHANGE</u>
L22-171	2.710	2.694	-0.016
L22-216	2.710	2.697	-0.013
L22-261	2.711	2.710	-0.001
L22-306	2.710	2.721	0.011
L22-351	2.709	2.734	0.025
L23-36	45.008	44.833	-0.175
L23-81	45.008	44.794	-0.214
L23-126	45.008	44.747	-0.261
L23-171	45.009	44.747	-0.262
L23-216	45.009	44.779	-0.230
L23-261	45.010	44.795	-0.215
L23-306	45.010	44.819	-0.191
L23-351	45.009	44.838	-0.171

**CYLINDER
DIMENSIONAL INSPECTION DATA**

END IMPACT, TEST 6

<u>MEASUREMENT DESIGNATION</u>	<u>PRE-TEST</u>	<u>POST-TEST</u>	<u>MEASUREMENT CHANGE</u>
L1-36	2.706	2.707	0.001
L1-81	2.708	2.707	-0.001
L1-126	2.708	2.708	0.000
L1-171	2.706	2.708	0.002
L1-216	2.703	2.708	0.005
L1-261	2.699	2.709	0.010
L1-306	2.700	2.708	0.008
L1-351	2.703	2.707	0.004
L2-36	2.708	2.707	-0.001
L2-81	2.710	2.709	-0.001
L2-126	2.710	2.709	-0.001
L2-171	2.708	2.707	-0.001
L2-216	2.705	2.704	-0.001
L2-261	2.702	2.704	0.002
L2-306	2.703	2.702	-0.001
L2-351	2.705	2.702	-0.003
L3-36	2.709	2.715	0.006
L3-81	2.711	2.709	-0.002
L3-126	2.710	2.706	-0.004
L3-171	2.709	2.703	-0.006
L3-216	2.706	2.704	-0.002
L3-261	2.704	2.710	0.006
L3-306	2.705	2.713	0.008
L3-351	2.707	2.715	0.008
L4-36	2.710	2.727	0.017
L4-81	2.711	2.694	-0.017
L4-126	2.710	2.671	-0.039
L4-171	2.710	2.670	-0.040
L4-216	2.708	2.698	-0.010
L4-261	2.707	2.733	0.026
L4-306	2.709	2.756	0.047
L4-351	2.709	2.753	0.044
L5-36	2.710	2.727	0.017
L5-81	2.711	2.694	-0.017
L5-126	2.710	2.670	-0.040
L5-171	2.710	2.668	-0.042
L5-216	2.708	2.696	-0.012
L5-261	2.708	2.735	0.027
L5-306	2.709	2.758	0.049
L5-351	2.709	2.757	0.048
L6-36	2.711	2.729	0.018
L6-81	2.711	2.693	-0.018
L6-126	2.711	2.669	-0.042
L6-171	2.710	2.668	-0.042
L6-216	2.708	2.698	-0.010
L6-261	2.708	2.734	0.026

**CYLINDER
DIMENSIONAL INSPECTION DATA**

END IMPACT, TEST 6

<u>MEASUREMENT DESIGNATION</u>	<u>PRE-TEST</u>	<u>POST-TEST</u>	<u>MEASUREMENT CHANGE</u>
L6-306	2.709	2.760	0.051
L6-351	2.709	2.756	0.047
L7-36	2.711	2.729	0.018
L7-81	2.712	2.694	-0.018
L7-126	2.711	2.669	-0.042
L7-171	2.710	2.670	-0.040
L7-216	2.709	2.696	-0.013
L7-261	2.708	2.734	0.026
L7-306	2.709	2.761	0.052
L7-351	2.710	2.757	0.047
L8-36	2.711	2.728	0.017
L8-81	2.712	2.694	-0.018
L8-126	2.711	2.671	-0.040
L8-171	2.710	2.671	-0.039
L8-216	2.709	2.697	-0.012
L8-261	2.709	2.733	0.024
L8-306	2.709	2.759	0.050
L8-351	2.710	2.756	0.046
L9-36	2.711	2.727	0.016
L9-81	2.712	2.695	-0.017
L9-126	2.711	2.674	-0.037
L9-171	2.710	2.675	-0.035
L9-216	2.709	2.698	-0.011
L9-261	2.709	2.731	0.022
L9-306	2.709	2.757	0.048
L9-351	2.710	2.753	0.043
L10-36	2.711	2.727	0.016
L10-81	2.712	2.698	-0.014
L10-126	2.711	2.678	-0.033
L10-171	2.710	2.680	-0.030
L10-216	2.709	2.700	-0.009
L10-261	2.709	2.728	0.019
L10-306	2.710	2.753	0.043
L10-351	2.711	2.751	0.040
L11-36	2.711	2.725	0.014
L11-81	2.712	2.700	-0.012
L11-126	2.711	2.681	-0.030
L11-171	2.710	2.681	-0.029
L11-216	2.709	2.703	-0.006
L11-261	2.710	2.728	0.018

**CYLINDER
DIMENSIONAL INSPECTION DATA**

END IMPACT, TEST 6

<u>MEASUREMENT DESIGNATION</u>	<u>PRE-TEST</u>	<u>POST-TEST</u>	<u>MEASUREMENT CHANGE</u>
L11-306	2.710	2.750	0.040
L11-351	2.711	2.746	0.035
L12-36	2.711	2.724	0.013
L12-81	2.712	2.702	-0.010
L12-126	2.711	2.684	-0.027
L12-171	2.711	2.685	-0.026
L12-216	2.710	2.705	-0.005
L12-261	2.710	2.727	0.017
L12-306	2.710	2.748	0.038
L12-351	2.711	2.746	0.035
L13-36	2.711	2.724	0.013
L13-81	2.712	2.702	-0.010
L13-126	2.711	2.688	-0.023
L13-171	2.711	2.688	-0.023
L13-216	2.710	2.706	-0.004
L13-261	2.710	2.725	0.015
L13-306	2.710	2.744	0.034
L13-351	2.711	2.743	0.032
L14-36	2.711	2.723	0.012
L14-81	2.712	2.707	-0.005
L14-126	2.711	2.691	-0.020
L14-171	2.711	2.689	-0.022
L14-216	2.710	2.706	-0.004
L14-261	2.710	2.723	0.013
L14-306	2.711	2.741	0.030
L14-351	2.711	2.741	0.030
L15-36	2.712	2.722	0.010
L15-81	2.712	2.708	-0.004
L15-126	2.711	2.694	-0.017
L15-171	2.711	2.695	-0.016
L15-216	2.710	2.708	-0.002
L15-261	2.710	2.722	0.012
L15-306	2.711	2.738	0.027
L15-351	2.711	2.741	0.030
L16-36	2.712	2.722	0.010
L16-81	2.712	2.711	-0.001
L16-126	2.711	2.699	-0.012
L16-171	2.711	2.697	-0.014
L16-216	2.710	2.709	-0.001
L16-261	2.710	2.718	0.008
L16-306	2.711	2.734	0.023
L16-351	2.711	2.733	0.022
L17-36	2.712	2.720	0.008

**CYLINDER
DIMENSIONAL INSPECTION DATA**

END IMPACT, TEST 6

<u>MEASUREMENT DESIGNATION</u>	<u>PRE-TEST</u>	<u>POST-TEST</u>	<u>MEASUREMENT CHANGE</u>
L17-81	2.712	2.712	0.000
L17-126	2.711	2.701	-0.010
L17-171	2.711	2.699	-0.012
L17-216	2.710	2.710	0.000
L17-261	2.710	2.718	0.008
L17-306	2.711	2.728	0.017
L17-351	2.711	2.731	0.020
L18-36	2.712	2.719	0.007
L18-81	2.712	2.713	0.001
L18-126	2.711	2.701	-0.010
L18-171	2.711	2.701	-0.010
L18-216	2.710	2.710	0.000
L18-261	2.710	2.713	0.003
L18-306	2.711	2.726	0.015
L18-351	2.711	2.727	0.016
L19-36	2.712	2.717	0.005
L19-81	2.712	2.714	0.002
L19-126	2.711	2.702	-0.009
L19-171	2.711	2.701	-0.010
L19-216	2.710	2.707	-0.003
L19-261	2.710	2.710	0.000
L19-306	2.711	2.720	0.009
L19-351	2.712	2.720	0.008
L20-36	2.712	2.715	0.003
L20-81	2.712	2.709	-0.003
L20-126	2.711	2.704	-0.007
L20-171	2.711	2.702	-0.009
L20-216	2.710	2.706	-0.004
L20-261	2.710	2.712	0.002
L20-306	2.711	2.716	0.005
L20-351	2.712	2.713	0.001
L21-36	2.712	2.714	0.002
L21-81	2.712	2.709	-0.003
L21-126	2.711	2.705	-0.006
L21-171	2.711	2.703	-0.008
L21-216	2.711	2.705	-0.006
L21-261	2.711	2.708	-0.003
L21-306	2.711	2.713	0.002
L21-351	2.712	2.710	-0.002
L22-36	2.712	2.711	-0.001
L22-81	2.712	2.709	-0.003
L22-126	2.711	2.708	-0.003
L22-171	2.711	2.704	-0.007

