PDR

EGG-LOFT-5360

PROJECT NO. P394

JULY 27, 1981

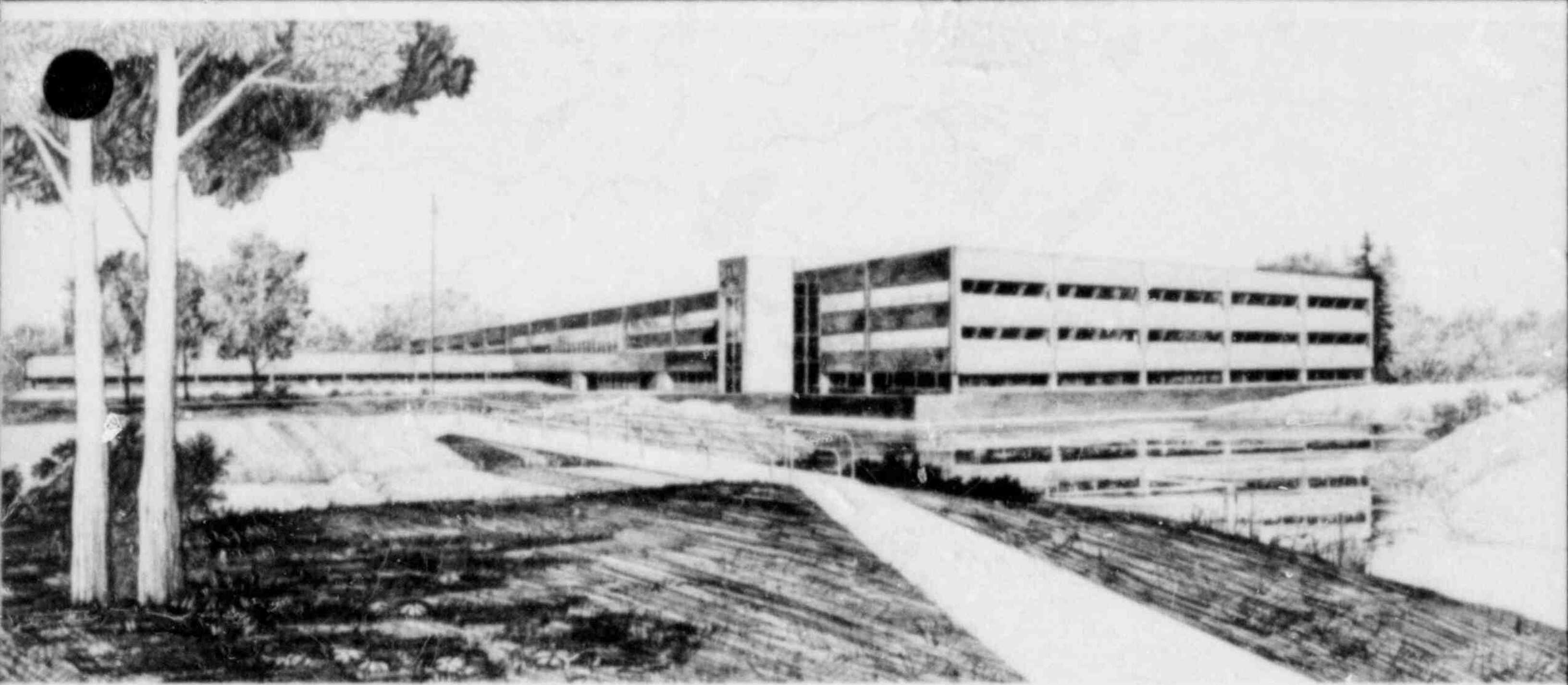
LOFT EXPERIMENT DEFINITION DOCUMENT (EDD)

NUCLEAR EXPERIMENT L6-7/L9-2

S. C. Madden

NRC Research and/or Technical Assistance Rept

U.S. Department of Energy
Idaho Operations Office • Idaho National Engineering Laboratory



This is an informal report intended for use as a preliminary or working document

Prepared for the
U. S. Nuclear Regulatory Commission
Under DOE Contract No. DE-AC07-76ID01570
FIN. No. A6048

EG&G Idaho

EG&G Idaho, Inc.

