COO-4068-14

REFUELING OUTAGE AVAILABILITY STUDY

Phase 1 Final Report

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November 1977

Prepared for
THE U. S. DEPARTMENT OF ENERGY
UNDER CONTRACT NO. EY-76-C-02-4068
Formerly E(11-1)-4068
B&W Contract No. CRD-1002

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ACKNOWLEDGMENT

This project has been accomplished through the cooperation and team effort of the individuals listed in Figures 2-1, 2-2, and 2-5. As can be seen from the Contents, this report covers a large scope of work in a number of different areas and has required extensive effort from the persons involved.

ABSTRACT

Babcock & Wilcox entered into a contract with the Department of Energy (formerly the Energy Research and Development Administration) for the performance of a refueling outage availability study with the cooperation of Duke Power Company and Arkansas Power & Light Company. The objective was to improve plant availability through reduction of refueling outage time.

The conclusions of the study were drawn from data gathered during the 1976 Oconee 3 and 1977 Arkansas Unit One refueling outages. The onsite effort was one of observation and data recording, which included time-lapsed photography and video tape. The collected data were then evaluated and analyzed for potential improvements and to identify in detail where resources were consumed.

The overall result was a listing of (1) specific recommendations for implementing improvements in the facilities, equipment, tools, procedures, and techniques for the participating utilities; (2) generic recommendations of immediate benefit to other applicable utilities; and (3) recommendations for further work in the succeeding phases of the DOE program.

The results indicate that, by incorporating the recommendations and taking credit for the time savings, an ideal refueling outage length of 21 to 22 days for the nuclear steam system (NSS) could be realized. Additional benefits would be a reduction in man-Rem exposure and manpower requirements.

LIST OF ABBREVIATIONS

AE	Architect-engineer
ANO	Arkansas Nuclear One
ANTI-C	Anti-contamination
AP&L	Arkansas Power & Light
APSR	Axial power shaping rods
B&W	The Babcock & Wilcox Company
BOP	Balance of plant
BS	Building spray
CC	Component cooling
CFT	Core flood tank
CRD	Control rod drive
CRDM	Control rod drive mechanism
CRT	Cathode ray tube
CSA	Core support assembly
DH	Decay heat
DOE	Department of Energy
ECT	Eddy-current testing
ERDA	Energy Research & Development Administration
FA	Fuel assembly
FH	Fuel handling
FM	Figure of merit
FM_D	Figure of merit delay avoidance/work effort reduction
FP	Full power
FSAR	Final safety analysis report
FTC	Fuel transfer canal
FW	Feedwater
h	hour
HP	Health physics
HP	High pressure

ABBREVIATIONS (Cont'd)

HPT	High-pressure turbine
I&C	Instrumentation and controls
I&E	Instrumentation and electrical
ISI	Inservice inspection
LP	Low pressure
LPT	Low-pressure turbine
mR	MilliRem
mR/h	MilliRem per hour
MS	Main steam
MSR	Moisture separator reheater
NSS	Nuclear steam system
ONS	Oconee Nuclear Station
OSHA	Occupational Safety and Health Act
OTSG	Once-through steam generator
PI	Position indicator
PM	Preventive maintenance
QA	Quality Assurance
QC	Quality Control
RB	Reactor building
RC	Reactor coolant
RCP	Reactor coolant pump
RCS	Reactor coolant system
RV	Reactor vessel
RWP	Radiation Work Permit
Rx	Reactor
SFP	Spent fuel pool
SSHT	Surveillance specimen holder tube
UT	Ultrasonic testing

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1. SUMMARY DESCRIPTION OF DOE PROJECT EFFORT

1.1. Participants

Under DOE (formerly ERDA) sponsorship, Babcock & Wilcox (B&W) undertook a study of refueling outages to identify and quantify means by which nuclear power plant refueling outage time and the resources required to perform such work could be reduced. This is one of four similar studies being sponsored by DOE. The initial studies were conducted in conjunction with and participation by the Duke Power Company. Duke Power Company's Oconee 3 nuclear unit's refueling outage of 1976 was selected for the study.

After the initial studies were completed, B&W and DOE concluded that a follow-on study at another utility site was necessary to confirm the initial findings and to broaden the available data base for key outage observations. The follow-on study was conducted in conjunction with and participation by the Arkansas Power & Light Company. This study was performed during the refueling outage of the Arkansas Nuclear One, Unit 1 plant in 1977.

1.2. Program Objectives

In 1976, as part of the Light Water Reactor Technology Program, DOE established a refueling outage technology improvement program. The objective was to develop and demonstrate improved refueling, maintenance, and inspection procedures and equipment. Such improvements would reduce the consumption of oil and gas for the generation of electricity and thus reduce U.S. dependence on foreign energy resources by making better use of existing and future nuclear generation stations.

To carry out such a program, DOE elected to assist the nuclear industry through jointly funded programs for the accelerated development and demonstration of improved procedures and new equipment. As shown in Table 1-1, the operating history of commercial nuclear generating plants exceeding 400 MWe capacity points out the importance of efforts to reduce refueling outage times. It has been anticipated that an improvement of 3% or more in plant availability is achievable through such a joint DOE industry effort to reduce refueling outage time.

The first phase of the program involved the observation of refueling outage activities, analysis of data, preparation of recommendations, editing of photographs and video tapes, report preparation, and planning for continuing work under the program.

The second phase of the program, which covers the actual development, design, procurement, installation, and evaluation of improved equipment as well as the use of improved procedures, scheduling, and outage management tools, needs to be carried out to evaluate the projected savings resulting from the first phase; this work is currently being planned by the parties participating in the program to date.

The third phase, which may be initiated in parallel with the second, would cover the work necessary for developing and implementing recommended improvements; these can only be applied to a new plant in the design and construction phases. This phase is needed to effectively realize the full benefits of the recommendations from Phase 1 and thus promote the maximum reduction in the consumption of oil and gas for electrical generation.

This report concludes the first phase of the program directed toward primary refueling activities as conducted by Babcock & Wilcox except for similar observation studies on the balance of plant that have been added to this phase, for which a separate report will be prepared.

1.3. Phase 1 Study Effort

The Phase 1 work under the DOE study program contract was initiated by Babcock & Wilcox in August 1976 with the formation of an outage observation team for refueling activities at the Oconee 3 site. Each observation team consisted of B&W engineers and technicians who were experienced in nuclear refueling outages. The individuals assigned to each area were responsible for observing the work activities being conducted by the utility, evaluating equipment, monitoring personnel performance, and making recommendations for improvements.

This type of involvement allowed the responsible personnel to "live through" the refueling outage together with the site personnel who were responsible for a specific aspect of the outage. Full utility support was provided to the observation teams. Using this approach, team members were able to visually observe events as they occurred, photograph and record on video tape the key refueling activities, and experience the feelings and pressures placed on site personnel during the course of the refueling outage.

A team approach has been carried forward in the preparation of this final report. Personnel who will potentially have the responsibility for ongoing activities have developed a detailed knowledge of facts gathered during the outage observations and have assisted in the analysis and evaluation of data and the preparation of this report.

The work performed to date under Phase 1 of this program consisted of the four tasks shown below.

Task	Completion date: Oconee 3	Completion date: ANO 1
1 Data Collection, Outage Planning, Outage Observation	12/76	4/77
2 Analysis and Evaluation of Data	2/77	5/77
3 Application, Evaluation, Categorization of Potential Improvements	6/77	7/77
4 Final Report, Phase 1	11/77	11/77

The raw data were assembled under Task 1 of this program. The data and observations were recorded on (1) data sheets (see Appendix E for a list of activities recorded on data sheets and an example of a data sheet), (2) video tapes (see Appendix A for an index of the raw data tapes), and (3) time-lapse photographs (see Appendix B for an index of photographs, Appendix C for a photographic summary of the Oconee 3 refueling outage, and Appendix D for selected photos of the ANO 1 outage). Additional data were collected from completed work/job orders and completed Radiation Work Permits.

Once the raw data were assembled, the observation teams began the evaluation effort. The previously collected data sheets, as well as the video and still photographs, were reviewed by the appropriate team members. The data were evaluated to determine areas of (1) lost productivity, (2) manpower requirements, (3) conflicts in schedule, (4) time span for typical activities, (5) factors leading to inefficiency, (6) equipment and tool availability problems, (7) adequacy of personnel training, and (8) plant layout improvements.

The result of Task 2 was a list of (1) specific recommendation for implementing improvements to the tooling, procedures, and techniques in the Oconee 3 and ANO 1 plants, (2) generic recommendations of immediate benefit to other B&W units, and (3) recommendations for further work in the succeeding phases of the DOE program. The recommendations cover all aspects of the primary plant work conducted during the refueling. In addition, estimates of savings in outage time were made for some of the recommendations. Subsequent sections of this report describe in detail these recommendations and their effect on improving plant availability.

For reporting purposes, the recommendations have been categorized as follows:

1. Immediate-benefit including procedures, techniques, tooling and parts, and outage management and scheduling (section 4).

2. State-of-the-art retrofit (section 5).

3. Retrofit requiring equipment development (section 6).

4. Future plant design changes (section 7) and continuing work problems (section 8).

These recommendations include improvements that directly impact critical path activity items as well as improvements that could avoid delays or increase the possibility of achieving the desired reduction in refueling outages.

In order to achieve the target refueling outage time, equivalent attention will have to be given to the total plant outage activities. Therefore, Phase 1 of this study has been extended to include the balance-of-plant (BOP) maintenance activities. The following areas are to be evaluated:

1. Plant preventive maintenance program.

2. Turbine and auxiliary building arrangements for access and laydown of major components.

3. Large valve and large pump/motor maintenance.

4. Equipment inspection and test procedures and results.

5. Technical Specification surveillance testing.

6. Tool control.

7. Turbine-generator inspection.

A supplement to the final report will be prepared upon completion of this portion of the study.

1.4. Summary and Conclusions

The results of the Phase 1 study show that significant improvement in plant availability is attainable. The following table summarizes the data and results of the critical path analysis provided by this study for the Oconee 3 and ANO 1 plants (values given in days).

	Scheduled	Actual	Typical	Ideal	Expected annual savings
Oconee 3	45	56	33	21	12
ANO 1	48	65	32	22	10

The "scheduled" and "actual" values represent the refueling outage length from pre-outage planning and the as-built schedule as they actually happened at those sites. The "typical" column is derived from the as-built schedule and shows what the refueling outage length should have been if abnormal activities and delays were deleted from the as-built schedule. (These schedules are presented in section 2.) By incorporating the recommendations resulting from the study that reduce the refueling critical path and taking credit for the time savings, a typical NSS outage length (referring to the Oconee 3 and ANO 1 plants at one time in life and under conditions that existed during that time) could be reduced to 21-22 days with an expected average annual outage time reduction of 10-12 days for each plant implementing the recommendations provided by this study. See Table 9-1 for a listing of generic recommendations. The typical and ideal NSS refueling outage schedules in this study can be used as a basis for planning future refueling outages, but additions to this schedule will have to be made as a result of periodic and surveillance tests, and required inservice inspections. Although this study was limited to the two specific plants of the 177-Fuel Assembly (FA) design, the findings can be extrapolated to other nuclear plants of similar design and construction.

Four types of savings can result from implementation of these recommendations:

1. There is a savings of an estimated 10-12 critical path days,* resulting in lower replacement power costs. This time savings represents a replacement energy cost savings of more than $2 million per unit to Duke Power Company and similar savings to Arkansas Power & Light.

2. There is also an equivalent oil savings. If the replacement power were from an oil-fired unit, the oil savings would be approximately 345,000 barrels.

3. There is a savings in manpower resulting from approximately 10-12 less working days during the outage.

4. There is a significant savings in personnel radiation exposure resulting from fewer people working for shorter times during an outage.

Recommendations believed to have significant benefit to the industry were evaluated in detail to determine their applicability and the cost benefit for a utility implementing those recommendations. The majority of these recommendations may be implemented immediately by utilities without further technical development. Improvements having significant benefit but requiring further development have been proposed to DOE for prototype demonstration at Duke Power Company under Phase 2 of the DOE Refueling/Maintenance Outage Improvement Program. These recommendations and their estimated savings in reduced outage time, replacement power cost, and barrels of oil conserved are shown in Table 1-2. Plans are now underway for implementation of all items in Table 1-2 at the Oconee Nuclear Station. A similar program for demonstrating selected additional recommendations at AP&L is contemplated.

In addition to recommendations, edited video tapes covering the following subjects were produced (see also Appendix A):

1. Outage summaries for Oconee 3 and ANO 1.

2. Recommendations for improved refueling outages at Oconee 3 and ANO 1.

3. Manpower utilization and tooling improvements.

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*Critical path is defined as those activities that establish and control the length of a refueling outage.

The production of such tapes has proven very useful in familiarizing management personnel with the problems that must be overcome in carrying out a refueling outage and in training new site personnel in outage activities. These tapes indicate a potential for the use of video for personnel training and improved personnel efficiency, all resulting in improved plant availability. Using specially prepared video tapes, management and site personnel can observe in detail the steps required to carry out the refueling outage and can develop ways of improving performance without increasing exposure to personnel or delaying critical work items.

In conclusion, the improvements recommended in this study are applicable to a broad class of similar nuclear plants in the design and construction phases as well as those currently in operation. The recommendations and outage information contained in this report can be used as a basis to plan and conduct the first outages of new plants and to improve the planning and facilities of currently operating plants. Many of the recommendations can readily be incorporated in plants currently in the design and construction phases as well as in the design of future plants. Many of these recommended improvements can be implemented immediately by utilities without further technical development, and planning for joint industry-DOE support of improvements requiring development and demonstration is in progress.

Table 1-1. Refueling Outage Times for >400-MWe Plants

Item	Days
Average outage time for all plants	70
Longest outage reported	151
Shortest outage reported	29

Note: These statistics are based on data reported by the utility industry in NU Reg. 0020 for the period June 1974 through May 1977.

Table 1-2. Recommended Improvements and Expected Savings

	Recommendation	Outage reduction time, h	Annual benefit: 1000-MW plant replacement power value saved, $	Annual benefit: 1000-MW plant fuel conserv value, bbl of oil saved
1.	Computerized outage management and scheduling assistance	72	1,500,000	114,300
2.	Canal seal improvement*	7.5[(a)]	155,000	11,811
3.	Heavy lift rigging improvement*	12	250,000	19,050
4.	RCP seal maintenance tooling improvement	10	210,000	16,002
5.	Fuel transfer canal water cleanup improvement*	24	500,000	38,100
6.	Head insulation improvement*	8[(b)]	165,000	12,573
7.	CRDM access improvement	8	165,000	12,573
8.	Stud handling equipment*	8	165,000	12,573
9.	CRDM service and tooling equipment*	13	270,000	20,754
10.	Fuel mechanical assessment and refueling equipment modifications*	20	415,000	31,623
11.	Multi-function mast and controls changeout*	20	415,000	31,623
12.	Refueling TV addition*	3	65,000	4,953
13.	Advanced preliminary design & feasibility evaluation	72	1,500,000	114,300

(a) Repeatable savings; leakage has resulted in 1-3 days' delay at Oconee and ANO.

(b) Repeatable savings; savings of up to 17 hours experienced at ANO.

*These items directly impact the refueling critical time.

2. KEY OUTAGE EVENTS AND COMPARISONS

2.1. Oconee 3 Refueling Outage

2.1.1. Pre-Outage Schedule

Task 1 of the Refueling Outage Availability Study, "Data Collection," was begun in late August 1976 with the formation of an outage observation team for the Oconee 3 Refueling Outage of 1976. Figure 2-1 shows the observation team assignments and responsibilities at that site. The actual observation effort started the week of September 13, 1976, with the arrival of the DOE team at Oconee 3 for health physics training, site orientation, and office setup. The late start of the contract resulted in essentially no time for observation of pre-outage planning and scheduling techniques. Consequently, no time was available to conduct an extensive historical review of past outages; therefore, the experiences of various team personnel were used to generate a list of activities to study and data to collect. The personnel assignments and responsibilities with respect to final report preparation are shown in Figure 2-2. The following observations were made before the start of the outage:

Preplanning for the Oconee 3 outage began in June 1976 and quickly became a dual program because of the once-through steam generator (OTSG) tube failure in July. Once that problem was resolved, more emphasis was placed on scheduling the refueling outage in September. Detailed outage preparations were initiated approximately ten weeks before plant shutdown by establishing weekly outage meetings. Prefabrication of materials for site modifications and overhauling of special equipment were begun. Six weeks before the outage, a detailed schedule was developed to include identification of all work items and required activities, listing necessary spare parts and identifying manpower requirements.

The pre-outage schedule for the primary system at Oconee 3 is shown on Figure 2-3. As originally planned, the pre-outage critical path schedule included such activities as complete defueling, removal of the core support assembly for removal of surveillance specimen holder tubes (SSHTs), and refueling. This schedule also included removal of one reactor coolant pump stuffing box and rotating assembly for inspection, eddy-current inspection of both OTSGs, and inspections and tests required prior to power operations.

Secondary plant activities comprised the main turbine/generator warranty inspection, main steam reheater inspection and repair, main steam stop and control valve inspection, main feed pump and turbine inspection, installation of numerous site modifications, preventive maintenance, and miscellaneous valve and piping repair. (See Appendix C, photos 34 through 44.)

2.1.2. Summary of Key Outage Events

Shutdown for the first cycle refueling occurred on September 18, 1976. The reactor coolant system (RCS) was ready for heatup on October 29, 1976, 41 days after the outage. The unit was returned to service (generator on line) on November 13, 1976, for a total outage length of 56 days. The outage was originally scheduled to run 45 days from plant shutdown to "generator on line." The plant was at full power on November 21, 1977.

Several factors caused the delay:

1. Damage to two new fuel assemblies.
2. A last-minute discovery of a CRDM problem requiring inspection and partial disassembly of several of the mechanisms.
3. Required surveillance specimen holder tube (SSHT) repair, which accounted for 5-6 days in the critical path schedule.
4. Canal seal plant and incore tank door leakage.
5. Fuel handling (FH) equipment problems.
6. Minor core flood valve packing repair, which delayed filling the fuel transfer canal.
7. Improper installation of a primary plant valve during the outage, which delayed heatup of the plant.

Several secondary plant maintenance items delayed hot well filling and feedwater cleanup, causing the secondary plant to impact the refueling outage length (approximately 4 days).

2.1.3. Manpower Sources

The Oconee Nuclear Station (ONS) is organized and staffed to perform most of the activities required during a refueling outage. The station consists of a large staff; however, it is not separated into distinct groups assigned to Units 1, 2, and 3. Discounting administrative and operations personnel, the permanent maintenance department is manned by about 65 persons of various classifications (welders, machinists, mechanics, storekeepers, etc.). The Instrument and Electrical Department includes approximately 51 persons, primarily instrument technicians. The Health Physics and Chemistry Departments are staffed with 26 and 16 persons, respectively, and each department assigns four people to regular shift rotation.

The sources of manpower at Oconee 3 during the outage may be divided into three general areas: (1) contracted offsite labor, (2) permanent personnel at ONS, and (3) temporary labor brought in from the company labor pool (maintained by Duke Power Company). It is estimated that these sources were distributed by ratios of 10, 5, and 85% contracted, permanent, and temporary labor, respectively.

2.1.4. Outage Performance

Detailed data collection by the B&W observation team began the week of September 20, 1976, after the plant was shutdown over the weekend. This effort continued through approximately September 30, 1976, at which point the data collection work was halted except for observing fuel handling and control component shuffling in the spent fuel pool while SSHT removal was conducted. Data collection resumed on October 9, 1976, with the start of refueling. The data collection produced a large volume of data sheets, radiation exposure data, and completed work orders. In addition, video tape and time lapse photography were used extensively.

The early stages of the outage proceeded slowly for several reasons. The reactor building temperature was extremely high for the first four days, making working conditions almost unbearable. The personnel elevator was out of commission for the first two days, making it difficult for personnel with anti-C clothing to climb three or four levels with tooling and fixtures; thus, productivity suffered.

The activities that controlled the sequence of events during the outage and the resultant delays are shown on the as-built critical path schedule, Figure 2-3. With reference to this schedule, the following summary of the outage observations includes major delays that caused the schedule to slip and the factors that led to recommendations:

1. Canal Seal Plate Installation — It took about 8 hours to install the canal seal plate; however, seal leakage necessitated draining of the fuel transfer canal (FTC) and repairing the seal, resulting in a 24-hour delay.

2. Removal of the reactor vessel (RV) head insulation took 8 hours for removing and transporting one or two pieces at a time (16 pieces total) to the storage racks on the fourth level (Appendix C, photo 10). Insulation removal should normally take about 3 hours if the racks were bolted together and placed in the transfer canal, thus reducing the number of lifts.

3. Detensioning the RV head, including removal and parking of studs, was accomplished in 17 hours. There were delays due to frequent heat breaks, extended lunch periods, and equipment failures. Using three tensioners and rotating work crews should cut this time to nine hours (Appendix C, photo 12).

4. Uncoupling the control rods required 24 hours due to several delays. Health Physics and I&E support was not properly coordinated; the RCS level was found to be too low to run the axial power shaping rod (APSR) drives; frequent breaks caused delays. Uncoupling and "parking" the APSR and shim drives should normally take about 9-10 hours (Appendix C, photo 13).

5. The reactor head including rigging, was removed in about 7 hours. There were only minor delays due to rigging storage and adjustments (Appendix C, photos 17-23).

6. The time required for indexing fixture installation and plenum removal, including rigging, was about 14 hours. Four hours' delay was attributed to what appear to be errors in procedures; i.e., fuel handling bridge in the wrong location, an attempt to remove the plenum without the indexing fixture, a spreader ring misoriented, etc. (Appendix C, photos 26 and 28). The plenum was removed with the fuel transfer canal dry. This method did not result in excessive exposure to personnel (~100-300 mR/h).

7. The time required to chromate and seal the RV stud holes was 6 hours. With the plenum out of the way, filling and capping the stud holes were accomplished in a 20 to 40 mR/h field as opposed to a 1R/h field (Unit 3 March 1976 outage) with the plenum in the RV. This new method of filling and capping the stud holes with the plenum removed resulted in reduced radiation exposure.

8. An additional 12-hour delay during canal filling was caused by leakage of the incore tank.

9. Defueling operations progressed well despite minor problems with the fuel handling equipment and difficulty with fuel placement due to assembly distortion. The planned schedule was extended only 7 hours.

10. The SSHT removal was completed ahead of schedule with no major problems (Appendix C, photos 31-33).

11. During refueling, two new fuel assemblies were damaged, resulting in approximately 2 days' delay for repair and replacement of these assemblies (Appendix C, photos 49-52).

12. The as-built schedule indicates that stud installation and tensioning the RV head required 50 hours; however, no work was scheduled for half of this time. Sixteen hours' delay was due to tensioner malfunction.

13. Twelve hours were required to replace the head insulation. The same method was used during removal; in addition, two pieces had to be removed to check stud elongation, causing a 2.75-hour delay.

14. Reinstallation of the pressurizer spray valve (RC-1 was installed backwards) caused a 6-day extension of the outage schedule, including cooldown and heatup time.

2.1.5. Outage Activity Manpower and Radiation Exposure

Based on collected data, viz., radiation work permits (RWPs), work orders, time lapse photographs (see Section 2.1.7), Plan-a-Log data, and DOE Study data sheets, a study was conducted to determine the manpower used, the time required, and the radiation exposure received in accomplishing the various tasks. Figure 2-4 shows this information for the activities pertaining to the primary system that were required to refuel the reactor. The figure also shows the sequence in which these tasks were performed during the outage.

The RWP data were used to determine the exposure rate in milliRem/hour (mR/h) for the various tasks. In cases where no RWP data were available, the exposure for these tasks was estimated using exposure rates for the other activities performed in the same vicinity. Table 2-1 shows the average exposure rate for selected activities in the primary system. These values reflect the average exposure rate for an individual assigned to the task, i.e., from the time he signs in upon entry into the reactor building to the time he signs out; it is not the exposure rate the individual would experience while actually performing the work. The radiation data values that are representative of the exposure rate that the individual would experience while actually doing the work are presented in Figure 9-2. These values were obtained from radiation surveys made on local areas prior to starting the work.

The following is a summary of radiation exposure to personnel working on major refueling activities:

1. Tensioning RV Head — The tensioning of the RV head was performed with eight persons, accounting for 2150 mR. There seemed to be excessive personnel in the area, resulting in unnecessary exposure. Figure 2-3 reflects that it took 50 hours to accomplish this task. However, only one shift per day was assigned to this activity. The crew members also had trouble keeping the tensioners working; the cost was 10 hours in time and 1040 mR.

2. Defueling/Refueling the Reactor — Defueling and refueling the reactor accounted for 6675 mR for five people in the reactor building. Another 1068 mR was received by three people in the spent fuel building while shuffling the reactor components. Because of the SSHT problem, it was necessary to completely remove the fuel and refuel the reactor. The plant saved critical path time by doing the control component shuffling in the spent fuel pool (while SSHT repair work was being done in the reactor building) instead of doing it after the assemblies were returned to the reactor.

3. Plenum Removal/Installation — Movement of the plenum out of and into the reactor accounted for 1430 mR for six persons. These activities were done without water in the FTC.

   The plenum was reinstalled before removing the RV stud hole seal plugs, pumping out the chromate, and cleaning and lubricating the stud holes. Therefore, these activities had to be accomplished in a high-radiation area ($\sim$1000 mR/h Vs 34 mR/h).

4. Install/Remove RV Stud Hole Seal Plugs and Fill/Empty Chromated Water — Installing the RV stud hole seal plugs and filling the holes with chromated water accounted for 2244 mR for 11 people. There seemed to be excessive personnel in the area, resulting in unnecessary exposure. This was accomplished while the plenum was out of the reactor vessel. Removing the seal plugs and the chromated water after canal draining accounted for 3600

mR for six persons. As mentioned in item 3, this was accomplished with the plenum reinstalled in the reactor vessel, causing higher radiation exposure.

5. SSHT Repair and Unexpected CRDM Work — Unscheduled CRDM work and the planned SSHT repair work, which required pulling the core support assembly (CSA), building a CSA platform, and completely defueling and refueling the reactor, accounted for approximately 51,100 mR with half of this value (24,500 mR) attributed to the CRDM work.

6. Install/Remove Fuel Transfer Canal Seal Plate — The installation and removal of the seal plate, using six persons, accounted for 1056 mR. During the filling of the FTC, a leak around the seal plate was discovered. The repair crew used a portable shield (6 by 6 ft portable lead partitions) between them and the plenum.

7. Installation and Removal of Indexing Fixture — At present, it is necessary to install and remove the indexing fixture separately for removal and installation of the plenum, which occur before and after refueling activities. Moving the indexing fixture four different times accounted for 1248 mR to six persons.

8. Withdrawal and Insertion of Incore Detectors — The movement of the incore detectors in and out of the reactor, using five persons, accounted for 1320 mR. The fuel transfer canal had to be drained down when a leak was discovered around the incore tank door. Repairing the door took about 8 hours' outage time and 96 mR.

9. Removal and Installation of RV Head — The removal and setting of the RV head accounted for 743 mR. Using seven versus five persons to remove the head seems excessive and results in unnecessary exposure.

10. CRD Uncoupling/Coupling — The uncoupling and coupling of the control rod drives (CRDs) with six to eight persons accounted for 3504 mR. Having so many people on the service structure seems excessive and results in unnecessary exposure.

The radiation exposure data for other refueling outage activities at Oconee 3 are shown on Figure 2-4. The radiation exposure for routine maintenance activities associated with refueling (i.e., head and internals preparation and removal, refueling, and head and internals installation including tensioning and

CRDM coupling) adds up to approximately 28.7 man-Rem expended throughout the refueling outage. This is a surprisingly low number when compared to the total of 154 man-Rem expended throughout the outage. However, it should be noted that approximately 125 man-Rem of exposure was attributed to abnormal activities, such as SSHT repair work, unexpected delays (such as CRDM work with the head on the stand), and extraneous activities inside the RB (such as valve repairs, station modifications and RB general entry). Eddy-current inspection of the OTSGs and other inservice inspections accounted for approximately 12 man-Rem. Thus, it appears that the greatest reduction in man-Rem exposure can be obtained by minimizing the number of unexpected delays and extraneous activities.

2.1.6. Outage Schedule Comparisons

Comparisons of the pre-outage and as-built schedules, shown in Figure 2-3, revealed several abnormal activities and delays that were unique to this outage. If these abnormal activities and delays are deleted from the as-built schedule, we can make an estimate of what should have occurred at Oconee 3 and derive a typical critical path schedule. The activities that make up the typical schedule can then be evaluated and analyzed to determine whether outage time savings can be attained by implementing the recommendations derived from the study.

This typical schedule is shown in Figure 2-3. The following major abnormal activities and delays were deleted from the as-built schedule (with their estimated times):

1. SSHT repairs including complete defueling, removal and installation of the CSA, SSHT removal, and canal filling — estimate 130 hours critical path time.

2. Awaiting delivery and installation of a replacement fuel assembly — estimate 30 hours critical path time.

3. Repair of incore tank door, including initial filling (partial) — estimate 10 hours critical path time.

4. Work on RCP seal leakage measurement — estimate 18 hours critical path time.

5. Reinstall pressurizer safety valves — 20 hours critical path time.

6. Install RC pump seal injection breakdown coils — 8 hours critical path time.

7. Delay in filling the condensate and feedwater system including feedwater cleanup — 94 hours critical path time.

8. Replace shorted CRD stator — 54 hours critical path time.

9. Valve RC-1 repairs — 143 hours critical path time.

10. Miscellaneous minor delays due to equipment failures (such as stud tensioner), canal seal plate leakage, uncoupling the CRDMs, installation of indexing fixture for plenum removal, etc. — estimate 29 hours critical path time.

It is important to note that this schedule is derived from the as-built schedule for a specific site at a given time in life and under conditions that existed during that time. In addition, the following assumptions were made to arrive at the typical schedule:

1. Activities performed by the operations group were conducted 24 hours per day, seven days per week.

2. Critical path activities performed by the maintenance group were conducted with two 10-hour shifts per day, six days per week. Shifts run from 0700 to 1700 and 1600 to 0200.

3. The refueling cycle was normal; i.e., it was not necessary to completely defuel and refuel the reactor.

4. The time between the maintenance shifts can be used for HP surveys, radiography, etc.

5. The schedule does not reflect standby work performed as necessary by maintenance on Sundays to prevent schedule delays.

The activities and assumptions described above represent a total of approximately 23 days of critical path time from plant shutdown to "generator on line." Thus, it appears that if no delays and abnormal activities occurred during the outage, the total outage time would have been approximately 33 days from plant shutdown to "generator on line," compared to 56 days' actual outage time.

2.1.7. Time-Lapse Photography — Manpower Analysis

The Oconee 3 time lapse photographic sequences were reviewed to obtain manpower loadings on various jobs where workers are exposed to radiation. This manpower analysis can be used to determine where improvements can be made in manpower utilization to either reduce radiation exposure or avoid unnecessary exposure.

The results of this manpower study are displayed in graphs of manpower versus time for selected activities (Appendix F). Table 2-2 lists the selected activities used for manpower analysis. The Appendix F graphs show three lines: a broken line with dots represents total number of workers in the reactor building, a broken line represents the number of men actually working on a particular job, and a solid line represents the number of men in the building who are not working.

These graphs show that in some activities, such as CRDM uncoupling and RV stud tensioning, an excessive number of persons were assigned to these jobs, resulting in unnecessary exposure. The recommendations for improvements in manpower utilization resulting from this study are included in sections 4 through 8.

2.2. ANO 1 Refueling Outage

2.2.1. Pre-Outage Schedule

After the data collection and outage observation at Oconee 3 were completed, B&W and DOE concluded that a follow-up study at ANO 1 was necessary to confirm the initial findings and to broaden the data base for key outage observations.

Initial deployment of B&W observation personnel to the ANO 1 site began in January 1977. Program objectives, specific ANO observation objectives, and the observation team organization (shown in Figure 2-5) were reviewed with ANO 1 site personnel. At this time, the pre-outage planning and scheduling activities conducted by ANO 1 personnel were well underway. Thus, the B&W observation team was not able to observe the detailed pre-outage planning (the outage started on 1/28/77). The extent of pre-outage planning observations conducted by the B&W observation team is limited to the discussions below.

The actual detailed planning effort for ANO's first-cycle refueling outage was begun in late fall of 1976 when an outage planner was appointed. Prior to this time, some small planning effort had been conducted. This gave ANO 1 only about two months for real outage preparation, planning, and generating a detailed schedule. This included identifying the required activities, listing required spare parts, and identifying manpower requirements. No problems were evident until later during the outage when it was discovered there was a lack of spare parts and manpower to support the outage.

Figure 2-6 is the pre-outage refueling critical path schedule for the primary system at ANO 1. As originally planned, the total outage schedule was governed by the BOP critical path due to the changeout of the plant computer from the Bailey 855 to a Systems Engineering Laboratories (SEL) computer. Thus, the primary and secondary plant maintenance activities would be under less pressure than would be expected during a normal refueling outage. The secondary plant activities consisted mainly of the warranty inspection of the A and B low-pressure turbines, inspection and modification of the moisture separator reheaters, and other miscellaneous work.

On the primary side, the refueling activities were planned in a somewhat different sequence than would normally be expected. Since the primary plant was not critical path and there was a need for control rod drive mechanism (CRDM) stator replacement, RV head removal was scheduled later than normal. This allowed stator replacement with the head on the vessel and thus minimized radiation exposure. Other primary plant activities included inservice inspection, eddy-current testing of the OTSGs, pouring concrete for additional shield walls, replacing the control rod mast, and using B&W's noise detection equipment to locate a suspected loose part. The original schedule also called for a normal fuel shuffle. Some of the other activities planned for the outage included radiographic inspection of decay heat (DH) and building spray (BS) system piping weld heat-affected areas for cracking, diesel generator inspection and testing, valve repairs, etc.

2.2.2. Summary of Key Outage Events

Shutdown for the first cycle refueling occurred January 27, 1977. The unit was returned to service (generator on line) on April 2, 1977, for a total outage length of 65 days. However, the plant was not at full power until April 11, 1977, 74 days after shutdown. The outage was originally scheduled for 48 days from plant shutdown to generator on line.

The major factor causing the delay was the unexpected repair required on one of the blade retaining rings of the A low-pressure turbine rotor (approximately 18 days critical path time). Delays on the primary side included (1) repeated leakage problems with the fuel transfer canal seal plate, (2) problems in getting the main fuel handling bridge control rod handling mast modified and operational, (3) CRDM stator replacement, and (4) damage to a new fuel assembly during fuel reloading.

2.2.3. Manpower Sources

The maintenance staff used at the ANO-1 outage was relatively small — 63 persons (excluding administrative and operations personnel). This number may be broken down: 22 mechanics, 21 instrument and control (I&C) technicians, 8 electricians, 8 health physicists, and 4 chemists. Due to the small staff, ANO 1 maintenance was restricted to conducting mostly normal refueling activities, while the rest of the activities were contracted out to various vendors.

Approximately 60% of the Arkansas outage work force was contracted from outside labor. Of these, Bechtel made up the largest group (approximately 50 persons), and they were assigned all safety-related design changes. Bechtel is also the architect-engineer (AE) on ANO Unit 2, sited adjacent to Unit 1. Next largest was Westinghouse (about 30 persons), whose prime responsibility was turbine inspection and associated work. The B&W Construction Co. and B&W Nuclear Service provided 18 persons each to perform inservice inspection (ISI), OTSG tube inspection, and work on primary-related (RCS) components. Graves Insulation provided 4-6 persons for insulation work. The Fagen Company provided 14 workers for non-safety-related design changes. Ten additional Health Physics technicians were supplied by a Philadelphia firm (Rent-a-Tech), and four men from Peabody performed radiography tests on the DH pump suction piping. Other contractors on the site in smaller number were Conesco, Diamond Power, and Stearns-Roger, doing reactor building tendon inspection, control rod drive work, and fuel handling equipment modification, respectively. The total number of contracted personnel at AP&L is estimated at 150.

2.2.4. Outage Performance

The B&W/DOE observation team began collecting data at ANO 1 on January 27, 1977, when the plant was shut down. Major emphasis in the collection of data was placed on video taping in conjunction with observations recorded on data sheets. Very little work was done on time lapse photography at this site as compared to that at Oconee 3 since its usefulness was found to be limited only to manpower analysis and pictorial displays of the outage.

The early stages of the outage proceeded very well, with most activities being conducted either on or ahead of schedule. However, problems occurred that caused some delays. The activities that controlled the sequence of events during the outage and the resultant delays are shown on the as-built critical path schedule, Figure 2-6. With reference to this schedule, the following paragraphs summarize the outage observations and the factors that led to the study recommendations.

1. It took about 5 hours to uncouple the APSRs because the portable power supply was required; using this method, only one APSR can be uncoupled at a time. The normal power supply was out of service because of the plant computer changeout. Uncoupling the shim drives took about 12 hours; 12 of the drives were uncoupled using the standard method (long-handled tool) due to a torque check that had to be made, necessitating lead screw removal. The remaining drives were uncoupled using the alternate method of uncoupling (short tool). The standard long tool must still be used to "park" the lead screw.

2. The RV head insulation was removed and stored in about 3 hours. The procedure was to move the four storage racks into the FTC and place the insulation on the racks, then transport the racks individually to a storage location using the polar crane. This resulted in savings of up to 17 hours for this operation compared to removing the insulation one piece at a time.

3. The canal seal plate was installed in about 6 hours using a manual wrench for nut installation. Removing the plate took about the same time, using the same tool.

4. Detensioning and tensioning were accomplished using two stud tensioners. Detensioning involved no problems; however, during tensioning one tensioner broke down (with no spare available), forcing the task to be completed using one tensioner. This caused a 2-hour delay. Six hours were required for tensioning, which normally takes about 4 hours.

5. The RV head studs were removed using the stud runner. The stud runner raises the stud enough to release it from the RV head flange. The operation of the existing stud runner is too slow, causing this operation to take about 10 hours.

6. In preparation for RV head removal, 36 of the 60 studs, stud nuts, and washers were removed from the head and placed on storage racks to allow the head to be lifted from the vessel. The storage racks were then transported to a temporary storage area outside the transfer canal. It was necessary to remove these studs, stud nuts, and washers because of recent Occupational Safety and Health Act (OSHA) limitations on the polar crane, which preclude head removal with all 60 studs, nuts, and washers left parked in the flange. This entire method took about 4 hours. It is not only time-consuming but an increased hazard to both personnel and equipment.

7. Removing the fuel transfer tube blank required three men for 3 hours, using a manual wrench for bolt removal.

8. The primary plant schedule was planned to allow a 5-day period with the head on the reactor vessel in order to change out the CRDM stators. This changeout effort was started February 3, 1977 (day 7), but problems occurred when the new stators would not seat properly on the motor tubes. A pin in the lower retaining ring of the stator fits a slot in the motor tube to provide indexing and prevent stator rotation. This pin is supposed to be masked off during manufacturing when the retaining ring is plated, but it was overlooked, resulting in a tolerance problem. The problem was corrected by removing metal from the pin, but this effort delayed stator replacement to sometime later in the schedule. The stator replacement actually was conducted from March 10 (day 42) to March 13, 1977 (day 45), after head replacement.

9. During the outage, the polar crane required repairs on more than one occasion, causing delays of up to 12 hours in the primary system.

10. Rigging for RV head lift took about 3 hours. The RV head lifting cables were stored on the floor due to lack of permanent wall-mounted storage locations. The turnbuckles used to level the RV head and latch boxes for lifting the plenum were also lying on the grating floor due to lack of storage locations. This method increased the time required to assemble

the rigging components and caused minor difficulties in inserting the connecting pins due to buckling of the lifting cables.

11. The FTC seal plate was a continuous problem throughout the outage. The FTC had to be drained twice to repair the seal plate due to excessive leakage. This resulted in more than 3 days' lost time.

12. Eddy-current testing of the A&B OTSG tubes was originally scheduled to start on February 1 (B, day 5), February 8 (A, day 12) and be completed on February 3 (B, day 7), February 9 (A, day 13). This would have completed the eddy-current testing before fuel shuffle, when there are no ANO-imposed manpower restrictions in the reactor building. However, the eddy-current tests did not start until February 7 (B, day 11), February 16 (A, day 20) with completion on February 9 (B, day 13), February 18 (A, day 22). Since these tests can be done with the primary system level either raised or lowered, the delay caused no refueling critical path delays.

13. After about two weeks into the outage, it became apparent that some delays were being caused by problems with manpower and spare parts. To relieve the delays, some jobs were shifted to later in the outage, some were cancelled, and spare parts location was expedited. The cause of the manpower problem was the high radiation exposure to the ANO maintenance staff. This resulted in AP&L requesting that B&W supply manpower for some of the head replacement efforts.

14. The indexing fixture and plenum were removed and installed with the fuel transfer canal filled with borated water. Prior to filling the canal, the RV head stud holes were prepared and cleaned and seal plugs were installed. This activity took about 15 hours with personnel exposed to as much as 300 mR/h (due to plenum in vessel). Several sites, including Oconee 3, have already undergone refueling operations with the refueling canal dry while the plenum was being removed. Dry plenum removal results in better visibility and accessibility for hookup of the rigging equipment for lifting. Subsequently, with the plenum removed from the vessel, radiation exposure to personnel preparing and cleaning the stud holes and seal plugs prior to canal filling will be reduced (about 50-100 mR/h).

15. ANO decided to defuel the entire core in order to perform a detailed inspection of the fuel assemblies and the reactor vessel. B&W provided video assistance for this investigation.

16. A contributing factor to defueling the core was the operability of the control rod mast. The mast had been removed during a previous outage to allow replacement of some cracked guide plates. It was reinstalled and worked on by Stearns-Roger personnel but still did not perform as well as it should. With the decision to defuel the core, the control rod mast was only used for about 30 component moves prior to fuel off-load and the same 30 component moves after fuel reloading.

17. Reloading of the core was started of 0600 on February 23, 1977 (day 27), but proceeded very slowly because of the manipulations required to seat the assemblies; this was required because of bowing and twisting of irradiated assemblies. A further delay was encountered when a fuel assembly had to be removed due to damage during the loading operations.

18. During the scheduled inspection of the DH and BS piping weld heat-affected zones, extensive pitting was discovered. As a result, two sections were removed and replaced with nine spool pieces.

19. The most significant item (causing the greatest delays) during the outage was the problem encountered during the warranty inspection of the low-pressure sections of the main turbine. During this inspection, cracks were discovered in the "steeples" of the blade-retaining ring of the L-5 stage of the A low-pressure turbine rotor. The solution at ANO was to remove the blades from the L-5 stages and cut the steeples back to remove the cracked areas. This problem caused a 20-day delay in the original schedule (about 13 days critical path time).

2.2.5. Outage Activity Manpower and Radiation Exposure

Based on collected data (RWPs, work orders, Plan-a-Log data, and DOE Study data sheets and logs) a study was performed to determine the manpower used, the time required, and the radiation exposure received to accomplish the various tasks. Figure 2-6 shows this information for the activities pertaining to the primary system that are required to refuel the reactor. The figure also shows the sequence in which these tasks were performed during the outage.

The RWP data were used to determine the exposure rates (mR/h) for the various tasks. In cases where no RWP data were available, the exposure for these tasks was estimated by using exposure rates for the other activities performed in that vicinity. Table 2-3 shows the average exposure rate for selected activities performed during the outage. These values reflect the average exposure rate for an individual assigned to the task, i.e., from the time he signs in on entry to the reactor building to the time he signs out. They do not reflect the exposure rate to the individual while actually performing the work. The values of the radiation data that are representative of the exposure that the individual would experience while actually doing the work are presented in Figure 9-4. These values were obtained from radiation surveys made on local areas prior to starting the work.

The following is a summary of radiation exposure to personnel working on major refueling activities:

1. Uncoupling/Coupling Control Rod Drive — The uncoupling and coupling of the CRDs, using 9 persons, (some for training) accounted for 5423 mR.

2. Defueling/Refueling Reactor — Complete removal and refueling of the reactor was necessary to permit the retrieval of loose parts. These activities, using 4 persons, accounted for 1760 mR.

3. Shuffling Reactor Components in Spent Fuel Building — This work, which was done in the spent fuel building with 3 people, accounted for 1274 mR.

4. CRD Stator Removal and Loose Parts Retrieval — The planned removal and replacement of CRD stators and the unscheduled retrieval of loose parts from the reactor (which required the complete removal and refueling of the reactor) and the delay associated with the damaged fuel assembly accounted for 236 hours' outage time and 8036 mR. The fuel assembly control components were shuffled in the spent fuel building while the loose parts were being retrieved, saving critical path time, as opposed to doing it after returning the fuel assemblies to the reactor.

5. Tensioning/Detensioning RV Head — The detensioning and tensioning of the RV head was accomplished using 5 people, accounting for 1945 mR.

6. Removal/Installation of Plenum — The plenum was removed and installed using 3 persons, accounting for 123 mR.

7. Installation/Removal of Indexing Fixture — In the present design it is necessary to install and remove the indexing fixture in order to remove and install the plenum, which occurs before and after refueling activities. Moving the indexing fixture four different times using 3 persons accounted for 753 mR.

8. Install/Raise FTC Seal Plate — During canal filling, repeated seal plate leakage required draining of the FTC and repair of the seal plate gasket. Gasket repair accounted for 2448 mR and 21 hours' outage time. Installing and raising the FTC seal plate accounted for 955 mR.

9. Withdraw/Insert Incore Detectors — The movement of the incore detectors out of and into the reactor, using 5 persons, accounted for 1035 mR.

10. Install/Remove RV Stud Hole Seal Plugs, Fill/Empty Chromated Water — These activities, which were accomplished with the plenum in the RV, accounted for 1740 mR. As shown in Table 2-3, these activities accounted for the highest exposure rate. This can be reduced by removing the plenum with the canal dry, then preparing and cleaning the stud holes.

11. Remove/Install RV Head — The removal and installation of the RV head, including rigging with 6 persons, accounted for 1674 mR. While preparing to remove the head, it was necessary to stop rigging operations to repair the polar crane, causing a 24-hour delay.

Radiation exposure data for other refueling outage activities are shown on Figure 2-7 for ANO 1. The radiation exposure for routine maintenance activities associated with refueling (i.e., RV head and internals preparation and removal, refueling, and head and internals installation, including stud tensioning and CRDM coupling) adds up to 28.3 man-Rems. This value compares very closely to that obtained at Oconee 3. A total of approximately 166 man-Rems was expended throughout the outage. As in the case of Oconee 3, the largest toll in man-Rem exposure was attributed to unscheduled delays, such as the complete defueling of the reactor and retrieval of loose parts, such abnormal activities as the planned CRDM stator removal and replacement, and extraneous maintenance work in the RB. The inservice inspection accounted for approximately 23 man-Rems. Thus, it appears that the greatest reduction in man-Rem exposure can be obtained by minimizing the number of unexpected delays and extraneous activities.

2.2.6. Outage Schedule Comparisons

Comparisons of the pre-outage and as-built schedules (shown on Figure 2-6) revealed several abnormal activities and delays that were unique to this outage. If these abnormal activities and delays were deleted from the as-built schedule, an estimate of what should have occurred at ANO-1 can be made, resulting in a typical critical path schedule. Evaluation and analysis of the activities that make up the typical schedule can then be made to determine whether outage time savings can be attained by implementing the recommendations derived from the study.

A typical schedule is shown in Figure 2-6. The major abnormal activities and delays that were deleted from the as-built schedule and their estimated times are as follows:

1. Replacement of CRD Stators — Estimate 99 hours of scheduled time used on this activity.
2. Repair of Polar Crane — Estimate 12 hours critical path time used on this activity.
3. Replacement of the Equipment Hatch Gaskets — Estimate 35 hours critical path time used on this activity.
4. Repair of FTC Seal Plate — Estimate 84 hours critical path time used on this activity.
5. Retrieval of Loose Parts From RV — Estimate 78 hours of scheduled time used on this activity.
6. Repair of Damaged Fuel Assembly — Estimate 2 hours waiting time for replacement of fuel assembly.
7. Repair of Turbine — Estimate 432 hours critical path time used on this activity.
8. Miscellaneous minor delays associated with CRDM uncoupling and shifting the incore detector work off the critical path — Estimate 47 hours critical path time.

It is important to note that the typical schedule is derived from the as-built schedule for a specific site at a given time in life and under the conditions that existed during that time. In addition, the following assumptions were made to derive the typical schedule:

1. Activities performed by the Operations group were conducted for 24 hours per day, 7 days per week.
2. Critical path activities performed by the Maintenance group were conducted in two 10-hour shifts per day, 6 days per week. Shifts run from 0700 to 1700 and 1600 to 0200.
3. The refueling cycle was normal, i.e., it is not necessary to completely defuel and refuel the reactor.
4. The time between the maintenance shifts can be used for HP surveys, radiography, etc.
5. The schedule does not reflect standby work performed as necessary by Maintenance on Sundays to prevent schedule delays.

These activities and assumptions represent a total of approximately 33 days of critical path time from plant shutdown to generator on line, or approximately 42 days from plant shutdown to 100% power, assuming about 9 days for power escalation. Thus, it appears that if delays and abnormal activities did not occur during the outage, the total outage time would have been approximately 32 days from plant shutdown to generator on line compared to 65 days actual outage time.

Table 2-1. Average Exposure Rates for Selected Activities — Oconee 3 Outage

Activity	Exposure rate, mRem/h
Move miscellaneous equipment into reactor building and into fuel transfer canal	6.3
Install fuel transfer canal seal plate	6.2
Replace gasket for fuel transfer canal seal plate	15.9
Detension and spin out studs	6.8
Remove head	7.9
Remove/replace reactor coolant pump seals	2.3
Remove plenum	14.8
Defueling/refueling	4.5
Pull core barrel	5.7
Install plenum	24.5
Set head	22.8
Clean stud holes	33.8
Eddy-current inspection	8.9
Uncouple/couple control rod drives	12.2
Fuel shuffling in spent fuel building	3.1

Table 2-2. Selected Activities Used for Manpower Analysis

Time lapse film sequence	Activity[a]
2	Removing shield blocks
4	CRDM venting
4, 6	CRDM uncoupling
5	Insulation removal
10	Rigging for head lift
10	Rigging pendants
32	Refueling bridge
35, 39	Reactor vessel head stand work
41	Reactor vessel head work, CRDMs
41	Attaching pendants to tripod
42	Stud hole cleaning
42	Rigging tripod to reactor vessel head
42	Reactor vessel head installation
42	Indexing fixture removal
42	Unrigging tripod (latch boxes)
44	Running in studs
44	Stud tensioner work

[a] From Oconee 3 outage.

Table 2-3. Average Exposure Rates for Selected Activities — ANO 1 Outage

Activity	Exposure rate, mRem/h
Remove missile shield	2.1
Uncouple control rod drives	42.1
Remove head insulation	8.1
Detension reactor vessel head	20.8
Remove and place studs in rack	13.1
Remove head	60.0
Install indexing fixture	28.5
Remove upper plenum	7.6
Remove indexing fixture	8.9
Refueling operations	1.9
Remove seal plugs and chromated water, clean and lubricate stud holes	68
Install/raise canal seal plate	17.3
Withdraw/insert incore detectors	2.7

Figure 2-1. B&W-DOE Team at Oconee 3

F. R. Thomasson*

- **R.B. Operations Observations**
  - J. R. Shetler*
  - R. E. Wascher
  - M. H. Fish
  - R. D. Newcomb
- **Planning & Scheduling Overview**
  - P. G. Perry*
  - S. L. Fraley
  - C. W. Litchford
  - T. F. Scott
- **Special Areas**
  - **RC Pump Maintenance**
    - R. F. Smith*
    - R. B. Camper
  - **FH Equipment Operations & Modifications**
    - C. L. Finch
    - D. Cutsinger
    - T. L. Wilson
    - L. L. Joyner
  - **Tooling Modifications, Maintenance Observations, Etc.**
    - E. L. Brown*
- **Support Services Observations**
  - N. M. Seeling*
  - R. J. Ansell
  - J. W. Large
- **TV Coverage & Recording**
  - P. J. Abbott*
  - L. M. Mace
  - P. E. Conner
- **Office**
  - J. C. Stratton

*Primary Contacts

Figure 2-2. B&W-DOE Team — Report Preparation

A. L. Mercado
(Overall Coordinator)

Figure of Merit Evaluations
Time Lapse Photographic Studies
Generic Plant Recommendations

R. Latorre — Task Leader
D. J. Belcher
S. L. Fraley
M. F. Penovich

Evaluation of Data
Report Preparation

W. H. Abbott
P. C. Rouse
R. Latorre
A. T. Russell
C. N. Drummond
L. N. Mace

Video Tape
Edits

M. W. Culver
S. J. Smith
P. G. Perry
J. R. Shetler
R. D. Newcomb
A. T. Russell
G. N. Elliott
R. Latorre

Special
Studies

R. D. Newcomb
R. F. Ryan
F. R. Fahland

Figure 2-3, Sheet 1. Oconee 3 Refueling Schedule

REFUELING SCHEDULES

Based on the DOE-Sponsored Reactor Availability Study

Notes for SCHEDULED

1. Pre-outage schedule is estimated Duke schedule for Oconee 3 outage prior to shutdown.

Notes for AS-BUILT

1. AS-BUILT schedule is official Duke schedule as it actually occurred for the Oconee 3 outage.

Notes for TYPICAL

1. This schedule is an estimate by the DOE team of what should have occurred at Oconee 3 if delays and SSHT repair work were deleted from the AS-BUILT schedule and the following assumptions were made:

   a. Activities performed by the Operations group conducted 24 hours/day, 7 days/week (noted by asterisks (*)).

   b. Critical path activities performed by the Maintenance group conducted on two 10-hour shifts/day, 6 days/week; shifts run from 0700 to 1700 and 1600 to 0200.

   c. Equilibrium refueling cycle.

   d. Time after the 20-hour work day by maintenance personnel can be used for HP surveys, radiography, etc.

   e. This schedule does not reflect standby work performed as necessary by Maintenance on Sundays to prevent schedule delays.

