AIM

Association for Information and Image Management

1100 Wayne Avenue, Suite 1100
Silver Spring, Maryland 20910
301/587-8202

Centimeter

Inches

MANUFACTURED TO AIM STANDARDS
BY APPLIED IMAGE, INC.

1 of 1

(CLASSIFICATION)

HW-76977

GENERAL ELECTRIC

DATE _____

March 18, 1963

TITLE

PROPOSAL FOR IRRADIATION OF TARGET ASSEMBLIES

OTHER

AUTHOR

V. L. Gelezunas

CIRCULATING COPY
ISSUED FILE
RECEIVED 300 AREA

MAR 21 1963

RETURN TO

TECHNICAL INFORMATION 100

☐ OTHER OFFICIAL CLASSIFIED INFORMATION
THIS MATERIAL CONTAINS INFORMATION AFFECTING
THE NATIONAL DEFENSE OF THE UNITED STATES
WITHIN THE MEANING OF THE ESPIONAGE LAWS,
TITLE 18, U. S. C., SECS. 793 AND 794, THE TRANS-
MISSION OR REVELATION OF WHICH IN ANY MANNER
TO AN UNAUTHORIZED PERSON IS PROHIBITED BY
LAW.

ROUTE TO:

PAYROLL NO.

LOCATION

FILES ROUTE
DATE

SIGNATURE AND DATE

MASTER
DECLASSIFIED

DISTRIBUTION OF THIS DOCUMENT IS UNLIMITED

(CLASSIFICATION)

DECLASSIFIED

HW-76977

DISTRIBUTION:

1. L. V. Barker	12. R. Neidner
2. R. A. Carlson	13. R. H. Nelson
3. R. L. Dillon	14. R. E. Olson
4. T. W. Evans	15. J. W. Riches
5. V. L. Gelezunas	16. E. D. Sayre
6. A. K. Hardin	17. F. W. Van Wormer
7. W. K. Kratzer	18. O. J. Wick
8. G. A. Last	19. M. J. Wise
9. C. G. Lewis	20. 300 Area Files
10. J. E. Minor	21. Records Center
11. M. R. Moon	

This document consists of
13 pages.

PROPOSAL FOR IRRADIATION OF TARGET ASSEMBLIES

V. L. Gelezunas

Classification Cancelled by [redacted]

DECLASSIFIED

March 18, 1963

By Authority of CG PR-2
DS Lewis, 3-18-94.
By Cheri Mally, 3-30-94.
Verified By DK Hanson, 4-9-94

[redacted]

[redacted]

DECLASSIFIED

HW-76977

PROPOSAL FOR IRRADIATION OF TARGET ASSEMBLIES

I. INTRODUCTION

A proposal has been made to achieve a greater overall total production from the N-reactor through multi-product operation. Apparently, this can be achieved by producing tritium along with plutonium. Tritium production technology is presently based on low temperature and pressure water environments at SRP using targets which contain Al-Li alloy.⁽¹⁾ Past experience has shown that the transport of tritium and lithium and the swelling which can result from helium agglomeration are all strong functions of temperature. Since operation of target elements at N-reactor conditions constitutes an extrapolation from available operating experience, a R&D effort is required in order to delineate and resolve any problems associated with target element operation in the N-reactor. This proposed irradiation test is a significant part of this R&D effort.

II. TEST OBJECTIVES

The primary objectives of this irradiation test series are:

- 1) To determine the rate of swelling of the overall target assembly ($\% \text{ vol. change/GVR}$)* and the Al-Li alloy under N-reactor conditions.
- 2) To determine the effect of irradiation on the mass transport of Li and T in the target assembly under N-reactor conditions.

$$\text{*GVR} = \frac{\text{cc of T}_2 + \text{He at STP}}{\text{cc of metal}}$$

(1) Gelezunas, V. L., The Production of Tritium at Intermediate Temperatures by Means of the $\text{Li6}(n,\alpha)\text{H3}$ Reaction. (A Literature Review), HW-76297, 1/21/63, (Secret).

DECLASSIFIED

HW-76977

- 3) To determine the effect of surface treatments of Al on the transport of Li and T under N-reactor conditions.

III. TEST DESIGN

This is the first test of a series of three which is designed to yield information on swelling and mass transport of Li and T under N-reactor conditions. There will be eight target assemblies irradiated in the first test: two target assemblies per Zircaloy-2 basket. The four baskets should be located end-to-end in the peak flux region of the loop. Each basket will contain the following assemblies.

