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COMPILATION OF CURRENT TECHNICAL EXPERIENCE AT
ENRICO FERMI ATOMIC POWER PLANT

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PREFACE

PURPOSE

The purpose of this monthly report is to make available to the fast reactor program the current experience being gained from the Enrico Fermi Atomic Power Plant.

SCOPE

The scope of this report includes all phases of current nuclear operating and maintenance experience at the Enrico Fermi Atomic Power Plant.

Earlier Fermi experience in certain selected areas is being recorded in a series of technical reports completed or in preparation by Atomic Power Development Associates Inc. for the US Atomic Energy Commission under AEC Contract No. AT(11-1)-865, Project Agreement 15. This series of reports provides detailed information on the nuclear testing, rod drives, machinery dome, fuel subassemblies, fuel handling, steam generators, pumps, flowmeters, level detectors, sodium sampling and development of the primary sodium system.

Items A, B, and C in Section II are usually reported each month; items in the other sections are selected on the basis of their special significance during the month. Other items may be found in the monthly report submitted to the Atomic Energy Commission by Power Reactor Development Company in compliance with the requirements of Provisional Operating License No. DPR-9, as amended.

BACKGROUND

The Fermi reactor achieved initial criticality on August 23, 1963. An extensive series of nuclear tests was conducted at power levels below one megawatt thermal, through 1965. A high power (200 Mwt) license was issued on December 17, 1965, and operation in excess of 1 Mwt was initiated on December 29, 1965. In January 1966, the power was raised in a series of steps to 20 Mwt. On April 1, 1966, power was first raised to 67 Mwt and on July 8, 1966, operation at 100 Mwt was initiated. On October 5, 1966, fuel damage occurred during an approach to power, since this time the reactor has been shut down while the cause and extent of the damage are being investigated.

It is assumed that those reading this report have a general familiarity with the plant. As an aid to the reader, a perspective drawing of the plant was included at the back of Report No. 1.

Since this report is intended to follow closely the current proceedings at the Fermi Plant, it must necessarily be treated as preliminary information, subject to supersedence in the light of subsequent experience.

SECTION I

CURRENT EXPERIENCE SUMMARY

The reactor continued to remain shut down because of the fuel damage sustained on October 5, 1966. More information on the condition of the core and blanket subassemblies in the reactor was obtained using the reactor's offset handling mechanism. None of the 67 outer radial blanket subassemblies, checked during December by lifting less than 3/4-inch, were stuck to the support plates.

Core subassembly M098 cannot be pulled free from adjoining core subassembly M127; they are apparently attached to one another. Subassembly M098 has been under suspicion, because on October 5th its outlet temperature was reading higher than expected by 85 F. A special method probably will be required for removing these two subassemblies simultaneously; more information on the procedure will be reported in the January monthly report when the procedure has been more completely defined.

At the beginning of the month, two core subassemblies were removed from positions near the center of the core. They were replaced by inner radial blanket subassemblies to reduce the reactivity of the core.

Subassembly M140 was then transferred from core position NO4-PO4 to a finned pot in the transfer rotor container. This subassembly has been under suspicion because its outlet temperature on October 5th was 126 F higher than expected. It is suspected of being twisted or bowed because it required a considerable force to insert it into the finned pot in the transfer rotor container. Oversized transfer pots have since been fabricated to accept subassemblies suspected of being distorted.

With M140 removed, the forces required to lift several other subassemblies south of M140 in the same row decreased to forces only slightly greater than normally expected.

Subassembly M091 was removed from core position NO1-PO5 and replaced by inner radial blanket subassembly M304 from a storage position at the outside of the outer radial blanket. M091 was then transferred via the cask car to the Fuel and Repair Building transfer tank. Like M140, this subassembly also indicated a

high outlet temperature on October 5th and earlier, although not as high as M140. The M091 temperature was 40 percent higher than expected in July and August, and 40 percent higher than predicted on October 5th. Subassemblies M091, M098 and M140 are the only three subassemblies under thermocouples that were indicating higher than expected outlet temperatures on October 5th.

Inner radial blanket subassembly M393 was removed from position NO3-PO6 and taken to the Fuel and Repair Building where it was steam cleaned and examined in the cut-up pool with underwater TV cameras. Nothing unusual was observed.

