SODIUM TECHNOLOGY PROGRESS REPORT JULY—SEPTEMBER 1980

Hanford Engineering Development Laboratory

Compiled by
J.M. Atwood

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December 1980

APPLIED TECHNOLOGY

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ABSTRACT

This report presents a quarterly summary of progress made at Westinghouse Hanford Company in the areas of radioactivity control technology and sodium systems technology.

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SODIUM TECHNOLOGY PROGRESS REPORT

JULY - SEPTEMBER 1980

MANAGEMENT SUMMARY

Sodium technology programs provide the technical basis for safe and efficient use of sodium as a reactor coolant. In addition to developing a broad base of technology, the HEDL programs provide support for Fast Flux Test Facility start-up and operation. Overall program objectives are to establish sodium and cover gas purity requirements; develop and demonstrate purification, sampling, and analysis methods, components, and instrumentation; characterize mass and activity transport effects in reactor systems; develop radioactivity control methods required to permit contact maintenance on the primary heat transport system; and develop a decontamination process for removing radioactivity from primary system components requiring maintenance and reuse.

During this reporting period, the following were accomplished:

- Two prototype radionuclide traps have each finished two cycles in EBR-II.
- Source Term Control Loop 3 (STCL-3) was being gamma-scanned at 60 selected locations to determine radionuclide distribution in sodium loops without radionuclide traps.
- An 8000-hour test was completed to evaluate radionuclide deposition and penetration into AISI 304 and 316 stainless steels.
- Based on potential transport of ^{58}Co from the core region, an improved configuration for radionuclide traps would have nickel coating on only the gas plenum region of fuel pins.
- Planning continued for the surveillance of radioactivity buildup in the FFTF heat transport system.
- Examination of the deposition sampler from the EBR-II Breached Fuel Test Facility was completed. Most of the contamination deposited in the sampler was associated with fuel particulates.

- A test with an improved cesium trap design was started in the Fission Product Transport Loop.
- Laboratory equipment was set up for investigation of oxygen-silicon chemistry in sodium, as part of the program to characterize and control particulate formation in high temperature sodium systems.
- A data base was established during 800°F testing of FFTF, in preparation for surveillance of silicon effects in FFTF systems during full power operation.
- Sodium frost tests were completed to characterize deposition pattern and rates with flat plate condensers and with varying impurity levels in the argon cover gas. Additional tests were started to determine plug formation time and conditions in cover gas lines, both heated and unheated.
- Cold trap performance was evaluated during the final Maximum Isothermal Sodium Temperature test period on FFTF.
- Studies were completed on effects of mesh packing on natural convection in a cold trap crystallizer.
- Installation and acceptance testing of the Fuel Failure Monitoring System on FFTF were completed.
- Responses of two absorber/collimator devices were measured, and a modified gamma ray subtraction device was tested on the EBR-II Fuel Failure Monitoring equipment proof test.

I. RADIOACTIVITY CONTROL TECHNOLOGY

W. F. Brehm

The Radioactivity Control Technology Program is developing technology to predict, measure, control and remove radioactivity from sodium-cooled reactor systems. Activated corrosion products, fuel particulates, tritium and fission products species are of interest. The complexity and magnitude of radionuclide transport and deposition require investigation and development of several control methods. This quarter's report describes progress in radionuclide trap development, decontamination process development, examination of deposition and diffusion specimens, cesium trap testing, and radiation level calculations.

A. RADIONUCLIDE TRAP DEVELOPMENT

J. C. McGuire and W. F. Brehm

1. Objective

The objective of this program is to develop a method for removing long-lived gamma-emitting radionuclides from LMFBF primary loop sodium to control deposition in areas where maintenance is required.

2. Accomplishments

EBR-II Radionuclide Traps 3 and 4 (X-356 and X-357) have each completed two irradiation cycles without incident. X-357, the test of nickel-plated driver pins, will be removed during Run 112, disassembled, one plated dummy pin removed, and the experiment reconstituted for further irradiation. Examination of the removed pin will provide essential information on weight loss, nickel corrosion, ^{58}Co generation, downstream effect and ^{54}Mn gettering. Specimens of FFTF fuel cladding were successfully sputter-coated with nickel. The coating appears to be ductile, smooth and very adherent. Nickel thicknesses of 0.0003 in. and 0.003 in. have been applied.

Source Term Control Loop 3 (STCL-3) has operated without a radionuclide trap for 9000 hours. We are now completing a detailed gamma scan of loop activity to determine activity movement in the absence of a trap. The scans to date show that activity has not only built up in the cold leg, but that it has moved through the system. Cobalt is now seen in all parts of the loop with a significant concentration in the area where sodium is being heated before entering the hot sample stringer. This indicates that cobalt is present in the sodium stream throughout the loop, and that it deposits preferentially in the hot zone, even after passing through a cooler area.

In an investigation of alternative approaches for installing radionuclide traps in future reactors, a single 28-in. diam x 24-in. long rolled nickel sheet trap installed in the outlet pipe of each primary circuit will provide over twice the getter area of a conventional trap unit mounted in every core assembly.

3. Future Work

Design a trap unit with 0.060-in. spacing between layers for low pressure drop.

Test the properties of sputter-coated cladding.

B. FISSION PRODUCT AND FUEL TRANSPORT BEHAVIOR AND CONTROL

R. P. Colburn, H. P. Maffei and M. B. Hall

1. Objective

The objectives of this program are: 1) to determine fission product and fuel particulate transport kinetics and deposition patterns in LMFBR primary heat transport systems, 2) to determine impacts that transport and deposition of these radionuclides will have on plant maintenance, 3) to

develop methods to monitor and control their deposition, and 4) to provide interpretive information for the Run-Beyond-Cladding-Breach (RBCB) Program.

2. Accomplishments

Examination of the deposition sampler, ST-1A, used in the Breached Fuel Test Facility (BFTF) at EBR-II during the XY-2 breached fuel test was completed. This examination included disassembly of the sampler, gamma scanning of the individual pieces and characterizations of the deposits. Analysis of these data is continuing. The sampler is illustrated schematically in Figure 1. A detailed description of the sampler, its exposure conditions and a summary of preliminary examination findings were given in References 1, 2 and 3. It was previously noted that over 80% of the total contamination activity deposited in the sampler was deposited on the filter. Further analysis indicates over 90% of the total was associated with the filter, with 40% of that material contained in the loose debris that accumulated around the standpipe below the filter (Sample Position 1 in Figure 1).

The concentrations of some of the major contaminants on various surfaces are shown in Table 1. The calculated fuel and fission product inventories in the breached pin at the time of cladding failure are also shown. The ratios of Pu to U in the deposits on the filter and around the stand pipe below the filter (Sample Positions 1, 2 and 3) were similar to the ratio in the source pin. These data, together with the general coincidence of alpha and gamma activity distributions on a microscopic scale on the filter surface, suggest that most of the contamination transport of these species was by fuel particulate entrainment in the sodium.

The contaminants on the inner surface of the top piece (Sample Position 4) represent the deposition downstream from the filter. Contamination on the outer surface of the top piece represents deposition at the outlet of the unfiltered flow path. The much lower concentrations on the inner surface for similar mass transfer conditions indicates substantial removal

HEDL 8007-028.1

FIGURE 1. Deposition Sampler.

