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SNAP-19 RESIDUAL FIRE TEST

R. E. Berry, 9512

AEROSPACE NUCLEAR DEPARTMENT 9510

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SNAP-19 RESIDUAL FIRE TEST

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August 1969

Approved by:

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ABSTRACT

Two residual fire tests were performed on SNAP-19 test items to evaluate the response of the test items to a 30 minute JP-4 fire environment which produces a temperature of about 1850°F at 24 inches above the liquid level. The first test included only a SNAP-19 Dispersion System Generator. The second test included four test items, and each test item was positioned to provide specific fire information on that item. The items were: (1) a Dispersion System Generator, (2) a Dispersion System Capsule, (3) an Intact Reentry Heat Source Generator System, and (4) an Intact Reentry Heat Source Capsule.

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SUMMARY

Two SNAP-19 generators and two fuel capsules were subjected to the thermal environment from a residual fire. The first residual fire test contained only a SNAP-19 Dispersion Generator System setting on a section of the magnesium satellite mounting ring. This magnesium ring burned unevenly and toppled the generator into the remaining liquid within the fire pit. This action resulted in quenching of the magnesium fire which was burning the generator parts.

The second residual fire test contained the remains of the SNAP-19 Dispersion Generator System from the previous fire test. The generator was partially rebuilt to make it acceptable for reuse. In addition, this fire contained a SNAP-19 Intact Reentry Heat Source Generator System, an Intact Reentry Heat Source, and a Dispersion System Capsule.

Each test item was positioned to provide specific fire information on that item. The Dispersion System Generator was placed on a stainless steel stand, thereby forcing the system to remain in the residual fire. The Dispersion System Capsule was placed upright on a six-inch sandpile, thereby exposing the top portion of the capsule immediately to the fuel fire and later to a magnesium fire as the fuel level receded. The Intact Reentry Heat Source Generator System was placed on a 24-inch high magnesium stand mounted on the 6-inch sandpile, thereby placing the generator in the fuel fire and subsequently in a magnesium fire on top of the sandpile; and the Intact Reentry Heat Source Capsule was placed horizontally on the stainless steel stand, thereby forcing the capsule to remain in the residual fire.

The data from the first fire test was too limited for further analysis, but the data from the second fire test was longer and more complete. These data from the second residual fire test were analyzed by computer modeling. A code was developed which reproduced the experimental results and then the thermal response of the test items was calculated using a constant thermal output from the capsule centerline (this simulated the heat produced in a real capsule by radioactive fuel decay).

The computer modeling is intended to reproduce the fire flux as measured, but the match is not exact. Time and manpower were not available for the refinements indicated. The computer modeling does indicate that the capsule clad approaches the melting point when contained within a generator system and the generator system is forced to remain at approximately 24 inches above the liquid surface. When the generator and/or capsule are allowed to rest on the ground surface, the effects of the residual fire are reduced.

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SNAP-19 RESIDUAL FIRE TEST

Introduction

The normal sequence when placing a radioactive isotope fueled power generator into space does not subject the fuel capsule to adverse environments. However, in the event of an explosive abort of the launch vehicle, the fuel capsule may be subjected to shock overpressure, fireball thermal flux, fragment impact, and residual fire thermal flux. Each of these environments is probably severe enough to cause fuel release providing the designed protection has been previously removed or severely damaged. To design a test program to properly test the total environment could only be accomplished with an actual launch vehicle abort at various levels of explosive force. This approach is unreasonable, and therefore each environment has been approached individually. This test report concerns the residual fire environment.

When an explosion occurs, not all of the launch vehicle propellant is consumed in the resulting fireball. The fuel that spills upon the ground creates a residual fire by normal combustion of the fuel using atmospheric air. This residual fire has a peak temperature of about 1850°F and lasts for minutes rather than seconds after the launch vehicle abort. The tests performed were designed to produce the fire environment and were programmed to burn for 30 minutes. This length of time is possible and is not considered to be excessive.

