TECHNICAL DATA RECORD

NAA-82-
TDR NO. 10777

APPROVALS

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SECURITY CLASSIFICATION

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SNAP 10A, Stainless Steel-316 Vessel
Wall Ablation. Final Report

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PROGRAM
Aerospace Safety

SUBACCOUNT TITLE
SNAP 10A Influence Coefficients

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UNCL.	☒	☐
CONF.	☐	☐
SECRET	☐	☐

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STATEMENT OF PROBLEM

To make a parametric study of the process of reactor vessel wall melting and disintegration during reentry to the upper atmosphere.

ABSTRACT:

The altitudes and times of ablation have been determined for the SNAP-10A, SS-316 vessel wall reentering under various conditions.

The results of this study are confined to one typical location on the reactor and to one typical reentry trajectory. The location is the side wall of the vessel and the trajectory is the one used in NAA-SR-8303.

The following variables are considered:

- (1) Vessel wall emissivity
- (2) Vessel wall thickness
- (3) Solar heating
- (4) Initial temperature of reactor prior to reentry
- (5) Presence or absence of NaK inside the vessel
- (6) Radiation gap between the beryllium (Be) reflectors and vessel wall
- (7) Altitude of external Be reflector ejection.

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Introduction

The object of this report is to present final results from a SNAP-10A vessel wall ablation study. This study was conducted to determine how a variance in a given parameter will affect the temperature history and time of initial melting of the vessel wall during reentry.

Two TAP-3 models have been developed to simulate the reactor for this study. One is a detailed representation of the reactor void of NaK coolant. The second model represents the reactor containing NaK during reentry.

The conditions for each case investigated are given in Table 1. The times of initial melting of the vessel wall and the approximate altitude at which initial melting occurs for each case are listed in Table 2.

Assumptions

The assumptions upon which the analytical models are based are:

- (1) the reactor vessel remains cylindrical during reentry ablation,
- (2) the heat flux generated during reentry is uniform around the circumference of the vessel due to spinning or random tumbling,
- (3) the ablating material is dispersed at melting temperature,
- (4) no heat is generated internally during the reentry process,
- (5) no heat is lost from or generated at the top and bottom of the reactor,
- (6) emissivity of the fuel rods is 0.3,
- (7) emissivity of the Be reflectors is 0.6,
- (8) the combined emissivity and shape factor is

$$\mathcal{F} = F_A F_\epsilon$$

where:

F_A = shape factor = 1.0 for radiation between fuel rods and radiation from Be internal reflector to the fuel rods.

$$F_E = \text{emissivity factor} = \frac{1}{\frac{1}{E_1} + \frac{1}{E_2} - 1}$$

if E_1 and $E_2 \leq 0.8$

(9) for the radiation from the reactor to space

$$\mathcal{F}_R = E_R F_{R \rightarrow S} = E_R (1.0)$$

where the shape factor $F_{R \rightarrow S} = 1.0$

Theory and Methods

The TAP-3 model representing the SNAP-10A reactor void of NaK coolant during reentry is fully discussed in reference 1. Adaptation of the basic NaK VOID model to represent the reactor reentering with the external Be reflectors attached and to simulate a radiation gap between the internal Be reflector and the vessel wall will be discussed later in this report.

The initial TAP-3 model representing the reactor containing NaK during reentry is illustrated in figure 1. This initial model was a detailed representation of the actual physical case but the computer time necessary to solve a problem utilizing the model was prohibitive. The homogeneous TAP-3 model given in figure 2 was developed which yields results comparable to those of the detailed NaK FILLED model in reasonable computer time.

A homogeneous material having a volume weighted density was used to represent the heterogeneous mixture of fuel elements and NaK coolant within the core.

The homogeneous model was assumed to reenter the earth's atmosphere under full daylight conditions. The heat input is, therefore, the sum of the aerodynamic heating and the solar heating:

$$q_t = q_{sol} + A_R \bar{q}_{cyl}$$

where

$$q_{SOL} = \alpha_S G_S A_R$$

$$\bar{q}_{CYL} = \frac{2 \sqrt{\pi}}{\pi} A_R \text{ in free-molecule regime}$$

$$\bar{q}_{CYL} = \frac{2 \sqrt{\pi}}{\sqrt{2} \pi} A_R \text{ in continuum regime}$$

(See Nomenclature of Terms for definition of symbols).

