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WANL-TME-874
June 26, 1964

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MASTER

WANL FUEL MATERIAL IRRADIATION PROGRAM
CAPSULE SERIES T-T (PHASE II)

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Installation Requirements and Insertion Proc.

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July 15, 1964

*Mr. R. W. Schroeder
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Cleveland 35, Ohio

Subject: WANL-TME-874, "WANL Fuel Material Irradiation Program Capsule
Series T-T (Phase II)," dated June 26, 1964

Dear Mr. Schroeder:

Transmitted herewith are three (3) copies of the subject report. This
report is transmitted for your information.

Respectfully,

H. F. Faught
Program Manager
NERVA Nuclear Subsystem

Enclosures - 3

cc: Mr. R. Wilke, SNPO-C Resident Office at WANL
Mr. G. O'Brien, SNPO-C Resident Office at WANL

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Introduction

The major portion of the instrumentation and hardware to be used in the second phase of the WANL program have already been used in the first phase and consequently, are presently at the GETR. These are:

- (a) WANL Instrument Cabinet No. 302
- (b) Honeywell 24 point recorder.

However, there have been some design modifications made to the first phase capsules, viz., the number of thermocouples to be used and the coolant inlet hose. Consequently, WANL will supply the required new hardware and GETR must make the appropriate modifications to the 24 point recorder. The following new equipment will be supplied by WANL:

- (a) Flexible metal coolant delivery hose
- (b) Thermocouple extension cable
- (c) Recorder extension cable.

The required installations and modifications are described in detail herein. Also included are the recommended insertion procedures.

Part 1 - Systems and Installations

I. Instrumentation and Hardware

The instrumentation and hardware can be divided into four systems, (a) the coolant delivery system, (b) the coolant temperature monitoring system, (c) the timing system, and (d) the thermocouple recorder system. Each system is described in detail below.

A. The Coolant Delivery System

The coolant delivery system consists of 44 feet of braided, flexible, metal hose. The inside diameter of the hose is 0.75 inch and the outside diameter is 1.07 inches. The hose is rated as having a 500 psi working pressure. The hose will be in two parts, (a) a 40 foot reuseable section, and (b) a 4 foot section which will be permanently connected to each capsule.

The out-of-pile section of the flexible metal hose terminates with a quick disconnect socket. The hose will be connected directly to the GETR water supply. GETR is to supply the appropriate flow and pressure monitoring devices.

B. The Coolant Temperature Monitoring System

The purpose of the coolant temperature monitoring system is to alarm a boiling condition within the water annulus of the capsule assembly. The system is shown in Figure 1. The principal instrument in the system is a signaling controller, (Thermoelectric No. 80025). The input signal is received from an iron (+)/constantan (-) thermocouple located within the water annulus of the capsule assembly.

Both visual and audible alarms are provided. The visual alarm is an integral part of the signalling controller. For convenience, an audible alarm by-pass is provided. A by-pass indicator is also provided so as to alert an operator if the audible alarm has been by-passed.

Figure 1

Thermocouple-Recorder System

C. The Timing Device

The timing system is provided to allow the operator to accurately record elapsed time during an insertion. The system is shown in Figure 2. The principal instrument in the system is a running time meter with a zero reset. The full range of the meter is 10^4 minutes and the unit count is 0.1 minute. The system includes a switch and an indicator light.

D. The Thermocouple-Recorder System

The thermocouple-recorder system is shown in Figure 1. The W-5% Re/W-26% Re thermocouples are numbered from bottom to top, i. e., the thermocouple associated with the bottom pellet is designated No. 1, etc. The iron/constantan thermocouple in the coolant annulus is designated by W.

The thermocouple-recorder system is divided into 4 segments (1) the trail-cable segment, (2) the extension cable segment, (3) the instrument cabinet segment, and (4) the recorder segment. A description of each segment follows.

1. The Trail-Cable Segment

In the trail-cable segment of the system, all thermocouple leads are brought out of the trail-cable facility through a stainless steel flexible hose. The leads terminate at a socket type Amphenol connector (3106 A-24-28S).

2. The Extension Cable Segment

The extension cable segment consists of 5 pairs of lead wire bundled in polyethylene tubing. The cable will link the trail-cable segment to the instrument panel segment. The leads at one end of the extension cable are connected to a pin type Amphenol connector (3101 A-24-28P) which mates with the connector on the trail-cable segment. The leads at the other end of the extension cable are connected to a socket type Amphenol connector (3106 A-24-28S) which mates with a panel mounted connector.