**CYLINDER
DIMENSIONAL INSPECTION DATA**

END IMPACT, TEST 6

<u>MEASUREMENT DESIGNATION</u>	<u>PRE-TEST</u>	<u>POST-TEST</u>	<u>MEASUREMENT CHANGE</u>
L22-216	2.711	2.704	-0.007
L22-261	2.711	2.708	-0.003
L22-306	2.711	2.709	-0.002
L22-351	2.712	2.704	-0.008
L23-36	45.010	44.802	-0.208
L23-81	45.010	44.746	-0.264
L23-126	45.011	44.701	-0.310
L23-171	45.011	44.702	-0.309
L23-216	45.012	44.779	-0.233
L23-261	45.011	44.805	-0.206
L23-306	45.011	44.834	-0.177
L23-351	45.010	44.859	-0.151

**CYLINDER
DIMENSIONAL INSPECTION DATA**

END IMPACT, TEST 7

<u>MEASUREMENT DESIGNATION</u>	<u>PRE-TEST</u>	<u>POST-TEST</u>	<u>MEASUREMENT CHANGE</u>
L1-36	2.699	2.709	0.010
L1-81	2.698	2.710	0.012
L1-126	2.697	2.710	0.013
L1-171	2.696	2.710	0.014
L1-216	2.700	2.711	0.011
L1-261	2.701	2.711	0.010
L1-306	2.700	2.710	0.010
L1-351	2.699	2.710	0.011
L2-36	2.703	2.713	0.010
L2-81	2.702	2.717	0.015
L2-126	2.701	2.716	0.015
L2-171	2.701	2.716	0.015
L2-216	2.702	2.712	0.010
L2-261	2.703	2.710	0.007
L2-306	2.703	2.709	0.006
L2-351	2.703	2.710	0.007
L3-36	2.705	2.722	0.017
L3-81	2.705	2.722	0.017
L3-126	2.704	2.720	0.016
L3-171	2.703	2.717	0.014
L3-216	2.705	2.714	0.009
L3-261	2.705	2.715	0.010
L3-306	2.705	2.717	0.012
L3-351	2.704	2.720	0.016
L4-36	2.707	2.740	0.033
L4-81	2.707	2.723	0.016
L4-126	2.706	2.706	0.000
L4-171	2.705	2.703	-0.002
L4-216	2.706	2.714	0.008
L4-261	2.707	2.731	0.024
L4-306	2.707	2.744	0.037
L4-351	2.706	2.746	0.040
L5-36	2.707	2.740	0.033
L5-81	2.707	2.723	0.016
L5-126	2.706	2.706	0.000
L5-171	2.705	2.701	-0.004
L5-216	2.707	2.711	0.004
L5-261	2.707	2.731	0.024
L5-306	2.707	2.746	0.039
L5-351	2.706	2.749	0.043
L6-36	2.707	2.740	0.033
L6-81	2.707	2.723	0.016
L6-126	2.706	2.706	0.000

**CYLINDER
DIMENSIONAL INSPECTION DATA**

END IMPACT, TEST 7

<u>MEASUREMENT DESIGNATION</u>	<u>PRE-TEST</u>	<u>POST-TEST</u>	<u>MEASUREMENT CHANGE</u>
L6-171	2.706	2.701	-0.005
L6-216	2.707	2.711	0.004
L6-261	2.707	2.732	0.025
L6-306	2.707	2.748	0.041
L6-351	2.706	2.750	0.044
L7-36	2.707	2.741	0.034
L7-81	2.707	2.723	0.016
L7-126	2.706	2.706	0.000
L7-171	2.706	2.702	-0.004
L7-216	2.707	2.712	0.005
L7-261	2.707	2.732	0.025
L7-306	2.707	2.748	0.041
L7-351	2.707	2.751	0.044
L8-36	2.707	2.741	0.034
L8-81	2.707	2.724	0.017
L8-126	2.707	2.708	0.001
L8-171	2.706	2.704	-0.002
L8-216	2.707	2.713	0.006
L8-261	2.707	2.731	0.024
L8-306	2.707	2.748	0.041
L8-351	2.707	2.751	0.044
L9-36	2.707	2.741	0.034
L9-81	2.707	2.724	0.017
L9-126	2.707	2.709	0.002
L9-171	2.707	2.706	-0.001
L9-216	2.707	2.714	0.007
L9-261	2.708	2.730	0.022
L9-306	2.707	2.747	0.040
L9-351	2.707	2.751	0.044
L10-36	2.708	2.740	0.032
L10-81	2.707	2.724	0.017
L10-126	2.707	2.711	0.004
L10-171	2.707	2.710	0.003
L10-216	2.708	2.716	0.008
L10-261	2.708	2.730	0.022
L10-306	2.708	2.745	0.037
L10-351	2.707	2.749	0.042
L11-36	2.708	2.739	0.031
L11-81	2.707	2.725	0.018
L11-126	2.707	2.713	0.006
L11-171	2.707	2.711	0.004
L11-216	2.708	2.718	0.010
L11-261	2.708	2.727	0.019

**CYLINDER
DIMENSIONAL INSPECTION DATA**

END IMPACT, TEST 7

<u>MEASUREMENT DESIGNATION</u>	<u>PRE-TEST</u>	<u>POST-TEST</u>	<u>MEASUREMENT CHANGE</u>
L11-306	2.708	2.743	0.035
L11-351	2.707	2.749	0.042
L12-36	2.708	2.738	0.030
L12-81	2.707	2.726	0.019
L12-126	2.707	2.716	0.009
L12-171	2.707	2.715	0.008
L12-216	2.708	2.718	0.010
L12-261	2.708	2.726	0.018
L12-306	2.708	2.744	0.036
L12-351	2.708	2.748	0.040
L13-36	2.708	2.737	0.029
L13-81	2.708	2.728	0.020
L13-126	2.708	2.718	0.010
L13-171	2.707	2.717	0.010
L13-216	2.708	2.719	0.011
L13-261	2.708	2.726	0.018
L13-306	2.708	2.740	0.032
L13-351	2.708	2.745	0.037
L14-36	2.708	2.736	0.028
L14-81	2.708	2.728	0.020
L14-126	2.708	2.720	0.012
L14-171	2.707	2.719	0.012
L14-216	2.708	2.722	0.014
L14-261	2.708	2.726	0.018
L14-306	2.708	2.739	0.031
L14-351	2.708	2.745	0.037
L15-36	2.708	2.735	0.027
L15-81	2.708	2.731	0.023
L15-126	2.708	2.722	0.014
L15-171	2.707	2.721	0.014
L15-216	2.708	2.723	0.015
L15-261	2.708	2.725	0.017
L15-306	2.708	2.737	0.029
L15-351	2.708	2.745	0.037
L16-36	2.708	2.735	0.027
L16-81	2.708	2.732	0.024
L16-126	2.708	2.724	0.016
L16-171	2.707	2.722	0.015
L16-216	2.708	2.723	0.015
L16-261	2.708	2.724	0.016
L16-306	2.708	2.736	0.028
L16-351	2.708	2.738	0.030
L17-36	2.708	2.734	0.026