TABLE 1

CONCENTRATIONS OF CONTAMINATION DEPOSITS ON
ST-1A DEPOSITION SAMPLER SURFACES

Sample Location		Fuel ($\mu\text{gm}/\text{cm}^2$)		Fission Products ($\mu\text{Ci}/\text{cm}^2$)			
No.	Description	Pu	U	^{95}Zr	^{141}Ce	^{144}Ce	^{103}Ru
2	Filter - Lower End	0.59	1.23	54.0	13.90	2.15	6.35
3	Filter - 25 cm from Lower End	1.31	4.25	68.6	28.51	3.52	8.86
4	Top Piece ID	0.0001	0.014	0.27	1.36	0.017	
5	Top Piece OD Ring 35	0.0091 0.014	0.022 0.027	2.29 2.25	1.29 0.41	0.08 0.12	0.19
6	Outer Casing ID	0.013	0.028	2.66	0.71	0.11	
7	Outer Casing OD	0.0008	0.0046	0.23	0.81	0.006	
1	Loose Deposits near Base of Standpipe	<u>(μgm)</u> 400	<u>(μgm)</u> 1400	<u>(μCi)</u> 5735	<u>(μCi)</u> 6239	<u>(μCi)</u> 967	<u>(Ci)</u> 1501
		<u>(gm)</u>	<u>(gm)</u>	<u>(Ci)</u>	<u>(Ci)</u>	<u>(Ci)</u>	
	Fuel Pin*	16.8	52.3	186	320	39.7	68.2

*Total quantity in the fuel pin at time of breach

**Not determined

of these contaminants by the filter. Similarly, a comparison of the deposit concentrations on the inner and outer surfaces of the outer casing (Sample Positions 6 and 7) reflects changes in the contamination concentration in the sodium stream. The inner surface reflects the deposition from the sodium during the initial upward flow through the sampler. They correspond well with the concentrations found on the deposition rings on the opposite annular wall. The concentrations on the outer surface, reflecting deposition from the sodium stream returning from the upper end of the BFTF, were much lower, suggesting that substantial deposition of these species occurred in the upper end of the BFTF. ^{141}Ce was a notable exception, showing a larger concentration on the outer surface. This may be explained by a transport mechanism in which some of the ^{141}Ce was released from the breached pin as its volatile short-lived precursor ^{141}Cs ($\tau_{1/2} = 25 \text{ s}$). While existing as a Cs species, it tends to remain dissolved in the sodium and not deposit on surfaces. However, after decay to ^{141}Ba , it tends to deposit rapidly and once deposited, decays in place to ^{141}La and ^{141}Ce . This type of transport and deposition behavior was observed for ^{137}Cs - ^{137}Ba in flowing sodium systems.⁽⁴⁾ A similar mechanism could explain the large downstream concentrations of ^{140}Ba - ^{140}La observed at the upper end of the BFTF. These relatively large concentrations of ^{140}Ba - ^{140}La were observed at the upper end of the BFTF during a gamma scan of the facility two weeks after its removal from the reactor.⁽¹⁾ Subsequent decay prior to the disassembly prevented accurate distribution measurements during the detailed examination.

A second deposition sampler test (ST-1B) was started in EBR-II during Run 108 in conjunction with the XY-5 breached fuel test. The test pins contain high burnup (14 at.%) mixed oxide fuel. The ST-1B sampler is identical to the previous unit (ST-1A). No pin breaches were detected through the middle of Run 109. Two additional sampler units were fabricated and shipped to EBR-II to be used in future breached fuels tests in the BFTF.

A cesium trap test was started in the Fission Product Transport Loop with an improved trap design that is expected to achieve lower Cs concentrations in the sodium and to make more efficient use of the trap packing.

3. Future Work

Complete analysis of ST-1A deposition sampler data and issue topical report.

Examine the ST-1B sampler at the conclusion of the XY-5 RBCB test.

Perform two additional deposition sampler tests in the BFTF.

Complete Cs trap test in FPTL.

C. FFTF HEAT TRANSFER SYSTEM RADIOACTIVITY SURVEILLANCE

H. P. Maffei

1. Objective

Maintenance operations for any nuclear plant are significantly affected by radiation levels in equipment cells. Reasonably accurate predictions of expected cell radiation levels must be available during plant startup to facilitate planning and designing for maintenance. Accurate radiation level predictions will answer the questions of whether plants should be designed for "hands-on" or remote maintenance.

2. Accomplishments

Significant progress was made in predicting activated corrosion product buildup in sodium-cooled reactor systems. These calculated predictions for the heat transport system (HTS) need to be validated during the startup of the FFTF. Without such validation, present calculated levels must be considered "best effort" predictions, with future maintenance techniques

based on these calculations. Actual measurements of radiation levels will allow selection of the correct maintenance techniques prior to need.

During FFTF construction, five penetrations were made in the operating floor over HTS Cell 3 for monitoring radioactive corrosion products within that cell. These penetration positions are shown in Figure 2. Penetrations 1 and 2 are positioned over the primary sodium hot leg. Penetration 3 is over the crossover piping between the primary pump and heat exchanger, while Penetrations 4 and 5 will monitor the cold leg piping and check valve, respectively. Each penetration is a 2-in. diameter hole through the concrete operating floor. The length of each hole is ~7 ft except for Penetration 3 over the crossover piping, which is 4 ft in length. The holes will supply a collimated beam of radioactivity from an area of ~320 cm² (50 in.²) of piping.

Calibration of the penetrations and counting equipment was previously reported.⁽⁵⁾ In order to correlate the nuclide concentration, which will be measured at the test holes with actual radiation exposure levels, additional instrumentation will be required. Ionization-type radiation level detectors have been purchased for installation in HTS Cell 3. The design of the instrument will allow installation of only the ionization probe in the cell, thereby avoiding radiation damage to the instrument during reactor power operation. Two probes will be installed in close proximity (~1 m) to the piping. One probe will be under Penetration 1 and the second under Penetration 5. In order to ensure long probe life, the instruments will be kept with power off until the ²⁴Na has decayed following power shutdown.

D. RADIATION LEVELS IN FFTF HTS CELLS

W. F. Brehm

1. Objective

The objective of this work is to use the latest available nuclide release data and FFTF parameters to calculate radiation levels for radioactive material transport.

FIGURE 2. Radioactive Corrosion Product Monitoring Penetrations.

2. Accomplishments

In the latest two quarterly reports^(2,3) estimates were made of radiation levels at 360°C (680°F), 316°C (600°F) FFTF core inlet temperatures, and at 360°C core inlet with radionuclide traps installed. One concept of the radionuclide trap used a 0.0076-mm (0.3-mil) thick coating of nickel as the trap material, which coated the entire length of the fuel pin. The question was raised of ^{58}Co release and transport from the reaction $^{58}\text{Ni}(n,p)^{58}\text{Co}$ and subsequent corrosion.

