DOE/SF-71032 -- T23 J. Sims

Rockwell International Atomics International Division		SUPPORTING DOCUMENT		NUMBER N001TI570038	REV LTR/CHG NO. SEE SUMMARY OF CHG
PROGRAM TITLE Inherently Safe Core Design MASTER				DOCUMENT TYPE Technical Information	
DOCUMENT TITLE Notes on the Inherently Safe Core Design Meeting with DOE-RRT, AI, GE, W-ARD, EPRI, and ETEC (at AI, Canoga Park, California, November 7-8, 1978)				KEY NOUNS Program Review, Future Plans Schedules, Intro. to Large Plant Des.	
ORIGINAL ISSUE DATE November 9, 1978				GO NO. 09291 S/A NO. 10000 PAGE 1 OF TOTAL PAGES 161	
PREPARED BY/DATE DEPT MAIL ADDR A. S. Jackola <i>AS Jackola 11-21-78</i> 731 JB05 R. K. Paschall <i>RK Paschall 11-21-78</i> 731 JB05				REL. DATE 11-28-78 <i>et</i>	
IR&D PROGRAM? YES ☐ NO ☒ IF YES, ENTER TPA NO.				SECURITY CLASSIFICATION (CHECK ONE BOX ONLY) (CHECK ONE BOX ONLY) UNCL ☒ DOE ☐ DOD RESTRICTED DATA ☐ CONF. ☐ DEFENSE INFO. ☐ SECRET ☐	
APPROVALS E. R. Specht <i>ERS Specht / RKP</i> DATE 11-21-78 H. A. Morewitz <i>HAMorewitz</i> 11-21-78				AUTHORIZED CLASSIFIER DATE	
DISTRIBUTION		ABSTRACT			
* NAME	MAIL ADDR	The primary purpose of the meeting was to familiarize large LMFBR design managers with the capabilities of the Inherent Secondary Shutdown Systems (articulated rod and absorber balls) and to obtain inputs from them. The other purpose of the meeting was for the ISSS designers (AI, GE, and WARD) to present current work status, future plans, and schedules for their respective ISSS tasks. The attached appendices are as follows: A. Program Review of WARD LOA tasks. B. ISSS-ACA Test Programs for GE. C. AI Program Review of Hydraulically-Supported Neutron Absorber Balls ISSS. D. AI Development Program Review for ISSS Needs and Recommendations in Reliability and Safety. E. ETEC Test Milestones, Schedule, and Summary for ISSS-ACA.			
* R. Balent	LA05				
* D. Chung	JB05				
E. Baumeister	JB10				
J. Brunings	LB02				
L. Felten	LB04				
G. Galluzzo	JB05				
J. Hartung	LB02				
* A. Jackola	JB05				
* R. Schnurstein	LB17				
* R. Lancet	LB02				
J. McDonald	LB11				
* H. Morewitz	LB17				
* R. Paschall (5)	JB05				
J. Roecker	LB11				
* E. Specht	JB05				
P. Twichell	JB05				
J. Vitti	LB04				
H. Wieseneck	LB13				
* L. Eytel	JB05				
731-A.258/jbv		RESERVED FOR PROPRIETARY/LEGAL NOTICES THIS REPORT MAY NOT BE PUBLISHED WITHOUT THE APPROVAL OF THE PATENT BRANCH, DOE This report was prepared as an account of work sponsored by the United States Government. Neither the U. S. Government, nor any of its employees nor any of its 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.			
* COMPLETE DOCUMENT NO ASTERISK, TITLE PAGE/SUMMARY OF CHANGE PAGE ONLY		DISTRIBUTION OF THIS DOCUMENT IS UNLIMITED			

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.

11:21 AM

AGENDA

INHERENT SECONDARY SHUTDOWN SYSTEMS FOR LARGE LMFBR'S

November 7, 1978
Conference Room 1, Building 2
and

November 8, 1978
HTF (B863), ETEC (B486), Na Loop (B032),
and Conference Room (B038)

INHERENT SHUTDOWN SYSTEMS FOR LARGE LMFBR'S

- I. Introduction - RRT
- II. Functional Requirements
- III. Articulated Absorber Design and Tests
- IV. Hydraulically Supported Absorber Balls Design and Tests
- V. New Inherent Actuator Development
- VI. Large LMFBR Requirements and Recommendations
- VII. Summary
- VIII. Tour ETEC (November 8, 8:30 a.m.) - Water Loop Tests on Absorber Balls and Sodium Loop Tests on Articulated Absorber

Participants

Large LMFBR Program Representatives, AI, GE, WARD
Inherently Safe Shutdown System Designers, AI, GE, WARD
RRT-DOE
EPRI

DISCLAIMER

This book 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.

DISTRIBUTION OF THIS DOCUMENT IS UNLIMITED

STATUS AND DEVELOPMENT PLANS FOR INHERENTLY SAFE CORE DESIGNS

- I. Status and Plans for New Inherent Actuator Development
- II. Status and Plans for Articulated Absorber ISSS Concept
- III. Status and Plans for Absorber Balls ISSS Concept

Participants

Inherently Safe Shutdown System Designers, AI, GE, WARD
RRT-DOE

ATTENDEES

E. R. Specht	AI
W. A. Brummond	GE
H. S. Bailey	GE
R. T. Lancet	AI
Stan Davies	GE
Neil W. Brown	GE
Arthur S. Jackola	AI
R. K. Paschall	AI
L. S. Eytel	AI
J. F. Wett	W-ARD
R. B. Tupper	W-ARD
Marty Cooper	W-ARD
A. C. Millunzi	RRT
J. Hartung	AI
D. K. Chung	AI
H. A. Morewitz	AI
P. W. Twichell	AI
J. Vitti	AI
G. D. Baston	EPRI

NOTES ON THE INHERENTLY SAE CORE DESIGN MEETING
WITH DOE-RRT, AI, GE, W-ARD, EPRI, AND ETEC
HELD AT AI, CANOGA PARK, CALIFORNIA
NOVEMBER 7-8, 1978

Meeting Called to Order by E. R. Specht, AI

Introduction of participants and synopsis of 2-day program

Introduction by A. C. Millunzi, DOE-RRT

RRT wanted the large LMFBF plant design managers invited to see and know what the Inherent Secondary Shutdown Systems (ISSS) capabilities are so they could be factored into future systems designs (CDS requirements or any large plant requirements). RRT wants the design managers to be up-to-date on all ISSS activities and history.

RRT and ISSS designers want to know if currently established ISSS functional requirements are at odds with those of large plant designs. A point-by-point determination/verification is needed to establish agreement and confirmation of the requirements.

RRT is hopeful that a third shutdown system will not have to be added.

RRT feels that the large LMFBF designers should drive the ISSS test program with their inputs.

Summary of ISSS Functional Requirements by Marty Cooper, W-ARD

W-ARD's viewgraph package was distributed to the meeting participants.

W-ARD presented the general, secondary, and ISSS functional requirements summary and also the bounding initiating events (anticipated and unlikely) for TOP and TUC in the secondary system and the secondary system in the self-actuated mode or tertiary system.

Also, presented were design guides for the ISSS and performance estimates for the ISSS and the electromagnetic system.

Description of ISSS-ACA by R. B. Tupper, W-ARD

W-ARD presented sectioned views of the Articulated Control Assembly (ACA) including the electromagnet assembly (with temperature sensitive material), the pin-type absorber assembly sections, and the lower dash pot assembly.

Test performance curves and sketches were presented on the temperature sensitive nickel-iron alloy for Test Units 1 and 2 (cylindrical and hexagonal exterior, respectively). The nickel-iron cross-sectional area was increased in Unit 2 to improve the system performance, i.e., obtaining a higher magnetic breakaway force for any given magnet current.

Development tests were described for both argon and sodium testing of the electromagnet assembly with the temperature sensitive material. Effects of a 0.003-in. shim (to represent oxidation or crud in the parting plane) were also shown and test results showed the holding power to still be within design limits on the 125-lb dead weight (in sodium). The other three basic tests were breakaway force vs temperature, breakaway force vs magnet current at 1020°F, and also drag force as a function of current (found to be 40 lb, but wear pads should reduce it to less than 10 lb).

A thermal analysis model was presented on the temperature-sensitive magnet for a 9-second injection of 2200°F sodium into the ETEC test unit (starting from the 850°F primary sodium temperature flowing at 12.5 gpm). After 9 seconds, the model showed that 82.5% of the Ni-Fe was at 1050°F or higher.

Mr. Stan Davies (GE) felt that the 50-lb force margin between lift and drop was too low. He thought it should be somewhere between 50% and 100% of the lifting force. He extended the uncertainty to tolerance shifts in production models. He also asked about the possibility of operating in an overcurrent situation (2 amps instead of 1 amp) which would elevate the breakaway force for any given temperature. In addition, he stated that the magnet had some commonality with the primary system.

Dr. Chung (AI) suggested installing a thermal switch, in the driveline above the magnet, which would interrupt the current to the electromagnet.

W-ARD stated they would conduct 0.5 and 0.75-in. radial bow tests on the 57.5-in. long articulated absorber assembly (48-in. absorber length) in the sodium loop test at ETEC. The radial tube ovality ($\frac{0 \text{ initial} - 0 \text{ final}}{2}$) is theoretically 0.065 and 0.03 inches for these two test conditions.

ISSS-ACA Testing Program at ETEC by H. S. Bailey, (GE)

GE presented a matchup chart on the project milestones for large LMFBR control systems and the favorable ISSS development schedule. The order of desirability for a decision on large plant control systems was presented as: 1) primary + secondary with ISSS, 2) primary + secondary, and 3) primary + secondary + tertiary ISSS.

Mr. Davies (GE) felt this order of desirability was questionable.

The ISSS-ACA test program schedule and milestones were presented identifying participant organizational responsibility. Also, an ISSS-ACA test summary was presented depicting a specific sequence, number of individual tests and time estimates for them.

Lunch (In-situ)

Hydraulically Supported Absorber Balls (HSAB), ISSS Introduction, and General Description by E. R. Specht (AI)

AI described how the HSAB-ISSS assembly and its components function under the PPS and inherent TUC (LOF and TOP) actuation modes. A typical reactor installation schematic and core placement plan view, with 6 ISSS assemblies, were also presented.

Design Requirements, Water Loop Tests and Performance Analysis of HSAB-ISSS by R. K. Paschall (AI)

AI presented the reactor core design and performance parameters. Then the design requirements, including those affecting these parameters, were shown such as the tradeoffs of low ball density to produce a low pressure drop and smooth stacking plus a low flowrate requirement vs a high ball density to produce a shorter drop time. It was pointed out, however, that the system could be tailored to the design requirements, i.e., a larger ball size decreases the drop time to compensate for lower density. In any case, regardless of ball size or density tested, sufficient absorber insertion (10%) takes place in less than 1 second to initiate a turnaround for any incident. Balls tested to date include 1/4 and 3/8-in. diameter balls in both tungsten alloy ($\rho \sim 17 \text{ g/cm}^3$) and stainless steel ($\rho \sim 8 \text{ g/cm}^3$).

The test configuration and results were described for a 48-in. stack of 1/4-in. W-alloy balls (same density as tantalum). Negative reactivity inserted in the first second was 33% with 100% inserted in 3 seconds after top flow shutoff valve trip.

It was pointed out that the top shutoff test valve was presently designed to drop (close) inherently at 45% of lifting flow on a ΔP basis across an orifice plate. The orificing could be designed to cause valve closure over a wide range of differential pressures (near 20% of lifting flow to 60% lifting flow). This valve can easily be made to function with use of the temperature sensitive (Curie Point) electromagnet as in the case of the ISSS-ACA except that the magnetic holding power requirements are much lower in the valve closure case.

The lower self-lifting test plug was presently designed to drop out at 40% flow which is 5% lower than the upper shutoff valve to preclude a premature drop. However, it has been experimentally shown that even if the lower self-lifting plug is opened before the top valve is closed, the absorber ball column will not drop into the core zone.