**CYLINDER
DIMENSIONAL INSPECTION DATA**

END IMPACT, TEST 7

<u>MEASUREMENT DESIGNATION</u>	<u>PRE-TEST</u>	<u>POST-TEST</u>	<u>MEASUREMENT CHANGE</u>
L17-81	2.708	2.732	0.024
L17-126	2.708	2.725	0.017
L17-171	2.708	2.722	0.014
L17-216	2.708	2.724	0.016
L17-261	2.708	2.724	0.016
L17-306	2.708	2.733	0.025
L17-351	2.708	2.737	0.029
L18-36	2.708	2.732	0.024
L18-81	2.708	2.731	0.023
L18-126	2.708	2.726	0.018
L18-171	2.708	2.723	0.015
L18-216	2.708	2.724	0.016
L18-261	2.708	2.724	0.016
L18-306	2.708	2.732	0.024
L18-351	2.708	2.735	0.027
L19-36	2.708	2.730	0.022
L19-81	2.708	2.731	0.023
L19-126	2.708	2.726	0.018
L19-171	2.708	2.723	0.015
L19-216	2.708	2.723	0.015
L19-261	2.708	2.723	0.015
L19-306	2.708	2.730	0.022
L19-351	2.708	2.732	0.024
L20-36	2.708	2.729	0.021
L20-81	2.708	2.730	0.022
L20-126	2.708	2.727	0.019
L20-171	2.708	2.724	0.016
L20-216	2.708	2.723	0.015
L20-261	2.708	2.723	0.015
L20-306	2.709	2.727	0.018
L20-351	2.709	2.727	0.018
L21-36	2.708	2.727	0.019
L21-81	2.709	2.730	0.021
L21-126	2.708	2.729	0.021
L21-171	2.708	2.725	0.017
L21-216	2.708	2.722	0.014
L21-261	2.709	2.720	0.011
L21-306	2.709	2.723	0.014
L21-351	2.709	2.725	0.016
L22-36	2.708	2.724	0.016
L22-81	2.709	2.729	0.020
L22-126	2.708	2.729	0.021
L22-171	2.708	2.726	0.018

**CYLINDER
DIMENSIONAL INSPECTION DATA**

END IMPACT, TEST 7

<u>MEASUREMENT DESIGNATION</u>	<u>PRE-TEST</u>	<u>POST-TEST</u>	<u>MEASUREMENT CHANGE</u>
L22-216	2.708	2.721	0.013
L22-261	2.709	2.718	0.009
L22-306	2.709	2.719	0.010
L22-351	2.709	2.722	0.013
L23-36	45.006	44.831	-0.175
L23-81	45.007	44.772	-0.235
L23-126	45.008	44.739	-0.269
L23-171	45.009	44.759	-0.250
L23-216	45.009	44.790	-0.219
L23-261	45.008	44.808	-0.200
L23-306	45.007	44.840	-0.167
L23-351	45.006	44.835	-0.171

**CYLINDER
DIMENSIONAL INSPECTION DATA**

END IMPACT, TEST 8

<u>MEASUREMENT DESIGNATION</u>	<u>PRE-TEST</u>	<u>POST-TEST</u>	<u>MEASUREMENT CHANGE</u>
L1-36	2.704	2.709	0.005
L1-81	2.701	2.709	0.008
L1-126	2.704	2.709	0.005
L1-171	2.706	2.709	0.003
L1-216	2.705	2.709	0.004
L1-261	2.703	2.709	0.006
L1-306	2.701	2.709	0.008
L1-351	2.703	2.709	0.006
L2-36	2.706	2.704	-0.002
L2-81	2.703	2.705	0.002
L2-126	2.705	2.707	0.002
L2-171	2.707	2.710	0.003
L2-216	2.707	2.711	0.004
L2-261	2.706	2.709	0.003
L2-306	2.706	2.708	0.002
L2-351	2.706	2.706	0.000
L3-36	2.707	2.709	0.002
L3-81	2.706	2.707	0.001
L3-126	2.707	2.705	-0.002
L3-171	2.708	2.708	0.000
L3-216	2.708	2.711	0.003
L3-261	2.708	2.714	0.006
L3-306	2.707	2.715	0.008
L3-351	2.708	2.713	0.005
L4-36	2.708	2.735	0.027
L4-81	2.709	2.709	0.000
L4-126	2.709	2.686	-0.023
L4-171	2.710	2.679	-0.031
L4-216	2.710	2.695	-0.015
L4-261	2.709	2.721	0.012
L4-306	2.708	2.743	0.035
L4-351	2.709	2.748	0.039
L5-36	2.710	2.735	0.025
L5-81	2.709	2.709	0.000
L5-126	2.709	2.686	-0.023
L5-171	2.710	2.678	-0.032
L5-216	2.710	2.691	-0.019
L5-261	2.709	2.721	0.012
L5-306	2.708	2.745	0.037
L5-351	2.709	2.750	0.041
L6-36	2.709	2.736	0.027
L6-81	2.709	2.709	0.000
L6-126	2.709	2.686	-0.023

**CYLINDER
DIMENSIONAL INSPECTION DATA**

END IMPACT, TEST 8

<u>MEASUREMENT DESIGNATION</u>	<u>PRE-TEST</u>	<u>POST-TEST</u>	<u>MEASUREMENT CHANGE</u>
L6-171	2.710	2.677	-0.033
L6-216	2.710	2.691	-0.019
L6-261	2.710	2.721	0.011
L6-306	2.709	2.743	0.034
L6-351	2.709	2.752	0.043
L7-36	2.709	2.737	0.028
L7-81	2.710	2.709	-0.001
L7-126	2.710	2.686	-0.024
L7-171	2.710	2.678	-0.032
L7-216	2.710	2.692	-0.018
L7-261	2.710	2.720	0.010
L7-306	2.709	2.745	0.036
L7-351	2.709	2.753	0.044
L8-36	2.710	2.737	0.027
L8-81	2.710	2.709	-0.001
L8-126	2.710	2.687	-0.023
L8-171	2.710	2.680	-0.030
L8-216	2.710	2.693	-0.017
L8-261	2.710	2.719	0.009
L8-306	2.709	2.744	0.035
L8-351	2.709	2.752	0.043
L9-36	2.710	2.735	0.025
L9-81	2.710	2.709	-0.001
L9-126	2.710	2.690	-0.020
L9-171	2.710	2.684	-0.026
L9-216	2.710	2.695	-0.015
L9-261	2.710	2.717	0.007
L9-306	2.709	2.741	0.032
L9-351	2.709	2.750	0.041
L10-36	2.710	2.733	0.023
L10-81	2.710	2.709	-0.001
L10-126	2.710	2.693	-0.017
L10-171	2.711	2.690	-0.021
L10-216	2.710	2.698	-0.012
L10-261	2.710	2.716	0.006
L10-306	2.709	2.738	0.029
L10-351	2.709	2.748	0.039
L11-36	2.710	2.731	0.021
L11-81	2.710	2.709	-0.001
L11-126	2.711	2.695	-0.016
L11-171	2.711	2.693	-0.018
L11-216	2.710	2.701	-0.009
L11-261	2.711	2.715	0.004

**CYLINDER
DIMENSIONAL INSPECTION DATA**

END IMPACT, TEST 8

<u>MEASUREMENT DESIGNATION</u>	<u>PRE-TEST</u>	<u>POST-TEST</u>	<u>MEASUREMENT CHANGE</u>
L11-306	2.709	2.736	0.027
L11-351	2.709	2.745	0.036
L12-36	2.710	2.730	0.020
L12-81	2.710	2.710	0.000
L12-126	2.711	2.698	-0.013
L12-171	2.711	2.696	-0.015
L12-216	2.710	2.703	-0.007
L12-261	2.711	2.714	0.003
L12-306	2.709	2.734	0.025
L12-351	2.709	2.744	0.035
L13-36	2.710	2.729	0.019
L13-81	2.710	2.712	0.002
L13-126	2.711	2.702	-0.009
L13-171	2.711	2.700	-0.011
L13-216	2.711	2.706	-0.005
L13-261	2.711	2.713	0.002
L13-306	2.709	2.731	0.022
L13-351	2.709	2.740	0.031
L14-36	2.710	2.725	0.015
L14-81	2.710	2.713	0.003
L14-126	2.711	2.704	-0.007
L14-171	2.711	2.703	-0.008
L14-216	2.711	2.709	-0.002
L14-261	2.711	2.713	0.002
L14-306	2.710	2.728	0.018
L14-351	2.709	2.738	0.029
L15-36	2.710	2.723	0.013
L15-81	2.710	2.714	0.004
L15-126	2.711	2.708	-0.003
L15-171	2.711	2.708	-0.003
L15-216	2.711	2.711	0.000
L15-261	2.711	2.712	0.001
L15-306	2.710	2.725	0.015
L15-351	2.709	2.736	0.027
L16-36	2.710	2.721	0.011
L16-81	2.710	2.715	0.005
L16-126	2.711	2.712	0.001
L16-171	2.711	2.712	0.001
L16-216	2.711	2.714	0.003
L16-261	2.711	2.712	0.001
L16-306	2.710	2.722	0.012
L16-351	2.709	2.728	0.019
L17-36	2.710	2.719	0.009

