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Balance-of-Plant OUTAGE AVAILABILITY STUDY Phase 1 Extension Report

September 1978

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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 2-9.

We are grateful for the full cooperation given by the participating utilities in seeking cost-effective improvements. The keynote of this work is to derive improvements to reduce outage time, not to critique occurrences.

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ABSTRACT

After completion of the Phase 1 Refueling Outage Availability Study, Babcock & Wilcox and the U. S. Department of Energy entered into a supplemental agreement to perform a balance-of-plant maintenance, inspection, and test study with the cooperation of Duke Power Company and Arkansas Power & Light Company. The objectives were (1) to expand the Phase 1 data base, including balance-of-plant activities, to reduce outage time and increase plant availability and (2) to conduct an onsite review of plant maintenance practices to complement the utility efforts in reducing outage time and increasing on-line operational time.

Data were obtained from (1) observations during the 1977 refueling outage at Oconee 3, (2) review of maintenance practices during the Arkansas Nuclear One, Unit 1, operational cycle in 1977, and (3) selected observations of the 1978 refueling outage at ANO-1. Accumulated data were then reviewed and analyzed to produce a list of improvement recommendations for Oconee 3 and ANO-1 that can be generically applied to plants of similar design and construction. The improvements identified include a wide range of applications, such as (1) turbine building arrangements for laydown of large components, (2) the use of a hydraulic bolting system, and (3) obtaining a spare set of turbine bearings and diaphragms.

By incorporating the recommendations in this study, an annual savings of 13 critical path days for ANO-1 and 2 to 3 secondary system critical path days for Oconee 3 can be achieved. For an outage consisting of the disassembly of two turbines, the balance-of-plant work could impact the refueling outage as follows: for Oconee 3 it would not be the critical path item, but for ANO-1, it would control the outage length.

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LIST OF ABBREVIATIONS

AE	Architect-engineer
ANO	Arkansas Nuclear One
AP&L	Arkansas Power & Light
B&W	The Babcock & Wilcox Company
BOP	Balance of plant
CRD	Control rod drive
DOE	Department of Energy
DUKE	Duke Power Company
FM	Figure of merit
FM_D	Figure of merit — delay
FM-NA	Figure of merit — not applicable
FTC	Fuel transfer canal
FW	Feedwater
h	hour
HBS	Hydraulic bolting system
HP	Health physics
HPI	High-pressure injection
HPT	High-pressure turbine
I&C	Instrumentation and controls
I&E	Instrumentation and electrical
LP	Low pressure
LPI	Low-pressure injection
LPT	Low-pressure turbine
MH	Machinery history
MS	Main steam
MSR	Moisture separator reheater
NSM	Nuclear station modification
NSS	Nuclear steam system
OJT	On-the-job training
ONS	Oconee Nuclear Station

ABBREVIATIONS (Cont'd)

OSHA	Occupational Safety and Health Act
OTSG	Once-through steam generator
PM	Preventive maintenance
QC	Quality control
RB	Reactor building
RCP	Reactor coolant pump
RCS	Reactor coolant system
RV	Reactor vessel
SSD	Station Support Division
UT	Ultrasonic testing

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This letter to cover one customer and one subject only.

The following errors in the subject report were discovered after printing; please mark your copy to incorporate these corrections:

Page	
5-16	Time in this table is given in hours; this was omitted from the table.
B-2	Slide 2 — wrong photo shown here. The slide labeled Slide 2 in Appendix C is the proper photo for this description.
B-18	Slide 50 — the last two lines of the caption should read "... where non-contaminated water was spilled." (Not contaminated!)
C-2	Slide 2 — wrong photo shown here. The slide labeled Slide 2 in Appendix B is the proper photo for this description.
C-4	Slides 7 and 8 were accidentally interchanged.
C-11	Slide 28 — This photograph is upside down.

1. SUMMARY DESCRIPTION OF DOE PROJECT EFFORT

1.1. Maintenance Study Evolution and Objectives

Under the sponsorship of the DOE, Babcock & Wilcox (B&W) undertook a refueling outage availability study to improve nuclear power plant availability by reducing refueling outage time. Phase 1 of this study comprised a comprehensive program of outage observation, data analysis, and identification of improvement recommendations. This study was documented in a report[1] completed in November 1977. The report covered all aspects of the primary (nuclear steam) system refueling and maintenance activities. The results indicated that for the primary portion of the outage, the typical* outage schedules for the plants that were studied should have been 32-33 days. More important, an ideal schedule of 21-22 days could be attained if the recommendations resulting from the study were implemented. However, the study was devoted solely to the primary portion of the outage.

In order to achieve a decreased total plant outage time, equivalent attention would have to be given to the balance of plant (BOP). Therefore, B&W entered into an extended Phase 1 study with the following objectives:

1. To expand the Phase 1 data base to include BOP activities in order to achieve similar reduction in outage time and increased plant availability.
2. To conduct onsite reviews of preventive maintenance activities and other BOP maintenance practices during normal operation in relationship to complementing the utility's efforts to reduce refueling outage time and increase on-line operational time.

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[1]Refueling Outage Availability Study, Phase 1 Final Report, COO-4068-14, BAW-1464, Babcock & Wilcox, Lynchburg, Virginia, November 1977.

*Typical schedule is defined as the outage schedule that should have occurred at ANO-1 and Oconee 3 (1977 and 1976 outages, respectively) if all abnormal activities and unnecessary delays had been deleted from the actual schedule.

3. To expand conceptual recommendations to supplement the Phase 1 study for potential prototype developmental improvements to be implemented and demonstrated at ANO-1.

This supplemental report concludes Phase 1 of the DOE program.

1.2. B&W Team Efforts at Participating Nuclear Plants

The maintenance extension study was conducted in cooperation with Duke Power Company and Arkansas Power & Light Company at the Oconee-3 and ANO-1 plants, respectively. The two plants served as models in the previous Phase 1 studies and thus were selected for the maintenance study to provide continuity and a basis for outage data and schedule comparisons.

1.2.1. Arkansas Nuclear One, Unit 1

Two B&W project teams, one for each plant, were assigned to conduct the maintenance extension study effort. One team was sent to ANO-1 from August through December 1977 during the plant's second cycle of operation to collect data and review the specific BOP items listed below:

1. Outage preparation and manpower.
2. Training capabilities.
3. Secondary valve maintenance.
4. Work packages for secondary plant.
5. Plant preventive maintenance program.
6. Spare parts system.
7. Turbine testing and inspection for extended fuel cycles.
8. Work area support availability.
9. Equipment isolation and duplication for on-line maintenance.
10. System/equipment layout.

After the field study, the project team returned to Lynchburg to start the data evaluation and analysis, identification of improvement recommendations, and preparation of outage target schedules.

Preliminary analysis of data drawn from the ANO-1 study indicated the need for an outage observation effort beyond the original work scope. The differences in the turbines at ANO-1 and Oconee 3 reinforced the need to observe a portion of the ANO-1 outage. The turbine at Oconee 3 is a General Electric unit consisting of one HP and three LP turbines. The steam inlet to the LP turbines is on the horizontal axis with no obstructions above the turbines. The HP turbine casing studs are tensioned/detensioned by electrically heating the studs. The turbine at ANO-1 is a Westinghouse unit comprising one HP and two LP turbines. The steam inlet to the LP turbine is on the vertical axis with crossover lines above the LP turbines, which must be removed before the outer LP turbine casing can be removed. Another difference is that a hydraulic stud tensioner is used to tension/detension the HP casing studs. Because of these readily apparent differences, the ANO-1 observation team returned to ANO-1 during the first two weeks of the plant's second cycle refueling outage in February 1978 to observe the disassembly of the high-pressure turbine (HPT) and the "A" low-pressure turbine. These activities were observed with emphasis on time reduction and material improvements designed to reduce the BOP critical path time.

Data collected from the outage were then analyzed. Outside consultation was obtained through one vendor to confirm initial recommendations. This consultation led to the actual demonstration of a hydraulic bolting system (HBS) during the reassembly phase of the main steam piping. The demonstration was arranged by the team in cooperation with ANO-1 and the vendor.

1.2.2. Oconee 3

In parallel with the work at ANO-1, the second B&W project team was assigned to the Oconee 3 site shortly before the plants' second cycle refueling outage in October 1977. This study differed from that for ANO-1 in that full BOP outage activities were actually observed. Major emphasis on this study was devoted to the BOP activities of greatest impact on the schedule to determine how various activities could be speeded up. The following outage activities were observed:

1. Disassembly, inspection, cleaning, and reassembly of the HP turbine and the "A" LP turbine.
2. Moisture separator reheater work.
3. Feedwater pump and turbine testing and maintenance.
4. BOP valve work.
5. Miscellaneous secondary maintenance tasks.
6. Selected primary plant system activities to supplement the earlier Phase 1 study.

In addition to actual outage activities, observations were made in the areas of planning and scheduling, outage communications, coordination, and handling of nuclear station modifications. As in the Phase 1 study, the experienced

B&W team members were looked upon as impartial observers and judges. This type of involvement allowed objective, well-thought-out recommendations on how to improve the various facets that make up a refueling outage.

The data collected at Oconee consisted of completed work requests, activity codes, maintenance procedures, data sheets, and brief summary reports outlining the responsibilities and work methods of some departments and scheduling groups.

1.2.3. Improvement Recommendations

At the completion of the onsite study efforts, the project teams returned to Lynchburg to evaluate the data and prepare improvement recommendations. These were categorized into three general areas:

1. Immediate improvements — those that require no changes to hardware or facility.
2. Equipment/facility improvements.
3. Future plant design improvements.

The recommendations were then quantified in terms of time savings and impact on outage time and prioritized in terms of figure of merit (FM) values.

Although the study was limited to two plants, the recommendations were designed to assist the entire utility industry. A section of this report deals with generic recommendations that can be applied to plants of similar design and construction. Expected benefits for each recommendation were determined as applied to one plant and to multiple plants.

1.2.4. Edited Videotapes

Videotapes and slides were take (when applicable) to illustrate areas of improvements to reduce refueling outage time. From the raw tapes, edited videotapes covering BOP outage recommendations for ANO-1, Oconee 3, and generic plants were produced. A tape showing applications of the hydraulic bolting system was also developed. Similar tapes for the Phase 1 study have proved very useful in familiarizing the utility industry with the problems that must be overcome in carrying out a refueling outage and in training new personnel for refueling activities.

1.2.5. Supplemental Primary System Recommendations and Continuing Work Programs

In addition to the BOP extension study, a list of supplemental primary system recommendations for Oconee 3 and potential prototype implementations for improvement recommendations at ANO-1 was prepared. Some of these improvements were expanded from the Phase 1 study. The continuing work program is intended to evaluate the projected savings by actual development, design, procurement, installation, and demonstration of selected recommendations.

1.3. Results and Conclusions

1.3.1. Earlier Results of Study Effort

An earlier recommendation for an alternative means of supporting the HP turbine casing tensioners, which was confirmed during the field study, was implemented by ANO before the 1978 outage. A monorail arrangement, designed and erected by ANO and the turbine vendor representative, accounted for a savings of at least 48 hours of critical path time. Two tensioners for detensioning the turbine casing were supported by the monorail, thus allowing the turbine crane to be used for other activities that would have had to wait until the turbine casing was detensioned and removed.

One recommendation led to an actual demonstration of time savings. Outside consultation was obtained to confirm initial findings, and hydraulic bolting system (HBS) applications in the reassembly of one large main steam pipe coupling flange were demonstrated at ANO-1. This was arranged by the team in co-operation with ANO-1 and the HBS vendor; the demonstration proved that the reassembly time took 40 minutes using this power tool, whereas the manual method has taken over 3 hours.

Another recommendation that was implemented was modifying the HP turbine metal lagging to reduce interference with the movement of turbine components. Up to 2.5 hours of critical path time was saved during the outage with this modification.

1.3.2. BOP Outage Study Results

The results of the maintenance extension study show that the BOP activities can impact the refueling outage and have already done so, as in the case of ANO's first and second cycle refueling outages. This indicates and emphasizes the need to improve the BOP outage activities. For an outage that requires the disassembly, inspection, and cleaning of the HP turbine and one LP turbine, the ANO-1 study showed that the BOP outage activities will control outage length (see tabulation below). The total refueling outage time (breaker to breaker) is assumed to be 7 days longer than the turbine outage (turning gear to turning gear) as determined from the ideal schedule.

ANO-1 Outage Schedule Comparisons (Breaker-to-Breaker)

	Typical schedule days	Ideal schedule, days	Annual savings, days
From Phase 1 study, NSS only	32	22	10
From BOP study, total plant (outage including HP and one LP turbine disassembly)	40.5 (33*)	27.5 (20*)	13

*Turning gear to turning gear.

The tabulation above shows the effect fo BOP activities in lengthening the ideal outage schedule by 5.5 days. By incorporating the recommendations resulting from this BOP study, a critical path time savings of 13 days can be realized. This savings translates to an annual cost benefit savings of about $6,500,000 and about 495,200 barrels of oil conserved.

In contrast to the ANO-1 results, the Oconee 3 study showed that if the recommendations in this study are incorporated, the BOP outage activities will not control the outage length. The results for the typical and ideal outage schedules for BOP work and for the total plant are tabulated below.

Oconee 3 Outage Schedule Comparisons (Breaker-to-Breaker)

	Typical schedule, days	Ideal schedule, days	Annual savings, days
From Phase 1 study, NSS only	33	21	12
From BOP study, total plant outage (including disassembly of HP and one LP turbine)	32 (14-15*)	21** (11-12*)	11#

*Turning gear to turning gear.

#Savings from BOP recommendations is 2-3 days. The turbine is available for plant heatup about 1 day ahead of the NSS.

**For Oconee 3, the total refueling outage time (breaker to breaker) is 10-11 days longer than the turbine outage (turning gear to turning gear).

The disparity between the Oconee 3 and ANO-1 results can be attributed to two items:

1. Oconee 3 has excellent laydown facilities, thus allowing major components (turbine casing, rotors) to be laid down and worked on concurrently.

2. The capability of obtaining well trained, experienced personnel from a roving crew within the company whose primary responsibility is devoted to turbine work.

The recommendations and results obtained from this study can be applied to plants of similar design and construction. If all of the recommendations were implemented, savings similar to those in the ANO-1 and Oconee-3 plants could result.

1.3.3. Impact of Supplemental Primary System Recommendations

The primary system recommendations presented in section 6 of this report represents critical path savings of approximately 16 hours over those identified in the Phase 1 report through implementation of the following:

1. Equipment that combines the stud running and detensioning operations.
2. Stud runner modification to allow this tool to be returned to its ready position after running in a stud.
3. A new reactor vessel stud hole seal plug that is form-fitted to the hole.
4. Additional piping and a pump to allow faster filling and draining of the reactor coolant system.

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2. KEY OUTAGE EVENTS AND OBSERVATIONS

2.1. Oconee 3 Refueling Outage

2.1.1. B&W Team Formation and Summary of Observations

The maintenance extension study at Oconee began in early August 1977, with the formation of the B&W outage observation team (see Figure 2-1). In September, the lead engineer reported to the site, followed later by two observers. The remaining outage observers reported to the site when the second cycle refueling outage began on October 21, 1977.

Detailed data collection by the B&W observation team began on October 22, 1977, with coverage of the testing of the main steam relief valves and hot hanger inspections in the reactor building. A few primary side operations were witnessed by the observation team, but the main emphasis was on the secondary side of the plant. The data collected comprised completed work requests, activity codes, maintenance procedures, data sheets, and brief summary reports outlining the responsibilities and work methods of some departments and scheduling groups. Further documentation of the outage was included in the numerous videotapes and slides taken.

For reporting purposes, the key areas for observations have been summarized as follows:

1. Planning and scheduling.
2. Key outage events in terms of total outage time and delays experienced during the outage.
3. Balance of plant performance.
4. Balance of plant manpower sources and usage.

A typical BOP schedule, which would result if abnormal delays unique to the 1977 outage were deleted, was developed for Oconee 3.

The evaluation of data, identification of recommendations, videotape productions, and report preparation were carried out by the team effort shown in Figure 2-2.

2.1.2 Planning and Scheduling

The site team's initial assignment was to observe Oconee's planning and scheduling techniques both before and during the outage. This section discusses observations made in the following areas:

1. Preoutage meetings.
2. Outage preparation.
3. Functions of key outage personnel.
4. Daily planning and scheduling activities.
5. Preoutage schedule.
6. Planned work and manpower for main turbine.

Preoutage Meetings

A number of preoutage meetings were held at Oconee (1) to discuss the outage work effort with attention given to support groups (such as quality assurance and health physics), (2) to discuss possible problems that could arise, and (3) to provide an opportunity for those participating in the meetings to present recommendations or ideas that could improve outage performance. Later meetings were also conducted to consider problems that could arise if the unit were to come down before the scheduled time. Attendance at these individual meetings varied depending on the scope of each meeting. General planning meetings usually included the personnel responsible for the various tasks, (excluding vendor assistance) and sometimes personnel from the home office. Other meetings concerned with a single task consisted of only the outage coordinator and the three or four others associated with the task.

Outage Preparations

Before these general meetings began, other preparations were made. Approximately one year in advance of the outage, the various work activity categories were identified and responsibilities for them delegated. The various department heads then maintained a cumulative list of work for the outage along with the necessary information for scheduling. In addition, the department heads were also responsible for ensuring that required parts or equipment were ordered. The year of advance preparation was primarily to provide time to acquire parts having long lead times.

Outage Organization Functions

About 90 days before the outage, the unit's operating engineer was assigned the position of outage coordinator. This supports the station's belief that the outage coordinator's position should be held by an individual who has overall working knowledge of the plant and systems as well as the Technical Specification requirements. From the work list packages maintained by the department heads (mentioned above), the outage coordinator and the maintenance planner compiled an activity code list, which also included requirements in manpower, time, and other scheduling requirements. Most of the work items were identified at least 60 days prior to the outage. From these sources, the plan-a-log schedule was obtained.

The outage coordinator headed the outage organization. Detailed preparations were handled by the vendors, departments, or persons responsible for the successful completion of each task. Since maintenance was a major part of the outage, the maintenance planner and his support group handled most of these items.

Daily Planning and Scheduling Activities During Outage

The maintenance planner and/or the outage coordinator prepared the actual work schedules for most of the work crews. This was done by first updating the plan-a-log through verbal contact with the major coordinators and the completed crew supervisor daily schedule forms. From this information, a 48-hour schedule was produced. The next day's work request package was compiled from this schedule. The work request package was left with the operations department in the afternoon for clearance preparations and equipment tagging. This allowed work requests, clearances, and work list to be ready the next morning when the crew arrived for work.

Preoutage Schedule

The preoutage schedule is shown in Figure 2-5 for the BOP activities, including — in general — turbine maintenance, MSRH modification, and feed pump turbine work. Note that this schedule does not show the primary system activities since the main emphasis in this study was on the BOP. As shown, the turbine work is the major effort, with the MSRH modification work also contributing significantly.

The preoutage critical path mini-schedule was established as shown in Figure 2-4, based on the following:

1. Day 1 to day 4 — shutdown/cooldown to draining of steam generators.
2. Day 5 to day 35 — dismantle, clean, inspect, repair, and reassemble the HP turbine; the diaphragms were scheduled to be shipped to the vendor for repair. The total scheduled time from "turbine off-gear" to "turbine on-gear" was 29 days, including repair work on the diaphragm at the vendor shops (approximately 16 days).
3. Day 36 to day 43 — plant startup and heatup to generator on-line.

The primary system refueling activities were scheduled in parallel with the turbine work, and completion was estimated for four days ahead of the turbine work. As shown, some of the primary system parallel work included reactor vessel head removal, refueling, inspection of reactor vessel welds using the Automated Reactor Inspection System (ARIS), and RCP motor modification.

Planned Work and Manpower for Main Turbines

Since the turbine work dictated a large majority of critical path work, much thorough planning in terms of schedule and manpower allocation was done. Planned work for the main turbine included the following:

1. With unit still on turning gear, check oil lift pumps and remove lagging and insulation.
2. Dismantle, clean, inspect, and reassembly the HP and "A" LP turbines.
3. Install thermocouples in No. 3 and 4 bearings.
4. Inspect all other bearings.
5. Clean and inspect main oil tank.

The manpower to accomplish this work was planned as follows:

1. Before putting the turbine off the turning gear — one 8-hour shift/day with 15 men (day 1 to day 5 on Figure 2-5).
2. Beginning with turbine off the turning gear — three 8-hour shifts/day until the HP turbine was completely disassembled and sandblasted (day 5 to day 12 on Figure 2-5).
3. Then shift to two 10-hour shifts/day with two crews on the day shift, one crew on the night shift; part of the day shift was to work on the feed pump turbines. The shift changes (i.e., number of shifts, days working, hours working) was left to the discretion of the system maintenance engineer in charge of the work. This gave him the flexibility of changing, deleting, and adding shifts or crews depending on where the job stood in relation to the outage critical path at that time. Each crew was to consist of 10 mechanics, 1 rigger, 1 crane operator, 2 sandblasters, and 1 foreman — a total of 15 workers per crew.