Heat is lost from the reactor by radiation to space at -460°F . Radiation heat loss to space is given as:

$$q_{SP} = A_R \mathcal{F}_R \sigma (T_R^4 - T_{SP}^4)$$

where

$$T_{SP} = 0^{\circ}\text{R}$$

therefore

$$q_{SP} = A_R \mathcal{F}_R \sigma T_R^4$$

The radial and peripheral conduction resistance values in the vessel wall, the internal Be reflector, and the homogeneous core material are given by:

$$R = \frac{l}{KA}$$

Heat storage within various component materials of the reactor is defined by:

$$C = \sqrt{\rho} C_P$$

These equations form the mathematical basis for the thermal-electrical analog of the NaK-FILLED reactor model.

Data

The following data, in addition to those given in reference 1, were used in the calculation of the resistance and capacitance values used in this study.

$$(1) \text{ Thermal conductivity of external Be reflector} = 1.18 \times 10^{-3} \frac{\text{Btu}}{\text{sec. in. } ^{\circ}\text{F}}$$

$$(2) \text{ Thermal conductivity of fuel} = 3.48 \times 10^{-4} \frac{\text{Btu}}{\text{sec. in. } ^{\circ}\text{F}}$$

- (3) Thickness of external Be reflector = 2.3 in.
- (4) Thickness of gap between external Be reflector and vessel wall = 0.032 in.
- (5) Thickness of gap between internal Be reflector and vessel wall = 0.001 in.
- (6) Emissivity of external Be reflector = 0.6

Values of the aerodynamic heating were taken from the trajectory which was used in the analysis that led to report NAA-SR-8303. Critical conditions for this trajectory were as follows:

Initial velocity = 25,694 ft/sec.

Altitude = 400,000 ft.

Flight angle = -0.05 degrees

Latitude = 90.0 deg. North

The atmosphere used was that of the ARDC-1962 standard.

Figure 3 shows the reference aerodynamic heat rate, and altitude vs time.

Results and Discussion

The conditions for each case investigated are given in Table 1. The times of initial melting of the vessel wall and the approximate altitude at which melting occurs for each case are listed in Table 2.

The TAP-3 model simulating the SNAP-10A reactor, void of NaK coolant during reentry, and its electrical analog are given in Figure 1, of reference 1.

The initial TAP-3 model representing the reactor containing NaK during reentry is illustrated in Figure 1 of this report.

The homogeneous TAP-3 model which was used in this analysis to represent the NaK-FILLED reactor during reentry is given in Figure 2.

Figure 3 shows the aerodynamic heat rate per unit area, and altitude vs time.

Using the NaK-VOID model from reference 1, several parameters were varied to show their influence upon the maximum wall temperature vs time trace and the time and altitude of initial melting. The point

of maximum wall temperature is at that wall node which is located nearest the outside fuel element, with none of the internal Be reflector in between. Figures 4-8 give the maximum wall temperature vs time for the various cases investigated using this model. The initial conditions for these cases are:

Model - NaK VOID

Vessel wall thickness = 0.032 in.

Initial temperature = 0.0 °F

External Be reflector ejection altitude = 400,000 ft.

Emissivity of vessel wall = 0.6

The reactor is considered to reenter under full sun or daylight conditions.

Figure 4 shows the influence of vessel wall emissivity upon altitude of initial melting. Emissivity values of SS-316 in the existing literature vary from ~0.2 at 0°F to ~0.8 at 2100°F. The values used in Figure 4 are 0.2, 0.6 and 0.8. Of all the parameters investigated in this study, the variation of emissivity was found to cause the most marked effect upon the altitude of ablation.

The NaK-VOID model with initial conditions as listed earlier in this section was given wall thicknesses of 0.016, 0.032, and 0.064 inch during reentry. Figure 5 consists of the maximum wall temperature vs time for the three wall thicknesses used. Traces A, B, and C are for 0.016, 0.032, 0.064 inch walls, respectively.

Figure 6 shows the effect of extremely thick vessel walls upon the altitude of initial wall melting. Altitudes of initial wall ablation for wall thicknesses ranging from 0.016 to 0.500 inch for SS-316 emissivity values of 0.2 and 0.6 are given in traces A and B, respectively.

Solar heating was eliminated from the total heat input to the standard NaK-VOID model, to approximate reentry under dark sky conditions.