**CYLINDER
DIMENSIONAL INSPECTION DATA**

END IMPACT, TEST 8

<u>MEASUREMENT DESIGNATION</u>	<u>PRE-TEST</u>	<u>POST-TEST</u>	<u>MEASUREMENT CHANGE</u>
L17-81	2.711	2.716	0.005
L17-126	2.711	2.714	0.003
L17-171	2.711	2.713	0.002
L17-216	2.711	2.715	0.004
L17-261	2.711	2.712	0.001
L17-306	2.710	2.718	0.008
L17-351	2.709	2.726	0.017
L18-36	2.710	2.716	0.006
L18-81	2.711	2.718	0.007
L18-126	2.711	2.716	0.005
L18-171	2.711	2.714	0.003
L18-216	2.711	2.715	0.004
L18-261	2.711	2.712	0.001
L18-306	2.710	2.715	0.005
L18-351	2.709	2.722	0.013
L19-36	2.710	2.713	0.003
L19-81	2.711	2.718	0.007
L19-126	2.711	2.717	0.006
L19-171	2.711	2.715	0.004
L19-216	2.711	2.714	0.003
L19-261	2.711	2.710	-0.001
L19-306	2.710	2.712	0.002
L19-351	2.709	2.716	0.007
L20-36	2.711	2.710	-0.001
L20-81	2.711	2.715	0.004
L20-126	2.711	2.718	0.007
L20-171	2.711	2.719	0.008
L20-216	2.711	2.712	0.001
L20-261	2.711	2.710	-0.001
L20-306	2.710	2.708	-0.002
L20-351	2.709	2.711	0.002
L21-36	2.711	2.706	-0.005
L21-81	2.711	2.715	0.004
L21-126	2.711	2.718	0.007
L21-171	2.711	2.720	0.009
L21-216	2.711	2.712	0.001
L21-261	2.711	2.709	-0.002
L21-306	2.710	2.705	-0.005
L21-351	2.709	2.709	0.000
L22-36	2.711	2.705	-0.006
L22-81	2.711	2.714	0.003
L22-126	2.711	2.718	0.007
L22-171	2.711	2.720	0.009

**CYLINDER
DIMENSIONAL INSPECTION DATA**

END IMPACT, TEST 8

<u>MEASUREMENT DESIGNATION</u>	<u>PRE-TEST</u>	<u>POST-TEST</u>	<u>MEASUREMENT CHANGE</u>
L22-216	2.711	2.711	0.000
L22-261	2.711	2.707	-0.004
L22-306	2.710	2.705	-0.005
L22-351	2.709	2.707	-0.002
L23-36	45.009	44.862	-0.147
L23-81	45.008	44.848	-0.160
L23-126	45.005	44.794	-0.211
L23-171	45.005	44.741	-0.264
L23-216	45.005	44.727	-0.278
L23-261	45.008	44.776	-0.232
L23-306	45.009	44.806	-0.203
L23-351	45.010	44.848	-0.162

**CYLINDER
DIMENSIONAL INSPECTION DATA**

END IMPACT, TEST 9

<u>MEASUREMENT DESIGNATION</u>	<u>PRE-TEST</u>	<u>POST-TEST</u>	<u>MEASUREMENT CHANGE</u>
L1-36	2.703	2.708	0.005
L1-81	2.706	2.708	0.002
L1-126	2.703	2.708	0.005
L1-171	2.704	2.708	0.004
L1-216	2.702	2.708	0.006
L1-261	2.694	2.708	0.014
L1-306	2.687	2.708	0.021
L1-351	2.692	2.708	0.016
L2-36	2.705	2.703	-0.002
L2-81	2.707	2.705	-0.002
L2-126	2.705	2.709	0.004
L2-171	2.705	2.712	0.007
L2-216	2.704	2.711	0.007
L2-261	2.700	2.708	0.008
L2-306	2.694	2.704	0.010
L2-351	2.697	2.702	0.005
L3-36	2.707	2.706	-0.001
L3-81	2.708	2.707	-0.001
L3-126	2.706	2.710	0.004
L3-171	2.706	2.713	0.007
L3-216	2.706	2.713	0.007
L3-261	2.703	2.710	0.007
L3-306	2.700	2.707	0.007
L3-351	2.702	2.705	0.003
L4-36	2.708	2.728	0.020
L4-81	2.708	2.713	0.005
L4-126	2.707	2.697	-0.010
L4-171	2.707	2.691	-0.016
L4-216	2.708	2.699	-0.009
L4-261	2.707	2.714	0.007
L4-306	2.706	2.728	0.022
L4-351	2.706	2.734	0.028
L5-36	2.708	2.728	0.020
L5-81	2.708	2.714	0.006
L5-126	2.707	2.697	-0.010
L5-171	2.708	2.690	-0.018
L5-216	2.708	2.697	-0.011
L5-261	2.707	2.714	0.007
L5-306	2.706	2.729	0.023
L5-351	2.707	2.735	0.028
L6-36	2.708	2.729	0.021
L6-81	2.708	2.714	0.006
L6-126	2.707	2.697	-0.010

**CYLINDER
DIMENSIONAL INSPECTION DATA**

END IMPACT, TEST 9

<u>MEASUREMENT DESIGNATION</u>	<u>PRE-TEST</u>	<u>POST-TEST</u>	<u>MEASUREMENT CHANGE</u>
L6-171	2.708	2.690	-0.018
L6-216	2.708	2.697	-0.011
L6-261	2.708	2.714	0.006
L6-306	2.706	2.729	0.023
L6-351	2.707	2.736	0.029
L7-36	2.708	2.730	0.022
L7-81	2.708	2.714	0.006
L7-126	2.708	2.698	-0.010
L7-171	2.708	2.692	-0.016
L7-216	2.708	2.699	-0.009
L7-261	2.708	2.713	0.005
L7-306	2.706	2.729	0.023
L7-351	2.708	2.737	0.029
L8-36	2.709	2.729	0.020
L8-81	2.708	2.713	0.005
L8-126	2.708	2.699	-0.009
L8-171	2.709	2.695	-0.014
L8-216	2.709	2.701	-0.008
L8-261	2.709	2.713	0.004
L8-306	2.707	2.728	0.021
L8-351	2.708	2.736	0.028
L9-36	2.709	2.728	0.019
L9-81	2.708	2.711	0.003
L9-126	2.708	2.701	-0.007
L9-171	2.709	2.699	-0.010
L9-216	2.709	2.704	-0.005
L9-261	2.709	2.711	0.002
L9-306	2.708	2.725	0.017
L9-351	2.708	2.735	0.027
L10-36	2.709	2.725	0.016
L10-81	2.708	2.711	0.003
L10-126	2.708	2.703	-0.005
L10-171	2.709	2.705	-0.004
L10-216	2.709	2.709	0.000
L10-261	2.709	2.711	0.002
L10-306	2.708	2.722	0.014
L10-351	2.708	2.731	0.023
L11-36	2.709	2.722	0.013
L11-81	2.708	2.710	0.002
L11-126	2.708	2.705	-0.003
L11-171	2.709	2.707	-0.002
L11-216	2.709	2.710	0.001
L11-261	2.710	2.710	0.000

