RECORD COPY

Imbuddy
SNPO-C
Outto
records

70987

REON

SACRAMENTO PLANT

REPORT NO. RN-S-0347

TO

AEC - NASA SPACE NUCLEAR PROPULSION OFFICE

RADIATION EFFECTS PROGRAM PLANS

CY 1967

NERVA PROGRAM

CONTRACT SNP-1

DECEMBER 1966

MASTER

DISCLAIMER

This report was prepared as an account of work sponsored by an agency of the United States Government. Neither the United States Government nor any agency Thereof, nor any of their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof.

DISCLAIMER

Portions of this document may be illegible in electronic image products. Images are produced from the best available original document.

NOTICE

This report was prepared as an account of work sponsored by the United States Government. Neither the United States nor the United States Atomic Energy Commission, nor any of their employees, nor any of their contractors, subcontractors, or their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness or usefulness of any information, apparatus, product or process disclosed, or represents that its use would not infringe privately owned rights.

REPORT NO. RN-S-0347

RADIATION EFFECTS PROGRAM PLANS
CY 1967

NERVA PROGRAM

CONTRACT SNP-1

ROCKET ENGINE OPERATIONS - NUCLEAR

DECEMBER 1966

CLASSIFICATION CATEGORY

UNCLASSIFIED

W. L. Lumb
CLASSIFYING OFFICER

12-7-66

DATE

AEROJET - GENERAL CORPORATION
A SUBSIDIARY OF THE GENERAL TIRE & RUBBER COMPANY

DISTRIBUTION STATEMENT

SW

PAGE BLANK

REPORT NO. RN-S-0347

RADIATION EFFECTS PROGRAM PLANS
CY 1967

W. A. Greenhow

C. M. Rice
Program Manager
Rocket Engine Operations - Nuclear

ABSTRACT

This report presents the CY 1967 NERVA radiation effects Program Plans and includes input from Westinghouse Astronuclear Laboratory, General Dynamics/Fort Worth, and Aerojet-General Corporation.

Test schedules for all WANL and Aerojet radiation effects tests, as well as Los Alamos Scientific Laboratory tests at Plum Brook Reactor Facility, are presented. Information regarding test plans, test specifications, experimental plans, hazards analyses reports, test data reports and final test reports are contained herein for all NERVA radiation effects tests scheduled at GD/FW, PBRF, GETR and those experiments scheduled concurrent with NRX tests.

In addition to data regarding test activities, information describing the activities at PBRF in support of the cryogenic loop activation as well as the NERVA Radiation Effects Program activities at GD/FW and NRDS is also presented.

TABLE OF CONTENTS

	<u>Page</u>
ABSTRACT	iv
LIST OF TABLES	vii
INTRODUCTION	1
I. <u>CY 1967 RADIATION EFFECTS TEST PROGRAM</u>	3
A. TEST SCHEDULE	3
B. TEST PLANS	5
C. PERT CHARTS	27
II. <u>PLUM BROOK REACTOR FACILITY SUPPORT - PROGRAM PLANS</u>	37
A. W-1 LOOP ACTIVATION	37
B. CHARGING MACHINE ACTIVATION	37
C. CRYOGENIC MATERIALS TRANSFER SYSTEM ACTIVATION	39
D. IRRADIATION TEST PROGRAM	39
III. <u>GENERAL DYNAMICS/FORT WORTH PROGRAM PLANS FOR NERVA</u>	41
A. GTR-19 IRRADIATION TEST ACTIVITIES	41
B. GTR-20 IRRADIATION TEST ACTIVITIES	46
C. THERMAL CONDUCTIVITY EXPERIMENT	47
D. PARA/ORTHO HYDROGEN CONVERSION STUDY	47
E. CRYOGENIC MATERIALS IRRADIATION TESTER	48
F. NRX/EST BOLT AND NOZZLE TENSILE TESTS	49
G. GTR-18 IRRADIATION TEST ACTIVITIES	50
IV. <u>OTHER CY 1967 RADIATION EFFECTS ACTIVITIES</u>	53
A. SUPPORT TO NRX AND XE PROGRAMS	53
B. EXPLOSIVES IRRADIATION PROGRAM	54

TABLE OF CONTENTS (CONT.)

	<u>Page</u>
C. PROGRAM PLANNING	54
D. REPORT SCHEDULE	54
V. <u>CY 1966 ACTIVITIES TO BE COMPLETED</u>	59

	<u>LIST OF TABLES</u>	<u>Page</u>
I.	RADIATION EFFECTS TEST SUMMARY	4
II.	LIST OF TEST PLANS	6
III.	LIST OF PERT CHARTS	28
IV.	PBRF ACTIVITIES - CY 1967	38
V.	PBRF IRRADIATION TEST PROGRAM	40
VI.	GD/FW PROGRAM PLANNING ACTIVITIES - CY 1967	42
VII.	GD/FW IRRADIATION TEST PROGRAM	45
VIII.	OTHER CY 1967 ACTIVITIES	55
IX.	REPORT SCHEDULE	57
X.	CY 1966 ACTIVITIES TO BE COMPLETED	60

INTRODUCTION

The NERVA Radiation Effects Program Plans for the Contract Year 1967 (October 1, 1966 to September 30, 1966) are presented herein. The schedules and activities described represent the most accurate information known at this date. The data presented, which is to be utilized for planning purposes within the NERVA Radiation Effects Program, is also forwarded to all test facilities for advanced planning purposes. It is realized that changes will occur, since many of the activities are interrelated. Subsequent program planning meetings will be held throughout the contract year and all resulting changes will be coordinated with the facilities affected.

This report is presented in five sections. Section I presents the Radiation Effects Test Program and contains test schedules, test plans, and PERT-type charts for each test. Section II, which presents the Plum Brook Reactor Facility Program Plans, includes a facility utilization chart and a description and schedule of each major activity supporting the NERVA Radiation Effects Program at PBRF. Section III contains the Radiation Effects Program Plans for GD/FW activities in support of the NERVA program. Section IV describes activities not performed at GD/FW or PBRF. Included in this section are activities in support of the NRX and XE programs, the explosives irradiation program, and general support provided to the NERVA program. Section V presents the status of activities scheduled for completion in CY 1966 which were not completed by 1 October 1966.

PAGE BLANK

I. CY 1967 RADIATION EFFECTS TEST PROGRAM

A. TEST SCHEDULE

The NERVA Radiation Effects Test Program consists of materials and/or components testing at each of the following reactor facilities: the Nuclear Aerospace Reactor Facility (GTR) which is operated by the General Dynamics Corporation at Fort Worth, Texas; the Plum Brook Reactor Facility (PBRF) which is operated by the National Aeronautics and Space Administration at Sandusky, Ohio; and the Vallecitos Atomic Laboratory (GETR) which is operated by the General Electric Corporation at Vallecitos, California. In addition, materials and components radiation effects testing will also be performed in conjunction with NRX-A6 and XE testing at NRDS.

Table I summarizes the NERVA Radiation Effects Test Program for CY 1967. The plans for each test are presented in Section I-B and the detailed schedule for activities supporting these tests are contained in PERT type charts in Section I-C.

Facility utilization charts for PBRF and GD/FW, as well as detailed descriptions of other NERVA radiation effects activities at these facilities, are presented in Sections II and III respectively.

TABLE I
RADIATION EFFECTS TEST SUMMARY

<u>Component Test No.</u>	<u>Test Facility</u>	<u>Test Date</u>	<u>Test Sponsor</u>	<u>Component Description</u>	<u>Test Environment</u>	<u>Test Duration</u>
38/A001A	GETR	28 Oct 1966	AGC	Phase IA Explosives	70°F	Less than 2 hours/ capsule
37/R006	GTR	6 Nov 1966	AGC	Structural Materials	LH ₂ /LN ₂	400 hours
37/W405	GTR	6 Nov 1966	WANL	Structural Materials	LN ₂	400 hours
RE-4	PBRF	1 Jun 1967	WANL	Gamma Flux Measurement	135°F	12 hrs beginning and end of cycle
23/R512	PBRF	15 Jun 1967	AGC	Pressure Transducers	140°R	50 hours
23/W509	PBRF	1 Jul 1967	WANL	Pressure Transducers	140°R	10 hours
23/LA501	PBRF	10 Jul 1967	LASL	Pressure Transducers	140°R	50 hours
23/LA401	PBRF	20 Jul 1967	LASL	Strain Gages	140°R	50 hours
14/W004	NRX-A6	July 1967	WANL	Actuator	Ambient (80°F)	1 hour
23/W207	NRX-A6	July 1967	WANL	LVDT	Ambient (80°F)	1 hour
23/W510	NRX-A6	July 1967	WANL	Pressure Transducers	Ambient (80°F)	1 hour
23/LA502	PBRF	1 Aug 1967	LASL	Pressure Transducers	140°R	50 hours
37/W407/1	PBRF	10 Aug 1967	WANL	Structural Materials	140°R	312 hours
37/R007	GTR	30 Aug 1967	AGC	Structural Materials	LN ₂ /LH ₂ *	400 hours
37/W406	GTR	30 Aug 1967	AGC	Structural Materials	LN ₂	400 hours
37/W407/2	PBRF	7 Sep 1967	WANL	Structural Materials	140°R	312 hours
23/W208	PBRF	25 Sep 1967	WANL	LVDT	140°R	10 hours
37/R107	GTR	30 Aug 1967	AGC	Friction Wear Test	LH ₂ /RT	100 hours

*LH₂ testing may not be required - depends on analysis of GTR-19 test data.