LEGEND

1. Five-hour break in maintenance activities due to shift change:

2. Sundays not worked by maintenance personnel:

Figure 2-3, Sheet 2. Oconee 3 Refueling Schedule

Babcock & Wilcox

Figure 2-3, Sheet 3. Oconee 3
Refueling Schedule

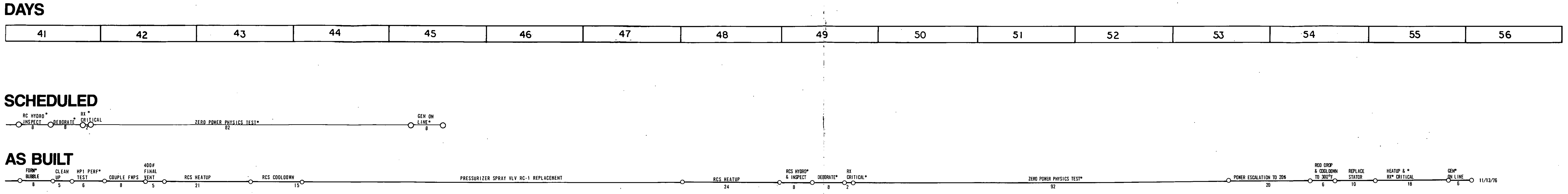
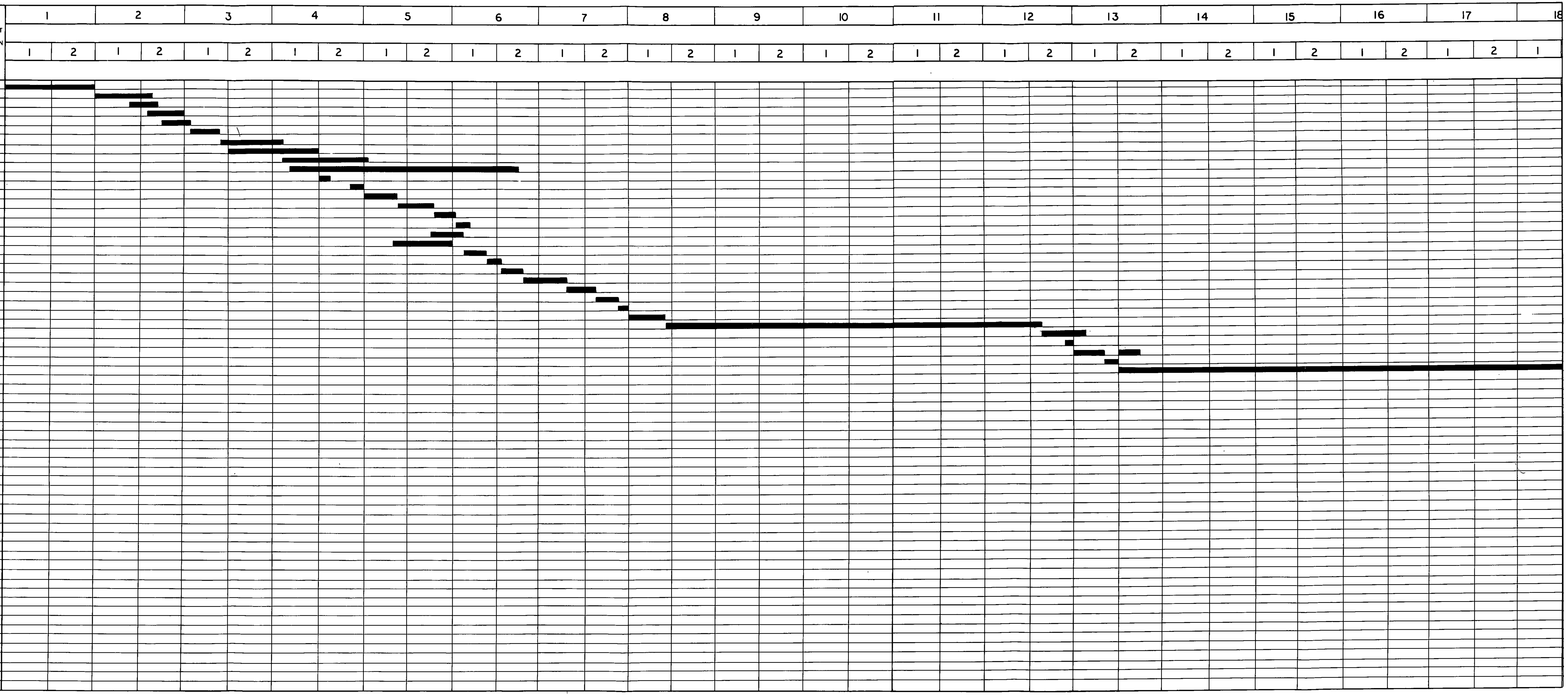


Figure 2-3, Sheet 4. Oconee 3 Refueling Schedule

Figure 2-4, Sheet 1. Oconee 3
As-Built Primary
Refueling Activities

ACTIVITIES ACTIVITIES IN ( ) ARE ACTIVITIES ADDED TO THE PLAN-A-LOG LIST OF ACTIVITIES	MANPOWER	ELAPSED TIME (HOURS)	AS-BUILT RADIATION EXPOSURE (MREM)
1. SHUTDOWN-COOLDOWN		24	
2. MOVE EQUIPMENT INTO BUILDING	10	15	345
3. REMOVE SHIELD BLOCKS AND GRATING	5	8	40
4. REMOVE PRESSURIZER RELIEF VALVES	4	10	2000
5. INSTALL CANAL SEAL PLATE	6	8	768
6. REMOVE HEAD INSULATION	4	8	192
7. DETENSION HEAD, REMOVE & PARK STUDS	10	17 (9)[1]	630
8. (CRD UNCOUPLING)	6	24	1584
9. RC PUMP SEALS REMOVAL	7	22	462
10. RC PUMP REMOVAL AND INSPECTION	10	62	2480
11. (REMOVE HEAD)	7	3	168
12. FILL TO 80 INCHES (RC PUMP INSPECTION)	OPERATIONS	4	
13. INSTALL INDEX FIXTURE	6	9 (4)	406
14. REMOVE PLENUM	6	10 (4)	406
15. (CHROMATE & SEAL STUD HOLES)	11	6	2244
16. REMOVE INDEX FIXTURE	6	4	406
17. SURVEILLANCE SPECIMEN HOLDER TUBE ROTATION	4	9	1224
18. (WITHDRAW INCORE DETECTORS)	5	16	320
19. CLEAN FUEL CANAL TANK/(REMV. TRANS. TUBE COVER INST. CANAL DR. BLS)	4	6	96
20. FILL & DRAIN CANAL	OPERATIONS	4	
21. REPAIR INCORE TANK DOOR	4	6	96
22. FILL & DRAIN CANAL	OPERATIONS	12	
23. REPAIR CORE SUPPORT ASSEMBLY	4	8	1098
24. FILL CANAL	OPERATIONS	6	
25. CHECK TRANSFER CANAL	3	3	36
26. CHECK BRIDGES & CRD MAST	3	10	120
27. DEFUELING	5	101	2525
28. PULL CORE BARREL	6	12	432
29. DRAIN CANAL FOR CSA WORK	OPERATIONS	2	
30. INSTALL CORE BARREL PLATFORM	4	14	168
31. SITE ASSEMBLY DRILL	OPERATIONS	4	
32. SURVEILLANCE SPECIMEN HOLDER TUBE REMOVAL	4	136	24100
33. VENT VALVE INSPECTION	4	18 (4)	544
34. REFILL CANAL	OPERATIONS	2	
35. INSTALL CORE BARREL	4	12	220
36. COMPONENT SHUFFLE REFUEL AND (FUEL VERIFICATION)	5	166	4150
37. DELAY FOR OPEN EQUIPMENT HATCH	DELAY	6	
38. AWAITING DELIVERY & INSTALLATION OF FUEL ASSEMBLY	DELAY	30	
39. DRAIN CANAL	OPERATIONS	8	
40. (INSTALL INDEX FIXTURE)	6	2	1300
41. REMOVE SEAL & CHROMATE FROM STUD HOLES	6	8 (1.5)	3600
42. INSTALL PLENUM	11	8	2992
43. (CLEAN "O" RING GROOVE)	2	2	136
44. REMOVE INDEX FIXTURE	6	8	1200
45. (INSERT INCORE DETECTORS)	5	40	1000
46. (INSTALL RCP SEALS)	4	24	192
47. (REPAIR RCP MOTORS)	3	96	864
48. REPLACE HEAD	5	5	575
49. REMOVE GUIDE STUDS AND SPIN IN STUDS	8	4	515
50. TENSION RV HEAD	8	50(25)	2150
51. (COUPLING CRD)	8	15	1920
52. REMOVE OTSG MANWAY A	2	5	120
53. OTSG EDDY CURRENT INSPECTION A	6	37	1555
54. INSTALL OTSG MANWAY A	3	8	240
55. REMOVE OTSG MANWAY B	2	5	150
56. OTSG EDDY CURRENT INSPECTION B	6	37	1555
57. INSTALL OTSG MANWAY B	3	8	240
58. INSTALL PRESSURIZER RELIEF VALVES	4	10	2000
59. INSTALL HEAD INSULATION	5	12	960
60. RAISE SEAL PLATE	6	8	288
61. INSTALL TRANSFER TUBE COVERS	3	8	96
62. REMOVE CANAL DRAIN BLANKS	3	4	48
63. INSTALL SHIELD BLOCKS	3	10	30
64. PLAN-A-LOG-DAY 34-55-MAINT. ACTIVITIES & RCS STARTUP			
65. SPENT FUEL BUILDING-FUEL SHUFFLING	3	267	1068



1 NUMBERS IN ( ) REPRESENT HOURS WORKED WHEN DIFFERENT FROM ELASPED TIME.
OPERATIONS-INDICATES CONTROL ROOM OPERATION

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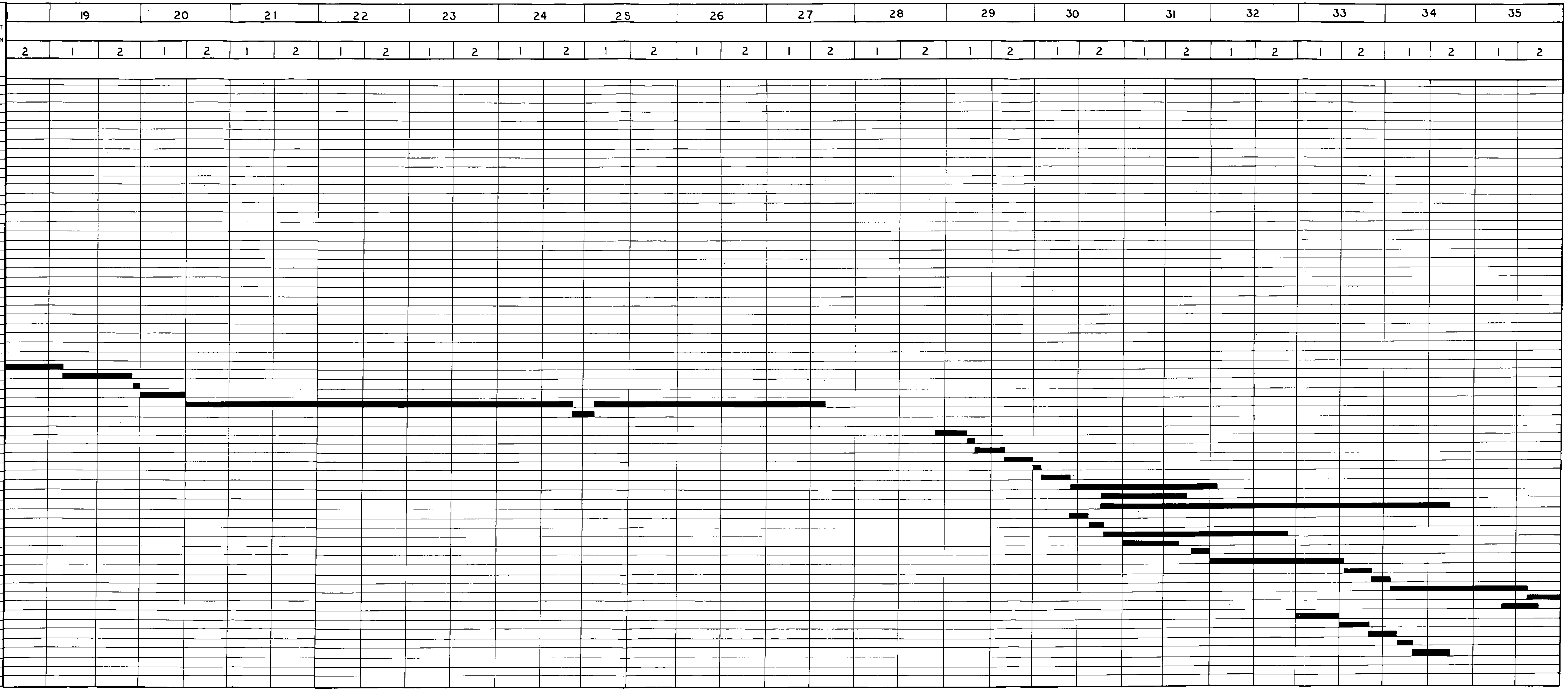
Figure 2-4, Sheet 2. Oconee 3 As-Built Primary Refueling Activities

ACTIVITIES ACTIVITIES IN ( ) ARE ACTIVITIES ADDED TO THE PLAN-A-LOG LIST OF ACTIVITIES	MANPOWER	ELAPSED TIME (HOURS)	AS-BUILT RADIATION EXPOSURE (MREM)
1. SHUTDOWN-COOLDOWN		24	
2. MOVE EQUIPMENT INTO BUILDING	10	15	345
3. REMOVE SHIELD BLOCKS AND GRATING	5	8	40
4. REMOVE PRESSURIZER RELIEF VALVES	4	10	2000
5. INSTALL CANAL SEAL PLATE	6	8	768
6. REMOVE HEAD INSULATION	4	8	192
7. DETENSION HEAD, REMOVE & PARK STUDS	10	17 (9)[1]	630
8. (CRD UNCOUPLING)	6	24	1584
9. RC PUMP SEALS REMOVAL	7	22	462
10. RC PUMP REMOVAL AND INSPECTION	10	62	2480
11. (REMOVE HEAD)	7	3	168
12. FILL TO 80 INCHES (RC PUMP INSPECTION)	OPERATIONS	4	
13. INSTALL INDEX FIXTURE	6	9 (4)	406
14. REMOVE PLENUM	6	10 (4)	406
15. (CHROMATE & SEAL STUD HOLES)	11	6	2244
16. REMOVE INDEX FIXTURE	6	4	406
17. SURVEILLANCE SPECIMEN HOLDER TUBE ROTATION	4	9	1224
18. (WITHDRAW INCORE DETECTORS)	5	16	320
19. CLEAN FUEL CANAL TANK/(REMV. TRANS. TUBE COVER INST. CANAL DR. BLS)	4	6	96
20. FILL & DRAIN CANAL	OPERATIONS	4	
21. REPAIR INCORE TANK DOOR	4	6	96
22. FILL & DRAIN CANAL	OPERATIONS	12	
23. REPAIR CORE SUPPORT ASSEMBLY	4	8	1098
24. FILL CANAL	OPERATIONS	6	
25. CHECK TRANSFER CANAL	3	3	36
26. CHECK BRIDGES & CRD MAST	3	10	120
27. DEFUELING	5	101	2525
28. PULL CORE BARREL	6	12	432
29. DRAIN CANAL FOR CSA WORK	OPERATIONS	2	
30. INSTALL CORE BARREL PLATFORM	4	14	168
31. SITE ASSEMBLY DRILL	OPERATIONS	4	
32. SURVEILLANCE SPECIMEN HOLDER TUBE REMOVAL	4	136	24100
33. VENT VALVE INSPECTION	4	18 (4)	544
34. REFILL CANAL	OPERATIONS	2	
35. INSTALL CORE BARREL	4	12	220
36. COMPONENT SHUFFLE REFUEL AND (FUEL VERIFICATION)	5	166	4150
37. DELAY FOR OPEN EQUIPMENT HATCH	DELAY	6	
38. AWAITING DELIVERY & INSTALLATION OF FUEL ASSEMBLY	DELAY	30	
39. DRAIN CANAL	OPERATIONS	8	
40. (INSTALL INDEX FIXTURE)	6	2	1300
41. REMOVE SEAL & CHROMATE FROM STUD HOLES	6	8 (1.5)	3600
42. INSTALL PLENUM	11	8	2992
43. (CLEAN "O" RING GROOVE)	2	2	136
44. REMOVE INDEX FIXTURE	6	8	1200
45. (INSERT INCORE DETECTORS)	5	40	1000
46. (INSTALL RCP SEALS)	4	24	192
47. (REPAIR RCP MOTORS)	3	96	864
48. REPLACE HEAD	5	5	575
49. REMOVE GUIDE STUDS AND SPIN IN STUDS	8	4	515
50. TENSION RV HEAD	8	50(25)	2150
51. (COUPLING CRD)	8	15	1920
52. REMOVE OTSG MANWAY A	2	5	120
53. OTSG EDDY CURRENT INSPECTION A	6	37	1555
54. INSTALL OTSG MANWAY A	3	8	240
55. REMOVE OTSG MANWAY B	2	5	150
56. OTSG EDDY CURRENT INSPECTION B	6	37	1555
57. INSTALL OTSG MANWAY B	3	8	240
58. INSTALL PRESSURIZER RELIEF VALVES	4	10	2000
59. INSTALL HEAD INSULATION	5	12	960
60. RAISE SEAL PLATE	6	8	288
61. INSTALL TRANSFER TUBE COVERS	3	8	96
62. REMOVE CANAL DRAIN BLANKS	3	4	48
63. INSTALL SHIELD BLOCKS	3	10	30
64. PLAN-A-LOG-DAY 34-55-MAINT. ACTIVITIES & RCS STARTUP			
65. SPENT FUEL BUILDING-FUEL SHUFFLING	3	267	1068



1 NUMBERS IN ( ) REPRESENT HOURS WORKED WHEN DIFFERENT FROM ELASPED TIME.
OPERATIONS-INDICATES CONTROL ROOM OPERATION

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Figure 2-5. B&W-DOE Team at ANO 1

Observation Coordinator

J. R. Shetler
(P. G. Perry)

Reactor Building Operations

K. L. Barclay
R. G. Burnley
H. H. Gooch
S. J. Smith

Planning & Scheduling Activities

M. H. Fish
S. L. Fraley

Special Study Areas

F. R. Fahland
J. F. Walters

Office & Video Assistance

J. C. Stratton
E. P. Ashwell
C. W. Litchford
J. R. Pugh

TV Coverage & Recording

P. J. Abbott
L. N. Mace

REFUELING SCHEDULES

Based on the DOE-Sponsored Reactor Availability Study

Notes for SCHEDULED

1. Pre-outage schedule is estimated ANO Unit 1 schedule for outage prior to shutdown.

2. SCHEDULED does not reflect refueling critical path (replacement of plant station computer was the scheduled critical path item). Time lapses between procedures are indicated with dashed lines and were used to schedule maintenance tasks other than critical path items.

Notes for AS-BUILT

1. AS-BUILT schedule is official ANO Unit 1 schedule as it actually occurred for the refueling outage.

Notes for TYPICAL

1. This schedule is an estimate by the DOE team of what should have occurred at ANO 1 if delays were deleted from the AS-BUILT schedule and the following assumptions were made:

   a. Activities performed by the Operations group conducted 24 hours/day, 7 days/week.

   b. Critical path activities performed by the Maintenance group conducted on two 10-hour shifts/day, 6 days/week; shifts run from 0700 to 1700 and 1600 to 0200.

   c. Equilibrium refueling cycle.

   d. Time after the 20-hour work day by Maintenance personnel can be used for HP surveys, radiography, etc.

   e. This schedule does not reflect standby work performed as necessary by maintenance on Sundays to prevent schedule delays.

LEGEND

1. Five-hour break in maintenance activities due to shift change:

2. Sundays not worked by maintenance personnel: ////////

3. Miscellaneous activities unrelated to primary system: – – – –

Figure 2-6, Sheet 2. ANO Unit 1
Refueling Schedule

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Figure 2-6, Sheet 3, ANO Unit 1
Refueling Schedule

Figure 2-6, Sheet 4. ANO Unit 1 Refueling Schedule

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Figure 2-7, Sheet 1. ANO Unit 1 As-Built Primary Refueling Activities

ACTIVITIES	MANPOWER	RADIATION RECEIVED (MREM)	ELAPSED TIME[1] (HOURS)
1. SHUTDOWN/COOLDOWN			28[2]
2. DELAY			15
3. REMOVE MISSILE SHIELDS & GRATINGS	4	24	3
4. (OPEN EQUIPMENT HATCH)	3	0	1
5. REMOVE CRD COOLING DUCTS	3	75	5
6. REMOVE CRD ELECTRIC & PI CABLES	5	50	2
7. UNCOUPLE APSR'S	5	375	5
8. INSTALL CANAL SEAL PLATE	3	255	5
9. REMOVE HEAD INSULATION	3	72	5
10. DRAIN RCS	OPERATIONS		15
11. DISCONNECT CRD COOLING WATER	3	45	3
12. DELAY (SUNDAY)			22
13. DETENSION HEAD	6	504	4
14. REMOVE 36 STUDS & PLACE IN RACK	6	468	6
15. DELAY			34
16 REMOVE TRANSFER CANAL FLANGE	3	72	3
17. INSTALL CANAL DRAIN FLANGE	3	24	1
18. CRD STATOR REPLACEMENT PROBLEM	7	1820	52
19. REMOVE OTSG MANWAYS B & A	2	300	10
20. OTSG EDDY CURRENT INSPECTION B & A	3	3110	425(129)
21.* PULL INCORES	5	315	21
22. DELAY			7
23. UNCOUPLE CRD	9	3780	48(10)
24. RIGGING & POLAR CRANE REPAIR	6	234	24(13)
25. REMOVE HEAD	6	400	2
26. INSTALL INDEX FIXTURE	3	168	5 (2)
27. CHROMATE & SEAL STUD HOLES	4	930	5
28. ESTABLISH RB INTEGRITY	OPERATIONS		37
29. FLOOD, DRAIN, FLOOD FUEL TRANSFER CANAL	12	3553	66(17)
30. REMOVE PLENUM	3	96	4
31. REMOVE INDEX FIXTURE	5	81	3
32. CHECKOUT FUEL HANDLING EQUIPMENT	5	824	41
33. DEFUEL	4	696	87
34. DRAIN FUEL TRANSFER CANAL	OPERATIONS		7
35. CLEAN CANAL WALLS & FLOOR	6	480	10
36. REPAIR CANAL SEAL PLATE	12	2448	24(12)
37. CLEAN STUDS	5	730	15
38. RETRIEVE LOOSE PARTS FROM RV	3	6216	76(56)
39. VENT VALVE INSPECTION	6	440	2
40. FILL CANAL	OPERATIONS		5
41. DELAY			5
42. REFUEL	4	1000	125
43. REMOVE DAMAGED FUEL ASSEMBLY	4	48	18
44. INSTALL OTSG MANWAYS	2	480	16
45. DELAY (SUNDAY)			28
46. FUEL VERIFICATION	2	16	4
47. DELAY			9
48. INSTALL INDEX FIXTURE	3	84	2
49. INSTALL UPPER PLENUM	3	27	3
50. DRAIN & WASHDOWN CANAL	6	1152	26(24)
51. REMOVE SEAL PLUGS & CHROMATE FROM STUD HOLES	2	810	6
52. REMOVE INDEX FIXTURE	3	420	2
53. SET HEAD	6	960	4
54. LOWER 36 STUDS AND PLACE IN HEAD	6	1920	22(8)
55. TENSION HEAD	6	1440	7(6)
56. INSERT INCORE DETECTORS	5	720	48
57. COUPLE CRD	9	2268	6
58. INSTALL HEAD INSULATION	3	72	3
59. RAISE CANAL SEAL PLATE	7	700	18(10)
60. INSTALL TRANSFER CANAL FLANGE	3	72	2
61. REMOVE CANAL DRAIN FLANGE	3	24	1
62. DELAY			7
63. INSTALL CRD COOLING DUCTS	3	75	5
64. INSTALL CRD ELECTRIC & PI CABLES	6	90	3
65. INSTALL CRD COOLING WATER PIPING	3	48	2
66. INSTALL STATORS	7	3920	70
67. FILL RCS TO COUPLE APSR'S	OPERATIONS		26
68. COUPLE APSR'S	5	900	12
69. INSTALL MISSILE SHIELD	2	16	4
70. DELAY			166
71. REMOVE EQUIPMENT FROM RB	4	32	8
72. CLOSE EQUIPMENT HATCH	2	0	3
73. REMAINING DAYS FROM DAY 54 TO 73-MAINT. ACT. & STARTUP ACTIVITIES			
74. SPENT FUEL BUILDING	3	1272	212

1 NUMBERS IN ( ) REPRESENT HOURS WORKED
2 ACTUAL SHUTDOWN/COOLDOWN STARTED ON 1/27/77
OPERATIONS - INDICATES CONTROL ROOM OPERATION

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Figure 2-7, Sheet 2. ANO Unit 1
As-Built Primary
Refueling Activities

ACTIVITIES	MANPOWER	RADIATION RECEIVED (MREM)	ELAPSED TIME[1] (HOURS)
1. SHUTDOWN/COOLDOWN			28[2]
2. DELAY			15
3. REMOVE MISSILE SHIELDS & GRATINGS	4	24	3
4. (OPEN EQUIPMENT HATCH)	3	0	1
5. REMOVE CRD COOLING DUCTS	3	75	5
6. REMOVE CRD ELECTRIC & PI CABLES	5	50	2
7. UNCOUPLE APSR'S	5	375	5
8. INSTALL CANAL SEAL PLATE	3	255	5
9. REMOVE HEAD INSULATION	3	72	5
10. DRAIN RCS	OPERATIONS		15
11. DISCONNECT CRD COOLING WATER	3	45	3
12. DELAY (SUNDAY)			22
13. DETENSION HEAD	6	504	4
14. REMOVE 36 STUDS & PLACE IN RACK	6	468	6
15. DELAY			34
16 REMOVE TRANSFER CANAL FLANGE	3	72	3
17. INSTALL CANAL DRAIN FLANGE	3	24	1
18. CRD STATOR REPLACEMENT PROBLEM	7	1820	52
19. REMOVE OTSG MANWAYS B & A	2	300	10
20. OTSG EDDY CURRENT INSPECTION B & A	3	3110	425(129)
21.* PULL INCORES	5	315	21
22. DELAY			7
23. UNCOUPLE CRD	9	3780	48(10)
24. RIGGING & POLAR CRANE REPAIR	6	234	24(13)
25. REMOVE HEAD	6	400	2
26. INSTALL INDEX FIXTURE	3	168	5 (2)
27. CHROMATE & SEAL STUD HOLES	4	930	5
28. ESTABLISH RB INTEGRITY	OPERATIONS		37
29. FLOOD, DRAIN, FLOOD FUEL TRANSFER CANAL	12	3553	66(17)
30. REMOVE PLENUM	3	96	4
31. REMOVE INDEX FIXTURE	5	81	3
32. CHECKOUT FUEL HANDLING EQUIPMENT	5	824	41
33. DEFUEL	4	696	87
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38. RETRIEVE LOOSE PARTS FROM RV	3	6216	76(56)
39. VENT VALVE INSPECTION	6	440	2
40. FILL CANAL	OPERATIONS		5
41. DELAY			5
42. REFUEL	4	1000	125
43. REMOVE DAMAGED FUEL ASSEMBLY	4	48	18
44. INSTALL OTSG MANWAYS	2	480	16
45. DELAY (SUNDAY)			28
46. FUEL VERIFICATION	2	16	4
47. DELAY			9
48. INSTALL INDEX FIXTURE	3	84	2
49. INSTALL UPPER PLENUM	3	27	3
50. DRAIN & WASHDOWN CANAL	6	1152	26(24)
51. REMOVE SEAL PLUGS & CHROMATE FROM STUD HOLES	2	810	6
52. REMOVE INDEX FIXTURE	3	420	2
53. SET HEAD	6	960	4
54. LOWER 36 STUDS AND PLACE IN HEAD	6	1920	22(8)
55. TENSION HEAD	6	1440	7(6)
56. INSERT INCORE DETECTORS	5	720	48
57. COUPLE CRD	9	2268	6
58. INSTALL HEAD INSULATION	3	72	3
59. RAISE CANAL SEAL PLATE	7	700	18(10)
60. INSTALL TRANSFER CANAL FLANGE	3	72	2
61. REMOVE CANAL DRAIN FLANGE	3	24	1
62. DELAY			7
63. INSTALL CRD COOLING DUCTS	3	75	5
64. INSTALL CRD ELECTRIC & PI CABLES	6	90	3
65. INSTALL CRD COOLING WATER PIPING	3	48	2
66. INSTALL STATORS	7	3920	70
67. FILL RCS TO COUPLE APSR'S	OPERATIONS		26
68. COUPLE APSR'S	5	900	12
69. INSTALL MISSILE SHIELD	2	16	4
70. DELAY			166
71. REMOVE EQUIPMENT FROM RB	4	32	8
72. CLOSE EQUIPMENT HATCH	2	0	3
73. REMAINING DAYS FROM DAY 54 TO 73-MAINT. ACT. & STARTUP ACTIVITIES			
74. SPENT FUEL BUILDING	3	1272	212

1 NUMBERS IN ( ) REPRESENT HOURS WORKED
2 ACTUAL SHUTDOWN/COOLDOWN STARTED ON 1/27/77
OPERATIONS - INDICATES CONTROL ROOM OPERATION

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3. BASIS FOR RECOMMENDATIONS

3.1. Introduction

In section 2 the outage data observed and compiled at both Oconee 3 and ANO 1 (Task 1) are presented. Once the raw data were assembled, the evaluation and analysis work was begun (Task 2). Each of the previously collected data sheets, video and still photographs, completed work orders, and radiation work permits was reviewed by the appropriate team members. The result was a listing of (1) specific recommendations for implementing improvements to the tooling, procedures, and techniques in the Oconee 3 and ANO 1 plants; (2) generic recommendations of immediate benefit to other B&W units; and (3) recommendations for further work in the succeeding phases of the DOE program. The recommendations cover all aspects of the primary plant work conducted during the refueling. Subsequent sections of this report contain detailed discussions concerning these recommendations and their effects on improving plant availability.

3.2. Basis for Improvements

Each of the recommendations resulting from the Task 2 work effort was evaluated to determine the benefits that could be derived if the given recommendation were implemented. Five basic factors were considered for the recommendations:

1. Time savings — the amount of time that the outage would be reduced. (If the outage time would not be reduced, this would be the time that could be saved in avoiding delays if the recommendation were incorporated.)
2. Manpower — the number of persons and manhours that could be saved.
3. Man-Rem exposure — the amount of radiation exposure that could be avoided.
4. Technical Feasibility — is the recommendation technically feasible?
5. Cost — the total cost to develop and implement the given recommendation.

3.3. Figure of Merit Evaluation

This section deals with the development of an empirical measurement for assigning priorities to implementation of recommendations. While all the recommendations will contribute to improved performance, they all do so with varying amounts of effort, cost and time.

To help determine which recommendations to follow first, it is important to select the basic elements considered in implementing a recommendation and to interpret the magnitude each element contributes to that recommendation. Six basic elements have been considered in evaluating the recommendations of the refueling outage availability study program. These are: the days saved, the total cost, the time to implement, the outage time to install, the number of nuclear plants to which it is applicable, and exposure reduction. In instances where there are no facts for the basic elements, there is either no input for that element, or reliable available information and well founded opinions must be considered.

In cases where the basic elements are available for the recommendations, a consistent evaluation method can be applied. This method has the form of a mathematical statement that produces a "figure of merit." This figure of merit can then be used to rate the recommendations. It should be noted that the figure of merit of the recommendations is an additional source of information that can be used in further decisions regarding possible implementation of the recommendations, and that it is not intended to provide a finite quantitative analysis of the relative worth of the recommendations.

The following correlation was developed to produce a figure of merit (FM) for the recommendations:

$$FM = E(8A) + 2B + 0.5C + D + F$$

where

1. Factor A — Based on the estimated time saved during the critical outage path. If the time saved is not directly related to the critical outage path, a modified FM can be calculated by using the delay avoidance time and work effort reduction times. In such cases where the modified FM is used, it is denoted as FM_D.

   Delay Avoidance — The amount of time that could be saved over the course of the outage in avoiding delays if the given recommendation were incorporated.

   Work Effort Reduction Times — The number of manhours that could be saved during the course of the outage by incorporating the given recommendation.

2. Factor B — Based on the estimated total cost of implementing the recommendation.

3. Factor C — Based on the estimated time to implement — the total time to develop the recommendation up to the point of but not including installation.

4. Factor D — Based on the estimated time to install — the time to actually install the recommendation during any plant outage.

5. Factor E — Based on the number of plants to which the recommendation would be applicable.

6. Factor F — Based on the estimated reduction of radiation exposure; if the recommendation results in an exposure reduction, factor F is added to the FM.

Table 3-1 contains the FM factors for each of the elements. Factors A and B are based on consideration of the importance of outage time savings and on the replacement energy cost of today's nuclear power plants. Factors C and D are also considered in the cost of implementing a recommendation, but they must also be considered as a part of its overall value. A value judgement was used to assign these factors based on the fact that the design and procurement work should be done during plant operations and, thus, should have only a minimal effect on the FM. The time to install during the outage is somewhat critical, but this work should not be on the critical path.

Factor E is based on the generic impact of the recommendation. If a recommendation is generic, its FM should be increased to reflect this factor. The factor is used as a multiplier for factor A to reflect the total number of outage days saved when all plants are considered. Factor F is to be added to the FM if there is a personnel radiation exposure reduction associated with the implementation of a recommendation.

Each factor of the recommendation can then be determined and used to calculate the FM. The recommendations having the higher FM value are the prime candidates for future implementation.

Time savings and FM values have been developed for most of the recommendations given in the following sections. Numbers indicated in parentheses at the end of the recommendations are judgments of the number of outage hours that could be saved by implementing the recommendation or outage time lost due to the problem for which a recommendation is made. These estimates are not cumulative in critical path times for a typical outage.

FM values are given at the right-hand margin after the recommendations and are indicated as FM-xxx when based on critical path time saved, FM_D-xxx when based on delay avoidance or work effort reduction.

The recommendations presented in the following sections are arranged and given priority in accordance with their rank (FM values).

Table 3-1. Figure of Merit Factors for DOE Recommendations

Factor A		Factor B		Factor C	
Time saved	Weighting factor	Total cost, $	Weighting factor	Time to implement	Weighting factor
5 days	10	>300,000	1	>1 yr	1
4 days	9	250,000	2	10-12 mo.	2
3 days	8	180,000	3	9-10 mo.	3
2 days	7	125,000	4	8-9 mo.	4
24 h	6	65,000	5	7-8 mo.	5
20 h	5	50,000	6	6-7 mo.	6
16 h	4	40,000	7	5-6 mo.	7
12 h	3	35,000	8	4-5 mo.	8
8 h	2	20,000	9	3-4 mo.	9
4 h	1	10,000 or less	10	<3 mo.	10

Factor D		Factor E		Factor F	
Outage time[(a)] to install, days	Weighting factor	No. of plants applicable to	Weighting factor	Exp red'n, man-Rem	Weighting factor
(b)	10	1	1	0.5	1
1-4	9	2	3	1	2
4-8	8	3	5	1.5	3
8-12	7	4	7	2	4
12-16	6	>5	10	2.5	5
16-20	5			3	6
20-24	4			3.5	7
24-28	3			4	8
28-32	2			4.5	9
>32	1			>5	10

$$FM = E(8A) + 2B + 0.5C + D + F$$

(a) Not critical path time.

(b) Can be done with no outage.

4. IMMEDIATE RECOMMENDATIONS

4.1. Procedures — Oconee 3 and ANO 1

One area in which a small investment in man-hours can help to achieve increased productivity is in the preparation and updating of work procedures. The majority of procedures in use were prepared before plant startup and often do not reflect operating experience gained by station personnel. These procedures should be upgraded to eliminate wasted time. In addition, the following factors should be considered in future work planning (4 h): FM_D-60

1. It is preferable that procedure changes other than those associated with equipment modification be initiated by maintenance personnel to reflect actual field experience. Other personnel could initiate the changes, but this could lead to misinterpretation.

2. Changes or additions to procedures should be implemented promptly in order to realize potential time savings and avoid undue delay during the outage while changes are being made. Prompt onsite review and approval would avoid outage delays.

3. Tools and parts showing serial number, size, and any other pertinent identification should be incorporated. This is to ensure that no time is lost in starting an activity without the right tool at the job site.

4. Personnel requirements, in terms of number and type of men required to do the job and estimated completion times based on actual experience, should be specified. This information will aid significantly in proper planning and scheduling of activities.

5. Where applicable, estimated radiation exposure should be included to aid in exposure planning. This is particularly important to prevent overexposure to key personnel.

Data (manhour, elapsed time, and radiation exposure) presented in this report provide historical baseline data and could be used to upgrade the existing procedures.

4.1.1. Refueling Equipment Manuals

All manuals associated with this equipment should be checked, prior to the refueling outage, against the latest revisions available from the manufacturers.

This will ensure that the latest information is available for both operations and maintenance in the event of equipment malfunction.

Updated copies of the electrical drawings should be posted inside the control console for each fuel bridge. This will provide a ready reference for both operators and maintenance personnel.

4.1.2. Work Request Forms and Outage Documentation

A study should be conducted to determine whether these forms can be standardized to improve personnel efficiency based on reducing the processing of excess paperwork.

4.2. Techniques

Improvements to techniques can provide flexibility, avoid problems, and improve quality. The following immediate-benefit recommendations are given:

4.2.1. Oconee 3

1. During the review of the pre-outage critical path schedule, it was determined that wet* (in lieu of dry) eddy-current OTSG inspection would save approximately 3.5 days of outage time. Inspection by this method was performed during the second part of the outage and was successful. This new technique requires the same amount of time but made it possible to shift this work off the critical path. Radiation exposures are not affected. (50 h) FM-95

2. When complete core unloading is necessary, the sequencing of refueling operations should be revised to allow partially burned fuel assemblies to be loaded into positions that are boxed in. This technique will provide proper alignment of partially burned fuel assemblies. (12 h) FM-59

3. At present, excessive direction is required for positioning the polar crane for routine work. Locations of all routine work such as heavy lift rigging and reactor component removal and replacement, should be checked and changed as required to properly index the polar crane. This will speed up such operations (7 h). FM-49

4. The reactor vessel head insulation storage racks should be bolted together in pairs and lowered into the fuel transfer canal. Once the insulation is placed on the racks, the racks can be lifted out of the canal. This will require only two lifts with the polar crane as opposed to the 16 now required. The process could be reversed for installation of the insulation. See Appendix C, photo 10 (4 h) FM-46

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*Wet eddy-current testing uses a probe while water remains in the OTSG tubes; dry eddy-current testing requires the water to be drained from the OTSG.

5. Efficiency in lifting operations could be improved by instructing the crane operator that, while handling "critical loads," he should increase the speed of the crane when the load is clear of obstructions (5 h). FM-43

6. The gaskets for the canal seal plates should be precut to template fit before taking the gasket down into the fuel transfer canal. This should provide a better fitting gasket and reduce the time required to install it thereby reducing personnel exposure (2 h). FM-41

7. For all small rigging equipment, tie the pins to their shackles to prevent dropping the pins into the core or off a piece of rigging, thereby losing time (3 h). FM-40

8. Every effort should be made to reduce the number of false reactor building evacuation alarms. As a rule of thumb, every false alarm results in about one hour of lost productive time for each man in the building (2 h). FM_D-39

9. Efficiency in tensioning and detensioning the reactor vessel studs could be improved by:

   a. Using three tensioners for the actual tensioning and detensioning and having a spare as backup. With three units on one site, four tensioners could be justified (8 h). FM-37

   b. Performing tensioner checkout before and after the studs have been detensioned. This effort would reduce the possibility of tensioner failure or malfunction during tensioning (12 h). FM_D-60

   c. Using two men per tensioner plus an overall coordinator. See Appendix C, photo 12.

10. When reactor building integrity is not required, consideration should be given to leaving both doors on the personnel hatch open. This would facilitate personnel entry and the movement of tools into and out of the building and decrease wear and tear on door interlocks and mechanisms (24 h). FM_D-83

11. A program should be undertaken to upgrade the reactor building elevator, including preventive maintenance and changeout of controls if necessary. The elevator is required for personnel and equipment movement during the entire outage, and it must be dependable to maintain personnel efficiency (10 h). FM_D-55

12. The underload/overload setpoints on the fuel handling equipment should be changed to agree with the latest values established by B&W. These setpoint are designed to protect the fuel assembly and still allow a tolerance band large enough to handle the assemblies efficiently. FM_D-48

13. Several temporary electrical, welding, air and water headers should be installed in the reactor building. These would eliminate many of the loose hoses and leads that are now strung all over the building during the course of an outage. In locations where there is repeated use of such equipment, permanent connections should be installed (6 h). FM_D-45

14. More preservation and cleaning work should be done on the vessel stud holes and threads to prevent corrosion and deterioration later in the life of the plant, which could cause maintenance problems. FM_D-43

4.2.2. ANO 1

1. Wet rather than dry eddy-current testing of OTSG tubes has been accomplished successfully during the outage. This new technique made it possible to shift this work off the critical path; therefore, it is recommended for future refueling outages (50 h). FM-95

2. A review/revision of the ANO 1 FSAR and Administrative Procedures should be conducted prior to the next outage. A comparison review of pertinent requirements from similar plants would be helpful in this endeavor. The following requirements need to be modified to reduce unnecessary time loss and personnel exposure:

   a. Remove and install the plenum assembly with the fuel transfer canal dry. This procedure has been performed on some plants and has produced no excessive exposures during plenum movement. The primary reason for dry plenum removal is to reduce exposure during RV head stud hole work and RV flange work (12 h). FM-59

   b. Access limitations during fuel handling should be changed to allow as many people as necessary to support other activities in the reactor building (5 h). FM_D-45

3. The AP&L method of placing the reactor vessel head insulation storage racks in the canal and placing the insulation on the racks for moving to their storage area is an improvement over the method used at Oconee 3. A further improvement would be to bolt the racks together and lift them in pairs. This would save time and cut down on crane usage (2 h). FM-42

4. The equipment loading hatch final closure and subsequent leak tests were delayed for two shifts due to a faulty gasket on the hatch. Consideration should be give to routine replacement of the gasket with each outage (20 h). FM_D-75

5. Preventive maintenance on such reactor building equipment as the elevator, cranes, and fuel handling equipment should be more extensive and strictly adhered to; these components are vital to the overall outage effort. Limit switches, relays, and other items with a high probability of failure should be replaced regularly at the beginning of each outage (20 h). FM_D-73

6. Tasks that must be performed in areas of high-level radiation should be set up to require a dry run (away from "hot" equipment) before starting the task. Such tasks must be performed as quickly as possible to reduce unnecessary radiation exposure. Dry runs will also be beneficial as a learning experience for new personnel and will bring up questions that may be answered prior to starting the job. FM_D-40

7. A means for locking the index fixture lifting pendants to the tripod should be investigated to prevent inadvertent dropping of the pendants while they are hanging from the polar crane. FM_D-39

4.3. Tooling and Parts

4.3.1. Oconee 3

1. All routine procedures performed during a refueling outage should be evaluated to determine the tools required for each job. The various tool boxes should then be inventoried to ensure that all the required tools will be available for the next outage. The proper tools should be used for each job; i.e., a crescent wrench should not be used when a socket wrench is the proper tool.

   A system should be established for the identification of tools so that they can be rapidly located in their storage locations (20 h). FM_D-76

2. Movement of tooling and parts necessary to perform some outage operations was complicated by the need to pack various tools for transportation to Warehouse No. 4 and the reverse — unpacking the same equipment. It is suggested that a controlled-area warehouse for tools needed during the outage be located within the security fence area. Tools should be packaged in appropriate sealed chests or boxes instead of the present bagging process; an inventory list should be attached to the outside of each chest. The chests themselves may be regarded as adequate containers for tools, and with environmental controls in the warehouse, there should be little concern for potential radioactivity spread (20 h). FM_D-75

3. Spare parts for new components should be ordered at the same time the component is ordered. Because of the long lead time required for most spare parts, such a procedure would ensure that (a) spares would be available when needed, and (b) the required QA documentation would be enclosed with the part and not by separate letter. At present, too many parts arrive without the required documentation and are placed on "QA hold" until the paperwork arrives. If the documents were package with the part, this problem would be eliminated (12 h). FM_D-55

4. Staging areas should be set up in the reactor building for tools and equipment no longer needed in the reactor building. This would allow for periodic removal of nonessential tools during the outage. This would result in better tool control and reduce the amount of contamination the equipment picks up during the outage. Tools and equipment placed in these areas could be moved out of the building, cleaned up as required, and made ready for reissue. In conjunction with the staging areas, a tool room should be set up in the reactor building during the outage. Tools would be issued from this room and returned after the completion of the work effort. This will provide better tool availability. FM_D-40

4.3.2. ANO 1

1. All routine procedures performed during a refueling outage should be evaluated to determine the tools required for each job. The various tool boxes should then be inventoried to ensure that all the required tools will be available for the next outage. The proper tools should be used for each job; i.e., a crescent wrench should not be used when a socket wrench is the proper tool.

A system should be established for the identification of tools so that they can be rapidly located in their storage locations (20 h). FM_D-76

2. Power equipment such as drills, sanders, vacuum cleaners, etc. should be operationally checked before being taken to a site. At least one hour is lost each time work is stopped to obtain a replacement for a broken tool (10 h). FM_D-56

3. Future pre-outage planning should show a greater effort toward acquiring spare parts. Jobs should not be delayed or cancelled due to inavailability of parts. Expediting of spare part orders in depth should begin 6 months ahead of the refueling outage (8 h). FM_D-51

4. The lack of adequate spare parts for each job is a problem. ANO is now computerizing its spare parts inventory; this will help considerably in reducing outage time if used in conjunction with a parts requirement list for each job. Increased emphasis should be placed on completing this task before the next outage (10 h). FM_D-44

4.4. Outage Management and Scheduling

4.4.1. Oconee 3

1. Closer coordination of the work going on in the reactor building is desirable, provided a coordination base within the building can be established and continuously manned. It is suggested that PORTA offices, together with a supervisor for all reactor building operations, be utilized. This would enable crews held up on one task to proceed promptly with other alternate tasks without the delays associated with attempting to obtain outside instructions (24 h). FM_D-83

2. Both the video and the time lapse photograph portions of the DOE team observation are recommended for any utility wishing to have a record with which to train employees on procedures. Both of these products of the DOE study, if used in conjunction with mockups, should help to develop familiarity with refueling operations and to relieve the load on the supervisory staff during an outage. A comprehensive course employing this material should be given to all key personnel potentially involved in an outage just before the outage begins. Training tapes of specific procedures should be prepared on an as-required basis (24 h). FM_D-79

3. The manpower required for various work tasks during an outage should be further evaluated. This evaluation should be directed toward eliminating excess personnel so that exposure can be reduced and more work can be assigned per shift. This evaluation should include the personnel necessary to process the paper work generated during the outage. Such personnel should be programmed to work shifts with the maintenance and operations personnel. In this manner, a backlog of paper work will not accumulate during the back shifts (20 h). FM_D-76

4. An evaluation should be conducted to determine where steps could be eliminated in the administrative system to smooth the flow of information from the worker to management and back. Definite contact points (such as the coordinator's office) should be established for use by supervisory

personnel of each department, including Health Physics. Such an office would provide a place for the exchange of information away from the work area, thus allowing shop personnel to continue to work during shift changes (16 h). FM_D-67

5. The preplanning and training effort for a refueling outage should be evaluated. The more effort placed in this area the better the outage will go and the lower the personnel radiation exposure will be. The use of mock-ups and existing training aids should be evaluated to assess their role in reducing exposure and time to perform a task. The use of procedures should be stressed through proper training and job preparation (12 h). FM_D-61

6. Some reduction in outage time may be possible through the use of two 10-hours shifts and expedited completion of all activities whether or not they are on the critical path (12 h). FM_D-60

7. The arrival of construction help should be scheduled so that, on the first day of the outage, up to 250 new people do not arrive at the same time. Build up the work force on site over a couple of days. Allocate time for these persons to be trained in health physics and site orientation (12 h). FM_D-60

8. Improvements are needed in the area of health physics. The following items should be re-evaluated to determine how personnel radiation exposure could be reduced (12 h): FM_D-60

   a. Make personnel aware of the radiation levels in the area in which they are working. This can be accomplished, for example, by placing plexiglass boards in various areas of the reactor building and in the change rooms. The boards would have mockups of reactor building locations and show the expected radiation levels and any hot spots in the area.

   b. When handling core or vessel components, personnel should keep away from the components to reduce exposure. They should not climb onto the index fixture to monitor the progress of removing the plenum or core support assembly.

   c. Standardize the health physics procedures for given areas; if one person involved in a job is required to wear a mask, then all personnel in the immediate work area should wear a mask. Such standardization should reduce personnel exposure.

   d. Conduct an evaluation to determine what tasks can be performed in zones of lower radiation. For example, CRDM top closure assemblies could be cleaned off of the vessel head assembly and thereby reduce the exposure to personnel performing this task.

9. Increase the number of personnel assigned to quality control (QC) during the outage. Such an increase is required to support the outage work effort for the following reasons (12 h): FM_D-60

   a. High radiation exposure in some of the work areas.

   b. To allow time for the inspector to become familiar with all aspects of the job.

c. Training time required for QC inspectors coming in from other plants or organizations.

d. To allow relief for inspectors on the job so the work effort can be continuous.

e. To allow for changes in work items due to schedule changes that occur during the outage.

f. To allow for the proper review of maintanance procedures by the Quality Assurance organization to determine the type and extent of QC coverage required on each job.

10. Operations personnel should be trained in trouble-shooting and repairs so that they could perform minor maintenance work on the fuel handling equipment. This would allow them to keep the fuel handling equipment operational throughout a large percentage of the outage without involving the maintenance force (12 h). FM_D-60

11. The fuel transfer and spent fuel bridges should be pre-indexed to all storage racks and transfer stations; this will save time during fuel handling evolutions. The indexing can be performed off the critical path. At present, excessive time is consumed in such indexing evolutions. An alternative would be to use Duke's indexing display panel (12 h). FM_D-60

12. The outage coordinator should have a list of jobs that can be worked if openings occur in the schedule. This would require the cataloging of jobs to allow rapid evaluation of the conditions necessary to do the work as well as manpower and time requirements. Such a list can be assembled from jobs that require no refueling outage to complete and items that develop during the course of an outage but are of lower priority than critical path items (10 h). FM_D-56

13. Radiography should be scheduled for times when there is minimal activity, e.g., after the second shift or during lunch breaks. The radiography equipment should be set up during normal shift hours and the actual radiography performed when the reactor building is empty. When required, radiography should be planned as part of the work effort (10 h). FM_D-56

14. Maintenance personnel should be trained in the operation of the fuel handling equipment. This would allow them to properly trouble-shoot the equipment before performing maintenance and to check it out afterwards without involving operations personnel. Such an arrangement would reduce dependence on operations personnel and free them for other assignments.

    Personnel should be trained in the use of fuel handling equipment by actual operation of the spent fuel pool equipment. This will allow workers to become familiar with the equipment and better understand the problems of operating and maintaining it (8 h). FM_D-52

15. Management should set up several small, specialized crews of maintenance people who are assigned to various equipment items for the duration of the outage. These assignments are justified for such equipment as the fuel handling equipment and the stud tensioners. With such assignments, there would be no delay in starting repairs on the components if a

failure occurred. When not actually engaged in repair work on their assigned equipment, these teams could be assigned to other noncritical maintenance work (8 h). FM_D-50

16. Specially trained maintenance crews should be assigned to each refueling machine. This will provide a readily available maintenance force for work on these pieces of equipment. The time saved by such quick response will more than compensate for the training time spent and will avoid having these persons idle for some periods of time. They should be trained by the equipment manufacturers in the operation of the various items of fuel handling equipment (8 h). FM_D-50

17. Equipment hatch opening should be scheduled around the refueling work. This would avoid delays in the fuel handling effort which must be stopped if the equipment hatch is opened. A list of equipment to be moved in during each opening should be prepared to prevent unnecessary openings. See Appendix C, photos 74-77 (6 h). FM_D-48

18. A short training course for maintenance personnel would provide an overall concept of the working of the various systems of the plant. Such training would give maintenance personnel a better understanding of the systems and could reduce the number of errors caused by the lack of such knowledge (4 h). FM_D-44

19. A short training course for the operating personnel would provide an overall understanding of what is actually involved in the maintenance effort on various components. Such an understanding would give the operators a working knowledge so that they could better describe the problems to a maintenance man and shorten the troubleshooting and repair effort (4 h). FM_D-44

20. Excess welding leads should be removed from work areas. This will remove a potential personnel hazard as well as reduce the time required to remove them at the end of the outage. Early removal would also reduce the contamination picked up by such leads (4 h). FM_D-44

21. Many operations in the early part of the outage work were started under adverse environmental conditions for personnel to work inside the reactor building. With sufficient manpower available it is recommended that the work crews be subdivided into smaller groups with frequent rotation during periods when the RB temperature remains at a higher level (4 h). FM_D-43

22. Work crews should be rotated from one shift to the other; such a rotation could be done over the Sunday when no work is scheduled. This rotation would provide better overall working conditions and improve personnel efficiency (4 h). FM_D-43

23. Direct communication should be established with the polar crane operator, particularly during the course of an outage when polar crane usage is at a maximum. "Walkie talkies" should be considered; an alternative would be a telephone. The activity for the polar crane should be specified by a schedule for the duration of the outage. The reactor building coordinator should control the polar crane and adjust its schedule as conditions change (4 h). FM_D-43

24. Cleaners should be sent into the reactor building periodically during the outage to do general cleanups. Drums should be placed throughout the reactor building for general waste. These drums should be clearly marked "TRASH." This would allow the removal of a large amount of the "junk" from the building during the outage and prevents its accumulation. In addition, this would keep the reactor building cleaner and minimize the spread of contamination. FM_D-40

4.4.2. ANO

1. Management should increase their efforts to stimulate the interest of maintenance and operations personnel in the overall concept of the outage, In certain instances, communications gaps existed between maintenance and management because the individual worker felt "left out" or not-listened-to. Although these attitudes are common to some extent throughout industry and are not prevalent at AP&L, they still can cause problems. For example, during the handling of the missile shields, it was noted by the operator that the polar crane was not functioning properly. This problem was not noted or resolved until breakdown occurred during reactor vessel head removal. Management should try to impress on all individual laborers that management is always interested in what they have to say (48 h). FM_D-91

2. Overall outage time may be reduced by increasing the efficiency of maintenance and operation personnel in operating refueling equipment. A possible aid here would be an extensive audio/visual training program utilizing as many training aids as possible. This type of program could also cross-train personnel in the troubleshooting of equipment and reduce overall repair time if breakdown occurs (30 h). FM_D-86

3. Consideration should be given to more extensive training programs for maintenance and operations personnel. This training should begin several months before the planned outage and continue through the outage where time is available. Video/audio training aids and mockups of the actual components should be used whenever possible. Component disassembly and assembly, including filling and venting procedures, should be covered during this training (24 h). FM_D-86

4. At the end of and during the early stages of each outage, an effort should be made to reduce levels of contamination in the reactor building, especially in areas that might be highly contaminated from pump seal or valve packing leakage. This was done at ANO, resulting in time savings of up to 20 hours during the course of the outage from the extra time that would otherwise be spent to dress out in additional anti-C clothing and respirators and reduced personnel efficiency (20 h). FM_D-77

5. The placement of 55-gallon drums with poly-bag liners on each level of the reactor building and near the elevator doors and stairway landings will help to reduce the amount of debris and refuse left at work sites. Site cleanup after the work is finished should be made mandatory by the work permit (20 h). FM_D-77

6. During the initial part of the outage, it was noted that there was a lack of good information feedback to the planner. This was causing problems since delays were not being readily identified so that plans could be

made to avoid those delays. This was recognized by the outage coordinator and corrected. The status meetings were improved by making the coordinators realize that they must be aware of the activities they are coordinating. It is recommended that all planning and status meetings be held in the plan-a-log room. This would aid each supervisor to coordinate his group's effort with others' and to increase supervisor familiarization with the plan-a-log (20 h). FM_D-75

7. The most efficient utilization of the plan-a-log can be derived from around-the-clock updating. If any time work is in progress, the plan-a-log should be in the process of continuous update (20 h). FM_D-75

8. Lack of manpower, on both the supervisory and technical labor levels, is a recurring problem. Additional manpower for work in radiation areas will relieve the supervisory and maintenance load on key AP&L personnel and allow for the parallel scheduling of more maintenance items. An example would be simultaneous fuel shuffle, reactor vessel head work, and OTSG inspection (16 h). FM_D-68

9. Since the reactor building is very compact and storage space is at a premium, the following recommendations are made to use available space more efficiently:

   a. There appeared to be considerable unnecessary material and tools lying about in the building. These should be removed and disposed of appropriately or stored.

   b. The top level of the secondary shield walls has grating that is stored on top of the missile shield blocks. A further study should be made to determine whether some of the grating can be replaced and this space used for storage (8 h). FM_D-60

10. A possible aid to the planner and to the overall outage effort would be to assign a full-time coordinator in the reactor building to expedite the work effort inside the reactor building to prevent possible delays. Such a coordinator would also provide a rapid source of feedback to the planner. A similar position could be created on the turbine work for future outages (10 h). FM_D-56

11. Job scheduling has caused some problems in the area of work coordination. Each supervisor entering the reactor building with a work crew should be provided with at least one alternate job. In this way, if work is held up on the original job, the alternate job could be worked on to prevent the time loss and additional exposure to work crews who may be forced to stand and wait while other work is in progress (10 h). FM_D-56

12. Cross-training of maintenance and operations personnel in the operation and troubleshooting of pertinent test equipment items and specialized tools will improve overall maintenance and testing of equipment. Operating personnel will be capable of troubleshooting their own equipment, which will speed up the process of repair and reduce overall outage time (10 h). FM_D-56

13. In several instances during the outage, personnel were not able to enter the reactor building due to a lack of anticontamination clothing. The supply of anti-"C" clothing should be increased by purchasing additional quantities and increasing the capacity of the laundry facility. Increased use of disposable clothing may also help to eliminate this problem (10 h). FM_D-55

14. Increased effort should be made to ensure that the work performed in high-radiation areas is kept to a minimum. Any job that can be moved to an area of lower radiation levels should be moved. The few hours lost due to moving jobs will be more than compensated for by the reduced exposure to personnel. As an example, the containment for OTSG inspection was constructed in the area of the OTSG. The tent could have been constructed outside the reactor building and transported to the OTSG for assembly (8 h). FM_D-55

4.5. Generic Improvements

The following recommendations to reduce outage time are made for other utilities supplied by B&W based on observations of equipment and/or procedures at Oconee 3 and ANO:

1. Perform wet eddy-current testing on the OTSG in lieu of the dry method. See 4.2.1-1 and 4.2.2-1 (50 h). FM-635

2. Remove and install the plenum assembly with the fuel transfer canal dry. See 4.2.2-2a (12 h). FM-275

3. Consider fuel shuffle schemes to load fuel assemblies into positions that are boxed in. See 4.2.1-2 (12 h). FM-275

4. Improve reactor vessel head insulation storage operations by lowering paired storage racks into the FTC. See 4.2.1-4 and 4.2.2-3 (4 h). FM-118

5. When using the latch boxes for reactor vessel internal lifts, start with the boxes in the latched position. The boxes will automatically unlatch and latch as they are lowered over the lifting lug. Using this method will eliminate the requirement to latch the boxes with long-handled tools and thereby reduce outage time. In addition, attach ropes to the latching mechanism so that the boxes can be unlatched without using long-handled tools (4 h). FM-117

6. The canal seal plate gasket should be precut prior to taking into the FTC. See 4.2.1-6 (2 h). FM-77

7. Train operations personnel in minor troubleshooting and repairs. See 4.4.1-10, -19, 4.4.2-2, -3, -12 (30 h). FM_D-536

8. Train maintenance personnel in the operation of equipment. (See 4.4.1-14, -18, 4.4.2-2, -3, -12 (30 h). FM_D-536

9. Consideration should be given to keeping both personnel hatches open when reactor building integrity is not required. See 4.2.1-10 (24 h). FM_D-515

10. Increase efforts to reduce the level of contamination in the building. See 4.4.1-24 and 4.4.2-4, -5 (20 h). FM_D-437

11. Conduct an evaluation of the tools needed for each job. See 4.3.1-1 (20 h). FM_D-436

12. Provide further coordination and planning of activities and manpower requirements. See 4.4.1-3, -7, -12 (20 h). FM_D-436

13. Perform routine replacement of the equipment hatch gasket. See 4.2.2-4 (20 h). FM_D-435

14. Performance of preventive maintenance on facilities, such as the reactor building elevator and cranes. See 4.2.1-11 and 4.2.2-5 (20 h). FM_D-433

15. Schedule radiography for times when there is minimal activity. See 4.4.1-13 (10 h). FM_D-236

16. Perform equipment checkout prior to taking it into the reactor building. See 4.3.2-2 (10 h). FM_D-236

17. All maintenance personnel — such as mechanical, electric, electronic, health physics, and quality control technicians — need a means of identification while wearing anti-"C" clothing. A color-coded piece of tape placed on the coverall would provide this. An additional piece of colored tape adjacent to the color-coded tape would identify supervisors. Being able to identify the various people from a distance would eliminate the confusion and associated time loss incurred when job coordination is necessary. This is especially true when large numbers of non-site personnel are working in the reactor building (10 h). FM_D-235

18. Provide for spare parts availability at the beginning of the outage. See 4.3.1-3 (12 h). FM_D-235

19. Set up specialized maintenance crews for critical equipment. See 4.4.1-16 (8 h). FM_D-194

20. Stud hole seal plugs should be installed after the head has been removed. This procedure can result in a savings of 4 to 6 hours and reduces the chances of damaged stud holes and seal plugs. After the head is lifted and the index fixture is installed, the stud hole plugs can be manually installed with minimal chance of dropping equipment or tools into the reactor (6 h). FM_D-157

21. The fuel handling equipment overload and underload setpoints should be updated. See 4.2.1-12 (6 h). FM_D-156

22. Procedures should be reviewed and updated prior to the outage. See 4.1 (4 h). FM_D-116

5. STATE-OF-THE-ART RETROFIT RECOMMENDATIONS

5.1. Oconee 3 Modifications

1. Include allowances for fuel assembly growth when setting the limits for grappling and ungrappling. This will reduce the number of delays due to height adjustments for grappling of fuel assemblies (6 h). FM-48

2. Upgrade the air conditioning unit in the polar crane. Because of its location and impact on the outage schedule, the polar crane must remain operational throughout the outage. It can become the critical path item at the start of an outage if the crane operators have to take repeated heat breaks (5 h). FM-46

3. Widen the tolerance band on the Z tape readings to allow for fuel assembly growth and manufacturing tolerances. This will reduce delays due to readings outside the tolerance range due to fuel assembly growth (4 h). FM-44

4. Label all rigging equipment boldly so that components can be properly aligned with the minimum amount of effort and wasted time. Present markings should be removed and a uniform system established to ensure that all markings are clearly visible and properly placed (4 h). FM-44

5. One of the underwater light brackets should be relocated to prevent its interference with raising and lowering the canal seal plate. This will speed installation and removal of the seal plate and eliminate the problem of removing and reinstalling the light twice during the outage (3 h). FM-41

6. The speed of the stud handling tool should be increased. The gear ratio should be changed to allow faster withdrawal of studs; this will speed up stud removal and parking thus reducing critical path time and radiation exposure. See Appendix C, photo 73 (3 h). FM-40

7. Efficiency in rigging and lifting operations could be improved by the following:

    a. Ream out the guide stud bushings on the indexing fixtures. This should prevent binding of the indexing fixture to the guide studs (2 h). FM-40

    b. Install permanent ladders and platforms to allow access to rigging storage stands. See Appendix C, photo 18 (2 h). FM-39

    c. Install small jib cranes to handle the fuel transfer tube covers; this will free the polar crane for other procedures. The covers themselves could be left in the canal during refueling. This would reduce the time for completion of this procedure (3 h). FM-38

d. Conduct an evaluation to determine whether the indexing fixture and plenum can be stored together. This would reduce the number of lifts and reduce the time required for the polar crane (2 h). FM-37

e. Install a jib crane for handling the reactor vessel studs during the cleaning process (4 h). FM_D-44

f. Relocate the structural steel interfering with the indexing of the polar crane when lifting and installing the shield block near the equipment hatch. At present, the structural steel is placed so that one block cannot be lifted by the polar crane, thus requiring considerable manpower to properly position or remove the blocks in this area. Alternate methods would be (1) to permanently remove the shield block or (2) to repour the concrete and reorient the two shield blocks so that their centers are accessible by the polar crane for lifting (2 h). FM_D-36

8. Improve efficiency in tensioning and detensioning the reactor vessel head studs by the following (4 h): FM-40

   a. Shorten the chains used to raise and lower the tensioners so that they no longer interfere with positioning the tensioner over a stud.

   b. Develop an air operator for positioning the trolley for the tensioners. This would give the tensioner operator better positioning control and could reduce manpower requirements.

9. Store the tripod and lifting link on the same side of the fuel transfer canal to reduce the time required for rigging the tripod. In addition, the storage area for the lifting link should be upgraded. At present, the link is stored so that the personnel installing the link on the polar crane cannot properly align the components without much effort and wasted time. Storage racks should be designed to allow access and proper alignment without manhandling the various pieces of equipment. See Appendix C, photos 17 and 18 (3 h). FM-40

10. If available, use high-volume, low-pressure injection pumps to drain the fuel transfer canal. This will shorten the time needed to drain the canal and directly reduce the time of the outage (7 h). FM-29

11. Approximately two days of outage time was attributed to the lack of adequate feedwater during restart. With multiple units at the Oconee Nuclear Station, it is recommended that at least a one-unit supply of condensate from the storage tanks should be available. FM_D-91

12. Provide more room for change facilities. A temporary trailer outside the equipment hatch might be used to help speed the flow of personnel into and out of the reactor building. At present, there is a large backlog of personnel in the change room and personnel hatch areas; time spent in these areas is lost productive time and should be reduced to a minimum. More locker space is needed for the large number of persons assigned during the outage (12 h). FM_D-60

13. Many operations inside the reactor building in the early part of the outage were started under adverse environmental working conditions. The DOE team's suggestions include the following (16 h): FM_D-56

a. Investigate means to vent the containment while the equipment hatch is open.

b. Utilize local area coolers where and when local work areas can be cooled by refrigeration units while the building temperature remains at a higher level.

c. Determine means to reduce heat losses from the reactor coolant system.

14. Evaluations should be made to determine where air-driven and/or electrically driven wrenches and gang wrenches can be used to reduce the time required to remove bolts from components. Such wrenches should only be used where torque wrenches are not required. However, air-driven wrenches can be used to "snug up" bolts and to drive off nuts in applications where torque wrenches are required. Some jobs may allow the use of adjustable-torque air wrenches (12 h). FM_D-56

15. Investigate ways to improve CRD venting provisions. The combination of too few spare tools for this operation and inexperienced crews led to approximately 8 hours' delay. It is understood that this is normally accomplished within 4 hours; thus, some investigation should be made in this area to avoid repeated delays (8 h). FM_D-52

16. Ensure that there are an adequate number of telephones in the reactor building, at the proper locations, to allow personnel to communicate with personnel outside the building. This will reduce the delays caused by personnel waiting to contact the various shops or other areas (6 h). FM_D-47

17. Provide temporary lighting in maintenance areas such as reactor coolant pump seal cavities, eddy-current test control areas, and areas where valves are being repacked. Better lighting will improve personnel efficiency and reduce the time required to complete some procedures. Portable floodlights should be installed in the fuel transfer canal (6 h). FM_D-47

18. Rework the steam generator closure studs to provide larger wrench flats. This would facilitate removal and avoid potential damage to the studs. Using the jam-nut approach can damage threads (2 h). FM_D-42

19. Consider extending the FTC auxiliary crane to the equipment hatch area to relieve the small lift load on the polar crane. Interference with the reactor vessel head lift would also have to be considered. See Appendix C, photo 17 (10 h). FM_D-42

20. Install a large-face clock on some structure in the reactor building. This is a convenience item for the personnel working in the building.

5.2. ANO 1 Modifications

1. Tool storage for both contaminated tools and stockroom supply is generally located outside the reactor building. Due to access restrictions, considerable time is often lost as workmen suit out, procure tools (and

usually take a break), and suit in again. To avoid this bother, workmen will too often use whatever tool is available within the reactor building. This leads to "scrounging" of untended tools in other work areas. The use of makeshift tools such as crescent wrenches, hammers, screwdriver chisels, and channel lock torque wrenches leads to poor productivity and equipment damage. A tool issue room should be added in the reactor building (20 h). FM-75

2. Upgrade and recertify the lifting capability of the polar crane so that the head and all studs may be lifted as one unit. This will save time through reduced work requirements (10 h). FM-44

3. The speed of the stud handling tool should be increased. The gear ratio should be changed to allow faster withdrawal of studs. This will speed up stud removal and parking (3 h). FM-40

4. The placement of an extra building adjacent to the reactor building equipment hatch should be considered. This structure could be of either permanent or temporary construction and would provide the following advantages (36 h): FM_D-94

   a. A contained work area for assembly/disassembly of large components.

   b. A storage area for clean or contaminated parts and special tools.

   c. An auxiliary change out area for shift changes or special conditions where a large number of persons are entering or leaving the reactor building.

5. Such areas as reactor coolant system piping, the reactor coolant pump cavity, D-rings, etc., should have additional catwalks and platforms. The installations could be permanent or temporary (installed at the beginning of each outage). Many jobs, such as piping and component inspections, are held up or slowed down while crews await for arrangements to be made for access to individual components (4 h). FM_D-72

6. Many operations inside the reactor building in the early part of the outage were started under adverse environmental working conditions. The DOE team's suggestions include the following (16 h): FM_D-56

   a. Utilize local area coolers where and when local work areas can be cooled by refrigeration units while the building temperature remains at a higher level.

   b. Determine means to reduce heat losses from the reactor coolant system.

7. Determine where air-driven or electrical wrenches, hoists, and tools may be used in place of hand-operated equipment. Such areas as those around RC pump cavities, reactor vessel head insulation, reactor vessel seal plate, and the equipment loading hatch could have permanently installed air and electrical connections to facilitate rapid hookup and use of power-driven tools (12 h). FM_D-56

8. Additional support facilities are needed in the reactor building; such facilities as air, water, and electrical outlets are generally in short supply. The maze of air lines, water hoses, and extension cords is not only confusing but hazardous to personnel. Some of the areas where air-driven or electrical wrenches, hoists, and tools could be used are reactor coolant pump cavities, reactor vessel head insulation, reactor vessel seal plate, CRDM closure heads, fuel transfer tube covers, and the equipment loading hatch. Furthermore, maps should be posted showing the outlet locations on each level (6 h). FM_D-48

9. Provide temporary lighting in maintenance areas such as reactor coolant pump seal cavities, eddy-current test control areas, and areas where valves are being repacked. Better lighting will improve personnel efficiency and reduce the time required to complete some procedures. Portable floodlights should be installed in the fuel transfer canal (6 h). FM_D-47

5.3. Generic Existing Plant Modifications

The following recommendations to reduce outage time are given to other utilities supplied by B&W based on observations of equipment and/or procedures at Oconee 3 and ANO 1:

1. Add a tool issue room in the reactor building. See 5.2-1 (20 h). FM-435

2. Use air motors to operate the mechanism of the engaging nut on the stud tensioners. Such motors speed the operations of the tensioner and increase operator efficiency (12 h). FM-271

3. Build a catwalk around the top of the tripod used to lift the reactor vessel head and internals. Such a catwalk will allow direct access for personnel to connect the tripod to the polar crane and thus reduce the time required for this procedure (3 h). FM-96

4. Increase the speed of the stud handling tool. See 5.1-6 (3 h). FM-94

5. Use a "hydrolazer" or similar high-pressure spray for decontamination of the fuel transfer canal; this will provide a cleaner pool in less time. Take care to use such equipment properly to prevent the spread of contamination (20 h). FM_D-436

6. Add an extra building adjacent to the reactor building equipment hatch. See 5.2-4 (36 h). FM_D-634

7. Use local area coolers and venting provisions to reduce the reactor building temperature. See 5.1-13 (16 h). FM_D-344

8. Use air/electric wrenches, equipment, and hoists whenever possible. See 5.1-14 and 5.2-7 (12 h). FM_D-272

9. Duke Power Company has several other features that are recommended to other utilities, including the following:

   a. The use of jib cranes to relieve the work load on the polar crane.

   b. The use of auxiliary cranes over the fuel transfer canal and reactor coolant pumps.