3. The Instrument Panel Segment

All 5 pairs of lead wire enter the instrument cabinet through a panel mounted, pin type Amphenol connector (3102 A-24-28P). The iron/constantan

Figure 2

lead wires are taken to the signalling controller and the W-5% Re/W-26% Re wires are connected to another pin type, panel mounted Amphenol connector (3102 A-24-28P) which serves to take the leads out of the instrument cabinet.

4. The Recorder Segment

In the recorder segment the four pairs of W-5% Re/W-26% Re lead wires, bundled in polyethylene tubing (recorder extension cable) are taken from the instrument cabinet by means of a socket type Amphenol connector which mates with the panel mounted connector. The leads then extend through the polyethylene tubing to the terminal board of the multi-point recorder.

II. Required Installations

A. Connecting the Recorder Lead Cable and Modifying the Recorder Terminal Board

A new recorder extension cable will be supplied by WANL. It consists of four pairs of W-5% Re/W-26% Re compensating lead wires bundled in four feet of polyethylene tubing. The lead cable is to extend between the pin type Amphenol connector (3102 A) mounted on the side of the instrument cabinet and the terminal board of the multi-point recorder. One end of the cable terminates in a socket type Amphenol connector (3106 A) which mates with the panel mounted connector. The wires extending from the other end of the cable are to be connected to the terminal board of the recorder, in the manner outlined in Table 1 and shown in Figure 2. Each pair of thermocouple wire is identified with its appropriate letters. It is useful to note that the negative W-26% Re lead wire is magnetic.

Since the multi-point recorder will print out 24 points and since only four thermocouples are in use, the terminal board of the recorder must be modified in such a way that the input signal from a given thermocouple is recorded as more than one point. Table 1 outlines the required thermocouple-recorder point relationships. Included in the table is the letter designation of each thermocouple lead in the Amphenol connectors.

Table 1 - Thermocouple-Recorder Point Relationship

<u>Thermo-</u> <u>couple</u>	<u>Amphenol Letter</u>		<u>Recorder Points</u>
	<u>+ Lead</u>	<u>- Lead</u>	
1	A	B	1, 5, 9, 13, 17, 21
2	G	H	2, 6, 10, 14, 18, 22
3	K	L	3, 7, 11, 15, 19, 23
4	T	U	4, 8, 12, 16, 20, 24

B. Installation of Coolant Leads

GETR is to make the appropriate connections between their water supply and the flexible metal, coolant delivery hose. GETR is also to supply all appropriate flow and pressure monitoring devices.

C. Electric Power

115 v, A.C. power can be supplied to the instrument cabinet by means of a recessed male plug mounted on the side of the instrument cabinet.

GETR is to make the necessary provisions for supplying electrical power to the temperature recorder.

D. Installing the Thermocouple Extension Cable

A new thermocouple extension cable will be supplied by WANL. It consists of 5 pairs of lead wire, bundled in 30 feet of polyethylene tubing. It extends between the instrument cabinet and the port of the trail-cable facility. There are Amphenol connectors at either end of the extension cable. The socket type connector (3106 A) is to be mated with the pin type connector mounted on the front of the instrument cabinet. The pin type connector on the opposite end of the cable (3101 A) will mate with the socket connector which terminates the trail-cable segment of the capsule assembly.

E. Checking the Continuity of the Leads within the Thermocouple-Recorder System

After the recorder lead cable and the extension cable have been connected and the recorder terminal board has been modified, the continuity of all leads within the system is to be checked. This may be done by simultaneously touching a pin in the Amphenol connector on the extension cable and the corresponding terminal on the recorder board with the probes of an ohmmeter.

Part 2 - Insertion Procedures

I. Preparation for Insertion

The following are the recommended procedures for preparing the capsule assemblies and instrumentation system for the insertion of the WANL Phase II T-T capsules. At the onset of preparation for insertion the switches, valves, and instrumentation are to be set according to the following:

- (a) Main power switch: off
- (b) Audible alarm by-pass: alarm (by-pass light out)
- (c) RTM switch: off (RTM light out)
- (d) RTM setting: 00000
- (e) Water shut-off valve: closed
- (f) Temperature recorder: off
- (g) Signaling controller: ON - 100°C.