RRT stated that the full-sized water loop plexiglas hex column mocks up everything. The ISSS system will always protect against an LOF incident. RRT also stated that the so-called top shutoff valve is nothing more than a cap and the lower self-lifting plug is merely a plug with a flange to create lift from surrounding flow.

AI described the pickup and electronic network used in the experimental acoustic detection of ball position. It was pointed out that the detection probe only needed physical contact against the internal SS hex sleeve installed inside the plastic hex housing in the ball travel zone. Excellent and

comparable acoustic resolution was obtained whether the acoustic pickup was installed at a position 6 inches or 60 inches (on a 3/8 in. steel rod) from the point of contact with the SS housing. A strong signal was obtained (even though off by a factor of 3) when the pickup rod was pulled away from contact by 1/8-in. In all of these tests, the low frequency background noise was filtered out.

The impacting hammer type of sonic generator was described briefly.

A 3-minute movie was shown of the 48-in. W-alloy ball column in several lift and drop sequences and of the sonic hammer in operation (or silence) as a function of the physical position of the ball column.

Operation with N-1 loops was described to be readily accommodated by design options and/or plant design considerations for the ISSS. For example, incorporation of the simple bypass flow eductor (ejector) can improve pumping power to achieve an 8-10 psi reduction in ΔP . Lifting at 50% flow was examined for specific reactor designs. In test, it was determined that a 42-in. column of SS balls could be stacked at a 20 psi ΔP , and a 42-in. column of W-alloy balls at 45 psi ΔP (all 1/4-in. diameter). A similar B₄C ball column can probably be stacked at a 10 psi ΔP .

RRT reiterated that the design manager has many options at his disposal. Testing has shown that for specific input actions (conditions), predictable and repeatable reactions have been obtained.

Predictions were presented (Table) of critical NPSH and power required for the inducer pump at various operating conditions, i.e., 4 pumps at 100%, 1 pump locked, and 3 pumps at 100/120%, and 1 pump removed with 3 pumps at 100/120%.

Viewgraphs were shown as to how the HSAB-ISSS meets both the functional and design requirements.

Present and future HSAB-ISSS test programs were outlined and the water loop performance parametric test data and systems analyses were described in detail.

Testing with ball channel distortion inserts (27% and 40% blockage) was described to have very little effect on ball column performance. Even with a 40% blockage, the ball drop time was only increased by about 1/3 from 2.9 to 4.2 seconds.

Mr. G. D. Baston (EPRI) asked about the tolerances on the balls being used. He said there was some Hanford data on particles jamming in hoppers.

AI pointed out that in all the tests conducted over a 1-year period, there has never been any indication of jamming possibilities. The balls being used having the loosest tolerances are the W-alloy balls (as pressed, sintered, and burnished) with a dimetral tolerance of ± 0.003 inches in both the 1/4-in. and 3/8-in. sizes. These balls all have a slight circumferential pressing die ridge on them which still falls into the tolerance range. The Type 302 stainless steel balls are AFBMA Standard Grade 100 (± 0.0001) and Grade 200 (± 0.0002) in the 1/4 and 3/8-in. sizes, respectively. The wide difference in the tolerances between W-alloy and SS was selected to see if there were any differences in ball stacking and dropout behavior. None were apparent. AI would check into the Hanford data on the hopper problem.

A more detailed description was given of the hammer type of sonic generator. It was shown that the hammer impact frequency varied directly with pressure drop in the hammer probe tube zone (core zone). Therefore, one could tell how many inches of balls were

in or out of the core. Postulated abnormal stack conditions were experimentally simulated and the sonic hammer would sound off appropriately. The postulated conditions were achieved by putting in different levels of too many balls to cover the upper end region of the hammer probe tube. In the present configuration, the hammer is designed to sound off at a ΔP of 3 psi.

Dr. Chung (AI) stated that the spring tang used in the present design was not necessary and that a hinged link could be used.

Marty Cooper (W-ARD) said that a sensitivity analysis was needed for materials property changes.

Mr. Stan Davies (GE) asked what the maintenance and test cycles were. He thought we should demonstrate that the balls will never jam.

RRT agreed and thought we should build a case on system understanding.

Mr. G. D. Baston (EPRI) said that we must always physically know where the balls are.

Marty Cooper (WARD) stated that FFTF requires an interlock signal to say the balls are out before the primaries can be pulled.

R. T. Lancet (AI) said we might be able to use the inherent ball characteristics in 1 measure or 2 measures. For example, an exit flowmeter could provide adequate assurance for an interlock signal after sufficient testing. He said a systematic systems examination was required. The present reference design does contain an eddy current exit flowmeter.

Mr. G. D. Baston (EPRI) explained that it may be necessary to operate at 25% power due to steam system conditions in the IHX.

Because of time limitations, AI moved the discussion to materials property testing. Samples of Ta, T-111, and coated Ta absorber ball materials have been received and are ready for test in a small sodium loop at ETEC. The AI Metallurgy Department is currently examining a low density $\text{Eu}_2\text{O}_3/\text{Ni}$ cermet ($\rho \sim 8 \text{ g/cm}^3$) for use as absorber balls.

The discussion then moved on to reactor transient analyses, i.e., pressure drop, pressure distribution, dropping ball location (insertion rate), negative reactivity insertion rates, and transient reactor performance (30¢ step SSE + LOF and 5¢/sec TOP and LOF).

Mr. Stan Davies commented that it appears two sets of new technology problems will be carried into the plant design, namely, inexperience with the Curie Point magnet and the absorber balls.

Description of the HSAB-ISSS by A. S. Jackola (AI)

AI presented the HSAB-ISSS reference design to the meeting participants. The inlet sodium flow routes were described which included the ball column flow, bypass tube flow, the central fuel tube channel flow, and the recombining of the bypass tube flow with the ball column flow through the pressure recovery flow eductor above the bypass tube. The bottom self-lifting plug, top flow shutoff cap, and temperature sensitive electromagnet functions were described relative to the absorber ball column performance status at any given time in fluidization, stacking and/or dropout.

Mr. G. D. Baston (EPRI) said that the upper dropout weight (between electromagnet and flow shutoff cap) was too long and

could create jamming possibilities. It was pointed out that it could be much shorter and still achieve the dropping weight required.

Mr. Stan Davies (GE) had reservations about having a single outer element wall in the ball travel zone.

New Inherent Actuator Development (ISSS-FC) by H. S. Bailey (GE)

GE introduced their ISSS programs and new inherent actuator development program.

ISSS-FC Development by W. A. Brummond (GE)

GE presented the fluidic control (FC)-ISSS schematics, as to position, in a plant startup sequence and modes of operation. The fluid (sodium) lifted absorber assembly is an absorber-filled cylindrical housing that slides up and down in the control element housing. Its vertical position is determined by flow diversion switching in a fluidic valve at the bottom of the assembly.

A mono-stable fluidic valve was described, in which the flow could be switched from clinging to either of two fluidic channel walls (circuits) on the basis of positive, zero, or negative pressure in an adjacent plenum. Negative pressure diverts the flow upward.

An improved bi-stable fluidic valve was shown where a separate injection to the flow switching point would divert the flow upward. Then, when the adjacent plenum pressure returns to zero or positive, the flow switches to a downward direction.

An ISSS-FC water loop test installation was described for testing the Bi-stable diverter valve with an absorber column housing and simulated absorber assembly (weighted slug). Parameters for the initial tests (static, dynamic, and flow) were also described.

Summary by A. C. Millunzi (RRT)

RRT stated that, in the ISSS effort, the functional requirements for safety are based on the PLBR design and there is not much difference between all 3 plants (AI, GE, and W-ARD). A consideration was that we would only need 2 systems.

It was decided to pursue the hydraulically supported absorber balls and the articulated absorber after an exhaustive search and brainstorming of inherent shutdown systems.

Where no design details were available from the PLBR, the GE 1200 MW design was used. The CRBR design restrictions are more severe than the PLBR.

A careful safety analysis was done where we looked at the possible accidents. It looked like the biggest problem was the electro-magnet with the Curie Point magnet. Potential failure modes were looked into. We have to be able to convince ourselves that the Curie magnet is heated soon enough. RRT is confident with the electromagnet if W-ARD has solved the wiring problem. How fast is the roller nut? RRT feels that the absorber ball system can meet the functional requirements when the questions of materials compatibility (in sodium) and ball position are answered.

In reactor transients, the slower the transient, the better the electromagnet/Curie Point magnet will work and large plants have slow transients.

We are talking about 2 systems. ETEC testing will make that determination. As a result, licensing could become much easier.

RRT states that the ISSS systems have been discussed around the world. The absorber balls system has more appeal on an emotional basis.

The ISSS (ISCD) participants are to have a close interaction with large projects, now particularly with CDS. If necessary, we will rewrite the functional requirements or change them as needed. We do not want to drive the large plant design program.

RRT said we do not solve problems with things that appear gimmicky and that is the first impression obtained from the sonic hammer description.

RRT commented that the ISSS program participants have done a good job on relatively little money.

GE asked about the reliability connection to the ISSS designs.

RRT felt that, thus far, it has been too early to turn Reliability loose on them.

Mr. Stan Davies (GE) thinks the balls and articulated absorbers will scram; however, "what is the penalty on availability?" That is how the actual choices are made.

Mr. G. D. Baston (EPRI) asked, "why not hook the ISS up to the primary system?"

Mr. Stan Davies (GE) said the SCRS is 5 years ahead of the inherent systems in development.

RRT disagreed and said, "not really that far." From a scheduling standpoint, the ISSS has plenty of time.

Mr. J. F. Wett (W-ARD) feels that the ISSS will only have proof-of-principal in the next two years.

RRT disagreed.

Introduction to ISSS Development Program Review by R. T. Lancet (AI)

AI introduced the subject matter.

ISSS Development Program Review by J. Hartung (AI)

After presenting the shutdown system reliability criterion, AI went into the reliability analysis and safety requirements.

The results showed, for a criterion of 3×10^{-6} mean failures/reactor year, reliability improvements were needed in the areas of the initiating events of TUC pump coastdown, seismic, and significant distortion in the upper internals or core (other than seismic).

It was shown that the ISSS might have the capability to improve reliability in the 3 areas needed, among other options, but was definitely the preferred option for the TUC pump coastdown.

Safety requirements were presented and followed by recommendations for the ISSS Development Program.

RRT was very pleased with the presentation.

RRT reiterated to the design managers, "Don't tell us it can't be done - tell us what you need."

RRT also stated that the inherent system must not devalue the PPS system.

Adjourned.

ETEC, SANTA SUSANA FIELD LABORATORIES
NOVEMBER 8, 1978 (a.m.)

Assembly

All meeting participants met at the Main Lobby at AI (De Soto) and proceeded to the HTF at Santa Susana.

HTF Tour - HSAB Water Loop Test

Several lifts and drops were shown of a 43-in. stack of 1/4-in. diameter tungsten alloy balls. The functions of the top flow shutoff cap, the lower self-lifting plug, and the sonic hammer were also visible through the plexiglas hexagonal housing. The somewhat slower drop time was shown when the bottom self-lifting plug was held closed at ball dropout. In this test configuration, it was demonstrated that the inlet flow could be reduced to 33% of lifting flow without ball dropout. Also, an ultrasonic method of determining ball position was demonstrated. During discussions, it was pointed out that the balls have never jammed during the 15-month test period, when removing them from the test assembly through a hole having only 10% of the area of the ball column channel. This opening results as a comparison of the 1-7/8-in. bottom bung on the side of the test assembly compared to the net cross-sectional area inside the 5.75-in. (across flats) ball column hex. Whenever the bottom bung was opened, all of the balls had to be removed (because of inability to stop their flow) before the bung could be closed.

ISSS-ACA Briefing at Building 038 Conference Room by Dr. H. Zweig
ETEC

ETEC described the ACA test assembly being installed in Building 032 Santa Susana, and also went over the system P&I diagram.