   Such cranes allow work in these areas to be performed without depending on the polar crane (10 h). FM_D-269

10. Each site should develop a stud cleaning tool that can be used for the reactor vessel head studs. Such a tool should be motor-operated (air or electric) to brush the stud clean in the minimum amount of time. Duke Power has such a tool, which speeds the cleaning of the studs and does a better job than hand cleaning (6 h). FM_D-159

11. Provide additional support facilities in the reactor building. See 5.2-8 (6 h). FM_D-156

12. Drive the CRDMs after uncoupling to expedite the lead screw withdrawal process when using the alternate uncoupling tool. Some Units are equipped with tooling and mechanisms to allow the CRDMs to be driven after uncoupling. This procedure should be used, if available, to reduce the time required for this process. This will reduce personnel exposure and shorten the time for the procedure (6 h). FM_D-158

13. Use temporary lighting in maintenance areas. See 5.1-17 (6 h). FM_D-155

14. An air tool has been designed to permit alternate uncoupling of CRDMs without relying on an overhead crane for suspension. This tool should be used at all sites for uncoupling; it eliminates the need for a crane operator and permits multiple uncoupling operations, thus reducing outage time (6 h). FM_D-153

15. The holding rod used by Duke Power Company to hold the withdrawn incore detectors is an improvement over the original design, and other utilities should contact Duke to upgrade their designs. FM_D-76

6. RETROFIT RECOMMENDATIONS REQUIRING EQUIPMENT DEVELOPMENT

6.1. Oconee 3 Modifications

1. One of the critical refueling operations is the removal and replacement of fuel assemblies by the fuel handling equipment operator. Studies have shown that present handling operations are often hampered by poor water clarity. It is recommended that a pump filter design be implemented and demonstrated that will improve the water clarity in the fuel transfer canal during refueling operations. Improved water clarity will increase efficiency in the fuel handling operations by improving operator visibility, thus reducing the outage duration (24 h). See Figure 6-1. FM-67

2. A significant reduction in critical fuel loading time is possible if the existing fuel handling mast on the fuel handling bridge is replaced with a newly designed multiple-function mast. An effort, consisting of a design review, work planning, field package preparation, order placement, field implementation (with the aid of an outside consultant), field tests, and final demonstration and evaluation should be pursued to reduce the time for handling control components, reduce the number of parts, simplify operation and maintenance, and improve accessibility for installation of optional equipment. See Figures 6-2 and 6-3 (20 h). FM-53

3. The data gathering, analysis, and assessment associated with fuel assembly behavior and distortion should be undertaken together with the development of matching fuel handling equipment features (20 h). The following specific items should be studied: FM-50

   a. Establish optimum values for operating fuel handling setpoints.

   b. Establish margin limits for grappling and ungrappling to include allowances for fuel assembly growth.

   c. Study fuel handling grapple position indication lights, especially the TUBE DOWN light.

   d. Add stepping motors controlled by a jog switch to move the bridge or trolley in 1/16-inch increments.

   e. Improve identification of electrical connections and wiring.

4. The existing stud handling tools should be evaluated and modified with the goal of obtaining more rapid operation. Modifications to the air supply system, increasing the hoist speed, and providing motorized trolleys should be considered (8 h). FM-45

5. Some means to remove the head insulation in two halves should be developed together with means for quick coupling and uncoupling of the two halves installed on the reactor vessel head. The benefit would be to reduce operations associated with insulation removal and replacement. See Figure 6-4 (8 h). FM -38

6. Four facets of the heavy lifting equipment used during critical path refueling operations should be reviewed and modifications made to improve handling operations. See Figures 6-5 through 6-10 (12 h): FM -37

   a. Tripod handling assembly.

   b. Indexing fixture lifting arrangement.

   c. Lifting knob assembly.

   d. Reactor vessel head handling.

7. The implementation of an underwater TV system to aid the operator on the fuel handling bridge would significantly reduce time spent on properly positioning, identifying, and inspecting fuel assemblies and control components in the reactor core region and the upender during refueling and defueling. This task should include engineering, design (telescoping mast and TV attachment), drafting, procurement of component parts, field installation, and demonstration of outage time savings. See Figures 6-11 and 6-12 (4 h). FM -36

8. Refueling outage critical path operations could potentially be reduced by replacing the existing canal sealing arrangement with an inflatable seal plate concept. A thorough review of all existing data, design, feasibility demonstration, mockup tests, and implementation and demonstration of a revised seal plate should be made. See Figure 6-13 (8 h). FM -30

9. An important consideration in reducing annual outage time and thus increasing plant power generation availability is the need for a management tool to coordinate and display the planning, scheduling, and management functions during the outage. A computerized planning, scheduling, and management program (utilizing a time-sharing principle) that could be used by any utility to efficiently plan and conduct the refueling outage should be developed to enable such inputs as work orders, station modifications, manpower requirements, Technical Specification requirements, job requirements, and schedule requirements, to be computerized with continuous status displayed on cathode ray tube units as well as printed hard copy reports and hard copy schedule plots. See Figures 6-14 and 6-15 (72 h). FM_D-78

10. A continuous work task should be undertaken to accomplish preliminary design work for improvements not specifically described in this section. Some areas for consideration include the following: FM_D-70

    a. Eliminate the internals indexing fixture.

    b. Combine the head and plenum lift.

    c. Revise CRD service connections and disconnection.

    d. Improved steam generator tube inspection techniques.

e. A high-flow-capacity submerged filtration system for refueling water cleanup.

f. Permanently installed canal seal plate.

g. Re-assess the advantages of a multi-stud tensioning/detensioning machine.

11. Many of the tooling items associated with removal and replacement of the existing reactor coolant pump shaft seal can be eliminated through redesign. The pump removal tooling should be redesigned to reduce the outage time involved with removing and reinserting the seals. See Figure 6-16 (10 h). FM_D-41

12. Six areas have a potential for reducing CRDM service time by design changes (13 h): FM_D-38

a. An alternate method of securing square head screws.

b. Alternate seals to replace present metal O-rings.

c. A tool for simultaneously loosening or tightening the CRDM housing (nut) closure studs.

d. A hoist system to eliminate the need for the polar crane during maintenance.

e. An improved lead screw withdrawal tool.

f. An improved uncoupling tool.

See Figures 6-17 through 6-21. Design and shop fabrication, field checkout, installation and testing and evaluation should be performed on these items.

13. Redesign efforts should be made to modify the existing CRDM service structure to incorporate eight access doors in the lower shell region. In the present design, repair, servicing, or inspection of the drive mechanisms and drive nozzles requires that access to the lower region of the drives be gained by removing one or more of the cooling fans and entering the structure through the fan holes in the service structure wall. See Figures 6-22 and 6-23 (8 h). FM_D-38

6.2. ANO 1 Modifications

1. A significant reduction in critical fuel loading time would be possible if the existing fuel handling mast on the auxiliary bridge were replaced with a newly designed multiple-function mast. An effort, consisting of a design review, work planning, field package preparation, order placement, field implementation (with the aid of an outside consultant), field tests, and final demonstration and evaluation should be pursued to reduce the time for handling control components, reduce the number of parts, simplify operation and maintenance, and improve accessibility for installation of optional equipment. See Figures 6-2 and 6-3 (20 h). FM -53

2. Incorporate a finger system on the mast that would move all fuel assemblies adjacent to the assembly to be lifted and push them slightly to the side during grappling and insertion operations (8 h). FM-50

3. Storage racks and wall-mounted hangers for rigging used for reactor vessel head and internals handling should be installed. This will reduce the time required to hook up rigging and prevent damage that might occur if rigging equipment were left lying on the floor. In addition, permanent ladders and platforms should be installed to allow access to rigging storage areas or stands (4 h). FM-42

4. The plenum and index fixture should be lifted and let down together when wet handling of the plenum is required. This would require modifications to the tripod and index fixture. The change would reduce the number of lifts and the time required for the polar crane (4 h). FM-37

5. Refueling outage critical path operations could potentially be reduced by replacing the existing canal sealing arrangement with an inflatable seal plate concept. A thorough review of all existing data, design, feasibility determination, mockup tests, and implementation and demonstration of a revised seal plate should be made. See Figure 6-13 (8 h). FM-30

6. An electric or air-driven lift should be installed for workers to enter and exit to and from the fuel transfer canal area. This will save time, reduce fatigue, and aid in preventing equipment being dropped and personal injury (4 h). FM_D-44

6.3. Generic Existing Plant Modifications

The following developmental recommendations believed to have significant benefit to the industry to reduce outage time are given to other utilities supplied by B&W based on observations of equipment and/or procedures at Oconee 3 and ANO 1:

1. Improve water clarity in the fuel transfer canal. See 6.1-1 (24 h). FM-499

2. Use a multiple-function fuel assembly mast. See 6.1-2 (20 h). FM-413

3. Perform fuel assembly mechanical assessment and equipment modifications. See 6.1-3 (20 h). FM-410

4. Modify the heavy lifting equipment to improve the handling operations. See 6.1-6 and 6.2-4 (12 h). FM-254

5. Upgrade the CRDM service and tooling equipment. See 6.1-12 (13 h). FM-254

6. Incorporate a finger system on the mast to move adjacent fuel assemblies. See 6.2-2 (8 h). FM-194

7. Improve the stud handling equipment. See 6.1-4 (8 h). FM-189

8. Replace the canal sealing arrangement with an inflatable seal plate concept. See 6.1-8 (8 h). FM-174

9. Develop new methods for removing & storing the head insulation. See 6.1-5 (8 h). FM-146

10. Use an underwater TV camera during the refueling operations. See 6.1-7 (4 h). FM-108

11. Provide for computerized outage management and scheduling assistance. See 6.1-9 (72 h). FM_D-654

12. Perform preliminary design work and feasibility evaluations for further improvements. See 6.1-10 (72 h). FM_D-646

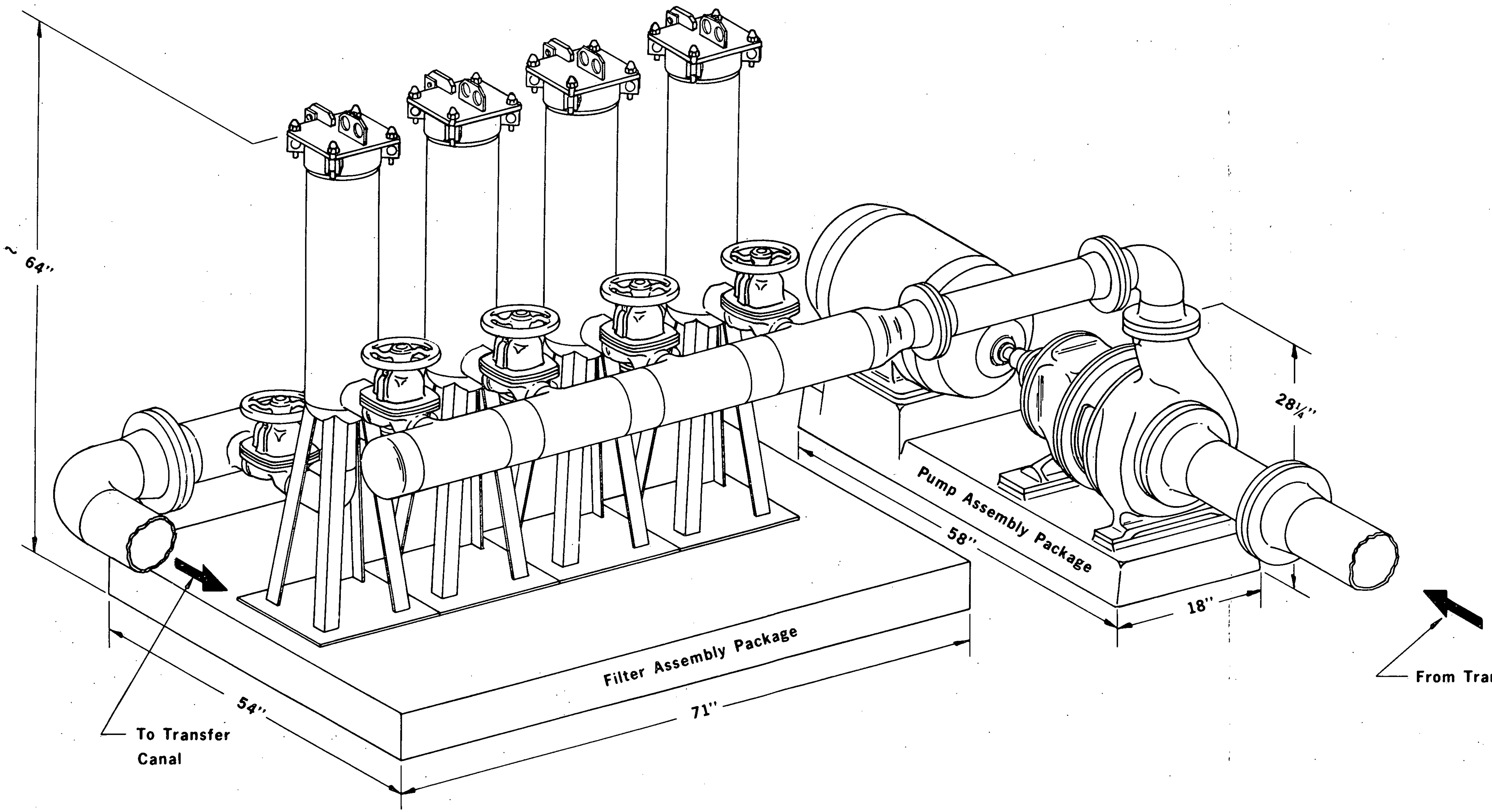
13. Modify the RCP seal maintenance tooling. See 6.1-11 (10 h). FM_D-221

14. Modify the access to the CRDM service structure. See 6.1-13 (8 h). FM_D-182

15. Install a lift to enter and exit to and from the fuel transfer canal area. See 6.2-6 (4 h). FM_D-116

16. Develop special communications devices for men wearing anti-contamination respirators. FM_D-113

Figure 6-1. Transfer Canal Cleanup System



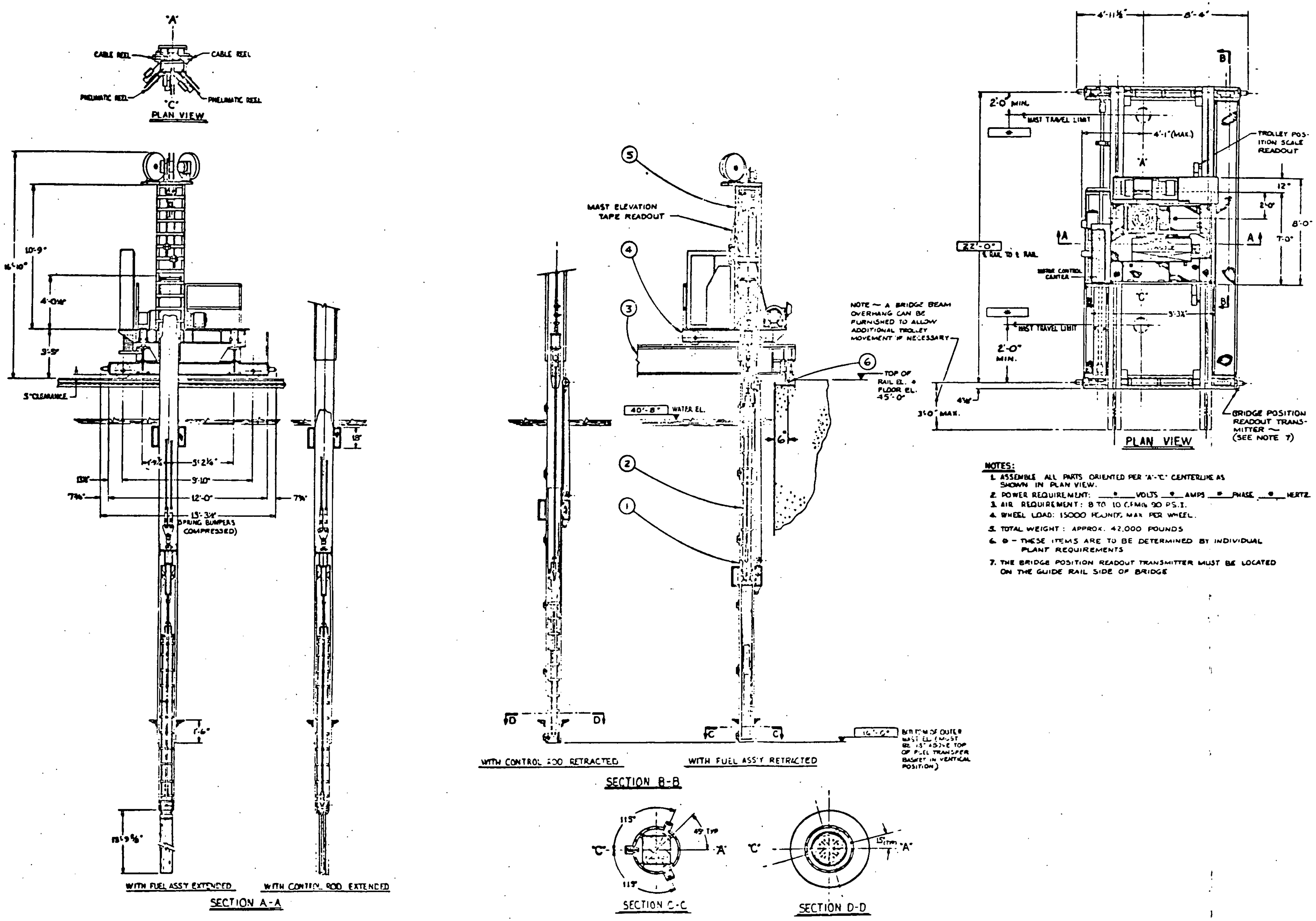
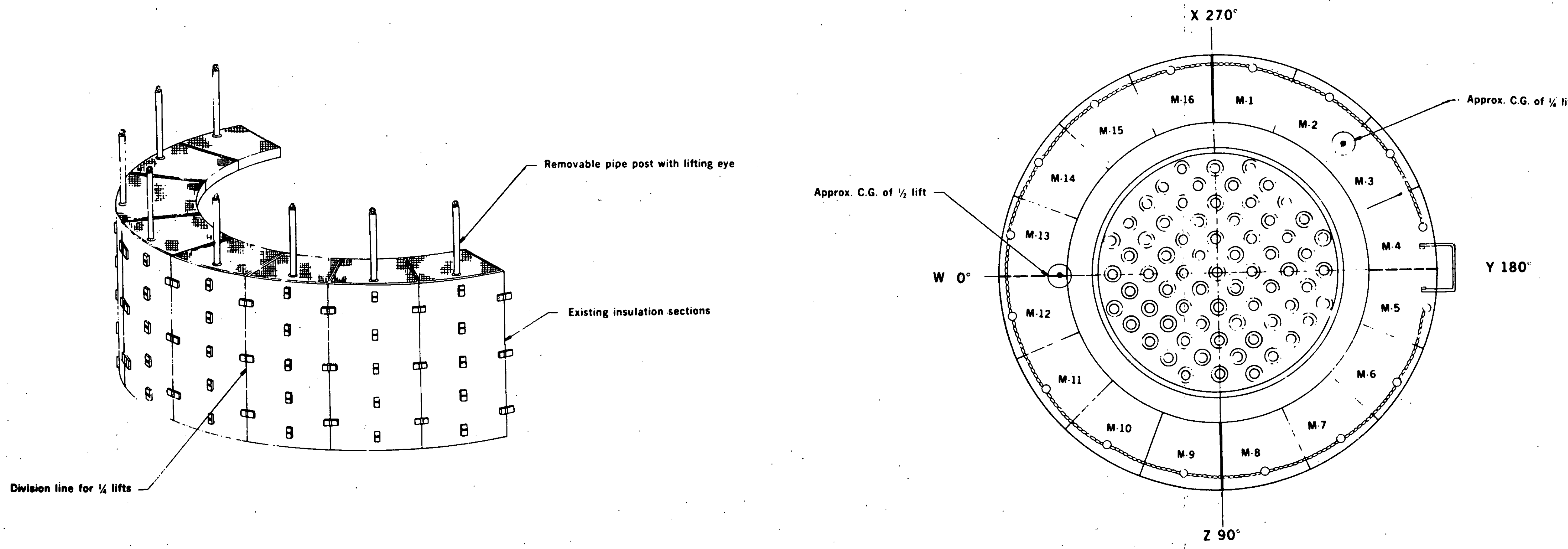


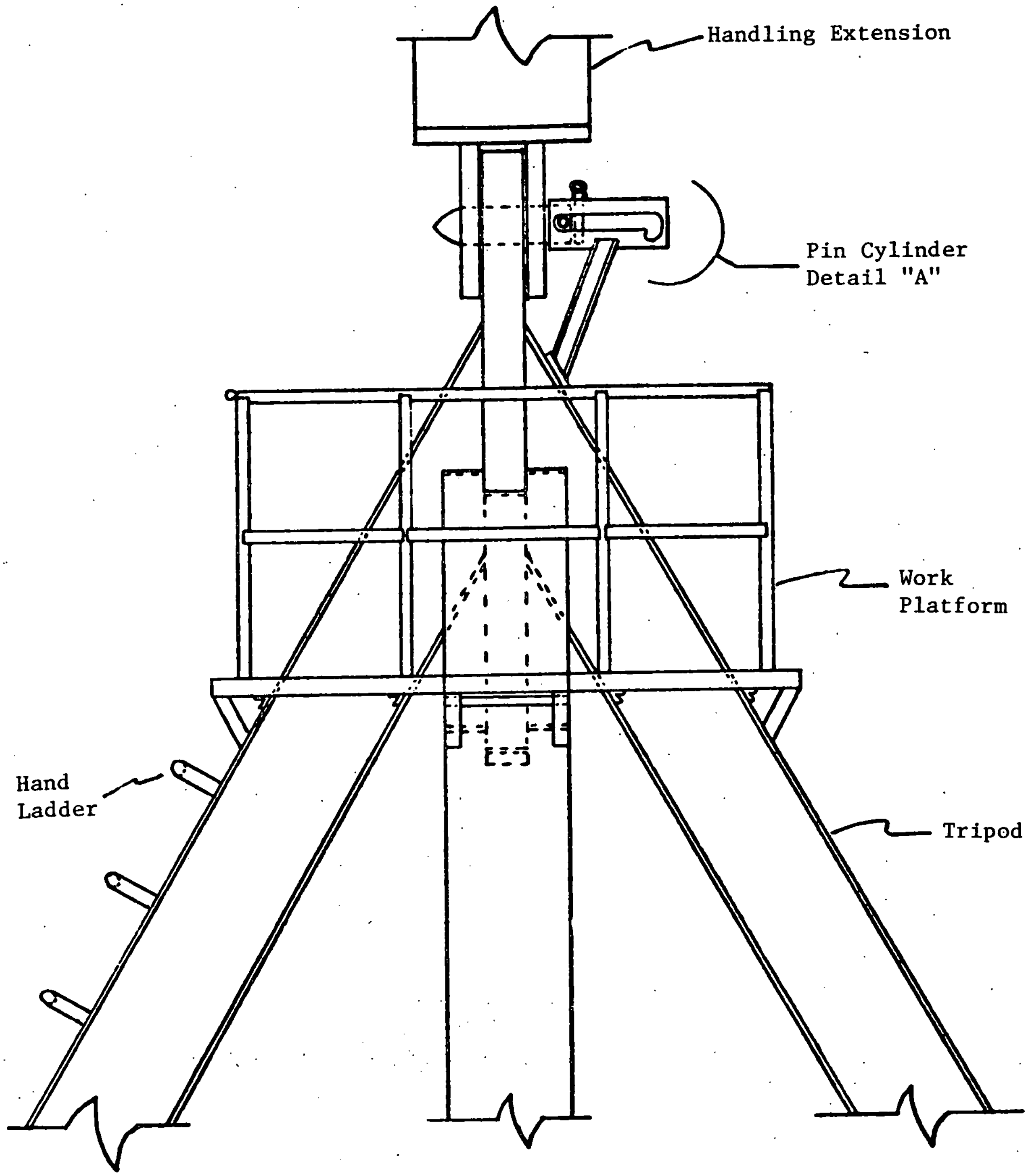
Figure 6-2. Main Fuel Handling Bridge With Multiple Function Mast Operation


"F"
"E"
"D"
"C"
"B"
"A"
SECTION "F-F"
SECTION "E-E"
SECTION "D-D"
SECTION "C-C"
SECTION "B-B"
SECTION "A-A"



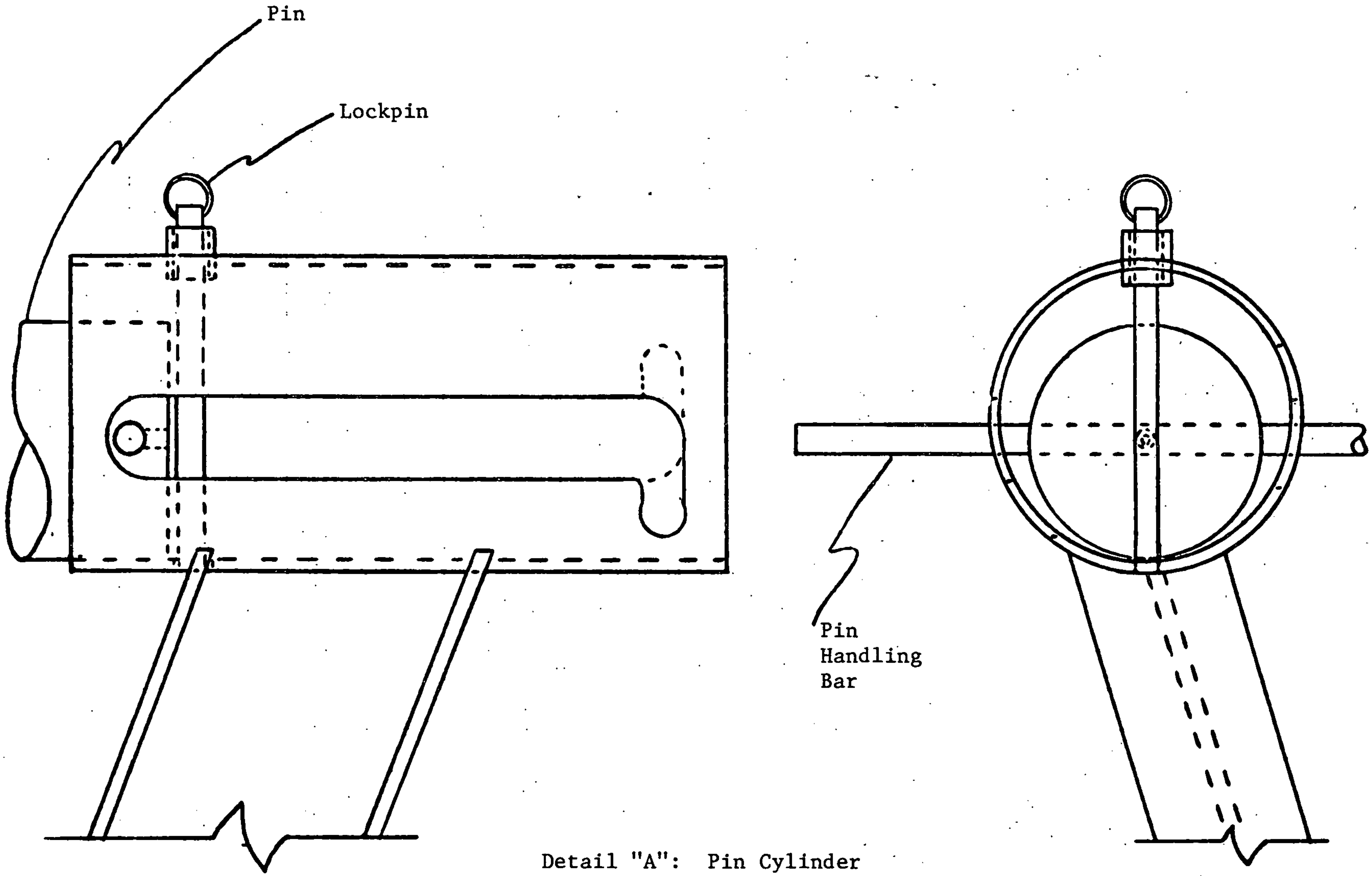
PLAN VIEW OF INSULATION SECTIONS

Figure 6-5. Tripod Handling Fixture Modifications



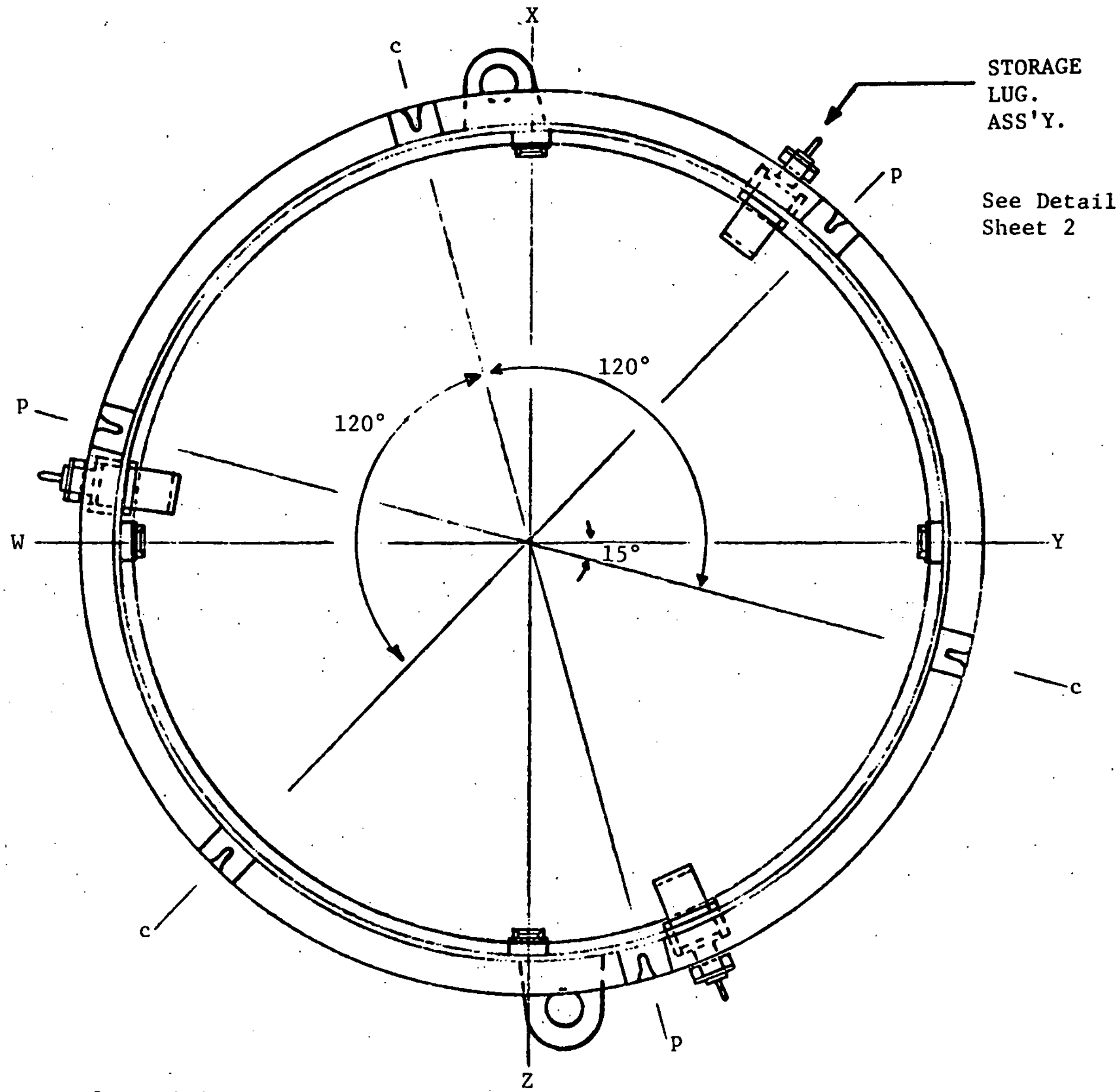
Not to scale.

Figure 6-6. Tripod Handling Assembly Modifications



Detail "A": Pin Cylinder

Figure 6-7. Indexing Fixture Modification



C: CSA Lift Position

P: Plenum Lift Position

Not to scale

Figure 6-8. Indexing Fixture Storage Lug Details

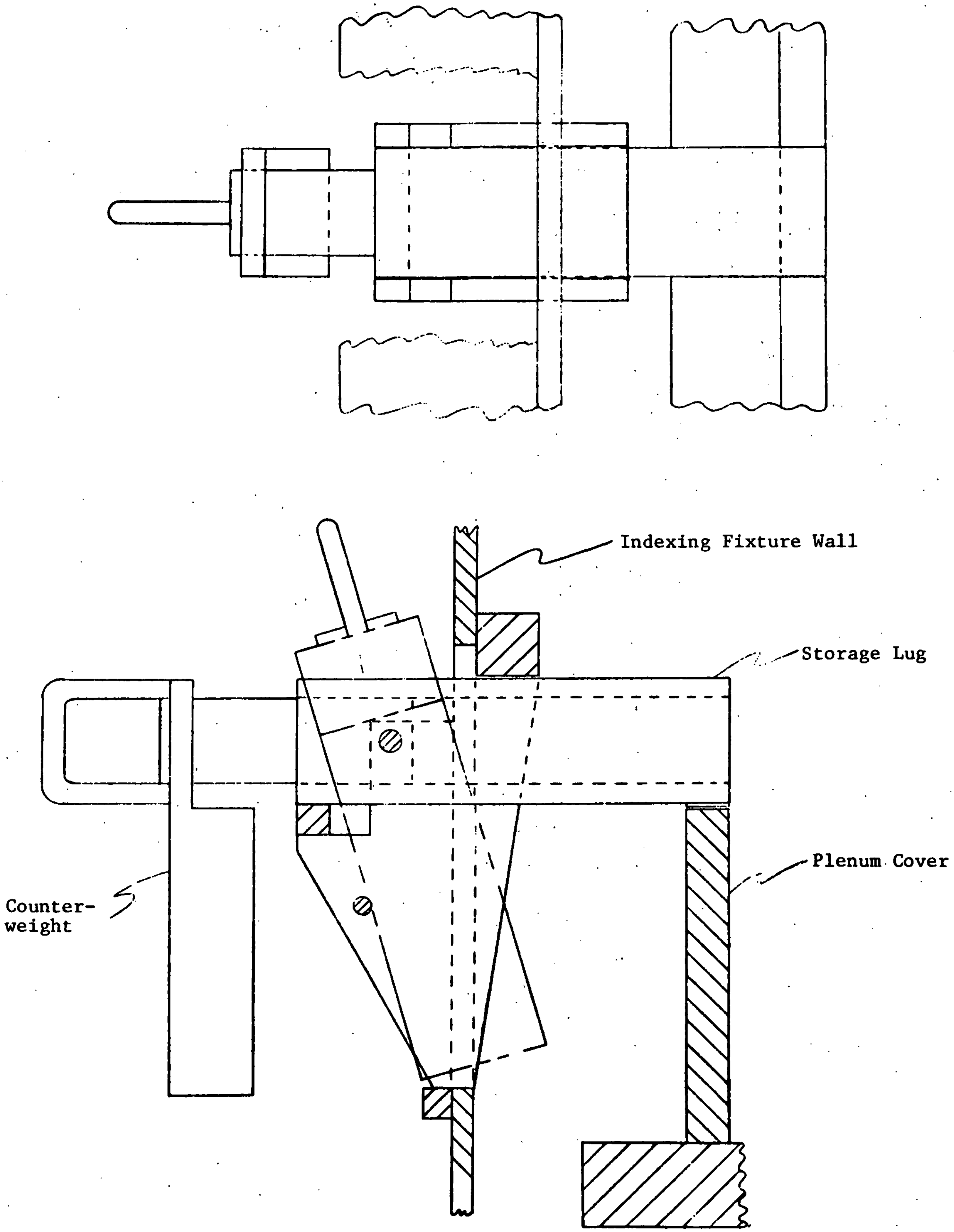
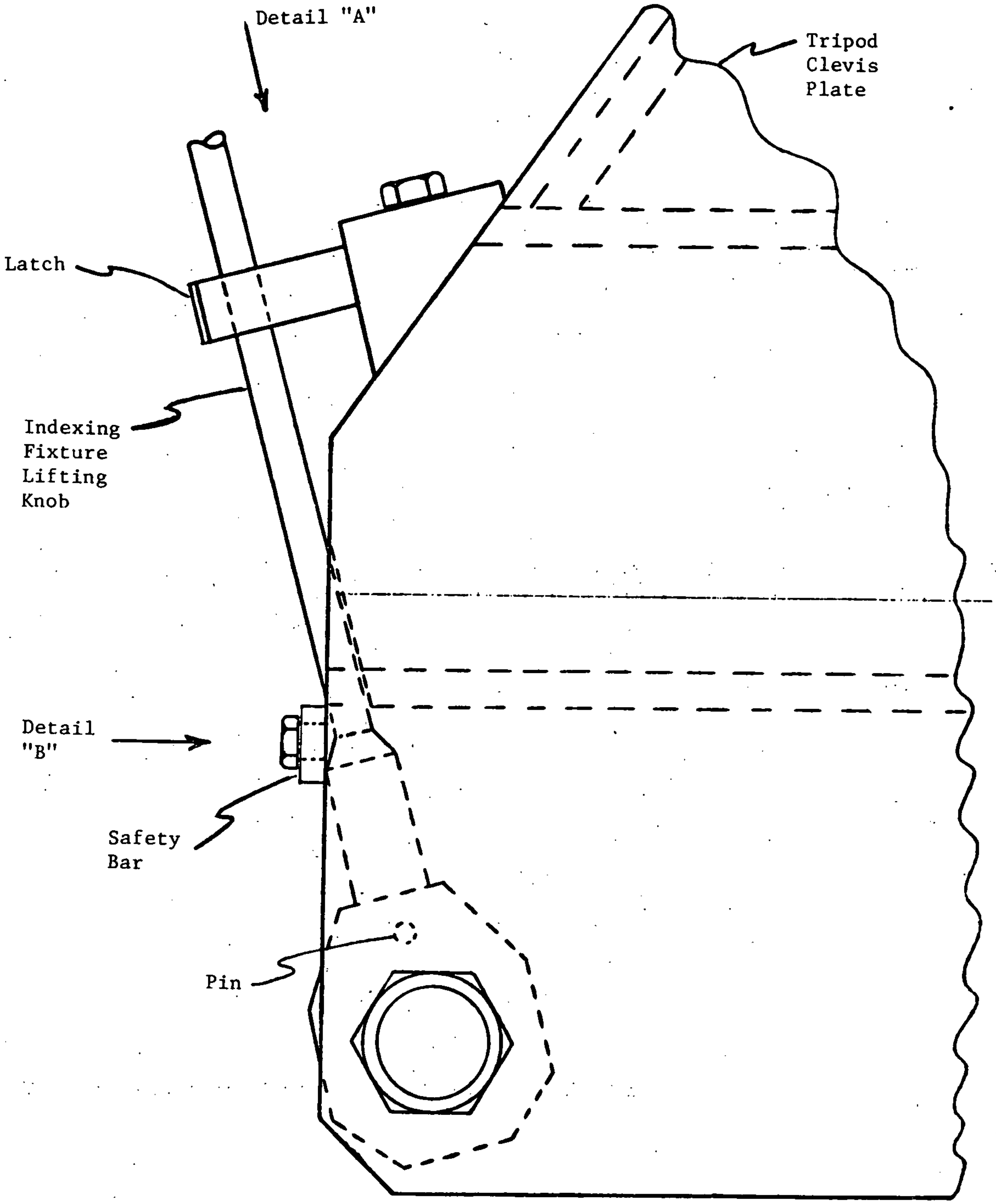


Figure 6-9. Lifting Knob Assembly Latch



Not to scale.

Figure 6-10. Service Structure Lifting Scheme

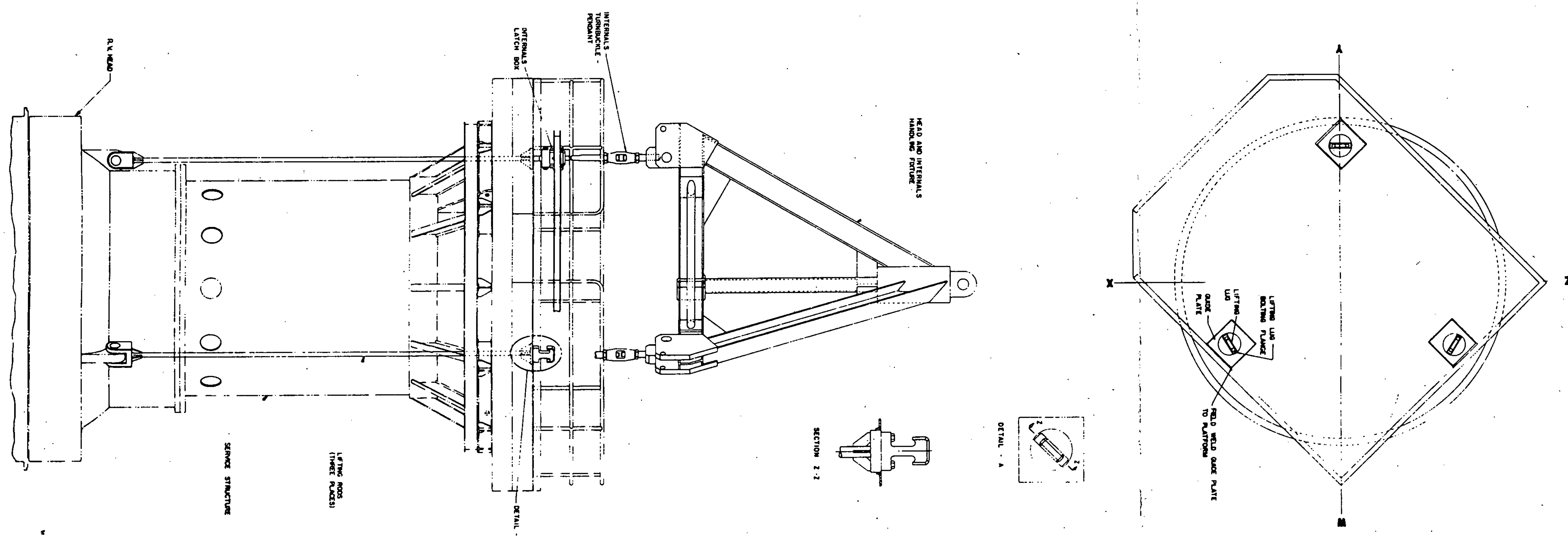


Figure 6-11. TV Camera Mast

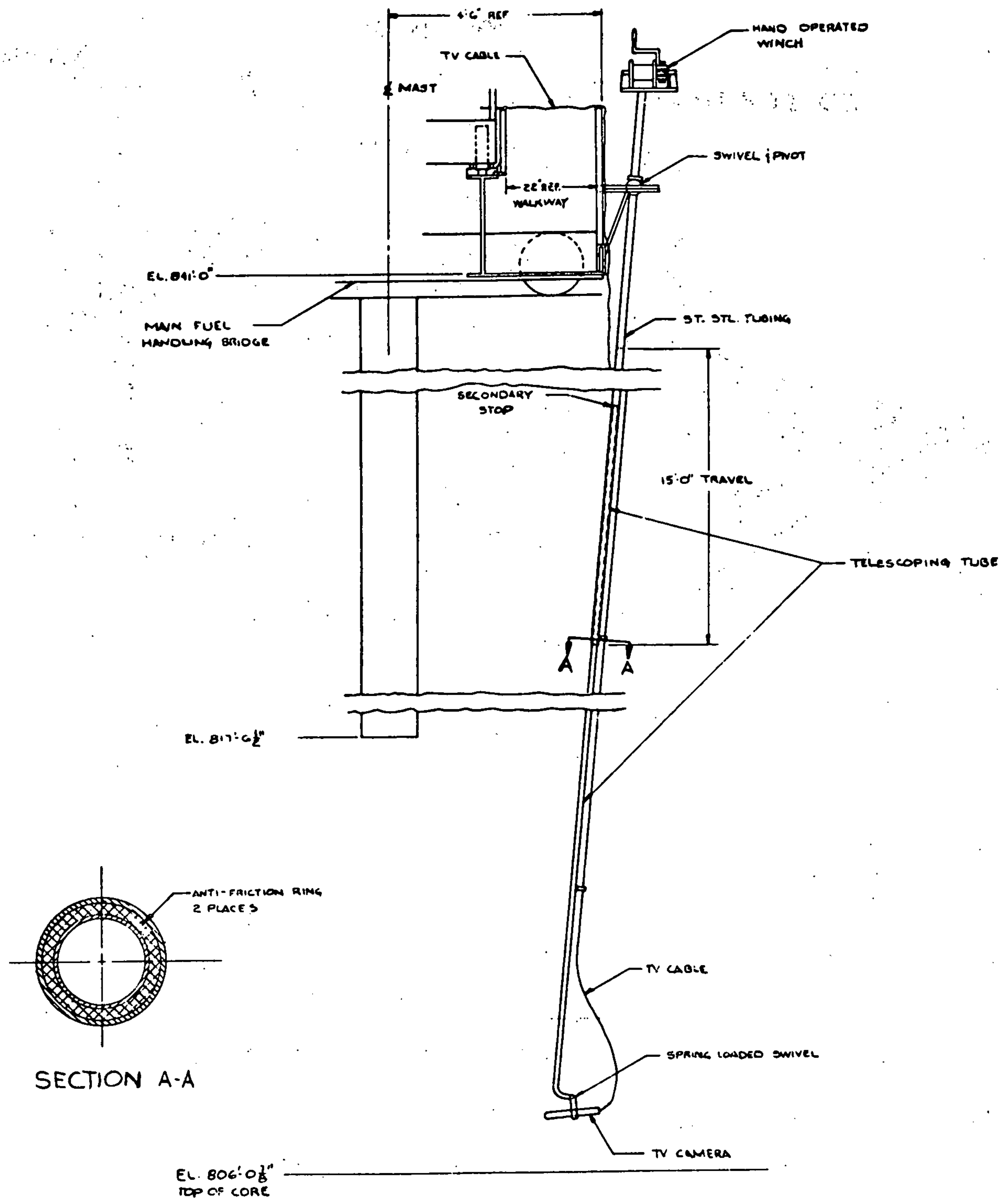
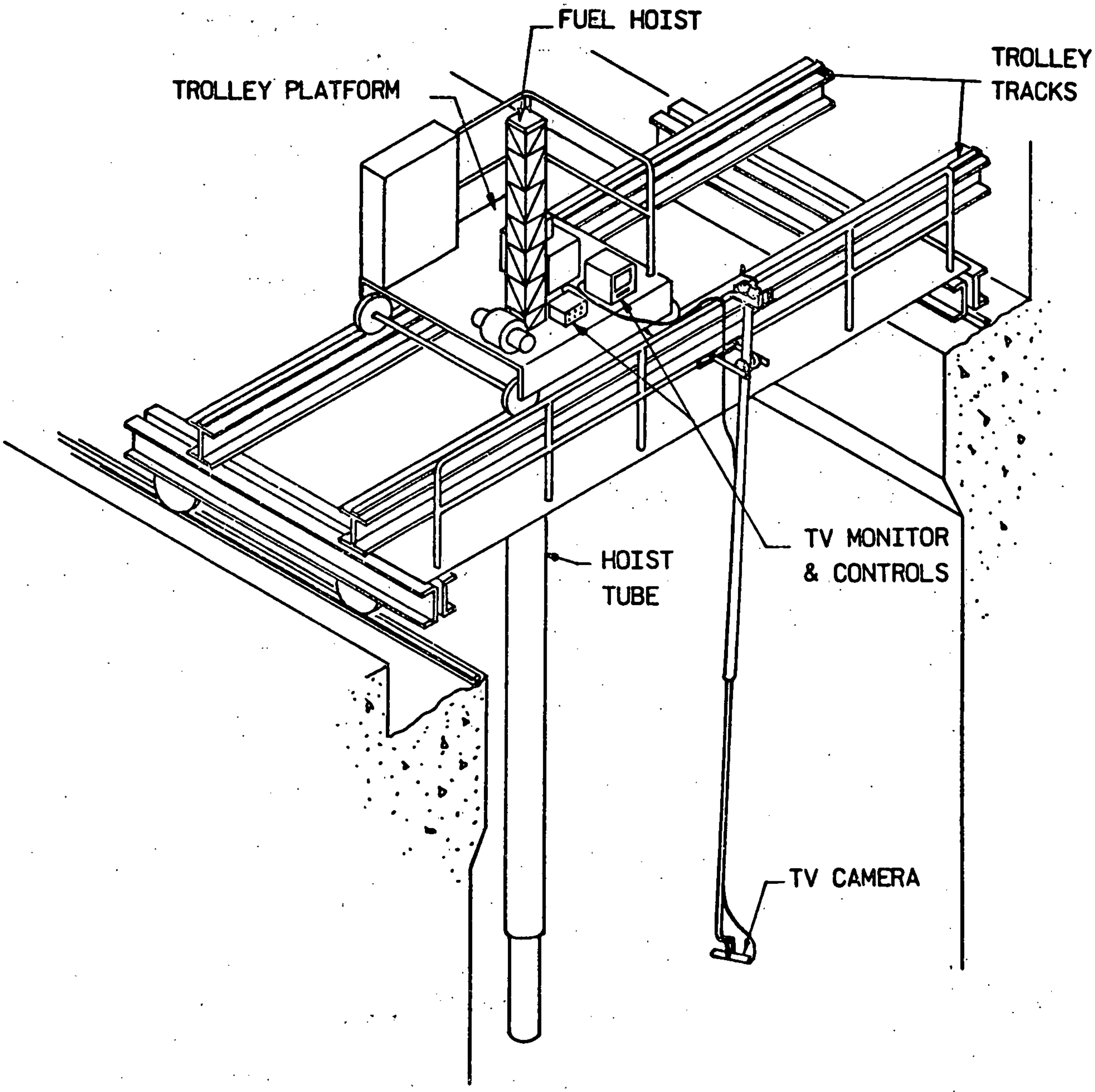


Figure 6-12. Fuel Handling Bridge With TV Camera



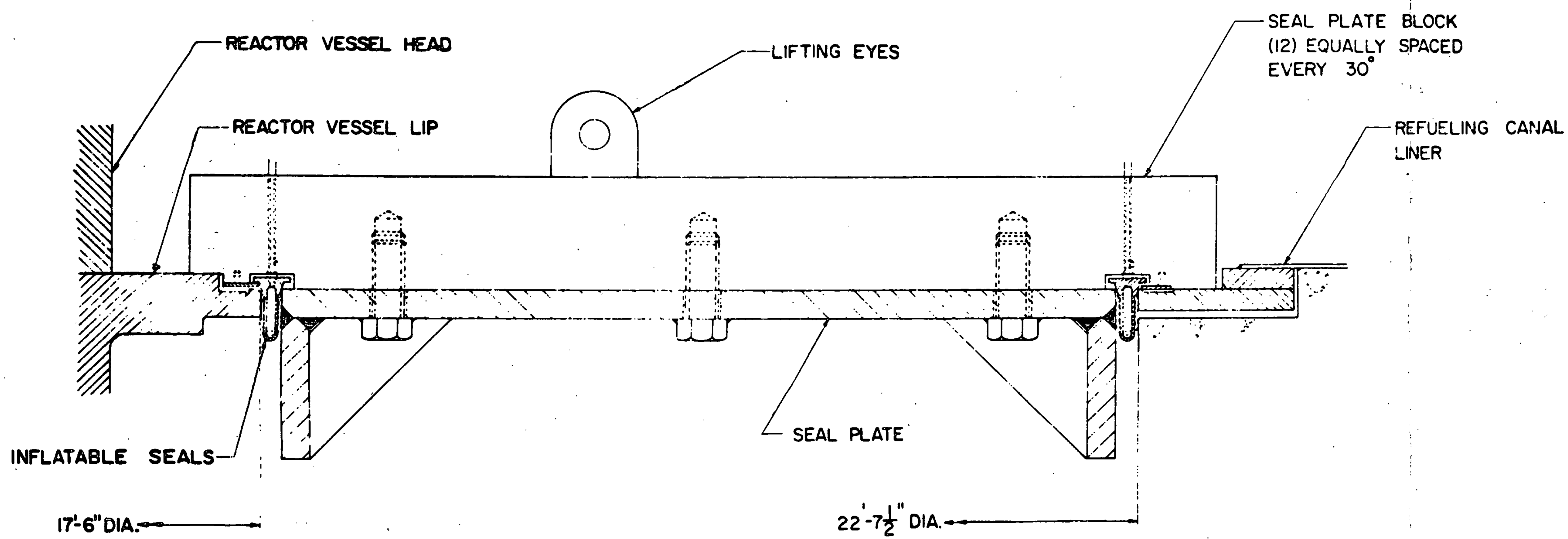


Figure 6-13. Seal Plate and Shield Ring With Inflatable Seal

Figure 6-14. Computerized Planning

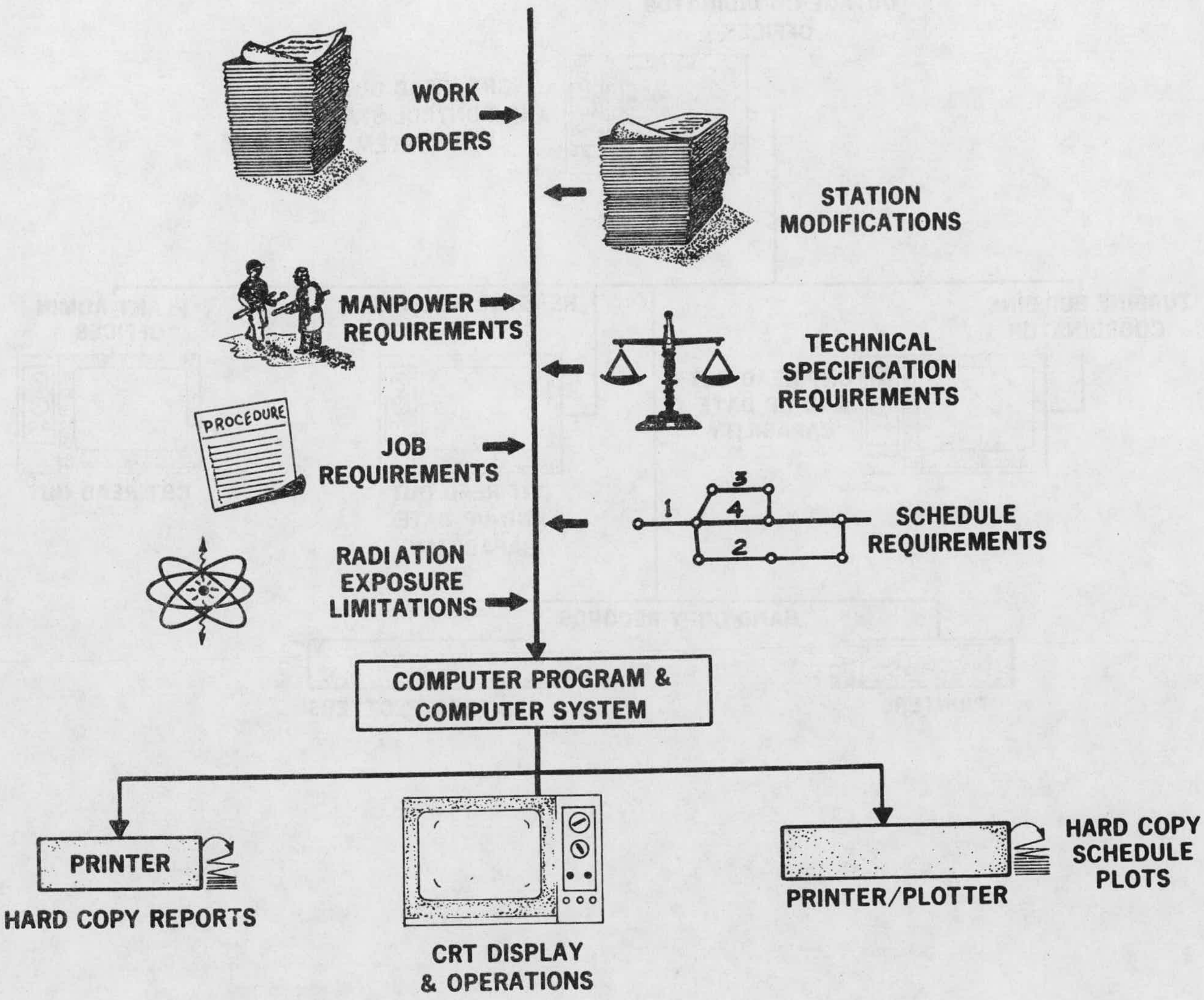


Figure 6-15. CRT Displays and Outputs

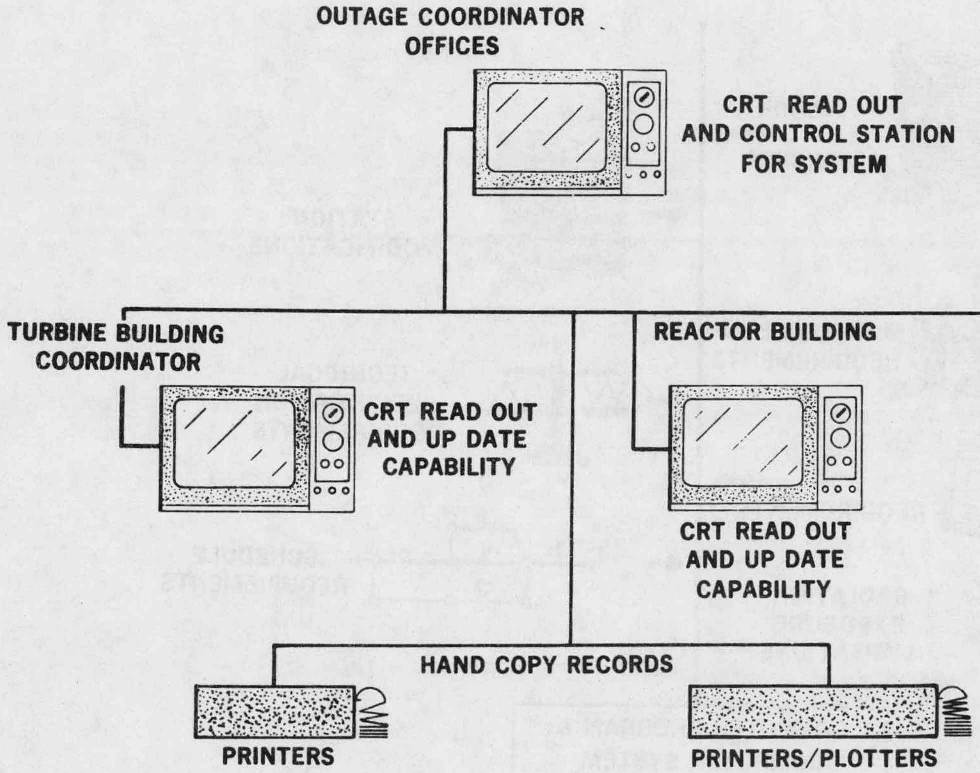
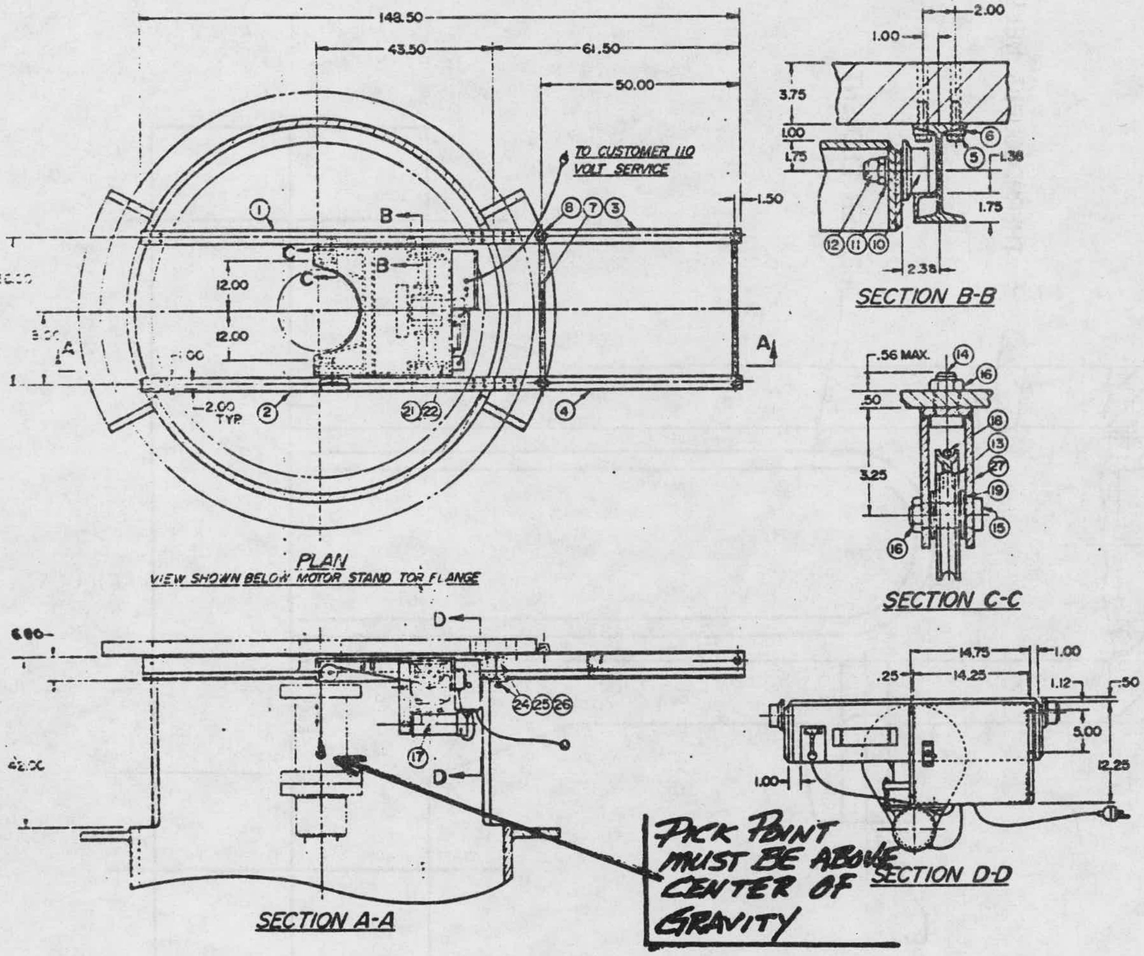