The situation can be analyzed as follows: The equilibrium radiation levels in FFTF hot leg and cold leg sections of the HTS cell due to ^{58}Co are 0.08 and 0.06 R/h, respectively. This material comes almost entirely from the corrosion of material in the core (fuel stack) region of the pin, since the $^{58}\text{Ni}(n,p)^{58}\text{Co}$ reaction is a high energy transmutation, which occurs only in the core region and not in the fission gas plenum region of the fuel pin. The fuel cladding starts irradiation exposure at ~12% nickel; leaching of the nickel by sodium reduces the nickel concentration at the surface to as little as 2% (hence reducing the potential for ^{58}Co production and transport). This fact was accounted for by Kuhn⁽⁶⁾ in his original calculations of radiation level; and in subsequent estimates.^(2,3) The potential for ^{58}Co transport, if the entire fuel pin is nickel coated, would be at least $100/12 = 8.3$ times as high, and perhaps $100/2 = 50$ times as high. This release would lead to radiation levels of at least 0.66 R/h in the hot leg and 0.50 R/h in the cold, possibly much higher. Such radiation levels, added to the ^{60}Co and (reduced) ^{54}Mn levels, would still result in radiation levels at least 1 R/h.

Therefore, we recommend that nickel coating of the fission gas plenum region only be considered for this concept of radionuclide traps. Nickel coating in that region will produce negligible ^{58}Co .

3. Future Work

The temperature and flux parameters used in Reference 6 were 1974 values. These will be compared with the latest data to see if significant changes are present that would affect radiation level estimates.

E. DECONTAMINATION OF BREEDER REACTOR COMPONENTS

R. P. Anantatmula, J. M. Lutton, S. J. Bos and M. B. Hall

1. Objective

The objective of this activity is to develop and demonstrate decontamination processes that will permit contact maintenance and requalification of breeder reactor primary system components.

2. Accomplishments

Test DECON-I, a study of radionuclide deposition and penetration into AISI 304 and AISI 316 stainless steels was completed. The stainless steel test specimens were downstream from the radionuclide source at a temperature of 534°C and were exposed for a total time period of 8000 h in Source Term Control Loop 3 (STCL-3). The radionuclide sources were pieces of irradiated AISI 316 stainless steel kept in the 549°C hot leg of the pumped ΔT loop (STCL-3) upstream from the test specimens. This arrangement is assumed to simulate the temperature drop from reactor outlet to a hot leg pump. Two specimen arrangements were used: one with the coupons parallel to a high velocity sodium flow of 3.5 m/s (11 ft/s), the other perpendicular to the flow, at a nominal velocity of 0.3 to 0.6 m/s (1 to 2 ft/s).⁽⁷⁾

The activities of the radionuclides deposited on the specimens were counted with a Ge-Li detector and a multi-channel analyzer, and corrections were applied for detector efficiency and geometry. Incremental radiochemical analysis for the depth distribution of ⁵⁴Mn and ⁶⁰Co was also performed on selected specimens. ⁵⁴Mn diffusion coefficients measured from the analysis of Phase I (2500 h) and Phase II (4500 h) specimens were

reported earlier.⁽⁸⁾ Optical metallography of as-received specimens was also reported.⁽⁹⁾ At the completion of test DECON-I, the test specimens were weighed and counted, and post-test metallography was performed on 4000-h specimens encompassing all heats of the AISI 304 and AISI 316 materials. Incremental radiochemical analysis is also currently being performed on a few selected specimens.

Optical micrographs of cast and wrought AISI 304 and AISI 316 stainless steel exposed for 8000 h at 534°C are presented in Figures 3 through 12. Different heats of the materials had different carbon concentrations. Table 2 lists the specimens examined by optical metallography with their carbon compositions.

As mentioned in the previous quarterly report⁽⁹⁾, the amount of ferrite is more in AISI 316 cast material than in AISI 304 cast steel contributing to a larger lattice diffusion coefficient for ⁵⁴Mn. Casting porosity can be seen in all the cast materials and is exemplified by large holes in specimen OE (Figure 4). There is precipitation, presumably carbide, near the sodium-exposed surface of all the cast materials. Carbide precipitation seems to have actually started at the ferrite-austenite interface, and precipitation continued into the ferrite islands. A small amount of carbide precipitation was noticed at the austenite-ferrite interface of the as-received materials. Sodium exposure at 534°C for 8000 h led to transformation of ferrite.

The wrought stainless steels generally displayed equiaxed grain structure with annealing twins. Exposure to 534°C sodium for 8000 h resulted in carbide precipitation around grain boundaries and also within the grains. In addition to carbides, Specimen 9E (Figure 12) had stringer-type inclusions. The amount of carbide precipitation generally seems to be consistent with the amount of carbide present in the alloy. There are fine unresolved precipitates at 1000x magnification within the austenite grains. In addition, specimen 8E with 0.08 wt% carbon has large precipitates within some austenite grains. These precipitates were not identified. Some or all

(a) 120 μm

(b) 60 μm

FIGURE 3. Optical Micrographs of Specimen 2E (304-C-1).

(a) $120\ \mu\text{m}$

(b) $30\ \mu\text{m}$

FIGURE 4. Optical Micrographs of Specimen OE (304-C-3).

(a) 120 μm

(b) 60 μm

FIGURE 5. Optical Micrographs of Specimen 1F (304-C-2).

(a) 120 μm

(b) 60 μm

FIGURE 6. Optical Micrographs of Specimen 3E (316-C-3).

(a) $120\ \mu\text{m}$

(b) $30\ \mu\text{m}$

FIGURE 7. Optical Micrographs of Specimen 4F (316-C-2).

(a) 120 μm

(b) 30 μm

FIGURE 8. Optical Micrographs of Specimen 5F (316-C-1).

(a) $120\ \mu\text{m}$

(b) $30\ \mu\text{m}$

FIGURE 9. Optical Micrographs of Specimen 6F (316-W-1).

(a) 120 μm

(b) 60 μm

FIGURE 10. Optical Micrographs of Specimen 7E (316-W-2).

(a) 120 μm

(b) 60 μm

FIGURE 11. Optical Micrographs of Specimen 8E (304-W-1).

(a) 60 μm

(b) 30 μm

FIGURE 12. Optical Micrographs of Specimen 9E (304-W-2).

TABLE 2
CARBON CONCENTRATION OF METALLOGRAPHY SPECIMENS

<u>Sample No.</u>	<u>Material*</u>	<u>Wt% Carbon</u>
2E	304-C-1	0.09
0E	304-C-3	0.07
1F	304-C-2	0.05
3E	316-C-3	0.06
4F	316-C-2	0.05
5F	316-C-1	0.08
6F	316-W-1	0.04
7E	317-W-2	0.07
8E	304-W-1	0.08
9E	304-W-2	0.03

*C - Cast; W - Wrought

of these precipitates may be carbides that have agglomerated to large-size particles. Although it has been theorized in the literature⁽¹⁰⁾ that sigma-phase precipitates are favored in AISI 304 SS with a high carbon content, the sodium-exposure temperature of 534°C is not high enough to promote the diffusion of substitutional elements leading to the formation of sigma phase.