ISSS-ACA Test Facility Tour of Building 032, Santa Susana

The sodium loop installation for the ISSS-ACA was nearing completion. The external insulation work was almost done, and the upper internal (gas zone) ACA operating mechanisms were being installed.

Adjournment for Large LMFBR Design Managers

STATUS AND DEVELOPMENT PLANS FOR ISSS
NOVEMBER 8, 1978 (p.m.)
BUILDING 038 CONFERENCE ROOM, ETEC

Introduction by A. C. Millunzi (RRT)

RRT brought up the following areas to be improved on when talking to LMFBR designers:

1. Concentrate on engineering, in addition to research effort.
2. Should update our previous evaluations and conclusions as to what the large plant systems designers want in the way of objectives and functional requirements.
3. Should have dry runs for presentations. We will become more and more visible as time goes on to more and more diverse groups.
4. Get a handle on what incentives there are for reactor designers to incorporate the ISSS into their designs.
5. In all questioning, the ISSS systems provide protection for both TOP and LOF incidents. There are two backup positions:
 - a) less risk
 - b) in the event that control rods cannot provide everything, the ISSS is a good backup.

RRT commented that we should concentrate on making the balls system simple and solid.

Status and Plans for New Inherent Actuator Development
by W. A. Brummong (GE)

GE presented their future ISSS-FC work necessary to qualify as a design for large reactors. They also discussed their test manager role for the ISSS-ACA at ETEC.

Status and Plans for Articulated Absorber ISSS by Marty Cooper
(W-ARD)

W-ARD presented their past and future program schedules and milestones. In discussion, W-ARD stated that they are starting an analysis of the pin flow (hot injection) mixing problem.

RRT stated they should be careful in not conducting too detailed an analysis. He would discuss it further with Cooper and the analyst.

Differences in some number values, between W-ARD and AI, came up in transient calculations. RRT asked AI and W-ARD to get together on their numbers.

W-ARD stated that they had a seismic water and sodium loop available for testing the ISSS. They stated that the ISSS-ACA temperature sensitive electromagnet was designed not to shake off in a 0.4 g earthquake. W-ARD is still working on coil optimization.

W-ARD said they had submitted an AIP for in-pile testing of the ISSS-ACA in the FFTF at Hanford. However, it was bogged down at Hanford, awaiting a W-ARD test design concept.

RRT is going to look into the situation.

The script for the audiovisual ISSS presentation is being worked on.

Status and Plans for Absorber Balls by R. K. Paschall (AI)

RRT asked if bigger balls are better relative to channel blockage.

AI stated that they are within limits and that they drop faster. In any case, the first balls are inserted in less than a second regardless of the size and density tested to date, and that 17% of the reactivity is within 0.5 seconds.

The postulated abnormal stacking tests were described and discussed.

It was stated that the ball loading, into an ISSS shutdown assembly, had to be fairly accurate to maintain the proper stacking relationship to the bypass flow tube perforations. Several methods of verification were discussed.

Concluding Remarks by A. C. Millunzi (RRT)

RRT stated that we need to develop a performance envelope package of ISSS capabilities and limitations. Define where the HSAB-ISSS system starts to develop problems for each of the many possible configurations. The performance package is to include tables, curves, and other data in designers language.

The ISSS designers would have more frequent meetings in the future, many of which would be at Germantown. Mr. Al Opdenecher is joining RRT on this program.

We are to concentrate on ISSS system design work.

AI is to get wear tests on the balls.

In looking at the absorber ball water loop test, RRT observed a vibration at the lower end of the dropping weight for the top valve. It was explained that some of the less critical components were looser boiler-plate type hardware.

RRT wants a comprehensive list of design questions to be answered, i.e., materials development, component design considerations, future testing, and so forth.

APPENDIX A

PROGRAM REVIEW OF WARD
LOA TASKS

PRESENTATION AT PROGRAM REVIEW OF
WARD LOA TASKS

at

Atomics International
Canoga Park, California

November 7, 1978

and

Energy Technology Engineering Center
Chatsworth, California

November 8, 1978

R. B. Tupper
M. H. Cooper

WESTINGHOUSE ELECTRIC CORPORATION
Advanced Reactors Division
Madison, Pennsylvania 15663

CONTENTS

November 7, 1978

- I. Functional Requirements
- II. Description of ISSS-ACA
- III. Development Tests
 - A. Argon Tests of Magnet
 - B. Sodium Tests of Magnet
 - C. Test Unit

November 8, 1978

- IV. FY-78 Schedule Status
- V. FY-79 Schedule
- VI. Westinghouse Supported Effort
 - A. Coil Optimization
 - B. Audio-Visual

I. Functional Requirements

GENERAL FUNCTIONAL REQUIREMENTS

- **SECONDARY MODE — PROTECT PLANT AND PUBLIC**
- **INHERENT MODE — PROTECT PUBLIC (PLANT AS GOAL)**
- **TESTABLE IN-SITU (EXCEPT NATURAL PHENOMENA)**
- **RESETTABLE IN SECONDARY AND INHERENT MODE**
- **REPLACEABLE WITH REFUELING SYSTEM**
- **NO EFFECT (GREATER THAN 2 HR DURING STARTUP) ON PLANT AVAILABILITY**
- **NO EFFECT ON PLANT PERFORMANCE**
- **OPERATE OVER FLOW RANGE OF 50% TO 100% FULL REACTOR FLOW**
- **ALL COMPONENTS MUST FIT IN CONTROL ASSEMBLY DUCT AND DRIVELINE SPACE ENVELOPE**
- **DESIGN LIFE**
 - **CRDM — 40 YRS**
 - **DRIVELINE — TBD**
 - **ABSORBER — ONE REFUELING CYCLE**
- **POSITION LOCATING SYSTEM WITH INTERLOCK**
- **INDEPENDENT OPERATION**

FUNCTIONAL REQUIREMENTS FOR SECONDARY AND INHERENT SECONDARY SHUTDOWN SYSTEMS

PLANT CONDITION	SHUTDOWN SYSTEM	DAMAGE SEVERITY	GENERAL REQUIREMENT	SPECIFIC REQUIREMENTS		
				MAX. CLAD TEMP. °F, °C (HOT CHANNEL)	MAX. NA TEMP. (HOT CHANNEL)	MAX. AREAL MELTING (PEAK ROD)
ANTICIPATED EVENT (WITH FAILURE OF PRIMARY SHUTDOWN SYSTEM)	SECONDARY	MINOR INCIDENT	LIMITED DAMAGE	1600 (871)		10
UNLIKELY EVENT (WITH FAILURE OF PRIMARY SHUTDOWN SYSTEMS)	SECONDARY	MAJOR INCIDENT	MAINTAIN COOLABLE GEOMETRY	2475 (1357)	< NA BOILING AT CORE OUTLET	30
EXTREMELY UNLIKELY EVENT (WITH FAILURE OF PRIMARY SHUTDOWN SYSTEM ⁽¹⁾)	SECONDARY	MAJOR INCIDENT	MAINTAIN COOLABLE GEOMETRY	2475 (1357)	< NA BOILING AT CORE OUTLET	30
BEYOND DESIGN BASIS EVENT (ANY PRECEDING EVENT WITH FAILURE OF BOTH PRIMARY AND SECONDARY SHUTDOWN SYSTEMS)	SECONDARY IN INHERENT MODE	MAJOR INCIDENT	MAINTAIN COOLABLE GEOMETRY	2475 (1357)	< NA BOILING AT CORE OUTLET	30

(1) THIS EVENT IS LIMITED TO THE SAFE SHUTDOWN EARTHQUAKE FOR THIS PROGRAM

BOUNDING EVENTS

	ANTICIPATED INITIATING EVENTS		UNLIKELY INITIATING EVENTS	
	TOP	TUC	TOP	TUC
SECONDARY SYSTEM	2¢/SEC*	CRBRP FLOW COASTDOWN	5¢/SEC*	SSE (LOF + 30¢ STEP)
SECONDARY IN SELF- ACTUATED MODE OR TERTIARY SYSTEM	2¢/SEC*	CRBRP FLOW COASTDOWN	5¢/SEC*	SSE (LOF + 30¢ STEP)

***WITH FLOW COASTDOWN INITIATED AT PRIMARY SYSTEM TRIP POINT**

DESIGN GUIDES FOR INHERENT SECONDARY SHUTDOWN SYSTEM⁽¹⁾

	<u>LOF EVENT</u>	<u>TOP EVENT</u>	<u>SSE EVENT⁽⁴⁾</u>
REACTIVITY REQUIREMENT	\$4.50	\$5.50	\$5.50
<u>SECONDARY SHUTDOWN MODE</u>			
BEGIN INSERTION OF NEG. K	2.8 SEC	9.2 SEC ⁽²⁾	2.8 SEC
<u>SELF-ACTUATED SECONDARY SYSTEM</u>	<u>FLOW, %</u> <u>TIME, SEC</u>	<u>FLOW, %⁽³⁾</u> <u>TIME, SEC⁽³⁾</u>	<u>FLOW, %</u> <u>TIME, SEC⁽³⁾</u>
CRBRP COASTDOWN	50 4.5	63 5.2	63 2.7

(1) BASED ON 5-SEC INSERTION TIME, HOT CHANNEL TEMPERATURE, 1050°F AVERAGE CORE EXIT TEMPERATURE, AND ZERO SAFETY MARGIN.

(2) TOP (2¢/SEC) WITH LOF DELAYED BY 7.5 SEC BASED ON A PRIMARY SHUTDOWN SYSTEM TRIP POINT OF 115% POWER.

(3) TOP (5¢/SEC) WITH LOF DELAY BY 2.5 SEC BASED ON A PRIMARY SHUTDOWN SYSTEM TRIP POINT OF 115% POWER

(4) LOF PLUS 30¢ STEP REACTIVITY INSERTION

MAXIMUM COOLANT TEMPERATURES FOR NSCRAMMED 30¢ STEP REACTIVITY INSERTION WITH LOSS OF FLOW

PERFORMANCE ESTIMATE-ELECTROMAGNETIC SYSTEM LOSS-OF-FLOW PLUS 30¢ REACTIVITY STEP (SSE)

	<u>EXTENDED COASTDOWN</u>		<u>CRBRP COASTDOWN</u>	
<u>TIME FOR Na TO REACH 1050°F (AVG CHANNEL), SEC</u>	1.5		1.0	
<u>TRANSPORT LAG, SEC</u>	1.0		1.0	
<u>HEATING LAG, SEC</u>	0.5		0.5	
TOTAL TIME LAG, SEC	3.0		2.5	
FLOW AT INSERTION, %	77		65	
	1-SEC INSERT	5-SEC INSERT	1-SEC INSERT	5-SEC INSERT
<u>HOT CHANNEL</u>				
REQUIRED START OF INSERTION	60%, 6.0 SEC	64%, 5.2 SEC	57%, 3.3 SEC	62%, 2.8 SEC
FLOW MARGIN, %	17	13	8	3
TIME MARGIN, SEC	3.0	2.2	0.8	0.3
<u>PEAK CHANNEL</u>				
REQUIRED START OF INSERTION	49%, 9.0 SEC	52%, 8.4 SEC	45%, 4.9 SEC	50%, 4.2 SEC
FLOW MARGIN, %	28	25	20	15
TIME MARGIN, SEC	6.0	5.4	2.2	1.7

TABLE III

SUMMARY OF ESTIMATED PERFORMANCE OF ELECTROMAGNETIC SYSTEM IN PROTECTING HOT CHANNEL

<u>ACCIDENT</u>	<u>EXTENDED COASTDOWN</u>			<u>CRBR COASTDOWN</u>		
	<u>ESTIMATED INSERTION</u>	<u>MARGIN</u>		<u>ESTIMATED INSERTION</u>	<u>MARGIN</u>	
		1-SEC	5-SEC		1-SEC	5-SEC
<u>LOF:</u>						
FLOW	63%	19%	18%	55%	12.5%	10%
TIME	5.3 SEC	5.7 SEC	5.2 SEC	3.5 SEC	1.9 SEC	1.4 SEC
<u>TOP</u>						
TIME	8.5 SEC	0.7 SEC	0.1 SEC	8.5 SEC	0.7 SEC	0.1 SEC
<u>LOF + TOP (5c/SEC):</u>						
FLOW	67%	10.5%	8.5%	55%	5.5%	2.5%
TIME	4.7 SEC	2.1 SEC	1.7 SEC	3.5 SEC	0.7 SEC	0.3 SEC
<u>LOF + 30c STEP</u>						
FLOW	77%	17%	13%	65%	8%	3%
TIME	3.0 SEC	3.0 SEC	2.2 SEC	2.5 SEC	0.8 SEC	0.3 SEC