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2.1.3. Summary of Key Outage Events

On October 21, 1977, Oconee Unit 3 was shut down for its second cycle refueling/maintenance outage. The preoutage schedule had indicated a duration of 41 days, 15 hours. However, it was discovered early in the outage that an additional 2 days would probably be required for steam generator work; this produced a schedule of 43 days, 15 hours. The unit returned to on-line power production on December 4, 1977. The outage was 43 days, 5 hours breaker-to-breaker, 10 hours less than the scheduled outage.

Experience gained by personnel from previous outages resulted in many instances of time gains. Unfortunately, a number of delays occurred, totaling approximately 330 hours, which essentially offset all outage gains.

The delays experienced during the outage (stated in hours) were as follows:

1.	Discrepancies in breathing-air system	12
2.	Stud tensioner gage problems	8
3.	Installation of Automated Reactor Inservice System delayed by weather	8
4.	Control rod mast alignment	10
5.	Profilometer* inspection and removal of steam generator tube	16
6.	OTSG repairs	50
7.	Vendor's strike caused delays due to unavailable parts for RCP motor thrust runner modification	168
8.	Reactor building cooling unit modification	16
9.	Stuck control rod drive mechanism vent valves and tool problems	10
10.	High sodium content in steam generator and resultant RCS cooldown	24
11.	CRD group 5 power supply problems	6

2.1.4. BOP Outage Performance Observations

The BOP performance observations consisted primarily of major secondary system activities such as turbine and MSRH work. Observations were also made in the area of outage communication, coordination, task assignments, and handling of nuclear station modifications. This section discusses those observations.

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*The profilometer is a B&W-developed tool for measuring steam generator tube ID and changes in ID; it can be used in combination with an eddy-current probe drive assembly.

Communication

The Oconee 3 outage was reasonably successful in terms of interdepartmental cooperation and communication. Problems of insufficient support by Quality Assurance (QA) and Health Physics (HP) groups still occurred occasionally, but this was much less serious than in previous outages because of increased communication between the groups. Another factor that aided in this situation for activities inside the reactor building was the use of color bands on anti-Cs to identify maintenance, QA, HP, etc., as was recommended in the Phase 1 refueling outage report. This permitted members of the support groups to be recognized instantly when needed.

Coordination

Another factor that aided in increasing cooperation and coordination between the groups was the use of outside vendor maintenance coordinators. These coordinators were viewed as impartial judges on interdepartmental disputes and were able to handle these situations more effectively than could site personnel because they did not have to consider personality conflicts between themselves and maintenance personnel that could develop months later over something that happened during the outage.

Task Assignments

Contributing still further to the excellent performance during the outage was the method of assigning tasks. Tasks were assigned based on previous experience and ability. More important, these tasks were assigned prior to the outage, which gave the supervisors an opportunity to make detailed plans and crew assignments. In many cases, it was possible to assign personnel to tasks similar to those they had performed only a few months before on Oconee Units 1 and 2.

Nuclear Station Modifications

Approximately 30 nuclear station modifications were accomplished during this outage. In most cases, the packages were complete and the scheduling was done so that they did not affect critical path items. However, two delays were observed: (1) reactor coolant pump thrust runner modifications and (2) receipt of the wrong relay for modifying circuits for the reactor building cooling units.

Major BOP Outage Activities

The major BOP activities during the outage are shown in the as-built outage schedule, Figure 2-3. The turbine work proceeded extremely well and in the early phases was ahead of schedule. Some major activities resulted in recommendations:

1. Detensioning of the HP turbine studs and removing the castellated nuts took approximately 6 hours using heating rods. This was one of the first turbine work items begun, and little else could be done until it was completed. Shortening this time could directly affect the length of the secondary side critical path.

2. Each turbine rotor uncoupling operation took approximately 5 to 6 hours. In the method used, the crane was necessary to assist in uncoupling. Since the number of overhead cranes was limited, so was the number of uncouplings that could be done simultaneously. The method was also troublesome because it tied up the cranes and prevented them from doing work elsewhere.

3. The HP turbine diaphragms were scheduled to be sent to the manufacturer for repair. This decision was based on damage discovered in the previous outage inspection. However, upon removing the diaphragms from the turbine, it was found that the damage was not as serious as anticipated. The diaphragms were not shipped offsite for repairs, resulting in a shorter schedule of turbine work.

4. When it was removed for inspection, one of the turbine bearings was found to be damaged; it required return to the manufacturer for repair. The time between shipping the bearing offsite and receiving it back was about 13 days. However, the turbine work was no longer the controlling item of the outage during this time, so it did not directly impact the outage length although it did slow down the secondary side work effort. If the abnormal events and problems (listed in 2.1.3) had not occurred, or if this had been a normal outage where the ARIS inspection and RCP motor modifications were not being performed, this problem could have extended the outage critical path by about a week.

5. As can be seen from the as-built schedule, much time was needed to sandblast the turbine parts, which was required before reassembly could proceed.

The method used for sandblasting required temporary tents, which only partially controlled the spread of the sandblasting material. Thus, the surrounding area had to be cleaned to prevent fouling of equipment or tools.

6. Damaged welds and lines in the hot well were found during inspection and for a time threatened to become a critical path extension. Fortunately, the work was completed before the scheduled end of the outage. However, at least one day of possible work time was lost because a complete and thorough inspection of the hot well was not made when the hot well was first opened, and even that did not occur until day 11 of the outage.

7. A sizable task, shown on the as-built schedule, was modification of the moisture separator reheater (MSRH). No known major problems occurred here — it was simply a modification to improve equipment. This was an abnormal rather than recurring item.

2.1.5. BOP Manpower Sources and Usage

Outage manpower assignments were finalized and requests were submitted approximately 30 days prior to the outage. The resultant number of Duke personnel and their sources were as follows:

Steam support division	225
Electric motor & controls/relay meters & controls	30
ONS personnel	45

Assistance was also contracted from offsite vendors for specific tasks. The numbers of personnel provided by each vendor thus depended heavily on the vendor's estimate of what was required for the task. The labor force utilized by each vendor was, however, small in number compared to the total amount of manpower on site. The number of persons involved and the plant outage organization can be seen in Figures 2-6 and 2-7. Figure 2-6 displays the ONS maintenance organization used during this outage. The outage force was divided into 24 crews assigned under four sections. For example, the secondary system coordinator had seven work crews assigned to him (identified as crews 11-14, 16, 17, and 24 in Figure 2-6). Figure 2-7 identifies the responsibilities of the 24 work crews and, in parentheses, the number of men assigned to each crew.

Despite the generation of approximately 1200 work requests for this outage, not all the outage activities were covered by separate work requests. This was particularly true of various BOP tasks, such as the turbine maintenance and inspection work. In many cases, the work had been contracted to the SSD group and, since they were familiar with their work, the work requests were essentially formalties for the convenience of the planners. In such instances, several related or interdependent work items were placed on the same work request. This prevented very accurate accounting of manpower for specific tasks concerning the turbine.

From data collected at Oconee, the following examples of manpower usage are presented:

1. Feedwater Pumps — The number of persons used here varied depending on the task. When cleaning the FW pump oil coolers, three to four men were present initially. However, later during the operation only two were present. Personnel for this job were pulled from turbine maintenance and inspection work. Later, work on the FW pumps included uncoupling the pump turbines for overspeed tests. This took three men and was a matter of only a few hours for each FW pump turbine.

2. BOP Valve Work — Twelve workers were scheduled for this work. Valve work at Oconee involved dividing the plant into areas, and then doing all required valve work in that area before moving to the next. This, of course, did not include systems being maintained in standby or in operation; the method involved much less movement of tools and supplies.

3. MSRH Manway Removal and Cleaning — These two different jobs, were completed by the same group of personnel; at times, both tasks were being done simultaneously. The total number of men involved varies between 19 the first day and 8 the next. Because of problems with leaking manways, the MSRH manways had been tightened and seal welded shut. A combination of slug wrench use and arc-gouging was required to remove the manways.

4. Turbine Maintenance and Inspection Work — This work was the largest single BOP use of manpower, with three scheduled 15-man crews. During initial disassembly of the turbine, all the men were employed as planned, but when it was found that the diaphragms would not have to be sent offsite for repairs, turbine work was shifted off the critical path. Thus, working hours and days were slightly reduced with the same number of personnel assigned. Personnel were sometimes loaned out for other work. One instance was the loss of an entire shift while the crew examined a problem on the Oconee

Unit 2 turbine. However, most of the personnel worked on the turbine maintenance and inspection.

2.1.6. Typical BOP Outage Schedule for Oconee 3

Comparisons of the preoutage and as-built schedules (shown in Figures 2-5 and 2-3, respectively) revealed two items that were unique to these outages. If we delete these items from the schedules, an estimate of what should have occurred at Oconee 3 can be obtained, resulting in a typical schedule. Evaluation and analysis of the typical schedule can then be made to determine whether outage time savings can be attained by implementing the recommendations resulting from this study.

The typical schedule is shown in Figure 2-8 along with assumptions. Two major items were deleted from the actual schedule:

Repair of No. 1 HP turbine bearing — 1.5 days delay.

Two Saturdays not worked — 2 days.

The activities and assumptions shown in Figure 2-8 represent a total of 14 days from turbine off-gear to turbine on-gear. Three and one half days of delays listed above were deleted from the actual schedule of 18 days (turning gear-to-turning gear).

The No. 1 HP turbine bearing was offsite for repairs for 264 hours. However, parallel work was being performed during this time, and the resultant critical delay time was 1.5 days.

Comparing this with the Phase 1 study results shown below indicates that even with complete disassembly, inspection, cleaning, maintenance, and reassembly of the HP turbine and one LP turbine, the BOP work at Oconee 3 will not be the controlling item for the outage.

Phase 1 study results, NSS outage — typical schedule	33 days breaker-to-breaker
BOP typical outage schedule from this study	14 days turning gear-to-turning gear*

- - - - -

*Typically, it should take 2-3 days from breaker-open to when the turbine can be taken off the turning gear. During plant startup, it should take 16-17 days from turbine on turning gear to when the breaker is closed.

2.2. Selected Observation and BOP Maintenance Study at ANO-1

2.2.1. B&W Team Formation and Summary of Work Effort

The maintenance extension study for ANO-1 began in July 1977. This study differed from that at Oconee because the main emphasis was devoted to conducting onsite surveillance of preventive maintenance activities and other secondary plant maintenance practices during normal plant operation. In contrast, the Oconee study was concerned primarily with BOP outage activity observations.

A site project team (Figure 2-9) was assembled to conduct the extension study at ANO from August 9, 1977, to December 1977, while the plant was in operation. During this time, the team performed the majority of the work by collecting data and conducting reviews of such specific BOP items as operational records, procedures, equipment use and design, systems layout, work area availability, spare parts, etc. The utility was examined as a whole as well as by its individual parts. After the field study, the team returned to Lynchburg to begin the data evaluation, analysis of recommendations, and preparation of outage target schedules.

Preliminary data from the study indicated the need for outage observation beyond the original work scope. Therefore, two team members returned to ANO-1 to selectively observe the first two weeks of the second cycle refueling outage in February 1978. Disassembly of the HP turbine and other major equipment was observed and videotapes were taken where appropriate.

Data collected from the outage were then analyzed. Outside consultation was obtained through one vendor to confirm initial findings. This led to the actual demonstration of hydraulic bolting system (HBS) applications during the reassembly phase of the large main steam pipe coupling flange. This demonstration, arranged by the team in cooperation with ANO-1 and the vendor, proved that reassembly took 40 minutes using the hydraulic tool, whereas the manual method has taken over 3 hours.

2.2.2. Review of BOP Maintenance/Outage Practices

The project team reviewed the maintenance records and specific BOP items listed below at ANO-1.

1. Outage preparation and manpower.
2. Training capabilities.
3. Secondary valve maintenance.

4. Work packages for secondary plant.
5. Plant preventive maintenance program.
6. Spare parts system.
7. Turbine testing and inspection for extended fuel cycles.
8. Work area support availability.
9. Equipment isolation and duplication for on-line maintenance.
10. System/equipment layout.

This section presents findings from the review of these specific BOP items to determine where improvements could be made to reduce refueling outage time and/or increase operational time, thus improving plant availability. The recommendations resulting from this review are presented in section 5.

Outage Preparation and Manpower

Although the team was not present during all preparations for the 1978 refueling/maintenance outage, the initial preparation was observed. Preoutage meetings were held by ANO plant supervisory personnel to identify major areas of concern. After these initial meetings, the weight of the outage fell on the plant scheduling and planning coordinator, who was responsible for scheduling all work items to be accomplished and for assigning the different maintenance groups their tasks.

ANO has shifted its emphasis on outage preparation to a year-round job. This allowed (1) early identification of tasks and evaluation of their repair requirements, and (2) early acquisition of spare parts for the tasks involved.

The number of persons assigned to the Scheduling and Planning Department has been increased. Until 1977, ANO had only one scheduler and planner to contend with the Unit One outages. But with the increasing work load and with Unit Two approaching completion, ANO has supplemented its Scheduling and Planning Department with several persons to relieve the demand on the one employee.

ANO has been increasing its plant manning since the 1977 refueling outage in preparation for commercial operation of Unit Two. This allowed more flexibility in using ANO maintenance personnel versus drawing heavily on vendor personnel. ANO entered its 1978 refueling outage with the following staff personnel:

Maintenance	113
Operations	61
Supervisory (including clerical)	73

These numbers reflect total plant manning for both Unit One and Unit Two. Although these numbers are an increase over last year, ANO's total staff remains small. The utility plans to continue plant manning increases until full staffing is accomplished.

Training Capabilities

At present, ANO's training capabilities are limited to licensing operations personnel. In the past, this was caused by a small manpower commitment to the Training Department. Recently though, ANO has been increasing its Training Department staff to allow expansion of its training functions to areas other than licensing.

From our review of training facilities and existing methods, the needs for developing a training program for maintenance personnel and for a comprehensive video training library were identified. These training programs are valuable aids in increasing personnel efficiency, thus reducing individual task time and overall outage time.

Secondary Valve Maintenance

Review in this area resulted in the following findings:

1. Many valves with remote operators are included under the PM program, but very few manually operated valves are included.
2. There is no regular valve maintenance schedule during plant operation.
3. Adding extra rings of packing of top of existing old packing versus replacing the packing is a method being practiced.

Improvements in the area of secondary valve maintenance practices could account for reducing the manhours spent on valve repair during each outage.

Work Packages for Secondary Plant

A work package is used to accomplish nuclear safety-related tasks in the primary plant. However, it is not used for the majority of secondary work. Due to the success of these work packages, it is felt that a similar work package for use in the secondary plant would reduce the time required to accomplish tasks. Review of primary system work packages provided the following good reasons why they should be considered for use in the secondary plant:

1. It would eliminate the need for a worker to personnally accumulate information pertinent to his task, such as the vendor's technical manual for the work procedure, parts lists, tool lists and other information he may find useful.

2. The work package would be written prior to the outage; thus, it would contain all information necessary to complete the assigned task efficiently.

3. Once a work package has been completed for a job that occurred during each outage or at regular intervals, a copy need only be issued each time that job occurs. This would allow the benefits from the work package to be realized many times over from a small initial investment.

Plant Preventive Maintenance Program

ANO-1 is implementing a PM program consisting of a scheduling function designed to ensure that certain predetermined maintenance items are completed according to a master schedule. When implemented, it would provide for the following:

1. Allow as much on-line maintenance as possible, along with accurate and predictable component evaluation.

2. Enable ANO-1 to schedule and perform as many maintenance, inspection, and test items as possible prior to a refueling/maintenance outage. This function in itself would help reduce the number of required tasks during an outage, thus reducing its overall length and manpower requirements.

3. Allow identification of equipment trends, permitting potential problems to be identified and corrected prior to component failure. This ability to predict equipment failure is a valuable aid in maintaining the plant in the desired operating status.

ANO's PM program was reviewed in relation to checksheet format and data collection methods, scheduling, baseline data, and integration of job orders into the PM program. Recommendations for improvement are identified in section 5.

Spare Parts System

AP&L is engaged in implementing a computerized spare parts system with multiple capabilities. When fully operational, the system will (1) ensure up-to-date stock inventory, (2) automate spare parts locating, (3) provide low stock readouts, and (4) permit automatic preparation of order forms.

AP&L will be sharing a common computer with other utilities in the Middle South Utilities Network. This sharing of the computer will benefit all participating utilities in the ability to check the parts inventory of other utilities on the network. Consquently, a rapid determination can be made as to where to obtain a critical item if the vendor cannot supply the part. The review of ANO's spare parts has shown the available inventory of spare parts to be adequate, but improvements are indicated in some areas. This is presented in section 5.

2

Turbine Testing and Inspection for Extended Fuel Cycles

In 1979, it is projected that ANO-1 will refuel its reactor with an extended-life fuel. With an extended-life core, ANO will undergo three refueling outages in a five-year period.

ANO-1 has one HP and two LP turbines and a generator, which are on a five-year inspection schedule. This means that all turbines and the generator must be inspected during the 60-month period. At present, the ANO turbine and generator elements are inspected at a rate of two elements per outage.

Work Area Support Availability

Support facilities (such as ladders, platforms, and walkways) were reviewed to determine where improvements could be made to reduce the work effort around equipment and inaccessible components. During ANO's previous outages, many hours were spent erecting temporary platforms and scaffolding to support valve repair and other outage tasks. This problem will increase when the plant ages, with more leaking valves and components needing adjustment. At present, ANO uses temporary scaffolding and portable lifts to accomplish work in inaccessible areas. We have found some areas of excellent support for maintenance, such as around the tops of the heater drain tanks and the extraction steam isolation valves. Permanent installations like these would eliminate the need for installing temporary supports for every outage and removing them after use.

Equipment Duplication and Isolation for On-Line Maintenance

One area of review for the maintenance extension study was increasing on-line maintenance capabilities. This achieves the goal of the Refueling Outage Availability Study by reducing unscheduled outages caused by malfunctioning equipment and reducing the overall workload for a refueling/maintenance outage. All these lead to longer operating periods and lower replacement energy costs.

Two areas that were reviewed in achieving this goal of increased on-line maintenance were equipment duplication and isolation capabilities.

As to equipment duplication, several components in the secondary system for most nuclear plants are capable of reducing the unit's power level below that desired by the utility for continuous operation. For example, there are two main FW pumps at ANO-1, both of which are required to operate the plant at 100% power output. If one pump is out of operation, Unit One is required to reduce its power level to 60% until that pump can be returned to operation. This power level is far below optimum for the utility.

With regard to equipment isolation capabilities, a review of system construction reveals several major components that cannot be isolated for on-line maintenance. Specific items, for example, are the heater drain pumps and the main FW pumps. The loss of any of these components would result in reduced plant generating capacity. It would be desirable to repair or perform PM items on these components at power, but the lack of isolation capabilities precludes this.

System/Equipment Layout

The secondary system/equipment layout was reviewed to determine areas of construction not conducive to efficient maintenance. One area of concern is the main condensate pumps. ANO-1 has three half-capacity condensate pumps, two of which are required to operate at 100% power. This leaves the third pump as a standby or available for maintenance. However, to work on a condensate pump, it must be lifted from the basement and laid down on the turbine deck. Unfortunately, the relief lines for one of the moisture separator reheaters (MSR) run directly across the hatch area through which one of the condensate pumps must be withdrawn. This layout precludes any major maintenance on this pump during plant operations. AP&L is aware of this problem and is presently reviewing the recommendation to reroute the relief lines away from the hatch area. This would allow removal of the condensate pumps one at a time for preventive maintenance during the operational cycle without conflicting with turbine work for floor space during the outage.

2.2.3. Selected BOP Outage Activity Observations

After the initial field study at ANO-1, the B&W team returned to Lynchburg to evaluate the data collected, identify improvements, and prepare target outage schedules. Preliminary data from this study indicated the need for outage observation. Therefore, two team members returned to ANO-1 to observe the first two weeks of the February 1978 (second cycle) refueling outage. This section summarizes the key outage events and observations.

2

Summary of Outage

On February 2, 1978, ANO-1 shut down for its second cycle refueling outage. The unit was returned to line on March 31, 1978, resulting in a 57-day outage. The key factor in the length of the outage was replacement of the No. 1 LP turbine rotor. The entire rotor assembly in the turbine was replaced, and the HP turbine was disassembled, inspected, and reassembled. The entire rotor assembly in the No. 1 turbine had to be replaced because structural irregularities were discovered in the rotor during the 1977 refueling outage.

BOP Outage Observations

During the observation period for the ANO-1 1978 refueling outage, several key outage events were reviewed and the results compiled with observations from the plant's 1977 refueling outage. These observations were then reviewed with emphasis on time reduction or material improvements designed to reduce the BOP critical path or to reduce the manpower necessary to complete the tasks. Some of the key outage events reviewed are discussed in the following text.

Limited Turbine Laydown Area

It was observed that the limited laydown area available in ANO-1 was holding up turbine inspection and overhaul. Components stored on the turbine deck were moved to make room for new components and readjusted to allow room for inspection and cleaning. The lack of sufficient laydown space in the turbine building caused delays of several days during the outage.