There were two fire tests performed on the SNAP-19 test items. The first test included only a SNAP-19 Dispersion System Generator placed upon a portion of the satellite mounting ring (magnesium casting). The second test included four test items and each test item was positioned to provide specific fire information on that item. The items were: (1) a Dispersion System Generator placed on a stainless steel stand, thereby forcing the system to remain in the residual fire; (2) a Dispersion System Capsule placed upright on a six-inch sandpile, thereby exposing the top portion of the capsule immediately to the fuel fire and later to a magnesium fire as

the fuel level receded; (3) an Intact Reentry Heat Source Generator System placed on a 24-inch high magnesium stand mounted on the 6-inch sandpile, thereby placing the generator in the fuel fire and subsequently in a magnesium fire on top of the sandpile; (4) an Intact Reentry Heat Source Capsule placed horizontally on the stainless steel stand, thereby forcing the capsule to remain in the residual fire.

The ideal fire test conditions would include the proper amount of internal heat prior to and during the residual fire test. Lacking the proper internal heat, it is necessary to prepare a computer code which matches the thermal response experienced by instrumentation during a residual fire with no internal heat and then inputting the proper internal heat and having a computer calculate the thermal response to this condition.

The first test item (Dispersion System Generator) had no internal heat. The second fire test included two items with internal heat and two without internal heat. The SNAP-19 Intact Reentry Heat Source Generator System and the Intact Reentry Heat Source were electrically heated internally; the Dispersion Generator System and the Dispersion System Capsule were not heated.

Although two of the test items were heated prior to actual fire test ignition, the electric heaters failed very shortly after the fire began and therefore all test items were subjected to computer modeling to obtain their real response to the fire.

Description and Instrumentation of the Test Items

As indicated previously, there was only a SNAP-19 Dispersion System Generator in the first residual fire test and both a Dispersion System Generator and an Intact Reentry Heat Source Generator as well as two fuel capsules in the second residual fire test. The capsules were a Dispersion System (reentry burnup) Capsule and an Intact Reentry Heat Source (IRHS).

All of the hardware was fabricated and assembled by the Martin Co. Instrumentation was designed jointly but installed by the Martin Co. Each test item is described, both with respect to components used, modifications necessary, and instrumentation included for data acquisition.

SNAP-19 Dispersion System Generator

This generator system was previously used for inhouse testing at the Martin Company plant and therefore was originally a functional generator. The inhouse testing was performed with an electrically heated capsule assembly. For the residual fire test, a fuel capsule with simulated fuel was substituted and therefore the generator was unheated at the time of the fire test. Figure 1 shows the generator setting on the magnesium casting (satellite mounting ring) and this in turn setting on a stainless steel stand for the first fire test. Table I lists the thermocouples installed on the generator and fuel capsule, and Figure 2 shows the locations for the instrumentation.

The Dispersion System Generator used for the second fire test consisted of the remains of the generator previously placed in the first fuel fire. The magnesium top cover, the magnesium fins, and about 20 percent of the magnesium side-wall were missing from the assembly. Figures 3 and 4 show the partially destroyed generator as reconstructed and instrumented for use in the second residual fire test. Table II lists the instrumentation for the second residual fire test of this test item.

Figure 1. SNAP-19 Dispersion System Generator
on magnesium casting mounting ring

TABLE I

Instrumentation of First Residual Fire Test of SNAP-19 Dispersal System Generator

SNAP-19 generator and capsule instrumentation

Thermocouple Number	Location
1	Welded, top of Haynes-25 alloy capsule (Figure 2)
2	Welded, center of Haynes-25 alloy capsule (Figure 2)
3	Welded, bottom of Haynes-25 alloy capsule (Figure 2)
4	Pressed between graphite and mica insulation (Figure 2)
5	Pressed between graphite and mica insulation (Figure 2)
6	Under screwhead on aluminum cold end hardware (Figure 2)
7	Under screwhead on aluminum cold end hardware (Figure 2)
8	Under screwhead, fin root, top (Figures 1 and 2)
9	Under screwhead, fin root, center (Figures 1 and 2)
10	Under screwhead, fin root, bottom (Figures 1 and 2)

SNAP-19 Intact Reentry Heat Source Generator

This generator system was also used by the Martin Company for inhouse testing and was also a functional generator system with an inert fuel capsule. The assembly was heated with six 600-watt electric heaters installed in the ATJ graphite heat accumulator block. These heaters were regulated to produce about 1240°F on the surface of the IRHS at the beginning of the fire test. The temperature was regulated to simulate the output expected from an isotopically fueled capsule. These heaters were used during the fire test to simulate heat output of a real capsule. Table III lists the instrumentation installed in the generator for the residual fire test. Figures 5 and 6 show the location of the electric heaters and the installed instrumentation.

