KNAPP MILLS INC.
WILMINGTON, DELAWARE

MASTER

**PIQUA-ELK RIVER REACTORS
SPENT FUEL SHIPPING CASK**

THERMAL TEST REPORT

COO-1028-2

Prepared by:

KNAPP MILLS, INCORPORATED
Wilmington, Delaware

For:

UNITED STATES ATOMIC ENERGY COMMISSION
CHICAGO OPERATIONS OFFICE

Contract AT (11-1)-1028

May 29, 1964

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I - SUMMARY

A test program designed to verify the thermal design and obtain performance data on the Piqua-Elk River Spent Fuel Shipping Cask was carried out in February and March 1964. Tests with the cask water-filled and dry were performed. Also, cooldown tests designed to bring the dry cask from relatively high internal equilibrium temperatures to immersion temperatures for unloading were performed.

Test results are in good agreement with design calculations. Areas in which analysis was known to be conservative are evident from the test data. Cask design is based on the requirement to ship 19 Piqua and Elk River Reactor fuel assemblies which have operated at full power for design core life in the hottest region of the core within 120 days after reactor shutdown. Dry test results show that the cask meets this requirement with slightly lower maximum fuel temperatures than calculated. Wet test results show that the cask has additional heat dissipating capacity beyond that required. Ability to safely cool the dry cask was demonstrated and sufficient data were obtained from cooldown tests to develop a standard air-water cooldown procedure and alternate steam-water procedure. Inspection of cask and internal components after completion of test program showed that thermal cycling had no detrimental effects on the cask assembly.

Based on test results extrapolated to design conditions of 100°F ambient and maximum solar heat, cask capacity is 36,000 Btu/Hr. water-filled and 28,000 Btu/Hr. dry using 10 CFR 72 limitation on maximum accessible surface temperature of 180°F. Based on 10 CFR 72 limitation of 50 psig maximum allowable internal pressure, cask capacity water-filled is estimated at 56,000 Btu/Hr. Since the 28,000 Btu/Hr. capacity is 4% less than Piqua design heat load, an additional decay time of approximately 10 days may be required to fully comply with 180°F accessible surface temperature limitation in 10 CFR 72.

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TEST PROCEDURE

Thermal tests were carried out in accordance with the procedure included in this section dated August 16, 1963, with the following exceptions:

1. Section III - 3 Cooldown Tests Required

Review of data obtained in wet and dry tests indicated that it would be desirable and possible to perform cooldown tests at maximum anticipated heat load rather than the lesser value of rated cask capacity. Therefore, the cask was brought to equilibrium at 40,000 Btu/Hr. and cooldown tests carried out from that point. Also, in addition to water spray and forced air coolants specified, a water-air "atomized" mixture was tried.

2. Section V - 3 Cooldown Test Set-Up

Thermocouples 17 through 28 and 38 through 40 on Drawing B-1032 were disconnected and removed for cooldown test to minimize sealed penetrations for thermocouple wires in test head. Also, individual flow meters were used on spray ring and drain line to measure flows independently. Pressure Gage P₁ on B-1033 was placed upstream of air line valve and a water atomizing fitting installed just downstream of air valve.

3. Section VI - C Cooldown Test Procedure

Steps 7 through 22 were modified to try the different coolants consecutively in one heatup-cooldown cycle rather than individually. This was decided early in test when limited effectiveness of forced air coolant alone was observed. In general, procedure was carried out as follows:

- a. External water spray from spray ring was turned on and left on throughout test.
- b. When outer shell temperature curve appeared to level off, forced air was turned on to cask drain line.

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- c. When center adapter temperature curve appeared to level off, water was admitted to forced air line through special fitting forming an atomized air-water mixture.
- d. Water-to-air ratio was gradually increased until internal temperatures were reduced to levels at which direct water filling could safely be carried out.
- e. Air was shut off and water increased to 5 GPM for filling and circulating to complete cooldown.

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PIQUA-ELK RIVER REACTORS

SPENT FUEL SHIPPING CASK

THERMAL TEST PROCEDURE

Rev. 1 8/16/63

PREPARED BY:
KNAPP MILLS, INCORPORATED
WILMINGTON, DELAWARE

FOR

UNITED STATES ATOMIC ENERGY COMMISSION
CHICAGO OPERATIONS OFFICE
CONTRACT AT(11-1)-1028

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I. INTRODUCTION

The Piqua-Elk River Reactors Spent Fuel Shipping Cask is designed to transport 19 fuel assemblies from either reactor 120 days after shutdown from operation at full power for design core life. The Piqua fuel assemblies are carried directly in the cylindrical fuel basket; to carry Elk River fuel assemblies a set of adapters is added to the basket. The cask is designed for dry shipment normally but is also suitable for using water or inert gas coolants. This test program is required to confirm the design, demonstrate compliance with 10 CFR 72 and obtain information for detailed operating procedures.

II. OBJECTIVES

The specific objectives of the Thermal Tests are as follows:

1. Determine decay heat removal capacity of cask with water coolant within limitations of 10 CFR 72.38.
2. Determine decay heat removal capacity of cask air-filled and unpressurized within limitations of 10 CFR 72.38.
3. Obtain data for detailed cooldown procedures by simulating actual cooldown operations of the dry cask.

III. TESTS REQUIRED

To accomplish the above objectives, the following tests are required. In all tests, the cask will be assembled with the Elk River adapters in place and the test head installed. Decay heat release in the cask will be simulated by 19 electrical heaters. The cask will be placed in the vertical position in an area where ambient air is "still".

1. Wet Tests - With the cask filled with water, the equilibrium coolant temperature, internal pressure and outer shell temperature will be measured at heat release rates of 10,000, 20,000, 30,000 and 40,000 Btu/Hr.
2. Dry Tests - With the cask air-filled and unpressurized, adapter, basket, inner shell and outer shell equilibrium temperatures will be measured at heat release rates of 10,000, 20,000, 30,000 and 40,000 Btu/Hr.
3. Cooldown Tests - After results of wet and dry tests have been analyzed to determine maximum decay heat removal capacity, the cask, air-filled

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III. TESTS REQUIRED (Continued)

and unpressurized, will be brought to equilibrium at this capacity and cooldown operations simulated. The two procedures listed below will be tried to determine the best method.

- a. Water spray on external surface followed by forced air circulation through cask drain line; then controlled water filling.
- b. Water spray on external surface followed by controlled water fill through cask drain line.

The objective of each method will be to reduce cask, basket and fuel temperatures as much as possible before cask is immersed in unloading pool. Cask temperatures will be indicated by installed cask inner shell thermocouples. Basket and adapter temperatures will be indicated by thermocouples installed for dry tests. Air flow rates will be regulated to carry off decay heat release and reduce cask and basket temperatures.

IV. EQUIPMENT REQUIRED

The following equipment is required to perform the above test. Those items marked (*) are available at Knapp Mills. All others will be purchased or fabricated.

WET AND DRY TESTS

1. Power Supply (*) 100 KW 230V D.C. synchronous motor M-G set with voltage variable from 50 to 240 volts.
2. Temperature Indicator (*) Thermo Electric Model 80049 self-compensating direct reading potentiometer for I-C thermocouples 0-600°F scale in 1°F increments.
3. Thermocouple Switches (*) Bank of six ten point L&N thermocouple switches total thermocouple capacity - 60.
4. Pressure Gage (*) 0-300 psi Heise Gage graduated in 1 psi increments.
5. Thermocouples (Cask and Basket) - 500 feet TG-26-AT and 500 feet TG-20-AT Iron-Constantan thermocouple wire.
6. Thermocouples (coolant) - Five Thermo Electric Iron-Constantan, Type 5-AT 1444 - 10" long and one Type 5-AT 1444 - 82" long, thermocouples in stainless steel probes.

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IV. EQUIPMENT REQUIRED (Continued)

7. Thermometers (*) Eight 0-100°F Mercury-in-Glass thermometers for ambient air temperature indication.
8. Heaters - Nineteen 1 KW 230V heaters per Drawing A-148, Rev.3. Heater designed to simulate Piqua and Elk River fuel element as closely as required for adequate evaluation of cask heat removal capacity.
9. Test Head - One test head per Drawing A-149, Rev.1, with bolts and gaskets.
10. Vent Valve - 3/4" - 150 lb. Globe Valve.
11. Relief Valve - 1" - 150 lb. relief valve set for 75 psi @ 320°F.

COOLDOWN TESTS

12. Water Spray Ring - 60" O.D. 1-1/2" pipe ring drilled for water spray on cask external surface.
13. Water Catch Pan - 6' dia. by 6" deep sheet metal pan to catch and drain off water from cask during cooldown.
14. Flow Meter - 0-50 GPM water flow meter to indicate cooldown spray flow and cask filling rate.
15. Well Thermometers - Two 400°F well thermometers to indicate steam, air or water temperature in and out of cask.
16. Hoses and Fittings - Miscellaneous hoses for steam, air or water with standard hose fittings to connect to cask drain and vent valves.
17. Valves - Standard 1" - 150 lb. Globe Valves as required for air and water service.

V. TEST SET-UP AND INSTRUMENTATION

1. Wet Test

The cask will be assembled with basket and Elk River adapters in place. The 19 heaters and coolant thermocouple probes will be installed in test head and lowered carefully into the basket. Instrumentation will be as shown on Drawing E-1031. Heaters will be wired in parallel. Cask will be filled with water to about 3" above adapter upper end.

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V. TEST SET-UP AND INSTRUMENTATION (Continued)

2. Dry Test

The cask will be assembled with basket and Elk River adapters in place. Thermocouples will be located as shown on Drawing E-1032. Fine thermocouple wire will be used between center adapter and center basket cavity to indicate maximum basket temperature. Thermocouples will also be located in four cavities opposite cask inner shell thermocouples installed in cask body. These four thermocouples will indicate basket O.D. temperature. Thermocouple junction will be attached to basket and adapters by drilling a very small shallow hole and peening aluminum to retain junction. The vent valve on test head will be cracked open to prevent pressurizing the cask but will not be open wide enough to allow air circulation. Heaters will be installed in same manner as in wet test.

3. Cooldown Test

The cask will be assembled with basket and adapters in place. Heaters will be installed in same manner as in wet tests. Instrumentation will be as shown on Drawing B-1032 and B-1033. Air and water supply will be arranged as shown schematically on Drawing B-1033 to permit convenient changing of coolants. Coolant inlet pressure and temperature and outlet temperature will be measured at points shown. Water flow rate will be measured directly. Air flow will be indicated by inlet pressure.

VI. TEST PROCEDURE

A. Wet Tests

1. Assemble cask body, basket and Elk River adapters in vertical position in test area.
2. Install heaters in test head.
3. Fill cask with water to 2-1/2" over top of adapters.
4. Position gasket on container body and install test head on cask body. Make certain basket orientation with respect to closure bolts is such that heaters will be centered in basket adapters.
5. Install five 10" and one 82" coolant thermocouples in test head (Thermocouples 17 thru 22, Dwg. B-1031).

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VI. TEST PROCEDURE (Continued)

A. Wet Tests (Continued)

6. Install relief valve, vent valve and pressure gage in test head.
7. Pressure test cask with water; no leakage permissible.
8. Make up 14 thermocouples and check in boiling water.
9. Attach 12 thermocouples to outer shell as shown on Dwg. B-1031.
10. Attach one thermocouple to test head surface as shown on Dwg. B-1031.
11. Attach one thermocouple to fin tip clamp.
12. Connect cask body thermocouples to switchboard with I-C wire.
13. Connect all thermocouples to switchboard and switchboard to potentiometer.
14. Calibrate potentiometer against "mini-mite" potentiometer.
15. Connect 19 heaters in parallel and connect power leads to control panel. Install fuses for 100 amps.
16. Start M-G set and energize heaters. Increase power level to 2930 watts. Take initial readings on all instrumentation.
17. Record all data at 30 minute intervals during approach to equilibrium.
18. When equilibrium conditions are established, search for hottest point on cask outer shell or fin tip using thermocouple 24 Dwg. B-1031. Record maximum temperature observed.
19. Obtain approval from test engineer to change power level and increase power level to 5860 watts.
20. Continue to record data at 30 minute intervals during approach to equilibrium.
21. When equilibrium conditions are established, search for hottest point on cask outer shell or fin tip using thermocouple 24 Dwg. B-1031. Record maximum temperature observed.

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VI. TEST PROCEDURE (Continued)

A. Wet Tests (Continued)

22. Obtain approval from test engineer to change power level and increase power level to 8780 watts.
23. Continue to record data at 30 minute intervals during approach to equilibrium.
24. When equilibrium conditions are established, search for hottest point on cask outer shell or fin tip using thermocouple 24 Dwg. B-1031. Record maximum temperature observed.
25. Obtain approval from test engineer to change power level and increase power level to 11700 watts.
26. Continue to record data at 30 minute intervals during approach to equilibrium.
27. When equilibrium conditions are established, search for hottest point on cask outer shell or fin tip using thermocouple 24 Dwg. E-1031. Record maximum temperature observed.
28. De-energize heaters and allow cask to cool sufficiently to permit work on test head.
29. Make certain cask is depressurized and remove coolant thermocouples.
30. Remove test head.
31. Circulate water through cask to cool basket and cask to less than 70°F and drain cask dry.
32. Using basket lifting gear, lift and rotate basket to determine if thermal cycling has caused any significant distortion of basket.

B. Dry Tests

1. Make up 23 thermocouples and check out in boiling water.
2. Attach 21 thermocouples to five adapters as shown on Dwg. B-1032.
3. Thread thermocouple leads through holes in test head and install test head on cask body. Make certain basket orientation with respect to closure bolts is such that heaters will be centered in basket adapters.