Spare Parts Tracking Problem

Although no delays were observed due to insufficient spare parts inventory, tracking the parts caused delays during the outsge. Time was lost in locating and verifying parts to be used.

Procedural Delays

Time delays were caused by workmen searching for procedures and proper tools. Tools were originally located in one central area but were soon scattered throughout the plant. When procedures were used, significant time delays resulted while they were located and verified as correct. At times there was confusion between shifts as to how much of a job had been completed by the previous shift.

Valve Work

Considerable valve work was conducted by vendor personnel. Whole valves were replaced as well as more minor adjustments, such as repair of packing leaks and body-to-bonnet leaks. Some lapping of valves also occurred.

Preparations for Lifting HP Turbine Rotor

A time delay was observed during preparations to lift the HP turbine rotor. The lifting segments on the lifting beam were adjusted according to a diagram that had incorrect measurements on it, thus necessitating readjustment. This held up the turbine rotor lift by about one hour.

Tools for Disassembly of Nuts and Bolts

Much of the old slugging wrench method of disassembling large steam piping flange joints was observed. This process was lengthy and had a low safety factor. In almost every case of using an impact wrench and a sledge hammer, it is possible to overtorque nuts and bolts. The awkward slugging wrench method was a direct contributor to the length of the critical path.

Hand Tools

The use of hand tools to remove small bolts from inspection covers and other equipment lengthened several jobs, specifically generator cover disassembly and LP turbine outer cylinder bolt removal. One man was assigned to this task and spent several days working at the job on a part-time basis.

Housekeeping

Poor housekeeping in several areas caused some delays. One example was when the block insulation was being removed from the HP turbine and a large amount of lagging dust accumulated in the area. Just before the HP turbine casing was removed, the insulation dust was blown off with compressed air. This insulation dust settled into the No. 1 LP turbine inner casing and onto the rotor and other exposed system piping. This added time to the cleaning task before turbine inspection. If could also have increased the flush time required for the condensate and lubricating oil systems (we did not observe these flushes).

2

Damaged Studs

Large studs on the turbine casings were left unprotected while the casings were removed and stored. This resulted in several studs being damaged, necessitating replacement and causing delays.

HPT Monorail

During the 1977 ANO-1 refueling outage, it was initially recommended that an alternate means of supporting the HP turbine casing tensioner unit be installed to free the turbine building crane. This recommendation was verified by the ANO extension study field work in 1977. The possibility of using a portable frame or other supportive structure was discussed with ANO and its turbine vendor representative.

Prior to the ANO-1 1978 refueling outage, ANO and the turbine vendor representative designed and installed a monorail arrangement around the HP turbine. The monorail was used during the 1978 outage to support two tensioning units without using the overhead crane. This allowed the crane to be used for large steam line removal that would have had to wait until the HP turbine casing was detensioned and removed.

The design and erection of the HP turbine monorail arrangement by ANO and the turbine vendor representative saved at least 48 hours of critical path time.

Rigging and Lifting Large Turbine Components

Rigging and lifting large turbine components involved many hours spent in ensuring that each load point in the lifting rig was properly adjusted. Once the lifting rig was installed, "kicks, hits, and shakes" were used to ascertain whether each suspension was adequately loaded.

Storage and Accountability of Special Tools

Storage and accountability of special tools tend to be a recurring problem. One example was the special tooling for lifting and moving the turbine components. These tools were purchased specifically for use with the turbines and are not usually useful in other work areas; however, there were instances where these tools were used for such other work. This led to delays in locating the lifting tools when needed for their specific function and in some cases led to tool damage.

HP Turbine Metal Lagging Interference

Since the 1977 refueling outage, ANO has gone a long way in solving the interference problem with the HP turbine metal lagging. Prior to ANO's modification of the lagging, up to 2.5 hours of critical path time was lost in moving each of the larger turbine components around the metal lagging for storage.

ANO has modified the lagging so that it no longer interferes with movement of turbine components; however, it still interferes with the smooth flow of work in the vicinity of the turbine. The close proximity of the lagging to the HP turbine and the limited access through it restrict the movement of personnel and tools, hamper the installation of temporary scaffolding, and interfere with the use of extension cords and air lines.

HP Turbine Insulation

Approximately 8 hours were spent removing the block insulation and insulation pads from the HP turbine prior to disassembly.

2.2.4. Demonstration of Hydraulic Bolting System

The data collected from the 1978 refueling outage observation was analyzed and evaluated. One observation that led to further study was ANO's method of disassembly and reassembly of large steam line piping flanges, turbine couplings, and casing bolts. The slug-torquing method using wrenches and sledge hammers was used to bolt and unbolt these items, sometimes in precarious positions. In addition to the safety factor involved, damage to the components was a real threat and the possibility existed.

Outside consultation was obtained through one vendor* to determine whether existing hydraulic bolting systems (HBS) could improve the disassembly and reassembly of the items described above. Arrangements were made with the vendor and ANO for an actual demonstration during reassembly of the large main steam piping flanges. One week was spent at ANO for this demonstration, and videotapes were taken during this period.

Normally, the two LP turbine crossover steam lines required 3 hours or more to bolt each of the six flanges involved. With the HBS, this minimum 3 hour bolting time per flange was reduced to 40 minutes. The device was not only considerably faster but proved to be safer than present methods. The system was

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*This vendor is N-S-W Corporation of Houston, Texas.

available in a number of sizes, including one with many possible applications yet small enough that one man was able to carry it around.

2.2.5. ANO-1 Proposed Typical BOP Outage Schedule

From data collected during selected observations of the first and second cycle refueling outages, overall maintenance review, and outage historical records, a proposed typical BOP outage schedule was developed. This schedule will be used to derive an ideal BOP outage schedule which would result if recommendations resulting from this study were implemented. The proposed typical schedule represents what is achievable at ANO for the BOP work. Figure 2-10 shows the schedule along with assumptions. The results show that a BOP outage length of 33 days from turbine-off-gear to turbine-on-gear can be achieved considering complete disassembly, inspection, cleaning, and reassembly of the high pressure turbine and one low pressure turbine.

For comparison purposes, the results of the Phase 1 study for the NSS are shown below:

Typical outage length for ANO-1, NSS — from phase 1 report	32 days breaker-to-breaker
Proposed typical length for ANO-1, BOP	40.5 days breaker-to-breaker 33 days turning gear-to-turning gear

This indicates that for an outage involving the disassembly and maintenance of the HP turbine and one LP turbine, the BOP work will most likely control the outage length. When considering the whole plant, a typical outage length would be 40.5 days.

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

L. N. Mace
Lead Engineer

Outage Observers

W. H. Abbott
A. A. Bovino
M. W. Culver
T. Dalton
R. Latorre
A. L. Mercado
R. F. Ryan
J. S. Scearce
H. W. Shipman

Office Personnel

E. P. Ashwell
J. S. Shetler
M. Underwood

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

A. L. Mercado
Overall Coordinator

Evaluation of Data and Report Preparation

M. W. Culver
L. N. Mace
M. F. Penovich

Generic Recommendations

J. E. Anderson
M. W. Culver
S. J. Engel
L. N. Mace
M. F. Penovich

Videotape Production

J. E. Anderson
M. W. Culver
J. L. Wilfong
M. F. Penovich
F. B. Mahaffey
A. L. Mercado
L. N. Mace

Special Studies

J. E. Anderson
S. L. Stratton

Figure 2-3. Oconee 3 1977 BOP As-Built Schedule, Sheet 1

Figure 2-3. Oconee 3 1977 BOP As-Built Schedule, Sheet 2

Figure 2-3. Oconee 3 1977 BOP As-Built Schedule, Sheet 3

Figure 2-4. Oconee 3 1977 Critical Path Preoutage Schedule

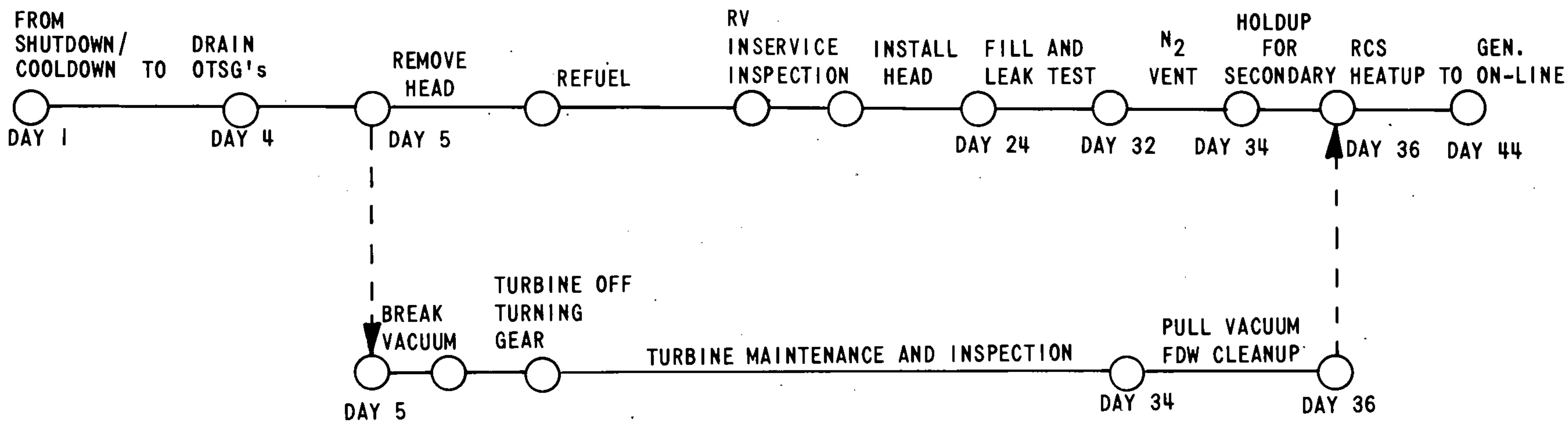

Figure 2-6. Oconee 3 Outage Planned Organization — Part 1

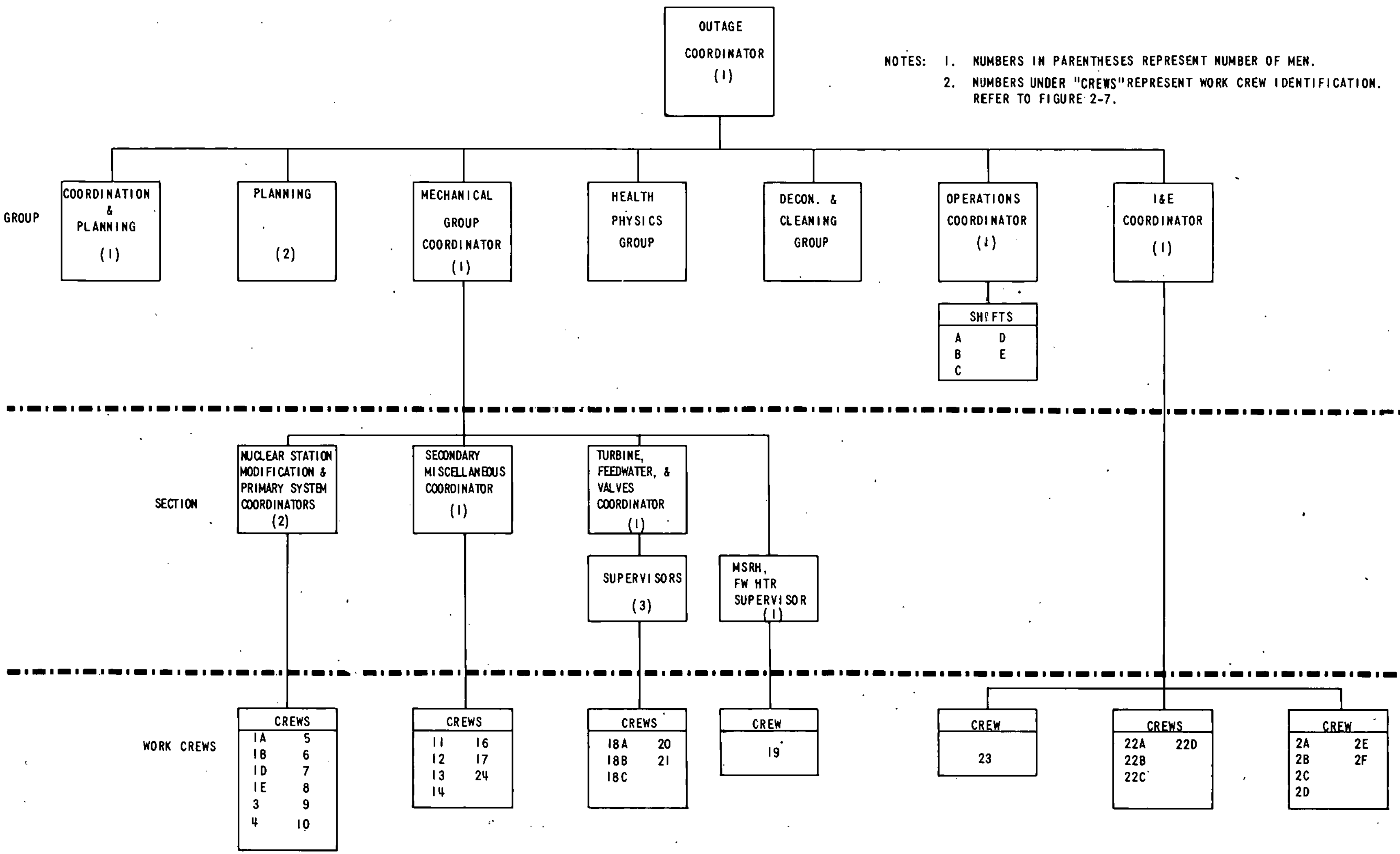

Figure 2-7. Oconee 3 Outage Planned Organization — Part 2

Primary system			Balance of plant		
Crew ID No.	Description	No. of men per crew	Crew ID No.	Description	No. of men per crew
1A	RV head	(10)	2A	I&E	(1)
1B	RV head	(10)	2B	I&E	(1)
1D	RC pumps	(13)	2C	I&E	(1)
1E	RC pumps	(12)	2D	I&E	(1)
3	ECT/ISI	(12)	2E	I&E	(1)
4	Misc	(6)	2F	I&E	(1)
5	NSMs	(13)	11	Valves	(12)
6	NSMs	(13)	12	Scaffolding	(10)
7	NSMs	(14)	13	Insulation	(9)
8	NSMs	(8)	14	Suppressors	(8)
9	FHE support	(4)	16	ONS welding	(4)
10	ARIS	(20-10) from RV head work	17	ONS shop	(3)
			18a	Turbine	(15)[a]
			18b	Turbine	(15)[a]
			18c	Turbine	(15)[a]
			19	MSRH, FW heater	(6)
			20	FWPT	(from turbine)
			21	Turbine valves	(from turbine)
			22a	Breaker	(4)
			22b	Motors, generator	(5)
			22c	Doble test	(2)
			22d	Relays, meters	(4)
			23	Electrical	(18)
			24	Hanger inspection	(37)

[a] These numbers represent 15 men per midnight shift, 15 men per evening shift, and 15 men per day shift, respectively.

Figure 2-5. Oconee 3 1977 BOP Preoutage Schedule, Sheet 1

*GENERAL TURBINE WORK CONSIST OF:

1. MAINTENANCE AND INSPECTION WORK ON LP "A" TURBINE.
2. MAINTENANCE AND INSPECTION WORK ON 2 "A" CRV'S.
3. INSPECT BEARINGS; INSTALL THERMOCOUPLES

Figure 2-5. Oconee 3 1977 BOP Preoutage Schedule, Sheet 2

Figure 2-8. Oconee 3 Typical BOP Outage Schedule

Figure 2-9. B&W-DOE Observation Team at ANO-1

M. F. Penovich
Lead Engineer

S. J. Engel
A. T. Russell
D. G. Culberson

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Figure 2-10. ANO-1 Proposed Typical BOP Outage Schedule

3

3. BASIS FOR RECOMMENDATIONS

3.1. Introduction

The observation data collected are presented in the previous sections of this report. As the data were being accumulated, they were also being analyzed for possible recommendations, and the majority of the recommendations given in this report originated while the observation teams were still at the sites. After returning from the sites, the data were reviewed again for any further recommendations that could be obtained. Although the primary purpose of reviewing the data was for new recommendations, a secondary objective was to analyze and expand or eliminate, as appropriate, the recommendations made while the teams were at the sites.

3.2. Basis for Improvements

In the evaluation phase discussed above, the recommendations were examined with respect to several factors:

1. Time Savings — This time savings could be in terms of critical or parallel path time, depending on the plant and the scheduling method being used. For example, at Oconee the BOP work took less time than the primary work; therefore, the savings would be in parallel hours. At ANO the BOP was the critical path; therefore, the savings would be critical path time savings. It should also be realized that even at Oconee the BOP work time was only slightly shorter than the primary work time, and the primary involved inspections not normally incurred.

2. Manpower Reductions — The recommendations were analyzed with respect to any direct manpower savings, such as two men instead of three for a job, and also with respect to reduced manpower due to reassignment of men where job times were reduced, as mentioned in item 1.

3. Technical Feasibility — The recommendations were examined to determine whether they were technically feasible. Equipment recommendations were also examined to find out whether the equipment was available on the present market, a device capable of development with the present technology, or one that required an advance in technology.

4. Cost — The cost of developing or implementing the recommendations was also considered.

3.3. Figure of Merit Evaluation

This section deals with the development of an empirical measurement for assigning priorities to implementation of recommendations.[1] 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. Five basic elements have been considered in evaluating the recommendations of the refueling outage availability study program: the days saved, the total cost, the time to implement, the outage time to install, and the number of nuclear plants to which it is applicable. 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 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 (FM) can then be used to rate the recommendations. It should be noted that the FM 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 an FM for the recommendations:

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

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.

3

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 a part of its overall value. A value judgment was used to assign these factors based on the fact that the design and procurement work should be done during plant operations and should thus 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.

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).

3.4. Reference

[1]Refueling Outage Availability Study, Phase 1 Final Report, COO-4068-14, BAW-1464, Babcock & Wilcox, Lynchburg, Virginia, November 1977.

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	10	<3 mo.	10

Factor D		Factor E	
Outage time to install, days	Weighting factor	No. of plants applicable to	Weighting factor
(a)	10	1	1
1-4	9	2	3
4-8	8	3	5
8-12	7	4	7
12-16	6	>5	10
16-20	5		
20-24	4		
24-28	3		
28-32	2		
>32	1		

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

(a) Can be done with no outage.

4. OCONEE 3 RECOMMENDATIONS

The recommendations listed here have been organized in the following categories:

1. Immediate Recommendations — Improvements that can be implemented immediately by the utility, such as general and preventive maintenance, procedures, general personnel policies, and spare part practices.
2. State-of-the-Art Recommendations — Improvements that require changes to existing hardware/facility.
3. Recommendations requiring development, evaluation or design work.
4. Future Plant Design Recommendations — Improvements affecting future plant design.

Figure of merit values are given for each recommendation except where not applicable as noted. Future plant design recommendations were not given FM values.

4.1. Immediate Recommendation

4.1.1. General and Preventative Maintenance

1. Because of the large number of valves in the BOP and the possible effect even one valve can have on plant performance, special consideration should be given to valve maintenance. Some suggestions to improve valve performance and simplify valve maintenance are as follows:

   a. Preformed packing should be used whenever possible. Using preformed packing provides for a more accurate fit and eliminates the time required to trim packing to length, thereby reducing the time required to repack a valve. An important consideration in the use of preformed packing is its use in areas where the mechanic is required to wear an air mask and/or rubber gloves. Cutting bulk packing to the proper length and obtaining a proper fit under these conditions is very difficult, and the air mask makes visual examination of the packing being fitted marginal at best. The use of preformed valve packing eliminates these problems.