**CYLINDER
DIMENSIONAL INSPECTION DATA**

END IMPACT, TEST 9

<u>MEASUREMENT DESIGNATION</u>	<u>PRE-TEST</u>	<u>POST-TEST</u>	<u>MEASUREMENT CHANGE</u>
L11-306	2.708	2.720	0.012
L11-351	2.709	2.730	0.021
L12-36	2.709	2.721	0.012
L12-81	2.708	2.710	0.002
L12-126	2.708	2.708	0.000
L12-171	2.709	2.710	0.001
L12-216	2.709	2.713	0.004
L12-261	2.710	2.711	0.001
L12-306	2.708	2.717	0.009
L12-351	2.709	2.728	0.019
L13-36	2.709	2.718	0.009
L13-81	2.708	2.711	0.003
L13-126	2.708	2.710	0.002
L13-171	2.709	2.714	0.005
L13-216	2.709	2.716	0.007
L13-261	2.710	2.712	0.002
L13-306	2.709	2.715	0.006
L13-351	2.709	2.725	0.016
L14-36	2.709	2.717	0.008
L14-81	2.708	2.712	0.004
L14-126	2.708	2.713	0.005
L14-171	2.709	2.716	0.007
L14-216	2.709	2.720	0.011
L14-261	2.710	2.712	0.002
L14-306	2.709	2.713	0.004
L14-351	2.709	2.723	0.014
L15-36	2.709	2.714	0.005
L15-81	2.708	2.712	0.004
L15-126	2.708	2.716	0.008
L15-171	2.709	2.719	0.010
L15-216	2.709	2.723	0.014
L15-261	2.710	2.713	0.003
L15-306	2.709	2.711	0.002
L15-351	2.710	2.718	0.008
L16-36	2.709	2.711	0.002
L16-81	2.708	2.713	0.005
L16-126	2.708	2.718	0.010
L16-171	2.709	2.723	0.014
L16-216	2.710	2.723	0.013
L16-261	2.710	2.714	0.004
L16-306	2.709	2.710	0.001
L16-351	2.710	2.713	0.003
L17-36	2.709	2.709	0.000

**CYLINDER
DIMENSIONAL INSPECTION DATA**

END IMPACT, TEST 9

<u>MEASUREMENT DESIGNATION</u>	<u>PRE-TEST</u>	<u>POST-TEST</u>	<u>MEASUREMENT CHANGE</u>
L17-81	2.708	2.713	0.005
L17-126	2.708	2.721	0.013
L17-171	2.709	2.725	0.016
L17-216	2.710	2.724	0.014
L17-261	2.710	2.714	0.004
L17-306	2.710	2.706	-0.004
L17-351	2.710	2.710	0.000
L18-36	2.709	2.706	-0.003
L18-81	2.708	2.713	0.005
L18-126	2.708	2.723	0.015
L18-171	2.709	2.726	0.017
L18-216	2.710	2.725	0.015
L18-261	2.711	2.715	0.004
L18-306	2.710	2.704	-0.006
L18-351	2.710	2.708	-0.002
L19-36	2.709	2.702	-0.007
L19-81	2.708	2.713	0.005
L19-126	2.708	2.724	0.016
L19-171	2.709	2.729	0.020
L19-216	2.710	2.724	0.014
L19-261	2.711	2.714	0.003
L19-306	2.710	2.700	-0.010
L19-351	2.710	2.703	-0.007
L20-36	2.709	2.699	-0.010
L20-81	2.708	2.711	0.003
L20-126	2.708	2.724	0.016
L20-171	2.709	2.733	0.024
L20-216	2.710	2.723	0.013
L20-261	2.711	2.713	0.002
L20-306	2.710	2.698	-0.012
L20-351	2.710	2.706	-0.004
L21-36	2.710	2.696	-0.014
L21-81	2.708	2.710	0.002
L21-126	2.708	2.726	0.018
L21-171	2.709	2.732	0.023
L21-216	2.709	2.723	0.014
L21-261	2.711	2.712	0.001
L21-306	2.710	2.695	-0.015
L21-351	2.710	2.699	-0.011
L22-36	2.710	2.699	-0.011
L22-81	2.708	2.708	0.000
L22-126	2.708	2.724	0.016
L22-171	2.709	2.731	0.022

**CYLINDER
DIMENSIONAL INSPECTION DATA**

END IMPACT, TEST 9

<u>MEASUREMENT DESIGNATION</u>	<u>PRE-TEST</u>	<u>POST-TEST</u>	<u>MEASUREMENT CHANGE</u>
L22-216	2.709	2.723	0.014
L22-261	2.711	2.709	-0.002
L22-306	2.710	2.692	-0.018
L22-351	2.710	2.695	-0.015
L23-36	45.008	44.856	-0.152
L23-81	45.006	44.802	-0.204
L23-126	45.003	44.739	-0.264
L23-171	45.001	44.722	-0.279
L23-216	45.001	44.751	-0.250
L23-261	45.003	44.781	-0.222
L23-306	45.005	44.841	-0.164
L23-351	45.007	44.850	-0.157

**CYLINDER
DIMENSIONAL INSPECTION DATA**

END IMPACT, TEST 10

<u>MEASUREMENT DESIGNATION</u>	<u>PRE-TEST</u>	<u>POST-TEST</u>	<u>MEASUREMENT CHANGE</u>
L1-36	2.701	2.708	0.007
L1-81	2.703	2.707	0.004
L1-126	2.705	2.708	0.003
L1-171	2.705	2.708	0.003
L1-216	2.707	2.708	0.001
L1-261	2.708	2.709	0.001
L1-306	2.707	2.709	0.002
L1-351	2.703	2.709	0.006
L2-36	2.705	2.698	-0.007
L2-81	2.706	2.696	-0.010
L2-126	2.706	2.704	-0.002
L2-171	2.706	2.716	0.010
L2-216	2.707	2.722	0.015
L2-261	2.709	2.720	0.011
L2-306	2.709	2.712	0.003
L2-351	2.706	2.702	-0.004
L3-36	2.707	2.692	-0.015
L3-81	2.707	2.692	-0.015
L3-126	2.708	2.702	-0.006
L3-171	2.707	2.720	0.013
L3-216	2.708	2.730	0.022
L3-261	2.710	2.730	0.020
L3-306	2.710	2.719	0.009
L3-351	2.708	2.706	-0.002
L4-36	2.709	2.724	0.015
L4-81	2.709	2.692	-0.017
L4-126	2.709	2.688	-0.021
L4-171	2.709	2.694	-0.015
L4-216	2.709	2.713	0.004
L4-261	2.710	2.731	0.021
L4-306	2.711	2.744	0.033
L4-351	2.710	2.741	0.031
L5-36	2.709	2.725	0.016
L5-81	2.709	2.692	-0.017
L5-126	2.709	2.688	-0.021
L5-171	2.709	2.693	-0.016
L5-216	2.709	2.710	0.001
L5-261	2.711	2.732	0.021
L5-306	2.711	2.746	0.035
L5-351	2.710	2.743	0.033
L6-36	2.710	2.724	0.014
L6-81	2.709	2.692	-0.017
L6-126	2.709	2.688	-0.021

**CYLINDER
DIMENSIONAL INSPECTION DATA**

END IMPACT, TEST 10

<u>MEASUREMENT DESIGNATION</u>	<u>PRE-TEST</u>	<u>POST-TEST</u>	<u>MEASUREMENT CHANGE</u>
L6-171	2.709	2.693	-0.016
L6-216	2.709	2.712	0.003
L6-261	2.711	2.732	0.021
L6-306	2.711	2.746	0.035
L6-351	2.710	2.743	0.033
L7-36	2.710	2.724	0.014
L7-81	2.710	2.691	-0.019
L7-126	2.709	2.687	-0.022
L7-171	2.709	2.696	-0.013
L7-216	2.709	2.714	0.005
L7-261	2.711	2.733	0.022
L7-306	2.711	2.745	0.034
L7-351	2.710	2.743	0.033
L8-36	2.710	2.722	0.012
L8-81	2.710	2.690	-0.020
L8-126	2.709	2.688	-0.021
L8-171	2.709	2.699	-0.010
L8-216	2.710	2.719	0.009
L8-261	2.711	2.734	0.023
L8-306	2.711	2.744	0.033
L8-351	2.711	2.742	0.031
L9-36	2.710	2.719	0.009
L9-81	2.710	2.691	-0.019
L9-126	2.710	2.689	-0.021
L9-171	2.710	2.704	-0.006
L9-216	2.710	2.724	0.014
L9-261	2.711	2.736	0.025
L9-306	2.711	2.742	0.031
L9-351	2.711	2.740	0.029
L10-36	2.711	2.712	0.001
L10-81	2.710	2.689	-0.021
L10-126	2.710	2.694	-0.016
L10-171	2.710	2.713	0.003
L10-216	2.710	2.732	0.022
L10-261	2.711	2.738	0.027
L10-306	2.711	2.739	0.028
L10-351	2.711	2.733	0.022
L11-36	2.711	2.711	0.000
L11-81	2.711	2.688	-0.023
L11-126	2.710	2.694	-0.016
L11-171	2.710	2.718	0.008
L11-216	2.710	2.735	0.025
L11-261	2.711	2.738	0.027