B. TEST PLANS

Test Plans for each NERVA radiation effects test scheduled in CY 1967 are presented in numerical order (see Table II). These test plans briefly summarize the requirements and purpose of the test and outline the environmental test conditions. The best available information is presented in these plans: The test specifications, which will be issued later for each test, will contain the detailed description of the test requirements.

TABLE II
LIST OF TEST PLANS

<u>Component Test Number</u>	<u>Test Description</u>
14/W004	Actuator
23/W207	Linear Voltage Displacement Transducers
23/W208	Linear Voltage Displacement Transducers
23/LA401	Strain Gages
23/LA501	Pressure Transducers
23/LA502	Pressure Transducers
23/R512	Pressure Transducers
23/W509	Pressure Transducers
23/W510	Pressure Transducers
37/R006	Structural Materials
37/R007	Structural Materials
37/R104	Thermal Conductivity Test
37/R107	Friction Wear Test
37/W405	Structural Materials
37/W406	Structural Materials
37/W407	Structural Materials
38/A001-A	Phase I-A Explosives
RE-4	Gamma Flux Measurement

TEST PLAN SUMMARY

I. TEST IDENTIFICATION

A. Test No. 14/W004
B. Test Date July 1967
C. Test Item Description Pneumatic Control Drum Actuator
D. Number of Units to be Tested 1
E. Manufacturer and Part Number AG-20

F. Parameters to be Measured Temperature, actuator load,
coolant flow rate

G. Test Sponsor WANL

II. REACTOR INFORMATION

A. Test Facility NRX-A6 (side by side)
B. Test Duration 1 hour
C. Special Test Requirements Pre and post irradiation test to be at the
same condition cryogenic temp. and vibration as during radiation test.

III. PURPOSE OF TEST

To evaluate performance of control drum actuator for upgraded NERVA
reactors.

IV. TEST ENVIRONMENT

A. Temperature 150 - 500°R (actuator internals)
B. Pressure 700 psig (max)
C. Operational Conditions Operate during radiation run. Use Helium
40 SCFM at 200 psig for actuation. Use Helium 165 SCFM at 700 psig for
actuator coolant and Helium 135 SCFM at 700 psig for shield coolant.
D. Maximum Neutron Flux 1×10^{13} nv ($E > 1.0$ Mev)
E. Neutron Fluence To be determined
F. Maximum Gamma Dose Rate 3.0×10^{10} ergs/gm (C) hr
G. Gamma Dose To be determined
H. Test Measurements Actuator load, temperature, dosimetry,
vibration spectrum, gas consumption, pressure drop.

TEST PLAN SUMMARY

I. TEST IDENTIFICATION

- A. Test No. 23/W207
- B. Test Date July 1967
- C. Test Item Description LVDT - Transducer Test
- D. Number of Units to be Tested 6
- E. Manufacturer and Part Number 3 Schevitz, 3 Crescent - East
- F. Parameters to be Measured Displacement, temperature, dosimetry
- G. Test Sponsor WANL

II. REACTOR INFORMATION

- A. Test Facility NRX-A6 (Side-by-Side)
- B. Test Duration 1 hour
- C. Special Test Requirements Pre and post irradiation test conditions to be the same

III. PURPOSE OF TEST

To evaluate this transducer at close to operational conditions for use in subsequent tests.

IV. TEST ENVIRONMENT

- A. Temperature 300°R (transducer surface)
- B. Pressure Atmospheric
- C. Operational Conditions Coolant as required to maintain temperature.
- D. Neutron Flux To be determined
- E. Neutron Fluence Maximum attainable
- F. Gamma Dose Rate To be determined
- G. Gamma Dose Maximum attainable
- H. Test Measurements Electrical output vs displacement, temperature, dosimetry, linearity, repeatability, electrical resistance.

TEST PLAN SUMMARY

I. TEST IDENTIFICATION

A. Test No. 23/W208

B. Test Date September 1967

C. Test Item Description LVDT - Transducer Test

D. Number of Units to be Tested 6

E. Manufacturer and Part Number 3 Schevitz, 3 Crescent - East

F. Parameters to be Measured Displacement, temperature, dosimetry

G. Test Sponsor WANL

II. REACTOR INFORMATION

A. Test Facility PBRF

B. Test Duration 10 hours

C. Special Test Requirements Cryogenic System

III. PURPOSE OF TEST

To develop radiation resistant displacement transducers

IV. TEST ENVIRONMENT

A. Temperature 300°R (surface temperature of transducer)

B. Pressure Atmospheric

C. Operational Conditions Cryogenic W-1 loop cold helium flow

D. Neutron Flux 3×10^{13} nv ($E > 1.0$ Mev)

E. Neutron Fluence 1×10^{18} nvt ($E > 1.0$ Mev)

F. Gamma Dose Rate 1.4×10^{11} to 2.4×10^{11} ergs/gm (C) hr

G. Gamma Dose To be determined

H. Test Measurements Electrical output as a function of transducer displacement

TEST PLAN SUMMARY

I. TEST IDENTIFICATION

- A. Test No. 23/LA401
- B. Test Date July 1967
- C. Test Item Description Strain Gages
- D. Number of Units to be Tested To be determined
- E. Manufacturer and Part Number To be selected from the following list: Budd 700 series, Dentronix Modified Kaman, Dentronix PT-W Alloy, BLH Foil gage, BLH wire gage, Microdot weldable Evan-ohm wire, Microdot weldable PT-W alloy wire.
- F. Parameters to be Measured Deflection, sensitivity, repeatability, linearity, hysteresis, zero shift.
- G. Test Sponsor Los Alamos Scientific Laboratory

II. REACTOR INFORMATION

- A. Test Facility Plum Brook Reactor Facility
- B. Test Duration 50 hours
- C. Special Test Requirements Cryogenic system cold helium

III. PURPOSE OF TEST

Develop reliable radiation resistant strain gages for use on Phoebus reactors.

IV. TEST ENVIRONMENT

- A. Temperature 50°R
- B. Pressure 100 psi (in helium coolant)
- C. Operational Conditions Cryogenic system W-1 loop cold helium flow.
- D. Maximum Neutron Flux 3×10^{13} nv ($E > 1.0$ Mev)
- E. Neutron Fluence 5×10^{18} nvt ($E > 1.0$ Mev)
- F. Gamma Dose Rate 2×10^{11} ergs/gm (C) hr
- G. Gamma Dose To be determined
- H. Test Measurements Electrical output vs deflection, electrical resistance, linearity, repeatability, hysteresis, zero shift.

TEST PLAN SUMMARY

I. TEST IDENTIFICATION

- A. Test No. 23/LA501
- B. Test Date July 1967
- C. Test Item Description Pressure Transducers
- D. Number of Units to be Tested To be determined
- E. Manufacturer and Part Number To be selected from 6 different vendors.
Kaman Nuclear, Statham 732, Ceramic Cement Bond, Spartan Southwest
variable reluctance, Spartan Southwest potentiometer type, and
Servionics
- F. Parameters to be Measured Pressure, linearity, hysteresis,
repeatability, sensitivity change, zero shift, electrical
resistance.
- G. Test Sponsor Los Alamos Scientific Laboratory

II. REACTOR INFORMATION

- A. Test Facility Plum Brook Reactor Facility
- B. Test Duration 50 hours
- C. Special Test Requirements Cryogenic System

III. PURPOSE OF TEST

To develop pressure transducer for Phoebus reactor.

IV. TEST ENVIRONMENT

- A. Temperature 50°R
- B. Pressure 100 psig (helium for coolant)
- C. Operational Conditions Cryogenic System W-1 loop cold helium flow
- D. Neutron Flux (Maximum) 3×10^{13} nv ($E > 1.0$ Mev)
- E. Neutron Fluence 5×10^{18} nvt ($E > 1.0$ Mev)
- F. Gamma Dose Rate 2×10^{11} ergs/gm (C) hr
- G. Gamma Dose To be determined
- H. Test Measurements Electrical output vs pressure, linearity,
hysteresis, sensitivity change, zero shift, electrical resistance.