Figure 6-16. RCP Seal Maintenance Tooling Equipment



MATERIAL LIST			
PART No.	QTY.	DESCRIPTION	MFG. DWG.
1	1 ASS'Y	RAIL, RIGHT HAND	D-15743-1
2	1 ASS'Y	RAIL, LEFT HAND	D-15743-2
3	1 ASS'Y	RAIL EXTENSION, RIGHT HAND	D-15743-3
4	1 ASS'Y	RAIL EXTENSION, LEFT HAND	D-15743-4
5	24 PCS.	CAPSCREW, HEX HD. 5/8-11 UNC 2.00 LG.	
6	24 PCS.	WASHER, BEVEL - SPECIAL	A-46357
7	2 PCS	TIE BAR 3/4 DIA. 39.00 LG.	A-46358
8	8 PCS.	NUT, HEX 3/4-10 UNC	
9	1 ASS'Y	TROLLEY, WELDMENT	E-15486
10	4 PCS.	ROLLER, OSBORN FLR 2-3/4 DIA. BALL	OSBORN
		BRG. FLG'D 1"-14 NS THREAD	
11	4 PCS.	FLAT WASHER 1" TYPE A PLAIN	
12	4 PCS.	NUT, LOCKING FC-1614 1"-14 NS FLEXLOC	FLEXLOC
13	2 PCS.	SHEAVE, WIRE ROPE 31.68 T56	MCMASTER
		BRONZE BUSH. 4" DIA. x 3/4 BORE	
14	2 PCS.	SCREW, SHOULDERED SPECIAL	B-33170-1
15	2 PCS.	SCREW, SHOULDERED SPECIAL	B-33170-2
16	4 PCS	NUT, LOCKING FK101 5/8-11 UNC	FLEXLOC
17	1 ASS'Y	HOIST ASS'Y: MOTOR, REDUCER, DRUMS,	
		SPROCKETS, ELEC. CONTROL, &	
		LIFTING CABLES	
19	4 PCS.	SPACER, WASHER, 1-1/2 O.D. x 13/16 I.D. x	
		1/8 THICK	
21	8 PCS.	CAPSCREW, HEX HD. 1/2-13 UNC x 2" LG.	
22	8 PCS.	NUT, LOCKING FK-813 1/2-13 UNC	FLEXLOC
24	8 PCS.	CAPSCREW, HEX HD. 5/8-11 UNC x 1.25 LG.	
25	8 PCS.	NUT, HEX 5/8-11 UNC	
26	8 PCS.	LOCKWASHER, 5/8 STD.	
27	2 PCS.	PULLEY FRAME	B-33169

HOIST & TROLLEY ASSEMBLY

Figure 6-17. Torquing Mechanism

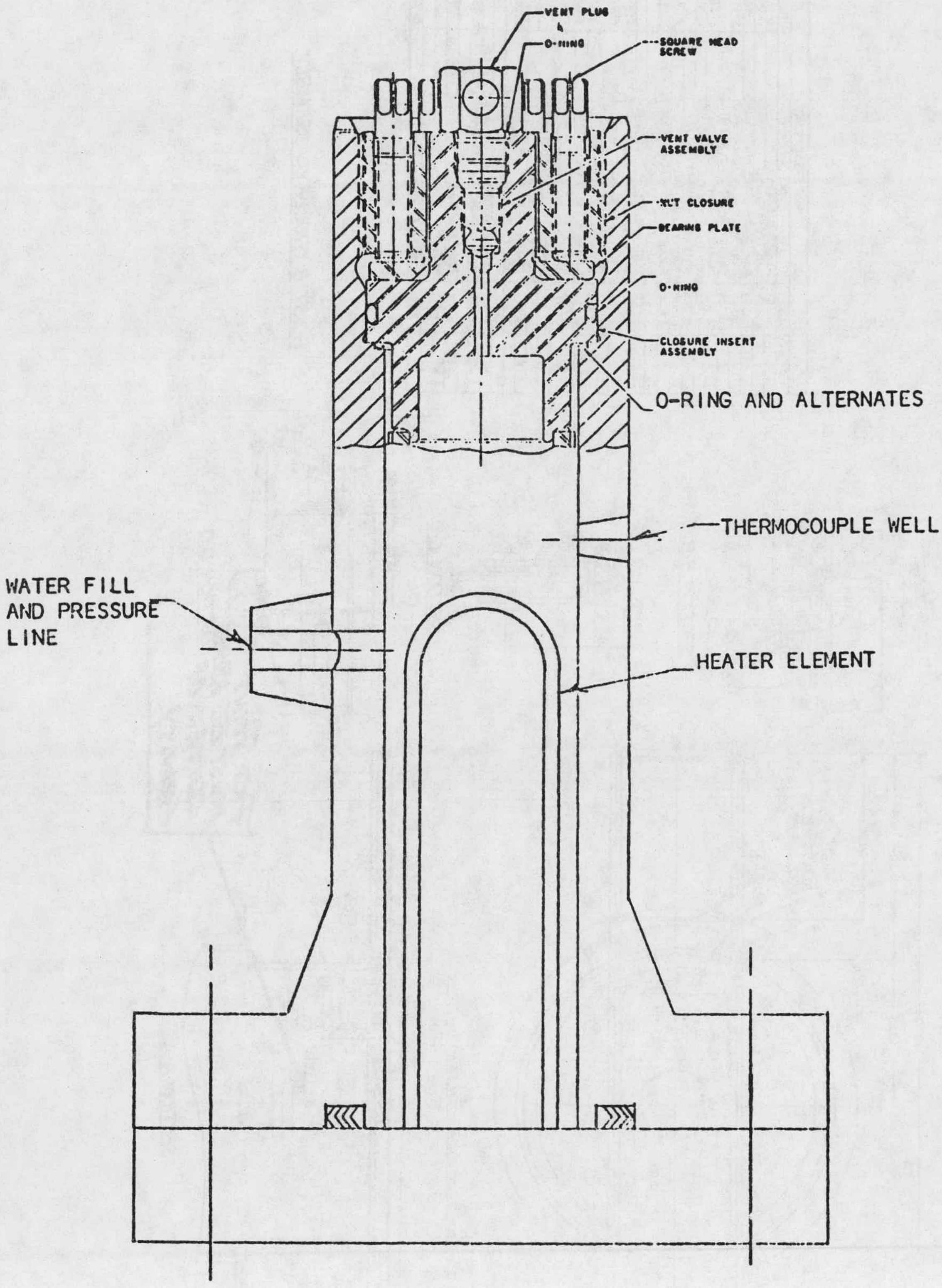


Figure 6-18. Seal Ring Pressure/Temperature Test Fixture

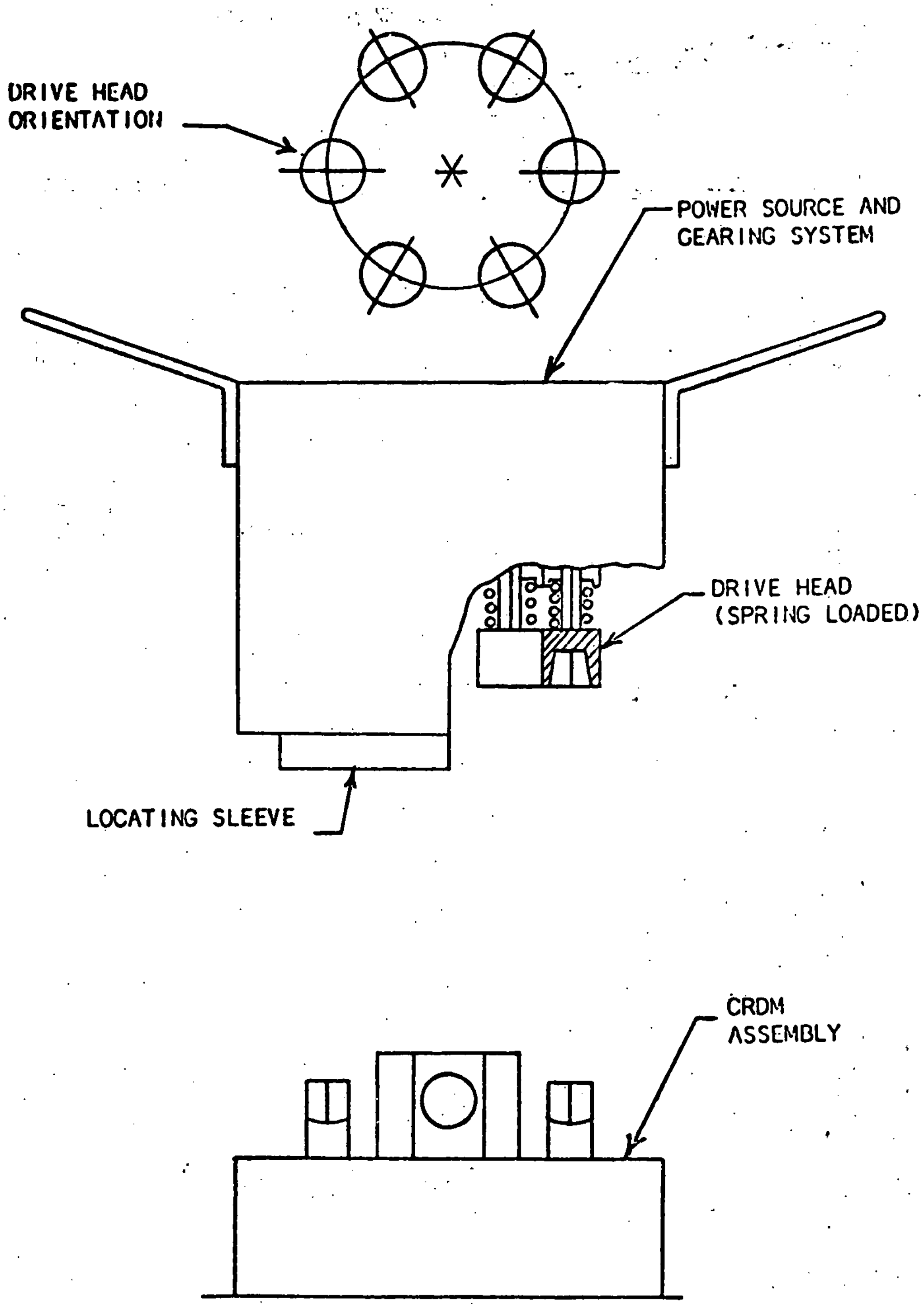


Figure 6-19. CRDM Hoist System

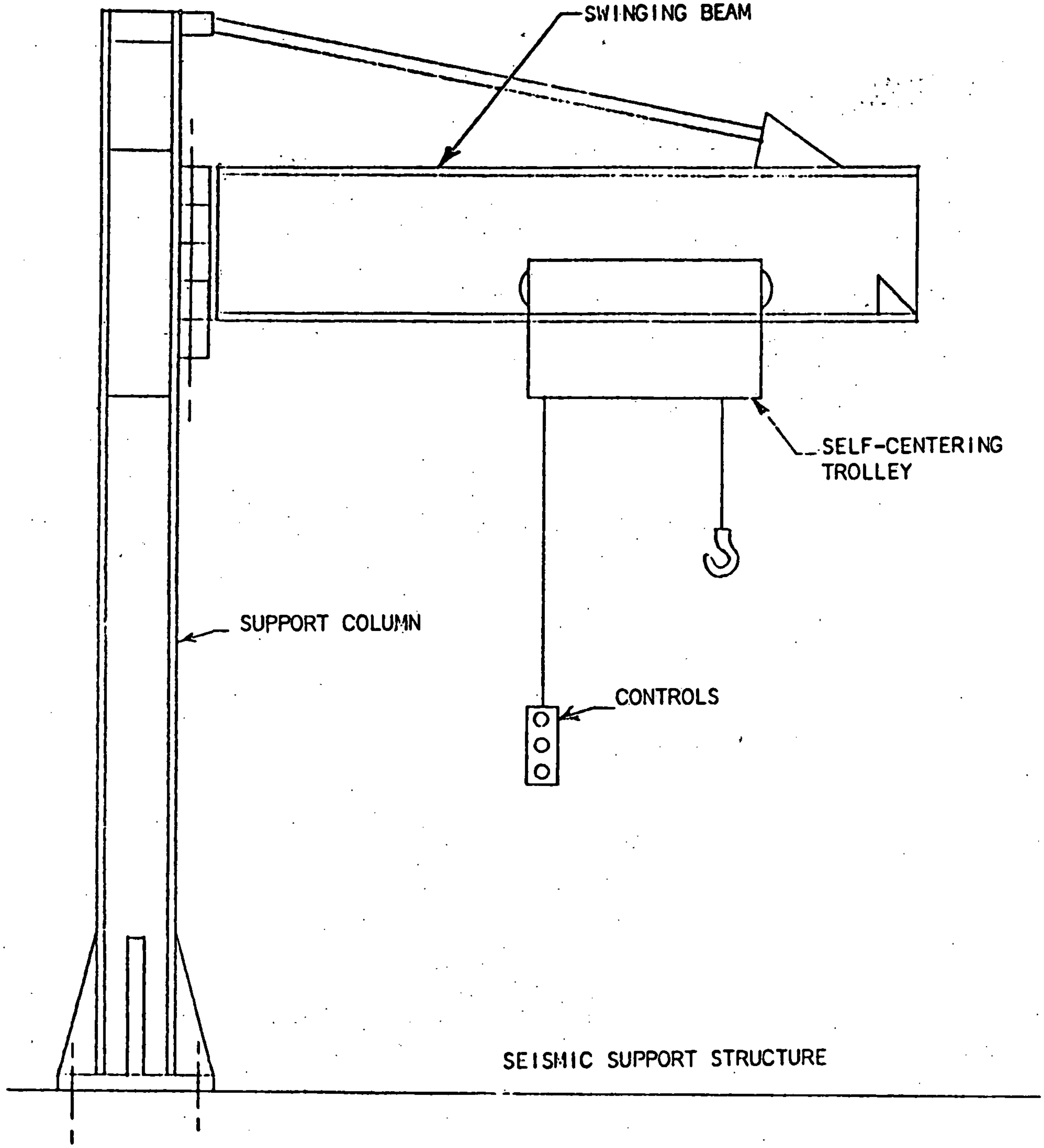


Figure 6-20. Leadscrew Withdrawal and Parking Tool

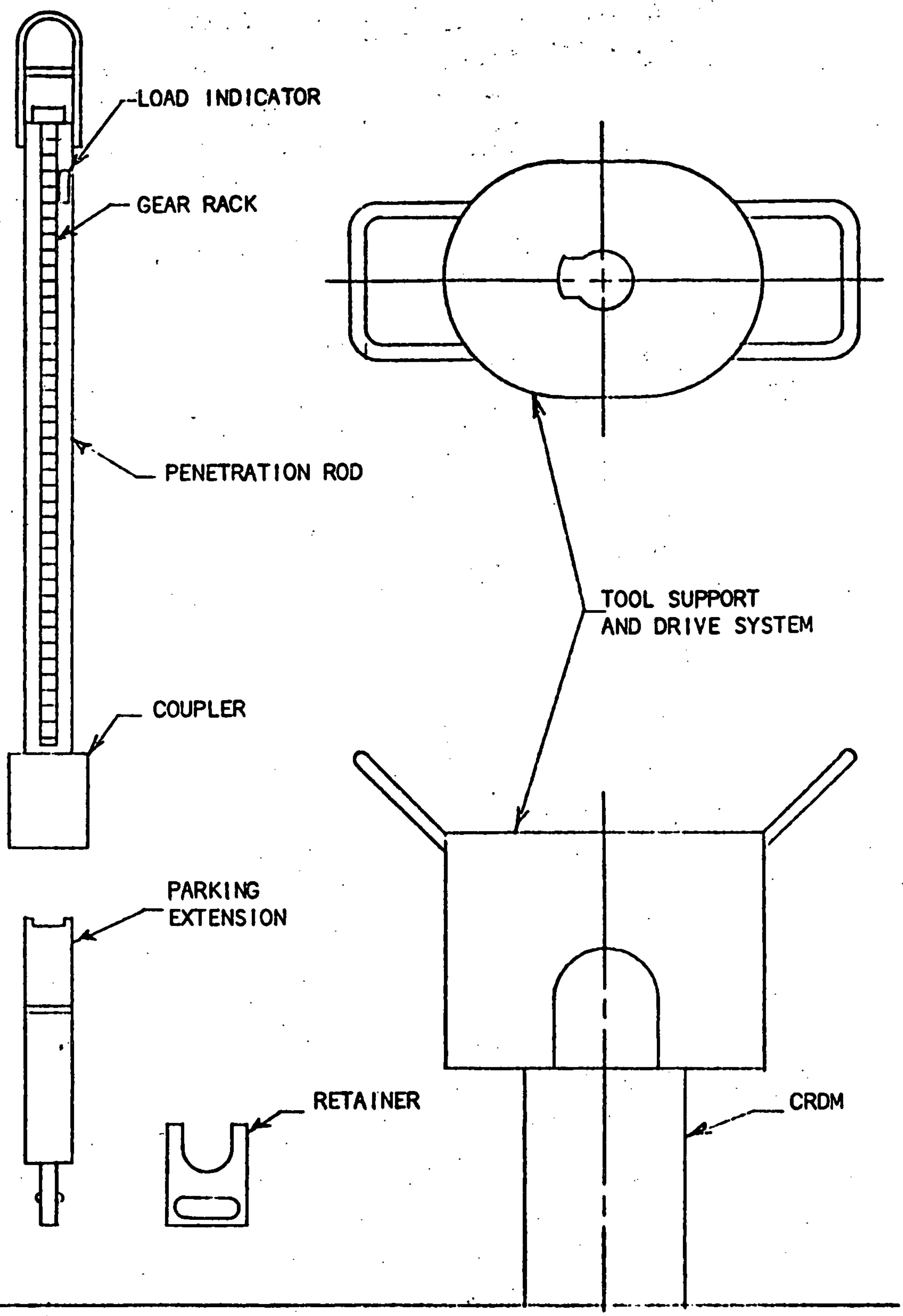


Figure 6-21. Improvement of Alternate Uncoupling Tool

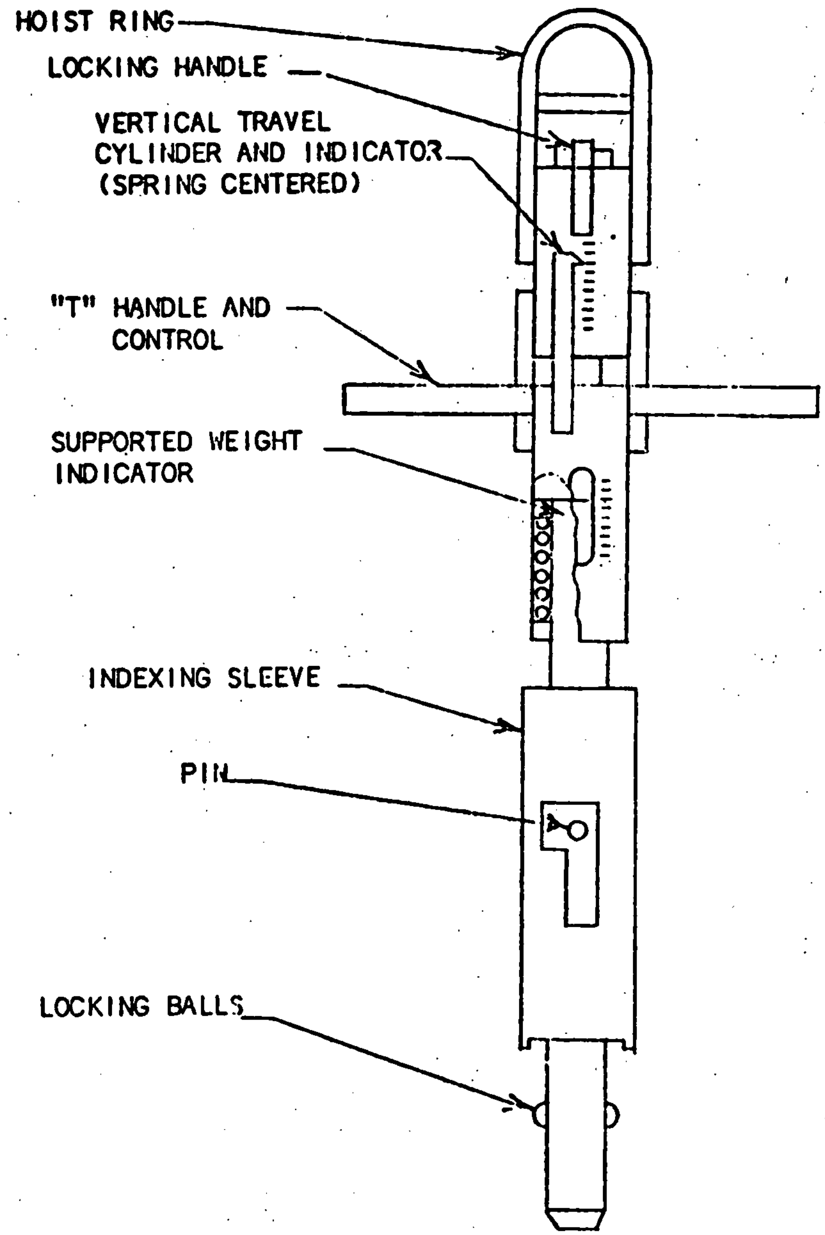


Figure 6-22. Access Door Arrangement

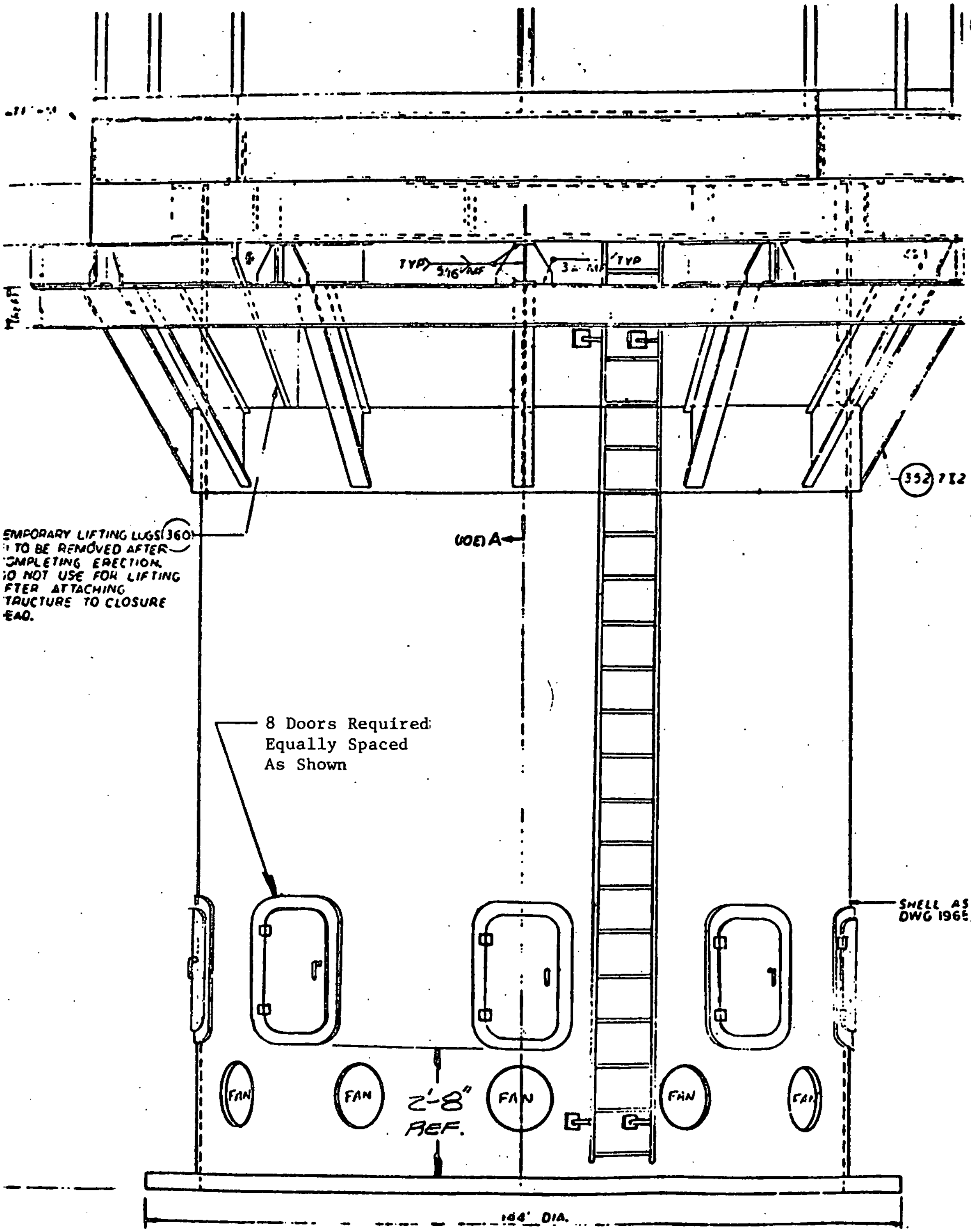
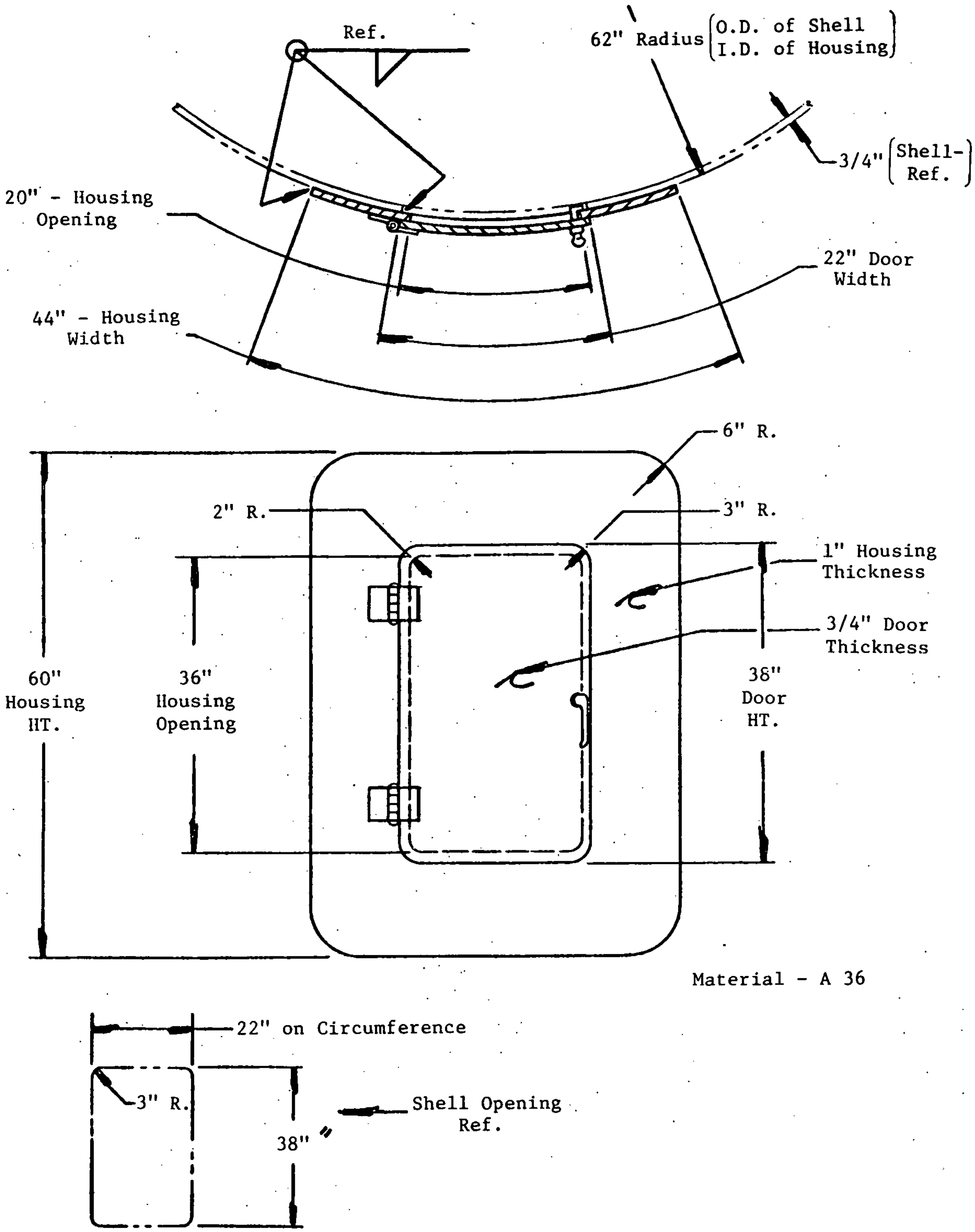


Figure 6-23. Access Door Design Details



7. RECOMMENDATIONS FOR FUTURE PLANT DESIGN CHANGES

B&W plants that are in the construction or design stages have nearly identical reactor building (RB) layouts. There is continued emphasis on standardizing plant designs. However, these plants were designed during the mid- to late 1960's and early 1970's when the bulk of nuclear orders were placed. With limited operating experience on which to base the overall plant design, too little attention was paid to future maintenance requirements. The unique nature of nuclear maintenance dictates that any maintenance items, particularly routine tasks, receive close scrutiny during the initial design phase of the plant. This section lists recommendations applicable to future plant designs.

7.1. State-of-the-Art Equipment and Facilities

1. Tooling Availability — Tools (both contaminated tools and stockroom supply) are generally stored outside the RB. Due to access restrictions, considerable time is frequently lost as workmen suit-out, procure tools (and generally take a break) and suit-in again. To avoid the bother, workmen will too often use whatever tool is available within the RB. This leads to "scrounging" of untended tools in the other work areas. The use of makeshift tooling, such as crescent wrenches, hammers, screwdriver chisels, and channel lock torque wrenches, leads to poor productivity and equipment damage. A tool issue room should be added in the RB (20 h). FM-435

2. Lack of Space/Maintenance Work Areas — The RB is very compact; thus, there is very limited room for maintenance of large contaminated parts. Consequently, storage of large contaminated parts is at a premium. Factors that govern space availability include the following: primary and secondary shielding, auxiliary systems and their attendant piping, seismic support, hangers, electrical items, instrumentation, and control cabling and trays. Lower priority is generally given to personnel access, working platforms, and the like. A recommendation for future plant designs is to consider maintenance requirements when making plant layouts. Thorough study of laydown areas for equipment during maintenances or overhaul should be considered (16 h). FM-338

3. Polar Crane Capacity — The polar crane should be designed to handle the maximum expected load. Most existing plants have this capability; however, at ANO 1, the RV head and all RV studs cannot be lifted as a unit. One study to be undertaken under Phase 2 is the feasibility of combined heavy lifts, such as the RV head and plenum. If this is successful, even greater loads for the polar crane must be considered (4 h). FM-116

4. Rigging Storage — Storage racks and wall-mounted hangers should be installed for the rigging used for RV head and internals handling. This would reduce the time necessary to hook up rigging and prevent damage that might occur to rigging equipment if it were left lying on the floor. In addition, permanent ladders and platforms should be installed to allow access to rigging storage areas or stands (4 h). FM-114

5. Hot Shop in RB — A "hot" shop is generally provided for machining contaminated components. Unfortunately, these hot shops are generally located outside the controlled area, making the transport of equipment and movement of personnel time-consuming. A hot shop facility should be built inside the RB or adjacent to the RB equipment or personnel hatch to permit direct access to the shop, thus expediting any jobs that need hot machining. Consideration should also be given to making this hot shop large enough to serve the following functions (4 h): FM-102

   a. Storage area for contaminated parts and tools that must be used during outages.

   b. Area for staging materials that will be used during the outage.

   c. Workshop area for performing repairs on large contaminated parts, such as CRDM repair work.

6. Building and Work Area Ventilation — During shutdown for the refueling outage, the temperature in the RB will gradually drop from above 140-160F (during extended power operation). However, due to the massive steel components and structures, the temperatures are still at unworkable levels (above 100F) for several (3 to 5) days. The oppressive heat, aggravated by the anti-C clothing, makes any work in the RB extremely difficult. It is recommended that means to improve ventilation and cooling in the RB be investigated. In addition, local ventilation of such work areas as the refueling canal, RC pump seal area, and OTSG manway areas should be investigated (16 h). FM_D-344

7.2. Equipment Requiring Development

1. Fuel Handling Equipment Modifications — The following recommendations are made to improve the FH equipment:

   a. Replace the existing mast with a combined fuel assembly/control rod mast on the main bridge. This would reduce the time needed to handle fuel and shuffle control components (20 h). FM-413

   b. Add stepping motors to the bridge and trolley. Such motors could be used to move the bridge and trolley precisely for locating a fuel assembly that is not in exact position (with the mast extended to within 6 inches of the core). These motors can be controlled by a "joy stick," which will move the bridge or trolley in 1/16-inch increments. An interlock could be provided to require the joy stick to be returned to neutral before movements could be made in another direction. The present arrangement does not allow for misalignment due to twisted fuel assemblies or errors in indexing of the fuel handling bridge. The stepping motors would provide protection for the fuel assemblies and allow for minor corrections (12 h). FM-258

c. Incorporate a finger system on the mast that would move all fuel assemblies adjacent to the assembly to be lifted and push them slightly aside during grappling and insertion operations; this would preclude the possibility of hangup (8 h). FM-194

d. Develop a grapple disengager for use when the handling equipment becomes improperly grappled (6 h). FM-154

e. Make the "tube up" limit switch (which allows the bridge and trolley to move when the fuel assembly is fully retracted into the outer mast) redundant; this would allow continued operation with a failed switch (6 h). FM-152

f. Operate the "hand-operated" jog switches on all bridges by hand or change the design of the switch to a heavy-duty, foot-operated switch. At present this switch is operated by stepping on it; it is not designed for this service, and this practice should be terminated or the switch upgraded to a normal foot-operated type (4 h). FM-112

2. Heavy Lifts/Combined Lifts — The plenum and indexing fixture should be lifted and set down together. This would require modifications to the tripod and indexing fixture. The change would reduce the number of lifts and the time required for the polar crane (4 h). FM-109

3. RV Head Insulation Modifications — At present, 16 pieces of insulation are removed or installed individually. Four racks are provided for insulation storage while not in use, and the racks are lifted into or out of the canal using the polar crane. A new design is recommended to allow reduced operations associated with insulation removal/installation. A conceptual design would be to remove/install the insulation in two halves, together with some means for quick coupling and uncoupling of the two halves installed on the RV head. Operations associated with current interim storage and replacement of 16 sections of insulation would be reduced using this modification. Storage locations and arrangements would have to be designed, but is is contemplated that no further need for storage racks will exist once this change is made (8 h). FM_D-146

7.3. Facility Layout and Capabilities

1. Working Platforms — The addition of working platforms in certain work areas is recommended for personnel safety, component accessibility, and availability of a laydown area for tools and parts. Most existing plants have little provision for safe working platforms in the following areas: the pump seal and motor, the upper OTSG manway, and the pressurizer upper head.

   Most of the existing plants have platforms around the pressurizer heater bundle for replacement and maintenance. At present, additional temporary platforms are installed during an outage. Consequently, many jobs are slowed down or held up while arrangements are being made for access to these components (16 h). FM_D-352

2. Work Area Access — Major work areas are generally accessible during an outage only by means of ladders. Particularly where safety cages are not used, this may be a dangerous practice. All components inside the secondary shield wall are accessible only by climbing from below or from above since secondary shield walls have no interior openings. For work in the

area of the pumps, the pressurizer, and (to a lesser extent) the steam generators, this means that all tools and fixtures must either be carried up and down ladders or lowered from above. Storing tools and fixtures in the work area should be considered. An example would be the tools used for pump seal maintenance. Purchasing multiple sets of this equipment along with work area storage would permit simultaneous seal removal on two or more pumps. Consideration should be given to incorporating elevators inside the secondary shield walls in future plants. As a minimum, the ladders and walkways leading to work areas should be cleared of obstructions to entry and exit.

Another such area is the CRD service structure when the RV head is on the storage stand; at present, access is generally by ladder. Constructing a catwalk from the top of the secondary shield wall to the platform would permit workmen to use elevators (12 h). FM_D-275

3. Change-Out Facilities — Although efficiently run, the change-out facilities where workmen change from normal clothes to anti-C clothing and vice-versa at Oconee 3 and ANO 1 created "bottlenecks" in personnel traffic flow. During maintenance outages the station personnel are generally augmented by outside personnel. Change rooms are overloaded, leading to congestion and delays. Future plant designs should provide for adequate change room facilities (10 h). FM_D-235

4. Addition of Cranes and Hoists — A frequent bottleneck in present-day plants is the polar crane. This is generally the only hoisting equipment that can lift heavy components above the secondary shield walls. In most plants it is the only provision for servicing areas in the equipment hatch, the RC pump seal and motors, the CRDM, the refueling canal, and the pressurizer. "Jury-rigged" portable hoists are sometimes used to alleviate this problem. The installation of permanently mounted hoists (jib, bridge, or monorail cranes) is recommended to free the polar crane for more critical operations and eliminate the dangers inherent in jury-rigging. The following are some of the areas that should be considered:

   a. One jib crane over each RC pump to help support motor and seal work. One of these cranes would also aid in pressurizer maintenance.

   b. One jib crane over the head storage stand to aid in CRD work.

   c. One jib crane over the equipment hatch bay area to aid in moving material and for servicing the equipment hatch.

   d. One jib crane located over the refueling canal for close work on reactor components and various equipment in the canal.

   The selection of commercial hoisting equipment must consider the heat, humidity, and radiation environment to which the equipment will be subjected during operation (10 h). FM_D-229

5. An electric or air-driven lift should be installed for workers to enter and exit to and from the fuel transfer canal area. This will save time, reduce fatigue, and aid in preventing equipment being dropped and personal injury (4 h). FM_D-116

6. RB and Work Area Lighting — Lighting is generally adequate within the RB except for some of the major work areas. Better lighting should be provided to improve personnel efficiency and reduce time required to complete some tasks. Permanently installed lighting is recommended to avoid the tangle of drop cords if temporary lighting were installed. Lighting is generally poor inside the secondary shield walls. Overhead lighting is not effective since missile shields, tool boxes, etc., which are customarily stored on top of the secondary shield walls during refueling, effectively block overhead lighting. Structures and other components inside the secondary shield walls will generally block any remaining light. The refueling canal is another area where better lighting is needed. Lamps normally used for lighting cannot be turned on until the canal is flooded (6 h). FM_D-156

8. CONTINUING WORK PROGRAM RECOMMENDATIONS

8.1. Introduction

A continuing program to evaluate and improve nuclear power plant availability is a vital part of managing the nation's energy resources. Through the combined efforts of Duke Power Company, Arkansas Power & Light, Babcock & Wilcox, the Department of Energy, and several major equipment suppliers, a significant reduction in outage time may now be realized. The goal of the shortest outage coupled with the completion of the maximum amount of work will go a long way toward improving nuclear power plant availability and reducing the dependence of the utility industry on expendable fossil fuel. More effort is required to achieve the shortest possible refueling outage.

8.2. Statistical Comparison of Refueling Outages

Statistics for commercial nuclear generating plants exceeding 400 MWe capacity point out the importance of continuing the work effort to examine all aspects of the refueling/maintenance outage. These statistics are presented in Table 8-1 and summarized below:

1. The average time for the 44 refueling outages studied was approximately 70 days.
2. The average time for the outages of the best 22 reported was 50 days.
3. The average time for the outages of the worst 22 reported was 91 days.
4. The longest outage reported was approximately 151 days.
5. The shortest outage reported was approximately 29 days.

Many First-of-a-Kind problems did occur during the outages making up the source and thus tend to distort the data. However, the statistics point out that outage times must be reduced to improve plant availability.

8.3. Further Study Program

Due to constraints in manpower and time, some recommendations have not been evaluated and assessed. This section describes in detail the type of program that should be undertaken to evaluate the given recommendations more thoroughly to determine whether they warrant possible application.

8.3.1. Extended Fuel Cycle Study

A study should be made to determine the potential unit downtime savings, increased plant capacity factor, and reduction in personnel man-hours and radiation exposure that would be realized by increasing the fuel cycle to 18 months. The following items should be considered in the course of this study: FM-823

1. Investigate the optimum fuel cycle length to avoid refueling outages during peak loads; keep records to verify which length cycle is the best choice.
2. Identify calculations needed to determine the fuel design that would accommodate continued 18-month cycles at B&W plants now in operation.
3. Study the increase in plant capacity, the impact on plant maintenance schedules, and the licensing requirements resulting from increased cycle length.
4. Study the impact of increased cycle length on increased forced outage rate, fuel failure probability, and inservice inspection schedules.
5. Determine the acceptance of increased fuel cycle length by utilities.
6. Assess known advantages and disadvantages quantitatively, and prepare a sample program and schedule to implement a longer fuel cycle at operating plants.

8.3.2. Facility Development

It is recommended that an in-depth review of reactor buildings under construction be made by visiting several plant sites where the layouts and drawings of the facilities can be studied. The objective of this study is to make recommendations to plants under construction to achieve potential outage benefits when these plants undergo their first refueling outage. Such recommendations would cost the utilities far less to implement now than after the plant has been started up. Recommendations to be considered in this study should include the following:

1. Improve personnel access to equipment (walkway, platforms, etc.) for maintenance of (for example) pumps, motors, fuel handling equipment, pressurizer, and control rod drives. FM_D-352

2. Improve working conditions during plant outages by reducing building ambient temperature, expecially during the period immediately following shutdown. FM_D-344

3. Improve lighting in work areas. FM_D-156

4. Improve tool and fixture storage and availability. FM_D-435

5. Improve anti-contamination clothing change room arrangement. FM_D-235

6. Study the installation of a small "hot" shop in the reactor building. FM-102

7. Review local application of small jib, bridge, or monorail cranes to assist in maintenance work, such as pump seals, CRDMs, and canal equipment. FM_D-229

8. Improve material handling and material flow at the building equipment hatch. FM_D-156

8.3.3. Distribution of Work Forces

The amount of time spent on primary plant critical path hours is divided rather unevenly between maintenance and operations personnel. The Oconee 3 refueling schedules (Figure 2-3) show that, in a typical outage, operations could account for 68% of the critical path hours. During the actual outage, this figure dropped to 55%, mainly because additional work not anticipated during a typical outage was work by maintenance personnel.

This same trend is illustrated and the ANO 1 refueling schedules (Figure 2-6), where the operations figures are 62 and 47% for the typical and actual outages. (These figures are derived by taking a ratio of the activities controlled by operations and maintenance in terms of hours, not manhours, to the length of the overall outage.)

Whereas maintenance has historically been the prime study area for potential improvement, operations actually hold the dominant position in critical path time allocation. To emphasize this point, the typical outage shown on the Oconee 3 refueling schedules shows that the first 24 hours (1 day) and last 162 consecutive critical path hours (6.75 days) are operations-controlled. In the actual outage, the first 24 hours and 397 hours (16.5 days) of the last 459 critical path hours (19.1 days) belonged to operations. Neither of these periods includes the very significant amount of time spent for the actual refueling midway during the outage, which ranges from 150 to 313 hours (or 6 to 13 days).

Based on these results, it is recommended that a further study be made to examine in detail the activities controlled by Operations during a typical refueling outage to determine where improvements can be made on these activities to reduce refueling outage time. Some activities that should be investigated for potential time savings are the following:

1. Filling and draining the fuel transfer canal.
2. Plant system limits that can be improved.
3. Water chemistry specifications and procedures.
4. Makeup water requirements for filling the RCS or the secondary system.
5. Surveillance test requirements.

8.3.4. Maintenance Procedures

One area in which an investment in man-hours can pay off in increased plant availability is in preparing and updating maintenance procedures. There are several common faults in procedure preparation today: FM_D-116

1. The majority of the procedures in use were prepared prior to plant startup and do not reflect operating experience gained by the station personnel or by personnel at similar plants.

2. Procedures are generally prepared and reviewed by engineering personnel. The communications gap between engineering and maintenance personnel can lead to misinterpretation. Maintenance personnel should be brought into the procedure writing and reviewing process early and should be encouraged to initiate procedural changes to reflect actual field experience.

3. Written procedures often reference other procedures, drawings, vendor manuals, etc. that cannot be taken into the reactor building due to risk of contamination. Written procedures should contain all pertinent information applicable to the task.

4. Procedures are frequently too rigid. Where alternate procedures are acceptable for accomplishing a task or a portion of a task, the maintenance

personnel should be able to proceed on the alternate without requiring extensive procedural changes. Where potential problems are known to exist, a recommended recovery action should be available.

5. Procedures should be updated to reflect all equipment changes and modifications.

The methods now used at selected utility plants to update procedures, instruction manuals, drawings, and other documents relating to equipment operation and maintenance should be studied. It is expected that this study would produce several recommendations:

1. More efficient and accurate methods of documenting changes.
2. A method of translating documented changes and information from operating experience into the working files of procedures.
3. A formal procedure to ensure that modifications and changes from any source (in-house, vendor, NSS supplier) would be collected and included in the procedure-update system.

8.3.5. Training

Maintenance personnel seldom receive adequate training. The inaccessibility of the plant during operation precludes inplant training during operation. The division between construction and plant personnel generally precludes "hands-on" training during construction, and vendors are unwilling to commit funds for adequate training centers or equipment due to the limited market potential.

What training _is_ available is generally of an academic type — slides, films, lectures, etc. The hands-on portion of the training is generally on-the-job training during an outage. This delays the work in progress and often results in unncessary radiation exposure if experienced workmen serve as instructors and can result in equipment damage if the trainee is simply "learning by doing."

Several methods should be considered to alleviate these problems: FM-536

1. Investigate facilities available from vendors and determine scope of training facilities available or that can be made available at reasonable cost.

2. Set up in-house training using existing spare parts and existing tooling. Where tools cannot be decontaminated at reasonable cost, obtain additional tooling. Many work items can be simulated:

   a. CRDM operations (coupling, uncoupling, disassembly and assembly, venting, removal, etc.).

   b. Tensioner operations (tensioning, detensioning, assembling, disassembling, adjusting, etc.).

   c. Incore detector operations (removal/replacement).

   d. Pressurizer operations (heater bundle removal/replacement, spray nozzle removal/replacement).

   e. Vent valve operations (install, remove, check).

   f. Pump operations (seal removal/replacement, assembly/disassembly, rotaing assembly removal, replacement assembly, disassembly.

   g. Valve operations, assorted types and sizes (operator adjustment, packing removal/replacement).

   Other work items may be added; this list is intended to illustrate examples only.

3. Fabricate mockups of major work items as realistically as possible. In addition to the operations listed above the following should be considered:

   a. OTSG operations (tube plugging, manway removal, orifice adjustments).

   b. Internals operations (removal/replacement, rigging assembly/disassembly). This would probably require scale models rather than full-sized mockups.

4. Combine the tasks described above with vendors and other utilities operating similar plants in a permanent facility or in portable form for transporting from one utility location to another to use in training programs.

5. The use of video tapes of actual refueling and maintenance activities is a potentially powerful training tool. These are particularly adaptable to classroom training since the lecturer can stop the action, discuss correct or incorrect procedures, and proceed at will. The use of tapes with carefully edited narratives is another source of valuable training material. Tapes of many refueling/maintenance activities exist, and these should be

expanded to provide a complete library of all important activities for training and viewing by maintenance personnel prior to refueling/maintenance activities.

It is recommended that training procedures at selected utilities be studied and a training program using the most beneficial methods of those discussed above be prepared to complement the existing utility program without excessive duplication.

8.3.6. Plant Startup

It is recommended that the startups of several plants of similar design be investigated to identify factors that have strong positive and negative effects on the length of time required for plant startup.

It has long been recognized that some plants have a very short and efficient startup, whereas other plants of similar design are continually delayed and have extended startups. The contributing factors to the gross differences in startup periods, and thus the costs of startup, can be defined by detailed study of various aspects of the startup. Beginning even at the initial construction planning stage, decisions are made that result in the plant being delayed during the startup stage. If the aspects of plant startup that have the greatest influence over the length of the startup can be controlled from the initial construction planning stage (i.e., front-end control), the length of the startup can be controlled. Even in plants with lengthy startups, isolated aspects of these startups are highly efficient and, if those aspects could be consolidated into a single startup operation, increased efficiency could be obtained.

The study would consist of startup data evaluation, data analysis, and the development of an optimized standard plant startup plan. The majority of the work would be performed by personnel deployed to the plant sites. The remainder of the work would be performed as supporting efforts by home office technical personnel and by the technical support required of the utility. The study objectives are as follows:

1. Identify the aspects of plant startup that have strong influences on the duration of the startup.

2. Identification of sound methods to achieve front-end control of the highly influential aspects of plant startup.

3. Demonstrate the influence of each of the aspects by application during a plant startup.
4. Develop an optimized standard plant startup plan.
5. Implement the startup plan with a utility to demonstrate the potential of in-depth startup planning.

Table 8-1. Statistical Data on Past Refueling Outages for Nuclear Power Plants Greater than 400 MWe

Commercial operation, date	Power, MWe	NSS supplier	Plant name	Refueling outage date	Performance ranking	Outage time Hours	Outage time Days
4/20/73	490	W	Point Beach 2	Oct-Dec 74	1	693.7	29
5/1/73	788	W	Surry 2	Apr-May 75	2	860.8	36
1/1/68	430	W	San Onofre	Mar-Apr 75	3	959.0	40
3/7/71	665	W	Robinson 2	Oct-Dec 75	4	961.9	40
9/2/74	792	B&W	TMI-1	Mar-May 77	5	1031.9	43
12/5/73	530	W	Prairie Island 1	Apr-May 77	6	1076.1	44
1/1/68	540	W	Conn. Yankee	May-Jul 77	7	1076.3	45
3/7/71	665	W	Robinson 2	Nov-Jan 77	8	1092.5	46
9/7/73	666	W	Turkey Point 4	May-Jul 76	9	1116.2	47
5/1/73	788	W	Surry 2	May-Jul 76	10	1173.4	49
12/21/70	490	W	Point Beach 1	Nov-Jan 76	11	1187.5	49
4/20/73	490	W	Point Beach 2	Apr-May 77	12	1198.6	50
3/7/70	470	W	Ginna	Mar-Apr 75	13	1224.5	51
12/21/70	490	W	Point Beach 1	Nov-Dec 76	14	1291.3	54
12/28/72	760	W	Maine Yankee	Jun-Oct 74	15	1356.0	57
12/16/74	871	B&W	Oconee 3	Oct-Dec 76	16	1357.5	57
6/7/74	525	W	Kewaunee	Feb-Mar 76	17	1370.8	57
5/15/73	871	B&W	Oconee 1	Feb-Apr 75	18	1393.6	58
12/21/74	530	W	Prairie Island 2	Nov-Jan 77	19	1439.0	59
12/5/73	530	W	Prairie Island 1	Mar-May 76	20	1439.5	60
12/14/72	666	W	Turkey Point 3	Oct-Dec 75	21	1442.2	60
1/1/68	540	W	Conn. Yankee	Jun-Aug 76	22	1457.5	61
8/27/75	1090	W	Cook 1	Jan-Mar 77	23	1483.7	62
9/9/74	871	B&W	Oconee 2	Jun-Aug 76	24	1491.8	62
9/7/73	666	W	Turkey Point 4	Mar-May 75	25	1536.4	64
12/19/74	836	B&W	Arkansas 1 Unit 1	Feb-Mar 77	26	1548.4	65
4/20/73	490	W	Point Beach 2	Oct-Dec 74	27	1566.3	65
12/14/72	666	W	Turkey Point 3	Dec-Feb 77	28	1627.0	68
12/22/72	788	W	Surry 1	Oct-Dec 75	29	1651.6	68
3/7/70	470	W	Ginna	Feb-Apr 76	30	1668.8	70
12/14/72	666	W	Turkey Point 3	Oct-Dec 74	31	1744.1	73
6/20/74	443	CE	Fort Calhoun	Nov-Jan 77	32	1768.2	74
12/31/73	850	W	Zion 1	Feb-May 76	33	1978.4	82
9/17/74	850	W	Zion 2	Jan-Apr 77	34	1986.8	83
6/20/74	443	CE	Fort Calhoun	Feb-May 75	35	2160.4	90
5/8/75	845	CE	Calvert Cliffs	Jan-Apr 77	36	2161.9	90
9/2/74	792	B&W	TMI-1	Feb-May 76	37	2300.1	96
12/22/72	788	W	Surry 1	Nov-Feb 77	38	2366.1	99
12/22/72	788	W	Surry 1	Oct-Feb 75	39	2411.7	100
12/28/72	760	W	Maine Yankee	Jun-Oct 74	40	2513.0	104
12/31/71	720	CE	Palisades	Dec-May 76	41	3380.5	141
7/15/73	871	B&W	Oconee 1	Oct-Mar 75	42	3427.3	143
1/1/68	430	W	San Onofre	Nov-Mar 77	43	3625.0	151
8/?/73	864	W	Indian Point 2	Jun-Oct 76	44	3637.5	151

Note: These statistics are based on data reported by the utility industry in NU Reg. -0020 (Gray Book) for the period from June 1974 through May 1977.

9. SUMMARY OF POTENTIAL BENEFITS

9.1. Introduction

This section summarizes the results of the Phase 1 study and includes the following:

1. The ideal refueling outage critical path schedules for Oconee 3 and ANO 1 showing the activities, durations, and the length to which a typical outage could be reduced by incorporating the recommendations. In addition, the resultant manpower and man-Rem exposure reductions are included.
2. Outage time savings, replacement power cost savings, and barrels of oil conserved for the recommendations proposed to DOE for prototype funding where plans are now underway to implement these recommendations at Duke Power Co. under Phase 2 of the DOE project.
3. Generic existing plant modifications and resultant time savings.

9.2. Oconee 3 Summary

9.2.1. Refueling Outage Time Savings

The Oconee 3 pre-outage and as-built schedules are presented in section 2. A typical critical path schedule has been derived showing what should have occurred if abnormal activities and delays were deleted from the as-built schedule.

The activities in the typical schedule were evaluated to determine outage time savings if all the applicable recommendations presented in the preceeding sections were implemented. The end result is an ideal critical path schedule showing (1) the ideal critical path activities for the NSS and their durations, and (2) the length to which a typical outage could be reduced by incorporating the recommendations.

The ideal refueling outage schedule for Oconee 3 is shown in Figure 9-1. In developing this schedule, the following additional assumptions were made:

1. The assumptions used in developing the typical schedule are applicable; i.e.,

   a. Activities performed by the Operations group were conducted 24 hours per day, 7 days per week.

   b. Activities performed by the Maintenance group were conducted with two 10-hour shifts, 6 days per week. Shifts run from 0700 to 1700 and 1600 to 0200.

   c. The refueling cycle was normal; i.e., it is not necessary to completely defuel and refuel the reactor.

   d. The time between the Maintenance shifts can be used for HP surveys., radiography, etc.

2. All DOE recommendations are incorporated. It is important to note that the estimate of time savings for each recommendations is cumulative only if it affects the critical path in the ideal schedule. Estimates of time savings for noncritical-path recommendations are not cumulative. However, when evaluated separately, these recommendations will result in improved personnel efficiency, faster processing of work orders and job assignments, elimination of wasted time, etc.

3. All equipment is operational throughout the outage.

4. Personnel errors cause no loss of time for the activities in the critical path.

5. All required spare parts are on site for the work planned.

6. No major facility changes are scheduled.

7. Refueling is conducted with a main bridge, an auxiliary bridge, two transfer tubes, and a multi-function mast.

8. Assume that the ideal schedule starts during midweek to include weekend effects on the schedule.

The results of the ideal schedule show that a significant improvement in plant availability is attainable. By incorporating the recommendations and taking credit for the time savings, a typical outage length could be reduced to 21 days for the NSS from plant shutdown to "generator on line," with an expected average annual outage time reduction of 12 days. A summary of Figure 9-1 is presented below:

	Days				Expected annual savings, days
	Scheduled	Actual	Typical	Ideal	
Oconee 3	45	56	33	21	12

9.2.2. Refueling Outage Activity Manpower and Radiation Exposure Reduction

The Oconee 3 as-built activity manpower and radiation exposure data for major refueling activities are presented in section 2.1.5. Based on these data, an evaluation was performed to determine outage activity manpower reduction and the resultant reduction in radiation exposure if all the applicable recommendations presented in the preceding sections were implemented.

Based on routine maintenance activities associated with refueling (RV head and internals preparation and movement, refueling, and head and internals installation, including stud tensioning and CRDM coupling), the savings in manpower is approximately 1510 man-hours. The resultant radiation exposure savings is approximately 14 man-Rem compared to the actual exposure of 28.7 man-Rem for these activities. This represents a 48% reduction for routine refueling activities and a 9% reduction for the entire refueling outage. An additional 16% or more reduction in radiation exposure for the entire outage can be achieved by minimizing unexpected delays and extraneous activities in the RB.

9.3. ANO 1 Summary

9.3.1. Refueling Outage Time Savings

The discussion in section 9.2.1 for Oconee 3 also applies to this section. There is one major difference, i.e., the assumption that refueling is conducted with a main bridge, an auxiliary bridge, two transfer tubes, and a multi-function mast does not apply to ANO 1 since there is only one transfer tube at that plant. This assumption should be revised for ANO 1 as follows: Refueling is conducted with a main bridge, an auxiliary bridge, one transfer tube, and a multi-function mast.

Figure 9-3 shows the ideal refueling outage schedule for ANO 1. The results of the ideal schedule show that a significant improvement in plant availability is attainable. By incorporating all the recommendations and taking credit for the time savings, a typical outage length could be reduced to 22 days for the NSS from plant shutdown to "generator on line," with an expected average annual outage time reduction of 10 days. A summary of Figure 9-3 is presented below:

	Days				
	Schedule	Actual	Typical	Ideal	Expected annual savings, days
ANO 1	48	65	32	22	10

9.3.2. Refueling Outage Activity Manpower and Radiation Exposure Reduction

In section 2.2.5, the ANO 1 as-built activity manpower and radiation exposure data for major refueling activities are presented. Based on these data, an evaluation was made to determine outage activity manpower reduction and the resultant reduction in radiation exposure if all the applicable recommendations presented in the preceding sections were implemented.

Based on routine maintenance activities associated with refueling (RV head and internals preparation and movement, refueling, and head and internals installation, including stud tensioning and CRDM uncoupling), the savings in manpower is approximately 717 man-hours. The resultant radiation exposure savings is approximately 7 man-rem compared to the actual exposure of 28.3 man-Rems for these activities. This represents a 24% reduction for routine refueling activities and a 4% reduction for the entire refueling outage. A greater reduction in man-rem exposure for the entire outage can be achieved by minimizing unexpected delays and extraneous activities.

9.4. Summary of Recommendations for Prototype Development and Demonstration

9.4.1. Oconee 3

Recommendations believed to have significant benefits to the industry were evaluated in detail to determine their applicability and the cost benefit for a utility implementing them. Recommendations having significant benefit have been proposed to DOE for prototype development and demonstration at Duke Power Co. under Phase 2 of DOE Refueling Maintenance Outage Improvement Programs. Plans are now underway for implementation of all items in Table 1-2 at the Oconee Nuclear Station.

By implementing those recommendation impacting the refueling critical path, a savings of an estimated 5 critical path days could be realized. This time savings represents replacement energy cost savings of approximately $2.4 million per unit to Duke Power Company. If the replacement power were from an oil-fired unit, the oil savings would be approximately 183,060 barrels.

By implementing the other recommendations in Table 1-2, i.e., item 1, 4, 7, and 13, additional savings of an estimated 7 days (with an equivalent savings of $3,375,000 replacement energy cost and 257,175 barrels of oil conserved) could be realized during the course of an outage. As outages become more complex, continuous shifting and reassignment of jobs and priorities will usually result, increasing the importance of these recommendations. Recommendations such as item 1 in Table 1-2 (computerized outage management and scheduling assistance) will increase in importance as an effective tool in reducing manhours (resulting in personnel availability), reducing personnel radiation exposure, allowing more jobs to be accomplished within that time frame without extending the critical path time and permitting more jobs to be done by the more experienced personnel. As outage complexity increases, more jobs are being done.

9.4.2. ANO 1

At ANO 1, the need to implement the prototype recommendations listed for Oconee 3 was confirmed. Once the prototype work is concluded at Oconee, it is believed that those items will be equally applicable to ANO 1. The major improvements recommended for further prototype development and demonstration at ANO 1 relate to further studies of facilities and operational improvements. Examples of these improvements include the following:

1. Reduced Refueling Frequency — Maximum reduction of refueling outage time is achievable through the adaptation of extended fuel cycles for the operation of the plant. Compared to a current fuel cycle time of 12 months, going to an 18-month cycle could increase operations by 33 to 55 days full power every three years, and going to a 24-month cycle could increase operations by 33 to 55 full power days every two years. If other maintenance work can be controlled to avoid unscheduled downtime, extended fuel cycles are the most significant change in operations to be pursued in depth to reduce refueling outage time; such a pursuit is recommended to ANO. FM-823

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4. Improvements in stud handling and tensioning equipment to obtain a more rapid operation; this would include modifications to the air supply system, increasing the hoist speed and provisions for motorized trolleys (same as for Oconee 3). FM-189

5. Improvements in design of the Byron-Jackson reactor coolant pump seal maintenance tool; this would include development of a more precise lift control among other items. FM_D-221

9.5. Generic Existing Plant Benefits

Implementation of recommendations affecting existing generic plants have the potential for providing the greatest cost benefits in terms of increasing the total industry operating plants' availability, and in turn, providing for the greatest reduction in the fossil fuel resources consumption.

Although this study was limited to two specific B&W plants of the 177-FA design, the findings can be extrapolated for applicability to other nuclear plants of similar design and construction. A summary of generic recommendations that have the potential for providing the greatest outage savings to current operating plants and to those plants presently in the design and construction stages has been prepared from the generic sections 4.5, 5.3, and 6.3 of this report. This summary is shown in Table 9-1, which also includes the expected benefits of each recommendation as it applies to a single plant and to multiple B&W design units expected on line. Both improvements directly reducing refueling critical path activities (FM) and other improvements (FM_D) are included in Table 9-1. Although all of these recommendations are believed to save outage time, their individual time savings are not cumulative. Critical path time savings will generally vary from one outage to the next for a given plant. However, based on a refueling outage similar to the Oconee 3 and ANO-1 plants as investigated in this study, it can be estimated that approximately 9 to 10 days could be saved through the implementation of the critical path recommendations listed in Table 9-1. If all generic recommendations are implemented by a utility, a significant additional number of outage hours could be saved in avoiding delays. This in turn would aid in reducing the total refueling outage length, and reduce manhours and man-Rem exposure.