FORM EG&G-398
(Rev. 12-78)

INTERIM REPORT

Accession No. ____________

Report No. EGG-LOFT-5360
NE L6 Series
NE L9 Series
EDD

Contract Program or Project Title:

LOFT Program Division

Subject of this Document:

Anticipated Transients with Multiple Failures
Test Series L6-7/L9-2

Type of Document:

LOFT Experiment Definition Document (EDD)

Author(s):

S. C. Madden

Date of Document:

July 27, 1981

Responsible NRC Individual and NRC Office or Division:

G. D. McPherson, Chief, LOFT Research Branch, Division of Reactor Safety Research, USNRC

> This document was prepared primarily for preliminary or internal use. It has not received full review and approval. Since there may be substantive changes, this document should not be considered final.

EG&G Idaho, Inc.
Idaho Falls, Idaho 83401

Prepared for the
U.S. Nuclear Regulatory Commission
and the U.S. Department of Energy
Idaho Operations Office
Under contract No. EY-76-C-07-1570
NRC FIN No. A6048

INTERIM REPORT

LOFT EXPERIMENT DEFINITION DOCUMENT

NUCLEAR EXPERIMENT L6-7/L9-2

Reviewed: CW Solbrig / ffw

Manager, LOFT Program Division

E. L. Johnson as per telecon 3-20-81 SCM

Manager, LOFT Facility Division

N J Hanson

Manager, LOFT Measurements Division

LH Blimmly for TF Pointer per telecon 3-25-81

Manager, LOFT Technical Support Division

Approved: LP Leach

Manager, LOFT Department

Authorized for Release: BR Freed

Configuration Document Control and Services

DOE/ID Approval Letter

From: J. E. Solecki
To: L. P. Leach
Date: July 17, 1981

CONTENTS

FOREWORD

This document provides the preliminary definition of test objectives, configuration, initial conditions, measurement requirements, and scenario for the L6-7 and L9-2 Loss of Fluid Test (LOFT) experiments. In addition, a discussion of special conditions and requirements to meet the test objectives is provided along with a description of the scaling criteria used for the test. The information provided in this document is intended to provide partial input to the Experiment Prediction (EP) and the Experiment Safety Analysis (ESA) and in the planning of instrument and data acquisition requirements. An Experiment Operating Specification (EOS) will further define and finalize the test requirements.

LOFT EXPERIMENT DEFINITION DOCUMENT

NUCLEAR EXPERIMENT L6-7/L9-2

1. INTRODUCTION

The LOFT Experiments L6-7 and L9-2 are excessive cooldown transients involving multiple failures. The first test (L6-7) simulates a turbine trip cooldown that occurred at Arkansas Nuclear One-Unit 2 (ANO-2). Experiment L9-2 follows Experiment L6-7 and assumes a second failure occurs causing a continuation of the initial cooldown that did not occur in the ANO-2 cooldown.

ANO-2, a Combustion Engineering (CE) reactor with a rated core power of 2764 MW, performed a turbine trip from 98% power on January 29, 1980 during start up testing.[1] Since there was no direct reactor scram on a turbine trip, the secondary and primary systems began a rapid pressure increase causing the steam dump and bypass valves on the secondary side and the pressurizer spray valve to actuate. Reactor scram was caused by low level in the secondary side of the steam generators. Pressures on both the secondary and primary sides began to decrease resulting in a signal for closure of the pressurizer spray valve and steam dump and turbine bypass valves. However, one atmospheric dump valve downstream of the Main Steam Isolation Valve (MSIV) stuck open and the pressurizer spray valve did not reseat completely. The effect, due primarily to the stuck open atmospheric dump valve, was an excessive and continuing system cooldown and shrinkage (see Figures 1 and 2).

Observing primary system pressure decreasing and the pressurizer emptying, the operators followed small break procedures and tripped the primary coolant pumps (PCPs),[2] unaware of the actual situation.

