APPENDIX 2.10.9

Southwest Research Institute Performance Evaluation of UF_6 Shipping Containers Under Hypothetical Accident Conditions

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PERFORMANCE EVALUATION OF UF_6 SHIPPING CONTAINERS UNDER HYPOTHETICAL ACCIDENT CONDITIONS SPECIFIED IN TITLE 10 CFR PART 71.73

FINAL REPORT
SwRI Project No. 01-1680a
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Prepared for:

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ABSTRACT

This report describes the methods and guidelines Southwest Research Institute (SwRI) followed for the preparation, instrumentation, and conditioning of test specimens; performance of drop tests, leakage tests, and fire endurance tests; reporting of test results; and all applicable documentation of these tasks in accordance with the requirements specified in SwRI Proposal No. 01-21593a and Eco-Pak Specialty Packaging (ESP), Division of Columbiana Boiler Company (CBC) Purchase Order No. 4319. This report includes the program objective, quality assurance requirements, test personnel qualifications, test facilities and instrumentation calibration, test procedure, test item description, test results, and applicable documentation.

The objective of this program was to conduct physical and fire performance evaluation tests of ESP's ESP-30X Uranium Hexafluoride (UF_6) Shipping Packages in accordance with the hypothetical accident conditions specified in Title 10 CFR Part 71.73, to verify the performance under the specified conditions. The ESP-30X UF_6 shipping package was subjected first to the physical tests simulating hypothetical accident conditions for free drop and puncture described in Title 10 CFR 71.73(c), (1) and (3). Following the drop tests, the ESP-30X UF_6 shipping package was subjected to the thermal effects of the fully engulfing hydrocarbon pool fire exposure described in Title 10 CFR 71.73(c), (4). Following each test, the physical condition of the ESP-30X UF_6 shipping package was inspected and the results were recorded.

The following table summarizes the results for the pre-drop/post-fire preliminary soap bubble tests, pre-drop/post-fire helium leak tests, and post-fire hydrostatic leakage test.

Table 1. Leakage and Hydrostatic Test Results

Test Item: ESP-30X, SN001 30B Cylinder, CB-1871-2

TEST PERFORMED	REQUIREMENT	MEASUREMENT	PASS/FAIL
Pre-Drop Soap Bubble	No Leaks	No Leaks	Pass
Pre-Drop Helium	$< 1.0 \times 10^{-7}$ std cc/sec	1.3×10^{-8} std cc/sec	Pass
Post Fire Soap Bubble	No Leaks	No Leaks	Pass
Post Fire Helium	$< 1.0 \times 10^{-7}$ std cc/sec	$< 3.9 \times 10^{-9}$ std cc/sec	Pass
Post Fire Hydrostatic	No Leaks	No Leaks	Pass

The following table summarizes the results of the drop testing performed on the ESP-30X. The test item received some damage following the drop test that was considered acceptable by ESP personnel.

Table 2. ESP-30X SN001 Drop Testing Performed.

Procedure	Dates	Comments
Conditioning Before Drop	3/13/98 3/16/98	-23°F on overpack insulation at end of conditioning
30-ft Drop	3/16/98	Good drop at 14.0°
Exterior Physical Measurements	3/16/98	By Fire Technology personnel
1-m Puncture	3/16/98	Good drop at 13.5°
Exterior Physical Measurements	3/16/98	By Fire Technology personnel
Conditioning Before Drop	3/16/98 3/17/98	Initial insulation temperature of 17°F. -30°F at end of conditioning.
1-m Puncture	3/17/98	Good horizontal drop at 45° rotation
Exterior Physical Measurements	3/17/98	By Fire Technology personnel

The Department of Fire Technology conducted the 30-min pool fire test described in Title 10 CFR 71.72 (c), (4) on March 21, 1998. The initial temperature of the 30B cylinder was 100°F. The maximum single point temperature recorded on the surface of the 30B cylinder during the 30-min pool fire exposure test was 117°F (Thermocouple [TC] 14 at 30 min), and the average of the maximum TC readings was 104°F.

The maximum single point temperature recorded on the surface of the 30B cylinder during the 11-hr cool down period was 177°F (TC 3 at 3 hr 52 min), and the average of the maximum TC readings was 152°F.

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1.0 INTRODUCTION

This report describes the methods and guidelines Southwest Research Institute (SwRI) followed for the preparation, instrumentation, and conditioning of test specimens; performance of drop tests, leakage tests, and fire endurance tests; reporting of test results; and all applicable documentation of these tasks in accordance with the requirements specified in SwRI Proposal No. 01-21593a and Eco-Pak Specialty Packaging (ESP), Division of Columbiana Boiler Company (CBC) Purchase Order No. 4319. This report includes the program objective, quality assurance requirements, test personnel qualifications, test facilities and instrumentation calibration, test procedure, test item description, test results, and applicable documentation.

2.0 PROGRAM OBJECTIVE

The objective of this program was to conduct physical and fire performance evaluation tests of ESP's ESP-30X Uranium Hexafluoride (UF_6) Shipping Packages in accordance with the hypothetical accident conditions specified in Title 10 CFR Part 71.73, to verify the performance under the specified conditions. The ESP-30X UF_6 shipping package was subjected first to the physical tests simulating hypothetical accident conditions for free drop and puncture described in Title 10 CFR 71.73(c), (1) and (3). Following the drop tests, the ESP-30X UF_6 shipping package was subjected to the thermal effects of the fully engulfing hydrocarbon pool fire exposure described in Title 10 CFR 71.73(c), (4). Following each test, the physical condition of the ESP-30X UF_6 shipping package was inspected and the results were recorded.

3.0 PROGRAM ORGANIZATION

The scope of work described in this report was performed by SwRI personnel at SwRI facilities. The program was supported by four of SwRI's 11 technical divisions, each with facilities, capabilities, and technical expertise necessary to successfully perform this program in a professional, cost effective, and timely manner. Figure 3-1 shows the organizational chart for SwRI's technical divisions, and Figure 3-2 depicts the program organizational chart.

The overall program was managed by Mr. James R. Griffith Jr., P.E., FPE, Project Manager in the Department of Fire Technology in the Chemistry and Chemical Engineering Division. The physical (drop) testing was performed by the Structural Dynamics and Environmental Testing G roup in the Mechanical and Fluids Engineering Division. The leakage and hydrostatic testing were performed by the

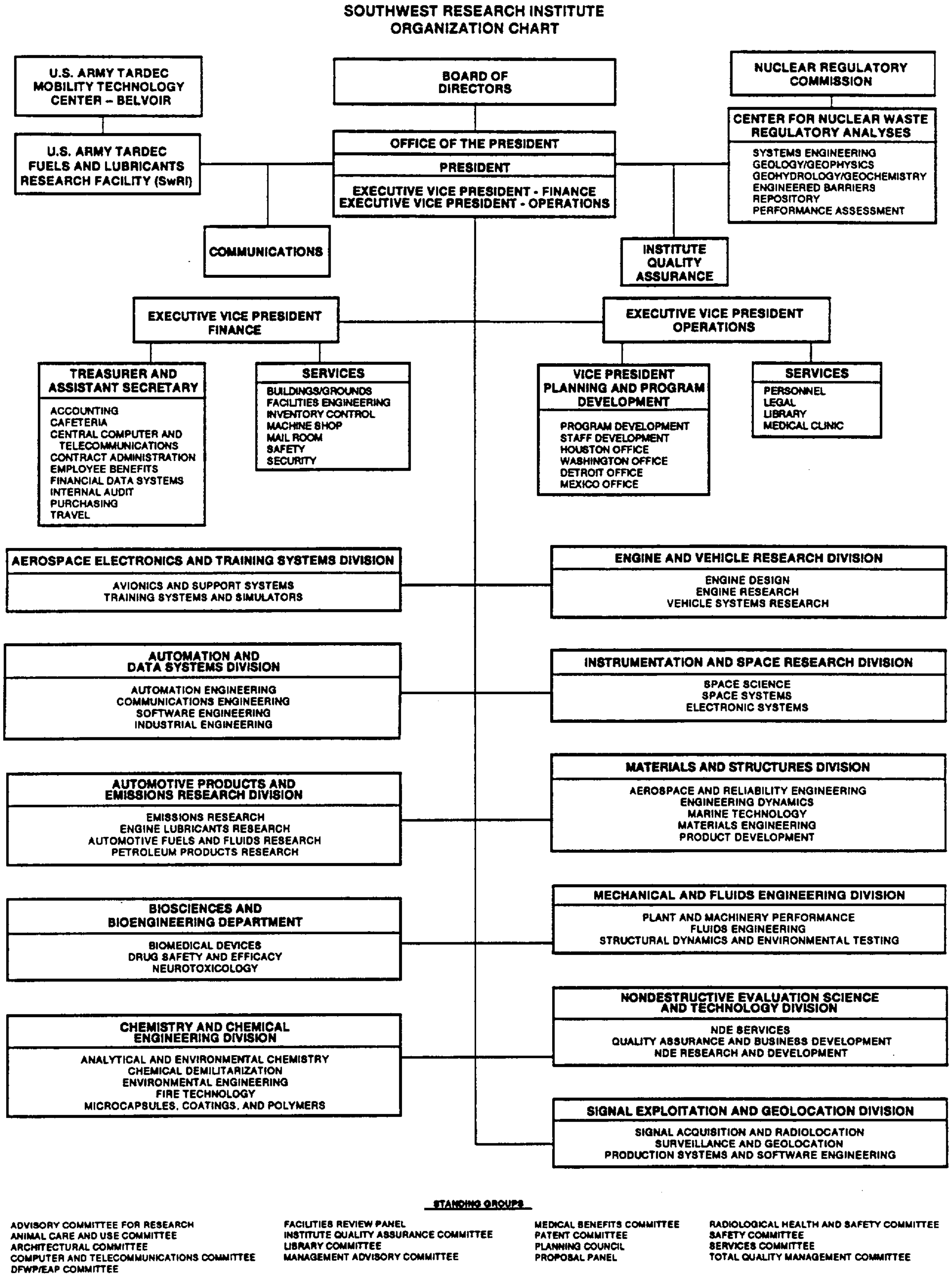


Figure 3-1. SwRI Organizational Chart.

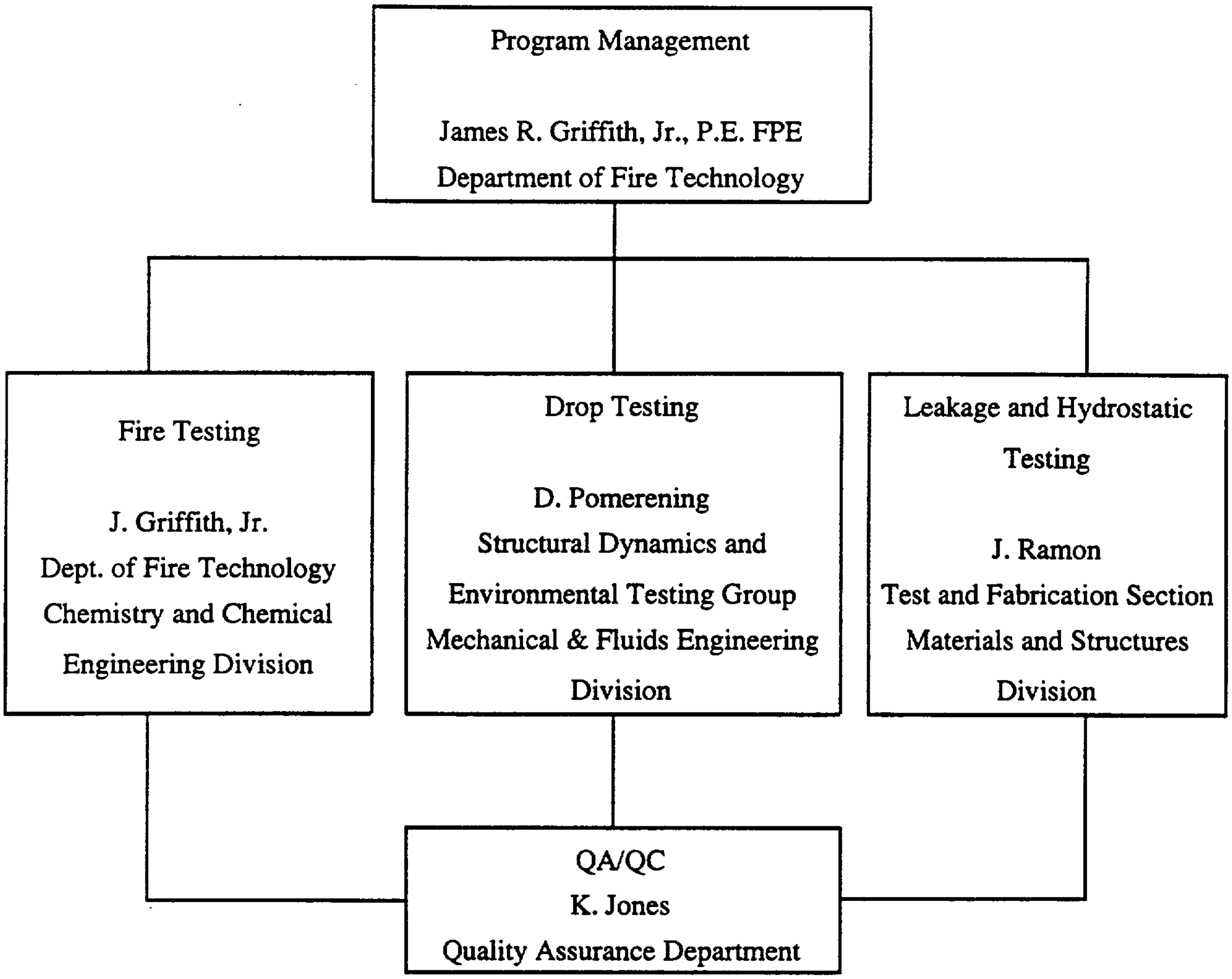


Figure 3-2. Program Organizational Chart.

Test and Fabrication Section of the Materials and Structures Division. SwRI's Quality Assurance Department provided independent surveillance, quality checks, and inspections during the course of this program, as required. The following sections provide further information for each of the supporting technical divisions.

4.0 QUALITY ASSURANCE REQUIREMENTS

All test activities for ESP were monitored and controlled under SwRI's Nuclear Quality Assurance Program Manual (NQAPM) and/or the Department of Fire Technology Quality Assurance Manual (DFTQAM). The NQAPM and DFTQAM meet the requirements of Title 10 CFR 50, Appendix B, and meet or exceed the requirements of Title 10 CFR 71, Subpart H. SwRI prepared a Project Quality Plan (PQP) Document No. NPQP-98-01-1680, which identified the specific sections of the NQAPM or DFTQAM which apply, and addressed specific requirements identified in the contract. SwRI Quality Assurance/Quality Control (QA/QC) personnel provided independent surveillance, quality checks, and inspections during the course of this program.

5.0 TEST ITEM IDENTIFICATION

Eco-Pak Specialty Packaging, Division of Columbiana Boiler Company, was responsible for the design, fabrication, and delivery of the ESP-30X UF_6 shipping container, which consisted of the overpack and 30B UF_6 cylinder. ESP performed the initial test item preparation including filling the 30B cylinder with clean steel shot, bending and repair of the skirt, and load measurements.

The ESP-30X overpack was identified as SN001 and the 30B cylinder was identified as CB-1871-2. The ESP-30X shipping container was constructed in accordance with the detail drawings provided by ESP. Dimensional measurements prior to the drop tests and following the drop and fire tests appear in Appendix C, Construction Details and Dimensional Measurements.

6.0 TEST FACILITIES

6.1 Leakage and Hydrostatic Testing Facilities

The leakage and hydrostatic testing phase of this program utilized various equipment, instrumentation, and dedicated facilities to perform experimental stress analysis, hydrostatic pressure tests, helium leak tests, and a variety of API and ASME tests.

The helium leakage tests were performed with the Department's VEECO MS-40 portable automatic leak detector manufactured by VEECO Instruments, Inc. The MS-40 is a fully automatic, dual mode, turbomolecular pumped portable leak detector. The sensitivity of the MS-40 is 4×10^{-11} std cc/sec air equivalent and leak rate range of 10×10^{0} to 4×10^{-11} std cc/sec air equivalent with external pump.

6.2 Drop Testing Facilities

6.2.1 Environmental Conditioning

Low temperature conditioning of the test item before drop testing was done in a chamber built specifically for this project. The facility, shown in Figure 6-4 and Figures 1 and 2 of Appendix A, was constructed in close proximity to the drop test site to minimize time between removal of the test item from conditioning and drop testing. The test chamber was a plywood box with rigid foam insulation. A removable top was provided for insertion and removal of the test item. A single insulated door was provided for access to the test item. Cooling to the facility was supplied by liquid nitrogen. Thermal monitoring was routed from the chamber to an adjacent building for acquisition and control of the flow of liquid nitrogen. A Watlow controller, referenced to a thermocouple (TC) measuring air temperature in the chamber, controlled the supply of liquid nitrogen. Additional thermocouples were used to monitor the air temperature in the chamber and test item temperatures during conditioning. These data were processed using a Fluke Hydra data logger attached to a computer for data storage. For reporting purposes, data files were reduced following the testing.

6.2.2 Wind Instrumentation

Wind speed was measured using a hand held anemometer supplied and monitored by fire Technology personnel.

6.2.3 Test Pad

The drop pad, an existing test facility that was specifically designed for this type of testing, is shown in Figure 1 of Appendix A. The test facility consists of a 10 x 10 x 6-ft reinforced concrete slab embedded in the ground. A 1-in. thick steel plate, attached to the slab using J-bolts, covers the upper surface of the concrete slab. The entire facility weight is estimated to be 95,000 lb. This does not include any effective mass of the surrounding soil, which is very compact.

SwRI Vertical Furnace

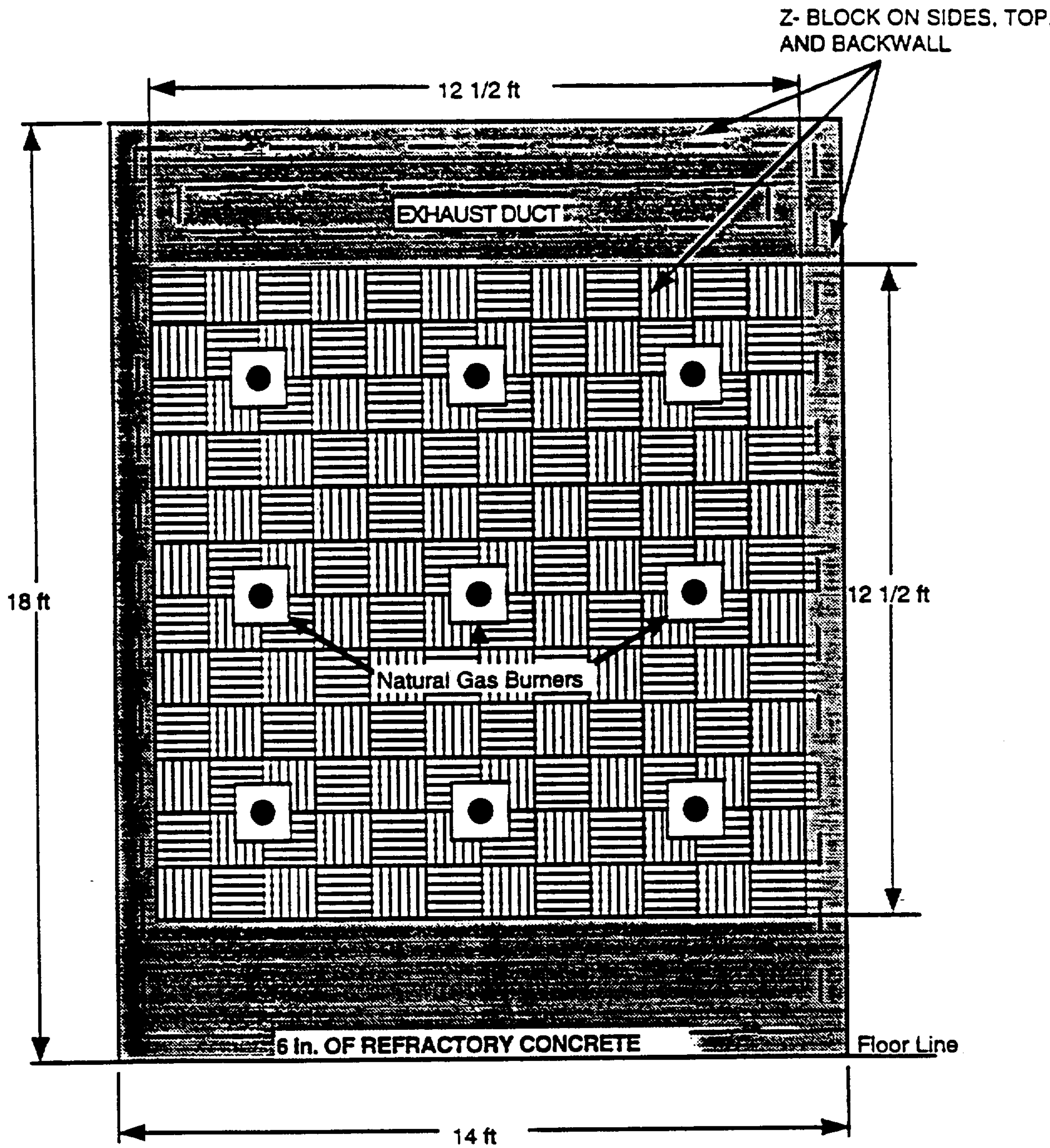


Figure 6-1. SwRI's Large-Scale Horizontal Furnace.

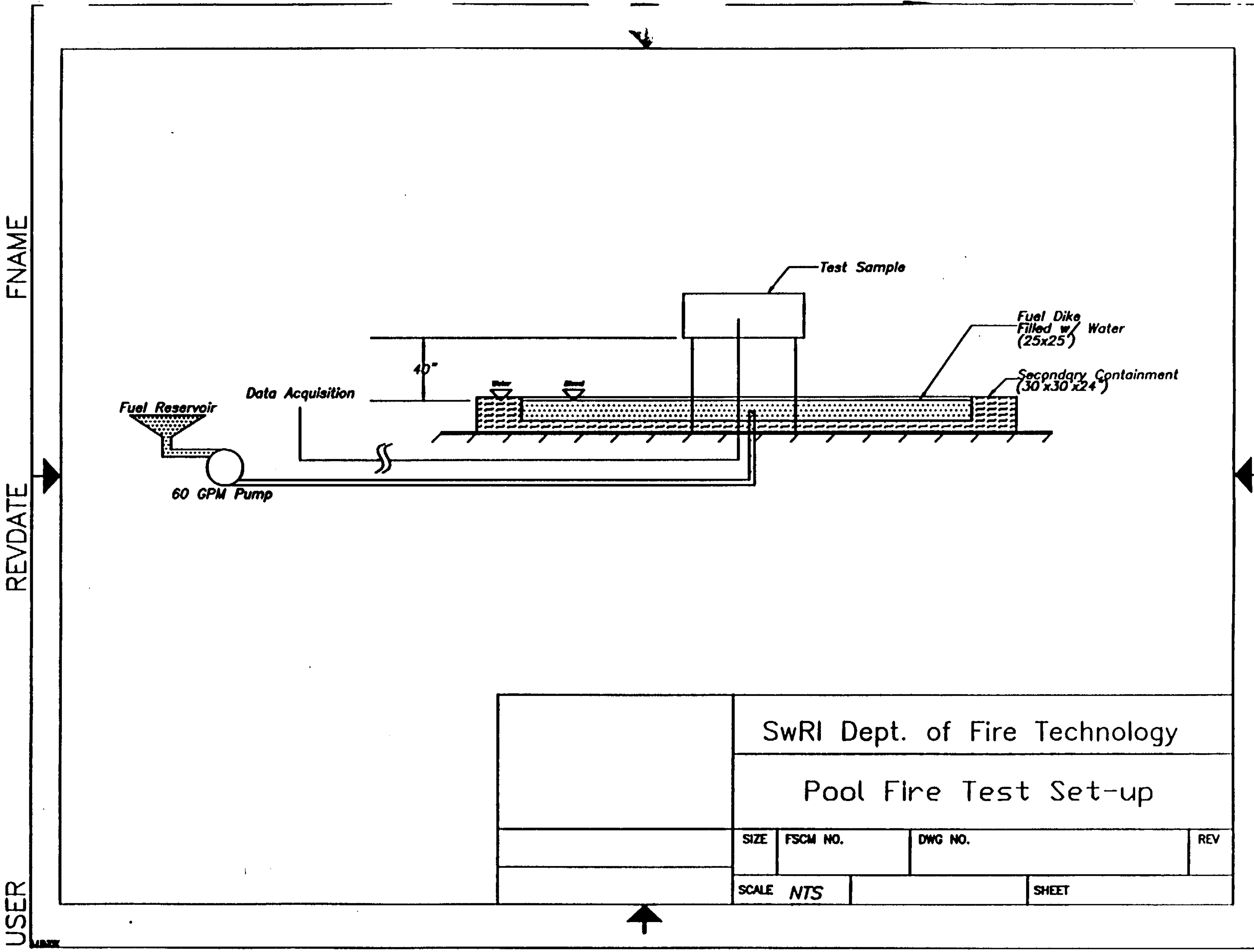


Figure 6-2. Pool Fire Test Setup.

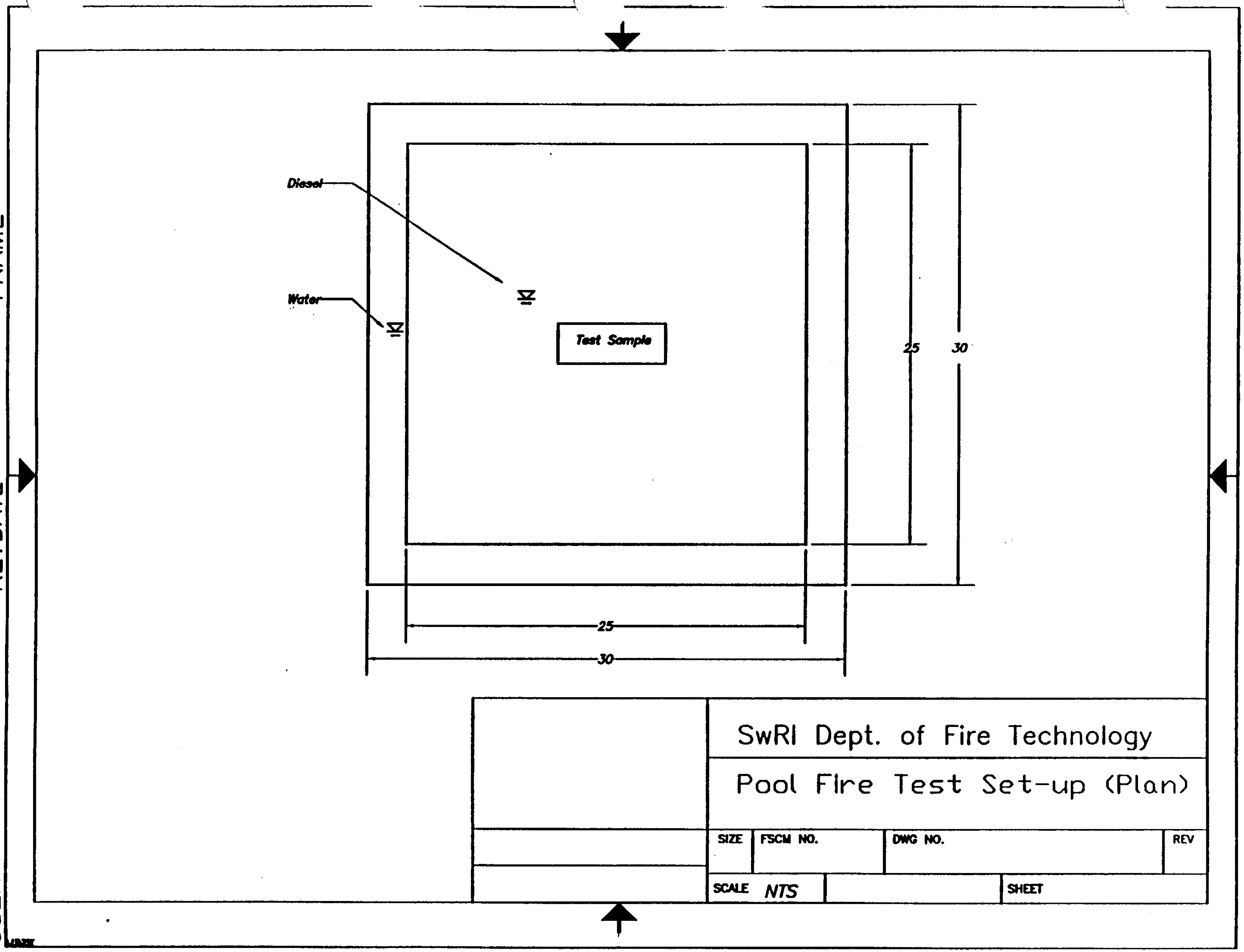


Figure 6-3. Pool Fire Test Setup.

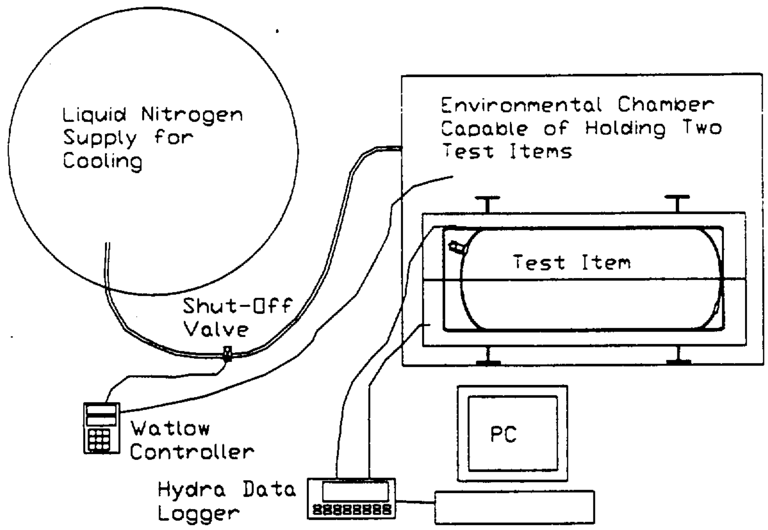


Figure 6-4. Low-Temperature Environmental Conditioning Chamber.

A plywood photographic backdrop was constructed for this project, Figure 1 of Appendix A. Each side of this structure was 12 ft high and 16 ft wide. The backdrop was painted and had a grid of black lines on 1-ft centers covering the surface. The horizontal lines were parallel to the drop pad. For the puncture testing, a puncture bar was attached using 8 bolts to the center of the drop pad. The puncture bar was fabricated out of a 6-in. diameter solid steel section welded to a 2-in. thick steel plate. The 6-in. diameter section was recessed into the plate to insure adequate strength. The distance from the top of the steel plate to the top of the puncture bar was 16 in. There was no significant damage to the puncture bar as a result of the testing. There was no indication of motion of the puncture bar during any testing.

A crane was used to handle the test items for the drop testing. The crane was situated so that it could pull the items out of the conditioning box and handle them for the drops, Figure 1 of Appendix A. SwRI personnel provided the crane operator instructions on how to position the test item for drops. During all testing, there was no tendency of the test item to move, before the drop, as a result of crane operations or wind conditions.

The orientation of the test item was controlled by the use of wire rope slings, specifically designed for this test. Adjustments of the orientation were made using turnbuckles attached at the required locations. The orientation of the test item was verified using the Smartlevel digital instrument.

The drop height was measured using two calibrated plumb bobs. The length of the plumb bobs were adjusted using a calibrated tape measure. The plumb bobs were attached to the test item at the impact point. The crane was used to raise the item to the required height. The impact point and location of the bob was adjusted as required prior to removal of the plumb bob from the test item.

For drops, the test item was released using a quick release mechanism. Under normal conditions, the jaws of the release hold a D-ring pin in place. The D-ring is attached to the wire rope sling supporting the test item. For release, pneumatic pressure is supplied to release the locking pin and allow the jaws to open.

6.3 Fire Testing Facilities

The Department of Fire Technology has more than 30,000 sq ft of laboratory space housing advanced fire science analysis equipment and state-of-the-art full-scale furnaces used to evaluate the fire endurance and fire resistance of full-scale construction elements and assemblies. SwRI's large-scale horizontal furnace (Figure 6-1) was used to condition the test item at elevated temperature prior to conducting the pool fire test.

The Department operates a remote test facility located approximately 40 miles from SwRI's San Antonio facility. The remote test facility is isolated on approximately 15,000 acres and has full utility service. The facility is equipped with a mobile technical support trailer housing state-of-the-art rapid data acquisition equipment, environmental condition station, high-speed computer equipment, and photo/video documentation equipment. The test facility and a diagram of the pool fire test setup are shown in Figures 6-2 and 6-3.

7.0 EQUIPMENT AND INSTRUMENTATION CALIBRATION

All applicable test and measurement equipment were calibrated in accordance with the NPQP. Test and measurement equipment calibration certificates are found in Appendix B. The instrumentation used during testing are listed in Table 7-1.

Table 7-1. Test Instrumentation.

Item	Model	S/N	Calibration Due Date	Comments
Data Logger	Fluke Hydra	6114608	28 Feb 1998	Calibration Overdue, readings verified using Omega Thermal Monitor
Thermal Monitor	Omega	26591	19 Aug 1998	Single channel verification of Hydra
Thermal Controller	Watlow 942		NA	Control only with independent monitoring
Plumb Bob 30 foot Drop Height	NA	NA	before use 13 March 1998	Length based on calibrated tape measure, s/n 30-100T cal due 16 Dec 1998
Plumb Bob 1 meter Drop Height	NA	NA	before use 13 March 1998	Length based on calibrated tape measure, s/n 30-100T cal due 16 Dec 1998
Level	Smartlevel Series 200	PLL-001	11 March 1999	Certificate # 28947
Data Acquisition	Fluke Helios	4889002	11 Aug 1998	Fire tests
Weather Station	NA	492	1 Dec 1998	Fire tests
Inconel Sheathed TC's (Cylinder)	NA	LOT#M069751	NA	Fire tests
Inconel Sheathed TC's (Flames)	NA	LOT#M294709	NA	Fire tests
Air Velocity Meter	NA	94030180	24 Oct 1998	Drop Tests
Psychrometer	NA	J82244-1	19 June 1998	All tests
Dead Weight Tester	1305B100	8371009	9 April 1998	Leakage Tests
Transducer	GP-43F-150-7159	3979	9 April 1998	Leakage tests
Veeco	7MS-40	0555	28 March 1999	Helium leak detector

8.0 TEST PROCEDURE

8.1 Initial/Final Inspection and Preparation of Test Item

SwRI performed initial inspection to verify the pretest condition of the ESP-30X UF_6 shipping package and 30B cylinder. Photographs of the condition of the cylinders were taken as necessary. The new 30B cylinder was provided to SwRI pre-filled with clean steel shot to simulate full payload and with the skirt having been pre-bent and straightened by ESP. Prior to shipping the test item to SwRI, ESP conducted an initial leakage test to confirm that the 30B cylinder was airtight. See Appendix C for See Appendix C for construction details and drawings of the ESP-30X UF_6 shipping package.

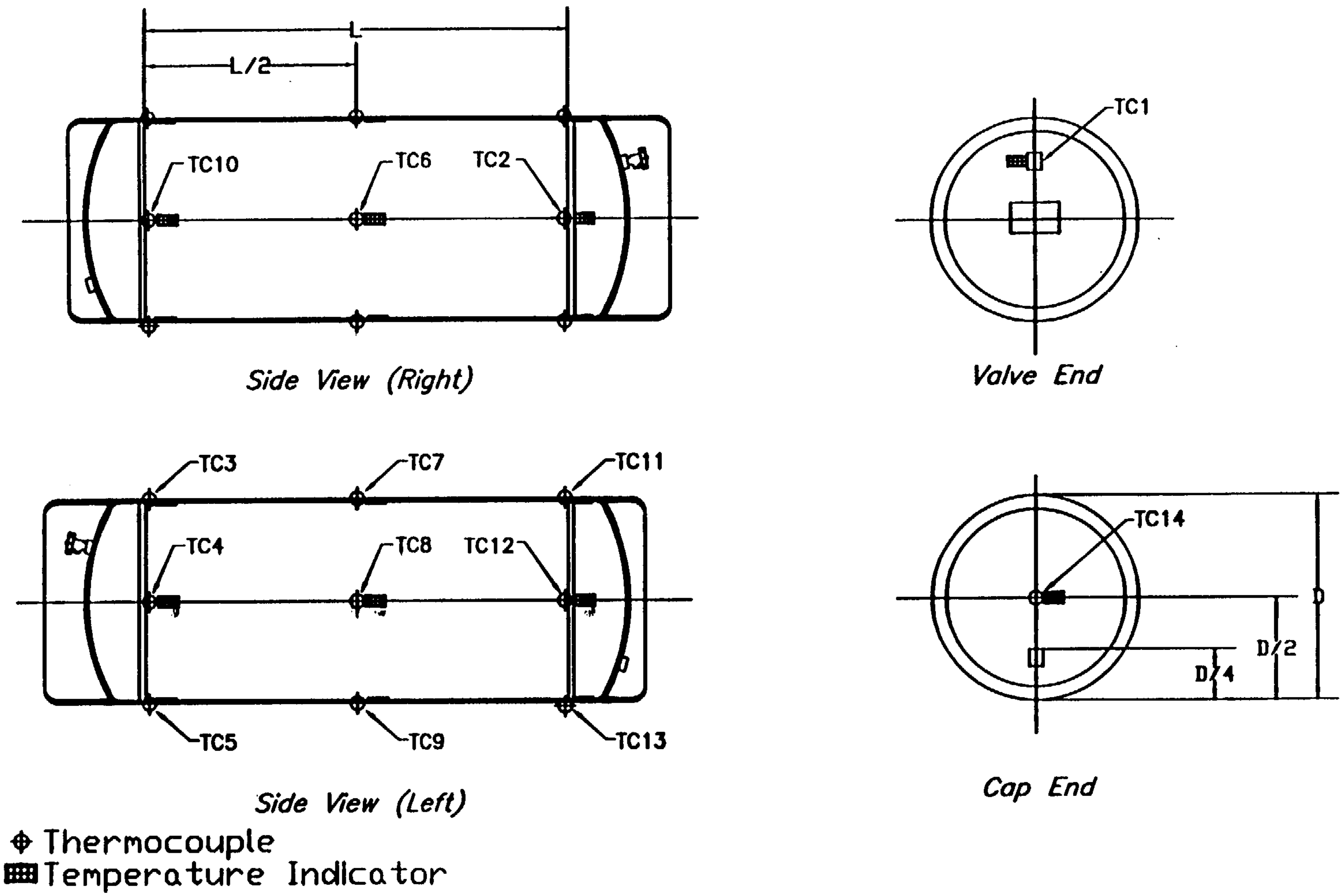
SwRI installed temperature measuring devices on the cylinders as necessary to monitor the temperature of the 30 B cylinder during the tests. The temperature measuring devices were selected to insure that the required information could be obtained without adversely affecting the performance of the system. This includes both the temperature time histories and the peak temperature readings. Slight modification of the cylinder and overpack was required to attach the temperature measuring devices. See Figure 8-1 for TC and thermal tape locations for the 30B cylinder.

Leakage tests were performed following the initial inspection and preparation of the ESP-30X package and completion of the pool fire test to insure that the 30B cylinder remained air tight.

8.2 Leakage and Hydrostatic Tests

8.2.1 Leakage Tests

Leakage tests were performed on the 30B cylinder prior to conducting the drop tests and following the pool fire exposure test. A preliminary soap bubble test was performed on the 30B cylinder with 100-psi internal pressure prior to performing the helium leak test. The helium leak test was performed by evacuating the entire cylinder to the required pressure using a ruffing vacuum pump. The cylinder pressure was reduced to the required level, helium was introduced in the region surrounding the valve, and the leak rate was measured with a helium leak detector and recorded.



Southwest Research Institute

Department of Fire Technology

TITLE	Instrumentation Layout, Thermocouples & Temperature Indicators
CLIENT	Eco-Pak Specialty Packaging
PROJECT NO.	01-1680-102
DRAWN BY:	Aaron Arellano
DATE OF TEST	March 21, 1998
FILE	c:\aaron\jim\eco-pac\tank3.dwg

Figure 8-1. Instrumentation Layout.

8.2.2 Hydrostatic Test

The final portion of the evaluation program was the post-fire hydrostatic test. Following successful completion of the drop and fire tests, the 30B cylinder was filled with water containing a dye. The test item was placed horizontally with the valve in the 6 o'clock position. The plug end was replaced with a port allowing for pressurization of the 30B cylinder to 19 psig. This pressure was held for a minimum period of 8 hr and monitored for any water leakage or pressure drop.

8.3 Drop Testing

The initial physical tests of the ESP-30X UF_6 shipping package were a series of drop tests as described in Title 10 CFR 71.73(c), (1)&(3).

A crane was utilized to raise the test items to the proper height. The test item was supported by a wire rope sling designed to insure that the test item would fall in the proper orientation. The drop angles for the test item were 13.5 and 30 degrees from vertical.

An air-actuated, quick-release mechanism was used, and no guidance of the test item was provided during the drop. Prior to each drop test, the average wind speed, direction, and air temperature was measured to determine if they were within acceptable limits.

The first drop test performed was a 30-ft drop onto the flat surface of the pad and damage to the ESP-30X UF_6 shipping package was recorded. The final drop test was a 40-in. drop onto a puncture bar attached to the center of the steel plate. The puncture bar was constructed of a 6-in. diameter mild steel bar welded into a 2-in. thick steel plate. This plate was, in turn, bolted to the steel plate on top of the drop surface. Following this test, the damage to the ESP-30X UF_6 shipping package was recorded.

Data recorded for each drop test included: normal speed video, color photographs, and measurements of deformations and atmospheric conditions. A backdrop with horizontal and vertical lines spaced at 1-ft increments was provided for reference during the drop event. No acceleration time histories were obtained during the drop. Following the drop test, the test items were inspected and the damage to the overpack was noted. Photo/video documentation was taken, after which the test items were submitted for fire exposure tests.

8.4 Fire Performance Evaluation

Following the drop tests, the test items were transported to SwRI's Department of Fire Technology for elevated temperature thermal conditioning prior to performing the pool fire test at SwRI's remote test facility. The test item was placed in SwRI's large-scale horizontal furnace, and conditioned to a temperature of 100-120°F for a minimum of 24 hr prior to the test. Temperature measurements were made at locations specified in the test procedure with the approval of the client.

Immediately following the elevated temperature thermal soak, the test article was insulated and transported to the remote test site, positioned on the test fixture, and exposed to the specified pool fire conditions for a minimum 30-min period. Documentation consisted of normal speed video and still photography at a minimum of two locations. The pool fire dimensions were 25 x 25 ft. Fuel was pumped into the pool fire pan during the test at a rate appropriate to maintain a fully engulfed pool fire for 30 min.

Following extinguishment, temperature data was recorded during the cool down period. During cool down, the test article was protected from precipitation and wind effects to eliminate enhanced cooling of the test article. The test article was then transported to SwRI for further analysis, post-fire leakage test, and the final hydrostatic test.

9.0 TEST RESULTS

9.1 Leakage and Hydrostatic Test Results

Initial soap bubble and helium leakage tests were performed on the 30B cylinder prior to conducting the drop tests and following completion of the pool fire exposure test. The preliminary soap bubble test was performed on March 11,1998. For this test, the 30B cylinder was pressurized to 100 psi, and the soap bubble indicator fluid was directed to the region surrounding the valve assembly and monitored for signs of leakage. After a period of 25 min, no leakage was detected. The acceptance criteria specified that any leakage greater than 1.0×10^{-7} std cc/sec of air is considered a failure.

The pre-drop helium leakage test was performed on March 11, 1998. A ruffing vacuum pump was used to evacuate the 30B cylinder to the required pressure of less than 1×10^{-3} atm (1×10^{-3} atm = .0147 psi = .761 Torr). Pressure in the 30B cylinder was 453-464MT; the background helium leakage rate was 1.4×10^{-8} std cc/sec; and helium was introduced in the region surrounding the valve. The leakage rate measured after 10 min with the helium leak detector was 1.3×10^{-8} std cc/sec.

Following completion of the pool fire exposure test on March 21, 1998, final post-fire soap bubble and helium leakage tests were performed on the 30B cylinder. The preliminary soap bubble test was performed March 23,1998. For this test, the 30B cylinder was pressurized to 100 psi; and the soap bubble indicator fluid was directed to the valve assembly and monitored for signs of leakage. After a period of 20 min, no leakage was detected.

The post-fire helium leakage test was performed on March 24, 1998. A ruffing vacuum pump was used to evacuate the 30B cylinder to the required pressure, and the background helium leakage rate was 4.0×10^{-9} std cc/sec. Helium was introduced in the region surrounding the valve, and the leakage rate measured after 7 min with the helium leak detector was 3.9×10^{-9} std cc/sec.

Following successful completion of the post-fire helium leakage test, the 30B cylinder was filled with water containing flourescent indicator dye. The test item was placed horizontally with the valve in the 6 o'clock position. The plug opposite the valve end was replaced with a port allowing for pressurization of the 30B cylinder to approximately 20 psig. The pressure was allowed to stabilize, was held for a minimum period of 8 hr, and monitored for any water leakage or pressure drop. After a period of 23 hr, no leakage was detected, and the pressure was 13 psi (pressure drop was due to changing environmental conditions, not to leakage).

Table 9.1 summarizes results for the pre-drop/post-fire preliminary soap bubble tests, pre-drop/post-fire helium leak tests, and post-fire hydrostatic leakage test. Data log sheets for all leakage and hydrostatic tests are found in Appendix D.

Table 9.1. Leakage and Hydrostatic Test Results
Test Item: ESP-30X, SN001 30B Cylinder, CB-1871-2

TEST PERFORMED	REQUIREMENT	MEASUREMENT	PASS/FAIL
Pre-Drop Soap Bubble	No Leaks	No Leaks	Pass
Pre-Drop Helium	$< 1.0 \times 10^{-7}$ std cc/sec	1.3×10^{-8} std cc/sec	Pass
Post Fire Soap Bubble	No Leaks	No Leaks	Pass
Post Fire Helium	$< 1.0 \times 10^{-7}$ std cc/sec	$< 3.9 \times 10^{-9}$ std cc/sec	Pass
Post Fire Hydrostatic	No Leaks	No Leaks	Pass

9.2 Drop Testing

The testing outlined in this section was designed to demonstrate the performance of the shipping configurations under hypothetical accident conditions.

The drop testing included the following major steps:

1) Conditioning to -20°F of ESP-30X SN001.
2) 30-ft drop test of SN001 at 13.5° on valve location.
3) Physical inspections of overpack.
4) 40 in. puncture test of SN001 at 13.5° on valve location.
5) Physical inspections of overpack.
6) Selection of SN001, by ESP personnel, for the final puncture test.
7) 40 in. puncture test of SN001 on shell.
8) Physical inspections of overpack.

Test facilities utilized for performance of the work under this project were adequate to accomplish the objectives of the project.

9.2.1 Assumptions

A basic assumption made for this testing was that the drops made are the worst case condition as required by 10 CFR Part 71. ESP defined these configurations.

9.2.2 Environmental Conditioning

The low temperature conditioning was done in a chamber to achieve the required test item temperature, -20°F (-29°C) on the overpack insulation. To measure this temperature, a 2-in. deep hole was drilled in the overpack and a TC installed. The TC hole was sealed with RTV to prevent air infiltration. To accelerate cooling, the air temperature in the chamber was varied. A target air temperature was -40°F, the minimum transportation temperature as defined in ANSI N14.1. In some cases, the air temperature was set lower than this to accelerate the cooling. Because of the thermal mass and insulation of the test item, its response to changes in the air temperature was slow.

Conditioning was performed until the test item had reached the required temperature. During the testing process (removal from the conditioning chamber, drop angle adjustments, drops, and physical

inspection), the test item temperature rose. When not being tested, the test item was returned to the chamber to stabilize the temperature. This low-temperature conditioning met the intent of the low-temperature requirements of 10 CFR Part 71.

Plots of the chamber air temperature and test item temperatures are included in this report as Figure 9-1. Low-temperature conditioning of the ESP-30X SN001 test item started on March 13, 1998, at 13:28 p.m., see Figure 2 of Appendix A. During the first 24 hr of conditioning, the chamber air temperature was set to a nominal -40°C. At this time, the test item temperatures were close to the required levels. To insure that they did not get too low, the chamber temperature was raised to -30°C for the rest of the weekend. Sunday, March 15 at 16:30 p.m., the liquid nitrogen supply ran out. Since this occurred late in the day on Sunday, it was not corrected until early Monday morning, March 16 at 6:07 a.m. During this time, the chamber and test item temperatures rose. On Monday morning, Dewars were connected to the chamber and the air temperature set to -40°C. These Dewars were used until the large tank was refilled and connected March 16 at 11:46 p.m. At that time, the air temperature was set to -50°C, to try and drive the test item temperatures down to the required levels prior to testing.

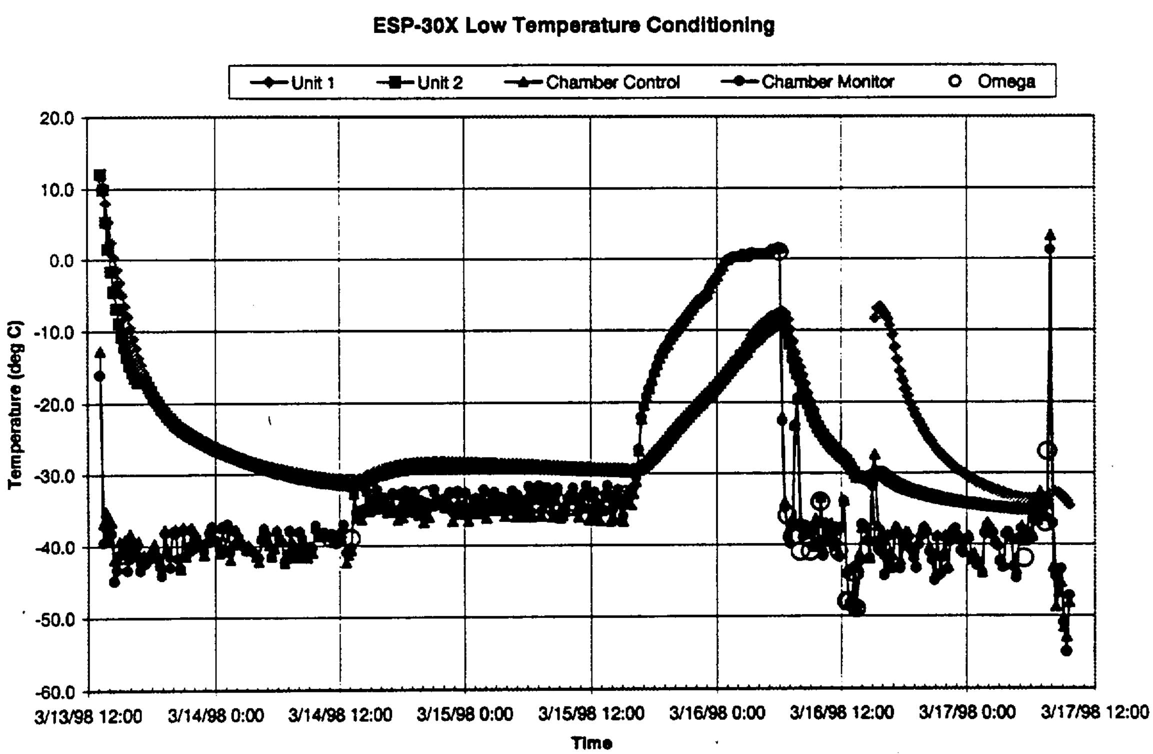


Figure 9-1. ESP-30X Low-Temperature Conditioning Time History.

On removal of ESP-30X SN001, which had an insulation temperature of -31 °C (-23 °F), from the chamber March 16 at 13:31 p.m., the air temperature was set back to -40 °C. Drop testing was performed on SN001 and it was returned to the chamber for additional conditioning over night. When placed back in the chamber, the insulation temperature was -8 °C (17 °F). The insulation temperature had risen 23 °C during the 1 hr 45 min of testing, about 1 °C every 5 min.

At 9:38 a.m., the insulation temperature of ESP-30X SN001 was -34 °C (-30 °F), and the cylinder was removed from the chamber for the final puncture test on this test item, as specified by ESP personnel. It was possible to keep the temperature at or below -20 °F (-29 °C) before the drop test.

9.2.3 Drop Testing

Immediately before opening the chamber, the test item temperature was -23 °F (-31 °C), Figure 3 of Appendix A. Three tests were performed on ESP-30X SN001. The first was a 30-ft drop onto the flat surface of the pad. One orientation of the test item, 13.5° from vertical with the impact at the valve location, was used, Figure 4 of Appendix A. The damage to the overpack exterior was measured and recorded following this testing. The second drop was a 1-m drop onto a puncture bar attached to the center of the steel plate. The damage to the overpack exterior was measured and recorded following this testing. The test item was then returned to the test chamber for additional conditioning. ESP personnel selected SN001 as the most damaged overpack, and a third drop consisting of a 1-m puncture onto the side of the overpack was performed. The damage to the overpack exterior was measured and recorded following this testing.

Table 9-2 summarizes the testing performed on this test item. All testing was completed successfully. The test item received some damage that was considered acceptable by ESP personnel.

Drop testing was performed with the cooled and undamaged ESP-30X overpack. After low temperature conditioning, the test item was removed from the chamber, Figure 3 of Appendix A, and a wire rope sling was attached to the overpack to orient the test item for drops with the longitudinal axis of the package at 13.5° ± 1.0° from vertical, Figure 4 of Appendix A. This orientation was such that the center of gravity of the package was over the 30B cylinder valve. Figure 4 of Appendix A illustrates the package orientation for testing.

Table 9-2. ESP-30X SN001 Drop Testing Performed.

Procedure	Dates	Comments
Conditioning Before Drop	3/13/98 3/16/98	-23°F on overpack insulation at end of conditioning
30-ft Drop	3/16/98	Good drop at 14.0°
Exterior Physical Measurements	3/16/98	By fire Technology personnel
1-m Puncture	3/16/98	Good drop at 13.5°
Exterior Physical Measurements	3/16/98	By Fire Technology personnel
Conditioning Before Drop	3/16/98 3/17/98	Initial insulation temperature of 17°F. -30°F at end of conditioning.
1-m Puncture	3/17/98	Good horizontal drop at 45° rotation
Exterior Physical Measurements	3/17/98	By Fire Technology personnel

The test item was raised to the required drop height with the crane. The drop height was determined using the calibrated plumb bob attached to the first impact point on the test item. The release of the test item was by a pneumatically actuated quick-release mechanism. No guidance of the test item was provided during the drop. Drop testing was performed under conditions that did not affect the results of the test. The average wind speed was noted, and found to be sufficiently low so that the packaging did not rotate during testing.

