# ENRICO FERMI ATOMIC POWER PLANT

## CURRENT EXPERIENCE SERIES

## COMPILATION OF CURRENT TECHNICAL EXPERIENCE AT ENRICO FERMI ATOMIC POWER PLANT NOVEMBER, 1967

R. H. Costello
Assistant Project Engineer

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APPROVED Charles E. Branyan
C. E. Branyan
Fermi Project Engineer
APDA



PREPARED BY
Atomic Power Development Associates, Inc.
with the Cooperation of
Power Reactor Development Company
and
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# DISCLAIMER

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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 U.S. Atomic Energy Commission under AEC Contracts 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 APDA-CFE-1. In addition, a topical index appears at the end of the APDA-CFE-11.

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 unidentified foreign object discovered in the reactor vessel core inlet plenum in September was moved close to the center of the plenum by means of the chain-type object-moving device, and straight-downward photographs were taken for the first time. These photographs revealed new features of the object, notably what appeared to be an expanse of flat surface that could have obstructed coolant flow to the melted subassemblies. The photographs are being studied using stereoscopic viewing and a special technique developed by Battelle Memorial Institute, Columbus, Ohio. Results of the study are expected to reveal the precise dimensions of the object.

Efforts to obtain a sample of the object using a punch and die tool have been unsuccessful. After observing the reaction of the object to a magnet attached to a tube inserted through the support plate holes, it appears that the object is slightly magnetic.

Object removal plans are still proceeding along two parallel paths: (1) by cutting up the object and retrieving it through the support plate holes and (2) by retrieving the object intact through the 14-inch sodium inlet line. The development of cut-up tools and manipulator devices is proceeding along many parallel paths. Some of the cut-up tools should be ready for use in December, and all the remaining cut-up tools should be available in January. The manipulators should be ready in mid January.

The methods of gaining access to the 14-inch line being investigated are either by removing a patch from the elbow immediately outside the secondary shield wall, or by removing the patch after welding a containing elbowlet fitting to the elbow. The principal considerations are the techniques of rewelding pipe reviously exposed to sodium and the resultant stress conditions on the pipe and elbow. Consultation and analysis with respect to these considerations is underway. The development of a device to be pushed through the 14-inch line to retrieve the foreign object is proceeding concurrently with plans to gain access to the 14-inch line.

Since the October 1966 incident, seven subassemblies have been sent to the Battelle Memorial Institute hot lab for inspection, and visual and dimensional investigations have been completed. The major work remaining is metallographic examination of subassembly sections.

## SECTION II

## INVESTIGATION OF FOREIGN OBJECT IN INLET PLENUM

### A. EXPERIENCES IN REACTOR VESSEL

Earlier reports of the investigation of the foreign object in the reactor core inlet plenum are given in APDA-CFE-14 and APDA-CFE-15. The object, discovered in September 1967, is believed to be the cause of the melting of two core subassemblies during power operation on October 5, 1966.

At the beginning of November, the object was in a position adjacent to the conical flow guide and under the Sunscope.* The object had been moved to this location by the chain-type object-moving device.**

After modifications to viewing and lighting equipment to adapt for straight-downward sighting (see Section II. B), the object-moving device tumbled the foreign object into many different positions, all within the range of downward viewing through the Sunscope. Figure 1 shows how the object-moving device is controlled from above the vessel rotating plug while the operation is viewed through the Sunscope.

Figures 2, 3, 4, and 5 are representative of a great number of photographs taken when viewing the object straight downward. They reveal features of the object that were not observable when viewing horizontally. Most notable of the newly-observed features are a pie-shaped silhouette and what appears to be an expanse of flat surface that may have obstructed sodium coolant flow to the two subassemblies. See Section II. C for results of a study of these photographs.

In mid November, after a favorable trial operation in the reactor vessel mock-up, the sampler tool was ready for use in the reactor. This tool, described in a previous report,*** is shown graphically in Figure 6 and photographically in Figure 7. With the object-moving device positioning the object, three unsuccessful attempts were made to punch out a sample; the object could not be positioned accurately enough for the tool to take a

* Sun Oil Company borescope.

** See Sec. II of APDA-CFE-14 and APDA-CFE-15 for background information on the chain-type object-moving device and experience in moving the object with it.

