AN ENGINEERING EVALUATION OF THE STRUCTURAL ABILITY OF KENASCO CORPORATION'S RADIOACTIVE MATERIAL WASTE CONTAINER, DRAWING NO. 6901-002B USA DOT 7A, TYPE B, TO MEET THE SPECIAL TESTS OF THE DEPARTMENT OF TRANSPORTATION'S RULES AND REGULATIONS PARAGRAPH 173.398

C-2295, Task 4
* Indicates Revised Paragraph

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1765 213

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TABLE OF CONTENTS

1.0 INTRODUCTION

The Department of Transportation requires that hazardous materials be transported in containers capable of surviving normal shipping and handling environments and that will remain intact after severe accident conditions. Reference 1 describes the applicable rules and regulations.

This report is an engineering evaluation of the ability of the Kenasco Corporation's Radioactive Material Waste Container, Drawing Number 6901-002B, to structurally survive the various test conditions of Reference 1.

This is a Type B container.

1765 215

2.0 CONTAINER CONFIGURATION

Drawings describing the construction and configuration of this nuclear waste shipping container are enclosed as Kenasco Corporation shop drawing No. 6901-002B, and the Bill of Material No. 6901-002C. The container consists of a one-inch thick steel outer box and a two-inch thick steel inner box. The inner and outer boxes are separated by a set of shock tubes.

The shock tubes are a special design feature of this waste container. These devices are intended to absorb the energy of impact and to support the inner box so that it will remain intact throughout severe accident conditions. The design characteristics of the shock tubes are described in Section 3.0.

* The cover of the outer box is secured with 46 1-1/4 inch diameter high strength bolts, type ASTM A490. The cover of the inner box overlaps the box sides by six inches. This overlap will ensure that the container contents will always remain totally enclosed by the inner box.

The container is completely constructed of mild steel. This will enable the container to survive severe impact conditions by absorbing impact energy through plastic deformation. The edges are welded with full penetration of the material thickness or with an equivalent fillet area.

The empty container weighs approximately 37,000 pounds and is intended to carry a maximum payload of 5,000 lb. The payload contents will consist of fifteen Type A, 55-gallon drums.

* The container is sealed by two lengths of Garlock single lip closure seals, Type 23. The seal pressure is maintained by finger type stainless steel springs which force the seal lip against the container wall. The seal is rated for intermittent use up to 250°F.

* After shock tube deformation, there can be a maximum of 3.5 inches of clearance between the inner container and outer wall. The 6 inch deep inner container cover skirt will insure that the inner cover always

1765 216

remains in place. The outer seal on the cover skirt is about 4 inches down from the inner container edge so that it will always remain effective.

* The outer surfaces of the inner container and inner cover are coated with aluminum foil to reduce the heat radiated into the inner container and payload.

3.0 CONTAINER DESIGN FEATURES

3.1 Shock Tube Design

A shock tube is a thin wall tube with a diameter generally about the same as its height. It is designed to collapse at a stress somewhat greater than the material yield stress, rather than buckle. The shock tubes used with this container are shown in Figure 1.

Typical force-deflection curves for shock tube collapse are shown in Figure 2. The characteristic shock tube energy absorption is shown in Figure 3 in nondimensional form. For given shock tube dimensions and material properties, the amount of energy which a particular shock tube can absorb by collapsing up to 80% of its original height can be predicted by this curve.

The maximum acceleration of the arrested body may also be calculated by noting that initial shock tube collapse occurs at approximately the calculated ultimate strength of the shock tube.

The shock tube is welded to the inner box. A small gap is left between the tube and outer box (except for a few of the shock tubes which are tack welded to the upper and lower sides of the outside box to provide stability during normal container shipping and handling). This single attachment is intended to prevent buckling of the shock tube by relative inner and outer box sliding motion.

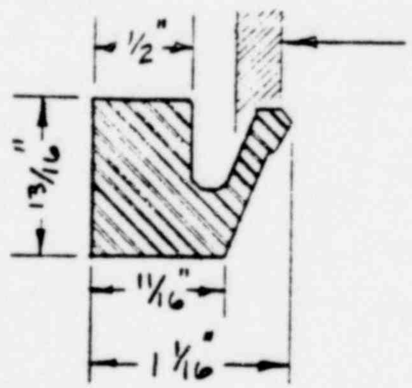
* 3.2 Inner Container Seals

The seal on the inner container, as shown on Kenasco Corporation Drawing 6901-002B, is a single lip split closure seal, Type 23, made by Garlock, Inc., Palmyra, New York. The seal section dimensions are shown below. Nominally, each seal is compressed 1/8" to 3/16". Under extreme conditions when the inner container sidewall is compressed against the inner cover lip, the outer seal will still be compressed from 1/16" to 5/16".

1765 218

In general, impact in any drop orientation will tend to compress the cover against the inner container. However, in an extreme case, the cover shock tubes could be crushed up to a maximum of 3-1/2" and subsequent bouncing could tend to keep the inner cover away from the inner container body. The wiping depth of the outside seal is therefore designed to be a minimum of 3-1/2".

The seal is capable of withstanding intermittent temperatures up to 250°F.



Garlock Single Lip Split Closure Seal, Type 23

1765 219

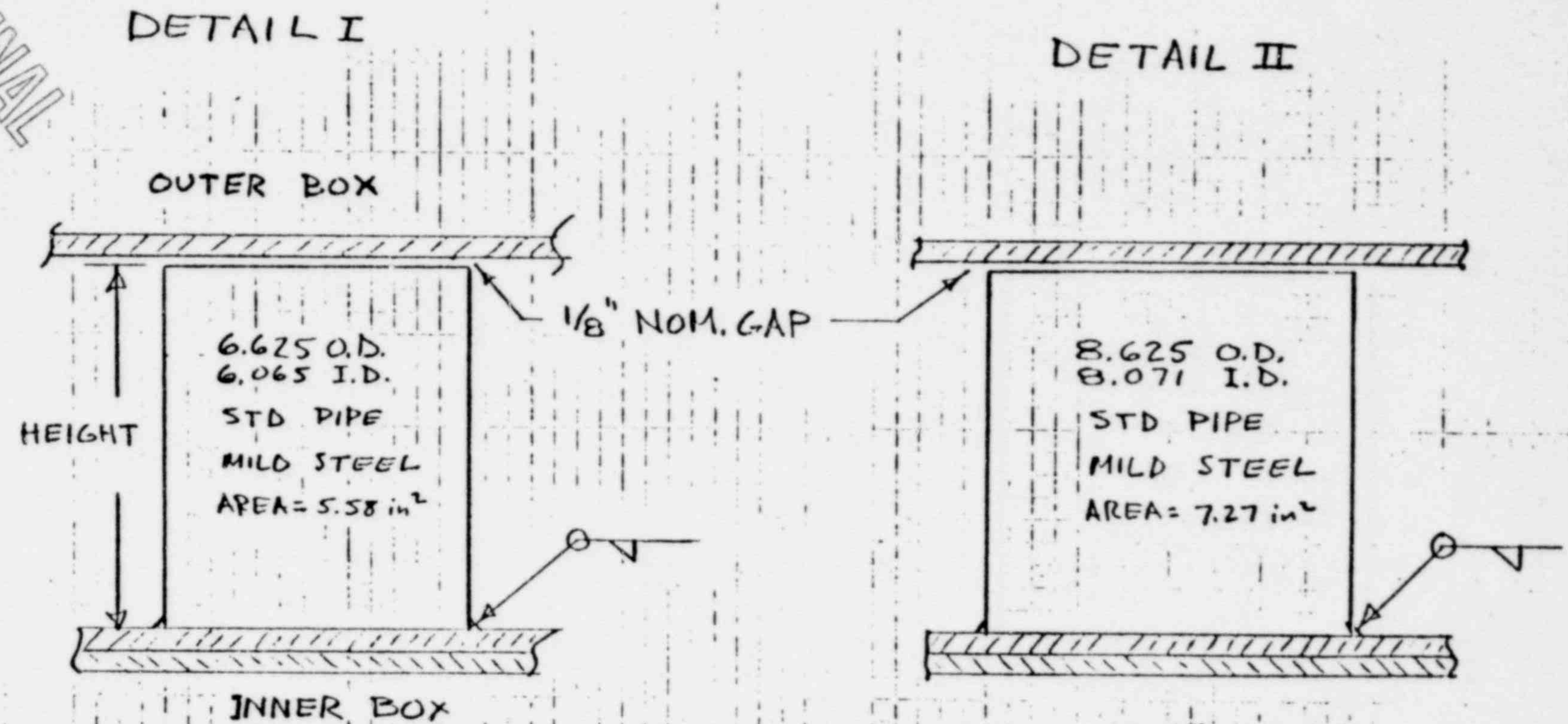

DETAIL I
OUTER BOX
1/8" NOM. GAP
6.625 O.D.
6.065 I.D.
STD PIPE
MILD STEEL
AREA= 5.58 in²
HEIGHT
INNER BOX
DETAIL II
8.625 O.D.
8.071 I.D.
STD PIPE
MILD STEEL
AREA= 7.27 in²

FIGURE 1

4.0 EVALUATION OF SPECIAL TEST REQUIREMENTS

The test requirements for which this container is being evaluated are given in paragraph 173.398 of the Department of Transportation Hazardous Materials Regulations (Reference 1). Since this is a Type B container, the standards of both subparagraphs b and c apply.