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b. The use of spare prepacked bonnets for valves smaller than 2.5-3 inches should be evaluated for use where possible and the old bonnet repacked in the machine shop (when manpower is available) and held for future use. This will reduce manhours required for valve work during the outage and allow repacking of bonnets under shop conditions, which should reduce the time required to repack a valve bonnet.

c. When repacking valves, all old packing should be removed, and all new packing should be used instead of adding new packing rings on top of the old packing already in the valve bonnet.

d. Whenever work is being done on a valve, the valve should always be repacked at the same time. The cost of repacking a valve that is already isolated for repair is small in both material and manpower compared to the cost of isolating a valve because of a packing leak. In addition, experience has shown that repacking a valve while performing other repairs reduces the number of work requests submitted in subsequent outages. (24 h) FM_D-275

2. Prior to each outage, all cranes that are to be used should be thoroughly checked for proper operation and lubrication to minimize the possibility of failure during the outage. The failure of an overhead crane during turbine maintenance and inspection has a direct impact on the expeditious accomplishment of these tasks since the major work items are time-sequenced, and the delay of one step delays all subsequent steps. (4 h) FM_D-75

3. Cal-rod heaters and associated power supplies for removing HP turbine bolts should have a complete PM check, and any necessary repairs should be completed prior to commencing the outage. The cal-rod heaters are used infrequently and therefore tend to be overlooked; however, they are vital items needed immediately upon starting the HP turbine disassembly, and failure of one or more heaters or their power supplies slows or delays disassembly. (4 h) FM_D-75

4. All possible non-isolable valves should be thoroughly inspected to check for indications of either body-to-bonnet or packing leakage and to ensure that sufficient packing gland adjustment remains to allow for future adjustment if it becomes necessary. This inspection should include primary as well as secondary system valves and should be conducted with the systems at normal operating conditions whenever possible. Any valves that are questionable should have work requests submitted and be reworked to ensure that they are in satisfactory condition before the system is returned to service. FM_D-74

4.1.2. Procedural Recommendations

1. Work requests should include fluid systems that need to be drained and isolated before work on any system component is authorized by the shift supervisor. This will minimize time lost by maintenance personnel while waiting for a system to drain. (8 h) FM_D-115

2. Priorities for accomplishing nuclear station modifications (NSM) should be assigned based on completed NSM packages, availability of materials, Nuclear Regulatory commitments, manpower availability, and the relative importance of the NSM. NSMs should be scheduled on the primary section of the Plan-a-log to provide a visual display of NSM status. FM_D-115

3. To support BOP activities as well, additional quality control (QC) personnel are required. It is standard practice to bring QC personnel from other sites to supplement the site QC staff. Since many work items have QC sign-offs that must be completed before continuing work, the need for a QC man can easily hold up several men and delay completion of a job. Because of this, it is imperative that adequate QC personnel be available at all times, including weekends, holidays, and back shifts. FM_D-115

4. Maintenance procedures should be used throughout the BOP and should have sign-off spots to encourage their active use. Some specific procedures that should be incorporated as soon as possible and requirements to be included are listed below: (8 h) FM_D-115

   a. A formal written procedure for turbine disassembly and reassembly with appropriate sign-offs to encourage its use should be required.

   b. A written procedure for magnafluxing turbine components with required cleanliness sign-offs by designated personnel should be instituted.

   c. A procedure should be issued outlining the steps required when performing a hot well inspection. This procedure should include a list of specific items to be inspected and drawings of the hot well in enough detail that defects can be indicated on the drawings to aid maintenance personnel in locating the defect. This inspection should be performed as early in the outage as possible to allow maximum time for repairs.

   d. Maintenance procedures should be issued to cover as many of the BOP valves as practical, specifically, large valves and safety-related valves. These procedures should include the requirements for system flush when appropriate and a list of tools needed to perform the required maintenance. This procedure should require the mechanic who performs the maintenance to briefly describe the repairs accomplished and sign the procedure to certify that the repair is complete.

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5. Valve maintenance should continue to be assigned by areas of the plant as currently done (except for valves in systems required to be in operation) to allow tool boxes, scaffolding, and other equipment to be centralized in a work area for maximum convenience and the fewest equipment moves. (4 h) FM_D-75

6. Work requests for valve maintenance should list required repair parts (i.e., gaskets and/or packing), and repair parts should be taken to the job site when initially reporting there. (4 h) FM_D-75

7. With upper management support, vendors should be given a deadline for submission of desired modifications or inspections of their equipment to allow for proper scheduling, manpower, and obtaining required supplies. FM_D-35

8. Paperwork authorizing material to enter or leave the site should be prepared as soon as the need to pass through the gate is known. This is of special interest on material scheduled to arrive or leave during shifts when authorizing personnel are not readily available. FM_D-35

9. Work requests for special equipment, such as power supplies, should be submitted immediately to allow maximum time for scheduling, manpower assignment, and obtaining the required equipment. FM_D-35

10. Expanding the use of the Plan-a-log for BOP work should be considered. BOP maintenance should be scheduled in more detail and updated daily to reflect its actual status. All BOP work items should be shown on the Plan-a-log, and major items — such as turbine inspection — should be shown by major steps that can be updated when appropriate. FM_D-35

11. All standing work requests should be prepared at least 90 days before the scheduled outage date to allow items to be preplanned and to allow maximum time available for processing emerging work items in the last 90 days before the outage. FM_D-35

12. Priorities should be established for the performance of local leak rate tests. Testing of penetrations should be scheduled so that the ones needed first are tested first. The present system is basically a first-come, first-serve method with the more convenient penetration being tested first. This method leaves some of the penetrations that are needed first to be the tested last, while some that are not required until late in the outage are tested first. FM_D-35

13. Scheduling planning meetings earlier in the day, preferably before the day shift comes on, should be considered. Although it requires a coordinator at all times to maintain continuity and provide input to the scheduling meeting, this would allow the day shift to start work promptly and would establish priorities early in the shift rather than half way through it. FM_D-35

14. A system should be established to follow up on items that were tested but passed marginally. An example is a penetration that fails a local leak rate test and is repaired by maintenance. After repair, the valve is retested and is just within specifications. Maintenance and performance are both satisfied with the penetration at this time; however, Maintenance knows the valve cannot be satisfactorily reworked again, and Performance knows from past trends the valve will not pass the next local leak rate test. Under the present system, nothing more will happen until the valve is tested during the next outage. Because of the long lead time associated with most nuclear grade items or systems, identifying items like the example needs to be established to provide follow-through action. FM_D-35

15. A procedure should be instituted for tracking a valve from the discovery of a leak until the valve has been repaired and the repair shown to be satisfactory. A suggested procedure to accomplish this is as follows:

    a. Upon finding a leaking valve, a work request to repair the valve is initiated, and a tag with the work request number, valve number, and nature of needed repair is placed on or as near as possible to the defective valve.

    b. When plant conditions allow, the valve is repaired using the appropriate maintenance procedure. When repairs have been completed, the tag previously placed at the valve is removed and replaced with a color-coded tag. The color code indicates the type of repair accomplished with one color indicating body-to-bonnet repair and repacking and a second color indicating a repacked valve. This tag should identify the mechanic performing the maintenance and the work request number under which the task was performed.

    c. When the system in which the valve is located is returned to operation, the valve should be checked for signs of leakage and adjustments made if necessary. After several days of operation, the valve is checked again and if it is satisfactory, the color-coded tag is removed and the work request completed. FM_D-35

4.1.3. Personnel Policies

1. Major jobs, such as turbine inspections, should be worked through to completion as quickly as possible and not paced with the critical path

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schedule. Work items not on the critical path may suddenly become controlling factors when a critical path item is completed ahead of schedule or is cancelled. This would apply to a situation where doing that work would not pull manpower from other potentially critical path jobs.

(48 h) FM-315

2. There should be enough qualified personnel designated to authorize "Confined Space Entry" permits or any similar permits so that during outage there is always someone readily available (on site) to preclude holding up work because of the lack of a permit. (6 h) FM_D-115

3. Communications and responses between various groups such as QC, HP, I&E, Performance, and Mechanical Maintenance need improvement. Supervisory personnel should review work requests and work procedures as soon as practicable and determine the support personnel required and should notify the appropriate supervisors so that advance personnel scheduling can be arranged. The attitude of many supervisors, "My jobs are the most important; I'll support so-and-so when I can," must be tempered so that the jobs most important to the overall outage receive priority over routine group work items. (8 h) FM_D-115

4. When possible, turbine crew members should receive on-the-job training (OJT) at fossil plants to minimize the slowdown associated with OJT during nuclear plant outages. Training during turbine maintenance and inspection at nuclear-powered generating stations should be kept to a minimum. Although turbines at fossil plants are generally more critical due to higher operating pressures and temperature than NSS turbines, the cost per hour of outage is substantially less at fossil plants, thereby making training at fossil plants preferable. (6 h) FM_D-115

5. Training facilities should be used more effectively by promulgating a list of training aids available and making the facilities available to station maintenance and SSD personnel. Station and SSD maintenance personnel should be encouraged and required to attend periodic refresher training classes. Maintenance personnel are not aware of the training aids available at the site, and time is not made available to maintenance personnel to take advantage of the facilities available. (4 h) FM_D-75

6. Special training should be given valve maintenance crews to ensure that proper procedures for valve maintenance are known and effectively used.

Classroom instruction and actual valve repacking under shop supervision should be conducted. (4 h) FM_D-75

7. The installation of "status boards" at various locations throughout the plant showing the jobs assigned to a maintenance crew and indicating the "percent complete" can be used to generate friendly competition between work crews and provide an incentive to get the work done. FM_DNA

8. Personnel should be encouraged to improve general housekeeping, such as keeping excess air hoses and extension cords picked up. To help minimize the use of long extension cords, additional power outlets and air connections should be permanently installed in the area of the turbine bedplate. FM_DNA

9. Responsibilities should be clearly defined at interfaces between various groups. A clear understanding of who has responsibility for each phase of tasks involving two or more groups is essential. During the outage, CO_2 for purging H_2 from the generator was in short supply because each of two groups held the other responsible for ordering additional CO_2. FM_DNA

10. Upper level management personnel should consider making tours through the turbine building on the back shift. It is not desirable to give the impression of "looking over their shoulders" but rather to show an interest in what is being accomplished on back shifts as well as the day shift. FM_DNA

11. Outside labor should be used for menial jobs whenever possible instead of drawing workers from the outage crew. FM_DNA

4.1.4. Spare Parts Recommendations

1. A spare set of turbine bearings should be obtained to provide immediate replacements for defective bearings discovered during turbine inspection and maintenance. This will eliminate the time lost when a bearing must be returned to the manufacturer for repair before the turbine can be reassembled. Duke Power Co. has already ordered a spare set of bearings as well as a set of HP turbine diaphragms and first stage nozzles. (72 h) FM_D-337

2. The oils and greases recommended by various manufacturers should be cross-referenced to minimize the different oils and greases required to be

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maintained on hand and also to provide an acceptable substitute if a specified oil or grease is not available. (4 h) FM_D-75

3. An adequate supply of tools should be kept readily available. Large tools required for turbine and large valve work and special tools required by equipment instruction manuals should be maintained in adequate numbers to support an outage without causing delay. (4 h) FM_D-75

4. Whenever Supply verifies that parts are available for a work request, the parts should be tagged and reserved for that particular work request unless released, by appropriate authority, for job of higher priority. FM_D-35

5. A system should be developed to check incoming supply items against parts needed for outstanding work requests. At present, incoming supplies that were ordered to replace stocked supplies are not checked against work requests being held because of a lack of parts; therefore, when the supplies arrive they are placed in stock, and work requests being held for parts or supplies remain in limbo until someone "follows up" on the work request to determine the status of the needed supplies. FM_D-35

6. A "min-max" system for supply parts should be incorporated to maintain a sufficient inventory and to provide for adequate lead time in ordering shelf-supply items. Under a min-max system, when a stocked item reaches a predetermined minimum quantity, the item is reordered to return to the maximum quantity in stock. The minimum and maximum quantities should be based on the turnover rate and the time required to obtain replacement stock. FM_D-35

7. A full-time supply department or group should be established for processing and expediting supply requisitions specially for nuclear steam systems. This group's primary job should be ordering, following-through, and expediting the parts required to support plant operation. This group must understand the unique requirements of NSS repair parts, the QC requirements, and the long lead time associated with most NSS repair parts. The importance of this group cannot be overemphasized. At present, requisitions are processed with the same urgency as for fossil plants, with little or no follow-up once a requisition is processed. This has led to widespread use of "emergency requisitions" to obtain needed supplies. FM_D-35

4.2. State-of-the-Art Retrofit Recommendations

1. A hydraulic bolting system (HBS) should be used to break out and make up threaded fasteners throughout the plant. An HBS is faster, safer, and physically much less demanding of personnel than the slugging wrenches presently used. The turbine rotor couplings are an area of special concern because of the present method of using the overhead crane to provide the torque to break out or make up the threaded fasteners. This method is quite slow, very dangerous, and ties up the overhead crane. By using two HBSs, two couplings could be worked at the same time and the overhead crane would still be available for other duties.

   A small portable HBS could handle the LP turbine inner and outer casing studs, the HP turbine outlet flanges, and the diaphragm retaining bolts in addition to many secondary application. A second portable unit in the reactor building could handle OTSC manways, RCP seals, Code relief valves, and numerous other tasks. (20 h) FM-231

2. A portable free-standing frame or monorail suitable for supporting at least two chain falls should be used for cold-torquing turbine casing studs and pulling bearing covers and bearing caps where possible. The use of a free-standing frame will serve two purposes: (1) It allows the use of two or more air impact tools simultaneously, rather than being limited to one impact wrench because of the need to suspend the tool from the crane hook. (2) Because the crane is not required for suspending the impact wrench or lifting relatively small items, it is free to be used in areas where there is no alternative to using the overhead crane. (9 h) FM-155

3. The availability and use of impact wrenches should be increased. Using two impact wrenches to remove turbine casing studs would cut the casing removal time in half, and an equivalent time savings could be achieved during assembly. (8 h) FM_D-115

4. The special tool used to support the lower castellated nuts on the HP turbine should be modified to eliminate the need for removing the small nut from the tool to shift to the next castellated nut. Using a lock-pin or a keyhole in the retaining plate instead of a threaded rod and nut would simplify and speed up work. In using the keyhole, the small nut on the threaded rod would be placed through the large section of the keyhole and

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then the rod moved to the smaller section to capture the castellated nut retaining plate. (2 h) FM_D-75

5. The overhead crane should be accurately benchmarked over all major lifts to allow rapid positioning in the correct location rather than jockeying back and forth to center over a lift. The benchmarks should be readily visible to the crane operator or the crane foreman. (<4 h) FM_D-75

6. The use of air or water lances should be considered in place of wire brushes to clean oil cooler tubes, as was the case with the main feedwater pump turbine lube oil cooler. FM_D-75

7. Consideration should be given to using load cells or gages to balance the load when making heavy lifts with the overhead crane instead of sounding the wire ropes, as done at present. Load cells or gages would be more accurate and faster. (4 h) FM_D-75

8. A standardized laydown pattern for turbine parts should be adopted for future outages. The laydown pattern used allowed maximum effective use of space for the storage of turbine rotors and casings and other large components and pre-staging of storage stands. It provided the rigger the convenience of knowing in advance where to lay down turbine components amd relieved the turbine coordinator to attend to other duties. By standardizing the laydown pattern, the overhead crane could be benchmarked over the storage area to facilitate the setting down and picking up of these large components. (4 h) FM_D-75

9. Storage bins used for small turbine components (nuts and bolts) should be clearly identified to allow prompt retrieval of these items during reassembly and to minimize the possibility of retrieving the wrong item. (2 h) FM_D-75

10. Installing permanent sandblasting facilities should be seriously considered. The erection cost would be offset by the manhours required to set up and tear down for each outage, the spread of sandblasting grit could be minimized, and cleanliness of the exposed systems on the turbine floor would be improved. A small self-contained sandblasting unit should also be considered to use in cleaning studs, lockwashers, and nuts, thereby removing the need for tying up the main sandblasting unit on small components. (4 h) FM_D-67

11. Using a cherry picker and/or fork lift on the turbine floor could reduce the need for the overhead crane by handling parts that are relatively small but still too large to handle manually, such as HP turbine casing studs, bearing caps and covers, and the smaller diaphragm halves. This would make the overhead crane available more of the time for the items that must be handled by it. (4 h) FM_D-65

12. Wherever feasible, the "remove, replace, and repair" concept should be used, as was the case with one condensate pump. This allows defective items to be repaired between outages without system shutdown and makes more efficient use of available manpower. Other examples include valves, pumps, and control rod drive mechanisms. FM_DNA

13. Additional ladders are needed to provide access to the overhead crane. This item is a major safety item as well as a time-saving recommendation. With only one ladder available, time is lost because the crane must return to that position for the operator to get down to the turbine floor safely. If the crane is tied up at shift change or break time, the operators climb down by the building structural members because no ladder is accessible. FM_DNA

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4.3. Recommendations Requiring Development, Evaluation or Design Work

1. The OTSG drain line to the hot well should be upgraded to allow the steam generator to be drained to the hot well while the RCS is at normal operating pressure and temperature. The existing drain line is made up partly of low-pressure, low-temperature components, which prevents its use for draining the OTSG to the condenser when the RCS temperature is above a specified limit. During most startups after a lengthy shutdown, the OTSG chemistry is within specifications, but in many cases by the time the RCS is at normal operating conditions, the OTSG water is outside specifications. With the existing drain system, the RCS must be cooled to a specified temperature to allow for a feed-and-bleed operation to clean up the secondary water. By upgrading the OTSG drain system, it would be possible to feed and bleed at normal operating conditions and use the feedwater purification system to clean up the secondary system water. (32 h) FM_D-254

2. The ultrasonic stud elongation measuring device for HP turbine studs should be perfected and made adaptable to the various HP turbines in use and also be capable of adaptation to other applications as they arise. (6 h) FM-212

3. The reliability of turbine overspeed trips and the method of adjusting the setpoint (when required) require improvement. Expanded use of electronic speed sensing circuits and trip devices and incorporating the capability of setting and checking the overspeed sensor with the turbine idle should be pursued. The ability to adjust and check the trip setpoint with the turbine idle and requiring only a quick functional check when placing the turbine in service could minimize the delays associated with resetting the turbine overspeed trip points. (12 h) FM_D-150

4. The moisture separator reheater (MSRH) manways should be modified to improve the reliability of the airtight seal under both vacuum and pressure. The present design of the MSRH manways applies system pressure to the manway in a manner that seats the manway. During startup the MSRH is under a vacuum before being under pressure, and vacuum applies a force that tends to unseat the manway cover and in many instances allows air to leak into the MSRH by unseating the manway gasket. When the system is back under pressure, steam leaks often exist because of the unseated gasket, necessitating shutting down to repair the leak. To minimize this problem, the MSRH manways are often seal-welded shut. This requires additional men and time to weld the manways shut before startup and to arc-gouge them open and repair the manways when shutting down. (12 h) FM_D-134

5. Using preformed metal insulation on the HP turbine in lieu of the mud pack insulation and insulation pads now in use should be explored. Several hours are expended in removing insulation pads at the beginning of an outage before the HP turbine studs are accessible for detensioning. At the end of the outage, many hours are spent repairing damaged or missing mud pack insulation. The use of preformed metal insulation, where practical, could reduce the time required at the beginning and end of the outage. (6 h) FM_D-115

6. The feasibility of earlier feed-system cleanup by using the flow path through an uncoupled FW pump should be investigated. (6 h) FM_D-115

7. Improved methods for turbine alignment should be developed. No basic change in equipment or methods have been incorporated for many years. With the technological advances of recent years, such as optical or laser alignment and direct-reading gages, the turbine vendors should be requested to provide updated methods of aligning turbine rotors. (<4 h) FM_D-74

8. The manufacturer of the overhead crane should be consulted about the possibility of increasing both the no-load travel speed and the no-load hook speed of the cranes. Although times involved on individual lifts are relatively short, the total time over the entire outage becomes substantial and has impact on outage time because of the necessary sequencing of many items that require the use of the overhead crane. (4 h) FM_D-71

9. The possibility of having two independent hooks on the overhead crane should be evaluated. Two hooks would facilitate the handling and turning over or "flipping" off of turbine casing halves for inspection and cleaning. This method of flipping casings would be faster and safer than the methods used now. (<4 h) FM_D-53

10. The possibility of making the HP turbine lower casing castellated nuts self-supporting and self-aligning should be evaluated both as a retrofit project and for incorporation on new units.

4.4. Future Plant Design and Equipment Recommendations

1. During the design of new plants or the expansion of existing facilities, major consideration should be given to equipment accessibility, maintenance requirements, reliability of support equipment (elevators in particular), and standardizing equipment when possible to reduce the number of spare parts required and to increase the economic feasibility of carrying major items in supply.

2. The use of tapered bolts in turbine couplings for new installations should be considered as a possible means of improving the coupling alignment process and also of simplifying removal and reinstallation of the coupling bolts.

5. ANO-1 RECOMMENDATIONS

The recommendations in this section are designed to aid AP&L in achieving reduced outage times and in avoiding unnecessary forced outages at ANO-1. For reporting purposes, the recommendations for ANO have been divided into three categories:

1. Overall Plant Maintenance Methods Improvements — Improvements that do not require changes to hardware or facility.
2. BOP Equipment/Facility Improvements.
3. Future Plant Design BOP Improvements.

Figure of merit (FM) values are given for each recommendation except where not applicable as noted. Future plant design recommendations were not given FM values.

5.1. Overall Plant Maintenance Methods Improvements

5.1.1. Implementation of Training Program for Maintenance Personnel (12 h) FM_D-50

1. It is recommended that ANO continue to emphasize implementation of training programs for its maintenance personnel. Programs on plant and system orientation as well as maintenance practices would benefit everyone. Plant and system orientation would make the maintenance personnel more aware of the components on which they are working and their effects on the overall plant, while maintenance practice lessons would familiarize the maintenance personnel with plant-approved practices and procedures. The benefits of a plant maintenance training program would be realized in the increased ability of personnel to repair equipment and in the more efficient execution of assigned tasks. Several training methods are available that should be emphasized for use by the Training Department.

   a. A review of the available training facilities and services offered by vendors would help to determine the scope of offered services.

   b. The continuing development of an in-house training course using existing spare parts and tools would be valuable in teaching maintenance practices and methods.