Figure 7 shows the comparison of the reactor reentering under full sun and dark sky conditions in traces A and B, respectively. The small amount of solar heating provided under full sun reentry is responsible for only a 40-50 degree increase in the wall temperature over the dark sky condition during initial reentry. After the reactor enters the continuum heating regime this difference becomes negligible and has no effect upon the altitude of initial ablation.

Figure 8 shows the influence of initial temperature, prior to reentry, upon the standard NaK-VOID model. The maximum wall temperature vs time for initial temperatures of 0, 500, and 1000°F is given as traces A, B, and C of Figure 8. Initial temperature has no appreciable effect upon the altitude of initial melting.

The basic NaK-VOID model discussed in reference 1 was modified as shown in Figure 9 to simulate the existence of a radiation gap between the internal Be reflector and the vessel wall. Due to the poor heat transfer by radiation across this gap through the free molecule heating regime the vessel wall retains a large portion of the aerodynamic heat input. Trace A of Figure 10 shows that during the free molecule heating regime the vessel wall reaches a maximum temperature of 250-400°F above that experienced by the standard NaK-VOID model with the internal Be reflector bonded to the vessel wall. As the reactor enters the continuum regime the temperature of the vessel wall increases rapidly and radiation heat transfer across the gap becomes more effective. This causes the temperature vs time trace of the NaK VOID simulated gap model to approach that of the model without a simulated gap. The NaK VOID reactor model with a simulated gap reaches the melting temperature approximately 14 seconds earlier than the same reactor without a radiation gap between the internal Be reflector and the vessel wall.

Figure 11 illustrates the NaK VOID, TAP-3 network with the external Be reflector added during reentry. A gap of 0.032 in. was assumed to exist between the external Be reflector and the vessel wall.

The TAP-3 network was developed to allow simulated external reflector ejection at any desired altitude. At the time of ejection, the heat input and radiation to deep space were switched from the exterior of the Be reflector to the vessel wall, and all the connectors between the reflector and the reactor were cut.

Figure 12, trace A, shows the maximum wall temperature vs time for the NaK VOID reactor reentering without the external reflector. Traces B and C represent the temperature of the same node when the external Be reflector is ejected at 250,000 and 300,000 ft, respectively. Traces D and E give the temperatures for the external surface of the Be reflector and the wall node nearest the outside fuel element, respectively, if the reactor and Be reflector remain intact during reentry. Traces D and E show that neither the external Be reflector nor the vessel wall will reach melting temperature if the reflector is not ejected during reentry. The external Be reflector reaches a maximum temperature of $\sim 1910^{\circ}\text{F}$ at an altitude of $\sim 100,000$ ft. At this altitude the vessel wall reaches a temperature of $\sim 1200^{\circ}\text{F}$. After peak heating the external reflector begins to cool due to radiation to space and to the vessel wall. The vessel wall temperature continues to increase due to radiation from the external reflector. Traces B and C show that if the external reflector is ejected prior to peak heating the vessel wall temperature will increase rapidly to its melting temperature.

The homogeneous NaK-FILLED model was used to analyze the effect of the presence of NaK coolant upon the altitude of vessel wall ablation.

Figure 13 shows the temperatures of the basic NaK VOID model (trace A) compared to those of the NaK-FILLED model (trace C), both models reentering under the same conditions. A value of 0.6 was used as the emissivity of the SS-316 vessel wall for traces A and C. The vessel wall of the NaK-FILLED model was given an emissivity value of 0.2 in trace B. The melting temperature was reached in the NaK-FILLED

case with an emissivity of 0.2 at an approximate altitude of 140,000 ft. The case with SS-316 emissivity equal to 0.6 attained a maximum wall temperature of $\sim 2500^{\circ}\text{F}$ at an approximate altitude of 125,000 ft.

Figure 14 shows the effect of initial temperature upon the NaK-FILLED reactor during reentry. The reactor was given initial temperatures of 0, 500, and 1000 $^{\circ}\text{F}$ prior to reentry. The maximum wall temperatures vs time for these cases are given in tracers A, B, and C, respectively. With an initial temperature of 1000 $^{\circ}\text{F}$, the vessel wall reaches melting temperature at an altitude of $\sim 159,000$ ft. For the case with 500 $^{\circ}\text{F}$ initial temperature, marginal melting will occur at approximately 125,000 ft. If the reactor has an initial temperature of 0 $^{\circ}\text{F}$, the vessel wall will reach a maximum temperature of $\sim 2500^{\circ}\text{F}$ at an altitude of $\sim 125,000$ ft.