*** APDA-CFE-15, Sec. II. D. 5.

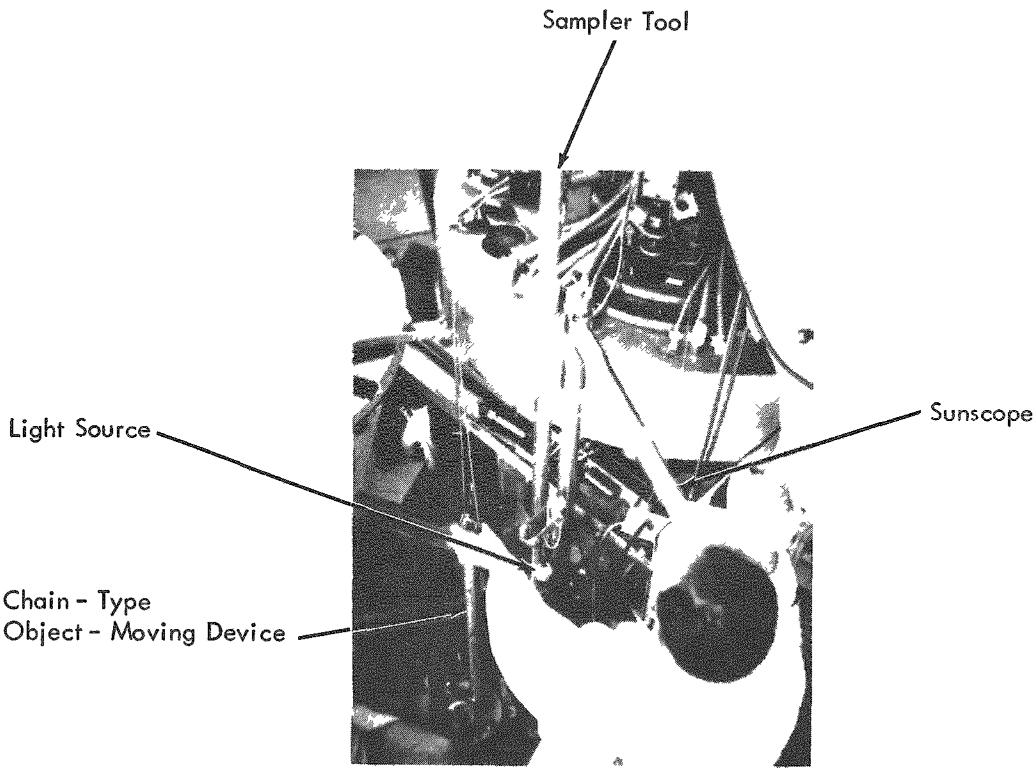


**FIG. 1 OPERATING THE OBJECT-MOVING DEVICE WHILE VIEWING THROUGH THE SUNSCOPE**

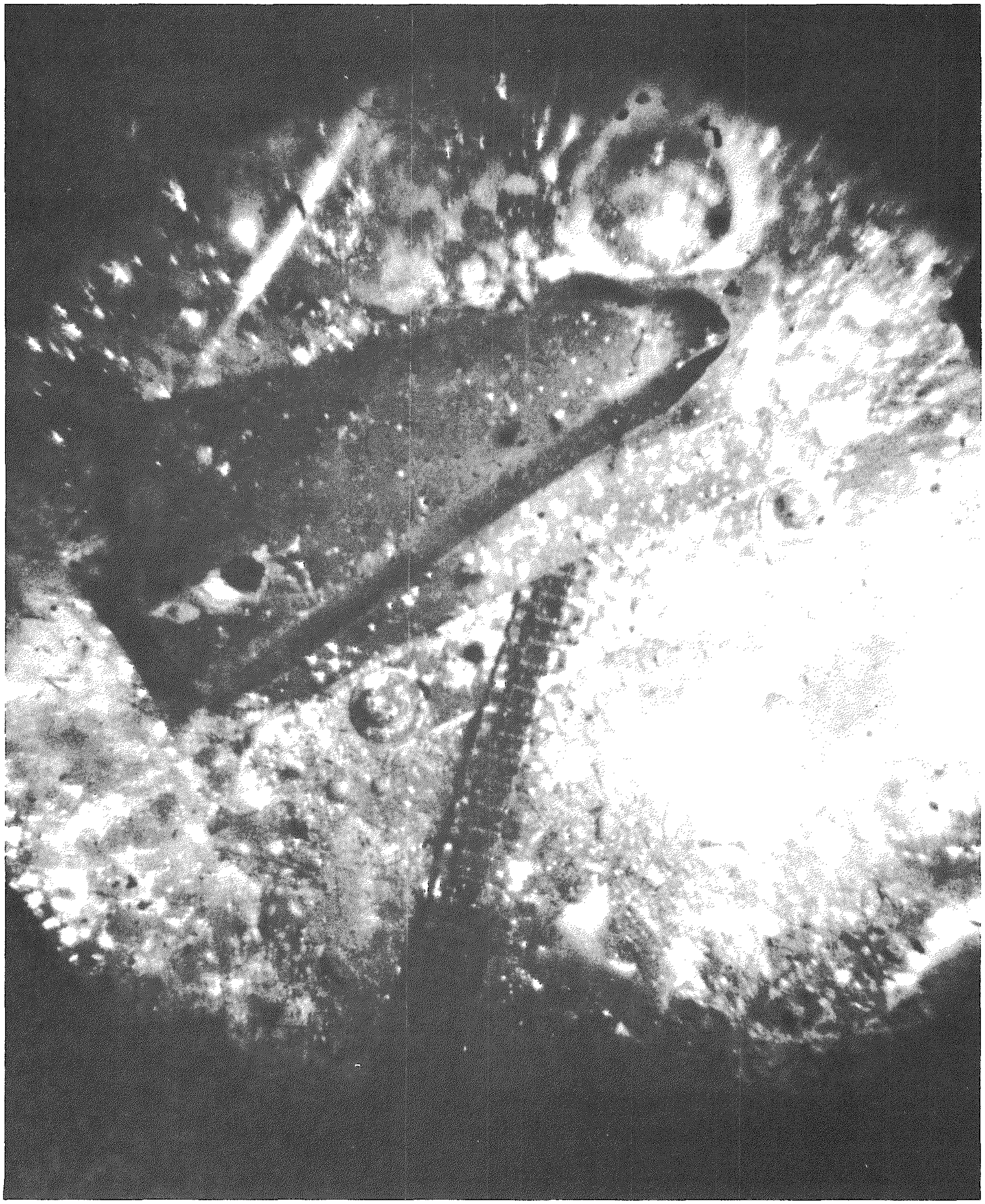

FIG. 2 PLAN VIEW OF ONE SIDE OF UNIDENTIFIED FOREIGN OBJECT

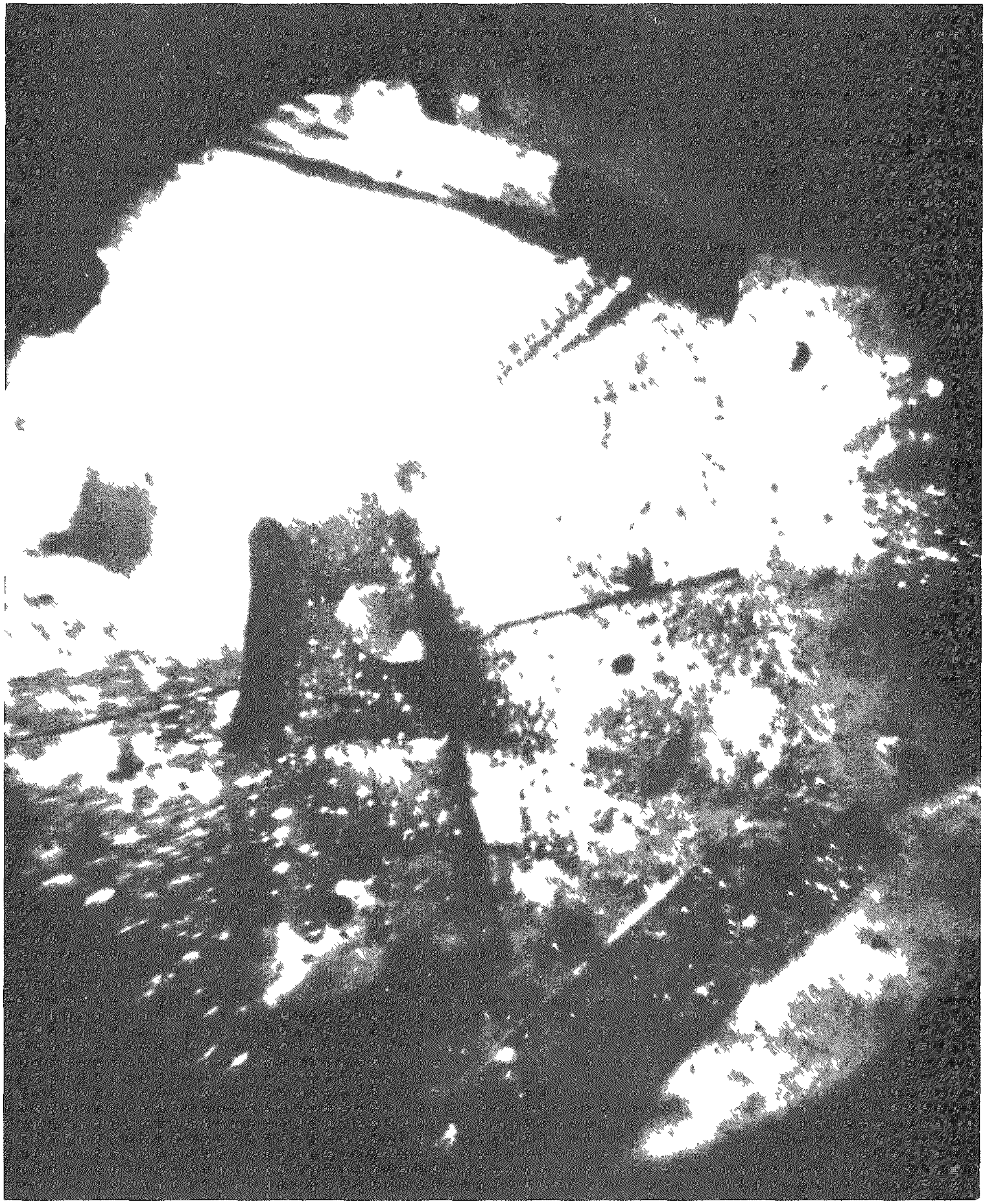

FIG. 3 PLAN VIEW OF OPPOSITE SIDE OF UNIDENTIFIED FOREIGN OBJECT

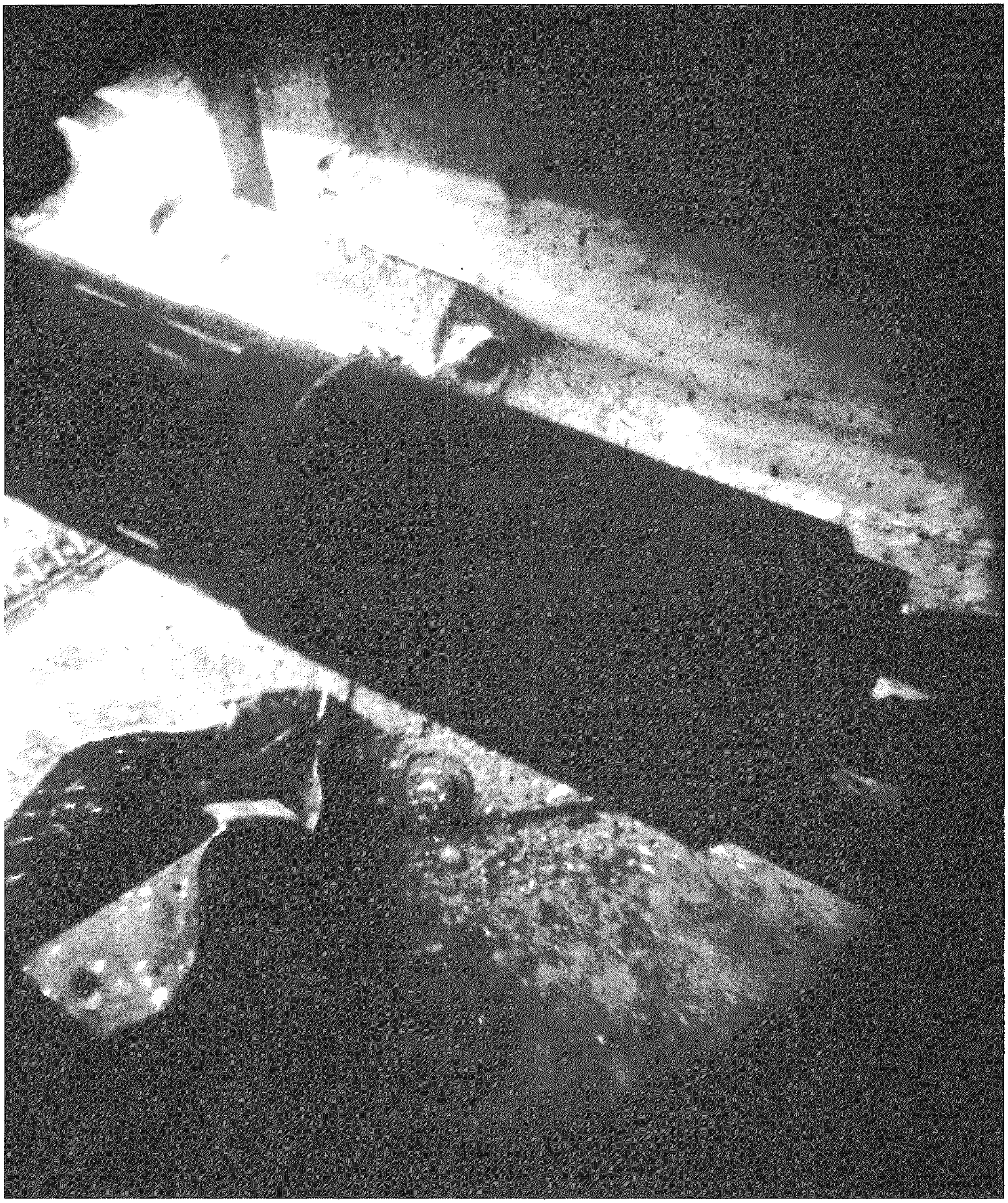

FIG. 4 VIEW OF UNIDENTIFIED FOREIGN OBJECT WITH LIGHT SOURCE TUBE ABOVE

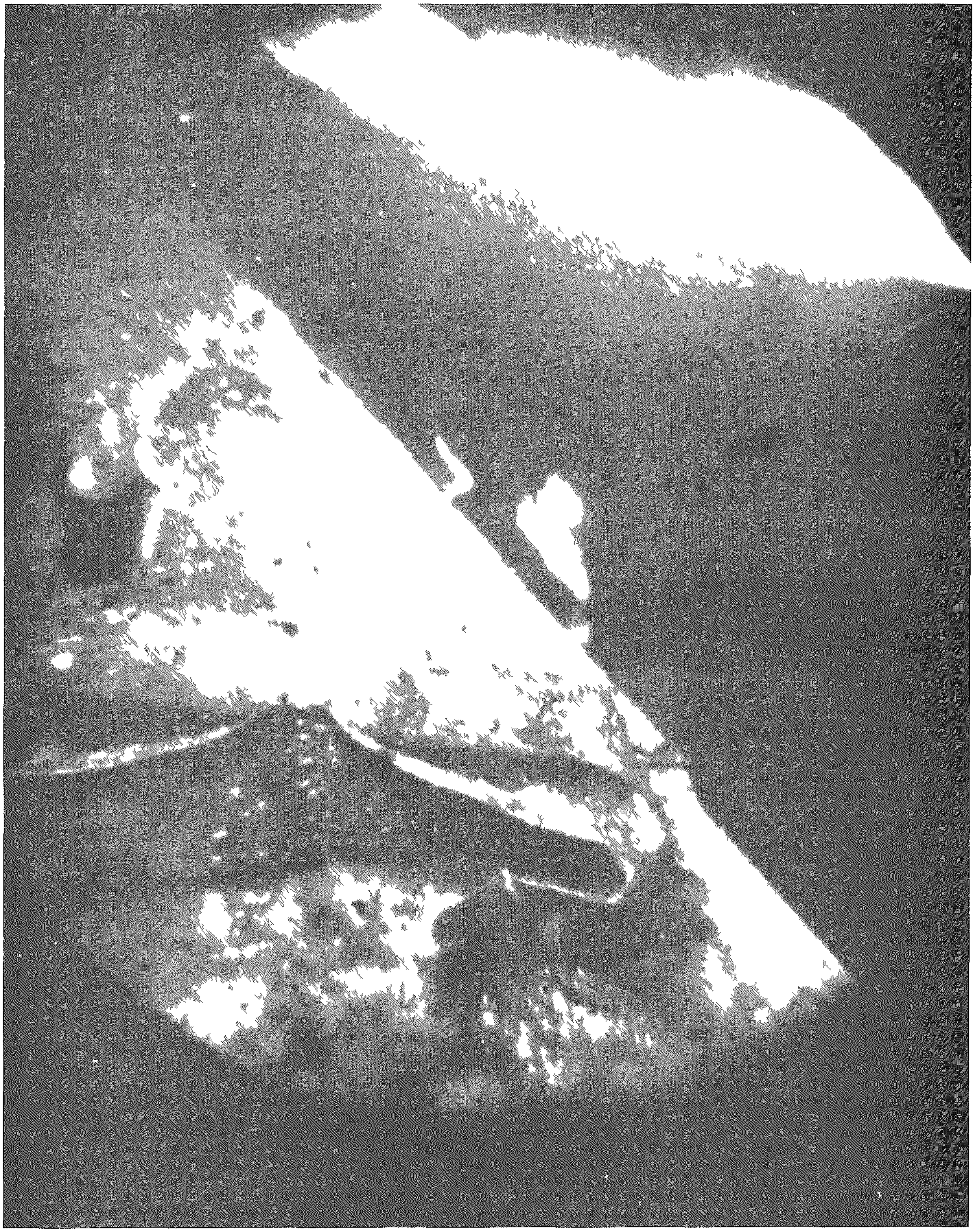

FIG. 5 CLOSE-UP OF UNIDENTIFIED FOREIGN OBJECT

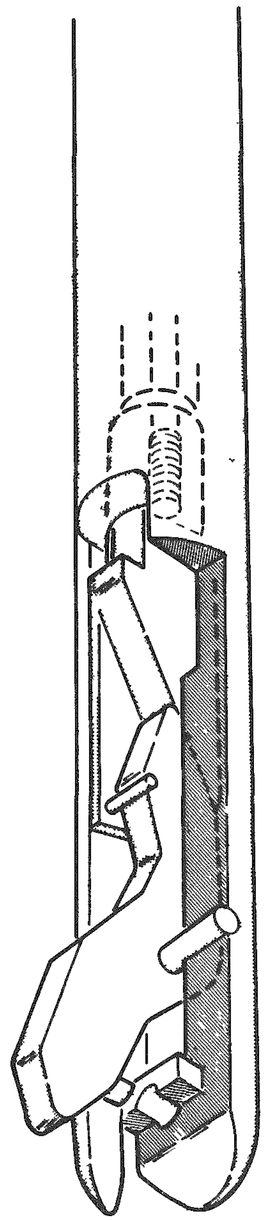

FIG. 6 FUNCTIONAL SKETCH OF SAMPLER TOOL

FIG. 7 TWO VIEWS OF TOOL FOR SAMPLING THE UNIDENTIFIED FOREIGN OBJECT

bite. The sampler tool was then modified to permit an easier lead-in of the object into the throat of the punch. Further attempts to sample the object were unsuccessful. It was then decided to discontinue use of this tool in favor of a back-up sampler and cutting tool (see Section II. D. 2) which had become available for use in the reactor.

At this point, a permanent magnet held over a corner of the object was observed to attract the object. The movement was small, but sufficient to warrant a conclusion that the object is slightly magnetic. The magnet was secured to a tube which was inserted through the core support plate holes in the position vacated by the sampler tool. Figure 1 shows the limited separations between positions of the sampler tool, the lighting and viewing equipment, and the chain-type object-moving device.

## B. MODIFICATIONS TO VIEWING AND LIGHTING EQUIPMENT

To improve image resolution, the 1/2-inch-diameter lower extension of the Sunscope was replaced by one of 1-1/2-inch diameter. The mirror component which had been attached to the Sunscope for horizontal viewing was removed to permit straight-downward viewing.

The light source tube was modified by articulating the lower section so that the lamp could be swung into the horizontal position in the plenum after it had passed vertically through the support plate holes (See Figure 8). This was done to improve illumination of the object during downward viewing. In the vertical position the lamp cast a cone-shaped shadow which shrouded the object.

The articulated lamp section was swung toward the horizontal by forcing the light source tube down against the plenum deck. A ratchet-type arrangement at the joint maintained the lamp section at the new position. Movement of the top of the light source tube caused the lamp section to swing to the vertical position for removal.

A voltage control feature was installed in the lamp circuit to permit switching between 220 volts and 110 volts for the purpose of prolonging lamp life and minimizing the number of time-consuming lamp changes. It was estimated that a lamp lasts only 2 hours when operated at 220 volts to provide the necessary illumination for taking photographs and for precise operations in the plenum.

## C. STUDY OF PHOTOGRAPHS

Representatives of Battelle Memorial Institute examined photographs of the foreign object through a stereoscopic viewer for the purpose of determining contour and dimensions as accurately as possible. According to preliminary estimates, the object is now thought to be slightly larger than

Note: In Operating Position Lanp
is Nearly Horizontal and
Directed Downward

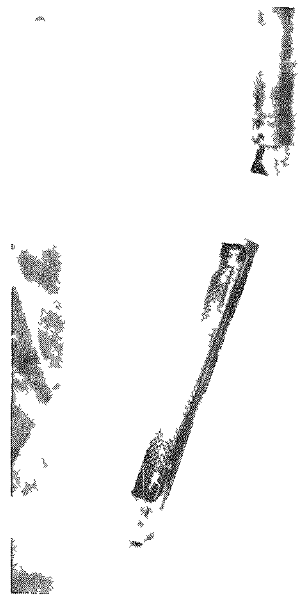