A. Preparing the Cable Systems

1. Check the continuity of the thermocouple-lead wire system in the capsule assembly. This may be done by simultaneously touching with the probes of an ohmmeter the two sockets within the socket type Amphenol connector corresponding to a given thermocouple. The thermocouple-Amphenol code relationships are listed in Table 1.

2. Connect the trail-cable segment of the thermocouple lead cable to the thermocouple extension cable by mating the Amphenol connectors.

3. Connect the 4 foot flexible metal hose segment of the coolant inlet system to the 40 foot segment.

4. Connect the trail-cable section of the coolant system to the GETR supply.

5. Visually inspect all permanent connections previously made in the coolant, recorder, and capsule assembly systems for proper connection.

B. Preparing the Instrumentation (see panel photograph)

1. Recorder

- a) Connect the electrical power line to the temperature recorder.
- b) Activate the temperature recorder. Observe the printouts to assure ambient temperatures are properly printing.

2. Temperature Alarm

- a) Plug the 115 v, A.C. electrical line from the GETR electrical supply into the recessed male plug marked "Power in 115 vac" on the side of the instrument panel.
- b) Turn the main power switch to the "on" position. The amber indicator marked "systems on" should immediately light, indicating power in the cabinet. The audible alarm may sound but will stop within a few seconds. The green light on the controller face will go on.
- c) Turn the "audible alarm by-pass" switch to the "by-pass" position. The by-pass indicator should light (red). No alarm will sound.
- d) Set the signaling controller to a temperature below ambient. The green light on the controller face should go out and the red light on the controller face should light.
- e) Turn the audible alarm by-pass switch to the "alarm" position. The audible alarm should sound and the by-pass indicator light should go out.
- f) Reset the signalling controller to 100°C. The green light on the controller face should re-light. Leave the by-pass switch in the "alarm" position.

3. Running Time Meter

- a) Turn the running time meter (RTM) switch "on". The amber RTM indicator should light. The timing meter should now be running. Check a one minute run on the meter against a convenient clock for accuracy.
- b) Turn the RTM switch "off." The amber light should go out and the timing meter should cease running. Reset the RTM to zero.

Figure 3

WANL INSTRUMENT CABINET #302

C. Preparing the Water Flow System

1. Insert the capsule sufficiently far into the trail-cable facility port so that any water emerging from the end of the capsule will flow into the reactor pool. DO NOT insert the capsule into or near the flux zone.

2. Start water flow.

3. Inspect the coolant flow system for leakage.

4. Check the flow meter to assure maintenance of the required water flow rate.

II. Insertion Procedure

A. General

The relatively high centerline temperatures required would induce rapid failure of the thermocouples. Therefore, the thermocouples have been placed on the fuel pellet surfaces. Consequently, the recorded temperatures will be that of the surface and must be converted to centerline temperatures. This may be done by using Figure 4 which relates the surface and centerline temperatures to the unperturbed thermal neutron flux. The WANL representative will apply this data to the depth of insertion, when the specific rod bank (flux profile) for a given insertion is known. This applied data will here-to-fore be known as the "insertion curve."

B. Irradiation Parameters

The required irradiation parameters are outlined in Table 2. These parameters may be changed by a WANL representative with appropriate GETR approval. The maximum allowable experimental conditions are outlined in WANL-TME-834 ("Safeguards Analysis, T-T Series, Phase II").

C. Insertion

1. Refer to the insertion curve and insert the capsule far enough into the flux zone to produce a centerline temperature of 1000°C in at least one pellet.

2. Allow the capsule to remain at this position for fifteen minutes.

Figure 4

Temperature Distribution in T-T Series Capsules
Unperturbed Thermal Neutron Flux

Table 2 - Irradiation Parameters

<u>Capsule</u>	<u>Pre-treatment</u>	<u>Max.Temp. (°C)</u>	<u>Max.Burnup (fiss/cm³)</u>	<u>Probable Flux** (N/cm² sec)</u>	<u>Irrad. Time (min)</u>
T-T 7	None	2700	1.5×10^{17}	6.2×10^{13}	105.5
T-T 8	None	2700	$1.5 \times 10^{17*}$	6.2×10^{13}	105.5*
T-T 9	None	2200	1.5×10^{17}	4.2×10^{13}	155.7
T-T 10	Stored inert atmos.	2500	1.5×10^{17}	5.4×10^{13}	171.1
T-T 11	Air Stored	2700	1.5×10^{17}	6.7×10^{13}	105.5
T-T 12	Air Stored	2200	1.5×10^{17}	4.2×10^{13}	155.7