For this drop, the pre-test conditions were:

- Drop Angle 14.0 degrees
- Drop Height 30 ft to impact face
- Wind Speed Acceptable

The test item was released cleanly and impacted the pad at the desired orientation. The test item impacted the drop pad, crushed the end of the overpack, and remained on its end. Videos were taken of the drop event. The condition of the overpack can be seen in Figures 4 and 5 of Appendix A. As a result of the drop, the exterior of the overpack was damaged. Deformation data of the overpacks were measured and recorded by Fire Technology personnel, see Figures 6 and 7 of Appendix A. Color photographs showing the extent of damage were taken. The overpack was not opened after this test. All phases of this testing were witnessed by SwRI QA/QC and ESP personnel.

The ESP-30X package was then dropped one meter onto a cylindrical 6-in. mild steel bar mounted on the unyielding horizontal surface. For this drop, the longitudinal axis of the package was at an angle of 13.5° from vertical. This orientation was such that the center of gravity of the package was over the cylinder valve. The puncture drop was onto the damaged surface from the previous 30-ft drop. Figure 8 of Appendix A illustrates the package orientation.

For this drop, the pre-test conditions were:

- Drop Angle 13.5 degrees
- Drop Height 1 m to impact face
- Wind Speed Acceptable

The test item was released cleanly and the drop was made (Figure 8 of Appendix A) with the impact in the proper location. Videos were taken of the drop event. Following the drop, the overpack was on its top and half off the drop pad. Deformation of the overpack was measured and recorded, by Fire Technology personnel. Color photographs showing the extent of damage were taken.

The ESP-30X package was returned to the thermal chamber for additional conditioning. ESP personnel determined that SN001 would receive the final puncture. The ESP-30X package was removed from the thermal chamber and dropped 1 m onto a cylindrical 6-in. mild steel bar mounted on the unyielding horizontal surface. For this drop, the longitudinal axis of the package was horizontal and the seam between the upper and lower halves of the overpack rotated 45°. Figure 9 of Appendix A illustrates the package orientation.

For this drop, the pre-test conditions were:

- Drop Angle Horizontal with 45° rotation
- Drop Height 1 m to impact face
- Wind Speed Acceptable

The test item was released cleanly and the drop was made (Figure 9 of Appendix A) with the impact in the proper location. Videos were taken of the drop event. Following the drop, the overpack was on its top still resting against the puncture bar. Deformation of the overpack was measured and recorded by Fire Technology personnel. Color photographs showing the extent of damage were taken.

There was damage to the ESP-30X overpack as a result of this testing. The seam between the upper and lower halves of the overpack did not open noticeably. ESP personnel judged the performance of the test item.

9.3 Fire Performance Evaluation Test

The ESP-30X package was placed in SwRI's large-scale horizontal furnace and conditioned to a temperature of 100-120°F for a minimum of 24 hr prior to the test. Immediately following the elevated temperature thermal soak, the test article was insulated and transported to the remote test site.

The pool fire test described in Title 10 CFR 71.73(c),(4) was performed on March 21, 1998. Present to witness the test were Mr. Mike Arnold and Ms. Heather Little representing ESP. Following initial startup procedures and transfer of 2000 gal of diesel fuel to the burn pan, the data acquisition equipment was verified and the fuel was ignited to begin the 30-min pool fire test. Table 9-3 lists the significant observations during the pool fire exposure and post-test cool down period.

Following extinguishment, temperature data were recorded during the cool down period. During the cool down, the test article was protected from precipitation and wind effects to eliminate enhanced cooling of the test article. The test article was then transported to SwRI for further analysis, post-fire leakage test, and the final hydrostatic test.

After 2 min 45 sec, the test item was fully engulfed and flame jets were observed emitting from the penetration in the overpack at the TC cooling jacket. At 5 min into the pool fire exposure, smoke was observed emitting from the TC junction box. The flame jets forced flames and hot gases down the cooling jacket and forcibly removed the ceramic fiber packing material used to seal the thermocouples in the cooling jacket raceway. Explosive venting occurred at 8 min 5 sec, and smoke was observed emitting from the TC junction box.

Flames and hot gases within the TC junction box caused intermittent interruption of four of the TC's starting at approximately 7 min. Readings of the remaining TC's were unaffected.

Immediately following the 30-min pool fire exposure, the junction box was opened and the TC connections were inspected. The affected TC's had melted insulation and connectors. The affected TC's were disconnected and the TC leads were isolated and a hand-held meter was used to verify function of the TC's. New connectors were installed and the data acquisition program was restarted to begin the cool down period.

Table 9-3. Pool Fire Test Observations.

TIME (Min:Sec)	OBSERVATIONS
-1:15	Pool fire ignited to begin pre-burn.
0:00	Pre-burn completed. Flames fully developed across pool surface.
1:00	Test item engulfed in flames.
2:45	Test item engulfed in flames. Flame jets emitting from penetration in overpack at TC cooling jacket.
5:00	Test item engulfed in flames. Smoke emitting from TC junction box.
6:30	Flame jets at TC cooling jacket intensify.
8:05	Explosive venting of overpack through TC cooling jacket with smoke cloud emitting from junction box.
10:00	Test item engulfed in flames. Light wind moves flame plume to east side. Flame jets continue from TC cooling jacket.
11:00	Test item engulfed in flames. Flame plume to east side. Intermittent view of top of test article.
15:00	Test item engulfed in flames. Flame plume vertical.
20:00	Test item engulfed in flames. Flame plume vertical.
25:00	Test item engulfed in flames. Flame plume vertical.
30:00	Flames subsiding. Residual burning allowed to self extinguish.
35:00	Initial inspection of test item and instrumentation.
40:00	TC repair and verification initiated.
60:00	TC repair and verification completed.
65:00	Data acquisition program restarted to monitor cool down period.
No significant observations for remainder of cool down period (7 hr)	

The affected TC's were disconnected and the TC leads were isolated and a handheld meter was used to verify function of the TC's. New connectors were installed and the data acquisition program was restarted to begin the cool down period.

The following time-temperature profiles were prepared using the TC data up until the time readings were interrupted and after the TC's were repaired and verified. Data for the affected TC's during the time no data was recorded has been interpolated.

The time-temperature profiles during the pool fire exposure and cool down period from the start of the test to 65 min for the primary instrumentation are shown in Figures 9-2 through 9-5.

CLIE. .: ECO-PAK SPECIALTY PACKAGIN.
SwRI PROJECT No.: 01-1680-102
DATE: 21 MARCH 1998
FILE ID: 08030SXT.DAT
08030SC2.DAT

ESP-30X PACKAGE
CYLINDER TEMPERATURES (1-4)

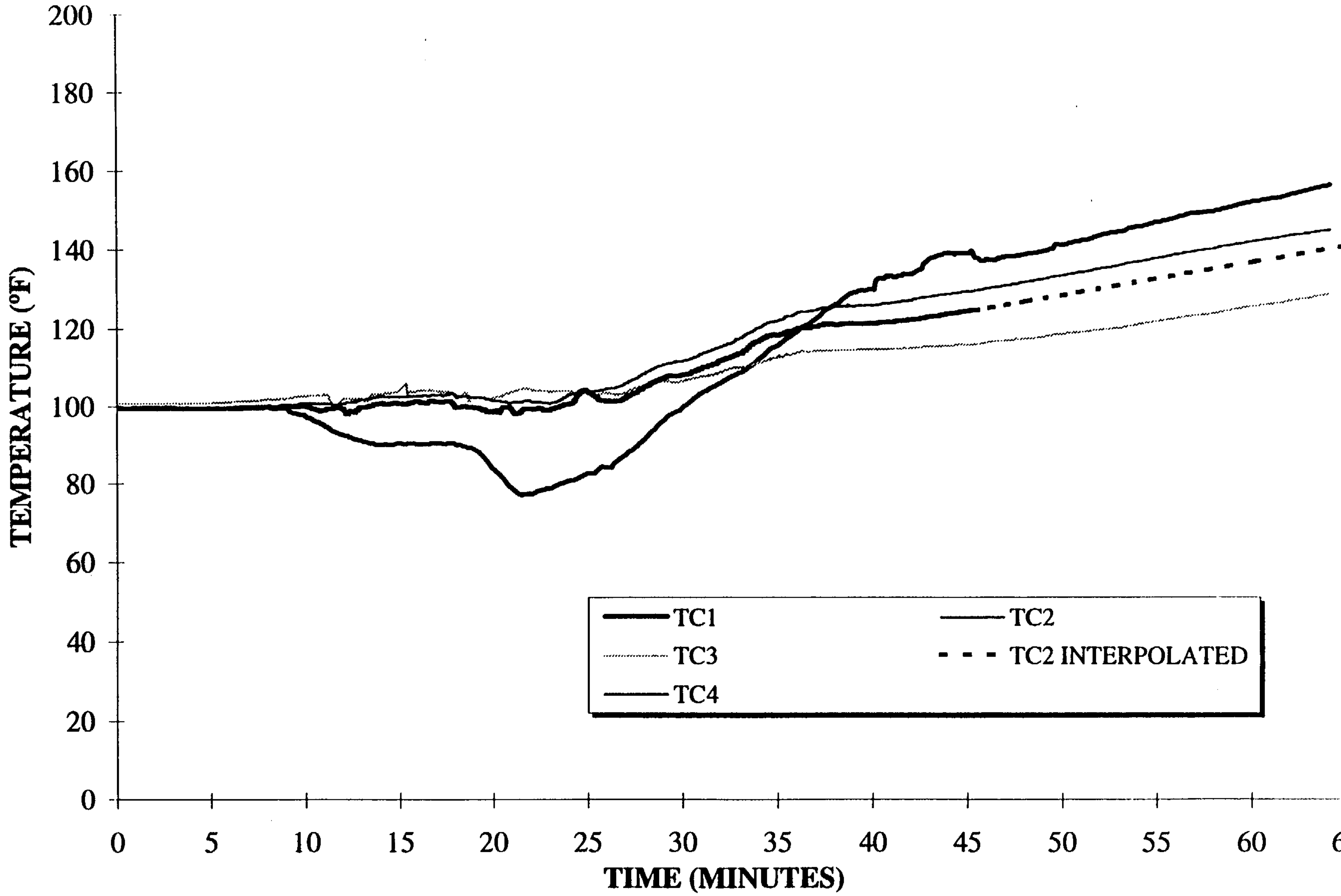


Figure 9-2. 30B Cylinder Thermocouple Readings.

CLIENT: ECO-PAK SPECIALTY PACKAGING
SwRI PROJECT No.: 01-1680-102
DATE: 21 MARCH 1998
FILE ID: 08030SC2.DAT
08030SXT.DAT

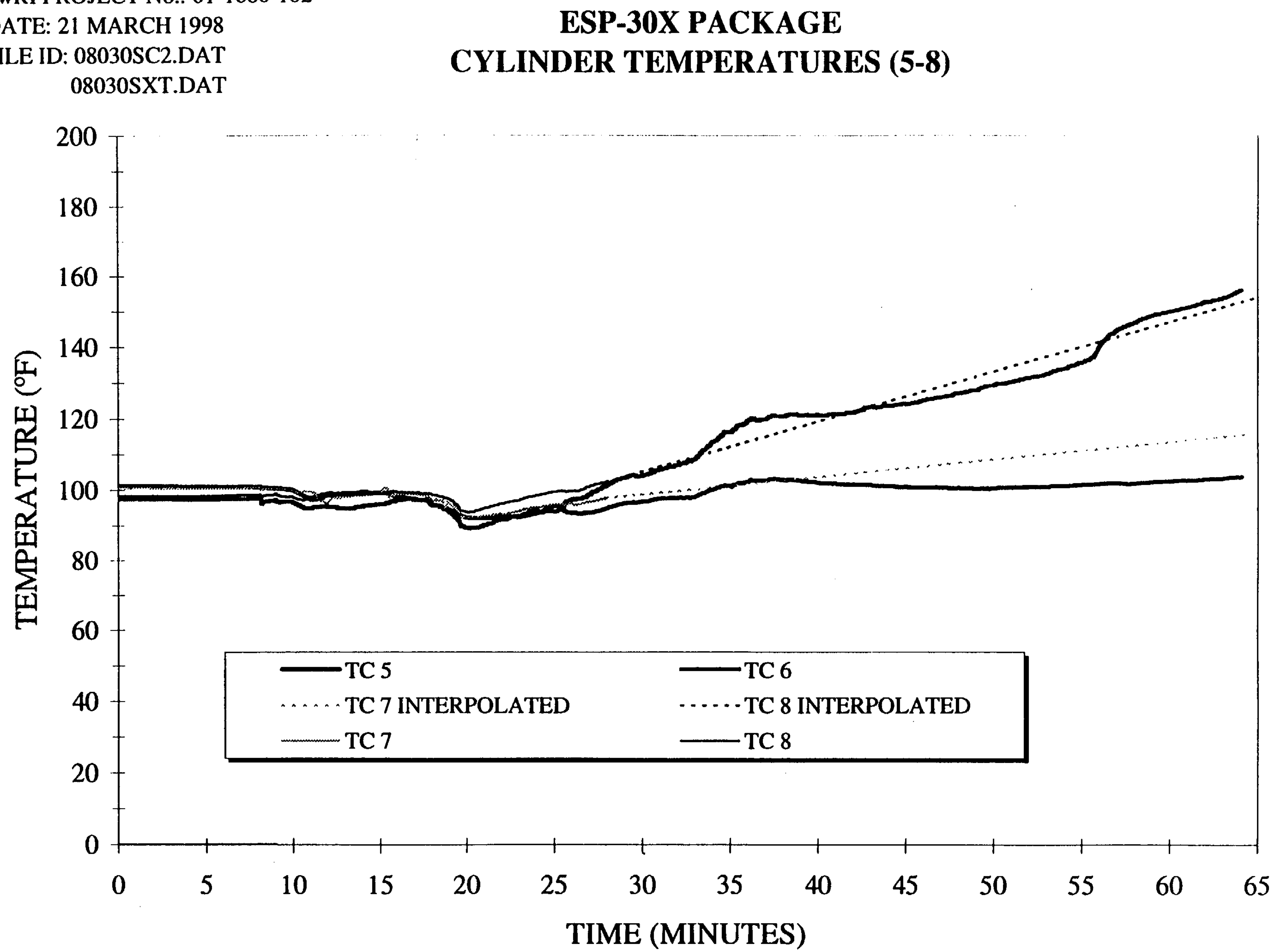


Figure 9-3. 30B Cylinder Thermocouple Readings.

CLIE. . ECO-PAK SPECIALTY PACKAGING
SwRI PROJECT No.: 01-1680-102
DATE: 21 MARCH 1998
FILE ID: 08030SC2.DAT
08030SXT.DAT

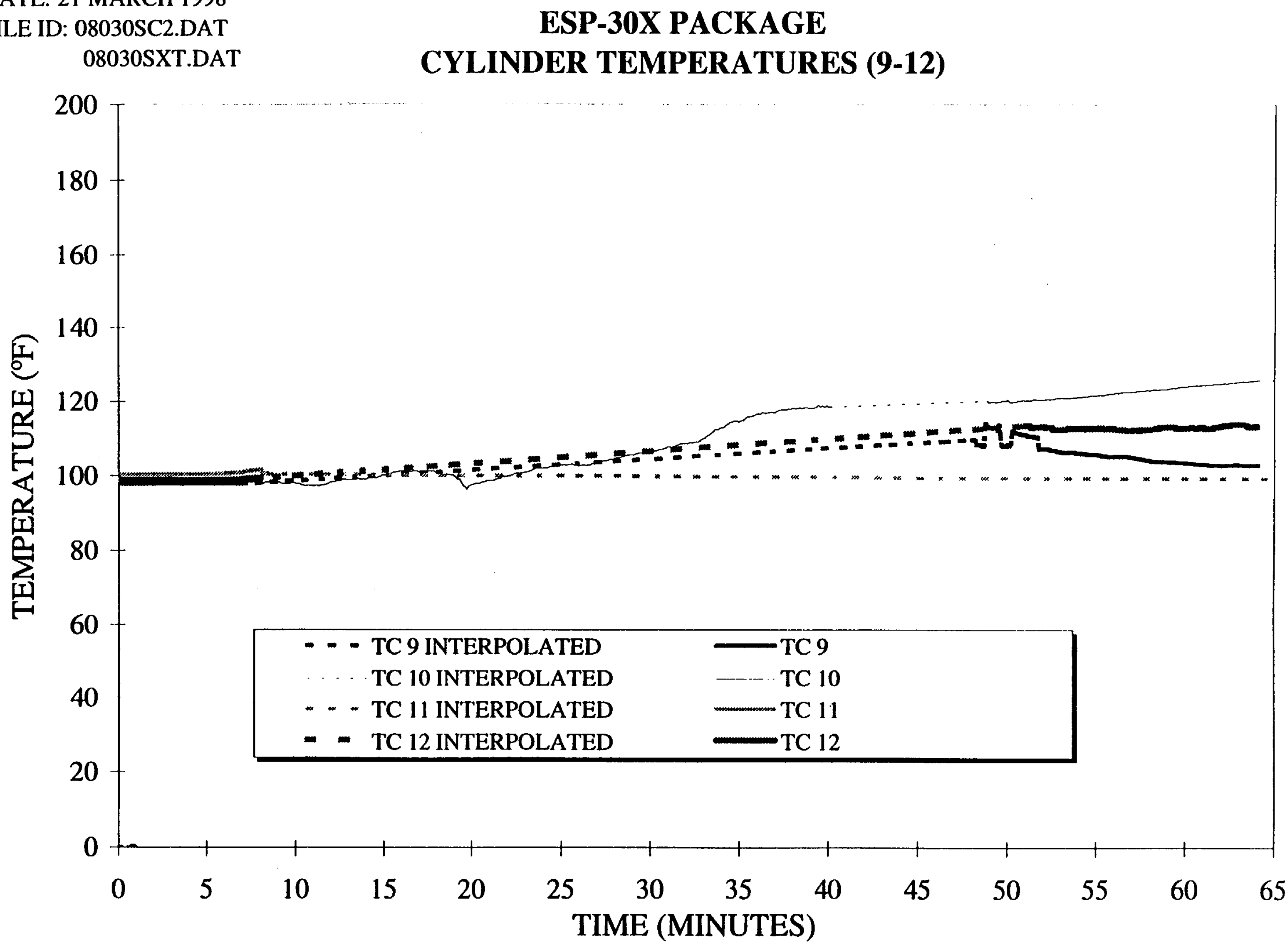


Figure 9-4. 30B Cylinder Thermocouple Readings.

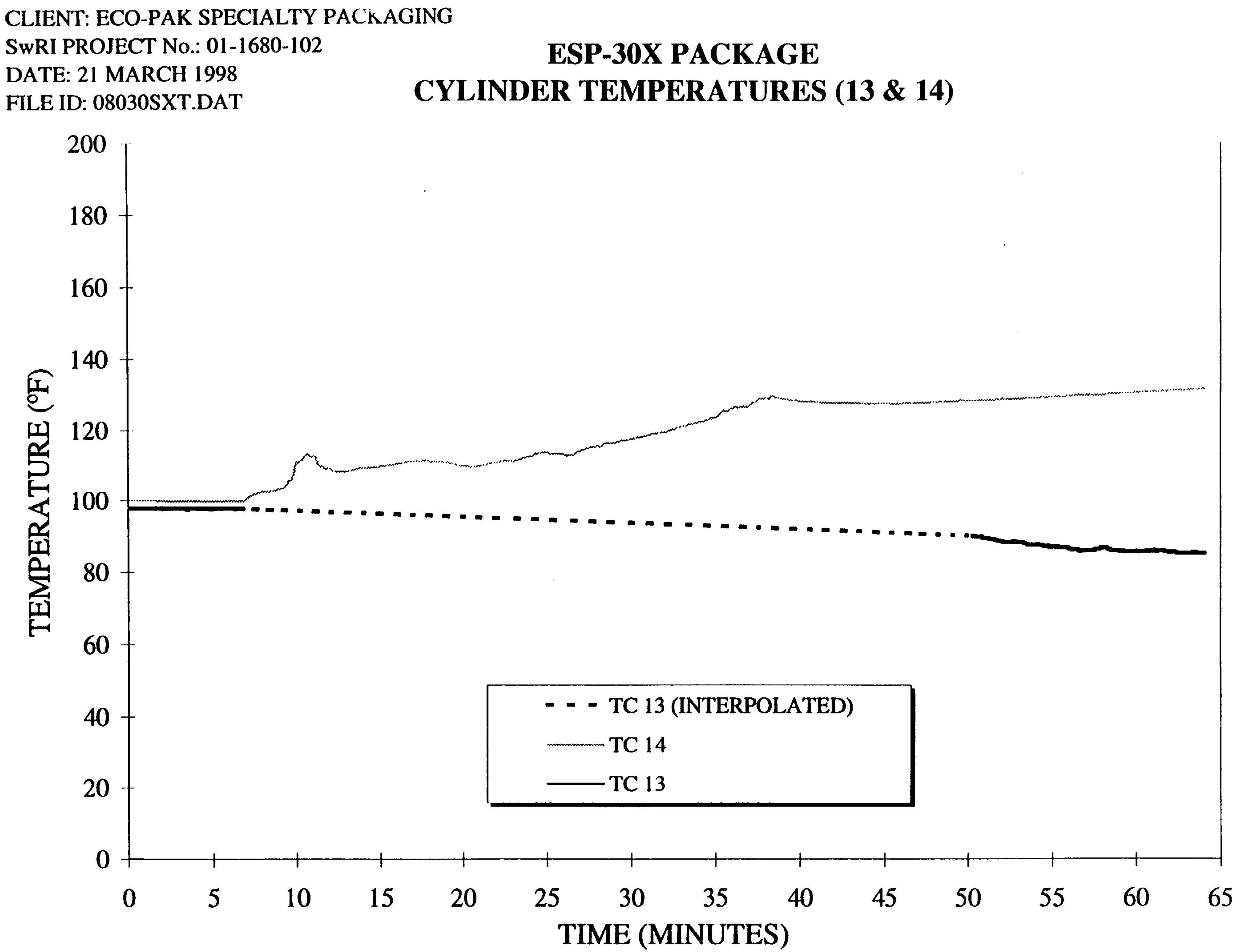


Figure 9-5. 30B Cylinder Thermocouple Readings.

Figures 9-6 through 9-9 show the time-temperature profiles for the 30B cylinder TC's during the cool down period. Table 9-4 shows the maximum temperature and time of occurance for each thermocouple during the 30-min pool fire exposure and 11-hr cool down period. Figure 9-10 shows the maximum temperature reading recorded by the surface TC's during the fire and cool down period.

Table 9-4. 30B Temperature Readings.

	Fire Exposure < 30 Min.		Cool Down > 30 Min.	
TC. No.	Max. Temp, °F	Time (Min)	Max. Temp, °F	Time (Hr:Min)
1	100	0	187	2:17
2	108	30	161	1:36
3	106	30	177	3:52
4	112	30	158	2:14
5	101	0	142	4:09
6	104	30	168	1:23
7	101	0	161	4:22
8	102	28	160	1:26
9	98	0	125	4:29
10	106	30	142	2:30
11	101	6	155	4:18
12	99	0	144	2:43
13	98	26	131	3:36
14	117	30	148	3:10

Figure 9-11 shows the maximum temperature reading recorded by the secondary instrumentation which consisted of temperature-sensitive labels located next to the TC's to monitor the maximum temperature during the pool fire exposure and cool down period.

Tabular data for the TC measurements appear in Appendix E. Photographic documentation for the fire tests appears in Appendix F.

10.0 SUMMARY OF TEST RESULTS

The Table 10-1 summarizes the results for the pre-drop/post-fire preliminary soap bubble tests, pre-drop/post-fire helium leak tests, and post-fire hydrostatic leakage test.

CLIENT: ECO-PAK SPECIALTY PACKAGING
SwRI PROJECT No.: 01-1680-102
DATE: 21 MARCH 1998
FILE ID: 08030SXT.DAT
08030SC2.DAT

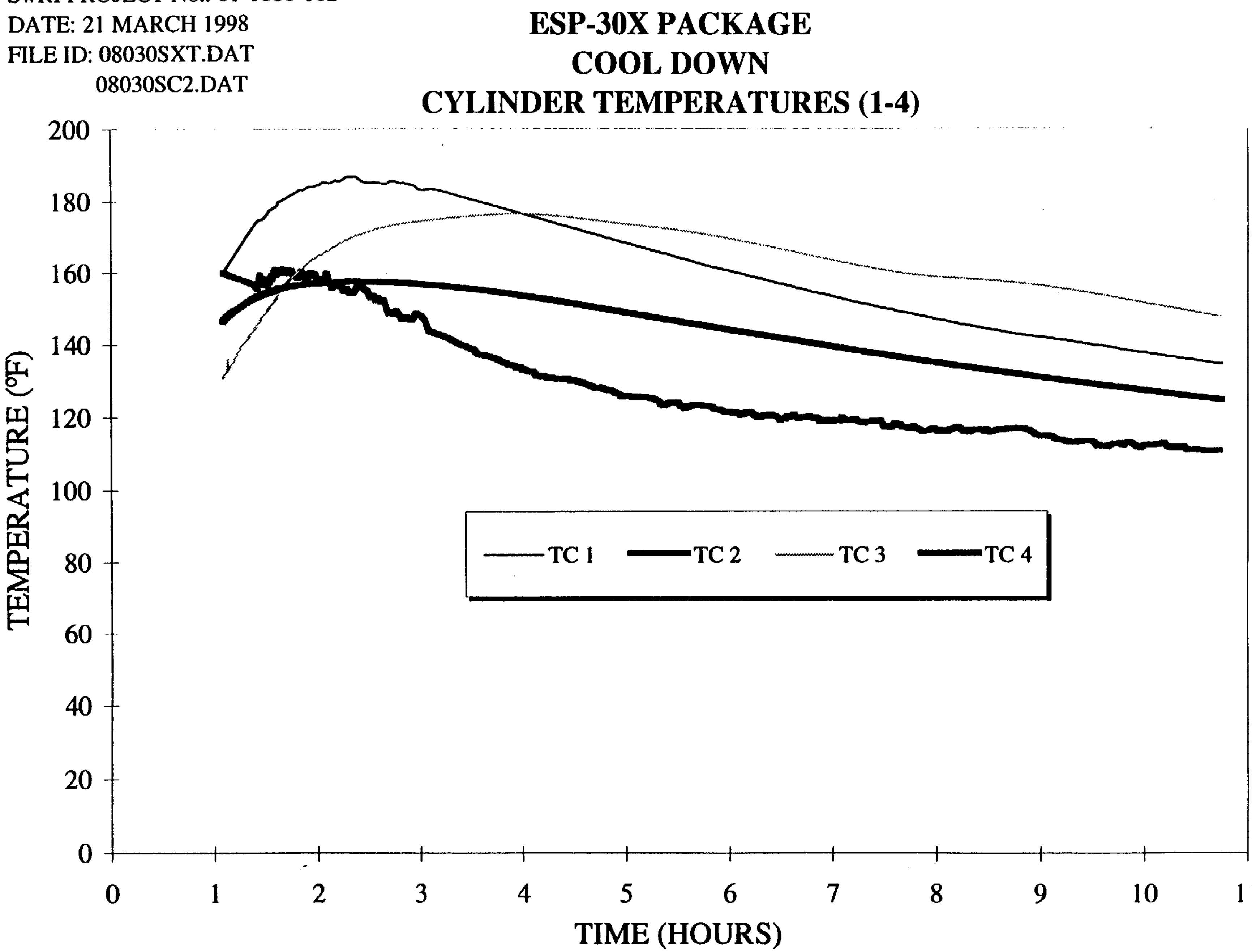


Figure 9-6. 30B Cylinder Thermocouple Readings.

CLIENT: ECO-PAK SPECIALTY PACKAGING
SwRI PROJECT No.: 01-1680-102
DATE: 21 MARCH 1998
FILE ID: 08030SXT.DAT
08030SC2.DAT

ESP-30X PACKAGE
COOL DOWN
CYLINDER TEMPERATURES (5-8)

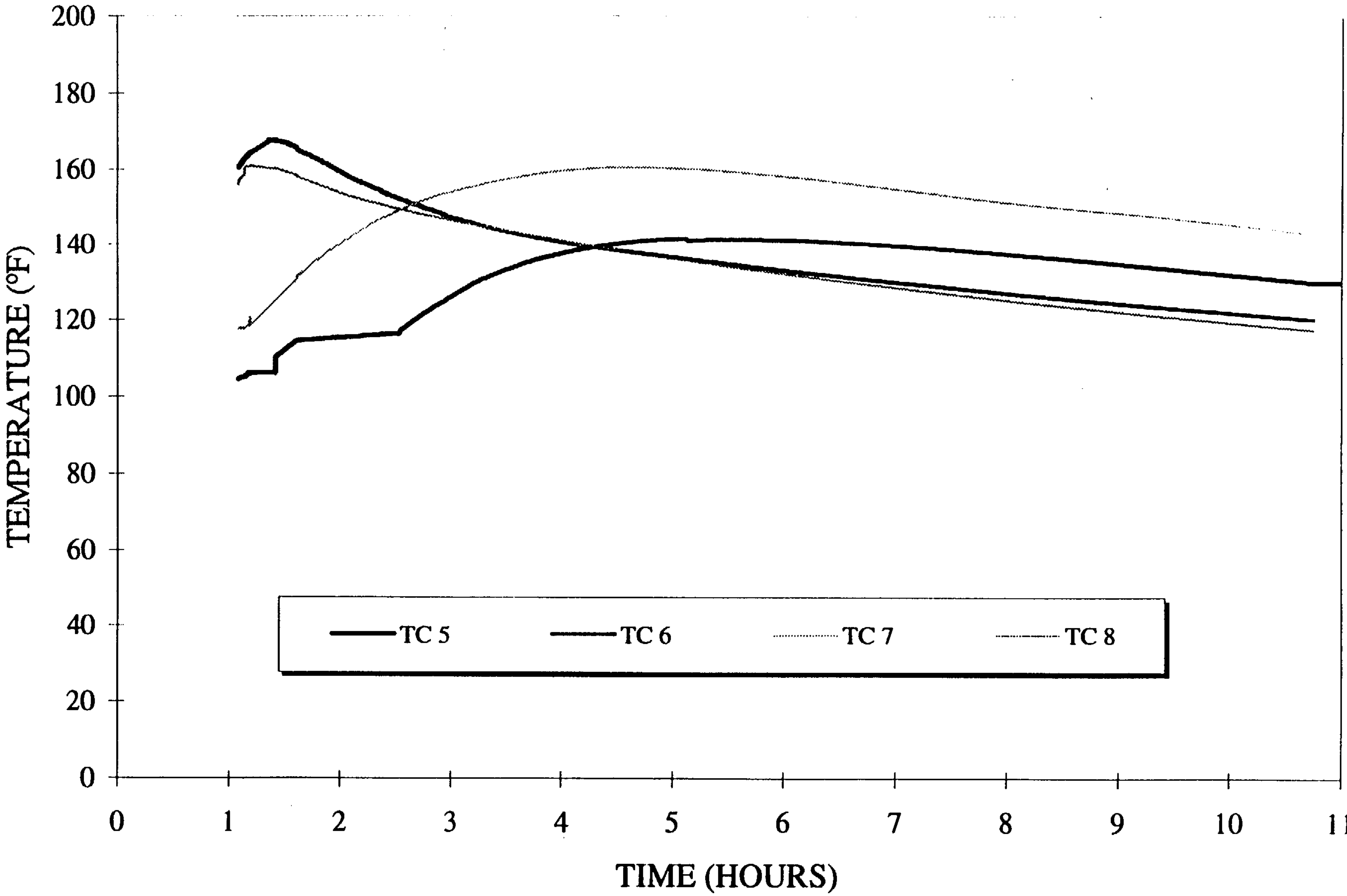


Figure 9-7. 30B Cylinder Thermocouple Readings.

CLIENT: ECO-PAK SPECIALTY PACKAGING
SwRI PROJECT No.: 01-1680-102
DATE: 21 MARCH 1998
FILE ID: 08030SXT.DAT
08030SC2.DAT

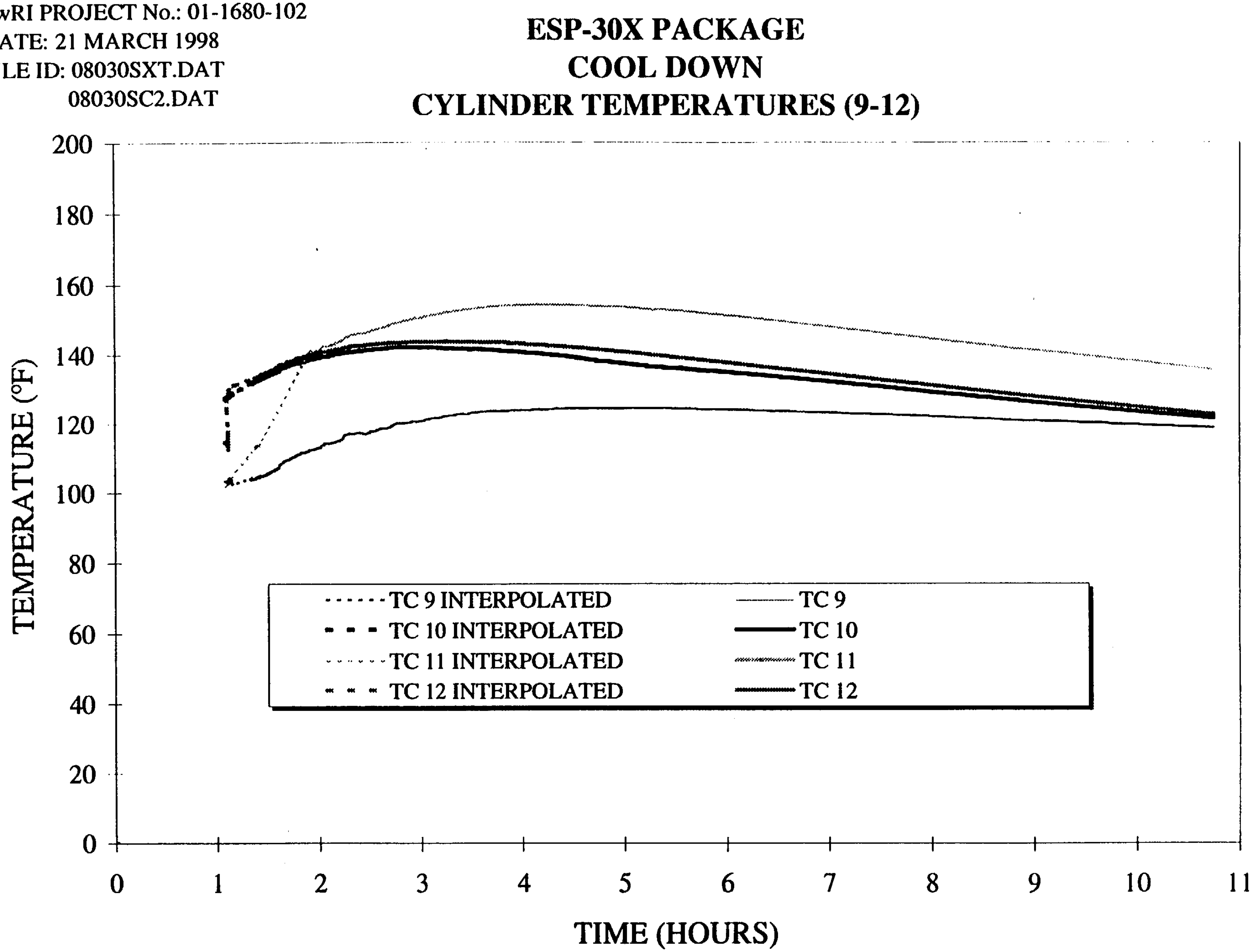


Figure 9-8. 30B Cylinder Thermocouple Readings.

CLIE. . .: ECO-PAK SPECIALTY PACKAGING
SwRI PROJECT No.: 01-1680-102
DATE: 21 MARCH 1998
FILE ID: 08030SXT.DAT
08030SC2.DAT

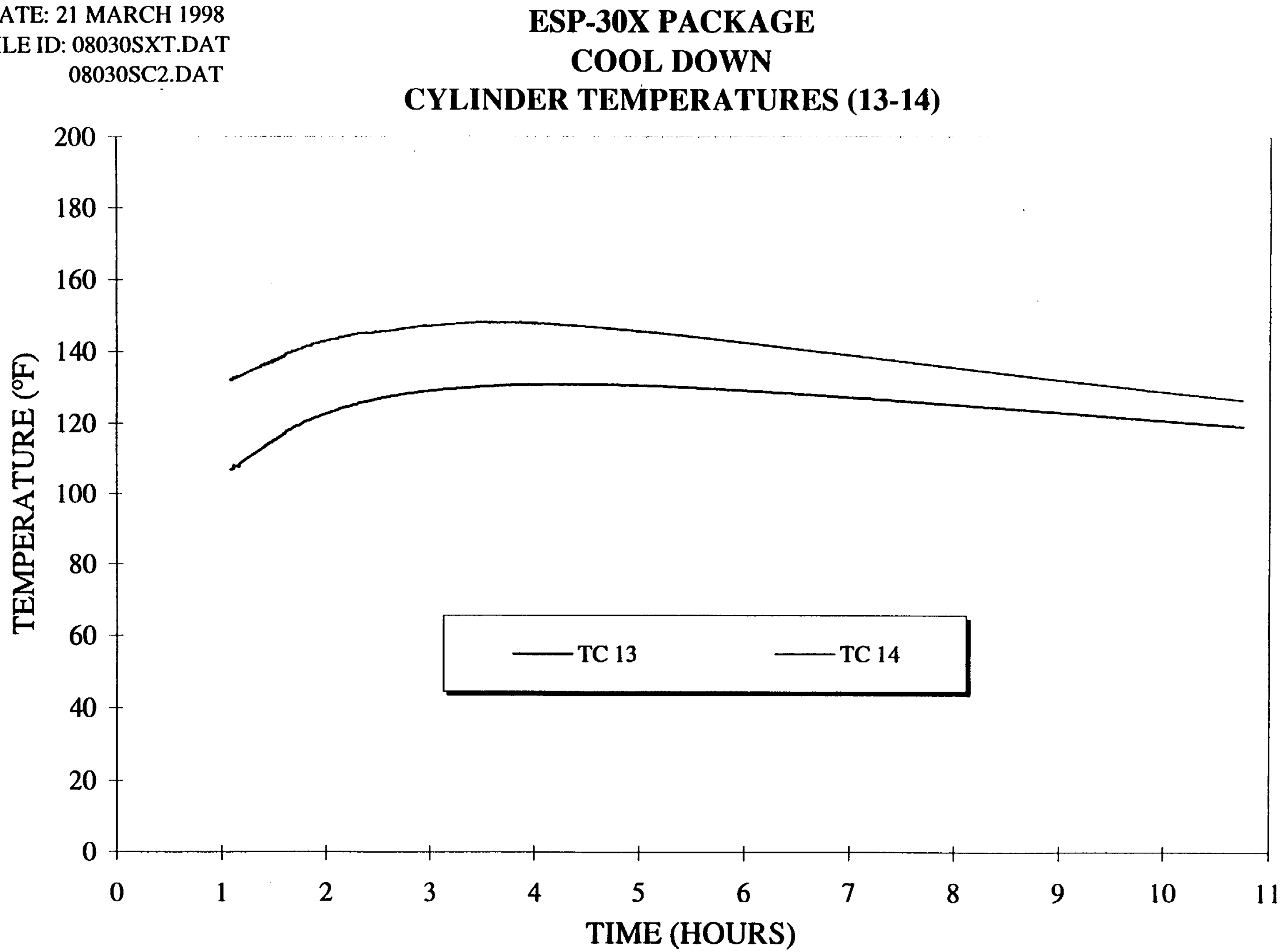
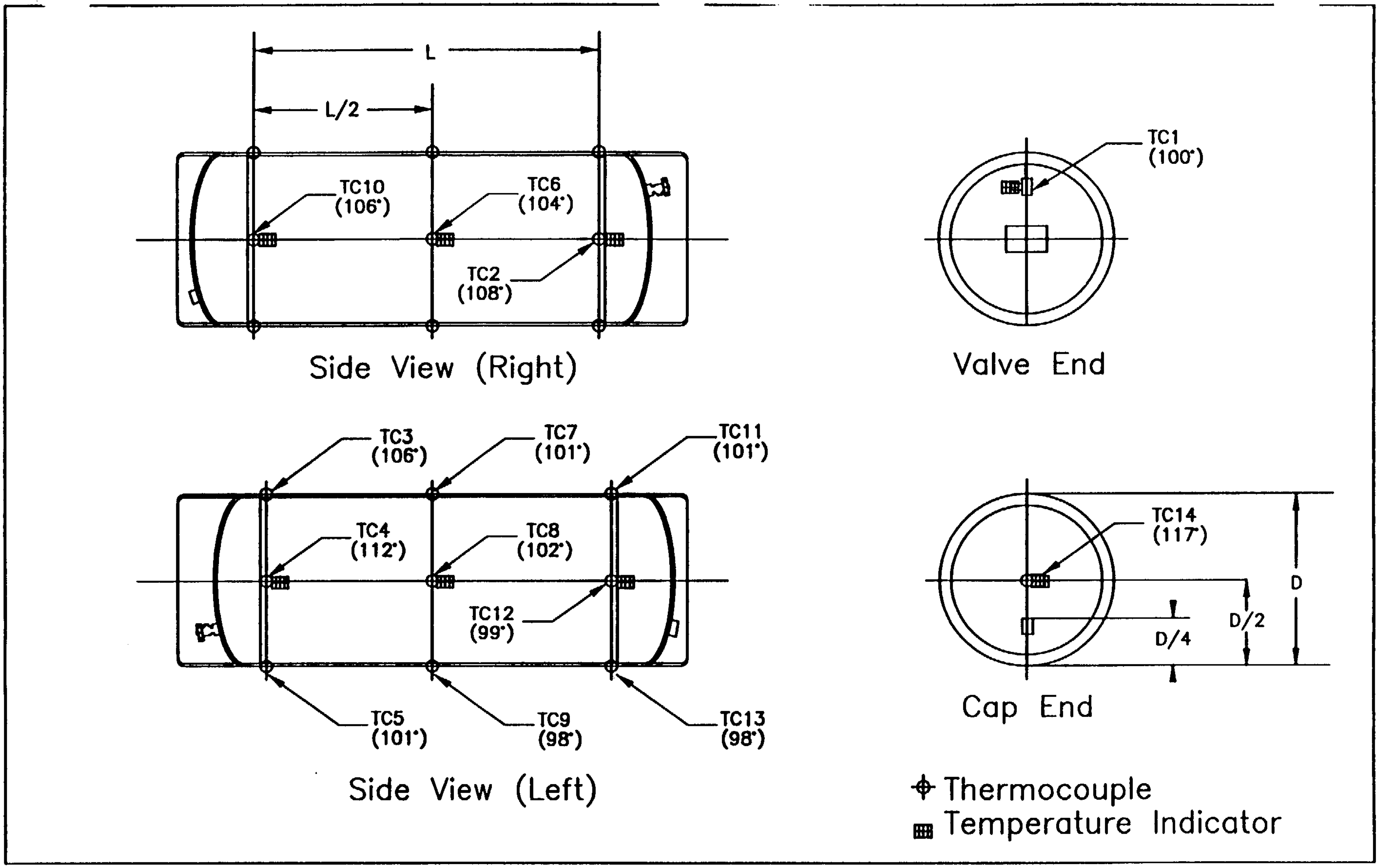


Figure 9-9. 30B Cylinder Thermocouple Readings.

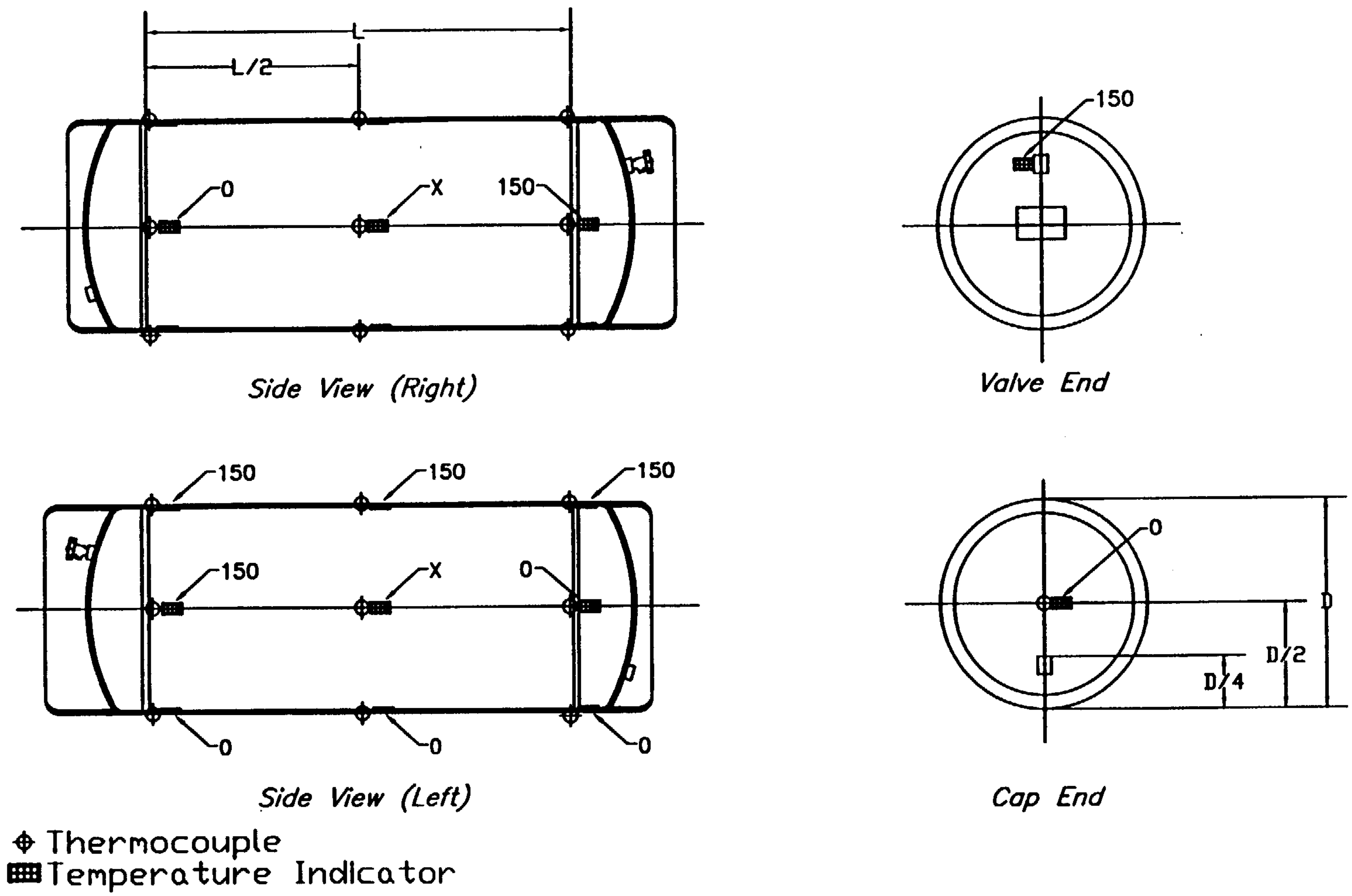


Southwest Research Institute *Department of Fire Technology*	TITLE *Instrumentation Layout, Thermocouples & Temperature Indicators*

CLIENT	PROJECT NO.
Eco-Pak Specialty Packaging	01-1680-102

DRAWN BY:	DATE OF TEST	FILE
William Aufrance	March 21, 1998	e:\jim\eco-pac\tank3.dwg

Figure 9-10. 30B Cylinder Thermocouple Readings.



Southwest Research Institute

Department of Fire Technology

TITLE		
Instrumentation Layout, Temperature Tags		
CLIENT: Eco-Pak Specialty Packaging Corp.		PROJECT NO. 01-1680-102
DRAWN BY: Aaron Arellano	DATE OF TEST: March 21, 1998	FILE: c:\aaron\jim\eco-pak\tank2.dwg

Figure 9-11. 30B Cylinder Temperature Indicator Readings.

Table 10-1. Leakage and Hydrostatic Test Results
Test Item: ESP-30X, SN001 30B Cylinder, CB-1871-2

TEST PERFORMED	REQUIREMENT	MEASUREMENT	PASS/FAIL
Pre-Drop Soap Bubble	No Leaks	No Leaks	Pass
Pre-Drop Helium	$< 1.0 \times 10^{-7}$ std cc/sec	1.3×10^{-8} std cc/sec	Pass
Post Fire Soap Bubble	No Leaks	No Leaks	Pass
Post Fire Helium	$< 1.0 \times 10^{-7}$ std cc/sec	$< 3.9 \times 10^{-9}$ std cc/sec	Pass
Post Fire Hydrostatic	No Leaks	No Leaks	Pass

Table 10-2 summarizes the results of the drop testing performed on the ESP-30X. The test item received some damage following the drop test that was considered acceptable by ESP personnel.

Table 10-2. ESP-30X SN001 Drop Testing Performed.

Procedure	Dates	Comments
Conditioning Before Drop	3/13/98 3/16/98	-23°F on overpack insulation at end of conditioning
30-ft Drop	3/16/98	Good drop at 14.0°
Exterior Physical Measurements	3/16/98	By Fire Technology personnel
1-m Puncture	3/16/98	Good drop at 13.5°
Exterior Physical Measurements	3/16/98	By Fire Technology personnel
Conditioning Before Drop	3/16/98 3/17/98	Initial insulation temperature of 17°F. -30°F at end of conditioning.
1-m Puncture	3/17/98	Good horizontal drop at 45° rotation
Exterior Physical Measurements	3/17/98	By Fire Technology personnel

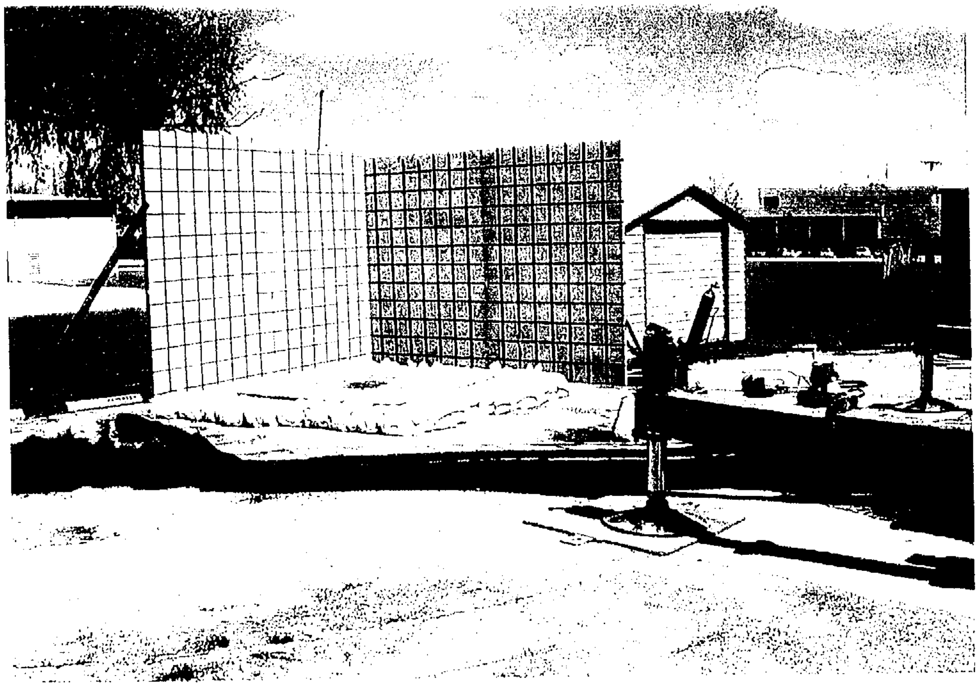
The Department of Fire Technology conducted the 30-min pool fire test described in Title 10 CFR 71.72 (c), (4) on March 21, 1998. The initial temperature of the 30B cylinder was 100°F. The maximum single point temperature recorded on the surface of the 30B cylinder during the 30-min pool fire exposure test was 117°F (TC 14 at 30 min), and the average of the maximum TC readings was 104°F.

The maximum single point temperature recorded on the surface of the 30B cylinder during the 11-hr cool down period was 177°F (TC 3 at 3 hr 52 min), and the average of the maximum TC readings was 152°F.

