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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 operations and maintenance experience concerning the nuclear portion and related systems of 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, machinery dome, steam generators, pumps, flowmeters, level detectors, sodium sampling and development of the primary sodium system.

Items in the sections of this report 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 were 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. In addition, a topical index appears at the end of the June 1967 report.

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

An unidentified foreign object was discovered lying on the meltdown pan at the outer edge of the core inlet plenum. The object appears to be a piece of crumpled sheet metal about 7 inches long by 4 inches high in its present configuration, with the other dimension not yet determined. The object is thought to be the probable cause of the reactor fuel damage. There appears to be little resemblance between the object and any known component or portion of the primary system.

An object-moving device will be used to maneuver the object closer to the center of the reactor where a better view can be obtained. The first attempts at moving the object with simple cables were unsuccessful. The next attempt will be with a special tool utilizing a chain which bends in only the upward direction.

Two approaches under consideration include removal in pieces from the top of the reactor through the core support plates, or intact through one of the 14-inch inlet lines. No decision on removal procedure will be made until a closer inspection of the object has been performed.

Investigations of the causes of malperformance of the three intermediate heat exchangers (IHXs) were recently completed. The heat transfer rates determined from data taken last year at 100 Mwt reactor power are 450-560 Btu/hr-ft²-F while the design heat transfer rate was expected to be 980 Btu/hr-ft²-F. It is predicted that at full power plant operating conditions the IHXs would transfer approximately 380 Mwt power rather than the design capacity of 430 Mwt, with a larger temperature difference across the IHX being required.

The lack of proper primary sodium flow distribution on the shell side is thought to be the major cause of the IHX malperformance. Since the inlet and outlet connections are approximately 90 degrees apart, the primary sodium flow is probably low in the remaining 270 degrees of the shell as well as in the spaces above the inlet and below the outlet connection. Other causes of the IHX malperformance may be secondary sodium (tube side) flow inequalities or fouling of the tubes.

SECTION II

DISCOVERY OF UNIDENTIFIED FOREIGN OBJECT IN INLET PLENUM

A. Inspection Method

Inspection of the core inlet plenum commenced on September 11 using the corescope and an iodine quartz lamp light source. These two items were inserted into the reactor vessel through the 6-inch I.D. lower guide tube access penetrations in the rotating shield plug and were lowered through empty positions in the core support plates into the inlet plenum. Preparations for the inspection had been completed as described in Section II D of Report No. 13.

B. Location and Description of Object

An unidentified foreign object (UFO) was detected shortly after the inspection started. The UFO was located at the outer edge of the zirconium meltdown pan in a northeast direction from the center of the core. Its approximate location is underneath lattice position N10-N10 on the outer radial blanket. The photograph of the UFO on Page 7 was taken through the corescope which was inserted in lattice position N05-N02 while the light source was in position N05-N01 (see Page 8 for a diagram of the reactor lattice positions and the reactor loading). The photograph shows a view of the UFO from a distance of about three feet, looking downward slightly from the horizontal.

The object appears to be about 7 inches long and 4 inches high. The object's third dimension cannot be determined from the present view. As can be seen from the photograph, it has a crumpled appearance suggesting that it may be constructed of thin gauge metal.

The drawings on Pages 9 and 10 show the core inlet plenum, the steel shield plates at the bottom of the reactor vessel and the zirconium-lined meltdown pan. The position of the UFO is indicated on the drawings.

C. Relation to Fuel Damage

The UFO is thought to be the probable cause of the fuel damage which occurred on October 5, 1966. Although a better view of the UFO is necessary, it appears to be about the right size and shape to have caused blockage of sodium flow to the melted core subassemblies. Flow in the inlet plenum could have swept up the object and caused it to be held against the underside of the core lower support plate. This could result in blockage of flow to several core subassembly inlet nozzles and could cause these subassemblies to melt even at low power operation.