TEST PLAN SUMMARY

I. TEST IDENTIFICATION

- A. Test No. 23/LA502
- B. Test Date August 1967
- C. Test Item Description Pressure Transducers
- D. Number of Units to be Tested To be determined
- E. Manufacturer and Part Number To be selected from the following manufacturers: Kaman Nuclear, Statham 732, Ceramic Cement Bonded, Spartan Southwest variable reluctance type, Spartan Southwest potentiometer type, Servonics potentiometer type.
- F. Parameters to be Measured Pressure linearity, hysteresis, repeatability, sensitivity change, zero shift, electrical resistance.
- G. Test Sponsor Los Alamos Scientific Laboratory

II. REACTOR INFORMATION

- A. Test Facility Plum Brook Reactor Facility
- B. Test Duration 50 hours
- C. Special Test Requirements Cryogenic System

III. PURPOSE OF TEST

To develop pressure transducer for Phoebus reactor.

IV. TEST ENVIRONMENT

- A. Temperature 50°R
- B. Pressure 100 psig (helium for coolant)
- C. Operational Conditions Cryogenic System W-1 loop cold helium flow
- D. Maximum Neutron Flux 3×10^{13} nv ($E > 1.0$ Mev)
- E. Neutron Fluence 5×10^{18} nvt ($E > 1.0$ Mev)
- F. Gamma Dose Rate 2×10^{11} ergs/gm (C) hr
- G. Gamma Dose To be determined
- H. Test Measurements Electrical output versus pressure, linearity, hysteresis, sensitivity change, zero shift, electrical resistance.

TEST PLAN SUMMARY

I. TEST IDENTIFICATION

A. Test No. 23/R512
B. Test Date June 1967
C. Test Item Description Pressure Transducers
D. Number of Units to be Tested 9 to 12
E. Manufacturer and Part Number Three Standard Controls
Model 470-3 and six Statham Model P812. If room is available,
three additional units provided by LASL will also be included.
F. Parameters to be Measured Pressure, temperature, insulation
resistance, bridge resistance
G. Test Sponsor REON

II. REACTOR INFORMATION

A. Test Facility Plum Brook Reactor Facility
B. Test Duration 15 hours
C. Special Test Requirements Cryogenic temperature cold helium

III. PURPOSE OF TEST

To develop radiation resistant pressure transducers for use in NERVA
reactor test.

IV. TEST ENVIRONMENT

A. Temperature 50°R
B. Pressure 100 psig (internal)
C. Operational Conditions Cold helium flow
D. Maximum Neutron Flux 1×10^{13} nv ($E > 1.0$ Mev)
E. Neutron Fluence 5×10^{17} nvt ($E > 1.0$ Mev)
F. Gamma Dose Rate 1.4×10^{11} ergs/gm (C) hr
G. Gamma Dose 2.1×10^{12} ergs/gm (C)
H. Test Measurements Electrical output versus pressure, bridge
resistances and instrument temperatures.

TEST PLAN SUMMARY

I. TEST IDENTIFICATION

A. Test No. 23/W509

B. Test Date June 1967

C. Test Item Description Pressure Transducers

D. Number of Units to be Tested 5

E. Manufacturer and Part Number 3 Wianko, 1 Statham, 1 Microdot

F. Parameters to be Measured Electrical output versus pressure, transducer temperature, insulation resistance, bridge resistance.

G. Test Sponsor Westinghouse Astronuclear Laboratory

II. REACTOR INFORMATION

A. Test Facility Plum Brook Reactor Facility

B. Test Duration 10 hours

C. Special Test Requirements Cryogenic temperature cold helium flow.

III. PURPOSE OF TEST

To develop increased accuracy of transducers in radiation environment.

IV. TEST ENVIRONMENT

A. Temperature 140°R inlet temperature 250°R transducer surface

B. Pressure 0 to 800 psig (internal)

C. Operational Conditions Cryogenic System (W-1 loop) cold helium flow.

D. Neutron Flux 3×10^{13} nv ($E > 1.0$ Mev)

E. Neutron Fluence 1×10^{18} nvt ($E > 1.0$ Mev)

F. Maximum Gamma Dose Rate 1.4×10^{11} ergs/gr (C) hr

G. Gamma Dose To be determined

H. Test Measurements Electrical output versus pressure for pressure cycle, 0 to 800 psig at 0.25 watts/gm increments up to 4 watts/gm. Insulation resistance, bridge resistance.

TEST PLAN SUMMARY

I. TEST IDENTIFICATION

A. Test No. 23/W510
B. Test Date July 1967
C. Test Item Description Pressure Transducers
D. Number of Units to be Tested 11
E. Manufacturer and Part Number Inside Pressure Vessel: 2 Wianko
P.T. 600755, 1 Statham P.T. P-812, 1 Wianko P.T. 600755. Outside
Pressure Vessel: 3 Wianko P.T. 600755, 2 Statham P.T. P-812,
2 Microdot.
F. Parameters to be Measured Electrical output versus pressure,
transducer temperature, coolant temperature. Insulation resistance,
bridge resistance, hysteresis, repeatability.
G. Test Sponsor WANL

II. REACTOR INFORMATION

A. Test Facility NRX-A6 (side by side)
B. Test Duration 1 hour
C. Special Test Requirements Coolant to maintain temperature
(approximately 0.3 lb/sec of helium).

III. PURPOSE OF TEST

To determine operational capability of transducer for use in subsequent
reactor test.

IV. TEST ENVIRONMENT

A. Temperature 250°R
B. Pressure 0 - 800° psig (internal)
C. Operational Conditions Provide coolant (0.3 lbs/sec helium) for
transducers located outside the pressure vessel. Provide capability
of pressurization of transducers from 0 - 800 psig and measurement.
D. Neutron Flux To be determined
E. Neutron Fluence Maximum attainable
F. Gamma Dose Rate 9×10^9 to 1.4×10^{11} ergs/gm (C) hr
G. Gamma Dose To be determined
H. Test Measurements Elect output as function of pressure from 0-800 psig
as 0.25 to 4.0 watts/gr heat generation rates. Temperature of trans-
ducer, coolant temperature. Insulation resistance, bridge resistance.

TEST PLAN SUMMARY

I. TEST IDENTIFICATION

- A. Test No. 37/R006
- B. Test Date November 1966 (GTR-19)
- C. Test Item Description Materials Tensile Test
- D. Number of Units to be Tested 649 test specimens
- E. Manufacturer and Part Number Various structural materials
- F. Parameters to be Measured Ultimate and yield tensile strength, notched strength, shear strength, elongation, area of reduction.
- G. Test Sponsor REON

II. REACTOR INFORMATION

- A. Test Facility General Dynamics, Fort Worth
- B. Test Duration 400 hours
- C. Special Test Requirements Cryogenic fluids (LH₂ and LN₂)

III. PURPOSE OF TEST

To determine the effects of nuclear radiation, LH₂ and LN₂ on tensile properties of candidate NERVA materials including comparison of the damage caused by LH₂ or LN₂ at 10¹⁸nvt (E>1.0Mev) integrated fast neutron fluence.

IV. TEST ENVIRONMENT

- A. Temperature -423°, -320° and 70°F
- B. Pressure Atmospheric
- C. Operational Conditions Static and Dynamic testing in LH₂ and LN₂
- D. Neutron Flux 2 x 10¹² nv (E>1.0 Mev)
- E. Neutron Fluence 3 x 10¹⁸ nvt (E>1.0 Mev)
- F. Gamma Dose Rate 4 x 10⁹ ergs/gm (C) hr
- G. Gamma Dose 1.6 x 10¹² ergs/gm (C)
- H. Test Measurements Temperature, pressure, Instron recordings, ram load, pull-rod movement, extensometer, strain gage, dosimeters, hardness, metallography, x-ray diffractions, elongation, area reduction.

TEST PLAN SUMMARY

I. TEST IDENTIFICATION

A. Test No. 37/R007

B. Test Date August 1967 (GTR-20)

C. Test Item Description Materials Tensile Test

D. Number of Units to be Tested 600 test specimens

E. Manufacturer and Part Number Several structural alloys

F. Parameters to be Measured Ultimate and yield tensile strength, notched strength, elongation, area reduction.

G. Test Sponsor REON

II. REACTOR INFORMATION

A. Test Facility GTR - General Dynamics, Fort Worth

B. Test Duration 400 hours

C. Special Test Requirements Cryogenic fluids (LH₂ and/or LN₂)

III. PURPOSE OF TEST

To conduct parametric studies on alloys under combined environment of cryogenic fluids and nuclear radiation, and to obtain mechanical properties data at high nuclear fluence.

IV. TEST ENVIRONMENT

A. Temperature -423°, -320°, 70°F

B. Pressure Atmospheric

C. Operational Conditions Static and Dynamic Testing in LH₂ and LN₂ after radiation.

D. Neutron Flux 2×10^{12} nv (E>1.0 Mev)

E. Neutron Fluence 3×10^{18} nvt (E>1.0 Mev)

F. Gamma Dose Rate 4×10^9 ergs/gm (C) hr

G. Gamma Dose 1.6×10^{12} ergs/gm (C)

H. Test Measurements Temperature, pressure, Instron recordings, ram load, pull rod movement, strain gages, dosimetry, hardness, metallography, x-ray diffraction elongation, area reduction.