From the results of this study it was concluded that the emissivity of SS-316 is the most important parameter affecting vessel wall ablation for both the NaK-VOID and NaK-FILLED SNAP 10A reactor models during reentry. While all the parameters investigated have an appreciable effect upon the maximum wall temperature during the free-molecular heating regime, only emissivity affected the altitude of initial wall melting appreciably. Once the reactor enters the continuum heating regime the substantial increase in aerodynamic heating tends to overcome any initial effect of varying wall thickness, q_{solar} or initial temperature.

In order for the vessel wall to melt at an altitude high enough to release the fuel elements prior to peak aerodynamic heating, it will be necessary to rid the reactor of NaK coolant prior to reentry. The only NaK-FILLED cases found to ablate were those with 0.6 SS-316 emissivity, 1000 $^{\circ}\text{F}$ initial temperature and 0.2 SS-316 emissivity, 0 $^{\circ}\text{F}$ initial temperature. Both of these cases reached the melting temperature after peak aerodynamic heating and appear optimistic.

From Figure 4, 5, and 6 of Reference 1 it was concluded that melting of the vessel wall will occur in vertical strips located at intervals around the circumference of the reactor. Further discussion of this conclusion is given on page 6 of Reference 1.

Recommendations

Based upon the results of this study it is recommended that the correct value of emissivity for SS-316 under reentry conditions be experimentally determined.

A method should be developed which will insure ejection of the coolant from the reactor prior to reentry.

As stated in Reference 1, it is also suggested that an investigation be made of various methods of incorporating the strip melting effect, found in this study, into the process of reactor breakup. One method of utilizing this effect would be to radially spring-load the vessel wall in such a manner as to peel back the strips once melting has occurred.

Nomenclature of Terms

A	=	Heat transfer area, L^2
		A_R , of the vessel surface
C	=	Thermal capacitance, H/T
C_P	=	Specific heat, H/M-T
F_A	=	Shape factor for radiation between fuel rods, and between internal Be reflector and fuel rods
$F_{R \rightarrow S}$	=	Shape factor from reactor surface to space
F_ϵ	=	Emissivity factor
$\mathcal{F}$	=	Combined emissivity and shape factor
		$\mathcal{F}_R$, from the reactor to space
G_S	=	Solar constant, H/tL^2
K	=	Thermal conductivity, H/tLT
l	=	Heat transfer path length, L
q	=	Rate of heat transfer, H/t
		q_{SOL} , solar input
		q_{SP} , dissipation to space
		q_t , total heat input
		$q_{F.M.}$, free molecular reference heat rate
		$q_{\sqrt{F}}$, continuum reference heat rate
		$\bar{q}_{CYL}$, average heat input to vessel surface due to aerodynamic heating/unit area
R	=	Thermal resistance, tT/H
T_R	=	Temperature, T, of the reactor surface
T_{SP}	=	Temperature, T, of deep space

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t	=	Time, sec
V	=	Volume, L^3
α_s	=	Reactor surface absorptivity
ϵ	=	Emissivity
σ	=	Stefan-Boltzmann constant, H/tL^2T^4
ρ	=	Density, M/L^3

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References

- (1) NAA-SR-TDR-10159, "Thermo-Physics Technical Note, No. 35: SNAP 10A, Stainless Steel-316 Vessel Wall Ablation, Initial Report,"
L. D. Montgomery, August 5, 1964
- (2) NAA-SR-8303, "Aerospace Safety Reentry Analytical and Experimental Program SNAP 2 and 10A," R. D. Elliott, July 1, 1963
- (3) NAA-SR-MEMO-7877, "Thermo-Physics Technical Note, No. 14: SNAP 10A Reactor Temperature and Power Decay in Space for Zero NaK Flow and Loss of NaK," S. R. Fields, October 11, 1963

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NO. NAA-SR-TDR-10777DATE 12-7-64PAGE 14 OF 33**TABLE I**