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VI. TEST PROCEDURE (Continued)

B. Dry Tests (Continued)

4. Position thermocouple 38 in plenum space above basket and attach thermocouple 39 to test head surface.
5. Close holes around thermocouple wires with insulation to prevent air circulation from cask cavity to ambient.
6. Connect all thermocouples and power leads.
7. Calibrate potentiometer against "mini-mite".
8. Start M-G set and energize heaters. Increase power level to 2930 watts. Take initial readings on all instrumentation.
9. Record all data at 30 minute intervals during approach to equilibrium.
10. When equilibrium conditions are established, search for hottest point on cask outer shell or fin tip using thermocouple 40 Dwg. B-1032. Record maximum temperature observed.
11. Obtain approval from test engineer to change power level and increase power level to 5860 watts.
12. Continue to record data at 30 minute intervals during approach to equilibrium.
13. When equilibrium conditions are established, search for hottest point on cask outer shell or fin tip using thermocouple 40 Dwg. B-1032. Record maximum temperature observed.
14. Obtain approval from test engineer to change power level and increase power level to 8780 watts.
15. Continue to record data at 30 minute intervals during approach to equilibrium.
16. When equilibrium conditions are established, search for hottest point on cask outer shell or fin tip using thermocouple 40 Dwg. B-1032. Record maximum temperature observed.
17. Obtain approval from test engineer to change power level and increase power level to 11700 watts.
18. Continue to record data at 30 minute intervals during approach to equilibrium.

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VI. TEST PROCEDURE (Continued)

B. Dry Tests (Continued)

19. When equilibrium conditions are established, search for hottest point on cask outer shell or fin tip using thermocouple 40 Dwg. B-1032. Record maximum temperature observed.
20. De-energize heaters and allow cask to cool sufficiently to permit work on test head.

Note:

While cask is cooling, test data will be analyzed to establish cask heat removal capacity based on 180°F maximum accessible surface temperature at 100°F ambient temperature.

C. Cooldown Tests

1. Install flow meter, pressure gage and inlet and outlet thermometers as shown on Dwg. B-1033.
2. Connect air and water supply hoses and vent hose as shown on Dwg. B-1033.
3. Install cooldown spray ring and connect to water supply as shown on Dwg. B-1033.
4. Reconnect all thermocouples and power leads used in dry tests
5. Energize heaters and increase power level to rated cask capacity specified by test engineer.
6. During approach to equilibrium record data at 30 minute intervals.
7. When equilibrium is established and with test engineer present, turn on cooling water to spray ring and begin recording thermocouples 13 thru 16 and 32 thru 34 at 15 minute intervals; all others at 30 minute intervals. Adjust water flow rate for good coverage of cask external surface and record flow rate.
8. When equilibrium conditions are established (or when directed by test engineer), record data and crack inlet air valve to internal cavity. Record thermocouples 29 thru 37 at 15 minute intervals; all others at 30 minute intervals.

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VI. TEST PROCEDURE (Continued)

C. Cooldown Tests

9. Slowly build up air pressure at inlet until exit air temperature is 200°F to 220°F.
10. When equilibrium conditions are established (or when directed by test engineer) record data, shut off air supply. With test engineer present, crack inlet water valve. Slowly increase flow rate to 2 GPM over flow going to spray ring.

Note:

If steam generation in cask from introduction of water causes cask internal pressure to approach 10 psig shut off water immediately and obtain further instructions from test engineer for remaining steps in this procedure.

11. During cask filling record thermocouples 29 thru 37 at 15 minute intervals; all others at 30 minute intervals.
12. If when cask is full, internal temperatures are not below 100°F, increase water flow as required to reduce thermocouples 13 thru 16 and 29 thru 37 to less than 100°F. Record flow rate and time required to accomplish this.
13. De-energize heaters, disconnect thermocouple and power leads required for test head removal and remove test head.
14. Drain cask dry.

Note:

At this point results of the above water-air-water cooldown procedure will be evaluated and conclusions reached with respect to the need for and safety of the following water-water cooldown procedure.

15. Using basket lifting gear, lift and rotate basket to determine if thermal cycling has caused any significant distortion of basket.
16. When directed by test engineer, replace test head, connect thermocouple and power leads.
17. Energize heaters and increase power level to rated cask capacity previously determined.
18. During approach to equilibrium, record all data at 30 minute intervals.

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VI. TEST PROCEDURE (Continued)

C. Cooldown Tests

19. When equilibrium is established and with test engineer present, turn on cooling water to spray ring and begin recording thermocouples 13 thru 16 and 32 thru 34 at 15 minute intervals; all others at 30 minute intervals. Adjust water flow rate for good coverage of cask external surface and record flow rate.

20. When equilibrium conditions are established (or when directed by test engineer), record data and crack inlet water valve to internal cavity. Record thermocouples 29 thru 37 at 15 minute intervals; all others at 30 minute intervals. Slowly increase flow rate to 2 GPM over flow going to spray ring.

Note:

If steam generation in cask from introduction of water causes cask internal pressure to approach 10 psig shut off water immediately and obtain further instructions from test engineer for remaining steps in this procedure.

21. During cask filling record thermocouples 29 thru 37 at 15 minute intervals; all others at 30 minute intervals.

22. If when cask is full, internal temperatures are not below 100°F, increase water flow as required to reduce thermocouples 13 thru 16 and 29 thru 37 to less than 100°F. Record flow rate and time required to accomplish this.

23. De-energize heaters, disconnect thermocouple and power leads required for test head removal and remove test head.

24. Drain cask dry.

25. Using basket lifting gear, lift and rotate basket to determine if thermal cycling has caused any significant distortion of basket.

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VI. TEST PROCEDURE (Continued)

C. Cooldown Tests

26. When directed by test engineer, disassemble and remove all test equipment and return cask to shop personnel for final cleaning, painting, assembly and preparation for shipment.

VII. ANALYSIS OF RESULTS

The test results will be analyzed and a detailed report prepared. The report will contain the following.

1. Analysis showing adequate heat removal capacity for Piqua and Elk River fuel.
2. Analysis establishing rated heat removal capacity.
3. Analysis showing compliance with 10 CFR 72.38 at rated capacity.
4. Thermal performance curves for future use of cask.
5. Analysis of cooldown methods and recommendation on best method.

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SPECIFICATIONS

- 1- POWER SUPPLY - 230V DC
- 2- HEAT OUTPUT - 1100 WATTS.
- 3- SHEATH MATL. - INCONEL
- 4- FLUID TO BE HEATED - WATER OR AIR
- 5- DESIGN PRESSURE - 50 PSI.
- 6- DESIGN TEMPERATURE - 300°F (WET) 1500°F (DRY)
- 7- HEATING ELEMENT MUST FIT INSIDE 3 1/2" φ CIRCLE
- 8- AXIAL HEAT DISTRIBUTION

ZONE A -	25.0	WATTS/LINEAR INCH OF HEATED LENGTH
ZONE B -	21.7	"
ZONE C -	16.7	"
ZONE D -	10.0	"

PIQUA ELK RIVER SPENT FUEL SHIPPING CASK
HEATER FOR THERMAL TEST

KNAPP MILLS INCORPORATED
FOOT OF WEST ST. WILMINGTON, DEL.

DRAWN BY- MFM
DATE- 6-18-63
CHKD-

PRODUCTION NO.
W- 3100

DRWG. NO.

A-148

SHEET

REV.

3

OF

PIQUA ELK RIVER SPENT FUEL SHIPPING CASK
TEST HEAD FOR THERMAL TEST

DRAWN BY- MEM
DATE- 6-18-63
CHKD-

DRWG. NO.

REV.

KNAPP MILLS INCORPORATED

FOOT OF WEST ST.

WILMINGTON, DEL.

PRODUCTION NO.

W-3100

A-149

1

SHEET OF

REV.		DRWG. NO.	DRAWN BY: MEM DATE: 6-18-65 CHKD:		KNAFF MILLS INCORPORATED WILMINGTON, DEL. FOOT OF WEST ST.
1		B-1031	PRODUCTION NO. W-3100		FROD BIK RIVET SPALT PULL SHIPPING CASE WET THERMAL TEST INSTRUMENTATION
SHEET		OF

REV.		DRWG. NO.	DRAWN BY - MFM DATE - 6-16-52 CHKD - PRODUCTION NO.	KNAFF MILLS INCORPORATED FOOT OF WEST ST. WILMINGTON, DEL.
B-1032		SHEET	W-3100

PIQUA RIVER SPENT FUEL SHIPPING CASK COOLDOWN TEST SET-UP AND INSTRUMENTATION		DRAWN BY- MEM DATE- 6-18-63 CHKD-	DRWG. NO.	REV.
KNAPP MILLS INCORPORATED		PRODUCTION NO.	B-1033	1
FOOT OF WEST ST. WILMINGTON, DEL.		W-3100	SHEET	OF

III - TEST RESULTS

Included in this Section are the reduced test data from the wet, dry and cooldown tests. Equilibrium data from wet and dry tests are tabulated on Page 6 and from cooldown tests on Page 10. The data from wet and dry tests normalized to 45°F ambient are plotted on pages 7 and 8. The approach to equilibrium prior to cooldown tests is plotted on page and the actual cooldown transient data is plotted on page 12. Description of test results and pertinent observations are given below.

Wet Tests

Equilibrium data with the cask water-filled to normal operating level was obtained at four heat release rates covering the expected range of cask capacity. Maximum and minimum coolant temperatures were measured at water surface and bottom of internal cavity. Inner shell temperatures were indicated by installed cask thermocouples at mid-plane. Outer shell temperature was measured at 12 points and averaged for tabulation, plotting and analysis. Average outer shell temperature was compared with outer shell mid-plane temperature and it was found that the two are very nearly equal. For this reason outer shell mid-plane temperatures are not only useful for comparison with mid-plane design calculations, but also are representative of heat dissipating ability of entire outer shell. Outer shell maximum temperature occurred as expected at the top of the cask body between top of fins and closure flange. Fin tip temperature was measured at this point at the two higher release rates to obtain maximum fin tip temperature.

Maximum coolant temperature and inner shell and outer shell mid-plane equilibrium temperatures normalized to 45°F and plotted indicate a nearly linear variation of temperature with heat release rate in the range of interest. This makes linear interpolation and extrapolation possible with negligible error.

The build-up of internal pressure indicated in tabulated data was due to expansion of air and water in cask, not coolant temperatures above 212°F. During testing the cask was not vented; however, in actual

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REDUCED TEST DATAWet Tests (Water Coolant)

	<u>10,000</u>	<u>20,000</u>	<u>30,000</u>	<u>40,000</u>
Heat Release - Btu/Hr.				
Coolant (Max.) - °F	86	128	162	185
Coolant (Min.) - °F	64	89	110	123
Internal Pressure - PSIG	0	6	12	20
Inner Shell - °F	76	113	146	166
Outer Shell (Max.) - °F	74	102	132	147
Outer Shell (Avg.) - °F	65	86	110	121
Fin Tip (Max.) - °F	-	-	109	118
Ambient - °F	44	37	45	40

Dry Tests (Air Coolant)

	<u>10,000</u>	<u>20,000</u>	<u>30,000</u>	<u>40,000</u>
Heat Release - Btu/Hr.				
Center Adapter - °F	128	192	244	283
* Coolant - °F	118	168	211	234
Basket O.D. - °F	113	160	197	222
Inner Shell - °F	94	131	167	191
Outer Shell (Max.) - °F	80	104	133	150
Outer Shell (Avg.) - °F	76	96	122	135
Fin Tip (Max.) - °F	-	-	110	124
Ambient - °F	44	40	43	43

* Above Basket

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loading, the cask will be vented during approach to equilibrium and closed if and when coolant reaches boiling point.

Dry Tests

Equilibrium data with cask vented and dry was obtained at four heat release rates covering expected range of cask capacity. Mid-plane data of center adapter, basket O.D., inner shell and outer shell are plotted on page 8. Also, air temperature above basket is shown. Comparing curves of wet and dry tests, it can be seen that temperatures were higher in the dry condition for the same heat load. This was caused by the reduced effective area over which heat is transferred to cask inner shell in dry condition. However, it is interesting to note from the tabulated data that maximum outer shell temperature is not significantly different from water-filled condition. The decreasing slope of inner shell, basket and center adapter curves with increasing heat release rate indicates that radiation becomes a significant mode of heat transfer at these higher temperatures.

Cooldown Tests

The approach to equilibrium plotted on page 12 shows the time required to reach equilibrium at 40,000 Btu/Hr. The outer shell reaches equilibrium in about 14 hours whereas center adapter requires approximately 17 hours. This is significant in actual loading operations because cask cannot be transported until equilibrium is established.

After the cask reached equilibrium at 40,000 Btu/Hr, the effectiveness of various cooldown procedures was tested. First, cooling water was sprayed uniformly around the cask body just under closure flange in sufficient quantity to provide a uniform film over the full height of outer shell. Cooling water flow was 12 GPM at a temperature of 47°F. Curve on page 13 shows that this procedure rapidly reduced outer shell temperature to a "leveling-off" point in two hours. Effect on internal temperatures, though significant, was much more gradual.