TEST PLAN SUMMARY

I. TEST IDENTIFICATION

A. Test No. 37/R104
B. Test Date November 1967 (GTR-21)
C. Test Item Description Thermal Conductivity
D. Number of Units to be Tested 5
E. Manufacturer and Part Number Specimens made of Tl-110 AT-ELI,
Inconel 718, Al-7039-T61, A-286, Beryllium (supplied by NBS)
F. Parameters to be Measured Thermal conductivity and electrical
resistivity
G. Test Sponsor REON

II. REACTOR INFORMATION

A. Test Facility General Dynamics, Fort Worth
B. Test Duration 100 hours
C. Special Test Requirements Cryogenic fluids LH₂ and LN₂)

III. PURPOSE OF TEST

To determine the effect of nuclear radiation on thermal conductivity and
electrical resistivity of several NERVA materials and to obtain actual or
verify these properties at liquid hydrogen temperature

IV. TEST ENVIRONMENT

A. Temperature -423° and 70°F
B. Pressure Vacuum 10⁻⁷ millimeters Hg
C. Operational Conditions Static in LH₂
D. Neutron Flux 2 x 10¹² nv (E>1.0 Mev)
E. Neutron Fluence 7 x 10¹⁷ nvt (E>1.0 Mev)
F. Gamma Dose Rate 4 x 10⁹ ergs/gm (C) hr
G. Gamma Dose 4 x 10¹¹ ergs/gm (C)
H. Test Measurements Thermal conductivity electrical resistivity
chemistry, microstructure, hardness.

TEST PLAN SUMMARY

I. TEST IDENTIFICATION

A. Test No. 37/R107

B. Test Date 30 August 1967 (GTR-20)

C. Test Item Description Friction Wear Test

D. Number of Units to be Tested 20

E. Manufacturer and Part Number Various bearing cage materials

F. Parameters to be Measured Wear resistance, coefficient of friction

G. Test Sponsor REON

II. REACTOR INFORMATION

A. Test Facility General Dynamics, Fort Worth

B. Test Duration 100 hours

C. Special Test Requirements Cryogenic fluids (LH₂)

III. PURPOSE OF TEST

To determine the effects of nuclear radiation and liquid hydrogen on wear resistance of bearing case materials and changes in the coefficient of friction due to the environment.

IV. TEST ENVIRONMENT

A. Temperature -423° and 70°F

B. Pressure Atmospheric

C. Operational Conditions Dynamic test in LH₂

D. Neutron Flux 2×10^{12} nv (E>1.0 Mev)

E. Neutron Fluence 7×10^{17} nvt (E>1.0 Mev)

F. Gamma Dose Rate 4×10^9 ergs/gm (C) hr

G. Gamma Dose 4×10^{11} ergs/gm (C)

H. Test Measurements Wear, density, coefficient of friction

TEST PLAN SUMMARY

I. TEST IDENTIFICATION

A. Test No. 37/W405
B. Test Date November 1966 (GTR-19)
C. Test Item Description Reactor Structural Materials
D. Number of Units to be Tested 885 test specimens
E. Manufacturer and Part Number Beryllium, Titanium, Inconel 718,
Inconel 750, Aluminum 2219, Lackalloy

F. Parameters to be Measured Ultimate and yield tensile strength,
notched strength, elongation, area reduction

G. Test Sponsor WANL

II. REACTOR INFORMATION

A. Test Facility GTR - General Dynamics, Fort Worth
B. Test Duration 400 hours
C. Special Test Requirements Liquid Nitrogen

III. PURPOSE OF TEST

To obtain mechanical properties of reactor structural materials at LN₂
temperature and nuclear radiation

IV. TEST ENVIRONMENT

A. Temperature -320° and 70°F
B. Pressure Atmospheric
C. Operational Conditions Static testing after radiation at LN₂ or
ambient temperature

D. Neutron Flux 2×10^{12} nv (E>1.0 Mev)
E. Neutron Fluence 3×10^{18} nvt (E>1.0 Mev)
F. Gamma Dose Rate 4×10^9 ergs/gm (C) hr
G. Gamma Dose 1.6×10^{12} ergs/gm (C)
H. Test Measurements Temperature, pressure, Instron recordings, ram
load, pull rod movement, strain gages, dosimeters, hardness, metal-
lography, x-ray diffraction, elongation, and area reduction.

TEST PLAN SUMMARY

I. TEST IDENTIFICATION

A. Test No. 37/W406
B. Test Date August 1966 (GTR-20)
C. Test Item Description NERVA Structural Materials
D. Number of Units to be Tested 800 test specimens
E. Manufacturer and Part Number Test specimens of various materials

F. Parameters to be Measured Tensile strength, compressive strength, flexural strength, elongation, area reduction, hardness, metallography
G. Test Sponsor WANL

II. REACTOR INFORMATION

A. Test Facility General Dynamics, Fort Worth
B. Test Duration 400 hours
C. Special Test Requirements Liquid Nitrogen

III. PURPOSE OF TEST

To obtain mechanical properties of various structural materials at liquid nitrogen and nuclear radiation environment for use in the reactor components design

IV. TEST ENVIRONMENT

A. Temperature -320°F
B. Pressure Atmospheric
C. Operational Conditions Static testing after radiation in LH₂

D. Neutron Flux 2×10^{12} nv ($E > 1.0$ Mev)
E. Neutron Fluence 3×10^{18} nvt ($E > 1.0$ Mev)
F. Gamma Dose Rate 4×10^9 ergs/gm (C) hr
G. Gamma Dose 1.6×10^{12} ergs/gm (C)
H. Test Measurements Temperature, pressure, Instron recordings, pull rod movement, strain gages, dosimetry, hardness, metallography, x-ray diffraction, elongation, area reduction

TEST PLAN SUMMARY

I. TEST IDENTIFICATION

A. Test No. 37/W407/1

B. Test Date August 1967

C. Test Item Description Beryllium Material

D. Number of Units to be Tested 30

E. Manufacturer and Part Number Tensile specimens

F. Parameters to be Measured Tensile strength, elongation, area reduction, metallography, hardness

G. Test Sponsor WANL

II. REACTOR INFORMATION

A. Test Facility PBRF

B. Test Duration 312 hours

C. Special Test Requirements Cryogenic system cold helium

III. PURPOSE OF TEST

To obtain mechanical properties of beryllium for use in the NERVA reactor design

IV. TEST ENVIRONMENT

A. Temperature <140°R

B. Pressure Atmospheric

C. Operational Conditions Cryogenic system, cold helium flow W-1 loop

D. Neutron Flux 3×10^{13} nv (E>1.0 Mev)

E. Neutron Fluence 3×10^{19} nvt (E>1.0 Mev)

F. Gamma Dose Rate Not Applicable

G. Gamma Dose Not Applicable

H. Test Measurements Tensile yield and ultimate strength elongation, area reduction at various controlled test temperature. Metallography and hardness.

TEST PLAN SUMMARY

I. TEST IDENTIFICATION

A. Test No. 37/W407/2

B. Test Date August 1967

C. Test Item Description Beryllium Material

D. Number of Units to be Tested 30

E. Manufacturer and Part Number Tensile specimens

F. Parameters to be Measured Tensile strength, elongation area reduction, metallography, hardness

G. Test Sponsor WANL

II. REACTOR INFORMATION

A. Test Facility PBRF

B. Test Duration 312 hours

C. Special Test Requirements Cryogenic system cold helium

III. PURPOSE OF TEST

To obtain mechanical properties of beryllium for use in the NERVA reactor design

IV. TEST ENVIRONMENT

A. Temperature <140°R

B. Pressure Atmospheric

C. Operational Conditions Cryogenic system, cold helium flow W-1 loop

D. Neutron Flux 3×10^{13} nv (E>1.0 Mev)

E. Neutron Fluence 3×10^{19} nvt (E>1.0 Mev)

F. Gamma Dose Rate Not Applicable

G. Gamma Dose Not Applicable

H. Test Measurements Tensile yield and ultimate strength elongation, area reduction at various controlled test temperatures. Metallography and hardness.

