MASTER

SNAP-III

THERMOELECTRIC GENERATOR
SAFE HANDLING PROCEDURES

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Technical Approval

Melvin Barmat

Written by
Thaddeus J. Dobry, Jr.
Paul Guinn

MND-P-2514

April 1959

Prepared by Martin Nuclear Division
for the
U.S. Atomic Energy Commission

Printed in the USA

MARTIN
NUCLEAR DIVISION

FOREWORD

This report has been prepared by the Nuclear Division of The Martin Company for the United States Atomic Energy Commission. It presents a discussion of the safe handling procedures for the SNAP-III thermoelectric generator which has been demonstrated in the United States.

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CONTENTS

	Page
Foreword	ii
Legal Notice	iii
Contents	iv
I. Introduction	1
II. Safe Handling of the SNAP-III Thermoelectric Generator	2
A. Bureau of Explosives Permit	2
B. Radiation Levels	3
C. Labeling of the Shipping Container	3
D. Labeling of the Transportation Vehicle	3
E. Handling Procedures	4
F. Exposure Control During Exhibition	8
G. Emergency Procedures	8
III. Hazard Summary	10
A. Thermal Excursion	10

I. INTRODUCTION

A method for the safe handling of the SNAP-III thermoelectric generators designed by The Martin Company is presented in this report. It provides information regarding shipping regulations, general handling instructions for packing, unpacking and demonstrating the device, and procedures to follow in an event of an accident. Finally, it summarizes the possible hazards involved in handling the device, and the probability of any of these hazardous incidents occurring while it is being demonstrated.

Containment of the radioisotope fuel used in the SNAP-III device has been assured under rigorous conditions, including short time external thermal temperature excursions to 1600 degrees centigrade, when in the shipping container. The probability of the device encountering such temperatures are remote.

II. SAFE HANDLING OF THE SNAP-III THERMOELECTRIC GENERATOR

This section summarizes the procedures for the safe handling of the SNAP-III unit during transportation and exhibition and to ensure compliance with existing regulations.

In a conference on 20 March 1959 with the Bureau of Explosives in New York, the regulations governing transportation of the SNAP-III unit were reviewed. Some of the more important regulations are discussed here.

A. BUREAU OF EXPLOSIVES PERMIT

The drawing of the Martin-designed shipping container was reviewed and Bureau of Explosives Permit No. 738 issued. Several restrictions on the use of this permit were specified. These are:

- (1) The permit only allows up to 2,000 curies of Polonium-210 to be shipped in the Martin-designed shipping container. If the container is to be used for shipping any material other than Polonium-210 or for more than 2,000 curies of Polonium-210, prior approval of the Bureau of Explosives must be obtained.
- (2) Each time the SNAP-III unit is moved the Bureau of Explosives must be notified by letter, telegram or telephone on or before the date of shipment. The Bureau of Explosives must be informed as to the permit number, point of origin and destination, date of shipment, type of transportation and the quantity of material in curies.
- (3) The shipping container must have a seal which will indicate that the container has been opened. This seal must be applied each time the unit is shipped.
- (4) The applicable laws and regulations of each individual state must be adhered to.

B. RADIATION LEVELS

Bureau of Explosives Permit No. 738 does not in any way supersede the Interstate Commerce Commission regulations regarding the permissible radiation levels from the shipping container. The Interstate Commerce Commission regulations state:

- (1) Beta-gamma radiation must not exceed 200 milliroentgens per hour on the surface of the shipping container and/or ten milliroentgens per hour at a distance of one meter from the center of the shipping container.
- (2) Neutron radiation as measured at one meter from the center of the shipping container must not exceed the equivalent of two milliroentgen per hour of gamma radiation.

C. LABELING OF THE SHIPPING CONTAINER

The SNAP-III shipping container must have a red Interstate Commerce Commission label affixed to the outside surface. This will comply with the regulation requiring a red label whenever the following are exceeded:

- (1) The activity of the contents exceed 1.3 millicuries
- (2) The radiation level on the outside surface of the shipping container exceeds 0.4 milliroentgen per hour (10 milliroentgens per 24 hours).

The number of radiation units, defined as the reading in milliroentgens per hour at one meter from the center of the shipping container, must appear on the Interstate Commerce Commission label.

D. LABELING OF THE TRANSPORTING VEHICLE

Every motor vehicle used to transport the SNAP-III unit must have a placard on each side and rear of the vehicle reading: "Dangerous, RADIOACTIVE MATERIALS." The letters must be in red on a contrasting background and must be at least three inches high.

This is a brief summary of the more important regulations covered in Title 49, Parts 71 to 90 of the Code of Federal Regulations.

Prior to any movement of the SNAP-III unit, a certified health physicist with a knowledge of these shipping regulations should be consulted. This will ensure compliance with all regulations governing the shipment of radioactive materials.

E. HANDLING PROCEDURES

In order to ensure safe handling of the SNAP-III unit during transportation and exhibition, the following procedures are to be followed.