4.1 Thirty-foot Drop Test

The principle of the conservation of energy requires that when a falling body impacts against an unyielding surface, the impact force multiplied by the distance over which it acts must equal the kinetic energy of the falling body. The practical significance of this principle to the evaluation of an impacting container is that some deformation must occur to absorb the energy of motion.

The principle of the conservation of energy is expressed a.

$$\int F d\delta = 1/2 \ mv^2$$

For the impact of a freely falling body

$$v^2 = 2 gh$$

so that

$$\int F d\delta = Wh$$

where W is the container weight and h is the drop height.

The inner container and payload weigh approximately 26,000 lb. The kinetic energy of the inner box and payload for a 30 foot drop condition is

$$Wh = 26,000 \times 30 \times 12 = 9.4 \times 10^6 \text{ in-lb.}$$

The ultimate strength of the 6-inch diameter shock tubes are

$$F_{u6} = \sigma_u A = 75,000 \times 5.58 = 4.2 \times 10^5 \text{ lb.}$$

where σ_u is the material ultimate strength and A is the shock tube area.

TYPICAL SHOCK TUBE LOAD-DEFLECTION CURVES

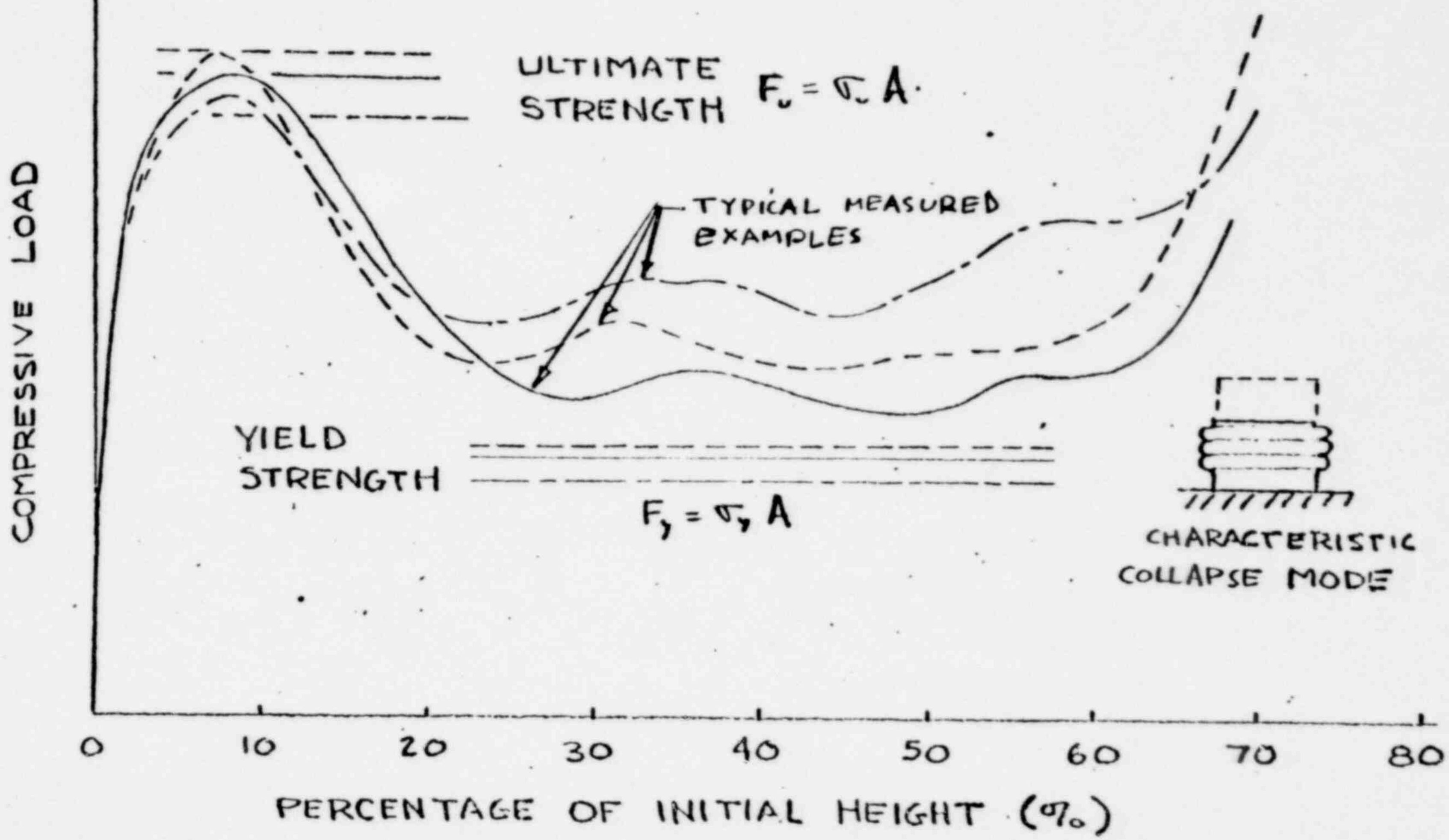
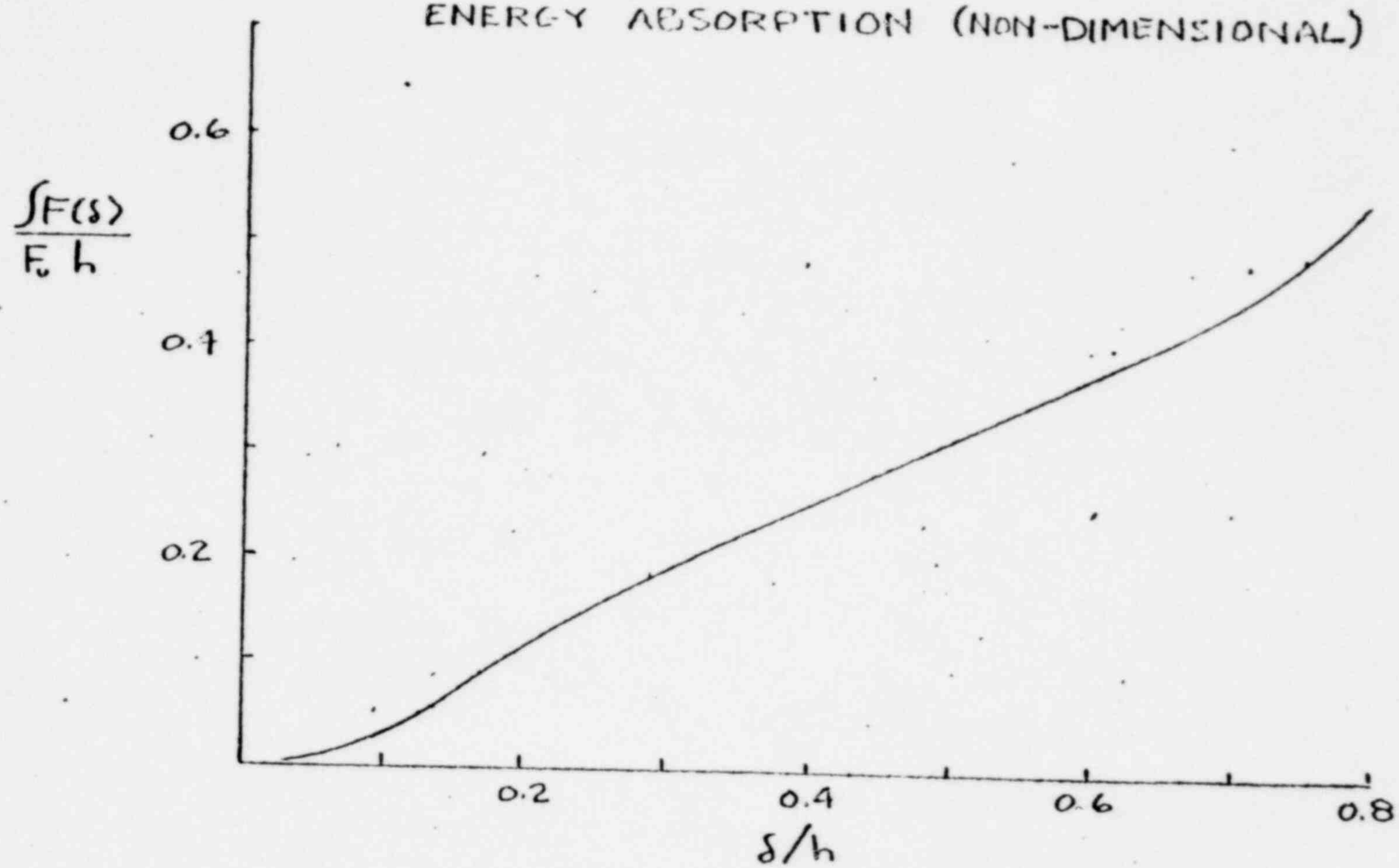


FIGURE 2

CHARACTERISTIC SHOCK TUBE

ENERGY ABSORPTION (NON-DIMENSIONAL)