**FIG. 8 ARTICULATED LIGHT SOURCE TUBE SHOWING LAMP AND PROTECTIVE SCREEN**

the approximated dimensions of 9 inches by 4 inches by 4 inches reported in Section II. A of APDA-CFE-15.

In the study process, sets of two near-alike photographs are examined simultaneously in the viewer. The use of a special feature in the viewer makes it possible to determine dimensions of the object by computation. Objects of known dimension which also appear in the photographs are used for comparison. Final results of the study are expected to be available in December.

## D. OBJECT REMOVAL PLANS

The decision made in October to pursue two parallel paths leading to the removal of the object remained in effect at the end of November. Efforts will continue in both directions. One method involves cutting the object into pieces and removing the pieces through the 1.69-inch-diameter holes in the core support plates via one of the 6-inch access penetrations in the reactor vessel rotating shield plug. By the other method, the object would be removed intact through the 14-inch sodium inlet line of Loop No. 1. Developments to date have not progressed to the point where one method is clearly more advantageous than the other.

### 1. Removal Through Core Support Plate Holes

Efforts along this removal path have been expended in the development of cut-up tools and manipulator devices intended for operation through the support plate holes. It is expected that two types of cut-up tools will be available in December. The first of two planned manipulator devices needed to feed the object to the cut-up tools will not be ready for reactor service until January. All tools and devices will be operationally tested in the reactor vessel mock-up before being used in the reactor. (See page 16 of APDA-CFE-14 for description and photographs of the mock-up of core inlet plenum.)

### 2. Cut-Up Tools

The first cut-up tool expected to be available to the reactor is the "hawk-bill nibbler". This design concept, suggested by a hardware store tool, was intended as a back-up sample tool. It has the capability of nibbling the object into thin strips that may be extracted through the core support plate holes. In this latter operation, the tool requires a manipulator to hold the object. Figure 9 is a photograph of the hawk-bill nibbler and its off-the-shelf predecessor. Figure 10 is a cross-section sketch of the tool. This tool was designed to cut through 1/16-inch Type 304 stainless steel. The punched-out piece of metal is intended to be retained in the body of the tool.

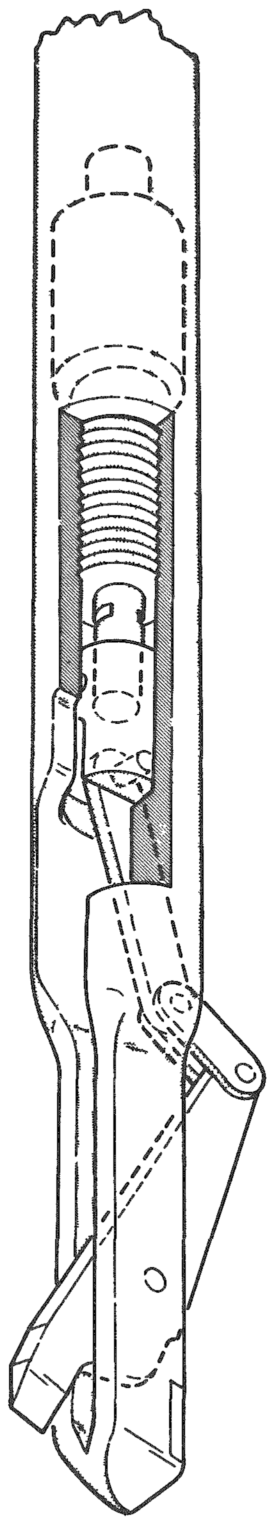

FIG. 10 FUNCTIONAL SKETCH OF HAWK-BILL NIBBLER TOOL

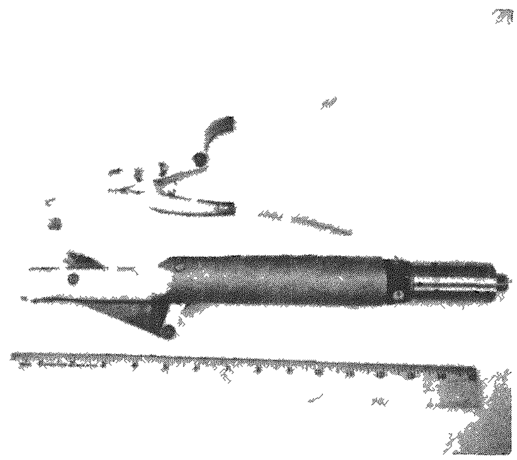

FIG. 9 HAWK-BILL NIBBLER, A CUT-UP TOOL AND A BACK-UP SAMPLING TOOL

For identification, the second cut-up tool is termed the "organ pipe nibbler." This tool was described in Section II. D. 6 of APDA-CFE-15. In a shop test demonstration, excessive torque was required to operate the nibbler so as to punch through 1/16-inch stainless steel. The cutting edge of the punch will be modified to a guillotine configuration to reduce the operating torque. This tool also requires a manipulator to feed the foreign object to it. It may use an external device or one that is intended to be built into the organ pipe tool. The latter feature includes a set of fingers (spring-to-open, pull-to-close) which are controlled by a rod and wire combination through the bottom of the punch cylinder and the opening in the die tube.