The time savings of 9 to 10 critical path days, if applied to 1000-MW plants, represents an annual replacement energy cost savings of approximately $5,000,000 per unit. If the replacement power were from an oil-fired unit, the oil savings would be approximately 381,000 barrels. By 1985, 23 B&W nuclear plants, which are now either operating or in the construction and design stages, will be in commercial operation. The effect of these generic recommendations to this number of plants will increase the expected benefit to 207 to 230 outage days per year saved, with an equivalent savings of approximately $115,000,000 replacement energy cost and 8,760,000 barrels of oil conserved.

Table 9-1. Generic Existing Plant Benefits Summary

Recommendation	Single-plant annual implementation benefit			1978 annual implementation benefit, 8 plants			1985 annual implementation benefit, 23 plants		
	Outage reduction time, h	1000-MW plant replacement power value, $	1000-MW plant fuel conservation value, barrels of oil	Outage reduction time, h	1000-MW plant replacement power value, $	1000-MW plant fuel conservation value, barrels of oil	Outage reduction time, h	1000-MW plant replacement power value, $	1000-MW plant fuel conservation value, barrels of oil
1. Design and feasibility evaluations for further improvements (sec 6.1-10)	72	1,500,000	114,300	576	12,000,000	914,400	1,656	34,500,000	2,628,900
2. *Wet eddy-current testing (sec 4.5-1)	50	1,041,667	79,375	400	8,333,333	635,000	1,150	23,958,332	1,825,625
3. Training of operations personnel (sec 4.5-7)	30	625,000	47,625	240	5,000,000	381,000	690	14,375,000	1,095,375
4. Training of maintenance personnel (sec 4.5-8)	30	625,000	47,625	240	5,000,000	381,000	690	14,375,000	1,095,375
5. *Fuel transfer canal water improvement (sec 6.1-1)	24	500,000	38,100	192	4,000,000	304,800	552	11,500,000	876,300
6. *Tool issue room in RB (sec 5.2-1)	20	416,667	31,750	160	3,333,333	254,000	460	9,583,333	730,250
7. *Use of multifunction mast (sec 6.1-2)	20	416,667	31,750	160	3,333,333	254,000	460	9,583,333	730,250
8. *Fuel mechanical assessment & equipment modification (sec 6.1-3)	20	416,667	31,750	160	3,333,333	254,000	460	9,583,333	730,250
9. *Plenum movement with FTC dry (sec 4.5-2)	12	250,000	19,050	96	2,000,000	152,400	276	5,750,000	438,150
10. *Heavy lift rigging improvement (sec 6.1-6)	12	250,000	19,050	96	2,000,000	152,400	276	5,750,000	438,150
11. *Finger system on mast (sec 6.2-2)	8	166,667	12,700	64	1,333,333	101,600	184	3,833,333	292,100
12. *Stud handling equipment improvement (sec 6.1-4)	8	166,667	12,700	64	1,333,333	101,600	184	3,833,333	292,100
13. *Canal seal improvement (sec 6.1-8)	8	166,667	12,700	64	1,333,333	101,600	184	3,833,333	292,100
14. *Latch box assembly procedure revision (sec 4.5-5)	4	83,333	6,350	32	666,667	50,800	92	1,916,667	146,050
15. *Refueling TV addition (sec 6.1-7)	4	83,333	6,350	32	666,667	50,800	92	1,916,667	146,050
16. *Catwalk around tripod (sec 5.3-3)	3	62,500	4,763	24	500,000	38,100	69	1,437,500	109,538
17. *Precut canal seal plate gasket (sec 4.5-6)	2	41,667	3,175	16	333,333	25,400	46	958,333	73,025
18. *Use of air motors on stud tensioner (sec 5.3-2)	12	250,000	19,050	96	2,000,000	152,400	276	5,750,000	438,150
19. *Fuel shuffle to load boxed in fuel assemblies (sec 4.5-3)	12	250,000	19,050	96	2,000,000	152,400	276	5,750,000	438,150
20. Computerized outage management (sec 6.1-9)	72	1,500,000	114,300	576	12,000,000	914,400	1,656	34,500,000	2,628,900
21. Extra building adjacent to RB (sec 5.3-6)	36	750,000	57,150	288	6,000,000	457,200	828	17,250,000	1,314,450
22. *CRDM service and tooling improvement (sec 6.1-12)	13	270,833	20,638	104	2,166,667	165,100	299	6,229,167	474,663
23. RCP maintenance tooling (sec 6.1-11)	10	208,333	15,875	80	1,666,667	127,000	230	4,791,667	365,125
24. CRDM service structure access (sec 6.1-13)	8	166,667	12,700	64	1,333,333	101,600	184	3,833,333	292,100
25. Support facilities in RB (sec 5.3-11)	6	125,000	9,525	48	1,000,000	76,200	138	2,875,000	219,075
26. *Head insulation improvement (sec 6.1-5)	8	166,667	12,700	64	1,333,333	101,600	184	3,833,333	292,100
27. Lift in fuel transfer canal (sec 6.2-6)	4	83,333	6,350	32	666,667	50,800	92	1,916,667	146,050

*These items directly impact the refueling critical time.

Figure 9-1, Sheet 1. Oconee 3 Ideal Refueling Outage Schedule

REFUELING SCHEDULES

Based on the DOE-Sponsored Reactor Availability Study

Notes for SCHEDULED

1. Pre-outage schedule is estimated Duke schedule for Oconee 3 outage prior to shutdown.

Notes for AS-BUILT

1. AS-BUILT schedule is official Duke schedule as it actually occurred for the Oconee 3 outage.

Notes for TYPICAL

1. This schedule is an estimate by the DOE team of what should have occurred at Oconee 3 if delays and SSHT repair work were deleted from the AS-BUILT schedule and the following assumptions were made:

   a. Activities performed by the operations group conducted 24 hours/day, 7 days/week (noted by asterisks (*).

   b. Critical path activities performed by the maintenance group conducted on two 10-hour shifts/day, 6 days/week; shifts run from 0700 to 1700 and 1600 to 0200.

   c. Equilibrium refueling cycle.

   d. Time after the 20-hour work day by maintenance personnel can be used for HP surveys, radiography, etc.

   e. This schedule does not reflect standby work performed as necessary by Maintenance on Sundays to prevent schedule delays.

Notes for IDEAL

1. The assumptions listed under TYPICAL apply.

2. The IDEAL schedule is based on the following:

   a. Incorporation of all DOE recommendations.

   b. All equipment operational throughout the outage.

   c. No personnel errors causing loss of time on the critical path.

   d. All required spare parts are on site for the work planned.

   e. No major facility changes are scheduled for the outage.

   f. Refueling is conducted with a main bridge, an auxiliary bridge, two transfer tubes, and a combined CRDM/fuel assembly mast.

3. Assume that the IDEAL schedule starts on a weekday.

LEGEND

1. Five-hour break in maintenance activities due to shift change: ▒▒▒

2. Sundays not worked by maintenance personnel: //////

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Figure 9-1, Sheet 3. Oconee 3
Ideal Refueling
Outage Schedule

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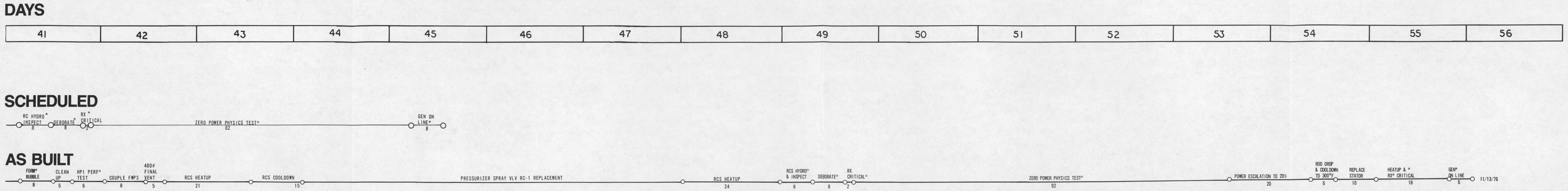

Figure 9-1, Sheet 4. Oconee 3 Ideal Refueling Outage Schedule

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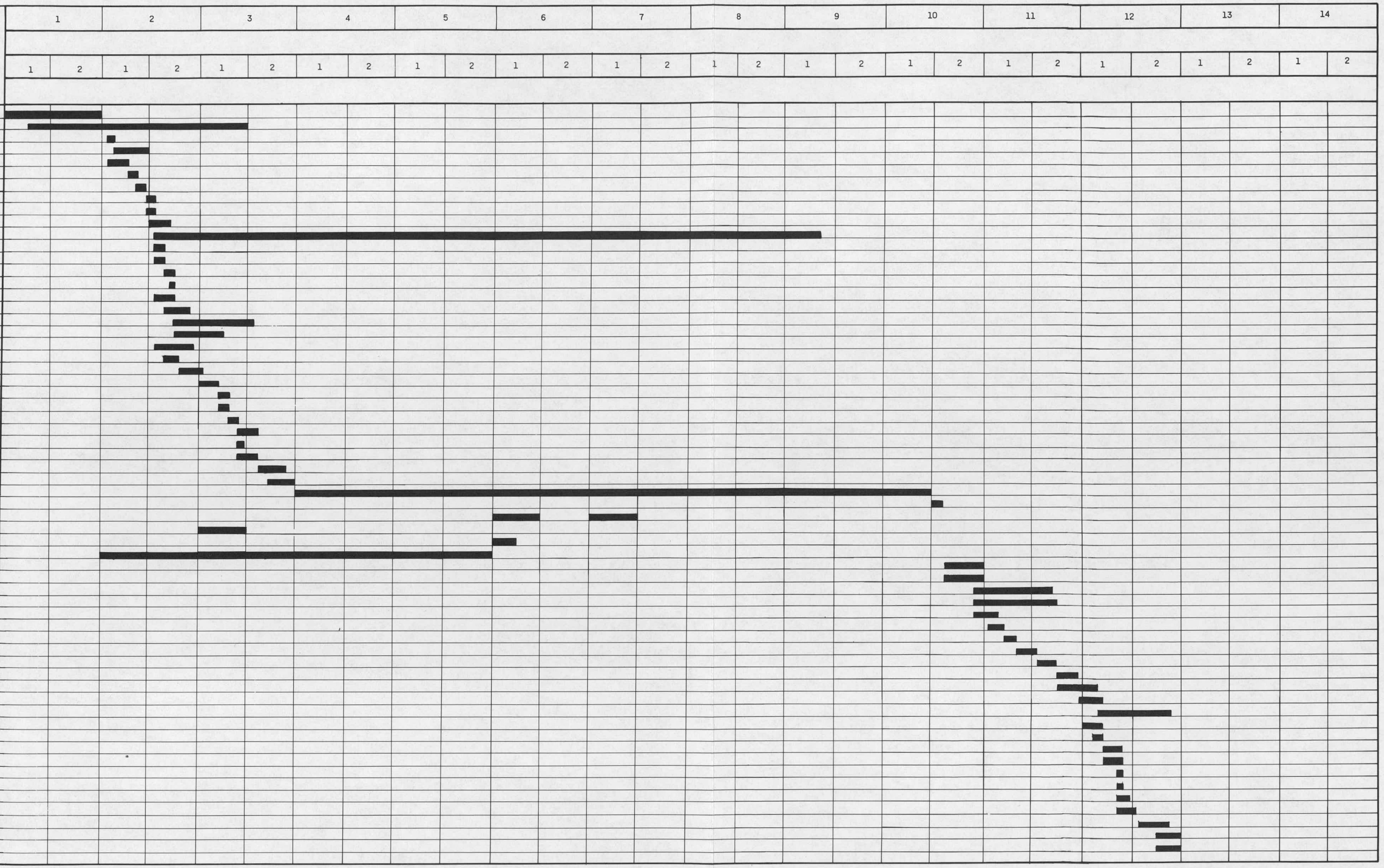
Figure 9-2. Oconee 3 Ideal Primary Refueling Activities

ACTIVITY	MANPOWER	RADIATION (MR/HR)	ELAPSED TIME (HOURS)
1 SHUTDOWN-COOLDOWN	OPS		24
2 * DECON-CHECKOUT EQUIP., PM EQUIP.	8H	5	45
3 OPEN EQUIP. HATCH	4M	3	1
4 MOVE EQUIP. INTO RX BLDG.	2M	3	8
5 REMOVE MISSILE SHIELDS & GRATING	P, 2M, F	5	4
6 * INSTALL CANAL SEAL PLATE	3M, F	35	2
7 * REMOVE HEAD INSULATION	P, 3M	35	2
8 MOVE EQUIP. INTO CANAL	P, 4M, F	15	2
9 * UNCOUPLE APSR DRIVES	2M, OPS	60	2
10 * REMOVE OTSG MANWAYS	P, 2M	30	5
11 OTSG EDDY CURRENT INSPECTION	3T	10	152
12 DISCONNECT CRDM ELEC. & INST.	2E, 2I	60	2
13 REMOVE CRDM COOLING WATER LINES	P, 2M	20	2
14 * REMOVE TRANSFER TUBE BLANKS	2M	30	2
15 INSTALL CANAL DRAIN BLANKS	1M	30	1
16 DRAIN RCS TO MAINTENANCE LEVEL	OPS		4
17 REM. PZR CODE RELIEFS	2M	20	5
18 * REMOVE RCP SEALS & INSTALL BLANKS	8M, F	3	16
19 WITHDRAW INCORES	3I	35	10
20 * UNCOUPLE CRDM	2M, OPS	60	8
21 * DETENSION HEAD	6M, F	35	4
22 * REMOVE & PARK STUDS, INSTALL GUIDE STUDS	4M	45	5
23 * RIG & REMOVE HEAD	P, 4M, F	35	4
24 * RIG FOR INDEXING FIXTURE & PLENUM	P, 4M, F	3	2
25 * ESTABLISH RX BLDG. INTEGRITY; PRELIM. EQUIP. HATCH TEST	2M	3	2
26 * INSTALL INDEXING FIXTURE, REMOVE PLENUM & INDEX FIX.	P, 4M, F	200	2
27 CHROMATE STUD HOLES, INSTALL SEAL PLUGS	4M	40	4
28 * EXERCISE INTERNALS VENT VALVES, INSPECT RV FLANGE	2M, F	40	1
29 CLEAN CANAL	4H	15	4
30 * FLOOD CANAL	OPS		5
31 FINAL CHECKOUT FUEL HANDLING EQUIP.	OPS	5	6
32 * REFUELING	OPS	5	156
33 FUEL VERIFICATION	OPS	5	2
34 REBUILD RCP SEALS	2M, F	100	20
35 * CLEAN & LUBRICATE STUDS	2M	60	10
36 CLEAN HEAD FLANGE & REPLACE HEAD O-RINGS	4M, F	600	5
37 INSERVICE INSPECTIONS	2T	600	80
38 INSTALL OTSG MANWAYS	P, 2M, F	30	8
39 * DRAIN & DECON CANAL	4H	250	8
40 INSERT INCORES	3I, F	35	15
41 * INSTALL RCP SEALS	8M, F	3	16
42 REMOVE STUD HOLE SEAL PLUGS, PUMP CHROMATE	4M	40	5
43 * CLEAN & LUBRICATE STUD HOLES	4M, F	40	3
44 CLEAN & INSPECT RV FLANGE	2M, F	40	2
45 * RIG & INSTALL INDEXING FIX. PLENUM, &REMOVE FIXTURE	P, 4M, F	200	4
46 RIG & INSTALL HEAD	P, 4M, F	35	4
47 * REMOVE GUIDE STUDS, INSTALL STUDS	4M	45	4
48 * COUPLE CRDM	2M, OPS	60	8
49 * TENSION HEAD STUDS	6M, F	35	6
50 CONNECT CRDM ELEC. & INST.	2E, 2I	60	12
51 FILL RCS TO COUPLE APSR	OPS		4
52 CONNECT CRDM COOLING WATER	P, 2M	20	2
53 * COUPLE APSR	2M, OPS	60	4
54 * INSTALL HEAD INSULATION	P, 3M	35	4
55 * RAISE CANAL SEAL PLATE	2M	35	1
56 REMOVE CANAL DRAIN BLANKS	1M	30	1
57 * INSTALL TRANSFER TUBE BLANKS	3M	30	4
58 MOVE EQUIP. OUT OF CANAL	P, 3M	15	4
59 INSTALL PZR. CODE RELIEFS	P, 2M	20	5
60 INSTALL MISSILE SHIELDS	P, 2M, F	5	4
61 MOVE EQUIP. OUT OF RX, FINAL CLOSURE OF EQUIP. HATCH	4M	3	5



LEGEND:

M - MECHANICAL
E - ELECTRICAL
I - INSTRUMENTATION
F - FOREMAN
P - POLAR CRANE
H - HELPER
OPS - OPERATIONS
T - TECHNICAL

*DENOTES ACTIVITIES WHERE TIME AND/OR MANPOWER AND EXPOSURE CAN BE REDUCED ASSUMING THAT ERDA TEAM RECOMMENDATIONS WERE IMPLEMENTED.

11. THIS ACTIVITY ELAPSED TIME DOES NOT INDICATE ANY TUBE REPAIRS BUT INSPECTION ONLY. IF TUBE WORK IS NECESSARY, THE WORK CAN BE DONE CONCURRENT WITH REACTOR REASSEMBLY AND WILL NOT EXTEND THE PRIMARY SYSTEM ACTIVITIES SIGNIFICANTLY.

Figure 9-3, Sheet 1. ANO Unit 1 Ideal Refueling Outage Schedule

REFUELING SCHEDULES

Based on the DOE-Sponsored Reactor Availability Study

Notes for SCHEDULED

1. Pre-outage schedule is estimated ANO Unit 1 schedule for outage prior to shutdown.

2. SCHEDULED does not reflect refueling critical path (replacement of plant station computer was the scheduled critical path item). Time lapses between procedures are indicated with dashed lines and were used to schedule maintenance tasks other than critical path items.

Notes for AS-BUILT

1. AS-BUILT schedule is official ANO Unit 1 schedule as it actually occurred for the refueling outage.

Notes for TYPICAL

1. This schedule is at estimate by the DOE team of what should have occurred at ANO 1 if delays were deleted from the AS-BUILT schedule and the following assumptions were made:

   a. Activities performed by the operations group conducted 24 hours/day, 7 days/week.

   b. Critical path activities performed by the maintenance group conducted on two 10-hour shifts/day, 6 days/week; shifts run from 0700 to 1700 and 1600 to 0200.

   c. Equilibrium refueling cycle.

   d. Time after the 20-hour work day by maintenance personnel can be used for HP surveys, radiography, etc.

   e. This schedule does not reflect standby work performed as necessary by Maintenance on Sundays to prevent schedule delays.

Notes for IDEAL

1. The assumptions listed under TYPICAL apply.

2. The IDEAL schedule is based on the following:

   a. Incorporation of all DOE recommendations.

   b. All equipment operational throughout the outage.

   c. No personnel errors causing loss of time on the critical path.

   d. All required spare parts are on site for the work planned.

   e. No major facility changes are scheduled for the outage.

3. Assume that the IDEAL schedule starts on a weekday.

LEGEND

1. Five-hour break in maintenance activities due to shift change: ▒▒▒▒

2. Sundays not worked by maintenance personnel: ////////

3. Miscellaneous activities unrelated to primary system: — — — — —

Figure 9-3, Sheet 2. ANO Unit 1
Ideal Refueling
Outage Schedule

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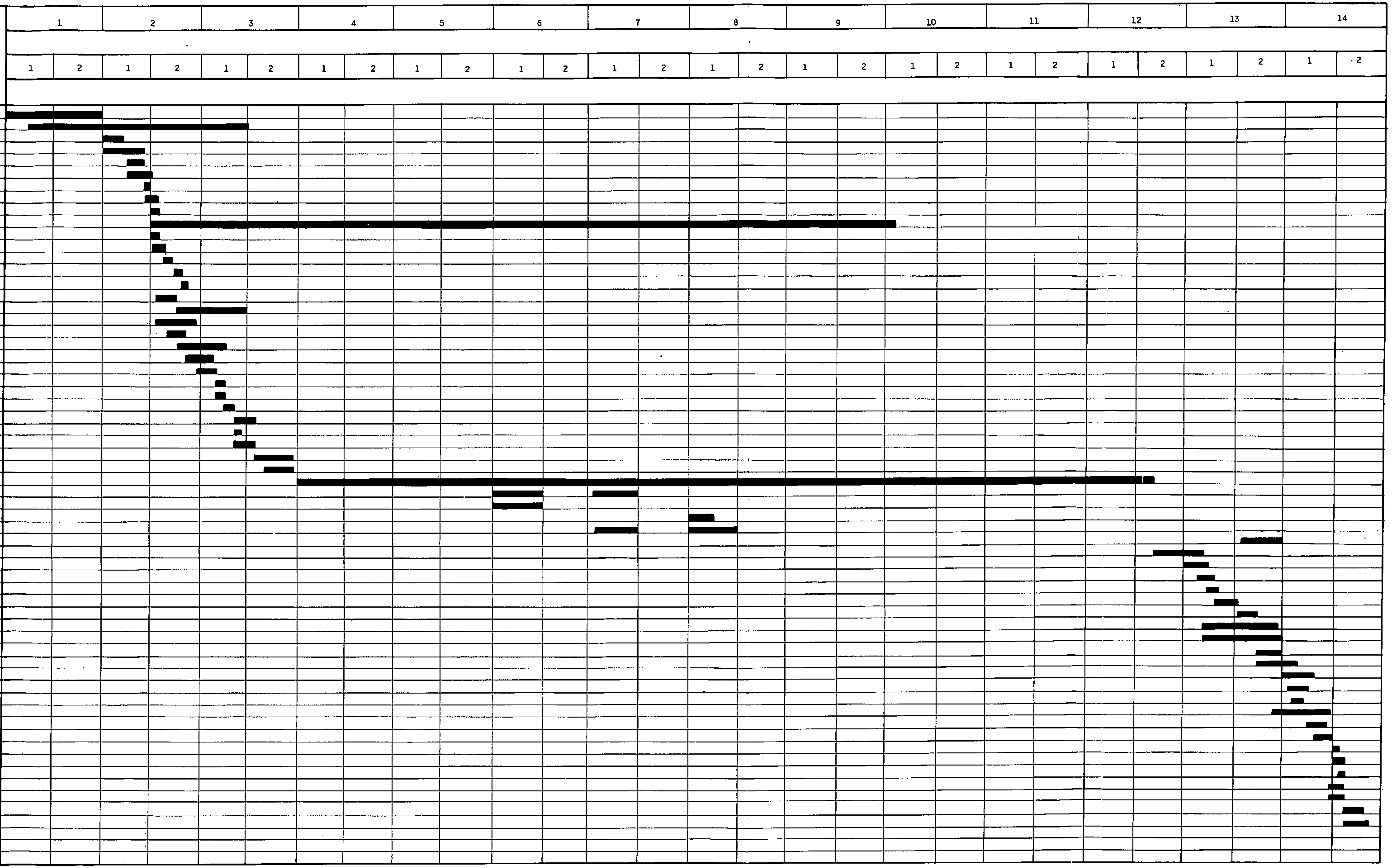
Figure 9-3, Sheet 3. ANO Unit 1
Ideal Refueling
Outage Schedule

Figure 9-3, Sheet 4. ANO Unit 1 Ideal Refueling Outage Schedule

Babcock & Wilcox

Figure 9-4. ANO Unit 1 Ideal Primary Refueling Activities

ACTIVITY	MANPOWER	RADIATION MR/HR.	ELAPSED TIME (HOURS)
1 SHUTDOWN-COOLDOWN	OPS		24
2 * DECON-CHECKOUT EQUIP., PM EQUIP.	8H	5	45
3 REMOVE MISSILE SHIELDS	P,2M,F	3	4
4 * OPEN EQUIP.HATCH-MOVE EQUIP. INTO RX.	2M	3	8
5 REMOVE CRDM VENTILATION	2M	15	3
6 * REMOVE OTSG MANWAYS	P,2M	50	5
7 MOVE EQUIP. INTO CANAL	P,4M,	20	1
8 * UNCOUPLE APSR	2M,OPS	60	2
9 DISCONNECT CRDM ELEC. & INST.	2E,2I	60	2
10 EDDY CURRENT OTSG INSPECTION	3T	5	152
11 * INSTALL CANAL SEAL PLATE	3M,F	45	2
12 REMOVE HEAD INSULATION	P,3M	45	2
13 * REMOVE TRANSFER TUBE BLANK	P,3M	30	2
14 REMOVE CRDM COOLING WATER LINES	P,2M	15	2
15 INSTALL CANAL DRAIN BLANKS	1M	30	1
16 DRAIN RCS TO MAINTENANCE LEVEL	OPS		4
17 * REMOVE RCP SEALS & INSTALL BLANKS	8M,F	5	16
18 * UNCOUPLE CRDM	2M,OPS	60	8
19 * DETENSION HEAD	6M,F	45	4
20 WITHDRAW INCORES	3I,F	10	10
21 * REMOVE & PARK STUDS, INSTALL GUIDE STUDS	4M	55	5
22 * RIG & REMOVE HEAD	P,4M,F	40	4
23 * RIG FOR INDEXING FIXTURE & PLENUM	P,4M,F	2	2
24 * ESTABLISH RX BLDG.INTEGRITY,PRELIM.EQUIP.HATCH TEST	2M	2	2
25 * INSTALL INDEXING FIX.,REMOVE PLENUM & INDEXING FIX.	P,4M,F	250	2
26 CHROMATE STUD HOLES, INSTALL SEAL PLUGS	4M	100	4
27 * EXERCISE INTERNALS VENT VALVES, INSPECT RV FLANGE	2M,F	100	1
28 CLEAN CANAL	4H	20	4
29 * FLOOD CANAL	OPS		8
30 FINAL CHECKOUT FUEL HANDLING EQUIP.	OPS	15	6
31 * REFUELING ACTIVITY & VERIFICATION	OPS-2	15	204+2
32 REBUILD RCP SEALS	2M,F	100	20
33 * CLEAN & LUBRICATE STUDS	2M	55	10
34 CLEAN HEAD FLANGE & REPLACE O-RINGS	4M,F	650	5
35 HEAD & STUD INSERVICE INSPECTIONS	2T	650	20
36 INSTALL OTSG MANWAYS	P,2M,F	50	8
37 DRAIN & DECON CANAL	4H	250	12
38 REMOVE, STUD HOLE SEAL PLUGS, PUMP CHROMATE	4M	100	5
39 CLEAN & LUBRICATE STUD HOLES	4M,F	100	3
40 CLEAN & INSPECT RV FLANGE	2M,F	100	2
41 * RIG & INSTALL INDEXING FIXTURE,PLENUM, & REMOVE FIX.	P,4M,F	250	4
42 RIG & INSTALL HEAD	P,4M,F	40	4
43 INSERT INCORES	3I,F	10	15
44 * INSTALL RCP SEALS	8M,F	5	16
45 * REMOVE GUIDE STUDS, INSTALL STUDS	4M	55	5
46 * COUPLE CRDM	2M,OPS	60	8
47 * TENSION HEAD STUDS	6M,F	45	6
48 FILL RCS TO COUPLE APSR	OPS		4
49 CONNECT CRDM COOLING WATER	P,3M	15	2
50 CONNECT CRDM ELEC. & INST.	2E,2I	60	12
51 * COUPLE APSR	2M,OPS	60	4
52* INSTALL HEAD INSULATION	P,3M	45	4
53 * RAISE CANAL SEAL PLATE	2M	45	1
54 * INSTALL TRANSFER TUBE BLANK	P,3M	30	2
55 REMOVE CANAL DRAIN BLANKS	1M	30	1
56 INSTALL CRDM VENTILATION DUCT	2M	15	3
57 MOVE EQUIP. OUT OF CANAL	P,3M	20	3
58 INSTALL MISSILE SHIELDS	P,2M,F	3	4
59 MOVE EQUIP.OUT OF RX.FINAL CLOSURE OF EQUIP.HATCH	4M	3	5



LEGEND:

M - MECHANICAL
E - ELECTRICAL
I - INSTRUMENTATION
F - FOREMAN
P - POLAR CRANE
H - HELPER
OPS - OPERATIONS
T - TECHNICAL

*DENOTES ACTIVITIES WHERE TIME AND/OR MANPOWER AND AND EXPOSURE CAN BE REDUCED ASSUMING THAT ERDA TEAM RECOMMENDATIONS WERE IMPLEMENTED.

11. THIS ACTIVITY ELAPSED TIME DOES NOT INDICATE ANY TUBE REPAIRS BUT INSPECTION ONLY. IF TUBE WORK IS NECESSARY, THE WORK CAN BE DONE CONCURRENT WITH REACTOR REASSEMBLY AND WILL NOT EXTEND THE PRIMARY SYSTEM ACTIVITIES SIGNIFICANTLY.

10. CONCLUSIONS — TOTAL BENEFITS

The results of the Phase 1 study show that a significant improvement in plant availability is attainable. By incorporating the recommendations and taking credit for the time savings, an ideal refueling outage length of 21 to 22 days for the NSS could be realized with an expected average annual outage time reduction of 10 to 12 days for each plant, implementing the recommendations provided by this study. There is a savings in manpower of 717 to 1510 man-hours for routine refueling activities only; there is also a savings of 7 to 14 man-Rem in personnel radiation exposure, which represents a 24 to 48% reduction for routine refueling activities and a 4 to 9% reduction for the entire refueling outage. An additional 16% or more reduction in radiation exposure for the entire refueling outage can be achieved by minimizing unexpected delays and extraneous activities in the RB. There is a savings in replacement energy cost in excess of $2 million/unit to Duke Power Company and a similar savings to Arkansas Power and Light. If the replacement power were from an oil-fired unit, the oil savings would be approximately 345,000 barrels.

The longer-range savings expected from the implementation of the generic recommendations will benefit both currently operating plants and plants presently in the design and construction stages. Based on the generic recommendations, it is estimated that the average annual outage will be decreased by as much as 11 days for these plants. It is estimated that by 1985, a total annual savings from 23 nuclear power plants of B&W design will be approximately 207-230 days. The savings in replacement energy cost is estimated to be $115 million. A savings in oil displaced by the improved availability of nuclear generating plants will be equivalent to 8.7 million barrels. These savings are based on an assumed nuclear operating capacity of 22,871 MWe supplied by the same 23 nuclear power plants.

The program to evaluate and improve nuclear power plant availability is a vital part of managing the nation's energy resources. Through the combined efforts of Duke, AP&L, B&W, DOE, and several major equipment suppliers, a significant reduction in outage time is being realized. The goal of the shortest outage coupled with the completion of the maximum amount of work will go a long way in improving nuclear power plant availability and reducing the dependence of the utility industry on expendable fossil fuels.

APPENDIX A

Index of Video Tapes

This appendix lists all the raw data recorded on video tapes for the Oconee 3 and ANO 1 refueling outages. The video tape effort produced approximately 36 hours (or 86,000 feet) of video tape for the Oconee 3 outage and an equal or greater amount for the ANO 1 outage. From these raw tapes, edited video tapes covering the following subjects were produced:

1. One-hour outage summary tapes for Oconee 3 and ANO 1.
2. Half-hour tapes illustrating recommendations for improved refueling outages at Oconee 3 and ANO 1.
3. One 15-minute tape illustrating manpower utilization and tool control improvements.

These tapes have proved very useful in familiarizing management personnel with the problems that must be overcome in carrying out a refueling outage and training new site personnel for refueling activities.

VIDEO TAPE LOG SHEET FOR OCONEE 3 FALL (1976) REFUELING OUTAGE

Tape number	Footage	Brief description
1p	000-070	Overall shots of site. Equipment hatch
	071-155	area prior to staging personnel hatch prior to building entry.
	156-230	Moving equipment in through outside hatch
	231-581	Shots of RB for hatch opening and equipment placement. Missile shield block removal (also handling fixture move)
	941-END	"B" grating removal.
2p	000-156	Transfer tube cover removal (overall view).
	157-194	CRD top closure loosening.
	195-356	"B" OTSG tent installation.
	357-428	CRD venting.
	429-742	"B" OTSG manway removal purge hookup.
	743-822	Transfer tube cover removal.
	823-832	Seal plate prep install. gaskets.
	833-860	Install safety bar on canal ladder.
	860-882	CRD top closure removal.
	883-970	Install seal plate gasket.
	971-END	Tape not used.
3p	000-059	Seal plate support removal.
	060-077	Cleaning seal plate inner gasket surface.
	078-210	CRD cable removal.
	211-255	Installing seal plate inner-gasket.
	256-355	CRD cable.
	356-382	Canal seal plate lower into place.
	383-467	CRDM uncoupling.
	468-670	Torquing seal plate.
	671-953	Head insulation removal and storage.
	954-987	Missile shield lift and storage.
	988-END	Stud tensioner lift and mounting.
4p	000-240	Stud tensioner mounting.
	241-484	Staging detensioner.
(Bad tape — tracking lines)	485-518	Head after insulation removal.
	519-624	Preparation head storage stand.
	625-985	CRD uncoupling.
	986-END	Tape not used.
5p	000-259	Stud detensioning
	260-289	In-core access cover.
	290-295	CRDM work.
	296-482	Polar crane moving shipping reel to in-core area.
	483-510	In-core reel can.
	511-798	Head stud detensioning.
	799-816	Eddy current equipment layout.
	817-END	CRDM leadscrew parking.

Tape number	Footage	Brief description
6p	000-790	RC pump seal removal (A side).
	791-833	General scan of Rx building work.
	834-END	Fuel bridge mast installation.
7p	000-316	Fuel bridge mast installation. (cont'd)
	317-710	Rx head stud parking.
	711-905	Fuel bridge mast installation. (cont'd)
	905-END	Eddy current testing "B" OTSG.
8p	000-052	Eddy current testing "B" OTSG. (cont'd)
	053-296	RC pump seal removal preparation (trolley).
	297-307	Platforms removed from head.
	308-328	Pan showing parked studs.
	329-362	In-core tank after in-core removal.
	363-965	Misc building activities prior to head removal.
9p	000-025	Equipment hatch closing.
	026-040	Overall view of RB
	041-560	Head (tripod rigging) removal prep.
	561-END	Head rigging setup.
10p	766-END	Head removal.
	553-765	Head tripod rigging.
	000-552	Head tripod leveling. (Bad tape — tracking lines)
11p	000-447	Head removal.
	448-585	Rigging for indexing fixture.
	586-875	Picking up and setting down of indexing fixture.
	876-END	Plenum removal setup.
12p	000-499	Plenum removal setup.
	500-648	Plenum removal.
	649-807	Stud hole plugging.
	808-END	Indexing fixture removal.
13p	000-067	Rx building scan prior to start of defueling.
	068-985	Defueling operations in Rx building.
	986-END	Defueling operations (control room).
14p	000-038	Defueling operations control room.
	039-086	Defueling SFP (bridge problem).
	087-END	RCP motor tear down operation.
	087-END	RCP motor bearing removal.
15p	000-357	RCP motor bearing and oil ring removal.
	358-404	Installing relief valve on pressurizer for hydro test.
	405-446	Erecting floor shoring for polar crane load test.
	447-471	Erecting head stud MT booth.
	472-552	In-service inspection of OTSG welds.

Tape number	Footage	Brief description
	553-582	Main fuel handling bridge operators controls.
	583-673	SFP fuel handling operations.
	674-684	Floor shoring for polar crane load test.
	685-911	In-core removal and TV inspection.
	912-933	Pressurizer relief valve installation.
	934-1015	Insulation replacement "A" suction line.
	1016-END	Replacement of seal on "A" OTSG lower manway insp.
16p	000-111	Replace seal on lower manway inspection post.
	112-441	Prep for stud removal and cleaning. (set up booth)
	442-538	Head stud removal.
	539-576	MT booth and MT testing.
	577-632	Stud removal.
	633-947	Setup for and load test polar crane.
	948-END	Hydraulic suppressor removal & P.M.
17p	000-096	Hydraulic suppressor P.M. (cont'd).
	097-230	Fill RCP with oil.
	231-273	SFP component shuffle.
	274-446	Clean component coolers.
	447-538	Setup RCP motor hoists.
	539-560	CRDM disassembly.
	561-680	Pulling CRD stators.
	681-END	Pulling CRD motor tube assemblies.
18p	000-239	Set platform on CSA.
	240-END	CSA move after SSHT work.
19p	000-519	Refueling sequence.
	520-653	Problems seating assembly.
	654-680	Assembly in upender and transfer.
	681-850	Control rod shuffle.
	851-END	Tape not used.
20p	000-526	Pulling CRD motor tube removal and installation.
	527-656	Stud cleaning.
	657-702	Prep for and setting of index fixture.
	703-834	Set index fixture (cocked on guide studs).
	835-920	Rig to plenum.
	921-END	Plenum move (polar crane problems).
21p	000-418	Set plenum.
	419-452	Remove stud hole seal plugs.
	453-585	Drain and clean stud holes.
	586-683	Remove index fixture.
	684-925	Head rigging.
	926-END	Head move.

Tape number	Footage	Brief description
22p	000-632	Head move.
	633-744	Disconnect tripod.
	745-884	Canal cleaning.
	885-	Began moving eddy current equipment.
	-END	Move eddy current and set up on "A".
23p	000-380	Pressurizer spray valve change out.
	381-1025	Unpark head studs.
	1026-END	Mounting stud tensioner.
24p	000-END	RCP seal replacement. (problems dropping on to keyway)
25p	000-670	RCP seal replacement
	671-890	Remove packing on 3RC43 (also on 27p).
	891-END	Replace packing on 3RC43 (also on 27p).
26p	000-245	Stud tensioner set up.
	246-750	Tensioning studs.
	751-END	CRD coupling.
27p	000-290	Eddy current testing "A" OTSG.
	291-664	CRDM coupling — normal method.
	665-947	3RC43 repacking.
	948-982	CRDM cooling water hookup.
	983-999	CRDM work removing top closure O-rings, etc.
	1000-END	Start of CRDM coupling — normal method.
28p	000-692	Hooking up APSR electrical cabling.
	693-780	Monorail in air lock RCP seal handling.
	781-963	CRDM work.
	964-END	Building pan, general activities.
29p	000-536	Electrical penetration removal and replacement.
	536-643	Final canal decon and cleaning.
	643-850	In-core instrument replacement.
	850-END	Install basement block — close hatch.
30p	000-449	Head insulation replacement.
	449-469	Stud elongation recheck.
	469-630	Pressurizer relief valve installation.
	630-670	Remove eddy current equipment "A".
	670-915	Mount hoist for seal replacement.
31p	000-558	Missile shield block replacement.
	559-835	Route and connect CRD cables.
	836-END	Replace transfer tube covers.
32p	000-478	Replace in-cores.
	478-559	Attach connectors to in-cores.
	559-576	Hook up P.I. cables on head.
	576-592	Pan.
	592-693	Seal plate untorquing.
	693-1024	Seal plate lift and parking.

Tape number	Footage	Brief description
33p	000-128	Seal plate lift cont.
	128-160	Pan of refueling flor.
	160-171	Pressurizer after valve installation.
	171-209	New cranes being used to remove scaffolding.
	209-459	RB interior general inspection as of 1000 on 10-27-76.
	459-860	Rework to pressurizer spray valve.
1s	000-069	Turbine hall prior to outage. Unit III.
	070-125	Turbine tool layout. Cooling fans and vents.
	126-158	Valve work (valves in stands).
	159-198	Turbine bolt removal.
	199-256	Block removal for secondary work access.
	257-268	Prep for turbine shell removal.
	269-362	Misc work on secondary valves.
	363-416	Move turbine shell to stand.
	417-475	Shots of turbine floor work.
	476-515	Prep for HP turbine shaft removal. Stop valve work.
		Final prep for turbine shaft lift. HP turbine shaft lift and placement.
	516-550	Removal of generator rotor bearing cap.
	551-557	Overall view of turbine floor.
	558-614	LP shell removal.
	615-END	Stop valve's reinstalled. View of turbine floor
2s	000-END	Replace HP turbine rotor.
3s	000-066	Replace HP turbine rotor (cont'd).
	067-	Work on HP diaphrams.
	153	Misc generator work.
	154-222	Prep for HP shell replacement.
	223-270	Inspection of moisture separator.
	271-289	Misc turbine work.
	290-701	Replace HP shell.
	702-780	Replace valve seal in secondary.
	781-END	Tape not used.

VIDEO TAPE LOG SHEET FOR ANO 1 SPRING (1977) REFUELING OUTAGE

Tape number	Footage	Brief description
1p	000-357	APSR uncoupling, removal of closure inserts, APSR service power supply, CRDM stator thermocouple bridge, alternate uncoupling tool.
	358-554	Removing RV head insulation and bolting down canal seal plate.
	555-END	Pan of RB 4th level, open secondary shield wall cavity, grating stored on missile shields.
2p	000-199	Pan of RB 4th level.
	200-324	APSR uncoupling.
	325-329	HP checking RV head area.
	330-384	APSR uncoupling.
	385-462	Removing RV head insulation racks.
	463-474	Torquing seal plate bolts.
	475-504	Removing RV head insulation racks.
	505-625	Pan of RB 4th level.
	626-END	Removal of CRD CC water lines.
3p	000-174	Moving RV head stud racks into canal.
	175-204	Removal of CRD CC water lines.
	205-275	Caulking canal seal plate.
	276-443	Stud tensioners going into canal.
	444-END	New storage racks going into SFP.
4p	000-179	Placing new storage racks in SFP.
	180-244	Open RB equipment hatch.
	245-END	Detensioning RV head studs.
5p	000-053	View of stud storage racks.
	054-094	Detensioning RV head studs.
	095-164	Pan of RB 4th level, service structure, transfer canal.
	165-585	Detensioning RV head studs.
	586-607	OTSG top view.
	608-618	Stud hole plug storage.
	619-END	Open equipment hatch.
6p	000-134	Detensioning of RV head studs.
	134-363	Removal of stud tensioners.
	364-375	View of stud support spacers.
	376-575	Removing stud using stud runner.
	576-END	Stud handling.
7p	000-END	Stud removal and handling.
8p	000-END	Stud removal, handling, and parking.
9p	000-122	Service structure cooling air duct removal.
	123-239	RB basement, scaffolding piled up, view of quench tank.

Tape number	Footage	Brief description
	240-502	Insulation work on RCS cold leg drain line.
	503-END	Removal of transfer tube cover.
10p	000-166	Removal of transfer tube cover.
	167-460	CRD stator exchange, cleaning operation.
	461-END	Tape not used.
11p	000-020	Off-site shots.
	021-322	CRD stator exchange.
	323-END	CRD stator uncrating and testing in canal.
12p	000-END	CRD stator exchange.
13p	000-286	CRD stator exchange.
	287-297	Tool box area RB 3rd level.
	298-END	Preparing to pull in-cores (in-core tank)
14p	000-053	Unidentified grinding work.
	054-328	Work in in-core tank.
	329-END	Tape not used.
15p	000-220	Pan of RB 4th level, head insulation storage racks, missile shields, OTSG purge line, OTSG top area.
	221-495	Incore work (hanging in-cores).
	496-648	Pan of RB 4th level, head lift cables, purge equipment, turnbuckles, latch boxes, stator shipping crates, close-up of FH equipment, stud hole cover storage racks, stud racks, mess around tool boxes, ECT equipment, secondary shield wall cavity.
	649-END	Work on RCP motor.
16p	000-146	Work around RCP motor.
	147-283	CRDM closure insert removal.
	284-325	CRD uncoupling tool (standard).
	326-409	CRD uncoupling.
	410-420	Digital load cell readout.
	421-	CRD uncoupling and leadscrew removal using plastic bag.
17p	000-337	CRD leadscrew removal and reinstallation.
	338-393	OTSG tube eddy current test (ECT) equipment.
	394-527	CRD leadscrew parking and pan of RB area.
	528-591	FH equipment mast repairs.
	592-END	Open equipment hatch, pouring concrete in RB basement, shot of cold leg piping.
18p	000-427	Parking CRD leadscrews.
	428-469	Preps for RTD weld.
	470-END	Service structure platform removal.

Tape number	Footage	Brief description
19p	000-237	Service structure platform removal.
	238-END	Rigging cables for head lift.
20p	000-END	Rigging tripod for lift and connection to lift cables at service structure.
21p	000-159	Completion of rigging tripod.
	160-379	Connection of Dillon load cell for head lift and calibration of cell.
	380-END	Level check and head lift.
22p	000-436	Placing head on head storage stand.
	437-END	Rigging tripod with index fixture lift pendants.
23p	000-130	Move of FH bridge.
	131-250	Tripod with index fixture pendants in place, and index fixture positioned.
	251-279	View of head and service structure.
	280-419	Lowering dummy fuel assembly.
	420-569	Filling RV flange stud holes and installing covers.
	570-END	Equipment movement in hatch loading area.
24p	000-359	Installing B_4C test control rods in new fuel assembly.
	360-504	Checking out CRD mast on main FH bridge.
	505-525	View of SFP.
	526-585	Filling transfer canal and incore tank.
	586-END	Engaging index fixture for removal.
25p	000-108	Removal of index fixture.
	109-327	Decon of tripod and index fixture.
	328-439	FH bridge movement.
	440-621	Reinstallation of index fixture.
	622-END	View of leaking seal plate.
26p	000-121	UT inspection of RV head.
	122-275	Loose part found on tube sheet of B OTSG.
	276-END	Tape not used.
27p	000-064	View of plenum and index fixture.
	065-225	Seal plate rework with RTV.
	226-END	Rig tripod with latch boxes.
28p	000-402	Rigging tripod for plenum lift.
	403-END	Plenum removal and move to canal deep end.
29p	000-239	Completion of plenum set and disengagement of latch blocks.
	240-342	Removal and decon of tripod.
	343-410	Attaching pendants for index fixture lift.
	411-632	Removal and decon of index fixture.
	633-END	Movement of index fixture to allow repositioning of FH bridges.

Tape number	Footage	Brief description
30p	000-024	Completion of FH bridge move.
	025-269	Placement of index fixture in shallow end of canal and disengagement of lift pendants.
	270-339	Decon of tripod.
	340-END	Removal of OTSG manway and handhole covers.
31p	000-100	Removal of OTSG hand hole cover.
	101-294	Movement of ECT equipment.
	295-629	Movement of scaffolding and ECT equipment.
	630-END	UT on pressurizer.
32p	000-411	Erection of ECT enclosure.
	412-527	Rigging OTSG purge line.
	528-END	Fuel handling at upender.
33p	000-449	Setting up ECT equipment.
	450-489	FH equipment operation.
	490-532	Manual indexing.
	533-END	Fuel handling equipment close-up.
34p	000-221	Repair of FH bridge.
	222-349	Dry transfer canal and defueled vessel.
	350-END	Control component shuffle in SFP.
35p	000-099	Canal seal plate lift.
	100-177	Loose material.
	178-END	Stud handling and cleaning.
36p	000-END	Stud handling and cleaning.
37p	000-295	Stud handling and cleaning.
	296-314	Open equipment hatch.
	315-END	Vent valve exercise.
38p	000-456	Loose part retrieval operation.
	457-END	General RV shots.
39p	000-389	Incore detector disposal.
	390-399	Equipment hatch loading area.
	400-579	Fuel handling operation.
	580-END	Damaged fuel assembly.
40p	000-081	FH operations.
	082-141	Equipment hatch loading area.
	142-199	FHB rails.
	200-234	View of core.
	235-319	FH operations.
	320-453	Pan of transfer canal and fueling operations.
	454-550	FHB monitor of FA in upender.
	550-END	Tape not used.

Tape number	Footage	Brief description
41p	000-069	Pan of SFP area.
	070-575	Preps for shipping out damaged FA.
	575-END	Tape not used.
42p	000-099	View of transfer canal.
	100-179	Pressurizer insulation.
	180-239	Letdown coolers and RB basement.
	240-266	Stud nuts and studs.
	267-END	Installation of plenum in RV.
43p	000-295	Latch block disengagement from plenum.
	296-339	OTSG area insulation.
	340-381	Drain and decon of transfer canal.
	382-418	Transfer tube cover plate and bolts.
	419-425	OTSG manway removal.
	426-END	Preps for RV head "O-ring" installation.
44p	000-228	Placing O-ring on RV head flange.
	229-464	Removing stud hole covers and clean threads.
	465-479	Threading nuts on to studs.
	480-541	RV flange work.
	542-595	Deconning incore tank.
	596-634	Cleaning out O-ring grooves.
	635-END	Preps for head lift.
45p	000-044	Cleaning out O-ring grooves.
	045-119	Preps for head lift.
	120-221	Cleaning out O-ring grooves.
	222-359	Preps for head lift.
	360-END	RV head lift and set over guide studs.
46p	000-245	Setting head on RV.
	246-496	Disengagement of lift cables.
	497-END	Stud handling.
47p	000-439	Stud handling.
	440-664	CRDM coupling.
	665-END	Preps for removing RV head lift cables.
48p	000-621	Unparking studs and use of stud runner.
	622-664	Lowering and setting up stud tensioner.
	665-END	CRDM coupling.
49p	000-044	CRDM coupling.
	045-067	Stud tensioner preps.
	068-239	CRDM coupling.
	240-END	Stud tensioning operations.
50p	000-219	Stud tensioning.
	220-250	Cleaning canal seal plate.
	251-END	(New) incore detector installation.
51p	000-243	Incore installation.
	244-284	Cleaning canal seal plate.
	285-434	Removing stud tensioners.
	435-549	Lowering RV head insulation racks into canal.

Tape number	Footage	Brief description
	550-594	Installation of RV head insulation panels.
	595-END	Repositioning service structure platforms.
52p	000-194	Removal of RV head insulation panel racks from transfer canal.
	195-389	Canal seal plate cleaning and lift.
	390-END	Exchanging CRDM stators.
53p	000-414	Trash removal from RB.
	415-END	Tape not used.
54p	000-289	Exchanging CRDM stators.
	290-487	Replacing pressurizer insulation.
	488-END	General RB shots, missile shields, APSR service power supply, tripod, head stand, stud racks, etc.
55p	000-127	CRDM cable verification tests.
	128-169	Secondary shield wall cavity, missile shields and grating.
	170-END	Tape not used.
1s	000-199	Computer installation in control room, pan of control room area.
	200-272	Pan of turbine deck.
	273-282	Classroom.
	283-521	Pan of turbine deck.
	522-END	Rigging for #1 LPT outer casing lift.
2s	000-439	Lift of #1 LPT outer casing.
	440-END	View of rotor and inner casing.
3s	000-139	Storage of LPT casing.
	140-193	Pan of turbine deck.
	194-236	Control room.
	237-264	#1 LPT rotor.
	265-289	Pan of turbine deck.
	290-429	#1 LPT rotor.
	430-609	Crossover pipe assembly storage.
	610-END	Tape not used.
4s	000-139	Pan of turbine building and #1 LPT exhaust cavity.
	140-239	Close-up of #1 LPT rotor.
	240-289	Work on MSR.
	290-315	Administration building.
	316-359	Turbine building.
	360-END	Rigging for #1 LPT inner casing lift.
5s	000-369	Detensioning inner case studs.
	370-569	Inner case lift.
	570-629	Pan of turbine deck.
	630-639	Unbolting shaft coupling flange.
	640-END	Preps for inner case ring lift.

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Tape number	Footage	Brief description
13s	000-416	LPT machining and UT inspection.
	417-454	Bent guide vane.
	455-469	Preparing stud threads.
	470-569	Replacing inner half ring.
	570-604	MSR work.
	605-END	LPT inspection.
14s	000-END	Reassembly of LPT.
15s	000-499	Reassembly of LPT outer casing.
	500-END	Lift of LPT rotor.
16s	000-649	Movement and reinstallation of LPT rotor.
	650-END	Preparing bearing surfaces.
17s	000-END	LPT rotor replacement.
18s	000-057	Outside shots of ANO entrance.
	057-182	View of Lake Dardenelle and site from Mt. Nebo.
	183-199	ANO entrance signs.
	200-239	View of reactor buildings and cooling tower.
	240-309	Immediate outside area shots, administration building, RB tendon inspection, surveillance TV camera.
	310-END	View of Lake Dardenelle and site from Mt. Nebo.
19s	000-144	LPT rotor bearing installation.
	145-END	Installation of inner half ring.
20s	000-024	Installation of inner half ring.
	025-034	Unidentified welding.
	035-061	Pan of turbine deck.
	062-414	Installation of inner half ring.
	415-447	Preparing crossover piping gasket.
	448-467	LPT rotor.
	468-564	Gasket prep and LPT outer casing installation.
	565-END	Tensioning studs on LPT inner casing.
21s	000-099	Stud tensioning.
	100-134	LPT outer casing installation.
	135-632	Removal of MSR relief valves and RV piping prior to pulling condensate pump.
	633-END	Prep for removal of LPT #1 inner casing (forget to install seals)
22s	000-534	Removal of inner casing and two center half rings.
	535-549	Seals going in.
	550-END	Reinstallation of two center half rings.

Tape number	Footage	Brief description
23s	000-351	Reassembly of LPT #1.
	352-620	Installation of HPT enclosure.
	621-END	Setting inner casing.
24s	000-162	Installation of LPT inner casing.
	163-319	Removal of condensate pump.
	320-362	Installation of inner LPT casing.
	363-462	Removal of condensate pump.
	462-END	Installation of inner LPT casing.
25s	000-104	Installation of inner LPT casing.
	105-589	Removal and laydown of condensate pump.
	590-END	Condensate pump upper casing removal.
26s	000-511	Removal of condensate pump upper casing.
	512-589	Reinstallation of LPT outer cover.
	590-END	Preparing LPT flange matting surfaces.
27s	000-562	LPT outer casing replacement.
	563-END	Crossover pipe installation.
28s	000-197	Crossover pipe installation.
	198-362	Making up shaft coupling.
	363-463	Disassembly of condensate pump.
	464-488	Pan of turbine deck.
	489-496	Control room.
	497-END	Condensate polisher area.