II. Description of ISSS-ACA

ARTICULATED CONTROL ASSEMBLY FBR PROTOTYPE

ARTICULATED CONTROL ASSEMBLY CROSS SECTION

MIDDLE ABSORBER ASSEMBLY

DASH POT ASSEMBLY

MAGNETIC SATURATION FLUX FOR NICKEL-IRON ALLOY vs TEMPERATURE

NICKEL-IRON FLUX CONDUCTOR, TEST UNIT I

III. Development Tests

APPARATUS FOR TESTING ELECTROMAGNET IN ARGON

BREAKAWAY FORCE vs TEMPERATURE, TEST UNIT II

EFFECT OF 0.003 INCH NON-MAGNETIC SHIM AT 950°F

<u>CURRENT, AMPERE</u>	<u>WITH SHIM, LB</u>	<u>WITHOUT SHIM, LB.</u>	<u>% DECREASE</u>
0.5	61 ⁺⁴ ₋₃	93 ± 3	34
1.0	142 ⁺¹ ₋₂	187 ± 2	24
1.5	181 ⁺⁶ ₋₂	230 ⁺¹ ₋₂	21
2.0	206 ⁺⁰ ₋₁	256 ⁺⁰ ₋₁	19
2.5	222 ⁺¹ ₋₂	269 ± 1	17
3.0	229 ⁺⁰ ₋₁	277 ± 0	17

BREAKAWAY FORCE vs MAGNET CURRENT FOR TEST UNITS I AND II

COMPARISON OF BREAKAWAY FORCES IN ARGON AND SODIUM, TEST UNIT II

BREAKAWAY TEMPERATURES AT 125 LB. LOAD AND 1.0 AMPERE

<u>RUN</u>	<u>T_{BREAK}, °F</u>	<u>R, OHMS</u>
1	1045	18.8
2	1048	18.1
3	1049	19.2
4	1049	19.4
5	1044	19.4

$$\bar{T} = 1047^{\circ}\text{F}$$

$$\sigma = 2.3^{\circ}\text{F}$$

$$\bar{T}_{\text{BREAK}} = 1047 \pm 4.6^{\circ}\text{F WITH 95\% CONF. LIMITS}$$

BREAKAWAY TEMPERATURES AT 125 LB. LOAD AND 1.2 AMPERES

<u>RUN</u>	<u>T_{BREAK}, °F</u>	<u>R, OHMS</u>
1	1044	18.2
2	1044	16
3	1036	16
4	1044	17.2
5	1045	17.3

$$\bar{T} = 1043^{\circ}\text{F}$$

$$\sigma = 3.7^{\circ}\text{F}$$

$$\hat{T} = 1043 \pm 7.2^{\circ}\text{F WITH 95\% CONF. LIMITS}$$

TEMPERATURE-SENSITIVE MAGNET THERMAL ANALYSIS MODEL

TEMPERATURE SENSITIVE MAGNET MODEL

MATERIAL AVG. TEMP. °F

Ni-Fe 1078

SODIUM 1035

STEEL 993

CROLOY 977

NODE #

TEMP (°F)

TIME = 9.0 SEC

AVG. TEMP = 1055.1°F

HOT SODIUM = 1100.0°F

COLD SODIUM = 850.0°F

GPM = 12.5

82.5% OF Ni-Fe AT 1050°F OR GREATER

TEMPERATURE SENSITIVE MAGNET PREDICTED CORNER THERMOCOUPLE TEMPERATURE RESPONSES

THEORETICAL ALLOWABLE BOW RADIAL TUBE OVALITY

INSERTION DISTANCE vs TIME AFTER RELEASE OF ARTICULATED ROD ASSEMBLY

CONCLUSIONS FROM ARGON TESTS

- **INCREASING THE NICKEL-IRON CROSS-SECTIONAL AREA IMPROVED SYSTEM PERFORMANCE**
- **COIL CURRENT OF 1.0 AMPERE SELECTED FOR ISSS-ACA TEST AT ETEC**
- **MARGIN AT 1.0 AMPERE IS 60 LB**
 - **SUFFICIENT FOR 0.003-INCH PARAMAGNETIC PARTICULATES AT PARTING PLANE**
 - **SUFFICIENT TO OVERCOME FRICTION FORCES DURING WITHDRAWAL**
 - **SUFFICIENT FOR SEISMIC LOADS**
- **FORCE REDUCTION AT 1050°F WILL CAUSE RELEASE OF ABSORBER**

CONCLUSIONS FROM SODIUM TESTS

- **PERFORMANCE OF ELECTROMAGNET IS NOT SIGNIFICANTLY AFFECTED BY SODIUM**
- **BREAKAWAY FORCES COMPARE FAVORABLY WITH THOSE MEASURED IN ARGON**
- **INHERENT RELEASE OF A 125 LB LOAD AT 1.0 AMPERE WAS DEMONSTRATED WITHIN THE DESIGN TEMPERATURE RANGE (i.e., $1020^{\circ}\text{F} > T_{\text{RELEASE}} < 1050^{\circ}\text{F}$)**
- **INHERENT RELEASE TEMPERATURE IS REPEATABLE**
- **AVERAGE INHERENT RELEASE DATA IN ARGON IS AFFECTED BY TEMPERATURE GRADIENTS**
- **SHORT CIRCUIT IN THE COIL WAS MECHANICAL, AND NOT RELATED TO SODIUM**
- **MODIFICATIONS HAVE BEEN MADE IN SUBSEQUENT COIL TO ELIMINATE POTENTIAL SHORT CIRCUITS**

OBJECTIVES OF ETEC TESTS

- **DEMONSTRATE THE MAGNET LATCH FEASIBILITY**
- **MEASURE DRAG FORCES DURING ROD WITHDRAWAL**
- **DETERMINE HEX ALLOY RESPONSE TO STEADY STATE AND TRANSIENT NA TEMPERATURES**
- **MEASURE THE DROP TIME OF ASSEMBLY FOR NORMAL SCRAM**
- **CONFIRM THE ABILITY OF SYSTEM TO WITHSTAND LONG TERM DWELL**
- **CONFIRM THE ABILITY OF THE SYSTEM TO OPERATE WITH BOWED DUCT**

BREAKAWAY FORCE vs COIL CURRENT, ISSS-ACA AT ROOM TEMPERATURE

IV. FY-78 Schedule Status

FY-1978 SUBTASK/MILESTONE SCHEDULE

SUBTASK

**ELECTROMAGNETIC
SYSTEM
DEVELOPMENT**

**FLOW DIVERTER
DEVELOPMENT**

**SYSTEM DESIGN/
ANALYSIS**

**ARTICULATED ROD
TEST UNIT
FABRICATION**

MILESTONE KEY

- 1. COMPLETE FABRICATION OF ELECTROMAGNET.**
- 2. COMPLETE TESTING IN ARGON.**
- 2a. COMPLETE TESTING OF MODIFIED UNIT.**
- 3. START SODIUM TESTING OF ELECTROMAGNET.**
- 4. COMPLETE INITIAL SODIUM TESTS OF ELECTROMAGNET.**
- 5. COMPLETE FABRICATION OF FLOW DIVERTER.**
- 6. INSTALL DIVERTER IN WATER LOOP.**
- 7. COMPLETE WATER TESTING.**
- 8. COMPLETE REPORT ON FLOW DIVERTER.**
- 9. COMPLETE CONCEPTUAL DESIGN OF ARTICULATED ROD.**
- 10. COMPLETE DETAILED DESIGN OF ARTICULATED ROD TEST UNIT.**
- 11. COMPLETE ANNUAL SUMMARY REPORT.**
- 12. INITIAL MACHINING OF COMPONENTS.**
- 13. RECEIVE TUBING.**
- 14. COMPLETE AND SHIP TO ETEC.**

V. FY-79 Schedule

FY 1979 MILESTONES

SUBTASK

TEMPERATURE
SENSITIVE MAGNET
DEVELOPMENT

SYSTEM DESIGN
AND ANALYSIS

ISSS-ACA
TEST PROGRAM

IN-PILE PROTOTYPE
TEST DESIGN

MILESTONE KEY

- 1. COMPLETE FABRICATION OF COPPER Na TEST COIL.**
- 2. TEST E-M WITH REPLACEMENT COIL IN SODIUM.**
- 3. ISSUE REPORT ON ARD SODIUM TESTS.**
- 4. COMPLETE Ni-Fe THERMAL ANALYSIS.**
- 5. COMPLETE FUEL PIN THERMAL UNCERTAINTY ANALYSIS.**
- 6. COMPLETE PRELIMINARY DESIGN OF SEISMIC TEST.**
- 7. FOLLOW ISSS-ACA INSTALLATION AT ETEC.**
- 8. FOLLOW ISSS-ACA TEST AT ETEC.**
- 9. EVALUATE ISSS-ACA TEST RESULTS AND PREPARE REPORT.**
- 10. SELECT REACTOR FOR IN-PILE TESTS AND PREPARE PRELIMINARY REQUEST FOR AIP.**
- 11. PREPARE PRELIMINARY DESIGN LAYOUT.**
- 12. COMPLETE PRELIMINARY THERMAL & HYDRAULIC ANALYSIS OF IN-PILE PROTOTYPE.**
- 13. COMPLETE PRELIMINARY STRUCTURAL ANALYSIS OF IN-PILE PROTOTYPE.**

VI. Westinghouse Supported Effort

COIL OPTIMIZATION

- **COMPLETE A COMPARISON OF SILVER PLATED WIRE WITH NICKEL CLAD COPPER FOR USE AS A COIL CONDUCTOR**
- **DETERMINE THE OPTIMUM COIL INSULATION THICKNESS**
- **DETERMINE THE EFFECT OF DIFFERENT FABRICATING PROCEDURES ON COIL INSULATION PERFORMANCE**

APPENDIX B

ISS-ACA TEST PROGRAMS
FOR GE

INHERENTLY SAFE SHUTDOWN DESIGN
STATUS REVIEW MEETING
7 & 8 NOV. 1978

INHERENTLY SAFE SHUTDOWN SYSTEMS
ISSS-ACA TEST PROGRAM

PREPARED BY:

H. S. BAILEY

W. A. BRUMMOND

GENERAL ELECTRIC COMPANY
ADVANCED REACTOR SYSTEMS DEPARTMENT
SUNNYVALE, CALIFORNIA

LARGE LMFBR CONTROL SYSTEM SCHEDULE

CALENDAR YEAR

, 1978 , 1979 , 1980 , 1981 , 1982 , 1983 , 1984 , 1985 , 1986 , 1987 , 1988 , 1989 , 1990 ,

PROJECT MILESTONES

- Establish Safety & Licensing Strategy & Basic Plant Features (LPDS Phase I) Δ————Δ
- Detailed Conceptual Design (LPDS Phase II) Δ————Δ
- Large Plant Project Δ
Decision to Commit to Construction Δ
PSAR Δ
FSAR Δ
Critical Δ

CONTROL SYSTEM DEVELOPMENT

ISSS - LPDS INTEGRATION

- REVIEW FUNCTIONAL REQUIREMENTS FOR LARGE PLANT DESIGN AND SAFETY/LICENSING STRATEGY
 - * SCRAM TIME
 - * SCRAM POINT
 - * REACTIVITY WORTH, NUMBER OF RODS
 - * STARTUP/SHUTDOWN OPERATIONS
 - * SCALE UP EFFECTS
 - * ALTERNATE CORE CONCEPTS
- INCORPORATE SCRS/ISSS INTO LPDS PLANNING AND SAFETY ANALYSIS
- FOCUS ON EARLY 1981 DECISION AND SUPPORTING EXPERIMENTS
 - * MOST DESIRABLE OPTION IS COMBINED SCRS/ISSS WITH DEMONSTRATED PERFORMANCE.