Subassembly M148 was removed from position NO5-PO3 and placed in the transfer rotor container. Materials Surveillance subassembly MS-1 was removed from core position NO1-PO3 and taken to the FARB transfer tank. It will be steam cleaned and disassembled in the cut-up pool for inspection of the contained materials samples. Subassembly M122 was removed from core position NO3-PO4 and placed in the transfer rotor container.

Subassembly M099 had been transferred in July from the core to a fuel storage position in the reactor vessel as the first of a series of scheduled removals for the fuel inspection program. This subassembly was transferred to the Fuel and Repair Building in November for processing prior to shipment off site. It has been steam cleaned, cut into sections and shipped to the Battelle Memorial Institute hot lab where the disassembly and inspection program is currently underway. No significant abnormalities had been discovered at the date of this report.

At the end of December, detailed design was nearing completion on a fuel examination facility to be located at the reactor exit port in the containment building, and most items were on order. The facility consists of a 10-inch diameter chamber, 13 feet long, mounted on a platform above the exit port and connected to it by means of an isolation valve. Individual subassemblies are to be drawn up through the exit port into the chamber from the transfer rotor container by means of a hoist mechanism mounted above the chamber. The chamber is shielded and heated. There are three viewing windows and five valved penetrations for inspection of the subassembly. Inspections include periscope viewing of the ends of the subassembly, dimensional checking and a gamma scan. Provisions have also been made for weighing the subassembly and checking internal pressure drop by means of gas flow.

The platform over the exit port can also accommodate the revised multipurpose shipping cask which will be used to ship selected subassemblies to the Battelle hot lab for destructive examination. These subassemblies will be shipped in a sealed container filled with frozen sodium. The sodium will be removed in an argon atmosphere at the hot lab.

Inspection at the exit port and at Battelle is expected to begin in April when the equipment will become available. In order to obtain a quick look at the inlet strainers on the subassemblies, a borescope is being adapted for use in the new subassembly loading tunnel of the steam cleaning machine in the Fuel and Repair Building. The self-illuminated borescope will be located under the valve that normally admits new subassemblies into the machine. Parts were on hand or readily available and the installation will be complete in January.

SECTION II

PLANT OPERATIONS

A. Reactor Unloading

The diagram on page 9 shows the core loading at the end of December 1966. Eight subassemblies were removed from the core and inner radial blanket during the month of December. Three of the core subassemblies were replaced by IRB subassemblies transferred from storage positions in the reactor vessel. The other five positions were left open.

The chart on page 10 summarizes the changes in the reactor loading during December and the reasons for the changes.

After difficulty was experienced while inserting M140 into a normal finned transfer pot, several special pots were fabricated. The top portion of the special pots is unchanged from the normal design and, in fact, these pieces were obtained by cutting off the tops of several extra normal transfer pots. The outside diameter and length are also unchanged so that the units are interchangeable with the normal pots and adaptable to the existing fuel handling equipment. Space occupied by the cooling fins on the normal pots has been used to increase the inside diameter on the special pots, to accomodate swollen or warped subassemblies which may be removed during the reactor unloading program. The cooling fins are not necessary for these subassemblies because of the small amount of decay heat present, 7 watts for an average core subassembly as of December 31, 1966. This low amount of decay heat also permits the pots to have drain holes at the bottom so that the sodium from the reactor vessel is not carried over to the Fuel and Repair Building transfer tank and does not spill over into the cask car during the fuel transfer operation.

B. Other Fuel Handling Experience

1. Steam Cleaning Machine

The machine successfully cleaned subassemblies M099 and M393 and two dummy subassemblies during the month. Only one dummy subassembly remains to be cleaned to complete the twenty subassembly test run. At the end of the month the shutter valve at the bottom of the cleaning chamber stuck. It was freed by flushing and manipulating.

A check was made of the pressure drop in the cleaning chamber resulting from the argon flow through M099 and M393. There was no indication of detectable flow blockage on either subassembly.

N16 N15 N14 N13 N12 N11 N10 N09 N08 N07 N06 N05 N04 N03 N02 N01 N00 P01 P02 P03 P04 P05 P06 P07 P08 P09 P10 P11 P12 P13 P14 P15 P16

KEY:

CR Control Rod No. 430169-
SR Safety Rod No. 430192-
OR Oscillator Rod
CS Core Shim Subassembly
CF Core Foil Subassembly
BF Blanket Foil Subassembly
CT Coarse Filter, Take-apart, Dummy Core Subassembly
NOTE: Dummy Core subassemblies in the reactor meet "Core A" core subassembly specifications and bear the suffix "CF"

NA Sodium Worth Subassembly
NS Neutron Source
TIT Temporary Instrument Thimble
MS APDA Materials Surveillance Subassembly
M Subassembly Manufactured by D.E. Makepeace Co.
S Subassembly Manufactured by Sylcor Division, Sylvania Electric Products Co.