APPENDIX B

Index of Time Lapse Photographs

OCONEE 3 1976 REFUELING OUTAGE
TIME LAPSE PHOTOGRAPHY INDEX

Film sequence number	Description
1	Equipment Hatch
2	Shield Block Removal
3	General Activities in FTC
4	Eddy Current Testing of "A" OTSG Venting of CRDMs Removal of Transfer Tube Cover
5	Mirror Insulation Removal Stud Tensioners Lifted Uncoupling of CRDMs
6	Uncoupling of CRDMs Eddy Current Testing of "B" OTSG Detensioning of RV Studs Disconnecting of CRDM Control & Electrical Cables Work Starting on Pressurizer & Pumps
7	Work in "B" Side Cavity Detensioning of RV Head Eddy Current Work Continuing RCP Work Continuing CRD Superstructure Guide Studs Installed on RV Head
8	"B" Side Cavity Work Continuing Check Out of Main Fuel Bridge Control Rod Mast Internals Removed
9	Pressurizer Work RCP Seal Work Eddy Current of "B" OTSG Continuing Draining of CRDMs Component Cooling System Lines Attaching Main Lifting Pendant to Polar Crane Lifting Tripod Being Hooked to Polar Crane Attaching Lifting Cables to RV Head
10	Preparing the RV Head Stand RV Head Removal & Placing on Stand Detachment of Lifting Cables CSA/Plenum Latch Box Assemblies Being Attached
11	Indexing Fixture Removed From FTC Check Out of Fuel Handling Bridge Continues Plenum Plenum Removed & Placed in Deep End
12	Removal of High Pressure Turbine Covers Removal of Bearing Caps Removal of Diaphragms

Film sequence number	Description
13	Work on & Removal of HP Turbine Diaphragms Work on Turbine Stop Valves Removal of HP End Bell Removal of Bearings & Bearing Caps
13A	General Activities in Spent Fuel Pool
14	Spent Fuel Pool Activities
15	Bearing Inspection Stop Control Valve Reworking Activities & Equipment Around Turbine Deck Turbine Rotor
16	Generator/Turbine Coupling Removal Sand Blasting Inspection of HP Turbine Diaphragms
17	Fuel Handling Work Various Projects on "A" Side Cavity Polar Crane Picks up Lifting Tripod Spreader Ring Attached to Latch Box Assemblies CSA Moving Out of RV
18	CSA Placed on Stand Unlatching Latch Box Assemblies Misc Tasks on "B" Side Cavity Lowering of FTC Water Level SSHT Platform Installed Lug Covers Inserted on CSA Lifting Lugs
20	Component Shuffling in Spent Fuel Pool Use of "Pie" Mast Upender in Spent Fuel Pool
21	Component Shuffling Activities
22	Lowering Cask Into Transfer Mechanism (SFP) Removing Fuel From Cask Removing Cask
23	Handling Spent Fuel Element & Spent Fuel Transportation Cask Cask Closure Head Removed
24	Component Shuffling in Spent Fuel Pool Activities on Spent Fuel Pool Bridge "Pie" Mast Removed From Pool
25	Handling Spent Fuel Element Handling Spent Fuel Transportation Cask
26	Unloading Spent Fuel Cask From Truck "Pie" Mast Removed From Pool for Repairs Spent Fuel Cask Head Being Replaced Cask Removed From Bottom of Pool & Placed on Stand

Film sequence number	Description
26A	Spent Fuel Cask on Storage Stand Cask Waiting for Placement in Decon Cavity Preparations are Made on Cask for Shipment
27	Spent Fuel Cask Hanging in Decon Pit From 100 Ton Crane Torquing Cask Head in Place Leak Check Performed on Cask Cask Scrubbed With Deconing Agent
28	Lower Section of Generator & Bell is Lowered to Allow Removal of Rotor
29	Work on South End of Generator Work on North End of Generator
30	North End of Rotor Removed Connection, Cable & Hoist Shown Rotor Removed "B" LP Turbine Shown Misc Pictures of Turbine Lay-Down Area Unit III Control Room
31	Generator Rotor Interior of Housing SSHT Work in Progress Mandrel Puller, ID Tube Cutter, Tube Removal Tool
32	SSHT Work
32A	Refueling Activities Fuel Bridge With Operator CR Stator Being Removed From RV Head
33	Turbine Generator Reassembly "B" Stage LP Turbine Reassembled "B" Stage Cover Lifted, Inspected & Cleaned Cover Inserted on "B" LP Turbine
34	Vent Valves in CSA Platform Inserted for Valve Inspection Platform Removed
35	Lifting Tripod Being Attached to Polar Crane Indexing Fixture Attached & Lowered & Attached to CSA Tripod, Indexing Fixture, CSA Are Waiting for Transfer to the Reactor Vessel
35A	Reactor Vessel Head on Stand CRDM Work Men Working in Full Flow Respirators
36	CSA Lifted & Rotated Locking Clips Inspected Insertion of CSA in Reactor Vessel

Film sequence number	Description
39	RV Head on Stand Work on CRDs Preparation for Removing Drives
41	Work on Reactor Vessel Head Indexing Fixture Installed Plenum Latched & Installed
42	Tripod & Spreader Ring Suspended Draining Stud Holes Index Fixture Removed Index Fixture Placed in Canal Latch Box Assemblies Removed From Tripod Tripod Attached to Head Installation of Reactor Vessel Head on RV Head Installed on RV Lifting Cables Detached
43	Fuel Verification of Core With Video Equipment Technical Equipment & Operator's Action
44	CRDM Work on Reactor Vessel Head in Fuel Transfer Canal Checking Torque on Locking Nuts Work Started on RV Studs RV Studs Run in Stud Holes Check Out of Stud Tensioner Stud Tensioning Begins
46	Rebuilding RCP Seals in Hot Machine Shop Disassembly of #3 Seal Package and Checking Alignment Wrapping Seals in Plastic Checking Second Set of Seals
47	Equipment Removal From Reactor Building Replacing Basement Shield Blocks
48	Cleaning of FTC Wall Monitored Equipment Hatch Monitored Equipment Hatch Raised 1/3 of Way Equipment Hatch Being Closed

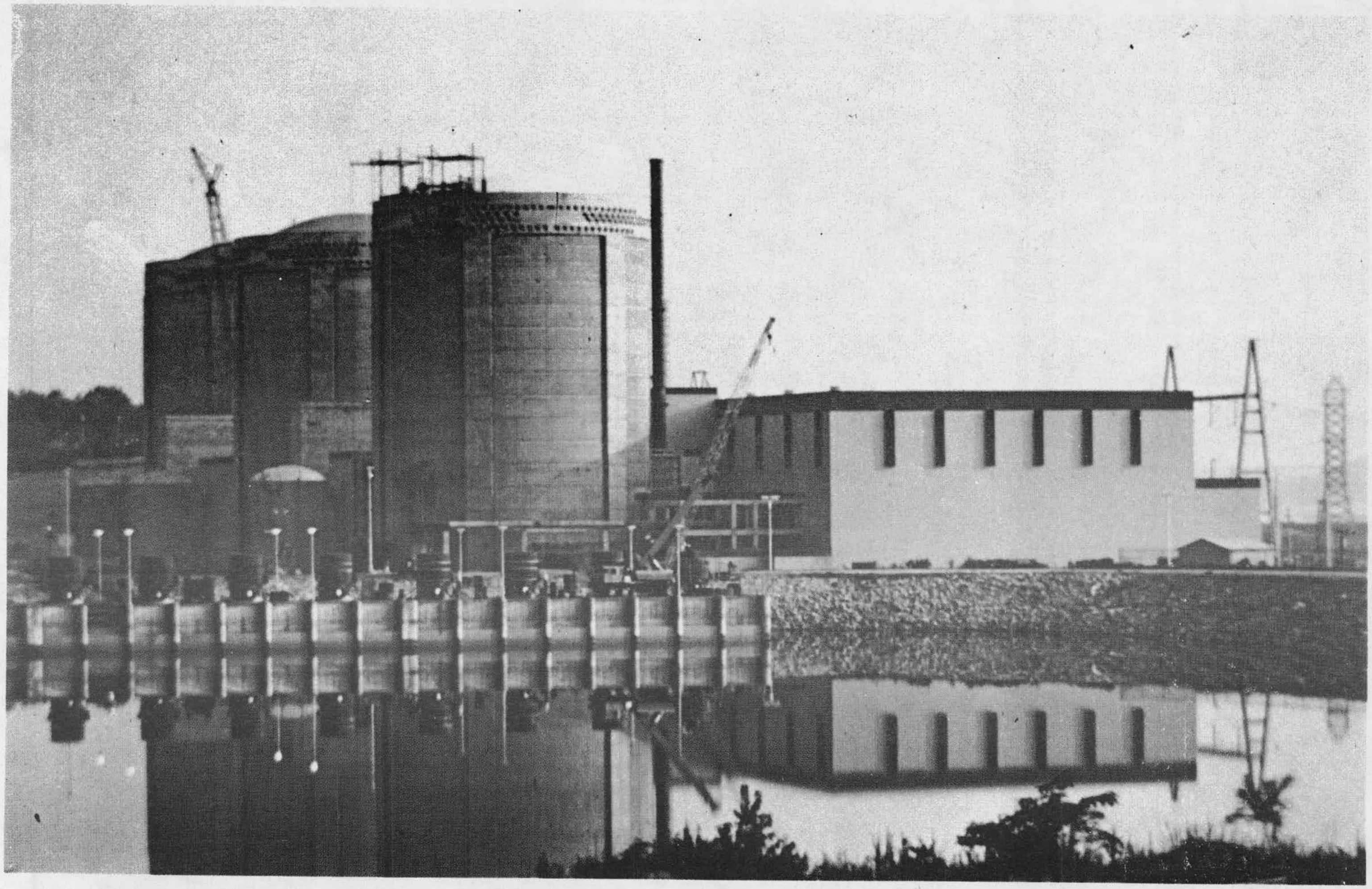
ANO 1 1977 Refueling Outage
Time Lapse Photography Index

Film sequence number	Description
2	Replacement of LP Turbine Diaphragms General layout pictures inside & outside Turbine Hall
4	CRDM Coupling RV Stud Tensioning Mirror Insulation installed CRDM uncrated LP Turbine Rotor removed HP Casing removed Bearing inspection HP Turbine Rotor on Storage Stand General arrangement of Turbine Casing & Rotor Dressing & undressing in change room
6	Turbine Rotor Installation Rotor connection between the HP & LP Turbines General work on Turbine
7	Turbine Jacking Motor Lower Casing Diaphragms LP Turbine Rotor on Storage Stand Micrometer readings taken on Turbine Shroud RV Stud Storage Stand Canal Seal Ring removal Removing Index Fixture RV Head removed from Storage Stand & placed in FTC General pictures of LP Turbine Rotor on Storage Stand
9	Coupling of Turbines Diaphragm Installation Pictures of Fuel Transfer Canal RV Studs cleaned & moved into Fuel Transfer Canal
11	General pictures of Turbine Hall HP Turbine Rotor lifting & placement in the casing Replacing of Turbine Casing

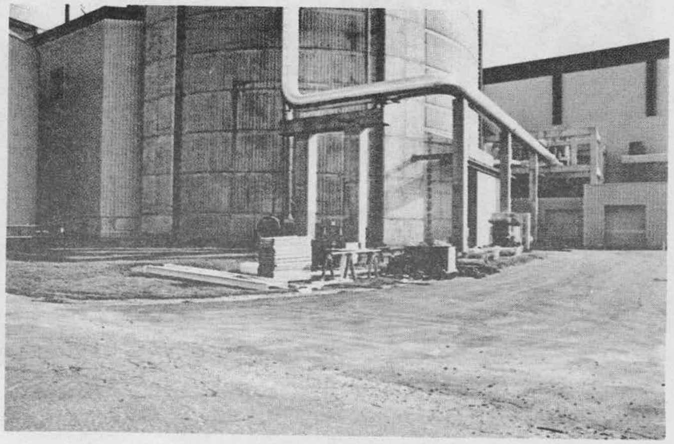
APPENDIX C

Oconee 3 Refueling Outage —
Photographic Summary

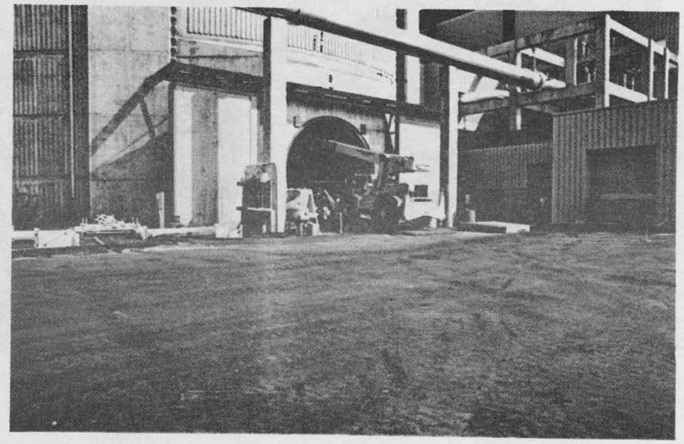
1. Duke Power Company's Oconee Nuclear Station



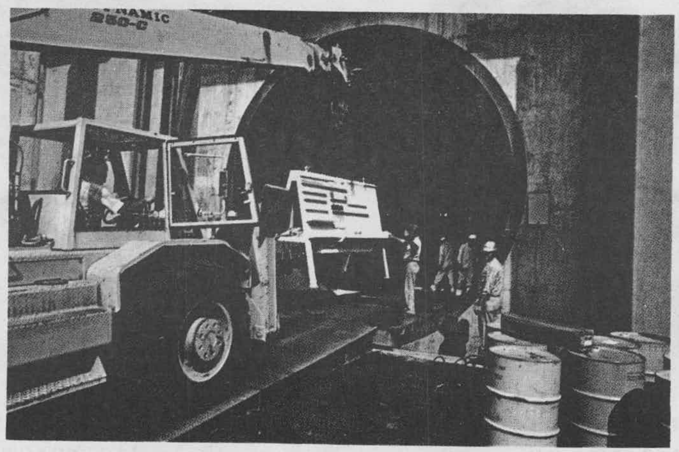
2. Staging Outage Support Materials Near Equipment Hatch



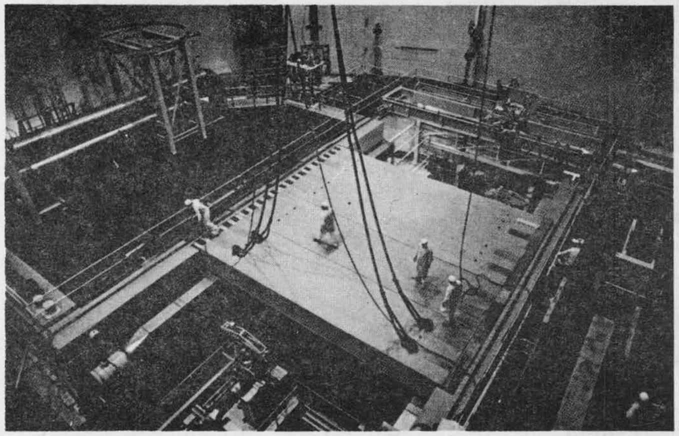
3. Transferring Outage Support Materials Into Reactor Building



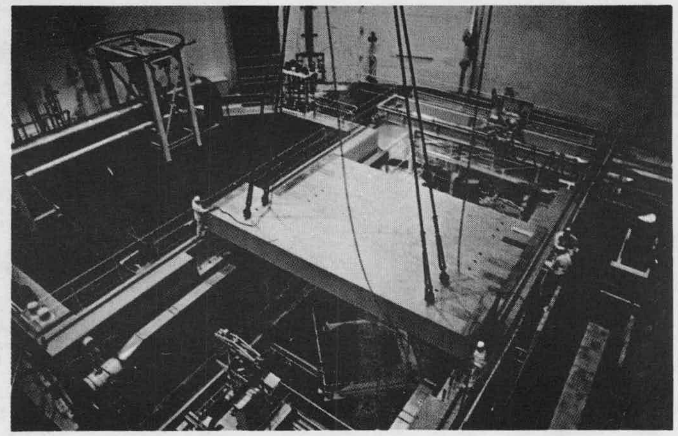
4. Transferring Outage Support Tools Into Reactor Building



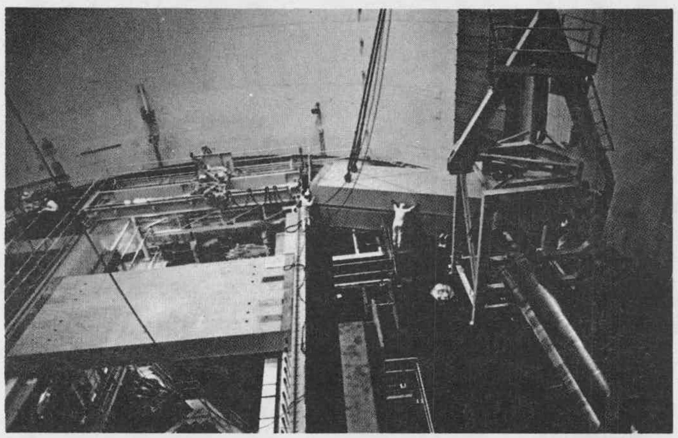
5. Preparations for Removal of Missile Shields



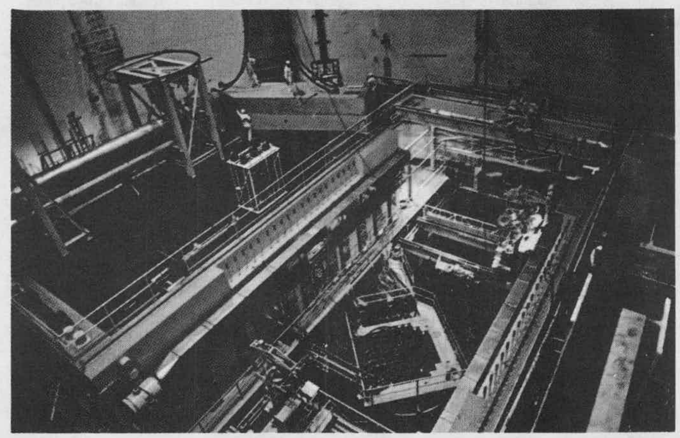
6. Lifting and Moving First Missile Shield



7. Storing Second Missile Shield

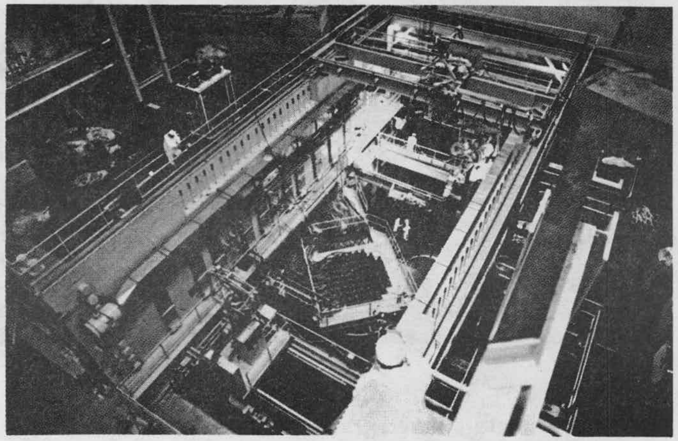


8. Storing Fourth Missile Shield

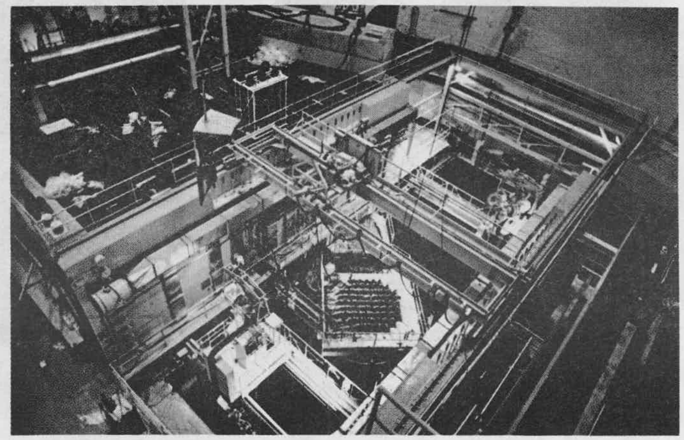


[redacted]

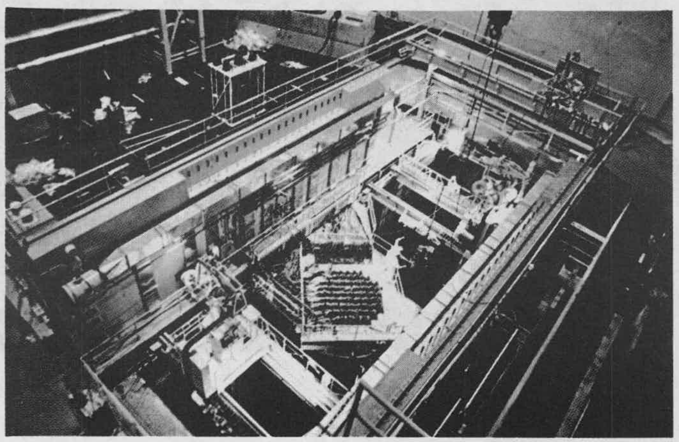
9. Transfer Tube Work Within Fuel Transfer Canal



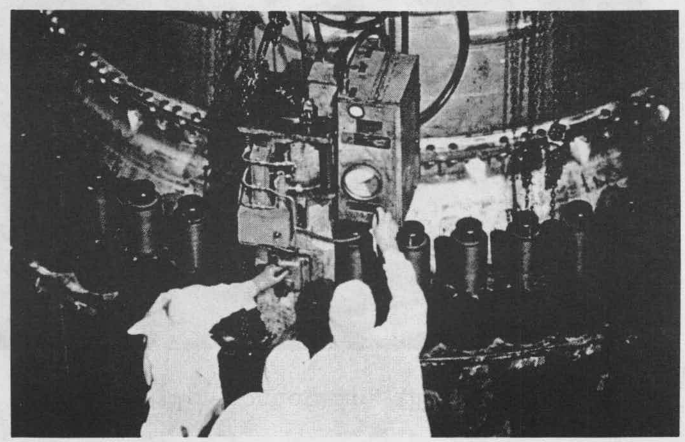
10. Removal of Reactor Vessel Head Insulation



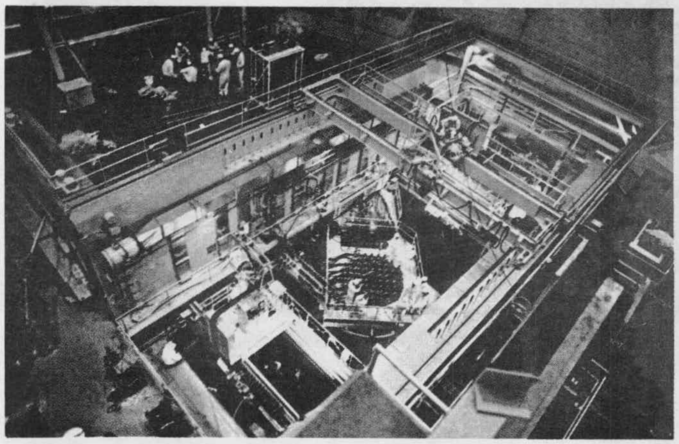
11. Lowering Reactor Vessel Head Stud Tensioner



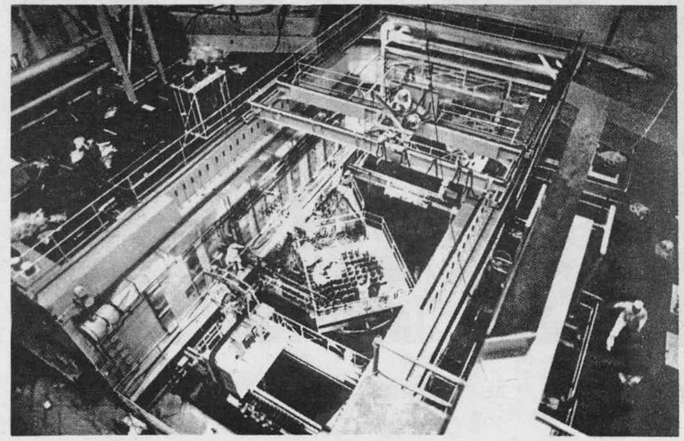
12. Detensioning Reactor Vessel Head Studs



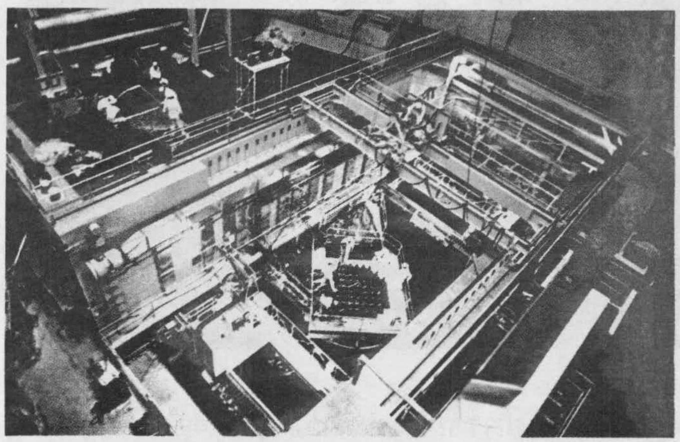
13. Uncoupling the CRDMs



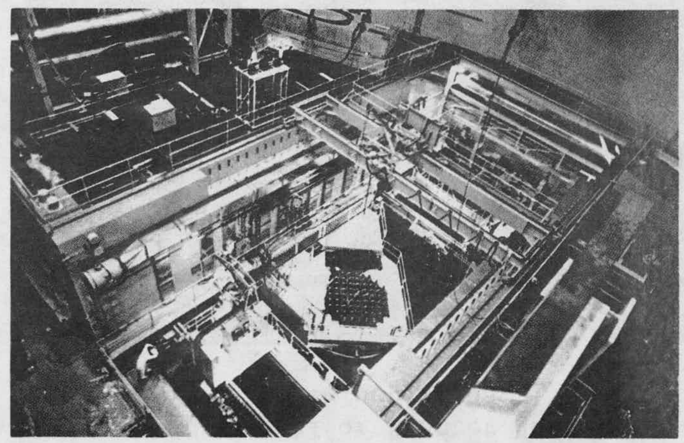
14. Disconnecting CRDM Cables



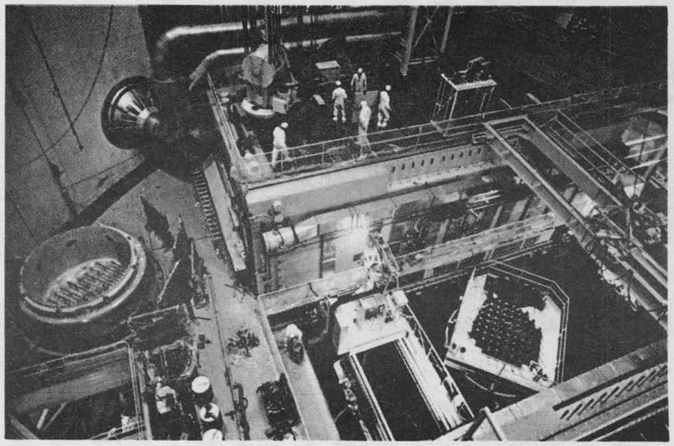
15. Installation of Steam Generator Remote-Controlled Inspection Tooling



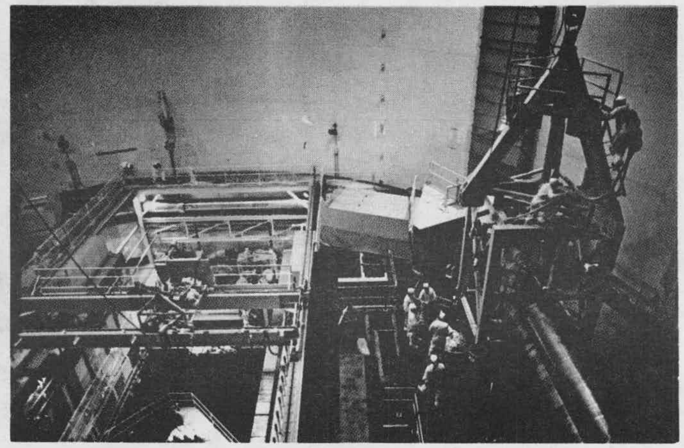
16. Completion of CRDM Cable Disconnection



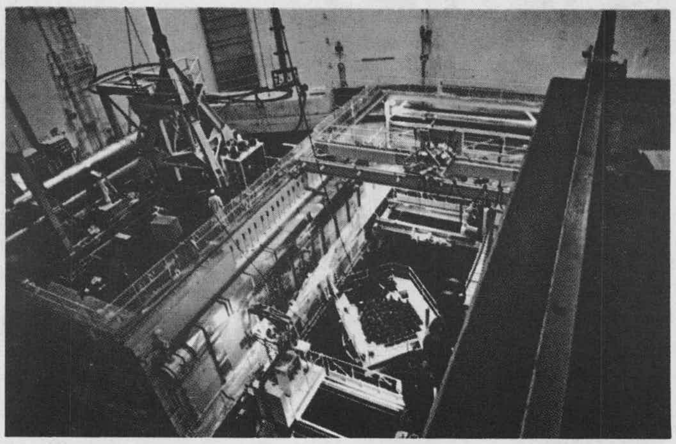
17. Preparing to Attach Extension Link to Polar Crane



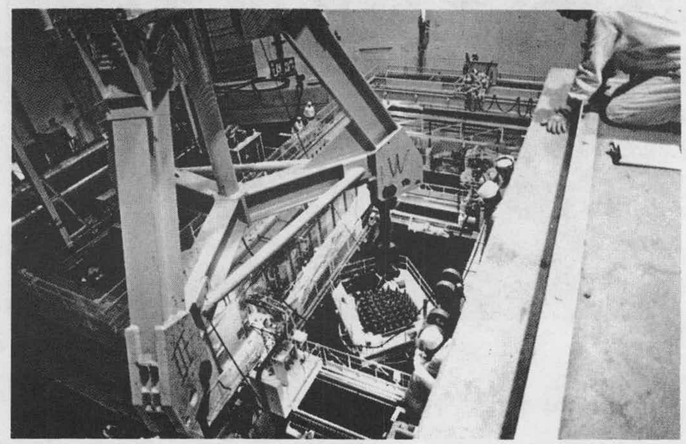
18. Preparing to Attach Lifting Tripod to Polar Crane



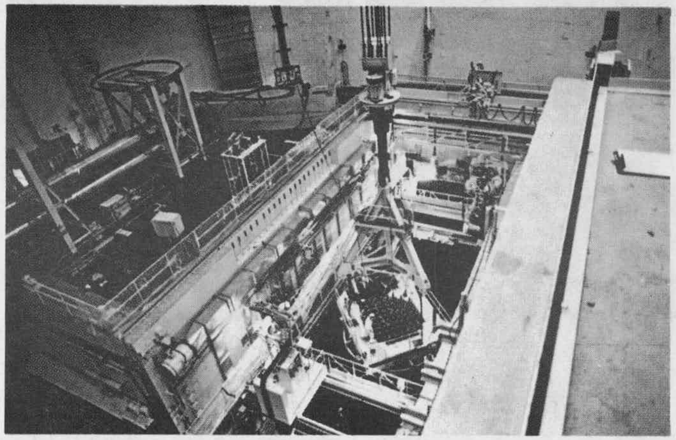
19. Rigging Lifting Tripod With Leveling Turnbuckles



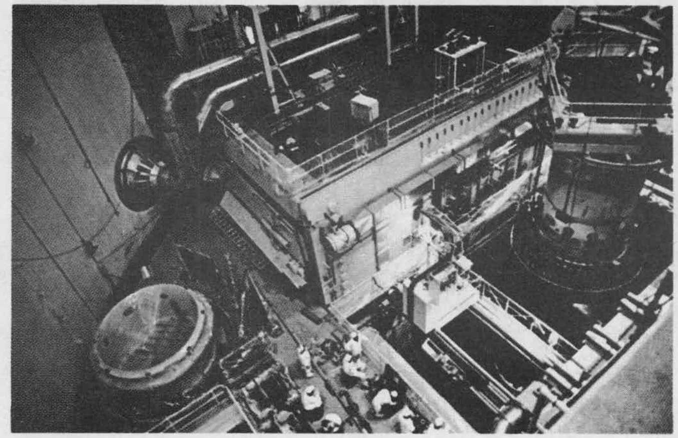
20. Preparing to Attach Reactor Vessel Head Lifting Cables to Tripod



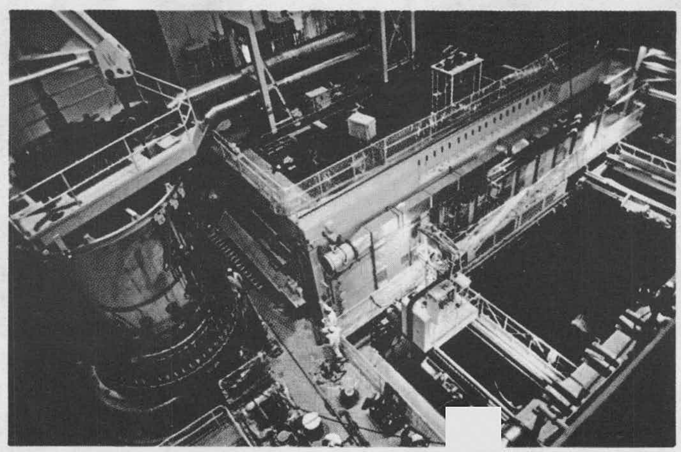
21. Lowering Lifting Cables Through CRD Service Structure



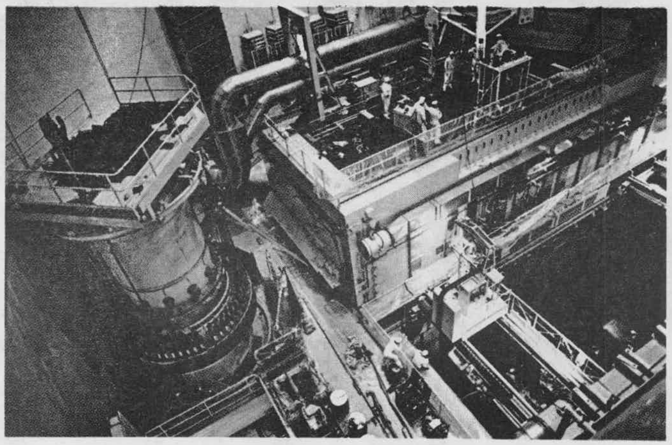
22. Lifting Reactor Vessel Head and CRD Service Structure



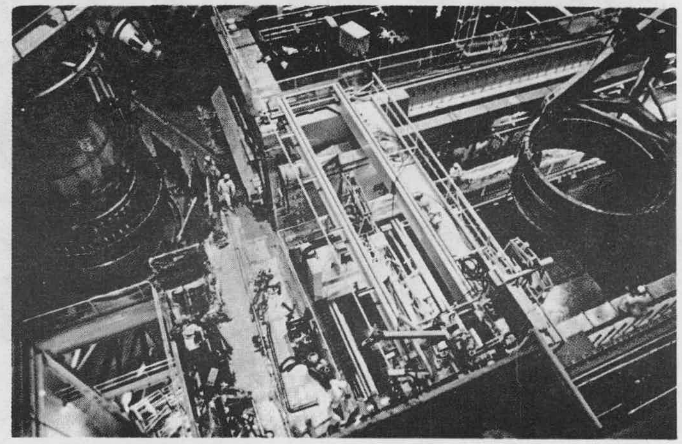
23. Storing Reactor Vessel Head and CRD Service Structure



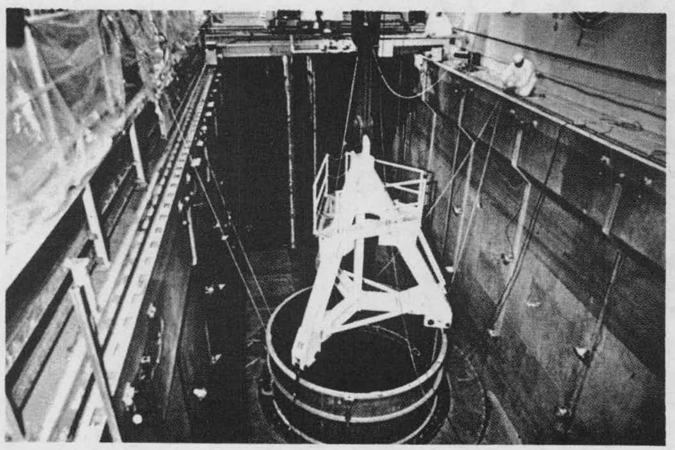
24. Replacing Lifting Tripod Leveling Turnbuckles With Latch Box Assemblies



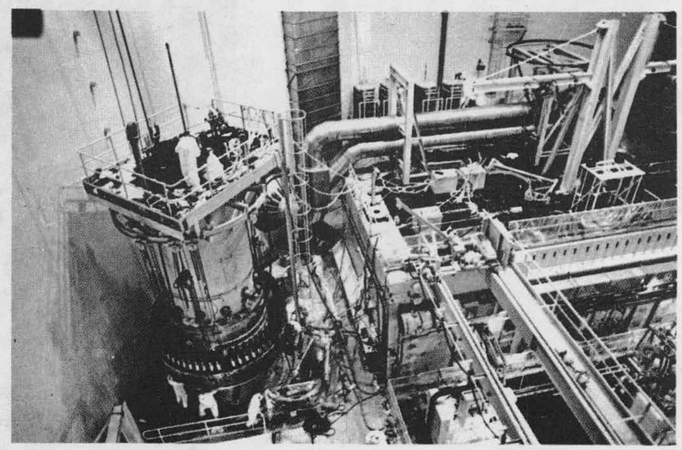
25. Transferring Indexing Fixture to Reactor Vessel



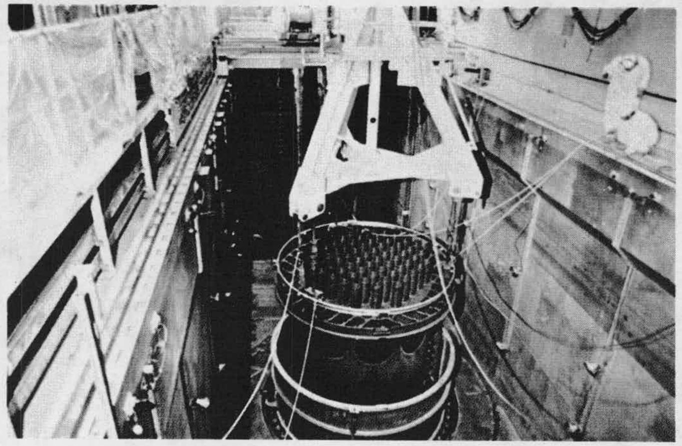
26. Placing Indexing Fixture Over Reactor Vessel



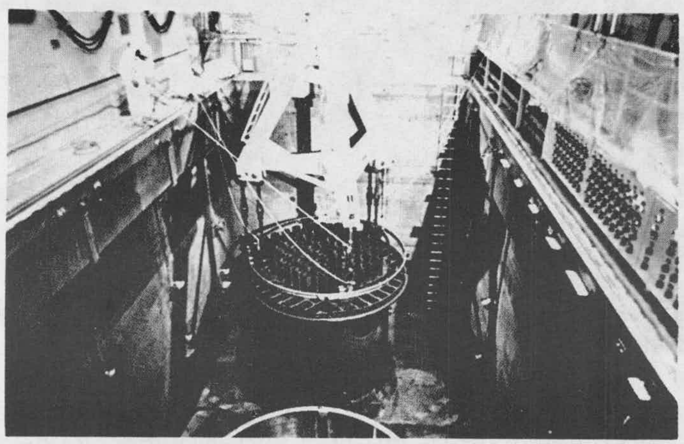
27. Reactor Vessel Head and CRDM Inspection Operations



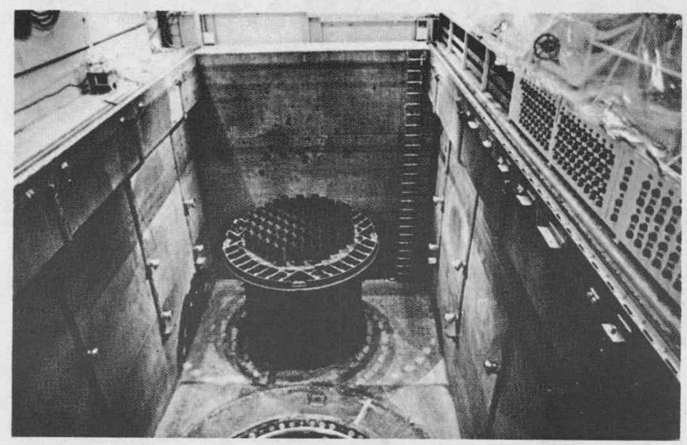
28. Removal of Plenum Assembly From Reactor Vessel



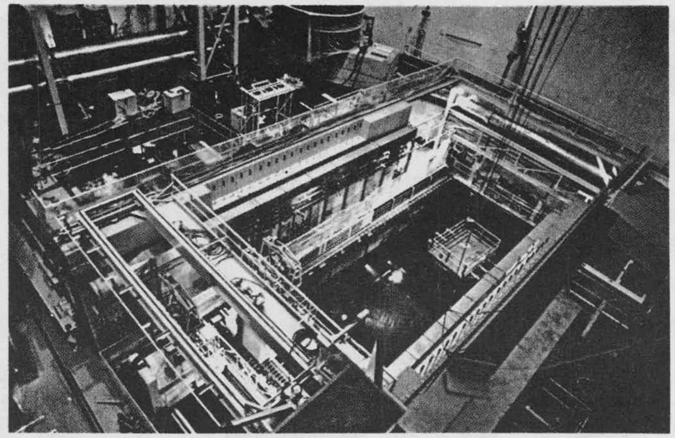
29. Transferring Plenum Assembly to End of Fuel Transfer Canal



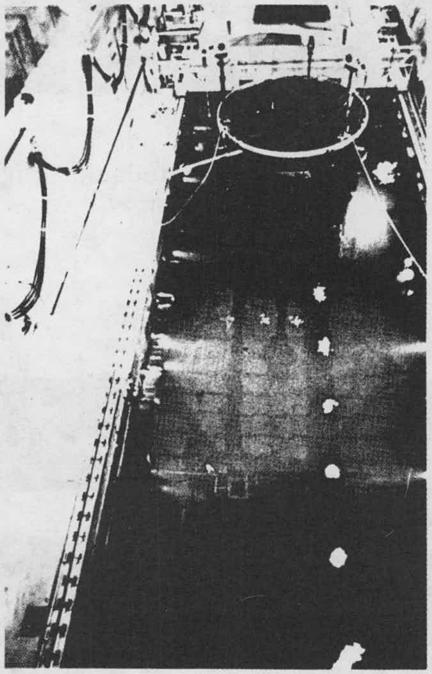
30. Stored Plenum Assembly at End of Fuel Transfer Canal



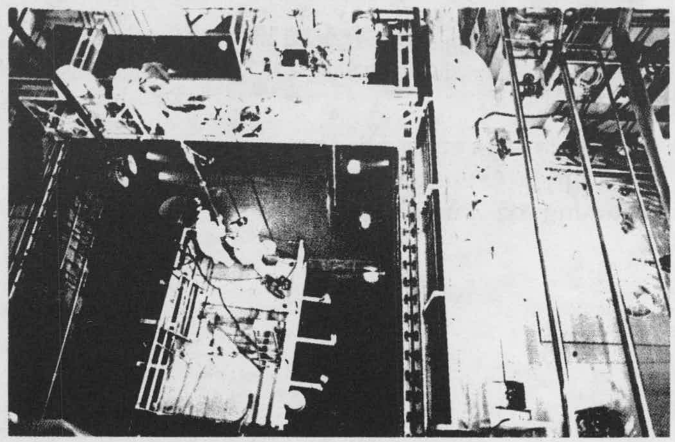
32. Installation of Inspection/Work Platform Over Core Support Assembly



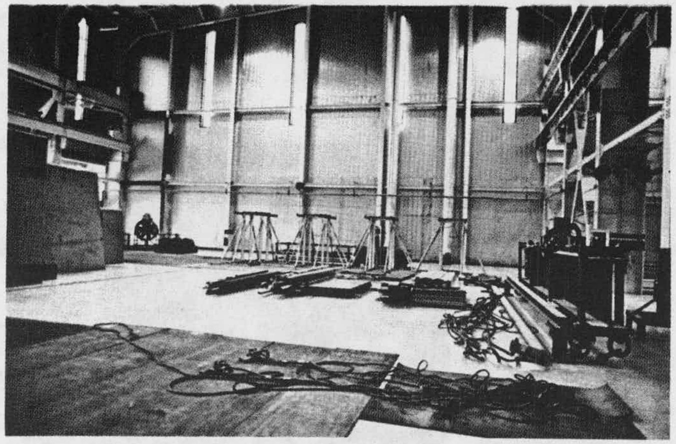
31. Transferring Core Support Assembly to Deep End of Fuel Transfer Canal



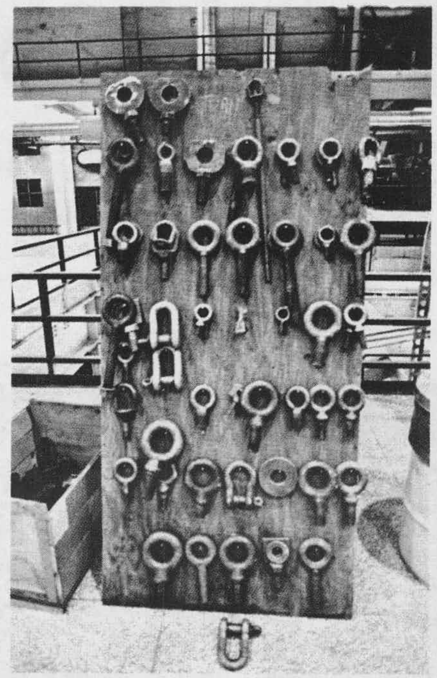
33. Work Progress on Core Support Assembly



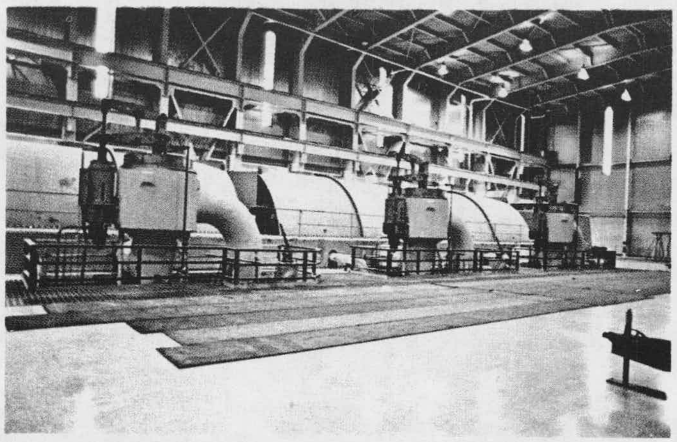
34. Materials Staging to Support Plant Secondary Side Outage Activities



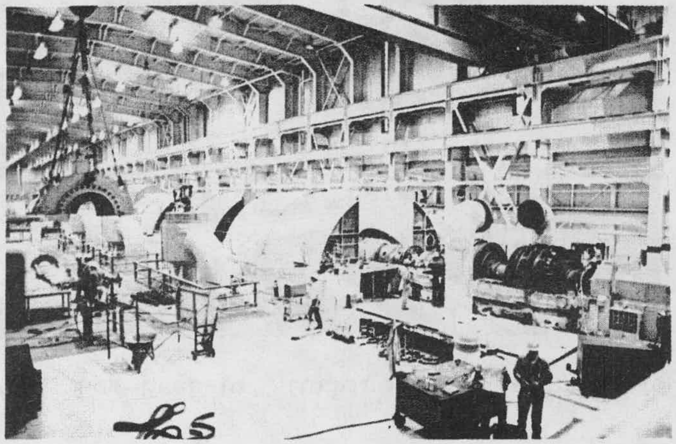
35. Tool Staging to Support Plant Secondary Side Outage Activities



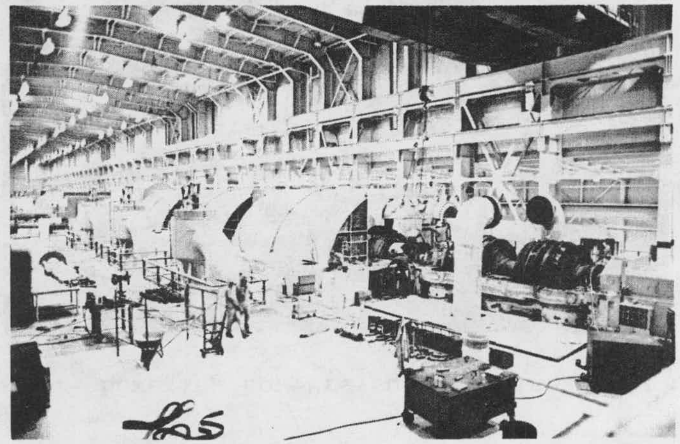
36. Preparing Laydown Areas for Storage and Inspection Activities



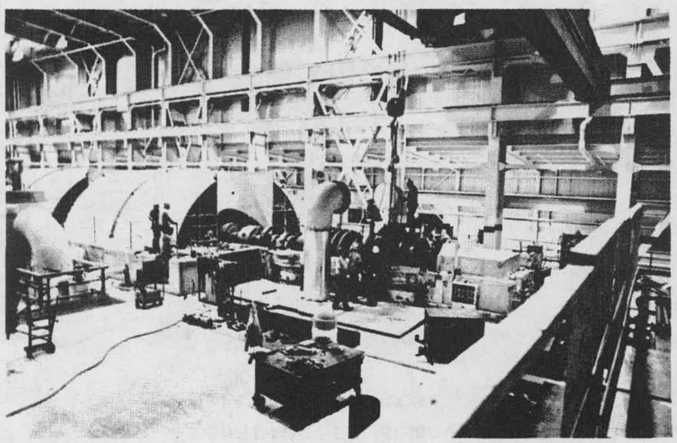
37. Removal of High-Pressure Turbine Cover



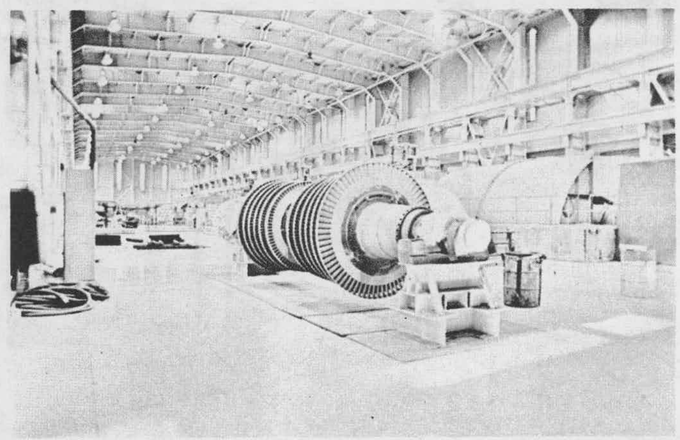
38. Removal of High-Pressure Turbine Bearing Cap



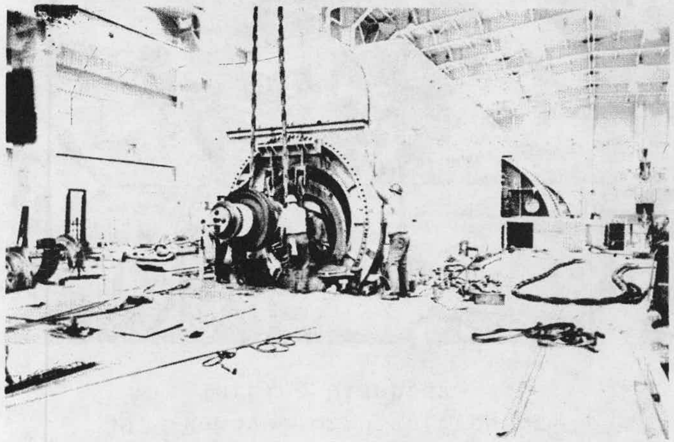
39. Removal of High-Pressure Turbine Diaphragm



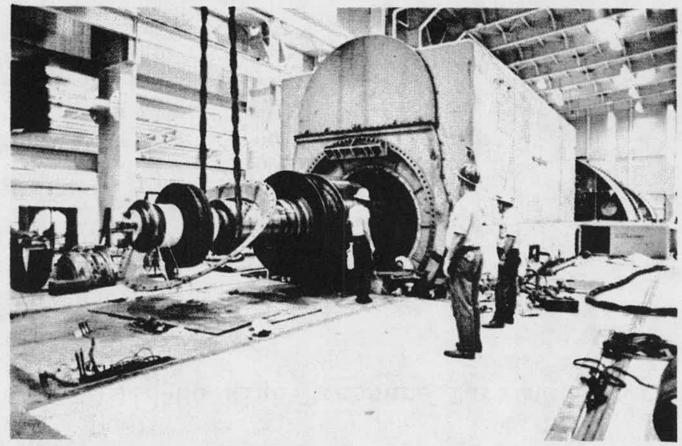
40. Laid-Up High-Pressure Turbine Rotor



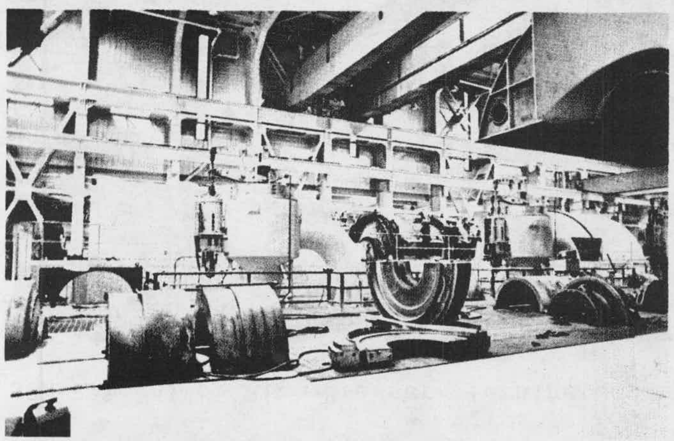
41. Preparing to Remove Rotor From Generator



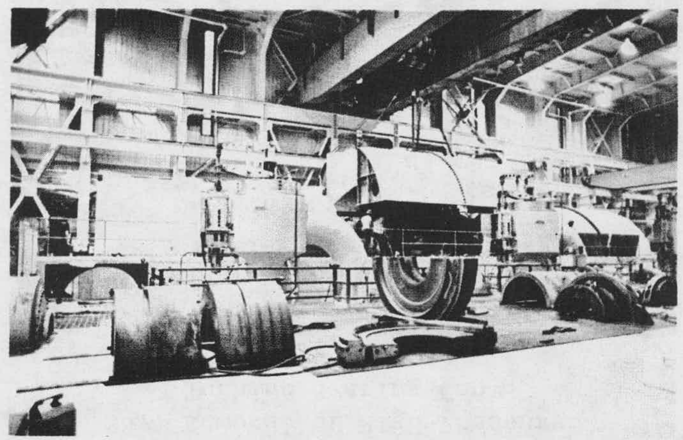
42. Removing Rotor From Generator



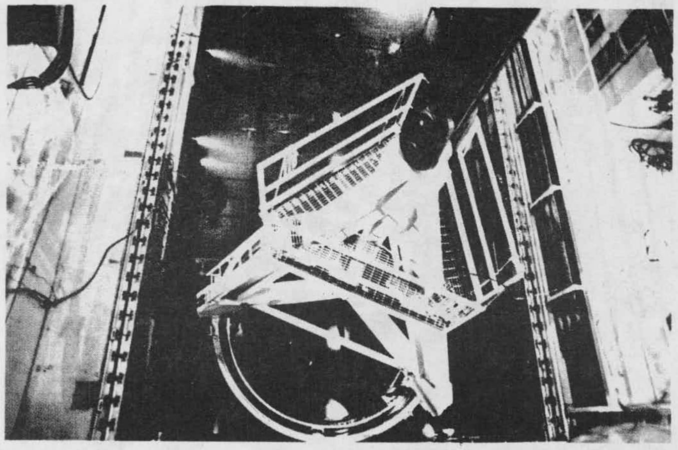
43. Low-Pressure Turbine Work in Progress



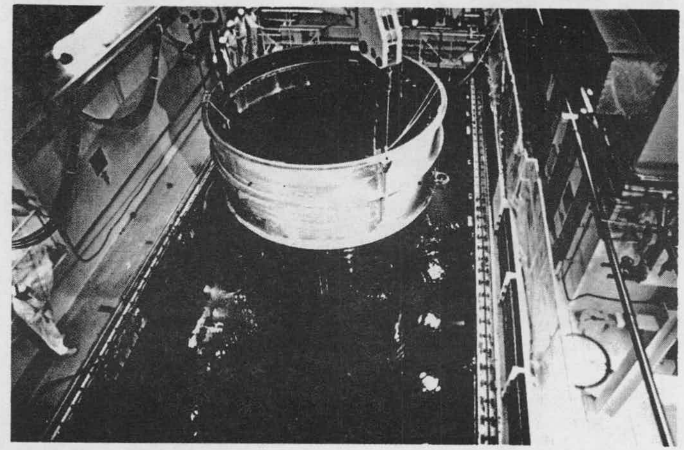
44. Lowering Low-Pressure Turbine Cover



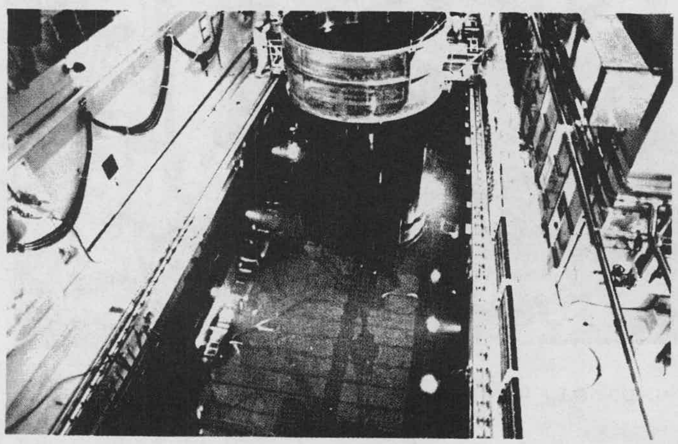
45. Lowering Indexing Fixture Over Core Support Assembly



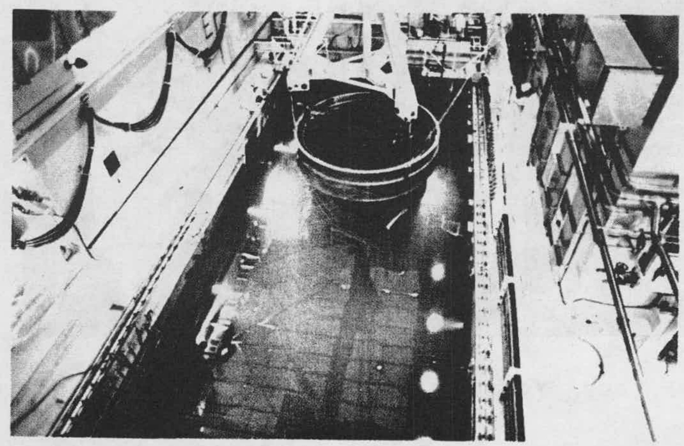
46. Transferring Core Support Assembly



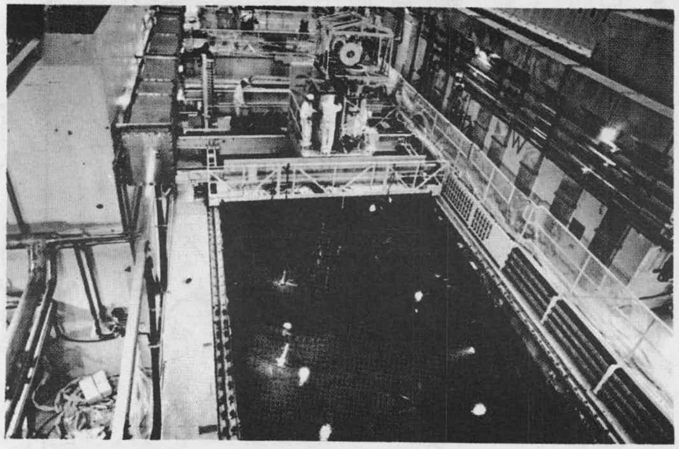
47. Aligning Core Support Assembly Over Reactor Vessel



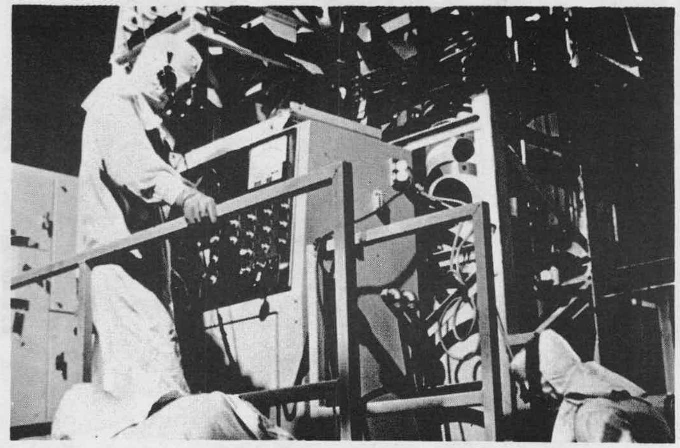
48. Inserting Core Support Assembly in Reactor Vessel



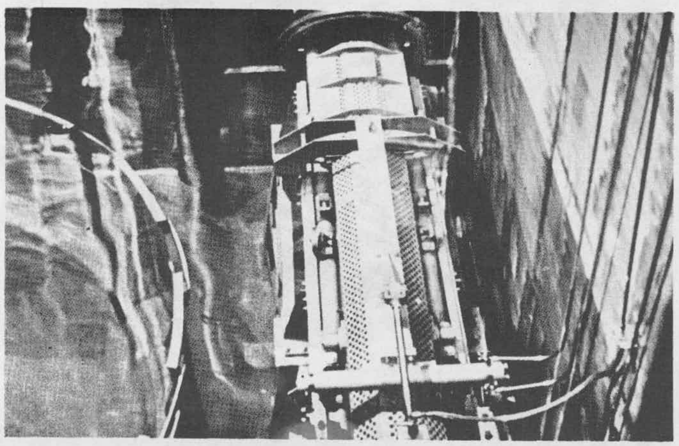
49. Fuel Transfer Operation in Progress



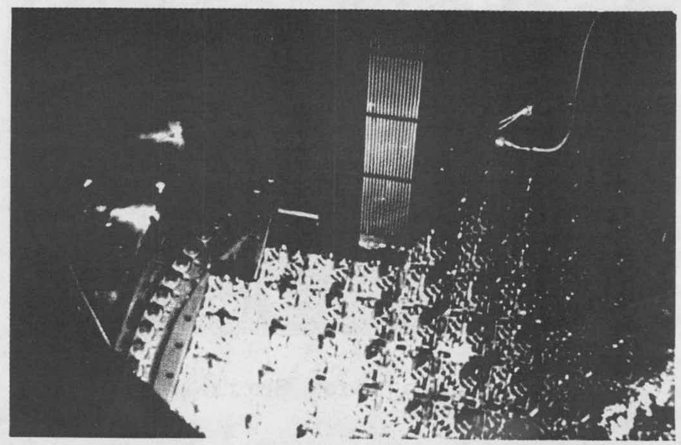
50. Fuel Transfer Mast Control Panel



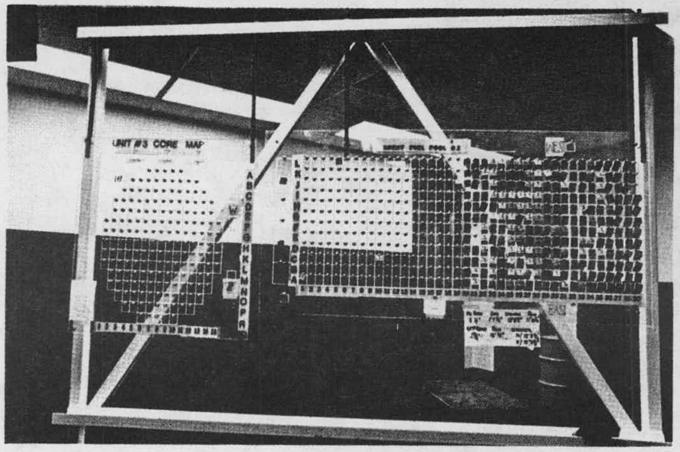
51. Upender Receiving Fuel Assembly in Transfer Basket



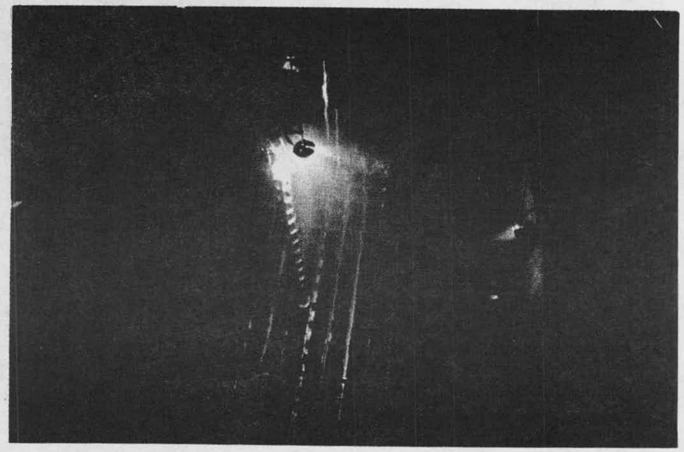
52. Fuel Assembly Loading



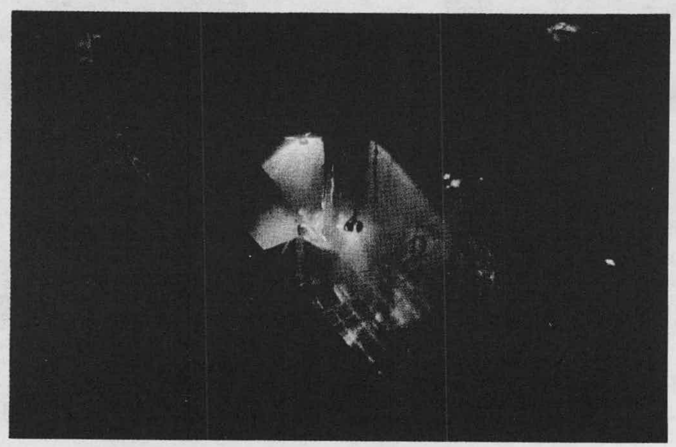
53. Control Room Fuel Assembly and Control Component Position Chart



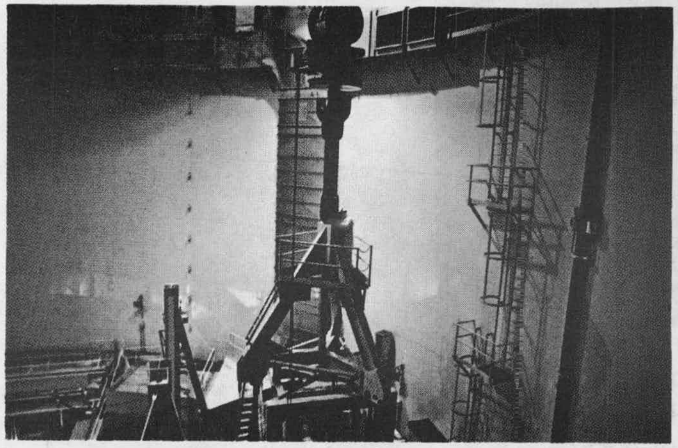
54. Control Component Shuffling in Spent Fuel Pool



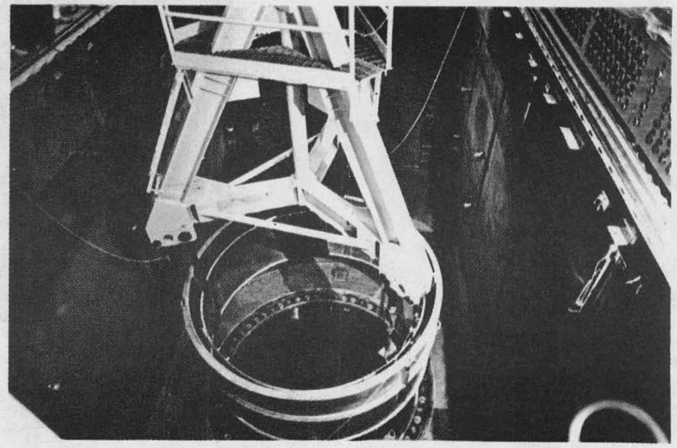
55. Fuel Assembly Movement in Spent Fuel Assembly Shipping Cask



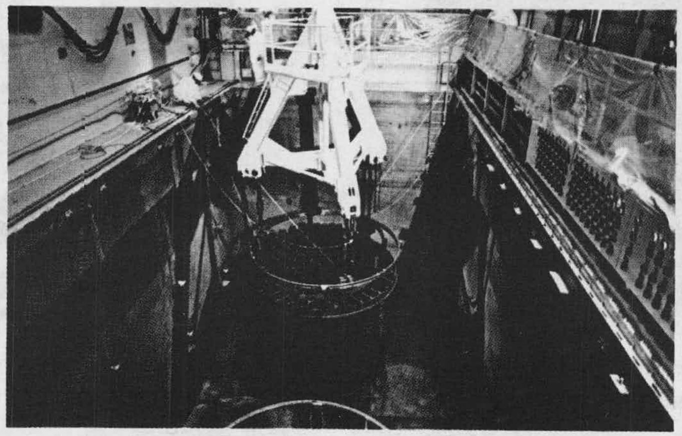
56. Attaching Lifting Tripod to Polar Crane



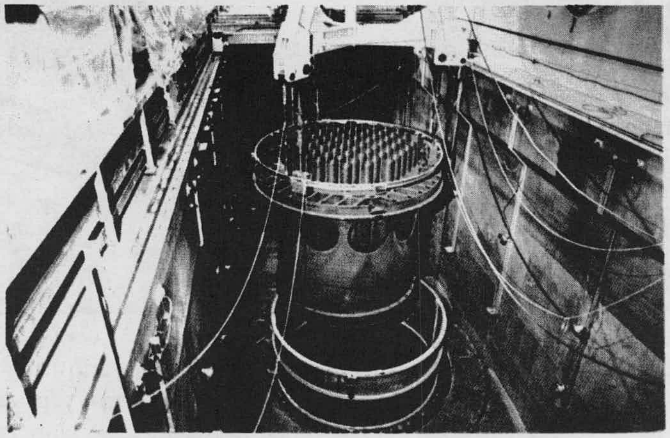
57. Lowering Indexing Fixture Over Reactor Vessel