P16	P15	P14	P13	P12	P11	P10	P09	P08	P07	P06	P05	P04	P03	P02	P01	P00	N01	N02	N03	N04	N05	N06	N07	N08	N09	N10	N11	N12	N13	N14	N15	N16
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☐ 1	Handling Head Start	Unit
☐ 2	Test Floor Subassembly (S-400)	(1)
☐ 3	Slugs Previously Used in a Test Subassembly	14 11
☐ 4	CP Slugs	3 C
☒ 5	Left and Available For Left and Right	5 5

Unit 1: Introduction to the course
Unit 2: The history of the course
Unit 3: The importance of the course
Unit 4: The role of the course
Unit 5: The future of the course

ELEVATION OF REACTOR VESSEL

MELT-DOWN SECTION IN LOWER REACTOR VESSEL

D. Identification

The object had not been identified as of the end of the month. Photographs, such as the one on Page 7, were distributed to a number of people intimately familiar with the Fermi primary system, but no one was able to identify the object. However, there is (at the date of this report) the general feeling that the UFO does not appear to be an internal part which has come loose from its proper position. Present prevailing opinion is that the object is foreign to the primary system and entered during construction or during previous maintenance programs.

The object appears to be too large to have passed through the intermediate heat exchangers (IHXs) because of their close tube-to-tube spacing and the close spacing between the tube bundles and shells. For this reason, it seems the object was probably originally located in the inlet plenum, in the primary pumps, or in the piping connecting the pumps and the reactor or the pumps and the IHXs.

E. Preparations for Obtaining a Better View

Two attempts were made during September to move the UFO to a new position, hopefully nearer the center of the meltdown pan to obtain a closer view for detailed inspection. The actions were intended to establish contact with the object by means of flexible aircraft-type control cables, and to give it a nudge. The cables were threaded down the tube holding the light source and were guided out horizontally at the bottom of the tube. The first attempt was unsuccessful because of binding between the inner cable and its sheath. The second attempt using a wire failed because the wire curled up after making the 90-degree bend when leaving the guide tube at the meltdown pan elevation.

Movement of the UFO towards the center will give some indication of its weight and mobility, and viewing of the top of the object will then be possible. The additional viewing from different angles and from a closer location will permit a better evaluation of the UFO. This closer inspection and resulting evaluation will help to determine how the object should be removed.

F. Object-Moving Device

Work commenced in late September to design and construct a more sophisticated tool for moving the UFO, after the two earlier attempts had not been successful. This object-moving device makes use of an extendable four foot length of link chain. Tabs on each link will prevent the chain from bending downward as it exits horizontally from the tube which inserts it into the

reactor vessel, after it is directed horizontally by a curved slot at the lower end of the tube. A break-away feature is being incorporated into the design to permit the curved slot to disengage and enable the chain to drop to the vertical position if the chain freezes in the slot.

A special adapter has been fabricated so that the device, the light tube and the corescope tube can all be simultaneously inserted into the same 6-inch penetration in the rotating shield plug. The upper photograph on Page 13 shows the adapter being tested. The other 6-inch penetration in the rotating shield plug, shown in the lower left corner of the photograph, contains a shielded viewing window. The third 6-inch penetration contains the reactor sweep mechanism which has not been removed.

The lower photograph on Page 13 is a disassembled view of the lower end of the light source tube. The protective screen is at the right in the picture, the 500-watt bulb is at the center and a small spring claw and retractor tube are shown above the bulb. The light duty claw can be extended out the bottom of the light tube.

The photographs on Page 14 show details of the lower end of the object-moving device. A small wire cable is fastened to the chain at close intervals. The lower end of the cable is preformed in the shape of a partially bent finger. By tugging on the top end of the cable, which is accessible above the 6-inch penetration, the cable and chain can be made to curl or flex.

The gas-cooling sheath has been removed from the corescope to provide additional space, enabling the 6-inch penetration adapter to mount the corescope, light and object-moving device. Recent experience with the corescope in the 350 F reactor argon atmosphere has indicated that the cooling gas is not necessary. It is planned to try substituting the Sunscope for the corescope when the Sunscope extension is complete. See Section II D of Report No. 13 for further details on the Sunscope. The Sunscope was obtained from the Sun Oil Company and the corescope from Atomics International. Both instruments are actually borescopes.

G. Proposed Removal Programs

Several methods have been proposed for removing the object from the core inlet plenum. No decision on the removal procedure will be made until a closer inspection of the object has been performed and until the relative merits of each proposed procedure have been carefully evaluated.