ISSS - INHERENTLY SAFE SHUTDOWN SYSTEM

LPDS - LARGE PLANT DESIGN STUDY

ISSS - ACA TEST PROGRAM SCHEDULE

<u>MILESTONE</u>	<u>DATE</u>	<u>RESPONSIBILITY</u>
A. Issue Preliminary Test Request	2/28/78	WARD
B. Issue Approved Test Request	4/15/78	WARD
C. Issue Program Plan	3/31/78	GE
D. Place Order for Test Article	3/31/78*	WARD*
E. Transmit Test Rig Requirements & P&ID Approval	3/31/78	LMEC
F. Transmit ICD for Approval	3/31/78	WARD
G. Approve Test Req. & P&ID	4/15/78	GE
H. Approve ICD	4/15/78	GE/LMEC
I. Conduct Review of Test Rig Design	5/2/78	LMEC
J. Test Article At Test Site	8/15/78*	WARD*
K. Complete Test Rig Construction	10/1/78	LMEC
L. Complete Test Rig Shakedown and Initiate Test Program	10/15/78	LMEC
M. Complete Test Program	4/30/79	LMEC
N. LMEC Data Report	6/30/79	LMEC
O. Issue Test Program Final Report	7/31/79**	GE
P. Issue final Performance and Post Test Ex. Evaluation Report	9/30/79	WARD

* Subject to DOE approval of test article procurement by 3/31/78.

**Excludes performance evaluation & post test examination.

	<u>Tests</u>	<u>Time Estimate (Weeks)</u>
1. Instrumentation Checkout and Calibration	--	2
2. Facility Checkout and Preheat	--	2
3. Sodium Fill and Cleaning	--	2
4. Heatup & Injection Checkout 6 Tests @ 3 Injections/Test	18	2
5. Pretest Characterization		
A. Withdrawal Drag Force	1 (New)	
B. Preload Requirement	5 (New)	
C. Temperature Sensitive Alloy Thermal Characteristics	1	2
D. Drop Current	10* (New)	
6. Inherent Release	10* (5 New)	1.5
7. Drop Time & Withdrawal Loads	25	1
8. Dwell Test	1	6 Months
9. Post-Dwell Inherent Release	5*	1.5
10. Post-Dwell Drop Time & Withdrawal Loads	25	1
11. Test Article Bowing Operation	--	1.5
12. Bowed Duct (0.5 inch) Drop Time & Withdrawal Loads	25	1
13. Test Article Bowing Operation	--	1.5
14. Bowed Duct (0.75 inch) Drop Time & Withdrawal Loads	25	1
15. Sodium Drain, Cleaning, Disassembly and Shipping of ISSS-ACA Test Components	--	4

* Minimum Time Between Tests: Approximately 3 Hours.

PLANT START-UP SEQUENCE

MODES OF OPERATION

CONTROL ROOM

SET

SECONDARY

TOP

LOF

$\frac{LP}{P}$

FALSE RECOVERY

MONO-STABLE

BI-STABLE

32 FT-0.00

16 FT-6.00

7 FT-0.00

0 FT-0.00

DECK

DECK

EXPERIMENT
SUPPORT

4.00 DRAIN

WEIGHTED
SLUG

WATER
COLUMN

DASH POT

DIVERTER
VALVE

1000 GAL
TANK

220V 1Ø
CONTROL
PUMP

440 V 3Ø
MAIN PUMP

WATER TEST LOOP
ISSS-FC

PARAMETERS FOR INITIAL TESTSSTATIC TESTS

VARY: GAP, PLUGHOLE, WEIGHT

MEASURE: TIME

DYNAMIC TESTS

VARY: GAP, PLUGHOLE, WEIGHT

MEASURE: FLOW RATE, ΔP

FLOW TESTS

VARY: GAP, PLUGHOLE, WEIGHT, FLOW RATE

MEASURE: INSERTION TIME

FUTURE WORK TO QUALIFY AS DESIGN FOR LARGE REACTOR

- WATER LOOP TESTS
- VALVE EROSION AND FOULING TESTS
- SENSOR DEVELOPMENT
- POSITION VERIFICATION
- SYSTEM TEST - FULL SCALE
- CONTINUING REVIEW OF LARGE PLANT CONSTRAINTS REQUIREMENTS

FY 79

APPENDIX C

AI PROGRAM REVIEW OF
HYDRAULICALLY SUPPORTED NEUTRON ABSORBER BALLS ISSS

ATOMICS INTERNATIONAL
INHERENTLY SAFE CORE DESIGN PRESENTATION

STATUS REPORT

HYDRAULICALLY SUPPORTED NEUTRON ABSORBER BALLS
INHERENT SECONDARY SHUTDOWN SYSTEM (ISSS)
FOR ADVANCED LMFBR'S

NOVEMBER 78, 1978

PREPARED BY:

E. SPECHT
R. PASCHALL
D. CHUNG
A. JACKOLA
L. EYTEL

OUTLINE

SYSTEM DESCRIPTION

DESIGN AND OPERATION

HOW SYSTEM MEETS FUNCTIONAL AND DESIGN REQUIREMENTS

TEST PROGRAM

WATER LOOP HYDRAULIC TESTS COMPLETED

MATERIALS PROPERTY TESTS IN SODIUM INITIATED

SODIUM LOOP HYDRAULIC TESTS BEING PLANNED

IN-REACTOR TESTS BEING INVESTIGATED

ANALYSES

HYDRAULIC PERFORMANCE

REACTOR TRANSIENTS

SCHEDULE

SUMMARY

SYSTEM DESCRIPTION

DESIGN AND OPERATION

SHUTDOWN ASSEMBLY DESIGN AND OPERATION
INCORPORATION IN REACTOR

HOW SYSTEM MEETS REQUIREMENTS

FUNCTIONAL REQUIREMENTS
DESIGN REQUIREMENTS

INHERENT SECONDARY SHUTDOWN SYSTEM (ISSS)

- HAS TWO MODES OF OPERATION
 - 1) ACTUATED BY PLANT PROTECTION SYSTEM (PPS)
 - 2) INHERENTLY SELF-ACTUATED BY TRANSIENT-UNDERCOOLING (LOF OR TOP)

FIGURE 1. TYPICAL ISS REACTOR SCHEMATIC

77-J4-3-7, -8, -9, -10

Figure 2 Bullseye Core Configuration

HYDRAULICALLY SUPPORTED ABSORBER BALLS INHERENT SHUTDOWN ASSEMBLY

Rockwell International
Atomics International Division

9105-3B

TABLE 4-1
REACTOR CORE DESIGN AND PERFORMANCE PARAMETERS

Reactor Power (MWt)	2,600
Reactor Outlet Sodium Temperature ($^{\circ}\text{F}$)	930
Reactor Inlet Sodium Temperature ($^{\circ}\text{F}$)	650
Total Sodium Flow (lb/h)	1.04×10^8
Reactor Pressure Drop — Plenum to Plenum (psi)	87
Total Number of Subassemblies	703
Driver Assembly Data (Cold)	
Pin Pitch/Diameter Ratio	1.20
Cladding OD [in. (mm)]	0.300 (7.6)
Cladding Wall Thickness [in. (mm)]	0.017 (0.43)
Wire Wrap Diameter	
Interior Channels [in. (mm)]	0.060 (1.52)
Edge Channels [in. (mm)]	0.030 (0.76)
Peak Linear Power (kW/ft)	14.1
Average Linear Power (kW/ft)	9.2
Driver Nominal Hot Spot Cladding Temperature ($^{\circ}\text{F}$)	1,067
Maximum Coolant Velocity (ft/s)	24
Temperature Degradation (Annual Blanket Orificing) ($^{\circ}\text{F}$)	34
Heavy Metal Mass (MOEC*) (kg)	
Driver	21,170
Blanket	98,980
Fissile Mass (kg)	
In-Core Inventory (BOEC [†])	4,710
Ex-Core Inventory	1,940
Gain Per Cycle	273
Breeding Ratio (MOEC*)	1.36
Compound System Doubling Time (yr)	19
Burnup Decrement (\$)	10
Sodium Void Worth (EOEC [§])** (\$)	1.76
Driver + Axial Blanket Doppler	
Coefficient (-Tdk/dT)	0.0056
Total Reactor Doppler	
Coefficient (-Tdk/dT)	0.0095

*MOEC Middle of equilibrium cycle

†BOEC Beginning of equilibrium cycle

§EOEC End of equilibrium cycle

**Active core plus axial blanket voided inside duct

DESIGN REQUIREMENTS (AND AFFECTING PARAMETERS)

- LOW PRESSURE DROP AND SMOOTH STACKING
 - . SHORT BYPASS PERFORATION NEAR THE END OF THE STACKED BALLS
 - . SELF-LIFTING BOTTOM VALVE
 - . BYPASS FLOW DIFFUSER FOR PRESSURE RECOVERY
 - . BALLS OF LOW DENSITY
- LOW FLOW RATE
 - . SMALL BALL SIZE
 - . BALLS OF LOW DENSITY
 - . VARIABLE FLOW RESTRICTOR
- SHORT DROP TIME
 - . SELF-LOCKING FLOW CUTOFF VALVE WITH MINIMAL LEAKAGE
 - . SELF-LIFTING BOTTOM VALVE
 - . LARGE BALL SIZE
 - . BALLS OF HIGH DENSITY
- ACCURATE STEPWISE DROPOUT POINT
 - . SELF-ACTUATING FLOW CUTOFF VALVE
 - . CURIE POINT MAGNET CUTOFF VALVE ASSEMBLY
- BALL LOCATION DETECTION
 - . HAMMER SONIC GENERATOR
 - . ACOUSTIC SIGNAL FROM BALL COLLISIONS

HYDRAULICALLY SUPPORTED NEUTRON ABSORBER BALLS
INHERENT SECONDARY SHUTDOWN ASSEMBLY
REFERENCE DESIGN

0.25-IN.-DIAMETER TANTALUM ALLOY BALLS ($\rho \sim 17\text{G}/\text{CM}^3$)

48-IN.-LONG BALL COLUMN

$\Delta P \sim 70$ PSI ACROSS ASSEMBLY

$Q \sim 450$ GPM THROUGH ASSEMBLY

FLOW SHUTOFF VALVE WITH CURIE POINT MAGNET TRIGGER

SELF LIFTING PLUG IN BOTTOM OF BYPASS TUBE

DROP TIME OF BALLS (AFTER FLOW SHUTOFF VALVE CLOSES)

1.0 SEC (FIRST BALLS REACH BOTTOM GRATE)

3.0 SEC (ALL BALLS IN CORE)

NEGATIVE REACTIVITY INSERTION

33% IN FIRST SECOND (33% OF BALLS IN CORE)

100% IN 3.0 SEC

VG MCGRAW
1/21/70

LOCATION OF IMPACTING HAMMER SONIC GENERATOR

OPERATION WITH N-1 LOOPS

READILY ACCOMMODATED BY DESIGN OPTIONS FOR ISSS

BALLS WITH LOWER SPECIFIC GRAVITY

SHORTER STACK LENGTH

FLOW EDUCTOR

POSSIBLE PLANT DESIGN MODIFICATIONS

PHTS CHECK VALVES

INCREASE COVER GAS PRESSURE (TEMPORARY)

OFF-DESIGN PUMP OPERATION (TEMPORARY)