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c. The continuing development or acquisition of mockups to simulate the work methods and practices used in the actual performance of tasks would greatly improve the ability of personnel to respond correctly to a given task.

2. Work on a comprehensive video tape library of actual maintenance tasks should be continued. As a training aid, video tape allows more diversified use of training personnel, while allowing standard procedures and practices to be taught to all maintenance personnel easily and efficiently. Reviewing previously taped maintenance tasks allows experienced personnel to critique their own work while exposing new personnel to accepted work practices and methods.

   A complete video studio at ANO will allow the utility to produce its own in-house tapes using its own plant staff. Once a video studio has been implemented, it can be used to produce video tapes for maintenance, operations, and supervisory personnel and could even supply a valuable service to the rest of the AP&L network.

   With four major suppliers of power generation equipment at the ANO site, maintenance, operations, and supervisory personnel will be hard-pressed to become completely familiar with all the equipment and procedures involved. The use of video tape to update personnel on equipment and procedures would greatly increase the plant's ability to maintain its high level of competency.

5.1.2. Development of Secondary Valve Maintenance Practices (100 h) FM_D-105

It is recommended that the scope of the valve maintenance schedule be enlarged for at least a selected number of secondary valves, including safety-related, major isolation, and throttle valves. The emphasis in such a program would be on PM inspection with the goal of avoiding forced outages due to valve problems and on reducing overall refueling/maintenance outage lengths.

Because of the large number of valves in the secondary plant and the limitations on available manpower, it is recommended that a formal secondary valve team be formed several weeks before the refueling/maintenance outage starts in order to review the condition of overall plant valves not covered by the proposed PM program. The valve team would take appropriate corrective maintenance actions on valves requiring only minor adjustments, thus reducing the number of valves requiring work during the outage. A program like this would also ensure that valves requiring major repair are included in the outage schedule.

The practice of replacing valves rather than repairing them during the outage should continue. This recommendation should receive special consideration where there is a risk of delaying the outage due to valve repair. Entire valves should be replaced during the completion of a task, and the faulty valves should be repaired in onsite maintenance facilities during the subsequent operating cycle. Such valve repairs could also be included in the training program for new personnel to orient them with site procedures and work practices.

In general, the packing in valves undergoing repair or maintenance during the outage should be replaced with new packing. The practice of replacing packing will help ensure that packing for the valves worked will probably not be the cause of problems during the subsequent operating period. Plant-wide standards for valve maintenance practices and packing acceptance should be implemented to guide maintenance personnel. This will help to ensure uniform maintenance practices.

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5.1.3. Development of Secondary Work Package (24 h) FM_D-91

It is recommended that a work package be implemented for use in the secondary plant for significant work items that would consist of the following:

1. A cover sheet (Figure 5-1) containing specific information about the task to be accomplished, identifying any support required from other groups and work authorization signatures for initiating and completing the task.

2. A list of all tools that are needed to accomplish the task (Figure 5-2). This list would be accumulated from the vendor's technical manual and from personal experience.

3. A materials list compiled from the vendor's technical manual showing all parts necessary to accomplish the task (Figure 5-3). A section would also be included designating the parts used and those returned to Spare Parts. This added feature would ensure that all unused parts were returned to stock and not left lying in the work area or the shops. At current prices for parts, this requirement should be effective in reducing the total cost of spare parts.

4. The work procedure with space to sign off work accomplished during a shift and for steps to be verified (Figure 5-4).

5. A comments and description page to be used in feeding specific task information back into the machinery history program for future reference (Figure 5-5). This is an important function since the information feedback after job completion is somewhat less than desirable at present.

A secondary work package, while requiring a small initial manpower output, will reduce the time necessary to complete every job on which it is used. The ability to issue a work package and have the task begin immediately is very desirable and feasible with this type of system. A secondary work package would also help to prevent mistakes during task performance. Reworking a task not only results in lengthening the original job time but could also delay other work and interfere with the critical path.

5.1.4. Implementing Preventive Maintenance System and Modifications (24 h) FM_D-90

It is recommended that ANO implement its complete PM program as soon as possible and that the program include (1) the ability to check component or system performance over a period of time as to a reference or baseline set of data and (2) the ability to record specific rather than general data requirements during the scheduled maintenance tasks. The following areas of the planned PM program need further attention:

1. The existing comprehensive machinery history (MH) program should be fully implemented with inputs from the other sections of the PM program to serve as a storage and recall center for the information collected during execution of PM tasks. The MH program is crucial in allowing accurate predictions of component malfunction and/or failure and subsequent corrective action determination.

2. On PM checksheets that require data to be recorded, limitations or specifications should be added to allow immediate reference for problem conditions.

3. All PM checksheets should include the applicable procedure number, whether it is an ANO procedure or a vendor's technical manual instruction.

4. Accurate and precise data should always be recorded when completing individual PM items. Non-specific terms such as "Sat" or "Unsat" should be

deleted for more specific information. Actual temperatures, flows, pressures, etc., should be recorded so as to be useful in determining equipment trends. Using more specific information also makes the MH program more valuable as an aid in predicting equipment performance.

5. General terminology such as "Done" or "Accomplished" should be replaced by more descriptive discussion of the work accomplished. The MH program can only be useful in predicting component/system performance if it is updated with descriptive information. If maintenance personnel are unfamiliar with the PM system, supervisors should prepare a written guideline outlining the type of comments and information desired on the checksheets.

6. Two operating cycles have expired since the initial startup of ANO-1. Consequently, equipment/component acceptance data that were to be used for baseline data are outdated. When ANO-1's full PM program is implemented, new baseline data should be run to avoid large discrepancies between initial machinery performance information and present operating characteristics.

7. ANO should ensure that all plant equipment is on the PM program schedule. Plant components should not be discriminated against because they are small or of minor importance. Although the ANO plant is new, this should not be relied upon to avoid performing maintenance on all plant equipment. A PM program can be effective only if it encompasses the total, integrated plant and involves all plant personnel.

8. In the performance of PM tasks, it is important to ensure that the data recorded are as accurate as possible. Some information is difficult, if not impossible, to record accurately using standard recording instruments or the human senses. In these cases, special instruments and tools should be used to ensure accurate data. Some examples are listed below:

   a. When a PM checksheet calls for checking the vibration of a pump or bearing, vibration analysis equipment will produce an accurate printed readout to be used in comparison with previous readouts from the MH program in determining component performance. The human senses are not precise enough to determine small changes in vibration frequency that could be indicative of pending problems with the component. Vibration analysis equipment also produces hard data that are easily returned to update the MH program at the conclusion of the PM check.

   b. For temperature measurements that are difficult or impossible to take with standard temperature-measuring devices, hand-held, remote infrared thermometers are available. The regular use of these instruments is encouraged because of their precision and speed of operation.

These items are given as examples of equipment commercially available to update the PM program data gathering system. Many devices are available to assist in the execution of a comprehensive PM program, and their use should be investigated to upgrade the accuracy of the recorded data.

All three sections of the PM program (Figure 5-6) — data collection, machinery history, and corrective maintenance — must be used to complement each other to realize the full potential of the program. Likewise, accurate performance evaluation of all equipment is possible only if data are record in detail and stored in the MH program for future reference.

5.1.5. Review and Upgrade of Spare Parts System (12 h) FM_D-50

The spare parts system is vital to reducing refueling/maintenance outage time and to increasing on-line maintenance efforts. A review of ANO's spare parts has shown the available inventory of spare parts to be adequate, but improvements are indicated in some areas.

1. A continuing review of all vendors' recommended spare parts with the subsequent ordering of deficient items is recommended. If the equipment technical manual does not list recommended spare parts, or if there is no technical manual, ANO should request such information from the vendor. Vendors' recommended spare parts are essential to the basic spare parts system. Having these items in stock at all times can be crucial to returning the plant to operation after a forced outage or in reducing the overall length of a refueling/mainentance outage.

   Safety-grade equipment should be given special attention since several items can force a plant shutdown if they cannot be repaired within a specific time limit.

2. Once a comprehensive, current list of vendors' recommended spare parts is compiled, it should be on hand for ready reference in the warehouse and should be used to continuously update the stock inventory.

ANO's computerized spare parts system should contain a base list of parts to coincide with the vendors' recommended spare parts list. This base list will be the foundation for the low-readout function.

All parts should be given a number that allows cross-referencing of similar parts even though they may be stocked for different components. This cross-reference feature could result in fewer components required to be in stock.

5.1.6. Work Area Support (12 h) FM_D-50

An increase in permanently installed work area support items is recommended to enhance the preventive maintenance program with emphasis on section 5.1.2, "Secondary Valve Maintenance." The following areas need work support improvements:

1. Valves over the feedwater heaters: All feedwater preheaters except E3 and 4A and E3 and 4B, have valves in the overhead that require periodic attention. At present, temporary work area support must be erected to work these valves.

2. On the turbine side of the HP feedwater heaters is a small mezzanine area. The valves in this area need a permanent work area support installed.

3. Valves in the overhead in the area of the heater drain pumps need additional work area support.

4. Several areas in the basement of the turbine building need attention:

   a. At the southeast corner of the basement are several large isolation valves that had packing leaks and needed general attention. Work access to work these valve is limited; the area needs review for work area support.

   b. Just to the west of the valves mentioned in item a are several throttle valves for a fluid system. The only way to get to these valves for maintenance or adjustment is to stand on other piping. This area also needs review for further work area support development.

   c. Valves on the west side of the main condenser in the basement (in the overhead) need permanently installed work area support. During a refueling/maintenance outage, temporary ladders — some up to 30 feet long — must be used to gain access to the valves. Not only does this make general PM difficult, but is also a safety hazard. This area needs immediate attention.

5.1.7. Re-evaluation of Turbine Testing and Inspection for Extended Fuel Cycles FM_D-NA

To obtain the maximum operating capabilities of the new long-lived fuel, consideration should be given to re-evaluating the present inspection program. On an extended-life core, ANO will undergo three refueling/maintenance outages in a five-year period. To reduce the length of these outages and avoid possible delays associated with an outage, ANO should evaluate the possibility of incorporating the inspections of all turbines and the generator into one outage at the end of the five-year cycle. By disassembling and inspecting all generating elements every five years, the other two outages would be controlled

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only by the refueling operations. During the two refueling/maintenance outages when the turbine and generator elements are not scheduled to be disassembled a cursory check through the casing manholes or steam line piping could be conducted to check for cracks, unexpected equipment deterioration, or chemical buildup.

Even though inspecting all generating elements during one outage would lengthen that outage considerably, the shortness of the two outages preceding it would give ANO-1 considerably more operating time. The offset of this added operating time should be considered.

The extended-life fuel for ANO-1 is a real advance for the nuclear utility industry. It should be taken to its full advantage by maximizing operational time to its fullest. With the advent of extended-life cores and longer operating cycles, the ability to perform the required maintenance and inspection tasks during the outages in the shortest possible time is paramount.

5.1.8. Equipment Duplication and Isolation FM_D-NA

ANO should review their secondary system for further areas that would benefit from equipment duplication. One example is the feedwater pumps; two FW pumps are required to operate the plant at 100% power. Installing a third pump would allow the flexibility of having one pump off for repairs (corrective or preventive) while maintaining the plant at 100% power.

ANO should also review the secondary plant for isolation capabilities and implement a program to review the benefits of changing systems to include complete isolation capabilities for maintenance purposes. Examples of lack of isolation capabilities are the heater drain pumps and the main FW pumps.

Equipment isolation and duplication will become more important during an 18-month extended fuel cycle.

5.1.9. System Layout FM_D-NA

It is recommended that ANO review the total plant for areas not conducive to efficient maintenance, such as the condensate pumps, that can be modified to facilitate maintenance activities.

5.2. BOP Equipment/Facility Improvements

5.2.1. Hydraulic Bolting System (100 h) FM-111

It is recommended that an HBS be used for disassembly/reassembly of large steam line piping flanges, turbine couplings, and casing bolts. With an HBS piping, couplings, and casing can be accurately and safely disassembled and reassembled in a fraction of the time necessary using the old slug-torquing method. Coupling the LP turbine crossover steam lines would take only 40 minutes versus 3 hours by the old method.

There are many other applications for the HBS during each outage. Turbine casings, the moisture separator reheater, bearing caps, generator end bells, and the HP turbine governor and throttle valves are just a few areas where an HBS would be beneficial. There are literally hundreds of applications throughout the plant.

The HBS can also be a major contributor in reducing work times in the reactor building. HBSs can be used to work such items as canal seal plates, transfer tube covers, equipment access hatches, and OTSG manways. Again, this is only a short list naming major work areas. There are many more applications in the reactor building for an HBS. Table 5-1 summarizes some typical tasks and associated time savings using the HBS. This table is not all-inclusive but a summary of the more immediately identifiable areas.

An HBS would also be a major addition to the site's PM effort. Such an instrument would be able to reduce considerably the time required to complete PM items and the downtime for equipment.

5.2.2. Turbine Building Arrangement for Laydown of Large Components (100 h) FM-96

One of the largest areas for improvement in secondary maintenance at ANO is in the turbine building arrangement for access and laydown of major components. Whether through building modification or addition, re-evaluation of the existing work and laydown area would be a major contributor in decreasing the critical path time for outages requiring turbine inspection and repair work and maintenance on large components.

ANO should increase its laydown area by modifying the existing turbing building by either extending the Unit One building end or by modifying Unit One's roof and adding an external crane. The addition of an external crane after roof modification would allow direct lifting of large components, such as turbine casings and rotor, to the large area available outside for laydown and maintenance. Consequently, this would make more space available inside the turbine building for work on smaller components and for the inspection and cleaning of turbine parts.

This recommendation is also important when considering the extended-life fuel proposed for Unit One. To maximize the use of the extended-life fuel and to ensure the quickest possible refueling/maintenance outages, ANO needs more laydown and maintenance area. The solution to the needed work area improvements would be a major factor in bringing the BOP work into line with the refueling sequence.

5.2.3. High-Pressure Turbine Monorail (48 h) FM-91

The addition of an HP turbine monorail at ANO has saved at least 48 hours of critical path time. This allowed the use of the overhead crane for other critical path activities since the monorail was able to support two tensioning units to detension and tension the turbine casing.

5.2.4. Steam Line Support (24 h) FM-83

On some turbines with overhead steam lines running above the turbine deck, procedures call for removal of these lines during the outage. This practice causes significant delays in beginning work on turbine disassembly and inspection.

It has been proved at ANO-1 that supporting these lines with scaffolding during the outage, rather than removing them, is feasible. This procedure eliminates the need to tie up the turbine building crane for their removal and allows work to progress sooner on turbine disassembly and inspection. The support of large steam lines is recommended, rather than their removal.

5.2.5. Housekeeping Practices (4 h) FM_D-59

Cleanliness in the secondary work areas needs to be improved. When the turbine casings are open and the internals exposed, a conscientious effort should be made to ensure that foreign objects do not enter the system. Rescheduling insulation removal and capping open-ended systems will reduce the overall time to return the plant to operation.

5.2.6. Damaged Studs (4 h) FM_D-59

Many large turbine casing bolts were left unprotected while the casings were removed and stored; this resulted in damage to several bolts and studs. The damaged threads on the bolts and studs necessitated replacing these items. Threads should be protected properly during component removal and storage to save time during reassembly.

5.2.7. Turbine Building Tool Issue Room (12 h) FM_D-59

Several hours' outage time were lost by persons having to locate tools that were either lost or in use at other points in the plant. The construction of a manned tool issue room in the turbine building is recommended. Each time a tool is issued, a charge card would be filled out with the person's name and the job to be worked. If another person needs the same tool and there are none left in the tool room, the person could check the charge card to see where the tool was being used and obtain it there if the first user was finished.

Also, with a charge card for each tool, it would be easy to determine where and by whom tools have been used. This will lead to fewer lost tools and ensure their return after completion of a job.

5.2.8. Preformed Metal Insulation for HP Turbine Casing (6 h) FM-51

Approximately 8 hours were spent removing the block insulation and the insulation pads from the HP turbine prior to disassembly. Development of a preformed metal insulation for the HP turbine should be investigated to reduce this time. Such metal insulation with snap fasteners would reduce the number of workers required to accomplish this task as well as eliminate the insulation dust problem.

5.2.9. Pneumatic Tools for Removing Small Bolts (6 h) FM_D-51

Using a small, currently available, pneumatic tool to aid in removing bolts will save time and free personnel for other tasks. The use of pneumatic tools is encouraged wherever practical. Several hours' time savings are possible with their use. A hydraulic bolting system, discussed in section 5.2.1, should be used to make up or break out large threaded fasteners.

5.2.10. Rigging and Lifting (4 h) FM-43

It is recommended that an alternative means of verifying load for lifting turbine casings and other large components be implemented. One way is to verify proper loading of the segments of a lifting rig with load cells and hydrasets. Both of these lifting aids are used in line with existing lifting gear and are capable of giving accurate loading information.

With load cells, maintenance personnel need only adjust each segment of the lifting rig until the load cell readout is equal for all portions. At that point, all segments of the lifting rig are loaded equally, and continuous adjustment is not necessary.

Hydraset equipment is also installed in line with the lifting rig, but with one big difference. Instead of having to adjust the rig itself with turnbuckles (as with the load cells), the hydraset is a small hydraulic system in itself. Adjustment of the lifting rig with an installed hydraset consists of using hydraulic pressure to move the hydraset forward and backward to achieve proper loading. Accurate readouts of segment loading are also available with the hydraset equipment.

It is estimated that as much as 10% of lifting time can be saved by proper use of load cells and/or hydraset equipment. Another factor that must be given serious consideration is the safety factor involved. When lifts of several tons are being made, it is very important to exercise accurate and precise control of the lifting function. Damage to large pieces of equipment and personnel injury could be the result of improper lifting methods. ANO personnel exercise every possible precaution when lifting large items, but with no accurate loading information available, much time is spent adjusting and readjusting lifting rigs. ANO should review the potential benefits available from the use of commercially available lifting rig loading devices.

Another recommendation is to index the turbine rotor lifting beam directly on the beam. With the beam physically indexed, the positioning of the segments can be attained with ease with no readjustment necessary.

5.2.11. Storage and Accountability of Special Tooling (4 h) FM_D-43

A strict accounting system for special tools in the secondary plant, such as those for turbine lifts, should be implemented. In most cases, it would be advisable to store these special tools in locked storage areas to preclude their use for unauthorized tasks. Storage and accountability of special tools tend to be a recurring problem. Much time is lost in searching for misplaced tools and in repairing or replacing damaged tooling.

5.3. Future Plant Design BOP Improvements

5.3.1. Main Steam Crossover Pipe Design

At present, some turbine designs have main steam inlet lines to the LP turbines entering from the top of the turbine casing. Other designs have the main steam lines entering horizontally into the LP turbines at their horizontal joint. When utilities consider the merits of each design, they should also consider maintenance.

With the turbines that have an overhead crossover pipe entering in the top of the casing, consideration should be given to the fact that the crossover pipe must be removed and the adjacent steam lines removed or supported before turbine disassembly. This involves about 24 hours' critical time to complete. In the turbine design with steam lines entering at the horizontal joint, no time is spent clearing the overhead before removing the casing and rotor. Although both designs have considerations in their favor, a detailed review of maintenance should be conducted before expressing a preference.

5.3.2. Work Area Support

A real consideration for future plants should be work area support (see section 5.1.6). The installation of ladders, platforms, and walkways throughout the plant would be a major accomplishment in providing adequate work support for maintenance and adjustment of plant equipment and components. The installation of permanent work area supports would reduce the time needed to perform tasks, thus reducing the overall outage length and manpower requirements.

5.3.3. Equipment Duplication, Isolation, and System Layout

New plants should be reviewed with attention to equipment duplication, isolation, and layout.

Equipment duplication is essential in allowing the plant to remain at maximum operating capabilities (refer to sections 5.1.8, 5.1.9). Certain equipment has been identified as essential to maximum plant output. Adequate components should be included in the design or added during construction to allow equipment to be taken out of service for preventive maintenance or to allow the plant to continue operating at maximum power if certain key pieces of equipment are out of service for repair. Review of this area and subsequent corrective action can be a major contributor to maintaining a plant at full power.

A review of certain operating nuclear utilities indicates that many major plant components are not capable of being isolated for on-line repair or maintenance. This can lead to unnecessary outage time to repair faulty equipment that could be corrected during operation if the components were isolable. A review of existing isolation capabilities would identify components that fall into this category. Upgrading component isolation capabilities would ensure protection against outage time caused by limited maintenance capabilities while at power.

System layout is another area that, like equipment duplication and isolation capabilities, deserves comment. Plant systems should be closely reviewed with concern for maintenance and inspection feasibility. In some current plant designs, systems are constructed in such a way as to inhibit maintenance. Piping runs are built too close together without adequate work space, equipment and components are installed with no forethought to maintenance or removal and installation, and some systems are built directly in the path of other systems' removal or repair paths.