<u>Basket No.</u>	<u>w/o Li in Al-Li target</u>	<u>w/o Li⁶ in Al-Li</u>	<u>Anodized film on outer surface of Al can</u>
1	1.0	0.40	yes
1	1.0	0.40	no
2	1.0	0.40	yes
2	1.0	0.40	no
3	2.0	0.40	yes
3	2.0	0.40	no
4	2.0	0.40	yes
4	2.0	0.40	no

The baskets should be positioned with respect to one another in the order listed.

The temperature of the assemblies will not be directly measured. Heat for the loop will have to be provided by heater elements.

IV. DESCRIPTION OF TARGET ASSEMBLIES

A. Geometry

The details of the target assembly are shown in Dwg. No. H-3-20838.

The overall length of the target assemblies are $9.000 \pm .010$ inches.

Three standard Zircaloy-2 supports, except for the overall height .000 which is $0.375 \pm .015$ inches, will be welded 120° apart near each

DECLASSIFIED

-3-

HW-76977

end of the assembly. The target assemblies will be inserted in Zircaloy-2 shroud tubes of the type shown in Dwg. No. SK-3-8453.

B. Materials

The target alloy core is machined from an extruded Al-Li alloy. The billet for the extrusion is made by melting Al-3.18 w/o Li (40.1 w/o Li⁶) alloy with 2S Al alloy to yield the desired compositions.

The Al can is machined from extruded C-64 Al alloy tubing while the Zircaloy-4 can is machined from reactor grade tubing.

The inner end caps are machined from 2S-Al alloy rod while the outer end caps are machined from reactor grade Zircaloy-2 rod.

C. Fabrication

The Al-Li target core is inserted into a C-64 Al alloy can.

The 2-S Al end caps are inserted and the resulting sub-assembly is die sized to provide an intimate contact between the core and the Al cladding. Both end caps are welded using the TIG process (tungsten inert gas). One of the end caps has a drilled and tapped hole machined into it. A plug is screwed into this hole after the sub-assembly has been evacuated and back-filled with helium in a welding glove box. The final closure is made by welding the plug by the TIG process in the helium filled glove box.

This sub-assembly is removed from the glove box and inserted into a Zircaloy-4 can in which one cap has already been electron-beam welded. The other cap is inserted after the assembly has been evacuated and back-filled with helium in a glove box. The final

DECLASSIFIED

HW-76977

closure is made by the TIG process. It has been found that no special techniques are necessary in order to make the final closure in helium as is the case for the Al.

The target assembly is completed by welding on supports to the Zircaloy-4 cladding.

D. Inspection and Proof Testing

The welds will be inspected by X-ray and helium leak checking at various steps of assembly. Also the target assembly including supports will be autoclaved at 300 C for 48 hours or longer.

V. EXPECTED PERFORMANCE

A. Mechanical Behavior

The void volume in the target alloy slug is designed to accommodate any swelling of the target alloy which may occur as a result of gas agglomeration. The calculations for the void volume are presented in Appendix I. To allow for the difference in thermal expansion between Al and Zircaloy-4, a 0.002 inch gap at room temperature is provided between the Al can and the Zircaloy-4 can. This gap as well as the core-Al can gap contains helium in order to facilitate heat transfer. The Zircaloy-4 can thickness has been chosen so that it will be "free standing" at NPR conditions. Autoclave tests have shown that an empty Zircaloy-4 can with a 0.035 inch wall collapses at 2200 psi at 300 C. The dimensions of the Zircaloy-4 can in a target assembly remain unchanged after a similar treatment to 5300 psi at 300 C.

B. Failure Behavior

There has been no experience with the in-reactor failure behavior

DECLASSIFIED

HW-76977

of these target assemblies at N-reactor conditions. However, several test assemblies will be cycled from 20-300 C ten times to simulate startup and shutdown of the K-reactor. Since at any time after startup the target elements will contain tritium, a leak in the Zircaloy-4 can would probably result in tritium discharge to the loop water.

C. Charge and Discharge of Target Assemblies

The target assemblies can be charged and discharged in the normal manner.

VI. OPERATIONAL LIMITATIONS

The loop water temperature should not exceed 300 C. In the event of the detection of rupture, the target assemblies should be discharged.

VII. IRRADIATION CONDITIONS

- 1) Exit coolant temperature - $280\text{ C} \pm 5\text{ C}$.
- 2) Time of exposure - 50 days of full power reactor operation.