To accelerate internal cooldown, air coolant was introduced into cask cavity through drain valve. Air flow was provided by supplying compressed air at 40-43 psig to a 1/8" NPT nipple fitted to drain valve. Temperature of air coolant entering cask was 43-45°F. Center adapter

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REDUCED COOLDOWN TEST DATAHeat Release 40,000 Btu/Hr.Ambient Temp. at Equilibrium 50°F

Time	Center Adapter°F	Inner Shell°F	Outer Shell°F	Q _s GPM	T _s °F	Pair PSIG	Q _c GPM	T _c In-°F	T _c Out-°F	P _c PSIG
0900	61	54	56							
1030	162	80	62							
1200	199	108	72							
1230	206	116	78							
1330	219	125	84							
1400	227	132	93							
1500	236	142	100							
1600	243	146	100							
1700	253	158	113							
1800	260	166	120							
1900	264	170	125							
2000	267	173	128							
2100	271	177	131							
2200	274	179	133							
2300	276	180	134							
2400	278	182	135							
0100	279	183	135							
0200	281	184	135							
0300	282	185	135							
0400	283	185	134							
0500	282	185	133							
0600	281	185	132							
0700	280	184	131							
0800	280	184	131							
0845	Water	spray	on	12	47					
0900	280	169	85	12	47					
0910	278	162	75	12	47					
0920	273	153	70	12	47					
0930	270	150	68	12	47					
0940	266	145	64	12	47					
0950	260	139	63	12	47					
1000	259	138	62	12	47					
1010	255	137	61	12	47					
1020	253	135	60	12	47					
1030	249	132	59	12	47					
1040	246	129	58	12	47					
1045	Air	Coolant	on			43				
1050	227	129	58	12	47	43		45	127	3

Notation

- Q_s - Spray flow on outer shell
T_s - Spray temperature
Pair - Air supply pressure on 1/8 NPT Nipple
Q_c - Coolant Flow
T_c - Coolant Temperature
P_c - Cask internal pressure

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Time	Center Adapter ^{OF}	Inner Shell ^{OF}	Outer Shell ^{OF}	Q _s GPM	T _{OS} °F	Pair PSIG	Q _c GPM	T _C In- ^{OF}	T _C Out- ^{OF}	P _c PSIG
1100	195	127	58	12	47	43		45	143	3
1110	184	125	58	12	47	41		45	142	3
1120	180	122	57	12	47	41		45	140	3
1130	177	121	57	12	47	42		45	138	3
1140	174	119	57	12	47	42		45	137	3
1145	Air / Water mixture					42	<1			
1150	166	118	57	12	47	42	<1	43	185	3
1200	175	117	57	12	47	44	<1	43	205	3
1210	192	114	56	12	47	40	<1	43	212	3
1220	194	111	56	12	47	42	<1	43	203	3
1230	193	108	55	12	47	43	<1	43	182	3
1240	185	106	55	12	47	42	<1	43	172	3
1245	Increase Air / Water Mixture						1			
1250	175	104	55	12	47	40	1	43	162	3
1300	138	100	55	12	47	40	1	43	150	3
1305	Increase Air / Water Mixture						1.5			
1310	129	91	55	12	47	40	1.5	43	137	3
1315	Increase Air / Water Mixture						2			
1320	111	89	55	12	47	42	2	43	122	3
1330	104	88	55	12	47	42	2	43	112	3
1335	Air Off - Water Increased						5			
1340	103	88	55	12	47	0	5	45	100	0
1350	96	86	55	12	47	0	5	45	100	0
1355	Cask full water from vent									
1400	79	78	55	12	47	0	5	45	98	0
1410	67	66	57	0	47	0	5	45	85	0

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curve shows that the air coolant was effective in reducing center adapter and adjoining basket temperature for approximately one hour.

At that point water was admitted to the air stream at a flow less than 1 GPM to form an air-water suspension. Coolant outlet temperature curve shows that fuel basket temperature was not below 212°F even though center adapter was at 172 when water was admitted. This is obvious from the rapid increase of coolant outlet temperature to 212°F indicating steam formation. The increase in center adapter temperature observed following steam formation was apparently caused by the transfer of heat from areas in basket at higher temperatures by the steam. Based on these observations, it was concluded that a coolant baffle should be installed at drain line inlet in bottom of internal cavity to better distribute coolant and minimize non-uniform basket cooldown.

When coolant outlet and center adapter temperature again resumed a downward trend, the water-to-air ratio was gradually increased until center adapter and coolant outlet temperature were approximately equal. At that point, the air was shut off and water flow increased to a 5 GPM filling rate. The cask was full in approximately 20 minutes and ten minutes of circulation after filling was adequate to reduce all cask temperatures below 90°F.

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IV - COMPARISON OF DESIGN CALCULATIONS AND TEST RESULTS

Included in this Section are curves of reduced test data extrapolated to 100°F ambient design temperature and a comparison of observed readings to design calculations for both Piqua and Elk River Reactor fuels. Extrapolation is done by direct addition of difference between design and test ambient to test temperatures which is slightly conservative. Since the design was based on the dry condition, the comparison includes only data from dry tests. Also, cask mid-plane data is used since this was the assumption in design calculations. Reduced data extrapolated to 100°F ambient are plotted on page 16. Tabulated comparison with design calculations is given on pages 15 and 17.

Piqua Reactor Fuel

Referring to Design Report, page 6 of Thermal Analysis, the total decay heat load on cask is 29,300 Btu/Hr. Tabulated comparison of design calculations and test results for this heat release rate is given below. Test data are taken from curves plotted on page 16; design data from Thermal Analysis, pages 8 thru 18. Basket center temperature given under "Test" is center adapter from test data and is slightly higher than actual basket center temperature because thermocouples were attached to adapter. Fuel temperature given is calculated using this temperature as a basis and applying same method used in design calculations pages 13 thru 18.

		<u>Design</u>	<u>Test</u>
Fuel	-°F	600	557
Basket Center	-°F	359	300
Basket O.D.	-°F	275	253
Inner Shell	-°F	220	222
Outer Shell	-°F	181	177

The above comparison shows very good agreement on outer and inner shell temperatures indicating cooling fin performance and efficient conduction through the cask wall was achieved. At the basket O.D. the conservative analytical approach is evident in that the temperature difference required to transfer the heat was 31°F, and that calculated was 55°F. As expected the thermal performance of the fuel basket is much better than predicted by analysis because of the conservative model used in calculations (pages 11 and 12 - Thermal Analysis). The 44% lower temperature difference

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PIQUA-ELK RIVER REACTORS
 SPENT FUEL SHIPPING CASK
 TEST DATA EXTRAPOLATED
 TO 100°F AMBIENT TEMP

observed from center to O.D. is directly related to the greater area of aluminum actually available for conduction compared to the simplified analytical model. The net result is a maximum fuel temperature based on test results 43°F less than predicted by analysis. This fuel temperature is still considered to be an upper limit because of method of extrapolating to 100°F ambient, Using center adapter temperature as basket center temperature and method of calculating temperature differences from fuel to basket.

Elk River Reactor Fuel

Referring to design report, Page 18 of Thermal Analysis, the total decay heat load on cask is 21,800 Btu/Hr. Tabulated comparison of design calculations and test results for this heat release rate is given below. Test data are taken from curves plotted on page 16; design data from Thermal Analysis pages 18 thru 25. Design temperatures of inner shell and basket O.D. are omitted because they were not specifically calculated in thermal analysis. Basket center test temperature is also omitted because it was not measured. Fuel temperature given under "test" is calculated using center adapter temperature as a basis and applying same method used in design calculations pages 22 through 25.

		<u>Design</u>	<u>Test</u>
Fuel	-°F	618	575
Center Adapter	-°F	340	259
Basket Center	-°F	305	-
Basket O.D.	-°F	-	226
Inner Shell	-°F	-	197
Outer Shell	-°F	166	161

The above comparison again shows performance of outer shell in good agreement with calculations and considerably better performance of fuel basket in transmitting heat to cask wall. The full effect of this improved performance is not reflected in fuel temperature because radiation is the most significant mode of heat transfer in Elk River fuel. For this reason greater temperature differences are required at the lower temperatures to transfer the heat. The net result is a maximum fuel temperature 43°F less than predicted by analysis. This temperature is also considered to be a conservative upper limit because of the method of extrapolating to 100°F ambient and the method of calculating temperature differences from fuel to adapter.

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Comparison of Dry and Wet Tests

The results of wet tests extrapolated to 100°F are plotted on page 19. No formal analysis of the cask water-filled was carried out because it was known performance water-filled would be better than dry. This can be seen by comparison of wet and dry curves on pages 16 and 19. Outer shell temperatures are significantly lower for equivalent heat loads because of greater effective height of heat dissipating surface (see page 9). Based on the curves, coolant temperatures for cask loaded with Elk River and Piqua Fuel will be 197°F and 218°F respectively. This means cask will not pressurize in the Elk River case but may reach 3 PSIG in the Piqua case. In both cases the cask will be operating well within design limitations. Therefore, cask may be used water filled as well as dry.

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PIQUA-ELK RIVER REACTORS
 SPENT FUEL SHIPPING CASK
 TEST DATA EXTRAPOLATED
 TO 100°F AMBIENT TEMP

DETERMINATION OF CASK RATING

This Section establishes rated decay heat dissipation capacity of cask within limitations of 10 CFR 72. The important limitations are:

1. Maximum allowable accessible surface temperature of 180°F.
2. Maximum allowable internal pressure of 50 psig.
3. Maximum allowable coolant temperature 20°F below boiling point
4. Maximum allowable fuel temperature 300°F below failure temperature.

All of the above limitations are under conditions of 100°F ambient with maximum anticipated solar heat load.

It can be seen from design calculations and test data that the cask will operate well within limitations No. 2, 3 and 4. Therefore, cask rating is based on limitation No. 1 and "accessible surface" is taken as the fin tips within reach of personnel around the cask. Area above fins under cask closure flange where maximum shell temperature was observed are not truly "accessible" without specific intent such as climbing a ladder. Therefore, safety to personnel during transport is still assured using fin-tip temperature.

Referring to Thermal Analysis, page 31 thru 34, solar heat raises outer shell temperature 16°F and fin root-to-tip temperature drop is conservatively estimated at 10°F. This means a net allowance of 6°F must be made in using test data to establish cask rating based on 180°F accessible surface temperature. Entering curve page 16 at 174°F, the cask rating is 28,000 Btu/Hr which is more than adequate for dry shipment of Elk River fuel but 4% below the 29,300 Btu/Hr Piqua design heat load. This means that if Piqua fuel is operated at full power for core life, fin tip temperature may exceed 180°F limit by 3°F as predicted in Thermal Analysis, page 32. However, the protective screen mentioned on page 32 is not justified for the 3°F excess. An additional decay time of approximately 10 days is the best alternative. Entering curve page 19 at 174°F, the cask rating is 36,000 Btu/Hr water-filled, which is more than adequate for both Piqua and Elk River fuel.

Higher cask ratings water-filled are attainable by providing a protective screen or framework around cask during transport to limit personnel access

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to cask. This is practical and may be desirable for future use of cask. In this case, limitations 2 and 3 govern. Subtracting 20°F from saturation temperature and entering coolant temperature curve (extrapolated) on page 19, cask rating is 56,000 Btu/Hr at a total internal pressure of 50 psig.

Higher cask ratings dry are also attainable using the protective screen or framework but to a lesser extent. This is because it is not possible to accurately apply limitation No. 4 to a particular fuel and take full advantage of maximum allowable fuel temperatures. Also it is not desirable to allow fuel temperatures to exceed the 600°-700°F range from the standpoint of cooldown operations. However, it can be seen from test data and calculations, if maximum allowable fuel temperature in the cask during transport is taken as 600°F, cask rating is increased to approximately 32,000 Btu/Hr. for Piqua fuel and 23,000 for Elk River fuel. It should be noted that the protective screen or framework would not be required at the 23,000 Btu/Hr rating.

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RECOMMENDED COOLDOWN PROCEDURE

Based on test results, it is possible to establish a general procedure for actual cooldown operations. This procedure can be adapted to suit the facilities and local operating procedures of a particular activity.

Since minimum cooldown time is an objective, certain operations are carried out simultaneously in the General Procedure rather than consecutively as in the test. Also, since certain activities may be equipped to handle contaminated steam better than contaminated air, steam coolant may be used in place of air. Use of steam will increase temperature to which intervals can be reduced. However, it will also heat filling water in later stages of cooldown and minimize thermal shock to fuel elements and cask internals.

The General Procedure is as follows:

A. Equipment Required

1. Outer shell spray manifold.
2. Air-water or steam-water mix fitting.
3. Inlet and outlet well type thermometers.
4. Portable potentiometer for I/C thermocouples.
5. Hoses, valves and fittings for steam, air and water supply
6. Water flow meter 0-5 GPM

B. Preparation for Cooldown

1. Remove cask from transport vehicle and shipping structure and place in washdown area.
2. Install outer shell spray manifold to direct coolant on outer shell just under closure flange.
3. Install air-water (steam-water) mixing fitting and inlet thermometer at cask drain valve.
4. Install outlet thermometer at cask vent valve in closure head.

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5. Connect air (steam) and water supply to mixing fitting and spray manifold.
6. Connect hose from cask vent to contaminated air (steam) system.
7. Connect four cask inner shell thermocouples to portable potentiometer.
8. Remove closure head nut lockwire and loosen nuts until they are just hand tight against closure head flange.

C. Cooldown Operations Using Air

1. Turn on cooling water to outer shell spray manifold and cooling air to cask internals.
2. When inner shell and air outlet temperatures are less than 180°F, crack water inlet valve (flow less than 1 GPM) to mixing fitting and observe outlet temperature for any sudden increase. Any increase means fuel and/or basket temperatures are still above 212°F.
3. When outlet temperature is less than 200°F and decreasing, gradually increase water flow to mixing fitting to 2 GPM.
4. When inner shell and outlet temperatures reach 120°F, shut off air, increase water flow to a filling rate of 5 GPM, and divert outlet hose discharge to contaminated water system.
5. After cask is full, circulate coolant until outlet and inner shell temperatures are reduced to 100°F.
6. Disconnect cooldown equipment and proceed with unloading operations.