Conditions For Each Case Investigated

FIG.	TRACE	MODEL	WALL THICKNESS INCHES	INITIAL TEMPERATURE °F	ALTITUDE PRIOR TO REENTRY (ft)	SKY CONDITION	OF VESSEL
4	A	NaK Void	0.032	0.0	400,000	Full Sun	0.2
4	B	NaK Void	0.032	0.0	400,000	Full Sun	0.6
4	C	NaK Void	0.032	0.0	400,000	Full Sun	0.8
5	A	NaK Void	0.016	0.0	400,000	Full Sun	0.6
5	B	NaK Void	0.032	0.0	400,000	Full Sun	0.6
5	C	NaK Void	0.064	0.0	400,000	Full Sun	0.6
6	A	NaK Void	0.016	0.0	400,000	Full Sun	0.2
6	A	NaK Void	0.032	0.0	400,000	Full Sun	0.2
6	A	NaK Void	0.064	0.0	400,000	Full Sun	0.2
6	A	NaK Void	0.075	0.0	400,000	Full Sun	0.2
6	A	NaK Void	0.125	0.0	400,000	Full Sun	0.2
6	A	NaK Void	0.200	0.0	400,000	Full Sun	0.2
6	A	NaK Void	0.250	0.0	400,000	Full Sun	0.2
6	A	NaK Void	0.350	0.0	400,000	Full Sun	0.2

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FIG.	TRACE	MODEL	WALL THICKNESS INCHES	INITIAL TEMPERATURE °F	ALTITUDE PRIOR TO REENTRY (ft)	SKY CONDITION	OF VESSEL
6	A	NaK Void	0.500	0.0	400,000	Full Sun	0.2
6	B	NaK Void	0.016	0.0	400,000	Full Sun	0.6
6	B	NaK Void	0.032	0.0	400,000	Full Sun	0.6
6	B	NaK Void	0.064	0.0	400,000	Full Sun	0.6
6	B	NaK Void	0.075	0.0	400,000	Full Sun	0.6
6	B	NaK Void	0.125	0.0	400,000	Full Sun	0.6
6	B	NaK Void	0.200	0.0	400,000	Full Sun	0.6
6	B	NaK Void	0.250	0.0	400,000	Full Sun	0.6
6	B	NaK Void	0.350	0.0	400,000	Full Sun	0.6
6	B	NaK Void	0.500	0.0	400,000	Full Sun	0.6
7	A	NaK Void	0.032	0.0	400,000	Full Sun	0.6
7	B	NaK Void	0.032	0.0	400,000	Dark Sky	0.6
8	A	NaK Void	0.032	0.0	400,000	Full Sun	0.6
8	B	NaK Void	0.032	500.0	400,000	Full Sun	0.6
8	C	NaK Void	0.032	1000.0	400,000	Full Sun	0.6

TABLE I (Continued)

FIG.	TRACE	MODEL	WALL THICKNESS INCHES	INITIAL TEMPERATURE °F	ALTITUDE PRIOR TO REENTRY (ft)	SKY CONDITION	OF VESSEL
10	A	NaK Void	0.032	0.0	400,000	Full Sun	0.6
10	B	NaK Void	0.032	0.0	400,000	Full Sun	0.6
12	A	NaK Void	0.032	0.0	400,000	Full Sun	0.6
12	B	NaK Void	0.032	0.0	400,000	Full Sun	0.6
12	C	NaK Void	0.032	0.0	400,000	Full Sun	0.6
12	E	NaK Void	0.032	0.0	400,000	Full Sun	0.6
13	A	NaK Void	0.032	0.0	400,000	Full Sun	0.6
13	B	NaK Filled	0.032	0.0	400,000	Full Sun	0.2
13	C	NaK Filled	0.032	0.0	400,000	Full Sun	0.6
14	A	NaK Filled	0.032	0.0	400,000	Full Sun	0.6
14	B	NaK Filled	0.032	500.0	400,000	Full Sun	0.6
14	C	NaK Filled	0.032	1000.0	400,000	Full Sun	0.6

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Results Obtained From Each Case Analyzed