As part of the decontamination studies, three pilot plant runs were made to evaluate the on-line corrosion meter. The corrosion meter performed very well during one of the runs as compared to the electrochemical cell. However, trouble was experienced in trying to restart the operation after the decontamination solution was changed. The decontamination solution seemed to be concentrating over a period of time; and the recirculating pumps were leaking, presumably due to acid attack. The pump seals have been replaced.

3. Future Work

Complete the evaluation of incremental chemical and radiochemical analysis data and gamma counting data and prepare a final interpretation of radionuclide deposition on stainless steels.

F. FFTF SUPPORT

J. M. Lutton and S. J. Bos

1. Objective

The objective of this program is to provide technical support in sodium removal for FFTF.

2. Accomplishments

A third control rod drive mechanism was cleaned in the pilot plant and returned to Engineering.

Parts from a failed periscope were sent to us for cleanliness evaluation. A cleaning technique for removing residual graphite from thread lubricants was developed and used to clean sixteen long sections and numerous small pieces.

II. SODIUM SYSTEMS TECHNOLOGY

(FF058, F0001, F0003)

J. J. McCown

Sodium Systems Technology programs cover development of methods for sampling, monitoring and controlling impurities in sodium and cover gas in experimental loops and on sodium-cooled reactors. The programs include Fuel Failure Monitoring studies for the detection and location of elements containing cladding breaches.

To ensure that the FFTF and subsequent sodium-cooled reactors operate using sodium and cover gas of adequate purity, methods for sampling and on-line monitoring of impurities were developed and tested on sodium facilities. Continuous on-line cover gas monitoring as well as gas tagging methods were established for fuel failure monitoring purposes.

The major program emphasis is upon laboratory studies on sodium frost, preparation for laboratory studies of silicon control by chemical interactions with other sodium impurities and final loop checkout of small oxygen, hydrogen and carbon meters as inserts in the Multipurpose Sampler. Technical support continued to be provided in the areas of sodium and cover gas purification and characterization and fission product monitoring.

This section of the report discusses work underway in Sodium Systems Technology including: particulate control and surveillance for effects in FFTF; sodium frost formation and control in cover gas piping; monitoring of FFTF chemistry during MIST-3; modification and testing of Fuel Failure Monitoring (FFM) equipment on EBR-II and completion of preparations on FFTF FFM systems prior to full power operations.

A. SILICON COMPOUND PARTICULATE EFFECTS

W. Yunker and D. Paine

1. Objective

The objectives of the Silicon Compound Particulate Effects program are to determine 1) methods for control of the silicon compound in liquid sodium systems and 2) effects of the material on FFTF startup and operation.

Data from the preceeding Flow Impedance Phenomena program proved that a sodium-silicon compound caused changes in the thermal/hydraulic performance of sodium heat transfer systems.

2. Accomplishments

Results of Flow Impedance Phenomena tests on the FIAS/PAL System⁽¹¹⁾ indicate that the oxygen impurity in sodium and perhaps other chemical components interact with silicon and affect the mass transfer process. Since a cold trap is the primary device in most sodium systems for controlling both oxygen and silicon concentrations, some understanding of this interaction should be useful to control the silicon concentration to a value that is harmless to a specific system. Laboratory equipment is being assembled and installed for conducting pot tests during FY 1981. These tests will be designed to clarify the FIAS results by controlling and measuring specific sodium impurities. During this quarter, the equipment collected has included 1) an inert atmosphere glovebox, gas recirculation/purification train, and gas atmosphere monitoring equipment for test preparations; 2) test furnace power service and temperature measurement and control equipment, and a high vacuum pumping system for atmospheric control of the test vessel.

The findings of the Flow Impedance Phenomena program⁽¹¹⁾ are being applied to an FFTF observation program for its full power operation. These observations are to determine whether any effects on the plant are from

silicon compound particulates. In conjunction with FFTF Engineering and Operations, observations are planned of the main heat transport system flow resistance, subassembly flow and temperature distributions and the performances of the intermediate heat exchangers, the primary cold-trap heat exchanger and auxiliary plugging meter. Overflow cup sampling for silicon particulates is also being planned. Most of the data for analysis will be from the data base being placed on the Boeing Computer Services, Richland UNIVAC computer. The necessary processing codes are being written. The MIST-III FFTF test in August 1980 provided a useful opportunity to collect 30-ml reference samples for silicon analysis and to check the Auxiliary Plugging Temperature Indicator for operation in the 350°F to 800°F range. The recent silicon analyses are summarized in Table 3.

TABLE 3
FFTF SILICON ANALYSIS SUMMARY

MIST-III		
Reactor Temperature (°F)	Silicon (wppm)	Silicon (Estimated) Solubility (wppm)
400	0.02	0.001
780	0.06	0.004 $\pm$ (x 10)

PREVIOUS ANALYSES

<u>Date</u>	<u>System</u>	<u>Concentration (wppm)</u>
1/79	Sec-1	0.4
2/79	PRI	0.2
3/79	Sec-3	0.3
4/79	Sec-2	<0.1
10/79	PRI	0.1
6/80	Sec-3	0.5

3. Future Work

The test pot/furnace design will be completed and procurement started of components and materials.

Plans for silicon particulate effects in FFTF will be completed and implemented during the initial two days of operation at full power.

B. SODIUM FROST TECHNOLOGY

G. B. Barton and A. P. Bohringer

1. Objective

The purposes of this program are to prevent sodium vapor deposits from affecting operation of FFTF and to develop operating and design criteria for liquid metals systems. Tests are intended for developing Sodium Vapor Deposit Accumulation (SVDA) rates for forecasting maintenance requirements. The scope includes the effects of sodium pool temperature, condenser surface configurations, cover gas impurities, piping configuration and temperature, and gas flow rates.

2. Accomplishments

Flat plate condenser tests were continued to examine the effect of higher oxygen concentration than previously reported, hydrogen impurity, and the effect of plating the condenser surfaces so that it was wetted by sodium. The results are summarized in Table 4.

The rate of evaporation and the rate of accumulation on the condenser plate are only very slightly affected by changing the gas composition. However, the retention on the plate does vary with the atmospheric and surface conditions of the plate. (See Figure 13, which illustrates the difference in distribution and accumulation of the deposit.) Oxygen increases the viscosity of the molten sodium as it piles up (Run 26). The tin coating was

TABLE 4

SODIUM VAPOR DEPOSITION OF FLAT PLATE CONDENSER INCLINED AT 90°

Run No.	Na Pool Temp		Time at Temp (h)	Atmospheric Composition	Condenser		Evaporization Rate** (g/s·m ²)	Condensation Rate*** (g/s·m ²)	Fraction Effected on Condenser (%)	Fraction of Condensate Remaining on Condenser (%)
	(°C)	(°F)			Incl(°)	Surface*				
24	538	1000	24	Ar 0.68 ppm H ₂ O	g	Used	0.218	0.0195	35.5	31.4
25	538	1000	24	Ar, 23 ppm H ₂ 7.5 ppm H ₂ O	g	Used	0.210	0.0180	33.9	30.9
26	538	1000	24	Ar, H ₂ O ppm O ₂ 0.62 ppm H ₂ O	g	Used	0.215	0.0185	34.1	42.1
27	538	1000	24	Ar 0.67 ppm H ₂ O	g	Tinned	0.214	0.0198	36.7	36.5
31 28	538	1000	24	Ar 0.65 ppm H ₂ O	g	Ag Plated	0.218	0.0171	31.1	53.8

*The condenser used for these experiments had been used for 9 previous tests. The collection and removal of sodium leaves a tarnish on the surface of the stainless steel. The tinned surface was generated by melting pure tin under a soldering flux. The silver plate was generated by using Roccelle salts mirror silvering solution. Both coatings were applied only to the upper surface.