$\int F(\delta)$ = Energy Absorbed $\quad F_u$ = Shock Tube Ultimate Strength

h = Shock Tube Original Height $\quad \delta_m$ = Shock Tube Crushed Distance

FIGURE 3

Similarly, the ultimate strength of the 8-inch diameter shock tube is

$$F_{u8} = 75,000 \times 7.27 = 5.5 \times 10^5 \text{ lb.}$$

* For a container impact against the top, bottom or sides (see Dwg. 6901-002B the total shock tube deformation required to absorb the kinetic energy of the inner box can be calculated from Figure 3 to be

$$\frac{\int F(\delta)}{N F_u h} = \frac{9.4 \times 10^6}{10 \times 4.2 \times 10^5 \times 5} = 0.45$$

where N is the number of shock tubes and h is the original shock tube height. Then, the maximum crushing of the shock tube, δm is:

$$\frac{\delta m}{h} = 0.70$$

$$\delta m = 0.70 \times 5 = 3.5 \text{ inches}$$

The maximum inner box deceleration, G_m, is

$$G_m = \frac{F_u \times N}{W} = \frac{4.2 \times 10^5 \times 10}{2.6 \times 10^4} = 163 \text{ g's}$$

* For a container impact against the end sides, (Figure 3), the 8 inch diameter shock tubes will deform. The total shock tube deformation, δ m, is predicted by

$$\frac{\int F(\delta)}{N F_u h} = \frac{9.4 \times 10^6}{8 \times 5.5 \times 10^5 \times 5} = 0.43$$

then,

$$\frac{\delta m}{h} = 0.68$$

and

$$\delta m = 3.4 \text{ inches}$$

The maximum inner box deceleration is

$$G_m = \frac{5.5 \times 10^5 \times 8}{2.6 \times 10^4} = 167 \text{ g's}$$

The cover is secured in place by 46 1-1/4" diameter ASTM
* A490 high strength bolts. Each bolt is capable of withstanding a tension load of 150,000 lb. The bolt pattern is located such that at least four bolts are adjacent to each shock tube.

The peak force exerted by each cover shock tube is 4.2×10^5
* lb. and since the four bolts together can withstand at least 6.0×10^5 lb., the cover will remain in place during impact conditions where the shock tubes react against the outer cover surface.

The inner container surface, opposite the impact surface,
* is loaded like a plate during flat impact against a side. See Figure 4. Assuming a uniform deceleration across the surface of 163 G's, the inner container cover stress and deflection, for each of the 1" thick plates, may be calculated from the table given in Roark, page 246. The factor

$$\frac{wb^4}{Et^4} = \frac{163 \times 0.283 \times 75^4}{30 \times 10^6 \times 1^4}$$

$$= 50$$

For this factor, the maximum deflection is about,

$$\frac{\delta}{t} = 1.2 \qquad \delta = 1.2 \times 1 = 1.2 \text{ inches}$$

The diaphragm or direct tension stress σ_d, is

$$\sigma_d = 3.8 \frac{Et^2}{b^2} = \frac{3.8 \times 30 \times 10^6 \times 1^2}{75^2}$$

$$\sigma_d = 20,000 \text{ psi}$$

The maximum stress , σ, due to tension and bending combined is:

$$\sigma = 9.9 \frac{Et^2}{b^2} = \frac{9.9 \times 30 \times 10^6 \times 1^2}{75^2}$$

$$\sigma = 53,000 \text{ psi}$$

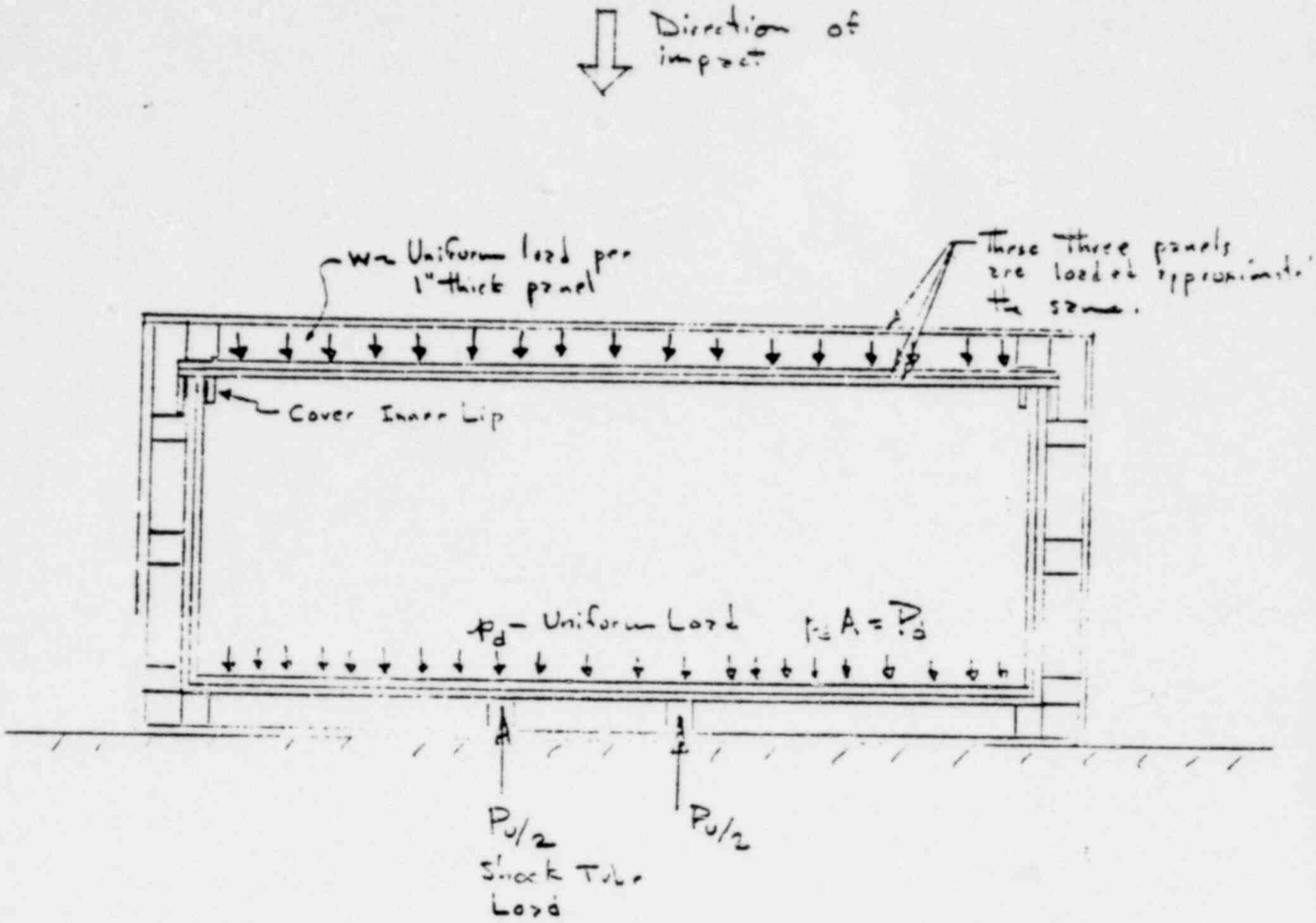

Direction of impact
w = Uniform load per 1" thick panel
These three panels are loaded approximately the same.
Cover Inner Lip
p_d – Uniform Load
$p_d A = P_d$
$P_D/2$
Shock Tube Load
$P_D/2$

FIGURE 4

The ultimate strength of the steel from which this container was fabricated ranges from 60,000 to 72,000 psi. Therefore, the container panels will not rupture.

The 1.2" deflection is well within the 3" clearance between the cover and the top of the 17H drums.

Most of the shock tubes are arranged on the inner container to react directly against the container edge and do not appreciably load the container surface. On the top, bottom and long inner container sides, two shock tubes have been placed toward the center of the panel to provide support for the deceleration of the container panel plus payload. (See Figure 4)

The total downward load P_d, for a top or bottom panels plus a 5,000 lb payload is:

$$P_d = 163\ (2 \times 0.283 \times 126 \times 75 + 5,000)$$

$$P_d = 16.8 \times 10^5 \text{ lb.}$$

The upward reaction of the two shock tubes, P_u, is:

$$P_u = 2 \times 4.2 \times 10^5 = 8.4 \times 10^5 \text{ lb}$$

Since the stress and deflection of a load concentrated near the center of a plate is approximately equal to that caused by 1.5 times the same total load if it were uniformly distributed, the action of the center shock tubes will largely cancel the stress and deflection of that caused by deceleration of the panel plus payload.

The inner lip of the inner container cover must prevent the inner container sidewalls from excessively bending inward. There are two shock tubes which directly load the inner lip and two more which contribute to the load. Assuming that the force against the inner lip is

1765 227

equivalent to the peak load of three shock tubes, the peak force is,

$$F_p = 3 \times 4.2 \times 10^5 = 1.26 \times 10^6 \text{ lb}$$

If this force is uniformly distributed along the inner lip, the shear stress σ_s, is:

$$\sigma_s = \frac{F_p}{A} = \frac{1.26 \times 10^6}{124 \times 1} = 10,000 \text{ psi}$$

The shear strength of the weld is about 20,000 psi so that the inner lip will not tear away from the cover.