FIG.	TRACE	PARAMETER VARIED		TIME OF INITIAL MELTING AFTER START OF REENTRY (sec)	ALTITUDE OF INITIAL MELTING (ft)
4	A	Emissivity of vessel wall 0.2		1397	277,122
4	B	Emissivity of vessel wall 0.6		1561	249,670
4	C	Emissivity of vessel wall 0.8		1604	237,635
5	A	Vessel wall thickness 0.016 in.		1559	250,158
5	B	Vessel wall thickness 0.032 in.		1561	249,670
5	C	Vessel wall thickness 0.064 in.		1566	248,417
		WALL THICKNESS IN.	EMISSIONITY		
6	A	0.016	0.2	1389	277,940
6	A	0.032	0.2	1396	277,214
6	A	0.064	0.2	1409	275,695
6	A	0.075	0.2	1412	275,286
6	A	0.125	0.2	1430	272,985
6	A	0.200	0.2	1456	269,417
6	A	0.250	0.2	1474	266,717

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FIG.	TRACE	PARAMETER VARIED		TIME OF INITIAL MELTING AFTER START OF REENTRY (sec)	ALTITUDE OF INITIAL MELTING (ft)
		WALL THICKNESS IN.	EMISSIVITY		
6	A	0.300	0.2	1510	260,566
6	A	0.500	0.2	1557	250,631
6	B	0.016	0.6	1559	250,212
6	B	0.032	0.6	1561	249,648
6	B	0.064	0.6	1565	248,567
6	B	0.075	0.6	1567	248,166
6	B	0.125	0.6	1574	246,350
6	B	0.200	0.6	1584	243,624
6	B	0.250	0.6	1591	241,627
6	B	0.350	0.6	1606	236,994
6	B	0.500	0.6	1626	230,083
7	A	Sky Condition Full sun		1561	249,670
7	B	Sky Condition Dark Sky		1562	249,419
8	A	Initial Temp. 0.0 °F		1561	249,670

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NO. NAA-SR-TDR-10777DATE 12-7-64PAGE 19 OF 33TABLE II (Continued)

FIG.	TRACE	PARAMETER VARIED		TIME OF INITIAL MELTING AFTER START OF REENTRY (sec)	ALTITUDE OF INITIAL MELTING (ft)
8	B	Initial Temp. 500.0 °F		1560	249,921
8	C	Initial Temp. 1000.0 °F		1558	250,394
10	A	Gap between internal Be reflector and wall		1555	250,625
10	B	No gap between internal Be reflector and vessel wall		1561	249,670
12	A	External Be reflector ejection - 400,000 ft		1561	249,670
12	B	External Be reflector ejection - 350,000 ft		1561	249,670
12	C	External Be reflector ejection - 250,000 ft		1605	237,317
12	D	0.0 Exterior Temp.		Did not melt Maximum temperature reached at 1770	Maximum Temp. 1885 °F
12	E	0.0 Wall Temp.		Did not melt Maximum temperature reached at 1900	Maximum Temp. > 1300 °F
13	A	Model NaK Void	Emissivity 0.6	1561	249,670
13	B	Model NaK Filled	Emissivity 0.2	1753	150,195
13	C	Model NaK Filled	Emissivity 0.6	Did not melt Maximum temperature reached at 1770	Maximum Temp. 2505 °F
14	A	Initial Temp. 0.0		Did not melt Maximum temperature reached at 1775	Maximum Temp. 2500 °F
14	B	Initial Temp. 500.0 °F		Did not melt Maximum temperature reached at 1775	Maximum Temp. 2580 °F
14	C	Initial Temp. 1000.0 °F		1744	158,920

Figure - 1
TAP - 3, SNAP -10A, SS-316 VESSEL WALL
ABLATION MODEL
DETAILED NAK FILLED MODEL

Figure - 2

**HOMOGENEOUS NAK FILLED, TAP - 3, SNAP - 10A,
ABLATION MODEL**

**all nodes have
capacitors**

Figure 4
 MAXIMUM WALL TEMPERATURE vs. TIME

CONDITIONS
 Model - Wax void
 Wall thickness - 0.032 in.
 Initial Temperature - 0.0 °F
 Release Altitude - 400,000 ft.
 Sky Condition - Daylight
 Buissivity
 Trace A - 0.2
 Trace B - 0.6
 Trace C - 0.8

26×10^2

24

22

20

18

16

14

12

10

8

6

4

2

0

TEMPERATURE

TIME - SEC

200

400

600

800

1000

1200

1400

1600

1800

2000

2200

2400

Figure - 4
MAXIMUM WALL TEMPERATURE vs. TIME

CONDITIONS

Model - Nak Void
Wall thickness
Trace A - 0.016 in.
Trace B - 0.032 in.
Trace C - 0.064 in.
Initial Temperature - 0.0 °F
Release Altitude - 400,000 ft.
Sky Condition - Daylight
Emissivity - 0.6