1. Preparation of Unit for Shipment

The SNAP-III unit should be thoroughly monitored prior to placement in its shipping container. This should include a reading of the external radiation levels for gammas and neutrons and monitoring for alpha contamination. The latter would be determined by leak testing the device by wiping a water- or alcohol-dampened cloth over the outside surface of the copper (black) sphere. This cloth is then dried and counted with a sensitive alpha detector.

2. Preparation of the Shipping Container

Prior to placing the SNAP-III unit in its shipping container, a thorough contamination check should be made. This will require smear or wipe tests of the shipping container. No contamination above background radiation levels should be permitted. If contamination is not detected, the SNAP-III unit may be placed in the shipping container and the seal and Interstate Commerce Commission labels attached.

The shipping container is six inches in diameter and ten inches long. It is fabricated from Series 300 stainless steel with a one-half inch thick wall. The approximate weight of the cask is 50 pounds, and for ease of handling, a handle is provided. The container is sealed tight by a screw cap employing a metal gasket between the faying surfaces of the capsule and the cap. Figure 1 shows a view of the complete container. A 12-point external wrench is supplied with the cask so as to provide ready access should it be necessary.

Figure 1. Shipping Cask

Accessories such as a mounting cradle and models are transported with the generator in convenient carrying cases.

3. Opening of the Shipping Container

Upon arriving at its destination, the outside surface of the shipping container should be thoroughly checked for contamination by means of smears or wipes in the manner described previously. The seal should be checked to determine whether there is evidence of tampering. If the seal is broken, extreme caution should be used in opening the container. The following procedures must be followed:

- (1) Open the accessory carrying case and remove mounting cradle (Figure 2).
- (2) Remove the wing nut from the generator shipping cask to free the external wrench.
- (3) Remove the wrench, and use it to open the cask by turning the nut on the cap counterclockwise. Care should be taken to not lose the metal gasket, as it can be reused. A smear or wipe test should be made on the cap for alpha contamination.
- (4) Remove the steel wool packing material from the cask, and lift the generator out of the capsule. This may be accomplished by cautiously pulling the two electrical terminals attached to the top of the generator. The device should not be forced. If it cannot be freed immediately, turn the cask over, and very gently tap out the generator. Because the device is thermally hot, it is recommended that a pair of asbestos gloves be used during this operation.
- (5) Remove the shorting bar attached to the leads of the generator.
- (6) Place the steel wool packing material and the shorting bar into the cask for storage, assembly the cap and remount the wrench.
- (7) Keep the container near the demonstration area. It can be used as a containment vessel, if an unforeseen accident should occur.
- (8) Inspect the generator and perform a daily leak test. If the check is deemed satisfactory, the generator is ready to supply power for the demonstration model.

Figure 2. Mounting Cradle

F. EXPOSURE CONTROL DURING EXHIBITION

The U.S. Atomic Energy Act of 1954 limits exposures to ionizing radiation as follows:

- (1) Three hundred millirems per week and/or 15 rems per year exposures for personnel who are monitored for radiation exposures by means of film badges, pocket chambers, pocket dosimeters, etc.
- (2) One hundred-millirem exposure in any seven consecutive days or an average exposure of two millirems per hour for personnel over 18 years of age who are not monitored for exposures to ionizing radiation.
- (3) Thirty millirem exposure in any seven consecutive days for personnel under 18 years of age.

In order to comply with these regulations, an area five or more feet in diameter should be established around the SNAP-III unit to prevent anyone, other than those in charge of the exhibit, from getting any closer. Those in charge of the exhibit should wear film badges and pocket chambers and should limit their time within the five-foot area to that established by a competent health physicist.

A daily leak test of the device should be performed as previously described.

G. EMERGENCY PROCEDURES

The only potential health hazard that need cause concern in the SNAP-III unit is a leaking source. In event that the daily leak tests show evidence of the unit leaking, these procedures should be followed:

- (1) Place the unit in the shipping container and fasten securely.
- (2) Evacuate all personnel immediately. If the alpha contamination levels are relatively high, all personnel should have their hands and clothing monitored for contamination.
- (3) Notify a competent health physicist who will establish necessary procedures based on the seriousness of the condition.

These procedures are brief and cover only some of the major requirements. It is not possible to establish procedures for every condition to assure the safe handling of the SNAP-III unit. In view of this, it is recommended that a qualified individual who has been advised of the hazards and safe handling procedures by a qualified health physicist accompany the SNAP-III unit when it is on display. He should have an alpha detector and a beta-gamma counter for use in routine monitoring and in the event of an emergency.

It is not anticipated that this device will cause any difficulties but should an incident occur, a qualified health physicist would be required. This would permit handling of the situation so as to prevent excessive exposures and wide-spread contamination.

III. HAZARD SUMMARY

The primary hazard involved in the use of the SNAP-III thermoelectric generator is the release of radioactive contamination from the isotopic fuel. If containment of the fuel is assured, there is no problem of environmental radioactive contamination and therefore the hazard is essentially eliminated.