SNAP-19 Dispersion System Fuel Capsule

This Dispersal System Fuel Capsule was placed in the residual fire to simulate the environmental condition of a fuel capsule being separated from the generator. The separation is assumed to occur during the shock overpressure phase of the

launch vehicle explosive abort. The Dispersion Capsule Assembly consisted of production parts and unfired zirconium oxide fuel simulant. The capsule was not pressurized and was not heated. Thermocouples were installed on one end in the center and in one location on the side midway between the ends (See Table IV and Figure 7). This capsule was placed under the magnesium stand on the sandpile.

Figure 2. Instrumentation locations on generator and capsule

Figure 3. Instrumented SNAP-19 Dispersal Systems Generator before second fire test

Figure 4. Instrumented SNAP-19 Dispersal Systems Generator before second fire test

TABLE II

Instrumentation of Second Residual Fire Test
of SNAP-19 Dispersal System Generator

<u>Thermocouple No.</u>	<u>Location</u>
21	Welded to capsule, center of bottom (Figures 3 and 4)
22	Welded to capsule, center of side (Figures 3 and 4)
23	Graphite heat shield, on line with root fin TC (Figures 3 and 4)
24	Cold end hardware, same line as TC No. 23 (Figures 3 and 4)
25	Fin root (Figure 4)

TABLE III

SNAP-19 IRHS Generator Instrumentation

<u>Thermocouple No.</u>	<u>Location</u>
1	Top, graphite heat shield (Figure 5)
2	Top, on line with TC No. 1, cold end hardware (Figure 5)
3	Top, 180° from TC No. 1, graphite heat shield (Figure 5)
4	Top, 180° from TC No. 2, cold end hardware (Figure 5)
5	Poco graphite, midpoint of case, 60° CW from TC No. 3 (Figure 5)
6	Poco graphite, midpoint of case, 180° from TC No. 5 (Figure 5)
7	Bottom, graphite heat shield, 60° CCW from TC No. 1 (Figure 6)
8	Bottom, cold end hardware, 60° CCW from TC No. 2 (Figure 6)
9	Bottom, graphite heat shield, on vertical line with TC No. 3 (Figure 6)
10	Bottom, cold end hardware, on vertical line with TC No. 4 (Figure 6)
11	Fin root adjacent to TC No. 2
12	180° from TC No. 11
13	In line with TC No. 12 at bottom
14	Fin root adjacent to TC No. 8

Figure 5. Top view of instrumented SNAP-19 IRHS generator

Figure 6. Bottom view of instrumented SNAP-19 IRHS Generator

TABLE IV

Instrumentation for SNAP-19 Dispersion System Fuel Capsule

<u>Thermocouple No.</u>	<u>Location</u>
19	Dispersal Systems Capsule, welded in center of capsule (Figure 7)
20	Dispersal Systems Capsule, welded in center of top (Figure 7)

Figure 7. Instrumented SNAP-19 Dispersal System Fuel Capsule

SNAP-19 Intact Reentry Heat Source (IRHS)

This fuel capsule was also placed in the residual fire to simulate the environmental condition of a fuel capsule being separated from the generator. The separation is assumed to occur during the shock overpressure phase of a launch vehicle explosive abort.

The intact capsule assembly consisted of a solid stainless steel shipping dummy capsule and an uncoated graphite heat shield. The stainless steel shipping dummy capsule was drilled and fitted with a 1000-watt electric heater which was regulated to produce about 830°F at the beginning of the fire. The shipping dummy capsule was a very close fit in the graphite heat shield and did not have the normal clearance for the differential expansion between steel and graphite. Table V lists the instrumentation placed on this assembly and Figure 8 shows the instrumentation.

Description of the Residual Fires

The residual fire was prepared to simulate the burning of excess fuel after an explosive abort of a launch vehicle. The fires were made large enough to assure that the SNAP-19 test items were completely engulfed in the flame. The first residual fire test was performed in a concrete and steel permanent fire pit. The pit was 30-feet square and 2-feet deep. The bottom was concrete and the walls were steel. To protect the pit from fire damage, 4000 gallons of water were first pumped into the cavity and then 3500 gallons of JP-4 fuel. (The JP-4 and the RP-1 fuels are both kerosene based and burn at essentially the same temperature. The JP-4 is a jet aircraft fuel and was readily available; therefore it was selected for the tests.) The fire temperature was measured with the two thermocouples shown in Figure 9.