* 4.2 Puncture and Penetration

A series of experiments were performed, as described in Reference 5, to determine the puncture resistance of flat panels. The resulting plot of puncture resistance for various skin thicknesses and weights is reproduced in Figure 5. Plotting the container total weight and outer skin thickness on these curves indicates that a 42,000 lb. container with a one-inch thick skin panel will pass this test without skin penetration.

The penetration test consists of dropping a steel rod weighing 13 lbs. through a distance of 40 inches onto the package surface. The energy of this condition, 520 in-lb, as compared to puncture test energy, 1.7×10^6 in-lb, indicates that if the skin panel will survive the puncture test it will easily survive the penetration test.

4.3 Reduced Pressure

The inner container seal is rated as being capable of withstanding a 7 psi pressure. The inner container walls can, of course, easily withstand this pressure differential.

4.4 Vibration

Vibration normally incident to transportation will not affect this container.

4.5 Water Spray

Since its construction is entirely of metal, the container is exempt from this requirement.

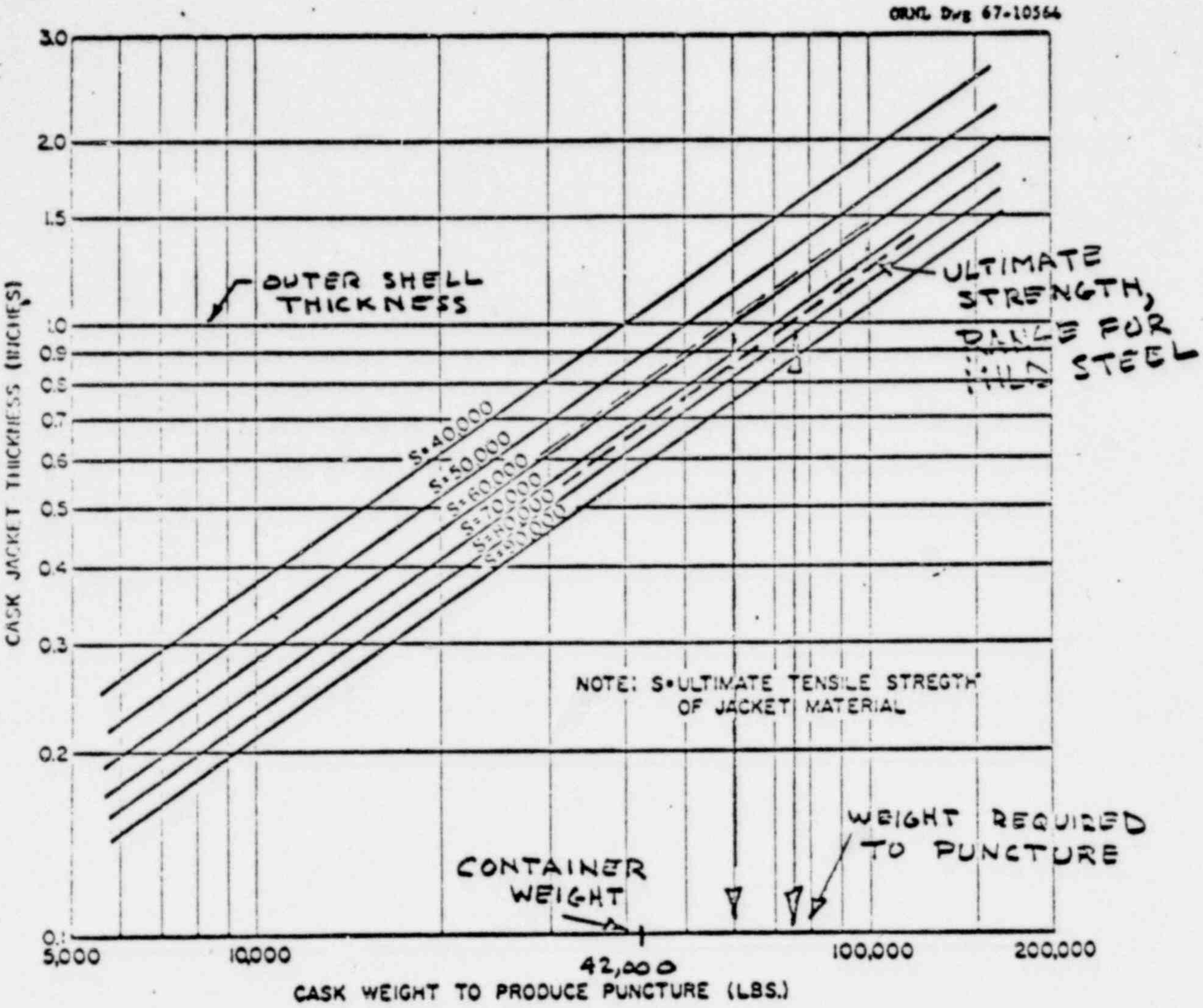


FIGURE 5

1765 229

* 4.6 **Fire Test**

The container has been analytically subjected to the required 1475°F fire test for a 30 minute period, using a transient electrical network analogy program (reference 8). The results of this analysis show for the modified design that the temperature of the payload at no time exceeds 160°F. Figure 6 illustrates the thermal and time history response of the container. The key feature of the modified design is the application of the thermal control surface to the outer surface of the inner box. This thermal control surface consists of bonded aluminum foil. Figure 7 illustrates the response of the original design without this thermal control coating. The temperatures of the payload in the unmodified original design approach 240°F. The aluminum foil thermal control coating is bonded to the steel inner box using a contact cement, Scotchgrip Rubber Adhesive - 1300, which maintains adhesive integrity up to 300°F.

Figure 8 illustrates both the analytic model used in this analysis and the equivalent electrical analog. The outer box wall has been subdivided into three nodes representing the thermal capacitance and conductance through the thickness of the outer box wall. The inner box has been idealized as four nodes, again representing both conductance and capacitance through the thickness of the inner box wall. The assumed emissivities for this problem are as follows:

Heat Source: $\epsilon = .9$

Outer Container Walls: $\epsilon = .8$

Inner box Walls

Outer wall: $\epsilon = .2$

Inner wall: $\epsilon = .8$

Payload: $\epsilon = .8$

1765 230

The model includes the following special features:

- Coupling between the outer box wall and the inner box wall consists of a radiant term, a temperature dependent air conduction term and a shock tube conduction term.