**CYLINDER
DIMENSIONAL INSPECTION DATA**

END IMPACT, TEST 10

<u>MEASUREMENT DESIGNATION</u>	<u>PRE-TEST</u>	<u>POST-TEST</u>	<u>MEASUREMENT CHANGE</u>
L11-306	2.711	2.737	0.026
L11-351	2.711	2.732	0.021
L12-36	2.711	2.708	-0.003
L12-81	2.711	2.686	-0.025
L12-126	2.710	2.697	-0.013
L12-171	2.710	2.723	0.013
L12-216	2.710	2.740	0.030
L12-261	2.711	2.739	0.028
L12-306	2.711	2.735	0.024
L12-351	2.711	2.728	0.017
L13-36	2.711	2.705	-0.006
L13-81	2.711	2.686	-0.025
L13-126	2.710	2.700	-0.010
L13-171	2.710	2.725	0.015
L13-216	2.710	2.745	0.035
L13-261	2.711	2.741	0.030
L13-306	2.711	2.733	0.022
L13-351	2.711	2.725	0.014
L14-36	2.711	2.700	-0.011
L14-81	2.711	2.686	-0.025
L14-126	2.710	2.702	-0.008
L14-171	2.710	2.732	0.022
L14-216	2.710	2.750	0.040
L14-261	2.711	2.744	0.033
L14-306	2.711	2.731	0.020
L14-351	2.711	2.721	0.010
L15-36	2.711	2.696	-0.015
L15-81	2.711	2.685	-0.026
L15-126	2.710	2.706	-0.004
L15-171	2.710	2.736	0.026
L15-216	2.710	2.755	0.045
L15-261	2.711	2.746	0.035
L15-306	2.711	2.729	0.018
L15-351	2.711	2.715	0.004
L16-36	2.711	2.688	-0.023
L16-81	2.711	2.683	-0.028
L16-126	2.710	2.709	-0.001
L16-171	2.710	2.741	0.031
L16-216	2.710	2.760	0.050
L16-261	2.711	2.747	0.036
L16-306	2.711	2.727	0.016
L16-351	2.711	2.710	-0.001
L17-36	2.711	2.682	-0.029

**CYLINDER
DIMENSIONAL INSPECTION DATA**

END IMPACT, TEST 10

<u>MEASUREMENT DESIGNATION</u>	<u>PRE-TEST</u>	<u>POST-TEST</u>	<u>MEASUREMENT CHANGE</u>
L17-81	2.711	2.683	-0.028
L17-126	2.711	2.711	0.000
L17-171	2.711	2.745	0.034
L17-216	2.711	2.763	0.052
L17-261	2.711	2.751	0.040
L17-306	2.711	2.725	0.014
L17-351	2.711	2.706	-0.005
L18-36	2.711	2.676	-0.035
L18-81	2.711	2.681	-0.030
L18-126	2.711	2.714	0.003
L18-171	2.711	2.750	0.039
L18-216	2.711	2.766	0.055
L18-261	2.711	2.752	0.041
L18-306	2.711	2.724	0.013
L18-351	2.711	2.700	-0.011
L19-36	2.711	2.671	-0.040
L19-81	2.711	2.681	-0.030
L19-126	2.711	2.715	0.004
L19-171	2.711	2.756	0.045
L19-216	2.711	2.767	0.056
L19-261	2.711	2.753	0.042
L19-306	2.711	2.722	0.011
L19-351	2.711	2.695	-0.016
L20-36	2.711	2.666	-0.045
L20-81	2.711	2.674	-0.037
L20-126	2.711	2.715	0.004
L20-171	2.711	2.758	0.047
L20-216	2.711	2.770	0.059
L20-261	2.711	2.753	0.042
L20-306	2.711	2.719	0.008
L20-351	2.711	2.687	-0.024
L21-36	2.711	2.658	-0.053
L21-81	2.711	2.672	-0.039
L21-126	2.711	2.715	0.004
L21-171	2.711	2.758	0.047
L21-216	2.711	2.771	0.060
L21-261	2.711	2.752	0.041
L21-306	2.711	2.715	0.004
L21-351	2.711	2.684	-0.027
L22-36	2.711	2.654	-0.057
L22-81	2.711	2.670	-0.041
L22-126	2.711	2.711	0.000
L22-171	2.711	2.757	0.046

**CYLINDER
DIMENSIONAL INSPECTION DATA**

END IMPACT, TEST 10

<u>MEASUREMENT DESIGNATION</u>	<u>PRE-TEST</u>	<u>POST-TEST</u>	<u>MEASUREMENT CHANGE</u>
L22-216	2.711	2.770	0.059
L22-261	2.711	2.750	0.039
L22-306	2.711	2.713	0.002
L22-351	2.711	2.677	-0.034
L23-36	45.012	44.881	-0.131
L23-81	45.009	44.830	-0.179
L23-126	45.007	44.753	-0.254
L23-171	45.006	44.717	-0.289
L23-216	45.007	44.737	-0.270
L23-261	45.008	44.783	-0.225
L23-306	45.009	44.844	-0.165
L23-351	45.011	44.876	-0.135

**CYLINDER DIMENSIONAL MEASUREMENTS
MEAN AND STANDARD DEVIATION**

END IMPACT TESTS

<u>MEASUREMENT DESIGNATION</u>	<u>MEAN</u>			<u>STANDARD DEVIATION</u>	
	<u>PRE-TEST</u>	<u>POST-TEST</u>	<u>NET CHANGE</u>	<u>PRE-TEST</u>	<u>POST-TEST</u>
L1-36	2.703	2.708	0.005	0.003	0.001
L1-81	2.704	2.708	0.004	0.004	0.001
L1-126	2.703	2.709	0.006	0.005	0.001
L1-171	2.703	2.709	0.006	0.004	0.001
L1-216	2.704	2.709	0.005	0.003	0.001
L1-261	2.704	2.709	0.005	0.006	0.001
L1-306	2.703	2.709	0.006	0.008	0.001
L1-351	2.703	2.708	0.005	0.005	0.001
L2-36	2.706	2.707	0.001	0.002	0.004
L2-81	2.706	2.707	0.001	0.003	0.005
L2-126	2.705	2.708	0.003	0.004	0.004
L2-171	2.705	2.709	0.004	0.003	0.004
L2-216	2.706	2.709	0.003	0.003	0.005
L2-261	2.706	2.707	0.001	0.005	0.006
L2-306	2.706	2.706	0.000	0.006	0.005
L2-351	2.706	2.706	0.000	0.004	0.003
L3-36	2.707	2.712	0.005	0.001	0.008
L3-81	2.707	2.709	0.002	0.002	0.008
L3-126	2.707	2.708	0.001	0.003	0.006
L3-171	2.706	2.709	0.003	0.002	0.007
L3-216	2.707	2.711	0.004	0.002	0.008
L3-261	2.707	2.711	0.004	0.004	0.009
L3-306	2.707	2.711	0.004	0.004	0.010
L3-351	2.707	2.714	0.007	0.003	0.005
L4-36	2.709	2.730	0.021	0.001	0.009
L4-81	2.709	2.711	0.002	0.001	0.011
L4-126	2.708	2.695	-0.013	0.002	0.017
L4-171	2.708	2.692	-0.016	0.002	0.019
L4-216	2.709	2.704	-0.005	0.001	0.012
L4-261	2.709	2.718	0.009	0.002	0.015
L4-306	2.709	2.731	0.022	0.002	0.028
L4-351	2.709	2.740	0.031	0.002	0.016
L5-36	2.709	2.731	0.022	0.001	0.010
L5-81	2.709	2.711	0.002	0.001	0.012
L5-126	2.708	2.695	-0.013	0.002	0.018
L5-171	2.708	2.691	-0.017	0.001	0.020
L5-216	2.709	2.702	-0.007	0.001	0.013
L5-261	2.709	2.718	0.009	0.002	0.017
L5-306	2.709	2.732	0.023	0.002	0.029
L5-351	2.709	2.745	0.036	0.002	0.021
L6-36	2.709	2.731	0.022	0.001	0.011
L6-81	2.709	2.711	0.002	0.001	0.012
L6-126	2.709	2.695	-0.014	0.002	0.018