The second fire test was contained in a 20-foot by 20-foot by 10-inch deep earthen pit lined with polyethylene. A sandpile was constructed in the center measuring 4-feet by 4-feet by 5-5/8-inches high. This sandpile was contoured to be about 1-1/2-inches lower at the center. About 10 pounds of scrap magnesium were scattered on the sandpile in the center. The sandpile in the second fire test was designed to prevent quenching of a burning test item should it topple from the

supporting stand into the remaining liquid fuel. The recovered generator from fire test number 1 was quenched by the water and liquid fuel when it toppled from the stainless steel stand.

TABLE V
SNAP-19 IRHS Capsule Instrumentation

Thermocouple No.	Location
15	Welded in center of capsule (Figure 8)
16	180° from TC No. 15 (Figure 8)
17	In Poco graphite, adjacent to TC No. 15 (Figure 8)
18	180° from TC No. 17 (Figure 8)

Figure 8. Instrumented SNAP-19 IRHS Capsule

The intact generator was mounted on a magnesium stand which weighed about 30 pounds and simulated the spacecraft structure. This stand was placed on and fastened to the sandpile in the center of the residual fire. The Dispersion Capsule was placed on the sandpile near an outside corner. The Dispersion Generator and the Intact Reentry Heat Source were placed on a stainless steel stand which was positioned adjacent to the sandpile. Both stands were designed to place the test items approximately 2 feet above the surface of the JP-4 fuel (Figures 10 and 11). Both fire tests were designed to burn for about 30 minutes total duration.

Description of the Location of the Test Items Within the Residual Fire

The JP-4 fuel burns in the vapor phase, and therefore the hottest portion of the fire is approximately 24 inches above the liquid surface. For this reason, the test items were placed on stands 24-inches high. This position for the test items provided the maximum thermal flux to the hardware. Figures 9, 10, and 11 show the relative positioning of the various test items. Note that all test items are centrally located within the fire pit area. Figure 9 shows the SNAP-19 Dispersion System Generator on the magnesium casting (satellite mounting ring). The base of the generator was 24 inches above the liquid surface.

Figures 10 and 11 show the second residual fire test layout. The remains of the SNAP-19 Dispersion System Generator and the SNAP-19 IRHS capsule were placed on a stainless steel stand which positioned them 24 inches above the initial liquid level. The SNAP-19 IRHS Generator was positioned on a magnesium stand which was designed to collapse and place the generator remains on the mound of dirt such that it would not fall into the remaining liquid fuel. The SNAP-19 Dispersion System Fuel Capsule was initially placed upon the mound of dirt such that the expected magnesium fire on the mound of dirt would radiate directly to the capsule.

Scrap magnesium was placed under the SNAP-19 IRHS Generator to simulate the remains of the satellite structure remaining around the generator after an abort.

Figure 9. SNAP-19 fire test setup (Dispersion System Generator)

Figure 10. Fire test setup

Figure 11. Fire test setup

Test Results

The fire tests were considered a good simulation of a launch vehicle abort residual fire. The test items were subjected to a realistic heat flux. The bare capsules appear to be marginal in this type of fire when analyzed by computer modeling. Computer modeling indicates that the capsules within the generator at the beginning of the residual fire appear to survive.

First Fire Test

The first fire test resulted in only partial damage to the SNAP-19 Dispersion System Generator because of the inadvertent collapse of the magnesium casting which allowed the generator to fall into the water and the remaining liquid JP-4 fuel, where the generator magnesium fire was quenched.

The melted and/or burned magnesium mounting ring shown in Figures 12 and 13 allowed the SNAP-19 Dispersion System Generator to fall from the stainless steel stand (Figure 12). Figure 14 shows the undamaged Dispersion System Fuel Capsule.

The fire temperature versus time is shown in Figure 15, and the fuel capsule response to the fire is shown in Figure 16. Note that TC-01 was broken at about four minutes, and that TC-02 and TC-03 started a very rapid rise to fire temperature, indicating that the generator had fallen from the stainless steel stand and that the thermocouples were torn from the fuel capsule.

