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HEAT TRANSMISSION TEST
OF AN L-3 CLASS II SHIPPING CONTAINER

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INTRODUCTION

To comply with the requirements of the Atomic Energy Commission Manual Chapter 0529, a Safety Analysis Report for Packaging (SARP) must include a study of the effects of a hot and a cold environment upon the package in question. The L-3 Class II shipping container had not been so studied previously, therefore, a heat transfer analysis was in order. It was decided to determine the thermal characteristics of the L-3 packaging, from the contents to the outer skin, by means of a test which is discussed below. The transfer of heat from the external surface of the L-3 to the environment was treated mathematically and is not a subject of this report.

DESCRIPTION OF TEST ITEM

The L-3 Class II shipping container, developed by the Rocky Flats Division of The Dow Chemical Company, is intended for the transportation of large quantities of fissile radioactive materials. These materials are contained in a nominal three-liter polyethylene bottle enclosed in a polyvinyl chloride bag (see figure 1). The bottle and bag are sealed inside a 4-13/16 inch inside diameter, stainless steel pressure vessel having a flanged, bolted closure. The pressure vessel is centered and supported by a welded tubular structure within an overpack of a 55-gallon removable-head drum. Vermiculite insulation material fills the space between the vessel and the drum. The fully-loaded weight is approximately 265 pounds.

TEST OBJECTIVES

This test had three objectives:

1. To determine the temperature difference between the radioactive solution and the skin of the L-3, due to decay heat.
2. To find the overall heat transfer coefficient for the shipping container.
3. To gain an appreciation of the thermal lag of the L-3, in terms of the temperature response of the contents of the packaging to a change in ambient temperature.

PROCEDURE

A complete L-3 Class II shipping container, serial number X-001, was requisitioned and partly disassembled. The polyethylene bottle was fitted internally with a waterproof heating tape and two thermocouples, numbers 4 and 5, located as shown in figure 2. The bottle was then filled with water to the level indicated and was capped. All electrical leads were brought out through a hole drilled in the center of the bottle cap.

The location of additional instrumentation is shown in figure 3. Thermocouples 1, 2, and 3 measured the temperature of the pressure vessel, while numbers 6 through 10 measured the temperature of the drum assembly. The ambient temperature was sensed by thermocouple 11.

The valve (part number 7, figure 3) was removed from the cover (part number 4, figure 3) and the wires from the polyethylene bottle were passed through the resulting opening before the cover was bolted in position. These wires were grouped with the leads from thermocouples 1, 2, and 3 and were brought out of the L-3 through a hole drilled in the center of the drum lid.

The test was performed in the storage room at the foot of stairwell 7 in 221-T Building. The temperature in this room was regulated by the output of two 115-volt heaters, which were manually controlled, and by two 230-volt heaters, operated by an automatic temperature controller. The 115-volt heaters, rated at 1,650 watts each, were located on the floor of the storage room, as was the 2,000-watt, 230-volt heater (see figure 4). The other 230-volt heater, rated at 4,000 watts and equipped with a small fan, was mounted high on one wall and aimed to move the air toward the floor. Although the Atomic Energy Commission Manual Chapter 0529, Annex 1, calls for still air, a slight movement of the air in the storage room was considered necessary for uniformity of temperature and accuracy of control.

A test stand (figure 5) was placed, legs up, in the center of the storage room floor. The L-3 was placed on top of the test stand, allowing all surfaces of the container to be exposed to the room air.

The thermocouple leads were attached to a Texas Instruments multi-point recorder, model FMW06B, serial number 662, and the chart speed was set at one and one-half inches per hour. Power to the heating tape was controlled by a Variac. A voltmeter (Midland, model 23-119, serial number 772) and an ammeter (Sensitive Research Instrument Company, model M1, serial number 704187) measured the inputs to the heating tape.

At 1216 on April 11, 1974 the storage room temperature was stabilized at 80 °F. At 1240 the Variac was turned on and adjusted to deliver 53.0 volts. The current was measured as 0.228 ampere, resulting in a power input to the

submerged tape heater of 12.1 watts. This value exceeds by about 25 percent the heat output of any plutonium solution to be shipped in the foreseeable future. It was chosen to produce voltage, amperage and temperature readings of sufficient magnitude for accurate results.

The test consisted of two experiments. The first experiment was concerned with objectives 1 and 2 above. The desired information was the equilibrium temperature of the water, when the room temperature and the heat input to the water were constant and known. Under the conditions described above, the solution reached equilibrium at 1500, April 14, approximately 74 hours after the start of the experiment. This part of the test was allowed to continue for an additional 41 hours (to 0800, April 16) to insure that the water temperature had indeed leveled off.

The second part of the test dealt with objective 3. The temperature of the storage room was raised as rapidly as possible to 100 °F, to determine the response of the contents of the packaging to a sudden temperature increase. Although interest was centered on ephemeral temperature excursions, the experiment was allowed to continue until it was certain that the new equilibrium had been reached.

The test was terminated at 1500, April 22, 1974.

DISCUSSION

During the test, fluctuations occurred in the voltage and amperage applied to the heater. These were small, equal to, or less than one percent, with the amperage remaining between 0.226 and 0.230. In terms of the power delivered, this works out to about plus or minus two percent variation from the nominal. The fluctuations are considered to be self-cancelling, and of no importance to the results of the test.