VIII. INSTRUMENTATION

The loop should have a detection system for either detecting T or Al.

IX. REACTOR DATA REQUIRED

At eight-hour intervals during reactor operation the following information is desired:

- a) Date
- b) Time
- c) Process Tube Power Level
- d) Water Inlet Temperature
- e) Water Outlet Temperature
- f) Water Flow Rate
- g) Water Inlet Pressure
- h) Water Outlet Pressure

X. DISPOSITION OF TARGET ASSEMBLIES

After discharge, the target assemblies should be stored for a sufficient decay period and then shipped to the basin in K-east.

VLG:lh

DECLASSIFIED

HW-76977

APPENDIX I

CALCULATION OF VOID VOLUME OF TARGET SLUG

The design philosophy is based on producing a conservative irradiation test in a relatively short time. Hence, the gas which is generated is assumed to all precipitate from solution and agglomerate and act as a perfect gas.

From the definition of GVR

$$1) \frac{V_H}{V_M} = \text{GVR}(\text{STP}) \frac{T_G}{273} \times \frac{14.7}{P_G}$$

where V_H = volume of hole which is equivalent to the volume of gas
which is generated

GVR = volume of T_2 + He/volume of metal

T_G = temperature of gas, °K

P_G = pressure acting on the gas, psia

Calculation of the effective pressure acting on the gas:

$$2) P_G = P_C + P_R$$

where

P_C = coolant pressure, psia

P_R = effective restraint pressure of the assembly, psia.

To calculate the effective restraint pressure, only the Zircaloy-4 cladding is assumed to offer any significant restraint. The restraint is set by allowing less than 1 percent creep strain in 5000 hrs. at 300 C. For fully annealed Zircaloy-2 the allowable stress is given as 15,000 psi.⁽¹⁾ Hence,

$$P_R = \frac{\sigma t}{R}$$

DECLASSIFIED

HW-76977

where

σ = allowable stress, psi

R = radius of Zircaloy-4 can, inches

t = thickness of Zircaloy-4 can, inches

$$P_R = \frac{15,000 \times 0.034}{0.682/2} = 1500 \text{ psi}$$

The coolant pressure is taken as $P_C = 1600$ psi

therefore $P_G = 1600 + 1500 = 3100$ psi

The maximum core temperature is taken as 300 C

therefore $T_G = 273 + 300 = 573^\circ\text{K}$

Sub. the values into Eq(1)

$$\frac{V_H}{V_M} = \text{GVR} \times \frac{573}{273} \times \frac{14.7}{3100} = 0.010 \text{ GVR}$$

now V_H/V_M is also equal to

$$2) \quad \frac{V_H}{V_M} = \frac{y}{1-y}$$

$$\text{where } y = \left(\frac{D_1}{D_0} \right)^2$$

(1) Pankaskie, P., Creep Properties of Zircaloy-2 for Design Application, HW-75267, 10/10/62, Unclassified.

-8-
DECLASSIFIED

HW-76977

and D_1 = diameter of hole

D_0 = diameter of Al-Li slug

hence

$$3) y = \frac{1}{\frac{100}{GVR} + 1}$$

On the basis of a P-3 calculation the GVR/day of full reactor power is 0.127.

The hole is sized for the highest GVR: the longest irradiation time planned is 150 days.

$$\therefore GVR = 150 \times .127 = 19.0$$

$$\therefore y = \frac{1}{\frac{100}{19.0} + 1} = \frac{1}{6.25} = .160$$

hence

$$\frac{D_1}{D_0} = \sqrt{y} = \sqrt{.160} = 0.400$$

$$\text{now } D_0 = .625$$

$$\text{hence } D_1 = .400 \times .625 = 0.250$$

$$\therefore \underline{D_1 = 0.250''}$$

DECLASSIFIED

HW-76977

APPENDIX II

HEAT TRANSFER CALCULATIONS

1) Calc. of Power Generation

From P-3 calculation the avg. flux in the Al-Li slug is

$$\bar{\phi} = 5.0 \times 10^{13} \text{ n/cm}^2\text{-sec}$$

For 1 w/o Li (40.1% Li^6) the macroscopic absorption cross-section corrected for Maxwellian distribution and neutron temperature is:

$$\bar{\Sigma}_a = \frac{\sqrt{\pi}}{2} \frac{T_0}{T_n} \Sigma_a = .513 \Sigma_a = .513 \times 1.002 = 0.514$$