24×10^3

24

22

20

18

16

14

12

10

8

6

4

2

0

TEMPERATURE - °F

TIME - SEC

0 200 400 600 800 1000 1200 1400 1600 1800 2000 2200 2400

Figure - 6
 MELTING ALTITUDE vs. WALL THICKNESS
 FOR NAL VOID REACTOR

Trace A - Efficiency of vessel wall = 0.2
 Trace B - Efficiency of vessel wall = 0.6

Figure - 7
 MAXIMUM WALL TEMPERATURE vs. TIME

CONDITIONS

Model - Wax void
 Wall thickness - 0.032 in.
 Initial Temperature - 0.0 °F
 Release Altitude - 400,000 ft.
 Sky Condition
 Trace A - Daylight
 Trace B - Darkness
 Emmissivity - 0.6

20×10^4

24

22

20

18

16

14

12

10

8

6

4

2

0

TEMPERATURE

TIME - SEC

0

200

400

600

800

1000

1200

1400

1600

1800

2000

2200

2400

Figure -6
 MAXIMUM WALL TEMPERATURE vs. TIME

CONDITIONS

Model - Nak Void
 Wall thickness - 0.052 in.
 Initial Temperature
 Trace A - 0.0 °F
 Trace B - 500.0 °F
 Trace C - 1000.0 °F
 Release Altitude - 400,000 ft.
 Sky Condition - Daylight
 Emissivity - 0.6

Figure - 9

**NAK VOID TAP-3, SNAP-10A, ABLATION MODEL
with
SIMULATED GAP BETWEEN INTERNAL BE REFLECTOR
AND VESSEL WALL**

Figure - 10
NAXOS WALL TEMPERATURE VS. TIME

CONDITIONS

Model - Nak Void

Trace - A - Simulated gap between internal
Ba. reflector and vessel wall

Trace - B - Internal Ba. reflector tightly
bonded to vessel wall

Wall thickness - 0.032 in.

Initial Temperature - 0.0 °F

Release Altitude - 400,000 ft.

Sky Condition - Daylight

Emissivity - 0.6

24×10^3

24

22

20

18

16

14

12

10

8

6

4

2

0

TEMPERATURE

TIME - SEC.

0

200

400

600

800

1000

1200

1400

1600

1800

2000

2400

Figure - 11
NAK VOID TAP-3, SNAP-10A, ABLATION MODEL
WITH EXTERNAL BE REFLECTOR ADDED

Figure - 12
 MAXIMUM WALL TEMPERATURE vs. TIME

CONDITIONS

Model - Nak Void
 Wall thickness - 0.032 in.
 Initial Temperature - 0.0 °F
 Release Altitude of Be. External Reflector
 Trace A - 400,000 ft.
 Trace B - 300,000 ft.
 Trace C - 250,000 ft.
 Trace D - 0.0 ft. Exterior surface temperature
 Trace E - 0.0 ft. Vessel wall temperature
 Sky Condition - Daylight
 Emissivity - 0.6

Figure - 13
 MAXIMUM WALL TEMPERATURE vs. TIME
 CONDITIONS

Model
 Trace - A - Wax void
 Trace - B - Wax filled
 Trace - C - Wax filled
 Wall thickness - 0.032 in.
 Initial Temperature - 0.0 °F
 Release Altitude - 400,000 ft.
 Sky Condition - Daylight
 Explosivity
 Trace - A - 0.6
 Trace - B - 0.2
 Trace - C - 0.6

24×10^3

24

22

20

18

16

14

12

10

8

6

4

2

0

TEMPERATURE °F

TIME - SEC

0 200 400 600 800 1000 1200 1400 1600 1800 2000 2200 2400

Figure - 14
MAXIMUM WALL TEMPERATURE vs. TIME

CONDITIONS

Model - Nak filled

Wall thickness - 0.032 in.

Initial Temperature

Trace A - 0.0 °F

Trace B - 500.0 °F

Trace C - 1000.0 °F

Release Altitude - 400,000 ft.

Sky Condition - Daylight

Emissivity - 0.6

26 x 10³

24

22

20

18

16

14

12

10

8

6

4

2

0

TIME - SEC

0 200 400 600 800 1000 1200 1400 1600 1800 2000 2200 2400