M 001 - M 206 Core Subassemblies
M 301 - M 400 Inner Radial Blanket Subassemblies
S 500 - S 798 Outer Radial Blanket Subassemblies
M 801 - M 1000 Outer Radial Blanket Subassemblies

Units shown without prefix are dummy outer radial blanket subassemblies.

- Oversize Nozzle Unit
- "F" Subassembly (Contains fuel pins with high iron plus nickel, high carbon or Zirconium content.)
- "W" Subassembly (Contains fuel pins with high iron plus nickel content.)
- Blanket slugs have high carbon content. (APDA Surveillance Program Unit)
- Stringering in Blanket Slugs
- Large Grain Blanket Material (Hash)
- Larger Than Normal Spacing Between the Blanket Elements and the Support Grid
- Type 347 Stainless Steel Wrapper Tube
- Handling Head Short
- Test Flow Subassembly (S-400)
- Slugs Previously Used in a Test Subassembly
- "CP" Slugs
- Space Where Subassembly Was Removed
- Space Last Vacated as of 12-31-66
- IRB'S Replacing Core Subassemblies

REACTOR LOADING 12-31-66

CHANGES IN REACTOR LOADING DURING DECEMBER 1966

Date	Subassy No.	From Position	To Position	Subsequent Moves	Replaced by Subassy No.	Position	Reason for Move	Remarks
12/1	M153	P01-P01	Transfer Rotor Container	None	M382	N14-P04	To reduce the core reactivity	This subassembly selected because it was near the core center, had normal lifting force and normal outlet temperature, therefore minimum risk.
12/1	M066	P01-N01	P04-N14 (Storage)	None	M330	N04-N14	Same as above	Same as above
12/2	M140	N04-P04	Transfer Rotor Container	None	None	-	1. Reduce core reactivity 2. Determine that it was free 3. Expedite its inspection	Apparently warped-required high force to remove and had to be pushed into normal transfer pot. Had high outlet temperature on and before October 5th.
12/21	M091	N01-P05	Transfer Rotor Container	To FARB Transfer Tank	M304	P01-N14	1. Reduce core reactivity 2. Expedite its inspection	Had high outlet temperature on and before October 5th. Fit OK in normal transfer pot but taken to FARB in special drainable pot.
12/22	M393	N03-P06	Transfer Rotor Container	To FARB Trans Tank, Steam Cleaned, to Leaker can in pool	None	-	1. No anticipated cleaning or inspection problems 2. Determine if orifice OK 3. Had a high pulling force 4. Relieve tight row	Fit OK in normal pot but taken to FARB in special drainable pot. Inspection at pool via TV showed nozzle OK and externally okay. Stored in cut-up pool leaker can.
12/29	M143	N05-P03	Transfer Rotor Container	None	None	-	1. Reduce core reactivity 2. Determine that it was free 3. Relieve area around suspect subassemblies	Fit OK in a normal transfer pot
12/29	MS-1	N01-P03	Transfer Rotor Container	To FARB Transfer Tank	None	-	1. Expedite its cleaning, disassembly and return of test specimens 2. Relieve tight row	This materials surveillance subassembly contains test specimens of non-fissionable material which has been irradiated.
12/27	M122	N03-P04	Transfer Rotor Container	None	None	-	1. Reduce core reactivity 2. Determine that it was free 3. Relieve area around suspect subassemblies	Placed in a special drainable pot

Note: Nos. M001-M206 are core subassemblies, Nos. M301-M400 are inner radial blanket subassemblies.

Samples were collected from the 80 gallons of wash water used to clean subassembly M099. The water from the cleaning machine collects in surge tank MK-9, and the samples were taken from the bottom of the tank. The major gamma emitting radionuclides were identified as Co-58, Cs-137 and possible Mn-54 plus some Zr-95 and Nb-95. The gross beta activity of the samples before and after agitating the tank contents was 8.2×10^{-2} microcuries/cc and 1.03×10^{-2} microcuries/cc, respectively. A chemical analysis of the wash water indicated that 73 grams of sodium had reacted off the subassembly. This compares closely with an earlier measurement of 77 grams reacted from a dummy subassembly with simulated pins.