CORESCOPE LIGHT AND
OBJECT MOVING DEVICE
INSERTED INTO REACTOR
VESSEL FOR TESTING OF
NEW SEAL GLAND
ADAPTER

VIEW OF LOWER END OF LIGHT
SOURCE TUBE PRIOR TO REASSEMBLY

CHAIN SECTION
EXTENDED AND
END CURLED BACK
BY MOVING ATTACHED
CABLE

CHAIN CHUTE PULLED OUT OF
THE TUBE. CHUTE AND DIRECTION
CHANGING HEAD ARE NORMALLY
INSIDE THE TUBE

BENT CABLE FINGER AND
CHAIN LINKS WITH TABS TO
PREVENT BENDING DOWNWARD

LOWER END OF OBJECT-REMOVAL DEVICE

One proposed method involves cutting one of the three 14-inch sodium lines which supply the lower plenum. The line would be cut at a point where it is accessible outside the secondary shield wall. A flexible tube and cable would be inserted from this point into the inlet plenum with means being provided for securing the object to the end of the cable.

Another suggested method would be to cut and/or compress the object into pieces which would be removable from above through one of the holes in the support plates with access through one of the 6-inch penetrations in the rotating shield plug. The core lower support plate holes have a minimum I.D. of 1.69-inches (at the orifice holders).

A full sized plywood mock-up of one half of the inlet plenum is being constructed to aid in planning removal of the object. The core support plates and one 14-inch inlet nozzle have been included in the mock-up. See Page 16 for photographs of the mock-up.

14-INCH INLET OPENINGS,
FLOW SPLITTER AND PERFOR-
ATED DEFLECTOR PLATE.
BOTTOM SURFACE SIMULATES
ZIRCONIUM LINER WITH BULGES,
BATTEN STRIPS SECURED WITH
ACORN NUTS AND WASHERS, AND
LINER LIP AT OUTER EDGE

DEFLECTOR PLATE, BAFFLE
PLATE AND CONICAL FLOW
GUIDE

CARDBOARD BOX DEMONSTRATING
LOCATION AT WHICH OBJECT
WAS DISCOVERED

VIEWS INSIDE MOCK-UP OF CORE INLET PLENUM

SECTION III

INSPECTION OF REMAINDER OF CORE INLET PLENUM

The corescope and light source were used to inspect all portions of the core inlet plenum. No evidence of any damage could be seen, but several areas were observed on the meltdown pan which will be rechecked and photographed to look for other objects. It is hoped that use of the modified Sunscope will provide a better view of these areas and a better view of the unidentified foreign object.

Several years ago, a pressure probe which was inserted into the core inlet plenum broke away from its mounting tube. The probe (about the size of a ball-point pen) was not retrieved at the time because it would be harmless due to its small size. Inlet plenum inspections have not as yet discovered this probe.

Page 12 of Report No. 12, describes the results of subassembly M098 having dropped onto the transfer rotor plate when the shipping pot lift cable parted. The short length of cable, clevis and clevis bolt separated from the lifting shaft and remain in the transfer rotor container, most likely in the bottom head. No operational difficulties have since been encountered and it is not planned to remove the loose objects. An inspection will be made, while the sodium is drained, of the transfer rotor table. The table will be examined through the exit port to determine if any of the objects are on its top surface. Presence of the objects on the table could prevent lowering the rotor to disconnect and remove the drive shaft and bearing if maintenance is required.

SECTION IV
SODIUM AND GAS SYSTEMS PERFORMANCE

A. Primary System Gas Activity

<u>Location</u>	<u>Sample Date</u>	<u>Gross Beta Concentration (microcuries/cc)</u>
Reactor Cover Gas	9-1-67	8.2×10^{-6}
Reactor Cover Gas	9-8-67	7.9×10^{-6}
Reactor Cover Gas	9-19-67	2.2×10^{-6}
Reactor Cover Gas	9-22-67	7.0×10^{-6}
Primary Shield Tank	9-22-67	6.2×10^{-7}
Primary Shield Tank	9-29-67	6.0×10^{-7}

B. Primary System Cover Gas Analysis

	<u>Reactor Cover Gas (Argon) ppm by Volume</u>	<u>Primary Shield Tank Atmosphere (Nitrogen) ppm by Volume</u>
Oxygen	Below 25	50*
Carbon Monoxide	Below 10	Below 10
Carbon Dioxide	Below 10	20
Hydrogen	4**	2.5
Helium	Below 4	Below 4
Methane	Below 10	Below 10
N ₂ O	Not measured	Below 10
Argon	Remainder	13,000
Nitrogen	600	Remainder
Dew Point	Not measured	-35 F
Sample Date	September 8, 1967	September 29, 1967

* Technical specifications state 1000 ppm maximum.