**Sodium container ID = 3.32 in., and calculated surface area = 55.85 cm².

***Condenser top surface area = 221 cm²; all the sodium collected on it appears to have been from setting of mist particles. Temperature distribution on condenser plate: Inlet end = 500 ± 15°F, middle = 402 ± 8°F; outlet end = 370 ± 8°F.

Run 24

Run 25 View of Condenser
Top at 90° Incline

Run 26 View of Condenser
Surface

Run 27

Run 28 Frost Test

FIGURE 13. Photographs Showing Change in Distribution of Sodium Accumulation on Condenser Plate. (See Table 1 for operating condition variables.)

removed by the sodium and formed massive patches of an intermetallic compound. (See area at left center of photograph of Run 27). The silver coating increased the wetting of the condenser plate by sodium and may have increased the viscosity since drainage was not as complete as on other tests.

Three tests were performed on a parallel plate baffle system similar to the thermal baffles used in various pieces of equipment. The plate spacing was greater to allow examination of a wider temperature range in a single test. The general apparatus is shown in Figure 14 along with pictures of the baffles with their sodium accumulation. The data are summarized in Table 5.

The first conclusion is that convective circulation of mist is the major sodium transport mechanism. The first test (No. 29) showed evidence of sodium refluxing off the bottom plate so the subsequent tests were shortened. Comparing the accumulation rates calculated for the three runs, there does not appear to have been significant distortion of the deposition pattern by refluxing. The higher evaporation rates for the two shorter runs result from the neglect of the evaporation occurring during heatup and cool-down. In the photograph through the viewport, Plates 4 and 5 are visible. Plate 4 is just below the level of the side arm. It appears that the expanded gas volume around this plate increases the deposition rate.

On the lower two plates the sodium was molten; on the center one, partially so; and on the upper two, it was a sponge.

At the oxygen level tested, it appears evaporation is slightly reduced over that in pure Ar, the deposition pattern is slightly modified, and a smaller fraction deposits on the plates. With the baffle clearance of 0.42 in., convection readily occurs. Whether this cell is going up one side and down the other or is laminar is not clear, but the unsymmetrical deposit on Plate 4 suggests the former.

The formation of sodium vapor deposits in pipes -- particularly the FFTF gas equalization lines and the reactor vessel exit line -- that could

General View of Apparatus

View of Upper Two Plates Showing Sodium Deposit

Top View of Plates

Bottom View of Plates Showing Small Amount of Accumulated Sodium on Bottom of Bottom Plate

FIGURE 14. Run 29 Apparatus and Results of the Sodium Vapor Deposition on Parallel Plates.

TABLE 5

SODIUM VAPOR DEPOSITION ON PARALLEL PLATE BAFFLES

Run No.	Na Pool Temp		Time at Temp (h)	Atmospheric Composition	Evaporation		Bottom Plate				2nd Plate			
	(°C)	(°F)			Total (g)	Rate (g/s m ²)	Temp		Sodium		Temp		Sodium	
							(°C)	(°F)	(g)	(g/h)	(°C)	(°F)	(g)	(g/h)
29	538	1000	5	Ar 0.30 ppm H ₂ O	21.03	0.209	249	480	2.12	0.424	157	315	1.54	0.308
30	538	1000	1.5	Ar 0.40 ppm H ₂ O	8.53	0.283	249	480	0.52	0.347	163	326	0.52	0.347
31	558	1000	1.5	Ar, 140 ppm O ₂ 0.40 ppm H ₂ O	7.95	0.264	249	490	0.41	0.273	197	387	0.34	0.227

Run No.	3rd Plate				4th Plate				Top Plate				Total Sodium (g)	Deposits on Plates (%)
	Temperature		Sodium		Temperature		Sodium		Temperature		Sodium			
	(°C)	(°F)	(g)	(g/h)	(°C)	(°F)	(g)	(g/h)	(°C)	(°F)	(g)	(g/h)		
29	112	233	1.44	0.288	78	172	1.71	0.342	62	143	1.47	0.297	8.28	39.4
30	118	245	0.46	0.307	88	190	0.53	0.352	68	155	0.43	0.287	2.46	28.8
31	142	287	0.36	0.240	93	200	0.45	0.300	63	146	0.33	0.220	1.83	23.0

Dimensions:

(in.)

Vessel Inner Diameter	3.84
Plate Diameter	3.00
Plate Spacing	2.5
Top Plate to Flange	5.
Overall Height of Vessel	20.5

impede gas flow is a question of concern. The character of these deposits and their mode of formation are being examined on a laboratory scale to provide understanding for control of these deposits.

The experimental setup is shown in Figure 15. The basic sodium evaporator is the same as that used for the flat plate condenser experiments. The photograph shows a glass collecting tube in place for Run 35. This was used for visual observation of the location and distribution of the deposit. Runs 33 and 34 employed stainless steel tubing, 3/4 x 0.035-in. The tubing was cut into lengths; the sodium contained in it was then removed and the quantity determined.

The results are summarized in Table 6 and Figure 16. Test 32 employed a 3-ft vertical section of 3/4-in. SS tubing. The data are interpreted as indicating flow of gas up the center of the tube until near the top the flow changes direction in a tee. This direction change induces turbulence in the gas that carries mist particles to the wall. Between the tee and the vapor trap there is a swagelok reducer from 3/4-in. to 1/2-in. tubing. The opening of the smaller section of this reducer was covered by the sodium deposit, but it had not stopped the gas flow.

The results from Tests 33 through 35 demonstrate that sodium collection in the tube is by settling of mist particles with a very minor direct condensation of vapor. Test 34 shows that raising the wall temperature above the melting point of sodium reduces the collection on the wall and moves the deposition further downstream. Some refluxing of sodium from the heated zone occurred.

Since it appears that sodium deposition in cool or cold pipes is largely a mist deposition process, more knowledge is needed of the generation and transport of mist as a function of sodium pool temperature, cover gas purity, temperature gradient, flow rate (velocity) and piping geometry. It is planned to conduct more experiments to elucidate some effects.