Data from samples taken during the steam cleaning of subassembly M393 and from the leaker can had not been analyzed at the end of December.

2. Leaker Cans

After subassemblies have been cleaned of sodium they are taken into the cut-up pool in the Fuel and Repair Building and placed in leaker cans to determine if they are releasing any fission product contaminants. At intervals the water from the bottom of the leaker can is flushed out into a five gallon sample container and checked for radioactivity.

Successive samples were taken from the M099 leaker can after 1, 24 and 48-hours. The one-hour sample had an activity of 5.8×10^{-4} microcuries/cc, while the 24 and 48-hour samples had an activity of 1.3×10^{-3} microcuries/cc. The major gamma emitting radionuclides were Co-58 and Cs-137. The former is apparently the result of corrosion of the nitrided surfaces on the nozzle and the handling head. This corrosion had been expected, see page 29 of the August report. The Cs-137 is a fission product. Based on the small quantities of the radionuclides in the leaker can, it was concluded that M099 had no significant leakage from its pins.

3. Cut-Up Machine

The machine successfully cut up underwater a test subassembly containing a bundle of dummy fuel pins. Base measurements of fuel pin bundle spacing were taken prior to putting the dummy fuel pin bundle in the simulated subassembly. The cutting was done using underwater TV cameras for observation. The operation caused little vibration of the subassembly. Measurements of pin spacing taken after the cutting operation indicated there was no significant change.

The machine then successfully cut the upper and lower axial blanket sections from subassembly M099.

4. Shipment of Subassembly M099

The three sections of M099 were removed from the cut-up machine by a special segment handling tool attached to the cut-up pool bridge crane. They were lowered into the Battelle Memorial Institute shipping cask which was resting in the bottom of the cut-up pool. The cask contained a three-legged stand in which were inserted three shipping pots. After the three segments of the subassembly were placed in the pots, the pots were sealed at the top by spring-loaded plugs and the top of the cask bolted in place.

The cask was loaded and shipped on December 9 on a straight-through truck shipment. It arrived at the Battelle Memorial Institute hot lab near Columbus, Ohio, after six hours in transit. An accelerometer was installed on the truck and the maximum impact recorded was one G.

C. Sodium and Gas System Performance

1. Sodium Cold Traps and Plugging Indicators

<u>December Operating Date</u>	<u>Primary System</u>	<u>Secondary System</u>		
		<u>Loop 1</u>	<u>Loop 2</u>	<u>Loop 3</u>
Cold Trap Operation (Hours)	8*	15	29	-
Maximum Plugging Temperature - F	Below 210 F	260	310	-
Minimum Plugging Temperature - F	Below 210 F	220	220	-

2. Primary Sodium Chemical Analysis, sample date - 12/11/66

Carbon 41, 43, 48, 69	
Oxygen 14, 15, 15, 15,	**Hydroxide hydrogen 0.9, 0.9, 0.9
Nickel below 0.2	**Nonhydroxide hydrogen 0.2, 0.2
Iron 1.4	
Chromium below 0.2	Note: Values are in ppm by weight

** 1.3 ppm recommended maximum total hydrogen

* Cold trap operated on 12/11/66 in order to obtain a representative sample of the primary sodium for chemical analysis.

3. Primary System Cover Gas Analysis

	Reactor Cover Gas (Argon) <u>ppm by Volume</u>	Primary Shield Tank Atmosphere (Nitrogen) <u>ppm by Volume</u>
Oxygen	below 25	45*
Carbon Monoxide	below 10	below 10
Carbon Dioxide	below 10	25
Hydrogen	below 4**	5
Helium	below 4	below 4
Methane	below 10	below 10
N ₂ O	not measured	below 10
NO ₂	not measured	below 1
Argon	balance	not measured
Nitrogen	1080	balance
Analysis Date	12/9/66	12/9/66

*Technical Specifications state 1000 ppm maximum

**10 ppm recommended maximum.

4. Sodium Activity

Primary System: 3.34×10^{-2} Microcuries/cc Na,
on December 30, 1966

Secondary System: Below instrument min sensitivity of
 2.5×10^{-4} Microcuries Na-24/cc Na

D. Plutonium Production

The production to date of P-239 in an average core subassembly was calculated to be about two grams, corresponding to 0.031 a/o burnup. Since no alpha activity has been observed (in excess of the minimum detectable level) in the primary sodium sample measurements, it was calculated that there could be at most two milligrams of plutonium in the entire primary sodium system.