CONTAINER - PAYLOAD THERMAL PROFILE

Modified Design

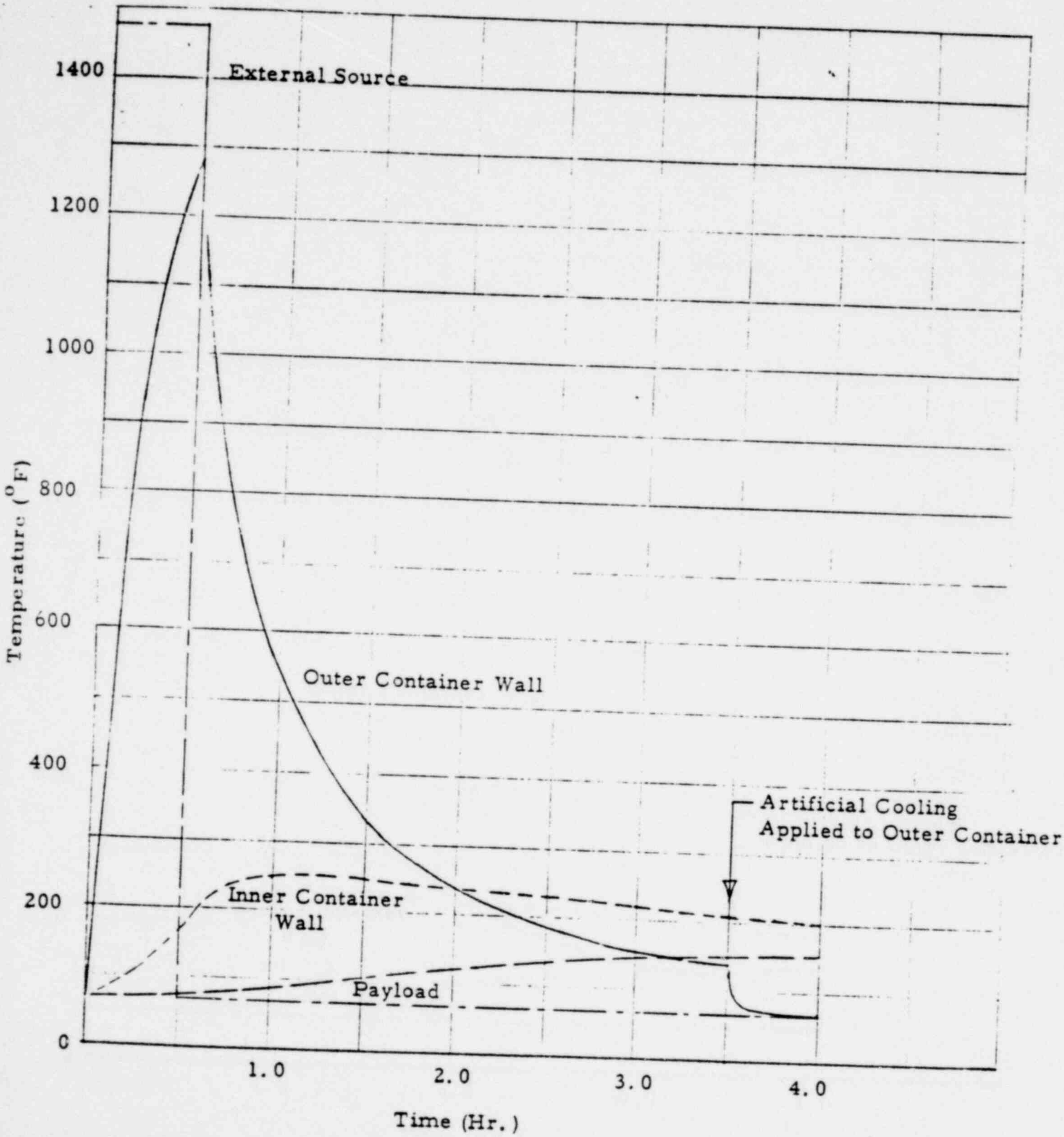


Figure 6

1765 231

CONTAINER - PAYLOAD THERMAL PROFILE
Original Design

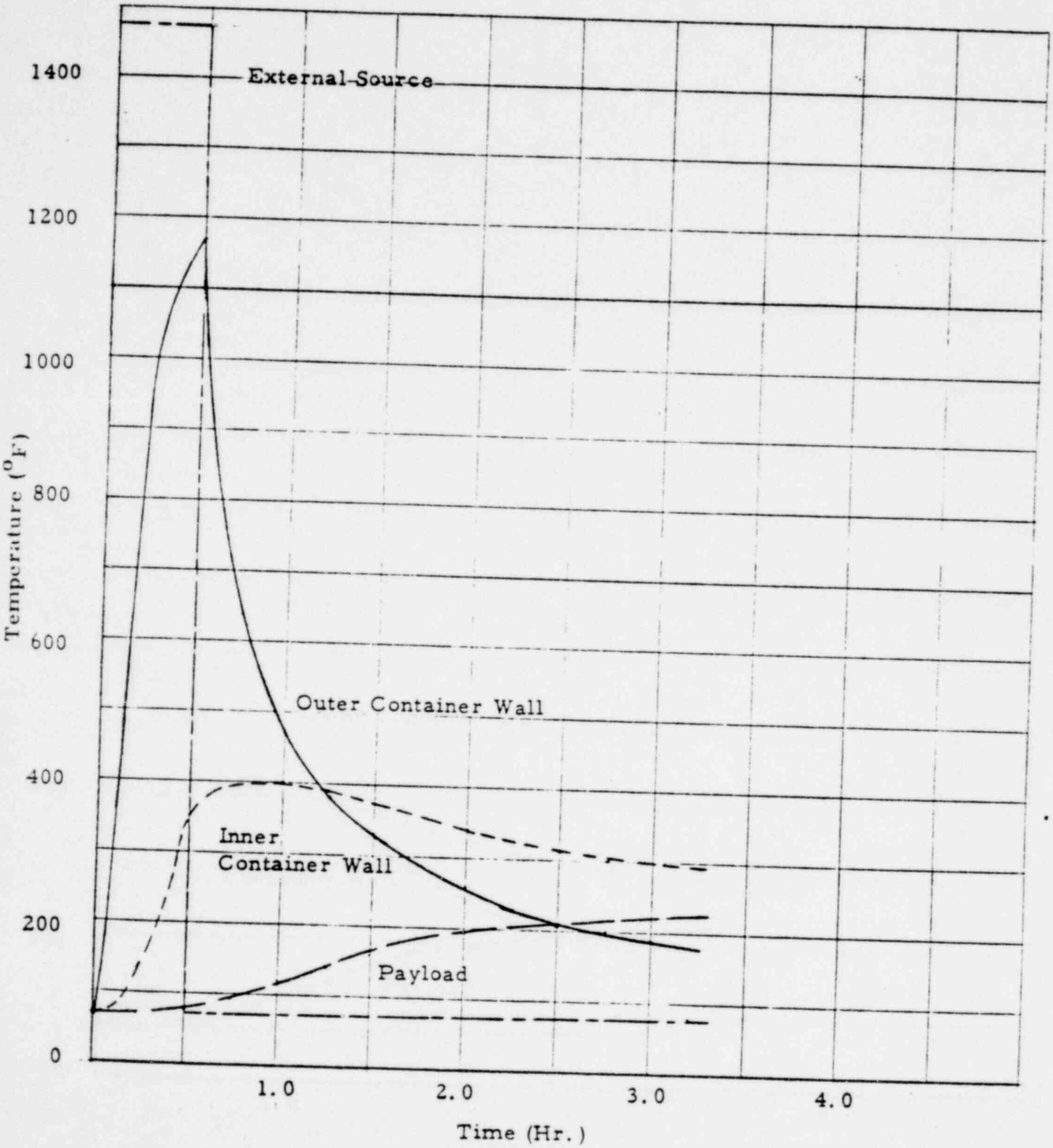


Figure 7

1765 232

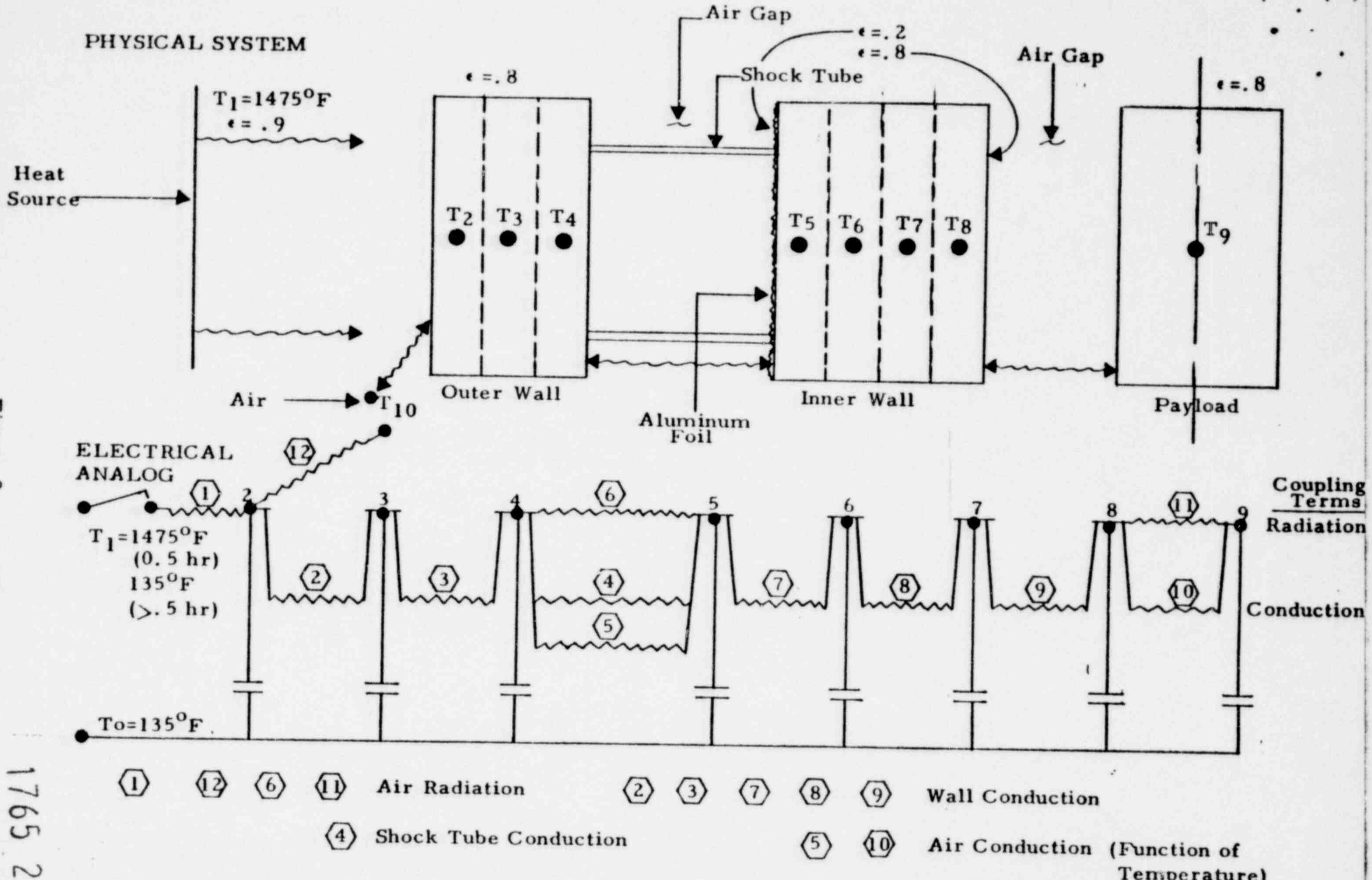


Figure 8

Thermal Analysis Model

1765 233

- Coupling between the inner box wall and the payload consists of a radiant term, and a temperature dependent air conduction term.
- Heat input consists of a programmed source temperature equal to 1475°F acting through a radiant coupling term to the outer box wall. This heat source at 30 minutes drops to a temperature of 70°F.
- At thirty minutes, a free convection and air radiation term is introduced coupling the outer box wall to an air temperature of 70°F. At 3-1/2 hours into the test sequence artifical cooling on the outer box wall is introduced as noted in Figure 6. This reduces the outer wall temperature to approximately 70° in about 15 minutes.