Some difficulty was encountered in regulating the temperature of the storage room. The 230-volt controller had a tendency to overcontrol and hunt while on automatic operation, and under certain conditions, to drift when operated in the manual mode. The hunting tendency was discovered before the test began. A preliminary run indicated that the room temperature could be controlled manually at 80 °F with sufficient accuracy, therefore it was decided to attempt to run both experiments in this mode. During the first experiment, the room temperature remained between 80 and 81.5 °F, a satisfactorily narrow range. In the second part of the test, run at a nominal 100 °F, a pronounced drift developed, resulting in overnight temperature excursions which were unacceptably large. The decision was then made to shift to automatic control, averaging the asymmetric temperature swings around 100 °F. Consequently the peak storage room temperature was 104 to 105 °F, and the minimum was 97 to 98 °F. Because

this part of the test was concerned only with the response of the contents of the L-3 to the sudden 20 °F rise in ambient temperature, the cycling around a 100 °F average did not affect the results. The typical period of the cycle was 19 minutes long, insufficient to reflect any measurable variation at the center of the L-3.

From the recorder chart, the following table of temperatures was constructed:

TABLE I
TEMPERATURES, °F

DAY, APRIL 1974	EXPERIMENT 1						EXPERIMENT 2				
	11	12	13	14	15	16	16	16	16	17	
TIME	1530	0800	1030	1000	0800	0800	0840	1240	1640	2040	
CUMULATIVE HOURS	2.8	19.3	45.8	69.3	91.3	115.3	116.0	120.0	124.0	128.0	
COMMENT	Test started at 1240					Increased heat input to room	Ambient reached 100 °F				
THERMO- COUPLE	1	79	107	119	122	123	123	125	128	130	
	2	80	108	120	123	124	124	126	129	132	
	3	78	93	103	106	107	107	110	113	115	
	4	82	114	127	130	131	131	133	135	138	
	5	85	117	130	132	133	133	135	138	140	
	6	80	80	81	82	83	82	89	97	98	100
	7	79	79	80	80	81	80	95	98	99	100
	8	79	79	80	81	82	81	95	98	99	100
	9	78	79	79	79	80	79	90	95	94	96
	10	79	79	80	80	80	80	90	93	93	93
	11	80	80	81	81	81	81	100	100	101	102

EXPERIMENT 1

The temperatures throughout the L-3 are considered to have reached equilibrium about 1500, April 14, 74 hours after the start of the experiment. All internal temperatures remained constant thereafter; external temperatures varied by about plus or minus .5 °F. An exception occurred on the morning of April 15, when all shipping container temperatures rose and fell approximately one degree in a variously delayed response to a similar overnight drift in the room temperature. The delay was greatest, of course, for the internal temperatures.

From thermocouples 4 and 5, in the table, the average temperature of the water at equilibrium is calculated to be $\frac{131 + 133}{2} = 132$ °F. The corresponding average of the drum temperatures (thermocouples 6 through 10) is $\frac{82 + 80 + 81 + 79 + 80}{5} \approx 80$ °F. Thus with a decay heat input of 12.1 watts, the average temperature differential through the L-3 Class II Shipping Container from the contents to the outer surface is:

$\Delta t = 132 - 80 = 52$ °F. From this, an overall heat transfer coefficient can be calculated:

$$U = \frac{Q}{\Delta t} = \frac{12.1}{52} = 0.233 \text{ watt/°F}$$

$$= 0.794 \text{ BTU/hr °F}$$

EXPERIMENT 2

Following a final reading of the temperatures of the L-3 stabilized in an 80 °F environment (Table I, 0800, April 16), the ambient temperature was raised as rapidly as possible to 100 °F. The time required to accomplish the increase was 40 minutes. Using Table I, and the recorder chart, the change in average water temperature and the time elapsed after the room reached 100 °F are determined and tabulated in the first two columns below.

TABLE II

TIME ELAPSED HOURS	AVERAGE WATER TEMPERATURE T_i °F	WATER TEMPERATURE INCREASE ΔT_i °F	RATIO $\Delta T_i / \Delta T_a$
0	132	0	0.0
4	134	2	0.10
8	137	5	0.25
12	139	7	0.35
16	141	9	0.45
20	142	10	
24	143	11	

Table II was extended to a 24-hour elapsed time, in order to indicate the trend of temperature values. However, the interest here centers on diurnal fluctuations, so 12, or at most, 16 hours should be enough time to cover the waxing portion of the daily cycle.

For a given object (in this case, the L-3) and over a specified time, the internal temperature increase is reasonably proportional to the increase in ambient temperature. Ratios of the change in internal (water) temperature to the 20 °F change in ambient temperature after a given elapsed period in this experiment are listed in the fourth column of Table II.

To illustrate the use of this information, consider an L-3 stabilized at 70 °F external and 120 °F internal temperatures, suddenly subjected to a 110 °F ambient temperature. Then $\Delta T_a = 110 - 70 = 40^\circ$. Eight hours later, $\Delta T_i = 0.25 \Delta T_a = 0.25 (40) = 10^\circ$, and the temperature of the contents is $120 + 10 = 130^\circ$ F. This is not an exact calculation, and diurnal fluctuations do not occur with suddenness. However, the method is sufficient as a "worst case" calculation in heat transfer problems where there exists the possibility that peak temperatures may induce unacceptable internal conditions in the L-3.

RESULTS

For the L-3 Class II Shipping Container:

1. With a heat input of 12.1 watts (41.3 BTU/hr) to the contents of the polyethylene bottle, the average temperature of these contents will stabilize at 52 °F above the average temperature of the drum. For a more normal loading of 5.9 watts the temperature difference is proportional and is calculated as 25 °F.
2. The overall heat transfer coefficient is 0.794 BTU/hr °F, calculated from the contents to drum surface.
3. A set of factors has been worked out to determine the internal temperature-time relationship following a sudden increase in the ambient temperature.

L - 3 CLASS II SHIPPING CONTAINER

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Figure 1

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NOVEMBER 1970

Storage Room
Figure 4

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