E. Core Integrated Sodium Flows

As part of the investigation of the October 5th partial core meltdown, the integrated hours of flow through the core has been compiled. Source of the flow information was the reactor plant primary sodium flow recorder 24-hour chart file. These charts record individual loop flow to the core and blanket. The flow information extends from August 23, 1963, at the conclusion of the initial loading to criticality, to October 5, 1966.

A value of 7.70×10^6 lb/hr sodium flow through the core has been selected as normal or 100 percent flow for three-loop operation. This value is based on a total pump flow of 2.95×10^6 lb/hr per loop with 13 percent of this flow per loop diverted to the reactor blanket subassemblies. For two-loop operation the core flow consists of the two pump core flows minus the back flow through the third loop to the blanket inlet plenum.

The bar graph on the following page displays the hours of operation at various flows for the period from January 1, 1966, to October 5, 1966. The bar graph on page 16 gives the same information integrated over the period from August 23, 1963, to October 5, 1966, and also presents a plot of core inlet pressure versus core flow.

HOURS AT DIFFERENT FLOW LEVELS JANUARY 1 - OCTOBER 5, 1966

**HOURS AT DIFFERENT FLOW LEVELS AUGUST 23, 1963 -
OCTOBER 5, 1966**

SECTION III

PLANT REPAIRS - CORE INVESTIGATION

A. Subassembly Lifting Forces Prior To Removal Of M140

At the end of November all core and inner radial blanket subassemblies had been checked by the offset handling mechanism (OHM) for the force required to start raising them, in the manner described in Section IIB 8, Report No. 4, November 1966. This method determines the deflection of lifting springs which act on the OHM upper overload plate that is attached to the lifting crane tube. Forces are computed from the spring rate. Twenty-five outer radial blanket subassemblies near the core were also checked.

Investigation of the data revealed that the lifting forces were highest in the rows and columns containing M140 and M098, the two subassemblies whose outlet temperatures were higher than normal. The tight rows and columns extended in east-west and north-south directions from both subassemblies, and in general the lifting forces increased with increasing proximity to M140 and M098. See page 19 for a diagram showing the lifting forces prior to the removal of any subassemblies.

B. Removal of Subassembly M140

After removing two subassemblies near the center of the core to reduce reactivity (see page 9), subassembly M140 was then removed. The required pulling force vs distance lifted was noted and compared with the forces required to lift the aforementioned central core subassemblies. The higher forces required by M140, and the variation in force, indicate that M140 or its neighbors have been distorted. When inserting M140 into a normal finned transfer pot in the transfer rotor container, an abnormally high force was required to push the subassembly the final 17-inches into the pot. There is nominally a 1/8 inch clearance across the diagonals between a subassembly and the inside diameter of the pot.

C. Recheck of Lifting Forces After M140 Removed

Forty-one subassemblies in the tight rows and columns plus ten in adjacent rows and columns were rechecked after subassembly M140 had been removed. It was thought that the force required to lift the subassemblies in these rows might have diminished, since distortion of M140 could have caused a lateral reaction on other subassemblies causing them to bind. The required lifting forces, after M140 was removed, are shown on the diagram on page 20. Several subassemblies immediately south of

M140 had significantly lower lifting forces. In most other cases, the difference in readings is probably within the repeatability error of the lifting process, estimated to be in the order of plus or minus 20 percent. At this time 46 additional outer radial blanket subassemblies in the affected rows and columns received a lifting force check, plus seven adjacent ORB subassemblies. These subassemblies had not been checked previously; their measurements fell within the previously established pattern, as shown on page 20.

D. Replacement of OHM Lifting Springs

The springs temporarily installed on the OHM for this investigation were replaced by the heavier original springs to permit measurement of larger forces applied to the subassemblies. The values obtained with the heavier springs are in general 30-100 lb higher than those obtained with the previous springs, most likely due to a shift in the base calibration point. Twelve subassemblies were rechecked in the tight rows and columns with the heavier springs, thirteen were rechecked in adjacent rows and columns and fourteen adjacent subassemblies were checked for the first time. Two anomalies were noted: inner radial blanket subassembly M393 at N03-P06 had an unusually high lifting force, and outer radial subassembly M918 at N03-P07 also had a high lifting force coupled with a 0.4-inch shift in OHM azimuth required to release this subassembly.