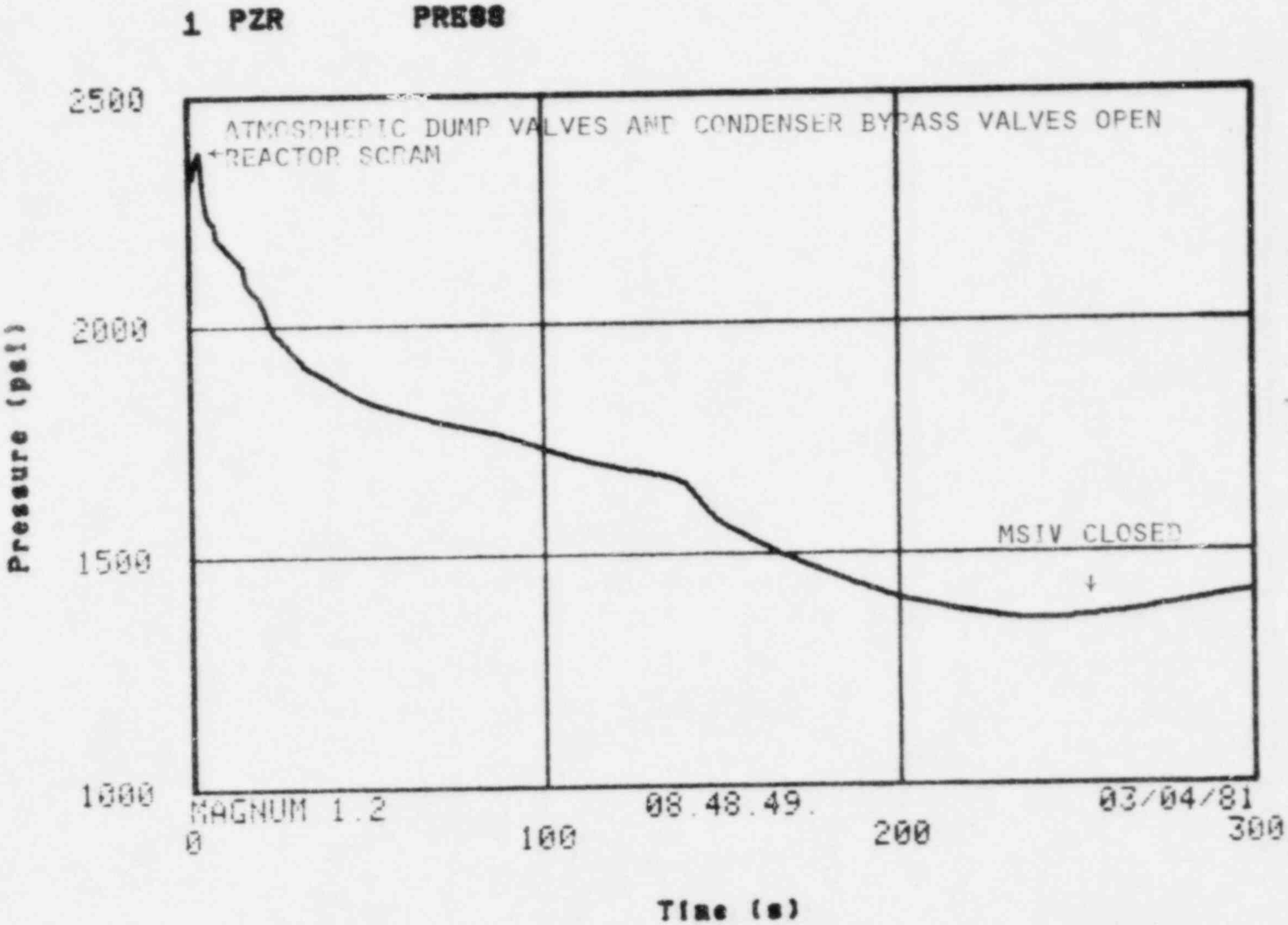


FIGURE 1. ANO-2 PRESSURIZER PRESSURE

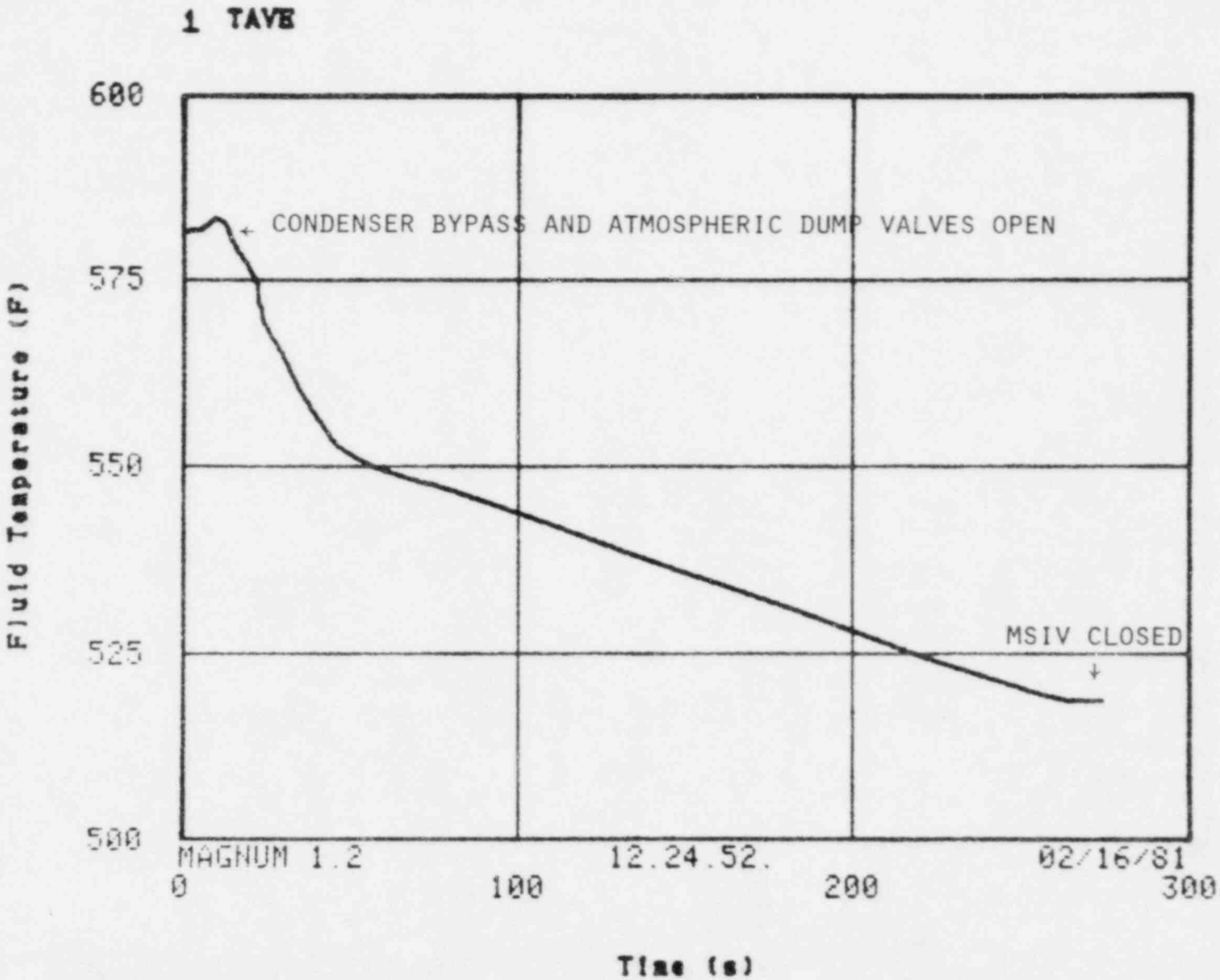


FIGURE 2. ANO-2 PCS AVERAGE TEMPERATURE

EDD

Natural circulation was established and eventually the steam generator low pressure caused the MSIV closure, isolating the stuck open valve (the pressurizer spray was made ineffective when the PCPs were tripped). The plant was safely returned to a stable condition.