D. Cooldown Operations Using Steam

1. Turn on cooling water to outer shell, spray manifold and steam to cask internals, crack water inlet valve to mixing fitting to obtain saturated steam (212°F on thermometer) at cask inlet.
2. Observe outlet temperature for amount of superheating of steam as an indication of internal temperatures.

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3. Gradually increase water flow to mixing fitting to obtain 212°F at outlet (no superheating) while maintaining 212°F at inlet fitting (wet steam).
4. When inner shell temperature is less than 150°F and outlet steam temperature is 212°F, gradually increase water flow to mixing fitting until inlet temperature starts dropping below 212°F (hot water now entering cask).
5. Gradually increase water flow to a 5 GPM maximum filling rate.
6. When cask is filled, shut off steam and circulate cooling water until inner shell and outlet temperatures are less than 100°F.
7. Disconnect cooldown equipment and proceed with unloading operations.

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VII - ORIGINAL TEST DATA

Included in this Section are the original test data from wet, dry and cooldown tests. Wet tests ran from 1300 Hrs. 2/19/64 to 1545 hours 2/22/64. Dry tests ran from 1530 Hrs. 2/26/64 to 2130 Hrs. 2/29/64. Heat-up cycle for cooldown test was started 0900 Hrs 3/6/64 and cooldown tests were completed 3/7/64.

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Piqua-Elk River Spent Fuel Shipping Cask
Wet Thermal Test Data Sheet

Test Engineer R. W. PETERSON Recorder CASSEDAY Date 2/19/64

Time Temp-°F	1318	1400	1500	1600	1700	1800	1900	2000	2100	2200	2300
1	44	44	42	43	45	46	48	50	51	52	54
2	45	45	43	44	45	46	48	49	51	52	54
3	45	45	44	45	46	48	49	50	51	53	55
4	45	45	43	45	47	49	50	51	53	54	56
5	44	45	44	46	48	49	51	53	54	56	57
6	45	46	44	46	48	49	51	53	54	55	57
7	45	46	46	47	50	51	53	54	57	59	60
8	45	46	46	48	50	52	54	55	57	59	60
9	44	44	44	47	49	51	53	55	57	59	60
10	45	46	46	48	50	52	54	56	58	60	61
11	46	47	48	50	53	54	57	58	60	62	63
12	46	47	48	51	53	56	59	61	63	65	66
13	44	46	48	51	54	56	57	61	63	65	66
14	45	47	50	53	56	59	61	64	66	67	68
15	44	45	47	51	53	55	58	60	62	64	67
16	44	46	48	51	53	56	60	61	64	66	68
17	45	45	44	47	49	50	50	52	53	55	56
18	49	52	55	58	61	64	67	69	71	73	75
19	50	53	57	60	63	65	68	70	72	74	76
20	50	54	57	61	63	65	68	70	72	74	76
21	50	53	57	61	65	67	68	71	73	75	78
22	50	54	57	48	64	67	69	71	74	75	78
23	48	47	46	44	48	50	53	54	55	55	58
24	40	40	39	44	42	45	51	53	49	50	51
Int. Press.	0	0	0	0	0	0	0	0	0	0	0
Amb Temp.	46	46	46	46	46	46	46	46	46	46	46
Volts	87.5	87.5	87.5	87.5	87.5	87.5	87.5	87.5	87.5	87.5	87.5
Amps	33.5	33.5	33.5	33.5	33	33.5	33.5	33.5	33.5	33.5	33.5

Special Observations or Remarks

① 1300 POWER ON ADJUSTED TO 2930 WATTS

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Piqua-Elk River Spent Fuel Shipping Cask
Wet Thermal Test Data Sheet

Test Engineer R. W. De Rosa Recorder K. L. C. Date 7/25/64

Time Temp-°F	2400	0100	0200	0300	0400	0500	0600	0700	0800	0830	0900
1	56	55	56	57	57	57	58	59	58	58	59
2	54	54	55	55	55	55	56	56	57	57	58
3	55	56	57	58	58	59	59	60	60	61	61
4	56	57	58	59	59	60	60	61	61	61	62
5	58	59	60	60	61	61	61	62	63	63	64
6	58	58	59	60	60	60	60	61	61	62	62
7	60	61	62	62	62	63	63	64	65	66	67
8	60	61	62	62	63	63	63	64	65	66	67
9	61	62	63	64	65	65	65	67	67	68	68
10	62	62	63	64	65	65	65	67	67	68	68
11	64	65	66	67	67	67	67	67	68	69	69
12	67	69	70	70	71	71	71	72	72	73	74
13	67	69	70	71	71	72	73	74	74	75	75
14	71	73	74	75	76	77	77	78	78	78	79
15	67	68	70	71	71	73	73	74	74	74	75
16	69	70	71	72	73	74	74	75	75	75	76
17	58	58	59	60	61	61	61	63	63	64	64
18	76	78	79	80	81	82	83	83	83	84	84
19	77	79	80	81	82	83	83	84	84	85	85
20	74	74	80	81	82	83	83	84	84	85	85
21	74	80	81	82	84	84	84	85	85	86	86
22	74	80	82	83	84	85	84	85	85	86	86
23	54	59	60	60	61	60	60	61	61	62	62
24	52	52	52	53	53	52	52	53	54	55	55
Int. Press.	0	0	0	0	0	0	0	0	0	0	0
Amb Temp.	46	43	43	43	42	41	41	41	43	44	44
Volts	87.5	87.5	87.5	87.5	87.5	87.5	87.5	87.5	87.5	87.5	87.5
Amps	33.5	33.5	33.5	33.5	33.5	33.5	33.5	33.5	33.5	33.5	33.5

Special Observations or Remarks

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Piqua-Elk River Spent Fuel Shipping Cask
Wet Thermal Test Data Sheet

Test Engineer RW. Peltz Recorder CONNELL Date 2/20/64

Time Temp-°F	0930	1000	1100	1200	1300	1400	1500	1600	1700	1800	1900
1	60	60	61	62	69	67	69	70	72	72	73
2	58	59	60	61	63	64	66	68	69	70	71
3	62	62	63	65	67	69	72	74	76	77	78
4	63	64	64	67	69	71	73	75	78	78	79
5	64	65	61	69	71	74	76	78	80	81	81
6	63	64	65	67	69	71	73	75	77	79	80
7	67	68	69	72	75	77	80	82	85	86	87
8	64	68	69	72	75	77	80	82	85	86	87
9	69	70	71	73	77	80	83	85	88	89	91
10	69	70	71	73	77	80	83	85	87	89	90
11	70	71	72	75	78	81	83	85	88	89	91
12	74	74	76	79	83	86	89	92	95	97	99
13	75	76	78	83	87	91	94	97	99	101	103
14	79	80	83	89	93	97	100	103	105	107	110
15	75	75	78	83	87	91	93	96	98	98	100
16	77	77	80	85	89	92	96	99	101	103	105
17	64	65	66	67	69	71	73	75	78	79	81
18	85	85	90	96	100	105	108	110	113	115	117
19	86	86	90	97	101	105	108	111	114	116	118
20	85	86	90	97	101	105	108	111	114	116	118
21	86	86	91	98	102	106	109	112	114	118	120
22	86	86	92	98	102	106	109	112	115	118	120
23	83	83	85	88	91	94	96	99	80	83	85
24	56	56	57	58	60	62	63	65	66	69	70
Int. Press.	0	0	0	0	1	1	2	2	3	3	4
Amb Temp.	45	46	48	49	49	50	50	48	48	48	48
Volts	87.5	86.5	125	125	125	125	125	127	125	125	125
Amps	33.5	33.5	47	47	47	47	47	47	47	47	47

Special Observations or Remarks

Ⓢ 1030 RETRIEVED POWER TO 5875 VOLTS

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Piqua-Elk River Spent Fuel Shipping Cask
Wet Thermal Test Data Sheet

Test Engineer R. W. P. E. E. E.

Recorder C. A. S. E. D. A. Y.

Date 2/20/69

Time Temp °F	1945	2100	2200	2300	2400	2/21 0030	0100	0130	0200	0230	0300
1	75	75	77	78	78	78	78	79	79	79	78
2	72	73	74	75	74	74	74	73	72	73	73
3	78	79	80	82	81	81	81	81	81	81	81
4	80	82	82	84	84	82	83	83	83	83	83
5	82	84	85	86	86	85	85	86	85	86	86
6	81	82	83	84	84	83	83	82	82	82	82
7	88	89	90	92	91	90	90	90	90	90	90
8	88	89	90	91	90	90	89	89	89	89	90
9	93	94	95	97	97	97	97	97	94	94	98
10	91	92	93	95	95	95	95	94	94	94	95
11	92	93	94	95	95	95	94	94	94	94	94
12	100	101	102	104	104	103	103	103	103	103	103
13	105	107	108	110	111	111	111	111	112	112	112
14	111	113	114	116	117	117	117	118	118	118	118
15	102	103	105	107	108	108	108	109	109	110	110
16	106	108	109	111	112	112	111	112	112	112	113
17	82	84	85	87	88	88	88	88	88	88	89
18	119	120	121	123	124	124	125	125	125	125	126
19	119	121	122	124	125	125	125	125	125	126	126
20	119	121	122	124	125	125	125	125	125	126	126
21	121	123	123	126	127	128	128	128	128	129	128
22	122	123	124	126	127	128	128	128	128	129	128
23	86	87	89	90	91	91	91	90	91	90	90
24	71	72	73	75	75	74	74	73	72	74	73
Int. Press.	4	4	5	5	5	5	5	5	5	6	6
Amb Temp.	48	47	46	45	44	43	43	42	41	40	40
Volts	125	125	125	125	125	125	125	125	125	125	125
Amps	46.5	46.5	46.5	46.5	46.5	46.5	46.5	46.5	46.5	46.5	46.5

Special Observations or Remarks

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KNAPP MILLS INC.
WILMINGTON, DELAWARE

Piqua-Elk River Spent Fuel Shipping Cask
Wet Thermal Test Data Sheet

Test Engineer R.W. PETERSON Recorder ELIENS Date 1/21/64

Time Temp °F	0330	0400	0430	0500	0600	0630	0700	0800	0900	1000	1100
1	79	79	78	78	78	78	77	79	81	83	84
2	73	72	72	72	71	71	71	72	75	77	78
3	81	81	80	80	80	79	79	83	85	86	89
4	83	83	83	82	81	81	81	85	87	89	90
5	86	86	85	85	85	85	85	88	91	94	96
6	82	82	81	81	80	80	80	83	86	88	90
7	90	90	89	89	89	88	89	93	96	99	100
8	90	90	89	89	89	87	88	93	96	98	100
9	98	98	98	98	97	97	98	101	104	106	108
10	95	95	95	95	94	94	95	98	100	103	105
11	93	93	92	93	91	92	93	96	99	102	104
12	103	103	102	102	102	102	103	107	110	113	115
13	113	113	112	112	112	114	116	119	122	125	127
14	118	118	118	118	118	120	122	126	129	132	133
15	110	110	110	110	110	112	114	118	120	123	125
16	113	113	112	113	112	114	116	120	123	125	127
17	89	89	89	89	89	89	89	90	92	93	94
18	126	126	126	126	126	130	132	136	139	141	143
19	126	127	126	126	126	130	132	136	139	141	143
20	126	127	126	126	126	130	132	136	139	141	143
21	128	128	128	128	128	131	134	137	140	142	144
22	128	128	128	128	128	132	134	138	140	143	145
23	90	90	90	89	89	89	90	93	96	98	100
24	73	73	73	72	72	72	73	74	92	95	98
Int. Press.	6	6	6	6	6	6	6	6	7	7	8
Amb Temp.	39	38	37	37	36	36	36	40	42	44	45
Volts	125	125	125	125	125	155	155	154	153	154	154
Amps	46.5	46.5	46.5	46.5	46.5	57	57	57	56	57	57

Special Observations or Remarks

- @ 0630 ADJUSTED POWER TO 8780 WATTS
- @ 0825 T/C #24 ON FIN TIP ADJACENT TO T/C #12
- @ 0920 READJUSTED POWER TO 8780 WATTS

REVISED

KNAPP MILLS INC.
WILMINGTON, DELAWARE

Piqua-Elk River Spent Fuel Shipping Cask
Wet Thermal Test Data Sheet

Test Engineer R. W. F. 12-5-61 Recorder CONNELL Date 2/21/64

Time Temp-°F	1200	1300	1400	1500	1600	1630	1700	1730	1800	1830	1900
1	86	88	90	91	93	93	94	95	96	96	97
2	80	82	83	84	85	85	86	87	87	87	88
3	90	92	94	95	95	95	97	97	97	97	98
4	92	94	96	98	98	99	100	100	101	101	102
5	98	100	102	104	105	105	106	107	107	107	108
6	92	94	96	97	98	98	99	100	100	100	101
7	103	105	106	108	109	109	110	111	111	112	112
8	102	104	106	107	108	108	110	110	111	110	111
9	110	113	114	117	118	119	120	120	121	121	122
10	108	110	111	113	115	115	116	117	117	117	118
11	106	108	109	111	112	112	113	114	115	115	115
12	117	119	121	124	125	126	127	128	128	129	130
13	129	132	134	136	139	139	140	141	142	142	143
14	135	138	140	142	143	144	145	145	146	146	148
15	127	129	131	134	136	137	138	140	140	140	142
16	136	132	134	136	138	138	140	140	140	141	142
17	96	98	100	101	103	104	105	106	106	106	107
18	146	148	150	153	155	155	156	157	157	158	159
19	146	148	150	153	155	155	156	157	157	158	159
20	146	148	150	153	155	155	156	157	157	158	159
21	146	149	151	154	156	156	157	158	159	159	160
22	147	150	151	154	156	157	158	158	159	160	161
23	103	105	107	110	112	112	114	115	115	116	118
24	99	100	102	102	105	105	106	106	107	108	108
Int. Press.	8	9	9	10	10	10	10	11	11	11	11
Amb Temp.	46	46	47	48	48	48	48	48	48	47	47
Volts	154	155	155	155	155	155	155	155	155	155	155
Amps	57	57	57	57	57	57	57	57	57	57	57
Special Observations or Remarks											

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KNAPP MILLS INC.