E. OHM Check of Subassembly Elevations

The elevations of the handling heads on 59 additional outer radial blanket subassemblies were checked. The elevations of 98 core and IRB subassemblies and 24 ORB subassemblies adjacent to the core had been checked in November. The elevations of the 59 subassemblies were all very close to normal. An accuracy of plus or minus 25 mils had previously been demonstrated. A recheck was made on the handling head elevations of 50 of the subassemblies which were checked in November. Several subassemblies near M098 were observed to be 1/4-inch to 1/2-inch high. A check was then made by lifting M098 1/4-inch and observing if other subassemblies also were pulled up by friction or because of bonding. Three other subassemblies were observed to have been raised about the same amount. When M098 was lowered 1/2-inch, subassembly M127 also lowered the same amount. At this point it was concluded that M098 and M127 may not be free from each other, whereas all other subassemblies appear to move independently of one another.

N16 N15 N14 N13 N12 N11 N10 N09 N08 N07 N06 N05 N04 N03 N02 N01 P00 P01 P02 P03 P04 P05 P06 P07 P08 P09 P10 P11 P12 P13 P14 P15 P16

SUBASSEMBLY LIFTING FORCES BEFORE M140 REMOVED

N16 N15 N14 N13 N12 N11 N10 N09 N08 N07 N06 N05 N04 N03 N02 N01 P00 P01 P02 P03 P04 P05 P06 P07 P08 P09 P10 P11 P12 P13 P14 P15 P16

Type Subassembly	Weight / Lbs (In Air)
Core	121
IRB	165
ORB	161

Note Underlined figures are lifting forces measured after offset handling mechanism lifting springs changed.

* Subassembly M140 Removed

Net Pounds - Corrected For Buoyancy

SUBASSEMBLY LIFTING FORCES AFTER M 140 REMOVED

F. Subassemblies M098 and M127 Appear Bonded

An attempt was made to lift M098 completely out of the core. After raising it about one inch it would not raise further. Apparently an adjacent subassembly is fused to M098 and at one-inch this adjacent subassembly strikes the stabilizer foot on the offset handling mechanism. The clearances at the stabilizer foot permit only one subassembly at a time to be lifted above one-inch, in fact, the purpose of the foot is to prevent other subassemblies adjacent to the one being raised from also lifting. An approximate 1500-pound lifting force failed to strip M098 free. A similar result was observed when attempting to lift M127.

As reported on page 10, eight subassemblies were removed from the reactor during December, with none except M140 showing any obvious evidence of distortion during the transfer operation.

SECTION IV

OTHER INVESTIGATIONS

A. Inspection of Subassembly M099

Subassembly M099 had been removed from the core in July 1966 and placed in a storage position in the outer row of the outer radial blanket. In November it was transferred to the Fuel and Repair Building. During December it was steam cleaned, cut up, shipped and disassembled for inspection at the Battelle Memorial Institute hot cell. The inspection program calls for twelve different inspection items on the core section, five on the lower axial blanket section and two items on the upper axial blanket section. At the date of this report visual observations and photography had not revealed anything relating to the October 5th incident on the wrapper can, inlet strainer or fuel pin bundle. All items appeared clean. The wrapper can was dimensionally checked and showed no abnormalities. At the end of December half of the wrapper can had been removed from the core section. The colmonoy spacer pads on the corners of the subassembly were brighter at the top of the pad than at the bottom. Chips from the cut-up machine transverse cut were observed to be lodged at one end of the fuel pin bundle. The investigation is continuing and will be reported in more detail in the January report.

B. Study of Particulates in the Sodium

A program has been initiated at the APDA sodium chemistry laboratory to look for particulate matter in the Fermi primary sodium. In one recent test a 100 gram sample was vacuum distilled at 650 F and 53 ppm of particulate matter remained. After washing the residue with water to remove all water soluble compounds it contained about 2 percent carbon. Included in the residue were a few black cinder-like particles with a maximum size of 40 mils across the largest dimension. Upon acid treatment some of the particles in the residue disintegrated into a mixture of clear crystalline particles and translucent fibres. The largest fibres are approximately 10 microns in diameter by 1 mm long. The crystals ranged up to 50 microns in size. The 40 mil particles are thought to have been agglomerates of the crystals.