TEST PLAN SUMMARY

I. TEST IDENTIFICATION

A. Test No. 38/A001A
B. Test Date 28 October 1966
C. Test Item Description Detonators and Explosives
D. Number of Units to be Tested 13 capsules
E. Manufacturer and Part Number Pseudo-Stable Materials

F. Parameters to be Measured Pressure buildup, weight loss,
ignition voltage, temperature stability, energy release

G. Test Sponsor REON

II. REACTOR INFORMATION

A. Test Facility General Electric Test Reactor - Vallecitos
B. Test Duration 0.5 - 2.0 hours per capsule
C. Special Test Requirements Explosion proof capsules

III. PURPOSE OF TEST

To evaluate radiation resistance of pseudo-stable materials

IV. TEST ENVIRONMENT

A. Temperature 50° - 250°C
B. Pressure Atmospheric or pressure buildup in the capsule approx 12
psig max
C. Operational Conditions

D. Neutron Flux 2.5×10^{12} nv ($E > 1.0$ Mev)
E. Neutron Fluence $5 \times 10^{15} - 2 \times 10^{16}$ nvt ($E > 1.0$ Mev)
F. Gamma Dose Rate 5×10^{10} ergs/gm (c) hr
G. Gamma Dose $2.5 \times 10^{10} - 1 \times 10^{10}$ ergs/gm (C)
H. Test Measurements Temperature and pressure of instrumented
capsule, passive temperature of non-instrumented capsule neutron
and gamma flux

TEST PLAN SUMMARY

I. TEST IDENTIFICATION

A. Test No. RE-4/1

B. Test Date June 1967

C. Test Item Description Gamma Heating Measurement Unit for HT-1

D. Number of Units to be Tested 3 calorimeters

E. Manufacturer and Part Number Calorimeter (GFE)

F. Parameters to be Measured Gamma heat generation rate at various radial and axial positions in HT-1.

G. Test Sponsor WANL

II. REACTOR INFORMATION

A. Test Facility Plum Brook Reactor Facility

B. Test Duration 12 hours

C. Special Test Requirements Water

III. PURPOSE OF TEST

To obtain gamma heating rates for HT-1 loop and determine the capability of the radiation facility (at beginning of reactor cycle) for use in subsequent tests.

IV. TEST ENVIRONMENT

A. Temperature 140°F

B. Pressure 135 psig (internal)

C. Operational Conditions Water 75 gpm

D. Neutron Flux Not important

E. Neutron Fluence Not important

F. Gamma Dose Rate Parameter being measured

G. Gamma Dose Not important

H. Test Measurements Temperature drop across heat generating elements.

TEST PLAN SUMMARY

I. TEST IDENTIFICATION

A. Test No. RE-4/2

B. Test Date June 1967

C. Test Item Description Gamma Heating Measurement Unit for HT-1

D. Number of Units to be Tested 3 calorimeters

E. Manufacturer and Part Number Calorimeter (GFE)

F. Parameters to be Measured Gamma heat generation rate at various radial and axial positions in HT-1.

G. Test Sponsor WANL

II. REACTOR INFORMATION

A. Test Facility Plum Brook Reactor Facility

B. Test Duration 12 hours

C. Special Test Requirements Water

III. PURPOSE OF TEST

To obtain gamma heating rates for HT-1 loop and determine the capability of the radiation facility (at end of reactor cycle) for use in subsequent tests.

IV. TEST ENVIRONMENT

A. Temperature 140°F

B. Pressure 135 psig (internal)

C. Operational Conditions Water 75 gpm

D. Neutron Flux Not important

E. Neutron Fluence Not important

F. Gamma Dose Rate Parameter being measured

G. Gamma Dose Not important

H. Test Measurements Temperature drop across heat generating elements.

C. PERT SCHEDULE

A PERT-type chart is presented for each radiation effects test scheduled during CY 1967. These figures, which are arranged in numerical order in Table III, show the estimated completion dates for each activity supporting the test and shows the interface of the Radiation Effects Program with other subtasks. The estimated time required to complete each event is shown in parenthesis under each activity. The estimated completion dates and the actual completion dates (designated by "S" and "A" respectively) are shown in the blanks. Activities for which the Radiation Effects program are not responsible are denoted by asterisks (*).

TABLE III
LIST OF PERT CHARTS

<u>Component Test Number</u>	<u>Test Description</u>	<u>Page</u>
23/W208	Linear Voltage Displacement Transducers	29
23/LA401	Strain Gages	29
23/LA501	Pressure Transducers	30
23/LA502	Pressure Transducers	30
23/R512	Pressure Transducers	31
23/W509	Pressure Transducers	31
37/R006	Structural Materials	32
37/R007	Structural Materials	33
37/R107	Friction Wear Test	33
37/W405	Structural Materials	32
37/W406	Structural Materials	33
37/W407	Structural Materials	34
38/A001-A	Phase I-A Explosives	34
RE-4	Gamma Flux Measurements	35

* NOT UNDER DIRECT CONTROL OF RADIATION EFFECTS PROGRAM

TEST NO. 23/W 208
 COMPONENT LVDT
 RECTOR PBRF
 TEST DATE SEPT 1967

* NOT UNDER DIRECT CONTROL OF RADIATION EFFECTS PROGRAM

TEST NO. 23/LA 401
 COMPONENT STRAIN GAGES
 RECTOR PBRF
 TEST DATE JULY 1967

* NOT UNDER DIRECT CONTROL OF RADIATION EFFECTS PROGRAM

* NOT UNDER DIRECT CONTROL OF RADIATION EFFECTS PROGRAM

TEST NO 23/R512
COMPONENT PRESSURE TRANSDUCERS
REACTOR PBRI
TEST DATE JUNE 1967

* NOT UNDER DIRECT CONTROL OF RADIATION EFFECTS PROGRAM

TEST NO 23/W 509
COMPONENT PRESSURE TRANSDUCERS
REACTOR PBRI
TEST DATE JULY 1967

```

graph LR
    T1[10/1/66] -- PREPARE TEST SPECIFICATIONS --> T2[A 10/2/66]
    T3[10/1/66] -- LOAD CAPSULES --> T4[A 10/15/66]
    T5[10/1/66] -- COMPLETE PRE-IRRADIATION REFERENCE TESTS --> T6[A 10/15/66]
    T2 --> T7[A 10/29/66]
    T4 --> T7
    T6 --> T7
    T7 -- PERFORM IRRADIATION TESTS --> T8[A 11/7/66]
    T8 --> T9[A 11/1/66]
    T9 -- PERFORM POST IRRADIATION TESTING --> T10[A 11/4/66]
    T10 --> T11[A 11/7/66]
    T11 -- ANALYZE TEST DATA AND PREPARE TEST REPORT --> T12[S 2/15/67]
  
```

34

* NOT UNDER DIRECT CONTROL OF RADIATION EFFECTS PROGRAM

TEST NO
COMPONENT
REACTOR
TEST DATE

RE-4/1 GAMMA FLUX MEASUREMENT
REACTIVITY CHECK
PBRF
JUNE 1967

PAGE BLANK

II. PLUM BROOK REACTOR FACILITY SUPPORT - PROGRAM PLANS

The engineering effort in support of the NERVA operations at the Plum Brook Reactor Facility during CY 1967 is concentrated in four major areas (1) W-1 Loop activation, (2) charging machine activation, (3) Cryogenic Materials Transfer System activation, and (4) the performance of irradiation tests. Table IV summarizes the key events for each of these efforts and their estimated completion dates.

A. W-1 LOOP ACTIVATION

The detailed activation plans for the W-1 cryogenic loop are described in TME-1343, Revision A (October 1966). The key activities in support of activation of the loop are summarized in Table IV. All activities are in support of a 1 June 1967 facility availability for testing.

B. CHARGING MACHINE ACTIVATION

The detailed activation plans for modifying the charging machine and activating the facility by 1 June 1967 are contained in TME-1343, Revision A (October 1966). The key events in support of this effort are summarized in Table IV. In addition to the new charging machine bed which is being designed, numerous modifications including load-limiting devices, a new seal assembly, etc. are planned to increase the reliability of the charging machine. In addition to obtaining Aerojet and SNPO-C approval, reviews of the design and schedule will be coordinated with NASA Lewis and NASA Plum Brook on a continuous basis.

TABLE IV
PBRF ACTIVITIES - CY 1967

<u>Item No.</u>	<u>Activities To Be Accomplished</u>	<u>Estimated Completion Date</u>
I	W-1 Loop Activation	
	(a) Complete SNPC-20 fabrication	1 Nov 66
	(b) Government acceptance of Linde work	1 Jan 67
	(c) Provide Operations Manual	30 Apr 67
	(d) Provide Design Manual and Hazards Analyses	30 Apr 67
	(e) Provide Maintenance Guide	31 Mar 67
	(f) Complete operator training program	30 May 67
	(g) Complete system mapping	20 Mar 67
	(h) Loop available for testing	1 Jun 67
	(i) Complete reactivity worth measurements	15 Jun 67
	(j) Complete capsule heat build-up tests	15 Jun 67
II	Charging Machine Activation	
	(a) Complete activation report	31 Oct 66
	(b) Complete fabrication and installation of all modifications	15 Mar 67
	(c) Complete Design Manual and Safety Analyses	15 Mar 67
	(d) Complete operational checkout	31 May 67
III	Cryogenic Materials Transfer System Activation	
	(a) Let Purchase Order	30 Nov 66
	(b) Complete design	15 Feb 67
	(c) Complete PBRF Facility modifications	15 May 67
	(d) Complete operational checkout	30 Jun 67
	(e) Complete Design Manual and Safety Analyses	30 Apr 67
IV	Irradiation Test Program	See Table V

C. CRYOGENIC MATERIALS TRANSFER SYSTEM ACTIVATION

Requests for proposals for designing, fabricating and installing the proposed cryogenic materials transfer system were transmitted to ten potential bidders. Three of these; Lockheed, Georgia; Battelle Memorial Institute, and American Machine and Foundry submitted bid packages which are presently being reviewed with selection of proposal and contract preparation scheduled by 30 November. Although the materials tests which required this capability are not scheduled before August 1967, operational checkout is planned for 30 June 1967. In addition to obtaining Aerojet and SNPO-C approval, reviews of the design and schedule will be coordinated with NASA Lewis and NASA Plum Brook on a continuous basis.