3. Manipulators

The spine device which was described in Section II. D. 4 of APDA-CFE-15 is expected to be the most versatile and first available all-purpose manipulator. This device, with temporary controls, was tested in the reactor vessel mock-up (see Figure 11) and the concept was found to be satisfactory. The intended mechanism for controlling the spine manipulator in the reactor is under development. Hand-operated pinions contained in a control head engage with racks attached to the top of the four control cables. Operation of the rack-and-pinion units pull or relax the control cables to bend the spine device in the desired direction. The hand controls for the rack-and-pinion units and for rotating the spine tube can be operated within the confined space above the reactor vessel rotating shield plug. The spine manipulator, complete with rack-and-pinion controls, is expected to be ready for use in the reactor in January.

The second type of manipulator is the mechanical arm device shown photographically in Figure 12 and illustrated graphically in Figure 13. To date, only a wooden model has been constructed. A change in design slowed the progress of development of the mechanical arm. The photograph shows the wooden model in the reactor vessel mock-up, at which time the concept appeared to be satisfactory.

4. Manipulator Grippers

Three types of grippers are planned for possible use with the manipulator devices. The three gripper types, all expected to be available for use in the reactor in January, are

- The Ameray miniature gripper, a modified vendor's stock item with a spring to open the jaws, and a cable pull to close. It is presently available and is shown at the end of the spine manipulator in Figure 11
- The spring gripper with a cable pull to open the jaws and a spring to close

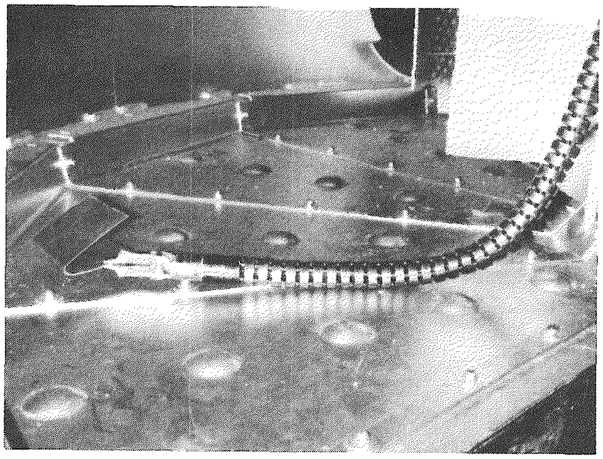

FIG. 11 SPINE-TYPE MANIPULATOR BEING TESTED
IN REACTOR VESSEL MOCK-UP

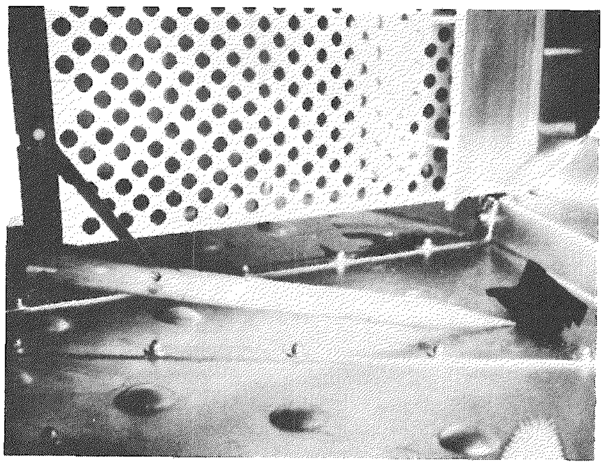

FIG. 12 WOODEN MODEL OF MECHANICAL ARM MANIPULATOR
BEING TESTED IN REACTOR VESSEL MOCK-UP

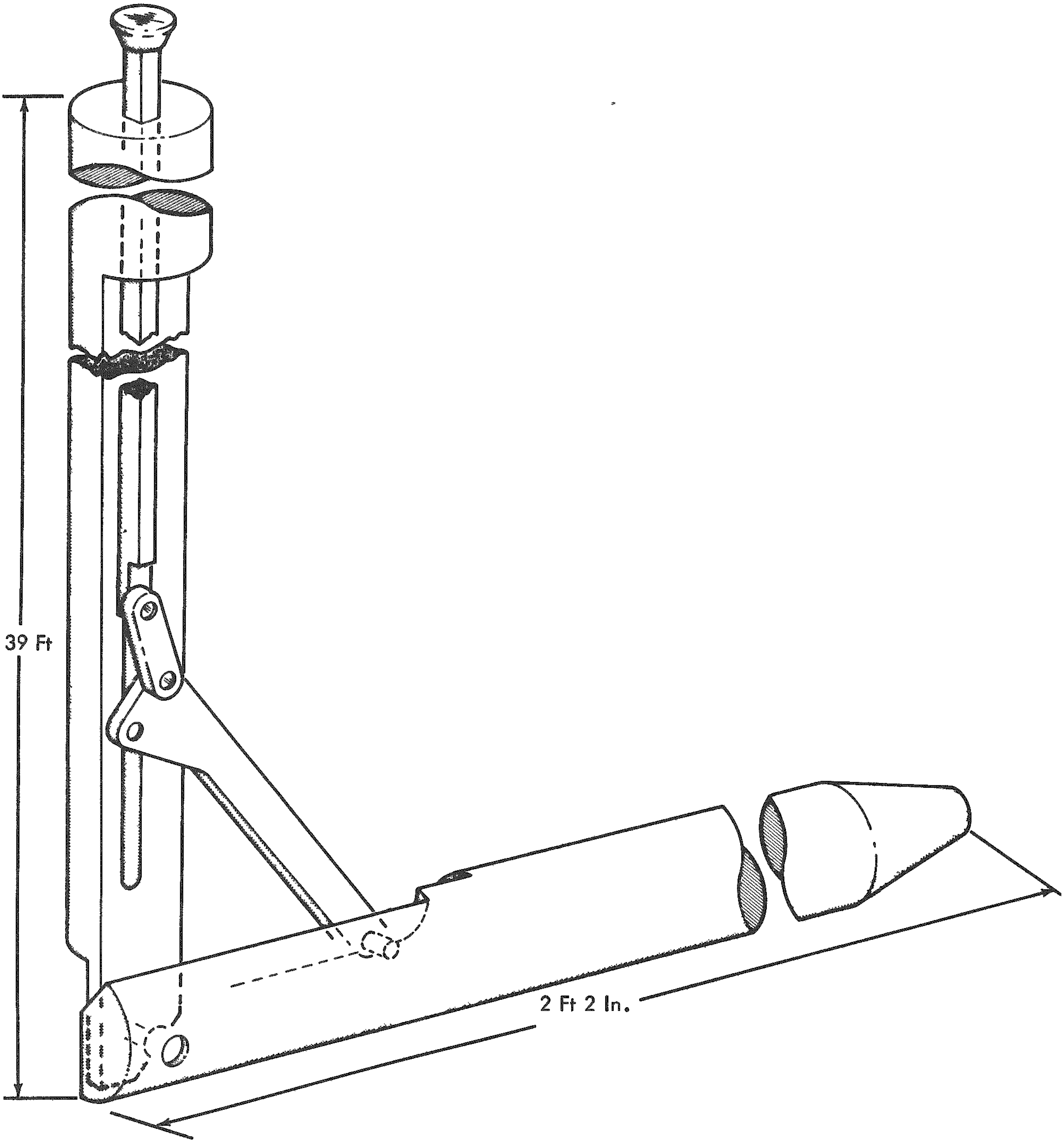


FIG. 13 FUNCTIONAL SKETCH OF MECHANICAL ARM MANIPULATOR

- The screw-drive gripper which provides positive opening and closing of the jaws.

5. Short-Radius Grippers

To provide close-in directional flexibility, two gripper devices are being designed to operate via tubes that pass through the core support plate holes. Both devices are expected to be available in mid January. These devices are

- A ball-socket gripper that is controlled by six wire cables. Two cables open and close the gripper jaws; the other four cables control movement of the ball to which the gripper is attached, to provide both swinging and rotary motion of the grippers. The bottom end of the gripper tube is articulated to provide a 40-degree swing of the ball-socket gripper assembly in one plane. Rotation of the gripper tube gives additional flexibility.

- A gear-driven gripper whose jaws are controlled by shaft-actuated gears and can be closed at any point within a 180-degree swing in a single plane. The bottom end of this gripper tube also is articulated and can be swung 30 degrees either way from vertical in a single plane. A shaft-actuated worm-and-gear arrangement controls the swing. The tube for this gripper can be rotated also.

Still another gripper which operates through a tube that passes through the support plate holes should be ready for use in the reactor in December. This gripper has a more limited range of action than the ball-socket and gear-driven types. Its jaws are spring-opened. Downward movement of a sleeve within the gripper tube closes the jaws on an object directly below the gripper. The gripper device can hold the object and move it up and down and in rotary motion.

6. Removal Through the 14-Inch Line

Section II. D. 2 of APDA-CFE-15 relates the initial considerations toward gaining access to the 14-inch sodium inlet pipe of the No. 1 loop for inserting a removal device with which to remove the foreign object intact. In November, a thorough study of the situation was conducted. Several access methods via the 14-inch line were explored and the questions associated with each method were identified. Four possible access methods were considered:

a. Completely remove the 90-degree elbow at the top elevation in the 14-inch line external to the secondary shield wall - butt reweld the elbow to close

b. Remove a patch from the elbow - butt reweld the patch to close

c. Weld an elbowlet (an open-ended box structure) to the elbow, enclosing the patch area on the elbow; remove the patch from the elbow, working through the elbowlet - weld a cover on the elbowlet to close

d. Remove sodium pump from pump tank for access to the 16-inch pump discharge line.