Arrangements are underway to obtain larger quantities of the Fermi sodium. The larger samples will permit more extensive and accurate analyses, such as X-ray diffraction measurements.

At present it is not believed that the particulate matter discovered could have plugged the subassembly inlet strainers.

As a check, samples of commercial sodium were analyzed for particulate matter and the residue was grossly comparable to that obtained from the Fermi sodium, except that it contained larger particles, between 100 and 800 microns in size, and a larger number of these particles.

C. Review of Fluorolube Leakage

A check was made to determine if a significant quantity of the fluorolube lubricant, used in the primary pump shaft seals, could have been introduced into the primary sodium. See page 11 of report 1, August 1966, for more information on the seals and lubricant.

The analysis of sodium samples has shown no evidence of fluorides and no correlations could be established between possible leakage dates and sodium impurity levels during or after these dates. It has, therefore, been concluded that probably no detectable amount of fluorolube lubricant has leaked into the primary sodium.

D. Tests of Subassembly Pin Clad Damage

Several tests were run to determine clad damage at elevated temperatures. It is possible that some subassemblies in the reactor may have been subjected to temperatures sufficiently high to cause cladding damage, due to a partial flow blockage, but not high enough to melt the fuel.

The first test was run on a depleted uranium pin identical to the Fermi core fuel pin except for the substitution of the depleted uranium for enriched uranium in the U-10 w/o Mo metal alloy. The clad is 5 mil thick zirconium. After one week at 1600 F (the boiling temperature of sodium) in an argon atmosphere, the uranium alloy had diffused almost completely through the clad. The cladding subsequently failed when a pin segment was given a 5 degree bend at room temperature, whereas prior tests had shown bend angles of greater than 150 degrees before failure. It appears that an undesirable embrittlement of the zirconium resulted from diffusion of the uranium into the zirconium.

Tests were then made on the upper axial blanket pins (or rods). These rods, as well as all other blanket rods, are depleted U-3 w/o Mo alloy, sodium bonded to 10 mil stainless steel cladding. The uranium-stainless steel eutectic formation occurs at approximately 1340 F as compared to the uranium alloy melting temperature of 2115 F. After holding a blanket rod at 1450 F for 20 hours, examination revealed that the eutectic had formed and had resulted in gross failure of the cladding.

It had been hoped that by nondestructively examining the upper blanket pins, local overheating of the core fuel pins could be deduced. The upper blanket pins could be readily examined through the essentially open top of the sub-assembly. However, further analysis has led to the conclusion that a partial flow blockage could cause the fuel pins to overheat sufficiently to damage their cladding, without the upper blanket pins heating to the point where their cladding was damaged.

SECTION V

INSPECTION FACILITY AND SHIPPING CASK DESIGN

A. Inspection Facility

A shielded inspection chamber is to be installed in the reactor building above the exit port. This facility will permit preliminary examination and evaluation of subassemblies removed from the reactor. The examination will help select one or more subassemblies, which appear to be damaged, for shipment to the Battelle Memorial Institute hot lab for disassembly and detailed examination. Design of the facility by APDA is almost complete and most items have been placed on order as of December 31st.

An outline sketch of the facility is shown on the following page. An enclosed gripper and hoist mechanism is mounted above the chamber with provision for a continuous argon purge of the hoist and chamber. A load cell on a cable pulley in the hoist mechanism permits weighing the subassembly. The gripper and hoist mechanism had already been built for another purpose and requires only minor modifications.

A support platform resting on the operating floor carries the weight of the facility, including six-inch thick lead block shielding. The space between the platform and the exit port contains a seal valve with a bellows to accomodate relative motion. Thermal insulation and six-inch thick lead block shielding surround the valve and bellows.

Sealing valves are provided for the chamber and hoist mechanism. There are three lighted viewing windows in the chamber and immediately outside these windows are 12-inch thick glass windows in the shield wall. The space between the wall and the chamber will be held at a negative pressure by ventilation circulation with the result that any out leakage from the chamber will be directed to the reactor building exhaust.

A jig transit fitted with an optical micrometer will be mounted on a vertical traverse mechanism outside the shield wall and will inspect the subassembly through the viewing windows for warpage, swelling or other gross distortion.