**CYLINDER DIMENSIONAL MEASUREMENTS
MEAN AND STANDARD DEVIATION**

END IMPACT TESTS

<u>MEASUREMENT DESIGNATION</u>	<u>MEAN</u>			<u>STANDARD DEVIATION</u>	
	<u>PRE-TEST</u>	<u>POST-TEST</u>	<u>NET CHANGE</u>	<u>PRE-TEST</u>	<u>POST-TEST</u>
L6-171	2.709	2.691	-0.018	0.001	0.020
L6-216	2.709	2.702	-0.007	0.001	0.013
L6-261	2.709	2.719	0.010	0.002	0.016
L6-306	2.709	2.734	0.025	0.002	0.031
L6-351	2.709	2.742	0.033	0.002	0.017
L7-36	2.709	2.732	0.023	0.001	0.011
L7-81	2.709	2.711	0.002	0.001	0.012
L7-126	2.709	2.695	-0.014	0.001	0.018
L7-171	2.709	2.693	-0.016	0.001	0.020
L7-216	2.709	2.703	-0.006	0.001	0.013
L7-261	2.709	2.719	0.010	0.002	0.017
L7-306	2.709	2.743	0.034	0.002	0.009
L7-351	2.709	2.743	0.034	0.002	0.017
L8-36	2.710	2.732	0.022	0.001	0.011
L8-81	2.709	2.710	0.001	0.001	0.012
L8-126	2.709	2.696	-0.013	0.001	0.018
L8-171	2.709	2.694	-0.015	0.001	0.020
L8-216	2.709	2.704	-0.005	0.001	0.013
L8-261	2.709	2.718	0.009	0.001	0.017
L8-306	2.709	2.733	0.024	0.002	0.030
L8-351	2.709	2.743	0.034	0.002	0.016
L9-36	2.710	2.731	0.021	0.001	0.011
L9-81	2.709	2.710	0.001	0.003	0.012
L9-126	2.709	2.698	-0.011	0.001	0.017
L9-171	2.709	2.697	-0.012	0.001	0.019
L9-216	2.709	2.706	-0.003	0.001	0.013
L9-261	2.710	2.717	0.007	0.001	0.017
L9-306	2.709	2.731	0.022	0.002	0.030
L9-351	2.709	2.742	0.033	0.001	0.015
L10-36	2.710	2.729	0.019	0.001	0.012
L10-81	2.710	2.710	0.000	0.001	0.012
L10-126	2.710	2.700	-0.010	0.001	0.015
L10-171	2.709	2.701	-0.008	0.001	0.017
L10-216	2.710	2.709	-0.001	0.001	0.014
L10-261	2.710	2.715	0.005	0.001	0.017
L10-306	2.710	2.729	0.019	0.001	0.028
L10-351	2.709	2.740	0.031	0.001	0.014
L11-36	2.710	2.728	0.018	0.001	0.011
L11-81	2.710	2.711	0.001	0.001	0.012
L11-126	2.710	2.701	-0.009	0.001	0.015
L11-171	2.709	2.703	-0.006	0.001	0.017
L11-216	2.710	2.710	0.000	0.001	0.014
L11-261	2.710	2.715	0.005	0.001	0.017

**CYLINDER DIMENSIONAL MEASUREMENTS
MEAN AND STANDARD DEVIATION**

END IMPACT TESTS

<u>MEASUREMENT DESIGNATION</u>	<u>MEAN</u>			<u>STANDARD DEVIATION</u>	
	<u>PRE-TEST</u>	<u>POST-TEST</u>	<u>NET CHANGE</u>	<u>PRE-TEST</u>	<u>POST-TEST</u>
L11-306	2.710	2.727	0.017	0.001	0.027
L11-351	2.710	2.738	0.028	0.001	0.013
L12-36	2.710	2.727	0.017	0.001	0.012
L12-81	2.710	2.711	0.001	0.001	0.012
L12-126	2.710	2.703	-0.007	0.001	0.014
L12-171	2.710	2.706	-0.004	0.000	0.016
L12-216	2.710	2.712	0.002	0.001	0.014
L12-261	2.710	2.714	0.004	0.001	0.017
L12-306	2.710	2.726	0.016	0.001	0.027
L12-351	2.710	2.738	0.028	0.001	0.013
L13-36	2.710	2.726	0.016	0.001	0.012
L13-81	2.710	2.712	0.002	0.001	0.013
L13-126	2.710	2.706	-0.004	0.001	0.013
L13-171	2.710	2.708	-0.002	0.001	0.015
L13-216	2.710	2.714	0.004	0.001	0.014
L13-261	2.710	2.714	0.004	0.001	0.017
L13-306	2.710	2.724	0.014	0.001	0.025
L13-351	2.710	2.735	0.025	0.001	0.011
L14-36	2.710	2.725	0.015	0.001	0.013
L14-81	2.710	2.713	0.003	0.001	0.012
L14-126	2.710	2.708	-0.002	0.001	0.012
L14-171	2.710	2.710	0.000	0.001	0.015
L14-216	2.710	2.716	0.006	0.001	0.015
L14-261	2.710	2.714	0.004	0.001	0.017
L14-306	2.710	2.722	0.012	0.001	0.024
L14-351	2.710	2.734	0.024	0.001	0.011
L15-36	2.710	2.723	0.013	0.001	0.013
L15-81	2.710	2.713	0.003	0.001	0.013
L15-126	2.710	2.710	0.000	0.001	0.011
L15-171	2.710	2.712	0.002	0.001	0.015
L15-216	2.710	2.718	0.008	0.001	0.016
L15-261	2.710	2.714	0.004	0.001	0.017
L15-306	2.710	2.720	0.010	0.001	0.023
L15-351	2.710	2.732	0.022	0.001	0.012
L16-36	2.710	2.721	0.011	0.001	0.015
L16-81	2.710	2.714	0.004	0.001	0.013
L16-126	2.710	2.712	0.002	0.001	0.010
L16-171	2.710	2.715	0.005	0.001	0.014
L16-216	2.710	2.719	0.009	0.001	0.017
L16-261	2.710	2.714	0.004	0.001	0.017
L16-306	2.710	2.719	0.009	0.001	0.022
L16-351	2.710	2.727	0.017	0.001	0.011
L17-36	2.710	2.720	0.010	0.001	0.016

**CYLINDER DIMENSIONAL MEASUREMENTS
MEAN AND STANDARD DEVIATION**

END IMPACT TESTS

<u>MEASUREMENT DESIGNATION</u>	<u>MEAN</u>			<u>STANDARD DEVIATION</u>	
	<u>PRE-TEST</u>	<u>POST-TEST</u>	<u>NET CHANGE</u>	<u>PRE-TEST</u>	<u>POST-TEST</u>
L17-81	2.710	2.714	0.004	0.001	0.013
L17-126	2.710	2.711	0.003	0.001	0.010
L17-171	2.710	2.716	0.006	0.001	0.015
L17-216	2.710	2.719	0.009	0.001	0.017
L17-261	2.710	2.715	0.005	0.001	0.017
L17-306	2.710	2.716	0.006	0.001	0.021
L17-351	2.710	2.725	0.015	0.001	0.011
L18-36	2.710	2.717	0.007	0.001	0.017
L18-81	2.710	2.715	0.005	0.001	0.014
L18-126	2.710	2.714	0.004	0.001	0.009
L18-171	2.710	2.717	0.007	0.001	0.015
L18-216	2.710	2.719	0.009	0.001	0.018
L18-261	2.710	2.714	0.004	0.001	0.018
L18-306	2.710	2.714	0.004	0.001	0.020
L18-351	2.710	2.723	0.013	0.001	0.012
L19-36	2.710	2.715	0.005	0.001	0.018
L19-81	2.710	2.715	0.005	0.001	0.014
L19-126	2.710	2.714	0.004	0.001	0.010
L19-171	2.710	2.718	0.008	0.001	0.017
L19-216	2.710	2.719	0.009	0.001	0.019
L19-261	2.710	2.713	0.003	0.001	0.018
L19-306	2.710	2.711	0.001	0.001	0.019
L19-351	2.710	2.719	0.009	0.001	0.013
L20-36	2.710	2.713	0.003	0.001	0.019
L20-81	2.710	2.712	0.002	0.001	0.015
L20-126	2.710	2.715	0.005	0.001	0.010
L20-171	2.710	2.719	0.009	0.001	0.017
L20-216	2.710	2.718	0.008	0.001	0.020
L20-261	2.710	2.712	0.002	0.001	0.019
L20-306	2.710	2.709	-0.001	0.001	0.019
L20-351	2.710	2.716	0.006	0.001	0.014
L21-36	2.710	2.710	0.000	0.001	0.020
L21-81	2.710	2.712	0.002	0.001	0.016
L21-126	2.710	2.715	0.005	0.001	0.010
L21-171	2.710	2.719	0.009	0.001	0.017
L21-216	2.710	2.717	0.007	0.001	0.021
L21-261	2.710	2.711	0.001	0.001	0.019
L21-306	2.710	2.707	-0.003	0.001	0.017
L21-351	2.710	2.713	0.003	0.001	0.014
L22-36	2.710	2.709	-0.001	0.001	0.021
L22-81	2.710	2.711	0.001	0.001	0.016
L22-126	2.710	2.714	0.004	0.001	0.010
L22-171	2.710	2.718	0.008	0.001	0.017