** 10 ppm is the recommended maximum for reactor operations.

SECTION V

SPECIAL INVESTIGATIONS

A. Inspection of Subassembly M127

Inspection of M127 was started in July at the Battelle Memorial Institute hot lab. Earlier inspection results have been described in Reports 12 and 13.

The core section was cut longitudinally in August and measurements in September showed that the center of gravity of the thin longitudinal section was located 6-1/8 inches below the spacer pad center line; the center of gravity of the thick section was located 5-1/2 inches below the spacer pad center line. It was calculated that the original center of gravity was 4.84 inches below the spacer pad center line.

Preliminary calculations based on examination of the core section indicate that 4.1¢ reactivity had been lost by subassembly M127, due to fuel relocation. This value is based on template measurements on the dimensions of the melted region.

B. Inspection of Subassembly M098

Inspection of M098 was started in July at the Battelle Memorial Institute hot lab. Earlier inspection results have been described in Reports 12 and 13.

Cutting of the M098 core section was completed in September. Four transverse cuts have been made, forming five axial segments of varying length, as shown on the diagram on Page 22. The lower section included a portion of the lower axial blanket because fuel had relocated in this region. The photographs on Pages 22 and 23 show end views of three of the segments. Longitudinal cuts were made on the upper and lower segments of the core section. A metallographic sample has been made of one of the transverse segments obtained from the cut made six inches from the top. The sample has been etched and a fax film transverse replicate has been made of the surface, shadowed, and is now ready for examination.

C. Intermediate Heat Exchanger Performance

1. General

A series of heat balance tests were made on the Fermi reactor plant in July and August 1966. As reported on Page 17 of Report No. 1, it was determined that the performance of the intermediate heat exchangers (IHXs) was considerably poorer than predicted. Two detailed investigations of the possible causes of the malperformance have recently been completed.

SECTIONING CUTS ON SUBASSEMBLY M098 CORE

TRANSVERSE SECTION THROUGH CORE AT 4TH GRID(M-098)

TRANSVERSE SECTION THROUGH CORE AT PADS (M-098)

TRANSVERSE SECTION BETWEEN GRIDS 11 AND 12 (M-098)

There is one IHX in each of the three main coolant loops. Primary sodium flows down through the shell and secondary sodium up through the tubes. See Page 27 for a sectional drawing of the IHX.

2. Predicted and Measured Performance

The overall heat transfer rate of the IHXs was specified by the manufacturer to be 980 Btu/hr-ft²-F for in-service conditions and in excess of 1,200 Btu/hr-ft²-F for clean heat transfer surface conditions. An in-service heat transfer rate of 1,300 Btu/hr-ft²-F was predicted during the investigation, based on more recent heat transfer correlations. The above heat transfer rates were calculated at design flow and temperature conditions, but only a small change in the rate is expected as a result of flow and temperature variations within the plant operating range.

The heat transfer rates determined from the plant heat balance data in June and July 1966 at 100 Mwt power are in the range of 450 to 560 Btu/hr-ft²-F. The average IHX performance is approximately 50 percent of that predicted from the manufacturer's design data. The No. 1 IHX rate was consistently approximately 20 percent higher than that of the other two heat exchangers.

It has been calculated that the three IHXs will probably have a total heat transfer capacity of 380 Mwt at full power plant operating conditions, rather than the manufacturer's predicted capacity for transferring 430 Mwt. However, a larger temperature difference than originally predicted between the primary and secondary sodium may be required. This would necessitate a higher reactor outlet temperature for given steam conditions or a reduction in the steam temperature for the same fuel temperature. The 380 Mwt heat transfer capacity is based on the assumption that the IHX malperformance is caused by flow maldistribution (resulting in ineffective heat transfer area) and/or fouling, which are discussed in the following section. It is further assumed that these causes are independent of flow within the plant operating range.

3. Causes for Malperformance

Various possible factors which could have an effect on the IHX performance were considered. The following items are considered to have only a slight effect on performance and/or a low probability of occurrence:

- a. Wear sleeves over limited portions of some tubes
- b. Shell side primary sodium level variation

- c. Primary or secondary sodium flow bypassing
- d. Non-wetting of surfaces by sodium
- e. Gas entrainment

Primary sodium flow maldistribution is thought to be the most probable contributor to the IHX malperformance. Other less likely causes are: secondary sodium flow maldistribution, primary fouling and secondary fouling.