APPENDIX A

DROP TESTING - PHOTOGRAPHIC DOCUMENTATION

(Consisting of 9 Pages)



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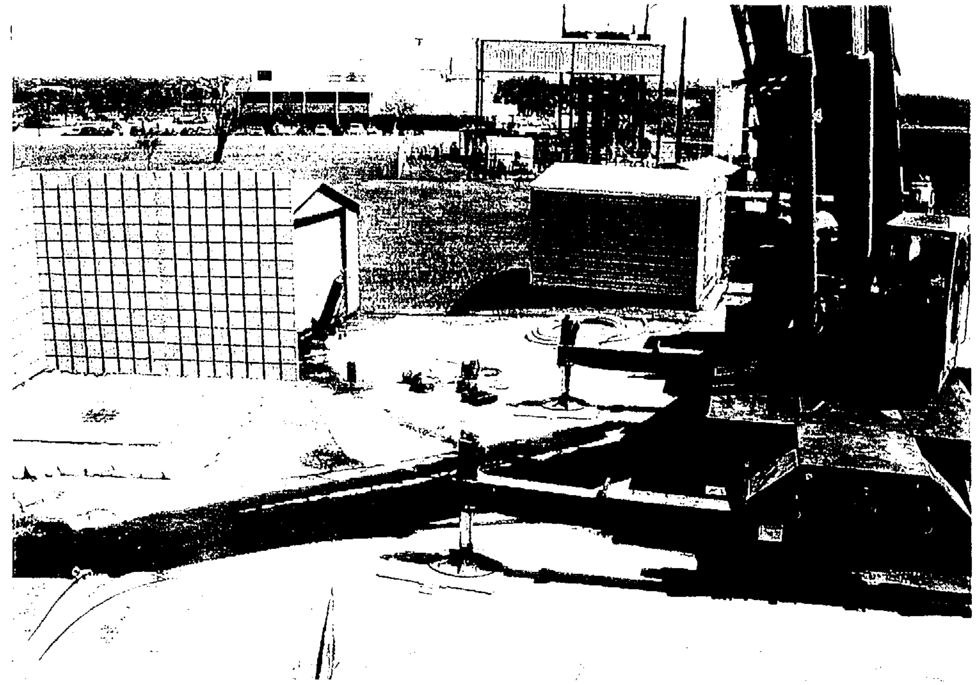


b

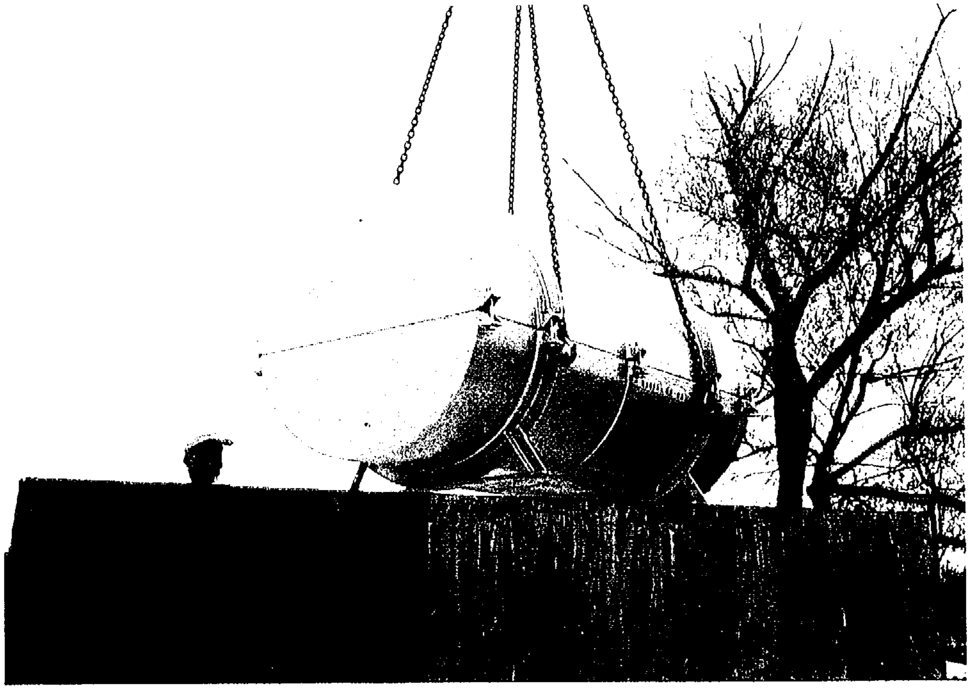
c

FIGURE 1 - DROP TEST FACILITY CONFIGURATION

a: **Drop Pad with Concrete Slab, Steel Impact Plate, and Backdrop**

b: **Test Item Lift Crane**

c: **Test Facility with Cooling Chamber to Far Left**



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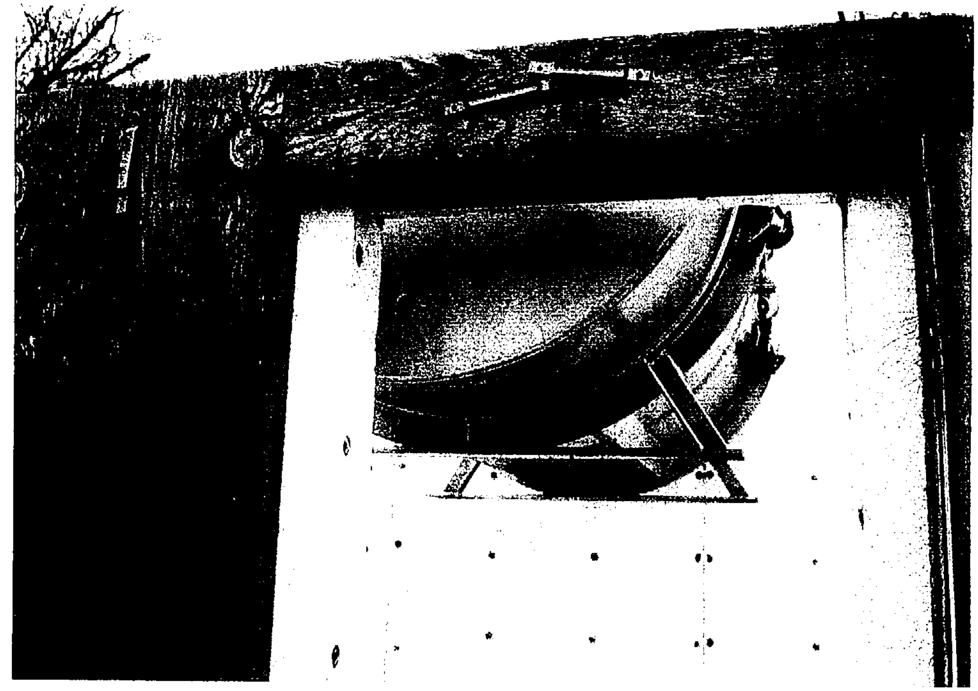


b

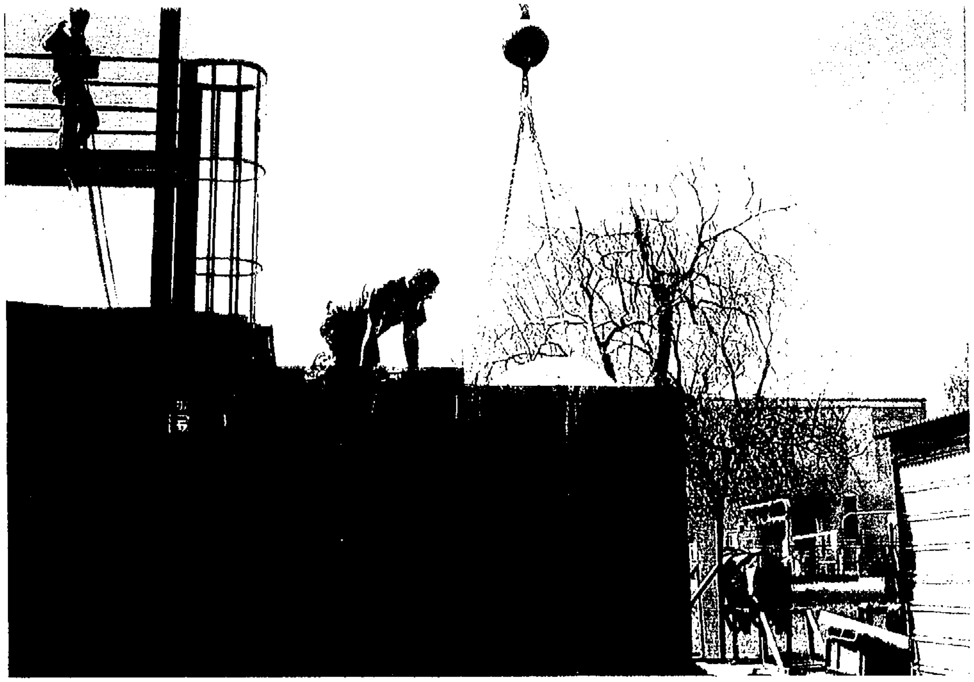
c

FIGURE 2 - INSERTION OF ESP-30X ITEM INTO COOLING CHAMBER

a: Insertion Through Removable Roof

b: Partial Insertion of Serial No. 1

c: Serial No. 1 in Place



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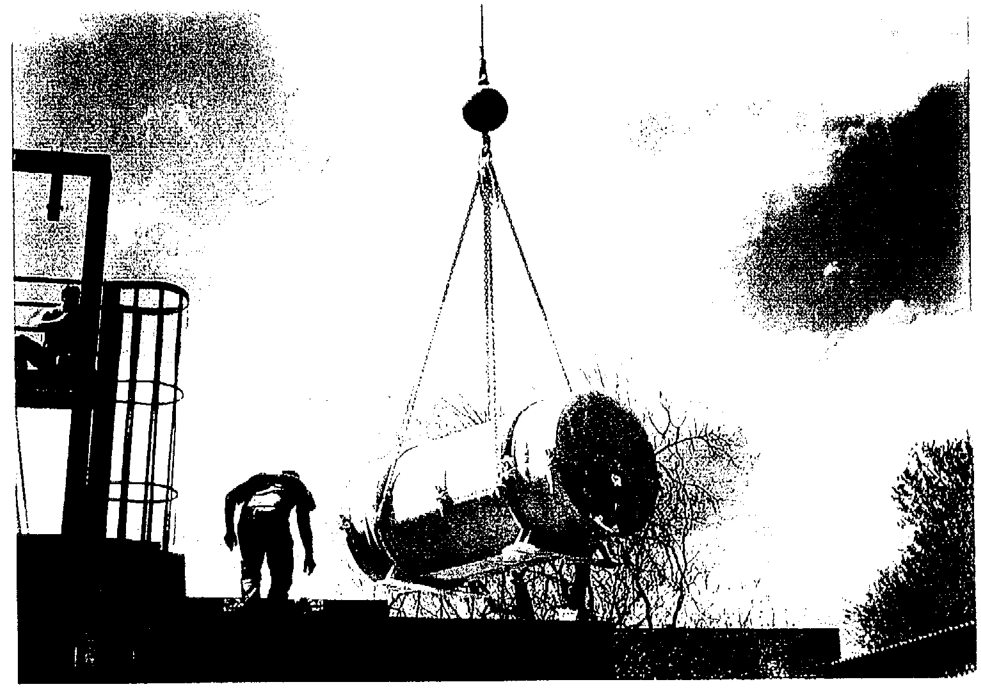

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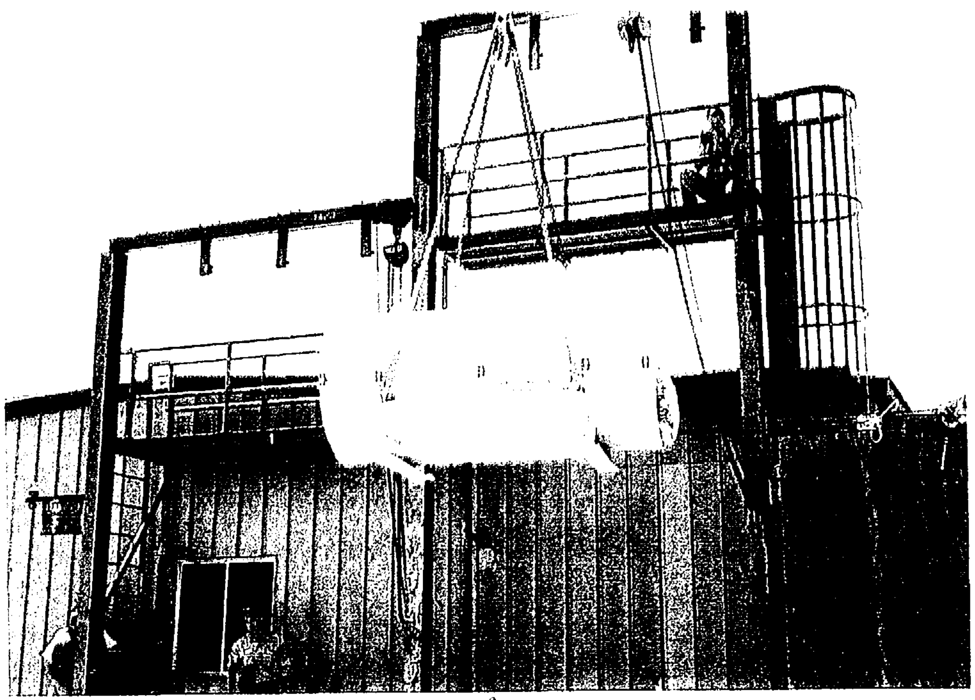


c

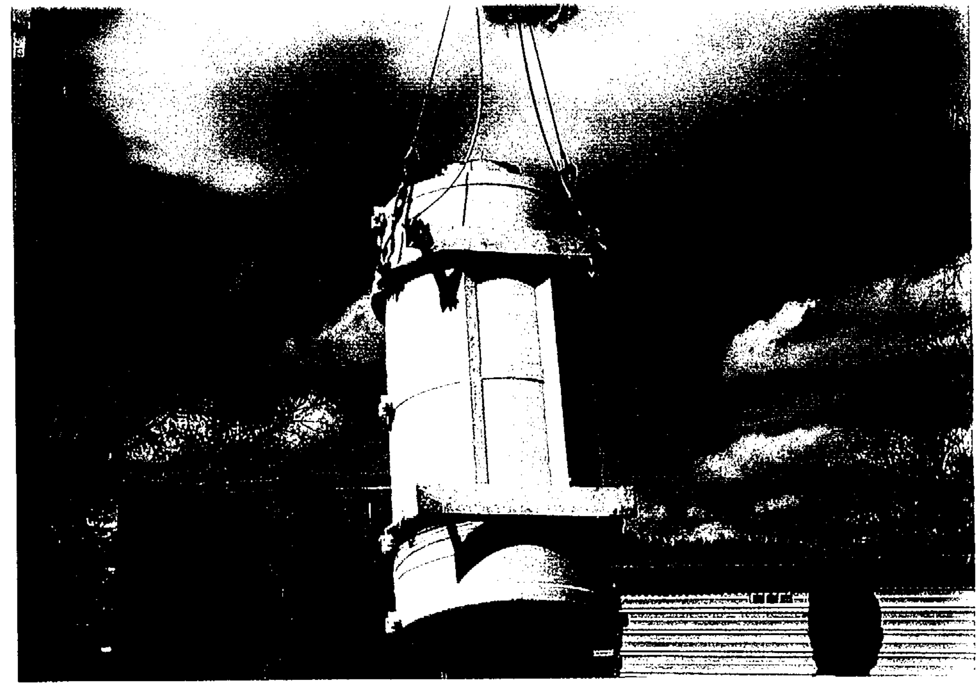
FIGURE 3 - REMOVAL OF SERIAL NO. 1 AFTER COOLING

a: **Partial Removal From Chamber**

b: **Item Out of Chamber**

c: **Positioning for Attachment of Lift Sling**

a



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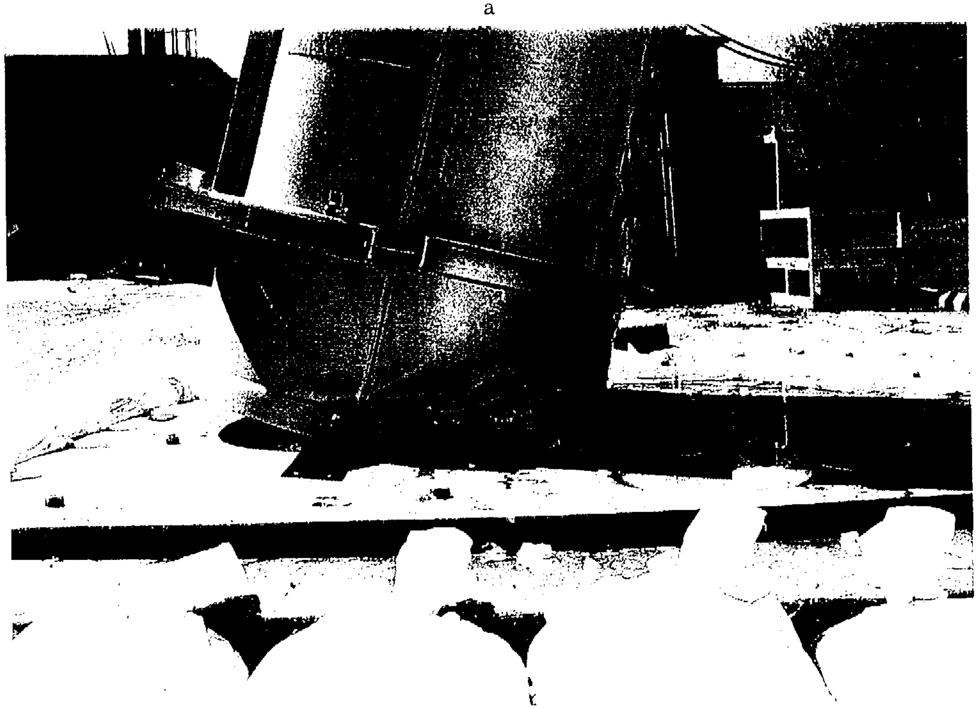


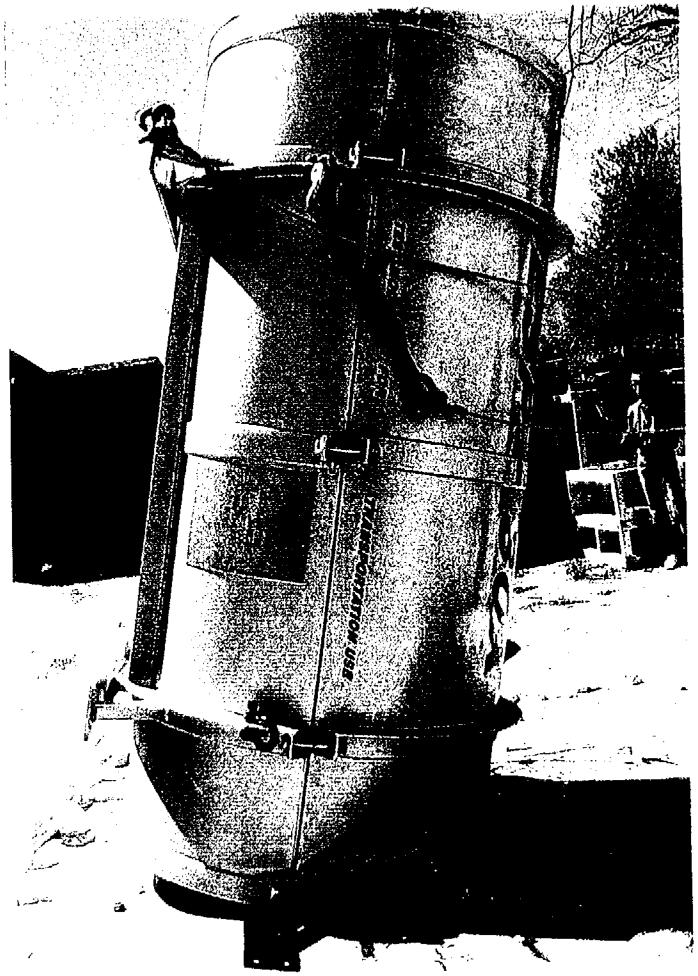
c

FIGURE 4 - THIRTY FOOT DROP AT 13.5° FROM VERTICAL ONTO VALVE

a: Side View of Drop Condition

b: Bottom View of Drop Condition

c: Test Item Following 30-Foot Drop



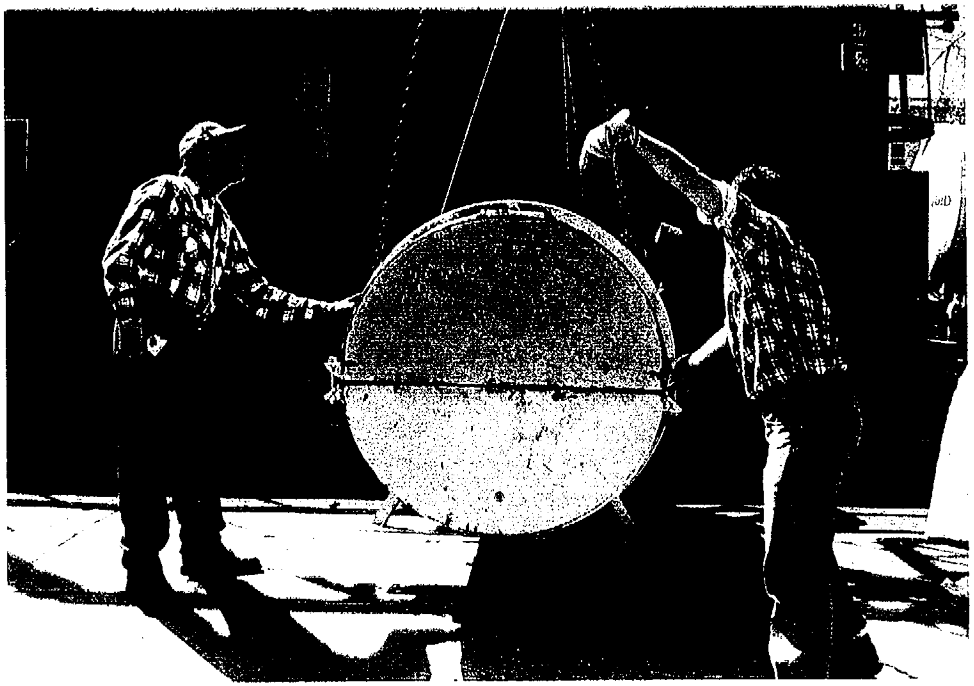
a

b

FIGURE 5 - POST TEST CONDITION FOLLOWING DROP AT 13.5° FROM VERTICAL ONTO VALVE

a: Overview of Test Item Orientation Following Drop

b: Condition of Impact Location



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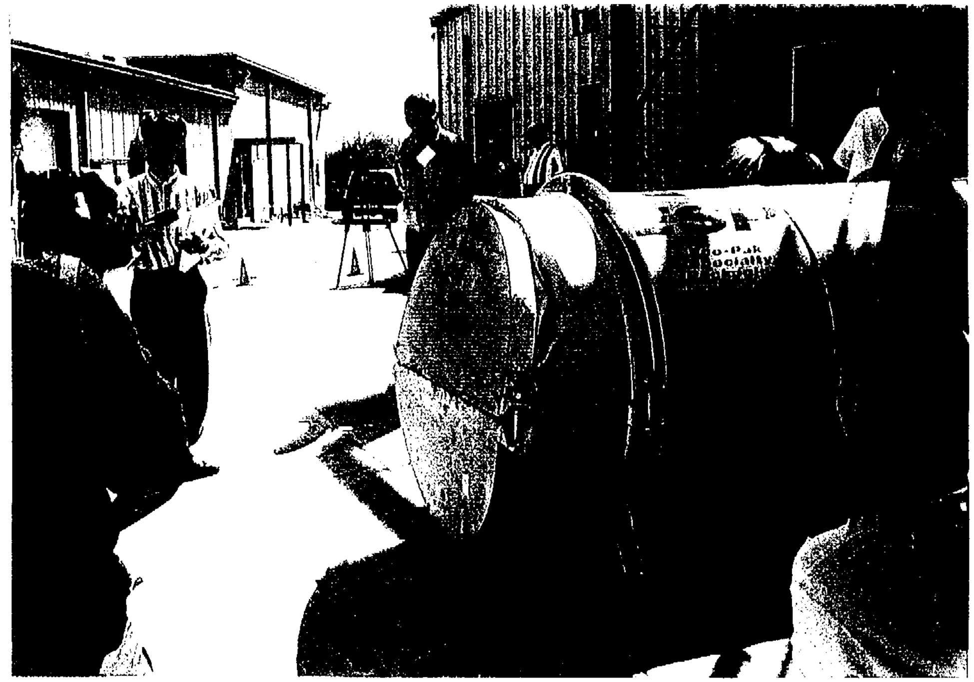


b

c

FIGURE 6 - POST TEST INSPECTION FOLLOWING DROP AT 13.5° FROM VERTICAL ONTO VALVE

a: End View

b: Side View

c: Measurement of Deformation

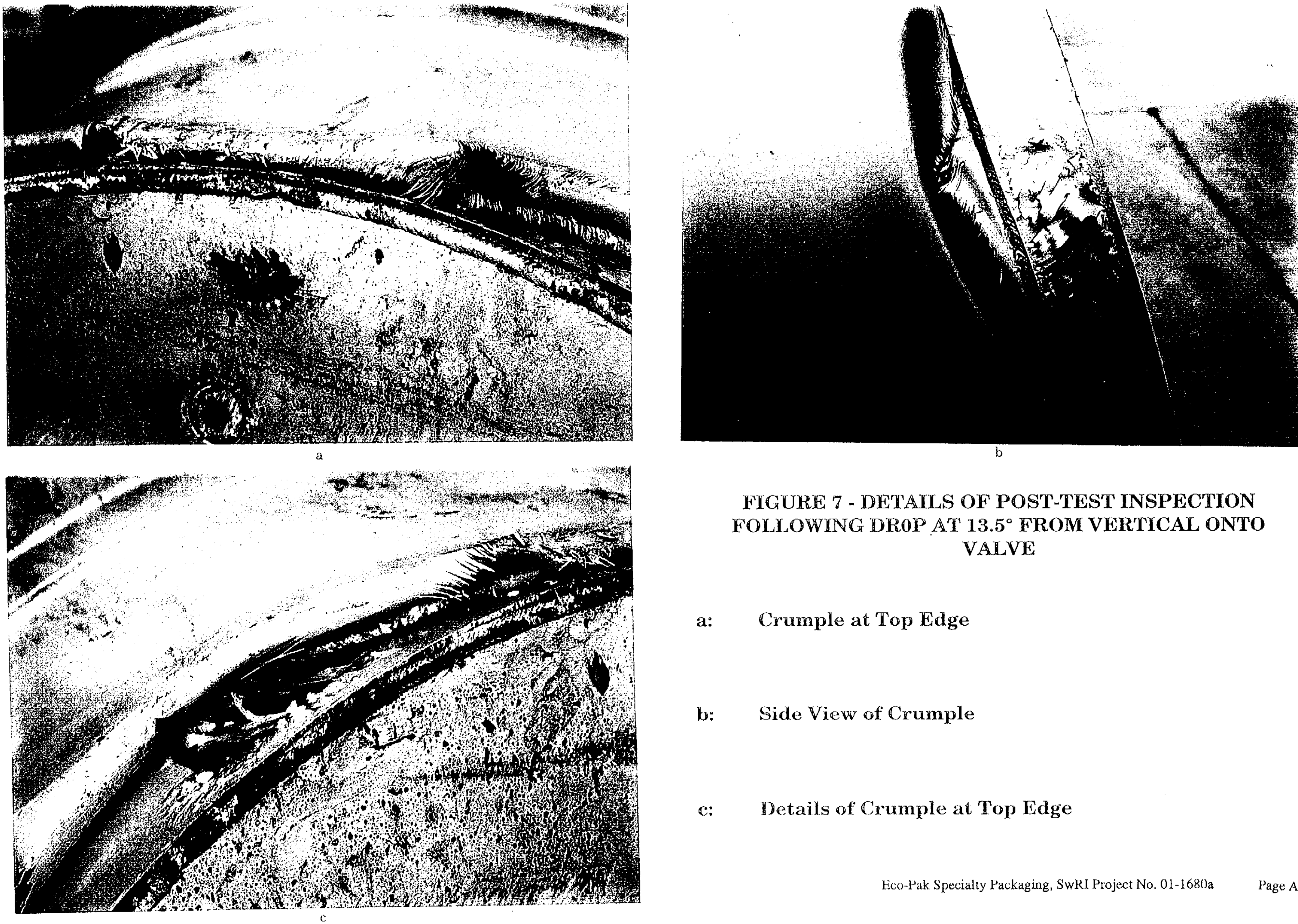


FIGURE 7 - DETAILS OF POST-TEST INSPECTION FOLLOWING DROP AT 13.5° FROM VERTICAL ONTO VALVE

a: Crumple at Top Edge

b: Side View of Crumple

c: Details of Crumple at Top Edge

APPENDIX B

TEST AND MEASURING EQUIPMENT CALIBRATION CERTIFICATES

(Consisting of 15 Pages)

Southwest Research Institute
6220 Culebra Road
San Antonio, TX 78238
Department of Quality Assurance
Calibration Laboratory

Certificate of Calibration

21 April 1997

Issued to: MARK MERCER DIV06 B81
Manufacturer/Model: ASHCROFT 1305B100
Description: DEAD WEIGHT TESTER
Serial Number: 8371009
Asset Number: 000760

Environmental Conditions

Temperature: 72.0 Deg. F **Humidity:** 64%

Calibration Information

Calibration was in accordance with requirements of MIL-STD-45662A and ANSI/NCSL Z540-1-1994. Measurements are traceable to the National Institute of Standards and Technology (NIST). This report may not be reproduced except in full without written approval of the originator. Inspection and test data are on file and available for inspection.

Calibration Date: 9 Apr 97 **Calibration Procedure:** PCP-8.10/4-19-93

Interval: 12 months **Accuracy:** *

Next Calibration Due: 9 Apr 98 **Received:** In Tolerance

Remarks: CALIBRATED BY TECHNOLOGY & CALIBRATION.
*ACCURACY .01% F.S.=10000 PSI/.03% F.S.=2000

Certificate # 25028 **Signed:**

LAST PAGE OF REPORT
Total Pages Printed: 1

TECHCAL
TECHNOLOGY & CALIBRATION, INC.

4120 SIEGEL
HOUSTON, TEXAS 77009-3923
FAX 713/692-1722
713/692-1600

Pressure Instrument Certification

Issued To: *Southwest Research*
San Antonio, Texas

This is to certify that this pressure instrument/device has been tested and calibrated in accordance with Technology & Calibration's procedure, PCP-8.10/4-19-93, with pressure measuring instruments certified to N.I.S.T. traceable standards. Certified in accordance with ANSI/NCSL, Z540-1 and ISO 10012-1. This certification performed under Technology & Calibration's quality assurance program dated 4-19-93, Rev.0. All calibrations performed at 72 degrees F. plus or minus 2 degrees F. and less than 65% relative humidity.

NOTE: The collective uncertainty of the measurement standards does not exceed 25% of the acceptable tolerance for each characteristic of the measuring and test equipment being certified.

Manufacturer	**Ashcroft**
Serial Number	**8371009**
Model / Type	**D. W. Tester**
Project Number	**51458**
Date	**04-09-97**
Recall Date	**04-09-98**
Verified Units	**PSI**
Verified Range	**10000.0**
Rated Accuracy	**0.01%**
P.O. Number	**38056**
Technician	**S. Hyde**
Remarks	**High Piston Dia. = .125**

Standard Serial No.	Standard Manufacturer	Calibration Date	Recall Date	N.I.S.T. Traceable No.
15544	Ametek	04-04-97	04-04-98	822/254480
70795	Ametek	07-01-96	07-01-97	822/251645
22028	Chandler	04-08-97	04-08-98	822/256610
CM58216	Heise	06-26-96	06-26-97	731/243669

Calibrated By: *Chandler, Heise, Marklyn Lab.*

Quality Representative

Technology and Calibration, Inc.

Pressure Instrument Calibration Report

Manufacturer:	Ashcroft	Customer:	Southwest Research
Model / Type:	D. W. Tester	Location:	San Antonio, Texas
Serial Number:	8371009	P.O. Number:	38056
Date:	04-09-97	Recall Date:	04-09-98
Capacity:	10000.0	Report Number:	51458
Resolution:	1.0	Technician:	S. Hyde

As Found Condition

Rated Accuracy: 0.01 % F/S Instrument Performance

	Standard	Inst. Reading	% Deveation
Units: PSI	0.0	0.0	0.00
	2500.0	2500.0	0.00
	5000.0	5000.0	0.00
	7500.0	7500.0	0.00

As Left Condition

Standard	Inst. Reading	% Deviation
1000.0	1000.0	0.0
2000.0	2000.0	0.0
4000.0	4000.0	0.0
6000.0	5000.0	0.0
8000.0	8000.0	0.0
10000.0	10000.0	0.0

* No error shown if less than 50 percent of the rated accuracy

Remarks: High Piston Dia. =.125

ANALOG / DIGITAL PRESSURE INDICATOR CALIBRATION

MARINE TECHNOLOGY DEPARTMENT
UNDERWATER ENGINEERING LABORATORY / BLDG. 81

Transducer / Pressure Gage No. /Serial No. 3979	Mfg.& Model No. TRANSDUCERS INC GP-48F-150-7159
Digital Indicator / Mfg.& Model No. Bell/Howell Serial No. MOD. 5332-SP-445, S/N 16301	Use at: For UFL Internal Pressure Tests SwRI PROJ. No. 01-1680
Dead Weight Tester/ Mfg.& Model No. Serial No. Ashcroft 1305B100, S/N 8371009	Calibration Due Date: 9 APRIL 98

PRESSURE Indicator Reading (Psig)	**DEAD WEIGHT TESTER** Applied Load (Psig)	**PRESSURE** Indicator Reading (Psig)	**DEAD WEIGHT TESTER** Applied Load (Psig)
0	0	80	80
20	20	0	0
40	40		
60	60		
80	80		
100	100		
120	120		

REMARKS:
Cal. Performed using low Press Piston Assy. of Dead wt. Tester
N. 8371009

Shunt Cal.Verification : N/A

Certificate No.: 01-1680-A

Calibration Performed By: [signature]

Calibration Date: 3-9-98 | Next Calibration Due Date: 4-9-98

QC Staff: | Date:

Lab Supervisor: [signature] | Date: 3-9-98

SwRI UEL-DOP-65.5.0(8/5/97)-QA Form UEL-1-A (c:\data\jir\qauel-65.jr\jdq)

Terminal Drive, Plainview, NY 11803 Veeco 516-349-8300 • Fax 516-349-7009

Veeco Instruments Inc.

CALIBRATION CERTIFICATE

incompliance with
ANSI/NCSL Z540-1-1994
ISO-10012-1:1992E

Veeco Instruments Inc. certifies the calibrated leak referenced below is accurate in accordance with measurement technique that compares, through the use of a Veeco Mass Spectrometer Leak Detector, each unit against a primary standard, serial number 0001[a] and / or 0003[b]. These standards are certified and calibrated by the National Institute of Standards and Technology (NIST). The reference Mass Spectrometer Leak Detector is continuously calibrated and becomes the instrument used to certify the Calibrated Leak. This instrument is maintained and calibrated in accordance with Veeco Standard Calibration Procedure for Helium Calibrators CP001-MS Rev. A.

We recommend the Calibrated Leak be returned to Veeco Instruments Inc. for recalibration annually.

NOTE: Calibrated Leaks should be stored and shipped with valve open.

MODEL: 7MS40 SERIAL NO: 0555

CAL DATE: 03/28/1997 CERTIFICATION NO: LB67607

The above sensitivity calibrator has been calibrated as of this date with the following results:

Helium Leak Rate:

0.0035 ± 10% Micron cu.ft/hr.
3.5×10^{-8} ± 10% Std. cc./sec.

Air Leak Rate Through Equivalent Leak:

0.0013 ± 10% Micron cu.ft/hr.
1.3×10^{-8} + 10% Std. cc./sec.

Calibration Temperature: 22 °C

Temperature Coefficient = ± 3% per degree C Leak rate decreases less than 5% per year

Final Inspection By: ______________
(Calibration Laboratory Technician)

a- NIST Test Number 255729-96R T144 b- NIST Test Number: 258587-97 T160

amm17

SOUTHWEST RESEARCH INSTITUTE
DEPARTMENT OF FIRE TECHNOLOGY
INSTRUMENTATION RECORD SHEET

Client: ECO-PAK

Test Date: 20-21 MAR 1998

Project No: 01-1680-102

Test ID: OPM1 - 002 / ESP-30X 001

Critical Test Equipment/Materials	Serial No./ID No	Calibration Expiration Date
Helios	4889002	11AUG98
Weather Station	492	1Dec98
TC's Sample	Lot # M069751	N/A
TC's Flame	Lot # M294709	N/A
Radiometer west	87188	N/A
Radiometer East	87183	N/A
~~Thermometer~~	~~2 Sept 9~~	
Thermometer	206	2Sept 98

Personnel List:

Jim Griffith
Bill Bendele
Raul Duarta
Joe Anderson
Able Deltoyos
Alex
Michael Sveñe

Southwest Research Institute
6220 Culebra Road
San Antonio, TX 78238
Department of Quality Assurance
Calibration Laboratory

Certificate of Calibration

12 February 1998

Issued to: BILL BENDELE DIV01 B143
Manufacturer/Model: FLUKE 2289A
Description: HELIOS I COMPUTER FRONT END
Serial Number: 4889002
Asset Number: 000249

Environmental Conditions

Temperature: 75.00 Deg. F **Humidity:** 33 % RH

Calibration Information

Calibration was in accordance with requirements of MIL-STD-45662A and ANSI/NCSL Z540-1-1994. Measurements are traceable to the National Institute of Standards and Technology (NIST). This report may not be reproduced except in full without written approval of the originator. Inspection and test data are on file and available for inspection.

The uncertainty of the calibration was sufficient to determine that the instrument met the manufacturer's specifications.

Calibration Date: 11 Feb 98 **Calibration Procedure:** MFG MANUAL P/N 793547, 4/86

Interval: 6 months

Next Calibration Due: 11 Aug 98 **Received:** In Tolerance

Remarks: CALIBRATED WITH 5 EA. ISOTHERMAL INPUT CONNE
CTOR S/N'S 488-1 THRU 488-5

Standards Used

Asset	MFR	Model	Description	Serial No.	Due Cal
000182	FLUKE	5700A	CALIBRATOR	5200003	2 Jul 99
004528	KAYE INSTRU	K150-2C	ICE POINT/REFERENCE	701173	4 Apr 98

Signed: Vincent Morales

Title: Cal Tech

LAST PAGE OF REPORT
Total Pages Printed: 1

Certificate # 28517

6220 Culebra Road
San Antonio, TX 78238
Department of Quality Assurance
Calibration Laboratory

Certificate of Calibration

17 December 1997

Issued to: BILL BENDELE DIV01 B143
Manufacturer/Model: QUALIMETRICS, INC. 1005
Description: WEATHER STATION
Serial Number: 492
Asset Number: 005072

Environmental Conditions

Temperature: 0 Deg. F **Humidity:** 0 % RH

Calibration Information

Calibration was in accordance with requirements of MIL-STD-45662A and ANSI/NCSL Z540-1-1994 Measurements are traceable to the National Institute of Standards and Technology (NIST). This report may not be reproduced except in full without written approval of the originator. Inspection and test data are on file and available for inspection.

The uncertainty of the calibration was sufficient to determine that the instrument met the manufacturer's specifications.

Calibration Date: 1 Dec 97 **Calibration Procedure:** MFG

Interval: 12 months

Next Calibration Due: 1 Dec 98 **Received:** In Tolerance

Remarks: CALIBRATED BY QUALIMETRICS, SACRAMENTO, CA.
NOT ON 'ASL'. CAL DEVIATION EXEC. 97-CD-44.

Results

WEATHER STATION CONSISTS OF: MODULE RACK #1005 S/N 492
MICRO RESPONSE ANEMOMETER #2030 S/N 795
MICRO RESPONSE VANE #2020 S/N 1203
CUP ASSEMBLY

Signed:

Title:

LAST PAGE OF REPORT
Total Pages Printed 1

Certificate # 27285

DURO-SENSE CORPORATION
20801 Higgins Court, Torrance, CA 90501
Phone: (310) 533-6877 Fax: (310) 533-0330

TO:	Southwest Research	Date:	March 9, 1998
	6220 Culebra Rd.	Calib No.:	45094A
	San Antonio, TX 78284	Cust. P.O.:	75567
		Calibration Cycle:	6 Months

CALIBRATION CERTIFICATE

This will certify that your **Type 'K' T/C Assy # MTC-B-1252-G-WP-GDW** was/were calibrated on **March 9, 1998** against our standard, which is traceable to the National Institute of Standards Technology. Re-Calibration should occur no later than **September 9, 1998**.

Ambient Temperature:	**76.70 °F**
Furnace Atmosphere:	**Air**
Humidity:	**38.20%**
Temperature Points:	**300 °F, 600 °F, 900 °F**
Lot #:	**MO69751**

CALIBRATION RESULTS ARE AS FOLLOWS:

Standard S/N	Corrections 300 °F	600 °F	900 °F
39	+0.2 °F	+0.6 °F	+0.9 °F
40	+0.3 °F	+0.5 °F	+0.8 °F
41	+0.3 °F	+0.6 °F	+1.0 °F
42	+0.4 °F	+0.7 °F	+0.9 °F
43	+0.3 °F	+0.6 °F	+1.0 °F
44	+0.2 °F	+0.5 °F	+1.0 °F
45	+0.2 °F	+0.6 °F	+0.9 °F
46	+0.3 °F	+0.5 °F	+0.9 °F
47	+0.2 °F	+0.5 °F	+0.8 °F
48	+0.4 °F	+0.8 °F	+1.0 °F

Calibration procedure I A W ISO 10012-1 1992(E), ANSI/NCSL Z540-1-1994, AMS 2750C
The calibration of thermocouples is subject to change during use. The amount of change depends on factors such as temperature, time, and condition of use.
Total Uncertainty of Readings is Less Than .01%

N.I.S.T. Recertification Date: **February 5, 1999**	**We hereby certify that the above is a true copy of our records.**
Leeds and Northrup K-5: **Model 7555**	**DURO-SENSE CORPORATION**
Precision Potentiometer S/N: **1752900**	
Eppley Standard Cell: **Model 100 - S/N 700851**	
Cage Code: **58042**	
Master Std. Thermocouple: **Type 'S'**	
N.I.S.T. Test Numbers: **259557**	Quality Control Department

DURO-SENSE CORPORATION
20801 Higgins Court, Torrance, CA 90501
Phone: (310) 533-6877 Fax: (310) 533-0330

TO: Southwest Research
6220 Culebra Rd.
San Antonio, TX 78284

Date: March 9, 1998
Calib No.: 45094A
Cust. P.O.: 75567
Calibration Cycle: 6 Months

CALIBRATION CERTIFICATE

This will certify that your Type 'K' T/C Assy # **MTC-B-1252-G-WP-GDW** was/were calibrated on **March 9, 1998** against our standard, which is traceable to the National Institute of Standards Technology. Re-Calibration should occur no later than **September 9, 1998**.

Ambient Temperature:	**76.70°F**
Furnace Atmosphere:	**Air**
Humidity:	**38.20%**
Temperature Points:	**300°F, 600 °F, 900 °F**
Lot #:	**MO69751**

CALIBRATION RESULTS ARE AS FOLLOWS:

Standard S/N	Corrections 300°F	600°F	900°F
49	+0.3°F	+0.5°F	+0.9°F
50	+0.2°F	+0.7°F	+1.0°F

Calibration procedure I A W ISO 10012-1 1992(E), ANSI/NCSL Z540-1-1994, AMS 2750C
The calibration of thermocouples is subject to change during use. The amount of change depends on factors such as temperature, time, and condition of use
Total Uncertainty of Readings is Less Than .01%

N.I.S.T. Recertification Date: **February 5, 1999**	We hereby certify that the above is a true copy of our records.
Leeds and Northrup K-5: **Model 7555**	DURO-SENSE CORPORATION
Precision Potentiometer S/N: **1752900**	
Eppley Standard Cell: **Model 100 - S/N 700851**	
Cage Code: **58042**	
Master Std. Thermocouple: **Type 'S'**	Quality Control Department
N.I.S.T. Test Numbers: **259557**	

DURO-SENSE CORPORATION
20801 Higgins Court, Torrance, CA 90501
Phone: (310) 533-6877 Fax: (310) 533-0330

TO: Southwest Research
6220 Culebra Rd.
San Antonio, TX 78284

Date: March 9, 1998
Calib No.: 45094A
Cust. P.O.: 75567
Calibration Cycle: 6 Months

CALIBRATION CERTIFICATE

This will certify that your **Type 'K' T/C Assy # MTC-B-1252-G-WP-GDW** was/were calibrated on **March 9, 1998** against our standard, which is traceable to the National Institute of Standards Technology. Re-Calibration should occur no later than **September 9, 1998.**

Ambient Temperature:	76.70°F
Furnace Atmosphere:	Air
Humidity:	38.20%
Temperature Points:	300°F, 600 °F, 900 °F
Lot #:	MO69751

CALIBRATION RESULTS ARE AS FOLLOWS:

Standard S/N	Corrections 300°F	600°F	900°F
51	+0.3°F	+0.7°F	+1.0°F
52	+0.4°F	+0.6°F	+0.9°F
53	+0.2°F	+0.5°F	+0.8°F
54	+0.4°F	+0.7°F	+1.0°F
55	+0.3°F	+0.6°F	+0.9°F
56	+0.4°F	+0.8°F	+1.0°F

Calibration procedure I A W ISO 10012-1 1992(E). ANSI/NCSL Z540-1-1994, AMS 2750C
The calibration of thermocouples is subject to change during use. The amount of change depends on factors such as temperature, time, and condition of use
Total Uncertainty of Readings is Less Than .01%

N.I.S.T. Recertification Date: February 5, 1999	We hereby certify that the above is a true copy of our records.
Leeds and Northrup K-5: Model 7555	DURO-SENSE CORPORATION
Precision Potentiometer S/N: 1752900	
Eppley Standard Cell: Model 100 - S/N 700851	
Cage Code: 58042	
Master Std. Thermocouple: Type 'S'	Quality Control Department
N.I.S.T. Test Numbers: 259557	

Flame TC's

DURO-SENSE CORPORATION

20801 Higgins Court, Torrance, CA 90501
Phone: (310) 533-6877 Fax: (310) 533-0330

TO: Southwest Research Institute
6220 Culebra Rd.
San Antonio, TX 78284

Date: March 18, 1998
Calib No.: 45218
Cust. P.O.: 75567
Calibration Cycle: 6 Months

CALIBRATION CERTIFICATE

This will certify that your Type 'K' T/C Assy # MTC-B-1252-G-GDW was/were calibrated on **March 18, 1998** against our standard, which is traceable to the National Institute of Standards Technology. Re-Calibration should occur no later than **September 18, 1998.**

Ambient Temperature:	78.20°F
Furnace Atmosphere:	Air
Humidity:	38.40%
Temperature Points:	300°F, 600 °F, 900 °F
Lot #:	M294709

CALIBRATION RESULTS ARE AS FOLLOWS:

Standard S/N	Corrections 300°F	600°F	900°F
65	+0.4°F	+0.6°F	+1.0°F
66	+0.3°F	+0.7°F	+0.9°F
67	+0.4°F	+0.8°F	+1.0°F
68	+0.2°F	+0.5°F	+0.8°F
69	+0.3°F	+0.7°F	+1.0°F
70	+0.4°F	+0.6°F	+0.9°F
71	+0.3°F	+0.7°F	+0.9°F
72	+0.2°F	+0.6°F	+1.0°F

Calibration procedure I.A.W. ISO 10012-1 1992(E), ANSI/NCSL Z540-1-1994, AMS 2750C
The calibration of thermocouples is subject to change during use. The amount of change depends on factors such as temperature, time, and condition of use.
Total Uncertainty of Readings is Less Than .01%

N.I.S.T. Recertification Date: February 5, 1999	We hereby certify that the above is a true copy of our records. DURO-SENSE CORPORATION
Leeds and Northrup K-5: Model 7555	
Precision Potentiometer S/N: 1752900	
Eppley Standard Cell: Model 100 - S/N 700851	
Cage Code: 58042	
Master Std. Thermocouple: Type 'S'	
N.I.S.T. Test Numbers: 259557	Quality Control Department

CERTIFICATE OF CALIBRATION

DATE 3/6/95
CUSTOMER Southwest Res.
CUSTOMER P.O. 51109

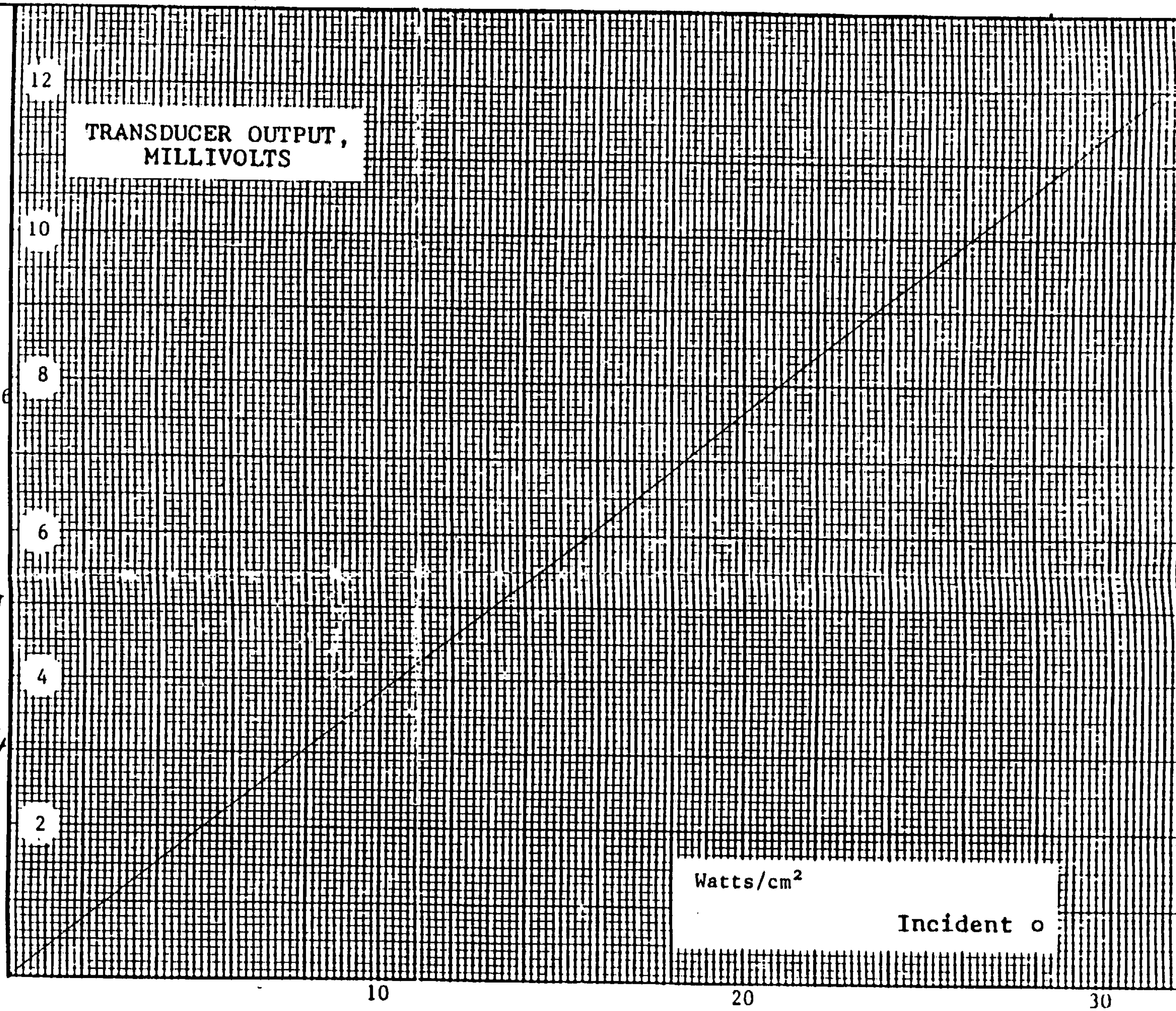
MODEL NO. 48NPT-EP-25F-21156
SERIAL NO. 87188
ABSORPTIVITY 0.96
WINDOW TYPE None
SENSOR - Schmidt-Boelter
REFERENCE STANDARD 325732
TESTED BY ED
QC ACCEPTANCE MEDTHERM INSPECT NO. 2 TEST ACCEPT

CERTIFIED CALIBRATION SUBSCRIBED AND SWORN TO BEFORE ME THIS 6th DAY OF March 19 95

Glenda Conner

GLENDA CONNER NOTARY PUBLIC ALABAMA STATE AT LARGE

11.46mv at 30 Watts/cm²



HEAT FLUX

This is to certify that all MEDTHERM calibrations are traceable to the National Institute of Standards and Technology (NIST) or to recognized natural physical constants. All calibrations are performed to written procedures in accordance with MIL-STD-45662A.

MEDTHERM CORPORATION

POST OFFICE BOX 412 / HUNTSVILLE, ALABAMA 35804 / TELEPHONE (... 37-2000

SwRI Project No. 01-1680a

CERTIFICATE OF CALIBRATION

DATE 3/6/95
CUSTOMER Southwest Res.
CUSTOMER P.O. 51109

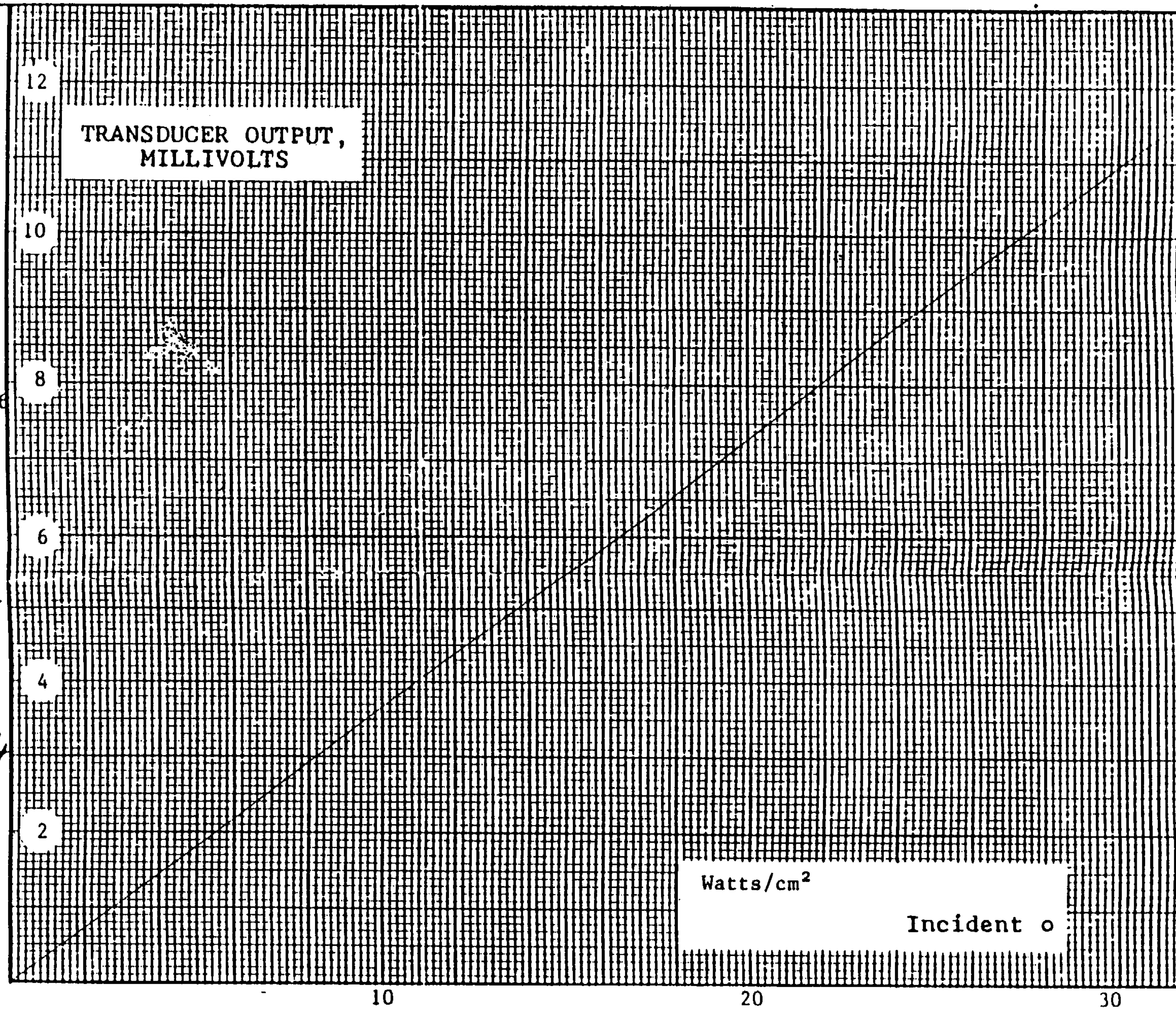
MODEL NO. 48NPT-EP-25F-21156
SERIAL NO. 87183
ABSORPTIVITY 0.96
WINDOW TYPE None
SENSOR - Schmidt-Boelter
REFERENCE STANDARD 325732
TESTED BY ED
QC ACCEPTANCE MEDTHERM INSPECT NO. 2 TEST ACCEPT

CERTIFIED CALIBRATION SUBSCRIBED AND SWORN TO BEFORE ME THIS 6th DAY OF March 19 95

Glenda Conner
Glenda Conner

GLENDA CONNER NOTARY PUBLIC ALABAMA STATE AT LARGE

10.95mv at 30 Watts/cm²



This is to certify that all MEDTHERM calibrations are traceable to the National Institute of Standards and Technology (NIST) or to recognized natural physical constants. All calibrations are performed to written procedures in accordance with MIL-STD-45662A.