Visual observation indicated a magnesium fire at two minutes, and apparently sufficient melting or burning occurred in two minutes to cause the generator to fall at four minutes. This generator was recovered and partially rebuilt and subjected to a second fire test. See Figures 3 and 4 for the appearance of the rebuilt SNAP-19 Dispersion System Generator.

Second Fire Test

The second fire test gave longer time thermocouple data, and therefore the data were usable for computer modeling of the generator response to the thermal flux.

Figure 12. Results of SNAP-19 first fire test

Figure 13. Remains of SNAP-19 generator after first fire test

Figure 14. Undamaged dispersion system fuel capsule after fire test

Figure 15. Temperature versus time for fire test of SNAP-19 fuel capsule and case

Figure 16. Temperature versus time for fire test of SNAP-19 fuel capsule

Two of the four test items were heated in an argon atmosphere. The argon atmosphere was used to reduce graphite oxidation at the elevated temperature, and the heating was used to better simulate the environment the generator would see. Figures 17A and 17B show the heating cycle prior to residual fire ignition. The thermocouples monitored were installed at the midsection of the fuel capsule. The dip in both heating curves resulted from power shut off at the time of placing the fuel in the fire pit. Table VI shows the step by step power settings for the heating cycle.

Initial Conditions at Beginning of the Fire -- The intact generator and intact capsule were preheated using the electric heaters installed. The temperatures within the generator were 1250°F on the capsule graphite heat shield, 1230°F in the graphite heat accumulator block, 240°F in the aluminum cold end hardware, and 170°F on the fin root. These temperatures were in line and were duplicated in four locations. The temperatures on the IRHS were 830°F on the stainless steel capsule and 810°F on the graphite surface. The Dispersion Generator and the Dispersion Capsule were 100°F and 60°F, respectively. The fire temperature thermocouples read 50°F just prior to fire ignition.

The pit was filled with about 2000 gallons of JP-4 fuel (Figure 18). This amount of fuel gave a fuel depth of about 7-1/2 inches. The fuel burns at about 1/4 inch per minute, giving a 30-minute fire.

Description of Fire -- The fuel fire burned for about 26 minutes and then began to reduce in intensity. The fire was essentially out within about 30 minutes. See Figures 19A and 19B for the fire temperature. The magnesium was observed to ignite at about 2 minutes and intermittent flashes were observed throughout the fuel fire. At about 25 minutes, a very pronounced magnesium fire was observed which burned for about 30 to 35 minutes.

Observations During the Fire -- Smoke from the fire was observed to rise at about 25 degrees from the vertical although the surface wind was almost non-existent (Figure 20). The IRHS electric heater failed at 2 minutes and 30 seconds after fire ignition. The IRHS generator electric heaters failed at 6 minutes after fire ignition. The first magnesium fire was observed at 2 minutes, and a sustained

Figure 17A. SNAP-19 Intact Reentry Generator System

Figure 17B. SNAP-19 Intact Reentry Heat Source

magnesium fire was observed to start at about 25 minutes after fire ignition (Figure 21). The magnesium stand collapsed at about 4 minutes.

TABLE VI
Manually Programmed Heating Cycle
for the SNAP-19 IRHS Generator and Capsule Heaters

<u>Time of Day</u>	<u>Generator Heater Power (watts)</u>	<u>Heat Shield Temp. (°F)</u>	<u>Capsule Heater Power (watts)</u>	<u>Capsule Temp. (°F)</u>	<u>Comments</u>
0020	104 ⁽¹⁾	58	-(2)	-	Start of preheat cycle
0059	183	530	-	-	Increased power
0222	208	700	-	-	Increased power
0330	-	-	200	53	Start of preheat cycle
0338	250	1050	-	-	Increased power
0345	-	-	310	140	Increased power
0433	292	1150	-	-	Increased power
0445	-	-	575	550	Increased power
0500	267	1210	-	-	Decreased power
0616	267	1210	575	840	Shutdown for fuel loading
0634	275	860	575	840	Pickup after fuel loading
0704	355	1030	-	-	Increased power
0723	350	1240	570	840	Fire start
0724	312	1240	-	-	Decreased power
072540	-	-	Heater shorted	1250	Shutdown heater power
0726	333	1250	-	-	Increased power
0729	Heaters shorted	1300	-	-	Shutdown heater power

(1) Single heater set (two heaters in parallel, 10 ohms hot resistance).