A review of the system layout plans for future plants is recommended to identify these areas and allow corrective action to be taken during the earliest stages of development.

5.3.4. Secondary Maintenance Work Area

With the cost of new construction for nuclear plants increasing, the trend appears to be to save as much as possible by cutting back in as many areas as possible. One area in which utilities would do well not to cut back is the secondary maintenance work area for maintenance and inspection.

With turbine work comprising lengthy disassembly, inspection, and reassembly procedures on a routine basis, work area becomes very important. If parts or components must be rearranged during an outage to make room for more parts or for inspection and repair items, many hours and even days can be lost on critical path items. The layout, inspection, and repair of turbine components and other secondary plant equipment should be considered when planning the secondary maintenance building. Turbine buildings (maintenance buildings) should be reviewed as to how the outage will progress with relation to space available for laydown of large items. No part of the turbine work should be delayed awaiting completion of other required maintenance. The following are recommendations to provide adequate work area:

1. The turbine building turbine deck should be large enough to accomodate all work projected for the longest predicted outage expected.

2. An outside laydown area for storage of large components and for subsequent maintenance on these items can be developed. Such an area would necessitate either the use of the turbine building crane, removing parts through the loading bay then transferring them to the area by truck or rail car, or developing a removable section of turbine building roof with an external crane to lift turbine components directly to the outside laydown area.

Either solution would have a positive impact on the secondary maintenance outage. With turbine components becoming so large and requiring significant time to inspect and repair, it is possible that turbine work could rival the refueling evolution for the critical path for future plants. Utilities should take this into consideration when planning the secondary maintenance area layout.

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5.3.5. HP Turbine Tensioning Operations and Overhead Cranes

The process of detensioning the HP turbine casing is a lengthy task requiring several persons and the overhead crane to support the tensioners. The development of a monorail or other frame arrangement around the HP turbine to support two or more tensioning units would greatly reduce the time required to accomplish detensioning and would free the turbine building crane for other tasks. A monorail or frame arrangement could save as much as 24 hours on detensioning the HP turbine casing and thus allow the overhead crane to be used on other turbine work. Similar time savings are possible during turbine reassembly.

Table 5-1. Hydraulic Bolting System Task Time Evaluation

	Application	No. of units (ANO-1 plant)	By existing methods		By HBS methods		Time savings benefit	
			Makeup	Breakout	Makeup	Breakout	Makeup	Breakout
1.	Main steam line piping flanges	12	>3.0	>3.0	0.5	0.75	>2.5	>2.25
2.	MSR manways	8	1.0	1.0	0.4	0.5	0.6	0.5
3.	FW preheater manways,	14	1.0	1.0	0.4	0.4	0.6	0.6
	heads		3.0	3.0	0.5	0.5	2.5	2.5
4.	Main steam intercept valves, hydraulic actuators	8	2.0	2.0	0.5	0.5	1.5	1.5
5.	HPT governor, throttle valves	8	4.0	6.0	0.75	2.0	3.25	4.0
6.	Turbine & generator couplings	3	6.0	8.0	3.0	3.5	3.0	4.5
7.	Main FW pump	2	3.0	4.0	0.5	0.75	2.5	3.25
8.	Main condensate pumps	3	4.0	6.0	0.8	1.75	3.2	4.25
9.	Reheater drain tank manways,	2	1.0	1.0	0.4	0.4	0.6	0.6
	drain pumps,	2	6.0	8.0	2.0	2.5	4.0	5.5
	associated valves	4	4.0	6.0	2.0	2.0	2.0	4.0
10.	Large main FW system valves	8	4.0	6.0	2.0	4.0	2.0	2.0
11.	MSR relief valves,	8	2.0	2.0	0.5	0.5	1.5	1.5
	relief piping	8	1.0	1.0	0.4	0.4	0.6	0.6
12.	Main generator end bells,	2	6.0	8.0	1.5	3.0	4.5	5.0
	exciter coupling	1	6.0	8.0	3.0	3.5	3.0	4.5
13.	Extraction steam isol. valves	8	4.0	4.0	0.9	2.2	3.1	1.8
14.	ICW coolers	3	3.0	4.0	0.7	1.5	2.2	1.5
15.	RB equip access hatch bolts (24)	1 hatch	3.0	3.0	0.8	1.5	2.2	1.5

Table 5-1. (Cont'd)

Application	No. of units (ANO-1 plant)	By existing methods Makeup	By existing methods Breakout	By HBS methods Makeup	By HBS methods Breakout	Time savings benefit Makeup	Time savings benefit Breakout
16. RCP spacer piece,	4	2.0	2.0	0.5	0.7	1.5	1.3
seal cartridge bolts,		2.0	2.0	0.5	0.7	1.5	1.3
motor mount bolts		3.0	4.0	0.7	1.0	2.3	3.0
17. Core flood tank manway,	1	1.0	1.0	0.5	0.5	0.5	0.5
isolation valve	1	2.0	2.0	0.5	0.5	1.5	1.5
18. OTSG manways	4	2.0	2.0	0.5	0.5	1.5	1.5
19. Pressurizer relief valves	3	1.0	2.0	0.5	0.5	0.5	1.5
20. Fuel transfer tube cover	1	4.0	6.0	0.75	1.0	3.25	5.0
21. Canal seal plate	1	6.0	10.0	4.0	4.0	2.0	6.0
22. Decay heat coolers	4	4.0	4.0	0.75	0.75	3.25	3.25
23. Decay heat pumps	4	4.0	4.0	0.75	0.75	3.25	3.25

Notes:

1. The times given for the items above are based on actual observation of the HBS in operation or from estimates based on the demonstrated capabilities of the HBS.
2. The HBSs used in this table are th N-S-W Select-a-Torque 5000 EPP 3000A, and the Select-a-Torq 2000A with standard available tooling.

Figure 5-1. Cover Page for Work Package

ARKANSAS NUCLEAR ONE
JOB ORDER UNIT

DATE: ___________
J.O.# ___________

GROUP:
TITLE:
JOB DESCRIPTION:

REFERENCE MATERIAL:

TROUBLE TICKET NO: DCR #: PROCEDURE NO: OTHER:
PRIORITY: ☐ ROUTINE ☐ EMERGENCY
SPECIAL PLANT CONDITIONS:

TAGS REQUIRED: ☐ YES ☐ NO TAG NO. _________
AFFECTS REACTOR SAFETY: ☐ YES ☐ NO
SPECIAL INSTRUCTIONS:
ASSISTANCE REQUIRED: ☐ M ☐ E ☐ I&C ☐ OPS ☐ HP ☐ OTHER
PERSONNEL ASSIGNED: ___________________________
APPROVED BY: (Cognizant Supervisor) ______________________
WORK AUTHORIZED (Conditions Fulfilled):

JOB COMPLETED (Including All Paper Work): Date: __________
Time: __________
PLANT/SYSTEM CONDITIONS RESTORED: Date: __________
WORK REVIEWED: Date: __________
QCE REVIEWED: Date: __________
MACHINERY HISTORY ENTRY COMPLETED: ☐ YES ☐ N/A (Signature) ________ Date: ________

COPIES TO: ☐ CONTROL ROOM ☐ GROUP SUPERVISOR _____ ☐ QC ☐ Date:
☐ MACHINERY HISTORY ☐ OTHER

Figure 5-2. Tool List for Work Package

TOOL LIST

ITEM NO.	DESCRIPTION	QTY
1		
2		
3		
4		
5		
6		
7		
8		
9		
10		
11		
12		
13		
14		
15		
16		
17		
18		
19		
20		
21		
22		
23		

Figure 5-3. Materials List for Work Package

MATERIALS LIST

DESCRIPTION	QTY	USED	RETURNED

Pg ___ of _____

J.O.# _______

Figure 5-4. Procedure for Work Package

PROCEDURE	SIGNATURE

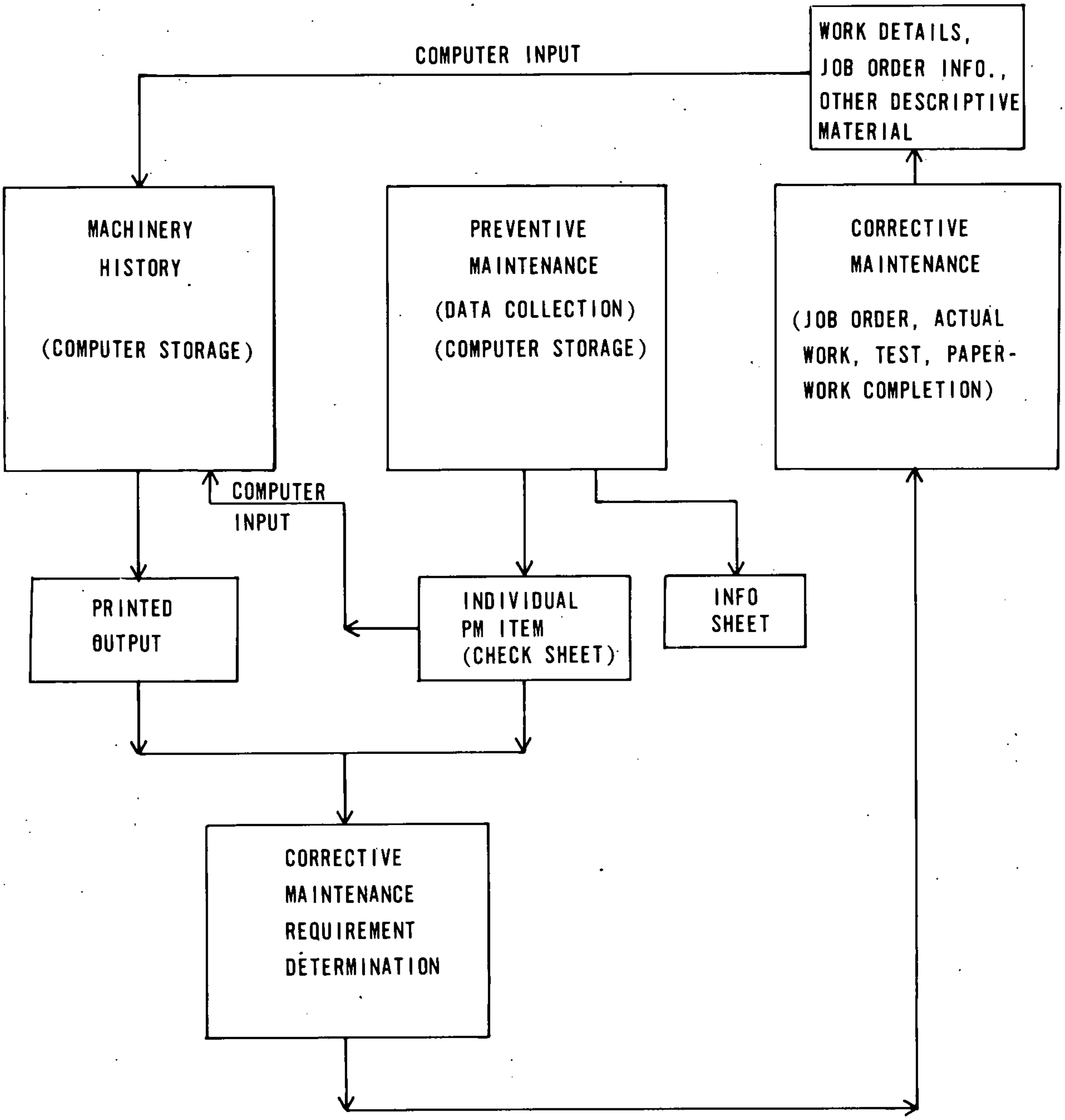
Pg __ of ______

J.O.# ______

Figure 5-5. Comments and Description Page for Work Package

COMMENTS AND DESCRIPTION
(CONDITIONS OF PARTS INSPECTED, OIL CHANGED AND OTHER ITEMS NOT COVERED IN THE JOB ORDER SHOULD BE COVERED HERE)

Figure 5-6. Block Diagram of the Preventive Maintenance System



6. SUPPLEMENTAL PRIMARY SYSTEM RECOMMENDATIONS AND CONTINUING WORK PROGRAMS

This section covers recommendations on selected observations of the primary system outage activities during the Oconee 3 1977 refueling outage. It is intended to supplement the recommendations identified in the Phase 1 study.[1] This section also treats the list of recommendations for continuing work programs as potential prototype developmental improvements to be implemented and demonstrated at ANO-1. Some of these recommendations have been expanded from the Phase 1 study.[1]

6.1. Oconee 3 Supplemental Primary System Recommendation

6.1.1. Preventive and General Maintenance

1. Complete preventive and corrective maintenance should be performed on the control rod drive (CRD) vent valves and vent valve tools, including neolube of vent valves threads, before the RCS is filled. (12 h) FM_D-154

2. Preventive maintenance and thorough testing of the fuel handling bridges should be conducted as soon as the reactor building is accessible. This PM should include all hoses, cables, and takeup reels as well as the proper operation of all switches. Any defective or marginal components should be repaired or replaced. (8 h) FM_D-114

3. The reactor building should be relamped at the end of the outage whenever non-critical path time is available, so that relamping will not be required during critical path time at the beginning of the next outage. (8 h) FM_D-114

4. Portable flood lamps should be used instead of the installed FTC lights until after the FTC has been flooded. The installed lighting is designed to be operated flooded, and operating the floodlamps dry shortens bulb life. (<4 h) FM_D-75

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[1]Refueling Outage Availability Study, Phase 1 Final Report, COO-4068-14, BAW-1464, Babcock & Wilcox, Lynchburg, Virginia, November, 1977.

5. Tasks to be performed inside the reactor building should be thoroughly reviewed and all workers familiarized with their assignment before they enter the reactor building. Communications outside the reactor building are much smoother than inside because of the high noise levels in the building. A second advantage is that radiation exposure is minimized by minimizing the time in the RB. (4 h) FM_D-75

6.1.2. State-of-the-Art Recommendations

1. In addition to existing onsite facilities for calibrating low-range gages, an in-house capability to calibrate high-range pressure gages should be obtained. Offsite calibration of such gages has proved to be slow and very unreliable. Proper head stud tensioning depends on the accuracy and proper operation of these gages, and since stud tensioning is normally a critical path item, many hours may easily be lost because of a single gage. (12 h) FM_D-155

2. The breathing air system and its supporting accessories should be improved to make it more effective. Several items that should be incorporated are as follows:

   a. The breathing air system should be upgraded by making it a high-pressure system. This would provide a larger effective air volume and sufficient air pressure to push water out of system low points instead of letting the water cause blockages as it does in the existing pressure system.

   b. The moisture content in the air should be reduced by using automatic blowdowns on the compressors, moisture separators, and manual blowdown lines or other effective and acceptable means.

   c. Ensure that sufficient air breathing masks are available on station. This should include enough repair parts to prevent air breathing masks being out of service because for lack of parts.

   d. Battery-powered and air-fed Scott Air Pack Hoods should be incorporated. These hoods are disposable and provide sufficient clearance to allow the wearing of glasses. The battery powered unit can also be used in areas when air is not readily available or where it would take longer to rig the air supply than would be required to perform the task using a self-contained air system. (8 h) FM_D-115

3. Special storage areas should be established for special tools, and the tools should be plainly identified. Tools that are boxed should have an inventory list included to ensure that all parts are available. (<4 h) FM_D-74

4. Incorporate hoop switch or similar devices to de-energize the fuel handling bridges when the mast comes in contact with solid objects, such as guide studs or the indexing fixture. (8 h) FM_D-109

5. Modify the "T" handle tool used to remove the plugs from the reactor vessel flange stud holes by welding a 3/4" drive socket to the top of the tool to allow use of a breaker bar or ratchet rather than a sledge hammer to pound on the T handle to break the plug loose. (<4 h) FM_D-75

6. It is recommended that the utility purchase at least two complete spare CRD mechanisms to have available as replacement components. However, the complete mechanism, as shipped from the vendor, arrives at the plant site in two boxes, completely disassembled. The mechanisms are inspected upon receipt, inventoried, and stored as they were shipped — completely disassembled. The spare mechanisms should be assembled onsite and stored in the reactor building in a ready-to-install condition. In the event a mechanism must be replaced, the utility would be prepared to complete the replacement quickly and repair the inoperable mechanism at their convenience. Adequate mounting brackets should be designed to facilitate storing the mechanism in an upright position. This concept would enhance the reliability of the spare parts inventory and thus plant reliability. It is also an excellent opportunity for training new personnel in assembling these mechanisms outside high-radiation zones. Storing the spare mechanisms in the reactor building would eliminate the need to open the equipment hatch to transport long parts, thus improving plant availability. (16 h) FM_D-195

6.1.3. Recommendations Requiring Development, Evaluation, or Design Work

1. At present, the RCS is filled with the bleed transfer pump, which is limited to 140 gpm. The system is drained using the loop drains to the component drain pump, which is limited to 120 gpm. A new method is recommended for filling and draining the RCS with an additional 300 gpm flow by adding piping and a pump connecting the bleed holdup tank and the LP injection system. This could decrease fill and drain time significantly. The 300 gpm increase in the fill and drain rate of the RCS is not expected to require modification of the system's vent capabilities or increased makeup water capacity. (12 h) FM-134

6

2. Facilities should be designed to clean up the holdup tank contents and improve the quality of the RCS fill water. This would aid in maintaining the RCS water within chemical specifications and minimize the delays associated with establishing proper RCS chemistry. (12 h) FM_D-134

6.2. Continuing Work Programs at ANO-1

6.2.1. Transfer Tube Cover Removal (Figure 6-1)

The current procedure for removing and storing the fuel transfer canal (FTC) transfer tube cover requires (1) Three men in the canal to work on the tube cover and (2) the polar crane to support the cover during removal and to move the cover out of the canal for storage. This procedure takes about 4 hours of critical path time and 16 manhours.

A solution to this situation is the installation of a breech-lock arrangement on the FTC end of the fuel transfer tube. Initial studies of this type of arrangement reveal that critical path time can be reduced to approximately 30 minutes (0.5 hour) and manpower to only one man. If the breech-lock tube cover were installed on a hinge, the need for the polar crane would also be eliminated. Without a hinged breech-lock assembly, the breech-lock cover could be removed by a jib crane over the end of the FTC as proposed in the Phase 1 Refueling Availability Outage Study report.[1] FM_D-23

Potential savings offered: 2-3 hours critical path time
4 hours polar crane time
13-14 manhours

6.2.2. RC Pump Seal Handling Tool (Figure 6-2)

The existing RC pump seal handling tool at ANO-1 is cumbersome to operate and has some design problems. An effort to redesign the tool is recommended and should include the following areas:

1. Removal of the air motor and installation of a hand-operated crank to raise and lower the seal unit. The ·resent air motor and operating valve are erratic and too fast. A hand operator would provide for smoother operation of the unit and would eliminate the possibility of binding the seal during removal be erratic or too rapid movement.

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[1]Refueling Outage Availability Study, Phase 1 Final Report, COO-4068-14, BAW-1464, Babcock & Wilcox, Lynchburg, Virginia, November, 1977.

2. Replacing the present link chain with braided wire rope is recommended. This would eliminate the tendency of the link chain to skip off the sprocket when lifting or lowering the seal. The main drive sprocket would also have to be replaced with a takeup drum assembly.

3. An overall evaluation of the unit should be conducted to determine whether the weight and the overall dimensions of the unit can be reduced. Since the RC pump seal weighs about 800 pounds, any weight reduction in the handling tool would increase the ease and stability of handling. The area in and around the RC pump motor stand is very small and allows only two persons in to work the seal. Reducing the physical size of the seal handling unit would create additional work area and an ultimate increase in the dexterity of handling the seal. Potential savings offered: 2 hours per seal or 8 hours outage time for changeout of all four RC pump seals. FM_D-43

6.2.3. Combination Stud Runner and Tensioner

6

The development of a combination stud runner and tensioner would reduce the overall time required to remove and replace the reactor vessel (RV) head. At present, the RV stud is run into place using a stud runner. This operation requires approximately 2-3 minutes per stud. The stud runner is then removed and the stud tensioner is put in place on the stud to prepare for tensioning. Removing the stud runner and placing the stud tensioner requires approximately 2 minutes per stud. There are 60 RV studs, so this evolution consumes approximately 2 hours. If a combination stud runner and tensioner were developed and the two units were used 180° apart, this would reduce tensioning or detensioning time by at least one hour.

Also, with a newly designed tool (with consideration being given to existing shortcomings of current equipment), additional time savings would be realized by avoiding delays due to equipment malfunction.

Potential savings offered: (1) 2 hours tensioning and detensioning; (2) newly designed tool will have more potential for avoiding delays due to malfunction. FM_D-27

6.2.4. New Seal Plug Design (Figure 6-3)

At present, RV stud holes are preserved during refueling by filling them with a corrosion inhibitor and plugging them with a metal seal plug. This is done to preclude the entry of borated water into the stud hole while the FTC is filled for refueling operations. This prevents the stud hole from corroding and having to be extensively cleaned upon draining of the canal. Consequently, upon completion of refueling operations and canal draining, the metal seal plug is removed, the corrosion inhibitor is pumped out, and the stud holes cleaned and lubricated in preparation for RV head replacement. These activities are also performed in an area of potentially high radiation exposure.