For each of the above methods the steps to be taken to retrieve the foreign object and restore system integrity were outlined. For each step the possible considerations were stated. A comparison of the considerations associated with each approach is given in Table I.

The first method to be discarded was pump removal, particularly because of the difficulties introduced in having to retrieve the foreign object through the additional 70 feet of pipe and the extra four elbows. It was decided to pursue further an investigation of the patch and elbowlet approaches. Emphasis was placed on consideration of welding pipe previously exposed to sodium, and the resultant stress conditions on the elbow and pipe. Advice has been sought from Argonne National Laboratory, as well as from the Grinnel Company, who engineered the primary sodium piping and would be expected to advise on feasibility and stress questions.

7. Object Retrieval Device

As reported in Section II. D. 2 of APDA-CFE-15, a 5-inch-diameter flexible metal duct was inserted into the core inlet plenum mock-up without difficulty (see Figure 14). To insert the object into the flexible duct, a manipulator will be required. An alternate method would employ the Ameray or spring gripper inside the duct to pull the object into the duct. The gripper would be controlled by rod and cable through the flexible duct and flexible cable.

Figures 15 and 16 illustrate two concepts being developed for retaining the object once it is in the duct. In one concept, spring fingers at the end of the duct allow the object to pass into the duct and then prevent it from falling out; in the other concept, clam-shell jaws fixed to a short, rigid cylinder offer the possibility of positively retaining the object in the retrieval device.

## TABLE I - METHODS FOR ACCESS TO 14-INCH LINE AND CONSIDERATIONS ASSOCIATED WITH EACH METHOD

| COMPLETE ELBOW REMOVAL | REMOVAL OF PATCH FROM ELBOW | REMOVAL OF PATCH WITH ELBOWLET | REMOVAL OF PUMP |
|---|---|---|---|
| 1. Technique of welding pipe previously exposed to sodium | 1. Same as item 1 for ELBOW REMOVAL | 1. Pipe stress conditions due to possible loss of elbow flexibility | 1. Maintenance of an inert gas cover over the system and pump, and containment of fission products during pump removal and reinstallation |
| 2. Fit-up for rewelding<br><br>Freezing or draining of sodium is required. | 2. Structural effect on elbow due to weld shrinkage while welding in the patch | 2. Elbow stress conditions during a subsequent thermal transient | 2. Difficulties in repeated use of the flexible cable for the object - retrieval device if sodium wets the cable and solidifies |
| 3. Stress conditions on pipe and elbow resulting from freezing sodium, welding, and subsequent sequential melting of sodium | 3. Possibility of introducing metal chips into the system when removing the patch | 3. Possibility of introducing metal chips into the system when removing the patch | 3. Difficulties in the retrieval operation due to the additional 70 feet of pipe and the additional 4 elbows |
| 4. Maintaining original plant standards for welding | 4. Possible need to reinforce the elbow | 4-7. Same as items 3, 4, 6, 8, for ELBOW REMOVAL | 4. Maintenance of an inert gas cover, and containment of fission products during the retrieval operation. |
| 5. Thorough cleaning of inside of pipe with limited access to pipe | 5-10. Same as items 2, 3, 4, 5, 6, and 8 for ELBOW REMOVAL | | |
| 6. Maintenance of inert cover gas and containment of fission products | | | |
| 7. Space to perform various operations and for supporting pipe | | | |
| 8. A good gas purge during welding | | | |

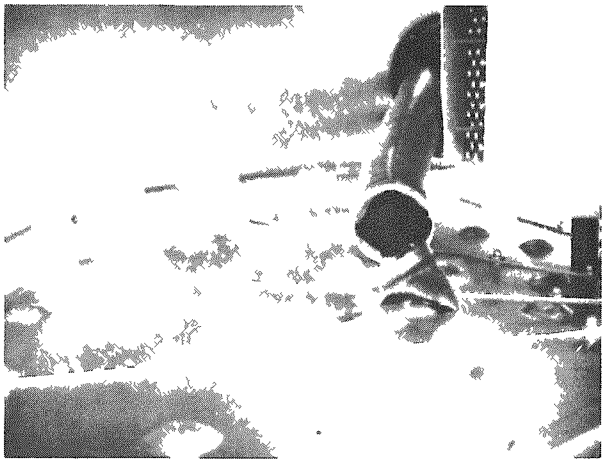

FIG. 14 FIVE-INCH-DIAMETER FLEXIBLE DUCT ENTERING INLET PLENUM MOCK-UP THROUGH 14-INCH INLET LINE

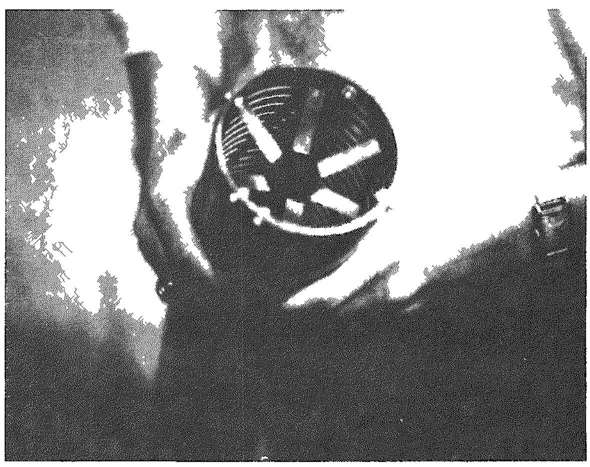

FIG. 15 END OF FIVE-INCH-DIAMETER FLEXIBLE DUCT SHOWING SPRING FINGERS DESIGNED TO ADMIT AND RETAIN UNIDENTIFIED FOREIGN OBJECT

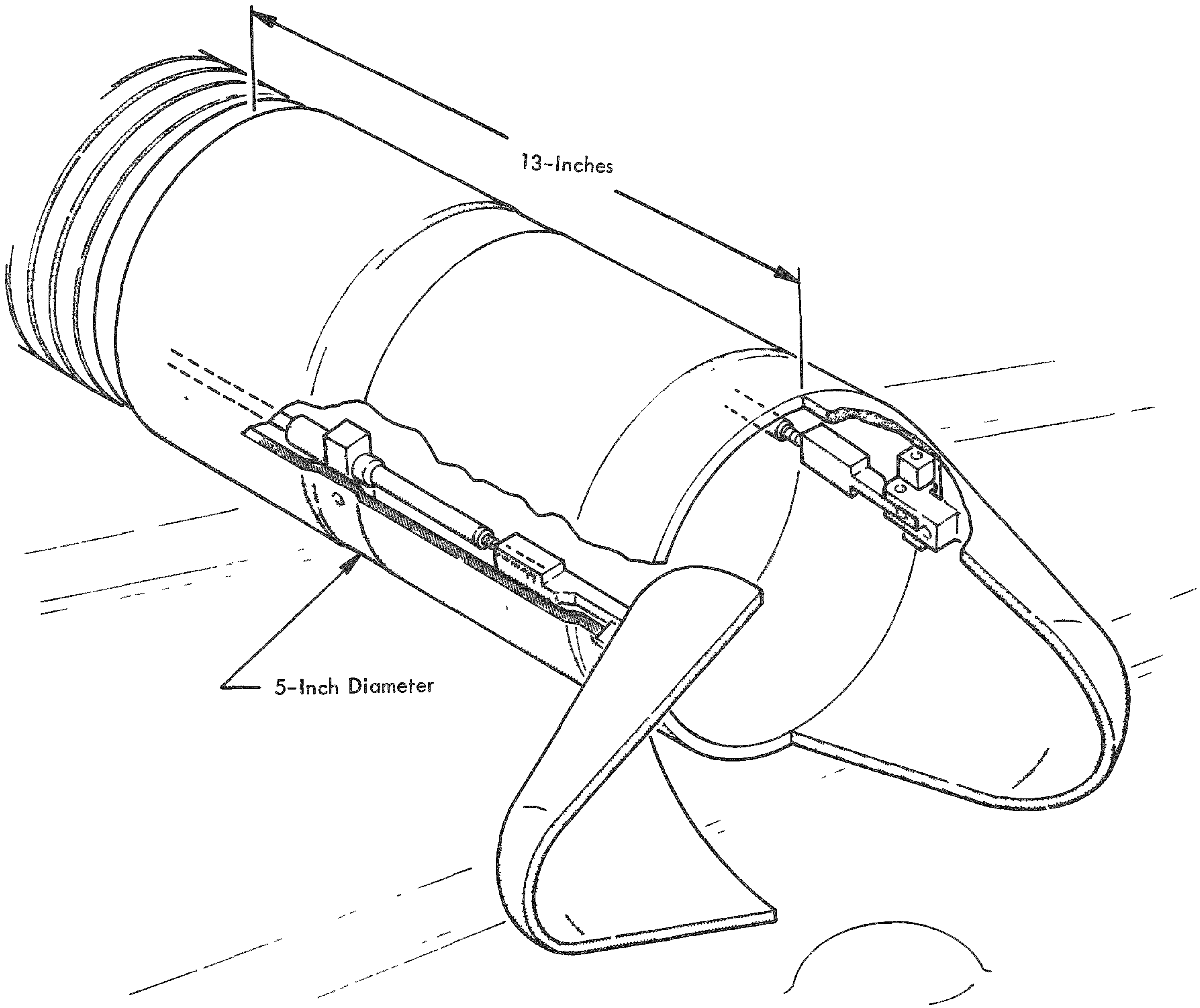


**FIG. 16 CONCEPT OF CLAM-SHELL JAWS TO ADMIT AND RETAIN UNIDENTIFIED FOREIGN OBJECT IN OBJECT-RETRIEVAL DEVICE**

In November the mock-up of the 14-inch line was completed. (See Figure 17.) This included piping from the reactor vessel mock-up back to the elbow that would be penetrated. The piping mock-up will be used to test the flexible cable to determine whether it can be used to maneuver the retrieval duct through the piping and past the elbows into the inlet plenum. Figure 18 depicts one type of penetration proposed.