HEAT FLUX

MEDTHERM
CORPORATION

POST OFFICE BOX 412 / HUNTSVILLE, ALABAMA 35804 / TELEPHONE (205) 837-2000

SwRI Project No. 01-1680a

6220 Culebra Road
San Antonio, TX 78238
Department of Quality Assurance
Calibration Laboratory

Certificate of Calibration

2 September 1997

Issued to: BILL BENDELE DIV01 B143
Manufacturer/Model: OMEGA 871
Description: DIGITAL THERMOMETER
Serial Number: 206
Asset Number: 002016

Environmental Conditions

Temperature: 74.0 Deg. F **Humidity:** 40%

Calibration Information

Calibration was in accordance with requirements of MIL-STD-45662A and ANSI/NCSL Z540-1-1994. Measurements are traceable to the National Institute of Standards and Technology (NIST). This report may not be reproduced except in full without written approval of the originator. Inspection and test data are on file and available for inspection.

Calibration Date: 2 Sep 97 **Calibration Procedure:** CLCP-TT-001

Interval: 12 months **Accuracy:** MFG SPECS

Next Calibration Due: 2 Sep 98 **Received:** In Tolerance

Remarks:

Standards Used

Asset	MFR	Model	Description	Serial No.	Due Cal
005325	XITRON TECH	2000M	PORTABLE V/A/T CALIBRA	20007920002	1 Apr 98

Certificate # 26525

Signed:

LAST PAGE OF REPORT
Total Pages Printed 1

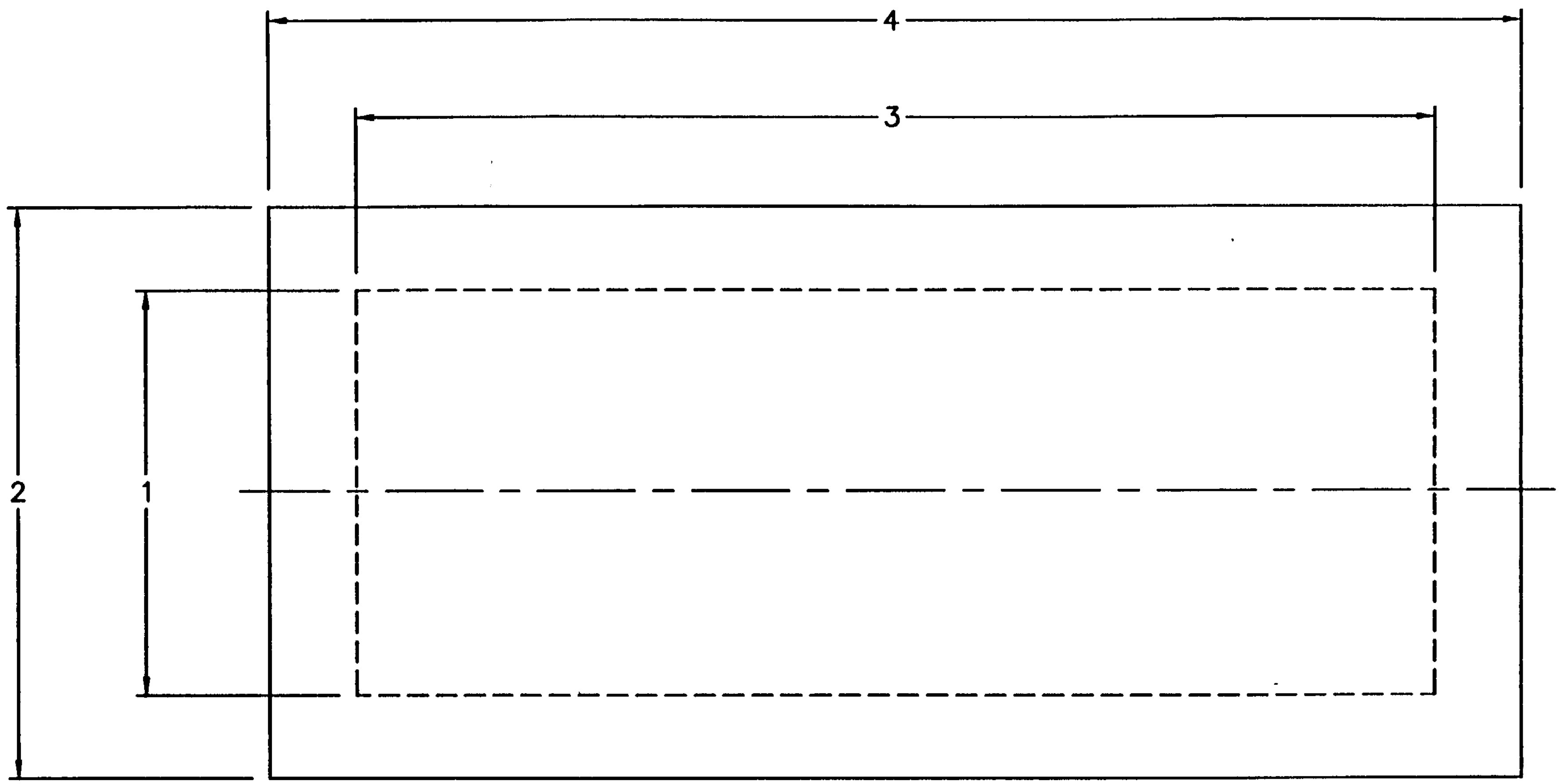
APPENDIX C
CONSTRUCTION DETAILS AND DIMENSIONAL MEASUREMENTS
(Consisting 7 Pages)

FIGURE WITHHELD UNDER 10 CFR 2.390

TOLERANCES	REVISIONS			NUCLEAR CONTAINERS, INC. ELIZABETHTON, TENN.		
	NO	DATE	BY			
DECIMAL ±	1			R & D		
	2					
FRACTIONAL ±	3			VS	DATE 5/96	
	4				DATE	
ANGULAR ±	5				DATE	1
	6					

FIGURE WITHHELD UNDER 10 CFR 2.390

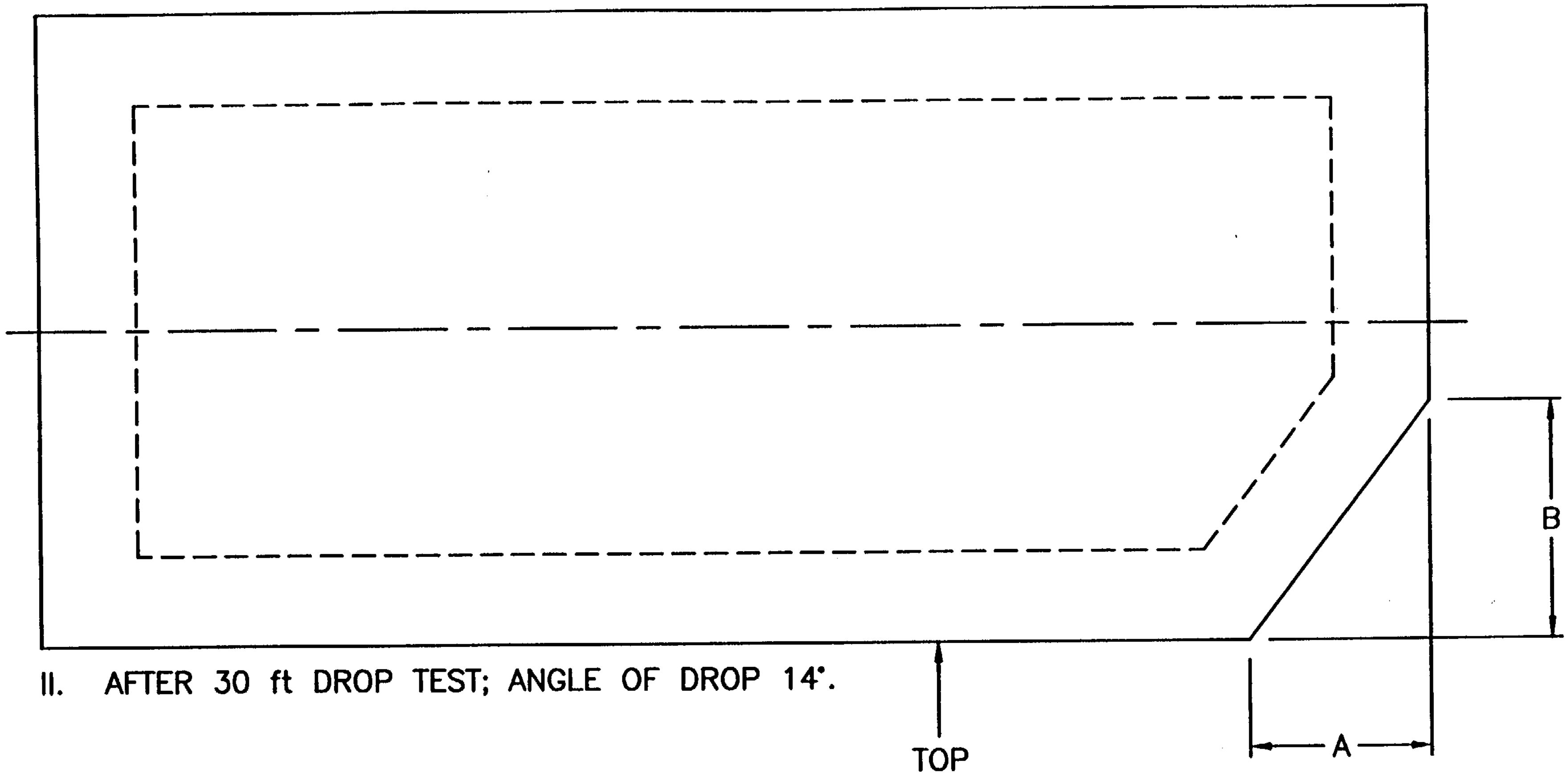
TOLERANCES	REVISIONS			NUCLEAR CONTAINERS. INC. ELIZABETHTON, TENN.		
	NO	DATE	BY			
DECIMAL	1			R & D ESP-30X		
±	2					
FRACTIONAL	3			NS	DATE 5/96	
±	4					2
ANGULAR	5					
±	6					



I. BEFORE DROP TEST

BOTTOM	001	TOP	001
1	785mm	1	937mm
2	1103mm	2	1095mm
3	2095mm	3	2259mm
4	2431mm	4	2426mm

DIMENSIONS OF ESP–30X SN001 PACKAGE PRIOR TO DROP TESTS

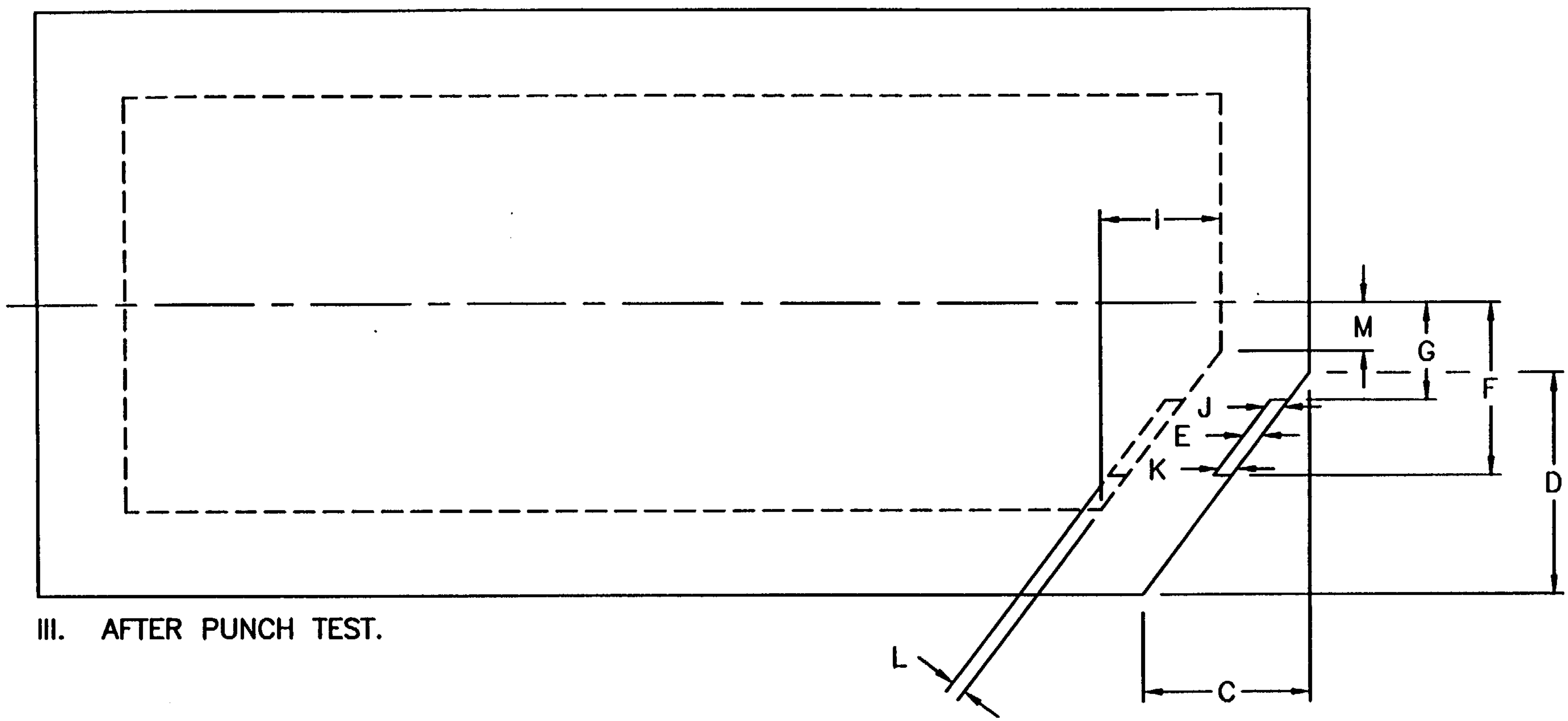


II. AFTER 30 ft DROP TEST; ANGLE OF DROP 14°.

DIMENSIONS AFTER 30 ft
FREE DROP.

	001
A	141mm
B	599mm

DIMENSIONS OF ESP–30X SN001 PACKAGE AFTER 30 FT DROP TEST.

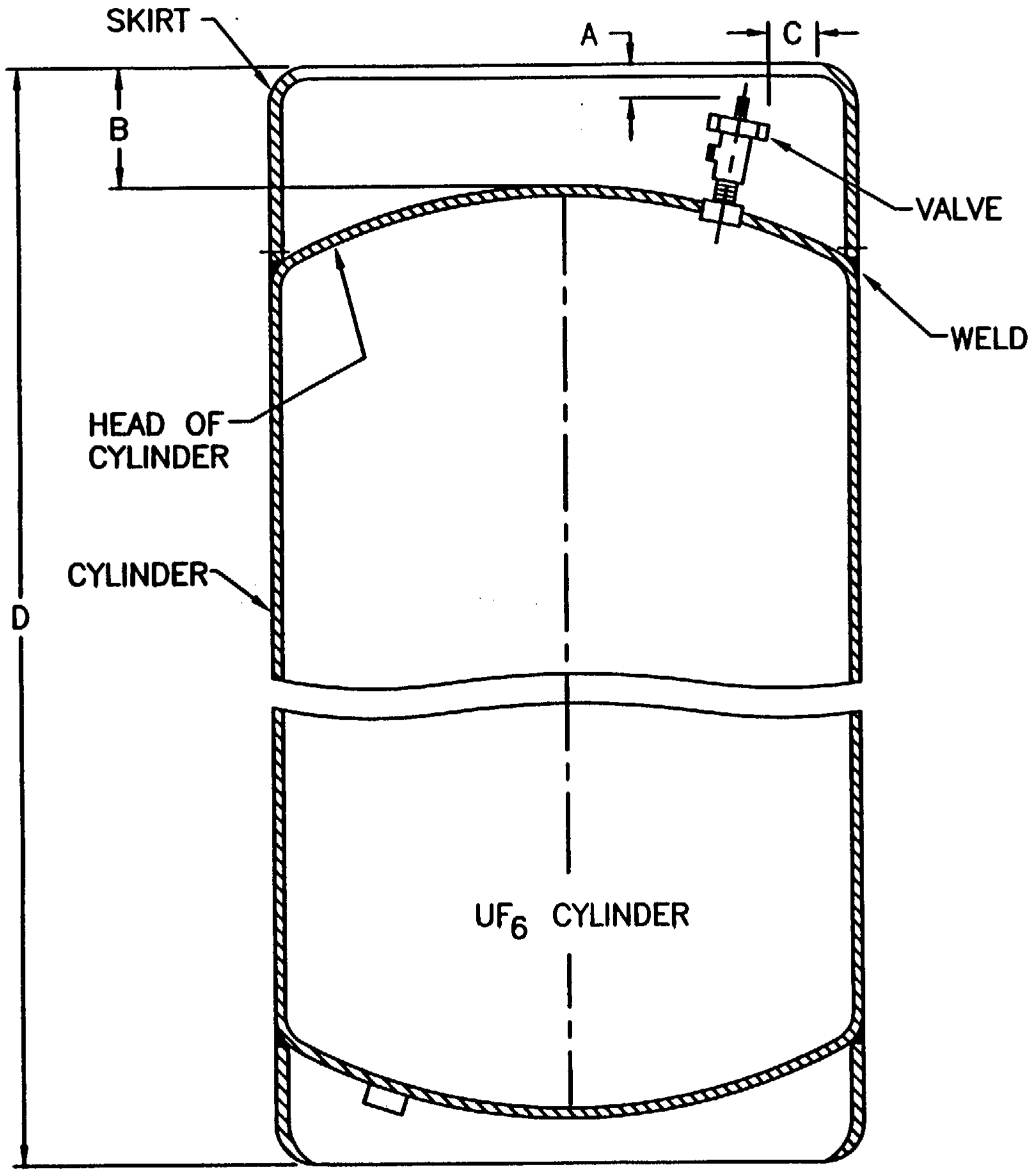


III. AFTER PUNCH TEST.

DIMENSIONS AFTER 30 ft
FREE DROP AND 40 inch
PUNCTURE TEST.

	001
C	161mm
D	617mm
E	14mm
F	345mm
G	190mm
H	NO MSRMNT
I	7mm
J	9mm
K	19mm
L	0mm
M	0mm

DIMENSIONS OF ESP–30X SN001 PACKAGE AFTER PUNCH TEST

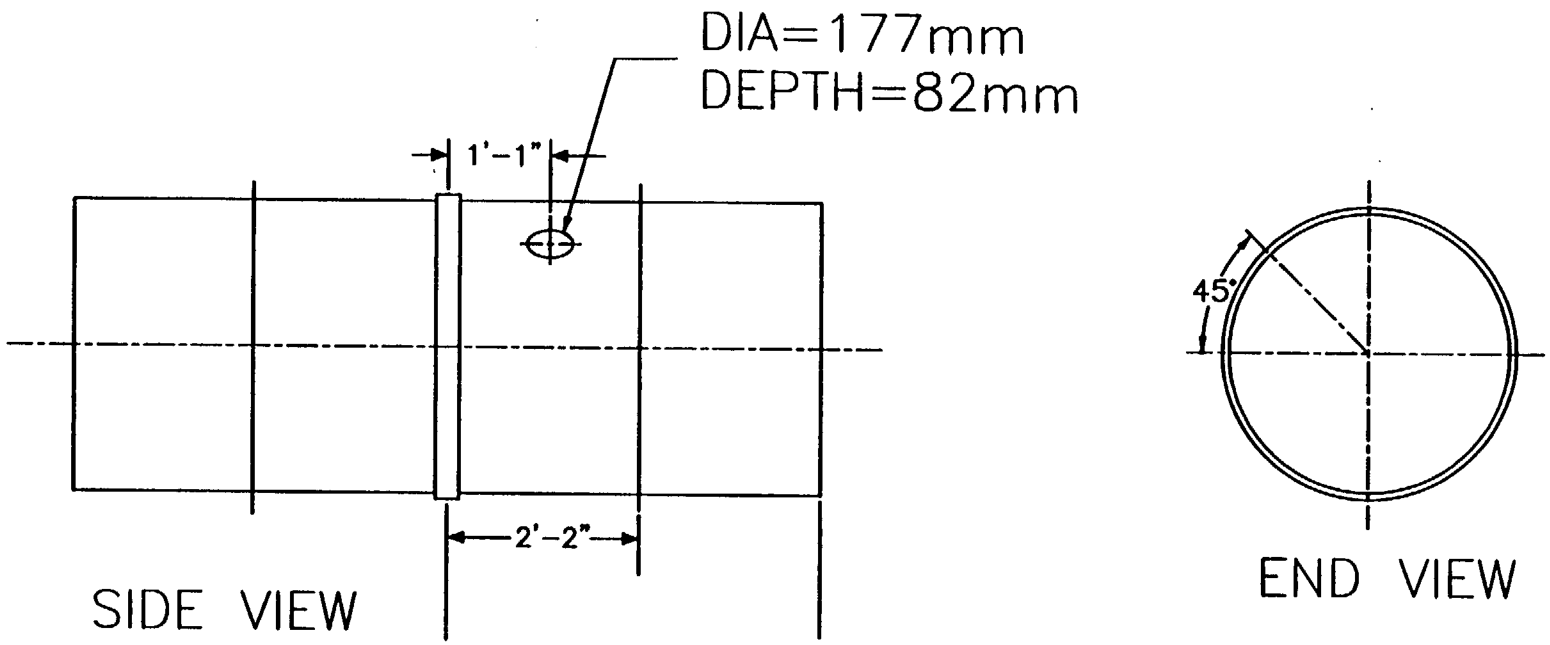


DATA LOGS FOR VALVE POSITION MEASUREMENTS

DROP SERIES: SERIES I 001

DROP ANGLE: 14°/30ft V=195ft/min
13.5°/40in. V=128ft/min

LOCATION	DIMENSIONS BEFORE DROP	DIMENSIONS AFTER 30ft DROP AND 40in PUNCH
A	24mm	24mm
B	135mm	135mm
C	58mm	58mm
D	2072mm	2065mm



SwRI	ESP-30X SN001				
	AFTER SIDE PUNCTURE				
ECO-PAC	SIZE	FSCM NO. 1	DWG NO. 01-1680-104		REV
	SCALE NA	WAUFRANCE	SHEET 1		

APPENDIX D

LEAKAGE AND HYDROSTATIC TEST DATA LOGS

(Consisting of 2 Pages)

SOUTHWEST RESEARCH INSTITUTE
DATA SHEET

SUBJECT Post Drop / Fire Test Air Leakage Test Tank

PROJECT 01-1680
DATE 3-23-98
BY L. Ries

TANK S/N 001 (Air/Bubble Leak Test)

5:45P Start Press.
5:52P 100 psig
6:07P 99 psig

No Visible Signs of Leakage LER

SwRI 51 QA

TANK S/N 001 Helium Leak Test

6:21P Start pump-down

3-24-98
8:45A Test Port Press on Tank - 49mT
Leak Rate Background - 3.6×10^{-9} Atm cc/sec
8:46A " " " 4.0×10^{-9} Atm cc/sec
START He Flow
8:52A STOP He Flow
Leak Rate 3.9×10^{-9} Atm cc/sec LER

SwRI 51 QA

3-24-98 Internal Hydro Test (Post Drop / Burn)
TANK S/N 001
9:40 A - Tank Filled w/ Fresh water & Fluorescein Indicator Dye
9:42A - Start Press
9:43A - 20 psig - Allow to Stabilize
10:40A - 19 psig - Start Hold Period
3-25-98 8:47A - 13 psig
No Visible Signs of Leakage

SwRI 51 QA

OPM 1 TANK S/N 002 (Post Drop / Burn Tests)
3-24-98 (Side Drop Side - Non Inst.)
He Background 5.0×10^{-8} Atm cc/sec → 1.6×10^{-8} Atm cc/sec
10:41 Start He Flow → 10:45A
10:55A 1.7×10^{-6} Atm cc/sec LER
11:00A 1.3×10^{-5} Atm cc/sec
11:05A 0.8×10^{-5} Atm cc/sec
11:10A 0.8×10^{-5} Atm cc/sec LER

SwRI 51 QA

PC-4

3-11-98

Columbia Boiler Co. UF_6 Tanks

01-1680

Tank Mod. No. 30B, CB-1871-7

Tank S/N 002, ESP-30X

Internal Air Pressure Leakage Test (100 psi Air/Bubble Test)

10:47 A — 100 psig Air Pressure

Leakage Detected (Bubbles) at Valve/Tank Male Pipe Threads

11:03 A - Release Pressure

SwRI 51 QA

Tank Mod No. 30B, CB-1871-2

Tank S/N 001, ESP-30X

Internal Air Press Leakage Test (100 psi Air/Bubble Test)

11:20 A - Start Press.

11:30 A - 100 psig Air Press

11:45 A - 100 psig - No Leakage Observed — [initials]

SwRI 51 QA

Tank S/N 001

Start Vacuum Pump Down 3-11-98 12:27 A

3:03 P: 631-644 mT Test Port Press

4:15 P 453-464 mT

Leak Rate Background 1.4×10^{-8} std cc/sec

4:24 P End He Flow (Test Port Press: 442-453 mT)

Leak Rate: 1.3×10^{-8} std cc/sec [initials]

SwRI 51 QA

APPENDIX E

FIRE TEST DATA

(Consisting of 40 Pages)

ECO-PAK SPECIALTY PACKAGING
THERMOCOUPLE TEMPERATURES (°F)

DATE: 21 MARCH 1998
FILE: 0803SXT.DAT
08030XC.DAT
08030SC2.DAT

SwRI PROJECT NO: 01-1680-102
TEST TYPE: 10CFR 71.73(C),(4)

TIME (h:mm)	TC 1	TC 2	TC 3	TC 4	TC 5	TC 6	TC 7
0:00	100	100	101	99	101	98	101
0:01	100	100	101	99	101	98	101
0:02	100	100	101	100	101	98	101
0:03	100	100	101	100	101	98	101
0:04	100	100	101	100	101	97	101
0:05	100	99	101	100	101	97	101
0:06	100	100	101	100	101	98	101
0:07	100	100	101	100	101	98	101
0:08	100	100	102	100	101	98	101
0:09	100	100	102	101	101	97	100
0:10	97	100	103	101	100	97	100
0:11	95	99	103	101	98	95	100
0:12	93	99	102	101	99	95	96
0:13	91	100	102	102	99	95	98
0:14	90	101	103	103	100	95	99
0:15	90	101	104	102	99	96	99
0:16	90	101	104	103	98	97	99
0:17	90	101	104	103	97	97	99
0:18	90	100	103	103	96	96	98
0:19	89	100	102	102	94	94	96
0:20	84	99	102	101	92	89	92
0:21	79	99	104	101	92	90	93
0:22	77	99	104	101	92	92	93
0:23	79	99	104	101	93	92	94
0:24	81	101	104	103	94	94	95
0:25	83	104	103	104	94	95	96
0:26	84	101	103	105	93	97	96
0:27	87	102	103	106	94	99	97
0:28	91	105	105	108	95	101	98
0:29	96	107	106	111	96	103	-
0:30	100	108	106	112	97	104	-
0:31	103	110	108	113	98	106	-
0:32	106	112	109	115	98	107	-
0:33	109	113	110	117	98	109	-
0:34	112	117	111	120	100	113	-
0:35	116	118	112	122	101	116	-
0:36	119	120	114	124	102	119	-
0:37	122	120	114	125	103	120	-
0:38	126	121	114	125	103	121	-
0:39	129	121	114	126	103	121	-

ECO-PAK SPECIALTY PACKAGING
THERMOCOUPLE TEMPERATURES (°F)

DATE: 21 MARCH 1998
FILE: 0803SXT.DAT
08030XC.DAT
08030SC2.DAT

SwRI PROJECT NO: 01-1680-102
TEST TYPE: 10CFR 71.73(C),(4)

TIME (h:mm)	TC 1	TC 2	TC 3	TC 4	TC 5	TC 6	TC 7
0:40	130	121	115	126	102	121	-
0:41	133	122	115	126	102	121	-
0:42	134	122	115	127	102	122	-
0:43	138	123	115	128	101	123	-
0:44	139	124	115	129	101	124	-
0:45	139	124	116	129	101	124	-
0:46	137	-	116	130	101	125	-
0:47	138	-	117	131	101	126	-
0:48	139	-	117	132	101	127	-
0:49	139	-	118	132	100	128	-
0:50	141	-	119	133	100	129	-
0:51	142	-	119	134	101	130	-
0:52	143	-	120	135	101	131	-
0:53	144	-	120	136	101	132	-
0:54	146	-	121	137	101	134	-
0:55	147	-	122	138	101	135	-
0:56	148	-	123	139	102	140	-
0:57	149	-	123	139	102	144	-
0:58	150	-	124	140	102	147	-
0:59	151	-	125	141	102	149	-
1:00	152	-	126	142	102	150	-
1:01	153	-	126	143	103	151	-
1:02	154	-	127	144	103	153	-
1:03	155	-	128	144	103	154	-
1:04	-	-	129	145	104	156	-
1:05	-	-	-	146	104	160	-
1:06	-	-	-	147	105	161	-
1:07	-	-	-	147	105	161	-
1:08	-	-	-	148	105	162	-
1:09	-	-	-	148	106	163	-
1:10	-	-	-	149	106	163	118
1:11	-	-	-	149	106	164	118
1:12	-	-	-	149	107	164	119
1:13	-	-	-	-	-	-	-
1:14	-	-	-	-	-	-	-
1:15	-	-	-	-	-	-	-
1:16	-	-	-	-	-	-	-
1:17	-	-	-	-	-	-	-
1:18	-	-	-	-	-	-	-
1:19	171	-	-	-	-	-	-

ECO-PAK SPECIALTY PACKAGING
THERMOCOUPLE TEMPERATURES (°F)

DATE: 21 MARCH 1998
FILE: 0803SXT.DAT
08030XC.DAT
08030SC2.DAT

SwRI PROJECT NO: 01-1680-102
TEST TYPE: 10CFR 71.73(C),(4)

TIME (h:mm)	TC 1	TC 2	TC 3	TC 4	TC 5	TC 6	TC 7
1:20	171	-	141	-	-	-	-
1:21	172	-	142	-	-	-	-
1:22	172	-	143	-	-	-	-
1:23	173	-	144	-	111	168	-
1:24	173	-	144	-	111	168	-
1:25	174	152	145	-	111	168	125
1:26	174	156	146	-	112	168	125
1:27	175	158	146	-	112	168	126
1:28	175	159	147	-	113	168	126
1:29	-	157	148	-	113	167	127
1:30	-	158	148	-	113	167	127
1:31	-	157	149	-	114	167	127
1:32	-	157	150	154	114	167	128
1:33	-	158	150	155	115	167	128
1:34	-	159	151	155	115	167	129
1:35	-	159	152	155	115	166	129
1:36	-	161	152	155	116	166	130
1:37	-	160	153	155	116	166	130
1:38	-	160	155	156	117	165	131
1:39	180	160	155	156	118	165	132
1:40	180	161	156	156	118	165	132
1:41	181	161	156	156	118	165	133
1:42	181	161	157	156	119	164	133
1:43	181	160	157	156	119	164	134
1:44	181	160	158	156	119	164	134
1:45	182	160	158	156	120	164	134
1:46	182	161	159	156	120	163	135
1:47	182	160	159	156	120	163	135
1:48	183	159	160	157	121	163	136
1:49	183	159	160	157	121	163	136
1:50	183	159	161	157	122	163	136
1:51	183	159	161	157	122	162	137
1:52	183	160	161	157	122	162	137
1:53	183	160	162	157	122	162	137
1:54	184	159	162	157	123	162	138
1:55	184	158	163	157	123	161	138
1:56	184	159	163	157	123	161	139
1:57	184	160	163	157	124	161	139
1:58	184	160	164	157	124	160	139
1:59	184	159	164	157	124	160	139

ECO-PAK SPECIALTY PACKAGING
THERMOCOUPLE TEMPERATURES (°F)

DATE: 21 MARCH 1998
FILE: 0803SXT.DAT
08030XC.DAT
08030SC2.DAT

SwRI PROJECT NO: 01-1680-102
TEST TYPE: 10CFR 71.73(C),(4)

TIME (h:mm)	TC 1	TC 2	TC 3	TC 4	TC 5	TC 6	TC 7
2:00	184	160	164	157	125	160	140
2:01	185	159	165	157	125	160	140
2:02	185	158	165	157	125	159	140
2:03	185	158	165	157	125	159	141
2:04	185	158	166	157	126	159	141
2:05	185	158	166	157	126	158	141
2:06	185	158	166	157	126	158	142
2:07	185	160	166	157	127	158	142
2:08	185	159	167	157	127	158	142
2:09	185	157	167	157	127	157	143
2:10	186	156	167	157	127	157	143
2:11	186	156	168	157	128	157	143
2:12	186	157	168	157	128	157	144
2:13	186	158	168	157	128	156	144
2:14	186	157	168	158	128	156	144
2:15	186	156	169	158	129	156	144
2:16	186	156	169	158	129	156	145
2:17	187	155	169	158	129	156	145
2:18	187	156	169	158	130	155	146
2:19	187	156	170	158	130	155	146
2:20	187	155	170	158	130	155	146
2:21	187	154	170	158	130	155	146
2:22	187	154	170	158	131	155	147
2:23	187	155	170	158	131	154	147
2:24	187	155	171	158	131	154	147
2:25	186	157	171	158	131	154	147
2:26	186	157	171	158	131	154	147
2:27	186	156	171	158	132	153	148
2:28	185	156	171	158	132	153	148
2:29	185	156	171	158	132	153	148
2:30	185	155	171	158	132	153	148
2:31	185	155	172	158	132	153	149
2:32	185	154	172	158	133	152	149
2:33	185	153	172	158	133	152	149
2:34	185	153	172	158	133	152	149
2:35	185	154	172	158	133	152	150
2:36	185	152	172	158	133	152	150
2:37	185	153	173	158	133	152	150
2:38	185	153	173	157	134	151	150
2:39	185	152	173	157	134	151	150

ECO-PAK SPECIALTY PACKAGING
THERMOCOUPLE TEMPERATURES (°F)

DATE: 21 MARCH 1998
FILE: 0803SXT.DAT
08030XC.DAT
08030SC2.DAT

SwRI PROJECT NO: 01-1680-102
TEST TYPE: 10CFR 71.73(C),(4)

TIME (h:mm)	TC 1	TC 2	TC 3	TC 4	TC 5	TC 6	TC 7
2:40	185	152	173	157	134	151	151
2:41	185	152	173	157	134	151	151
2:42	185	151	173	157	134	151	151
2:43	185	149	173	157	135	151	151
2:44	186	149	173	157	135	150	151
2:45	186	149	173	157	135	150	152
2:46	186	149	174	157	135	150	152
2:47	185	149	174	157	135	150	152
2:48	185	149	174	157	135	150	152
2:49	185	149	174	157	136	149	152
2:50	185	148	174	157	136	149	152
2:51	185	147	174	157	136	149	153
2:52	185	147	174	157	136	149	153
2:53	185	147	174	157	136	149	153
2:54	185	148	174	157	136	149	153
2:55	185	147	174	157	136	148	153
2:56	185	147	174	157	137	148	153
2:57	184	147	174	157	137	148	154
2:58	184	147	174	157	137	148	154
2:59	184	148	174	157	137	148	154
3:00	183	149	174	157	137	147	154
3:01	183	148	174	157	137	147	154
3:02	183	148	175	157	137	147	154
3:03	183	148	175	157	137	147	154
3:04	183	147	175	157	137	147	154
3:05	183	146	175	157	138	147	154
3:06	183	145	175	157	138	147	155
3:07	183	144	175	157	138	147	155
3:08	183	144	175	157	138	146	155
3:09	183	144	175	157	138	146	155
3:10	183	143	175	156	138	146	155
3:11	183	143	175	156	138	146	155
3:12	183	143	175	156	138	146	155
3:13	183	143	175	156	138	146	155
3:14	183	143	175	156	139	146	156
3:15	183	142	175	156	139	145	156
3:16	183	142	175	156	139	145	156
3:17	182	142	175	156	139	145	156
3:18	182	142	175	156	139	145	156
3:19	182	142	175	156	139	145	156

ECO-PAK SPECIALTY PACKAGING
THERMOCOUPLE TEMPERATURES (°F)

DATE: 21 MARCH 1998
FILE: 0803SXT.DAT
08030XC.DAT
08030SC2.DAT

SwRI PROJECT NO: 01-1680-102
TEST TYPE: 10CFR 71.73(C),(4)

TIME (h:mm)	TC 1	TC 2	TC 3	TC 4	TC 5	TC 6	TC 7
3:20	182	141	175	156	139	145	156
3:21	182	141	175	156	139	145	156
3:22	182	141	176	156	139	145	157
3:23	182	141	176	156	139	144	157
3:24	182	140	176	156	139	144	157
3:25	181	140	176	156	140	144	157
3:26	181	140	176	156	140	144	157
3:27	181	140	176	156	140	144	157
3:28	181	140	176	156	140	144	157
3:29	181	140	176	156	140	144	157
3:30	181	139	176	156	140	144	157
3:31	181	139	176	156	140	144	157
3:32	180	139	176	155	140	143	157
3:33	180	139	176	155	140	143	158
3:34	180	139	176	155	140	143	158
3:35	180	138	176	155	140	143	158
3:36	180	138	176	155	140	143	158
3:37	180	137	176	155	140	143	158
3:38	180	137	176	155	140	143	158
3:39	180	137	176	155	140	143	158
3:40	179	137	176	155	140	143	158
3:41	179	137	176	155	141	142	158
3:42	179	137	176	155	141	142	158
3:43	179	137	176	155	141	142	158
3:44	179	137	176	155	141	142	159
3:45	179	136	176	155	141	142	159
3:46	179	136	176	155	141	142	159
3:47	178	136	176	155	141	142	159
3:48	178	136	176	155	141	142	159
3:49	178	136	176	154	141	142	159
3:50	178	135	176	154	141	142	159
3:51	178	135	176	154	141	142	159
3:52	178	135	177	154	141	141	159
3:53	178	135	177	154	141	141	159
3:54	178	134	177	154	141	141	159
3:55	177	134	177	154	141	141	159
3:56	177	134	177	154	141	141	159
3:57	177	134	177	154	141	141	159
3:58	177	134	177	154	141	141	160
3:59	177	134	177	154	141	141	160

ECO-PAK SPECIALTY PACKAGING
THERMOCOUPLE TEMPERATURES (°F)

DATE: 21 MARCH 1998
FILE: 0803SXT.DAT
08030XC.DAT
08030SC2.DAT

SwRI PROJECT NO: 01-1680-102
TEST TYPE: 10CFR 71.73(C),(4)

TIME (h:mm)	TC 1	TC 2	TC 3	TC 4	TC 5	TC 6	TC 7
4:00	177	134	177	154	141	141	160
4:01	177	134	177	154	141	141	160
4:02	176	133	177	154	141	141	160
4:03	176	133	177	153	141	141	160
4:04	176	133	176	153	141	140	160
4:05	176	133	176	153	141	140	160
4:06	176	133	176	153	141	140	160
4:07	176	133	176	153	141	140	160
4:08	176	132	176	153	141	140	160
4:09	175	132	176	153	142	140	160
4:10	175	131	176	153	142	140	160
4:11	175	131	176	153	142	140	160
4:12	175	131	176	153	142	140	160
4:13	175	131	176	153	141	140	160
4:14	175	131	176	153	141	140	160
4:15	175	131	176	153	141	140	160
4:16	174	131	176	153	141	140	160
4:17	174	131	176	152	141	139	160
4:18	174	131	176	152	141	139	160
4:19	174	131	176	152	141	139	160
4:20	174	131	176	152	141	139	160
4:21	174	131	176	152	141	139	160
4:22	174	131	176	152	141	139	161
4:23	174	131	176	152	141	139	161
4:24	173	131	176	152	141	139	161
4:25	173	130	176	152	141	139	161
4:26	173	130	176	152	141	139	161
4:27	173	131	176	152	141	139	161
4:28	173	131	176	152	141	139	161
4:29	173	130	176	151	141	139	161
4:30	173	130	175	151	141	139	161
4:31	172	130	175	151	141	138	161
4:32	172	130	175	151	141	138	161
4:33	172	130	175	151	141	138	161
4:34	172	130	175	151	141	138	161
4:35	172	130	175	151	141	138	161
4:36	172	129	175	151	141	138	161
4:37	172	129	175	151	141	138	161
4:38	171	129	175	151	141	138	161
4:39	171	129	175	151	141	138	161

ECO-PAK SPECIALTY PACKAGING
THERMOCOUPLE TEMPERATURES (°F)

DATE: 21 MARCH 1998
FILE: 0803SXT.DAT
08030XC.DAT
08030SC2.DAT

SwRI PROJECT NO: 01-1680-102
TEST TYPE: 10CFR 71.73(C),(4)

TIME (h:mm)	TC 1	TC 2	TC 3	TC 4	TC 5	TC 6	TC 7
4:40	171	129	175	151	141	138	161
4:41	171	129	175	150	141	138	161
4:42	171	128	175	150	141	138	161
4:43	171	128	175	150	141	138	161
4:44	171	128	175	150	141	138	161
4:45	170	128	175	150	141	138	161
4:46	170	128	174	150	141	137	161
4:47	170	128	174	150	141	137	161
4:48	170	128	174	150	141	137	161
4:49	170	128	174	150	141	137	161
4:50	170	128	174	150	141	137	161
4:51	170	127	174	150	141	137	161
4:52	170	127	174	150	141	137	161
4:53	169	127	174	150	141	137	161
4:54	169	127	174	149	141	137	161
4:55	169	127	174	149	141	137	161
4:56	169	127	174	149	141	137	161
4:57	169	127	174	149	141	137	160
4:58	169	126	174	149	141	137	160
4:59	169	126	174	149	141	137	160
5:00	168	126	174	149	141	137	160
5:01	168	126	174	149	141	137	160
5:02	168	126	174	149	141	137	160
5:03	168	126	174	149	141	136	160
5:04	168	126	173	149	141	136	160
5:05	168	126	173	149	141	136	160
5:06	168	125	173	148	141	136	160
5:07	167	126	173	148	141	136	160
5:08	167	126	173	148	141	136	160
5:09	167	126	173	148	141	136	160
5:10	167	125	173	148	141	136	160
5:11	167	125	173	148	141	136	160
5:12	167	125	173	148	141	136	160
5:13	167	126	173	148	141	136	160
5:14	167	125	173	148	141	136	160
5:15	166	125	173	148	141	136	160
5:16	166	125	173	148	141	136	160
5:17	166	125	173	148	141	136	160
5:18	166	125	173	147	141	136	160
5:19	166	125	173	147	141	135	160

ECO-PAK SPECIALTY PACKAGING
THERMOCOUPLE TEMPERATURES (°F)

DATE: 21 MARCH 1998
FILE: 0803SXT.DAT
08030XC.DAT
08030SC2.DAT

SwRI PROJECT NO: 01-1680-102
TEST TYPE: 10CFR 71.73(C),(4)

TIME (h:mm)	TC 1	TC 2	TC 3	TC 4	TC 5	TC 6	TC 7
5:20	166	125	173	147	141	135	160
5:21	166	124	173	147	141	135	160
5:22	165	124	173	147	141	135	160
5:23	165	124	172	147	141	135	160
5:24	165	123	172	147	141	135	160
5:25	165	123	172	147	141	135	160
5:26	165	124	172	147	141	135	160
5:27	165	124	172	147	141	135	160
5:28	165	124	172	147	141	135	160
5:29	165	124	172	147	141	135	160
5:30	164	124	172	147	141	135	160
5:31	164	124	172	146	141	135	160
5:32	164	124	172	146	141	135	159
5:33	164	123	172	146	141	135	159
5:34	164	123	172	146	141	135	159
5:35	164	123	172	146	141	135	159
5:36	164	122	172	146	140	134	159
5:37	164	123	172	146	140	134	159
5:38	163	123	171	146	140	134	159
5:39	163	123	171	146	140	134	159
5:40	163	123	171	146	140	134	159
5:41	163	123	171	146	140	134	159
5:42	163	123	171	146	140	134	159
5:43	163	123	171	145	140	134	159
5:44	162	123	171	145	140	134	159
5:45	162	123	171	145	140	134	159
5:46	162	123	171	145	140	134	159
5:47	162	123	171	145	140	134	159
5:48	162	123	171	145	140	134	159
5:49	162	123	171	145	140	134	159
5:50	162	123	170	145	140	134	159
5:51	162	123	170	145	140	134	159
5:52	161	123	170	145	140	134	159
5:53	161	122	170	145	140	134	159
5:54	161	122	170	145	140	134	159
5:55	161	122	170	145	140	133	159
5:56	161	122	170	144	140	133	159
5:57	161	122	170	144	140	133	158
5:58	161	122	170	144	140	133	158
5:59	161	122	170	144	140	133	158

ECO-PAK SPECIALTY PACKAGING
THERMOCOUPLE TEMPERATURES (°F)

DATE: 21 MARCH 1998
FILE: 0803SXT.DAT
08030XC.DAT
08030SC2.DAT

SwRI PROJECT NO: 01-1680-102
TEST TYPE: 10CFR 71.73(C),(4)

TIME (h:mm)	TC 1	TC 2	TC 3	TC 4	TC 5	TC 6	TC 7
6:00	161	121	170	144	140	133	158
6:01	160	121	170	144	140	133	158
6:02	160	121	169	144	140	133	158
6:03	160	121	169	144	140	133	158
6:04	160	121	169	144	140	133	158
6:05	160	121	169	144	140	133	158
6:06	160	121	169	144	140	133	158
6:07	160	121	169	144	140	133	158
6:08	160	121	169	143	140	133	158
6:09	160	121	169	143	140	133	158
6:10	159	121	169	143	139	133	158
6:11	159	121	169	143	139	132	158
6:12	159	121	169	143	139	132	158
6:13	159	121	168	143	139	132	158
6:14	159	121	168	143	139	132	158
6:15	159	121	168	143	139	132	158
6:16	159	121	168	143	139	132	158
6:17	158	120	168	143	139	132	157
6:18	158	120	168	143	139	132	157
6:19	158	120	168	143	139	132	157
6:20	158	120	168	143	139	132	157
6:21	158	120	168	143	139	132	157
6:22	158	121	167	142	139	132	157
6:23	158	120	167	142	139	132	157
6:24	158	120	167	142	139	132	157
6:25	157	121	167	142	139	132	157
6:26	157	121	167	142	139	132	157
6:27	157	120	167	142	139	132	157
6:28	157	120	167	142	139	132	157
6:29	157	120	167	142	139	132	157
6:30	157	120	167	142	139	132	157
6:31	157	119	167	142	139	131	157
6:32	157	119	166	142	139	131	157
6:33	157	120	166	142	139	131	157
6:34	156	119	166	141	139	131	156
6:35	156	120	166	141	139	131	156
6:36	156	120	166	141	139	131	156
6:37	156	120	166	141	138	131	156
6:38	156	120	166	141	138	131	156
6:39	156	121	166	141	138	131	156

ECO-PAK SPECIALTY PACKAGING
THERMOCOUPLE TEMPERATURES (°F)

DATE: 21 MARCH 1998
FILE: 0803SXT.DAT
08030XC.DAT
08030SC2.DAT

SwRI PROJECT NO: 01-1680-102
TEST TYPE: 10CFR 71.73(C),(4)

TIME (h:mm)	TC 1	TC 2	TC 3	TC 4	TC 5	TC 6	TC 7
6:40	156	120	166	141	138	131	156
6:41	156	120	166	141	138	131	156
6:42	155	120	165	141	138	131	156
6:43	155	120	165	141	138	131	156
6:44	155	120	165	141	138	131	156
6:45	155	120	165	141	138	131	156
6:46	155	120	165	141	138	131	156
6:47	155	120	165	140	138	131	156
6:48	155	120	165	140	138	131	156
6:49	155	120	165	140	138	130	156
6:50	154	120	165	140	138	130	156
6:51	154	119	164	140	138	130	155
6:52	154	120	164	140	138	130	155
6:53	154	120	164	140	138	130	155
6:54	154	119	164	140	138	130	155
6:55	154	119	164	140	138	130	155
6:56	154	119	164	140	138	130	155
6:57	154	119	164	140	138	130	155
6:58	154	119	164	140	138	130	155
6:59	154	119	164	139	138	130	155
7:00	153	119	164	139	138	130	155
7:01	153	119	163	139	138	130	155
7:02	153	119	163	139	137	130	155
7:03	153	119	163	139	137	130	155
7:04	153	119	163	139	137	130	155
7:05	153	119	163	139	137	130	155
7:06	153	119	163	139	137	130	155
7:07	153	120	163	139	137	130	154
7:08	152	120	163	139	137	130	154
7:09	152	119	163	139	137	130	154
7:10	152	119	163	139	137	129	154
7:11	152	119	162	139	137	129	154
7:12	152	119	162	139	137	129	154
7:13	152	119	162	138	137	129	154
7:14	152	119	162	138	137	129	154
7:15	152	119	162	138	137	129	154
7:16	152	119	162	138	137	129	154
7:17	151	119	162	138	137	129	154
7:18	151	119	162	138	137	129	154
7:19	151	119	162	138	137	129	154

ECO-PAK SPECIALTY PACKAGING
THERMOCOUPLE TEMPERATURES (°F)

DATE: 21 MARCH 1998
FILE: 0803SXT.DAT
08030XC.DAT
08030SC2.DAT

SwRI PROJECT NO: 01-1680-102
TEST TYPE: 10CFR 71.73(C),(4)

TIME (h:mm)	TC 1	TC 2	TC 3	TC 4	TC 5	TC 6	TC 7
7:20	151	118	162	138	137	129	154
7:21	151	119	162	138	137	129	154
7:22	151	119	161	138	137	129	154
7:23	151	119	161	138	137	129	154
7:24	151	119	161	138	137	129	153
7:25	151	119	161	138	136	129	153
7:26	151	119	161	138	136	129	153
7:27	150	119	161	137	136	129	153
7:28	150	119	161	137	136	129	153
7:29	150	119	161	137	136	129	153
7:30	150	119	161	137	136	128	153
7:31	150	118	161	137	136	128	153
7:32	150	117	161	137	136	128	153
7:33	150	118	161	137	136	128	153
7:34	150	117	160	137	136	128	153
7:35	150	117	160	137	136	128	153
7:36	150	117	160	137	136	128	153
7:37	149	118	160	137	136	128	153
7:38	149	118	160	137	136	128	153
7:39	149	118	160	137	136	128	153
7:40	149	118	160	136	136	128	152
7:41	149	118	160	136	136	128	152
7:42	149	117	160	136	136	128	152
7:43	149	117	160	136	136	128	152
7:44	149	117	160	136	136	128	152
7:45	149	117	160	136	136	128	152
7:46	149	117	160	136	136	128	152
7:47	148	117	159	136	136	128	152
7:48	148	117	159	136	135	128	152
7:49	148	117	159	136	135	128	152
7:50	148	117	159	136	135	128	152
7:51	148	117	159	136	135	128	152
7:52	148	117	159	136	135	127	152
7:53	148	116	159	136	135	127	152
7:54	148	116	159	135	135	127	152
7:55	148	116	159	135	135	127	152
7:56	148	116	159	135	135	127	152
7:57	147	116	159	135	135	127	151
7:58	147	116	159	135	135	127	151
7:59	147	117	159	135	135	127	151

ECO-PAK SPECIALTY PACKAGING
THERMOCOUPLE TEMPERATURES (°F)

DATE: 21 MARCH 1998
FILE: 0803SXT.DAT
08030XC.DAT
08030SC2.DAT

SwRI PROJECT NO: 01-1680-102
TEST TYPE: 10CFR 71.73(C),(4)

TIME (h:mm)	TC 1	TC 2	TC 3	TC 4	TC 5	TC 6	TC 7
8:00	147	117	159	135	135	127	151
8:01	147	117	159	135	135	127	151
8:02	147	116	159	135	135	127	151
8:03	147	116	159	135	135	127	151
8:04	147	116	159	135	135	127	151
8:05	147	116	159	135	135	127	151
8:06	147	116	159	135	135	127	151
8:07	146	116	159	135	135	127	151
8:08	146	116	158	134	135	127	151
8:09	146	116	158	134	135	127	151
8:10	146	117	158	134	134	126	151
8:11	146	117	158	134	134	126	151
8:12	146	117	158	134	134	126	151
8:13	146	117	158	134	134	126	151
8:14	146	117	158	134	134	126	151
8:15	146	117	158	134	134	126	151
8:16	146	117	158	134	134	126	150
8:17	145	116	158	134	134	126	150
8:18	145	116	158	134	134	126	150
8:19	145	116	158	134	134	126	150
8:20	145	116	158	134	134	126	150
8:21	145	116	158	134	134	126	150
8:22	145	116	158	134	134	126	150
8:23	145	116	158	133	134	126	150
8:24	145	116	158	133	134	126	150
8:25	145	117	158	133	134	126	150
8:26	145	117	158	133	134	126	150
8:27	145	116	158	133	134	126	150
8:28	144	117	158	133	134	126	150
8:29	144	116	158	133	134	126	150
8:30	144	116	158	133	134	126	150
8:31	144	117	158	133	134	126	150
8:32	144	116	158	133	133	126	150
8:33	144	116	158	133	133	125	150
8:34	144	116	158	133	133	125	150
8:35	144	116	158	133	133	125	150
8:36	144	116	158	133	133	125	150
8:37	144	116	158	132	133	125	149
8:38	144	117	158	132	133	125	149
8:39	144	117	157	132	133	125	149

ECO-PAK SPECIALTY PACKAGING
THERMOCOUPLE TEMPERATURES (°F)

DATE: 21 MARCH 1998
FILE: 0803SXT.DAT
08030XC.DAT
08030SC2.DAT

SwRI PROJECT NO: 01-1680-102
TEST TYPE: 10CFR 71.73(C),(4)

TIME (h:mm)	TC 1	TC 2	TC 3	TC 4	TC 5	TC 6	TC 7
8:40	144	117	157	132	133	125	149
8:41	143	117	157	132	133	125	149
8:42	143	117	157	132	133	125	149
8:43	143	117	157	132	133	125	149
8:44	143	117	157	132	133	125	149
8:45	143	117	157	132	133	125	149
8:46	143	117	157	132	133	125	149
8:47	143	117	157	132	133	125	149
8:48	143	117	157	132	133	125	149
8:49	143	117	157	132	133	125	149
8:50	143	117	157	132	133	125	149
8:51	143	117	157	132	133	125	149
8:52	143	117	157	132	133	125	149
8:53	142	117	157	131	132	125	149
8:54	142	117	157	131	132	125	149
8:55	142	116	157	131	132	125	149
8:56	142	116	157	131	132	125	149
8:57	142	116	157	131	132	125	149
8:58	142	116	157	131	132	124	149
8:59	142	115	156	131	132	124	148
9:00	142	115	156	131	132	124	149
9:01	142	115	156	131	132	124	148
9:02	142	115	156	131	132	124	148
9:03	142	115	156	131	132	124	148
9:04	142	115	156	131	132	124	148
9:05	142	115	156	131	132	124	148
9:06	142	115	156	131	132	124	148
9:07	142	115	156	131	132	124	148
9:08	142	115	156	130	132	124	148
9:09	141	115	156	130	132	124	148
9:10	141	114	156	130	132	124	148
9:11	141	114	156	130	132	124	148
9:12	141	114	156	130	132	124	148
9:13	141	114	156	130	132	124	148
9:14	141	114	155	130	132	124	148
9:15	141	114	155	130	132	124	148
9:16	141	113	155	130	131	124	148
9:17	141	113	155	130	131	124	148
9:18	141	113	155	130	131	124	148
9:19	141	113	155	130	131	124	148