WILMINGTON, DELAWARE

Piqua-Elk River Spent Fuel Shipping Cask
Wet Thermal Test Data Sheet

Test Engineer RW PETERSON Recorder CASSEDAY Date 2/21/64

Time Temp °F	1930	2000	2050	2100	2130	2200	2230	2330	2/22 0100	0200	0300
1	97	97	98	98	99	99	99	101	101	102	102
2	88	89	89	90	90	90	91	91	92	92	93
3	99	99	100	100	100	100	101	102	102	103	104
4	103	103	103	104	104	104	105	106	106	107	108
5	108	109	109	110	110	110	111	112	113	114	115
6	101	102	102	102	103	103	104	104	106	106	107
7	113	113	114	114	114	115	110	117	119	120	120
8	112	112	112	112	112	112	114	116	115	116	117
9	122	122	123	123	123	124	125	127	129	130	131
10	118	119	119	120	120	120	121	123	125	127	128
11	116	116	116	116	116	117	117	119	121	122	122
12	131	130	131	131	131	132	133	135	128	140	141
13	144	144	144	144	145	145	147	151	155	157	158
14	149	149	149	149	150	150	149	157	161	163	165
15	142	143	143	143	144	144	146	150	154	156	158
16	143	143	143	144	144	144	146	150	154	156	158
17	108	108	109	109	110	110	110	111	113	114	116
18	159	159	160	160	160	161	164	169	174	176	177
19	159	159	160	160	160	161	164	169	174	176	178
20	159	159	160	160	160	160	164	169	173	175	177
21	161	161	161	161	161	161	165	170	174	176	178
22	162	162	161	161	162	162	165	170	175	177	179
23	118	118	118	118	119	119	120	123	126	130	132
24	109	109	109	109	109	109	110	111	111	111	111
Int. Press.	11	11	11	12	12	12	12	13	15	16	16
Amb Temp.	47	46	45	45	45	45	45	45	42	40	38
Volts	155	155	155	155	155	155	179	178	178	178	178
Amps	57	57	57	57	57	57	66	66	66	66	66

Special Observations or Remarks

@ 2215 ADJUSTED POWER TO 11,750 WATTS

REVISED

KNAPP MILLS INC.
WILMINGTON, DELAWARE

Piqua-Elk River Spent Fuel Shipping Cask
Wet Thermal Test Data Sheet

Test Engineer: RW PETERSON Recorder: BIGGS Date: 2/22/69

Time Temp-°F	0400	0500	0600	0700	0800	0900	1000	1100	1200	1230	1300
1	103	103	104	104	104	105	106	106	107	107	107
2	92	93	93	92	93	94	94	96	96	97	97
3	104	104	104	104	105	105	109	109	109	110	109
4	108	108	108	108	108	111	112	113	113	114	113
5	115	116	116	116	116	119	120	120	120	121	120
6	107	108	108	108	108	110	111	112	113	113	112
7	121	121	122	121	122	124	125	127	127	128	127
8	118	118	118	117	118	121	122	123	122	124	123
9	133	133	134	134	134	136	136	138	137	138	138
10	129	130	130	130	131	133	133	134	135	135	135
11	123	123	123	123	123	126	126	128	128	128	127
12	142	143	143	143	144	146	146	147	147	148	147
13	160	161	162	162	162	164	165	165	165	166	165
14	166	167	168	168	169	170	170	171	171	172	171
15	160	161	161	162	162	164	165	166	165	166	165
16	159	160	161	162	162	164	165	165	165	166	165
17	117	117	118	118	119	120	121	122	122	123	123
18	179	180	181	182	182	183	185	185	184	185	185
19	179	180	181	182	182	183	185	185	185	185	185
20	178	180	180	181	182	183	184	185	184	185	184
21	180	181	182	183	183	184	185	185	185	185	185
22	180	182	183	183	184	185	185	186	185	186	185
23	133	134	136	137	137	139	140	142	142	142	142
24	112	113	112	111	113	117	117	119	117	119	117
Int. Press.	17	17	18	18	18	19	19	19	20	20	20
Amb Temp.	37	36	35	33	36	37	38	38	39	39	39
Volts	178	178	178	178	178	182	182	177	177	177	177
Amps	66	66	66	66	66	67	67	66	66	66	66

Special Observations or Remarks

@ 1050 READJUSTED POWER TO 11,700 WATTS

REVISED

KNAPP MILLS INC.

WILMINGTON, DELAWARE

Piqua-Elk River Spent Fuel Shipping Cask
Wet Thermal Test Data Sheet

Test Engineer: R. N. PETERSON Recorder: CASSEDAY Date: 2/27/64

Time Temp. °F	1330	1400	1430	1500	1530						
1	107	108	108	109	109						
2	97	98	97	97	98						
3	110	110	110	110	111						
4	113	114	114	114	114						
5	120	121	121	121	121						
6	112	113	113	113	113						
7	127	127	127	127	127						
8	123	124	123	123	123						
9	138	138	138	138	138						
10	135	135	135	135	135						
11	127	128	127	128	128						
12	147	148	147	147	147						
13	165	165	165	165	165						
14	171	171	171	171	171						
15	165	166	165	165	165						
16	165	165	165	165	165						
17	123	123	123	123	123						
18	184	185	185	185	184						
19	185	185	185	185	184						
20	185	185	185	184	184						
21	185	185	185	185	185						
22	185	185	185	185	185						
23	142	142	142	142	142						
24	117	117	118	118	118						
Int. Press.	20	20	20	20	20						
Amb. Temp.	39	40	40	40	40						
Volts	177	177	177	177	177						
Amps	66	66	66	66	66						

Special Observations or Remarks

@ 1545 COMPLETED WET TESTS-LOADED OFF

REVISED

KNAPP MILLS INC.

WILMINGTON, DELAWARE

Piqua-Elk River Spent Fuel Shipping Cask
Dry Thermal Test Data Sheet

Test Engineer RWPETERSON Recorder CASSEY Date 2/26/64

Time Temp-°F	1600	1700	1800	1900	2000	2100	2200	2300	2400	2/27 0100	0200
1	46	51	54	56	59	60	63	69	71	71	73
2	46	51	53	55	57	58	60	66	67	68	69
3	46	51	53	55	58	60	61	69	70	70	71
4	47	52	54	57	60	62	65	71	73	74	75
5	47	53	56	60	63	66	69	75	76	76	78
6	48	53	54	56	59	61	63	69	71	71	73
7	48	53	55	58	61	63	66	72	75	75	76
8	49	53	55	59	62	65	68	74	76	76	77
9	49	53	55	59	61	64	67	74	75	76	78
10	48	53	55	57	60	61	65	71	72	74	76
11	49	54	55	58	60	62	65	71	72	73	74
12	49	54	56	59	62	65	68	74	76	77	79
13	47	58	63	70	74	77	81	88	91	92	95
14	47	56	62	68	73	77	80	88	90	92	95
15	47	54	59	63	67	70	74	81	84	85	88
16	47	55	60	65	70	74	77	84	86	87	90
17	47	58	63	70	74	78	81	88	91	92	95
18	47	59	67	74	80	84	87	95	98	99	102
19	47	60	68	75	80	84	88	95	98	99	101
20	47	58	65	71	75	79	83	90	92	94	96
21	48	63	70	77	82	87	90	92	100	102	105
22	49	66	76	83	89	94	98	105	108	110	113
23	49	67	76	84	89	94	98	105	108	109	113
24	49	66	74	80	85	90	93	101	103	105	107
25	49	65	72	79	84	89	92	100	102	104	107
26	49	65	75	82	88	93	96	103	106	108	111
27	49	67	76	84	89	94	98	105	107	109	112
28	49	67	75	82	88	92	96	103	106	107	110
29	49	66	75	84	90	94	98	105	108	110	113
30	49	66	75	83	88	93	97	104	107	108	112
31	48	63	71	79	84	89	93	100	102	104	108
32	50	76	86	94	100	106	110	118	120	121	124
33	55	78	86	94	100	105	109	116	119	121	124
34	56	79	87	95	101	105	109	117	119	121	124
35	53	75	85	94	100	104	108	115	118	120	123
36	53	75	85	93	99	104	107	115	118	120	123
37	53	75	85	93	99	103	107	115	117	120	123
38	65	86	90	94	98	101	104	111	112	114	116
39	52	58	59	61	63	65	67	72	73	73	75
40	47	51	51	54	56	59	61	67	68	67	70
Amb. Temp.	56	55	54	53	53	53	53	52	50	47	46
Volts	87.5	90	89.5	89	88	88	88	88	88	88	88
Amps	33.5	33.5	33	33	33	33	33	33	33	33	33

Special Observations or Remarks

@ 1530 POWER ON AT 2930 WATTS @ 2240 CALIBRATED BECOMEN

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KNAPP MILLS INC.

WILMINGTON, DELAWARE

Piqua-Elk River Spent Fuel Shipping Cask
Dry Thermal Test Data Sheet

Test Engineer RW PETERSON

Recorder BAGGS

Date 2/27/64

Time Temp. °F	0300	0400	0500	0600	0630	0700	0730	0800	0830	0900	1000
1	75	74	74	74	73	72	73	73	73	73	74
2	69	69	69	67	67	66	67	67	68	68	68
3	72	71	71	70	70	70	70	70	71	71	72
4	75	75	75	74	74	74	75	75	76	76	77
5	78	78	78	77	77	78	78	77	78	78	80
6	73	73	73	72	72	72	72	72	73	73	73
7	77	77	76	76	76	76	76	76	77	77	78
8	77	77	78	77	77	77	77	77	78	78	79
9	76	79	79	78	78	78	78	78	78	78	80
10	76	76	76	75	76	76	76	75	76	75	77
11	75	75	75	74	74	74	74	74	75	75	76
12	80	81	81	80	80	80	80	80	80	80	81
13	96	97	97	97	97	97	97	96	97	97	101
14	96	97	97	97	97	97	97	97	98	98	101
15	88	89	90	89	89	89	89	89	90	90	94
16	91	92	92	92	92	92	92	92	92	92	95
17	96	97	98	98	98	98	98	97	98	98	103
18	103	104	105	105	105	105	105	110	110	110	113
19	100	98	98	97	98	97	98	94	95	95	102
20	97	98	98	98	98	98	98	98	99	99	104
21	106	107	108	108	108	108	108	107	108	108	116
22	115	116	116	116	117	117	117	116	116	116	127
23	114	115	116	116	116	116	116	115	116	116	126
24	109	110	110	110	110	110	110	110	111	111	121
25	109	110	110	110	111	111	111	111	112	112	121
26	113	114	114	115	115	115	115	114	115	115	122
27	114	115	115	116	116	116	116	115	116	116	125
28	112	113	113	114	114	114	114	114	114	115	124
29	115	116	117	118	118	118	118	117	118	118	130
30	113	115	115	116	116	116	116	116	116	116	128
31	109	110	111	111	112	111	111	111	111	111	121
32	128	128	129	129	129	129	129	128	128	128	150
33	126	127	128	128	128	128	127	127	127	127	148
34	126	127	128	128	128	128	127	127	128	128	150
35	125	126	127	127	128	128	127	127	127	128	143
36	125	126	127	128	128	128	127	127	127	127	143
37	125	126	126	127	127	127	127	127	127	127	143
38	117	118	118	119	119	118	118	117	118	119	139
39	75	75	74	72	72	72	72	73	74	75	78
40	70	70	69	69	69	69	70	71	72	72	73
Amb. Temp.	44	42	41	41	40	42	42	43	44	44	45
Volts	88	88	89	89	90	88	88	85	88	88	127
Amps	33	33	33.5	33.5	33.5	33	33	33	33	33	46

Special Observations or Remarks

@ 0630 READJUSTED POWER TO 2930 WATTS

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KNAPP MILLS INC.