FIGURE 15. Apparatus for Study of Sodium Vapor Deposition in Pipes. Neg 8008649-3cn

TABLE 6

SODIUM DEPOSITION IN COVER GAS PIPING TESTS ON 3/4-INCH TUBING WITH GAS FLOW OF 100 cc/min

Run No.	Na Pool Temp		Time at Temp (h)	Atmospheric Composition	Evaporation		Na Collection				Comments
	(°C)	(°F)			Total (g)	Rate (g/s·m ²)	Section No.	Length (in.)	Weight of Na (g)	(wt/in.)	
32	470	800	97	Ar <0.1 ppm H ₂ O	23.9	0.01225	1	6	0.38	0.063	Vertical
							2	6	0.0025	0.00042	Vertical
							3	6	0.0029	0.00048	Vertical
							4	6	0.0024	0.00040	Vertical
							5	6	0.0029	0.00048	Vertical
							6	6	1.5	0.250	Vertical
							Tee		1.4		90° change in direction
33	427	800	97	Ar <0.1 ppm H ₂ O	26.84	0.01376	Vapor Trap		1.1		
							1	2-3/8	0.015	0.0063	Vertical
							2	5-1/2	1.6	0.29	Vertical to horizontal bend (50 radius)
							3	6-5/8	2.6	0.39	Horizontal, straight
							4	6	0.32	0.053	Horizontal, straight
							5	6-1/4	0.15	0.024	Horizontal, straight
							6	6	0.055	0.0092	Horizontal, straight
							7	6	0.020	0.0033	Horizontal, 90° bend
							8	6	0.019	0.0032	Horizontal, straight
							9	6	0.012	0.0020	Horizontal to vertical bend
							10	8	0.00086	0.00011	Vertical, straight
							11	8-3/4	0.00097	0.00011	Vertical, straight
							12	ELL	0.00021		90° elbow
							13	10-1/2	0.0076	0.00072	Horizontal, straight
							14	10	0.0047	0.00047	Horizontal, 45° bend
34	427	800	97	Ar <0.1 ppm H ₂ O	22.86	0.01172	15		0.0016		Tee and reducer
							16		0.0072		Vapor trap
							1	8	0.34	0.043	(50 radius) Vertical 2-3/4 in. & 90° bend 5-1/4 in.
							2	7	0.83	0.12	Horizontal end of heated section (350°F)
							3	9	1.0	0.11	Horizontal end of heated section (350°F)
							4	9	0.74	0.082	Horizontal end of heated section (350°F)
							5	6	0.10	0.017	90° bend to vertical
							6	12	0.0091	0.00076	Vertical
							7	7	0.020	0.0029	90° bend
35	427	800	96	Ar <0.1 ppm H ₂ O	22.2	0.01150	8	15	0.049	0.0033	Horizontal
							9		0.0017		Union & reducer
							Vapor Trap		0.030		
							1	6	0.032	0.0053	Vertical, SS
							2	10	4.7	0.47	90° bend, glass
							3	7	1.1	0.16	Horizontal, glass
							4	7	0.22	0.031	Horizontal, glass
							5	9	0.073	0.0081	90° bend, glass
							6		0.0022		Stainless steel, swagelok connector
36	427	800	96	Ar <0.1 ppm H ₂ O	22.2	0.01150	7	10	0.015	0.0015	90° bend, SS
							8	7-1/4	0.022	0.0030	Horizontal, SS
							9		0.0025		Union & reducer
							Vapor Trap		0.050

FIGURE 16. Deposition of Sodium in 3/4-in. Tubing from Flowing Argon Stream. (Sodium pool temperature is 427°C (800°F) with cover gas flow rate at 100 cc/min and velocity at 0.71 cm/s.)

C. COLD TRAP TESTING

G. R. Bloom and J. R. Welty*

1. Objective

The objective of this program is to provide technical support for design, procurement and operation of the FFTF and HEDL test facility cold traps. Crystallizer packing effects on liquid metal natural convection heat transfer film coefficients were determined for simulated cold trap heat transfer surfaces.

*Mechanical Engineering Department, Oregon State University, Corvallis, OR.

2. Accomplishments

Laboratory studies were performed to determine the crystallizer packing effect on sodium velocity and temperature generated by the natural convection heating in the core region of a cold trap crystallizer. Previous work by Humphreys and Welty⁽¹²⁾ determined velocity profiles for mercury contacting a heated bare vertical plane. The original work with the bare heated wall was extended from a Grashoff number (Gr^*) of 10^{11} to 2×10^{12} . The data are presented as generalized plots of Nussult number vs Grashoff number.

For a vertical heated plate the Grashoff number is defined as:

$$Gr^* = \frac{\beta b}{\nu^2 k} x^4 \dot{q}''$$

where:

$\dot{q}''$ = heat flux from heated wall

β = thermal coefficient of volumetric expansion

g = gravitational acceleration

ν = kinematic viscosity

k = fluid thermal conductivity

X = vertical distance along the plate

The Nussult number is defined as:

$$Nu = \frac{hX}{k}$$

where:

h = film heat transfer coefficient

X = vertical distance along the plate

k = fluid thermal conductivity

Mercury is a liquid metal with heat transfer properties that can be used to model heat transfer in a sodium cold trap crystallizer. Modeling is accomplished by matching the Grashoff number of the mercury test system to that typical of a "similar" sodium system. Mercury studies are valuable because velocity profiles can be measured experimentally while sodium velocity measurements with hot wire anemometer methods are not possible. The mercury temperature profile experiments are less expensive and easier to perform than similar sodium experiments.

The velocity profile and temperature profile data were extended for the case of higher Grashoff numbers. Previously data were for the case of the laminar flow regime. The higher Grashoff number data now extend into the transitional region between laminar and turbulent flow. The Grashoff number was increased in these experiments by increasing X (the vertical distance along the plate). The Grashoff number increases proportionally to the fourth power of the distance X .

The velocity and temperature profiles for the mercury at three different Grashoff numbers are given in Figures 17 and 18. The profiles were measured 27.3 cm from the bottom of the bare heated plate with similar data being obtained at 2.6 cm.

The mercury flow is concentrated into a narrow region with the majority of the flow being within 15 mm of the wall. The thermal boundary layer is also concentrated within 15 mm of the heated surface. These results are similar to previously reported velocity profiles⁽¹³⁾ for mercury obtained at lower Grashoff numbers.

A generalized plot of Nusselt number vs Grashoff number is presented in Figure 19 where the effects of cold trap crystallizer packing wire diameter are shown. The heated vertical plate was covered with prototypic woven wire cold trap packing having diameters of 0.25 mm and 0.12 mm. The woven wire packing density was varied to retain a constant specific surface area

FIGURE 17. Velocity Profiles for Mercury Next to a Heated Plate.

FIGURE 18. Temperature Profiles for Mercury Next to a Heated Plane.

FIGURE 19. Packing Effects on Natural Conduction Heat Transfer from a Vertical Heated Plate.

of $82 \text{ m}^2/\text{m}^3$ in the packed region. The packing density was $0.33 \text{ kg}/\text{m}^3$ for the 0.25-mm diameter wire packing and $0.2 \text{ kg}/\text{m}^3$ for the 0.12-mm diameter packing.

The wire diameter was observed to affect the film heat transfer coefficient. The 0.25-mm diameter wire increased the heat transfer coefficient about 50% compared to the 0.12-mm diameter packing. The heat transfer coefficient for the 0.12-mm diameter packing was similar to that for the bare heated plate.

The effects of natural convection heat transfer have been to increase the amount of heat transfer and to cause channeling near the cold trap crystallizer wall. The 0.25-mm diameter wire packing is seen to increase heat transfer and increase flow channeling even further. The 0.12-mm diameter wire packing has little or no effect on the heat transfer coefficient when the Grashoff number is below 10^{11} and does not increase the flow channeling. These results demonstrate that the 0.12-mm diameter wire packed to a $0.2\text{-kg}/\text{m}^3$ density provides better packing material.