Several safety issues were manifested in the ANO-2 transient.[3] The primary coolant system (PCS) cooldown was approximately 600°F/hr. Had the cooldown continued longer (i.e., if the atmospheric dump valve upstream of the MSIV stuck open), the PCS shrinkage would have created a significant steam bubble that may have inhibited natural circulation.

Had the operators been equipped with a real time method for differentiating between a cooldown transient and a small break loss of coolant accident (LOCA), they may not have been required to trip the pumps in order to mitigate a potentially severe situation. This type of transient could produce conditions that might inhibit natural circulation which would necessitate cooldown by a less desirable method.

A natural circulation cooldown (75°F/m) event has occurred at St. Lucie causing concerns within the Nuclear Regulatory Commission (NRC) relating to vessel head voiding during anticipated transients.[4] In the event of a natural circulation cooldown, the stagnant fluid in the vessel head may not remain subcooled and may flash forming steam voids which produce a pressurizer level increase. In addition, natural circulation may be inhibited by a vapor bubble in the reactor vessel head. As a result, a lower allowable cooldown rate may be required during natural circulation cooldown in Pressurized Water Reactors (PWRs) to prevent void formation in the vessel head [5]

2. EXPERIMENT OBJECTIVES

The major programmatic objectives for Experiment L6-7/L9-2 are:

1. To study the typicality of LOFT to a large pressurized water reactor through comparison of the LOFT primary system response to that of ANO-2 during a cooldown transient (L6-7).

2. To address NRC concerns related to overcooling transients which have been identified as a potential unresolved safety issue. Specifically, address the NRC concern that voids created during a cooldown transient could inhibit natural circulation[3,5] (L9-2).

3. To evaluate the ability of calculational methods to predict system parameters in a cooldown transient[6] (L6-7/L9-2).

The specific objectives for Experiment L6-7/L9-2 which support the programmatic objectives are:

1. To measure primary system pressures, temperatures, pressurizer level, mass flow and steam generator secondary system pressure, temperature and steam flow which will be used to perform energy balances to compare LOFT results with ANO-2 data (L6-7).

2. To measure PCS density and pressure (to calculate void fraction) and primary system flow rate in order to evaluate the effect of system voiding on natural circulation (L9-2).

4. To measure primary and secondary system pressures, temperatures, liquid levels, and mass flow rates to compare with system thermal hydraulic predictions (L6-7/L9-2).

3. EXPERIMENT DESCRIPTION AND SEQUENCE OF EVENTS

The L6-7 experiment simulates the single failure of the steam dump valve downstream of the MSIV to produce a cooldown at LOFT representative of that at ANO-2. This transient will provide data to evaluate our understanding of the typicality of the LOFT primary system relative to that of ANO-2. At the point where the ANO-2 transient is recovered by the isolation of the stuck open dump valve, L9-2 will begin. In L9-2, it is assumed that the MSIV fails to close (a mulitple failure) causing a continued cooldown in the primary and secondary systems.

T_o is defined to be the time the steam valve begins closing.

The following events provide a scenario of Tests L6-7 and L9-2 as currently planned.

1. Initiate automatic steam controller operation which causes the steam valve to begin closing. (The automatic steam controller is described in Section 6.1.)

2. Manually scram the plant at T_o + 6 seconds. (Automatic steam generator level control is maintained.)

3. Turn off pressurizer heaters at an indicated pressurizer level of 15 in.

4. Pressurizer empties due to excessive PCS shrinkage as a result of the system cooldown.

5. Resume manual control of the feedwater when the feed flow is within the capacity of the feed bypass valve (about 20,000 lbm/hr) and maintain the steam generator level between 116 and 126 inches above the steam generator tube sheet.

6. Trip the primary coolant pumps (PCPs) 100 s after pressurizer level indicates zero.

PCP trip marks the initiation of Experiment L9-2.