8. New Borescope

Fabrication work was started on a new borescope designed to provide improved viewing in the reactor. This instrument will have five lenses, one third of the number in the modified Sunscope now being used in the reactor, and is expected to provide a clearer image for photographing and for viewing precise operations in the reactor.

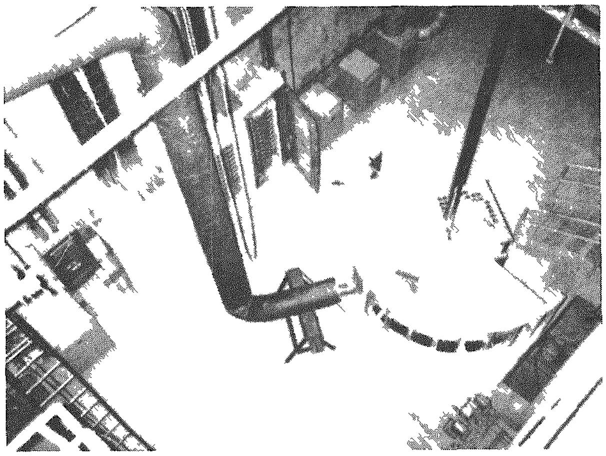

FIG. 17 MOCK-UP OF 14-INCH LINE AND LOWER REACTOR VESSEL

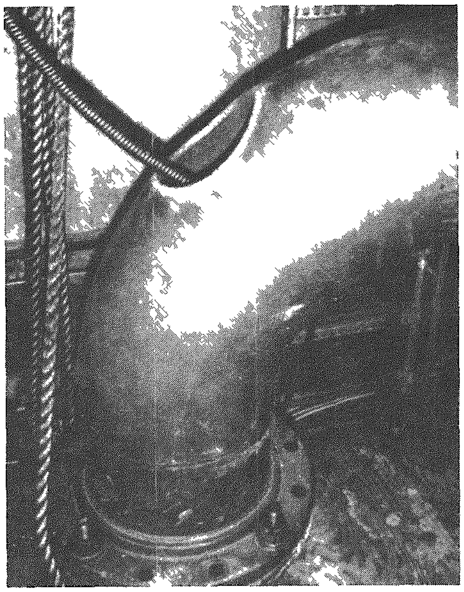

FIG. 18 EXAMPLE OF PATCH-TYPE PENETRATION
IN ELBOW OF 14-INCH LINE

## SECTION III

## EXIT PORT INSPECTION FACILITY

Preoperational testing of the exit port inspection facility was carried out in November. For information on this facility, see previous reports.* Figure 19 shows the inspection facility in position over the exit port.

The apparatus was leak-tested by the halogen sniffing method, and leaks that were detected, such as those at joints, were tightened. After modification, the leak rate was determined to be 20 cubic feet per hour from the chamber at 2 inches water column pressure and 350 F. Studies currently underway are expected to reveal whether this leak rate is satisfactory.

The stabilizer mechanism was tested for mechanical operation and found to be deficient. The force required to move the mechanism through the seal and into the chamber was excessive. In addition, movement in and out of the chamber was erratic. The stabilizer was returned to the vendor for repair and modification.

Bench-testing of the periscope revealed problems: Illumination was not sufficiently intense and was misdirected, and the focal length was too long for viewing into the upper end of a subassembly. The periscope had been designed for viewing into the strainer at the bottom end of the subassembly. These problems will have to be resolved to allow the use of the periscope at both stations.

* McCarthy, J. F. "Compilation of Current Technical Experience at Enrico Fermi Atomic Power Plant," APDA-CFE-5, APDA-CFE-8, APDA-CFE-9, and APDA-CFE-10 for November 1966, March 1967, April 1967, and May 1967, respectively.

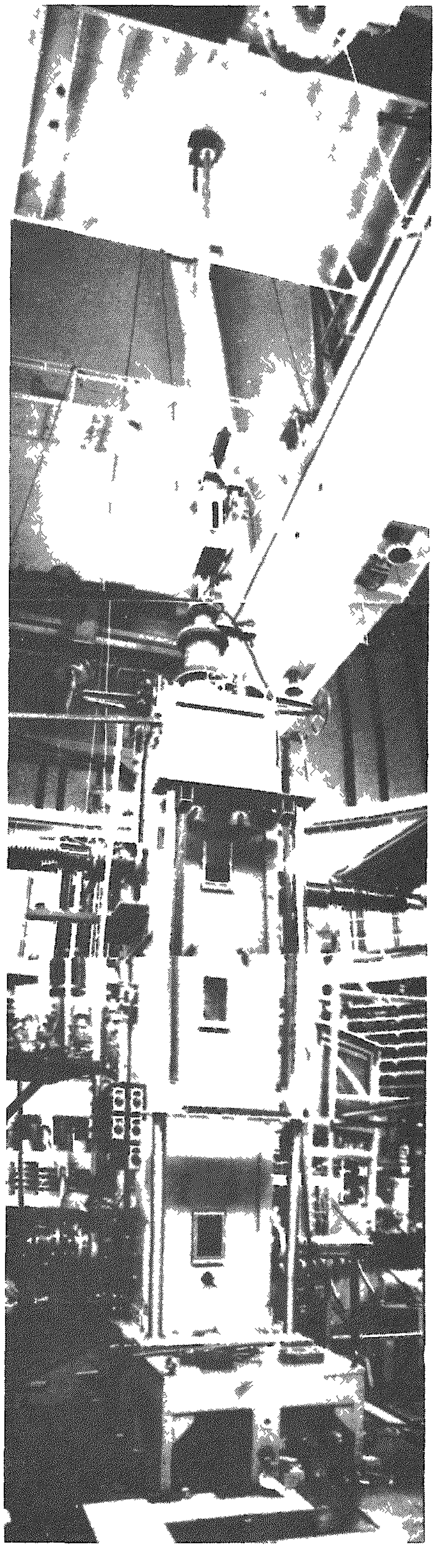

FIG. 19 SUBASSEMBLY INSPECTION FACILITY IN POSITION OVER EXIT PORT IN THE REACTOR BUILDING

# SECTION IV

## SPECIAL INVESTIGATIONS

### A. INSPECTION OF SUBASSEMBLIES M098 AND M127 AT BMI

Results of inspection of M098 and M127, started in July at the Battelle Memorial Institute hot lab, have been described in earlier reports.* Subassemblies M098 and M127 were the two subassemblies in which fuel melting had occurred.

By the replication technique, replicas were taken of the transverse sections through the spacer pads obtained in October. The section materials had been etched for zirconium structure and for uranium-molybdenum alloy. Replicas of sections etched for zirconium structure are to be analyzed for zirconium hydride distribution in the cladding and for uranium-zirconium thickness in the diffusion zone. Analysis of replicas of sections etched for uranium alloy are expected to give some insight into the radial temperature distribution by means of alloy phase transformation.

Replicas were processed and sent to the Engineering Research Laboratory of The Detroit Edison Company for detailed microscopic analysis; no results have been obtained to date.

### B. INSPECTION OF SUBASSEMBLY M122 AT BMI

Inspection of subassembly M122 was started in October at the Battelle Memorial Institute hot lab.** The sketch on page 27 of APDA-CFE-15 shows that M122 was adjacent to the melted subassemblies M098 and M127 in the reactor.

Chemical analyses were conducted on particulate residue obtained from the alcohol-water cleaning of various areas of M122. The purpose was to determine if meltdown debris from melted subassemblies had been carried into other subassemblies in the reactor. As yet no conclusions have been established from the results of the analyses. In the analysis results tabulated in Table II, the amounts of zirconium, copper, and zinc were reported to be significantly high, particularly in the residue from the two top grids. The reason for this is unknown. As a check on these analyses, it is

* APDA-CFE-12, 13, 14, and 15.

** See APDA-CFE-15, Section III, for earlier inspection results.

## TABLE II - RESULTS OF CHEMICAL ANALYSIS OF PARTICULATE RESIDUE FROM CLEANING SOLUTIONS USED ON SUBASSEMBLY M122

| | Analysis — % by Weight | | | | |
|---|---|---|---|---|---|
| | Top 2 | Bottom | Remaining Grids | | Wrapper |
| Element | Grids | Grid | Sample No. 1 | Sample No. 2 | Can |
| Uranium | 0.5 | 0.1 | 0.1 | 2.0 | 0.5 |
| Molybdenum | 1.0 | 0.1 | 0.5 | 1.0 | 1.0 |
| Niobium | 0.5 | 0.1 | 0.1 | 0.1 | 3.0 |
| Zirconium | 25.0 | 3.5 | 5.0 | 6.0 | 2.0 |
| Copper | 7.0 | 1.0 | 0.2 | 7.0 | 0.2 |
| Nickel | 3.0 | 6.0 | 6.0 | 6.0 | 5.0 |
| Iron | 44.5 | 70.0 | 68.0 | 66.0 | 65.0 |
| Chromium | 5.0 | 14.5 | 12.5 | 7.0 | 11.0 |
| Magnesium | 0.5 | 0.75 | 1.0 | 1.7 | 1.0 |
| Cadmium | 1.3 | 0.6 | 0.5 | 0.6 | 2.0 |
| Titanium | 0.1 | 0.3 | 1.0 | * | 0.8 |
| Zinc | 10.0 | 2.0 | 0.8 | 2.0 | 3.0 |
| Lead | 0.25 | 0.3 | 0.5 | * | 2.0 |

* Not detected

intended to conduct emission spectographic tests of residue from one location on the subassembly.

A thorough visual examination of subassembly M122 revealed swelling of the upper end caps of some fuel pins (see Figure 20). About seven of the ten pins on the side adjacent to M098 and two in the next row inward had swollen end caps. Two pins from each of these rows were longitudinally sectioned and prepared for metallographic examination.

Also noted was a dark stain on an upper axial blanket pin (see Figure 21). The pin will be metallographically examined to determine whether the stain was the result of internal overheating.

Sixteen fuel pins were removed from M122 and their diameters measured at 2-inch intervals. Results, ranging between 0.1575-inch diameter and 0.1597-inch diameter, indicated that there had been no significant diameter increase. The length of 20 fuel pins was measured. The measurements have not yet been analyzed.