The details of this analysis are summarized in the following calculations:

<u>Nodal Capacitances</u>

A. Outer Wall Nodes - 2, 3, 4

Total Weight = 13,860 lbs.; c=.11 for steel

$$C_{2,3,4} = \frac{.11 \times 13,860}{3} = 508.2 \text{ Btu/}^{\circ}\text{R}$$

B. Inner Wall Nodes - 5, 6, 7, 8

Total Weight = 23,120 lbs; c = .11 for steel

$$C_{5,6,7,8} = \frac{.11 \times 23,120}{4} = 635.8 \text{ Btu/}^{\circ}\text{R}$$

C. Payload Node - 9

Total Weight = 5,000 lbs

Assumed Specific Heat = .33 Btu/lb-°R

C_9 = 5,000 x .33 = 1650 Btu/°R

1765 234

Evaluation of Conductive Resistors

$$R_{ij} = \frac{\ell_{ij}}{A_{ij}\, k_{ij}}$$

A. Outer Wall Resistors - 2, 3

$$\text{Area} = \frac{wt}{\rho \cdot t} = \frac{13,860}{(.283)(1)} = 48,975 \text{ in}^2$$
$$= 340.11 \text{ ft}^2$$

ℓ = 1/3 inch/12 = .02777 ft.

k = 25 Btu/hr-ft-°F (1% carbon)

$$R_{2,3} = \frac{.02777 \text{ ft } (3600 \text{ sec/hr})}{(340.11 \text{ ft}^2)(25 \text{ Btu/hr-ft-}^\circ\text{F})}$$

$$= .011757 \ ^\circ\text{R/Btu/sec}$$

B. Shock Tubes - 4

Area = 543 in^2, ℓ = 5 in

$$R_4 = \frac{(5/12)}{\left(\frac{543}{144}\right)(25)} = 15.911 \ ^\circ\text{R/Btu/sec}$$

C. Inner Wall Resistors, 7, 8, 9

$$\text{Area} = \frac{wt}{\rho t} = \frac{23,120 \text{ lb}}{(.283)(2)} = 40,848 \text{ in}^2$$
$$= 283.667$$

$$\ell = \frac{2}{4.12} = .041666 \text{ ft}$$

$$R_{7,8,9} = \frac{.041666\,(3600)}{(283.7)(25)} = .021148 \ ^\circ\text{R/Btu/sec}$$

Radiation Resistors

Radiation Resistors assume conservative values for emissivities consisting of $\varepsilon = .8$, for bare metal surfaces and $\varepsilon = .2$ for aluminum foil surfaces. The conservatism of these assumptions is verified by Table 1 presented on page 4-110 of reference 6.

$$Rij = \frac{1}{Kij\,[(Ti)^2 + (Tj)^2]\,[Ti + Tj]}$$

$$Kij = \frac{\sigma A_i}{(\frac{1}{\varepsilon_i} - 1) + (\frac{1}{F_{ij}}) + \frac{A_i}{A_j}(\frac{1}{\varepsilon_j} - 1)}$$

$$\sigma = .1714 \times 10^{-8}\ Btu/hr\text{-}ft^2\text{-}{}^oR^4$$
$$= .4761 \times 10^{-12}\ Btu/sec - ft^2 - {}^oR^4$$

A. Inner Wall to Outer Wall Coupling Resistor - 6

$A_i = 283.67\ ft^2$

$A_j = 340.11\ ft^2$

$F_{ij} = 1.0$

$\varepsilon_i = .2$ (1), $= .8$ (2)

$\varepsilon_j = .8$

(1) $$K_6 = \frac{(.4761 \times 10^{-12})(283.67)}{(\frac{1}{.2} - 1) + 1 + \frac{283.67}{340.11}(\frac{1}{.8} - 1)}$$

$$= 25.932 \times 10^{-12} \quad Btu/sec - {}^oR^4$$

(2) $$K_6 = \frac{(.4761 \times 10^{-12})(283.67)}{(\frac{1}{.8} - 1) + 1 + \frac{283.67}{340.11}(\frac{1}{.8} - 1)}$$

$$= 92.63 \times 10^{-12} \quad Btu/sec - {}^oR^4$$

1765 236

B. Payload to Inner Wall Coupling - 11

Assume $K_{11} = .92631 \times 10^{-10}$ Btu/sec - $^{o}R^4$

C. Radiant Source to Outer Wall - 1

Assume $\frac{A_1}{A_2} = 1.0$

$$K_1 = \frac{(.1714 \times 10^{-8})(340.11)(1/3600)}{(\frac{1}{.8} - 1) + 1 + (1.) \quad (\frac{1}{.9} - 1)}$$

$$= .118976 \times 10^{-9} \text{ Btu/sec - } {}^{o}R^4$$

D. Space Radiation - 12

$$K_{12} = (.1714 \times 10^{-8})(340.11)(.8)(1/3600.)$$

$$= .129543 \times 10^{-9} \text{ Btu/sec - } {}^{o}R^4$$

Temperature Dependent Air Conduction Resistance

The conductivity assumed for air uses the imperical relation given in section 16 of reference 7, Table 20.

$$R_i = \frac{\ell_i}{A_i k_i} = \left(\frac{\ell_i}{A_i}\right) \cdot \left(\frac{1}{k_i}\right)$$

where $k = k_{.2}\left(\frac{492 + C}{T + C}\right)\left(\frac{T}{492}\right)^{1.5}$, Btu/hr/^{o}F/ft^2

For Air: $K_3 = 0.155$

$C = 225$

A. Wall Airgap - 5

$$\left(\frac{\ell}{A}\right)_5 = \frac{5/12}{283.667} = 1.468 \times 10^{-3}/\text{ft.}$$

B. Payload Airgap - 10

$$\left(\frac{\ell}{A}\right)_{10} = \frac{2/12}{283.667} = 5875 \times 10^{-3}/ft$$

^oR	k_i [Btu/hr-ft-^oF]	$1/k_i$ [ft-sec-^oR/Btu]*
530.	.013715	$.262486 \times 10^6$
810.	.018902	$.190456 \times 10^6$
1050.	.022646]	$.158968 \times 10^6$
1310.	.026213	$.137336 \times 10^6$
1550.	.029176	$.123389 \times 10^6$
1810.	.032113	$.112104 \times 10^6$
1950.	.033598	$.107149 \times 10^6$

* Note: See following page

Combined External Air Convection and Radiation

Following application of the simulated 1475 degree fire the outer box wall is assumed to be cooled by combined air convection and radiation. The coefficient utilized for this combined equivalent convection loss has been taken from the data presented in Table 11, pages 4-106 and 4-107 of reference 6.

$$q = (hc + hr)A\,\Delta T$$

$$h = (hc + hr) @ 150^\circ \;\Delta T = 2.40 \text{ (Avg.) } B\cdot\cdot/ft^2\text{-hr}/^oF$$

$$R = \frac{1}{hA} = \frac{1 \;(3600 \text{ sec/hr})}{(2.4 \text{ btu/ft}^2\text{-hr}/^oF)\;(340.11 \text{ ft}^2)}$$

$$= 4.41 \quad ^oF/Btu/sec$$

This resistor switches in @ .5 hr.

Sample output from the computer program, reference 8, is included in the following pages and to substantiate the plotted results, Figures 6 & 7.