7. The steam valve is manually controlled to produce a primary cooldown rate of about 600°F/hr.

8. Accumulator cold leg injection if 600 psig is reached.

9. Secure the steam flow control valve and/or steam bypass valve on accumulator float or at T_0 + 30 minutes, which ever occurs first.

10. Terminate the DAVDS recording and recover the system in accordance with the Experiment Operating Procedures (EOP).

4. INITIAL CONDITIONS

The nominal initial system operating conditions are as follows:[a]

1.	Core Power	50 MW
2.	Decay Heat Level (minimum)	448 kW at 4000 s
3.	PCS Flow	$3.8 * 10^6$ lbm/hr
4.	PCS Pressure	2156 psig
5.	PCS Cold Leg Temperature	542°F
6.	Pressurizer Level	40 inches

a. Section 6 describes the criteria used to establish these conditions. Specific operating bands will be documented in the EOS.

5. MEASUREMENT REQUIREMENTS

Details of the existing instrumentation may be found in References 7 and 8. Aside from these measurements, additional instrumentation requirements have been identified in order for the experiment objectives to be met. A complete list of the critical measurements for Experiment L6-7/L9-2 will be in the EOS.

1. Coolant Void Measurement in the PCS. Shrinkage of the PCS inventory will cause the pressurizer to void. The existing intact loop hot leg coolant density measurement should be fully operational in order to determine the extend of voiding in the hot leg.

2. Low Steam Flow Capability. RELAP5 calculations indicate a range of steam flow between 200,000 lbm/hr and about 15,000 lbm/hr. It will be necessary to measure the steam flow with an accuracy of ± 1000 lbm/hr below 30,000 lbm/hr (both main and bypass steam lines) and an accuracy of ± 10% above 30,000 lbm/hr.

3. Natural Circulation Measurement. Once the PCS pumps are tripped after the pressurizer is empty, it will be necessary to measure natural circulation in the intact loop. The hot leg pipe will vary between 25% and 100% full. The fluid velocity in the intact loop will range from 1 ft/s to 2 ft/s and should be known within ± 0.2 ft/sec accuracy with a response time of 1 sec.

6. DISCUSSION

The purpose of this section is to discuss the specific requirements and special operating conditions for Experiment L6-7/L9-2 that have not been addressed. In particular the subjects discussed in this section are:

6.1 Secondary Coolant System Control During Experiment L6-7/L9-2

6.2 System Configuration Anomalies

6.3 Scaling Criteria For Experiments L6-7 and L9-2

6.3.1 Initial Power Level

6.3.2 Pressurizer Level

6.3.3 Pressurizer Spray

6.1 Secondary Coolant System Control During Experiment L6-7 and L9-2

RELAP5 and HYBRID calculations were performed using the normal LOFT 100% power, high PCS mass flow initial conditions. Where it was possible, the ANO-2 sequence of events was maintained. The steam flow was controlled in the calculations to achieve a similar PCS cooldown rate in LOFT as in the ANO-2 transient. The calculated steam flow will be programmed into an automatic steam flow controller to be used during L6-7.

During L9-2, the automatic steam flow controller will not be used. The operators will manually control a PCS cooldown of about 600°F/hr.

The feedwater during L6-7 and L9-2 will be controlled to maintain the steam generator level between 116 and 126 inches above the tube sheets to assure heat transfer during the entire transient.

6.2 System Configuration Anomalies

The formation and propagation of steam voids and their effect on natural circulation will be addressed in Tests L6-7 and L9-2. Large Pressurized Water Reactors (LPWRs) are likely to form steam voids in the reactor vessel upper head during an overcooling transient. This is due to the effect of the stagnant fluid and hot vessel internals while the system is depressurizing. The broken loop steam generator simulator, as presently configured, could cause atypical behavior because of the potential for void formation in this region during the cooldown transient. Therefore, the steam generator simulator will be blanked off for Experiment L6-7/L9-2 to prevent voids from forming in or propagating to the steam generator simulator. Removal of the simulator spool piece will also reduce the deviation in the power to volume ratio by about 22%.