* Burnup to be accomplished in two separate insertions

** Unperturbed Flux

3. Referring to the insertion curve, choose the insertion depth which should produce the centerline temperature indicated in Table 3.
4. Slowly lower the capsule to the selected final depth for insertion.
5. Start timing meter when the capsule reaches the chosen insertion depth.
6. Observe temperature printouts and correct for centerline temperatures. If necessary, adjust the capsule position until at least one pellet sees the required centerline temperature.
7. Determine the perturbed flux by referring to the insertion curve and calculate the time required to produce the desired burnup.
8. Hold the capsule at position long enough to produce the desired burnup.

D. Withdrawal

1. After the capsule has received the required burnup, withdraw it from the flux zone and hold for the cooling time specified by Health Physics.
2. Record the RTM reading.
3. Mark the time of capsule withdrawal on the recorder strip chart.

III. Credible Hazards and Countermeasures

Table 3 shows the credible hazardous situations associated with the irradiation of the WANL capsule assemblies, and recommended countermeasures.

In certain situations, appropriate remedial action may be taken before or immediately after removal of the capsule from the flux zone. The decision to continue the irradiation rests with the WANL on-site representative subject to approval of the GETR representative.

IV. Thermocouple Calibration Curves

Figures 5 through 9 show thermocouple calibration data for the range 0-2300°C and 0-37 millivolts, for the tungsten-5% rhenium/tungsten-26% rhenium thermocouples.

TABLE 3 - CREDIBLE HAZARDS AND EMERGENCY PROCEDURES

<u>Hazard</u>	<u>Cause</u>	<u>Indication</u>	<u>Emergency Procedure</u>
Loss of electrical power	Main power failure, line break, short circuit, etc.	"Systems On" indicator will go out.	1) Immediately withdraw capsule from flux zone then restore power.
Insufficient coolant flow	Partial closing of supply valve, loss of pressure head, etc.	1) Flow meter indicates low flow. 2) Temperature alarm activates.	1) Check flow meter for low flow reading. 2) If flow is low, initiate steps to restore proper coolant flow. 3) If proper flow cannot be obtained, withdraw capsule from flux zone and remedy the flow condition.
Loss of water from in-channel coolant lead.	Cable rupture or disconnection.	1) Temperature alarm activates. 2) Flow meter indicates <u>proper</u> flow. 3) Temperature alarm stops after capsule removed from flux zone & cools.	1) Immediately remove capsule from flux zone. 2) Repair damage if necessary and re-insert.
Damaged coolant temperature monitoring thermocouple.	Open thermocouple circuit caused by mishandling, wear, etc.	1) Temperature alarm activates. 2) Temperature alarm does <u>not</u> shut off after capsule is removed from flux zone and cools.	1) Check the coolant flow meter. 2) If proper flow is indicated, immediately withdraw the capsule from the capsule from the flux zone. 3) If, after the capsule has cooled, the alarm still

Table 3 (cont'd)

<u>Hazard</u>	<u>Cause</u>	<u>Indication</u>	<u>Emergency Procedure</u>
			sounds, the coolant thermocouple is not functioning.
			4) If the capsule being inserted is first in the series, withdraw it from the trail cable facility.
			5) If a) capsule being inserted is a later capsule in the series and b) it has been previously demonstrated that no boiling results under desired conditions, then re-insert the capsule.

TEMPERATURE - MILLIVOLT EQUIVALENTS FOR TUNGSTEN - 5%
RHENIUM / TUNGSTEN - 25% RHENIUM THERMOCOUPLES - °C
GRAPH NO - 1 RANGE - 0 - 8157 MILLIVOLTS
0°C - 480°C

Figure 5
- 18 -

GRAPH NO. 2

RANGE 8.157 - 16.025 MILLIVOLTS

480°C - 890°C

Figure 6

GRAPH NO. 3
RANGE 16.213 - 23.972 MILLIVOLTS
900°C - 1340°C

Figure 7

GRAPH NO. 4

RANGE 23.972 - 30.489 MILLIVOLTS

1340 °C - 1800 °C

Figure 8

Figure 9

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