**CYLINDER DIMENSIONAL MEASUREMENTS
MEAN AND STANDARD DEVIATION**

END IMPACT TESTS

<u>MEASUREMENT DESIGNATION</u>	<u>MEAN</u>			<u>STANDARD DEVIATION</u>	
	<u>PRE-TEST</u>	<u>POST-TEST</u>	<u>NET CHANGE</u>	<u>PRE-TEST</u>	<u>POST-TEST</u>
L22-216	2.710	2.716	0.006	0.001	0.021
L22-261	2.710	2.710	0.000	0.001	0.020
L22-306	2.710	2.704	-0.006	0.001	0.018
L22-351	2.710	2.711	0.001	0.001	0.016
L23-36	45.006	44.831	-0.175	0.010	0.036
L23-81	45.005	44.792	-0.213	0.010	0.033
L23-126	45.004	44.751	-0.253	0.010	0.030
L23-171	45.003	44.745	-0.258	0.010	0.029
L23-216	45.003	44.772	-0.231	0.011	0.027
L23-261	45.004	44.792	-0.212	0.011	0.011
L23-306	45.005	44.819	-0.185	0.011	0.032
L23-351	45.006	44.832	-0.174	0.010	0.042

APPENDIX D
STRAIN GAGE MULTILOTS

Figure D-1. End-Impact Test 1 Axial Strain at 1 in.

Figure D-2. End-Impact Test 1 Hoop Strain at 1 in.

Figure D-3. End-Impact Test 1 Axial Strain at 3 in.

Figure D-4. End-Impact Test 1 Hoop Strain at 3 in.

Figure D-5. End-Impact Test 1 Axial Strain at 6 in.

Figure D-6. End-Impact Test 2 Axial Strain at 1 in.

Figure D-7. End-Impact Test 2 Hoop Strain at 1 in.

Figure D-8. End-Impact Test 2 Axial Strain at 3 in.

Figure D-9. End-Impact Test 2 Hoop Strain at 3 in.

Figure D-10. End-Impact Test 2 Axial Strain at 6 in.

Figure D-11. End-Impact Test 3 Axial Strain at 1 in.

Figure D-12. End-Impact Test 3 Hoop Strain at 1 in.

Figure D-13. End-Impact Test 3 Axial Strain at 3 in.

Figure D-14. End-Impact Test 3 Hoop Strain at 3 in.

Figure D-15. End-Impact Test 3 Axial Strain at 6 in.

Figure D-16. End-Impact Test 4 Axial Strain at 1 in.

Figure D-17. End-Impact Test 4 Hoop Strain at 1 in.

Figure D-18. End-Impact Test 4 Axial Strain at 3 in.

Figure D-19. End-Impact Test 4 Hoop Strain at 3 in.

Figure D-20. End-Impact Test 4 Axial Strain at 6 in.

Figure D-21. End-Impact Test 5 Axial Strain at 1 in.

Figure D-22. End-Impact Test 5 Hoop Strain at 1 in.

Figure D-23. End-Impact Test 5 Axial Strain at 3 in.

Figure D-24. End-Impact Test 5 Hoop Strain at 3 in.

Figure D-25. End-Impact Test 5 Axial Strain at 6 in.

Figure D-26. End-Impact Test 6 Axial Strain at 1 in.

Figure D-27. End-Impact Test 6 Hoop Strain at 1 in.

Figure D-28. End-Impact Test 6 Axial Strain at 3 in.

Figure D-29. End-Impact Test 6 Hoop Strain at 3 in.

Figure D-30. End-Impact Test 6 Axial Strain at 6 in.

Figure D-31. End-Impact Test 7 Axial Strain at 1 in.

Figure D-32. End-Impact Test 7 Hoop Strain at 1 in.

Figure D-33. End-Impact Test 7 Axial Strain at 3 in.

Figure D-34. End-Impact Test 7 Hoop Strain at 3 in.

Figure D-35. End-Impact Test 7 Axial Strain at 6 in.

Figure D-36. End-Impact Test 8 Axial Strain at 1 in.

Figure D-37. End-Impact Test 8 Hoop Strain at 1 in.

Figure D-38. End-Impact Test 8 Axial Strain at 3 in.

Figure D-39. End-Impact Test 8 Hoop Strain at 3 in.

Figure D-40. End-Impact Test 8 Axial Strain at 6 in.

Figure D-41. End-Impact Test 9 Axial Strain at 1 in.

Figure D-42. End-Impact Test 9 Hoop Strain at 1 in.

Figure D-43. End-Impact Test 9 Axial Strain at 3 in.

Figure D-44. End-Impact Test 9 Hoop Strain at 3 in.

Figure D-45. End-Impact Test 9 Axial Strain at 6 in.

Figure D-46. End-Impact Test 10 Axial Strain at 1 in.

Figure D-47. End-Impact Test 10 Hoop Strain at 1 in.

Figure D-48. End-Impact Test 10 Axial Strain at 3 in.

Figure D-49. End-Impact Test 10 Hoop Strain at 3 in.

Figure D-50. End-Impact Test 10 Axial Strain at 6 in.

APPENDIX E

ACCELEROMETER MULTILOTS

Figure E-1. End-Impact Test 1 Endevco 7270A-20K Accelerations Filtered at 10,000 Hz

Figure E-2. End-Impact Test 2 Endevco 7270A-20K Accelerations Filtered at 10,000 Hz

Figure E-3. End-Impact Test 3 Endevco 7270A-20K Accelerations Filtered at 10,000 Hz

Figure E-4. End-Impact Test 4 Endevco 7270A-20K Accelerations Filtered at 10,000 Hz

Figure E-5. End-Impact Test 5 Endevco 7270A-20K Accelerations Filtered at 10,000 Hz

Figure E-6. End-Impact Test 6 Endevco 7270A-20K Accelerations Filtered at 10,000 Hz

Figure E-7. End-Impact Test 7 Endevco 7270A-20K Accelerations Filtered at 10,000 Hz

Figure E-8. End-Impact Test 8 Endevco 7270A-20K Accelerations Filtered at 10,000 Hz

Figure E-9. End-Impact Test 9 Endevco 7270A-20K Accelerations Filtered at 10,000 Hz

Figure E-10. End-Impact Test 10 Endevco 7270A-20K Accelerations Filtered at 10,000 Hz

Figure E-11. End-Impact Test 1 B&K 8309 Accelerations Filtered at 10,000 Hz

Figure E-12. End-Impact Test 2 B&K 8309 Accelerations Filtered at 10,000 Hz

Figure E-13. End-Impact Test 3 B&K 8309 Accelerations Filtered at 10,000 Hz

Figure E-14. End-Impact Test 4 B&K 8309 Accelerations Filtered at 10,000 Hz

Figure E-15. End-Impact Test 5 B&K 8309 Accelerations Filtered at 10,000 Hz

Figure E-16. End-Impact Test 6 B&K 8309 Accelerations Filtered at 10,000 Hz

Figure E-17. End-Impact Test 7 B&K 8309 Accelerations Filtered at 10,000 Hz

Figure E-18. End-Impact Test 8 B&K 8309 Accelerations Filtered at 10,000 Hz

Figure E-19. End-Impact Test 9 B&K 8309 Accelerations Filtered at 10,000 Hz

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