1765 238

LOADER 6K CORE

Tr vs K

T(R) =530.0	T(F) = 70.0	K(IN) = 0.16456E+00	K(FT) = 0.13715E-01
T(R) =550.0	T(F) = 90.0	K(IN) = 0.16949E+00	K(FT) = 0.14124E-01
T(R) =570.0	T(F) = 110.0	K(IN) = 0.17432E+00	K(FT) = 0.14527E-01
T(R) =590.0	T(F) = 130.0	K(IN) = 0.17907E+00	K(FT) = 0.14923E-01
T(R) =610.0	T(F) = 150.0	K(IN) = 0.18374E+00	K(FT) = 0.15312E-01
T(R) =630.0	T(F) = 170.0	K(IN) = 0.18834E+00	K(FT) = 0.15695E-01
T(R) =650.0	T(F) = 190.0	K(IN) = 0.19287E+00	K(FT) = 0.16073E-01
T(R) =670.0	T(F) = 210.0	K(IN) = 0.19733E+00	K(FT) = 0.16444E-01
T(R) =690.0	T(F) = 230.0	K(IN) = 0.20172E+00	K(FT) = 0.16810E-01
T(R) =710.0	T(F) = 250.0	K(IN) = 0.20605E+00	K(FT) = 0.17171E-01
T(R) =730.0	T(F) = 270.0	K(IN) = 0.21032E+00	K(FT) = 0.17527E-01
T(R) =750.0	T(F) = 290.0	K(IN) = 0.21453E+00	K(FT) = 0.17878E-01
T(R) =770.0	T(F) = 310.0	K(IN) = 0.21866E+00	K(FT) = 0.18224E-01
T(R) =790.0	T(F) = 330.0	K(IN) = 0.22278E+00	K(FT) = 0.18565E-01
T(R) =810.0	T(F) = 350.0	K(IN) = 0.22682E+00	K(FT) = 0.18902E-01
T(R) =830.0	T(F) = 370.0	K(IN) = 0.23082E+00	K(FT) = 0.19235E-01
T(R) =850.0	T(F) = 390.0	K(IN) = 0.23476E+00	K(FT) = 0.19563E-01
T(R) =870.0	T(F) = 410.0	K(IN) = 0.23865E+00	K(FT) = 0.19888E-01
T(R) =890.0	T(F) = 430.0	K(IN) = 0.24250E+00	K(FT) = 0.20206E-01
T(R) =910.0	T(F) = 450.0	K(IN) = 0.24630E+00	K(FT) = 0.20525E-01
T(R) =930.0	T(F) = 470.0	K(IN) = 0.25006E+00	K(FT) = 0.20838E-01
T(R) =950.0	T(F) = 490.0	K(IN) = 0.25378E+00	K(FT) = 0.21148E-01
T(R) =970.0	T(F) = 510.0	K(IN) = 0.25745E+00	K(FT) = 0.21454E-01
T(R) =990.0	T(F) = 530.0	K(IN) = 0.26108E+00	K(FT) = 0.21757E-01
T(R) =1010.0	T(F) = 550.0	K(IN) = 0.26468E+00	K(FT) = 0.22057E-01
T(R) =1030.0	T(F) = 570.0	K(IN) = 0.26823E+00	K(FT) = 0.22353E-01
T(R) =1050.0	T(F) = 590.0	K(IN) = 0.27175E+00	K(FT) = 0.22646E-01
T(R) =1070.0	T(F) = 610.0	K(IN) = 0.27524E+00	K(FT) = 0.22937E-01
T(R) =1090.0	T(F) = 630.0	K(IN) = 0.27869E+00	K(FT) = 0.23224E-01
T(R) =110.0	T(F) = 650.0	K(IN) = 0.28210E+00	K(FT) = 0.23509E-01
T(R) =130.0	T(F) = 670.0	K(IN) = 0.28548E+00	K(FT) = 0.23790E-01
T(R) =150.0	T(F) = 690.0	K(IN) = 0.28883E+00	K(FT) = 0.24069E-01
T(R) =170.0	T(F) = 710.0	K(IN) = 0.29215E+00	K(FT) = 0.24346E-01
T(R) =190.0	T(F) = 730.0	K(IN) = 0.29544E+00	K(FT) = 0.24620E-01
T(R) =210.0	T(F) = 750.0	K(IN) = 0.29870E+00	K(FT) = 0.24891E-01
T(R) =230.0	T(F) = 770.0	K(IN) = 0.30192E+00	K(FT) = 0.25160E-01
T(R) =250.0	T(F) = 790.0	K(IN) = 0.30512E+00	K(FT) = 0.25427E-01
T(R) =270.0	T(F) = 810.0	K(IN) = 0.30830E+00	K(FT) = 0.25691E-01
T(R) =290.0	T(F) = 830.0	K(IN) = 0.31144E+00	K(FT) = 0.25953E-01
T(R) =1310.0	T(F) = 850.0	K(IN) = 0.31456E+00	K(FT) = 0.26213E-01
T(R) =330.0	T(F) = 870.0	K(IN) = 0.31765E+00	K(FT) = 0.26471E-01
T(R) =350.0	T(F) = 890.0	K(IN) = 0.32072E+00	K(FT) = 0.26726E-01
T(R) =370.0	T(F) = 910.0	K(IN) = 0.32376E+00	K(FT) = 0.26980E-01
T(R) =390.0	T(F) = 930.0	K(IN) = 0.32678E+00	K(FT) = 0.27232E-01
T(R) =410.0	T(F) = 950.0	K(IN) = 0.32977E+00	K(FT) = 0.27481E-01
T(R) =430.0	T(F) = 970.0	K(IN) = 0.33274E+00	K(FT) = 0.27729E-01
T(R) =450.0	T(F) = 990.0	K(IN) = 0.33569E+00	K(FT) = 0.27974E-01
T(R) =470.0	T(F) =1010.0	K(IN) = 0.33862E+00	K(FT) = 0.28218E-01
T(R) =490.0	T(F) =1030.0	K(IN) = 0.34152E+00	K(FT) = 0.28460E-01
T(R) =510.0	T(F) =1050.0	K(IN) = 0.34440E+00	K(FT) = 0.28700E-01
T(R) =530.0	T(F) =1070.0	K(IN) = 0.34727E+00	K(FT) = 0.28939E-01
T(R) =1550.0	T(F) =1090.0	K(IN) = 0.35011E+00	K(FT) = 0.29176E-01
T(R) =570.0	T(F) =1110.0	K(IN) = 0.35293E+00	K(FT) = 0.29411E-01
T(R) =590.0	T(F) =1130.0	K(IN) = 0.35573E+00	K(FT) = 0.29644E-01
T(R) =610.0	T(F) =1150.0	K(IN) = 0.35851E+00	K(FT) = 0.29876E-01
T(R) =630.0	T(F) =1170.0	K(IN) = 0.36128E+00	K(FT) = 0.30106E-01
T(R) =650.0	T(F) =1190.0	K(IN) = 0.36402E+00	K(FT) = 0.30335E-01
T(R) =670.0	T(F) =1210.0	K(IN) = 0.36675E+00	K(FT) = 0.30562E-01
T(R) =690.0	T(F) =1230.0	K(IN) = 0.36946E+00	K(FT) = 0.30788E-01
T(R) =710.0	T(F) =1250.0	K(IN) = 0.37215E+00	K(FT) = 0.31012E-01
T(R) =730.0	T(F) =1270.0	K(IN) = 0.37482E+00	K(FT) = 0.31235E-01
T(R) =750.0	T(F) =1290.0	K(IN) = 0.37748E+00	K(FT) = 0.31457E-01
T(R) =770.0	T(F) =1310.0	K(IN) = 0.38012E+00	K(FT) = 0.31677E-01
T(R) =790.0	T(F) =1330.0	K(IN) = 0.38274E+00	K(FT) = 0.31895E-01
T(R) =810.0	T(F) =1350.0	K(IN) = 0.38535E+00	K(FT) = 0.32113E-01
T(R) =830.0	T(F) =1370.0	K(IN) = 0.38794E+00	K(FT) = 0.32329E-01
T(R) =1850.0	T(F) =1390.0	K(IN) = 0.39052E+00	K(FT) = 0.32543E-01
T(R) =1870.0	T(F) =1410.0	K(IN) = 0.39308E+00	K(FT) = 0.32757E-01
T(R) =1890.0	T(F) =1430.0	K(IN) = 0.39563E+00	K(FT) = 0.32969E-01
T(R) =1910.0	T(F) =1450.0	K(IN) = 0.39816E+00	K(FT) = 0.33180E-01
T(R) =1930.0	T(F) =1470.0	K(IN) = 0.40067E+00	K(FT) = 0.33390E-01
T(R) =1950.0	T(F) =1490.0	K(IN) = 0.40318E+00	K(FT) = 0.33598E-01

ALL DONE
TYPE G TO CONTINUE, X TO EXIT.
X

EXIT
↑C

.COST
CONNECT $2.26
COMPUTE $1.78

.KJOB
CONFIRM:K

1765 239

15 BARREL NUCLEAR MATERIAL WASTE CONTAINER TRANSIENT THERMAL ANALYSIS

PRINT CODES

.0000 .1000+01 .5000 .0000 .0000 .0000 .0000 .1000 .0000

THERMAL RESISTANCE DATA

RESISTOR	ATTACHING NODES		RESISTANCE DEG.R/BTU/SEC	
1	1	2	.10000+01	RESISTOR DATA •• OUTER RAD COUPLING
2	2	3	.11757-01	OUTER WALL CONDUCTION
3	3	4	.11757-01	
4	4	5	.15911+02	SHOCK TUBE CONDUCTION
5	4	5	.10000+01	AIR GAP CONDUCTION
6	4	5	.10000+01	AIR GAP RADIATION
7	5	6	.21148-01	INNER WALL CONDUCTION
8	6	7	.21149-01	
9	7	8	.21145-01	
10	8	9	.10000+01	PAYLOAD CONDUCTION
11	8	9	.10000+01	PAYLOAD RADIATION
12	2	10	.10000+01	EXTERNAL AIR

INITIAL TEMPERATURE DATA

NODE	TEMPERATURE (DEG. R)	
1	.19347+04	INITIAL NODE TEMPS
2	.52369+03	
3	.52369+03	
4	.52369+03	
5	.52359+03	
6	.52369+03	
7	.52369+03	
8	.52359+03	
9	.52369+03	
10	.52369+03	

NODE CAPACITANCE DATA

NODE	CAPACITANCE BTU/DEG.R	
1	-.10555+01	NODE CAPACITANCE
2	.59620+03	
3	.59620+03	
4	.59625+03	
5	.67530+03	
6	.67530+03	
7	.67520+03	
8	.67590+03	
9	.15220+03	
10	-.10000+01	

