Summary of FY 1997 Work Related to JAPC-U.S. DOE Contract "Study on Improvement of Core Safety - Study on GEM (III)"

Prepared for the U.S. Department of Energy

Fluor Daniel Hanford, Inc.
Richland, Washington

Hanford Management and Integration Contractor for the U.S. Department of Energy under Contract DE-AC06-96RL13200

Approved for Public Release; Further Dissemination Unlimited
Summary of FY 1997 Work Related to JAPC-U.S. DOE Contract "Study on Improvement of Core Safety - Study on GEM (III)"

T. M. Burke
B&W Hanford

Date Published
February 1998

To Be Presented at
DOE Technical Exchange
Tokyo, Japan
February 10, 1998

Prepared for the U.S. Department of Energy

Fluor Daniel Hanford, Inc.
P.O. Box 1000
Richland, Washington

Hanford Management and Integration Contractor for the U.S. Department of Energy under Contract DE-AC06-96RL13200

Approved for Public Release; Further Dissemination Unlimited
RELEASE AUTHORIZATION

Document Number: HNF-2195

Document Title: Summary of FY 1997 Word Related to JAPC-U.S. DOE Contract "Study on Improvement of Core Safety - Study on GEM (III)"

This document, reviewed in accordance with DOE Order 1430.1D, "Scientific and Technical Information Management," and DOE G 1430.1D-1, "Guide to the Management of Scientific and Technical Information," does not contain classified or sensitive unclassified information and is:

APPROVED FOR PUBLIC RELEASE

V. L. Birkland
Lockheed Martin Services, Inc.
Document Control/Information Clearance

LEGAL 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, not 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 any third party's use or the results of such use 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 or its contractors or subcontractors. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof. This report has been reproduced from the best available copy. Printed in the United States of America.
SUMMARY OF FY 1997 WORK RELATED TO JAPC - U.S. DOE CONTRACT

“Study on Improvement of Core Safety - Study on GEM (III)”

February 10, 1998

T. M. Burke
B&W Hanford Company
PRESENTATION CONTENTS

- Fast Flux Test Facility history & status
- Overview of contract activities
- Summary of loss of flow without scram with GEMs testing
- Summary of pump start with GEMs testing
FAST FLUX TEST FACILITY - HISTORY & STATUS

- Originally designed & operated to develop LMFBR fuels and materials
- Design/construction completed in late 1970’s
- Initial criticality achieved in early 1980
- U.S. LMFBR program was de-emphasized in early 1980’s
- FFTF operation continues with multiple missions
  - International LMFBR development
  - U.S. LMR Safety
  - Fusion program support
  - Space power
  - Medical isotope production
FFTf History & Status (cont)

- U.S. Department of Energy places the FFTF in “Standby” in 1992 and orders shutdown in 1993
- Current FFTF status:
  - All fuel removed from reactor vessel in 1994
  - Non-usable fuel washed and placed in dry cask storage
  - Ready to initiate drain of sodium in 1995 but placed on hold
- FFTF placed back into standby in January 1997 to allow evaluation of:
  - Tritium production
  - Medical isotopes
OVERVIEW OF CONTRACT ACTIVITIES
OVERVIEW OF CONTRACT ACTIVITIES

- Original contract established August 1996
- Information on design/testing of GEMs at the FFTF provided to JAPC to support DFBR evaluation:
  - Three reports documenting the FFTF GEM design and loss of flow without scram tests
  - GEM specialists meeting at Hanford (December 1996)
  - Summary presentation to JAPC and utility representatives (February 1997)
  - Several series of related questions and answers
  - Reports documenting FY 1996 activities
OVERVIEW OF CONTRACT ACTIVITIES (cont)

- Contract extended from 03/31/97 to 03/31/98
  - Provided additional report describing the FFTF pump start with GEMs testing
  - Additional series of questions and answers
  - Participate in summary meeting
  - Reports documenting FY 1997 work will be issued by 03/31/98
SUMMARY OF LOSS OF FLOW
WITHOUT SCRAM WITH GEMS TESTING
INTRODUCTION

- FFTF was originally designed/constructed/operated to develop LMFBR fuels and materials
- Inherent safety became a major focus of the US nuclear industry in the mid 1980’s
- The inherent safety characteristics of LMFBRs were recognized but additional enhancement was desired
FFTF INHERENT SAFETY TESTING PROGRAM
FFTF UNPROTECTED PUMP COASTDOWN

INITIATED FROM FULL POWER (100% POWER)

PEAK CHANNEL SODIUM TEMPERATURE (°F)

SODIUM BOILING

W/O ENHANCEMENT DEVICE(S)

WITH ENHANCEMENT DEVICE(S)

SHUTDOWN REACTIVITY ASSOCIATED WITH ENHANCEMENT DEVICE(S)

TIME FROM INITIATION OF EVENT (SECONDS)
GEM (Gas Expansion Module)
Assembly in First Radial Blanket Row

Pumps On
Pumps Off

Increased Neutron Loss → Shutdown

Neutron
Core

Neutron
Core

Inert Gas

Liquid Sodium
FFT F GEM DESIGN GOALS

- Develop concept for reducing consequences of Loss of Flow Without Scram transient
- Design, fabricate, and test device in short time period at low cost
- Perform tests at significant power level (up to 50% power, 200 MW$_t$)
- Limit sodium temperatures during tests to normal operating values
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Concept Proposed</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Scoping Analyses</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Design/Fabrication</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Zero Power Tests</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>&quot;Precursor&quot; N.C. Tests</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>LOFWOS Tests</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pump Restart Tests</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
CALCULATED GEM SODIUM LEVEL vs. PLANT CONDITIONS