ECO-PAK SPECIALTY PACKAGING
THERMOCOUPLE TEMPERATURES (°F)

DATE: 21 MARCH 1998
FILE: 0803SXT.DAT
08030XC.DAT
08030SC2.DAT

SwRI PROJECT NO: 01-1680-102
TEST TYPE: 10CFR 71.73(C),(4)

TIME (h:mm)	TC 1	TC 2	TC 3	TC 4	TC 5	TC 6	TC 7
9:20	141	113	155	130	131	124	148
9:21	141	113	155	130	131	123	148
9:22	141	113	155	130	131	123	148
9:23	140	113	155	130	131	123	147
9:24	140	113	155	129	131	123	147
9:25	140	113	155	129	131	123	147
9:26	140	113	155	129	131	123	147
9:27	140	113	154	129	131	123	147
9:28	140	113	154	129	131	123	147
9:29	140	113	154	129	131	123	147
9:30	140	113	154	129	131	123	147
9:31	140	113	154	129	131	123	147
9:32	140	113	154	129	131	123	147
9:33	140	113	154	129	131	123	147
9:34	140	112	154	129	131	123	147
9:35	140	112	154	129	131	123	147
9:36	140	112	154	129	131	123	147
9:37	140	112	154	129	131	123	147
9:38	139	112	154	129	130	123	147
9:39	139	112	153	129	130	123	147
9:40	139	112	153	129	130	123	147
9:41	139	112	153	129	130	123	147
9:42	139	112	153	128	130	123	146
9:43	139	112	153	128	130	123	146
9:44	139	113	153	128	130	123	146
9:45	139	113	153	128	130	123	146
9:46	139	113	153	128	130	122	146
9:47	139	113	153	128	130	122	146
9:48	139	113	153	128	130	122	146
9:49	138	112	153	128	130	122	146
9:50	138	112	152	128	130	122	146
9:51	138	113	152	128	130	122	146
9:52	138	113	152	128	130	122	146
9:53	138	113	152	128	130	122	146
9:54	138	113	152	128	130	122	146
9:55	138	113	152	128	130	122	146
9:56	138	112	152	128	130	122	146
9:57	138	112	152	128	130	122	146
9:58	138	112	152	127	130	122	146
9:59	138	112	152	127	130	122	146

ECO-PAK SPECIALTY PACKAGING
THERMOCOUPLE TEMPERATURES (°F)

DATE: 21 MARCH 1998
FILE: 0803SXT.DAT
08030XC.DAT
08030SC2.DAT

SwRI PROJECT NO: 01-1680-102
TEST TYPE: 10CFR 71.73(C),(4)

TIME (h:mm)	TC 1	TC 2	TC 3	TC 4	TC 5	TC 6	TC 7
10:00	138	112	152	127	129	122	146
10:01	138	112	152	127	129	122	146
10:02	138	112	151	127	129	122	145
10:03	138	112	151	127	129	122	145
10:04	138	112	151	127	129	122	145
10:05	137	112	151	127	129	122	145
10:06	137	112	151	127	129	122	145
10:07	137	112	151	127	129	122	145
10:08	137	112	151	127	129	122	145
10:09	137	113	151	127	129	122	145
10:10	137	112	151	127	129	122	145
10:11	137	113	151	127	129	122	145
10:12	137	113	151	127	129	121	145
10:13	137	113	150	127	129	121	145
10:14	137	113	150	127	129	121	145
10:15	137	112	150	127	129	121	145
10:16	137	112	150	126	129	121	145
10:17	137	112	150	126	129	121	145
10:18	137	112	150	126	129	121	145
10:19	136	112	150	126	129	121	144
10:20	136	112	150	126	129	121	144
10:21	136	112	150	126	128	121	144
10:22	136	112	150	126	128	121	144
10:23	136	112	150	126	128	121	144
10:24	136	112	150	126	128	121	144
10:25	136	112	149	126	128	121	144
10:26	136	111	149	126	128	121	144
10:27	136	111	149	126	128	121	144
10:28	136	111	149	126	128	121	144
10:29	136	111	149	126	128	121	144
10:30	136	111	149	126	128	121	144
10:31	136	111	149	126	128	121	144
10:32	135	111	149	126	128	121	144
10:33	135	111	149	126	128	121	144
10:34	135	111	149	125	128	121	144
10:35	135	111	149	125	128	121	144
10:36	135	111	148	125	128	121	144
10:37	135	111	148	125	128	121	143
10:38	135	111	148	125	128	120	143
10:39	135	111	148	125	128	120	143

ECO-PAK SPECIALTY PACKAGING
THERMOCOUPLE TEMPERATURES (°F)

DATE: 21 MARCH 1998
FILE: 0803SXT.DAT
08030XC.DAT
08030SC2.DAT

SwRI PROJECT NO: 01-1680-102
TEST TYPE: 10CFR 71.73(C),(4)

TIME (h:mm)	TC 1	TC 2	TC 3	TC 4	TC 5	TC 6	TC 7
10:40	135	111	148	125	128	120	143
10:41	135	111	148	125	128	120	143
10:42	135	111	148	125	128	120	143
10:43	135	111	148	125	128	120	143
10:44	135	111	148	125	127	120	143
10:45	135	111	148	125	127	120	143
10:46	135	111	148	125	127	120	143

ECO-PAK SPECIALTY PACKAGING
THERMOCOUPLE TEMPERATURES (°F)

DATE: 21 MARCH 1998 — **SwRI PROJECT NO: 01-1680-102**
FILE: 0803SXT.DAT — **TEST TYPE: 10CFR 71.73(C),(4)**
08030XC.DAT
08030SC2.DAT

TIME (h:mm)	TC 8	TC 9	TC 10	TC 11	TC 12	TC 13	TC 14
0:00	98	98	98	100	99	-	100
0:01	98	98	98	100	99	-	100
0:02	98	98	98	100	99	98	100
0:03	98	98	98	100	99	-	100
0:04	98	98	98	100	99	98	100
0:05	98	98	98	100	99	98	100
0:06	99	98	98	101	99	98	100
0:07	99	98	98	101	99	-	100
0:08	99	-	98	-	-	-	103
0:09	99	-	99	-	-	-	103
0:10	98	-	98	-	-	-	111
0:11	97	-	97	-	-	-	113
0:12	98	-	98	-	-	-	109
0:13	99	-	99	-	-	-	108
0:14	99	-	99	-	-	-	109
0:15	99	-	100	-	-	-	110
0:16	100	-	101	-	-	-	110
0:17	99	-	101	-	-	-	111
0:18	99	-	101	-	-	-	111
0:19	98	-	100	-	-	-	111
0:20	94	-	98	-	-	-	110
0:21	95	-	99	-	-	-	110
0:22	96	-	100	-	-	-	111
0:23	97	-	101	-	-	-	111
0:24	99	-	102	-	-	-	112
0:25	100	-	103	-	-	-	114
0:26	100	-	103	-	-	-	113
0:27	101	-	104	-	-	-	114
0:28	102	-	105	-	-	-	115
0:29	-	-	106	-	-	-	116
0:30	-	-	106	-	-	-	117
0:31	-	-	108	-	-	-	118
0:32	-	-	109	-	-	-	119
0:33	-	-	110	-	-	-	121
0:34	-	-	113	-	-	-	122
0:35	-	-	114	-	-	-	123
0:36	-	-	116	-	-	-	126
0:37	-	-	117	-	-	-	126
0:38	-	-	118	-	-	-	129
0:39	-	-	118	-	-	-	129

ECO-PAK SPECIALTY PACKAGING
THERMOCOUPLE TEMPERATURES (°F)

DATE: 21 MARCH 1998
FILE: 0803SXT.DAT
08030XC.DAT
08030SC2.DAT

SwRI PROJECT NO: 01-1680-102
TEST TYPE: 10CFR 71.73(C),(4)

TIME (h:mm)	TC 8	TC 9	TC 10	TC 11	TC 12	TC 13	TC 14
0:40	-	-	119	-	-	-	128
0:41	-	-	-	-	-	-	128
0:42	-	-	-	-	-	-	127
0:43	-	-	-	-	-	-	127
0:44	-	-	-	-	-	-	127
0:45	-	-	-	-	-	-	127
0:46	-	-	-	-	-	-	127
0:47	-	-	-	-	-	-	127
0:48	-	-	120	-	-	-	128
0:49	-	-	120	-	-	-	128
0:50	-	-	120	-	-	-	128
0:51	-	-	121	-	113	-	128
0:52	-	-	121	-	113	88	129
0:53	-	-	121	-	112	88	128
0:54	-	-	122	-	113	87	129
0:55	-	-	122	-	113	87	129
0:56	-	-	123	-	113	86	129
0:57	-	-	123	-	112	86	130
0:58	-	-	124	-	112	86	130
0:59	-	-	124	-	113	86	130
1:00	-	-	125	-	113	85	131
1:01	-	-	125	-	113	86	131
1:02	-	-	125	-	113	85	131
1:03	-	-	126	-	114	85	131
1:04	-	-	126	-	113	85	132
1:05	-	103	127	-	115	84	132
1:06	-	103	127	-	114	84	132
1:07	-	103	128	-	117	84	132
1:08	-	103	128	-	-	84	133
1:09	145	-	128	-	-	-	133
1:10	144	-	-	-	-	-	133
1:11	-	-	-	-	-	-	-
1:12	-	-	-	-	-	-	-
1:13	-	-	-	-	-	-	-
1:14	-	-	-	-	-	-	-
1:15	-	-	-	-	-	-	-
1:16	-	-	-	-	-	-	-
1:17	-	-	-	-	-	-	-
1:18	-	-	-	-	-	-	-
1:19	-	-	-	-	-	-	-

ECO-PAK SPECIALTY PACKAGING
THERMOCOUPLE TEMPERATURES (°F)

DATE: 21 MARCH 1998
FILE: 0803SXT.DAT
08030XC.DAT
08030SC2.DAT

SwRI PROJECT NO: 01-1680-102
TEST TYPE: 10CFR 71.73(C),(4)

TIME (h:mm)	TC 8	TC 9	TC 10	TC 11	TC 12	TC 13	TC 14
1:20	-	-	-	-	-	-	-
1:21	-	-	-	-	-	-	-
1:22	-	-	-	-	-	-	-
1:23	-	104	132	-	133	-	-
1:24	-	104	133	113	133	-	136
1:25	-	104	133	114	133	-	136
1:26	160	105	133	-	134	114	136
1:27	160	105	133	-	134	114	137
1:28	160	105	134	-	134	114	137
1:29	160	105	134	-	135	115	137
1:30	160	105	134	-	135	115	137
1:31	160	106	134	-	135	115	138
1:32	159	106	134	-	135	115	138
1:33	159	106	135	-	135	116	138
1:34	159	106	135	-	136	116	138
1:35	159	107	135	-	136	116	138
1:36	159	107	135	-	136	117	139
1:37	159	107	135	-	136	117	139
1:38	158	108	136	-	137	118	139
1:39	158	108	136	-	137	118	140
1:40	158	109	136	-	138	118	140
1:41	158	109	137	-	138	118	140
1:42	157	109	137	-	138	119	140
1:43	157	110	137	-	138	119	140
1:44	157	110	137	-	138	119	140
1:45	157	110	137	-	138	119	141
1:46	157	110	137	-	138	120	141
1:47	156	111	138	-	139	120	141
1:48	156	111	138	-	139	120	141
1:49	156	111	138	-	139	121	141
1:50	156	111	138	-	139	121	142
1:51	156	112	138	-	139	121	142
1:52	156	112	138	-	139	121	142
1:53	155	112	138	-	140	121	142
1:54	155	112	139	-	140	122	142
1:55	155	112	139	-	140	122	142
1:56	155	112	139	141	140	122	142
1:57	155	113	139	141	140	122	142
1:58	154	113	139	141	140	122	143
1:59	154	113	139	141	141	122	143

ECO-PAK SPECIALTY PACKAGING
THERMOCOUPLE TEMPERATURES (°F)

DATE: 21 MARCH 1998
FILE: 0803SXT.DAT
08030XC.DAT
08030SC2.DAT

SwRI PROJECT NO: 01-1680-102
TEST TYPE: 10CFR 71.73(C),(4)

TIME (h:mm)	TC 8	TC 9	TC 10	TC 11	TC 12	TC 13	TC 14
2:00	154	113	139	141	140	123	143
2:01	154	113	139	142	141	123	143
2:02	154	113	139	142	141	123	143
2:03	154	114	140	142	141	123	143
2:04	153	114	140	143	141	123	144
2:05	153	114	140	143	141	123	144
2:06	153	114	140	143	141	124	144
2:07	153	114	140	143	141	124	144
2:08	153	114	140	143	141	124	144
2:09	153	115	140	143	141	124	144
2:10	152	115	140	143	142	124	144
2:11	152	115	140	144	142	125	144
2:12	152	115	140	144	142	125	144
2:13	152	115	140	144	142	125	144
2:14	152	115	141	144	142	125	144
2:15	152	116	141	144	142	125	145
2:16	152	117	141	145	142	125	145
2:17	151	117	141	145	142	125	145
2:18	151	117	141	145	142	125	145
2:19	151	117	141	146	142	126	145
2:20	151	117	141	146	143	126	145
2:21	151	117	141	146	143	126	145
2:22	151	117	141	146	143	126	145
2:23	151	117	141	146	143	126	145
2:24	151	117	141	146	143	126	145
2:25	151	117	141	146	143	126	145
2:26	150	117	141	146	143	126	145
2:27	150	117	141	146	143	126	145
2:28	150	117	141	146	143	127	145
2:29	150	117	141	147	143	127	145
2:30	150	117	142	147	143	127	145
2:31	150	117	142	147	143	127	145
2:32	150	118	142	147	143	127	146
2:33	149	118	142	147	143	127	146
2:34	149	118	142	147	143	127	146
2:35	149	118	142	147	143	127	146
2:36	149	118	142	148	143	127	146
2:37	149	119	142	148	143	127	146
2:38	149	119	142	148	143	128	146
2:39	149	119	142	148	143	128	146

ECO-PAK SPECIALTY PACKAGING
THERMOCOUPLE TEMPERATURES (°F)

DATE: 21 MARCH 1998
FILE: 0803SXT.DAT
08030XC.DAT
08030SC2.DAT

SwRI PROJECT NO: 01-1680-102
TEST TYPE: 10CFR 71.73(C),(4)

TIME (h:mm)	TC 8	TC 9	TC 10	TC 11	TC 12	TC 13	TC 14
2:40	149	119	142	148	143	128	146
2:41	149	119	142	148	143	128	146
2:42	148	119	142	148	143	128	146
2:43	148	119	142	149	144	128	146
2:44	148	119	142	149	144	128	146
2:45	148	120	142	149	144	128	146
2:46	148	120	142	149	144	128	146
2:47	148	120	142	149	144	128	147
2:48	148	120	142	149	144	128	147
2:49	148	120	142	149	144	128	147
2:50	148	120	142	150	144	128	147
2:51	148	120	142	150	144	129	147
2:52	147	120	142	150	144	129	147
2:53	147	120	142	150	144	129	147
2:54	147	120	142	150	144	129	147
2:55	147	120	142	150	144	129	147
2:56	147	121	142	150	144	129	147
2:57	147	121	142	150	144	129	147
2:58	147	121	142	151	144	129	147
2:59	147	121	142	151	144	129	147
3:00	147	121	142	151	144	129	147
3:01	146	121	142	151	144	129	147
3:02	146	121	142	151	144	129	147
3:03	146	121	142	151	144	129	147
3:04	146	121	142	151	144	129	147
3:05	146	121	142	151	144	129	147
3:06	146	121	142	151	144	129	147
3:07	146	122	142	151	144	129	147
3:08	146	122	142	152	144	129	147
3:09	146	122	142	152	144	130	147
3:10	146	122	142	152	144	130	148
3:11	145	122	142	152	144	130	148
3:12	145	122	142	152	144	130	148
3:13	145	122	142	152	144	130	148
3:14	145	122	142	152	144	130	148
3:15	145	122	142	152	144	130	148
3:16	145	122	142	152	144	130	148
3:17	145	122	142	152	144	130	148
3:18	145	122	142	152	144	130	148
3:19	145	122	142	152	144	130	148

ECO-PAK SPECIALTY PACKAGING
THERMOCOUPLE TEMPERATURES (°F)

DATE: 21 MARCH 1998
FILE: 0803SXT.DAT
08030XC.DAT
08030SC2.DAT

SwRI PROJECT NO: 01-1680-102
TEST TYPE: 10CFR 71.73(C),(4)

TIME (h:mm)	TC 8	TC 9	TC 10	TC 11	TC 12	TC 13	TC 14
3:20	145	122	142	153	144	130	148
3:21	145	122	142	153	144	130	148
3:22	144	123	142	153	144	130	148
3:23	144	123	142	153	144	130	148
3:24	144	123	142	153	144	130	148
3:25	144	123	142	153	144	130	148
3:26	144	123	142	153	144	130	148
3:27	144	123	142	153	144	130	148
3:28	144	123	142	153	144	130	148
3:29	144	123	142	153	144	130	148
3:30	144	123	142	153	144	130	148
3:31	144	123	142	153	144	130	148
3:32	144	123	142	153	144	130	148
3:33	144	123	142	153	144	130	148
3:34	144	123	142	153	144	130	148
3:35	143	123	142	153	144	130	148
3:36	143	123	142	154	144	131	148
3:37	143	124	142	154	144	130	148
3:38	143	124	142	154	144	131	148
3:39	143	124	142	154	144	131	148
3:40	143	124	142	154	144	131	148
3:41	143	124	142	154	144	131	148
3:42	143	124	142	154	144	131	148
3:43	143	124	142	154	144	131	148
3:44	143	124	142	154	144	131	148
3:45	142	124	141	154	144	131	148
3:46	142	124	141	154	144	131	148
3:47	142	124	141	154	144	131	148
3:48	142	124	141	154	144	131	148
3:49	142	124	141	154	144	131	148
3:50	142	124	141	154	144	131	148
3:51	142	124	141	154	144	131	148
3:52	142	124	141	154	144	131	148
3:53	142	124	141	154	144	131	148
3:54	142	124	141	154	143	131	148
3:55	142	124	141	154	143	131	148
3:56	142	124	141	154	143	131	148
3:57	141	124	141	154	143	131	148
3:58	141	124	141	154	143	131	148
3:59	141	124	141	154	143	131	148

ECO-PAK SPECIALTY PACKAGING
THERMOCOUPLE TEMPERATURES (°F)

DATE: 21 MARCH 1998
FILE: 0803SXT.DAT
08030XC.DAT
08030SC2.DAT

SwRI PROJECT NO: 01-1680-102
TEST TYPE: 10CFR 71.73(C),(4)

TIME (h:mm)	TC 8	TC 9	TC 10	TC 11	TC 12	TC 13	TC 14
4:00	141	124	141	154	143	131	148
4:01	141	124	141	154	143	131	148
4:02	141	124	141	154	143	131	148
4:03	141	124	141	154	143	131	148
4:04	141	124	141	154	143	131	148
4:05	141	124	141	154	143	131	148
4:06	141	124	141	154	143	131	148
4:07	141	124	141	154	143	131	148
4:08	140	124	141	154	143	131	148
4:09	140	124	141	154	143	131	148
4:10	140	124	140	155	143	131	148
4:11	140	124	140	154	143	131	148
4:12	140	124	140	154	143	131	148
4:13	140	124	140	154	143	131	148
4:14	140	124	140	154	143	131	148
4:15	140	124	140	154	143	131	148
4:16	140	124	140	154	143	131	147
4:17	140	124	140	154	143	131	147
4:18	140	124	140	155	143	131	147
4:19	140	124	140	154	143	131	147
4:20	139	124	140	155	143	131	147
4:21	139	124	140	154	143	131	147
4:22	139	124	140	154	143	131	147
4:23	139	124	140	154	143	131	147
4:24	139	124	140	154	142	131	147
4:25	139	124	140	154	143	131	147
4:26	139	124	140	154	142	131	147
4:27	139	124	140	154	142	131	147
4:28	139	124	140	154	142	131	147
4:29	139	125	140	154	142	131	147
4:30	139	125	139	154	142	131	147
4:31	139	124	139	154	142	131	147
4:32	138	125	139	154	142	131	147
4:33	138	125	139	154	142	131	147
4:34	138	125	139	154	142	131	147
4:35	138	124	139	154	142	131	147
4:36	138	124	139	154	142	131	147
4:37	138	124	139	154	142	131	147
4:38	138	124	139	154	142	131	147
4:39	138	124	139	154	142	131	147

ECO-PAK SPECIALTY PACKAGING
THERMOCOUPLE TEMPERATURES (°F)

DATE: 21 MARCH 1998
FILE: 0803SXT.DAT
08030XC.DAT
08030SC2.DAT

SwRI PROJECT NO: 01-1680-102
TEST TYPE: 10CFR 71.73(C),(4)

TIME (h:mm)	TC 8	TC 9	TC 10	TC 11	TC 12	TC 13	TC 14
4:40	138	124	139	154	142	131	147
4:41	138	125	139	154	142	131	147
4:42	138	125	139	154	142	131	147
4:43	138	125	138	154	142	131	146
4:44	138	125	138	154	142	131	146
4:45	137	125	138	154	142	131	146
4:46	137	124	138	154	142	131	146
4:47	137	125	138	154	141	131	146
4:48	137	124	138	154	141	131	146
4:49	137	124	138	154	141	131	146
4:50	137	124	138	154	141	131	146
4:51	137	124	138	154	141	131	146
4:52	137	124	138	154	141	131	146
4:53	137	124	138	154	141	131	146
4:54	137	124	138	154	141	131	146
4:55	137	124	138	154	141	131	146
4:56	137	124	138	154	141	131	146
4:57	137	124	138	154	141	131	146
4:58	136	124	138	154	141	131	146
4:59	136	124	138	154	141	131	146
5:00	136	124	137	154	141	131	146
5:01	136	124	138	154	141	131	146
5:02	136	124	137	154	141	131	146
5:03	136	124	137	154	141	131	146
5:04	136	124	137	154	141	131	146
5:05	136	125	137	154	141	131	145
5:06	136	125	137	154	141	130	145
5:07	136	125	137	154	141	130	145
5:08	136	124	137	153	141	130	145
5:09	136	124	137	153	140	130	145
5:10	136	124	137	153	140	130	145
5:11	136	125	137	153	140	130	145
5:12	135	124	137	153	140	130	145
5:13	135	124	137	153	140	130	145
5:14	135	125	137	153	140	130	145
5:15	135	124	137	153	140	130	145
5:16	135	124	137	153	140	130	145
5:17	135	124	137	153	140	130	145
5:18	135	124	137	153	140	130	145
5:19	135	124	137	153	140	130	145

ECO-PAK SPECIALTY PACKAGING
THERMOCOUPLE TEMPERATURES (°F)

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FILE: 0803SXT.DAT
08030XC.DAT
08030SC2.DAT

SwRI PROJECT NO: 01-1680-102
TEST TYPE: 10CFR 71.73(C),(4)

TIME (h:mm)	TC 8	TC 9	TC 10	TC 11	TC 12	TC 13	TC 14
5:20	135	124	136	153	140	130	145
5:21	135	124	136	153	140	130	145
5:22	135	124	136	153	140	130	145
5:23	135	124	136	153	140	130	145
5:24	135	125	136	153	140	130	145
5:25	135	125	136	153	140	130	145
5:26	134	124	136	153	140	130	144
5:27	134	124	136	153	140	130	144
5:28	134	124	136	153	139	130	144
5:29	134	124	136	153	139	130	144
5:30	134	124	136	153	139	130	144
5:31	134	124	136	153	139	130	144
5:32	134	124	136	153	139	130	144
5:33	134	124	136	153	139	130	144
5:34	134	124	136	153	139	130	144
5:35	134	124	136	153	139	130	144
5:36	134	124	136	153	139	130	144
5:37	134	124	136	153	139	130	144
5:38	134	124	136	152	139	130	144
5:39	134	124	136	152	139	130	144
5:40	133	124	136	152	139	130	144
5:41	133	124	136	152	139	130	144
5:42	133	124	136	152	139	130	144
5:43	133	124	136	152	139	130	143
5:44	133	124	136	152	139	130	143
5:45	133	124	135	152	139	130	143
5:46	133	124	135	152	139	130	143
5:47	133	124	135	152	139	130	143
5:48	133	124	135	152	138	130	143
5:49	133	124	135	152	138	130	143
5:50	133	124	135	152	138	129	143
5:51	133	124	135	152	138	129	143
5:52	133	124	135	152	138	129	143
5:53	133	124	135	152	138	129	143
5:54	133	124	135	152	138	129	143
5:55	132	124	135	152	138	129	143
5:56	132	124	135	152	138	129	143
5:57	132	124	135	152	138	129	143
5:58	132	124	135	151	138	129	143
5:59	132	124	135	151	138	129	143

ECO-PAK SPECIALTY PACKAGING
THERMOCOUPLE TEMPERATURES (°F)

DATE: 21 MARCH 1998
FILE: 0803SXT.DAT
08030XC.DAT
08030SC2.DAT

SwRI PROJECT NO: 01-1680-102
TEST TYPE: 10CFR 71.73(C),(4)

TIME (h:mm)	TC 8	TC 9	TC 10	TC 11	TC 12	TC 13	TC 14
6:00	132	124	135	151	138	129	143
6:01	132	124	135	151	138	129	142
6:02	132	124	135	151	138	129	142
6:03	132	124	135	151	138	129	142
6:04	132	124	135	151	137	129	142
6:05	132	124	135	151	138	129	142
6:06	132	124	135	151	137	129	142
6:07	132	124	135	151	137	129	142
6:08	132	124	135	151	137	129	142
6:09	132	124	135	151	137	129	142
6:10	132	124	135	151	137	129	142
6:11	131	124	134	151	137	129	142
6:12	131	124	135	151	137	129	142
6:13	131	124	134	151	137	129	142
6:14	131	124	134	151	137	129	142
6:15	131	124	134	151	137	129	142
6:16	131	124	134	151	137	129	142
6:17	131	124	134	150	137	129	142
6:18	131	124	134	150	137	129	142
6:19	131	124	134	150	137	129	141
6:20	131	124	134	150	137	129	141
6:21	131	124	134	150	137	129	141
6:22	131	124	134	150	136	129	141
6:23	131	124	134	150	136	128	141
6:24	131	124	134	150	136	128	141
6:25	131	124	134	150	136	128	141
6:26	131	124	134	150	136	128	141
6:27	130	124	134	150	136	128	141
6:28	130	124	134	150	136	128	141
6:29	130	124	134	150	136	128	– 141
6:30	130	124	134	150	136	128	141
6:31	130	124	134	150	136	128	141
6:32	130	124	134	150	136	128	141
6:33	130	124	133	150	136	128	141
6:34	130	124	133	150	136	128	141
6:35	130	124	133	150	136	128	140
6:36	130	124	133	149	136	128	140
6:37	130	124	133	149	136	128	140
6:38	130	123	133	149	136	128	140
6:39	130	123	133	149	136	128	140

ECO-PAK SPECIALTY PACKAGING
THERMOCOUPLE TEMPERATURES (°F)

DATE: 21 MARCH 1998
FILE: 0803SXT.DAT
08030XC.DAT
08030SC2.DAT

SwRI PROJECT NO: 01-1680-102
TEST TYPE: 10CFR 71.73(C),(4)

TIME (h:mm)	TC 8	TC 9	TC 10	TC 11	TC 12	TC 13	TC 14
6:40	130	123	133	149	136	128	140
6:41	130	123	133	149	136	128	140
6:42	130	123	133	149	135	128	140
6:43	129	123	133	149	135	128	140
6:44	129	123	133	149	135	128	140
6:45	129	123	133	149	135	128	140
6:46	129	123	133	149	135	128	140
6:47	129	123	133	149	135	128	140
6:48	129	123	133	149	135	128	140
6:49	129	123	133	149	135	128	140
6:50	129	123	133	149	135	128	140
6:51	129	123	133	149	135	128	140
6:52	129	123	133	148	135	128	140
6:53	129	123	133	148	135	128	139
6:54	129	123	133	148	135	128	139
6:55	129	123	132	148	135	127	139
6:56	129	123	132	148	135	127	139
6:57	129	123	132	148	135	127	139
6:58	129	123	132	148	135	127	139
6:59	129	123	132	148	134	127	139
7:00	129	123	132	148	134	127	139
7:01	128	123	132	148	134	127	139
7:02	128	123	132	148	134	127	139
7:03	128	123	132	148	134	127	139
7:04	128	123	132	148	134	127	139
7:05	128	123	132	148	134	127	139
7:06	128	123	132	148	134	127	139
7:07	128	123	132	148	134	127	139
7:08	128	123	132	148	134	127	139
7:09	128	123	132	148	134	127	138
7:10	128	123	132	147	134	127	138
7:11	128	123	132	147	134	127	138
7:12	128	123	132	147	134	127	138
7:13	128	123	132	147	134	127	138
7:14	128	123	132	147	134	127	138
7:15	128	123	132	147	134	127	138
7:16	128	123	131	147	134	127	138
7:17	128	123	131	147	134	127	138
7:18	127	123	131	147	133	127	138
7:19	127	123	131	147	133	127	138

ECO-PAK SPECIALTY PACKAGING
THERMOCOUPLE TEMPERATURES (°F)

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FILE: 0803SXT.DAT
08030XC.DAT
08030SC2.DAT

SwRI PROJECT NO: 01-1680-102
TEST TYPE: 10CFR 71.73(C),(4)

TIME (h:mm)	TC 8	TC 9	TC 10	TC 11	TC 12	TC 13	TC 14
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7:21	127	123	131	147	133	127	138
7:22	127	123	131	147	133	127	138
7:23	127	123	131	147	133	127	138
7:24	127	123	131	147	133	127	138
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ECO-PAK SPECIALTY PACKAGING
THERMOCOUPLE TEMPERATURES (°F)

DATE: 21 MARCH 1998
FILE: 0803SXT.DAT
08030XC.DAT
08030SC2.DAT

SwRI PROJECT NO: 01-1680-102
TEST TYPE: 10CFR 71.73(C),(4)

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ECO-PAK SPECIALTY PACKAGING
THERMOCOUPLE TEMPERATURES (°F)

DATE: 21 MARCH 1998
FILE: 0803SXT.DAT
08030XC.DAT
08030SC2.DAT

SwRI PROJECT NO: 01-1680-102
TEST TYPE: 10CFR 71.73(C),(4)

TIME (h:mm)	TC 8	TC 9	TC 10	TC 11	TC 12	TC 13	TC 14
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8:41	123	121	127	142	129	124	133
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ECO-PAK SPECIALTY PACKAGING
THERMOCOUPLE TEMPERATURES (°F)

DATE: 21 MARCH 1998
FILE: 0803SXT.DAT
08030XC.DAT
08030SC2.DAT

SwRI PROJECT NO: 01-1680-102
TEST TYPE: 10CFR 71.73(C),(4)

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ECO-PAK SPECIALTY PACKAGING
THERMOCOUPLE TEMPERATURES (°F)

DATE: 21 MARCH 1998
FILE: 0803SXT.DAT
08030XC.DAT
08030SC2.DAT

SwRI PROJECT NO: 01-1680-102
TEST TYPE: 10CFR 71.73(C),(4)

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ECO-PAK SPECIALTY PACKAGING
THERMOCOUPLE TEMPERATURES (°F)

DATE: 21 MARCH 1998
FILE: 0803SXT.DAT
08030XC.DAT
08030SC2.DAT

SwRI PROJECT NO: 01-1680-102
TEST TYPE: 10CFR 71.73(C),(4)

TIME (h:mm)	TC 8	TC 9	TC 10	TC 11	TC 12	TC 13	TC 14
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10:42	118	119	122	136	123	119	127
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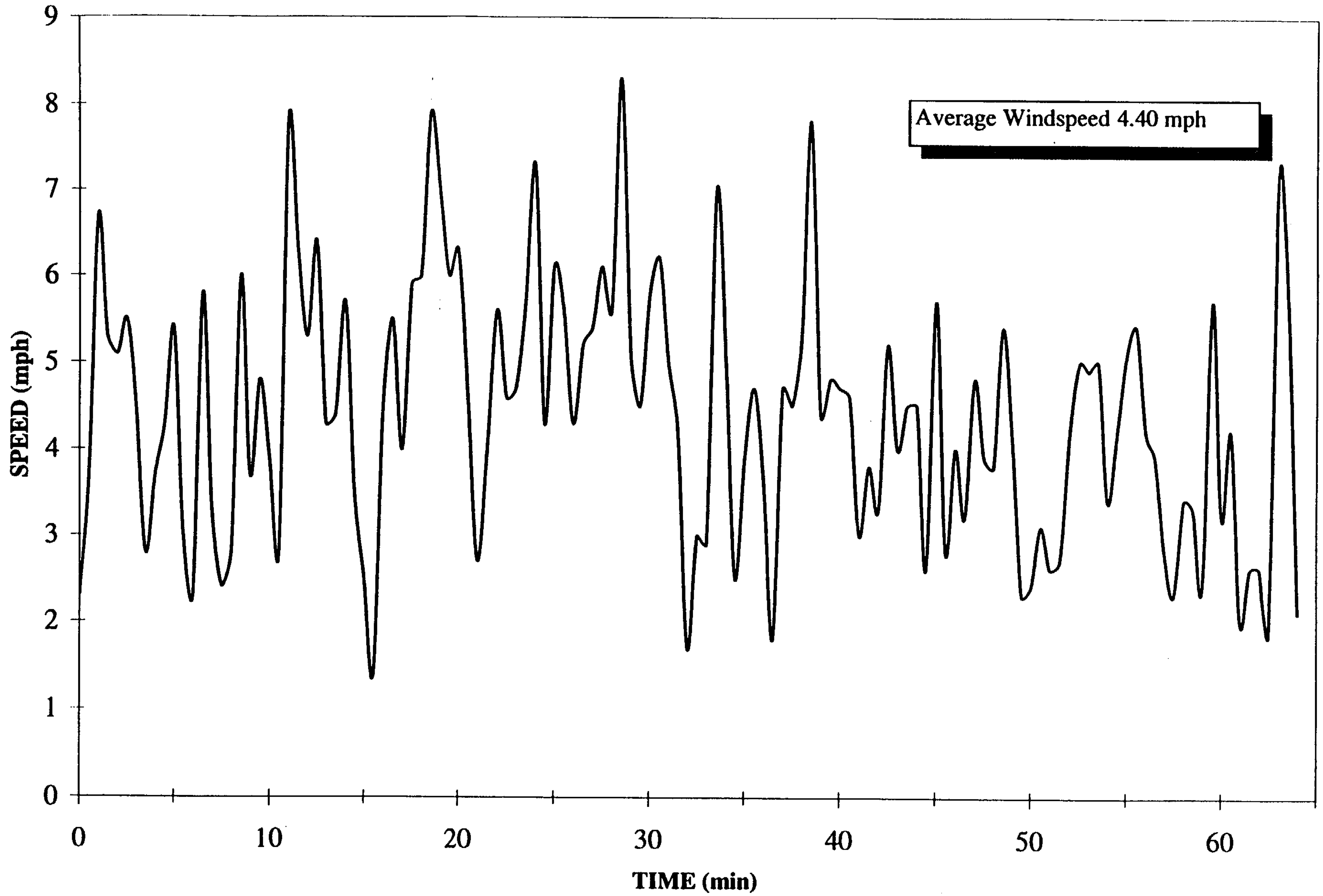
CLI : ECO-PAK SPECIALTY PACKAGING
SwRI PROJECT No.: 01-1680-102
DATE: 21 MARCH 1998
FILE ID: 08030SXT.DAT

TEST WINDSPEED DATA
ESP-30X



CLIENT: ECO-PAK SPECIALTY PACKAGING
SwRI PROJECT No.: 01-1680-102
DATE: 21 MARCH 1998
FILE ID: 08030SW1.DAT

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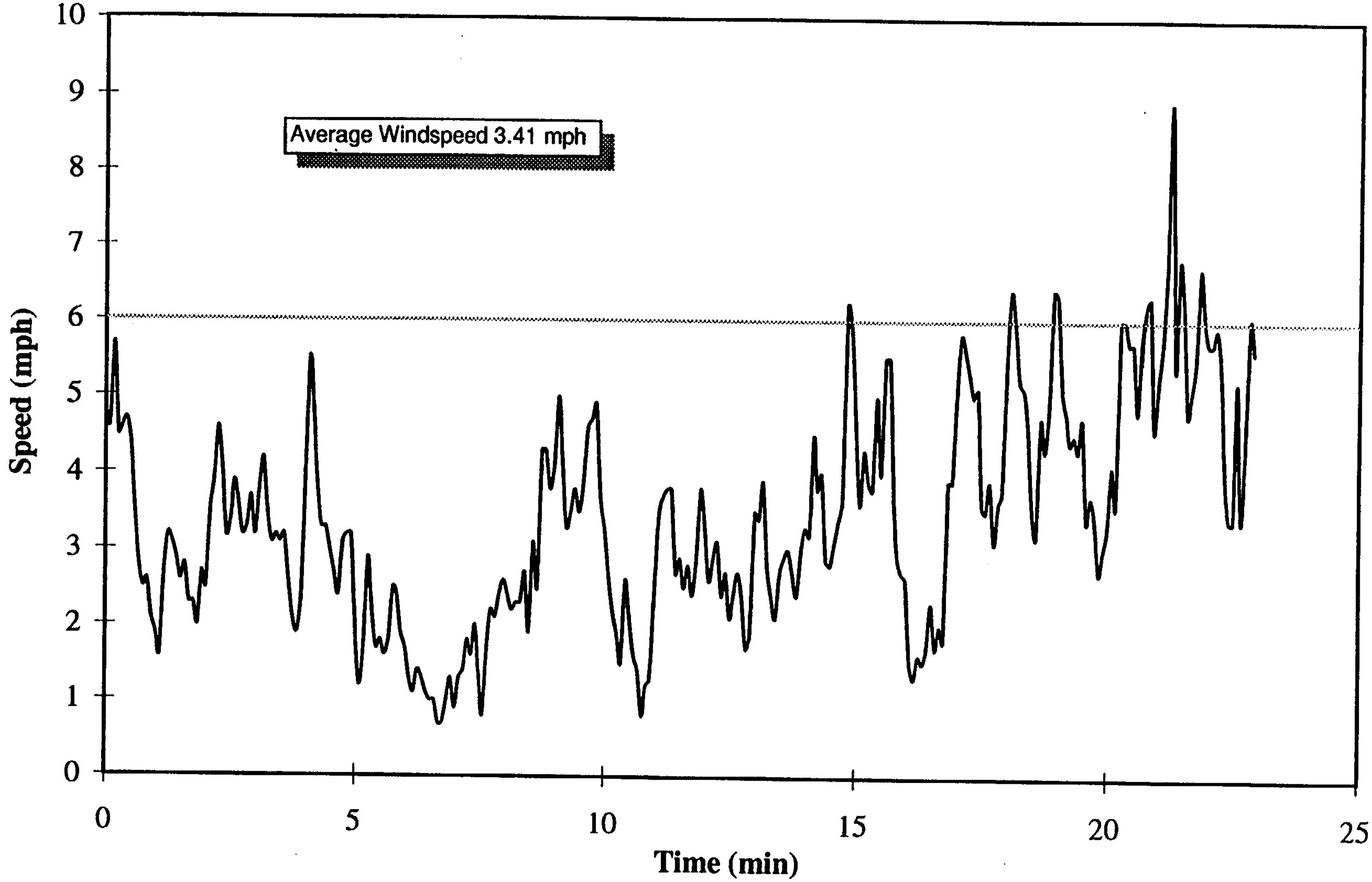
ESP-30X



CLI : ECO-PAK SPECIALTY PACKAGING
SwRI PROJECT No.: 01-1680-102
DATE: 21 MARCH 1998
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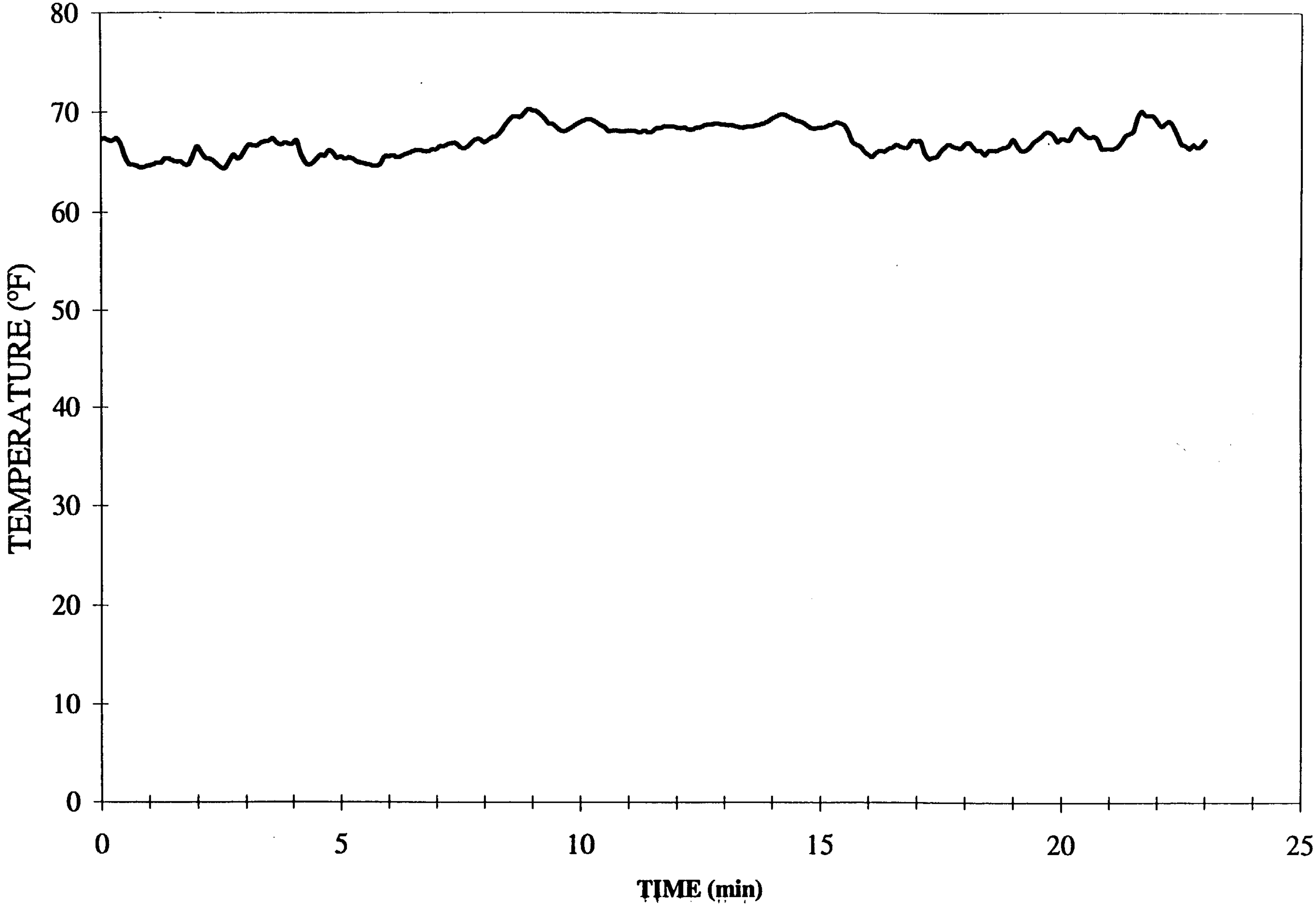
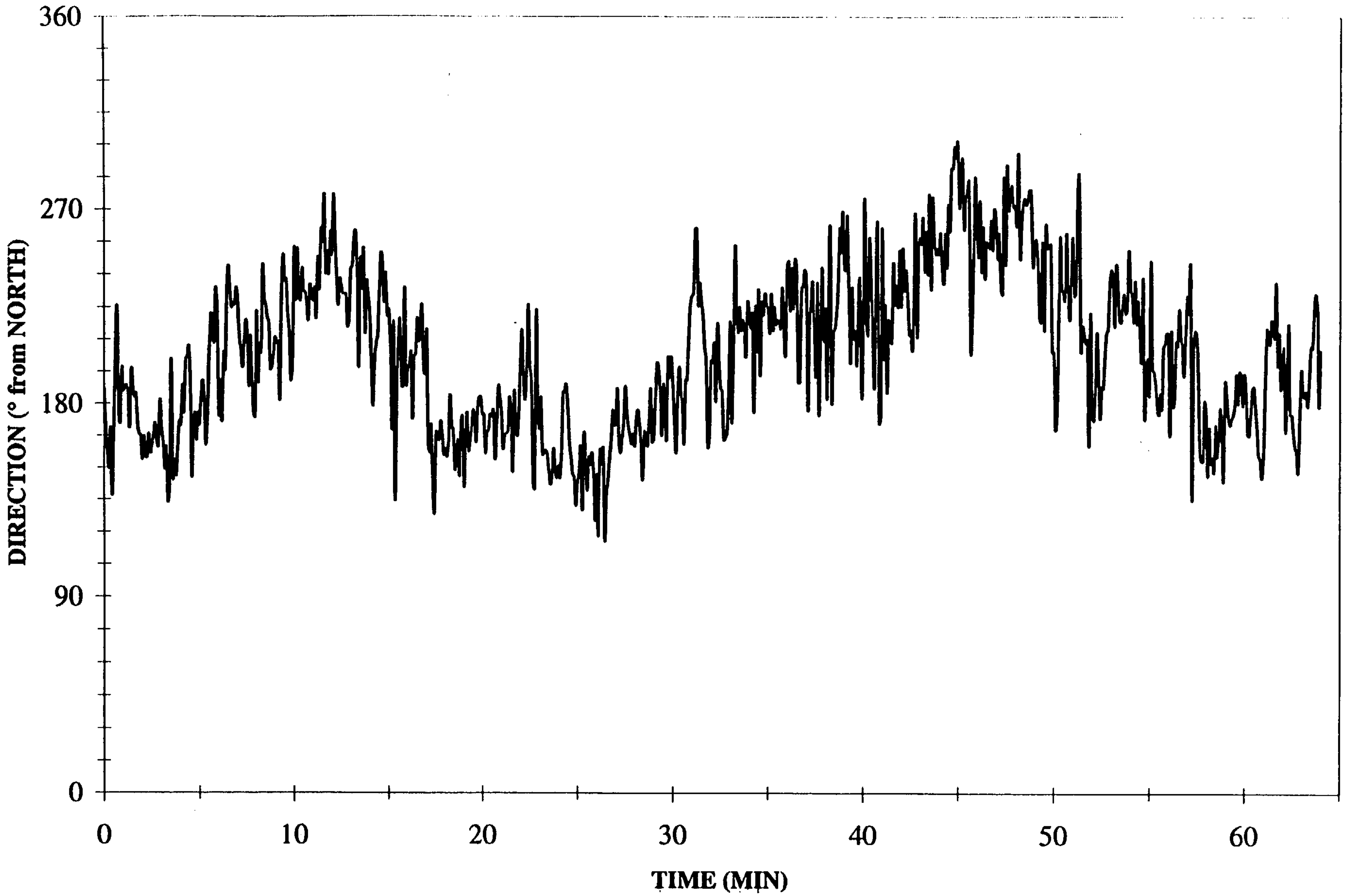
PRE-TEST AMBIENT TEMPERATURE
ESP-30X



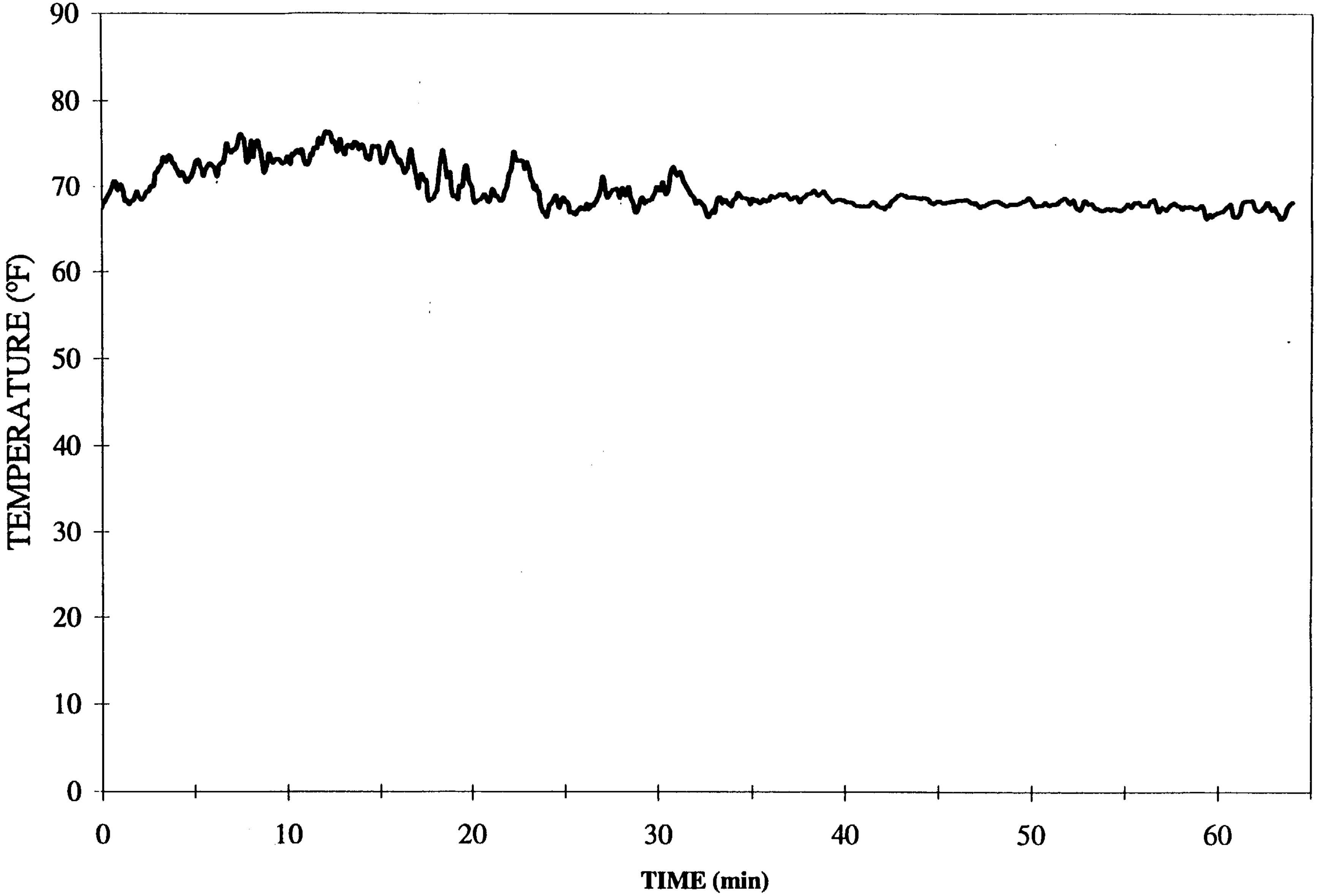
CLI : ECO-PAK SPECIALTY PACKAGING
SwRI PROJECT No.: 01-1680-102
DATE: 21 MARCH 1998
FILE ID: 08030SXT.DAT

WIND DIRECTION
ESP-30X



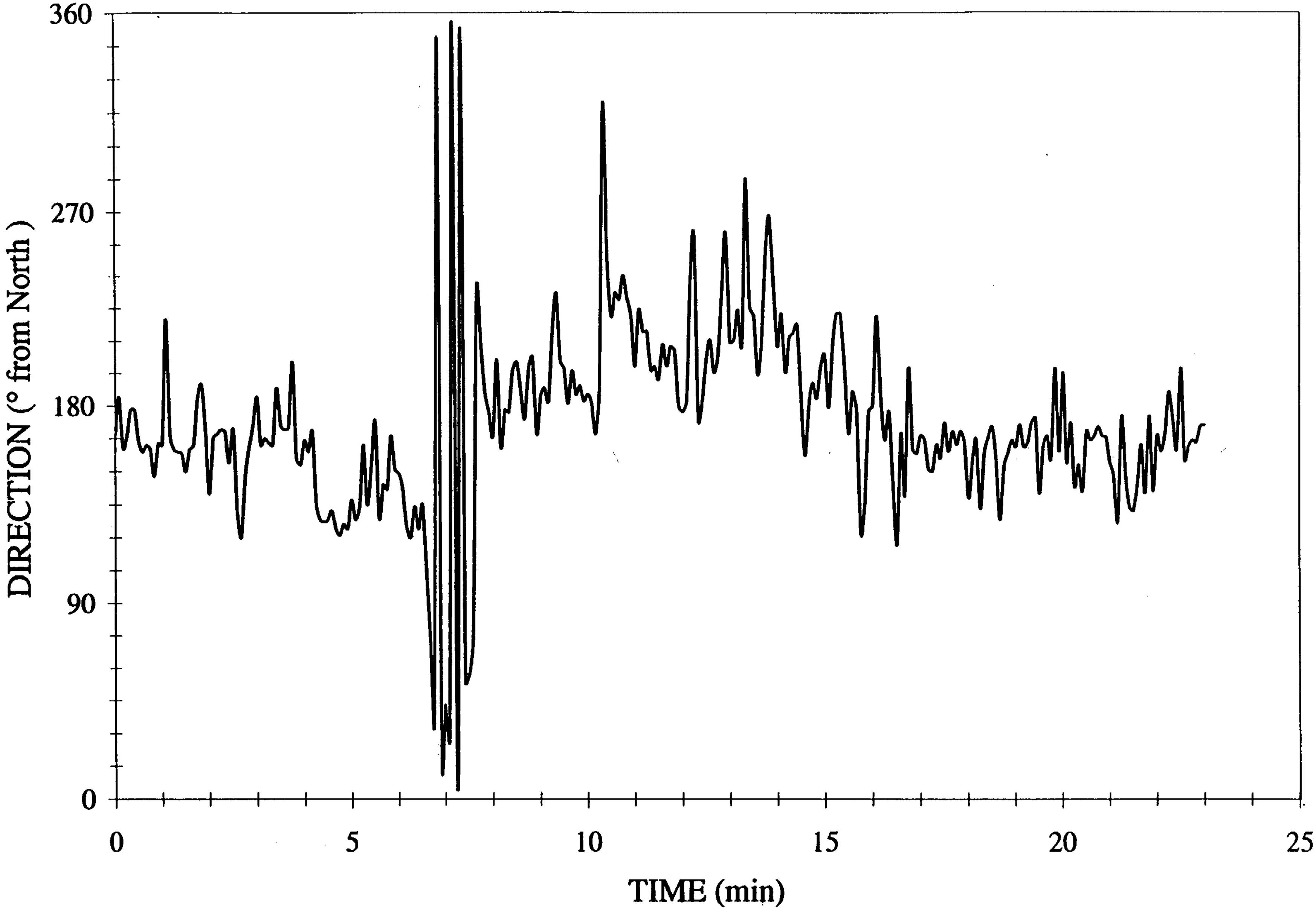
CLI : ECO-PAK SPECIALTY PACKAGING
SwRI PROJECT No.: 01-1680-102
DATE: 21 MARCH 1998
FILE ID: 08030SXT.DAT