A proposed seal plug design could reduce the time required to complete this task and also reduce man-rem exposure to maintenance personnel. The proposed seal plug would be made of plastic or light metal and would be form-fitting to the RV stud hole with an O-ring seal (Figure 6-3). Upon RV head removal, the new seal plugs would be lubricated with the same lubricant used on the RV head studs and inserted into the stud holes. Since the proposed seal plugs would be form-fitting, there would be no need to use a corrosion inhibitor. After completion of the refueling, all that would need to be done is to remove the seal plugs and replace the RV head and studs. Removal of the corrosion inhibitor is not necessary, and stud hole cleaning would be minimized. Critical path time savings with a new seal plug design is estimated at 5 hours. This is half the time now required to accomplish this task.

In addition to the reduction in time required to accomplish this task, a significant reduction in radiation exposure is possible. By reducing the time by one-half, radiation reductions of approximately 500 mr/man (2-3 man rem) are possible.

Other benefits of a new seal plug include (1) elimination of the need to store and handle the radioactive liquid chromate solution. This will reduce the overall site inventory of radioactive waste and eliminate the possibility of accidents or spills of this radioactive liquid and (2) eliminate delays due to chromate pump malfunction. Potential savings offered: (1) 5 hours critical path time, (2) approximately 500 mr/man (2-3 man-rem) radiation exposure, (3) elimates the use and storage of chemical preservatives. FM-56

6.2.5. Slip Clutch on Stud Runner

An immediate, short-term time reduction in critical path time would be obtained by development of a slip-clutch or split-nut arrangement on the stud runner.

The air-driven stud runner now requires approximately 3 minutes to return to its ready position after running in a stud. Multiplied by 60 studs, this accounts for 1.5 hours' critical path time based on using two stud runners. By installing a slip-clutch or split-nut arrangement that allows immediate return of the tool to its ready position, a time savings of one hour or more is possible. Potential savings offered: 1 hour critical path time. FM-42

6.2.6. RB Fan Arrangement for Movement

While not contributing directly to the critical path for a refueling-maintenance outage, the reactor building arrangement for building fan removal and replacement can be crucial to a forced outage to repair the RB fans. The present procedure for fan placement makes the task much longer than necessary. With redesigned fan support and lifting mechanisms, it would be possible to reduce the time for this task considerably.

RB fan problems and failures are not uncommon to the industry and appear to have some impact on overall availability. Researching the problem and proposing changes in RB fan design and placement along with improvements in removal and replacement equipment would directly reduce forced outage time and increase on-line time. FM_D-34

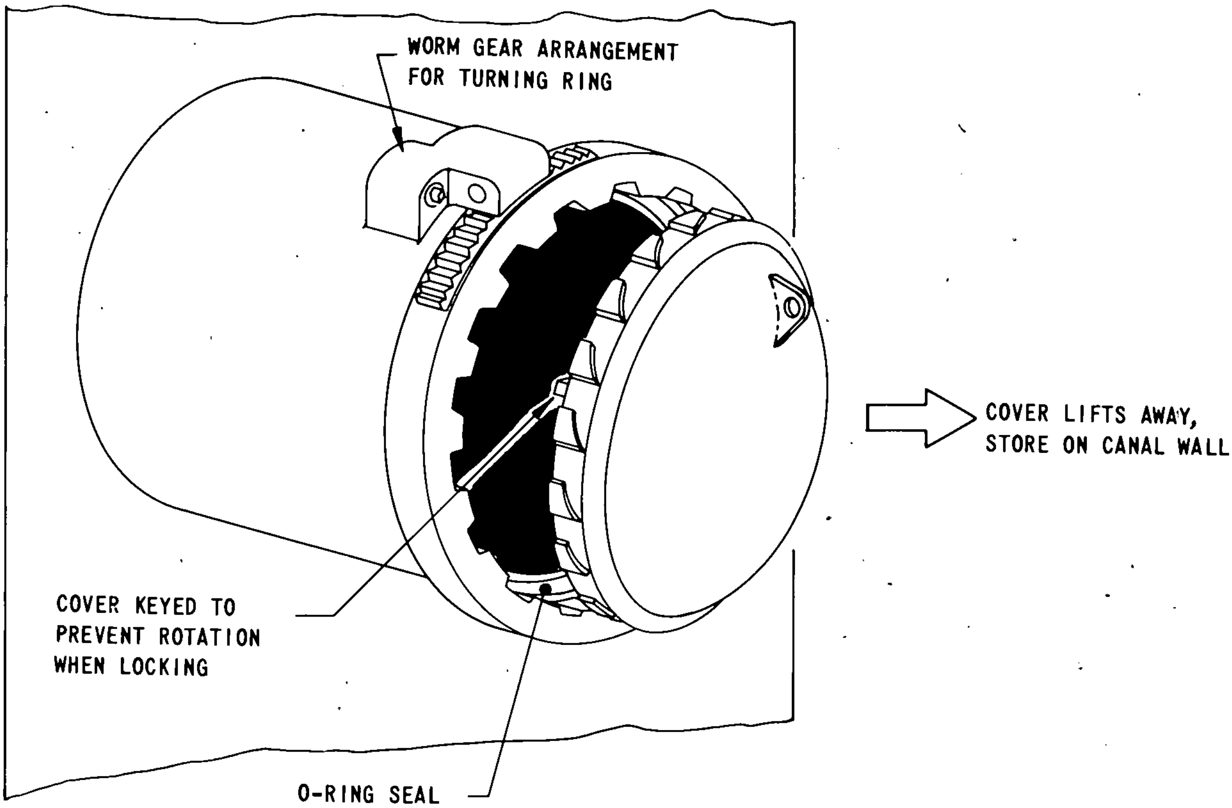
6.2.7. Industry Study of Equipment Duplication, Isolation, and Layout

An area that can result in significant reduction of outage is equipment/system duplication, isolation, and layout. Many instances in plant design allow equipment to be power-limiting if inoperable. This leads to reduced plant capacity if certain equipment is out of commission for repair. Also, plant designs have led to certain critical components that cannot be isolated for repair if a problem should develop. With certain equipment, if a problem develops, the plant must operate at reduced power until the affected equipment can be repaired. By current design, some of these items cannot be isolated for repair, and the plant must be shut down for repair work.

As for system layout, the present design sometimes does not adequately consider maintenance and repair of equipment. With PM programs being very important to plant maintenance efforts, the system layout should be reviewed with respect to complementing the site's maintenance efforts to reduce work load during the outage.

A study is recommended to review the complete plant layout with respect to equipment duplication and isolation and system layout. These areas would be reviewed and recommendations would be generated for design changes to currently operating utilities and for future plant design considerations. These recommendations would be directed at reducing the need for a utility to shut down to repair equipment and at reducing the overall maintenance work load during an outage by performing as much preventive and corrective maintenance as possible during the operating period. This study has the potential to impact significantly on plant availability for the industry as a whole.

Figure 6-1a. Fuel Transfer Tube Breech-Lock Cover



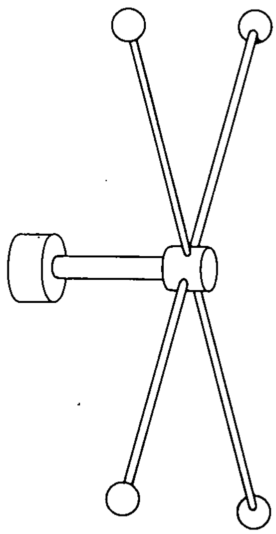
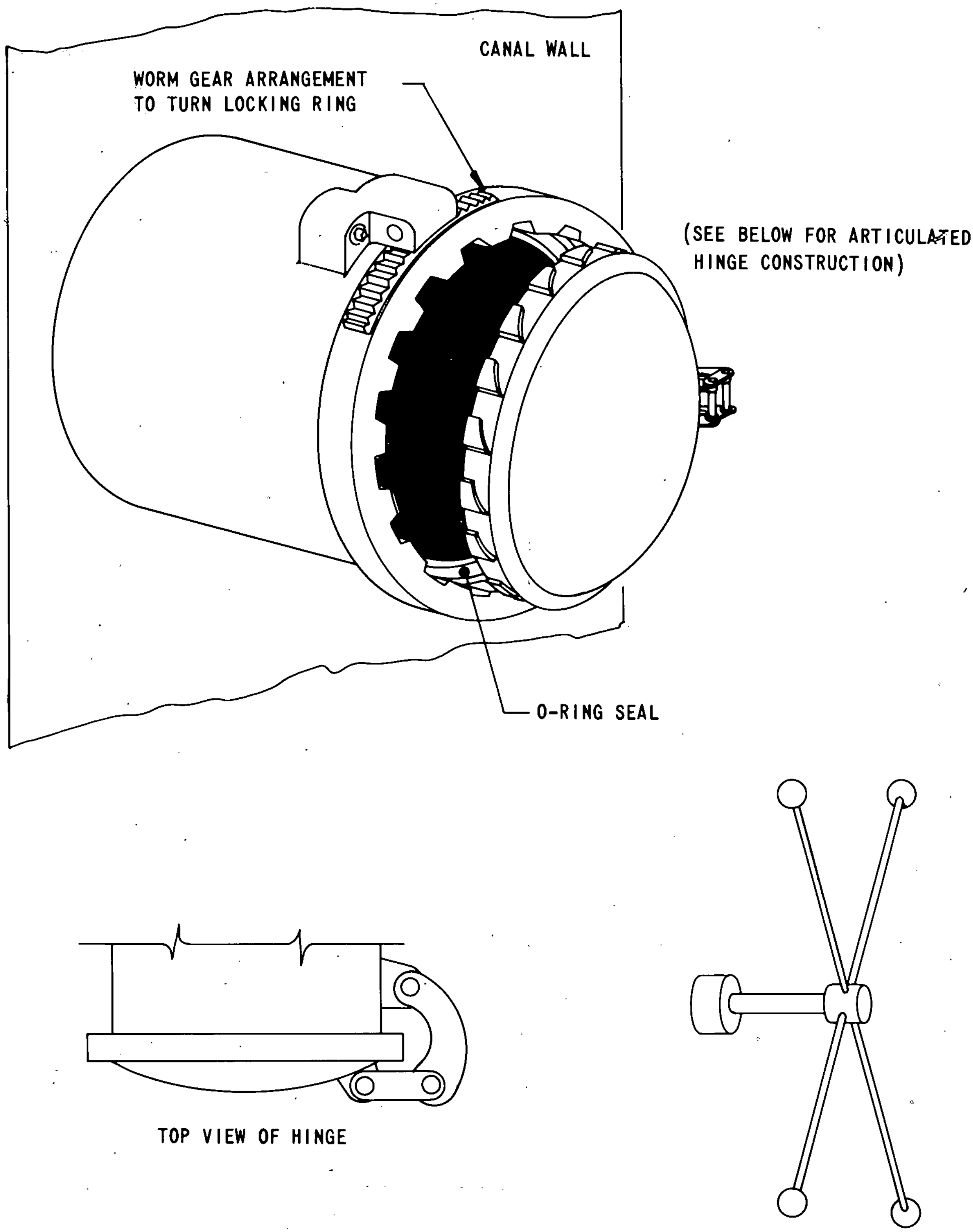


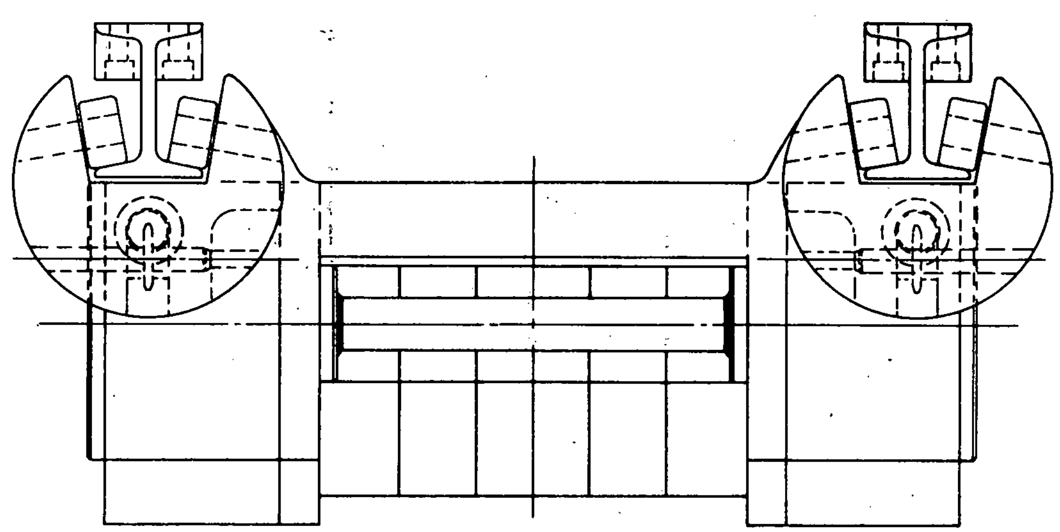
Figure 6-1b. Fuel Transfer Tube Breech-Lock Cover

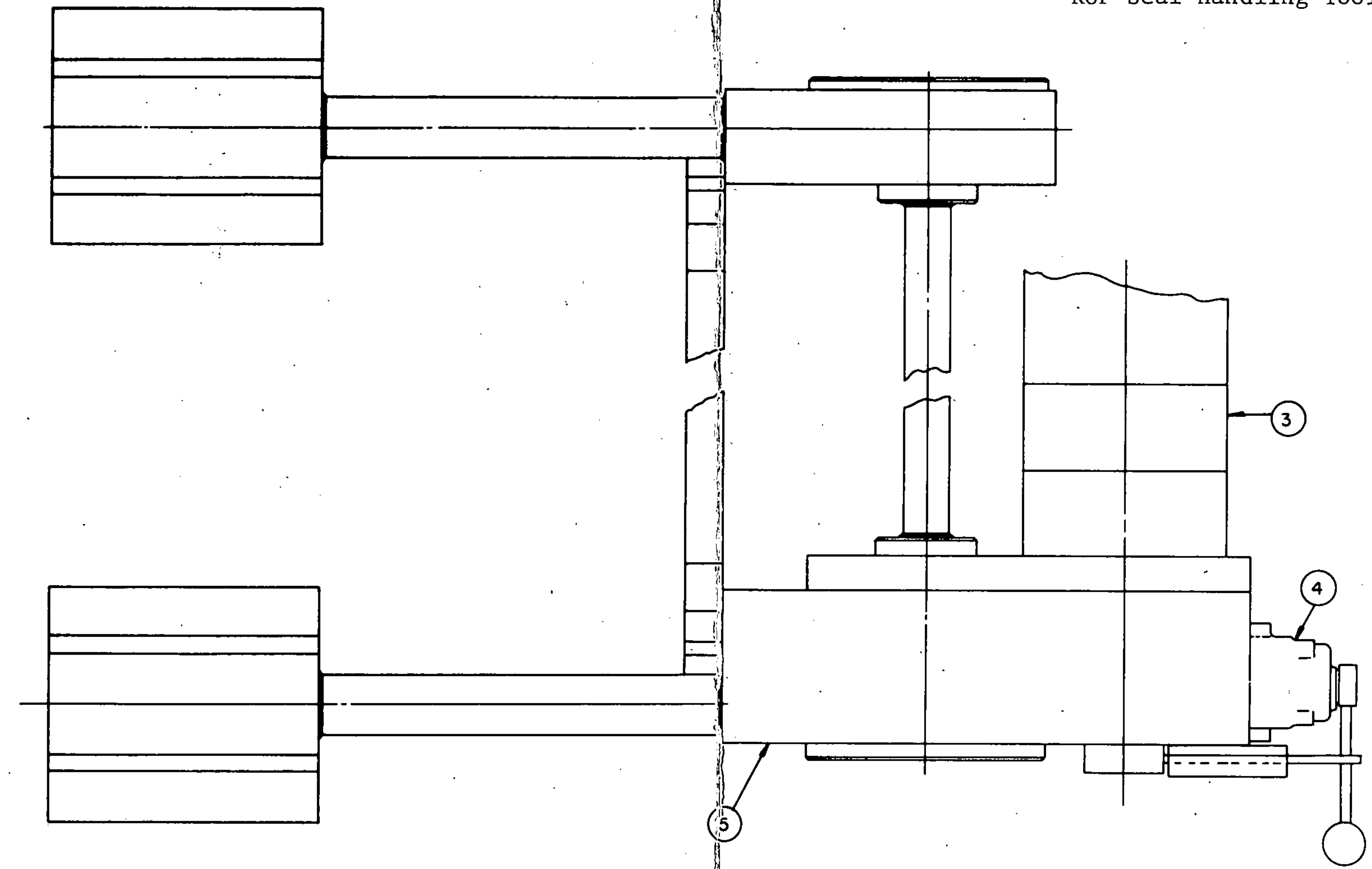


RECOMMENDED IMPROVEMENT

1. REPLACE THE EXISTING CHAIN LINK WITH A BRAIDED OR WIRE ROPE LIFTING ELEMENT.
2. REPLACE THE CHAIN LINK TAKE-UP GEAR WITH A TAKE-UP DRUM FOR THE WIRE ROPE LIFTING ELEMENT
3. REMOVE THE AIR DRIVE MOTOR.
4. REMOVE AIR MOTOR CONTROL VALVE.
5. REDESIGN GEAR BOX AND INSTALL A MANUAL HANDLE OPERATOR.
6. REVIEW OVERALL CONSTRUCTION MATERIALS TO DETERMINE IF WEIGHT REDUCTION IS POSSIBLE.