therefore the power generated assuming that 4.8 MEV is released per Li^6 fission is

$$Q_{n-\alpha} = 0.513 \times 5.0 \times 10^{13} \times 4.8 \times 1.55 \times 10^{-8} \frac{\text{BTU-cm}^2\text{-sec}}{\text{MEV-ft}^3\text{-hr}}$$

$$Q_{n-\alpha} = 1.95 \times 10^6 \text{ BTU/ft}^3\text{-hr}$$

assume the γ - heat is 1 watt/gm for the Al-Li core

$$Q_\gamma = 1 \frac{\text{w}}{\text{g}} \times 3.413 \frac{\text{BTU}}{\text{w-hr}} \times \frac{28317 \text{ cm}^3}{\text{ft}^3} \times \frac{2.59 \text{ g}}{\text{cm}^3} = 0.25 \times 10^6 \frac{\text{B}}{\text{ft}^3\text{-hr}}$$

$$Q_T = Q_{n-\alpha} + Q_\gamma = (1.95 + .25) \times 10^6 = 2.20 \times 10^6 \text{ B/ft}^3\text{-hr}$$

DECLASSIFIED

-10-

HW-76977

The volume/ft of target is given by

$$V = \frac{\pi}{4} \frac{(.625^2 - .250^2) \times 12}{1728} = 1.79 \times 10^{-3} \text{ ft}^3/\text{ft}$$

$$\text{now } q' = VQ_T = 1.79 \times 10^{-3} \text{ ft}^3/\text{ft} \times 2.20 \times 10^6 \text{ B/ft}^3\text{-hr}$$

$$= 3.94 \times 10^{-3} \text{ B/hr-ft}$$

The surface area per ft of length

$$A_2 = \frac{\pi \times .625 \times 12}{144} = 0.164 \text{ ft}^2/\text{ft}$$

hence the heat flux is given by

$$q'/A_2 = q = \frac{3.94 \times 10^{-3}}{.164} = 24,000 \text{ B/hr-ft}^2$$

2) Calc. of Temperature Drops

Assume the following values

Mat'l	Thermal Conductivity	BTU/hr-ft ² -°F/ft
Al-Li	72.6	
Al	145	
Zircaloy-4	10.6	

DECLASSIFIED

HW-76977

Heat transfer coefficients assumed BTU/hr-ft²-°F

Water film 2000

Contact conductance Al-Li to Al can 1200

Contact conductance Al can to Zirc can 1200

a) Temp drop across Li-Al core

neglect void volume and assume uniform heat generation

$$\Delta t_1 = \frac{Q_T a^2}{4k}$$

$$\Delta t_1 = \frac{2.20 \times 10^6 \times \frac{.625}{2} \times \frac{1}{12}^2}{4 \times 72.6} = 5 \text{ F}$$

b) Temp drop across the core-clad interface

$$\Delta t_2 = \frac{q'}{h_2 A_2} = \frac{24,000}{1200} = 20 \text{ F}$$

c) Temp drop across the Al-can

$$\Delta t_3 \approx \frac{q' \Delta x_3}{A_3 k_3} < 1^\circ \text{ F}$$

d) Temp drop across the Al-can Zirc-can interface

$$\Delta t_4 = \frac{q'}{A_4 h_4} = \frac{3940}{\left(\frac{\pi \times .682 \times 12}{144} \right) (1200)}$$

$$\Delta t_4 = 18^\circ \text{ F}$$

DECLASSIFIED

-12-

HW-h6977

e) Temp drop across the Zirc-4 can

$$\Delta t_5 \approx \frac{q' \Delta x_5}{A_5 k_5}$$

$$\Delta t_5 \approx \frac{3940 \times \frac{.034}{12}}{.188 \times 10.6}$$

$$\Delta t_5 \approx 6^\circ \text{ F}$$

f) Temp drop across the H₂O film

$$\Delta t_6 \approx \frac{q'}{A_6 h_6} = \frac{3940}{.198 \times 2000} = 10^\circ \text{ F}$$

Maximum core temp assuming bulk coolant temperature of 260 C

$$\Delta t_T = 5 + 20 + 18 + 6 + 10 = 60^\circ \text{ F or } 33^\circ \text{ C}$$

$$\therefore t_{\text{Al-Li core}} = 260 + 33 = 293^\circ$$

**DATE
FILMED**

8/18/94

END