(2) Power based on 50 ohms hot resistance.

Figure 18. Fire test layout with fuel in pit

Observations After the Fire -- The magnesium stand had collapsed and burned (Figure 22). The Intact Reentry System Generator remains were lying within the magnesium fire on the sandpile (Figure 23). The Dispersion System Capsule was still standing at the edge of the sandpile adjacent to the magnesium fire (Figure 24).

The Dispersion System Generator remains were still standing on the stainless steel stand; the generator had not disassembled even though the magnesium case had either melted and dripped to the ground or oxidized around the generator internals (Figure 25).

The Intact System Capsule Graphite Heat Shield had ruptured, but examination indicated that the cracking probably occurred as a result of differential thermal expansion and the close fit which existed between the graphite and the stainless steel shipping dummy (Figure 25).

There was a large amount of magnesium oxide on the stainless steel stand, on the ground beneath the stand, and covering the entire sandpile. Note in Figure 26 the roll of magnesium sheet which was buried by the oxides and nitrides, thereby preventing ignition.

Figure 19A. Temperature versus time for fire test

Figure 19B. Temperature versus time for fire test

Figure 20. Fire test

Figure 21A. Magnesium fire after JP-4 fuel has burned out

Figure 21B. Magnesium fire

Figure 22. Aftermath of fire test

Figure 23A. SNAP-19 Intact System Generator and Dispersion System Capsule after the fuel fire and magnesium fire

Figure 23B. Remains of SNAP-19 IRHS Generator

Figure 24. Remains of SNAP-19 IRHS Generator and Dispersal Systems Capsule

Figure 25. Remains of SNAP-19 IRHS Capsule and Dispersal Systems

Figure 26. Mild steel straps and roll of sheet magnesium after fuel fire and magnesium fire

The stainless steel sheath on the heater leads and the thermocouples installed in the Dispersion System Generator, the Dispersion Capsule, and the Intact System Capsule appeared undamaged (Figure 25).

The stainless steel sheath on the heater leads and the thermocouples on the Intact System Generator resided in the magnesium oxide and fire on the sandpile. Some damage was observed, although not all leads were burned through (Figures 24 and 27).

Table VII describes the apparent reaction of each thermocouple to the fire environments, both JP-4 and magnesium.

The mild steel straps fastening the magnesium stand legs to the sandpile structure were intact after the fire burned out (Figure 28). The magnesium was oxidized under the mild steel straps.

When the fire area cooled off, the four capsules were recovered and visually examined. None of the capsules were breached. The graphite heat shield on the IRHS had sustained some reduction in size, but it was not breached (Figure 29).

Figure 27. Heater and thermocouple leads after fire

TABLE VII

Explanation of Thermocouple Data from SNAP-19 Units

<u>TC No.</u>	<u>Explanations</u>
1	Plot appears reasonable to 50 minutes, then TC apparently opened.* TC checked open at end of fire.
2	Plot appears reasonable to 46 minutes, then TC apparently opened. TC checked open at end of fire.
3	Plot appears reasonable to 29 minutes. TC probably destroyed at that point. TC checked open at end of fire.
4	Plot appears reasonable to 85 minutes; however, it could have come loose from aluminum cold end hardware at approximately 7 minutes.
5	Plot appears reasonable to 45 minutes, then TC apparently opened. TC checked open at end of fire.
6	Plot appears reasonable to 28 minutes. Appears to have opened here, then possibly remade another junction. Checked good at end of fire.
7	Plot appears reasonable to 51 minutes, then TC apparently opened. Remade a junction later in test. Checked good at end of fire.
8	Plot appears reasonable to 47 minutes, then TC apparently opened. Checked opened at end of fire.
9	Plot appears reasonable to 30 minutes. Possible contact with magnesium fire could destroy original junction and remake a junction. Checked good at end of fire.
10	Plot appears reasonable to 30 minutes with possible TC break from aluminum at 12 minutes. Possibly remade junction after magnesium fire contact. Checked good at end of fire.
11	Plot appears reasonable to 4 minutes, then TC apparently pulled loose. Checked good at end of fire.
12	Plot appears reasonable to 3.5 minutes, then TC apparently pulled loose. Checked good at end of fire.

*Plots are not included in this report.