The primary sodium inlet and outlet connections are approximately 90 degrees apart on the IHX shells. Annular shrouds are provided to improve flow distribution but the path of least flow resistance is through the outer annular sections in the 90-degree sector between the inlet and outlet connections. The manufacturer's flow tests were with a model having the inlet and outlet 180 degrees apart; even so local velocities ranged from 1.8 to 3.6 ft/sec. Some shell side areas of very low flow probably exist in the sodium-filled spaces above the inlet nozzle and below the outlet. The tendency for stagnation in these spaces is considered to be a part of the shell-side sodium flow maldistribution problem. The original design assumption, that all tubing surface which is covered with sodium on the shell side is equally effective heat transfer area, appears to have been too optimistic. The investigations conclude that shell side maldistribution does exist and is probably the major contributor to the IHX malperformance.

The momentum of the sodium in the IHX downcomer and the toroidal flow pattern in the lower head tend to create radial flow maldistribution of the secondary sodium in the tube bundle. Flow tests conducted by SOGREAH on the French Rapsodie IHX, which is similar to the Fermi IHX, indicated a plus or minus 20 percent variation in secondary sodium flow. Low pressure drops on both the primary and secondary sodium sides make it difficult to equalize sodium flow and result in maldistribution of the flow.

Another possible cause of the IHX malperformance is fouling of the tubes. Measured impurity levels and existing information available on mass transfer and deposition do not predict any appreciable degradation due to this cause. However, it is conceivable that oxide, carbonaceous material or hydrogenous material fouling on either or both sides of the tube wall could produce a thermal resistance several times greater than the fouling resistance assumed by the manufacturer. The greater heat transfer rate of the No. 1 IHX is difficult to explain by causes other than fouling.

4. Proposed Inspections or Testing

The IHX investigations identified in a general way several methods of inspecting and testing the heat exchangers, and methods of correcting the deficiencies. The cause of the IHX malperformance cannot be pin-pointed by means of the calculations which have been made. An extensive testing and/or inspection program would be required to positively determine the cause(s) of the IHX malperformance and to take corrective measures. At present, the need and justification for such a program are not apparent since the predicted performance of the units is well above any plant power levels presently anticipated. The investigations recommended that consideration be given to conducting a 200 Mwt plant test program to verify the IHX assumptions and performance predictions made on the basis of 100 Mwt performance data.

Methods proposed for determining shell and tube side flow distribution are:

- a. Instrument an installed IHX and conduct plant tests.
- b. Construct and test a reduced-size flow model using water to simulate the sodium flow.
- c. Remove one of the IHX tube bundles, install in a special shell and flow test with water.

Flow maldistribution might be corrected by increased pump flows, by improved baffling, or by installing turbulators.

To determine if the tube surfaces are fouled excessively the tube bundle would need to be removed from the shell (a major undertaking) and the surfaces checked, with subsequent cleaning if necessary.

SECTION VI

MAINTENANCE

A. Tube-to-Tube Sheet Weld Repairs on the No. 2 Steam Generator

Approximately 800 of the 1,200 tubes had been rewelded to the water manifold tube sheet at the end of September. Details of the repair weld technique have been related in several earlier reports, starting with Report No. 7. The No. 2 steam generator rewelding is expected to be completed in early October; it was started in early September.

Page 24 of Report No. 7 mentions that the previous weld at the top of the tubes is removed before rolling the tubes into the tube sheet. The first bore welds on the No. 2 steam generator were made without removing the top weld. As a result, considerable difficulty was experienced with the bore welds. It is thought that the restraint of the top weld prevented the tube rolling operation from obtaining maximum effectiveness. No further difficulty was experienced after removal of the top welds was resumed.

B. Underwater Gaging Fixture

Preoperational testing of the fixture is continuing. The viewing problems described on Page 23 of Report No. 11 have been resolved. The fixture was lifted out of the water and the glass covers on the gages, which had been trapping air and causing distortion, were removed. The viewing telescope changes now enable the operators to obtain a good view of the gages.

Four of the seven dimensional checks on the subassembly are now functioning properly. To date, absolute spring load data have not been obtained. The tool to measure spacer pad size is not complete. The dial indicator plunger is stuck on the gage which measures spacer pad concentricity.

The underwater gaging fixture will be used to measure the dimensions of the materials surveillance subassembly and other core subassemblies.

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