WILMINGTON, DELAWARE

Piqua-Elk River Spent Fuel Shipping Cask
Dry Thermal Test Data Sheet

Test Engineer R. W. PETERSON Recorder Covey Date 2/22/64

Time Temp. °F	1100	1200	1300	1400	1500	1600	1700	1730	1800	1830	1900
1	75	77	80	82	84	85	85	86	87	87	87
2	69	71	72	73	75	77	78	80	80	80	80
3	73	75	77	80	82	82	83	85	87	85	86
4	78	80	83	85	86	86	85	88	89	88	90
5	82	85	88	92	94	95	95	97	98	97	98
6	75	77	79	81	83	86	86	87	88	88	88
7	80	83	86	89	93	94	94	96	98	97	98
8	81	84	87	90	93	92	93	95	96	95	96
9	82	85	88	92	95	96	97	99	100	99	100
10	79	82	85	88	90	92	93	94	95	94	95
11	78	80	83	85	88	90	90	91	93	92	92
12	83	86	89	93	95	97	98	100	100	100	100
13	108	113	118	122	125	127	128	130	131	130	131
14	109	114	120	124	126	130	131	132	133	133	132
15	100	114	109	113	116	118	119	120	122	122	122
16	100	104	109	113	116	117	118	119	120	120	128
17	110	114	119	123	126	128	130	131	132	132	132
18	123	127	132	136	139	141	142	143	144	143	144
19	106	111	116	119	122	124	125	126	127	127	128
20	110	115	120	124	127	130	131	132	134	133	134
21	124	129	133	137	140	142	143	144	145	145	145
22	136	142	148	152	154	157	158	159	160	160	160
23	136	142	147	151	154	156	157	158	159	158	159
24	129	134	140	143	146	148	150	150	152	151	152
25	129	134	139	143	146	147	149	150	150	150	150
26	129	134	139	143	146	149	150	151	152	152	152
27	134	140	145	149	151	154	155	156	157	157	157
28	134	140	145	149	151	153	155	156	157	156	157
29	140	146	152	156	159	161	163	164	165	165	165
30	138	144	149	154	157	158	160	161	162	162	162
31	130	136	141	145	148	150	152	153	154	153	154
32	161	167	173	177	179	182	183	184	186	185	186
33	157	164	170	174	177	179	181	182	183	183	184
34	160	167	172	176	179	181	183	184	185	184	185
35	154	161	166	171	174	175	177	179	180	179	180
36	154	161	166	171	174	175	177	178	180	179	180
37	154	161	166	171	174	175	177	178	180	179	180
38	146	150	153	156	159	160	161	162	164	163	164
39	82	84	87	89	91	91	92	93	94	94	92
40	75	78	80	82	85	82	85	88	88	87	88
Amb. Temp.	46	47	47	47	47	43	42	45	45	45	48
Volts	128	127	127	127.5	127	127	127	128	127	127	127
Amps	46	46	46	46	46	46	46	46	46	46	46

Special Observations or Remarks

@ 0910 ADJUSTED POWER TO 5860 WATT'S

@ 1530-1700 OUTSIDE POOL OPEN

@ 1820 CALIBRATED RECORDER

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KNAPP MILLS INC.

WILMINGTON, DELAWARE

Piqua-Elk River Spent Fuel Shipping Cask Dry Thermal Test Data Sheet

Test Engineer RW PETERSON Recorder CASSIDAN Date 2/27/64

Time Temp-°F	1930	2000	2100	2130	2200	2230	2300	2330	2400	2/26 0100	0130
1	87	87	88	88	88	89	90	90	91	90	90
2	82	82	83	83	84	84	86	86	86	85	83
3	87	89	89	90	90	91	92	92	92	90	90
4	89	90	91	91	92	92	93	93	93	91	90
5	98	98	99	99	100	100	100	100	101	100	100
6	89	90	90	91	91	92	92	92	93	91	91
7	99	100	100	101	101	102	102	102	103	101	100
8	97	98	98	99	99	100	100	100	102	98	97
9	100	101	101	102	102	103	104	103	102	104	104
10	96	97	97	98	98	98	99	99	100	99	98
11	93	94	94	95	95	96	96	96	96	95	95
12	101	102	103	104	104	105	105	105	106	105	105
13	131	132	132	133	134	135	135	135	136	135	136
14	134	135	136	136	137	138	138	138	139	139	138
15	123	124	125	126	126	127	127	128	128	128	127
16	121	122	123	123	124	125	125	125	126	125	124
17	133	134	135	135	136	136	137	137	138	138	137
18	144	145	146	146	146	147	147	147	148	147	147
19	128	129	130	131	131	132	132	132	133	132	132
20	135	136	137	137	138	139	139	139	140	139	139
21	145	146	147	148	148	149	149	149	150	150	150
22	161	162	162	163	163	164	165	165	165	165	166
23	160	161	161	162	162	163	163	163	164	164	164
24	153	154	154	155	155	156	156	157	157	157	157
25	151	152	153	153	154	154	154	155	155	155	155
26	153	154	154	155	155	155	156	156	157	157	157
27	158	159	160	160	161	161	162	162	162	163	162
28	158	159	160	160	160	161	162	162	162	162	162
29	166	167	169	169	169	170	170	171	171	171	171
30	163	164	165	166	166	167	167	167	168	168	168
31	155	156	157	157	158	158	158	159	160	160	161
32	187	188	188	189	189	190	191	190	191	191	192
33	185	186	187	187	188	188	189	190	190	190	190
34	186	187	187	189	189	190	190	190	191	191	191
35	181	182	183	183	184	184	185	185	186	186	186
36	181	182	182	183	183	184	185	184	185	186	186
37	181	182	182	183	183	184	184	184	185	186	186
38	166	165	165	166	167	168	168	168	169	168	168
39	95	95	95	96	96	96	96	96	96	96	96
40	89	90	90	91	92	92	92	92	91	90	88
Amb. Temp.	45	45	44	44	44	44	44	43	42	42	41
Volts	127	127	127	128	128	128	127	128	128	128	128
Amps	46	46	46	46	46	46	46	46	46	46	46

Special Observations or Remarks

REVISED

KNAPP MILLS INC.

WILMINGTON, DELAWARE

Piqua-Elk River Spent Fuel Shipping Cask Dry Thermal Test Data Sheet

Test Engineer RW PETERSON Recorder BIGGS Date 2/28/64

Time Temp-°F	0200	0230	0300	0330	0400	0430	0500	0600	0700	0800	0900
1	90	90	90	90	93	90	90	91	93	95	98
2	82	82	82	82	82	82	82	82	83	86	90
3	89	89	89	89	89	89	89	91	92	95	97
4	90	90	89	89	89	89	89	90	92	95	99
5	100	100	100	90	100	99	100	102	104	107	111
6	91	91	90	90	90	90	90	90	92	96	99
7	130	130	130	130	130	130	130	132	134	138	142
8	97	97	97	97	96	96	96	98	101	105	109
9	104	104	104	104	104	103	104	105	107	110	113
10	97	96	95	98	98	98	91	100	101	104	108
11	95	94	94	94	94	94	92	95	97	101	104
12	105	105	105	104	104	104	104	105	107	111	115
13	136	136	136	136	136	136	137	143	147	150	153
14	135	139	139	139	139	139	141	147	151	154	157
15	127	127	127	127	127	127	128	135	139	143	146
16	124	124	124	124	124	124	125	129	138	138	141
17	137	137	137	137	137	138	139	143	146	149	151
18	147	147	147	147	147	148	150	154	158	160	163
19	132	132	132	132	132	132	132	135	138	141	144
20	139	139	139	139	139	139	142	147	150	154	156
21	150	150	150	150	150	151	152	158	163	166	169
22	160	160	160	160	160	169	172	174	174	180	190
23	164	165	165	165	165	167	171	177	182	185	188
24	157	157	157	157	157	159	163	164	168	171	174
25	156	156	156	156	156	157	159	164	168	171	174
26	157	158	158	158	158	158	160	167	171	174	177
27	163	163	163	163	163	164	166	172	176	180	182
28	162	163	163	163	163	164	167	172	176	180	183
29	176	176	176	176	176	174	178	182	187	191	194
30	148	148	148	148	148	171	175	178	187	191	193
31	160	161	161	161	161	162	166	172	177	181	184
32	143	143	143	143	143	193	203	209	216	219	227
33	140	141	141	141	141	198	202	207	215	218	221
34	142	142	142	142	142	202	208	215	220	225	227
35	157	157	157	157	157	191	196	204	209	213	216
36	156	157	156	157	157	191	196	204	209	213	216
37	186	186	186	186	186	191	196	204	209	213	216
38	162	162	162	162	162	175	181	185	187	191	194
39	95	95	95	95	95	95	95	98	100	102	105
40	88	88	88	88	88	88	88	88	91	95	100
Amb. Temp.	40	40	40	40	39	36	37	39	39	44	47
Volts	128	128	128	128	128	156	156	156	156	156	157
Amps	46	46	46	46	46	56	56	56	56	56	56

Special Observations or Remarks

(@ 0400 LOWERED POWER TO 8750 WATTS)

REVISED

ORIGINATOR

APPROVED

DATE

PAGE 5 OF 9

KNAPP MILLS INC.
WILMINGTON, DELAWARE

Piqua-Elk River Spent Fuel Shipping Cask
Dry Thermal Test Data Sheet

Test Engineer RW PETERSON Recorder COVELL Date 2/25/64

Time Temp-°F	1000	1100	1200	1300	1400	1500	1600	1700	1800	1900	2000
1	101	103	106	109	110	112	116	116	117	118	117
2	93	96	99	101	102	104	107	108	109	108	109
3	102	105	108	110	111	113	116	116	116	116	116
4	102	105	108	110	111	113	116	118	117	116	116
5	114	117	120	121	123	124	127	127	128	128	128
6	103	106	110	112	114	116	120	120	121	121	120
7	116	119	122	124	126	128	132	132	132	132	132
8	113	116	118	120	121	123	126	125	126	125	126
9	116	119	121	123	125	127	132	132	133	133	133
10	111	114	117	120	122	124	128	128	129	130	130
11	108	111	114	116	118	120	123	123	124	124	124
12	118	121	123	126	128	130	134	134	135	135	135
13	156	159	161	163	166	167	171	172	173	173	173
14	159	161	162	164	166	167	172	171	173	173	173
15	150	153	155	157	159	161	165	165	166	166	167
16	144	147	150	152	153	155	159	159	160	160	160
17	153	155	156	157	159	160	164	163	164	164	164
18	166	167	170	172	173	175	179	179	180	180	180
19	163	164	165	161	168	169	175	179	185	186	187
20	159	160	162	163	165	167	171	170	171	171	171
21	171	174	175	178	179	181	185	185	186	186	187
22	192	194	196	197	200	200	209	209	205	205	205
23	190	192	193	195	197	199	201	201	202	202	202
24	181	184	186	188	189	191	194	194	195	195	195
25	176	178	181	183	185	187	190	191	192	192	192
26	179	181	183	185	187	188	192	192	193	193	193
27	184	186	188	189	190	191	195	195	195	195	195
28	185	187	190	191	193	194	198	198	198	199	200
29	201	204	206	208	211	213	212	217	217	217	218
30	196	198	200	201	203	205	208	208	209	210	210
31	186	188	190	192	194	195	198	198	199	200	200
32	230	232	234	235	238	239	242	242	243	244	244
33	227	229	229	230	233	235	238	238	239	240	240
34	229	231	233	235	237	239	242	241	243	243	243
35	218	220	221	223	225	227	230	230	230	231	231
36	218	219	221	223	225	227	230	230	231	230	230
37	218	219	221	223	225	227	230	229	231	230	230
38	196	200	202	204	206	208	211	213	212	211	212
39	108	110	112	114	115	117	120	119	119	118	118
40	103	106	108	110	110	112	115	116	115	115	115
Amb. Temp.	50	52	53	54	54	53	53	52	51	50	49
Volts	157	157	155	156	157	157	156.5	157	157	158	158
Amps	56	56	55	55.5	56	56	55	56	56	55.5	55.5

Special Observations or Remarks

① 1530 CALIBRATED RECORDER.

ORIGINATOR

APPROVED

DATE

PAGE

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KNAPP MILLS INC.
WILMINGTON, DELAWARE

Piqua-Elk River Spent Fuel Shipping Cask
Dry Thermal Test Data Sheet

Test Engineer RW PETERSON Recorder CASSEDAY Date 2/28/64

Time Temp-°F	2100	2130	2200	2230	2300	2330	2/29 0100	0130	0200	0230	0400
1	118	118	118	117	116	116	115	115	114	114	115
2	109	109	108	108	108	107	116	106	105	105	105
3	115	115	115	115	114	113	113	113	112	112	114
4	116	117	117	117	115	114	113	113	112	111	113
5	128	128	129	127	127	126	125	124	124	123	125
6	121	121	119	119	118	117	115	115	114	113	114
7	132	132	131	132	131	130	129	128	128	127	130
8	125	125	125	123	122	122	121	121	120	119	121
9	123	123	123	123	123	122	121	120	120	120	120
10	130	130	130	130	130	129	128	127	126	126	127
11	124	124	123	123	122	122	120	120	119	118	120
12	135	135	135	135	135	134	133	132	131	131	133
13	173	174	173	173	173	172	172	171	171	173	170
14	173	174	173	173	173	172	172	171	171	173	178
15	167	167	167	166	166	165	164	164	164	168	173
16	160	161	160	161	160	159	158	157	157	158	165
17	164	164	164	164	164	164	163	163	162	163	166
18	180	180	180	180	180	180	179	178	178	179	179
19	187	187	185	186	186	185	183	182	182	169	175
20	171	172	172	172	171	171	171	170	169	171	175
21	186	187	187	187	186	186	186	186	185	189	193
22	206	207	206	206	206	206	206	206	205	211	217
23	207	203	203	203	202	202	202	202	201	206	211
24	195	196	195	196	196	196	195	195	194	199	204
25	193	193	193	194	193	193	193	193	192	195	198
26	193	194	194	194	194	194	194	193	193	196	201
27	195	196	196	196	195	192	195	195	194	196	200
28	200	200	200	200	200	200	200	198	198	201	206
29	219	219	219	218	218	218	218	218	217	223	230
30	210	211	210	210	211	210	210	210	209	215	221
31	200	200	200	200	201	200	200	200	200	205	211
32	245	245	245	245	246	246	246	246	246	261	267
33	240	240	240	241	241	241	241	240	241	239	243
34	244	245	244	245	244	243	244	244	244	260	266
35	232	232	232	233	233	233	233	232	232	240	246
36	232	232	231	232	232	232	232	232	231	240	246
37	237	232	231	232	232	232	232	232	231	240	246
38	211	211	212	212	213	211	212	211	211	220	223
39	118	118	117	117	116	116	116	115	115	115	116
40	115	114	114	113	112	111	110	109	108	108	109
Amb. Temp.	48	48	48	47	46	45	43	43	42	41	40
Volts	158	158	158	159	159	159	159	159	159	180.5	180.5
Amps	56	56	56	56	56	56	56	56	56	64.5	64.5

Special Observations or Remarks

Ⓢ 0215 ADJUSTED POWER TO 11,700 WATTS

KNAPP MILLS INC.