TABLE VII (continued)

TC No.	Explanations
13	Plot appears reasonable to 4 minutes, then TC apparently pulled loose. Checked good at end of fire.
14	Plot appears reasonable to 41 minutes, then TC apparently opened.
15	Plot appears reasonable to 85 minutes.
16	Plot appears reasonable to 85 minutes.
17	Plot appears reasonable to 85 minutes.
18	Plot appears reasonable to 85 minutes.
19	Plot appears reasonable to 85 minutes.
20	Plot appears reasonable to 85 minutes.
21	Plot appears reasonable to 85 minutes.
22	Plot appears reasonable to 85 minutes.
23	Plot appears reasonable to 85 minutes.
24	Plot appears reasonable to 4 minutes, then TC apparently broke loose from aluminum cold end hardware and read fire temperatures.
25	Lost before test started.
26	Plot appears reasonable to 85 minutes.
27	Plot appears reasonable to 85 minutes.

Figure 28. Mild steel straps after fire

Figure 29. Undamaged capsules after fire test

The generator ATJ graphite heat accumulator blocks appeared undamaged when recovered from the Dispersion System Generator; the graphite heat accumulator blocks from the Intact System Generator appeared to be about one-half consumed (Figures 30, 31, and 32). Remains of thermoelectrics and springs were recovered from both systems.

Comments on Computer Modeling -- The thermocouple data were evaluated as shown in Table VII and then subjected to a computer modeling technique in order to acquire the maximum temperature to be expected had the fuel been real and the fuel heat generation constant throughout the fire duration. Figures 33 through 39 show the capsule temperatures measured in the fire, the temperatures as modeled by the computer, and the temperatures as modeled by the computer with constant internal heat generation. As can be seen, the capsule temperatures became somewhat marginal but do not melt except for the bottom of the capsule in Figure 38. This capsule was forced to remain at the maximum heat level (24 inches above the liquid level) for the entire duration of the fire.

Conclusions

This fire test was considered to be a successful demonstration of the reactions of the SNAP-19 hardware to a fire involving about 2000 gallons of JP-4 fuel and about 40 pounds of magnesium. It should be noted clearly that this fire test was not a true pad abort but gave a reasonable simulation of a typical pad abort residual fire. The fire subjected the SNAP-19 components to a strong fire environment and provided information which will allow improved engineering judgment.

However, the limitations of this fire test must be recognized. These limitations are as follows.

1. The Dispersion System Generator and extra capsule were not heated or pressurized.
2. The Intact System Generator was heated for only six minutes after fire ignition, and the electric heaters were around the fuel capsule rather than at the fuel capsule centerline.

3. The Intact Reentry Heat Source was heated for only 2 minutes and 30 seconds, and the fit between the stainless steel shipping dummy capsule and the graphite heat shield was too tight.

Subject to the limitations above, the following statements can be made.

1. Twenty-six of the twenty-seven thermocouples installed operated satisfactorily.
2. The four fuel capsules survived this fire test.
3. A generator does not necessarily disassemble when the outer case is melted or burned.
4. The magnesium fire is intermittent while the residual fire burns, and becomes steady only after the residual fire burns out.
5. There was little evidence of oxidation on the bare Intact Reentry Heat Source, but there was appreciable oxidation on the Intact Reentry Heat Source that resided in the magnesium fire after the residual fire had burned out.
6. Computer modeling indicates that the capsules may be marginal with internal heat present and if the fire were to last slightly longer.

The residual fire test did demonstrate, as outlined in Reference 5, that in a reducing atmosphere there is magnesium nitride formed rather than magnesium oxide. The presence of a strong odor of ammonia and shades of yellow in the residue indicate the nitride formation. This is very beneficial to preserving the integrity of the fuel capsule because the heat of combustion for magnesium in a nitrogen atmosphere is about 25 percent of that in air. This very drastically reduces the temperature to which the capsules are subjected.

Figure 30. Remains of SNAP-19 dispersal system generator

Figure 31. Intact system generator debris

Figure 32. Intact system generator debris

Figure 33. Intact reentry heat source within intact reentry system generator

Figure 34. Intact reentry heat source

Figure 35. Intact reentry heat source

Figure 36. Dispersion fuel capsule

Figure 37. Dispersion fuel capsule

Figure 38. Dispersion fuel capsule within dispersion system generator

Figure 39. Dispersion fuel capsule within dispersion system generator

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