AMBIENT TEMPERATURE
ESP-30X

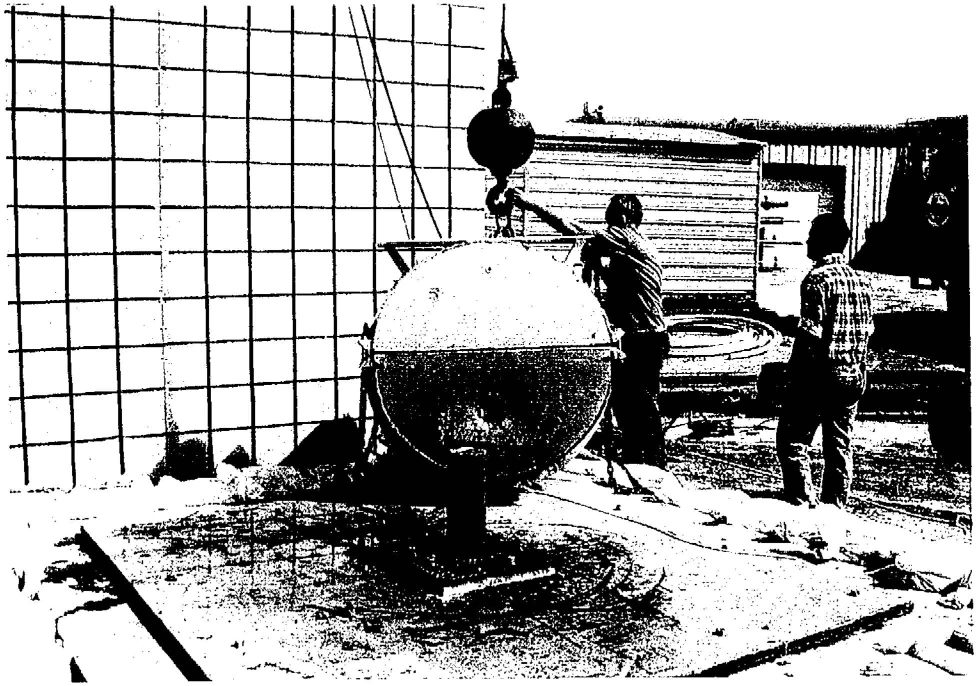


CLI : ECO-PAK SPECIALTY PACKAGING
SwRI PROJECT No.: 01-1680-102
DATE: 21 MARCH 1998
FILE ID: 08030SXT.DAT

PRE-TEST WIND DIRECTION
ESP-30X



APPENDIX F
FIRE TEST PHOTOGRAPHIC DOCUMENTATION
(Consisting of 6 Pages)



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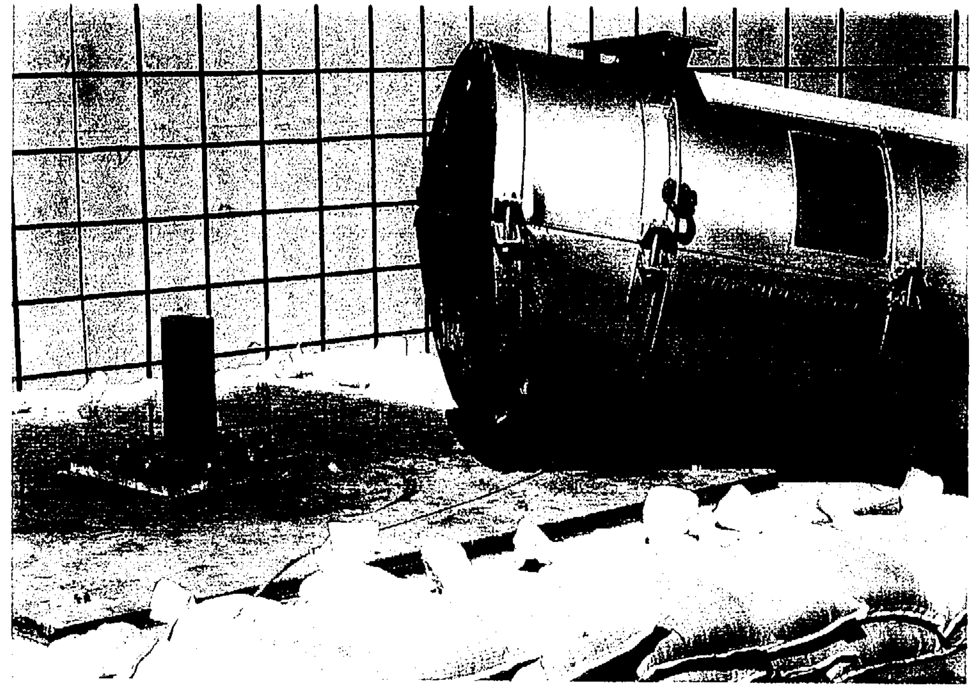


b

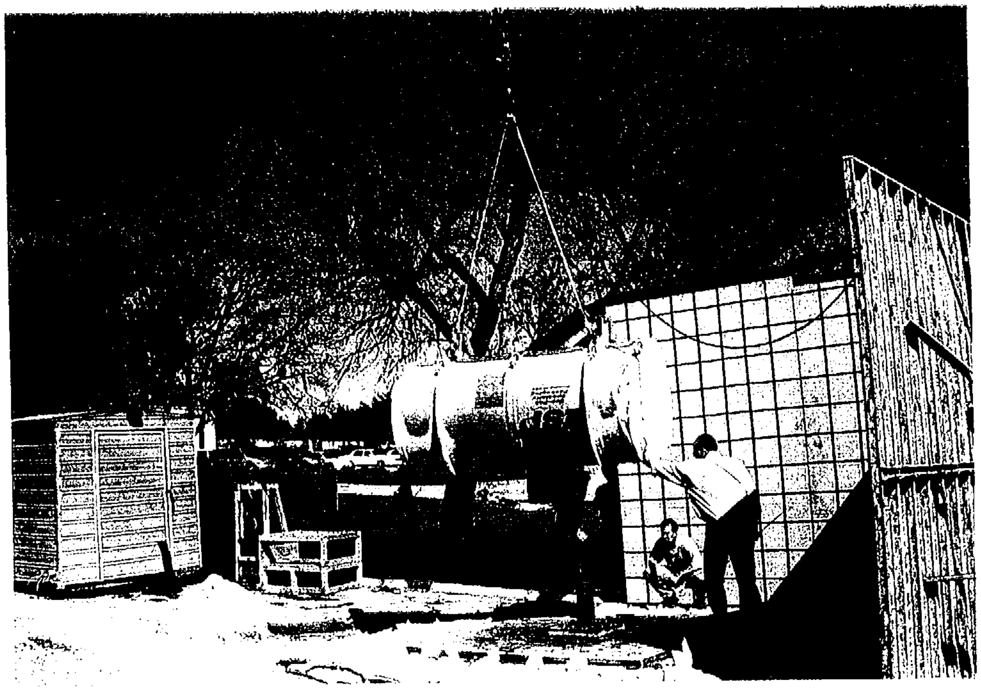
c

FIGURE 8 - PUNCTURE DROP AT 13.5° FROM VERTICAL ONTO VALVE

a: Test Item Following Drop

b: Side View Following Drop

c: Puncture Location



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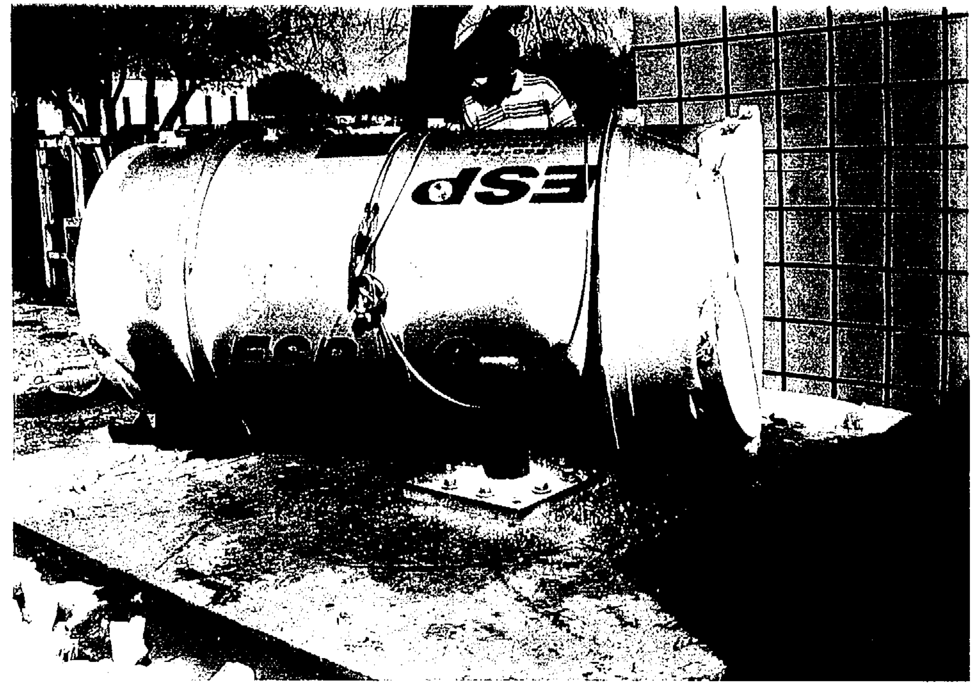


b

c

FIGURE 9 - PUNCTURE DROP ONTO SKIN

a: Drop Orientation

b: Test Item Orientation Following Drop

c: Damage at Impact Location

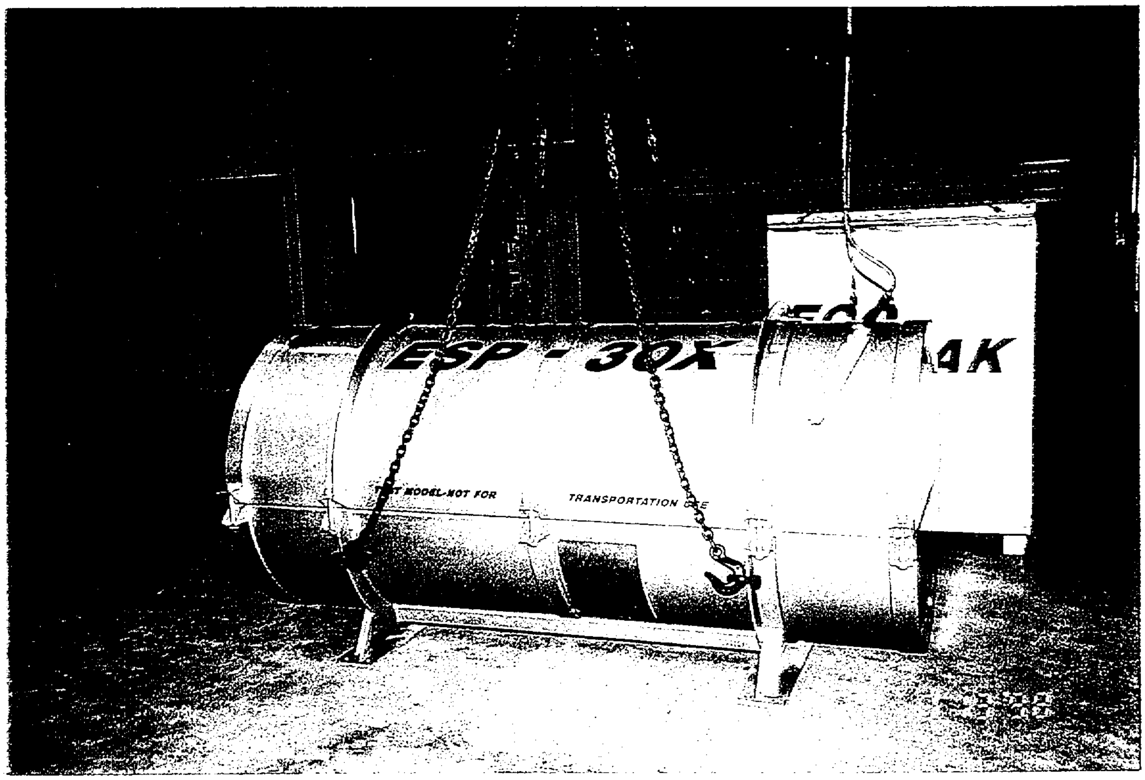


Figure F-1. ESP-30X Package Following Receipt Inspection.

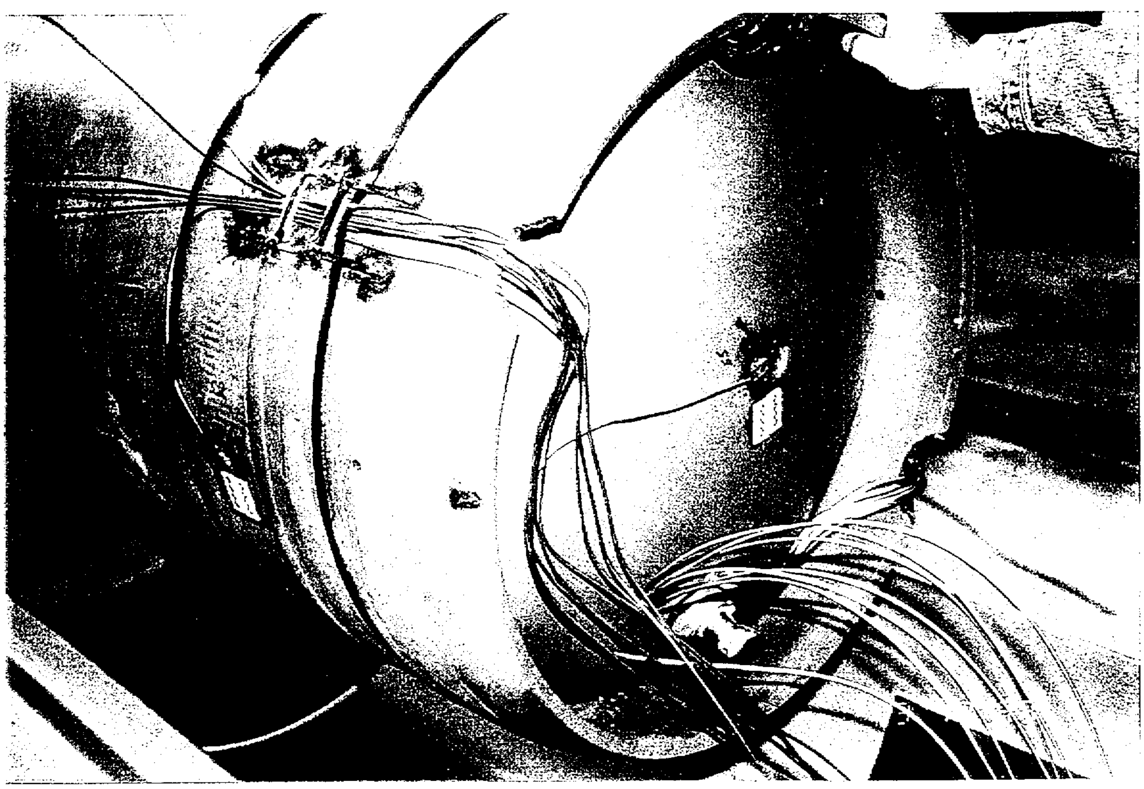


Figure F-2. Instrumentation of 30B Cylinder. Note Inconel-Sheathed Thermocouples and Thermal Sensitive Tape.

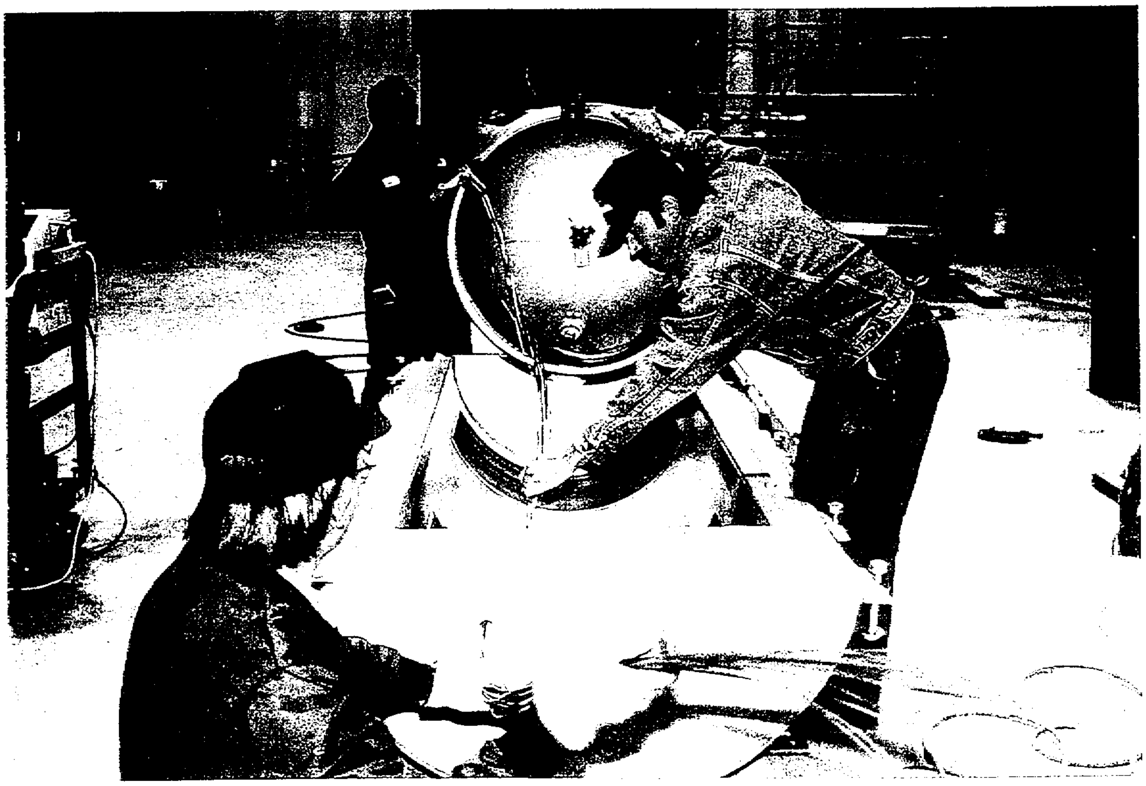


Figure F-3. Thermocouples Routed Through Overpack End Opposite Valve End.

Figure F-4. Close-Up View of TC's Being Routed Through Overpack.

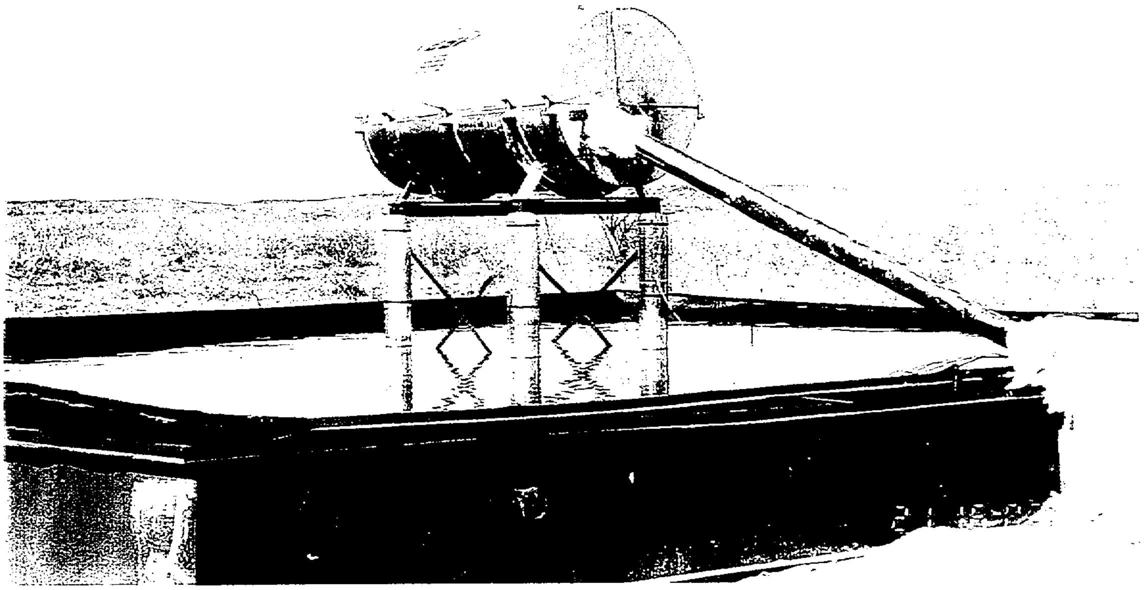


Figure F-5. ESP-30X Package Prior to Pool Fire Test.

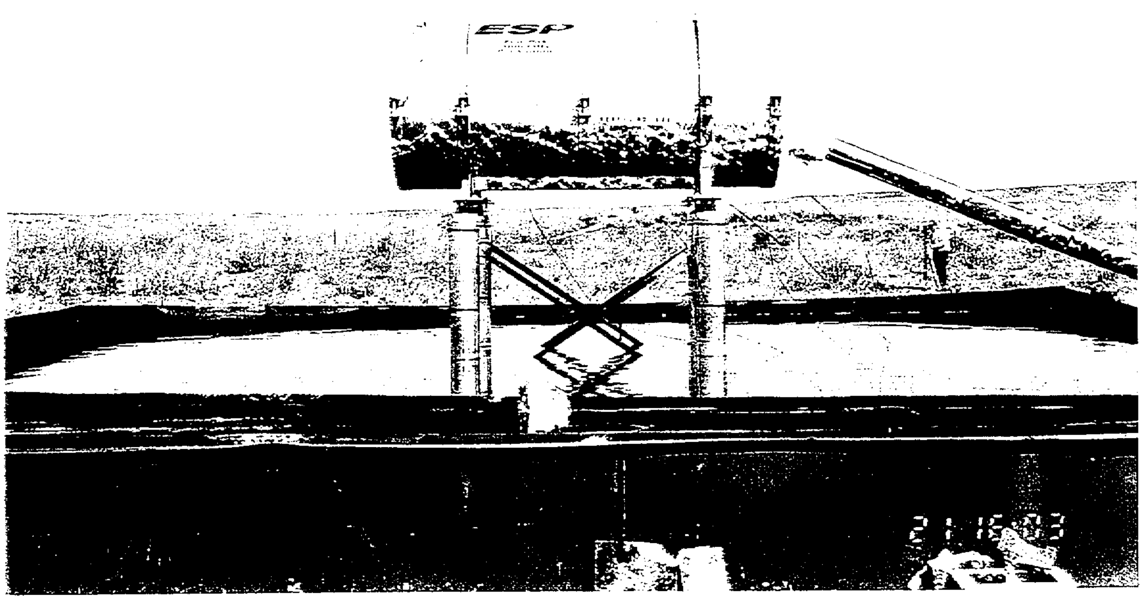


Figure F-6. ESP-30X Package Prior to Pool Fire Test.

Figure F-7. ESP-30X Package During 30-Min Pool Fire Test.

Figure F-8. ESP-30X Package During 30-Min Pool Fire Test. Note Flame Jets on Overpack at Instrumentation Cooling Jacket.

Figure F-9. ESP-30X Package During 30-Min Pool Fire Test. Note Smoke at Instrumentation Junction Box.

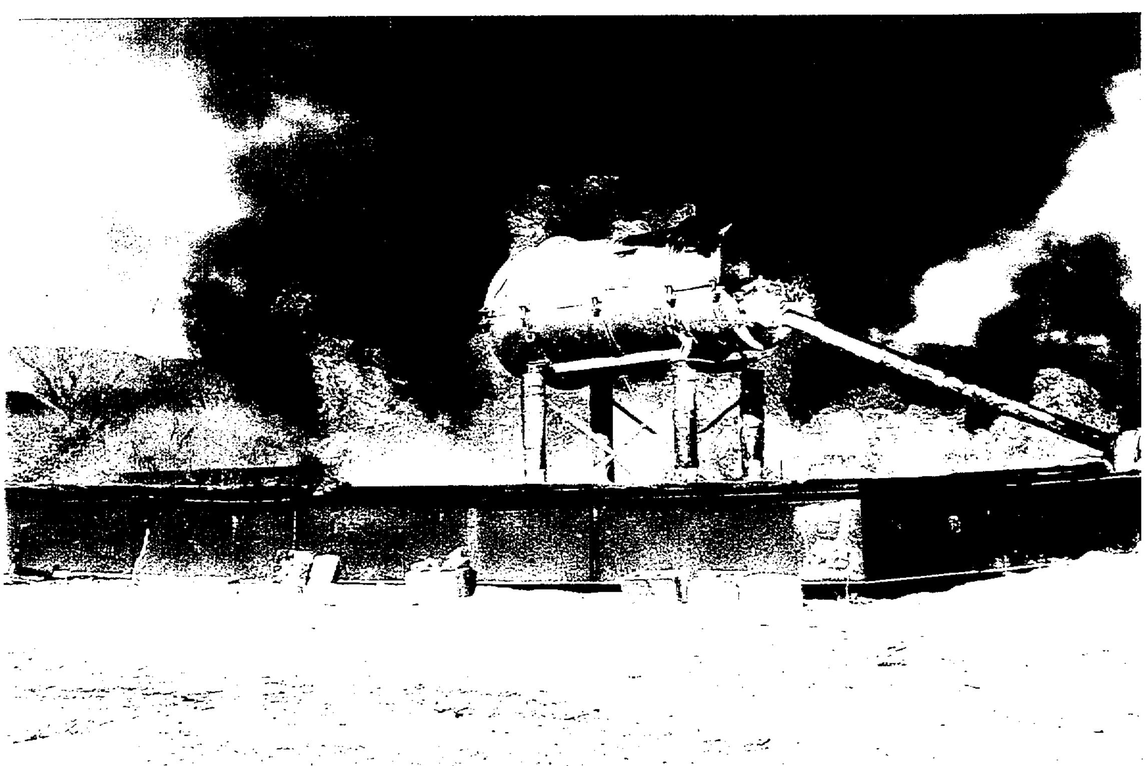


Figure F-10. ESP-30X Following 30-Min Pool Fire Exposure.

SECTION THREE THERMAL EVALUATION

TABLE OF CONTENTS

LIST OF FIGURES

3. *THERMAL EVALUATION*

3.1 Discussion

The ESP-30X is designed to maintain the temperatures and pressures of the 30B cylinder within specified limits during normal transportation and hypothetical accident conditions. This section presents an evaluation of the thermal performance of the packaging. The thermal tests and analyses performed for this evaluation are designed to:

- Determine the package's thermal limits;
- Determine the maximum and minimum temperatures of the uranium hexafluoride within a loaded 30B cylinder; and
- Determine the maximum and minimum pressures of the uranium hexafluoride within a loaded 30B cylinder.

3.1.1 Thermal Source- Specification

The decay heat generated by 5020 lb. of uranium hexafluoride (enriched 5% or less) is less than 3W and is therefore considered insignificant in the thermal evaluation of the overpack.

3.1.2 Thermal Acceptance Criteria

Thermal design criteria are associated with maintaining containment of the 30B cylinder during normal conditions of transport and the hypothetical accident conditions. In general, the thermal design criteria are limits on the temperature of the uranium hexafluoride within the 30B cylinder and the function of the overpack is to limit the temperature variations of the UF_6 in the 30B cylinder to the range specified below.

3.1.2.1 Minimum Temperature Limit

The 30B cylinder is manufactured in accordance with ANSI N14.1 (**Reference 3.7.1**). ANSI N14.1 lists the design temperature range for the 30B cylinder as -20°F to 250°F, with a minimum transport temperature of -40°F (6.10.1 Design Conditions). All 30B cylinders are fabricated in accordance with Section VIII, Division 1, of the ANSI/ASME Code, are ASME Code stamped, and certified in writing by the manufacturer to comply with ANSI N14.1. Therefore, the minimum temperature limit for the 30B cylinder is -40°F.

3.1.2.2 Maximum Pressure Limit

Section 6.10.4 (Testing) of ANSI N14.1 states that the cylinder shall be hydrostatically tested to 400 psig. Following the cleaning operation and valve installation, an air test at 100 psig shall be

carried out, and all connections and fittings (including the valve seat and packing) shall be leak tested using Carbona soapless lather or an approved equivalent. No leakage shall be permitted. When the cylinder is purchased without valves, this test shall be carried out by the purchaser. Therefore, the maximum pressure limit is conservatively taken to be 100 psig » 115 psia.

The 30B cylinder is filled (up to the maximum amount allowed by ANSI N14.1) with UF_6. Tight controls are followed to ensure that the cylinder contains only uranium hexafluoride. The vapor pressure of UF_6 at 250°F is 100 psia (**Ref. 3.7.2, Figure 3, UF_6 Phase Diagram**), so the maximum pressure limit of 115 psia is approximately equivalent to a temperature limit of 250°F.

3.1.2.3 Maximum Temperature Limit

The maximum temperature limit of UF_6 is that at which rupture of the 30B cylinder due to the increase of UF_6 volume at elevated temperatures would occur. In order to establish this limit, some background information on the manner in which the fill limit for the 30B cylinder was determined is presented below.

Cylinder volumes are authenticated by measuring the weight of water at 60°F which fills the cylinder. The water weight is required to be accurate to ±O.1% (**Ref. 3.7. 1, Section 6.10.9 Certification**). This weight, when divided by 62.37 lb/ft^3 (the density of water at 60°F) defines the actual volume of the cylinder. That volume shall not be less than the minimum of 26 ft^3, (**Ref. 3.7.1, Section 6.10**). This ensures that every 30B cylinder has more capacity than the minimum, so that fill calculations based on the certified minimum are conservative.

UF_6 exhibits significant expansion when undergoing the phase change from solid to liquid. The coefficient of expansion for UF_6 in the liquid phase is also unusually high. The expansion factor from a solid at 68°F to a liquid at 250°F is approximately 1.56, a 56 % increase in volume (**Reference 3.7.2**).

The safe fill limit is calculated such that the volume of UF_6 at 250°F, plus a 5% allowance for ullage, is less than the certified minimum volume of the 30B cylinder:

Density of UF_6 at 250°F:	203.3 lb/ft^3	**(Ref. 3.7.2)**
Certified Minimum 30B cylinder volume:	26 ft^3	**(Ref. 3.7.1)**
Allowance for ullage:	5 %	
Usable volume:	0.95 x 26 ft^3 = 24.7 ft^3	
Safe fill limit:	203.3 lb/ft^3 x 24.7 ft^3 = 5022 lb.	

The weight is rounded down to a published value of 5020 lb. (**Ref. 3.7.2, Appendix. UF_6 Cylinder Data Summary**).
Based on the design temperature range of the 30B cylinder of -20°F to 250°F (**Ref. 3.7.1, Section 6.10.1 Design Conditions**), and the safe fill limit of the cylinder, the maximum temperature

criteria for the 30B cylinder under hypothetical accident condition is 250°F. This temperature limit is the same as that derived in **Section 3.1.2.2**.

There are several conservative assumptions inherent to these maximum pressure and temperature criteria, significantly the assumption that the 30B cylinder will rupture hydraulically at 250°F when the volume of the UF_6 is equal to 95% of the volume of the cylinder. But realistically hydraulic rupture would be delayed until the pressure of the UF_6 reaches the rupture pressure of the cylinder at temperature. Other analysis **(Reference 3.7.3, "Investigation of UF_6 Behavior in a Fire", pg. 17-24)** has concluded that the 30B cylinder would fail at an internal pressure of 800 psia and a final UF_6 temperature of 367°F.

UF_6 cylinder contents are liquefied at up to 225°F -235°F at UF_6 facilities to attain required flow rates during cylinder unloading (**Ref. 3.7.3, "Maximum Cylinder Fill Limit Evaluation", p. 116**). The maximum temperature criteria under hypothetical accident conditions is therefore only 15°F greater than the temperature the cylinders routinely reach during unloading, another indication of the intrinsic conservatism that a maximum temperature limit of 250°F represents.

3.1.2.4 Thermal Acceptance Criteria Summary

Minimum Temperature Limit:	-40°F
Maximum Pressure Limit:	115 psia
Maximum Temperature Limit:	250°F

3.2 *Summary of Thermal Properties of Materials*

The thermal properties of materials used in the thermal analyses are listed below. The values are listed as given in the corresponding references.

a. Uranium hexafluoride (**Ref. 3.7.2** and **Ref. 3.7.3, p.3**)
Used for: contents of 30B cylinder under normal transport and hypothetical accident conditions calculations.

Temperature (°F)	**Phase**	**Specific Heat** Btu/lbm-°F	**Heat of Fusion** Btu/lbm
<147	solid	0.114	
147	melting		23.5
>147	liquid	0.130	

b. Steel Shot - Plain carbon steel (**Ref. 3.7.4, Table TDC, p. 650** and **Table F-2, p. 670**)
Used for: contents of 30B cylinder during fire test evaluation.

Temperature (F°)	Specific Heat Btu/lbm-°F
70	0.105
100	0.107
150	0.110
200	0.114
250	0.117
300	0.119

c. Phenolic Foam (**Appendix 2.10.2**)
Used for: foam in overpack during normal conditions of transport calculations.

Conductivity: 0.017 Btu/hr-ft-°F < k < 0.027 Btu/hr-ft-°F.
Analysis used: k = 0.10 Btu/hr-ft-°F.

d. Overpack Surface (**Ref. 3.7.5, Table 5-2, Emittance of Various Surfaces**)
Used for: solar absorptivity and emissivity of typical weathered surfaces during normal conditions of transport calculation.

Analysis used: emissivity = absorptivity = 0.85

3.3 Technical Specifications of Components

There are no additional thermal technical specifications for any of the overpack components.

3.4 Thermal Evaluation for Normal Conditions of Transport

3.4.1 Conditions Evaluated

The ESP-30X is designed to meet the standards specified in 10CFR71, Subpart E when subjected to the Normal Conditions of Transport as specified in 10CFR71.71. Three different conditions are evaluated. The relevant thermal conditions are:

(1) **Heat.** An ambient temperature of 100°F in still air and insolation according to the following table:

Form & location of surface	Total insolation for a 12-hour period (g cal/cm^2)
Flat surfaces transported horizontally: Base	None
Flat surfaces transported horizontally: Other surfaces	800
Flat surfaces not transported horizontally	200
Curved surfaces	400

(2) **Cold.** An ambient temperature of -40°F in still air and shade.

(3) A package must be designed and constructed, and prepared for transport so that in still air at 100°F and in the shade, no accessible surface of a package would have a temperature exceeding 122°F in a nonexclusive use shipment, or 185°F in an exclusive use shipment.

3.4.2 Acceptance Criteria for Normal Conditions of Transport

Generally, the limits on the temperature of the UF_6 within the 30B cylinder determine the thermal design criteria. The overpack itself must not degrade during normal transport conditions in such a way as to prevent it from providing protection to the cylinder in the event of a thermal accident.

The materials of construction of the overpack are not particularly sensitive to minimal temperature variations (**See Section 2.3**). The overpack materials do not degrade within the temperature range of -40°F to 185°F. Since the overpack is not air-tight, changes in pressure have no effect on it performance.

The acceptance criteria for the entire packaging under normal conditions of transport are therefore:

	30B Cylinder/UF_6	Overpack
Minimum Temperature Limit	-40°F	-40°F
Maximum Pressure Limit	115 psia	N/A
Maximum Temperature Limit	250°F	185°F

3.4.3 Thermal Model

Calculations assume zero decay heat load and a solar insolation load of 400 cal/12-hr-cm^2 (122.9 Btu/hr-ft^2 for 12 hours) followed by zero solar heat load for 12 hours, repeated indefinitely, on the surface of the cylinder. The solar absorptivity of the surface of the cylinder is estimated at .85. Ambient temperature is assumed to remain constant at 100°F. The solar heat load is calculated as:

$q_{solar} = 122.9$ Btu/hr-ft^2 x 0.85 = 104 Btu/hr-ft^2 for twelve hours and

$q_{solar} = 0$ for twelve hours

Heat is passively rejected to the environment through a combination of natural convection and radiation. The emissivity of the surface of the cylinder is taken to be 0.85.

$$h_{total} = h_{conv} + h_{rad}$$

$$h_{conv} = 0.18\,(T_s - T_{amb})^{1/3}$$ **(Ref. 3.7.5, Eqn. 7-26)**

$$q_{rad} = \sigma_b\, e\, [T_s^4 - T_{amb}^4]$$ (With T in °R)

The total energy into the overpack surface must equal the total energy out at steady-state. In the case of constant insolation, this reduces to:

$$q_{solar} = h_{conv}\Delta T + q_{rad}$$

The solution of this equation is T_s = 156°F when the insolation is equal to 104 Btu/hr-ft^2. The solution to this equation is T_s = 100°F when the insolation is equal to zero. The average surface temperature is therefore (100+156)/2 = 128°F and the peak surface temperature is 156°F.

Due to the low conductivity of the insulating foam and the extremely large thermal inertia of uranium hexafluoride it can be shown that the thermal response of the UF_6 is so slow that it never exceeds the average surface temperature by more than 8°F. Thus, the peak UF_6 temperature is 136°F. This is shown below:

At quasi-steady state, the maximum difference in temperature between the overpack outer shell and the UF_6 is 156°F - 128°F = 28°F.

If this gradient were constantly maintained, the heat flow to the UF_6 would be:

$$q = [2\pi k L / \ln(r_o/r_i)]\Delta T \qquad \textbf{(Ref. 3.7.5, Eqn. 2-6)}$$

The solution of this equation, assuming that $r_o = 21"$, $r_i = 15"$, $L = 90"$, and $k = 0.10$ Btu/hr-ft-°F = 0.00833 Btu/hr-in-°F, is:

$$q = 400 \text{ Btu/hr}$$

The rate at which the temperature of the UF_6 is changing is given by:

$$dT_{UF6} / dt = q/mc_p = 400 \text{ Btu/hr} / (5020 \text{ lb} \times 0.114 \text{ Btu/lb-°F}) = 0.7\text{°F/hr}$$

This temperature rise can occur for a maximum of 12 hours. The maximum deviation from the average temperature that the UF_6 will experience is equal to 12hr x 0.7°F/hr = 8.4°F. Therefore, the maximum temperature of the UF_6 is 128°F + 8°F = 136°F.

3.4.4 Maximum Temperatures

The maximum overpack surface temperature is 156°F. The maximum uranium hexafluoride temperature is 136°F. These temperatures are well below the limits specified in Section 2.6.2.

3.4.5 Minimum Temperatures

The minimum temperature is -40°F which is also the minimum acceptable temperature.

3.4.6 Maximum Pressure

The maximum pressure occurs when the UF_6 reaches its peak temperature of 136°F. Thus, the maximum pressure of UF_6 is less than 22 psia (**Ref. 3.7.2, Figure 3, UF_6 Phase Diagram**), less than the acceptable maximum pressure of 250 psia specified in Section 2.6.2.

3.5 Thermal Evaluation for Hypothetical Accident Conditions

3.5.1 Conditions Evaluated

Section 71.73 of 10CFR71 defines the hypothetical accident conditions. The relevant thermal conditions are taken from §71.73(c) and are listed below:

(4) Thermal. Exposure of the specimen fully engulfed, except for a simple support system, in a hydrocarbon fuel/air fire of sufficient extent, and in sufficiently quiescent ambient conditions, to provide an average emissivity coefficient of at least 0.9, with an average flame temperature of at least 800°C (1475°F) for a period of 30 minutes, or any other thermal test that provides the equivalent total heat input to the package and which provides a time averaged environmental temperature of 800°C. The fuel source must extend horizontally at least 1m (40 in), but may not extend more than 3m (10 ft), beyond any external surface of the specimen, and the specimen must be positioned 1m (40 in) above the surface of the fuel source. [...] Artificial cooling may not be applied after cessation of external heat input, and any combustion of materials of construction, must be allowed to proceed until it terminates naturally.

Section 71.73 requires that the package be subjected to "Free Drop" and "Puncture" tests prior to the thermal testing. The initial temperature of the packaging is that value between -29°C (-20°F) and 38°C (100°F) which is most unfavorable to the feature under consideration. For this packaging, 100°F is the most unfavorable starting point for the fire test.

3.5.2 Acceptance Criteria for Hypothetical Accident Conditions

In general, the thermal design criteria are limits on the temperature of the uranium hexafluoride within the 30B cylinder. The function of the overpack is to limit the temperature excursions of the contents of the 30B cylinder to the range specified below. The overpack is not required to survive the thermal accident.

Therefore, the acceptance criteria for the uranium hexafluoride within the 30B cylinder under hypothetical accident conditions are as given below:

	Uranium Hexafluoride
Minimum Temperature Limit	-40°F
Maximum Pressure Limit	115 psia
Maximum Temperature Limit	250°F

3.5.3 Thermal Model

3.5.3.1 Analytical Model

The licensing basis for the overpack, with respect to hypothetical thermal accident conditions, is full scale package testing. This testing program is described in more detail in **Appendix 2.10.8**

and Appendix 2.10.9, and in the following section. This test program precludes the need for an analytical model of the packaging during the hypothetical thermal accident conditions.

3.5.3.2 Test Model

The hypothetical accident conditions given above in **Section 3.5.1** were investigated by performing the specified tests on the actual packaging, where steel shot was substituted for the UF_6.

3.5.4 Package Conditions and Environment

The package was damaged as a result of the drop testing. See **Appendix 2.10.8** and **Appendix 2.10.9** for a complete description of packaging condition prior to and following the thermal test.

The measured ambient temperature during testing was approximately 68-74°F. The average wind speed during the first hour of testing was 4.4 mph.

The fire was fully engulfing. The package was spaced 40 inches above the surface of the fuel, and no artificial cooling was applied to the package following the fire. The package rested upon a simple support system that was incapable of shielding the package from the fire or cooling the package in any significant way. In order to obtain a fully engulfing fire, the fuel source extended beyond the package between 2 m and 4 m, which exceeds the 10CFR71.73 requirements of 1m to 3m, but results in a more severe thermal environment. The duration of the fire was 30 minutes, and the average measured flame temperature was 1479°F.

In summary, the thermal environment to which the packaging was subjected during the test met the requirements of 10CFR71, §73.73. For the purpose of calculations, it is assumed that the thermal environment created during the tests performed was identical to the environment required.

The data from the six thermocouples that were used to measure the fire temperature have been averaged and are shown in Figure 3.5-1A & B.

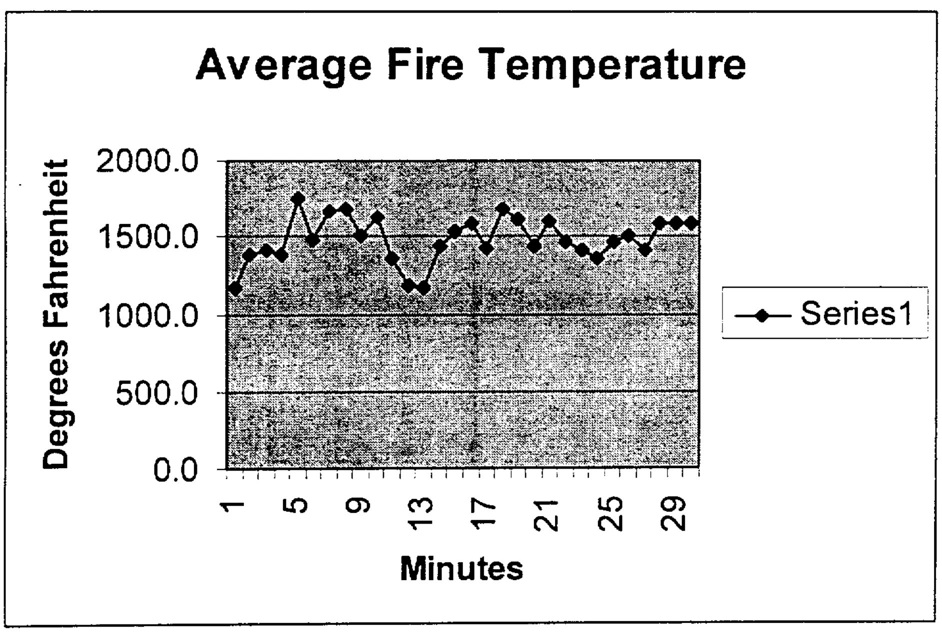
Figure 3.5-1

A

Elapsed Time (Minutes)	Temperature (°F)	Elapsed Time (Minutes)	Temperature (°F)
1	1164.5	16	1588.3
2	1384.5	17	1428.5
3	1409.2	18	1676.6
4	1376.8	19	1616.1
5	1740.4	20	1432.8
6	1479.1	21	1596.6
7	1663.9	22	1469.7
8	1672.6	23	1409.8
9	1502.9	24	1351.7
10	1624.6	25	1459.3
11	1351.1	26	1499.8
12	1183.0	27	1411.9
13	1171.0	28	1584.9
14	1432.8	29*	1584.9
15	1526.2	30*	1584.9
		Average	**1479.3**

* Extrapolated

B



3.5.5 Package Temperatures

Measured temperature data from the fourteen thermocouples attached to the 30B cylinder are presented in **Appendix 2.10.9.**

The initial starting temperature of the packaging was 99°F, as opposed to the desired 100°F. This difference is considered to be insignificant.

Maximum temperature measured by the thermocouples on the outside diameter of the 30B cylinder and the average maximum temperature are tabulated below:

Thermocouple #	1	2	3	4	5	6	7	8	9	10	11	12	13	14	Ave
Temp (°F)	187	161	177	158	142	168	161	160	125	142	155	144	155	148	156

3.5.6 Analysis of Test Data

The purpose of this section is to determine the temperature of a uranium hexafluoride filled cylinder from the data collected on the steel shot filled cylinder.

The total heat transferred to the contents of the cylinder is dependent on the thermal properties of the overpack insulation, the temperature difference between the cylinder content and the exterior flame environment, and the heat capacity of the cylinder and its contents. A one dimensional, electrical analogy, heat transfer analysis was used to assess each of these factors as they would affect a cylinder containing UF_6. For the case of the ESP-30X Test Article #1 a uniform cylinder temperature of 156°F was used, based on the test results.

The energy required to uniformly heat the cylinder and its contents from 99°F to 156°F was determined to be 43,347 kilojoules, with an average heat flow rate of 24.08 kilojoules per second during the thirty-minute test.

For the case of a cylinder containing UF_6, whose thermal properties in the solid phase are close to those of the steel shot, near uniform heating (and temperature increase) of the cylinder would be expected until the cylinder reached the UF_6 triple point at 147°F (melting temperature of UF_6). From the thermal test results, the average temperature increased to 156°F. Evaluation indicates that, for the maximum rated 5020 pound UF_6 load, it requires 36,747 kilojoules heat absorption to reach the triple point temperature, which is 147°F. It will take about 1526 seconds at the average heat transfer rate of 24.08 kilojoules per second. Therefore, during 30 minutes of fire test, the temperature of the UF_6 will reach the triple point temperature and 5.29 percent of the UF_6 load (265.6 pounds) will be transposed into liquid phase from the solid phase. The temperature of the solid and liquid would be 147°F.

If the fire test had been continued more than thirty minutes, then the temperature of UF_6 would have remained at 147°F until the entire load of UF_6 melted. It requires about 161,220 kilojoules heat absorption to melt the entire load of UF_6 which takes approximately 6778 seconds at the average heat transfer rate of 23.78 kilojoules per second. The temperature would remain constant at 147°F during the phase change from solid to liquid.

Based on the calculations derived from the temperature test data and the computation discussed above, a properly loaded cylinder of UF_6 when contained within an ESP-30X protective shipping package equal to the Test Article #1 and subjected to a thirty-minute fire condition represented by the test would go partial liquefaction. The pressure in the cylinder would increase from an initial atmospheric pressure of 14,7 psia to 16.53 psia (1.83 psi gage pressure) at the end of a thirty minute fire test.

3.5.7 Maximum Temperatures

Uranium hexafluoride in a 30B cylinder in an ESP-30X overpack subjected to the tests outlined above would initially reach a temperature of 147°F during the later part of the 30-minute fire test and 5.29% of the UF_6 load would be transposed into liquid phase. The temperature would remain constant until the entire load melted, an event which would not occur based on calculations derived from thermocouple readings gathered during the hypothetical accident condition testing.

3.5.8 Minimum Temperatures

The minimum temperature during hypothetical accident conditions is the initial temperature of the packaging, or 100°F.

3.5.9 Maximum Pressure

The maximum calculated for a load of UF_6 contained within an ESP-30X PSP would be 16.53 psia, well below the acceptable limit of 115 psia.

3.5.10 Partial Load Requirement

As calculated in Appendix 3.8.2, any mass of UF6, up to the maximum load, will not cause the cylinder to exceed the maximum allowable pressure of 115 psia under the hypothetical accident condition fire test.

3.6 Thermal Evaluation and Conclusions

The packaging's performance during normal transport conditions is acceptable. The maximum

overpack temperature is 187°F with an average maximum of 156°F. The maximum uranium hexafluoride temperature is 147°F. The minimum temperature is -40°F. The maximum pressure is 16.53 psia. These results all lie within the acceptable ranges.

Based on analysis of full scale package testing results, only a minimal amount of the UF_6 in a fully loaded 30B cylinder melts during the hypothetical thermal accident. The maximum UF_6 temperature is 147°F, less than the temperature limit of 250°F. The maximum pressure is 16.53 psia at the triple-point temperature of 147°F. This pressure is less than the 115 psia pressure limit. This demonstrates the large safety margin a fully loaded 30B cylinder possesses relative to the hypothetical thermal accident condition.

3.7 References

3.7.1 ANSI N14.1, Uranium Hexafluoride - Packaging for Transport, American National Standards Institute (ANSI).

3.7.2 USEC-651, Uranium Hexafluoride: A Manual of Good Handling Practices, United States Enrichment Corporation (USEC).

3.7.3 Uranium Hexafluoride - Safe Handling, Processing, and Transporting, Conference Proceedings, Oak Ridge, Tennessee, May 24-26, 1988.

3.7.4 1992 ASME B&PV Code, Section II, Part D - Properties, with 1994 Addenda.

3.7.5 Frank Kreith, Principles of Heat Transfer, 3rd Edition, 1973.

3.8 Appendix

3.8.1 Law Engineering Report of Thermal Evaluation

3.8.2 Law Engineering Report of Cylinder Pressure Evaluation

APPENDIX 3.8.1

LAW ENGINEERING REPORT OF THERMAL EVALUATION

LAW
ENGINEERING AND ENVIRONMENTAL SERVICES, INC.

June 11, 1998

Eco-Pak Specialty Packaging
125 Iodent Way
Elizabethton, TN 37643

Attention: Ms. Heather Little

Subject: **Report of Thermal Evaluation**
ESP-30X-Protective Shipping Package
Law Engineering Industrial Services Project 10810-8-7008, Phase 07

Dear Ms. Little:

As per your request and as authorized by your Purchase Order Number 4842, Law Engineering Industrial Services (LEIS) is pleased to present this report evaluating the thermal performance of the subject overpack, referred to as the "ESP-30X" protective shipping package. The purpose of this evaluation is to determine the solid/liquid condition of uranium hexafluoride (UF_6) contained in the cylinder, referred to as "30B" cylinder, when it is subjected to a 30 minute fire event. This report provides our understanding of the background information, a summary of the thermal test results performed by Southwest Research Institute (SwRI), Dept. of Fire Technology, our analysis method, and our conclusion.

Background Information

Eco-Pak Specialty Packaging provided following drawings of ESP-30X protective shipping package to LEIS.

DRAWING No.	DESCRIPTION	SHEET NO.	DATE
30X-1	30X PROTECTIVE SHIPPING PACKAGE	1 OF 12	8/97
30X-2	30X PROTECTIVE SHIPPING PACKAGE	2 OF 12	8/97
30X-3	30X PROTECTIVE SHIPPING PACKAGE	3 OF 12	1-30-98
30X-4	30X PROTECTIVE SHIPPING PACKAGE	4 OF 12	8/97
30X-5	30X PROTECTIVE SHIPPING PACKAGE	5 OF 12	8/97
30X-6	30X PROTECTIVE SHIPPING PACKAGE	6 OF 12	8/97

LAW ENGINEERING INDUSTRIAL SERVICES
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(704) 357-8600 • FAX (704) 357-8637

30X-7	30X PROTECTIVE SHIPPING PACKAGE	7 OF 12	8/97
30X-8	30X PROTECTIVE SHIPPING PACKAGE	8 OF 12	8/97
30X-9	30X PROTECTIVE SHIPPING PACKAGE	9 OF 12	8/97
30X-10	30X PROTECTIVE SHIPPING PACKAGE	10 OF 12	8/97
30X-11	30X PROTECTIVE SHIPPING PACKAGE	11 OF 12	8/97
30X-12	30X PROTECTIVE SHIPPING PACKAGE	12 OF 12	8/97

The inside cylinder, which was filled with steel shot, is constructed from carbon steel material. The outer cylinder, referred to as "Overpack", is also constructed from carbon steel material. The dimension between the cylinder and overpack shells is approximately 6 inches. The space between the shells is filled with a rigid foam material. The inside shell is approximately 30 inches in diameter and 82 inches in length.

Thermal Test Procedure and Results

Eco-Pak Specialty Packaging provided the information on June 9, 1998 regarding the pool fire test procedure and its results to LEIS. The thermal performance of the subject overpack was evaluated by conducting an open-pool fire as reported in the SwRI's report. The pool fire test was performed, as described in Title 10 CFR 71.73 (c), (4), at SwRI's remote test facility located in D'Hanis, Texas, approximately 40 miles west of the San Antonio campus. The facility is operated by the Department of Fire Technology and has full utility service and is equipped with a mobile technical support trailer and weather station facility.

Instrumentation requirements for this program were supported with a portable computer and rapid data acquisition equipment. Instrumentation consists of 14 thermocouples used to monitor the time temperature profiles on the surface of the 30B cylinder during the fire exposure and cool down period. Maximum temperature sensors were also used to monitor the maximum temperature during the test and cool down period.

The test cylinder was loaded with a steel shot to simulate a full load of solid UF_6 at atmospheric pressure. As mentioned in the SwRI's report, following the drop tests, the test items were transported to SwRI's department of Fire Technology for elevated temperature thermal conditioning. Prior to the fire test, the shipping package was placed in SwRI's large-scale horizontal furnace for a minimum of 24 hours to achieve an equilibrium temperature in the shipping package. The equilibrium temperature was 99 degrees Fahrenheit. For this packaging, this temperature is considered to be the most unfavorable starting point for the fire test.

Immediately following the elevated temperature thermal soak, the test article was insulated and transported to the remote test site, positioned on the test fixture, and exposed to the specified pool fire conditions for a minimum 30 minute period. The pool fire dimensions were 25 x 25 feet. Fuel was supplied to the pool fire pan through a pump during the test at a rate appropriate to maintain a fully engulfed pool fire for 30 minutes.