WILMINGTON, DELAWARE

Piqua-Elk River Spent Fuel Shipping Cask
Dry Thermal Test Data Sheet

Test Engineer RW PETERSON Recorder BIGGS Date 2/29/64

Time Temp-°F	0500	0600	0700	0800	0900	1000	1100	1200	1300	1400	1500
1	116	117	122	122	121	122	123	124	126	127	128
2	106	106	111	111	112	113	113	114	115	116	117
3	114	115	120	121	121	122	123	125	125	126	127
4	114	115	120	120	121	122	122	124	124	126	127
5	126	127	133	133	132	133	133	136	137	138	138
6	115	116	120	120	122	123	123	124	125	126	127
7	132	134	140	140	142	142	142	143	146	146	148
8	123	124	129	129	131	132	131	132	132	132	133
9	121	123	138	138	139	139	140	142	143	144	144
10	128	130	135	135	137	138	138	140	141	142	142
11	121	123	128	128	130	137	131	133	134	135	135
12	134	136	141	142	144	144	145	146	147	148	149
13	190	192	198	199	184	199	190	192	193	194	194
14	180	182	188	184	184	184	190	192	192	193	193
15	176	178	184	184	186	188	188	189	190	191	191
16	165	169	172	174	175	175	176	177	178	179	179
17	167	168	173	174	175	175	173	177	178	179	179
18	178	187	192	190	190	190	190	191	191	193	193
19	177	180	191	194	195	194	195	197	199	198	199
20	177	179	183	194	195	185	186	187	188	189	189
21	196	198	203	205	205	206	205	207	208	209	209
22	219	221	226	228	229	224	224	230	231	231	231
23	213	215	220	221	222	222	223	224	224	225	225
24	206	208	213	214	215	215	216	217	217	218	219
25	200	201	206	208	208	209	209	210	210	211	212
26	203	205	210	211	212	213	213	214	215	215	216
27	201	202	207	209	210	210	211	212	213	213	214
28	208	210	214	216	217	217	218	219	219	220	220
29	232	235	240	241	242	243	243	244	245	245	246
30	223	225	230	232	233	233	234	234	235	236	237
31	214	216	220	222	223	223	223	225	225	225	226
32	270	272	277	279	279	279	280	280	279	276	280
33	245	251	256	257	258	259	260	260	260	261	262
34	269	271	276	278	279	279	280	280	280	281	281
35	249	251	257	257	258	259	260	260	260	261	262
36	249	251	256	257	258	259	259	260	260	261	261
37	249	251	256	257	258	259	259	260	260	261	261
38	224	225	230	230	232	230	235	233	233	235	236
39	116	117	121	123	123	124	124	125	126	126	128
40	109	110	114	114	118	118	119	121	122	123	125
Amb. Temp.	40	40	40	40	41	41	41	42	43	43	44
Volts	180.5	180.5	180.5	180.5	180.5	180.5	180.5	180.5	180.5	180.5	180.5
Amps	64.5	64.5	64.5	64.5	64.5	64.5	64.5	64.5	64.5	64.5	64.5

Special Observations or Remarks

REVISED

KNAPP MILLS INC.

WILMINGTON, DELAWARE

Piqua-Elk River Spent Fuel Shipping Cask Dry Thermal Test Data Sheet

Test Engineer RW PETERSON Recorder COVELL Date 2/29/64

Time Temp - °F	1600	1700	1730	1800	1830	1900	1930	2000	2130	2100	2130
1	128	130	130	131	131	131	131	131	131	130	130
2	119	119	119	120	120	120	120	120	119	118	118
3	120	119	120	120	120	120	120	120	127	125	125
4	119	119	119	120	120	120	120	120	124	120	120
5	141	140	139	140	140	140	139	139	139	137	136
6	179	179	179	179	179	179	179	179	179	178	177
7	150	149	149	150	150	150	150	150	149	147	147
8	134	134	134	132	132	131	131	131	131	129	128
9	146	146	146	147	147	147	147	147	147	146	146
10	144	142	143	143	144	143	143	144	144	142	142
11	137	137	137	137	138	138	138	138	137	136	135
12	150	150	150	150	151	151	151	151	151	150	150
13	195	195	195	196	196	196	196	197	197	195	195
14	195	194	194	194	194	195	195	195	195	194	193
15	193	193	193	193	193	194	194	194	194	193	193
16	187	181	181	181	182	182	182	182	182	181	181
17	180	190	183	180	180	180	180	180	180	179	179
18	191	196	195	195	195	196	196	197	196	196	200
19	200	200	200	200	200	200	200	200	200	198	198
20	190	190	190	190	190	190	190	191	191	190	190
21	211	210	210	210	211	211	211	212	212	211	211
22	232	237	232	233	233	232	233	233	233	233	232
23	276	276	277	277	277	277	277	277	277	276	276
24	270	270	270	270	270	270	270	270	270	270	270
25	213	213	213	213	213	213	215	213	213	212	212
26	217	216	217	217	217	217	217	217	218	219	216
27	214	214	214	214	214	214	214	214	214	214	214
28	221	221	221	221	221	221	221	222	222	221	220
29	247	246	246	246	246	246	246	247	247	247	246
30	237	237	237	237	237	237	237	238	238	237	237
31	227	227	227	227	227	227	228	228	228	228	227
32	276	280	280	283	283	283	284	284	284	284	283
33	262	263	263	263	263	263	263	263	264	263	263
34	282	282	282	282	282	282	282	283	283	283	283
35	262	262	262	262	262	263	263	263	263	263	263
36	261	261	261	261	262	262	262	262	263	262	262
37	261	261	261	262	262	262	262	263	263	262	262
38	236	237	235	236	236	236	235	235	235	235	234
39	129	125	128	128	128	128	128	128	129	128	127
40	126	125	125	125	126	126	126	126	124	124	123
Amb. Temp.	46	46	46	46	45	44	44	44	43	43	43
Volts	180.5	180.5	180.5	180.5	180.5	180.5	180.5	180.5	180.5	180.5	180.5
Amps	64.5	64.5	64.5	64.5	64.5	64.5	64.5	64.5	64.5	64.5	64.5

Special Observations or Remarks

② 2130 COMPLETED DRY TESTS

REVISED

KNAPP MILLS INC.
WILMINGTON, DELAWARE

Piqua-Elk River Spent Fuel Shipping Cask
Cooldown Test Data Sheet

Test Engineer R.W. PETERSON Recorder BIGGS/CASER Date 3/6/64

TIME TEMP	0905	1030	1200	1230	1330	1400	1500	1600	1700	1800	1900	2000
1	55	57	67	69	74	79	81	92	100	106	110	114
2	56	58	64	65	70	75	81	86	93	99	104	111
3	56	59	71	75	80	86	92	96	105	110	112	116
4	57	59	69	72	78	83	90	95	102	108	112	115
5	55	63	74	82	88	96	103	100	115	122	125	128
6	57	59	66	69	75	81	90	94	103	110	115	119
7	57	63	75	83	89	99	107	106	120	128	133	137
8	56	62	74	79	86	94	102	101	114	120	125	128
9	53	60	68	76	81	90	99	94	110	119	124	128
10	57	60	68	75	80	88	97	94	111	120	125	130
11	58	62	68	75	80	89	98	90	111	119	124	128
12	57	64	72	78	83	91	100	98	114	122	127	131
13	55	85	111	122	121	138	145	150	160	167	172	177
14	55	85	116	127	129	146	154	160	170	175	179	180
15	53	77	114	114	120	128	140	144	158	165	171	175
16	53	75	92	100	109	117	124	132	145	157	167	170
29	58	129	162	173	184	192	199	205	215	221	227	230
30	58	125	158	169	179	185	192	199	209	215	220	224
31	58	118	150	161	171	176	183	189	197	204	209	211
32	61	157	190	203	217	227	237	244	254	260	265	267
33	61	163	199	205	211	214	218	223	232	238	242	243
34	62	167	200	211	221	227	235	242	253	260	264	267
35	60	146	180	191	201	207	214	220	230	237	241	245
36	60	145	180	191	200	206	213	220	230	237	241	245
37	60	146	180	191	200	206	213	220	230	237	241	245
T Amb	-	-	-	-	-	-	-	-	-	-	-	-
Qs - GPM												
Ts - OF												
Pair - PSIG												
Qc - GPM												
Tc In - OF												
Tc Out - OF												
Pc - PSIG												

Special Observations or Remarks:

@ 0900 POWER ON FOR HEAT-UP CYCLE 11,700 WATTS
@ 1215 CALIBRATED RECORDER AGAINST "MINI-MITE"

REVISED

KNAPP MILLS INC.
WILMINGTON, DELAWARE

Piqua-Elk River Spent Fuel Shipping Cask
Cooldown Test Data Sheet

Test Engineer R. W. PETERSON Recorder COVELL Date 3/6/64

TIME TEMP	2100	2200	2300	2400	3/7 0100	0200	0300	0400	0500	0600	0700	0800
1	119	120	121	122	123	124	125	125	125	125	125	125
2	110	111	112	113	114	113	114	112	112	112	112	114
3	120	120	121	122	123	124	124	124	123	124	123	123
4	119	120	121	122	123	122	122	121	120	120	120	122
5	132	133	134	134	134	134	134	134	133	131	130	129
6	123	125	125	126	126	126	126	125	124	124	123	124
7	140	140	145	147	148	148	148	148	148	148	147	147
8	120	131	132	132	131	132	130	128	125	123	121	121
9	133	135	136	138	139	140	141	141	140	140	139	144
10	135	138	140	141	142	142	142	142	141	140	139	141
11	133	134	135	137	137	138	138	138	138	138	137	145
12	134	140	142	144	145	147	147	147	148	148	147	150
13	181	183	185	187	188	190	190	191	191	191	190	190
14	182	184	185	185	186	187	188	187	188	189	187	187
15	179	181	183	185	186	187	187	188	188	187	186	186
16	165	167	169	170	171	173	173	173	173	173	172	172
29	235	237	238	239	241	243	243	243	244	243	242	243
30	229	230	232	234	235	237	237	238	238	237	237	237
31	216	218	220	221	222	223	224	224	225	223	222	219
32	272	275	279	279	280	283	283	284	284	282	281	281
33	250	250	254	255	254	258	259	260	260	258	257	257
34	271	273	275	276	278	280	280	281	281	279	278	278
35	250	252	254	256	257	259	260	260	260	260	259	258
36	250	251	254	256	257	259	260	260	260	259	258	258
37	250	251	254	256	257	259	260	260	260	259	258	258
T Amb	-	-	-	-	-	-	-	-	-	-	-	50
Q _s - GPM												
T _s - °F												
P _{air} - PSIG												
Q _c - GPM												
T _c In - °F												
T _c Out - °F												
P _c - PSIG												

Special Observations or Remarks:

REVISED

KNAPP MILLS INC.

WILMINGTON, DELAWARE

Piqua-Elk River Spent Fuel Shipping Cask
Cooldown Test Data Sheet

Test Engineer RW PETERSON Recorder BIGGS Date 2/7/64

TIME TEMP	0900	0910	0920	0930	0940	0950	1000	1010	1020	1030	1040	1050
1	118	95	84	81	77	73	72	70	69	66	66	66
2	96	84	75	73	68	65	64	63	62	61	60	60
3	100	86	79	77	68	70	69	67	66	65	64	63
4	115	104	92	88	83	77	76	74	72	70	69	68
5	90	79	71	69	65	64	63	63	61	60	60	60
6	81	71	70	65	61	59	58	57	57	56	56	56
7	81	69	70	68	65	64	63	62	61	60	59	59
8	101	97	76	74	70	67	65	64	63	62	61	61
9	64	60	57	56	55	54	53	52	52	52	50	50
10	61	58	55	55	54	54	53	54	53	53	52	52
11	51	51	51	51	51	51	51	51	51	51	51	51
12	61	60	57	57	56	55	55	55	54	54	53	53
13	176	162	151	148	142	136	135	138	138	135	133	133
14	171	172	175	173	170	165	164	161	157	153	151	150
15	170	159	151	147	142	136	135	132	129	126	123	122
16	160	152	137	134	128	121	120	117	114	112	109	109
29	244	240	235	233	229	223	221	215	215	212	205	151
30	237	234	228	226	221	215	213	209	206	202	199	183
31	223	222	218	216	212	206	203	203	199	195	193	137
32	242	274	274	271	267	261	249	256	234	231	247	258
33	258	254	248	246	243	237	236	232	229	225	221	222
34	214	217	272	270	266	260	259	255	256	245	245	227
35	260	259	254	252	248	242	240	236	233	229	225	216
36	260	258	254	252	248	242	240	236	233	229	225	216
37	260	258	254	252	248	242	240	236	233	229	225	216
T Amb	50	-	-	-	-	-	-	51	-	-	-	-
Qs - GPM	12	12	12	12	12	12	12	12	12	12	12	12
Ts - °F	47	47	47	47	47	47	47	47	47	47	47	47
Pair - PSIG	-	-	-	-	-	-	-	-	-	-	-	43
Qc - GPM	-	-	-	-	-	-	-	-	-	-	-	-
Tc In - °F	-	-	-	-	-	-	-	-	-	-	-	43
Tc Out - °F	-	-	-	-	-	-	-	-	-	-	-	127
Pc - PSIG	-	-	-	-	-	-	-	-	-	-	-	3