SPECIAL FUNCTION SPECIFICATIONS

RADIATION RESISTOR DATA - FUNCTION 2

RESISTOR	RESISTANCE DEG.F/BTU/SEC
1	.11339-09
6	.25332-10
11	.92631-10

RAD. RESISTOR K VALUES

TABULAR FUNCTION DATA - FUNCTION 7

DEP.I..	INDEP. ID	TABLE ID	FACTOR	
1	0	1	.10000+01	TABLE NO. 1 NODE 1 VS TIME
5	4	2	.14660-[illegible]	AIR GAP CONDUCTION
1[illegible]	8	2	.[illegible]6754-[illegible]	PAYLOAD CONDUCTION
1[illegible]	0	3	.10500+01	COMBINED AIR CONV/RADIATION

PRINT SPECIFICATION - FUNCTION 6

OUTPUT SPECIFICATION

CLASS	VARIABLE NO.	PLOTTING FACTOR
2	1	.0
2	2	.0
2	3	.0
2	4	.0
2	5	.0
2	6	.0
2	7	.0
2	8	.0
2	9	.0
2	10	.0
4	4	.0
4	5	.0
4	6	.0
4	10	.0
4	11	.0
4	12	.0

PROBLEM CONSTANTS

1 OUTPUT TIME INTERVAL = .60000+02

2 TIME INCREMENT BASED ON MINIMUM RC PRODUCT

3 RC[illegible] MULTIPLIER = .50000-00

4 PROBLEM CUT OFF TIME = .19920+05

5 TRANSIENT PROBLEM

6 INITIAL TIME = .00000

1765 241

POOR ORIGINAL

TABULAR FUNCTIONS

TABLE NO. 1
CLASS OF INDEPENDENT VARIABLE - 0
CLASS OF DEPENDENT VARIABLE - 2
PERIOD OF FUNCTION =. .000
CONSTANT FOR DEP. VARIABLE = .000

.0000000	.1935000+04
.1800000+04	.1935000+04
.1851000+04	.5300000+03
.1451000+05	.5300000+03

TABULAR FUNCTIONS

TABLE NO. 2
CLASS OF INDEPENDENT VARIABLE - [illegible]
CLASS OF DEPENDENT VARIABLE - 4
PERIOD OF FUNCTION =. .000
CONSTANT FOR DEP. VARIABLE = .000

.529500D+03	.262486D+06
.810000D+03	.190456D+06
.105000D+04	.15[illegible]580+0[illegible]
.131500D+04	.137336D+0[illegible]
.155000D+04	.12[illegible]990+06
.181900D+04	.11[illegible]040+06
.1[illegible]000D+04	.107199D+06

1765 243

TABULAR FUNCTIONS

TABLE NO. [illegible]
CLASS OF INDEPENDENT VARIABLE = 0
CLASS OF DEPENDENT VARIABLE = 4
PERIOD OF FUNCTION =. .000
CONSTANT FOR DEP. VARIABLE = .000

.0000000	.1000000+26
.1800000+04	.1000000+26
.1801000+04	.4410000+01
.1260000+05	.4410000+01
.1261000+05	.1000000+00
.1450000+05	.1000000+00

POOR ORIGINAL

1765 244

OUTPUT VARIABLES BY CLASS

TRANSIENT PROBLEM

TIME = .0000000 SEC.
MINIMUM RC PRODUCT = .0000000 SEC. ----- FOR NODE 0

NO. OF INCREMENTS = 0

CLASS 2 - TEMPERATURE, T

ID	DEGREES F	ID	DEGREES F	ID	DEGREES F	ID	DEGREES F
1	1475.7100000	2	70.0000000	3	70.0000000	4	70.0000000
5	70.0000000	6	70.0000000	7	70.0000000	8	70.0000000
9	70.0000000	10	70.0000000				

CLASS 4 - RESISTANCE, R

ID	DEG R/BTU/SEC	ID	DEG R/BTU/SEC	ID	DEG R/BTU/SEC	ID	DEG R/BTU/SEC
4	.1531100+03	5	.3852579+03	6	.5486922+02	10	.1541925+03
11	.1816610+02	12	.1000000+26				

-30-

1765 245

POOR ORIGINAL

OUTPUT VARIABLES BY CLASS

TRANSIENT PROBLEM

TIME = .1700031+02SEC.
MINIMUM RC PRODUCT = .2987454+01SEC. ----- FOR NODE 3

NO. OF INCREMENTS = 40

CLASS 2 - TEMPERATURE, T

ID	DEGREES F	ID	DEGREES F	ID	DEGREES F	ID	DEGREES F
1	1475.3100000	2	1288.3280200	3	1282.7431000	4	1278.1388000
5	130.2145500	6	175.2180200	7	172.8126200	8	170.2802900
9	72.3440620	10	70.0000000				

CLASS 4 - RESISTANCE, R

ID	DEG R/BTU/SEC	ID	DEG R/BTU/SEC	ID	DEG R/BTU/SEC	ID	DEG R/BTU/SEC
4	.1591150+02	5	.1691672+03	6	.4729971+01	10	.1396625+03
11	.1766295+02	12	.1000000+26				

POOR ORIGINAL

1765 246

OUTPUT VARIABLES BY CLASS

TRANSIENT PROBLEM

TIME = .1959200+04SEC.
MINIMUM RC PRODUCT = .2297454+01SEC. ----- FOR NODE 3

NO. OF INCREMENTS = 40

CLASS 2 - TEMPERATURE, T

ID	DEGREES F	ID	DEGREES F	ID	DEGREES F	ID	DEGREES F
1	70.3100850	2	1216.8349000	3	1225.2067000	4	1227.7529000
5	185.6537300	6	182.0160800	7	179.9187300	8	177.2283800
9	72.5424330	10	70.0000000				

CLASS 4 - RESISTANCE,R

ID	DEG R/BTU/SEC	ID	DEG R/BTU/SEC	ID	DEG R/BTU/SEC	ID	DEG R/BTU/SEC
4	.1591130+02	5	.1723776+03	6	.5060430+01	10	.1380142+03
11	.1339554+02	12	.4410050+01				

1765 247

OUTPUT VARIABLES BY CLASS

TRANSIENT PROBLEM

TIME = .4919967+04SEC.
MINIMUM OF PRODUCT = .2937454+01SEC. ----- FOR NODE 3

NO. OF INCREMENTS = 40

CLASS 2 - TEMPERATURE, F

ID	DEGREES F	ID	DEGREES F	ID	DEGREES F	ID	DEGREES F
1	75.3100050	2	384.1032300	3	385.0016000	4	385.3584300
5	250.4851600	6	250.1523900	7	249.8197100	8	249.4877600
9	99.4060900	10	70.0036000				

CLASS 4 - RESISTANCE,R

ID	DEG R/BTU/SEC	ID	DEG R/BTU/SEC	ID	DEG R/BTU/SEC	ID	DEG R/BTU/SEC
4	.1591150+02	5	.2728390+03	6	.2034996+02	10	.1271121+03
11	.1043747+02	12	.4410060+01				

POOR ORIGINAL

1765 248

OUTPUT VARIABLES BY CLASS

TRANSIENT PROBLEM

TIME = .1259971+05SEC.
MINIMUM RC PRODUCT = .2987454+01SEC. ----- FOR NODE 3

NO. OF INCREMENTS = 40

CLASS 2 - TEMPERATURE, T

ID	DEGREES F	ID	DEGREES F	ID	DEGREES F	ID	DEGREES F
1	70.3100050	2	137.4509600	3	137.6529000	4	137.7895800
5	212.6683700	6	212.7432300	7	212.7469700	8	212.6797700
9	159.9137500	10	70.0009000				

CLASS 4 - RESISTANCE,R

ID	DEG R/BTU/SEC	ID	DEG R/BTU/SEC	ID	DEG R/BTU/SEC	ID	DEG R/BTU/SEC
4	.1591150+02	5	.3597032+03	6	.3753545+02	10	.1326555+03
11	.1820035+02	12	.4410010+01				

-34-

OUTPUT VARIABLES BY CLASS

TRANSIENT PROBLEM

TIME = .14300[illegible]SEC.
MINIMUM RC PRODUCT = .2087454+01SEC. ----- FOR NODE 3

NO. OF INCREMENTS = 40

CLASS 2 - TEMPERATURE, F

ID	DEGREES F	ID	DEGREES F	ID	DEGREES F	ID	DEGREES F
1	75.[illegible]	2	71.1372100	3	71.2718770	4	71.4054370
5	[illegible]	6	206.7570520	7	2[illegible].2337[illegible]	8	206.8266160
9	15[illegible]	10	76.[illegible]				

CLASS 4 - [illegible]

ID	DEG [illegible]	ID	[illegible]	ID	DEG F/BTU/[illegible]	ID	[illegible]
[illegible]	.15[illegible]	6	.[illegible]	6	.4507670+[illegible]	10	.1344543+13
11	.1[illegible]	12	.1[illegible]				

1765 250

5.0 WEIGHT CALCULATIONS

5.1 INNER BOX

TOP = 0.283×130×83×2 =	6,110 lb
BOTTOM = 0.283×77×125×2 =	5,450
ENDS = 2×0.283×77×39×2	3,400
SIDES = 2×0.283×125×39×2	5,440
OVERLAP = 2×0.283×6×211 =	720
	23,120

5.2 OUTER BOX

TOP & BOTTOM = 2×0.283×138×90 =	7,020
SIDES = 2×0.283×138×53 =	4,140
ENDS = 2×0.283×90×53 =	2,700
	13,860
TOTAL	36,980

1765 251