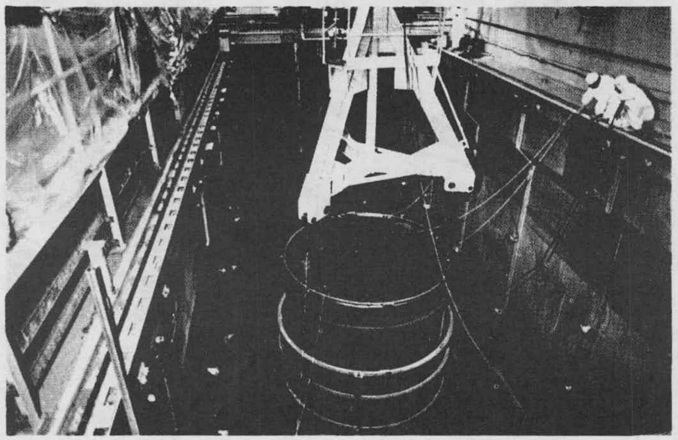
58. Preparing to Lift Plenum Assembly



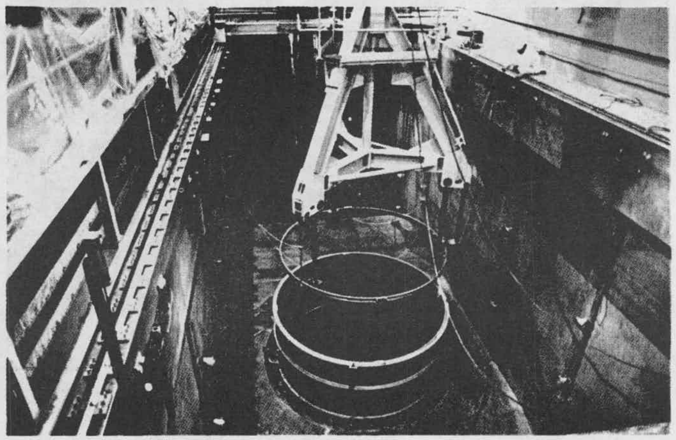
59. Transferring Plenum Assembly to Reactor Vessel



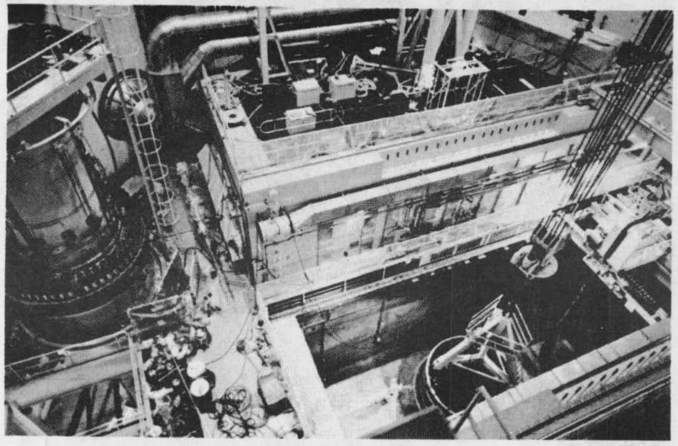
60. Lowering Plenum Assembly Into Reactor Vessel



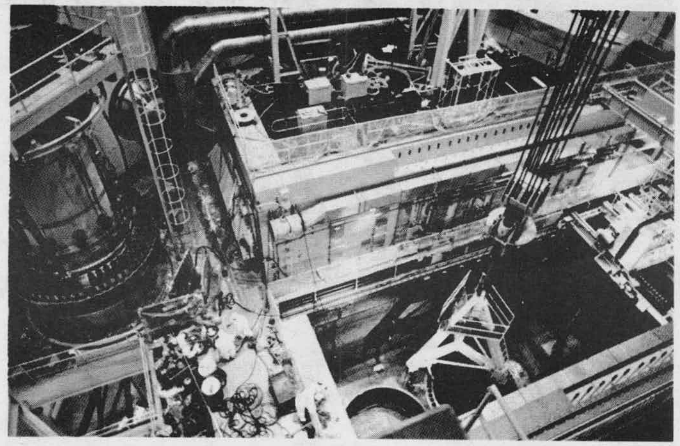
61. Raising Lifting Tripod After Plenum Assembly Installation



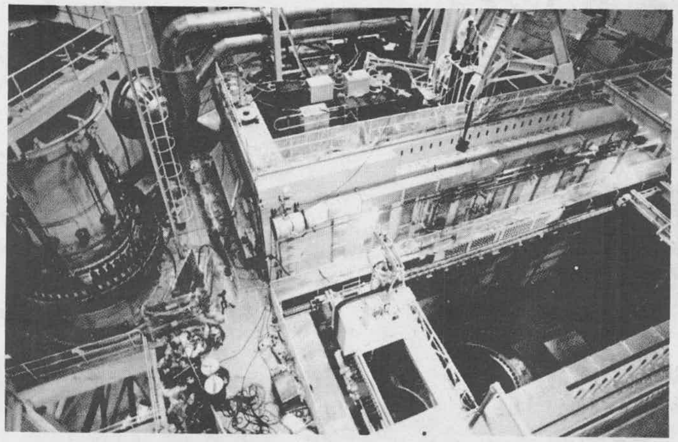
62. Lifting Indexing Fixture From Reactor Vessel



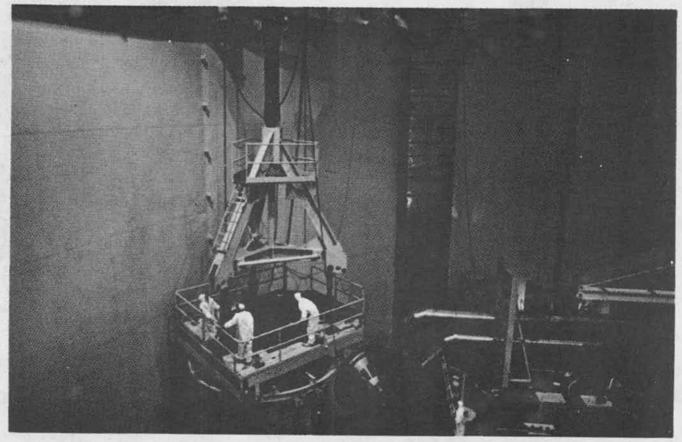
63. Raising Lifting Tripod After Storing Indexing Fixture



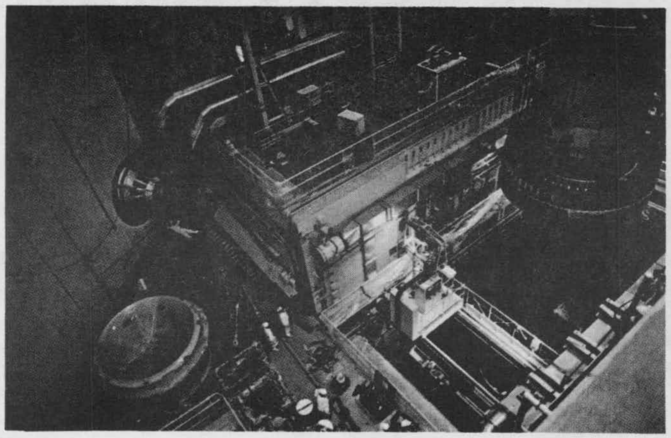
64. Replacing Lifting Tripod Latch Box Assemblies With Leveling Turnbuckles



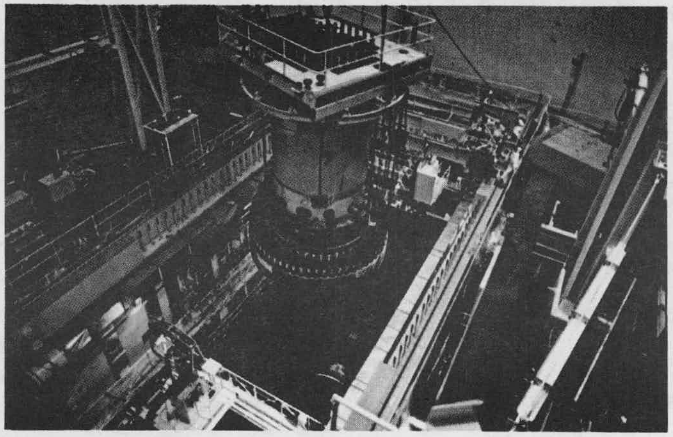
65. Attaching Reactor Vessel Head Lifting Cables to Tripod



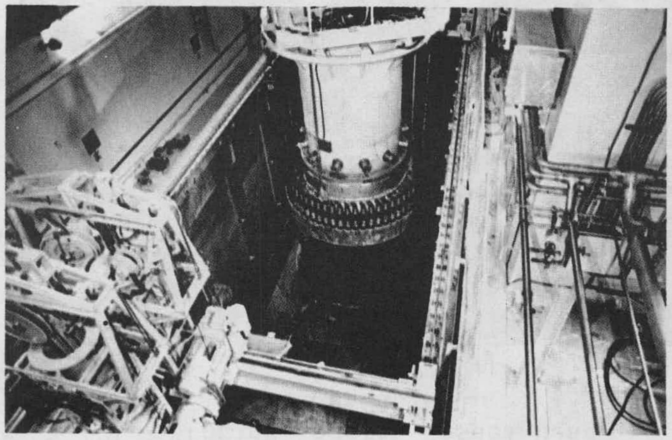
66. Transferring Reactor Vessel Head and CRD Service Structure



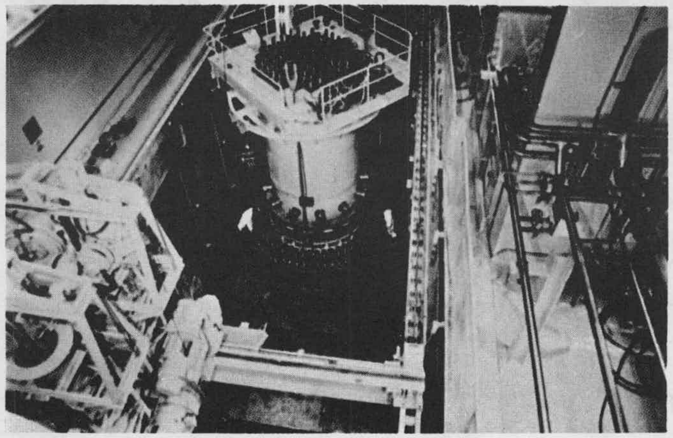
67. Aligning Reactor Vessel Head Over Reactor Vessel



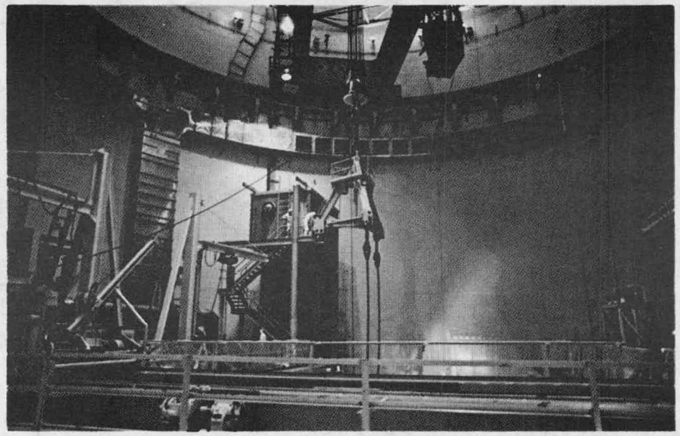
68. Lowering Reactor Vessel Head Onto Reactor Vessel



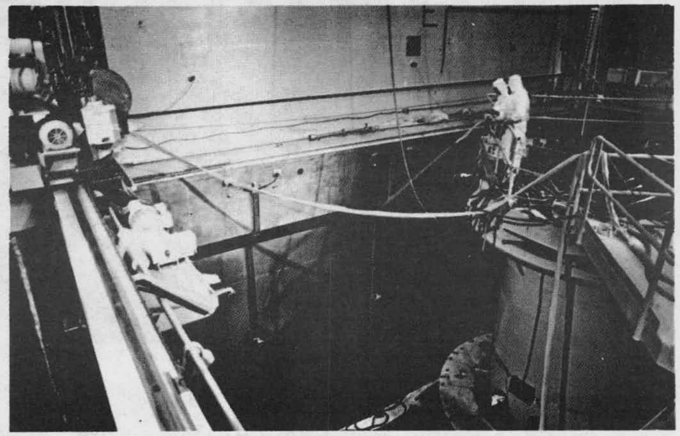
69. Seating Reactor Vessel Head on Reactor Vessel



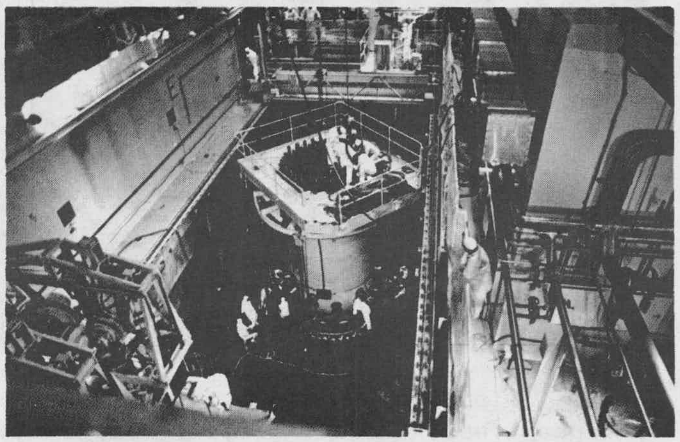
70. Storing Reactor Vessel Head Lifting Cables



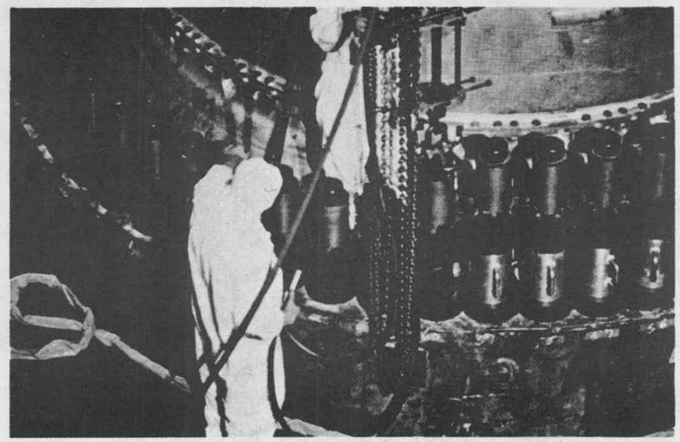
71. Decontamination of Fuel Transfer Canal



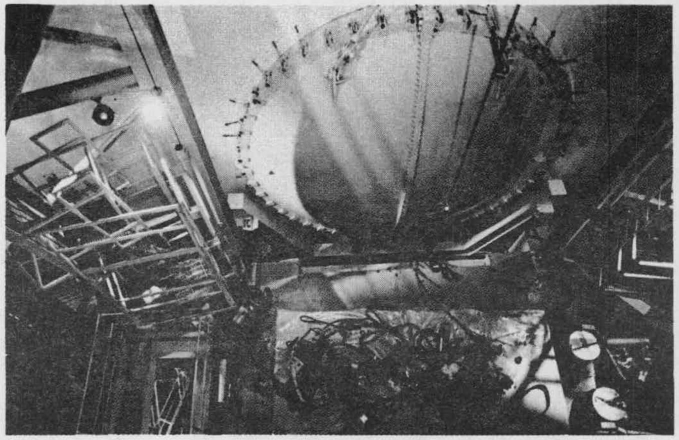
72. Coupling the CRDMs



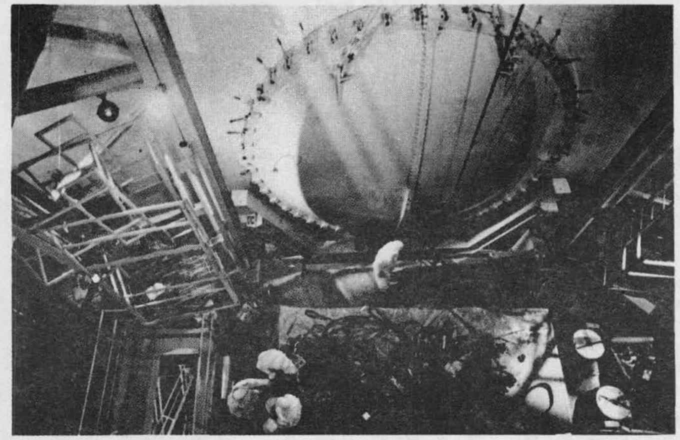
73. Running-In Reactor Vessel Head Studs



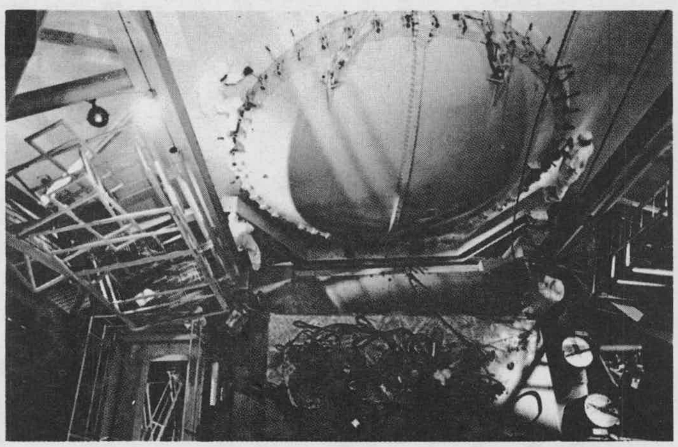
74. Staging Outage Support Equipment at Equipment Hatch



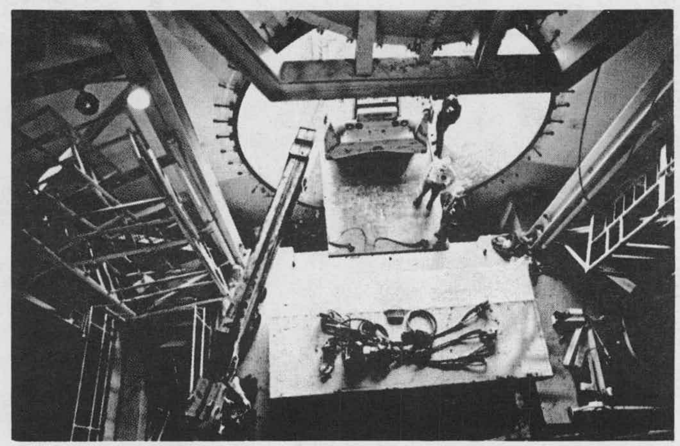
75. Preparing to Lift Equipment Hatch



76. Lifting Equipment Hatch



77. Removing Outage Support Equipment Through Equipment Hatch



Oconee 3 Refueling Outage — Photographic Summary

The following summary includes a brief description of each of the activities in the photographs of the Oconee 3 refueling outage. Recommendations for implementing improvements to equipment, tools, procedures, and techniques are given where applicable.

Photo No.	Description
1	This is an overall view of Duke Power Company's Oconee Nuclear Station. The first RB shown here is that of Unit 3, where the refueling outage observations took place.
2	In this view of the outside of the RB, the staging of materials and equipment needed to be transferred into the RB has taken place. Since the equipment hatch must be closed during refueling operations, it is necessary to schedule in advance the material movement through the hatch. A list of equipment to be moved in during each opening should be prepared to help prevent unnecessary openings that could delay the fuel handling effort.
3	On scheduled equipment hatch openings, the equipment required to be transferred can be moved into the RB expeditiously. During the scheduled equipment hatch openings, consideration should be given to venting the RB in order to moderate the adverse environmental conditions for personnel working inside.
4	Prior planning should have resulted in equipment and tooling lists for the specified outage activities. The specified equipment and tools should be inventoried and staged in tool boxes or storage racks. A tool storage rack (as shown here) simplifies transferring the preselected tools into the RB while providing for a tool storage area that also helps to prevent the spread of contamination.
5	The activities inside the RB start with preparation for removing the missile shields. Here, personnel are unfastening the holddown bolts, having completed the installation of lifting eyes on the first shield. The polar crane is used to lift and move these shields.
6	In this view, the first missile shield has been raised and is in the process of being transferred to its storage location.
7	The second missile shield is shown here, stored on top of the first shield. The large size of these shields requires considerable storage space within the RB, and for this reason preplanning of the actual storage location is necessary to ensure access to other equipment, storage areas, and personnel during the remainder of the outage operations.

Photo No.	Description
8	The missile shield removal operation is completed by storing the fourth and last shield. As shown here, the third and fourth shields are also placed together, but on the opposite sides of the FTC. Again, the correct location and orientation for the stored shields must be considered in advance to preclude their being in the way during the outage operations.
9	The outage continues with preparations in the fuel transfer canal area. One of these operations, shown here, involves removal of the fuel transfer tube cover located in the deep end of the FTC. The installation of small jib cranes to handle such items as the fuel transfer tube covers will free the polar crane for other activities.
10	Preparations for removal of the RV head includes removal of the RV head insulation. A segment of this insulation is shown here being lifted out of the FTC on its way to the storage racks located on the fourth level of the RB. The 16 lifts required by the polar crane to complete this task could be reduced if the storage racks were coupled and lowered into the FTC to accept the insulation.
11	Preparations for the removal of the RV head continue with the lowering of equipment into the FTC. Shown here is the transferring of the RV head stud tensioner tool. Consideration should be given to extending the FTC auxiliary crane travel so as to relieve the small lift load on the polar crane as shown here.
12	Detensioning the RV head studs has always been a time-consuming operation. Efficiency may be improved by using three tensioners with two men per tensioner plus an overall coordinator and by using air motors to position and actuate linkages of the tensioner. In addition, tensioner checkouts should be conducted before and after the detensioning process to reduce the possibility of equipment failure during the detensioning and tensioning operations.
13	While the RV head stud detensioning is in progress, work on the top of the CRD service structure is also started. The efficiency of uncoupling the CRDMs can be improved by using air-driven and/or electrically driven wrenches to remove the CRDM closure insert bolts and by driving the CRDMs after uncoupling to expedite the leadscrew withdrawal process.
14	In addition to the CRDM uncoupling, the power and instrumentation cables to the CRDMs must also be disconnected from the side of the FTC wall. Direct communication with the control room is required during the entire uncoupling process to ensure that no excess CR movement is initiated.
15	While the CRDM uncoupling continues, other outage activities are commencing. Shown here is the installation of the steam generator remote-controlled inspection tool on the fourth level.

Photo No.	Description
16	After completion of the CRDM uncoupling and cable disconnecting, the cables are stored in the service structure cable pit. The two extension platforms between the service structure and the FTC wall are all that remain to be removed before the RV head is lifted.
17	The next sequence of events deals with rigging the RV head lifting equipment. The first step, shown here, is preparation to attach the extension link to the polar crane. The efficiency of this operation can be improved by upgrading the extension link storage area or by providing a storage stand.
18	In this view, preparations are being made to attach the tripod to the polar crane. Note that while there is a catwalk and a ladder on the tripod that provides direct access for personnel to connect the tripod to the polar crane, there should be ladders or platforms to allow easy access to the storage stand.
19	The next operation involves rigging the tripod with the leveling turnbuckles. All rigging equipment should be boldly labeled so that components can be properly aligned with a minimum amount of time and effort.
20	The lifting tripod, with the leveling turnbuckles attached, is then brought to the other side of the FTC so that the lifting cables may be attached to it. Storing the rigging components on the same side of the fuel transfer canal and increasing the crane speeds for these operations will also help to reduce the total time involved to complete the rigging operations.
21	The lifting tripod is then centered over the reactor and lowered so that the lifting cables pass through the CRD service structure. The lower ends of the lifting cables are then attached to the RV head lifting lugs.
22	The RV head and CRD service structure are then lifted as a single unit. They will be transferred completely out of the FTC to provide the necessary maneuvering room for fuel assembly movement.
23	In this view, the RV head (with the CRD service structure) is being transported to the storage stand location. Before resting the RV head on the storage stand, new O-rings are stored on the storage stand to make them accessible for installation during later sequences of the refueling operation.
24	With the RV head on its storage stand, the lifting tripod is disconnected from the lifting cables, which are left attached to the RV head. The lifting tripod's leveling turnbuckles are then replaced with the latch box assemblies used for reactor internals movement.

Photo No.	Description
25	The indexing fixture is picked up by the lifting tripod and is moved over to the RV opening. This fixture provides alignment during removal and installation of the plenum.
26	The indexing fixture is shown here being placed directly over the RV flange. While two guide studs aid in installation of this fixture, pre-indexing the polar crane will reduce excessive directing for positioning of the crane.
27	While preparations for the refueling operations continue, the RV head and CRDM inspection operations can be started. The efficiency of these operations can be increased by the addition of support equipment, such as jib cranes and easy-access work platforms in the areas requiring equipment lifts and personnel access.
28	The next operation is removal of the plenum assembly from the RV. The lifting tripod latch box assemblies should be lowered in their latched position until they automatically unlatch and then latch onto the plenum lifting lugs. This method eliminates the requirement for latching the boxes with long-handled tools.
29	The plenum assembly is transported to the end of the FTC, where it will be stored during the refueling operation. The use of ropes in lieu of long-handled tools can also expedite the unlatching operations.
30	This view shows the stored plenum assembly. The procedure for plenum removal has now been completed and, as can be seen, the operation took place with the fuel transfer canal dry. This procedure has been performed on some nuclear plants and has not resulted in excessive exposures. The primary reason for dry plenum removal is to reduce exposure during RV head stud hole work and RV flange work. After the plenum is stored, the indexing fixture is removed with the polar crane. Refueling of the core can then be started.
31	The next series of three views shows activities associated with removal of the core support assembly after complete defueling. This operation is not normally done during a typical refueling outage. However, because of SSHT repairs, the core support assembly was removed. In this view, the FTC has been filled with borated water and the lifting tripod has been attached to and is in the process of removing the core support assembly (CSA) from the RV.
32	After removal of the CSA from the RV, it is transferred to the deep end of the FTC and it is placed on the storage stand. The water level of the FTC is lowered and the inspection/work platform can be placed for easy access to the CSA by the outage personnel for SSHT repair work.

Photo No.	Description
33	This overhead view shows the progress of work on the CSA. A submerged TV camera is an invaluable tool during these types of operation, which involve long-handled tools or difficult viewing access conditions.
34	While the outage continues on the primary side, secondary side plant outage activities must be conducted in parallel. As with the primary side, the secondary side material staging is of prime importance to support the scheduled maintenance.
35	Tools and spare parts accountability and staging is also of prime importance if delays of the scheduled maintenance activities are to be prevented. Time is lost many times during outage operations due to the unavailability of the proper tools or spare parts.
36	Equally important is the preparation of available laydown and storage locations for disassembled components. Plant layouts should be carefully considered during the design stages, to provide adequate laydown areas for conducting maintenance activities.
37	This is a general view of the turbine building. Work is in progress on the high-pressure turbine. In this type of work, the crane is used extensively to move these large components.
38	Preparations are underway to remove the high-pressure turbine rotor to allow access for maintenance activities. Maintenance personnel are shown here in the process of removing the high-pressure turbine bearing cap.
39	Next in the preparations to remove the high-pressure turbine rotor is removal of the high-pressure turbine diaphragms. Again, note that the crane is used for these operations, requiring that crane utilization be planned in order to avoid delays.
40	In this view, the laid-up high-pressure rotor is seen. The excellent laydown space available at this nuclear plant can be noted here. The availability of this space provides for more orderly and expeditious flow of the maintenance activities.
41	Another major outage activity on the secondary side is work done on the generator. In this view, preparations are underway to remove the generator rotor.
42	While the generator is being pulled out, the crane is also used to provide the required support. The use of the proper tools, rigging, and procedures for this operation is essential in order to preclude damage to the components and to provide for a more efficient operation.
43	Continuing secondary side plant outage activities include work with the low-pressure turbine. The number and availability of spare parts

Photo No.	Description
	for all of the outage operations favors the development of a computerized tracking system that can be used by maintenance personnel so that the work can be better planned, scheduled, and executed.
44	This view shows the movement of a large turbine component. The work in progress is the lowering of the low-pressure turbine cover after completion of the maintenance activities on the low-pressure turbine.
45	Back on the primary side plant outage activities, the work in progress is reinstallation of the CSA into the RV. Shown here is the lifting of the CSA from the storage stand at the end of the FTC.
46	The CSA is moved to the RV with the indexing fixture attached to the lifting tripod. This method provides the necessary indexing during the last stages of CSA insertion.
47	Shown here is the CSA being centered over the RV prior to insertion. This sequence can be expedited by pre-indexing of the polar crane. Constant communications with the crane operator also expedite the evolutions.
48	Once the CSA is properly centered and aligned, it is lowered into the RV. With the CSA installed in the RV, the fuel assembly transfer operations can then be started.
49	The fuel movement operations are conducted with the transfer mast. Since fuel movement is generally a time-consuming operation, operators should be trained in trouble-shooting and repairs so that they can perform minor maintenance work on the fuel handling equipment to keep it operational through the outage. In addition, combining the existing dual mast with a single fuel assembly and control component mast will reduce the time needed to perform the fuel shuffling operations.
50	This is a closeup of the fuel transfer mast control panel. Updated copies of the electrical drawings placed inside the control console will provide a ready reference for both operators and maintenance personnel.
51	Fuel assemblies are transferred from the spent fuel pool to the FTC through the transfer tube. Shown here is the receipt by the upender mechanism of a fuel assembly in the transfer basket.
52	Shown here is a fuel assembly being inserted into the reactor core. The installation of a TV camera on a separate mast would help the operators to monitor the positioning and withdrawal of fuel assemlies. Such a camera can also be used for core verification at the end of refueling.
53	The fuel shuffling sequence is an operation that requires detailed pre-outage planning. In addition to the actual fuel assembly

Photo No.	Description
	movements, the control components are also moved from one fuel assembly to another, which may require as many as 400 "moves" to complete the operation. A core and spent fuel pool map, such as the one shown here, provides a means of keeping track of the actual location of the fuel and control components during shuffling operations.
54	The fuel and control component shuffling also takes place in the spent fuel pool. The pre-indexing of the bridges to all storage racks and transfer stations simplifies and expedites the operations. The capability of maintaining pool visibility in the pools is also essential.
55	This is a view in the spent fuel pool, with fuel assembly movement taking place in the spent fuel shipping cask. Pre-outage personnel training on the use of fuel handling equipment by actual operation in the spent fuel pool becomes beneficial during the actual outage operations.
56	Once fuel assembly shuffling has been completed, the FTC can be drained and preparations can be made to re-install the plenum assembly. First, the lifting tripod is placed into operation for the upcoming lifts.
57	The stored indexing fixture is picked up by the lifting tripod and is then transferred and installed over the RV. The indexing fixture will provide the necessary indexing during the plenum assembly installation.
58	Once the indexing fixture is installed, the lifting tripod is moved over the plenum assembly where they will be attached through the latch box assemblies.
59	The plenum assembly is then lifted and transferred from the end of the FTC to the RV. Note again that these operations can be conducted with the FTC dry.
60	With the plenum assembly centered over the RV, the assembly is lowered through the indexing fixture into the RV. Note the use of ropes to expedite the unlatching operations when the plenum is seated.
61	This view shows withdrawal of the lifting tripod following plenum assembly installation. The spreader ring seen on the latch box assemblies is used to maintain the relative position of the latch box assemblies during the latching operations.
62	The next operation is removal of the indexing fixture from the RV. Again, the pre-indexing of the polar crane reduces the time required to align and complete the coupling operations.

Photo No.	Description
63	The indexing fixture is removed from the RV and it is stored in the bottom of the FTC. With the completion of this operation, preparations are started for the replacement of the RV head.
64	The lifting tripod must be re-rigged for RV head movement. First, the latch box assemblies attached to the lifting tripod are replaced by the leveling turnbuckles.
65	With the leveling turnbuckles attached, the lifting tripod is moved over the RV head and CRD service structure storage area. Here, the leveling turnbuckles can then be attached to the lifting cables which were also left attached to the RV head.
66	In this view, the RV head and CRD service structure have been lifted from the storage stand and are in the process of being transferred to the RV.
67	The RV head is then moved over the fuel transfer bridge and into the FTC area. The RV head is at this point already carrying the new O-rings previously installed at the storage location.
68	As the RV head is lowered, it is aligned over the RV. Note here that the two guide studs in the RV flange can be seen. These studs will act as final alignment devices during the last stages of RV head installation.
69	Shown here is the RV head as it is just about to be seated onto the RV. During these last stages, inspections are made to verify that the RV head is in a level position as it approaches the seating surfaces.
70	With the replacement of the RV head, the lifting tripod can be derigged. First the lifting cables and turnbuckles are removed and placed in their storage locations. The lifting tripod will also be placed on its storage stand and will then free the polar crane for other activities.
71	FTC decontamination is shown here. This operation is performed to prevent the spread of contamination and to reduce the exposure to maintenance personnel who will be conducting the remainder of the activities within the FTC.
72	As preparations are being made to tension the RV head studs, work is started on the coupling operation of the CRDMs. After CRDM coupling, the electrical and instrumentation cables will also be connected.
73	The stud tensioning operations begin with the running in of the studs, which have been parked on the RV head. Increased speed of this stud handling tool will also reduce the time to complete this operation.

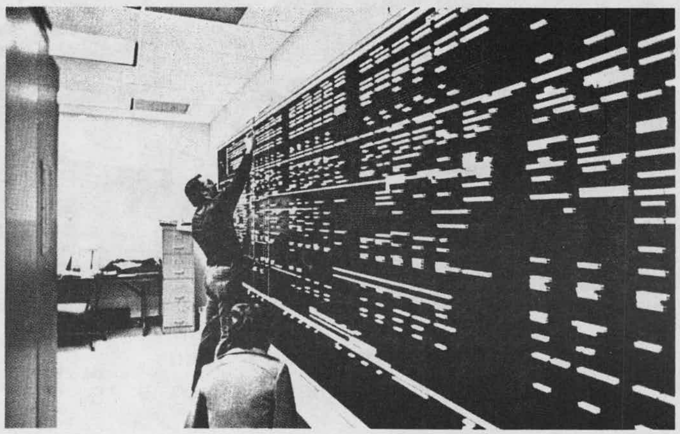
Photo No.	Description
74	Staging areas should be set up in the RB for tools and equipment no longer needed, especially toward the end of the outage. Tools can be collected as the remaining operations of RV head tensioning, RV head insulation installation, canal seal plate removal, and missile shield installation are completed.
75	Shown here are the preparations to remove the equipment hatch to transfer the excess equipment. As noted earlier, the opening of the equipment hatch should be scheduled, and a list of the equipment scheduled to be removed should be prepared in advance.
76	At the scheduled time, the equipment hatch is opened to allow removal of the collected equipment. Similar material staging should also be conducted for items that will be removed through the personel hatch.
77	As the equipment is removed, the tools removed and of the tools remaining in the RB should be accounted for. Upon completion of the scheduled activities in the RB, operations are started on the sequence of events leading to reactor startup, signifying completion of the refueling outage.

APPENDIX D

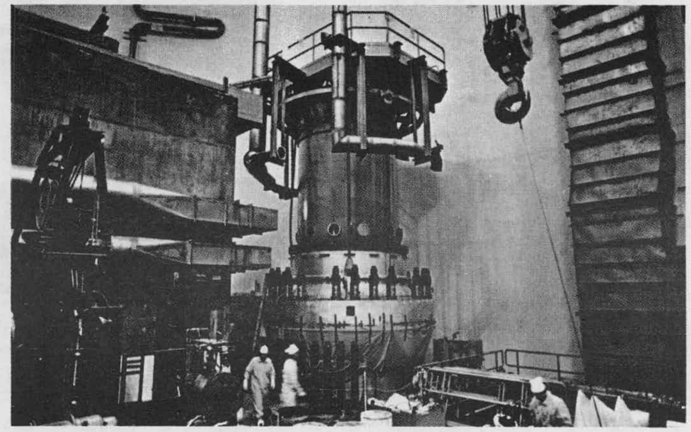
ANO 1 Refueling Outage —
Illustrative Photographs

1. Arkansas Nuclear One, Unit 1

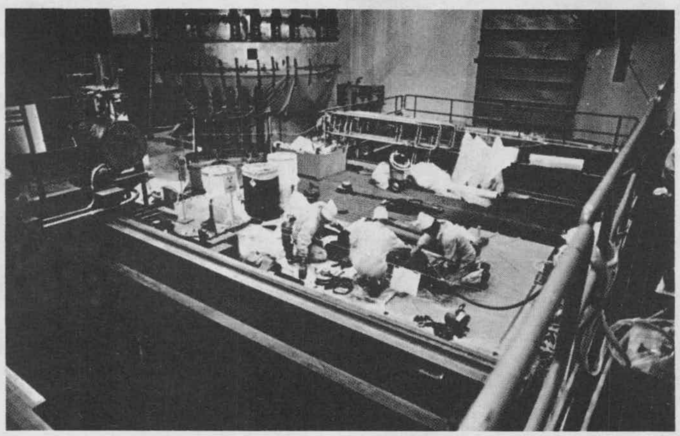
2. Refueling Outage Plan-a-Log Room



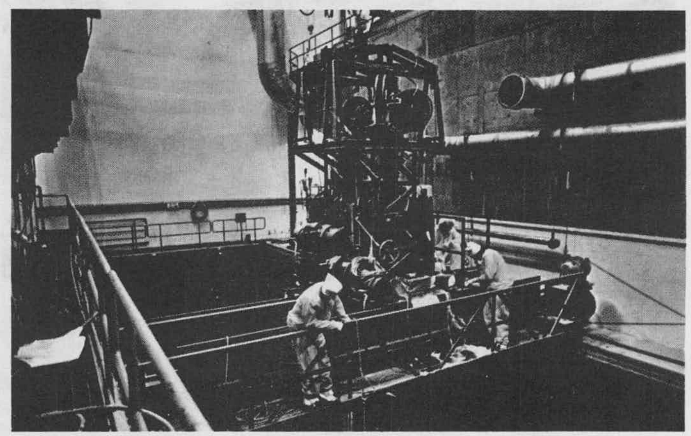
3. Stored Reactor Vessel Head and
CRD Service Structure



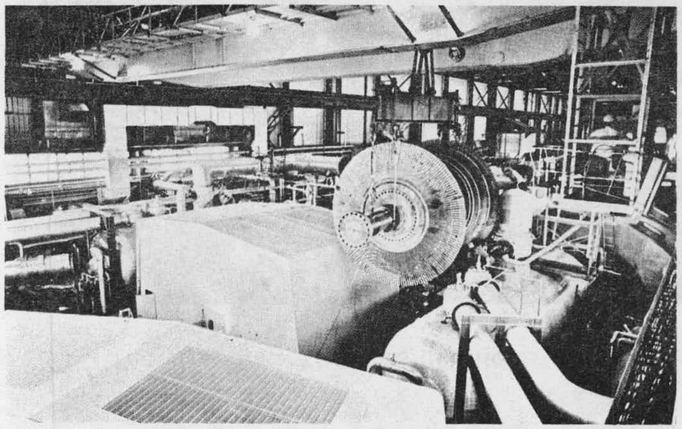
4. Cleaning Reactor Vessel Head Studs



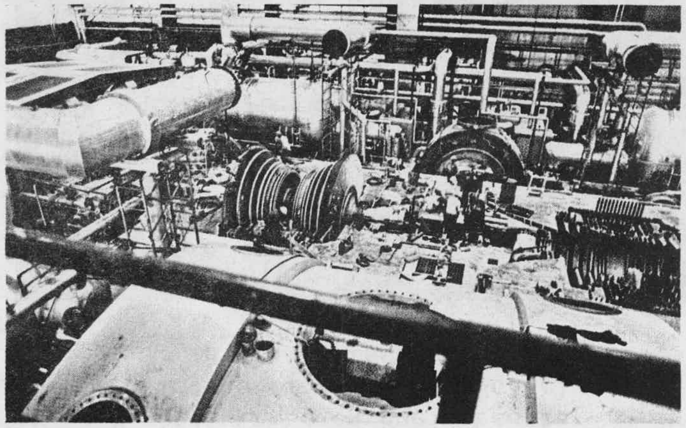
5. Activities on Fuel Transfer
Bridge During Reactor Vessel
Internals Inspection



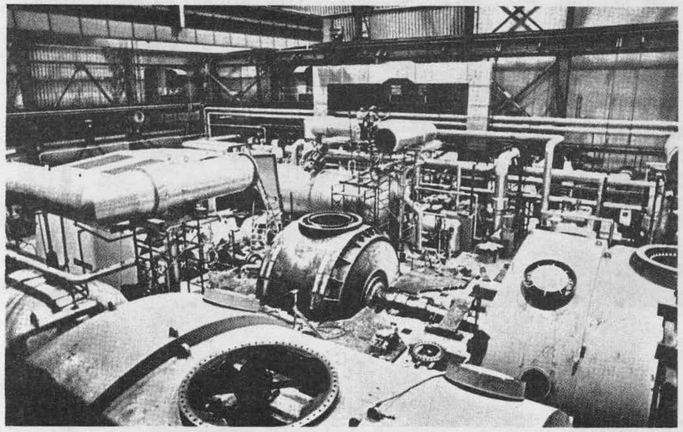
6. Transferring A Low-Pressure Turbine Rotor Back to Casing



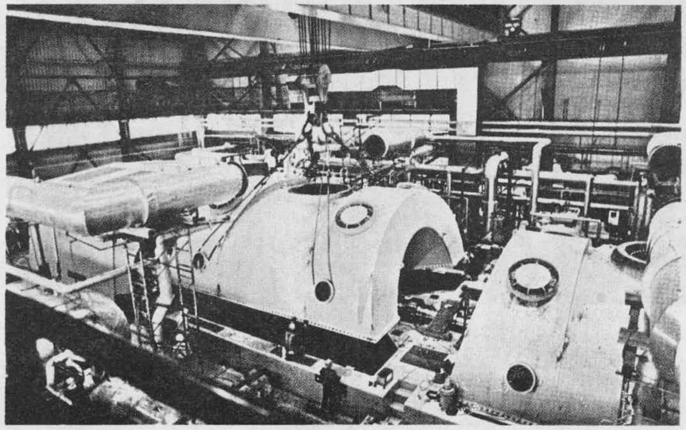
7. Maintenance Activities on A Low-Pressure Turbine Rotor



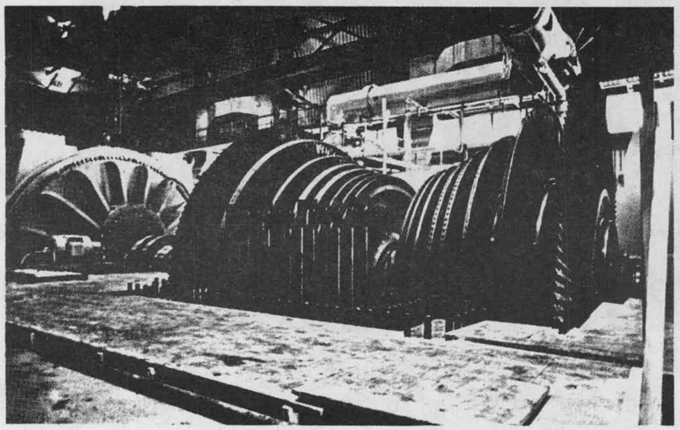
8. A Low-Pressure Turbine With Inner Casing Installed



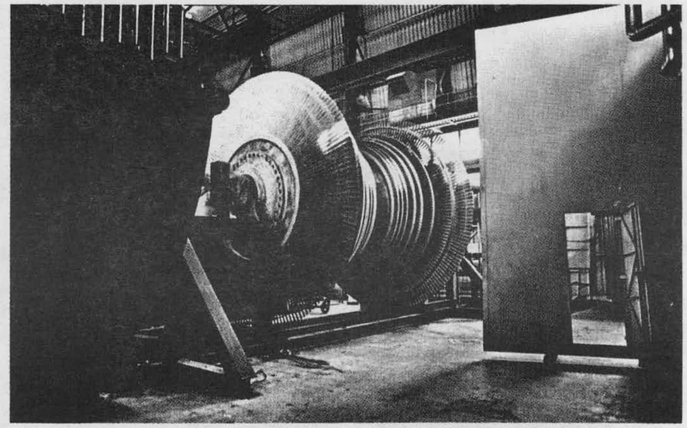
9. Lowering Outer Casing on A Low-Pressure Turbine



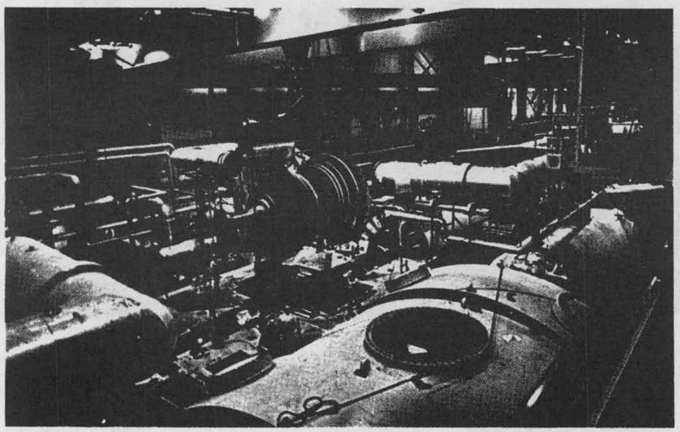
10. B Low-Pressure Turbine Rotor in Casing



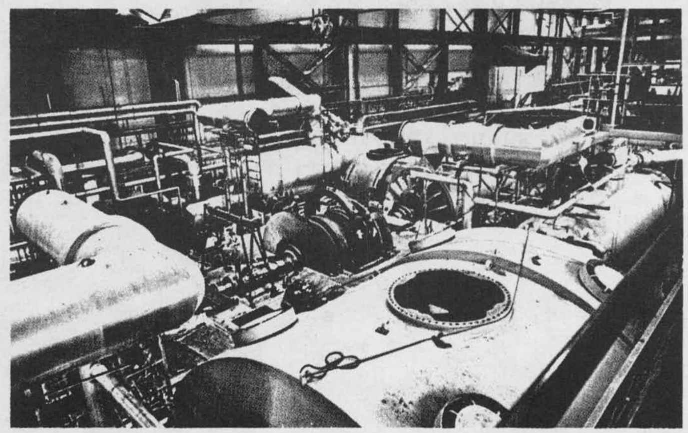
11. Laid-Up B Low-Pressure Turbine Rotor



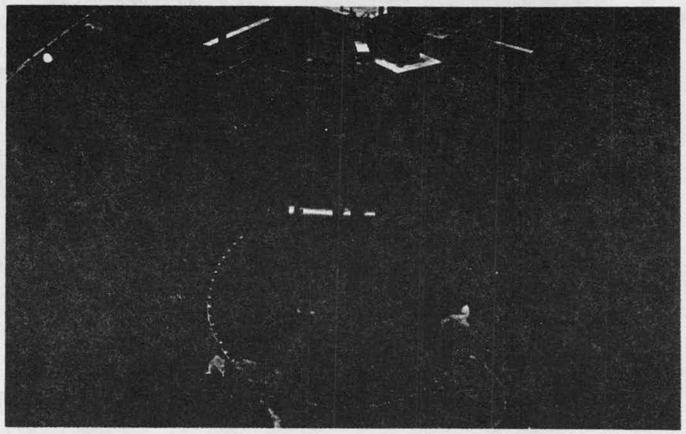
12. Lowering B Low-Pressure Turbine Rotor in Casing



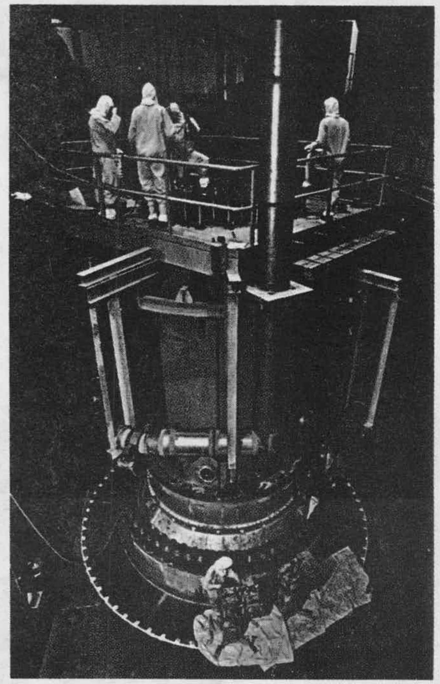
13. Replacing B Low-Pressure Turbine Diaphragm



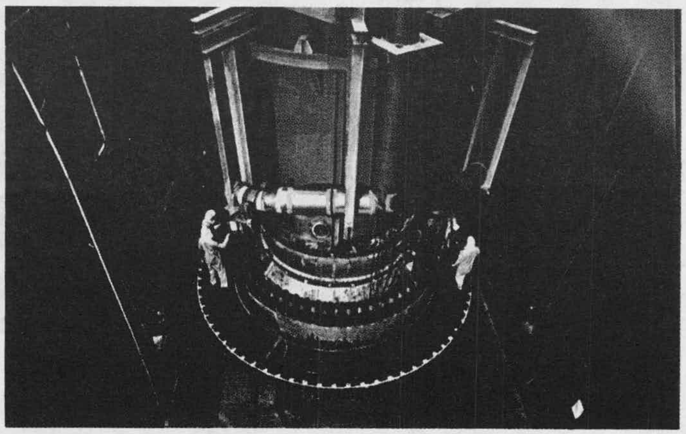
14. Installation and Running-In of Reactor Vessel Head Studs



15. CRDM Coupling and Stud Tensioner Checkout



16. Tensioning of Reactor Vessel Head Studs



ANO-1 Refueling Outage — Illustrative Photographs

The following summary is a brief description of the activities and plant conditions shown in the photographs of the ANO-1 refueling outage. These illustrative photographs are presented to supplement the various recommendations for improvements to equipment, tools, procedures, and techniques listed in this report and to illustrate the physical surroundings typical of a nuclear plant during the refueling outage.

Photo No.	Description
1	An overall view of Arkansas Power & Light's Arkansas Nuclear One, Unit 1. The refueling/maintenance observations were also conducted at this nuclear plant as part of the DOE-sponsored Refueling Outage Availability Study.
2	A partial view of the Plan-a-Log room showing portions of the scheduled outage activities. Considerable planning and updating of this master schedule is necessary to provide the current status of the outage and the relationship of upcoming activities on the critical outage path development.
3	The reactor vessel head and control rod drive service structure in its storage location after removal from the reactor vessel. Some of the reactor vessel head studs can be seen in their storage racks beside the reactor vessel head. At this site, the removal of some of these studs is necessary to comply with the rated lift capability of the polar crane during the reactor vessel head lifting operations. Outage time could be saved if the polar crane were upgraded to handle the reactor vessel head and all studs, thereby eliminating the required operations to completely remove some of the studs.
4	One of the maintenance activities required during the refueling outage is cleaning the reactor vessel head studs. This time-consuming operation, while conducted as a parallel activity to the critical path activities, could also be speeded up by using a motor-operated cleaning tool. Accessibility, adequate working area, maintenance supplies, and facilities need careful planning to prevent such an activity from influencing the refueling outage critical path.
5	During this particular refueling outage, all of the fuel assemblies were removed from the reactor vessel to allow inspection of the reactor vessel internals. This inspection operation was aided by the use of an underwater TV camera with its associated monitoring equipment mounted right on the fuel transfer bridge. This type of equipment can also be used as part of the fuel assembly verification operation after completion of the fuel shuffle operations.

Photo No.	Description
6	The major activities during this refueling outage were associated with the secondary side of the plant. This was due to extensive inspection and rework on the LP turbines. In this view the "A" LP turbine rotor is being transferred from its storage location back to the casing. As can be seen here, the efficiency of the transfer operation is hampered by the lack of maneuvering room to handle this large rotor. The requirements for these maintenance operations should be given due consideration during the plant's design stages in order to provide ample facility layouts.
7	In this view, preparations are being made to perform machining operations on the "A" LP turbine rotor. The "B" LP turbine rotor has been removed, and its exposed lower casing can be seen on the right hand side.
8	After machining and maintenance operations, the top half of the inner casing is installed on the "A" LP turbine. The availability of spare parts and proper tooling for this type of maintenance activity is critical to prevent undue delays that could easily extend the total outage time.
9	Installation of the "A" LP turbine outer casing. Considerable crane time is required to handle these large components; hence, proper scheduling of the work and crane utilization are required to prevent unnecessary delays.
10	The "B" LP turbine with casing removed. Note that temporary working areas have been provided around the rotor to facilitate maintenance activities. Providing adequate accessibility to the work areas go a long way toward improving the overall efficiency of the operation.
11	The outage activities at this plant required removal of both LP turbine rotors. Here the "B" LP turbine rotor is shown in its storage stand. Storage locations for such large components should also be given due consideration during the plant's design stages to provide laydown areas that contribute to expeditious maintenance activities.
12	The "B" LP turbine rotor is shown being lowered into its casing. Preparations have started to complete reinstallation of the turbine components.
13	One of the turbine diaphragms being lowered onto the rotor. Preparations have also been started to couple the two rotors and to couple to the generator.
14	The last series of photographs show the activities on the primary side after the completion of the fuel shuffle operations. In this view of the reactor vessel head and service structure,

Photo No.	Description
	preparations are started on installation of the reactor vessel head studs. A storage rack holding some of the studs has been lowered into the fuel transfer canal (bottom of photo).
15	Work is also started on the CRDM coupling activities on top of the service structure. Also shown are the two stud tensioners that have been lowered into the fuel transfer canal for the upcoming stud tensioning operations.
16	The two stud tensioners are being operated simultaneously and on opposite sides of the reactor vessel head. Several equipment improvements have been recommended in the areas of CRDM coupling and reactor vessel head stud work, which are aimed at reducing the time required for performing these operations and thus contribute to reduce the overall outage time.

APPENDIX E

Refueling Outage Activities Recorded on Data Sheets

Activity	Oconee 3	ANO 1
Shutdown and cooldown	X	X
Open equipment hatch		X
Move equipment into reactor building	X	
Remove missile shields	X	X
RCP seal removal, inspection, and blank flanges	X	
Install cleanroom for B OTSG	X	
Remove manway on B OTSG	X	X
Remove manway on A OTSG		X
Install eddy-current equipment	X	
Eddy-current inspection, B OTSG	X	X
Remove eddy-current equipment from B OTSG	X	
Eddy current inspection, A OTSG	X	X
Install canal seal plate	X	X
Remove reactor head insulation	X	X
Detension reactor vessel studs	X	X
Remove and place 36 studs in rack		X
Remove transfer tube cover	X	X
Uncouple CRDs and APSRs	X	X
Remove CRD electrical and PI cables		X
Install head lifting rig	X	X
Remove RV head and place on stand	X	X
Rig for plenum removal	X	
Install seal plugs and fill holes	X	X
Install indexing fixture	X	X
Remove plenum and store	X	X
Remove indexing fixture	X	X
Flood transfer canal	X	X
Pull core barrel	X	
Remove incore detectors	X	X
Checkout of fuel handling equipment		X
Install CRD mast on main fuel bridge		X
Defueling of reactor	X	X
Spent fuel pool storage	X	
Internal vent valve exercise		X
Refuel reactor	X	X

Activity	Oconee 3	ANO 1
Shuffle control rods	X	
Fuel verification		X
Install indexing fixture	X	X
Cut up incores		X
Replace pressurizer spray valve	X	
Clean RV head studs	X	X
Clean O-ring grooves (on RV head)	X	X
Install O-ring (on RV head)	X	X
Install plenum	X	X
Insert incore and torque seals		X
Install RV head	X	X
Complete canal drain	X	
Remove guide studs	X	X
Drain transfer canal to 4 inches below vessel flange		X
Install transfer tube covers	X	
Remove seal plugs		X
Clean stud holes — drain potassium chromate	X	
Install incores	X	
Tension RV head	X	X
Install head insulation	X	X
Raise canal seal plate	X	
Install RCP seals 3B1 and 3B2	X	
RCP motor checkout		X
Remove CRD stators		X
Uncrate/install new CRD stators		X
Couple CRDs	X	X
Remove and clean canal seal plate and flange		X
Clean canal and receiving area		X
Fill and vent RCS		X
Seal oil system modifications		X
Inspect and repair B reheater		X
Aux. FW pump overhaul		X
LP turbine A/B inspection		X
Install missile shield blocks		X
Equipment hatch in place and sealed		X

Activity	Oconee 3	ANO 1
Change out TE-1015 (temp element)		X
Calibrate PI 2415 (CFT level transmitter)		X
RCS inservice inspection		X
Plant heatup to hot shutdown		X
Post heatup physics test		X
Physics test at 75% FP		X
Physics test at 100% FP		X
Unit capability test		X

Sample of Data Sheet

DOE DATA SHEET

DATE 9-20-76

ACTIVITY CODE 59 ACTIVITY REMOVE TRANSFER TUBE COVER

TASK SAME SHR/WR NO. 11784A

RESPONSIBLE DEPARTMENT M/E

APPLICABLE PROCEDURES

OUTAGE DAY 5/2 SHIFT M(D) OBSERVER Shetler

OBSERVATIONS:

1. START TIME: CRITERIA Start to loosen first nut
   (12) SCH. 0400 ACT. *
2. COMPLETION: CRITERIA Last Cover stored
   SCH. 0800 ACT. 1315
3. MANPOWER: SCH. 3 ACT. ~ 2
4. TAPE NO. 2P
5. RADIATION LEVELS: ~ 3-5 mR/hr in FTC
6. DELAYS:

ITEM DESCRIPTION	TIME OCCURRED	TIME CLEARED	LOST HOURS
- waiting on crane avail.	mid shift	1245	

7. CONDITIONS:

ITEM	EXCEL.	GOOD	POOR	COMMENTS
a. TEMP.			X	~~Heat Oppressive for work~~
b. ACCESS		X		
c. LIGHTING		X		
d. TOOLING COND.		X		
e. MANPOWER UTIL.		X		

8. GENERAL OBSERVATIONS:

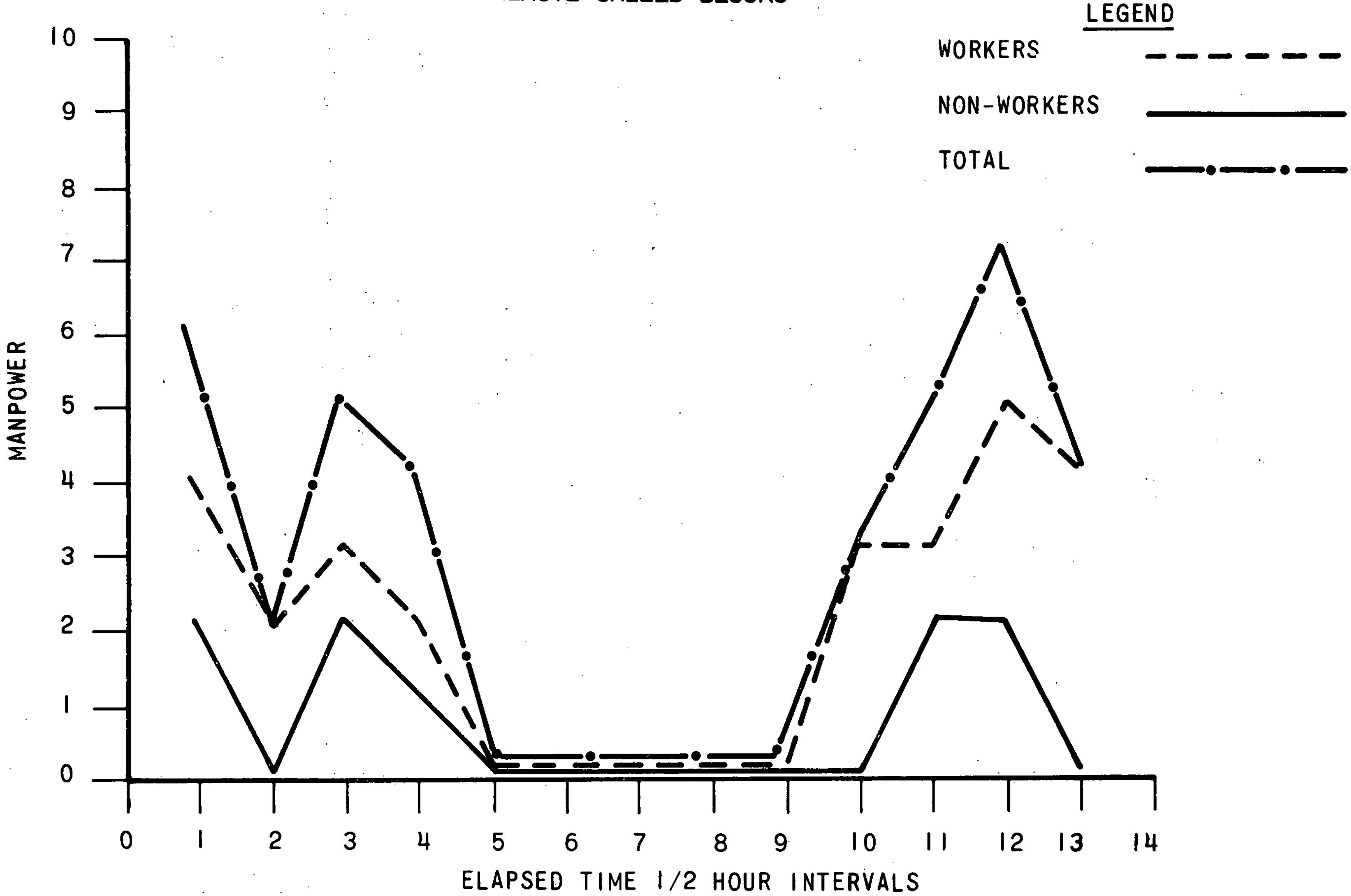
-* Bolts loosened during Mid-shift
- 1245-1315 - covers (2) lifted, placed & crane tree