MODIFIED PUMP DESIGN

SEPARATE COOLANT LOOP FOR ISSS

PREDICTION OF CRITICAL NPSH AND POWER REQUIRED
FOR INDUCER PUMP AT VARIOUS OPERATION CONDITIONS

Operation Condition	Reactor Flow (%)	$\Delta P_{\text{reactor}}$ (psi)	ΔP_{pump} (psi) (%)	Speed (%)	(NPSH) _{crit} (ft)	Pump Power (%)
Four Pumps at Design Condition	100	100	116 (100)	100	15.4	100
One Pump Locked and Three Pumps at 100% Flow	58.8	35	45 (39)	62	5.9	39
120%	71	50	64 (55)	78	20	66
One Pump is Removed. Three Pumps at 100%	75	56	68 (59)	76	9	59
or at 120%	90	81	98 (84)	96	28	101

ISSS MEETS FUNCTIONAL REQUIREMENTS

TESTABLE IN-SITU

RESETABLE

NORMAL REPLACEMENT OF ASSEMBLIES

DOES NOT SIGNIFICANTLY AFFECT PLANT AVAILABILITY

DOES NOT DEGRADE PLANT PERFORMANCE

LOCATION OF CONTROL MATERIAL MONITORED

IMPROVES LICENSABILITY

SUFFICIENT WORTH WITH ONE ASSEMBLY INOPERATIVE

INHERENT TRIGGER MODE

ALLOWS REACTOR TO OPERATE BETWEEN 50%-100%

OPERATES DURING APPROACH TO CRITICAL

ISSS MEETS DESIGN REQUIREMENTS

DIVERSE FROM PRIMARY SYSTEM

ACCOMMODATES TOP HEAD ROTATION AND CORE DISTORTION

POSITIONS ABSORBER MATERIAL FULL IN OR FULL OUT

ABSORBER MATERIAL FULLY CONTAINED IN ASSEMBLY

ASSEMBLY REMAINS STRUCTURALLY INTACT

SHUTS DOWN REACTOR IN SSE AND ABSORBER REMAINS IN CORE

ABSORBER REMAINS IN CORE DURING SHUTDOWN

TEST PROGRAM

WATER LOOP HYDRAULIC TESTS COMPLETED

FULL SCALE MOCKUP OF ASSEMBLY
PLASTIC HOUSING FOR VISUAL ANALYSES

MATERIALS PROPERTY TESTS IN SODIUM INITIATED

TEST REQUEST SUBMITTED
CANDIDATE MATERIALS PROCURED
TESTS READY TO COMMENCE

SODIUM LOOP HYDRAULIC TESTS BEING PLANNED

REQUEST FOR "APPROVAL-IN-PRINCIPLE" SUBMITTED
TEST ARTICLE IN DESIGN
TEST REQUEST BEING PREPARED

IN-REACTOR TESTS BEING INVESTIGATED

NEED TO IDENTIFY TEST REQUIREMENTS
POSSIBLE TEST FACILITIES

WATER LOOP HYDRAULIC TESTS

PARAMETRIC TEST DATA AND SYSTEM ANALYSES

PROVIDE SUFFICIENT INFORMATION TO CHANGE SYSTEM DESIGN
TO MEET CHANGING REACTOR DESIGN REQUIREMENTS

FULL SCALE MOCKUP OF SHUTDOWN ASSEMBLY

PLASTIC HOUSING FOR VISUAL ANALYSES

BALLS DROPPED RAPIDLY EVEN WITH LARGE BLOCKAGE IN CHANNEL

POSITION OF BALLS DETERMINED ACOUSTICALLY

MEASURED PARAMETERS

- STACKING BEHAVIOR
- PRESSURE DROP DURING STACKING
- PRESSURE DROP WHEN FULLY STACKED
- STABILITY OF BOTTOM BALLS AT LOW FLOW RATES
- DROPOUT POINT
- DROP TIME
- DROPPING BEHAVIOR (POSITION VS TIME FROM MOVIES)

COMPARISON OF BALL COLUMN PERFORMANCES FOR DIFFERENT LIQUIDS

	TA BALLS	SS BALLS
● PRESSURE DROP AT LIFTING FLOW:		
$\frac{\Delta P_{\text{SODIUM}}}{\Delta P_{\text{WATER}}} = \frac{\rho_{\text{BALL}} - \rho_{\text{SODIUM}}}{\rho_{\text{BALL}} - \rho_{\text{WATER}}}$	1.01	1.02
● LIFTING FLOW:		
$\frac{Q_{\text{SODIUM}}}{Q_{\text{WATER}}} = \sqrt{\frac{\rho_{\text{BALL}} - \rho_{\text{SODIUM}}}{\rho_{\text{BALL}} - \rho_{\text{WATER}}}}$	1.005	1.01
● DROP TIME:		
$\frac{\theta_{\text{SODIUM}}}{\theta_{\text{WATER}}} = \sqrt{\frac{\rho_{\text{BALL}} - \rho_{\text{WATER}}}{\rho_{\text{BALL}} - \rho_{\text{SODIUM}}}}$	0.995	0.99

ABSORBER BALL DROP TIME
WITH BOTTOM PLUG OPEN

STACK LENGTH (IN.)	FREE SPACE LENGTH (IN.)	DROP TIME (SEC)
40	11	3.2
40	5.5	2.8
40	0	2.4
34	0	2.0

EFFECT OF CHANNEL BLOCKAGE (1.75-IN. BYPASS TUBE)

- NO JAMMING WITH CHANNEL-DISTORTION INSERTS
- BALL DROP TIME (TOP VALVE CLOSED, BOTTOM PLUG OPEN, 5.5-IN. FREE SPACE)

2.9 SEC WITH NO CHANNEL BLOCKAGE

3.4 SEC WITH 27% BLOCKAGE

4.2 SEC WITH 40% BLOCKAGE

ART JACKOLA

PREPARED BY,

 NO01TI570038
 Page 106
 Rockwell International

Atomic International Division

S-10000-15

PAGE NO. 9 OF

CHECKED BY,

REPORT NO. NO01TI570028

1-18-78
DATE
 FLUIDIZED ABRASION BALL PLEXIGLAS
 HEX. COLUMN-CHANNEL DISTORTION ASSY.

NO SCALE

MODEL NO.

 DROPABLE WEIGHT/
 TUBULAR VALVE
 RETRACT ASSY.

 VARIABLE ORIFICE
 PLATE.

 TUBULAR FLOW
 SHUTOFF
 VALVE

 UPPER
 GRATE

 CHANNEL
 DISTORTION
 INSERTS
 (1.4 & 1.9
 INCHES DEEP)

 LOWER
 GRATE

 SELF-LIFTING
 BYPASS
 FLOW PLUG

2.5 (REF.)

35.5

20.5

14.0

103.25
(REF.)

40.75

86.25
(REF.)4.75
FREE SP.40.75
PACKED
COLUMN
(WET)

3.0

6.75

21.75

.125

.75

.125

.75

.125

.75

.125

.75

.125

.75

.125

.75

.125

.75

2.0 DROP

24.75

21.0

8.63

57.0

20.75

6.0 DIA. (REF.)

 FLOW
 BYPASS
 TUBE
 (1.75 O.D.
 X 1.61 I.D.
 X 100 IN. LG)

40 % CHANNEL
AREA OBSTRUCTION

27 % CHANNEL
AREA OBSTRUCTION

EFFECT OF CHANNEL BLOCKAGE (2.375-IN. BYPASS TUBE)

NO JAMMING WITH CHANNEL-DISTORTION INSERTS

BALL DROP TIME (0.25-IN.-DIAM TUNGSTEN ALLOY BALLS)

2.9 SEC WITH NO CHANNEL BLOCKAGE

3.3 SEC WITH 30% BLOCKAGE

BALL DROP TIME (0.25-IN.-DIAM SS BALLS)

4.3 SEC WITH NO BLOCKAGE

4.5 SEC WITH 30% BLOCKAGE

BALL DROP TIME (0.375-IN.-DIAM SS BALLS)

3.5 SEC WITH NO BLOCKAGE

3.8 SEC WITH 30% BLOCKAGE

TEST TO REDUCE PRESSURE DROP

OUTER BYPASS TUBES

WINGS ON CENTER BYPASS TUBE

LARGER DIAMETER CENTER BYPASS TUBE

FLOW EDUCTOR ON TOP OF CENTER BYPASS TUBE

BALLS WITH LOWER SPECIFIC GRAVITY

TEST ASSEMBLY
WITH PERIPHERAL FLOW BYPASS TUBES

EFFECTS OF BALL DENSITY

	<u>Tungsten Alloy Balls</u>	<u>SS Balls</u>
Pressure Drop	50 psi	25 psi
Balls Drop Time		
Bottom Plug Open	3 sec	5 sec
Bottom Plug Closed	6 sec	9 sec

EFFECTS OF BALL DIAMETER

	<u>0.25-in. Diam Balls</u>	<u>0.375-in. Diam Balls</u>
Pressure Drop	40 psi	40 psi
Balls Drop Time		
Bottom Plug Open	2.0 sec	1.5 sec
Bottom Plug Closed	2.5 sec	1.8 sec

BALL LOCATION DETECTION WITH
SONIC GENERATOR

PRINCIPLE

- ABNORMAL STACK CONFIGURATION CAUSES PRESSURE DROP ACROSS THE SONIC GENERATOR
- SONIC SIGNAL IS PRODUCED BY PRESSURE DROP ACROSS GENERATOR
- SONIC SIGNAL IS DETECTED BY A ACCELEROMETER (ATTACHED TO THE TOP OF DRIVELINE)

UNCOVERED VIEW OF IMPACTING HAMMER SONIC GENERATOR

CROSS SECTIONAL VIEW OF HAMMER SONIC GENERATOR

IMPACT FREQUENCY vs PRESSURE DROP FOR THE HAMMER SONIC GENERATOR

Rockwell International
Energy Systems Group

IMPACT FREQUENCY vs FLOWRATE

N001T1570038
Page 118

Rockwell International
Energy Systems Group

MEASURED SONIC SIGNAL FREQUENCY vs FLOWRATE THROUGH 3/8 IN.

ADVANTAGES OF HAMMER SONIC GENERATOR
OVER THE JET-EDGE SONIC GENERATOR

- IMPACT FREQUENCY IS FUNCTION OF PRESSURE DROP (QUANTITATIVE SIGNAL)
- PRESSURE DROP BETWEEN TWO LOCATIONS OF LONG DISTANCE CAN BE MEASURED
- SIMPLE RELIABLE OPERATION

COMPARISON OF OBSERVED FREQUENCIES WITH
THEORETICAL VALUES FOR THE END CLAMPED REEDS

THICKNESS OF REED (INCH)	LENGTH OF REED (INCH)	ΔP RANGE (PSI)	OBSERVED FREQUENCY (CPS)	THEORETICAL FREQUENCY CPS
0.031	1.5	4~30	240~268	428
0.062	1.5	5~50	630~640	857
0.083	1.5	4~50	930~940	1150

* WIDTH OF REED WAS 1/2 INCH.

* DISTANCE BETWEEN NOZZLE AND LEADING EDGE OF THE REED WAS 3/16 INCH.