## C. INSPECTION OF SUBASSEMBLY M099 AT BMI

Inspection of Subassembly M099 was started in December 1966 at the Battelle Memorial Institute hot lab. Earlier inspection results have been described in APDA-CFE-5, APDA-CFE-6, and APDA-CFE-7. 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 1966 it was transferred to the fuel and repair building, and in December it was steam-cleaned, cut up, shipped, and disassembled for inspection at the BMI hot cell.

In November a transverse section was taken from the subassembly at the fourth grid from the top for metallographic examination. The section was etched for zirconium structure. Replicas were made to determine whether hydriding of the cladding had occurred. The analyses have not yet been done.

## D. SUMMARY OF INSPECTION WORK AT BMI AND PRINCIPAL CONCLUSIONS

Seven subassemblies have been inspected at Battelle Memorial Institute. At the present time, no additional subassembly inspections are scheduled but there may be more hot cell inspection work if results of examination of core subassemblies in the exit port inspection facility so dictate.

Visual and dimensional work on the seven subassemblies has been concluded. The major work remaining is metallographic examination of longitudinal and transverse sections from the subassemblies. These exami-

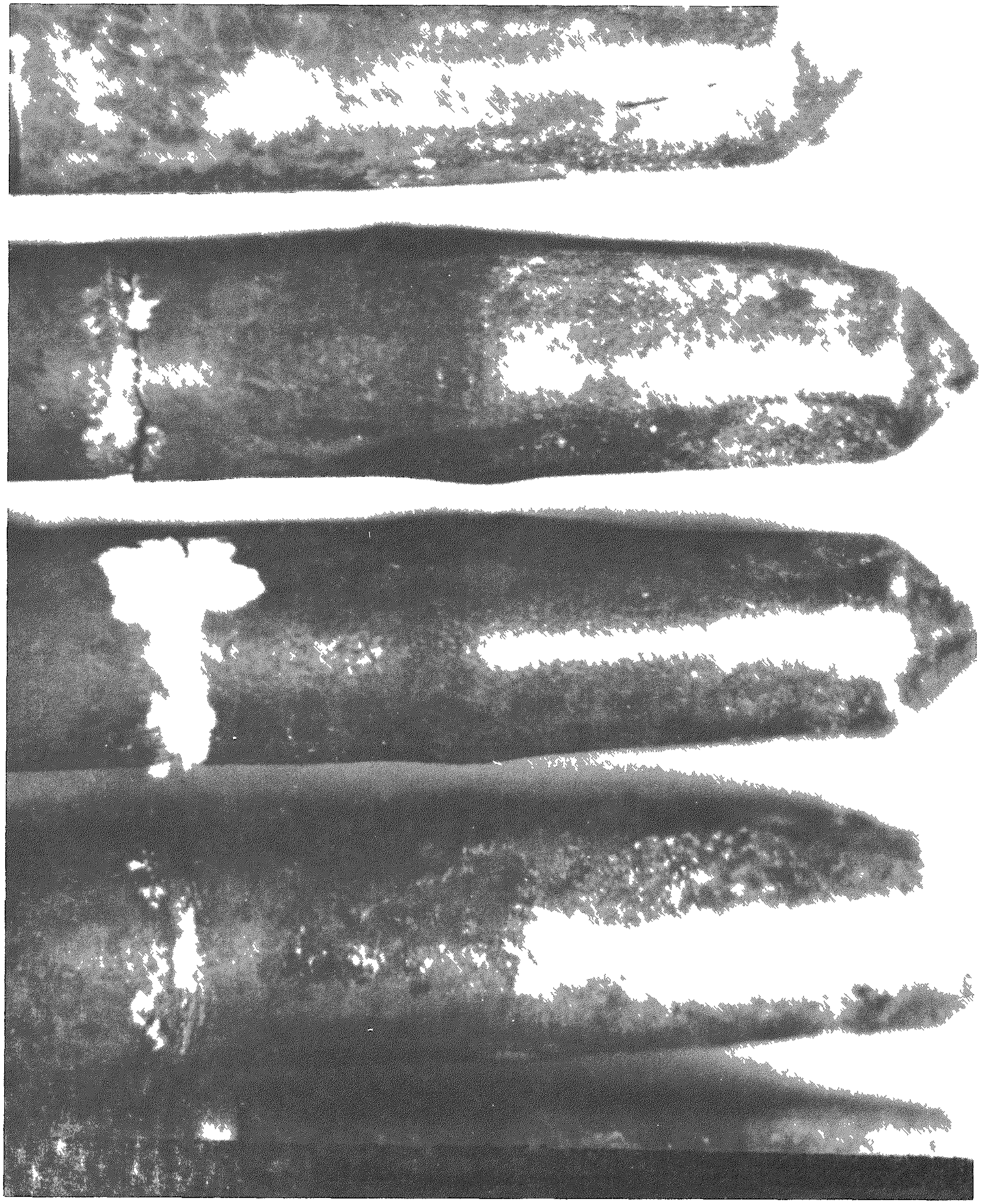

FIG. 20 SWOLLEN UPPER END CAPS OF SUBASSEMBLY M122 FUEL PINS FROM OUTER ROW ADJACENT TO SUBASSEMBLY M098

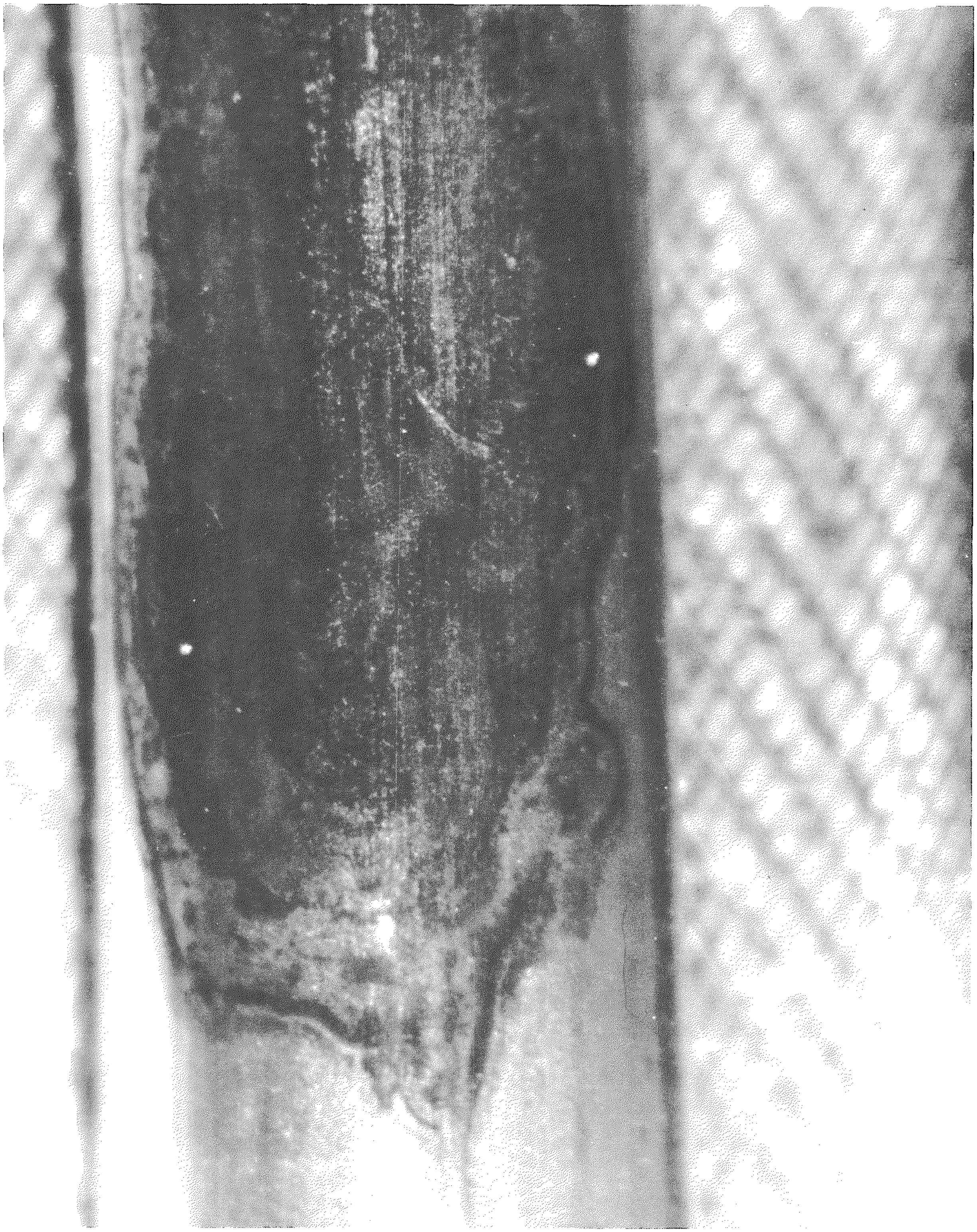

FIG. 21 DARK STAIN ON UPPER AXIAL BLANKET PIN FROM SUBASSEMBLY M122

nations will assist in the determination of the incident temperature condition, alloy phase transformation, and cladding condition.