D. IRRADIATION TEST PROGRAM

Table V summarizes the test schedule and requirements of NERVA Radiation Effects tests scheduled at the Plum Brook Reactor Facility.* Test specifications and safety analyses will be prepared for each test and submitted to SNPO-C and NASA Plum Brook for approval four weeks before each scheduled reactor test date. Upon completion of reactor testing, a flash report will be made to SNPO-C and a test data report will be published within 30 days of test completion.

*With the exception of the gamma flux measurement experiment, (RE-4/1 and RE-4/2), which requires the water cooled loop (W-2), all CY 67 tests are scheduled to be performed in the W-1 cryogenic loop.

TABLE V

PBRF IRRADIATION TEST PROGRAM

<u>Component Test No.</u>	<u>Component Description</u>	<u>Test Date</u>	<u>Test Duration (hours)</u>	<u>Remarks</u>
RE-4/1	Gamma flux measurement (beginning of cycle)	1 Jun 67	12	Test to be performed in W-2 water loop
--	Reactivity check	8 Jun 67	10	Determines reactivity of gas filled capsule
RE-4/2	Gamma flux measurement (end of cycle)	10 Jun 67	12	Test to be performed in W-2 water loop
23/R512	Pressure Transducers	15 Jun 67	50	Test in W-1 cryogenic loop
23/W509	Pressure Transducers	1 Jul 67	10	Test in W-1 cryogenic loop
23/LA501	Pressure Transducers	10 Jul 67	50	Test in W-1 cryogenic loop
23/LA401	Strain Gages	20 Jul 67	50	Test in W-1 cryogenic loop
23/LA502	Pressure Transducers	1 Aug 67	50	Test in W-1 cryogenic loop
37/W407/1	Structural Materials	10 Aug 67	312	Test in W-1 cryogenic loop tensile test in Instron machine using the cryogenic materials transfer system.
37/W407/2	Structural Materials	7 Sep 67	312	Second part of test 37/W407
23/W208	LVDT	27 Sep 67	10	Test in W-1 cryogenic loop

III. GENERAL DYNAMICS/FORT WORTH - PROGRAM PLANS FOR NERVA

The engineering effort in support of the NERVA program at the General Dynamics/Fort Worth Facility during CY 1967 is concentrated in 6 major areas: (1) The performance of structural materials irradiation runs GTR-19 and GTR-20; (2) performance of para/ortho hydrogen conversion studies; (3) supporting the thermal conductivity experiment, (4) performance of tensile tests on NRX/EST bolts and nozzle specimen, (5) activation of the cryogenic materials irradiation tester, and (6) completion of GTR-18 test activities. Table V summarizes the key events for each of these activities and their estimated completion dates. Table VI presents the test schedule and requirements of NERVA radiation effects tests scheduled at the Nuclear Aerospace Reactor Facility.

A. GTR TEST 19 IRRADIATION TEST ACTIVITIES

Irradiation test GTR-19 includes two structural materials tests (37/R006 and 37/W405). The objectives of these tests are:

(1) To tensile test candidate materials to an integrated exposure of 10^{18} nvt ($E > 1.0$ Mev) in both LN_2 and LH_2 utilizing identical equipment and determine if data obtained at LN_2 temperature can be correlated with data obtained in an LH_2 environment.

(2) Obtain design information on candidate structural materials at LN_2 temperature to integrated exposures of 3×10^{18} nvt ($E > 1.0$ Mev). The materials irradiated in LN_2 will be kept in LN_2 following the irradiation and subsequently tested directly in a tensile test machine at various temperatures. The irradiation and immediate tests will be completed in November 1966.

TABLE VI
GD/FW PROGRAM PLANNING ACTIVITIES

Item No.	Subject	Activities to be Accomplished	Estimated Completion Date
I	RTT Test 23/R104 (GTR-18)	Complete analysis of test data and prepare test report.	30 Dec 1966
II	Hot Boron Tests 37/R105 and 37/W403 (GTR-18)	(a) Complete post-testing tensile tests	15 Oct 1966
		(b) Complete post testing.	30 Nov 1966
		(c) Prepare GD/FW data report.	1 Jan 1967
		(d) Complete analysis of test data and prepare test report for test 37/R105.	1 Apr 1967
		(e) Complete analysis of test data and prepare test report for test 37/W403.	1 Apr 1967*
III	Wear Friction Test 37/R106 (GTR-18)	(a) Complete post-irradiation testing.**	30 Nov 1967
		(b) Complete analysis of test data and prepare test report.**	30 Jan 1967
IV	Beryllium Test 37/W404	(a) Complete post-irradiation tensile testing.	30 Nov 1966
		(b) Prepare GD/FW data report.	15 Jan 1967
		(c) Complete analysis of test data and prepare test report.	15 Apr 1967*
V	GTR-19	(a) Checkout reactor at 10 Mw	1 Oct 1966
		(b) Complete controls testing	30 Oct 1966
		(c) Complete mapping run	31 Oct 1966

* Completion of this activity is the responsibility of WANL materials department.

** Does not include results from specimen which are too hot for handling.

TABLE VI (continued)

Item No.	Subject	Activities to be Accomplished	Estimated Completion Date
V	GTR-19 (continued)	(d) Begin reactor irradiation	6 Nov 1966
		(e) Complete reactor irradiation	25 Nov 1966
		(f) Complete pulling dynamic specimen	30 Nov 1966
		(g) Complete tensile testing of static specimen	24 Feb 1967
		(h) Complete laboratory tests and measurements	24 Mar 1967
		(i) Complete GD/FW test report	24 Apr 1967
		(j) Analyze test data and prepare test report 37/R006	30 Aug 1967
		(k) Analyze test data and prepare test report 37/W405*	30 Aug 1967*
VI	GTR-20	(a) Prepare test specifications	15 Jun 1967
		(b) Deliver test specimen to GD/FW	22 Jul 1967
		(c) Perform controls tests	18 Aug 1967
		(d) Begin irradiation	18 Jul 1967
		(e) Complete irradiation	10 Sep 1967
		(f) Complete LH ₂ testing	17 Sep 1967
VII	Thermal Conductivity Test 37/R104	(a) Coordinate effort with WANL, NBS, GD/FW, SNPO-C and AGC	Continuous
		(b) Complete Phase I (testing of 2 prototype units)	30 Apr 1967
		(c) Complete fabrication and check-out of ten test assemblies	30 Sep 1967
		(d) Prepare test specifications	30 Jul 1967
		(e) Prepare experimental design plan	30 Jul 1967

* Completion of this activity is the responsibility of WANL materials department.

TABLE VI (continued)

Item No.	Subject	Activities to be Accomplished	Estimated Completion Date
VIII	Para/ortho Conversion Measurement	(a) Design system	1 Feb 1967
		(b) Fabricate system	1 May 1967
		(c) Redesign and rebuild gas analyzer	1 Jun 1967
		(d) Functional test gas analyzer	1 Jul 1967
		(e) Functional test system	1 Jul 1967
		(f) Set-up and checkout in Area 1	1 Aug 1967
		(g) Irradiate	15 Aug 1967
IX	Cryogenic Materials Irradiation Tester	(a) Complete preliminary design	15 Jan 1967
		(b) Complete checkout	1 Jul 1967
		(c) System available for use	1 Jul 1967
X	NRX/EST Pressure Vessel bolts and nozzle specimen tensile tests	(a) Begin work at GD/FW	17 Oct 1966
		(b) Begin tensile testing	28 Nov 1966
		(c) Complete testing and laboratory measurements	30 Jan 1967
		(d) Prepare GD/FW test report	3 Mar 1967
		(e) Integrate results into NRX/EST radiation effects report	30 Mar 1967

TABLE VII

GD/FW IRRADIATION TEST PROGRAM

Reactor Run No.	Component Test Number	Component Description	Test Duration (hours)	Irradiation Test Environment	Test Environment	Irrad. Test Date
GTR-18	37/R105	Structural materials (boron)	-	-	1000°R to 1540°R	Completed
	37/W403	Structural materials (boron)	-	-	1000°R to 1540°R	Completed
	37/W404	Beryllium specimen	-	-	LN ₂	Completed
GTR-19	37/R006	Structural materials	400	LH ₂ /LN ₂	LH ₂ /LN ₂	6 Nov 66
	37/W405	Structural materials	400	LN ₂	LN ₂	6 Nov 66
GTR-20	37/R007	Structural materials	400	LH ₂ /LN ₂ *	LH ₂ /LN ₂ *	15 Aug 67
	37/W406	Structural materials	400	LN ₂	LN ₂	15 Aug 67
	37/R107	Wear/friction test	100	LH ₂	LH ₂ & RT	15 Aug 67
	-	Para/ortho conversion	400	LH ₂	LH ₂	15 Aug 67

*LH₂ may not be required - requirements will be determined from analysis of GTR-19 test data.