Anotner difference between LOFT and ANO-2 concerns the secondary side steam valve. Following the manual turbine trip in ANO-2, the turbine stop valves acted within one second to isolate the turbine, creating immediate and sharp pressure increases on the primary and secondary sides which initiated the signal to open the turbine bypass and atmospheric dump valves.

The maximum rate of movement of the steam flow control valve in LOFT is 5%/s. The pressure increase, therefore, due to the loss of load will be more gradual in Experiment L6-7/L9-2 than that in ANO-2. The subsequent sequence of events will not correspond on a time scale to the ANO-2 turbine trip transient. This effect will be accounted for in the data comparisons between LOFT and ANO-2.

6.3 Scaling Criteria for Experiment L6-7/L9-2

Atypicalities exist between LOFT and ANO-2 that will affect the results of a simulated rapid cooldown. The following subsections discuss system atypicalities and scaling considerations for Experiment L6-7/L9-2.

6.3.1 Initial Power Level

The initial condition of maximum design power was chosen for Experiment L6-7/L9-2 in order to maximize decay heat. This is important in order to maintain the terms in the energy balance as similar as possible (on a volume basis) in the two systems. LOFT's decay heat will be lower than the scaled ANO-2 decay heat for two reasons. First, LOFT irradiation time (48 hrs) is substantially less than ANO-2 irradiation time (29 days); therefore, fission product concentrations will be lower. Second, the LOFT power-to-volume ratio with the steam generator simulator removed (0.193 MW/ft^3) is 70% of that of ANO-2 (0.277 MW/ft^3). To scale the power level to PCS volume would result in a LOFT power of 76.5 MW. LOFT will be operated at the highest allowable power of 50 MW.

6.3.2 Pressurizer Level

The pressurizer level for Experiments L6-7/L9-2 is set to establish a similar ratio of pressurizer vapor space to total effective PCS volume in both LOFT and ANO-2. This ratio will be important especially in Experiment L6-7 in simulating the ANO-2 transient since the volume of pressurizer vapor space is controlling the PCS pressure response. The ANO-2 pressurizer vapor volume is 6% of the PCS volume. Disregarding the broken loop volume which does not actively participate in this transient, an initial pressurizer liquid level of 40 inches in LOFT results in a similar vapor volume-to-PCS volume ratio as in ANO-2.

6.3.3 Pressurizer Spray

In the ANO-2 cooldown transient, the pressurizer spray valve failed to reseat completely, resulting in a minimal contribution to the plant cooldown. Since the amount of flow is not known for the partially open valve and the spray flow becomes insignificant once the primary coolant pumps are tripped, it is planned to allow the LOFT pressurizer spray to operate normally.

REFERENCES

1. D. P. Siska, CENP-1708, NSSS Transient Tests at ANO-2, 1981.

2. B. W. Sheron, Generic Assessment of Delayed Reactor Coolant Pump Trip During Small Break Loss-of-Coolant Accidents in Pressurized Water Reactors, NUREG-0623 (November 1979).

3. H. R. Denton, NRR, Inclusion of Steam Generator Transients as an Unresolved Safety Issue, SECY-80-325A (November 7, 1980).

4. T. Novak, NRC, letter to R. E. Uhrig, St. Lucie Unit 1 Cooldown on Natural Circulation Information Request, Docket No. 50-335 (July 8, 1980).

5. D. F. Ross (NRC) letter to D. G. Eisenhut, Followup Action on Natural Circulation Cooldown, (November 20, 1980).

6. J. E. Richardson memo to L. C. Shao, Use of the LOFT Facility for Structural, Mechanical and Materials Research Projects, (July 10, 1980).

7. R. W. Brower et al., LOFT Measurement Capability List, (March 1979).

8. M. J. Johnson, LOFT L9-1/L3-3 Series Data Acquisition Channel Configuration, MJJ-2-81, (February 1981).

9. D. L. Reeder, letter to E. A. Harvego, Pressurized Water Reactor Transient Characterization, Reed-7-81, (February 24, 1981).