Principal conclusions from subassembly inspections are as follows:

1. No physical blockage was found within any subassembly to cause meltdown

2. All subassembly handling heads and nozzle assemblies were in good condition

3. No distortion of the wrapper tube subassembly of M099 was observed. Subassemblies M099 and M156 had been sectioned prior to shipment to the BMI hot cell

4. Wrapper tubes of M122, M140, M098 and M127 were all bowed in two planes, from 0.2 inch to 1.1 inch

5. Fuel pins in subassemblies M140, M122, M091, M099 and M156 were, in general, found to be in good condition

6. Fuel melting occurred only in subassemblies M098 and M127, where molten fuel slumped to a point 8 inches below the lower boundary of the core region

7. What appeared to be molten fuel was found on the wrapper tube outer surfaces of M098, M127, M140, and M122. No deposits were found on the outside surfaces of this four-subassembly array as positioned in the reactor

8. The absence of observable weight loss in the subassemblies implies that little, if any, fuel left the subassemblies in which melting occurred

9. The melted subassemblies indicate coolant starvation. Distortion of subassemblies M140 and M122 was due to overheating and/or fuel alloy formation on the wrapper can due to being adjacent to the melted subassemblies

10. The shift of molten fuel in the two failed subassemblies has been calculated to account for about one-half the total measured loss of reactivity (22 cents) on October 5, 1966

11. All upper axial blanket rods appeared to be in good condition, except one upper blanket rod in subassembly M098 which indicated partial melting or corrosion and two in subassembly M122 which to date have not been examined

12. Penetrations of the wrapper tube walls were found only on the two melted subassemblies M127 and M098.

## SECTION V

## SODIUM AND GAS SYSTEMS PERFORMANCE

Since the last data reported,* the following primary system gas and cover gas and the sodium system analyses have been made:

### A. PRIMARY SYSTEM GAS ACTIVITY

| Location | Sample Date | Gross Beta Concentration microcuries/cc |
|---|---|---|
| Primary Shield Tank | 11-3-67 | $5.8 \times 10^{-7}$ |
| Reactor Cover Gas | 11-3-67 | $8.3 \times 10^{-6}$ |
| Reactor Cover Gas | 11-13-67 | $6.6 \times 10^{-6}$ |
| Primary Shield Tank | 11-17-67 | $1.2 \times 10^{-6}$ |
| Reactor Cover Gas | 11-20-67 | $5.6 \times 10^{-6}$ |
| Primary Shield Tank | 11-20-67 | $1.3 \times 10^{-6}$ |
| Reactor Cover Gas | 11-27-67 | $3.1 \times 10^{-6}$ |
| Primary Shield Tank | 11-27-67 | $4.6 \times 10^{-7}$ |

### B. PRIMARY SYSTEM COVER GAS ANALYSIS

| | Reactor Cover Gas (Argon) ppm by Volume | Primary Shield Tank Atmosphere (Nitrogen) ppm by Volume |
|---|---|---|
| Oxygen | Below 25 | 80 ** |
| Carbon Monoxide | Below 10 | Below 10 |
| Carbon Dioxide | Below 10 | 10 |
| Hydrogen | Below 4 *** | 2.5 |
| Helium | Below 4 | Below 4 |
| Methane | Below 10 | Below 10 |
| $N_2O$ | Not measured | Below 10 |
| Argon | Remainder | 13,000 |
| Nitrogen | 1,000 | Remainder |
| Dew Point | Not measured | - 40 F |
| Sample Date | November 3, 1967 | November 16, 1967 |

* APDA-CFE-14

** Technical specifications state 1000 ppm maximum.

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

C. PRIMARY SODIUM ACTIVITY

| Location | Sample Date | Analysis Date | Specific Activity (microcuries/cc) |
|---|---|---|---|
| Sample Coil from Sampling Station | August 2 | October 16 | $1.01 \times 10^{-2}$ (on October 16) |

D. PRIMARY SODIUM CHEMICAL ANALYSIS

| | | | |
|---|---|---|---|
| Oxygen | 6, 5, 6 | Iron | 2.1, 6.7 |
| Carbon | 47, 55, 63, 70, 81, 92 | Nickel | 1.8, 3.4 |
| *Hydroxide Hydrogen | 1.1, 1.2, 1.3 | Chromium | 0.5, 1.6 |
| *Nonhydroxide Hydrogen | 0.3, 0.3, 0.3 | | |

* 1.3 ppm recommended maximum for total hydrogen for high-temperature operation. During low-temperature shutdown conditions, higher values are allowed.

Note: Values are in ppm by weight. The sample was taken from the sampling station on August 19, 1967, and was analyzed at several different points to obtain the separate readings indicated.

# SECTION VI

# MAINTENANCE

## A. INSTALLATION OF FEEDWATER FLOW ORIFICES IN THE NO. 2 STEAM GENERATOR

During November, feedwater flow orifices were installed in the 1200 tubes of No. 2 steam generator at the water inlet header. Details of the flow orifice and its installation were given in a previous report.* Figures 22 and 23 show the installation. The orifices are intended to prevent flow instabilities at part load. Thermal cycling resulting from flow reversal is thought to be a contributing cause of the tube-to-tubesheet weld leaks which had be observed at the water inlet header.

The tube-to-tubesheet welds at the water inlet header were leak-tested by the gas bubble method. This was to ensure that rolling in the orifice sleeve inserts did not disturb the integrity of the tube-to-tubesheet welds. There were no defects. Details of the leak test method were also given in a previous report.**

## B. REPLACEMENT OF DETERIORATED HEATING CIRCUIT FEEDER WIRING IN THE PRIMARY INERT GAS BUILDING

Much of the feeder wiring for the induction and resistance heating on the sodium and inert gas piping in the primary inert gas building was found to be deteriorated and was replaced. This condition was caused by overcrowded cable trays in areas of high ambient temperature (about 120 F). Inadequate heat dissipation from the cable bundles caused cable insulation to dry and crack. The condition was discovered during an investigation of the cause of a defective lighting circuit.

All damaged wire was replaced by asbestos-insulated wire. No. 8AA wire was substituted for all of the No. 12AA wire originally installed. To alleviate the crowded condition, many cables were rerouted and additional cable trays were installed adjacent to existing trays. Cable grouping was changed as necessary so that there were no more than seven cables tied together in a single group.

To maintain adequate heating service during repairs, defective wires were replaced individually whenever possible. This also helped to maintain circuit identification. About 1500 feet of defective cable was replaced. Affected by the repair were 56 induction heating circuits and 5 resistance heating circuits. Figures 24 and 25 are representative of the before and after cable conditions.

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* APDA-CFE-12

** APDA-CFE-15, Sec. IV.B

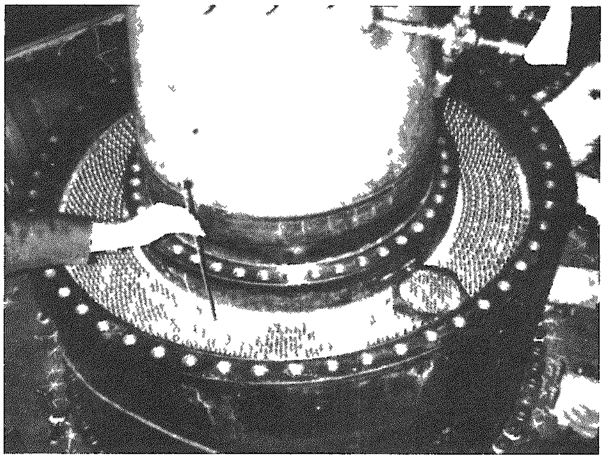

FIG. 22 INSTALLING FEEDWATER FLOW ORIFICE IN TUBE AT WATER INLET HEADER OF NO. 2 STEAM GENERATOR

Note: Screen at Upper Right is Located Under Water Inlet Pipe

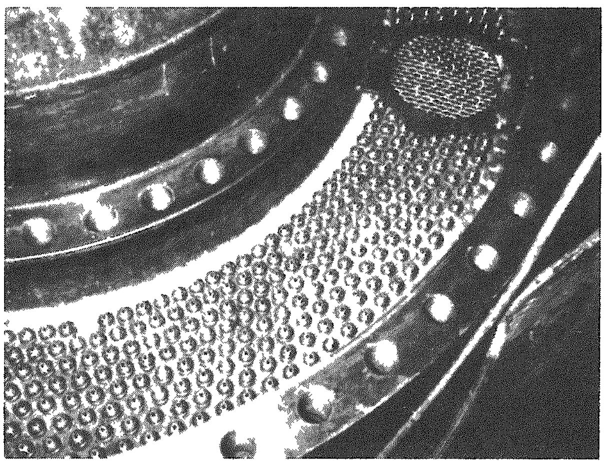

FIG. 23 CLOSE-UP OF FEEDWATER FLOW ORIFICE INSTALLATION IN NO. 2 STEAM GENERATOR

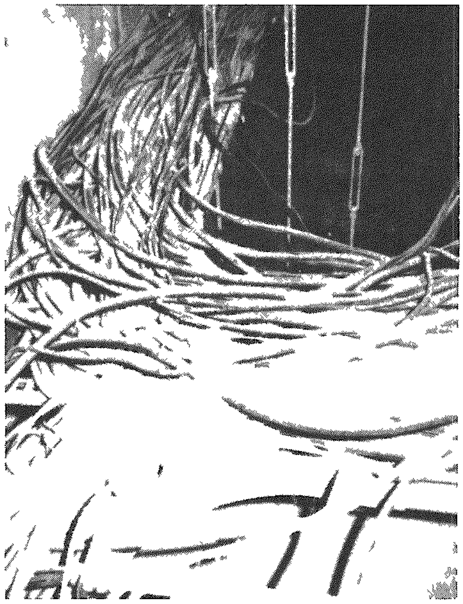

FIG. 24 CROWDED CABLE TRAY IN PRIMARY INERT GAS BUILDING BEFORE CABLE REPLACEMENT AND REROUTING

Note: 12-Inch Cable Tray, Left, was Installed Adjacent to Existing 6-Inch Tray

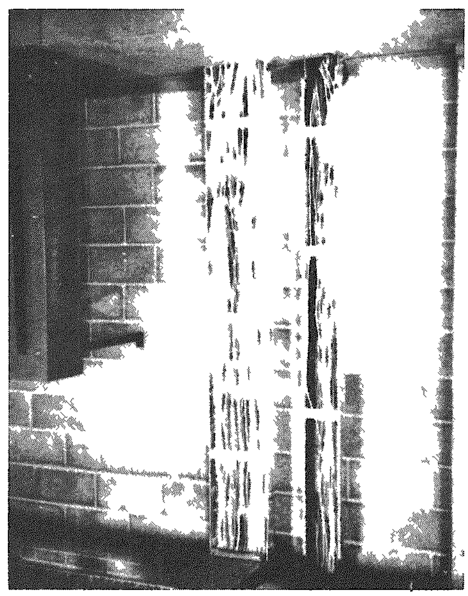

FIG. 25 CABLE TRAYS IN PRIMARY INERT GAS BUILDING AFTER CABLE REPLACEMENT AND REROUTING

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D. Gardiner
J. White

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R. E. MacPherson, Jr.

Pacific Northwest Laboratory, BMI
E. Astley (5)

Power Reactor Development Company
(1911 First Street, Detroit, Mich. 48226)
A. S. Griswold

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J. C. R. Kelly, Jr. (2)

Westinghouse Electric Corporation
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C. A. Anderson

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