(View Looking South)

SUBASSEMBLY INSPECTION FACILITY

There will be five valved penetrations on the chamber in addition to the three ports containing the viewing windows. At the bottom and top there are penetrations for installing a periscope for inspection of the inside of the subassembly from below or above. Also at the bottom is a penetration for installation of a fixture to support the subassembly and to measure the pressure drop of argon gas flowing down through the subassembly and out through the fixture. This will be a check for flow blockage. The other two penetrations, one at the center and one at the top, are spares - the center penetration may be used for a gamma scanning device.

Means are being provided to rotate the subassembly about its vertical axis and to prevent it from swaying while being inspected. The chamber and lower portion of the hoist mechanism will be electrically heated to about 350 F.

An existing plug removal cask will be modified slightly and used together with the overhead building crane for removal of the exit port shield plug. This operation must precede mounting of the inspection facility or shipping cask (described below) on the support platform. See page 29 for a drawing of the plug removal cask.

B. Shipping Cask Modifications

It had been planned for some time before the October 5th fuel damage to periodically inspect core subassemblies and other items from the reactor. As part of a program to do this inspection Battelle Memorial Institute was designing and fabricating a multipurpose shipping cask. This cask is being modified by BMI to accept a shipping pot which will contain a full length subassembly encased in frozen sodium. BMI is also sealing their hot cell so that the atmosphere inside may be inerted with nitrogen gas because of the possible pyrophoric nature of the damaged fuel and sodium.

Measurements that are to be conducted in the BMI hot cell include the following:

1. Visual observations and photography
2. Weight measurements of the over-all subassembly and core section individually
3. Radiochemical analysis of the sodium for fission products
4. Gross gamma scan
5. Dimensions of external hardware

6. Hardness tests along the length of the wrapper can
7. Metallography of wrapper can
8. Upper and lower axial blanket metallography
9. Fuel pin dimensions and pin spacing, if possible
10. Fuel pin metallography
11. Spring load-deflection characteristics
12. Fission product plate-out analysis on wrapper can
13. Strainer observations and analysis of any deposits

The multipurpose cask previously had been designed for top loading; the design has been modified to allow bottom loading as well. The cask will be positioned above the exit port and will mount on the same support platform used at other times for the inspection facility. See page 29 for a sketch of the cask installation at the exit port.

A special shipping pot will have been previously placed in the cask. The cask will be placed in position and the pot will be lowered from the cask through the exit port and into the transfer rotor, using the gripper of the cask. The gripper is lowered and raised by means of a long, jointed rod attached to the building crane and passing through a seal at the top of the cask.

The subassembly to be shipped will be placed in the pot and the pot picked up again with the cask gripper. A portion of the gripper is forced down onto the top of the special pot to form a plug, sealing the top of the pot. After the pot has been supported in the cask, the gripper rod is disconnected just above the top of the cask and the cask is sealed at the top and bottom.

After insertion into the hot cell at BMI the special pot will be heated, the sodium drained and the subassembly removed from the pot for examination.

C. Inspection of Inlet Nozzles

It will probably be April before damaged subassemblies can be examined at BMI or at the exit port inspection facility at Fermi. The exact date will depend on the performance of the fabricators and the amount of time needed to install and test the equipment. Meanwhile, late in December it was decided to proceed with a program which will permit examination of the inlet strainers on suspected subassemblies in the very near future - within a

PLUG REMOVAL AND SHIPPING CASKS

few weeks. Inspection will be made with a self-illuminated borescope installed under the valve that normally admits new subassemblies into the steam cleaning machine in the Fuel and Repair Building. There is ample space in the dry loading tunnel under this valve for the installation and for convenient viewing access, as shown in the sketches on pages 31 and 32.

A suitable borescope is on hand and a 90-degree adaptor piece is being fitted to it so that the viewer will be out of the radiation streaming path. Additional shielding and an extension pipe have been added under the steam cleaning machine valve. The pipe will preserve an inert atmosphere around the subassembly.

The subassembly will be lowered out of the cleaning chamber until the borescope projects up inside the inlet nozzle. Tests on new subassemblies have shown that a good view is obtained of the inlet strainer in the nozzle. Plugging of this screen is one of the potential causes of fuel overheating. No steam cleaning of the subassemblies is planned prior or subsequent to this inspection.

FUEL AND REPAIR BUILDING (PLAN)

FUEL AND REPAIR BUILDING (SECTIONAL ELEVATION)