- 210°C, 100% Flow = 233 cm
- 316°C, 100% Flow = 226 cm
- Full Power and Flow = 215 cm
- 210°C, 10% Flow (Refueling) = 107 cm
- 316°C, 10% Flow = 74 cm
- 10% Flow, Full Power Temperature = 0 cm

SODIUM LEVEL
SUMMARY OF GEM REACTIVITY WORTH MEASUREMENTS

- **PUMPS ON/PUMPS OFF WORTH**
  - $-0.15\$ PER GEM @ 440°F
  - $-0.16\$ PER GEM @ 600°F

- **REFLECTOR REPLACEMENT WORTH**
  - $-0.13\$ PER GEM @ 440°F

- **COMPARISON WITH PRE-MEASUREMENT CALCULATION**
  - 3D DIFFUSION THEORY (400°F) — $-0.17\$ PER GEM
  - MONTE CARLO (HOT) — $-0.18\$($0.08\$-10)$

![Graph showing reactivity versus time from pump trip](image-url)
LOF/WOS TO NATURAL CIRCULATION
ROW 2 ASSEMBLY OUTLET TEMPERATURE

TEST LIMIT – 992°F
# Preliminary Data Evaluation 50% LOF/WOS TO Natural Circulation WITH GEMs

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Evaluation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Row 2 outlet temperature</td>
<td>Measured peak temperature approximately 944°F versus 1136°F predicted</td>
</tr>
<tr>
<td>Total reactor flow</td>
<td>Good agreement - no significant contribution to discrepancy in outlet temperature</td>
</tr>
<tr>
<td>Total reactor power</td>
<td>Measured value 10-20% less than predicted value near time of peak temperature. Results in 50-100°F reduction in row 2 outlet temperature. Most likely due to uncertainty in reactivity feedbacks during transient</td>
</tr>
<tr>
<td>Core flow redistribution</td>
<td>Predictions assumed no core flow redistribution. Hot channel factor curves would predict 20-30% (100-150°F) reduction in hot assembly ΔT. Preliminary multi-channel analyses indicate similar reduction</td>
</tr>
<tr>
<td>Radial heat transfer</td>
<td>Not included in predictions. Probably small direct effect for central assemblies. May be important at core periphery with resulting impact on core flow distribution</td>
</tr>
</tbody>
</table>
**LOSSWOS WITH GEMS - CONCLUSIONS**

- 13 tests conducted
  - Power level: 40 MW - 200 MW (10%-50%)
  - Cooling mode: pony motors and natural circulation
- Peak sodium temperatures were lower than predicted
  - For most aggressive test (50% power/100% flow to nat. circ.)
    Peak sodium temperature W/O GEM (predicted)... 1670°F (boiling)
    Peak sodium temperature W/GEM (predicted)... 1136°F
    Peak sodium temperature W/GEM (measured)... 944°F
- GEM functioned as predicted
  - Nine GEMs tested 30 times
- The GEM is a viable device for safely terminating a LOFWOS event in an LMR
SUMMARY OF PUMP START
WITH GEMs TESTING
GEM PUMP START TEST

• Purpose
  - Support GE-PRISM design (testing performed in 1991)
    • 1- Demonstrate safety of pump start transient with GEM
      (inadvertent reactivity insertion concern)
    • 2 - Verify predictions
  - Obtain additional data for understanding the FFTF reactivity feedbacks

• Core configuration
  - 3 GEMs in Row 7 (compared to 9 GEMs in 1986 LOFWOS tests)
  - GEM reactivity worth about 50 cents
**FFTF PUMP START WITH GEMS**

- **Main experiment**
  - Three GEM assemblies in Row 7 (reflector)
  - Flow increased from pony motor flow to 70% of full flow
  - Reactor initially subcritical

<table>
<thead>
<tr>
<th>TEST RUN NUMBER</th>
<th>INITIAL REACT. c</th>
<th>FINAL POWER (%)</th>
<th>INFERRED GEM WORTH c</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>-38</td>
<td>3</td>
<td>48</td>
</tr>
<tr>
<td>2</td>
<td>-33</td>
<td>5</td>
<td>50</td>
</tr>
<tr>
<td>3</td>
<td>-25</td>
<td>8</td>
<td>N/A</td>
</tr>
<tr>
<td>4</td>
<td>-21</td>
<td>9</td>
<td>50</td>
</tr>
</tbody>
</table>
FFTTF Pump Start with GEMs Test

Reactor Flow versus Time
Flow Inferred from Pump Speed Measurements
Reactor Power During Pump Start Transients

Power (% of Full Power)

Time (s)

RUN #1

RUN #2

RUN #3

RUN #4
Measured and Predicted GEM Worths
RESULTS AND CONCLUSIONS

- GEMs are reliable

- Pump start with GEMs is benign in the FFTF

- Plant response close to prediction

- Data available for computer code validation
  (no detailed post-test analysis performed)
Summary of FY 1997 Work Related to JAPC-U.S. DOE Contract "Study on Improvement of Core Safety - Study on GEM (III)"