D. FFTF SODIUM SYSTEMS SUPPORT

G. B. Barton, G. R. Bloom, G. E. Meadows and W. Yunker

1. Objective

This program provides technical and engineering support to FFTF operations, monitors performance of FFTF purification and characterization systems, and evaluates impurity behavior in the sodium and cover gas.

2. Accomplishments

Impurities in the sodium and cover gas systems were followed and the impurity behavior evaluated. During this report period a third Maximum Isothermal System Temperature (MIST) was conducted. The bulk sodium temperature was increased from 204°C (400°F) to 421°C (790°F) for several days while the performance of system components was evaluated. Impurity changes

in the sodium and cover gas systems were of less magnitude than during the other two MIST tests. Table 7 gives the plugging temperatures for the MIST tests.

TABLE 7
MIST PLUGGING TEMPERATURES

<u>System</u>	<u>MIST I 2/79 (°C)</u>	<u>MIST II 8/79 (°C)</u>	<u>MIST III 7/80 (°C)</u>
Primary	167	145	146
HTS-1	146	~135	< 127
HTS-2	146	~135	< 127
HTS-3	146.5	~147	< 127

The primary cold trap was increased from 110°C to 127°C during the 421°C operation. The second cold traps were increased from 110°C to 116°C during the 421°C operation.

Oxygen, hydrogen and carbon in the primary sodium averaged 1.5 ppm O, 0.05 ppm H and 0.6 ppm C. The oxygen, hydrogen and carbon in the secondaries averaged 0.97 ppm O, 0.04 ppm H and 0.033 ppm C. Trace metal impurities in the primary and secondary sodium core were within acceptable limits and were <5 ppm for each element.

Hydrogen in the primary cover gas increased from ~3 ppm at 204°C to a maximum of 54 ppm during the temperature increase to MIST. While at MIST the hydrogen decreased to ~20 ppm and remained steady until the systems temperature was decreased to 204°C. The hydrogen then decreased to ~4 ppm. Methane in the primary cover gas remained below the detectable limit (~2 ppm) of the gas chronograph. Other impurities were <20 ppm in the primary cover gas. No changes were detected in the secondary cover gas systems.

FFTF secondary loop cold trap pressure drops have continued to increase to a maximum of about 5 psi. The pressure drop in the Loop 1 cold trap has

held fairly constant and is now at 4.7 psi at 14 gpm sodium flow. The secondary Loop 2 and Loop 3 cold trap pressure drops increased from a maximum of 1.5 psi to near 3.8 psi at 13 gpm sodium flow.

The pressure drop increases in Loops 2 and 3 are within the predicted value of 4 psi reported in the last quarterly.⁽³⁾ The pressure drop rate increase accelerated during the FFTF heatup to near 780°F during MIST III. The pressure drop increases are attributed to redistribution of impurities deposited in the cold trap crystallizers, and increasing the cold trap inlet temperature accelerated this process. The cold trap pressure drops are not expected to increase significantly above 5 psi unless additional impurities are introduced into the secondary systems. Initial startup impurity burdens have already been removed and deposited into the cold trap. No additional burdens are expected in the secondary sodium systems except for system maintenance or the proposed steam generators.

Technical support was provided on cover gas monitoring in the areas of oil vapor analysis, oxygen levels in RAPS, frost formation in unheated argon lines and frost behavior in shield plug annuli.

3. Future Work

Surveillance of sodium sampling and cover gas characterization and purification systems will continue. A study of the FFTF sodium and cover gas system impurities from sodium fill to the first power run will be made.

E. FFTF FUEL FAILURE MONITORING

D. V. Archer and F. E. Holt

1. Objective

This task provides technical support for the development, installation and startup of the Fuel Failure Monitoring System.

2. Accomplishments

Failure Detection Subsystem -- Technical assistance was provided to Plant Engineering and Operations to rectify current and expected problems and to determine actions to be taken in response to Fission or Absorber Gas Hi alarms.

Two problems were resolved and recommendations made to Plant Engineering to prevent the LN_2 flow rate to the detector Dewar from dropping sharply and recorder power supplies from burning out. The LN_2 flow rate dropped because the anti-splash filter, a closed-end tube of sintered bronze inside the detector Dewar, became filled with debris. The filter was replaced and the flow rate returned to normal. To prevent recurrence of this problem Engineering plans to make the recommended modifications to the anti-splash device and venting of the Dewar. One of the channels on a recorder failed because overheating caused its power supply to burn out. Additional ventilation of all recorders was recommended to prevent recurrence and is being implemented.

Recommended responses to Fission or Absorber Gas Hi alarms during normal and initial startup operations were transmitted to Plant Operations. The recommended responses during normal operation specified cover gas activity concentrations that would result in a reactor Scram, Power Descent, or Operation at Power. During the initial ascent to power and two-day power runs, it was determined that very little fission gas was present in the fuel pins. Consequently the recommended action was to continue operation even in the event of an alarm and to obtain other samples.

Failure Characterization Subsystem (FCS) -- The multichannel analyzer, mini-computer and data links that make up the FCS were checked and officially turned over to Operations with several test exceptions left outstanding. Most of the test exceptions are minor and do not prevent operation of the Subsystem. Operator training on the Subsystem is being pursued.

The FCS stores data on a magnetic tape for historical and further study purposes. A computer program is being written to decode that stored data. This program is about 20% complete.

Failure Location -- Air and hydrocarbons continued to appear in mass spectrometric analyses of gas obtained using the Gas Tag Sampling Trap (GTST) but not in the small, U-tube laboratory trap. Valves on at least two of the GTST assemblies were determined to be leaking in both directions and may be the cause of the problems. FFTF Operations is examining the valves in order to make corrections.

A lighter-weight, somewhat smaller trap design was proposed that could be used throughout most of the plant's life. The present GTST assemblies were designed and fabricated for use under conditions of the failure of two high rod power pins, an unlikely event during most of the plant's life. The proposed design recommends using 80 g of charcoal instead of 175 g to reduce the impact of ^{23}Ne and ^{41}Ar on the dose rates, while not compromising the Xe and Kr trapping capability. That reduction combined with expected activity levels in the cover gas under failed fuel conditions makes possible the use of aluminum in place of steel as shield material while still retaining the 500 mR/h dose rate limit. The proposed design would be smaller, lighter and less subject to impurity difficulties.

The formation of a Failed Element Location Team, a small group that would notify Plant Operations of the location of a failed fuel or absorber element, was begun. The team would be responsible for determining from GTST analytical data and core information, the location of the failed element by assembly number, and for recommending to Plant Operations the course of action to be taken.

3. Future Work

Provide technical support as needed.

Provide Failure Characterization Subsystem training.

F. FUEL FAILURE MONITORING - EBR-II PROOFTEST

F. E. Holt and D. V. Archer

1. Objective

This task provides design verification and performance evaluations of Fuel Failure Monitoring (FFM) components on an operating fast reactor.