Control tests of unirradiated specimens will be completed in January 1967. Testing of the statically-irradiated specimens will be started after the control tests, allowing the radioactivity to decay sufficiently to allow safe handling, and will be completed by March 1967. Metallographic analyses and other post-irradiation measurements will be performed concurrently with the tensile testing efforts. The final GD/FW data report will be issued in May 1967. The Aerojet and WANL test reports are scheduled for completion in August 1967.

B. GTR TEST 20 IRRADIATION TEST ACTIVITIES

Irradiation Test GTR 20 includes two structural materials tests (37/R007 and 37/W406) one wear friction test (37/R107) and the para/ortho conversion study which is described in Section III-D. The material tests include one group of specimens to be irradiated in LN_2 , kept in LN_2 for a period following, and then tested directly in a tensile test machine at various temperatures. A second group of specimens will be irradiated and tested in LH_2 utilizing an advanced Cryogenic Materials Irradiation Tester (CMIT) which is described in Section III-E.

Control tests will be performed in several stages to gain confidence in operation of the CMIT and analyses results. The control test for LN_2 specimens will precede the irradiation, availability of time, equipment, and specimens permitting. The irradiation test, scheduled to begin in August 1967, will be for 400 hours at a power level of 10 Mw. Testing of the specimens in the CMIT will immediately follow the irradiation. Testing of the statically-irradiated specimens will be started after sufficient decay time has elapsed to permit the required test operations, probably in October 1967.

The wear/friction specimen will be irradiated in LH_2 and then shipped to AGC Sacramento for testing.

C. THERMAL CONDUCTIVITY

The Thermal Conductivity Test (37/R104) effort will be conducted in two phases. Phase I will consist of the redesign of the thermal conductivity test units and the fabrication and checkout of two prototype test units. Phase II will consist of the fabrication of 10 production model thermal conductivity test units.

Phase I will consist of: technical liaison, evaluation of test hardware and design of new test units, fabrication of two prototype test units for use with National Bureau of Standards (NBS) beryllium specimens, modification of the thermal conductivity LH_2 test assembly to accept the two prototype test units, preparation of test instrumentation and the performance of a control run (LH_2 temperature) of approximately 100 hours duration. It is estimated that Phase I will be completed in late April 1967 if work on these tasks is initiated by early November.

Phase II will consist of: the fabrication of 10 thermal conductivity test units in accordance to design specifications approved in Phase I, modification of both LN_2 and LH_2 test assemblies to accept the 10 production units, and the installation and checkout of the 10 test units in the assemblies. It is estimated that Phase II will be completed in late September 1967 if Phase I is completed as scheduled above.

D. PARA/ORTHO CONVERSION MEASUREMENT

Measurements of radiation-induced hydrogen composition changes will be made during GTR-20 using the GTR as the radiation source. To obtain

the required data, effluent gas from a special LH_2 dewar will be monitored for para/ortho ratio after having been passed through a conditioner.

The conceptual design is complete and is believed adequate to provide the data required. The three major components of the system are a dewar, a conditioner, and a gas analyzer. A brief discussion of the design requirements of each follows.

Dewar: 20 gal. liquid capacity, sensitive liquid level indication, pressure capability to 25 psi, pressure indication and control, temperature sensors and control, boil-off rate control

Conditioner: Temperature monitor and control, pressure monitoring, large volume to surface ratio, no fixed eddy pockets, gas flow rate control and monitoring

Gas Analyzer: Good stability, sensitivity to at least 1 part per 1000 with less than 0.1% relative error, minimum temperature response drift.

The major tasks and completion dates associated with this project are summarized in Table VI.

E. CRYOGENIC MATERIALS IRRADIATION TESTER (CMIT)

Conceptual design sketches of a CMIT and support system capable of holding materials specimen during irradiation at LH_2 temperatures and subsequent tensile testing at LH_2 temperatures without warm-up were completed in CY 1966 and are currently being reviewed.

Design and procurement of vendor-furnished items will begin upon receipt of go-ahead. Preliminary design will be completed and all raw materials ordered in the first two months. Final design will be completed at the end of the fourth month.

The manufacture of detail piece parts will start during the third month and be complete at the end of the fifth month. Assembly of detail parts will start during the fourth month and be complete at the end of the sixth month.

Operational checkout of the system and integration with the Instron in a hydrogen environment will be accomplished during the seventh and eighth months.

Final checkout of the system will be accomplished by pulling the control specimen for GTR-20 the month prior to the irradiation.

F. NRX/EST NOZZLE MATERIAL AND BOLT TEST

A test program was conceived by Aerojet Sacramento and awarded to the GD/FW Radiation Effects Group to determine the materials properties of pressure vessel bolts and nozzle materials after operation of the NRX/EST engine.

Aerojet has furnished GD/FW with thirty-three irradiated nozzle and closure bolts and two irradiated sections cut from the nozzle of the NRX/EST engine for testing under this program. The bolts will be subjected to tensile tests at 80°F, 1200°F and possibly -320°F. They will also be subjected to stress-rupture tests at 1200°F. Following the above tests, micro-photographs will be made for metallographic examination.

One section of the nozzle material will be cut into six parts from which six tensile test specimens will be machined. The specimens will be tensile tested at 1000°F. Metallographic tests will be conducted on selected sections of both pieces of the nozzle material and on the broken tensile specimens.

The results of these tests will be incorporated into the report summarizing the information obtained from NRX/EST with regard to radiation effects.

G. GTR-18 IRRADIATION TEST ACTIVITIES

Irradiation Test GTR-18, which was completed in July 1966, consisted of the following components tests: 23/R104 (resistance temperature transducers); 37/R105 (structural materials containing boron); 37/W403 (structural materials containing boron); 37/R106 (wear friction tests); 37/W404 (beryllium specimen); and the para/ortho conversion study which was funded by SNPO-C. The key events in support of each of these tests and the estimated completion dates are summarized in Table VI.

The raw test data for the RTT test was reduced by Aerojet in CY 1966. Upon completion of analyses of the test data, a test report will be prepared.

Tensile testing of the boron containing structural materials which was initialed in CY 1966 was completed by 1 November. Testing at extremely low strain rates (0.0005 in/in/min) was performed at various temperatures between 1000°F and 1540°F. Upon completion of data analysis, a test report will be prepared.

Upon completion of GTR-18 irradiation run 15 wear/friction specimen were shipped to Aerojet-Sacramento for testing. The other six specimen were too hot (radioactive) to ship and are being stored at GD/FW until they decay to a safe level for shipment. The specimen will be subjected to flexure compression and tensile testing. Upon completion of data analysis, a test report will be prepared.

The beryllium specimen (test 37/W404) are being stored in LN_2 . The test fixtures for pulling these specimen have been reworked to improve axiality (5% desired). Tests with control specimen indicated a necessity for applying strain gages to test specimen during tensile tests. Table VI summarizes the estimated completion dates for major activities in support of this task.

The para/ortho hydrogen conversion study was performed under direct contract from SNPO-C to GD/FW. Based on preliminary review of the test data, a more refined test is scheduled in CY 1967. It is described in detail in Section III-D. The estimated completion dates for this activity are summarized in Table VI.

PAGE BLANK

IV. OTHER CY 1967 RADIATION ACTIVITIES

In addition to the efforts supporting the test programs at GD/FW and PBRF, the radiation effects program provides technical support to (1) NRX and XE systems tests, (2) the explosives irradiation program, (3) all NERVA design activities and (4) overall planning and coordination of the NERVA radiation effects program. Table VII summarizes the schedules of key events supporting these activities.

A. SUPPORT TO NRX AND XE PROGRAMS

The Radiation Effects Program provides technical support throughout all phases of the NERVA engine development program. In addition to technical conferences, all component designers are periodically provided informal radiation effects analyses, which include (1) literature surveys and a summary of applicable data from other experimenters; (2) nuclear analyses comparing the NERVA environment with test conditions and calculations regarding induced radioactivity; (3) thermal analyses which predict the temperature distribution throughout components; (4) materials reviews; (5) predictions of component performance and (6) recommendations regarding component application and/or alternate designs with higher radiation tolerances.

The Radiation Effects Program provides input to the NRX and XE test specifications for each reactor test. Procedures describing desired measurements, calibration, visual examinations, and post-mortem testing (at NRDS, WANL, AGC, and other facilities) as well as descriptions of potential radiation effects problems and justification for post-irradiation testing are provided. Technical liaison is provided during assembly, testing, disassembly, and post-irradiation testing. Reports are prepared for each reactor test summarizing the radiation effects information obtained.