Thermal Evaluation for Hypothetical Accident Conditions

For the fire test, the package was suspended as indicated in the SwRI's report over a pool of diesel fuel which was lit and allowed to burn, completely engulfing the test package for approximately 30 minutes. The temperature was monitored for eleven hours from the beginning of the fire test as shown in the attached time history data. Temperature sensitive labels located on the exterior walls of the inside cylinder recorded the peak surface temperature encountered at various locations during the test. For the location of thermocouples, please see Figure 9-10, Instrumentation Layout, Thermocouples & Temperature Indicators provided by SwRI Department of Fire Technology. Please note that recording of the temperature of various locations was continued even after end of the 30 minute fire test. Temperature recording was performed by SwRI Dept. of Fire Technology.

The overall average maximum temperature indicated by the thermocouple, at the outside surface of the "30B" cylinder, during the test, was 156 degrees Fahrenheit. This temperature exceeds the UF_6 triple point temperature of 147 degrees Fahrenheit (melting point of UF_6). Further evaluation of thermal test results, if the fire test had been continued, was performed to determine the potential extent and impact of liquefaction of cylinder contents during a simulated UF_6 accident event

Summary of Overpack Thermal Test Results

Cylinder Load (Steel Shot)	5047 Pounds
Total Cylinder Weight (Including Load)	6416 Pounds
Overpack Weight	2950 Pounds
Cylinder Max. Temp. Range (Outside Surface)	125 to 187 Degrees Fahrenheit
Average Max. Temperature	156 Degrees Fahrenheit
Pre-test holding average temperature	99 Degrees Fahrenheit
Inside Cylinder Pressure	Atmospheric
Total Engulfed Burn Time	30 Minutes

In general, the total heat transferred to the contents of the cylinder is dependent on the thermal properties of the overpack insulation, the temperature difference between the cylinder contents and the exterior flame environment, and the heat capacity of the cylinder and its contents. LEIS used a one dimensional, electrical analogy, heat transfer analysis to assess each of these factors, as they would affect a cylinder containing UF_6. For the case of the steel shot-filled cylinder and overpack under test, a uniform cylinder temperature of 156 degrees Fahrenheit was used, based on the test results.

Starting with electrical analogy, for the steel-shot contents of the test cylinder, the energy required to uniformly heat the cylinder and its contents from 99 degrees to 156 degrees Fahrenheit was determined. The total heat absorption computed for the 57 degree Fahrenheit increase was 43,347 kilojoules, with average heat flow rate of 24.08 kilojoules per second during the thirty-minute test.

Six thermocouples were used to determine the average flame temperature. The flame temperature readings were taken at every minute for approximately 30 minutes. Please refer the attached table for the average flame temperature. The temperature data was provided to LEIS. Please refer to the SwRI's report for more information. Using the average flame temperature of 1479 degrees Fahrenheit, the overall thermal heat transfer co-efficient of the overpack and its insulation were subsequently calculated.

For the case of a cylinder containing UF_6, whose thermal properties in the solid phase are close to those of the steel shot, near uniform heating (and temperature increase) of the cylinder would be expected until the cylinder reached the UF_6 triple point at 147 degrees Fahrenheit (melting temperature of UF_6). From the thermal test results, the average temperature increased to 156 degrees Fahrenheit. This temperature is higher than the UF_6 triple point temperature. Our evaluation indicates that, for the maximum rated 5020 pound UF_6 load, it requires 36,747 kilojoules heat absorption to reach the triple point temperature, which is 147 degrees Fahrenheit. It will take about 1526 seconds at the average heat transfer rate of 24.08 kilojoules per second. Therefore, during 30 minutes of fire test, the temperature of the UF_6 will reach the triple point temperature and 5.29 percent of UF_6 load (265.6 pounds) will be transposed into liquid phase from the solid phase. The temperature of the solid and liquid would be 147 degrees Fahrenheit.

If the fire test had been continued, more than thirty minutes, then the temperature of UF_6 would have remained at 147 degrees Fahrenheit until the entire load of UF_6 melted. It requires about 161,220 kilojoules heat absorption to melt the entire load of UF_6 which takes approximately 6778 seconds at the average heat transfer rate of 23.78 kilojoules per second. The temperature would remain constant at 147 degrees Fahrenheit during the phase change from solid to liquid.

Based on our review of the temperature test data and the computation discussed above, a properly loaded cylinder of UF_6, when contained within a ESP-30X protective shipping package equal to the one tested and subjected to a thirty-minute fire condition represented by the test, would go partial liquefaction. The pressure in the cylinder would increase from an initial atmospheric pressure of 14.7 psia to 16.53 psia (1.83 psi gage pressure) at the end of a thirty minute fire test.

Therefore, it is our opinion that the acceptance criteria given below for the hypothetical accident conditions for the uranium hexafluoride within the 30B cylinder, inside the ESP-30X protective shipping package, will be met as delineated below.

For Uranium Hexafluoride

Conditions	Acceptance Criteria	Measured/Calculated Conditions
Minimum Temperature Limit	-40 °F	98 °F
Maximum Pressure Limit (psia)	115 psia	16.53 psia
Maximum Temperature Limit	250 °F	147 °F

The properties of UF_6 and the cylinder configuration used in this analysis were obtained from the U.S. Department of Energy publication USEC-651 (Revision 7) Uranium Hexafluoride, A Manual of Good Handling Practices, dated January 1995, which was provided to us by Eco-Pak. The characteristics corresponding to the, ESP-30X protective shipping package were obtained from the drawings supplied to LEIS. If the data contained in this report are known to be incorrect or inappropriate for use in this analysis, please contact us so that we may re-evaluate our calculation accordingly.

Law Engineering Industrial Services appreciates the opportunity to assist you with this project. Please contact this office at 704-357-8600 if you have any questions. We look forward to continuing our working relationship with you on this and future projects.

Sincerely,
LAW ENGINEERING INDUSTRIAL SERVICES

M.N. Parikh

Mike N. Parikh, P.E.
Staff Engineer

James W. Page

James W. Page, P.E.
Chief Engineer

Attachment: Temperature Test Data
Figure 9-10 from SwRI's Report
Time History Temperature Graphs
LEIS Calculation Sheets
Drawing
Average Flame Temperature Sheet

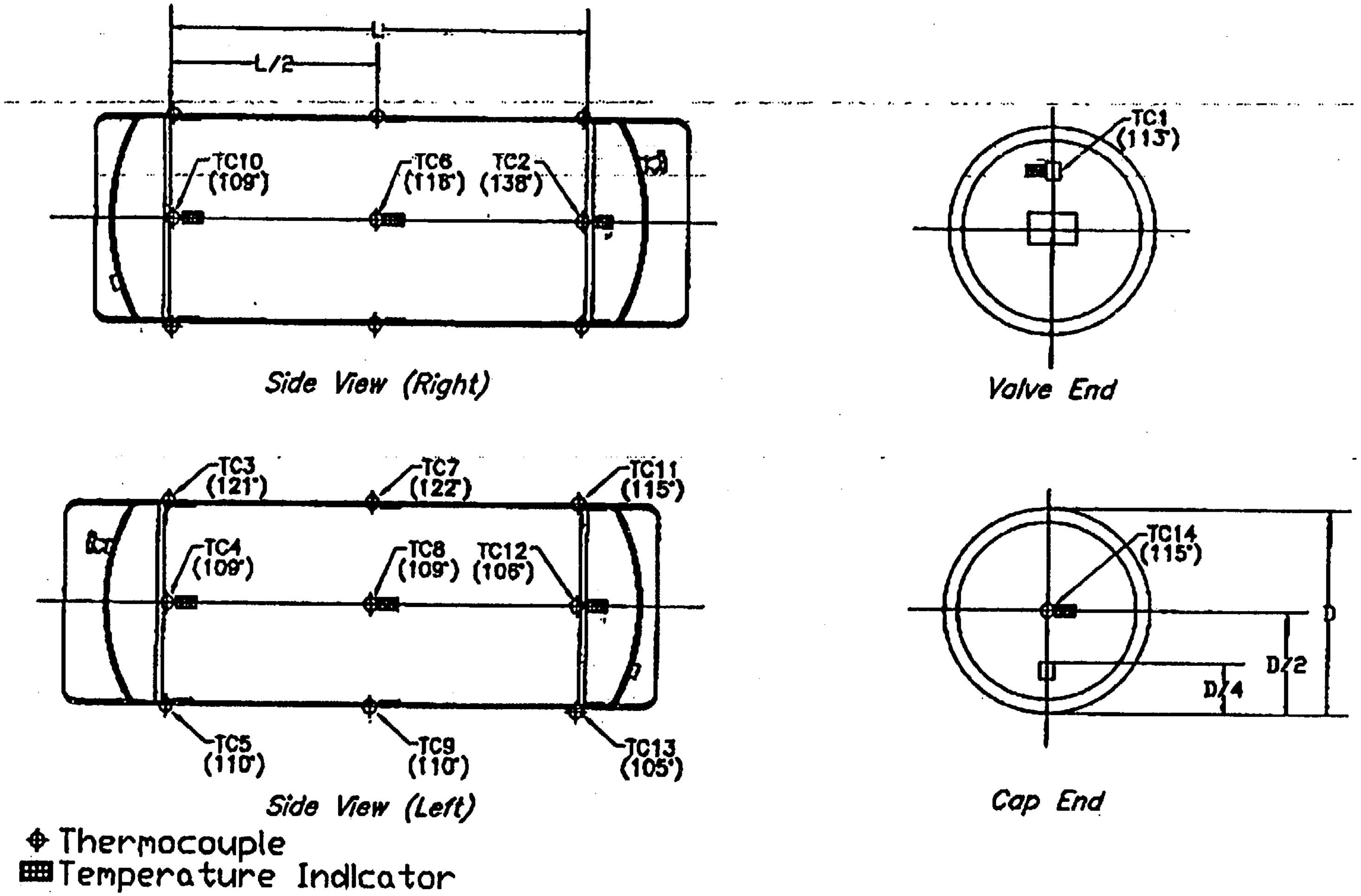
TEST OF ESP-30X PROTECTIVE SHIPPING PACKAGE *

INITIAL AND MAX. TEMPERATUREOF FOURTEEN THERMOCOULPES

THERMOCOULPE # AND LOCATION	INITIAL TEMPERATURE IN °F (ON OD. OF 30B CYLINDER)	MAXIMUM TEMPERATURE IN °F (ON OD. OF 30B CYLINDER)
1 (VALVE END)	100	187
2 (ON SHELL @ V. END)	100	161
3 (ON SHELL @ V. END)	100	177
4 (ON SHELL @ V. END)	100	158
5 (ON SHELL @ V. END)	100	142
6 (ON SHELL @ MIDDLE)	98	168
7 (ON SHELL @ MIDDLE)	100	161
8 (ON SHELL @ MIDDLE)	98	160
9 (ON SHELL @ MIDDLE)	98	125
10 (ON SHELL @ CAP END)	98	142
11 (ON SHELL @ CAP END)	100	155
12 (ON SHELL @ CAP END)	98	144
13 (ON SHELL @ CAP END)	98	155
14 (CAP END)	100	148
AVERAGE TEMP.	99	156

NOTES:

1. FOR LOCATION OF THERMOCOULPLES PLEASE SEE ATTACHED FIGURE 9-10 FROM SwRI'S REPORT.
2. INITIAL TEMPERATURES WERE TAKEN FROM THE BEGINNING OF THE TEST AND MAXIMUM TEMPERATURES WERE TAKEN FROM THE TEMPERATURE GRAPH OVER ELEVEN HOURS TIME.
3. PRE-TEST HOLDING TEMPERATURE WAS APPROXIMATELY 99 °F
4. INFORMATION PROVIDED TO LEIS BY ECO-PAK, SPECIALITY PACKAGING



Southwest Research Institute

Department of Fire Technology

TITLE: Instrumentation Layout, Thermocouples & Temperature Indicators		
CLIENT: Eco-Pak Specialty Packaging		PROJECT NO. 01-1680-102
DRAWN BY: Aaron Arellano	DATE OF TEST: March 21, 1998	FILE: c:\aaron\flm\eco-pac\tank3.dwg

Figure 9-10. 30B Cylinder Thermocouple Readings.

ENT: ECO-PAK SPECIALTY PACKAGING
SwRI PROJECT No.: 01-1680-102
DATE: 21 MARCH 1998
FILE ID: 08030SXT.DAT
08030SC2.DAT

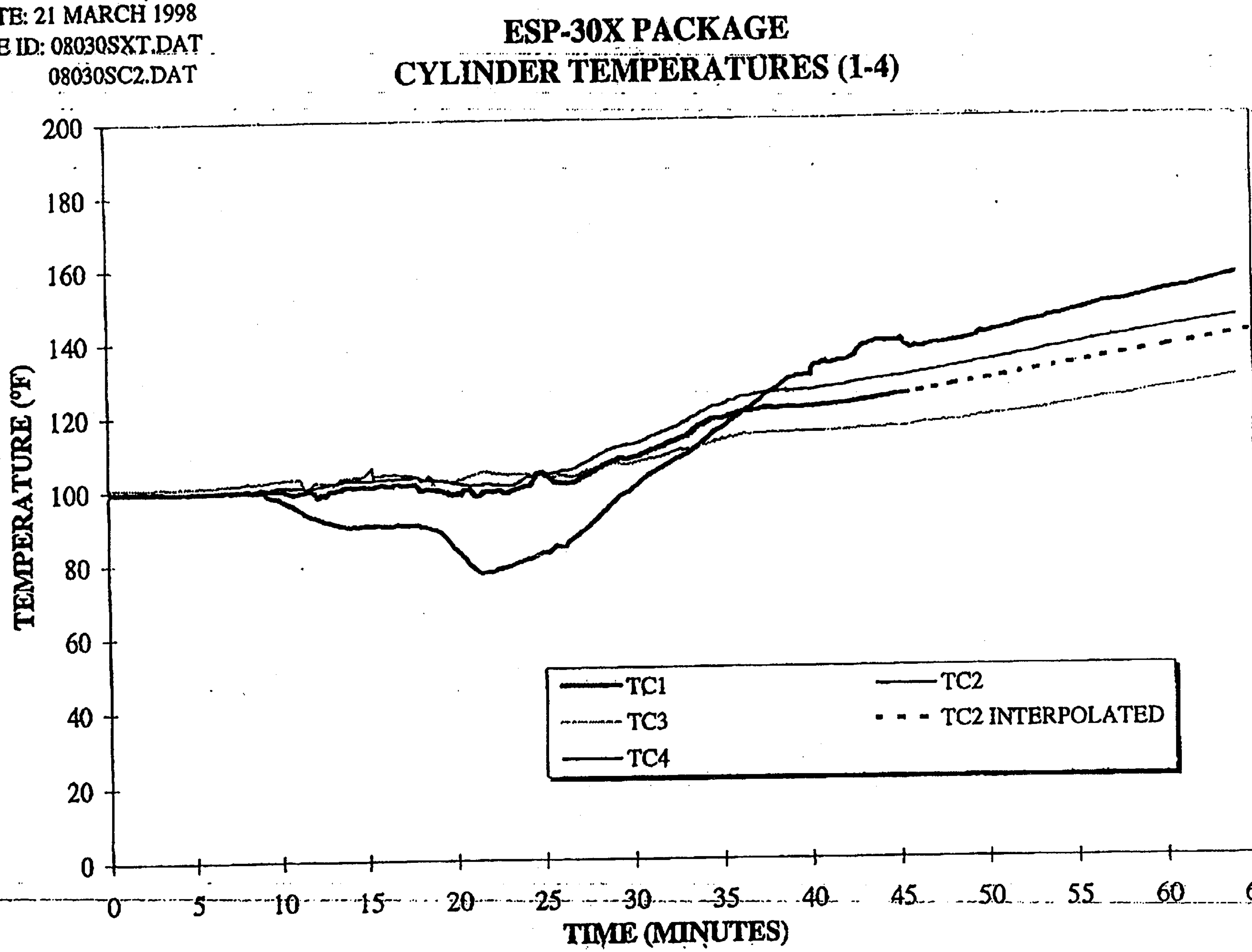


Figure 9-2. 30B Cylinder Thermocouple Readings.

CLIENT: ECO-PAK SPECIALTY PACKAGING
SwRI PROJECT No.: 01-1680-102
DATE: 21 MARCH 1998
FILE ID: 08030SC2.DAT
08030SXT.DAT

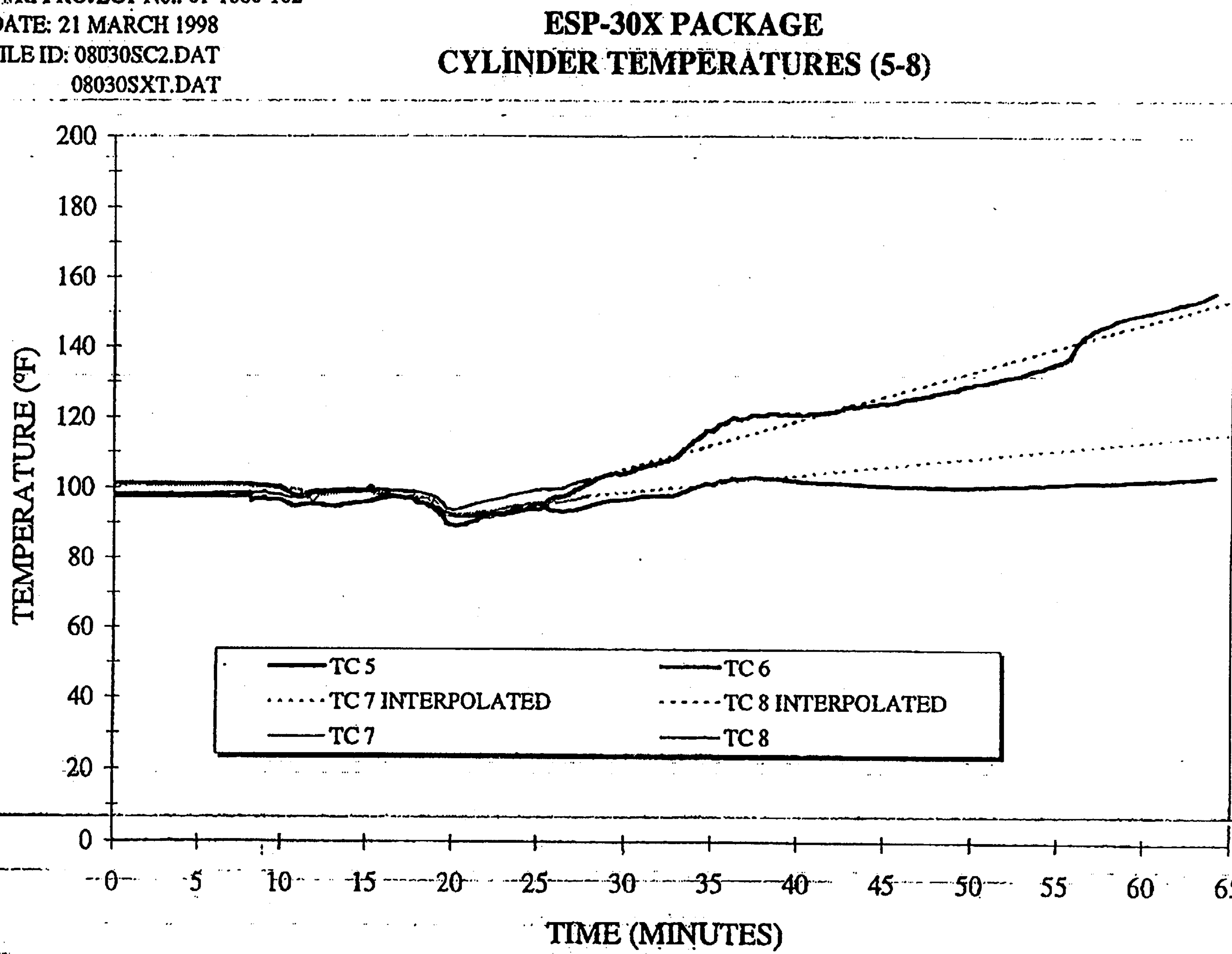


Figure 9-3. 30B Cylinder Thermocouple Readings.

CLIENT: ECO-PAK SPECIALTY PACKAGING
SwRI PROJECT No.: 01-1680-102
DATE: 21 MARCH 1998
FILE ID: 08030SC2.DAT
08030SXT.DAT

ESP-30X PACKAGE
CYLINDER TEMPERATURES (9-12)

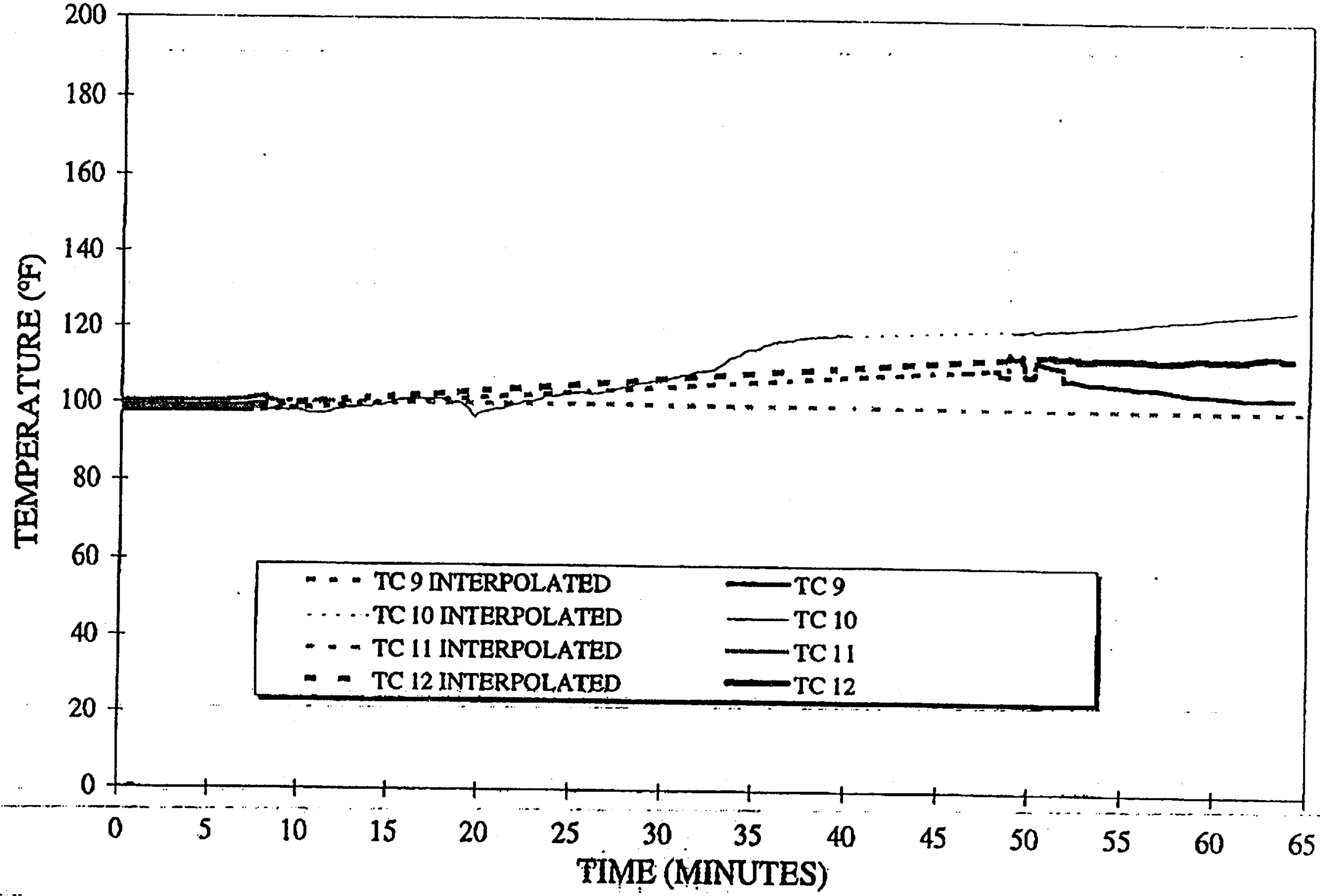


Figure 9-4. 30B Cylinder Thermocouple Readings.

CLIENT: ECO-PAK SPECIALTY PACKAGING
SwRI PROJECT No.: 01-1680-102
DATE: 21 MARCH 1998
FILE ID: 08030SXT.DAT

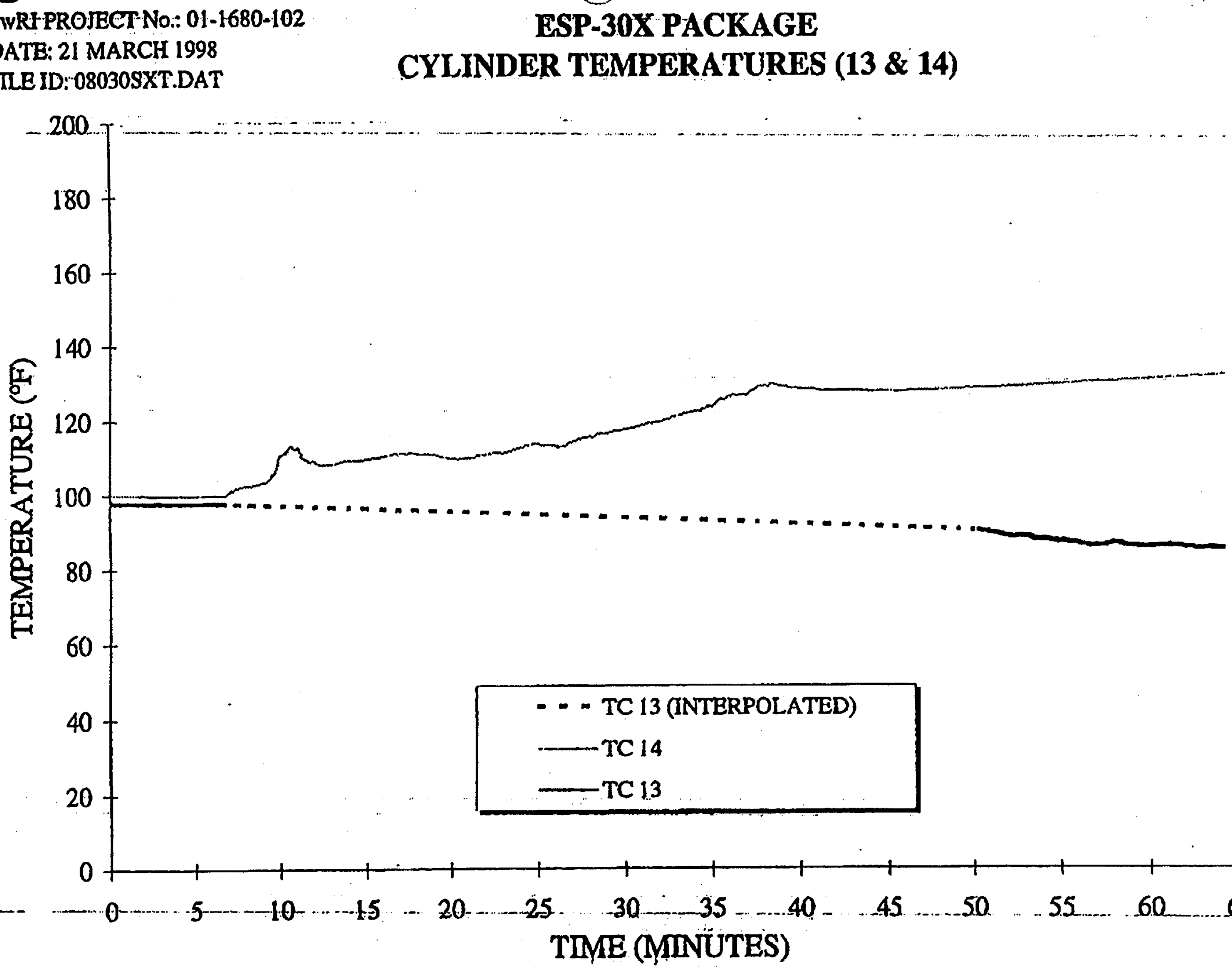


Figure 9-5. 30B Cylinder Thermocouple Readings.

CLIENT: ECO-PAK SPECIALTY PACKAGING
SwRI PROJECT No.: 01-1680-102
DATE: 21 MARCH 1998
FILE ID: 08030SXT.DAT
08030SC2.DAT

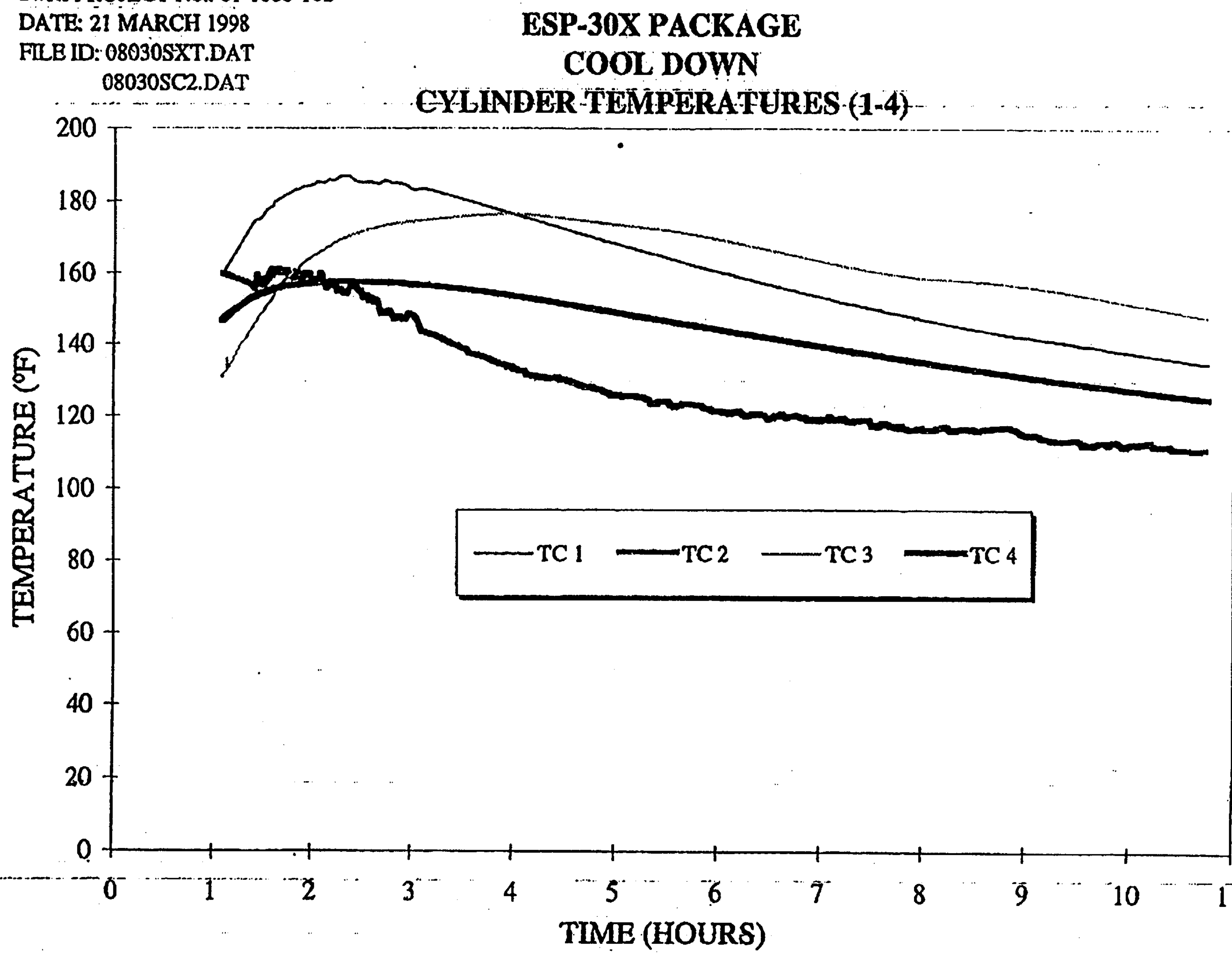


Figure 9-6. 30B Cylinder Thermocouple Readings.

CLIENT: ECO-PAK SPECIALTY PACKAGING
SwRI PROJECT No.: 01-1680-102
DATE: 21 MARCH 1998
FILE ID: 08030SXT.DAT
08030SC2.DAT

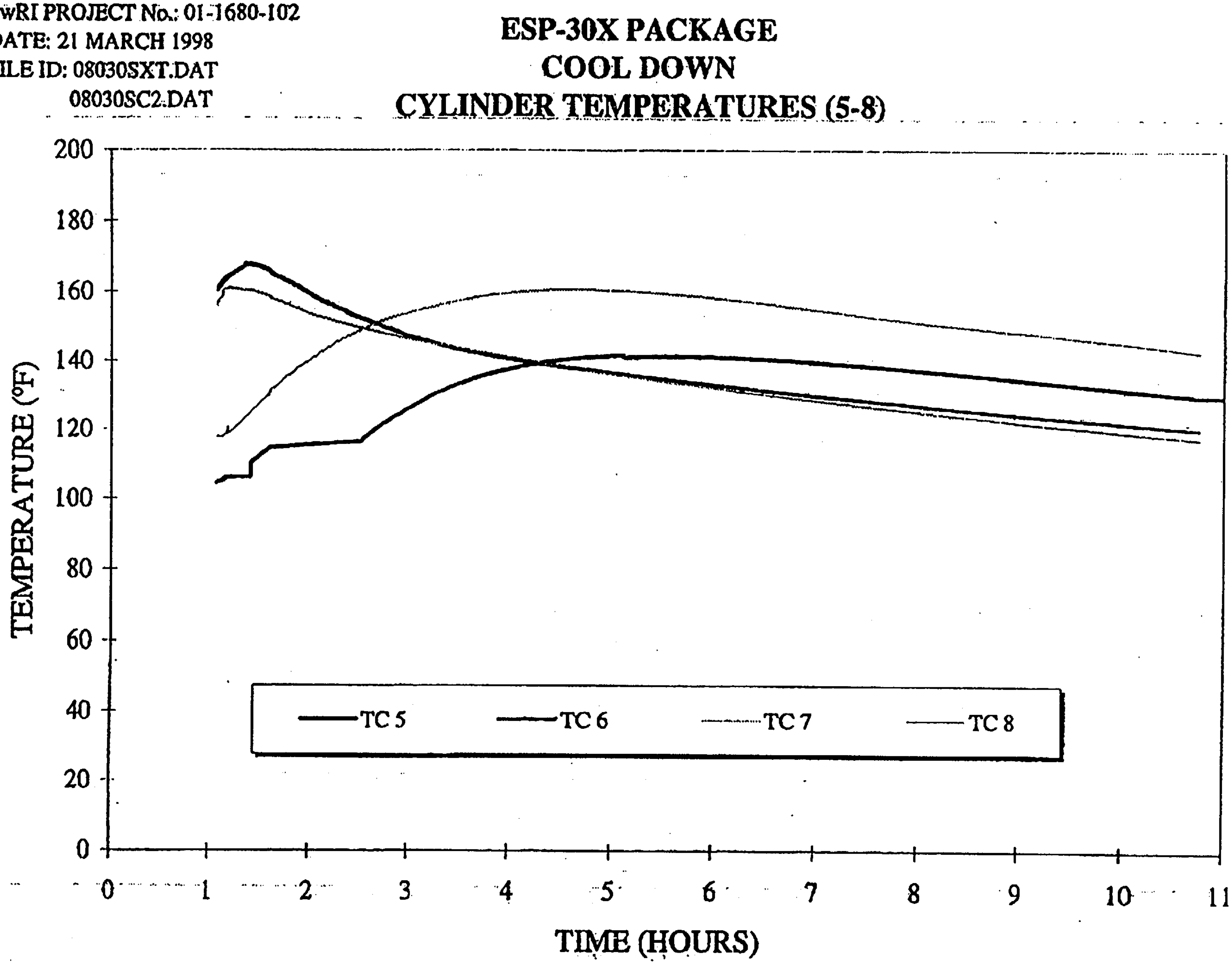


Figure 9-7. 30B Cylinder Thermocouple Readings.

Eco-Pak Specialty Packaging

31 of 35

SwRI Project No. 01-1680a

CLIENT: ECO-PAK SPECIALTY PACKAGING
SwRI PROJECT No.: 01-1680-102
DATE: 21 MARCH 1998
FILE ID: 08030SXT.DAT
08030SC2.DAT

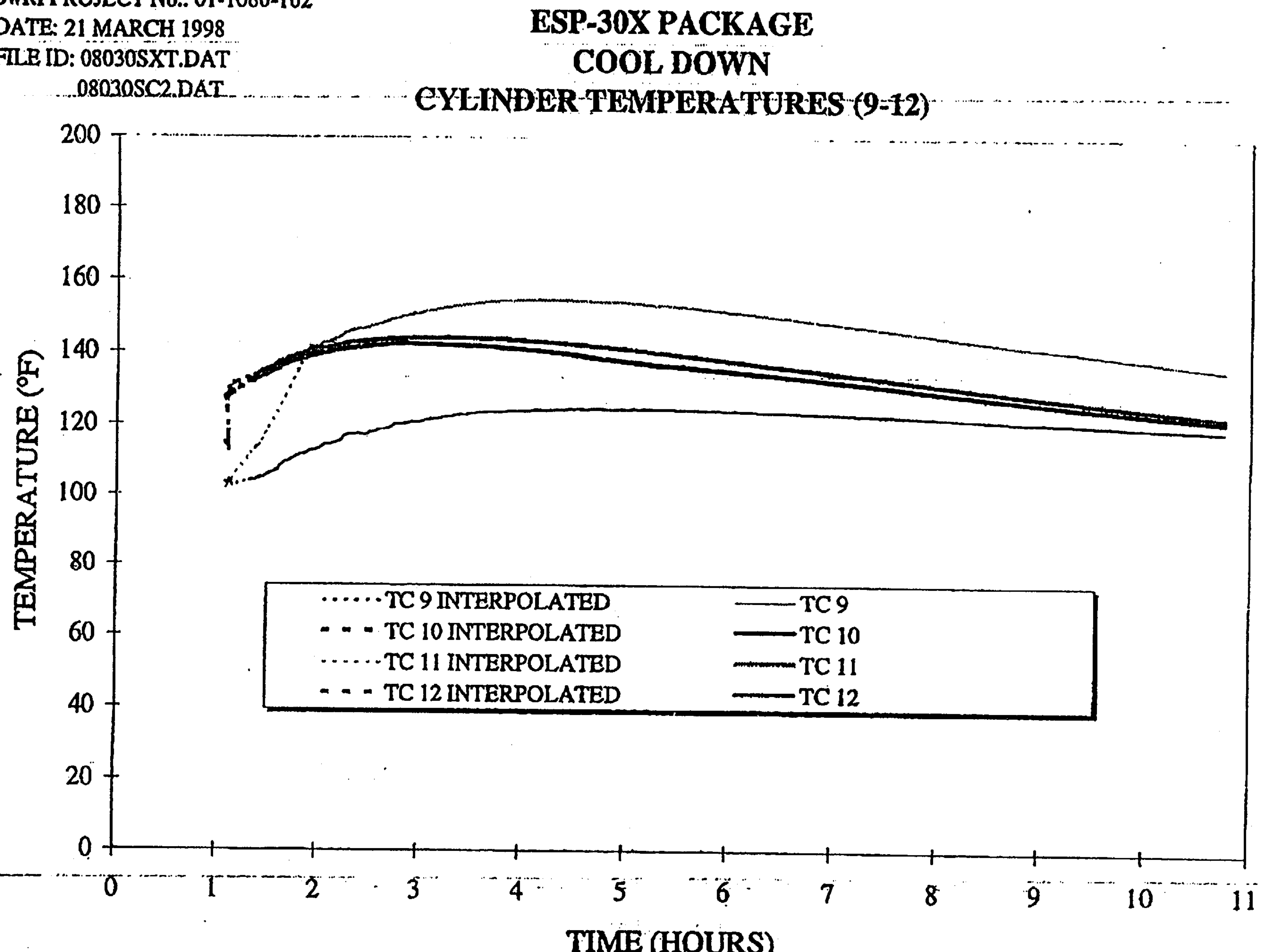


Figure 9-8. 30B Cylinder Thermocouple Readings.

ENT: ECO-PAK SPECIALTY PACKAGING
SwRI PROJECT No.: 01-1680-102
DATE: 21 MARCH 1998
FILE ID: 08030SXT.DAT
08030SC2.DAT

ESP-30X PACKAGE
COOL DOWN
CYLINDER TEMPERATURES (13-14)

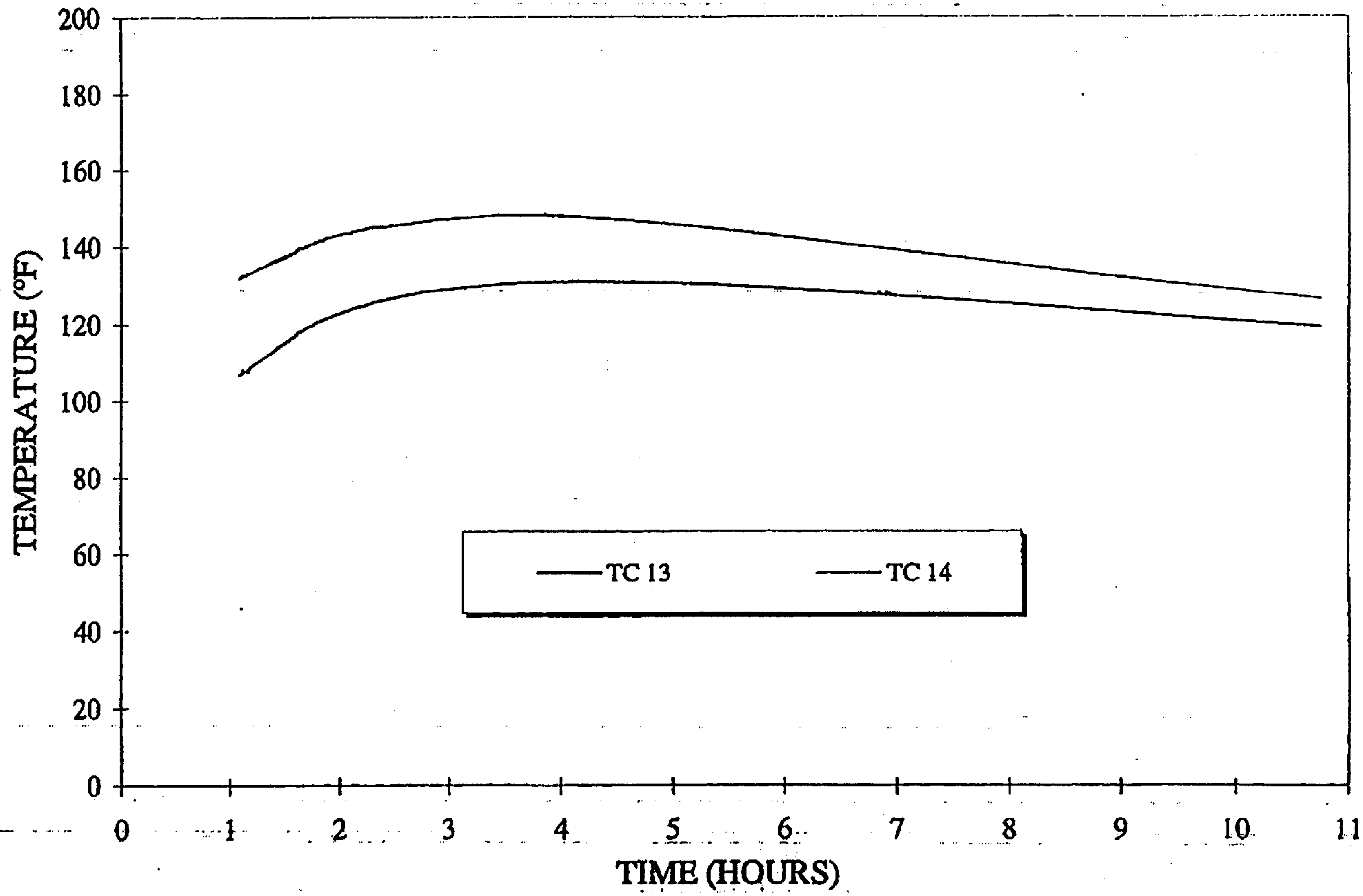


Figure 9-9. 30B Cylinder Thermocouple Readings.

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JOB NO. 10810-8-7008 SHEET 1 OF 12

JOB NAME ECO-PAK

BY MNP DATE 6-9-98

CHECKED BY DETIGNOR DATE 6/11/98

Thermal Analysis of ESP-30X Protective Container

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JOB NO. 10810-8-7008 SHEET 2 OF 12

JOB NAME ECO-PAK

BY MNP DATE 6-9-98

CHECKED BY DETIGNOR DATE 6 11 98

(1) ESP-30X PROTECTIVE SHIPPING CONTAINER

SITUATION: CYLINDER (30B) LOADED WITH STEEL SHOT, ENCLOSED IN OVERPACK (ESP-30X) PRE-HEATED TO APPROXIMATELY 99°F (37.22°C) AFTER THE DROP TEST. THEN THE OVER PACK WAS EXPOSED TO THE SPECIFIED POOL FIRE CONDITIONS FOR MINIMUM 30 MINUTE PERIOD. THE CYLINDER (30B) OUTSIDE SURFACE TEMPERATURES WERE RECORDED AT FOURTEEN LOCATIONS. THE AVERAGE TEMPERATURE WAS 1479°F (803.89°C)

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JOB NO. 10810-8-7008 SHEET 3 OF 12

JOB NAME ECO-PAK

BY MNP DATE 6-9-98.

CHECKED BY DETIGNOR DATE 6 11 98

REFERENCE:

A - PROTECTIVE SHIPPING PACKAGE FOR 30 INCH DIA. UF6 CYLINDER BY A J MALLETT AND C.E NEWLON UNION CARBIDE NUCLEAR DIV. REPORT NO K-1686 FOR INFO ONLY

B - HOLMAN J. P. HEAT TRANSFER 5th ED. McGRAW HILL 1981

C - U.S DEPT. REPORT USEC-651 (REV.7) URANIUM HEXA FLUORIDE - A MANUAL OF GOOD HANDLING PRACTICE, JANUARY 1995.

D - SAFETY ANALYSIS REPORT FOR TYPE 30 B CYLINDER, 1/1998. HYPOTHETICAL ACCIDENT CONDITION SEC 3.5

E - MARK'S HANDBOOK - HAND BOOK FOR MECH. ENGR. 10th EDITION. T. BAUMEISTER

F - TEMP. DATA BY SWRI DEPT OF FIRE TECHNOLOGY.

G AMERICAN NATIONAL STANDARDS INSTITUTE N14.1 1987

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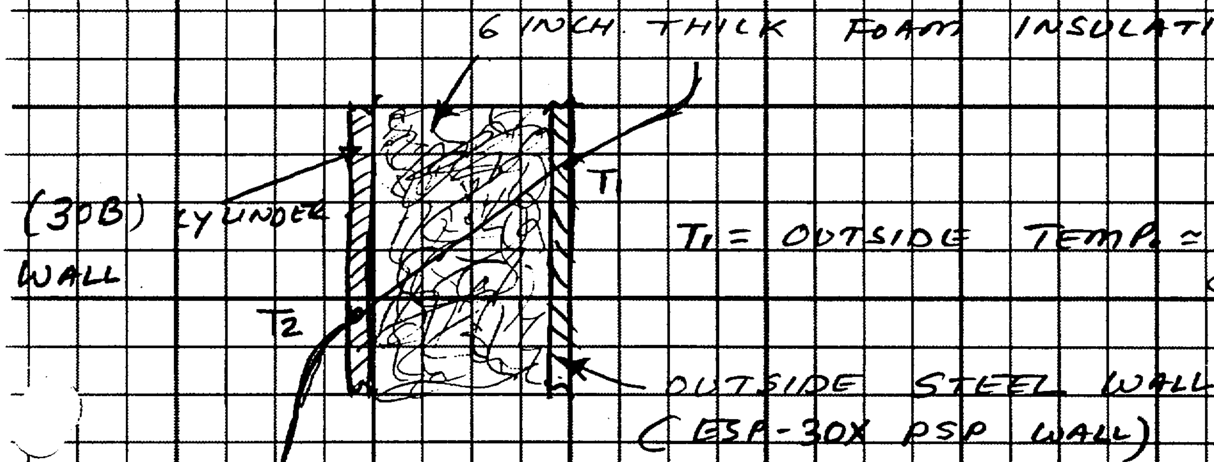
JOB NO. 10810-8-7008 SHEET 4 OF 12
JOB NAME ECO-PAK
BY MNP DATE 6-9-98
CHECKED BY DETIGNOR DATE 6/11/98

THERMAL EVALUATION - ESP-30X PROTECTIVE SHIPPING PACKAGE.



T_1 = OUTSIDE TEMP. ≈ 1479 °F (803.89 °C)

STEEL SHOT WT = 5047 lbs (2289.32 Kg)
SPECIFIC HEAT OF STEEL = 0.47 KJ/kg °C (REF B) TABLE A-2
STEEL DENSITY = 7801 kg/m3
CYLINDER WT = 1369 lbs = 621 kg

T_{2p} = PRE HEATED TEMP = 99 °F = 37.22 °C

T_{2m} = MAXIMUM AVERAGE TEMP AFTER 30 MINUTE FIRE TEST = 156 °F = 68.89 °C

$T_F = 32 + (9/5) T_C$

$T_C = (T_F - 32)\, 5/9$

ΔT = TEMPERATURE OF CYLINDER INCREASED DUE TO FIRE TEST.

$= T_{2m} - T_{2p} = 68.89 - 37.22 = 31.67$ °C

$T_{2\,AVG} = \dfrac{T_{2P} + T_{2M}}{2} = \dfrac{99 + 156}{2} = 127.5$ °F $= 53.06$ °C

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BY MNP DATE 6-9-98
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Q_1 TOTAL HEAT REQD. TO INCREASE THE CYLINDER (30B) TEMP FROM 37.22 °C TO 68.89 °C (FROM 99 °F TO 156 °F)

ΔT = TEMP. INCREASED = 68.89 − 37.22 = 31.69 °C

m = TOTAL MASS
= MASS OF CYLINDER + MASS OF STEEL SHOT
= 2289.32 + 621 = 2910.3 Kg (6416 lbs)

C_p = SPECIFIC HEAT OF STEEL = 0.47 KJ/Kg °C

$\therefore Q = m \cdot C_p \cdot \Delta T = 2910.3 \times 0.47 \times 31.69$ KJ

$\simeq 43,347$ KJ

$\therefore$ AVG. HEAT TRANSFER RATE $= q = \frac{Q}{30 \text{ min}} = \frac{43,347}{30 \times 60} = 24.08$ KJ/sec.

$\frac{Q}{t}$ — t = TIME OF TEST, Q = TOTAL HEAT TRANSFER

FROM HEAT TRANSFER RATE OR FLOW RATE q WE CAN CALCULATE THE OVERALL THERMAL RESISTANCE OF ESP-30X PROTECTIVE SHIPPING PACKAGE.

$$q_{avg} = \frac{T_1 - T_{2avg}}{\frac{1}{h_1 A} + \frac{\Delta x}{K_1 A}}$$

Where $\frac{1}{h_1 A} + \frac{\Delta x}{K_1 A}$ = OVERALL THERMAL RESISTANCE.
$= \Sigma R$.

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$\Sigma R = \frac{T_1 - T_{2\,AVG}}{q} =$ $T_1 = 803.89$ °C AVG. FLAME TEMP.

$T_{2\,AVG} = 53.06$ °C

$= \frac{803.89 - 53.06}{24.08} = \frac{750.83}{24.08} = 31.18$ m² °C/W

FROM OVERALL THERMAL RESISTANCE ΣR,

Initial heat transfer Rate = $q = \frac{\Delta T}{\Sigma R}$

Initial $\Delta T_I = 803.89$ °C $- 37.22 = 766.67$ °C

$q_{ini} = \frac{766.67}{31.18} \simeq 24.58$ KJ/sec

Similarly heat transfer rate at end of 30 min

$q_{end} = \frac{\Delta T_e}{\Sigma R}$, $\Delta T_e = 803.89 - 68.89 = 735$ °C

$q_{end} = \frac{735}{31.18} = 23.57$ KJ/sec.

Check: $q_{avg} = \frac{q_{start} + q_{end}}{2} = \frac{24.58 + 23.57}{2} \simeq 24.08$ KJ/sec.

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JOB NAME ECO-PAK
BY MNP DATE 6-9-98
CHECKED BY DEVIGNOR DATE 6/11/98

% Cylinder filled of UF6.

(30B) Cylinder volume = $\pi/4 \cdot D^2 \cdot L = V_c$

D ≈ 30 inch L = 84.25 inch 81½"

$V_c = \pi/4 (30)^2 (84.25)$

= 59,553 inch³ = 34.463 ft³

FOR CONSERVATIVE MIN. VOL. V = 26 ft³ (REF G) (D = 30", L = 63.56")

= 0.736 m³

UF6 Vol. WT = 2277 Kg

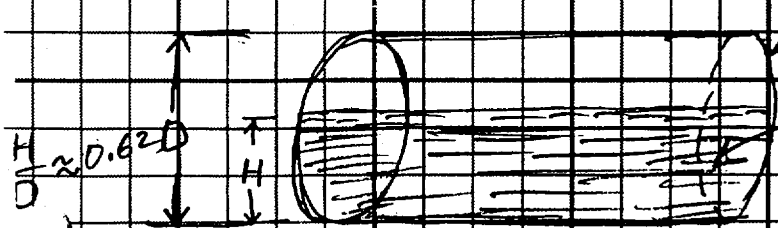
Density = 4997.76 Kg/m³

∴ Volume UF6 = 2277 / 4997.76 = 0.456 m³

∴ % Cy volume filled by UF6

= 0.456 / 0.736 = 0.62 × 100 = 62%

Say about 62% filled by UF6.



D = 30 INCH
L = 63.56"
[FOR 26 ft³ volume]

FOR 62% FILLED UF6 - SURFACE AREA OF CONTACT ≈ 0.62 (CYLINDER SURFACE)

$= 0.62 (2 \times \pi/4 D^2 + \pi D L) = 4589$ inch² ≈ 32 ft² ≈ 3 meter²

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JOB NO. 10810-8-7008 SHEET 8 OF 12

JOB NAME ECO-PAK

BY MNP DATE 6-9-98

CHECKED BY DETIGNOR DATE 6/11/98

New thermal Resistance = ΣR_N

So New Heat Resistance = ΣR_N = $\Sigma R + 1/h_2 A$

Where ΣR = PREVIOUSLY Heat Resistance = 31.18 m^2 °C/W

A = 3.02

h_2 = UF6 FILM CONDUCTIVITY UNKNOWN.

h_2 = KW / m^2 °C FROM 1 TO 10

A = 3 meter^2

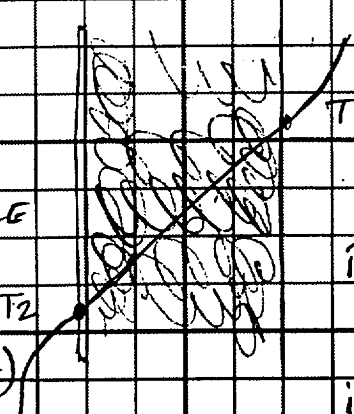
IF $h_2 = 10$

$$\Sigma R_N = 31.18 + \frac{1}{10(3)} = 31.21 \ m^2 \ °C/W$$

IF $h_2 = 1$

$$\Sigma R_N = 31.18 \ \frac{1}{1(3)} = 31.51 \ m^2 \ °C/W$$

$$q = \frac{T_1 - T_2}{\left[\frac{1}{h_1 A} + \frac{\Delta x}{KA}\right] + \frac{1}{h_2 A}}$$



T_1 = 803.89 °C

UF6 TRIPPLE PT

°F T_2

(63.89 °C)

$T_1 - T_2$ = 803.89 − 63.89 = 740 °C

if $h_2 = 10$, $q = \frac{740}{31.21}$ = 23.71 KJ/sec

if $h_2 = 1$, $q = \frac{740}{31.51}$ = 23.48 KJ/sec

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JOB NO. 10810-8-7008 SHEET 9 OF 12
JOB NAME ECO-PAK
BY MNP DATE 6-10-98
CHECKED BY DETIGNOR DATE 6/11/98

So q_1 heat transfer rate for solid phase
= 24.08 KJ/sec

q_1 heat transfer rate for melting phase
= 23.71 KJ/sec. (h2=10 for conservative assumption).