APPENDIX F

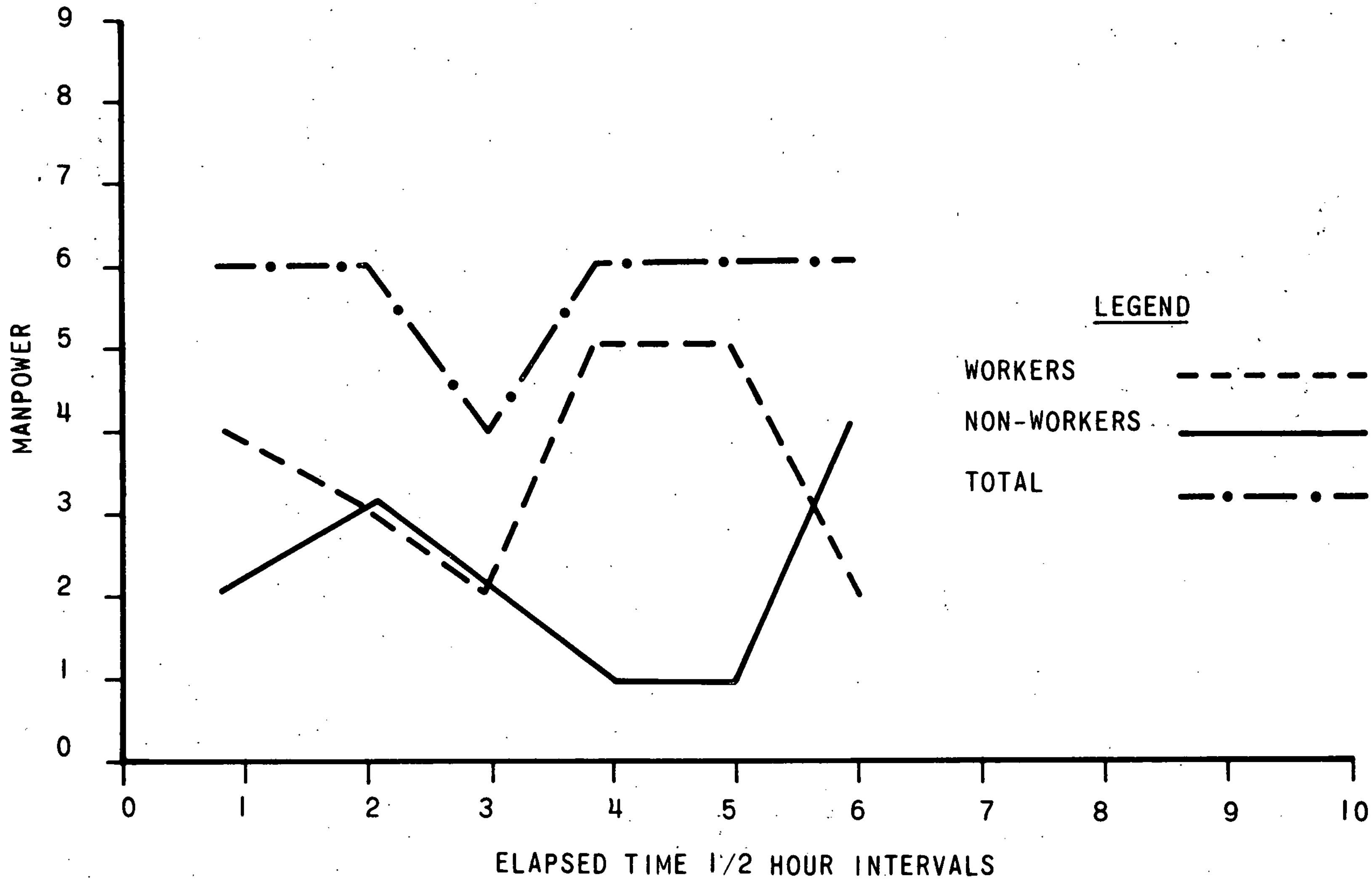
Graphs of Manpower Analysis

SEQUENCE # 2

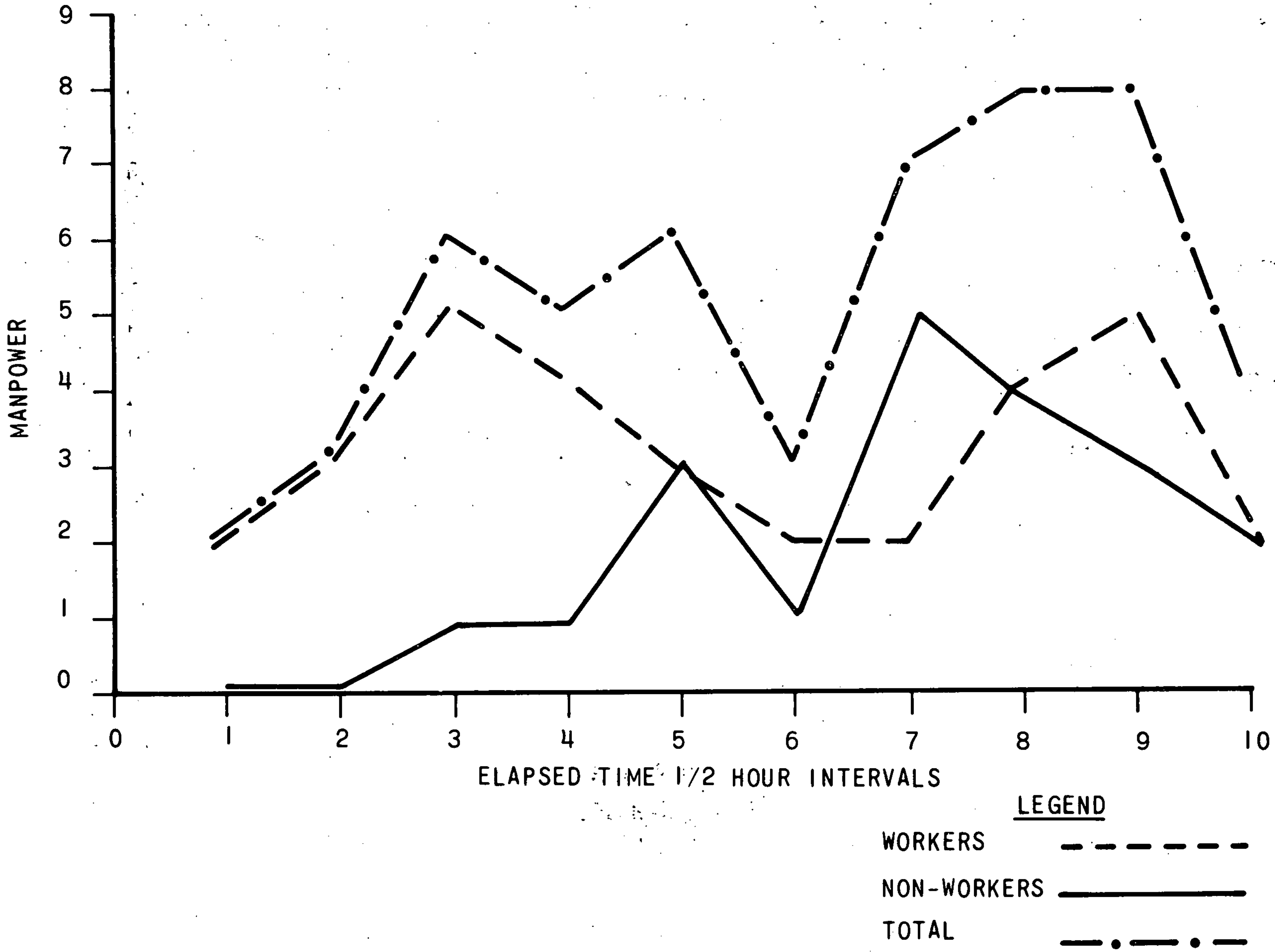
REMOVE SHIELD BLOCKS



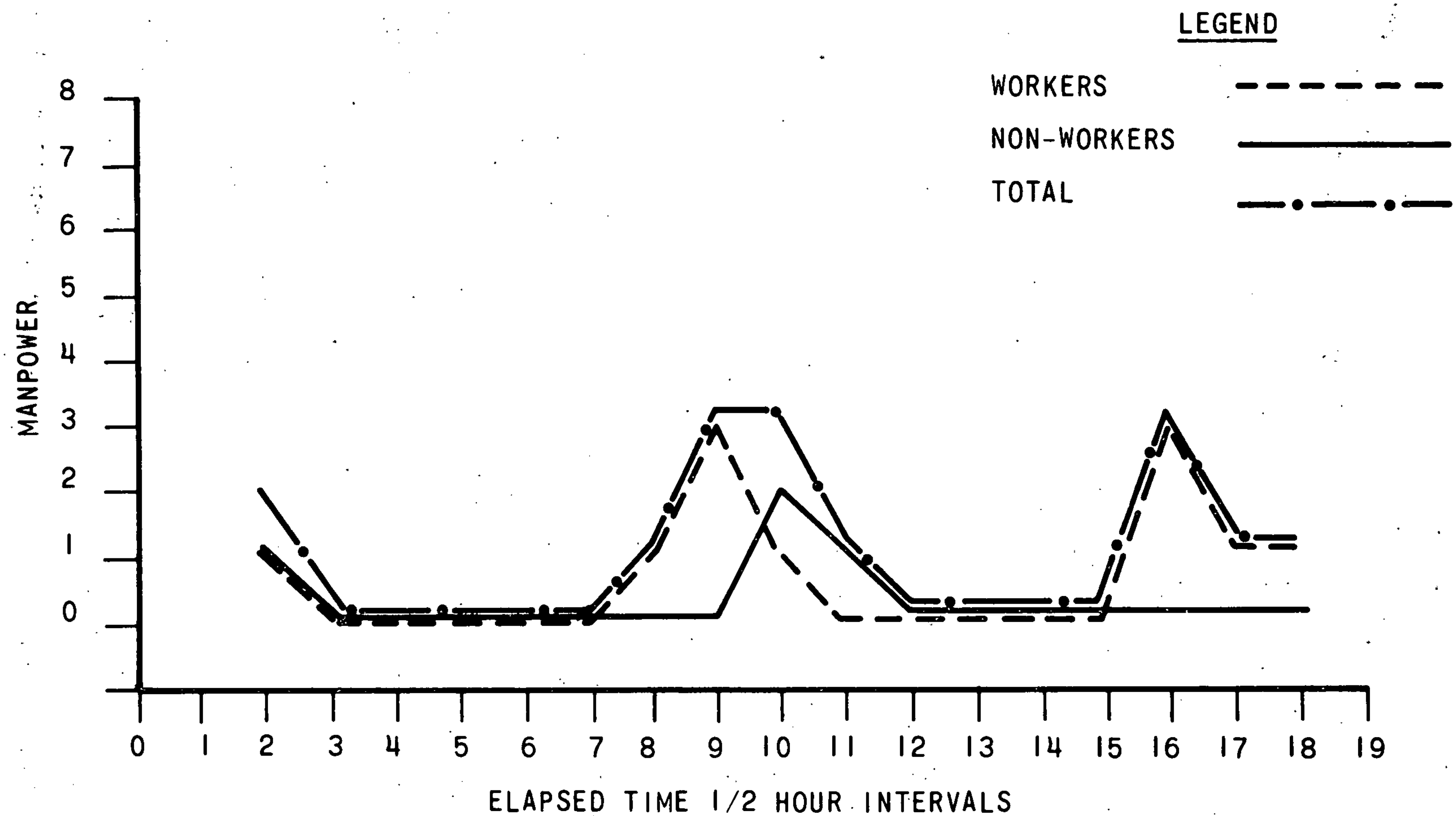
SEQUENCE # 4
CRDM VENTING



SEQUENCE # 4
CRD UNCOUPLING

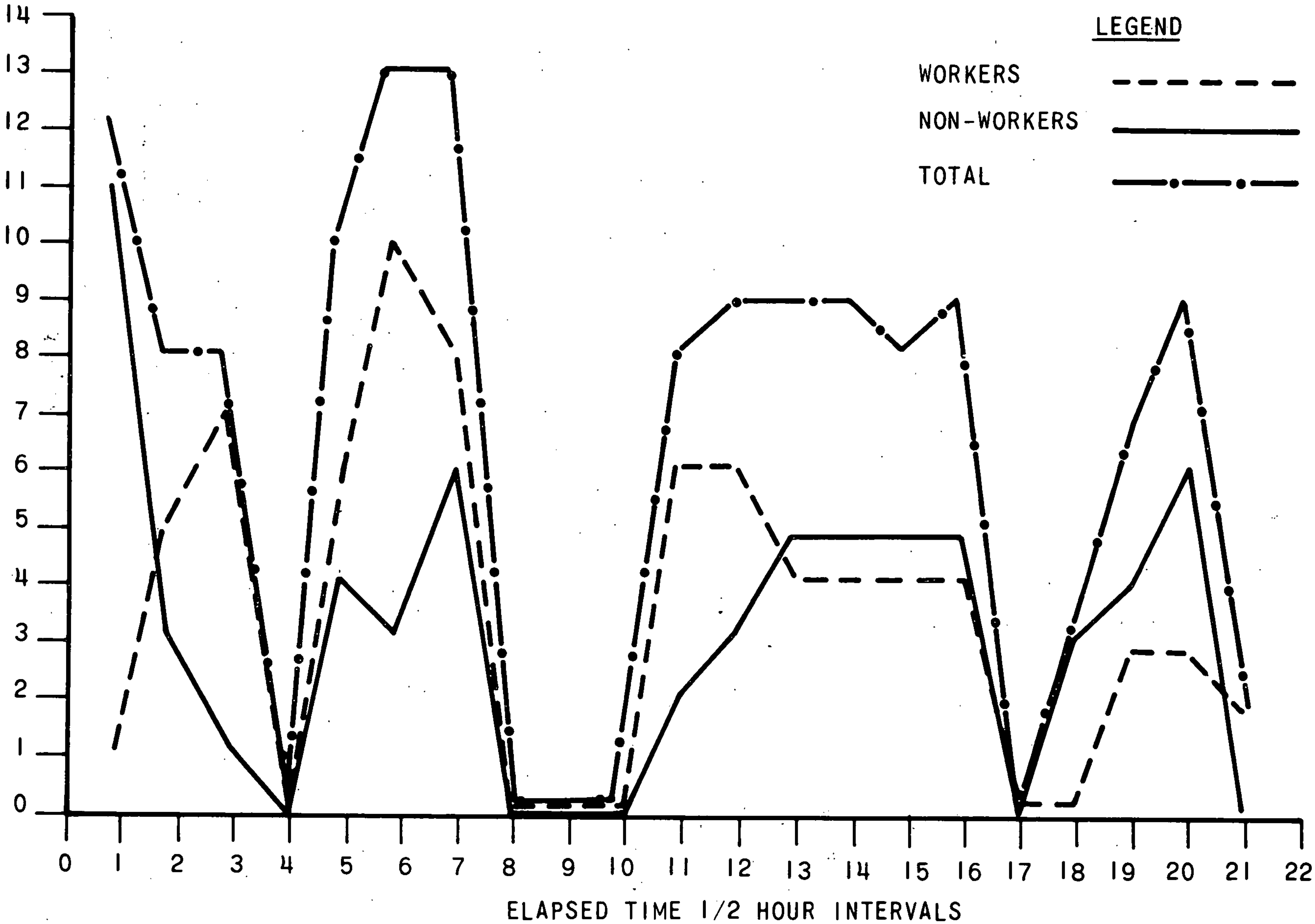


SEQUENCE # 5
INSULATION REMOVAL



SEQUENCE # 6

CRDM UNCOUPLING



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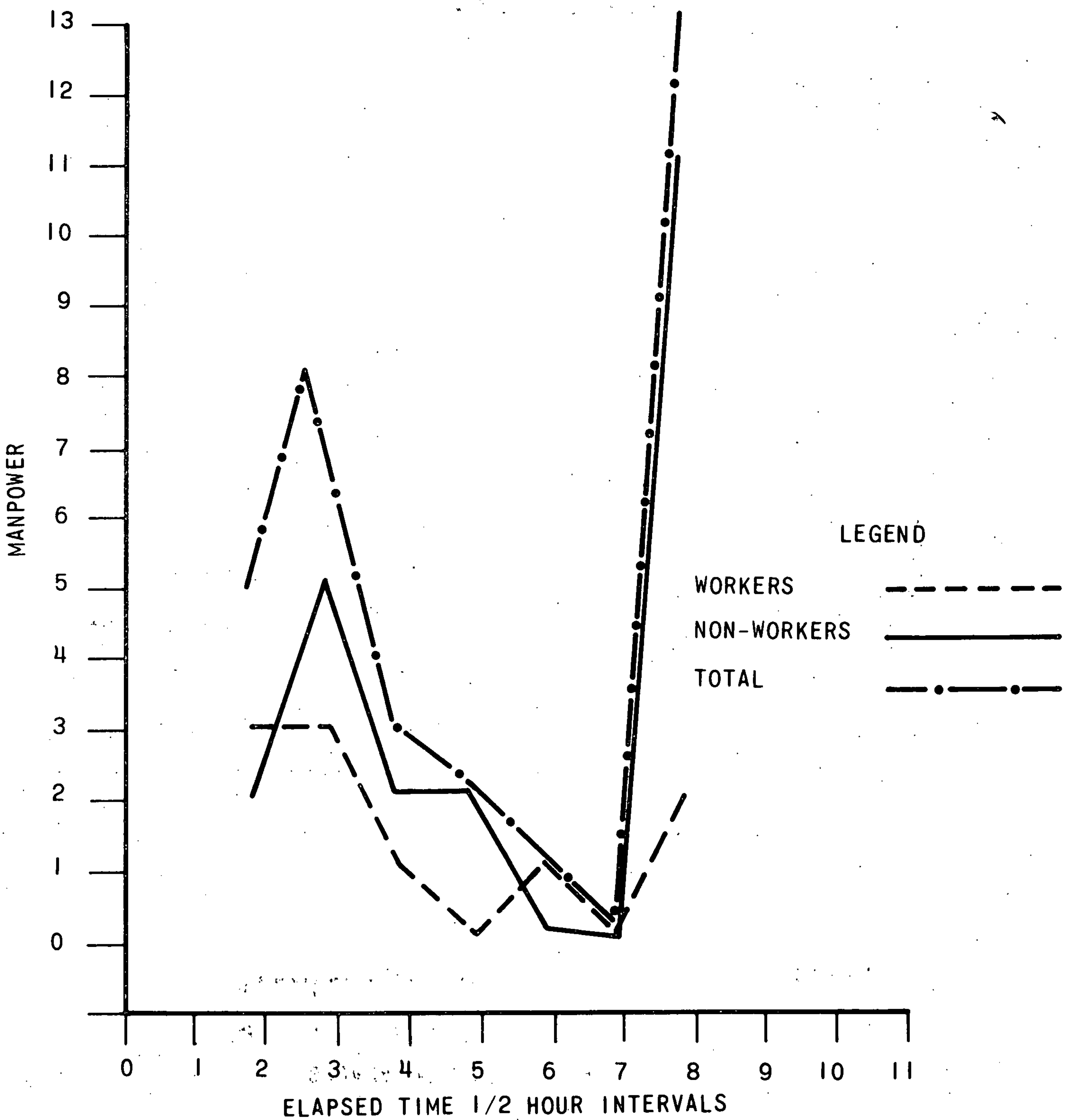
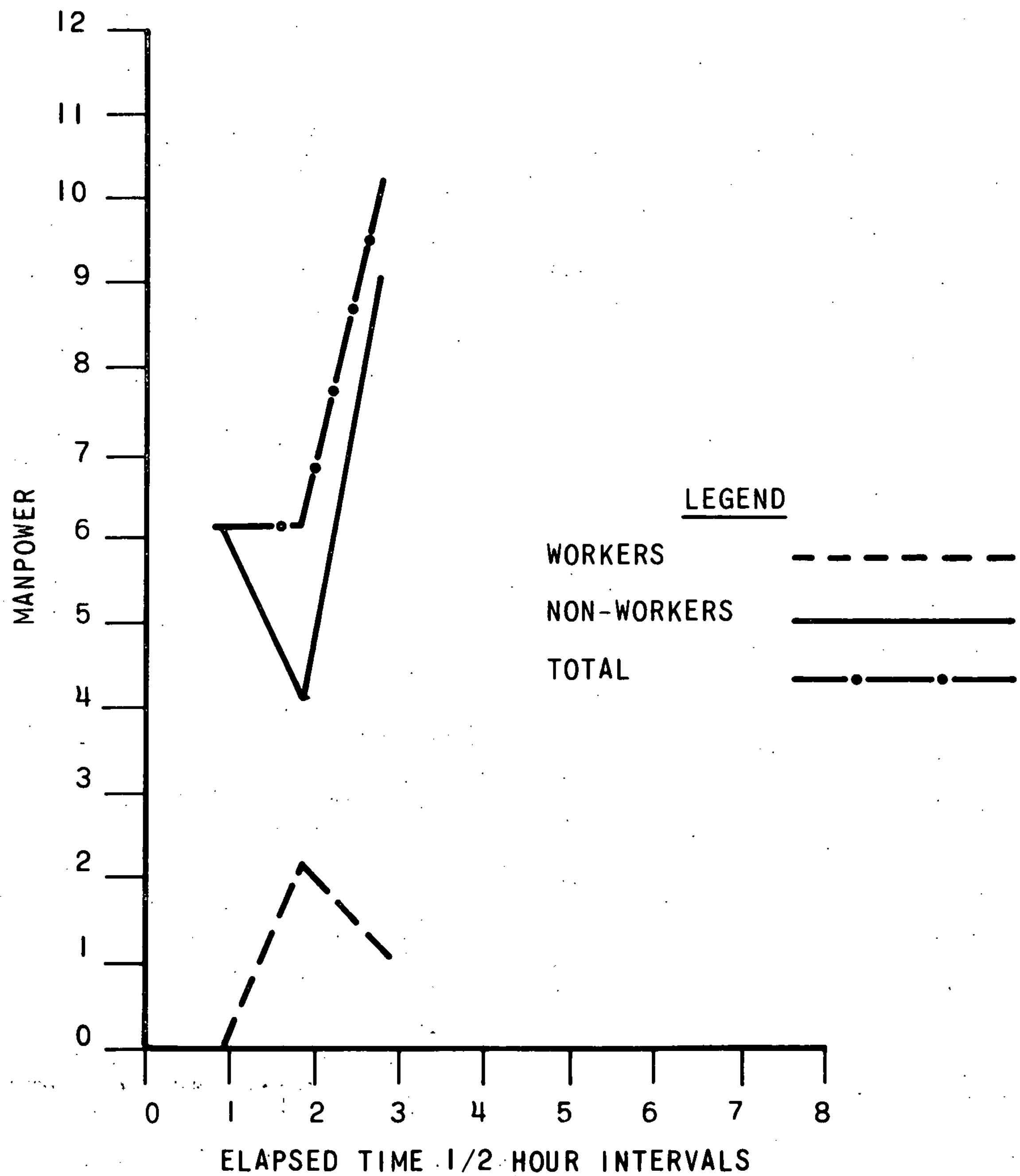
SEQUENCE # 10
RIGGING FOR HEAD LIFT

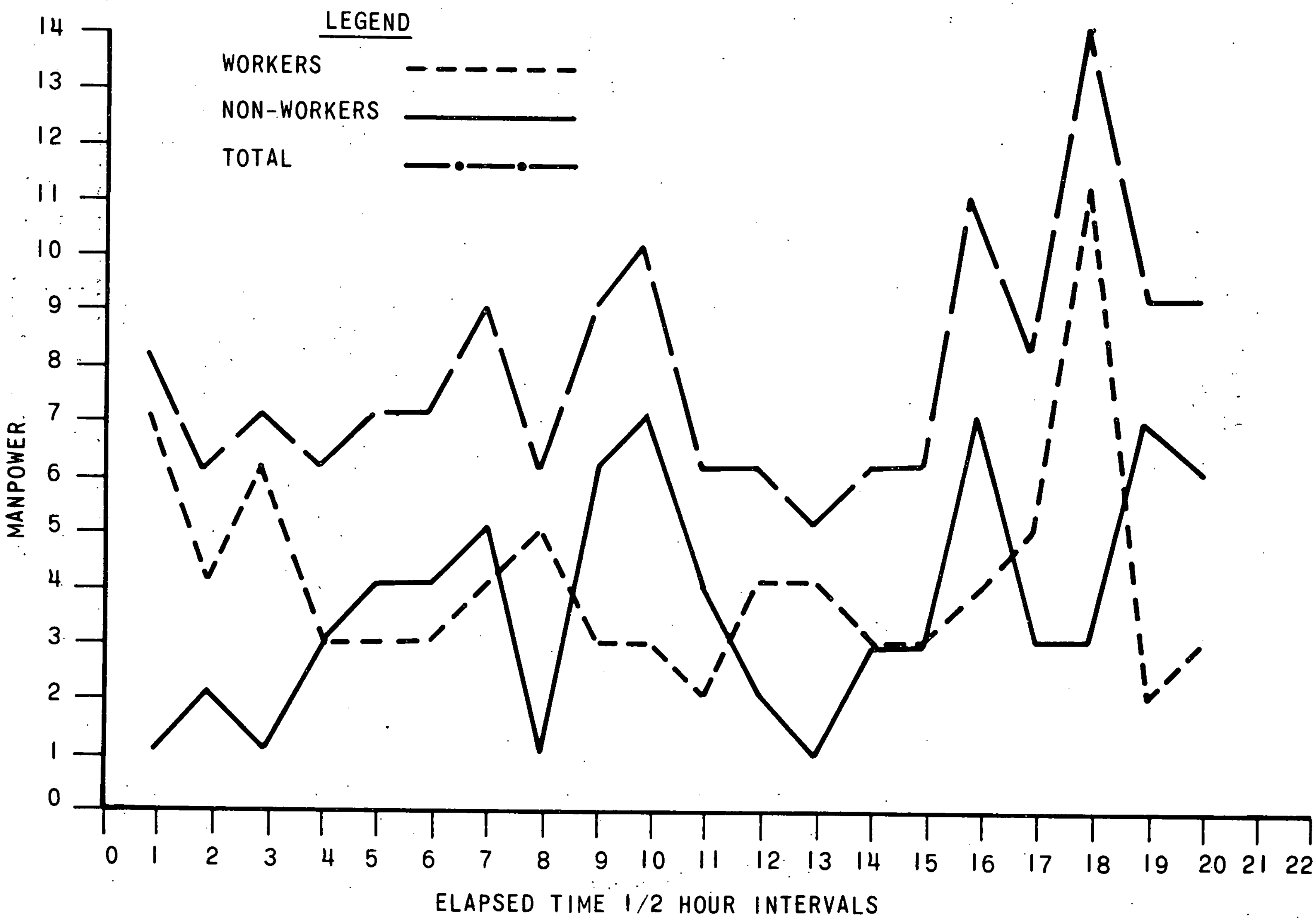


SEQUENCE # 10

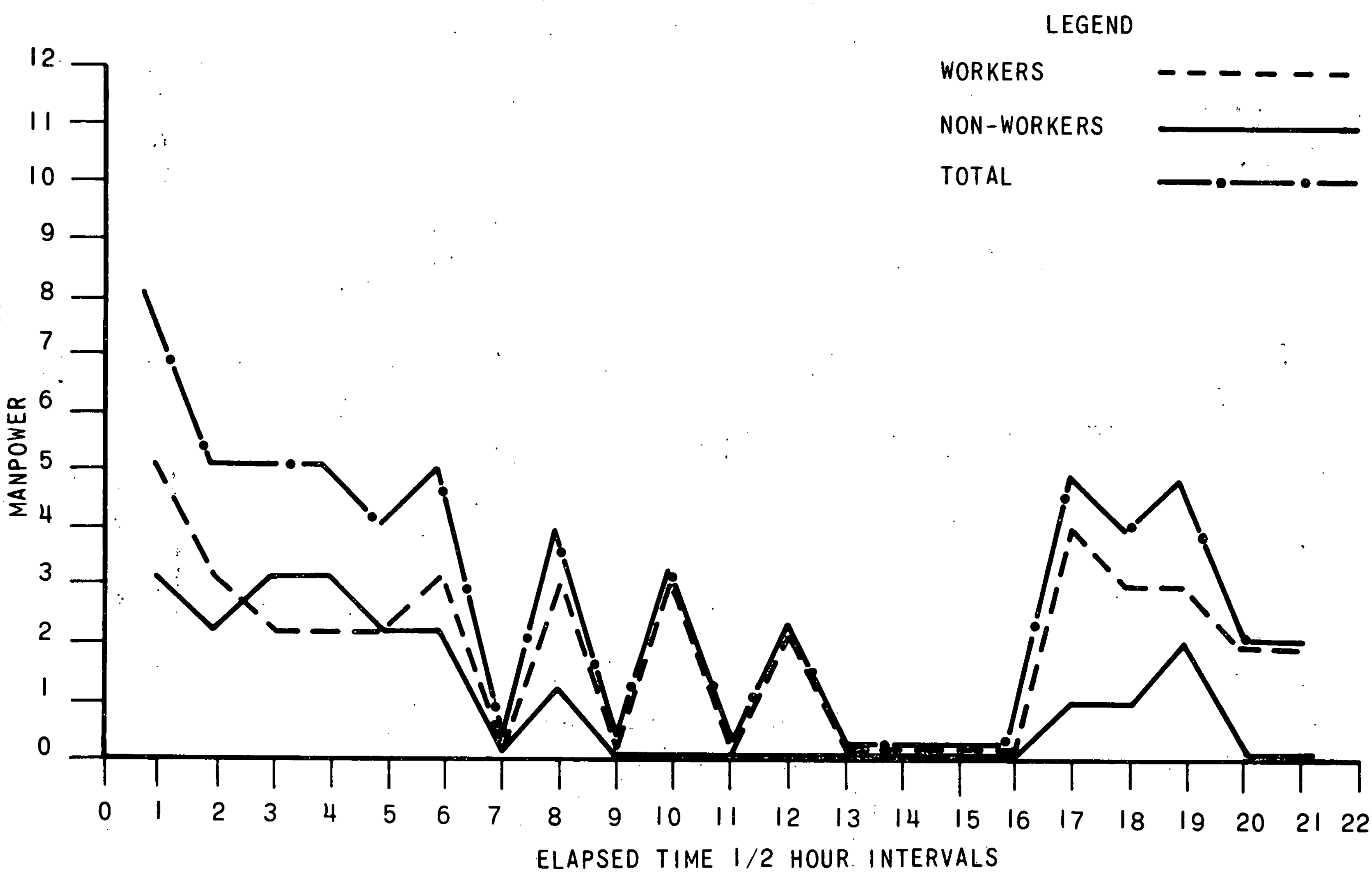
RIGGING PENDANTS



SEQUENCE # 32
REFUELING BRIDGE



SEQUENCE # 39
RV HEAD STAND WORK



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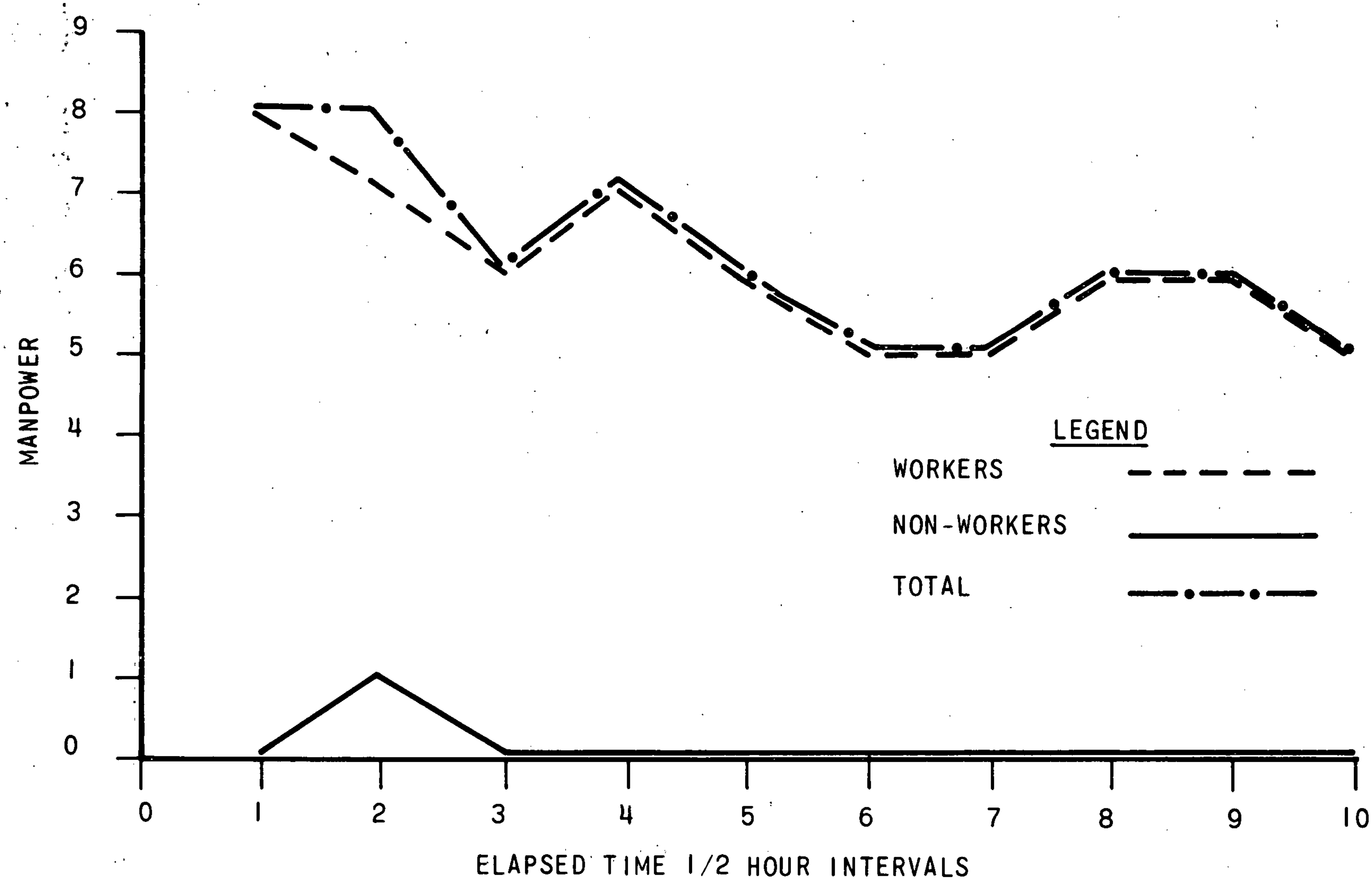
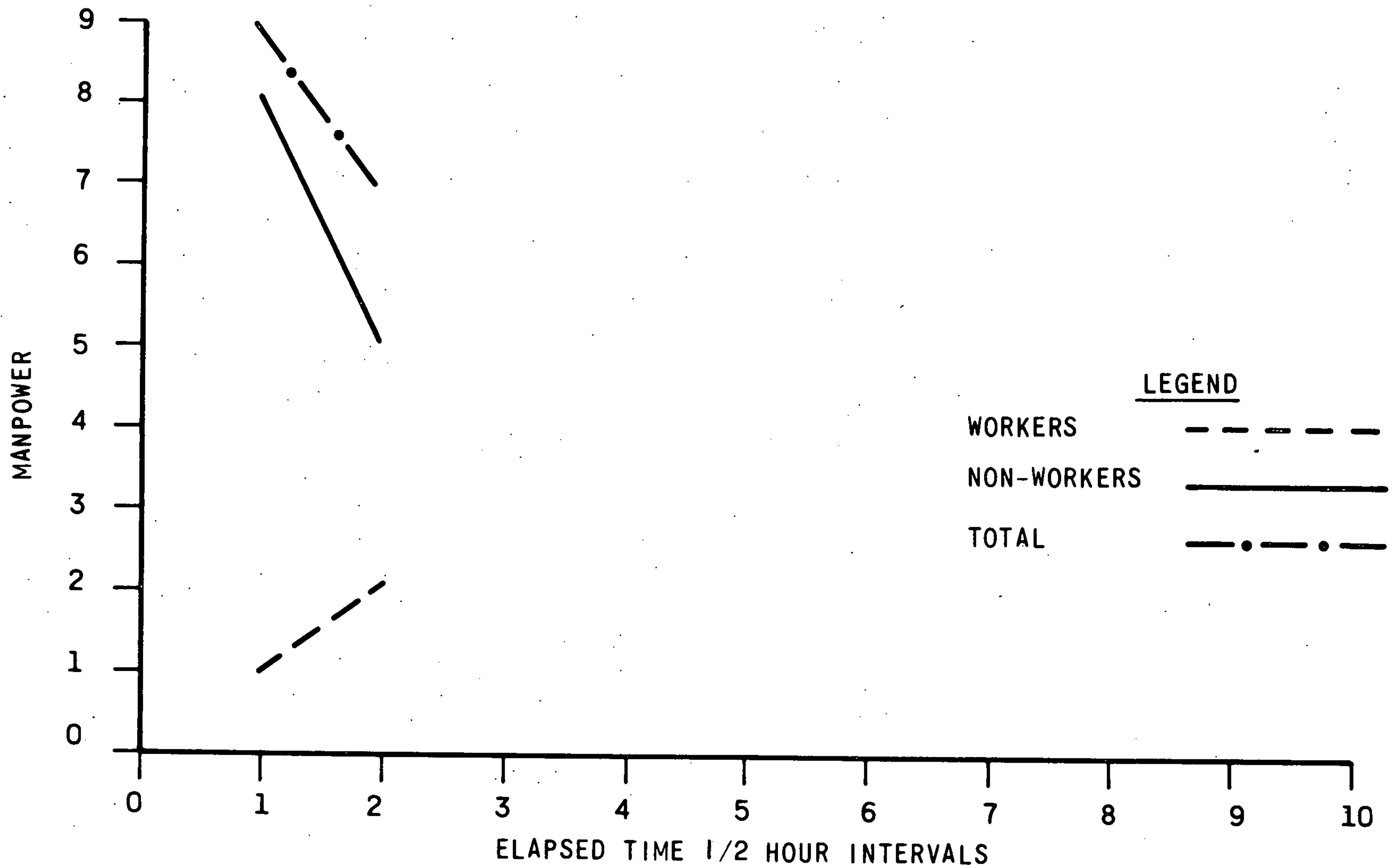
SEQUENCE # 41

RV HEAD WORK CRDM'S

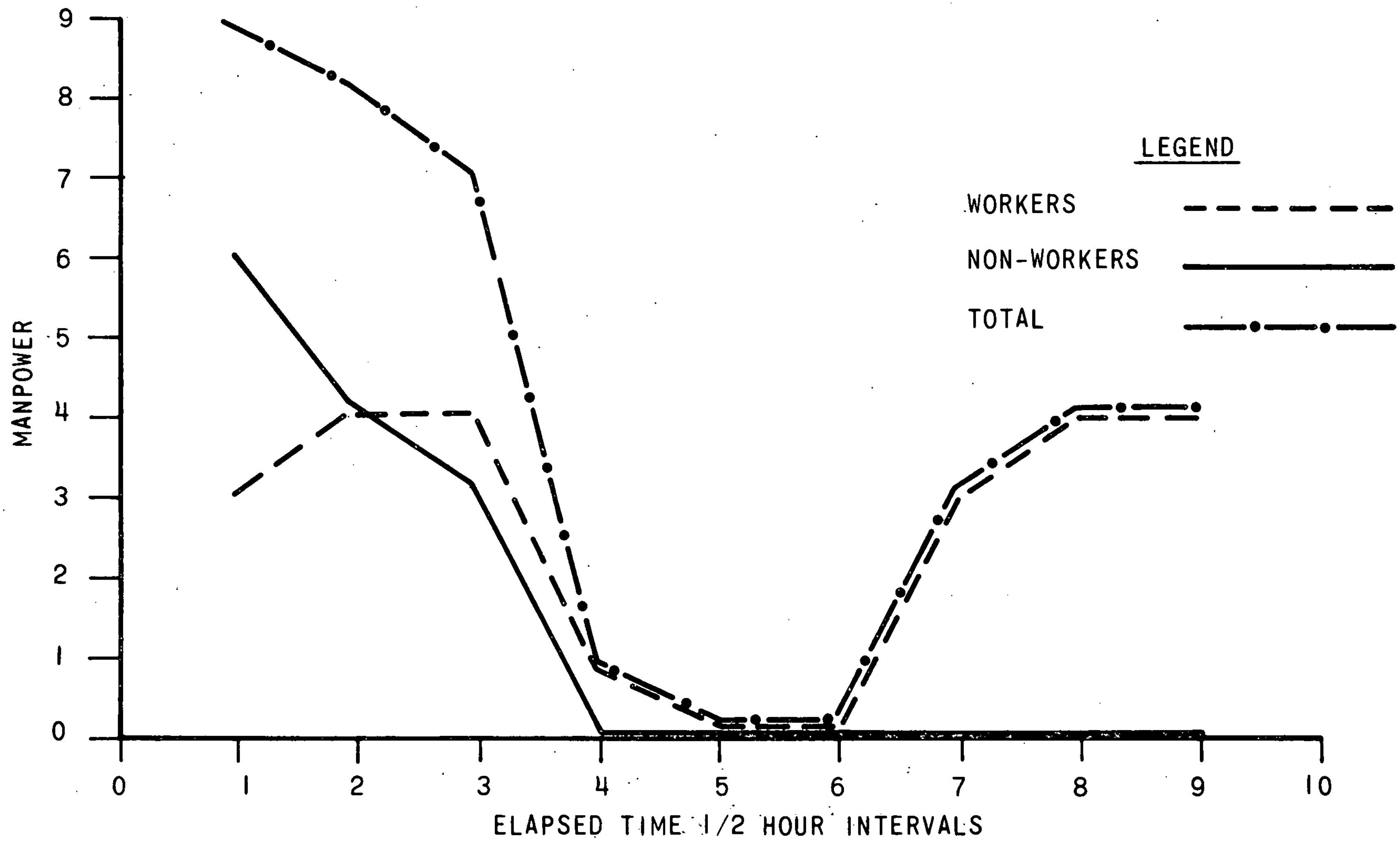


SEQUENCE # 41
ATTACHING PENDANTS TO TRIPOD

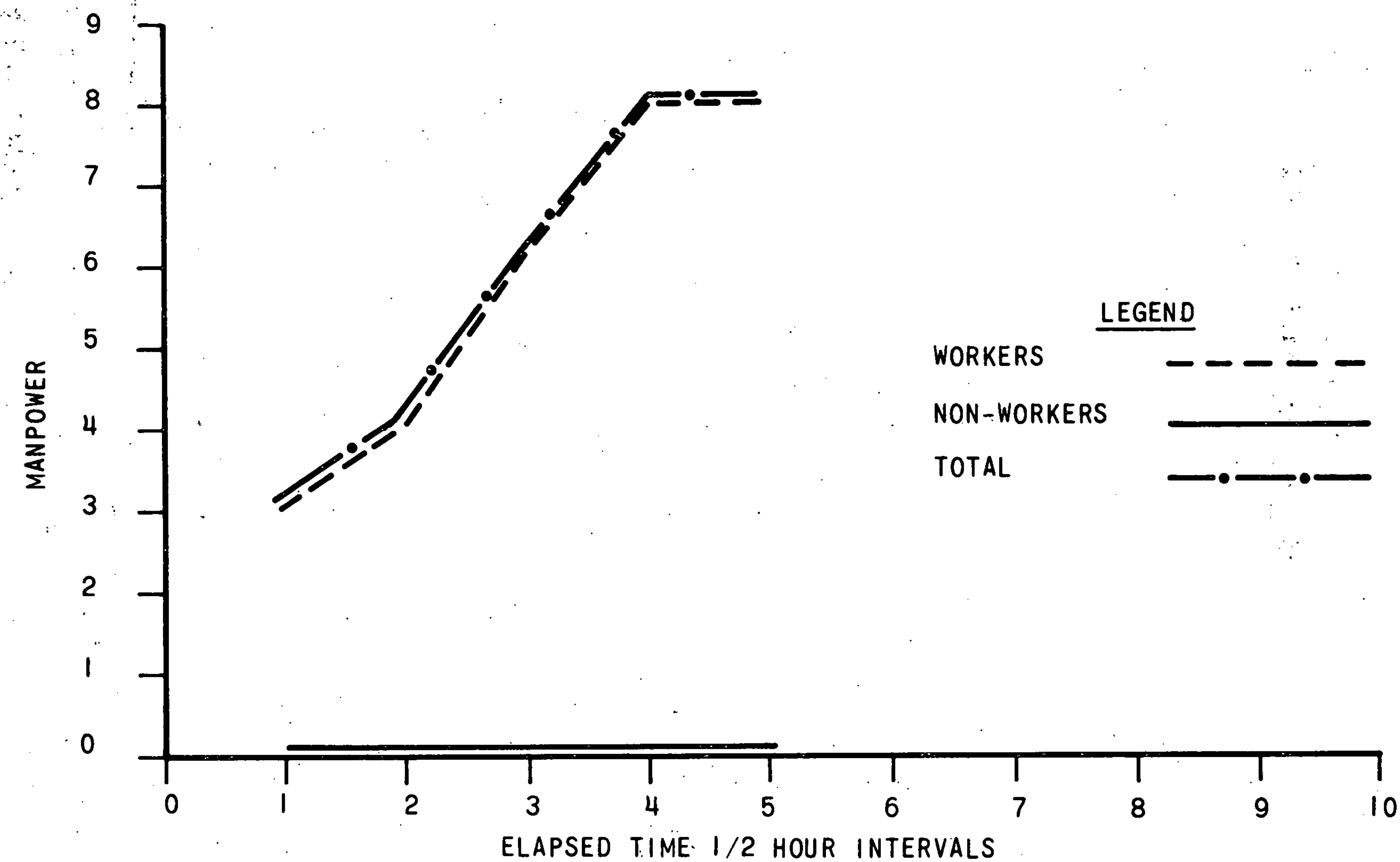


SEQUENCE # 41

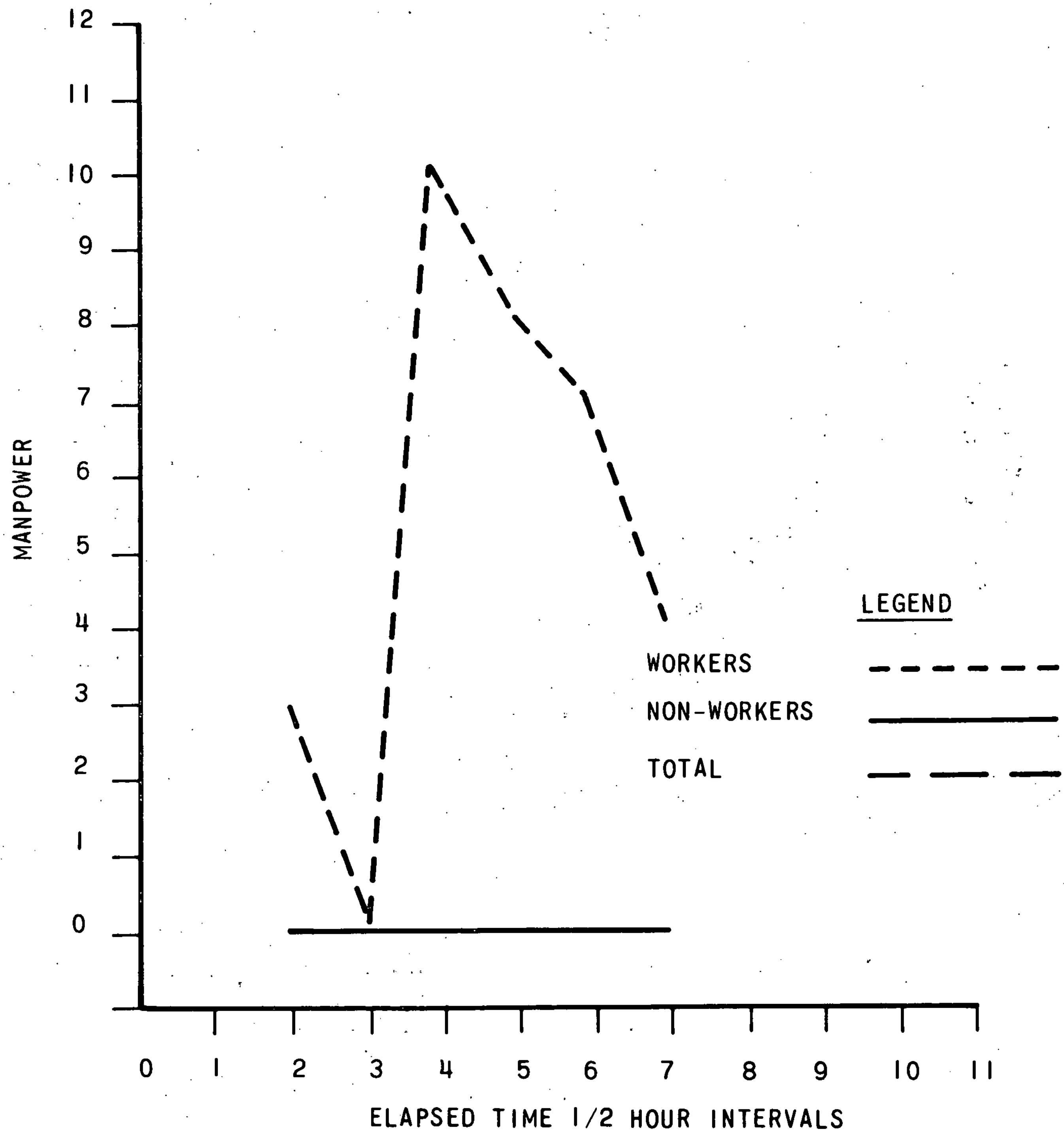
PLENUM INSTALLATION



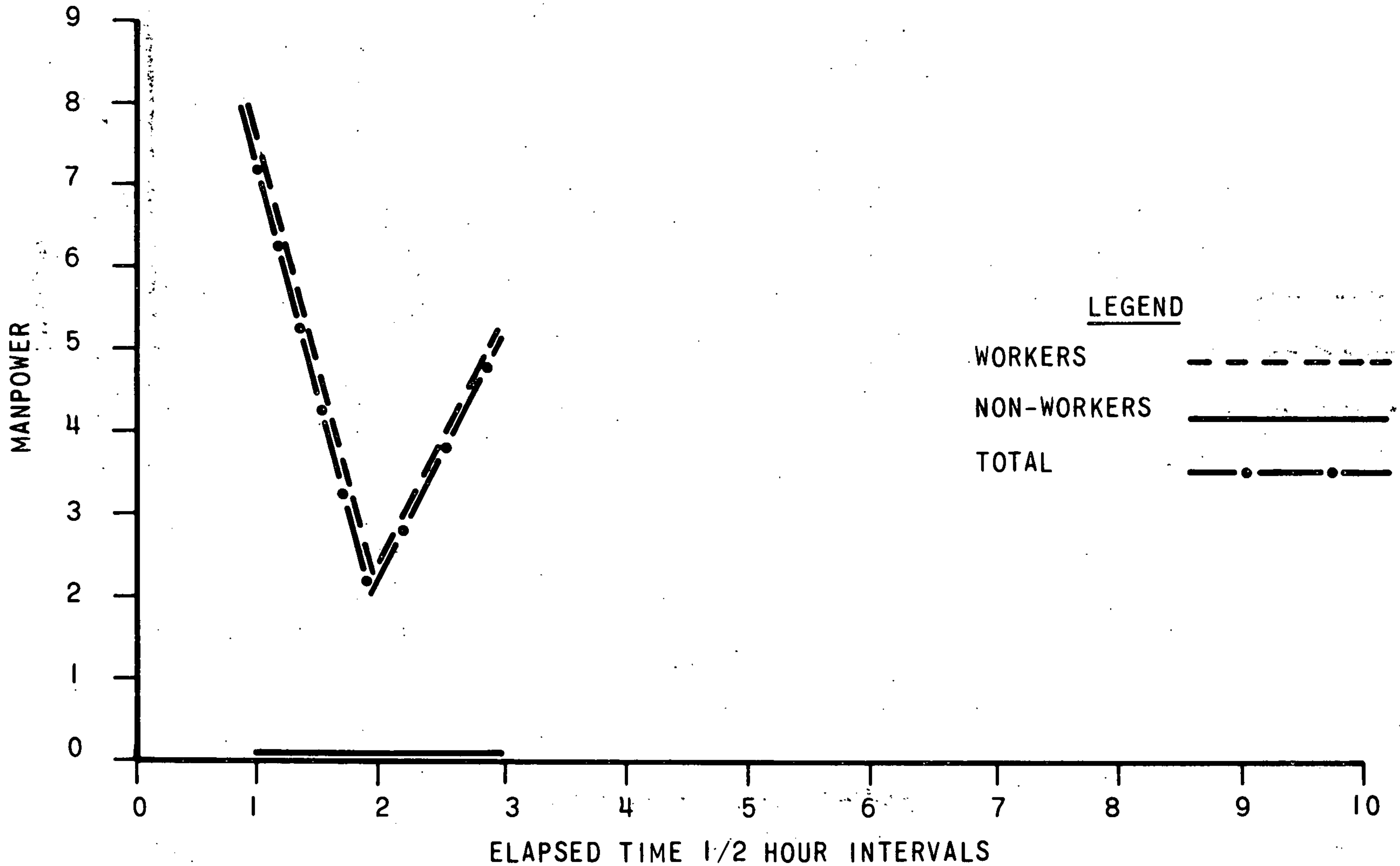
SEQUENCE # 42
STUD HOLE CLEANING



SEQUENCE # 42
RIGGING TRIPOD TO RV HEAD



SEQUENCE # 42
RV HEAD INSTALLATION



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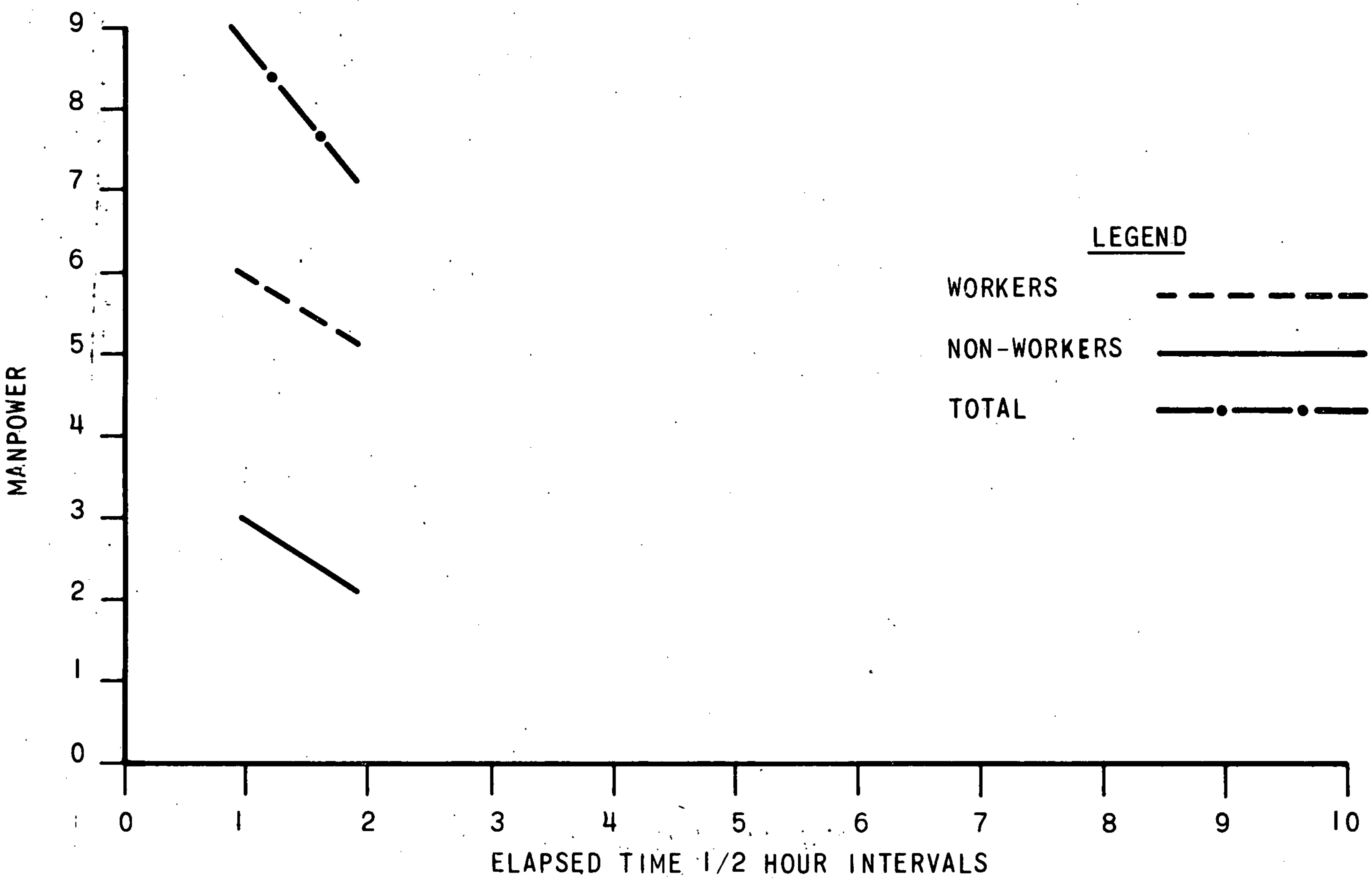
Babcock & Wilcox

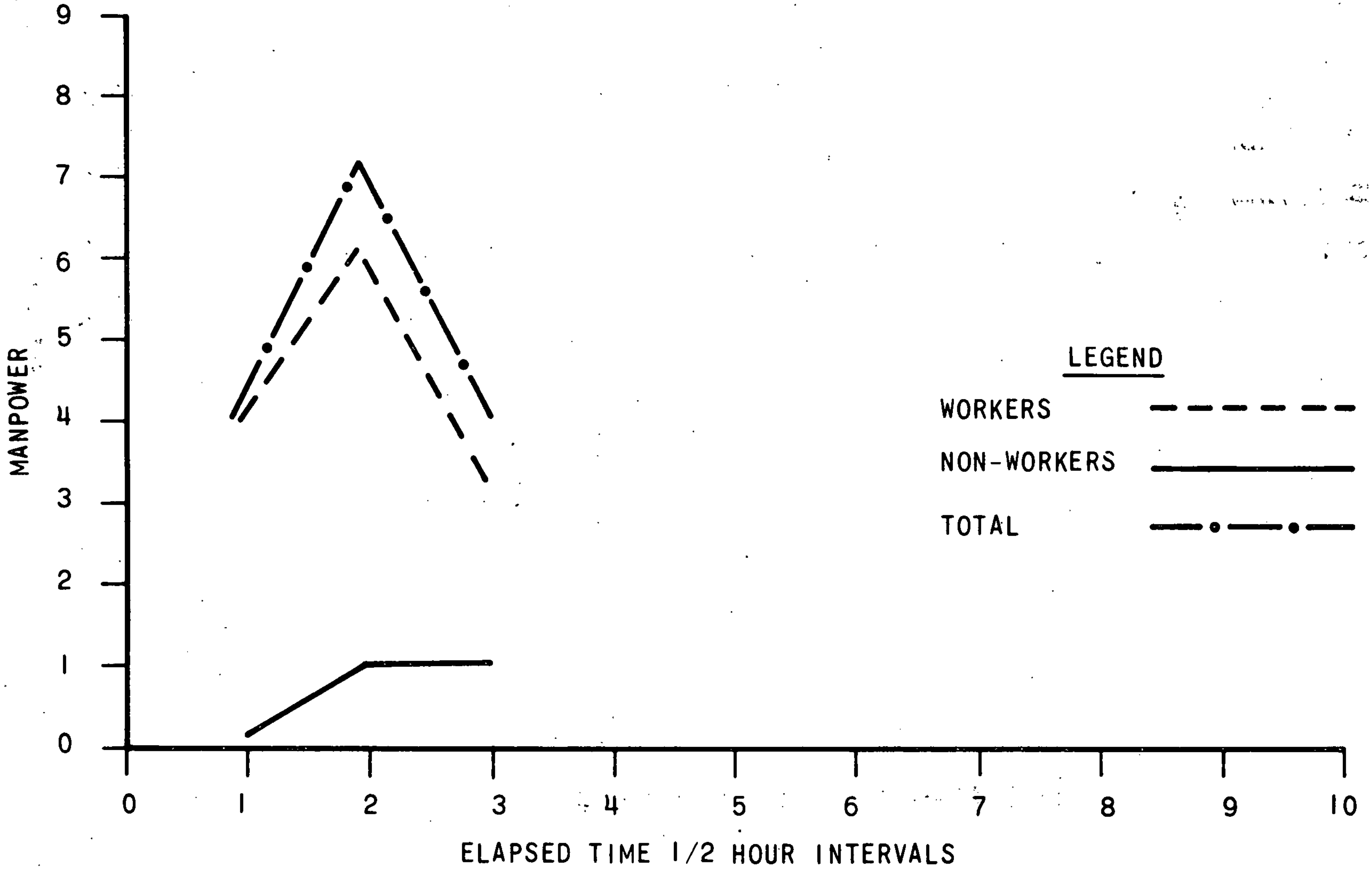
SEQUENCE # 42

INDEXING FIXTURE REMOVAL



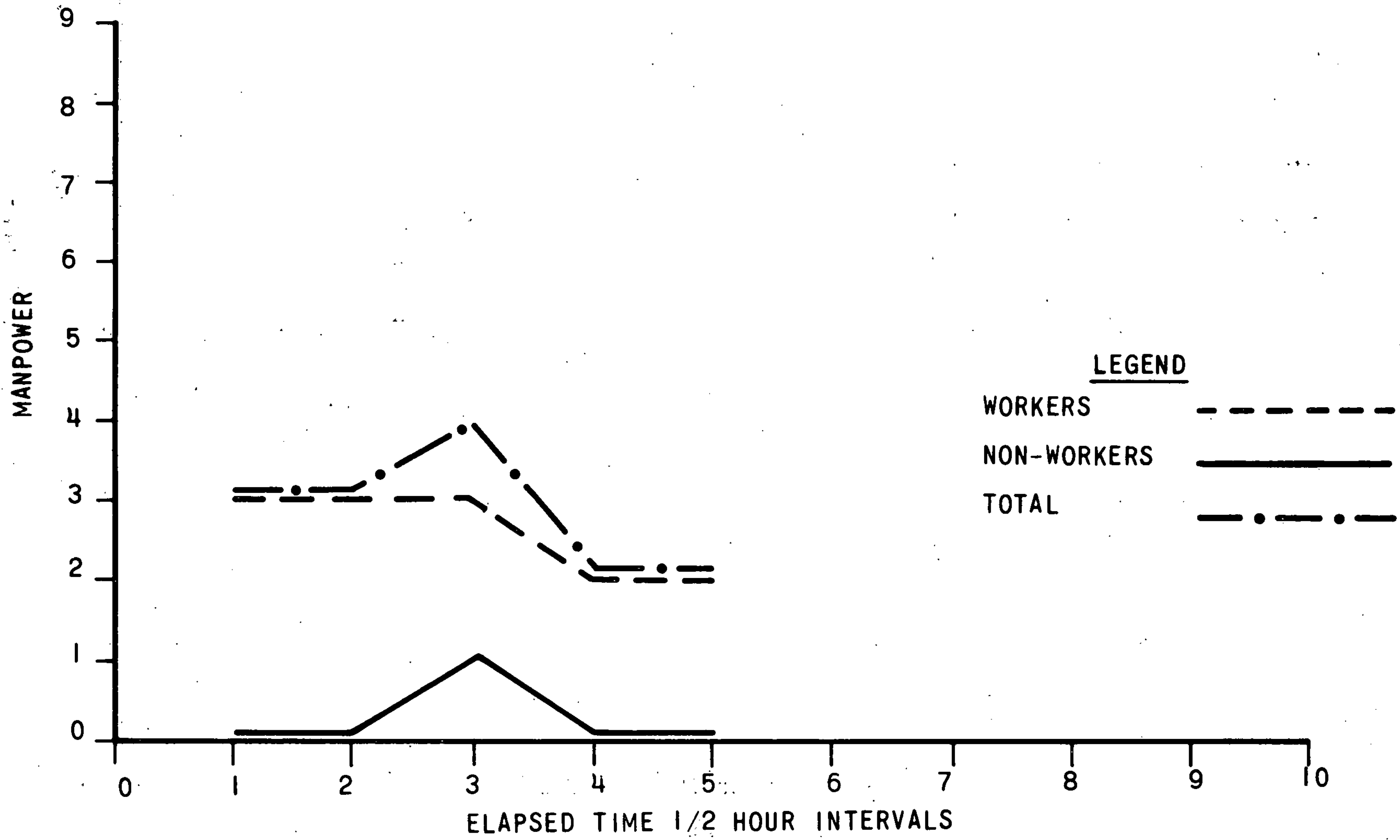
SEQUENCE # 42

UNRIGGING TRIPOD (LATCHBOXES)



SEQUENCE # 44

RUNNING IN STUDS (STUD TENSIONER)



SEQUENCE # 44

STUD TENSIONER WORK