B. EXPLOSIVES IRRADIATION PROGRAM

The Explosives Irradiation Program is a joint Picatinny Arsenal and Aerojet-Downey program. This program is coordinated with Sandia, Frankfort Arsenal and several other government agencies.

1. Phase IA: Twelve 3.6 gram capacity capsules containing igniters, detonators, and high temperature explosives are scheduled for testing at the General Electric Test Reactor at Vallecitos, California. The schedule for testing and completing key events are contained in PFRT chart 38/A001A. This work completes the explosives irradiation test program at Aerojet.

2. Phase II: Phase II capsules capable of testing 80 gram sample lots of explosives were designed by Picatinny Arsenal and qualification tests were performed in CY 1966. A report presenting the results of the qualification tests and heat build-up tests is being prepared.

C. PROGRAM PLANNING

Numerous planning and coordination meetings will be conducted with the Space Nuclear Propulsion Office - Cleveland, Ohio, General Dynamics/Fort Worth, Texas, Westinghouse Astronuclear Laboratory - Pittsburgh, Pennsylvania, Plum Brook Reactor Facility - Sandusky, Ohio, Picatinny Arsenal - Dover, New Jersey, National Aeronautics and Space Administration/Lewis Laboratory - Cleveland, Ohio, and Aerojet-General Corporation, Sacramento, California. In addition, the NERVA Radiation Effects Program will maintain an awareness of tests being conducted by other government agencies.

D. REPORT SCHEDULE

Table IX presents a list of reports scheduled for publication during CY 1967.

TABLE VIII

OTHER CY 67 ACTIVITIES

Item No.	Subject	Activities to be Accomplished	Estimated Completion Date
I	NRX/EST Radiation Effects Summary Report	(a) Complete GD/FW subcontract which prepares test specimen from nozzle and bolts and obtains materials properties.	3 Mar 1967
		(b) Complete post-mortem investigations of TPA and other components which are being conducted at AGC, San Ramon.	15 Dec 1966
		(c) Prepare Summary Report.	30 Mar 1967
II	NRX-A5 Radiation Effects Summary Report	(a) Perform post-mortem testing.	30 Jan 1967
		(b) Complete fission product plate-out investigations at NRDS.	30 Dec 1966
		(c) Prepare Summary Report.	30 Mar 1966
III	NRX-A6 Support	(a) Provide technical support.	Continuous
		(b) Provide input to test specifications.	30 Dec 1966
		(c) Review test data as it pertains to radiation effects.	15 Sep 1967
IV	XE Support	(a) Provide technical support.	Continuous
		(b) Provide input to test specifications.	30 Dec 1966
		(c) Review test data as it pertains to radiation effects.	15 Sep 1967
V	Explosives Irradiation Program-Phase I-A	(a) Complete Phase I-A loading and pre-irradiation tests.	15 Oct 1967
		(b) Perform irradiation.	6 Nov 1967
		(c) Perform post testing.	20 Nov 1967
		(d) Analyze data and prepare report.	28 Feb 1967

TABLE VIII (continued)

Item No.	Subject	Activities to be Accomplished	Estimated Completion Date
VI	Explosive Irradiation Program Phase II	Prepare report of Phase II test capsule qualification tests.	30 Mar 1967
VII	Program Planning	(a) Complete WANL CY 67 Program Plan Report.	31 Oct 1966
		(b) Complete NERVA CY 67 Program Plan Report.	15 Nov 1966
		(c) Prepare Preliminary CY 68 Test Schedule.	1 Aug 1967
		(d) Submit Progress Reports.	Monthly
VIII	Technical Support	(a) Provide technical support to NERVA.	Continuous
		(b) Prepare experimental design	Periodically
		(c) Maintain awareness of radiation programs outside of NERVA.	Continuous
IX	Support for CY 68 Radiation Effects Tests	(a) Coordinate and plan tests.	-
		(b) Initiate test specifications.	-
		(c) Initiate experimental Design Plan.	-

TABLE IX

REPORT SCHEDULE

Item No.	Report Title	Estimated Completion Date
1	WANL CY 1967 Program Plan	31 Oct 66
2	NERVA CY 1967 Program Plan	15 Nov 66
3	W-1 Loop Activation Plan	31 Oct 66
4	Monthly Progress Letters	30th of each mo.
5	Radiation Effect Summary Report for NRX-A2 and NRX-A3	30 Oct 66
6	Radiation Effect Summary Report for NRX/EST	30 Mar 67
7	Radiation Effect Summary Report for NRX-A5	30 Mar 67
8	W-1 Loop Operations Manual	30 Apr 67
9	W-1 Loop Design Manual and Hazards Analysis	30 Apr 67
10	W-1 Loop Maintenance Guide	31 Mar 67
11	Charging Machine Design Manual and Hazards Analysis	18 Mar 67
12	Cryogenic Materials Transfer System Design Manual for Hazards Analysis	28 Apr 67
13	Radiation Effects Design Information File	15 Oct 66
14	Radiation Effects Status Report	30 Nov 66
15	Test Specification for Test GTR-19	18 Oct 66
16	Test Specification for Test GTR-20	1 Jul 67
17	Test Specification for Test NRX-A6 input	30 Dec 66
18	Test Specification for Test XE input	30 Dec 66
19	Test Specification for Test RE-4/1 and RE-4/2	24 Mar 67
20	Test Specification for Test 23/R512	7 Apr 67
21	Test Specification for Test 23/W509	21 Apr 67
22	Test Specification for Test 23/LA 501	10 May 67
23	Test Specification for Test 23/LA 401	16 May 67
24	Test Specification for Test 23/LA 502	25 May 67
25	Test Specification for Test 37/W407/1	16 Jun 67
26	Test Specification for Test 37/W407/2	30 Jun 67
27	Test Specification for Test 23/W208	14 Jul 67

Table IX (Continued)

Item No.	Report Title	Estimated Completion Date
28	Design Manual and Safety Analysis for RE-4/1 and RE-4/2	9 Aug 67
29	Design Manual and Safety Analysis for 23/R512	25 May 67
30	Design Manual and Safety Analysis for 23/W509	6 Jun 67
31	Design Manual and Safety Analysis for 23/LA 501	22 Jun 67
32	Design Manual and Safety Analysis for 23/LA 401	28 Jun 67
33	Design Manual and Safety Analysis for 23/LA 502	7 Jul 67
34	Design Manual and Safety Analysis for 37/W 407/1	1 Aug 67
35	Design Manual and Safety Analysis for 37/W 407/2	1 Aug 67
36	Design Manual and Safety Analysis for 23/W208	31 Aug 67
37	Experimental Design Plans	Periodically
38	Final Test Report GTR-16 Materials Test	30 Nov 66
39	Final Test Report GTR-17 Organic Materials Test	30 Nov 66
40	Final Test Report RTT Test 23/R104	15 Dec 66
41	Final Test Report Boron Test 37/R105	15 Jan 67
42	Final Test Report Bearing Cage Materials Test 37/R106	30 Dec 66
43	Final Test Report Pressure Transducer Test 23/R510	30 Nov 66
44	Final Test Report Pressure Transducer Test 23/R511	15 Dec 66
45	Final Test Report Beryllium Test 37/W403	-
46	Final Test Report Boron Test 37/W404	-
47	Final Test Report Structural Materials Test 37/R006	1 Jan 67
48	PBRF Test Data Report RE-4/1 and RE-4/2	10 Jul 67
49	PBRF Test Data Report 23/R512	18 Jul 67
50	PBRF Test Data Report 23/W509	5 Aug 67
51	PBRF Test Data Report 23/LA501	15 Aug 67
52	PBRF Test Data Report 23/LA401	25 Aug 67
53	PBRF Test Data Report 23/LA502	5 Sep 67

V. CY 1966 ACTIVITIES TO BE COMPLETED

Table X lists the reports and activities originally scheduled for completion in CY 1966 which will be completed in CY 1967. The status of each activity as of 1 October 1966 is shown along with the estimated completion dates.

TABLE X

CY 1966 ACTIVITIES TO BE COMPLETED

Item No.	Activity	Status as of 1 October 1966	Estimated Completion Date
I	Radiation Effects Status Report	Rough draft 60% complete	11-15-66
II	Final Test Report for Pressure Transducer Test 23/R510	Rough draft of report is complete - awaiting dosimetry information	11-30-66
III	NRX A-2 and NRX-A3 Radiation Effects Summary Report	Report in publication	11-7-66
IV	Radiation Effects Design Information File	Report in publication	10-10-66
V	GTR-17 Test Report	Rough draft 90% complete	11-30-66
VI	GTR-16 Test Report	Draft complete - report being reviewed prior to publication	11-30-66
VII	Final Test Report for Pressure Transducer Test 23/R511	Rough draft of report is complete - awaiting dosimetry information	12-15-66