STACK CONFIGURATIONS WHICH INDUCE SONIC SIGNALS

NORMAL INSERTION

$\Delta P = 14$ psi

(40 in. TA BALLS)

SHIFTED STACKING

$\Delta P = 15$ psi

(1 in. TA BALLS)

JAMMED BALLS

$\Delta P = 15$ psi

(1 in. TA BALLS)

Rockwell International
Energy Systems Group

1A. NORMAL STACK (2 110% ΔP_{MIN})

$Q = 503 \text{ GPM}$

1B. PREMATURE STACK

$\geq 470 \text{ GPM}$

NORMAL AND PREMATURE
FIGURE 1. STACK CONFIGURATIONS

DETECT 1B. WITH
ACOUSTIC DETECTOR

TESTS SHOWED THERE WAS
INSUFFICIENT FLOW TO
STACK ALL BALLS ---
SOME BALLS CONSTANTLY
MOVING IN CORE REGION

FIGURE 2. BALLS TRAPPED ON BOTTOM GRATE IN LAYERS
 $> 470 \text{ gpm}$

DETECT WITH
 ACOUSTIC DETECTOR

TESTS SHOWED CONSIDERABLE
 AGITATION AND SWIRLING MOTION
 IN THIS REGION AT THE
 BOTTOM OF THE STACK

SOME BALLS CONSTANTLY
 MOVING IN CORE REGION

FIGURE 3. BALLS JAMMED ON BOTTOM GRATE IN LUMPS

DETECT WITH
FLOW METER AND
POSSIBLY ACOUSTIC
DETECTOR

TESTS SHOWED CONSIDERABLE
AGITATION AND SWIRLING
MOTION IN THIS REGION AT
THE BOTTOM OF THE STACK

FIGURE 5. ACOUSTIC SIGNATURE
ABSORBER BALLS STACKING
(MEDIUM FLOW RAMP-UP)

SMOOTHED ENVELOPE
OF INDIVIDUAL PULSES →

BALLS ARE
FLUIDIZED

PARTIAL
SLUG
FORMS

AGITATION OF
FLUIDIZED BALLS
INCREASES AS
FLOW INCREASES

SLUG AT
TOP GRATE

MOST OF
BALLS ARE
STACKED

INDIVIDUAL PULSES →

RELATIVE TIME (SEC)

10

FLOW HELD

CONSTANT WHILE

REST OF BALLS

GRADUALLY ATTACH TO BOTTOM OF STACK

30

50

70

90

110

RELATIVE TIME (SEC)

FIGURE 6. ACOUSTIC SIGNATURE
ABSORBER BALLS DROPPING

MATERIALS PROPERTY TESTS

- REPORT RELEASED 4/6/78 ON DETAILED INVESTIGATION
- MATERIALS PROPERTY TESTS NEEDED

MATERIALS

TA, T-111, COATED TA, $\text{Eu}_2\text{O}_3/\text{Ni}$ CERMET
NA COOLANT
SS LOOP

CONDITIONS

TEMPERATURE
FLOW RATE
OXYGEN CONCENTRATION
IMPURITIES

PROPERTIES

CORROSION
COATING INTEGRITY TESTS
FRETTING AND WEAR

TEST PARAMETERS

Temperatures (°F)	Oxygen Concentrations in Sodium		
	<2 ppm	5 ppm	20 ppm
700	X	X	X
900	X	X	X

TANTALUM MATERIAL REQUIREMENTS

Coupon or Sample	Material	Note Reference
No. 1	Tantalum-111	6
No. 2	90 Ta - 10 W	6
No. 3	Ta coated with Ta Carbide (TaC)	1, 2, 4, 6
No. 4	Carburized Ta	1, 2, 3, 4, 6
No. 5	Ta-Chromized	1, 2, 3, 4, 6
No. 6	Ta coated with Molybdenum	1, 2, 3, 4, 6
No. 7	Tantalum	1, 6
No. 8	316 Stainless Steel	6
No. 9	Ta-Aluminized	1, 2, 3, 4, 6
No. 10	Er_2O_3 (50%) - Ni(50%) cermet	7
No. 11	Er_2O_3 ceramic	7

Notes:

1. Tantalum is to be EB melted.
2. Vendor to provide composition of reagents and parameters used in the coating process.
3. Chromium, Carbon and Molybdenum is to be 99.9% pure.
4. Coatings are to be 2.5 mils.
5. Coating is to be 15 microns.
6. Manufacturer's certificate of analysis of all substrata materials is required.
7. To be manufactured at ESG.

Coupon 1 - T111

Coupon 2 - 90 Ta - 10 W

Coupon 3 - Ta coated with Ta Carbide

Coupon 4 - Carburized Ta

Coupon 5 - Ta-chromized

Coupon 6 - Ta coated with Molybdenum

Coupon 7 - Tantalum

Coupon 8 - 316 SS

Coupon 9 - Ta Aluminized

Coupon 10 - Er_2O_3 (50%) - Ni(10%) cermet

Figure 1. Tantalum Test Coupons

- Sample 1 - T111
- Sample 2 - 90 Ta - 10 W
- Sample 3 - Ta coated with Ta-Carbide (TaC)
- Sample 4 - Carburized Ta
- Sample 5 - Ta-Chromized
- Sample 6 - Ta coated with Molybdenum
- Sample 7 - Tantalum
- Sample 8 - 316 SS
- Sample 9 - Ta Aluminized
- Sample 10 - Er_2O_3 (50%) - Ni(50%) cermet
- Sample 11 - Er_2O_3

Figure 2. Tantalum Test Sample - Coating Integrity Tests (30-100 ksi Static Stress; each material to be tested vs. itself and 316SS)

LMEC-82289

Figure 3-43. Schematic of Variable-Velocity Friction and Wear Test Apparatus

PREPARED BY:	Rockwell International Atomics International Division	PAGE NO. 133 OF
CHECKED BY:		REPORT NO. N001TI570038
DATE:		MODEL NO.

Figure 43

TANTALUM CORROSION LOOP
SCHEMATIC FLOW DIAGRAM

ANALYSES

HYDRAULIC PERFORMANCE

STACKING BEHAVIOR

PRESSURES AND FLOW RATES

BALLS DROP TIME AND DISTRIBUTION

REACTOR TRANSIENTS

DETERMINE NEGATIVE REACTIVITY INSERTION RATE
WITH BALLS

CALCULATE EFFECT ON REACTOR TRANSIENTS

LOF

2¢/SEC TOP + LOF

5¢/SEC TOP + LOF

30¢ STEP SSE + LOF

HYDRAULIC ANALYSES

USED WITH PARAMETRIC HYDRAULIC TEST DATA
TO DESIGN, MODIFY, AND IMPROVE SYSTEM

CAN BE USED TO MODIFY ANY SYSTEM DESIGN TO MEET
CHANGING REACTOR DESIGN REQUIREMENTS

PRESSURE DROP ACROSS THE BALL COLUMN, ΔP (PSI), AS A
 FUNCTION OF NORMALIZED FLOWRATE $\frac{Q}{Q_{FULL}}$ (%) DURING STACKING
 (40 IN. TUNGSTEN BALLS, 6 IN. FREE SPACE)

PRESSURE DISTRIBUTION ALONG THE
STACKED BALL COLUMN AT FULL FLOW
(40 IN. LONG $\frac{1}{4}$ " W-ALLOY BALLS, $1\frac{3}{4}$ IN. BYPASS PIPE)

LOCATION OF BALLS DURING DROPPING
PERIOD (39 INCH. STACK. TUNGSTEN BALLS
BOTTOM VALVE CLOSED)

TRANSIENT ANALYSES

- RATE OF ABSORBER BALLS INSERTION
- RATE OF NEGATIVE REACTIVITY INSERTION
- REACTOR TRANSIENT CALCULATIONS
 - . LOF
 - . LOF + TOP (2¢/SEC)
 - . LOF + TOP (5¢/SEC)
 - . LOF + SSE (30¢ STEP)
- WITH AND WITHOUT TEMPERATURE SENSITIVE MAGNET
- EFFECTS OF VARIATIONS IN TRIP POINT OF TEMPERATURE SENSITIVE MAGNET
- EASILY MEETS ALL OF FUNCTIONAL REQUIREMENTS

NEGATIVE REACTIVITY INSERTION RATESFOR ABSORBER BALLS

40-INCH STACK & 0-INCH FREE SPACE

**TRANSIENT REACTOR PERFORMANCE FOR
30¢ STEP SSE + LOF
WITH CURIE POINT MAGNET TRIGGER**

TRANSIENT REACTOR PERFORMANCE FOR

5¢/SEC TOP + LOF

WITH CURIE POINT MAGNET TRIGGER

TABLE 1

ABSORBER BALLS* TRANSIENT PERFORMANCE(BOTTOM PLUG OPEN)

-- MAXIMUM TEMPERATURES OF COOLANT AND CLAD --

-- MAXIMUM % AREAL MELT OF FUEL --

SCRAM REQUIREMENTS	PPS SCRAM OF ELECTROMAGNET AT FLUX/FLOW = 1.35		INHERENT SCRAM OF CURIE-POINT MAGNET AT 1050°F		
	CLAD TEMP (°F)	FUEL % AR. MELT	COOLANT TEMP (°F)	CLAD TEMP (°F)	FUEL % AR. MELT
	<1600 HOT	<10 PEAK	<1763 HOT	<2475 HOT	<30 PEAK
LOF AVG. CHANNEL	1119	0	1176	1199	0
PEAK CHANNEL	1190	0	1247	1283	0
HOT CHANNEL	1328	0	1401	1446	0
2¢/s TOP + LOF** AVG.	1115	0	1167	1195	0
PEAK	1183	0	1240	1274	0
HOT	1319	0	1392	1435	0
5¢/s TOP + LOF** AVG.	1102	0	1174	1202	0
PEAK	1167	0	1247	1280	0
HOT	1299	0	1401	1443	0
30¢ SSE + LOF** AVG.	1056	0	1186	1214	0
PEAK	1115	0	1259	1293	0
HOT	1233	0	1416	1460	0

* \$4.20 Absorber worth inserted in 2.4 sec

** Pumps trip at 115% of full power

- Notes: 1) Coolant : $T_{in} = 687^{\circ}\text{F}$
 2) @ $t = 0$ sec $T_{out} = 988^{\circ}\text{F}$ Avg. Channel
 1035°F Peak Channel
 1130°F Hot Channel
 3) CRBR Hot Channel factor of 1.275 used

TABLE 2

TRANSIENT REACTOR PERFORMANCE WITH ABSORBER BALLS* ISSS (BOTTOM PLUG CLOSED)

	PPS SCRAM OF ELECTROMAGNET AT FLUX/FLOW = 1.35		INHERENT SCRAM OF CURIE-POINT MAGNET CLOSING FLOW SHUTOFF VALVE 2 SEC*** AFTER COOLANT OUTLET T = 1050°F AVG. CHANNEL		
	CLAD MAX. TEMP (°F)	FUEL MAX. AREAL MELT (%)	COOLANT MAX. TEMP (°F)	CLAD MAX. TEMP (°F)	FUEL MAX. AREAL MELT (%)
SAFETY LIMITS	<1600 HOT CHANNEL	<10 PEAK CHANNEL	<1763 HOT CHANNEL	<2475 HOT CHANNEL	<30 PEAK CHANNEL
<u>TRANSIENT EVENT</u>					
LOF					
PEAK CHANNEL	1234	0	1299	1327	0
HOT CHANNEL	1384	0	1467	1503	0
24/sec TOP + LOF**					
PEAK CHANNEL	1231	0	1290	1322	0
HOT CHANNEL	1381	0	1456	1497	0
54/sec TOP + LOF**					
PEAK CHANNEL	1235	0	1317	1348	0
HOT CHANNEL	1386	0	1490	1530	0
304 SSE + LOF**					
PEAK CHANNEL	1166	0	1323	1355	0
HOT CHANNEL	1296	0	1497	1539	0

* \$4.20 absorber worth inserted in 4.0 sec after flow shutoff valves close

** Pumps trip at 115% of full power

***2 sec includes: 1 sec for Na transport, 0.5 sec for magnet heating, 0.5 sec for delays and uncertainties

Notes: 1) Coolant: $T_i = 687^\circ\text{F}$
 2) Normal Coolant: $T_{out} = 988^\circ\text{F}$ Avg. Channel, 1035°F Peak Channel, 1131°F Hot Channel
 3) CRBR Hot Channel factor of 1.275 used