Special Observations or Remarks:

@ 0800 SPLASH SHIELD AROUND TOP OF CASK AT SPIRKY MANIFOLD

@ 0845 WATER SPRAY ON OUTER SHELL 12 GPM @ 47 °F

@ 1045 AIR COOLANT ON - 43 PSIG ON 1/8" NPT NIPPLE

NOTED THAT COOLING SPRAY SHOULD BE APPLIED TO HEAD AS WELL AS OUTER SHELL OR CLOSURE NUTS SHOULD BE LOOSENED PRIOR TO COOLDOWN TO PREVENT DIFFERENTIAL CONTRACTION BETWEEN BODY AND HEAD

REVISED

KNAPP MILLS INC.
WILMINGTON, DELAWARE

Piqua-Elk River Spent Fuel Shipping Cask
Cooldown Test Data Sheet

Test Engineer R. W. PETERSON Recorder BIGGS Date 3/7/69

TIME TEMP	1100	1110	1120	1130	1140	1150	1200	1210	1220	1230	1240	1250
1	65	65	64	64	64	63	63	61	61	61	59	59
2	60	60	58	58	58	58	57	58	57	56	55	55
3	62	62	62	61	61	61	61	60	59	59	58	58
4	68	67	66	65	64	64	64	62	62	61	61	61
5	60	60	60	60	59	59	59	59	58	57	57	57
6	56	56	55	55	55	54	54	54	54	54	54	54
7	58	58	57	58	58	58	58	57	56	57	56	56
8	61	60	60	60	59	59	59	58	58	58	58	58
9	50	50	50	50	50	50	50	50	50	50	49	49
10	52	52	52	52	52	52	51	51	51	51	51	51
11	51	51	51	50	50	50	50	50	50	51	50	51
12	53	52	52	53	53	52	52	51	52	52	52	52
13	121	129	127	126	123	123	121	118	118	112	110	104
14	148	146	143	142	139	137	135	132	129	125	122	121
15	122	120	117	116	115	115	114	109	106	103	100	98
16	106	105	103	101	99	99	97	96	94	91	90	90
29	138	135	131	129	127	95	97	160	170	175	186	193
30	176	169	161	163	160	145	151	151	151	152	150	149
31	127	125	123	122	121	75	76	75	75	79	83	86
32	196	185	181	178	175	161	175	195	195	192	191	184
33	194	184	179	177	174	166	175	190	192	192	192	191
34	193	184	179	177	174	166	175	191	194	194	195	170
35	198	188	183	180	176	176	182	195	197	199	196	193
36	197	188	183	180	176	176	182	195	197	196	192	190
37	197	188	183	180	176	176	182	195	197	198	195	192
T Amb	52	-	-	-	-	-	-	53	-	-	-	-
Q _s - GPM	12	12	12	12	12	12	12	12	12	12	12	12
T _s - °F	47	47	47	47	47	47	47	47	47	47	47	47
P _{air} - PSIG	43	41	41	42	42	42	44	40	42	43	42	40
Q _c - GPM	-	-	-	-	-	<1	<1	<1	<1	<1	<1	1
T _c In - °F	45	45	45	45	45	43	43	43	43	43	43	43
T _c Out - °F	143	142	140	138	137	195	203	212	203	182	172	162
P _c - PSIG	3	3	3	2	2	2	2	3	3	3	2	2

Special Observations or Remarks:

① 1145 CRACKED WATER VALVE TO MIX FITTING, < 1 GPM FLOW

② 1245 SLIGHTLY INCREASED WATER-TO-AIR MIX RATIO

NOTED RAPID RISE IN COOLANT OUTLET TEMP ABOVE CENTER ADAPTER TEMPERATURE WITH WATER-AIR MIXTURE. INDICATES EXCESSIVE NON-UNIFORM COOLING OF BASKET. BAFFLE MAY BE REQUIRED AT DRAIN LINE IN BOTTOM OF CASK CAVITY TO DIFFUSE COOLANT FLOW UNDER BASKET.

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KNAPP MILLS INC.

WILMINGTON, DELAWARE

Piqua-Elk River Spent Fuel Shipping Cask
Cooldown Test Data Sheet

Test Engineer RVP-15220 Recorder PAGES Date 3/1/80

TEMP	TIME	1300	1310	1320	1330	1340	1350	1400	1410	1420	1430	1440	1450	1500	1510	1520	1530	1540	1550	1600	1610	1620	1630	1640	1650	1700	1710	1720	1730	1740	1750	1800	1810	1820	1830	1840	1850	1900	1910	1920	1930	1940	1950	2000	2010	2020	2030	2040	2050	2100	2110	2120	2130	2140	2150	2200	2210	2220	2230	2240	2250	2300	2310	2320	2330	2340	2350	2400	2410	2420	2430	2440	2450	2500	2510	2520	2530	2540	2550	2600	2610	2620	2630	2640	2650	2700	2710	2720	2730	2740	2750	2800	2810	2820	2830	2840	2850	2900	2910	2920	2930	2940	2950	3000	3010	3020	3030	3040	3050	3100	3110	3120	3130	3140	3150	3200	3210	3220	3230	3240	3250	3300	3310	3320	3330	3340	3350	3400	3410	3420	3430	3440	3450	3500	3510	3520	3530	3540	3550	3600	3610	3620	3630	3640	3650	3700	3710	3720	3730	3740	3750	3800	3810	3820	3830	3840	3850	3900	3910	3920	3930	3940	3950	4000	4010	4020	4030	4040	4050	4100	4110	4120	4130	4140	4150	4200	4210	4220	4230	4240	4250	4300	4310	4320	4330	4340	4350	4400	4410	4420	4430	4440	4450	4500	4510	4520	4530	4540	4550	4600	4610	4620	4630	4640	4650	4700	4710	4720	4730	4740	4750	4800	4810	4820	4830	4840	4850	4900	4910	4920	4930	4940	4950	5000	5010	5020	5030	5040	5050	5100	5110	5120	5130	5140	5150	5200	5210	5220	5230	5240	5250	5300	5310	5320	5330	5340	5350	5400	5410	5420	5430	5440	5450	5500	5510	5520	5530	5540	5550	5600	5610	5620	5630	5640	5650	5700	5710	5720	5730	5740	5750	5800	5810	5820	5830	5840	5850	5900	5910	5920	5930	5940	5950	6000	6010	6020	6030	6040	6050	6100	6110	6120	6130	6140	6150	6200	6210	6220	6230	6240	6250	6300	6310	6320	6330	6340	6350	6400	6410	6420	6430	6440	6450	6500	6510	6520	6530	6540	6550	6600	6610	6620	6630	6640	6650	6700	6710	6720	6730	6740	6750	6800	6810	6820	6830	6840	6850	6900	6910	6920	6930	6940	6950	7000	7010	7020	7030	7040	7050	7100	7110	7120	7130	7140	7150	7200	7210	7220	7230	7240	7250	7300	7310	7320	7330	7340	7350	7400	7410	7420	7430	7440	7450	7500	7510	7520	7530	7540	7550	7600	7610	7620	7630	7640	7650	7700	7710	7720	7730	7740	7750	7800	7810	7820	7830	7840	7850	7900	7910	7920	7930	7940	7950	8000	8010	8020	8030	8040	8050	8100	8110	8120	8130	8140	8150	8200	8210	8220	8230	8240	8250	8300	8310	8320	8330	8340	8350	8400	8410	8420	8430	8440	8450	8500	8510	8520	8530	8540	8550	8600	8610	8620	8630	8640	8650	8700	8710	8720	8730	8740	8750	8800	8810	8820	8830	8840	8850	8900	8910	8920	8930	8940	8950	9000	9010	9020	9030	9040	9050	9100	9110	9120	9130	9140	9150	9200	9210	9220	9230	9240	9250	9300	9310	9320	9330	9340	9350	9400	9410	9420	9430	9440	9450	9500	9510	9520	9530	9540	9550	9600	9610	9620	9630	9640	9650	9700	9710	9720	9730	9740	9750	9800	9810	9820	9830	9840	9850	9900	9910	9920	9930	9940	9950	10000	10010	10020	10030	10040	10050	10100	10110	10120	10130	10140	10150	10200	10210	10220	10230	10240	10250	10300	10310	10320	10330	10340	10350	10400	10410	10420	10430	10440	10450	10500	10510	10520	10530	10540	10550	10600	10610	10620	10630	10640	10650	10700	10710	10720	10730	10740	10750	10800	10810	10820	10830	10840	10850	10900	10910	10920	10930	10940	10950	11000	11010	11020	11030	11040	11050	11100	11110	11120	11130	11140	11150	11200	11210	11220	11230	11240	11250	11300	11310	11320	11330	11340	11350	11400	11410	11420	11430	11440	11450	11500	11510	11520	11530	11540	11550	11600	11610	11620	11630	11640	11650	11700	11710	11720	11730	11740	11750	11800	11810	11820	11830	11840	11850	11900	11910	11920	11930	11940	11950	12000	12010	12020	12030	12040	12050	12100	12110	12120	12130	12140	12150	12200	12210	12220	12230	12240	12250	12300	12310	12320	12330	12340	12350	12400	12410	12420	12430	12440	12450	12500	12510	12520	12530	12540	12550	12600	12610	12620	12630	12640	12650	12700	12710	12720	12730	12740	12750	12800	12810	12820	12830	12840	12850	12900	12910	12920	12930	12940	12950	13000	13010	13020	13030	13040	13050	13100	13110	13120	13130	13140	13150	13200	13210	13220	13230	13240	13250	13300	13310	13320	13330	13340	13350	13400	13410	13420	13430	13440	13450	13500	13510	13520	13530	13540	13550	13600	13610	13620	13630	13640	13650	13700	13710	13720	13730	13740	13750	13800	13810	13820	13830	13840	13850	13900	13910	13920	13930	13940	13950	14000	14010	14020	14030	14040	14050	14100	14110	14120	14130	14140	14150	14200	14210	14220	14230	14240	14250	14300	14310	14320	14330	14340	14350	14400	14410	14420	14430	14440	14450	14500	14510	14520	14530	14540	14550	14600	14610	14620	14630	14640	14650	14700	14710	14720	14730	14740	14750	14800	14810	14820	14830	14840	14850	14900	14910	14920	14930	14940	14950	15000	15010	15020	15030	15040	15050	15100	15110	15120	15130	15140	15150	15200	15210	15220	15230	15240	15250	15300	15310	15320	15330	15340	15350	15400	15410	15420	15430	15440	15450	15500	15510	15520	15530	15540	15550	15600	15610	15620	15630	15640	15650	15700	15710	15720	15730	15740	15750	15800	15810	15820	15830	15840	15850	15900	15910	15920	15930	15940	15950	16000	16010	16020	16030	16040	16050	16100	16110	16120	16130	16140	16150	16200	16210	16220	16230	16240	16250	16300	16310	16320	16330	16340	16350	16400	16410	16420	16430	16440	16450	16500	16510	16520	16530	16540	16550	16600	16610	16620	16630	16640	16650	16700	16710	16720	16730	16740	16750	16800	16810	16820	16830	16840	16850	16900	16910	16920	16930	16940	16950	17000	17010	17020	17030	17040	17050	17100	17110	17120	17130	17140	17150	17200	17210	17220	17230	17240	17250	17300	17310	17320	17330	17340	17350	17400	17410	17420	17430	17440	17450	17500	17510	17520	17530	17540	17550	17600	17610	17620	17630	17640	17650	17700	17710	17720	17730	17740	17750	17800	17810	17820	17830	17840	17850	17900	17910	17920	17930	17940	17950	18000	18010	18020	18030	18040	18050	18100	18110	18120	18130	18140	18150	18200	18210	18220	18230	18240	18250	18300	18310	18320	18330	18340	18350	18400	18410	18420	18430	18440	18450	18500	18510	18520	18530	18540	18550	18600	18610	18620	18630	18640	18650	18700	18710	18720	18730	18740	18750	18800	18810	18820	18830	18840	18850	18900	18910	18920	18930	18940	18950	19000	19010	19020	19030	19040	19050	19100	19110	19120	19130	19140	19150	19200	19210	19220	19230	19240	19250	19300	19310	19320	19330	19340	19350	19400	19410	19420	19430	19440	19450	19500	19510	19520	19530	19540	19550	19600	19610	19620	19630	19640	19650	19700	19710	19720	19730	19740	19750	19800	19810	19820	19830	19840	19850	19900	19910	19920	19930	19940	19950	20000	20010	20020	20030	20040	20050	20100	20110	20120	20130	20140	20150	20200	20210	20220	20230	20240	20250	20300	20310	20320	20330	20340	20350	20400	20410	20420	20430	20440	20450	20500	20510	20520	20530	20540	20550	20600	20610	20620	20630	20640	20650	20700	20710	20720	20730	20740	20750	20800	20810	20820	20830	20840	20850	20900	20910	20920	20930	20940	20950	21000	21010	21020	21030	21040	21050	21100	21110	21120	21130	21140	21150	21200	21210	21220	21230	21240	21250	21300	21310	21320	21330	21340	21350	21400	21410	21420	21430	21440	21450	21500	21510	21520	21530	21540	21550	21600	21610	21620	21630	21640	21650	21700	21710	21720	21730	21740	21750	21800	21810	21820	21830	21840	21850	21900	21910	21920	21930	21940	21950	22000	22010	22020	22030	22040	22050	22100	22110	22120	22130	22140	22150	22200	22210	22220	22230	22240	22250	22300	22310	22320	22330	22340	22350	22400	22410
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