The SNAP-III generator itself is structurally capable of containment under extremely adverse conditions. It is, however, susceptible to failure when subjected to either internal or external temperature excursions. Because there is the remote possibility that a thermal excursion can be inflicted on the unit, it is essential that an analysis be made to determine the degree of thermal punishment that can be tolerated by the device, and the probability of such an incident occurring. This chapter offers a solution to these problems.

A. THERMAL EXCURSION

Because the SNAP-III generator is a thermal device, a temperature excursion could result from within or from without. An analysis to determine the behavior of this unit during such an excursion is quite complex. The following is the method used to determine the time required to melt down the unit under certain internal excursions and external fires.

1. Internal Thermal Excursions

If the device were to be perfectly insulated, what time would be required to melt down the essential containment materials? The following procedure was used to answer this question.

- (1) The mass of the various materials in the device was determined:

Material	Mass (grams)	Specific Heat (calories per gram degrees centigrade)	Melting Point (degrees centigrade)	Heat of Fusion or Sublimation (H_F) (calories per gram)
Copper	363	0.100	1083	50.46
Aluminum	341	0.260	660	95.3
Lead Telluride	259	0.038	825	227
Insulation	137	0.300	Above 1500	--
Molybdenum	173	0.061	2630	--
Stainless Steel	168	0.120	1425	--

- (2) An average specific heat for the device was calculated:

$$C_{av} = 0.143 \text{ calories per gram, degree centigrade}$$

- (3) The average temperature of the device with respect to time was determined from the following relationship:

$$T_{av} = T_o e^{-\lambda t}$$

where

T_{av} = average temperature of the device at time t ,
degrees centigrade

T_o = original average temperature of the device = 260
degrees centigrade

λ = decay constant of Polonium-210 = $5 \times 10^{-3} \text{ day}^{-1}$

t = time, days

$$T_{av} = 260 e^{-5 \times 10^{-3} t}$$

- (4) The heat produced by the isotope with respect to time was determined.

$$Q = 27.538 C e^{-\lambda t}$$

where

Q = heat produced by isotope, calories per hour

27.538 = Polonium-210 constant, calories per curie per hour

C = original number of curies, 2,000

$$Q = 27.538 \times 2000 e^{-5 \times 10^{-3} t} = 5.51 \times 10^4 e^{-5 \times 10^{-3} t}$$

- (5) The temperature increase per hour was calculated by:

$$\Delta T = \frac{Q}{C_{av} \times M}$$

where

ΔT = increase in temperature, degree centigrade per hour

m = mass of device = 1,441 grams

$$\Delta T = \frac{5.51 \times 10^4 e^{-5 \times 10^{-3} t}}{0.143 \times 1441} = 267 e^{-5 \times 10^{-3} t}$$

- (6) With these data, it is possible to calculate the time required to raise the temperature of the unit to 1260 degrees centigrade. This is the assumed temperature at which it appears that the helium gas contained in the stainless steel capsules will begin to release. The equation for this sequence of events with respect to age of the device is as follows:

$$\epsilon T = \frac{1260 - T_{av}}{\Delta T} + \frac{H_{F(AL)} \times M_{(AL)}}{Q} + \frac{H_{F(PbTe)} \times M_{(PbTe)}}{Q} + \frac{H_{F(Cu)} \times M_{(Cu)}}{Q}$$

where

ϵT = time required to raise temperature to 1260 degrees centigrade, hours

$H_{F(AL)}$ = heat of fusion of aluminum, calories per gram

$H_{F(PbTe)}$ = heat of fusion of lead telluride, calories per gram

$H_{F(Cu)}$ = heat of fusion of copper, calories per gram

M = mass, grams

$$\epsilon T = \frac{1}{5.51 \times 10^4 e^{-5 \times 10^{-3} t}} (3.7 \times 10^5 - 0.5 \times 10^5 e^{-5 \times 10^{-3} t})$$

(7) The relationship shown in the equation is plotted on Figure 3 as hours necessary to reach 1260 degrees centigrade versus the age of the device in days. It can be seen that potential temperature excursions within the device decrease substantially with age.

(8) The total heat required to raise the temperature to 1260 degrees centigrade was calculated from the following:

$$Q_T = Q \times \epsilon T$$

where

Q_T = total heat, calories

Figure 3 shows this relationship.

Figure 3. Thermal History of SNAP-III

2. External Thermal Excursion

Fire in an aircraft would create the most severe temperatures to which the SNAP-III device would be subjected. In a fire of this type it is estimated that approximately 10^9 calories per hour of heat would be released. If it is assumed that one tenth of one percent of this heat is absorbed by the device when it is in its shipping container, and that the fire would last about one-half hour, it would be possible to calculate the time required for melt down in such a fire. The following equation can be used to determine this time.

$$\epsilon F = \frac{Q_T}{\frac{Q}{2} + 10^9 \times 0.001 \times 1/2}$$

where

ϵF = time to melt down in a fire releasing 10^9 calories per hour, hours

From Figure 3, it can be seen that the shortest time that the device could remain intact would occur when the device was new. From the equation the time is determined as 0.58 hour. This length of time would get progressively greater as the device ages.

This analysis indicates that the SNAP-III thermoelectric generator can tolerate any fire to which circumstances might subject it.