To find out % UF6 charge melted

TOTAL HEAT TRANSFER DURING 30 MINUTE PERIOD

Q = 43,347 KJ.

Q_R REQUIRED TO REACH MELTING POINT.

m_{UF6} = MASS of UF6 = 2277 Kg (5020 lbs)
m_{cy} = MASS of Cylinder = 621 Kg
Cp of UF6 = 0.4773 KJ/kg °C
Cp of Cy = 0.47 KJ/kg °C
ΔT = Triple Temp. − Init. Te = 147 − 99 °F = 63.89 − 37.22 °C
= 26.67

Q_R = (2277) (0.4773) (26.67) + (621) (0.47) (26.67)
UF6 — Cylinder

= 28985.3 + 7771.6 KJ

= 36756.9 KJ.

≈ 36757 KJ

FROM TOTAL HEAT TRANSFE Q = 43,347 KJ

36757 KJ (Q_R) REQD TO RAISE THE

Cylinder (30B) & UF_6 SHOT TEMPERATURE

FROM 99 °F (32.22 °C) TO 147 °F (63.89 °C).

HEAT REQD (Q_m) TO MELT % UF_6 SHOT.

mass of UF_6 = 2277 Kg.

q melting of UF_6 = 54.661 KJ/Kg °C

Left over heat Remained after reaching the cylinder temp. of 147 °F or 63.89 °C

= 43,347 − 36,757 = 6590 KJ.

% UF_6 MELTED = X

6590 = (X) (2277) (54.661) KJ.

$$X = \frac{6590}{(2277)(54.661)} = 0.0529$$

OR 5.29 % of 2277 Kg of UF_6 Melted.
= 120.5 Kg

HEAT REQD TO MELT 100 % OF UF_6 SHOT

= 36,757 + 2277 (54.661) = 161,220 KJ.

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JOB NAME ECO-PAK
BY MNP DATE 6-10-98
CHECKED BY DETIGNOR DATE 6/11/98

HEAT REQ'D TO REACH 68.89 °C (156 °F)

$Q_{156} = 161,220 + M_{UF_6} \times C_{liquid\ UF_6} \times \Delta T + M_{cy} \times C_p \times \Delta T$

$C_{liquid} = 0.544$ KJ/kg °C

$\Delta T = 68.89 - 63.89 = 5\ °C$

$= 161,220 + (2277)(0.544)(5) + (621)(0.47)(5)$

$= 161,220 + 2279.7 + 1459.4 \approx \underline{164,959}$ KJ.

1) TIME REQ'D TO REACH MELTING POINT IF (147 °F OR 63.89 °C) CY. CONTAIN UF6 SHOT. PREDICTED IMPACT ON UF6.

q = HEAT TRANSFER RATE = 24.08 KJ/SEC.

$TIME = \frac{36,757}{24.08} \approx \underline{1526}$ sec.

2.) TIME REQ'D TO MELT 5.29% UF6 SHOT

$= \frac{36,757}{24.08} + \frac{6590}{23.7} \approx 1526 + 278 \approx \underline{1804}$ Sec.

TIME REQ'D TO MELT 100% UF6 $= 1526 + \frac{124,463}{23.7} = \underline{6777.6}$ sec

3.) TIME REQ'D TO REACH 156° F

$= 6777.6 + \frac{3739.1}{23.7} = 6777.6 + 157.8$ sec

$= 6935.4$ sec

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UF_6 VOLUME CHECK:

UF_6 CHARGE 5.29 % MELTED.

CAKE WT = (1 − 0.0529) 2277 = 2156.5 Kg

LIQUID WT = 2277 − 2156.5 = 120.5 Kg

ρ_{liquid} = 226 lb/ft³ = 3620 Kg/m³

ρ_{cake} 304 lb/ft³ = 4870 Kg/m³

∴ Vol. of liquid 120.5/3620 = 0.0333 m³

∴ Vol of cake = 2156.5/4870 = 0.443 m³

TOTAL $_{UF_6}$ VOL = 0.4763 m³.

Vol. of Cyl = Vol available = 0.736 m³ (page 7)

Vol. of UF_6 < Vol. available
(0.4763 m³) (0.736 m³)

Pressure:

$$\frac{P_1 V_{1c}}{T_1} = \frac{P_2 V_{2c}}{T_2}$$

V_{1c} (cyl. vol) = 0.736 − 0.4675 = 0.2685 m³

V_{2c} (cyl vol) = 0.736 − 0.4763 = 0.2593 m³

P_1 = 14.7 psi
V_{1c} = 0.2685
T_1 = 99 + 460 = 559 °R

P_2 = ?
V_2 = 0.2593
T_2 = 147 + 460 = 607 °R

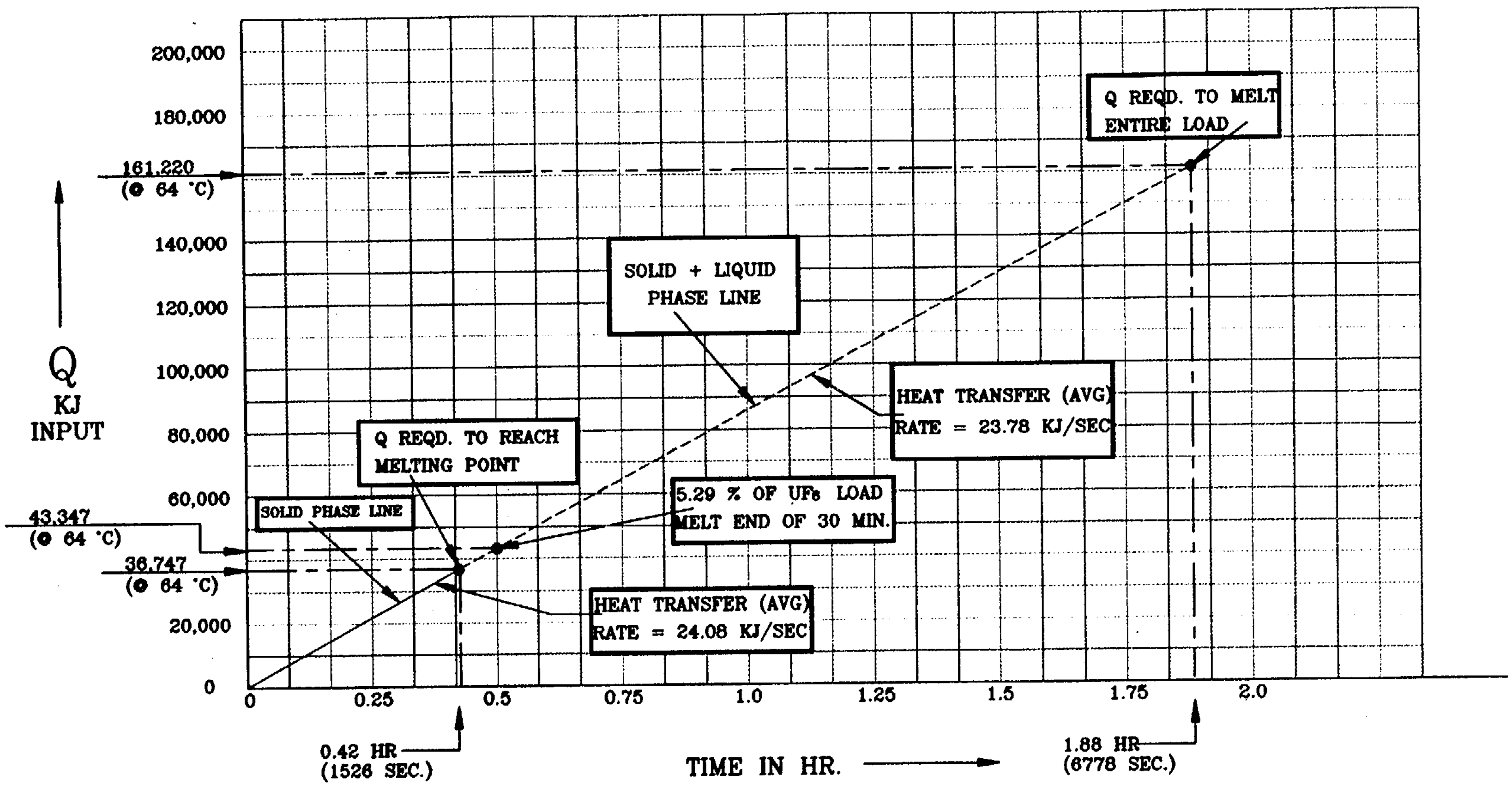
$$P_2 = \frac{P_1 V_1}{T_1} \cdot \frac{T_2}{V_2} = P_1 \left(\frac{V_1}{V_2}\right)\left(\frac{T_2}{T_1}\right) = 14.7\left(\frac{0.2685}{0.2593}\right)\left(\frac{607}{559}\right)$$

= 16.53 PSIA

OR P_2 = 1.8 PSIG

EQUIVALENT UF_6 SHOT STATUS

(IF THE FIRE TEST WOULD BE CONTINUED AFTER 30 MINUTES)



NOTES:

1. INITIAL PREHEATED TEMP. OF UF6 AND VESSEL IS 37.2° C (99 °F)
2. CYLINDER WEIGHT IS 621 Kg (1369 LBS).
3. STEEL SHOT WEIGHT IS 2289.2 Kg (5047 LBS).
4. MAXIMUM OVERALL AVERAGE TEMP. IS 68.89 °C (156 °F)
5. TEMP. WERE MEASURED AT OUTSIDE SURFACE OF CYLINDER.
6. MAXIMUM RATED UF6 LOAD IS 2277 Kg (5020 LBS).
7. THE AVERAGE FLAME TEMPERATURE IS 803.9 °C (1479 °F)

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ECO-PAK, SPECIALTY PACKAGING
30X, PROTECTIVE SHIPPING PACKAGE
ELIZABETHTON, TENNESSEE

JOB#: 10825-8-7008	FIGURE: UF6-TEMP
DRAWN BY: MNP	SCALE: NTS
APPR'D BY: [signature]	DATE: 6-11-98

FLAME TEMPERATURE DATA

Eco-Pak Specialty Packaging, Project No. 10810-8-7008

Flame Temperature

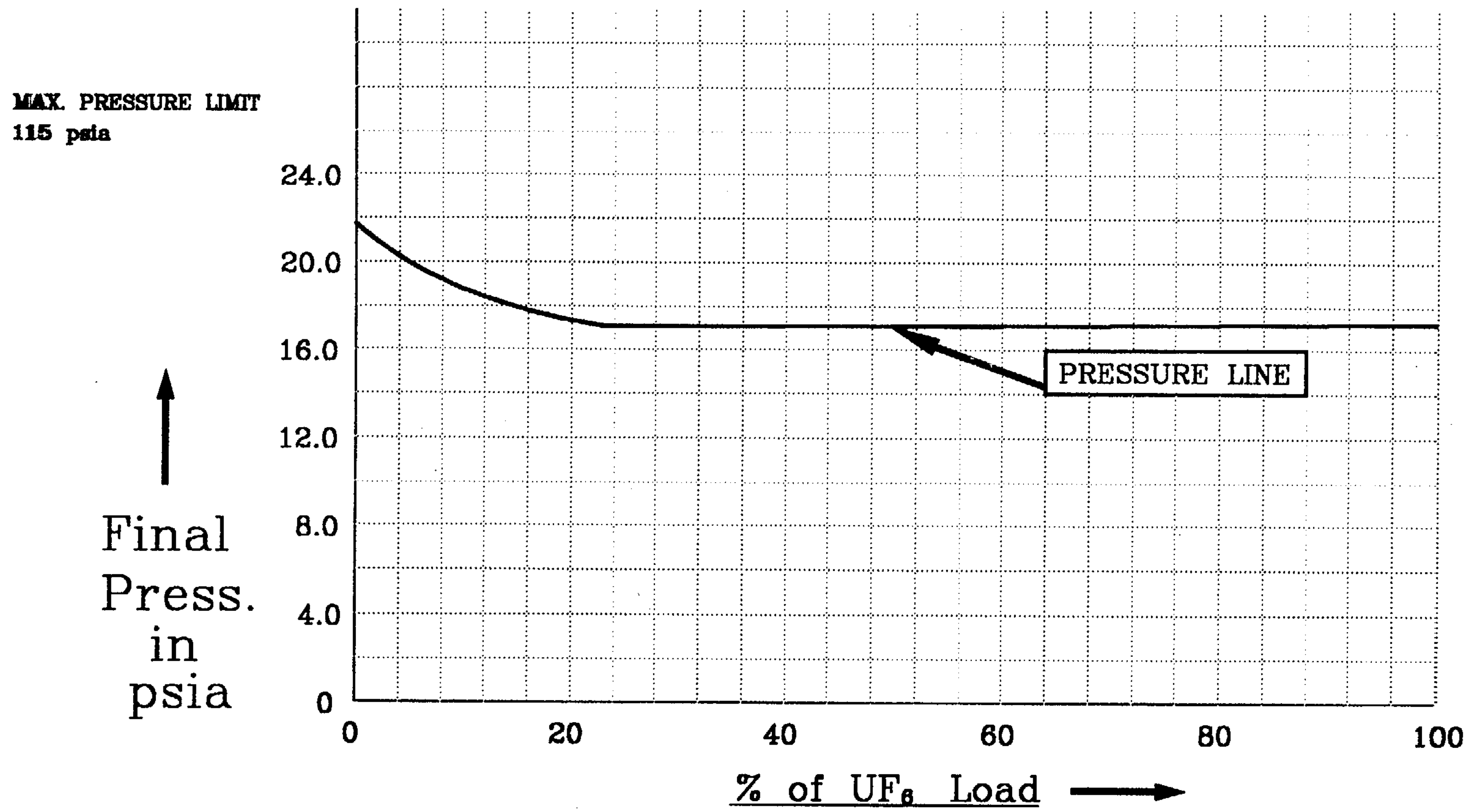
Thermocouple No.	TC15	TC16	TC17	TC18	TC19	TC20
0 MIN.	1505.7	992.9	712.9	180.9	177.8	275.4
1 MIN.	1657.0	1335.1	1022.1	582.7	1096.9	1293.2
2 MIN.	1970.6	1855.6	1393.6	946.0	945.5	1195.7
3 MIN.	2140.4	1767.0	1314.5	738.3	1153.6	1341.6
4 MIN.	2165.2	1711.4	1302.8	650.1	1133.5	1297.5
5 MIN.	2307.6	2123.7	1595.6	981.7	1585.6	1848.3
6 MIN.	1721.5	2163.9	1738.5	1089.3	1071.4	1089.8
7 MIN.	1687.5	2311.3	2190.8	1336.6	1216.5	1240.9
8 MIN.	1978.1	2265.0	1966.5	1068.2	1337.9	1420.0
9 MIN.	2032.1	1933.2	1631.2	923.6	1164.3	1332.9
10 MIN.	2195.2	2140.7	1736.0	975.6	1297.6	1402.3
11 MIN.	1513.3	1870.1	1709.0	932.8	1045.6	1035.9
12 MIN.	973.1	1490.3	1656.8	993.9	999.7	983.9
13 MIN.	1050.4	1497.6	1591.6	884.6	1052.3	949.7
14 MIN.	1546.4	1942.8	1796.7	1048.8	1134.2	1128.1
15 MIN.	2275.7	1908.3	1509.8	889.7	1247.0	1326.9
16 MIN.	2362.5	2047.2	1523.7	1004.3	1268.4	1323.6
17 MIN.	2075.8	1607.4	1391.6	868.7	1241.0	1386.5
18 MIN.	2383.5	1641.5	1346.5	1038.4	1663.9	1987.6
19 MIN.	2099.3	1467.8	1233.6	960.5	1770.2	2165.0
20 MIN.	2157.9	1728.4	1371.2	799.5	1175.6	1364.2
21 MIN.	2399.5	1906.0	1552.0	910.3	1325.8	1485.7
22 MIN.	2176.9	1570.0	1246.8	872.4	1419.7	1532.1
23 MIN.	1766.9	1989.0	1553.3	956.2	1087.9	1105.4
24 MIN.	1779.9	1246.9	1060.9	837.4	1423.4	1761.4
25 MIN.	1917.1	1305.9	1096.8	918.0	1599.5	1918.2
26 MIN.	2013.8	1322.9	1131.8	881.2	1640.2	2008.6
27 MIN.	2071.6	1604.0	1226.1	899.5	1244.0	1426.2
28 MIN.	2224.1	1587.9	1412.3	950.1	1511.1	1823.7
*29 MIN	2224.1	1587.9	1412.3	950.1	1511.1	1823.7
*30 MIN	2224.1	1587.9	1412.3	950.1	1511.1	1823.7
TOTAL OF 30	59091.1	52516.7	44126.7	27838.6	38874.5	43822.3

* ASSUMED TEMPERATURE SIMILAR TO 28 MIN. TEMPERATURE

59091.1	
52516.7	
44126.7	
27838.6	
38874.5	
43822.3	
266269.9	TOTAL OF ALL READINGS 30 x 6 = 180 READINGS

AVERAGE FLAME TEMPERATURE = 1479.28 DEGREES FAHRENHEIT

PRESSURE OF UF_6 UP TO MAXIMUM LOAD UNDER THE HYPOTHETICAL ACCIDENT CONDITION FIRE TEST



NOTES:

1. INITIAL PREHEATED TEMP. OF UF_6 AND VESSEL IS 37.2° C (99 °F)
2. INITIAL PRESSURE INSIDE CYLINDER (30 B) IS 14.7 PSI.
3. FINAL PRESSURES SHOWN ARE INSIDE THE CYLINDER (30 B).
4. CYLINDER WEIGHT IS 621 Kg (1369 LBS).
5. MAXIMUM RATED UF_6 LOAD IS 2277 Kg (5020 LBS, 100%).
6. TOTAL HEAT TRANSFER IS 43,347 KJ DURING 30 MINUTES FIRE TEST.

LAWGIBB GROUP

LAW ENGINEERING AND ENVIRONMENTAL SERVICES CHARLOTTE, NORTH CAROLINA

ECO-PAK, SPECIALTY PACKAGING
30X, PROTECTIVE SHIPPING PACKAGE
ELIZABETHTON, TENNESSEE

JOB# 10810-9-7003 Ph 08	FIGURE: 1
DRAWN BY: MNP	SCALE: NTS
APPR'D BY:	DATE: 6-8-99

APPENDIX 3.8.2

LAW ENGINEERING REPORT OF CYLINDER PRESSURE EVALUATION

June 8, 1999

Eco-Pak Specialty Packaging
107 Meadowview Farms Drive
Jonesborough, TN 37659

Attention: Ms. Heather Little

Subject: **Report of Cylinder Pressure Evaluation**
Protective Shipping Package and Inside Cylinder
Law Engineering and Environmental Services Project 10810-9-7003, Phase 08

Dear Ms. Little:

As per your request and as authorized by your Purchase Order Number 6413, Law Engineering and Environmental Services (LEES) is pleased to present this report evaluating the performance of the "ESP-30X" protective shipping package and the inside cylinder, referred as the "30B" cylinder. The purpose of this evaluation was to estimate the inside cylinder pressure with a given percentage of uranium hexafluoride (UF_6) contained in the internal cylinder during a hypothetical accident condition fire test. This report provides our understanding of the background information, services performed, and results.

Background Information

Eco-Pak Specialty Packaging provided information regarding the pool fire test procedure and its results to LEES on June 9, 1998. The thermal performance of the subject overpack "ESP-30X" was evaluated by conducting an open-pool fire test. We performed a thermal evaluation of uranium hexafluoride (UF_6) contained in the cylinder "30B" when the shipping package was subjected to a 30 minute fire test. For detailed information on this subject, please refer to our report dated June 11, 1998.

Subsequent to our report dated June 11, 1998, the Nuclear Regulatory Commission (NRC) requested Eco-Pak to "revise the application to show that any mass of UF_6, up to the maximum load, will not cause the cylinder to exceed the maximum allowable pressure under the hypothetical accident condition fire test."

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Industrial Services Business Segment
2801 Yorkmont Road, Suite 200 • Charlotte, NC 28208
P.O. Box 19667 • Charlotte, NC 28219
704-357-8600 • Fax: 704-357-8637

Ms. Heather Little of Eco-Pak requested LEES to perform calculations to satisfy the NRC request.

Services Performed

Pressure Evaluation for Hypothetical Accident Condition Fire Test

As mentioned in our previous report dated June 11, 1998, the cylinder "30B" and its contents temperature was increased from 99 degrees to 156 degrees Fahrenheit during the 30 minute fire test. The total heat absorption was calculated for the 57 degrees Fahrenheit increase to be 43,347 kilojoules, with an average heat flow rate of 24.08 kilojoules per second during the fire test.

For this project, LEES used the previously derived information to calculate the final pressure in the cylinder "30B" for various amounts of UF_6, starting from no load (0%) to full load (100%) condition. A graph showing the cylinder pressure vs. percent of UF_6 load is attached with this report. We assumed the following conditions for the cylinder pressure calculations:

- Initial preheated temperature of the cylinder and its contents (UF_6) is 37.2° Centigrade (99° Fahrenheit).
- Initial pressure inside the cylinder is 14.7 psia.
- The cylinder weight is 621 Kg (1369 Lbs).
- The maximum rated UF_6 load is 2277 Kg (5020 Lbs) = 100% load.
- Total heat transfer or absorption is 43,347 Kilojoules during 30-minute fire test (with an average heat flow rate of 24.08 kilojoules per second).
- Specific heat of steel = 0.47 Kilojoule/Kg °C.
- UF_6 Triple point temperature is 147 °F (63.89 °C).
- Volume of the cylinder "30B" = 0.736 meter^3.
- Density of UF_6 solid = 4997.76 Kg/meter^3.
- Density of UF_6 cake = 4870 Kg/meter^3.
- Density of UF_6 liquid = 3620 Kg/meter^3.
- Specific heat of UF_6 solid = 0.4773 Kilojoule/Kg °C
- Heat of Fusion of UF_6 (melting) = 54.661 Kilojoule/Kg

- Specific heat of UF_6 liquid = 0.544 Kilojoule/Kg °C.
- The final pressure in the cylinder was calculated using the ideal gas law.
- The cylinder wall temperature and its content UF_6 temperature are the same.

Please note that the heat required to bring UF_6 (100 % load) from 99 °F to 156 °F was 43,347 kilojoules, with an average heat flow rate of 24.08 kilojoules per second. A partially loaded cylinder will heat up more quickly than a fully loaded cylinder because it has less thermal mass. The rate at which heat enters the cylinder is proportional to the temperature difference between the cylinder "30B" wall and the overpack "ESP-30X" inner wall, and the mass of UF_6 contained in the cylinder. Therefore, the partially loaded cylinder will absorb less total heat than the fully loaded cylinder. However, in our analysis we conservatively assumed that the partially loaded cylinder would absorb the same amount of heat as a fully loaded cylinder.

Results Obtained

Based on our review of the pressure test data and the computation discussed above, the maximum pressure in the cylinder is approximately 21.8 psia, at 0% UF_6 load, which is lower than the allowable cylinder pressure of 115 psia.

Therefore, it is our opinion that any mass of UF_6, up to the maximum load, will not cause the cylinder to exceed the maximum allowable pressure of 115 psia under the hypothetical accident condition fire test, similar to the one tested and subjected to a thirty-minute fire condition represented by the test.

The properties of UF_6 and the cylinder configuration used in this analysis were obtained from the U.S. Department of Energy publication USEC-651 (Revision 7) Uranium Hexafluoride, A Manual of Good Handling Practices, dated January 1995, which was provided to us by Eco-Pak. The characteristics of the ESP-30X protective shipping package were obtained from the drawings supplied to LEES by Eco-Pak. If the data contained in this report are known to be incorrect or inappropriate for use in this analysis, please contact us so that we may re-evaluate our calculations accordingly.

Law Engineering and Environmental Services appreciates the opportunity to assist you with this project. Please contact this office at 704-357-8600 if you have any questions. We look forward to continuing our working relationship with you on this and future projects.

Sincerely,

LAW ENGINEERING AND ENVIRONMENTAL SERVICES

M.N. Parikh

Mike N. Parikh, P.E.
Senior Engineer

James W. Page

James W. Page, P.E.
Corporate Consultant

Attachment: Pressure Vs Percent of UF_6 Load Graph

SECTION FOUR CONTAINMENT

TABLE OF CONTENTS

4. CONTAINMENT

4.1 Containment Boundary

Containment for the ESP-30X protective shipping package is maintained by the Model 30B cylinder. **Appendix 1.3.3** (from ANSI N14.1) illustrates the 30B Cylinder.

4.1.1 Containment Vessel

The containment boundary for the ESP-30X Shipping Package is the 30B cylinder. Containment is maintained as long as there is no structural damage to the cylinder or its valve and as long as the cylinder is not over-heated or over-pressurized. ANSI N14.1 lists the following design requirements for the 30B Cylinder:

Design Pressure:	22 psig external
	200 psig internal
Design Temperature:	-40°F to 250°F

4.1.2 Containment Penetrations

The 30B cylinder has two penetrations: the fill valve in one end and the drain plug in the other end. The plug and valve meet the performance requirements specified in ANSI N 14.1.

4.1.3 Seals and Welds

The Model 30B cylinder is fabricated, inspected, tested, and maintained in accordance with United States Enrichment Corporation Report USEC-651 and ANSI N14.1. As required by ANSI N14.1, the cylinder is fabricated in accordance with Section VIII, Division 1, of the ASME Boiler and Pressure Vessel Code.

4.1.4 Closure

The 30B cylinder is closed by means of a threaded plug fitting on one end and on the other end by a special 1" gas valve which is fabricated, inspected, tested, and maintained in accordance with USEC-651 and ANSI N14.1 section 6.15. ANSI N14.1 states that the valve and plug inlet threads will be tinned; 7-12 threads will be engaged on the valve using between 200-400 ft-lb of torque; and 5-8 threads will be engaged on the plug using between 150-600 ft-lb of torque.

4.2 ***Requirements for Normal Conditions of Transport***

4.2.1 Containment of Radioactive Material

The only radioactive materials in fresh UF_6 are isotopes of uranium, primarily ^{235}U and ^{238}U which have unlimited A_2 values, with traces of ^{234}U. Reprocessed UF_6 contains traces of fission products, transuranics, and increased amounts of ^{232}U, ^{234}U, and ^{236}U. The maximum allowable leak rate for Type B shipments, assuming the maximum radioactive contents for reprocessed UF_6 and using the 30B cylinder, is 2.20E-6 ref-cm^3/sec (see Appendix 4.4.1 and 4.4.2) per ANSI N14.5-1997. The test results reported in Section 2 verify that the cylinder is capable of maintaining a leak tight condition (leak rate less than 10^{-7} ref-cm^3/sec) under the highest pressure expected under normal and hypothetical accident conditions (100 psia). Routine leak testing of each packaging (see Section 4.2.3) assures that containment is maintained during use.

The criticality safety of the package is maintained in part by assuring the package is leaktight. A rigorous quality assurance program insures that package leakage is maintained less than the maximum release rate specified for the package. Thus, the potential for water inleakage is very small. However, should inleakage occur, UF_6 reacts immediately and vigorously with water, producing considerable heat and UO_2F_2. The combined heat and UO_2F_2 will plug a hole larger than that specified previously for the maximum allowable leak rate, as demonstrated in practice throughout industry. Since water inleakage events are immediately self-extinguished, the specified maximum leak rate based on normal and hypothetical accident conditions are the more restrictive criteria.

4.2.2 Pressurization of Containment Vessel

During filling of the 30B cylinder with liquid UF_6, the maximum temperature inside the 30B cylinder is 180°F (USEC-651). This temperature would result in an internal UF_6 gas pressure of 60 psia. As stated in USEC-651, UF_6 is cooled and solidified and the internal pressure of a filled 30B cylinder is below atmospheric prior to shipment. At maximum normal temperature of UF_6, 136°F, the vapor pressure is less than 22 psia (**Sections 3.4.4** and **3.4.6**). At maximum temperature of UF_6 in a fire accident, 250°F, the vapor pressure would be 100 psia (**Sections 3.5.8** and **3.5.10**). All these are below the ANSI N14.1 internal design pressure of 200 psig.

4.2.3 Containment Criterion

Containment of the radioactive contents depends upon proper maintenance, periodic inspections, and preshipment inspections of the packaging. Containment boundary leak tests are performed using a leak test with a test sensitivity of at least 10^{-6} ref-cm^3/sec prior to the first use of each packaging, after maintenance, repair or replacement of components of the containment system, and periodically at intervals not to exceed 12 months. Pre-shipment leak tests are performed using a leak test with a test sensitivity of at least 10^{-3} ref-cm^3/sec. Per ANSI N14.5-1997, the required test

sensitivity for fabrication, maintenance, and periodic test activites is one half of the maximum allowable leak rate for the package, 1.10E-6 ref-cm^3/sec. The test sensitivity required for pre-shipment testing is 10^{-3} ref-cm^3/sec.

4.3 Containment Requirements for Hypothetical Accident Conditions

4.3.1 Fission Gas Products

Neither fresh nor reprocessed UF_6 contains fission gas products.

4.3.2 Containment of Radioactive Material

Using the methodology of ANSI N14.5-1997, the maximum permissible accident leak rate for a Type B shipment of UF_6 in a 30B cylinder is 2.61×10^{-4} ref-cm^3/sec. **Appendix 4.4.2** provides this calculation.

4.3.3 Containment Criterion

Full scale compliance testing was performed on the ESP-30X package. This testing is fully described in **Sections 2.10.8** and **3.5**. Upon completion of tests, two leak tests were performed. A 100 psig air pressure soap bubble leak test was performed on the valve threads, seat, cap, packing nut and stem of the 30B cylinder. This method is in accordance with new cylinder and periodic inspection requirements listed in ANSI N14.1. No bubbles were found.

Following the soap bubble test, a helium mass spectrometer was used to quantify the leak rate. The test results showed that the package before and after testing had a leak rate less 10^{-7} ref-cm^3/sec.

4.4 Appendices

4.4.1 Calculation of Permissible Leak Rate for Normal Conditions
4.4.2 Calculation of Permissible Leak Rate for Accident Conditions

APPENDIX 4.4.1
CALCULATION OF PERMISSIBLE LEAK RATE FOR NORMAL CONDITIONS

The package contents, as defined in Section 1.2.3, are assumed to be completely releasable in the form of UF_6 vapor at the maximum normal temperature (136°F). The maximum total radioactivity contained in the package (assuming the maximum isotopic content for reprocessed UF_6) is 24.6 Ci (calculated in Table A). The volume of the cylinder is 7.36E05 cm^3. The radioactivity concentration (releasable activity per unit volume) of the package for both Normal and Hypothetical Accident conditions is therefore:

$$24.6 \text{ Ci} / 7.36\text{E}05 \text{ cm}^3 = \mathbf{3.35E\text{-}05\ Ci/cm^3}.$$

The A_2 value for the mixture in the package is 0.0257 Ci (calculated in Table B).

The maximum allowable release rate for normal conditions, per ANSI N14.5-1997, is:

$$10^{-6} A_2 \text{ per hour} = 10^{-6} (0.0257) \text{ per hour} = \mathbf{7.15E\text{-}12\ Ci/sec.}$$

The maximum allowable leakage rate for normal conditions is:

$$7.15\text{E-}12 \text{ Ci/sec} / 3.35\text{E-}05\text{Ci/cm}^3 = \mathbf{2.14E\text{-}07\ cm^3/sec\ UF_6}.$$

The UF_6 maximum allowable leakage rate is correlated to the reference air leakage rate using the methods described in ANSI N14.5-1997 Annex B and the conditions listed in Table C. The allowable leak rate calculated for the package for the normal condition is **2.20E-6 ref-cm³/sec**.

Table A. Package Total Radioactivity

Isotope	Maximum Concentration	Total Mass in Package, g	Total Activity, Ci	Specific Activity, TBq/g[1]	Total Activity, TBq
U232	5.00E-09 g/gU	7.70E-03	1.73E-01	0.83	6.39E-03
U234	2.00E-03 g/gU	3.08E+03	1.91E+01	2.30E-04	7.08E-01
U235	5.00E-02 g/gU	7.70E+04	1.66E-01	8.00E-08	6.16E-03
U236	2.50E-02 g/gU	3.85E+04	2.50E+00	2.40E-06	9.24E-02
U238	9.23E-01 g/gU	1.42E+06	4.61E-01	1.20E-08	1.71E-02
TC99	5.00E-06 g/gU	7.70E+00	1.31E-01	6.30E-04	4.85E-03
TH228	1.17E-09 g/gU	1.80E-03	1.46E+00	30	5.40E-02
PU239	3.30E+00 Bq/gU	1.34E-06	1.37E-04	3.80E+00	5.08E-06
RU106/ RH106	2.10E+03 Bq/gU	2.69E-05	8.72E-02	1.20E+02	3.23E-03
RU103/ RH103	8.85E+02 Bq/gU	1.14E-06	3.68E-02	1.20E+03	1.36E-03
CE144/ PR144	8.35E+03 Bq/gU	1.07E-04	3.47E-01	1.20E+02	1.29E-02
SB125	1.03E+03 Bq/gU	4.07E-05	4.29E-02	3.90E+01	1.59E-03
CS134	2.83E+02 Bq/gU	9.08E-06	1.18E-02	4.80E+01	4.36E-04
CS137/ BA137	7.78E+02 Bq/gU	3.74E-04	3.24E-02	3.2	1.20E-03
ZR95	5.98E+02 Bq/gU	1.17E-06	2.49E-02	7.90E+02	9.21E-04
NB95	5.74E+02 Bq/gU	5.89E-07	2.39E-02	1.50E+03	8.84E-04
	Total	**Activity**	**24.5980 Ci**		**0.9114 TBq**

1 10CFR71, App. A.

Table B. Mixture A_2 Calculation

Isotope	Radioactive content (Ci)	Radioactive content per total UF_6 mass (Ci/g)	10CFR71 A_2 per isotope (Ci)	Releasable Activity Fraction	A_2 Fraction
U232	1.73E-01	1.12E-07	0.00811	7.01E-03	8.64E-01
U234	1.91E+01	1.24E-05	0.027	7.77E-01	2.88E+01
U235	1.66E-01	1.08E-07	Unlimited	6.76E-03	N/A
U236	2.50E+00	1.62E-06	0.027	1.01E-01	3.75E+00
U238	4.61E-01	2.99E-07	Unlimited	1.87E-02	N/A
TC 99	1.31E-01	8.51E-08	24.3	5.32E-03	2.19E-04
TH228	1.46E+00	9.49E-07	0.0108	5.93E-02	5.49E+00
PU239	1.37E-04	8.92E-11	0.00541	5.57E-06	1.03E-03
RU106/ RH106	8.72E-02	5.66E-08	5.41	3.54E-03	6.54E-04
RU103/ RH103	3.68E-02	2.39E-08	24.3	1.49E-03	6.15E-05
CE144/ PR144	3.47E-01	2.26E-07	5.41	1.41E-02	2.61E-03
SB125	4.29E-02	2.78E-08	24.3	1.74E-03	7.16E-05
CS134	1.18E-02	7.65E-09	13.5	4.78E-04	3.54E-05
CS137/ BA137	3.24E-02	2.10E-08	13.5	1.31E-03	9.73E-05
ZR95	2.49E-02	1.62E-08	8.11	1.01E-03	1.25E-04
NB95	2.39E-02	1.55E-08	13.5	9.69E-04	7.18E-05
Total	**2.46E+01**	**1.6E-05**			**38.89**
Mixture A_2					**0.0257 Ci**

Table C. Normal Condition Fluid Properties

Property	UF_6 Normal Condition	Equivalent Reference Air
Upstream Pressure, atm	1.07 [2]	1.00
Downstream Pressure, atm	1.00	0.01
Temperature, K	331	298
Molecular Weight, g/gmol	352	29
Viscosity, cP	0.0188 [3]	0.0185
Assumed hole length, cm	1.0	1.0
Hole diameter [4], cm	3.863E-04	3.863E-04

2 Vapor pressure over solid at 331 K, NUREG/CR-4360, p.5 Vol. 1.
3 NUREG/CR-4360, p. 9, Vol. 1.
4 Calculated for UF_6 per ANSI N14.5-1997 Annex B, Section B.3, Equations B.1 through B.5.

APPENDIX 4.4.2
CALCULATION OF PERMISSIBLE LEAK RATE FOR ACCIDENT CONDITIONS

The package contents, as defined in Section 1.2.3, are assumed to be completely releasable in the form of UF_6 vapor at the maximum HAC content temperature (250°F). The maximum total radioactivity contained in the package calculated in Appendix 4.4.1 is 24.6 Ci. The radioactivity concentration (releasable activity per unit volume) of the package, calculated in Appendix 4.4.1 for both Normal and Hypothetical Accident conditions, is 3.35e-05 Ci/cm^3. The mixture A_2, also calculated in Appendix 4.4.1, is 0.0257 Ci.

The maximum allowable release rate for HAC, per ANSI N14.5-1997, is:

A_2 per week = (0.0257) per week = **4.24E-8 Ci/sec.**

The maximum allowable leakage rate for HAC is:

4.24E-8 Ci/sec / 3.35E-05Ci/cm^3 = **1.27E-03 cm^3/sec UF_6.**

The UF_6 maximum allowable leakage rate is correlated to the reference air leakage rate using the methods described in ANSI N14.5-1997 Annex B and the conditions listed in Table D. The maximum allowable leakrate calculated for the package for HAC is **2.61E-4 ref-cm^3/sec.**

Table D. HAC Fluid Properties

Property	UF_6 Normal Condition	Equivalent Reference Air
Upstream Pressure, atm	6.775	1.00
Downstream Pressure, atm	1.00	0.01
Temperature, K	394	298
Molecular Weight, g/gmol	352	29
Viscosity, cP	0.02216	0.0185
Assumed hole length, cm	1.0	1.0
Hole diameter7, cm	1.36E-03	1.36E-03

---

5 Vapor pressure over liquid at 394 K, NUREG/CR-4360, p.5 Vol. 1.

6 NUREG/CR-4360, p. 9, Vol. 1.

7 Calculated for UF_6 per ANSI N14.5-1997 Annex B, Section B.3, Equations B.1 through B.5.

5. ***SHIELDING EVALUATION***

Gamma and neutron shielding are not required for cylinders of UF_6 because the 0.5 inch thick cylinder walls provide more than adequate shielding for low enriched uranium, both fresh and reprocessed. However, it is the responsibility of the shipper to assure compliance with 10CFR71.47 regarding radiation standards for each shipment.

SECTION SIX CRITICALITY EVALUATION

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LIST OF TABLES

6. *CRITICALITY EVALUATION*

6.1 Discussion and Results

For criticality control, the ESP-30X relies upon:

specification of maximum H/U ratio, or equivalently, minimum UF_6 purity;

impact absorption by the protective overpack, which prevents damage to the 30B cylinder sufficient to cause water in-leakage or reduction of package volume under normal and accident conditions; and

thermal protection of the cylinder by the overpack, which prevents damage to the cylinder which could cause the contents to leak out or water to leak in.

Purity control is provided according to ASTM C787 and C996 (**References 6.6.1** and **6.6.2**, respectively) which require minimum 99.5% purity. The maximum H/U atomic ratio of 0.088 allowed according to 49CFR173.417, Table 6, corresponds to 0.5% impurity, with all the impurity being hydrogen fluoride (HF). Drop, puncture, and fire testing described in **Section 2.7** demonstrate that water will not leak in, nor will the contents leak out under accident conditions. The testing also demonstrates that the overall dimensions of the overpack will remain essentially the same, so that the spacing assumed in modeling an array of packages is valid for both normal and accident conditions.

A criticality evaluation is provided in ORNL/TM- 11947 (**Reference 6.6.3**). This evaluation is directly applicable to this packaging. The report evaluates k_{eff} using the SCALE4 computer code system for an infinite array of packages with optimum interspersed moderation, and finds the worst case to be $k_{eff} = 0.817 \pm 0.003$. The worst case calculation is summarized in **Table 6-1**. An infinite array of damaged or undamaged packages remaining subcritical corresponds to a transport index for criticality control of zero. However, the transport index of 5 is used based on earlier revisions of the Certificate of Compliance for similar overpack designs, including the DOT-21PF-1 as specified in 49CFR173.417, Table 6.

6.2 Package Loading

The ESP-30X package contents may be either fresh or reprocessed UF6, The loading is

Cylinder Type:	Model 30B
Maximum Weight of UF_6:	5,020 lb
Maximum U^{235} Enrichment:	5 wt%
Minimum UF_6 purity:	99.5 wt%

Transport Index for criticality control: 5.0

Because the contents are loaded as a liquid which solidifies upon cooling before shipment, the geometric configuration of the contents can vary somewhat. The form of the contents is the same for both normal and accident conditions, except for variation of density with temperature. Several possible geometric configurations of the solid UF_6 and the variation of density with temperature are evaluated in the ORNL criticality calculation.

Hydrostatic testing has verified that water will not leak into the 30B cylinder after accident testing. The only moderation internal to the 30B cylinder is provided by the impurities, which may include HF, and which are limited as noted above. For the purpose of the criticality calculation, the maximum H/U ratio, 0.088, is assumed.

Table 6-1

Model Conditions	Normal and accident, same model
Number of packages in contact	Infinite
$k_{eff} \pm s$	0.817 ± 0.003
Optimum interspersed moderation	Water, specific gravity = 0.015
Close reflection by water	Not applicable
Package size, including overpack	54.81 cm radius, 231.14 cm height
Internal size of 30B cylinder	36.83 cm radius, 172.78 cm height
Overpack material	Water, same as interspersed
Package contents	UF_6, 5% enriched, 99.5% pure, 5.1 g/cm^3, 5030 lb
Temperature	20°C
Contents geometry	Solid UF_6 cylinder with central cylindrical void
Internal moderation	No water; 0.5% impurity entirely HF; H/U = 0.088

6.3 Model Specification

The model is described in Section 3.1 of ORNL/TM-11947 (**Reference 6.6.3**). Although the model is based upon the DOT-21PF-1 overpack, most of the calculations, including the worst case, used the outer dimensions of the overpack to maintain the spacing between packages, but replaced the actual overpack materials by water at the density of the interspersed moderator. The ESP-30X has slightly larger dimensions, providing even greater spacing between packages.

Substituting the materials is additionally conservative, making the model more than appropriate in evaluating the ESP-30X packaging despite any material differences between the overpacks. The diameter and length of the ESP-30X are 55.40 and 233.68 cm respectively.

6.4 Criticality Calculation

The calculations described in **Reference 6.6.3** were performed using the CSAS25 sequence from the SCALE4 computer code system with the SCALE 27 group ENDF/B-IV cross sections. The calculations first assume an internal geometric configuration of the contents, an infinite square lattice array, and a temperature of 20°C, and vary the water density to find the optimum interspersed moderation. At and near that water density, sensitivity studies are performed varying contents configuration, temperature and corresponding UF_6 density, and closer package spacing to simulate triangular pitch arrays.

The results are summarized in Table 4 of the report, and the worst case is summarized in **Table 6-1** above.

6.5 Criticality Benchmark Experiments

The validation of the computer code and cross sections against 51 critical experiment benchmarks is described in Sections 2.2 and 3.2.5 of Reference 6.6.3.

6.6 References

6.6.1 ASTM Standard C787, "Standard Specification for Uranium Hexafluoride for Enrichment."

6.6.2 ASTM Standard C996, "Standard Specification for Uranium Hexafluoride Enriched to Less Than 5% ^{235}U.

6.6.3 ORNL/TM-1 1947, Criticality Safety Review of 2 ½-, 10-, and 14-Ton UF_6, Cylinders, B.L. Broadhead, Martin Marietta Energy Systems, Oak Ridge National Laboratory, October, 1991.

SECTION SEVEN OPERATING PROCEDURES

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7. *OPERATING PROCEDURES*

The ESP-30X overpack is loaded and unloaded and the 30B UF_6 cylinder is filled, tested, and handled in accordance with standard, in-plant, operating procedures at various enrichment plants and at various nuclear fuel facilities. These procedures are described in USEC-651 and ANSI Standard N14.1. As a minimum, the specific procedures include steps described in the subsequent sections.

7.1 *Procedures for Loading Package*

7.1.1 Receipt and Filling of 30B Cylinder

Receipt and filling of the 30B cylinder shall be performed in accordance with USEC-651 and ANSI N14.1.

7.1.2 Cylinder Inspection

Complete inspection report verifying that the cylinder meets the guidelines of USEC-651 and the requirements of ANSI N14.1; that it has been leak-tested as required below; and that the cylinder and cylinder components are free from damage and are in working order as follows:

a. Cylinder is free from damage and is ASME "U" stamped, and has evidence that it has been cleaned and tested as required in USEC-651 and ANSI N14.1.

b. Cylinder and cylinder valve and plug are free from damage and has required evidence of proper inspection and leak testing in accordance with ANSI N14.1.

7.1.3 Additional Type B Requirements for Cylinder Inspection

If the cylinder is to be used for a Type B shipment of UF_6, the following items must be completed:

a. The isotopic and radionuclide contents of each cylinder must be determined, and the UF_6 must meet the contents limits specified in Section 1.2.3.

b. Based on (a.) above, the A_2 value for the cylinder contents must be established in accordance with 10CFR71, Appendix A. The cylinder must not contain more than an A_2 mixture value of 0.0257 Ci per Appendix 4.4.1.

c. The cylinder must have been leak tested with a test that has a sensitivity of 1.1×10^{-6} std cc/sec within the past 12-month period or since valve or plug replacement, demonstrating no leakage greater than 2.2×10^{-6} std cc/sec (Appendix 4.4.1).

d. After filling with UF_6, the cylinder and cylinder valve and plug shall have been leak tested with a test that has a sensitivity of 1×10^{-3} std cc/sec per ANSI N14.5, demonstrating no leakage at that rate.

7.1.4 Overpack Inspection

The user shall inspect the ESP-30X overpack in accordance with written procedures prior to every outgoing shipment and upon receipt of every incoming shipment to assure the following:

a. Overpack base and supports are sound with no broken welds or components.

b. Overpack inner and outer shells are free from corrosion, pitting, cracks, broken welds and pinholes.

c. Inner shell is free of debris and standing water and is intact and is not in a deteriorated or damaged condition.

d. Gaskets and cylinder support pads are in place and intact and are not in a deteriorated or damaged condition.

e. Cover plates and welds are sound and undamaged.

f. Overpack halves fit together properly with no gaps.

g. All four one-inch vent plugs are securely in place.

h. Check to see there is no closure bolt damage or loss.

i. Ensure that security seal holes are functional and capable of maintaining their integrity when seals are used.

j. Ensure that the overpacks are within the most recent five-year recertification performed in accordance with ANSI N14.1, USEC-651 and Section 8 of this application.

7.1.5 Procedure for Loading the ESP-30X Overpack

a. Make certain an inspection of the overpack has been completed in accordance with the latest revisions of both ANSI N14.1 and USEC-651, as well as Section 7.1.4 above.

b. Carefully load 30B cylinder into bottom half of overpack with the cylinder valve positioned up (at 12:00 o'clock position).

c. Carefully place lid on overpack.

d. Tighten all bolts closures alternating first corner-to-corner (4 closures) followed by side-to-side (6 closures). Properly torque all closure bolts at 150 ft-lbs.

e. Install security seals and record their numbers.

f. Complete inspection report.

g. Complete radiation survey in accordance with 10 CFR 71.87 (i.) and (j).

h. Remove old labels and re-label per applicable regulations.

i. Overpack surface temperatures must be in accordance with 10 CFR 71.43 (g) during transportation

7.2 Procedures for Unloading Package

Unload the ESP-30X overpack as follows:

a. Complete receiving report.

b. Remove and record the overpack seal.

c. Loosen all bolts

d. Remove the overpack lid.

e. Remove 30B cylinder from overpack.

f. Clean any loose debris from overpack interior.

g. Close overpack prior to storage.

7.3 Preparation of Empty Package for Transport

Preparation of an empty overpack for shipment:

a. Close the overpack.

b. Complete radiation survey in accordance with 10 CFR 71.87 (i.) and (j).

c. Remove old labels and re-label per applicable regulations.

SECTION EIGHT ACCEPTANCE TESTS AND MAINTENANCE PROGRAM

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8.0 ACCEPTANCE AND MAINTENANCE PROGRAMS

This section describes the activities to be performed in compliance with Subpart G of 10CFR71 to assure that the ESP-30X package conforms to the requirements of this Safety Analysis Report and remains in conformance following loading.

8.1 Acceptance Tests

8.1.1 Acceptance Tests for the ESP-30X Overpack

Each completed overpack shall be inspected to document compliance with the following drawing requirements:

a. Final dimensions as described below:
   - Inner cylinder cavity dimensions.
   - Outer shell dimensions.
   - Closure bolt locations.
   - Bolt center locations and hole diameters in tie down supports.
   - Flatness of gasket surface.

b. Installation of gaskets and cylinder support pads.

c. Lid to body fit.

d. Closure bolt and nut adjustments.

e. Installation of lifting shackles and security seal pads.

f. Actual weights of lid and bottom halves.

g. Final assembled weights.

h. Proper permanent marking and nameplates per 10CFR71.85(c), 49CFR172.310, and ANSI N14.1 (latest revision).

8.1.2 Acceptance Tests for the 30B Cylinder

Acceptance tests for the 30B cylinder shall be in accordance with ANSI N14.1.

8.1.3 Type B Acceptance Test for the 30B Cylinder

The 30B cylinder shall be leak tested with equipment and tests per ANSI N14.5 that has a sensitivity of 1.1 x 10-6 std cc/sec, demonstrating no leakage greater than 2.2 x 10-6 std cc/sec (Appendix 4.4.1).

8.2 Maintenance Programs

8.2.1 Maintenance Programs for the ESP-30X Overpack

The user shall establish written procedures for the periodic maintenance and inspection of each Model ESP-30X overpack requiring the following as a minimum:

8.2.1.1 Pre-shipment

a. Overpack base and supports are sound with no broken welds or components.

b. Overpack inner and outer shells are free from corrosion, pitting, cracks, broken welds and pinholes.

c. Inner shell is free of debris and standing water and is intact and is not in a deteriorated or damaged condition.

d. Gaskets and cylinder support pads are in place and intact and are not in a deteriorated or damaged condition.

e. Cover plates and welds are sound and undamaged.

f. Overpack halves fit together properly with no gaps.

g. All four one-inch vent plugs are securely in place.

h. Check to see there is no closure bolt damage or loss.

i. Ensure that security seal holes are functional and capable of maintaining their integrity when seals are used.

j. Ensure that the overpacks are within the most recent five-year recertification performed in accordance with ANSI N14.1, USEC-651 and Section 8.2.1.3 below.

8.2.1.2 Annually

a. Check that the lifting shackles, closure bolts and supports, and tie-down supports are sound and free from unacceptable discontinuities, damage and deterioration.

b. Check that all four one-inch vent plugs are properly sealed.

c. Check that the inner and outer shells are free of unacceptable discontinuities, and the inner shells are free of debris and standing water.

d. Check that the cover plates are sound and undamaged, and gasket sealing surfaces meet drawing requirements.

e. Individually weigh each half (lid and bottom) of each packaging to verify that neither half has gained more than 25 pounds. Weight gain must be assumed to be water. If either half exhibits a gain of more than 25 pounds, the packaging must be removed from service and dried to within 10 pounds of its original nameplate weight. New weights of each packaging half must be established after any modifications, refurbishment, or re-painting . After drying each packaging must be inspected, as above.

f. Check that gaskets are in place, intact, and not damaged or deteriorated.

8.2.1.3 Every Five Years

The owners are responsible for re-certifying the ESP-30X overpack every five years to meet original design specifications. The following inspections shall be performed:

a. Perform all pre-shipment and annual inspections stated above.

b. Full visual inspection of all welds for the presence of discontinuities. Any questionable condition of a weld shall be subject to further examination to assure that no unacceptable discontinuities are present. Weld defects shall be repaired.

c. Check the base and lid for warpage and/or distortion, which could prevent tight closure. Check that the gasket sealing surfaces meet design specifications.

d. Assure that vent plugs are properly sealed.

e. Verify that inner and outer shells are free of corrosion, pitting, unacceptable discontinuities, broken welds and pinholes.

f. Assure that security seal holes are functional and capable of maintaining their integrity when seals are used.

g. Permanently mark the exterior nameplate listing the date of recertification, the individual base and lid weights, and the name of the re-certifying company.

h. The overpack shall receive a full visual inspection for rusting and the presence of corrosion. This inspection shall include assurance that corrosion or other indications have not reduced the skin wall thickness by an average of 10% of the nominal thickness over any six-inch square area. When visual inspection cannot assure sufficient wall thickness, other examinations shall be utilized, such as ultrasonic testing, to assure acceptability.

i. All repairs shall be performed by competent sources. Allowable repairs shall include repairs to welds and base metal as referenced in (h.) above. Repairs that require welding shall be made by welders who are qualified in accordance with Section IX of the ANSI/ASME Boiler and Pressure Vessel Code or Section 5 of ANSI/AWS D1.1. The repair shop shall provide certification of weld procedures and welder qualifications.

8.2.2 Maintenance Program for the 30B Cylinder

Maintenance of the 30B Cylinders shall be performed in accordance with ANSI N14.1.

8.2.3 Type B Inspection for the 30B Cylinder

8.2.3.1 Pre-shipment

a. The isotopic and radionuclide contents of each cylinder must be determined, and the UF_6 must meet the contents limits specified in Section 1.2.3.

b. Based on (a.) above, the A_2 value for the cylinder contents must be established in accordance with 10CFR71, Appendix A. The cylinder must not contain more than an A_2 mixture value of 0.0257 Ci per Appendix 4.4.1.

c. After filling with UF_6, the cylinder and cylinder valve and plug shall be leak tested with a test that has a sensitivity of 1×10^{-3} std cc/sec per ANSI N14.5, demonstrating no leakage at that rate.

8.2.3.2 Annually

The cylinder shall be leak tested with equipment and a test in accordance with ANSI N14.5 that has a sensitivity of 1.1×10^{-6} std cc/sec, demonstrating no leakage greater than 2.2×10^{-6} std cc/sec (**Appendix 4.4.1**).