SCHEDULE

SUMMARY

A FULL SCALE SHUTDOWN ASSEMBLY WAS DESIGNED, BUILT, AND TESTED
HYDRAULICALLY IN WATER

THE ASSEMBLY MEETS FUNCTIONAL AND DESIGN REQUIREMENTS

TESTING TO BEGIN ON MATERIALS PROPERTIES OF CANDIDATE MATERIALS
FOR ABSORBER BALLS

FULL SCALE HYDRAULIC TESTS IN SODIUM STARTING IN ONE YEAR

IN-REACTOR TESTS PLANNED ON PROTOTYPE ASSEMBLY

FULLY TESTED PROTOTYPE EXPECTED IN 1984

APPENDIX D

AI DEVELOPMENT PROGRAM REVIEW FOR ISSS NEEDS
AND RECOMMENDATIONS IN RELIABILITY AND SAFETY

INHERENT SECONDARY SHUTDOWN SYSTEM (ISSS)
DEVELOPMENT PROGRAM REVIEW

OUTLINE OF PRESENTATION

- ISSS NEEDS FOR LARGE LMFBR'S
 - SHUTDOWN SYSTEM RELIABILITY CRITERION
 - RELIABILITY ANALYSIS OF CANDIDATE SHUTDOWN SYSTEM
 - ISSS SAFETY REQUIREMENTS
- RECOMMENDATIONS FOR ISSS DEVELOPMENT PROGRAM

THE SHUTDOWN SYSTEM (SDS) RELIABILITY CRITERION
IS BASED ON PUBLIC RISK CONSIDERATIONS

*MEAN VALUE

ASSUMPTIONS:

- LMFBR SAFETY COMPARABLE TO LWR SAFETY
- LMFBR'S SITED ON SITES TYPICAL OF LWR SITES
- EMPHASIZE CDA PREVENTION RATHER THAN MITIGATION

ALLOCATION:

• SDS FAILURE	=	30%
• DHRs FAILURE	=	50%
• MARGIN AND OTHER	=	20%

RELIABILITY ANALYSIS CAN ASSIST IN TRANSLATING THE SDS RELIABILITY
CRITERION INTO SPECIFIC DESIGN REQUIREMENTS

- REFERENCE SHUTDOWN SYSTEM POSTULATED FOR RELIABILITY ANALYSIS
PURPOSES:
 - PPS ACTUATED PRIMARY SHUTDOWN SYSTEM SIMILAR TO CRBRP'S, PLUS
 - DIVERSE PPS ACTUATED SECONDARY SHUTDOWN SYSTEM SIMILAR TO
CRBRP'S
- RELIABILITY ANALYSIS METHODOLOGY:
 - SCOPING-TYPE ANALYSIS
 - EVENT TREE FORMAT

DESIGN BASES FOR REFERENCE SHUTDOWN SYSTEM

INITIATING EVENT	SHUTDOWN SYSTEM	GENERAL REQUIREMENT	MAX CLAD TEMP (°F) (1)	MAX SODIUM TEMP (°F) (1)	MAX AREAL FUEL MELT (%) (2)
ANTICIPATED EVENT	PRIMARY	NO FUEL DAMAGE	1450	-	0
	SECONDARY	LIMITED FUEL DAMAGE	1600	-	10
UNLIKELY EVENT	PRIMARY	LIMITED FUEL DAMAGE	1600	-	10
	SECONDARY	MAINTAIN COOL- ABLE GEOMETRY	CLAD MELTING	SODIUM BOILING	30
EXTREMELY UNLIKELY EVENT	PRIMARY	MAINTAIN COOL- ABLE GEOMETRY	CLAD MELTING	SODIUM BOILING	30
	SECONDARY (3)	MAINTAIN COOL- ABLE GEOMETRY	CLAD MELTING	SODIUM BOILING	30

1. HOT CHANNEL
2. PEAK ROD
3. LIMITED TO SAFE SHUTDOWN EARTHQUAKE

SHUTDOWN SYSTEM FAILURE RATES CAN BE ESTIMATED
BASED ON PRIOR EXPERIENCE AND TESTS

- EXAMPLE PRIMARY SHUTDOWN SYSTEM
- COMMERCIAL LWR EXPERIENCE $10^{-4} \times 3^*$ FAILURES/DEMAND
(TO DATE)
- PROJECTED LWR VALUE $3 \times 10^{-5} \times 7^*$ FAILURES/DEMAND
(NEXT THOUSAND REACTOR YEARS)
- PROJECTED LMFBR VALUE $5 \times 10^{-5} \times 15^*$ ($2 \times 10^{-4}^{**}$)
(FIRST THOUSAND REACTOR YEARS) FAILURES/DEMAND

*MEDIAN VALUE AND 90% CONFIDENCE BOUNDS

**APPROXIMATE CORRESPONDING MEAN VALUE

RELIABILITY ANALYSIS RESULTS

INITIATING EVENT			MEAN FAILURES PER DEMAND		MEAN FAILURES PER REACTOR YEAR (FOR REFERENCE CONCEPT)	RELIABILITY IMPROVEMENT FACTOR NEEDED FOR LARGE LMFBR'S	RESULTANT MEAN FAILURES PER REACTOR YEAR
TYPE	EQUIVALENT SEVERITY	MEAN FREQ (PER REACTOR YEAR)	PRIMARY SHUTDOWN SYSTEM	SECONDARY SHUTDOWN SYSTEM (PPS MODE)			
TUC*	~PUMP COASTDOWN	10	.0002	.005	10×10^{-6}	~20	$.5 \times 10^{-6}$
	~PUMP SEIZURE	10^{-2}	.001	.01	$.1 \times 10^{-6}$	NONE	$.1 \times 10^{-6}$
	~DBA PIPE RUPTURE	10^{-4}	.01	.2	$.2 \times 10^{-6}$	NONE	$.2 \times 10^{-6}$
	>DBA PIPE RUPTURE	10^{-6}	.2	.5	$.1 \times 10^{-6}$	NONE	$.1 \times 10^{-6}$
TOP*	$\leq 5\phi/\text{SEC}$ $\leq 30\phi$ STEP	.2	.0002	.005	$.2 \times 10^{-6}$	NONE	$.2 \times 10^{-6}$
	~5-20 ϕ/SEC	10^{-2}	.001	.01	$.1 \times 10^{-6}$	NONE	$.1 \times 10^{-6}$
	~DBA	10^{-4}	.01	.2	$.2 \times 10^{-6}$	NONE	$.2 \times 10^{-6}$
	>DBA	10^{-6}	.2	.5	$.1 \times 10^{-6}$	NONE	$.1 \times 10^{-6}$
SEISMIC	~OBE	10^{-3}	.01	.05	$.5 \times 10^{-6}$	~5	$.6 \times 10^{-6}$
	~SSE	10^{-4}	.05	.2	1×10^{-6}		
	>SSE	2×10^{-5}	.2	.4	1.6×10^{-6}		
SIGNIFICANT DISTORTION IN UPPER INTERNALS OR CORE*		2×10^{-3}	.03	.1	6×10^{-6}	~10	$.6 \times 10^{-6}$
*ALL CAUSES EXCEPT SEISMIC EVENTS				TOTAL:	20×10^{-6}	-	2.7×10^{-6}
CRITERION: 3×10^{-6}							

COMPARISON OF RELIABILITY ANALYSIS RESULTS
FOR REFERENCE SHUTDOWN SYSTEM

SOURCE	ESTIMATED FAILURES PER REACTOR YEAR	
	MEAN	MEDIAN AND 90% CONFIDENCE BOUNDS
AI (CURRENT ASSESSMENT)	20×10^{-6}	-
CRBRP RISK ASSESSMENT	25×10^{-6}	$1.5 \times 10^{-6} \times 50$

AN ISSS IS NEEDED FOR LARGE LMFBR'S

INITIATING EVENT	REQUIRED RELIABILITY IMPROVEMENT FACTOR	OPTIONS AVAILABLE TO IMPROVE RELIABILITY	PREFERRED OPTION
TUC	20	<ul style="list-style-type: none"> • IMPROVE PPS-ACTUATED SDS AVAILABILITY • ELIMINATE PUMP TRIP WHEN PLANT TRIPS • PROVIDE ISSS 	ISSS*
SEISMIC EVENTS	5	<ul style="list-style-type: none"> • PROVIDE SEISMIC TRIP IN PLANT PROTECTION SYSTEM • PROVIDE ISSS 	?
DISTORTION	10	<ul style="list-style-type: none"> • PROVIDE EXTRA MARGIN IN PPS-ACTUATED SEC. SDS FOR STRUCTURAL FAILURES AND DISTORTION • PROVIDE ISSS 	?

*IF COST AND OPERATIONAL IMPACT ARE ACCEPTABLE, AND IF DEVELOPMENT PROGRAM IS COMPLETED IN A TIMELY FASHION

ISSS SAFETY REQUIREMENTS

● PPS ACTUATION MODE

- RAPID RESPONSE TO MEET FUNCTIONAL REQUIREMENTS
- $\leq 10^{-3}$ RANDOM FAILURES PER DEMAND

● INHERENT ACTUATION MODE

- TUC AND SEISMIC PROTECTION (PROTECTION FOR TOP EVENTS NEED NOT BE PROVIDED)
- $\leq 10^{-2}$ RANDOM FAILURES PER DEMAND

● COMBINED SYSTEM

- DIVERSE FROM PRIMARY SHUTDOWN SYSTEM
- $\leq 10^{-4}$ COMMON CAUSE FAILURE PER DEMAND* (PPS AND INHERENT ACTUATION MODES)
- REASONABLE MARGIN FOR DISTORTION IN UPPER INTERNALS AND CORE

*MEAN VALUE

RECOMMENDATIONS FOR ISSS DEVELOPMENT PROGRAM

- DEVELOP MOST COST-EFFECTIVE ISSS DESIGN(S)
 - DETERMINE COSTS AND BENEFITS OF DESIGNS WITH AND WITHOUT TOP PROTECTION
 - SELECT MOST COST-EFFECTIVE DESIGN(S) FOR FUTURE DEVELOPMENT
- PROVIDE COMPLETE IN-SITU TEST CAPABILITY OR VERIFY THAT EXTERNAL TESTING SCHEMES WILL PROVIDE ADEQUATE RELIABILITY
- PERFORM COMMON CAUSE FAILURE ANALYSES FOR:
 - ISSS PPS AND INHERENT ACTUATION MODES
 - PRIMARY SHUTDOWN SYSTEM AND ISSS
- PROVIDE DESIGN WHICH DOES NOT INTERFERE IN ANY WAY WITH PLANT OPERATION IN THE RANGE OF 50-100% FULL POWER AND FLOW OR VERIFY THAT ALTERNATE APPROACHES ARE ACCEPTABLE
- BEGIN PLANNING FOR IN-PILE TESTING IF SUCH TESTS ARE NECESSARY (E.G., FOR SYSTEMS WHICH USE FUEL AND CURIE POINT MAGNETS)

APPENDIX E

ETEC TEST MILESTONES, SCHEDULE AND SUMMARY
FOR ISSS-ACA

ZWENG/TESSIER

ARTICULATING ROD TEST (ISSS-ACA) BLDG. 032 8-30-78 PG. 10F 2

ARTICULATING ROD TEST (ISSS-ACA) BLDG. 032 8-30-78 P. 2 OF 2

ZWENG/TESSIER

	<u>Tests</u>	<u>Time Estimate (Weeks)</u>
1. Instrumentation Checkout and Calibration	--	2
2. Facility Checkout and Preheat	--	2
3. Sodium Fill and Cleaning	--	2
4. Heatup & Injection Checkout 6 Tests @ 3 Injections/Test	18	2
5. Pretest Characterization		
A. Withdrawal Drag Force	1 (New)	
B. Preload Requirement	5 (New)	
C. Temperature Sensitive Alloy Thermal Characteristics	1	2
D. Drop Current	10* (New)	
6. Inherent Release	10* (5 New)	1.5
7. Drop Time & Withdrawal Loads	25	1
8. Dwell Test	1	6 Months
9. Post-Dwell Inherent Release	5*	1.5
10. Post-Dwell Drop Time & Withdrawal Loads	25	1
11. Test Article Bowing Operation	--	1.5
12. Bowed Duct (0.5 inch) Drop Time & Withdrawal Loads	25	1
13. Test Article Bowing Operation	--	1.5
14. Bowed Duct (0.75 inch) Drop Time & Withdrawal Loads	25	1
15. Sodium Drain, Cleaning, Disassembly and Shipping of ISSS-ACA Test Components	--	4

* Minimum Time Between Tests: Approximately 3 Hours.