2. Accomplishments

Absorber/Collimator (A/C) Test -- The responses of the two A/C devices were tested during this quarter to determine their effectiveness. The Detector and A/C device No. 1 responded as expected, equivalent to laboratory tests, and resulted in gamma ray intensity reduction factors that increased the range of count rates accommodated. The Detector and A/C device No. 2 data yielded unexpected, and as yet unexplained, results for Position 3 but agreed with laboratory tests for Positions 2 and 4.

Each A/C device was manually set over a four-day period to count in three of its four positions for a fixed period of time. Counting times were set at 700, 2000, 7000 and 9000 seconds. The counting time chosen was dependent on the amount of intensity reduction expected and the predicted cover gas activity.

There is generally excellent agreement between the Proof test and GLASS data as evidenced by the percent, 1σ precisions. Counting rates for the various energies ranged from $7 \times 10^{-3}/s$ to 1000/s.

At the end of the test period, the several outputs from each detector and A/C positions were compared against the EBR-II plant's corresponding GLASS monitoring system outputs. Tables 8 and 9 list the results. From the c/s per d/s-ml values in the Tables, one obtains the intensity reduction factors versus A/C position. For example from Table 8 the reduction factor for ^{133}Xe 81 keV gamma ray when counting in Position 3 versus Position 1 is $0.0714/0.00218 = 32.7 \pm 1.9$. Table 10 lists the calculated factors and the laboratory measured ones from the last quarterly report.⁽³⁾

Conversion of Computer Program -- The computer program used to decode the Proof test's data stored on magnetic tape is being converted from CYBER to VAX processing. The CYBER computer is being phased out of service. Conversion of the applicable programs is almost complete.

Gamma Ray Subtract (GRS) Module Modification -- The GRS prototype module was modified to add a third set of countrate multipliers. The added set of multipliers will be used to normalize A/C Position 4 countrates to Position 1 countrates. The added flexibility is needed whenever the Position 4 configuration is not a simple combination of Positions 2 and 3. That situation occurs with the lead plug used in A/C Position 4, Detector No. 2 and with the use of "compound" absorber/collimators in different tungsten collimators.

The modification was accomplished by an outside vendor and tested in the laboratory. The outputs obtained were as expected. The prototype control panel and microprocessor with the new program were sent to EBR-II for further testing. Unfortunately, the prototype and installed control panels were wired slightly differently as the tests could not all be completed. Personnel at EBR-II will modify the Proof test's control panel and finish the requested tests.

3. Future Work

Determine cause of A/C No. 2, Position 3 reduction factor discrepancy.
Complete Proof test computer program conversion. Test modified GRS module at EBR-II.

TABLE 8

DETECTOR 1/GLASS 1 RATIOS VS A/C POSITION

Counting Time (s)	A/C Pos	^{133}Xe at 81 keV		^{135}Xe at 250 keV		^{135}Xe at 608 keV	
		c/nCi-ml	c/s per d/s-ml	c/nCi-ml	c/s per d/s-ml	c/nCi-ml	c/s per d/s-ml
700	1	$\bar{X}_7 = 1850$ $\pm 1.1\%$	7.14 E-2	$\bar{X}_9 = 584$ $\pm 1.3\%$	2.26 E-2	$\bar{X}_7 = 2.70$ $\pm 8.7\%$	1.04 E-4
2000	3	$\bar{X}_{14} = 150$ $\pm 5.7\%$	2.08 E-3	$\bar{X}_{13} = 131$ $\pm 2.9\%$	1.77 E-3	$\bar{X}_{13} = 3.89$ $\pm 15\%$	5.27 E-5
7000	4	$\bar{X}_4 = 14.2$ $\pm 1.3\%$	5.48 E-5	$\bar{X}_4 = 24.6$ $\pm 8.2\%$	9.50 E-5	$\bar{X}_4 = 1.32$ $\pm 43\%$	5.10 E-6
9000	4	$\bar{X}_{11} = 19.7$ $\pm 15\%$	5.92 E-5	$\bar{X}_{10} = 31.7$ $\pm 8.9\%$	9.52 E-5	$\bar{X}_{12} = 1.67$ $\pm 24\%$	5.02 E-6

TABLE 9
DETECTOR 2/GLASS 2 RATIOS VS A/C POSITION

Counting Time (s)	A/C Pos	^{133}Xe at 81 keV		^{135}Xe at 250 keV		^{135}Xe at 608 keV	
		$\frac{\text{c/nCi-ml}}{\text{d/s-ml}}$	$\frac{\text{c/s per}}{\text{d/s-ml}}$	$\frac{\text{c/nCi-ml}}{\text{d/s-ml}}$	$\frac{\text{c/s per}}{\text{d/s-ml}}$	$\frac{\text{c/nCi-ml}}{\text{d/s-ml}}$	$\frac{\text{c/s per}}{\text{d/s-ml}}$
700	1*	$\bar{X}_{10} = 22144$ $\pm 1.3\%$	0.855	$\bar{X}_{10} = 14305$ $\pm 0.8\%$	0.552	$\bar{X}_{10} = 97.0$ $\pm 1.1\%$	0.00375
2000	2	$\bar{X}_{14} = 1108$ $\pm 3.4\%$	0.0150	$\bar{X}_{14} = 807$ $\pm 2.2\%$	0.0109	$\bar{X}_{14} = 11.1$ $\pm 12\%$	0.00015
700	3	$\bar{X}_6 = 489$ $\pm 4.6\%$	0.0189	$\bar{X}_6 = 991$ $\pm 1.0\%$	0.0383	$\bar{X}_6 = 49.6$ $\pm 3.2\%$	0.00192
7000	3	$\bar{X}_4 = 4921$ $\pm 2.6\%$	0.0190	$\bar{X}_4 = 9901$ $\pm 1.0\%$	0.0382	$\bar{X}_4 = 491$ $\pm 0.9\%$	0.00189
9000	4	-	-	$\bar{X}_9 = 60.2$ $\pm 5.6\%$	0.00018	$\bar{X}_{11} = 248$ $\pm 6.3\%$	0.00074

*Data from 5/3/80 (Position 1 not used during this 7/29 to 8/4/80 A/C test).

TABLE 10

GAMMA RAY REDUCTION FACTOR COMPARISONS VS A/C POSITION AND DETECTOR

A/C Pos	Ni	Detector No. 1		Detector No. 2	
		A/C Test	Lab Test	A/C Test	Lab Test
2	^{133}Xe at 81 keV			57 ± 2	55
	^{135}Xe at 250 keV			51 ± 1	45
	^{135}Xe at 608 keV			25 ± 3	22
3	^{133}Xe	33 ± 2	25	45 ± 2	1070*
	^{135}Xe	12.7 ± 0.4	10	1.44 ± 0.3	270*
	^{135}Xe	2.0 ± 0.3	2	2.0 ± 0.1	23*
4	^{133}Xe	1206 ± 180	1070	-	-
	^{135}Xe	237 ± 21	270	3050 ± 170	3300
	^{135}Xe	21 ± 5	23	5.0 ± 0.3	5.5

*Cannot explain this discrepancy. EBR-II personnel determined that the correct A/C configuration is in this position.

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