Figure 6-2. Recommended Changes to RCP Seal Handling Tool





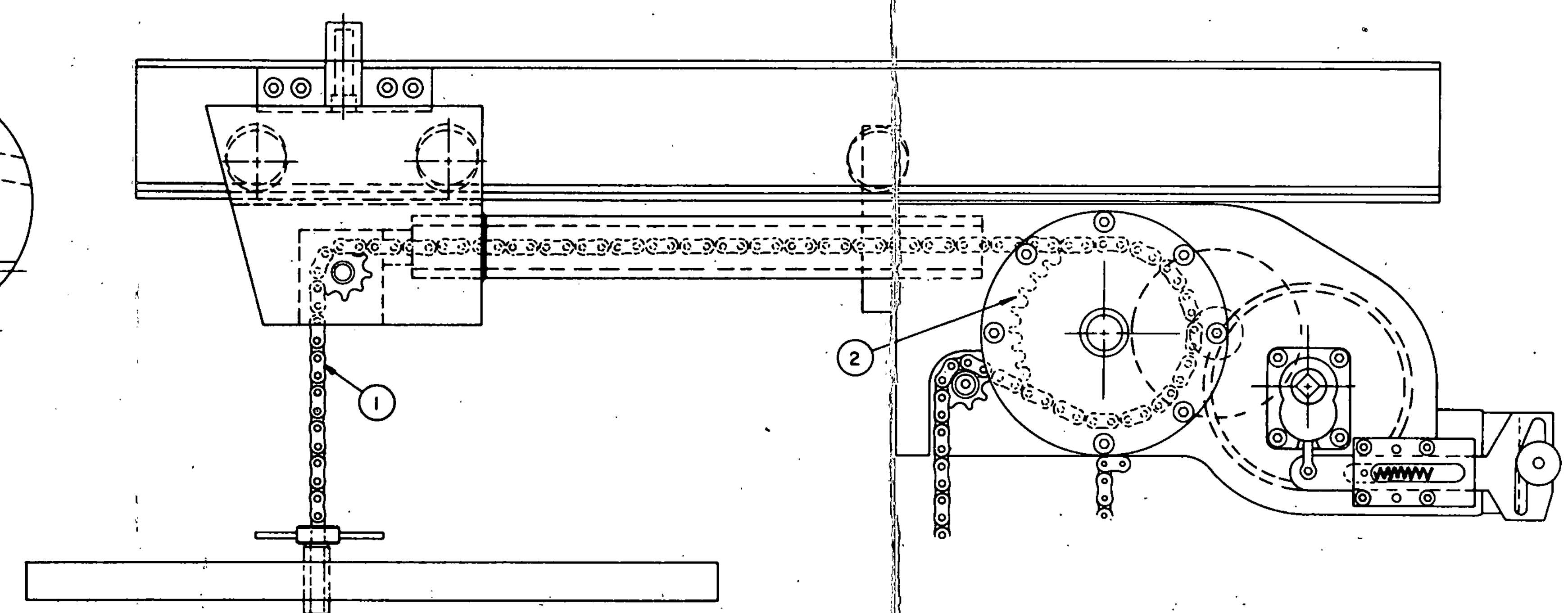
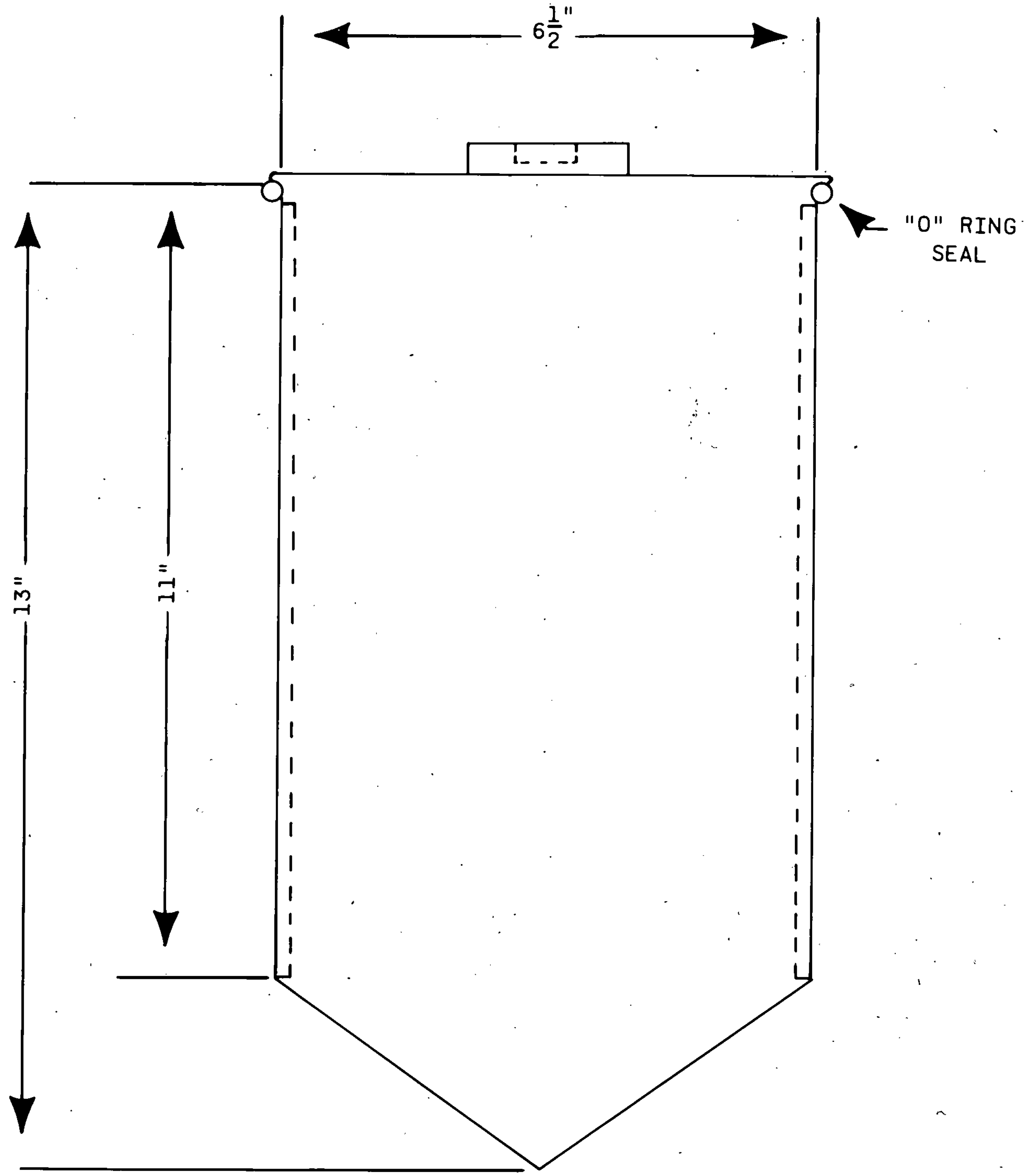


Figure 6-3. Recommended New Design of RV Seal Plug



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7. GENERIC RECOMMENDATIONS

Although this study was limited to two B&W 177-FA plants, the findings can be extrapolated for applicability to other nuclear plants of similar design and construction. The following recommendations for reducing outage time are given to other utilities based on the observations of equipment and/or procedures at Oconee 3 and ANO-1:

1. Use an A-frame or monorail arrangement around the HP turbine to allow the use of more than one tensioning unit and to free the turbine crane for other critical path work. (See 4.2.2 and 5.2.3.) (48 h) FM-1100

2. Review secondary valve maintenance practices and PM program coverage. (See 4.1.1.1, 4.1.1.4, 4.1.2.5, 4.1.2.14, 4.1.2.15, 5.1.2.) (100 h) FM_D-753

3. Review the secondary work area with emphasis on avoiding delays during routine outage inspection and maintenance of equipment. Work items should not be held up because of inadequate laydown space for equipment. (See 5.2.2 and 5.3.4.) (100 h) FM-815

4. Keep a spare set of turbine bearings to replace defective bearings. Utilities with only one turbine or turbines of different manufacture could consider a joint venture with other utilities having similar turbines to defray the large cost involved. (See 4.1.4.1.) (72 h) FM_D-652

5. Use secondary work packages wherever possible to avoid delays due to tools, parts, procedures, etc. (See 5.1.3.) (24 h) FM_D-550

6. Implement a complete PM system comprising scheduled maintenance items, machinery history, and corrective maintenance programs. (See 4.1.1.2, 4.1.1.3 and 5.1.4.) (24 h) FM_D-594

7. Initiate the use of HBSs throughout the primary and secondary plants and maximize their use for preventive and corrective maintenance items. (See 4.2.1 and 5.2.1.) (100 h) FM-831

8. Work major jobs (turbines) to completion rather than pacing work with the critical path where it would not pull personnel from other potentially critical path jobs. (See 4.1.3.1.) (48 h) FM_D-585

9. Conduct outage preplanning on a year-round basis to ensure that parts and manpower requirements are met during the outage. (See 4.1.2.2, 4.1.2.6, 4.1.2.8, 4.1.2.9, 4.1.2.11 and 4.1.2.12.) (24 h) FM_D-550

10. If possible, support overhead main steam lines rather than removing them during outages. (See 5.2.4.) (24 h) FM-550

11. Expand BOP planning and scheduling work in a manner similar to the attention given to the primary system side. A continuously updated system could be used by maintenance coordinators and supervisors to plan their maintenance and inspection items more effectively. Such a system would display manpower, Technical Specification, job, and schedule requirements and be integrated with a procedure or work package updating capabilities and with the spare parts system for advance preparation of spare parts and advance ordering of replacement parts. (See 4.1.2.10.) (24 h) FM_D-550

12. Modify the OTSG drain to the hot well to allow its use at normal operating pressure and temperature. (See 4.3.1.) (32 h) FM_D-494

13. Develop and incorporate an OTSG recirculation and chemical addition system similar to Nuclear Station Modification 31 installed at Oconee 3. This system allows independent recirculation of each OTSG, chemical addition, and sampling. It provides a sufficient flow rate to provide rapid mixing of the OTSG contents as well as allowing both OTSGs to be recirculated simultaneously rather than sequentially. (24 h) FM_D-484

14. Establish in-house high-range gage calibration capabilities. (See 6.1.2.) (12 h) FM_D-275

15. Improve the reliability and the method of resetting the turbine overspeed device. (See 4.3.3.) (12 h) FM_D-270

16. Install additional ladders, walkways, and platforms for work area support. (See 4.2.13, 5.1.7 and 5.3.2.) (12 h) FM_D-266

17. Update spare parts systems to increase efficiency and avoid delays. A computerized system is highly recommended along with a full-time expediting group. (See 4.1.4, 5.1.5) (12 h) FM_D-266

18. Mark and identify all systems and equipment to afford easy identification and location for maintenance and/or inspection, which will save considerable time. Components and equipment should be marked according to the P&ID, and systems should be labeled according to content and direction of flow. (12 h) FM_D-266

19. Initiate training programs for maintenance personnel, including system orientation and maintenance practices. Videotape should be used extensively as a tool for the training program. (See 4.1.3.4, 4.1.3.5, 4.1.3.6 and 5.1.1.) (12 h) FM_D-266

20. Develop the capability to fill and drain the RCS at increased rates. (See 6.1.3.1.) (12 h) FM-255

21. Develop cleanup capability for holdup tanks. (See 6.1.3.2.) (12 h) FM_D-254

22. Develop the capability of sealing the moisture separator reheater manways against vacuum and pressure. (See 4.3.4.) (12 h) FM_D-254

23. Generate and use written maintenance procedures for BOP work items. (See 4.1.2.4.) (8 h) FM_D-195

24. Authorize sufficient personnel to sign special work permits. (See 4.1.3.2.) (6 h) FM_D-195

25. Improve communications between various in-house groups. (See 4.1.3.3, 4.1.3.9.) (8 h) FM_D-195

26. Include draining of systems and availability of parts in work requests for valve maintenance. (See 4.1.2.1.) (8 h) FM_D-195

27. Improve air breathing capabilities. (See 6.1.2.2.) (12 h) FM_D-195

28. Evaluate the use of preformed metal insulation for application on the HP turbine. (See 4.3.5 and 5.2.8.) (6 h) FM-195

29. Ensure that sufficient support personnel are available. (See 4.1.2.3.) (8 h) FM_D-195

7

30. Use portable floodlamps for the FTC and relamp the RB at the end of the outage. (See 6.1.1.3 and 6.1.1.4.) (8 h) FM_D-194

31. Use an ultrasonic stud elongation measuring device when perfected. (See 4.3.2.) (6 h) FM-192

32. Benchmark overhead cranes. (See 4.2.5.) (<4 h) FM_D-115

33. Use load cells, gages or similar devices to balance the load on heavy lifts. (See 4.2.7.) (<4 h) FM_D115

34. Establish a standardized laydown pattern for large component. (See 4.2.8.) (4 h) FM_D-115

35. Attach label plates for storage bins used for small turbine components. (See 4.2.9.) (2 h) FM_D-115

36. Cross-index oils and greases. (See 4.1.4.2.) (4 h) FM_D-115

37. Develop improved methods of turbine alignment. (See 4.3.7.) (<4 h) FM_D-114

38. Increase the no-load travel and hook speed of the overhead crane. (See 4.3.8.) (4 h) FM_D-111

39. Install permanent sandblasting facilities on turbine floor. (See 4.2.10.) (4 h) FM_D-107

40. Use a cherry picker and/or a fork lift when turbine building space permits. (See 4.2.11.) (4 h) FM_D-105

41. Investigate making HPT lower casing castellated nuts self-supporting. (See 4.3.9.) FM_D-35

42. Establish deadlines for submission of vendor-requested modifications. (See 4.1.2.7.) FM_D-35

43. Review equipment duplication and isolation capability with respect to maintaining the plant at maximum output with equipment out of service for repair or periodic maintenance. (See 5.1.8 and 5.3.3) FM_D-(N/A)

44. Review the system layout as to complementing the utility's efforts to perform as much on-line maintenance as possible. (See 5.1.9 and 5.3.3) FM_D-(N/A)

45. Prepare in advance for forced outages to allow maximum use of the outage time. A list of needed maintenance items should be kept with the respective plant conditions necessary to work these items. This file can be kept manually or can be integrated into a computerized scheduling and planning system (if in use). Knowing in advance tasks that need to be accomplished and the conditions necessary to conduct them can reduce the overall work load during the refueling/maintenance outage.

FM_D-(N/A)

46. Install status or progress boards as morale aids. (See 4.1.3.7.)

FM_D-(N/A)

47. Improve general housekeeping as safety item (See 4.1.3.8.) FM_D-(N/A)

48. Incorporate the "remove, replace, and repair concept" whenever possible. (See 4.2.12.) FM_D-(N/A)

49. Establish a manpower pool of experienced, well-trained personnel whose sole responsibility is to overhaul turbines and perform secondary plant work. For a smaller utility, form a roving crew of selected personnel from various participating utilities and train them in turbine and secondary plant work. FM_D-(N/A)

50. Maintain at least two spare CRD mechanisms, completely assembled and properly stored in the reactor building. (See 6.1.2.6.) FM_D-195

8. SUMMARY OF POTENTIAL BENEFITS

This section summarizes the results of the BOP Maintenance Extension Study at Oconee 3 and ANO-1 and the effect of supplemental primary system recommendations. A summary of generic BOP recommendations, including the expected benefits that can be applied to other plants of similar design and construction, is also presented.

8.1. Oconee 3 — Summary of Potential Benefits

The 1977 Oconee 3 outage "as-built" schedule is presented in section 2 along with a typical BOP schedule. These schedules indicate 18 days and 14 days, respectively, from turbine turning gear-to-turning gear. The typical schedule was derived showing what should have occurred if abnormal activities and delays had been deleted from the as-built schedule.

The activities in the typical schedule were evaluated to determine BOP time savings if all the applicable recommendations presented in the preceding sections were implemented. The end result is an "ideal" BOP schedule showing the length to which a typical BOP outage (turning gear-to-turning gear) could be reduced by incorporating the recommendations. The ideal BOP schedule for Oconee 3 is shown in Figure 8-1. The following assumptions were made in developing this schedule:

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 in two 10-hour shifts, 6 days a week. Shifts run from 0700 to 1700 and 1600 to 0200.

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

8

2. All recommendations affecting the BOP critical path were incorporated. It is important to note that the estimate of time savings for each recommendation is cumulative only if it affects the turbine critical path schedule. These recommendations include (a) using a portable free-standing frame [section 4.2.2], (b) using an HBS [section 4.2.1], (c) completing all jobs relating to the turbine as quickly as possible and rather than pacing them with the outage critical path [section 4.1.3.1], and (d) using an ultrasonic stud elongation measuring device [section 4.3.2].
3. All equipment is operational throughout the outage.
4. Personnel errors cause no loss of time for the activities in the turbine inspection path.
5. All required spare parts are on site for the work planned.
6. No major facility changes are scheduled.
7. No major work emerges as a result of the turbine inspection, e.g., damaged blades, bearings, etc.

The results of the study show that, based on an outage requiring disassembly, inspection, cleaning, and reassembly of the HP turbine and one LP turbine or two LP turbines, a turning gear-to-turning gear schedule of 11 to 12 days can be achieved if all recommendations resulting from the study are implemented. A summary of expected time savings is given below.

This complements the results of the previously published study of a 21-day NSS outage length from breaker to breaker. The supplemental recommendations given in section 6 of this report provide an additional critical path time savings of 16 hours over those given in the Phase 1 report.[1] The total time savings would result in an NSS breaker-to-breaker outage of 20 to 21 days. Therefore, for the total plant, it can be concluded that the NSS for Oconee 3 will control the refueling outage length.

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1 Refueling Outage Availability Study, Phase 1 Final Report, COO-4068-14, BAW-1464, Babcock & Wilcox, Lynchburg, Virginia, November, 1977.

BOP outage length, turning gear-to-turning gear, days			Expected annual savings, days
Actual	Typical	Ideal	
17-18	14	11-12	2-3

8.2. ANO-1 — Summary of Potential Benefits

The proposed typical schedule for ANO-1 (discussed in section 2.2.5) was evaluated to determine outage time savings if all applicable recommendations in the preceding sections were implemented. From this typical schedule of 33 days turning gear-to-turning gear, an ideal schedule was developed showing (1) the ideal critical path activities for the secondary system and their duration and (2) the length to which a typical outage could be reduced by incorporating the recommendations.

The ideal schedule for ANO-1 is shown in Figure 8-2. In developing the ideal schedule, the assumptions listed in section 8.1 for Oconee 3 apply except for BOP critical path time savings.

For ANO-1, the BOP outage critical path recommendations include (a) improvements in turbine building arrangements for laydown of large components, (b) use of hydraulic bolting system, (c) improvements in rigging and lifting, and (d) use of Mirror insulation for easy removal and installation around the high pressure turbine.

The results of the ideal schedule show that significant improvement can be made in bringing secondary plant outage time in line with primary system refueling time. By incorporating the recommendations and taking credit for the time savings, a typical secondary outage length could be reduced to an ideal schedule of 27-28 days from breaker open to breaker closed with an expected annual time savings of 13 days. A summary of the expected time savings is given below:

BOP outage (turning gear-to-turning gear), days		Expected annual savings, days	
Proposed Typical	Ideal		
33	20	13	Turning gear to turning gear
40.5	27.5	13	Breaker to breaker

8

The Phase 1 Refueling Outage Study results showed the ideal outage length for the NSS to be 22 days breaker to breaker. The supplemental recommendations given in section 6 can save up to 16 additional critical path hours over the time savings given in the Phase 1 report.[1] This indicates that the BOP outage work will control the total outage length for an outage that involves the disassembly, inspection, cleaning, and reassembly of the high pressure turbine and one low pressure turbine.

8.3. Generic Plants — Summary of Benefits

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

Although this study was limited to two specific B&W 177-FA plants, the findings can be extrapolated for applicability to other nuclear plants of similar design and construction. Generic recommendations that could provide the greatest outage savings to current operating plants and to those in the design and construction stages are summarized in section 7 of this report. This section discusses the method of determining the expected cost benefit for each recommendation as it applies to a single plant and to multiple B&W units expected on-line. Improvements directly reducing critical path activity times and other improvements are included in section 7. 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 reported in this study, it can be estimated that approximately 3 to 13 critical path days can be saved by implementing the recommendations listed in section 7. If all generic recommendations were implemented by a utility, a significant number of outage hours could be saved in avoiding delays. This in turn would aid in reducing the total outage length and reduce the total manhours expended. Although all of the recommendations in section 7 are believed to save outage time, their individual time savings are not cumulative.

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[1]Refueling Outage Availability Study, Phase 1 Final Report, COO-4068-14, BAW-1464, Babcock & Wilcox, Lynchburg, Virginia, November, 1977.

Table 8-1 represents some of the significant generic recommendations and their cost benefits as they apply to one plant and to multiple &W units. Cost benefits for other recommendations can be determined based on the following:

1. Replacement power cost is $500,000/day.
2. Replacement power is a 1000 MW plant.
3. Oil conservation is 38,100 barrels/day if replacement power were from an oil-fired unit.

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 on this number of plants will increase the expected savings by 69 to 299 outage days per year.

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Table 8-1. Examples of Generic Plant Benefits

Recommendations	Single-plant annual implem'n benefits: Outage reduction, h	Single-plant: 1000-MW plant replacement power value, $	Single-plant: 1000-MW plant fuel conserv. value, bbl	1985 annual implem'n benefit, 23 plts: Outage reduction, h	1985: 1000-MW plant replacement power value, $	1985: 1000-MW plant fuel conserv. value, bbl
Use of HBS	100	2,083,333	158,750	2300	47,916,659	3,651,250
Arrangement of turbine bldg layout for laydown of large components	100	2,083,333	158,750	2300	47,916,659	3,651,250
Use of monorail around HP turbine	48	1,000,000	19,050	276	5,750,000	438,150
Work on major turbine jobs until complete, not paced with critical path work	48	1,000,000	19,050	276	5,750,000	438,150
Use of portable, free-standing frame to support tools, equipment	9	375,000	28,575	207	4,312,500	328,612
Use of preformed metal insulation for HP turbines	6	125,000	9,525	138	2,875,000	219,075
Use of ultrasonic stud elongation measuring device	6	125,000	9,525	138	2,875,000	219,075
Turbine parts: lifting and rigging improvements	4	166,666	12,699	92	1,916,666	146,049
Implementing PM system	24	500,000	38,100	552	11,500,000	876,300
Providing additional work area support	12	250,000	19,050	276	5,750,000	438,150
Improvements in secondary valve maintenance practices	100	2,083,333	158,750	2300	47,916,659	3,651,250
NSM scheduling recommendations	6	125,000	9,525	138	2,875,000	219,075
Maintaining spare bearings for turbines	72	1,500,000	114,300	1656	34,500,000	2,628,900
Improvements in moisture separator reheater manway	12	250,000	19,050	276	5,750,000	438,150
Upgrading steam generator drain line	32	666,667	50,800	736	15,333,341	1,168,400
Upgrading spare parts system	12	250,000	19,050	276	5,750,000	438,150
Additional training programs	12	250,000	19,050	276	5,750,000	438,150
Developing a secondary work package	24	500,000	38,100	352	11,500,000	876,300
Using overhead steam line support	24	500,000	38,100	352	11,500,000	876,300

Figure 8-1. Ideal Balance-of-Plant Schedule — Oconee 3

Figure 8-2. Ideal Balance-of-Plant Schedule — ANO-1

9. CONCLUSION — TOTAL BENEFIT

The results of the maintenance extension study, as demonstrated at ANO-1's first two refueling outages, show that the BOP could impact the refueling outage if all primary system recommendations were implemented. This indicates the need to improve the BOP outage activities. For an outage that requires the disassembly, inspection, and cleaning of the high pressure turbine and one low pressure turbine, equivalent attention should be given the BOP activities to achieve a reduced total plant outage time.

By incorporating the recommendations resulting from the BOP study, an annual savings of 13 outage critical path days for ANO-1 and 2-3 BOP critical path days for Oconee 3 can be achieved.

By combining the BOP study and the earlier Phase 1 study, the total plant ideal schedule would result in annual savings of 13 critical path days for ANO-1 and 12 critical path days for Oconee 3, if all recommendations were implemented. This represents a savings of $6,500,000 of replacement power costs and 495,300 barrels of oil conserved for each plant. Since the recommendations were designed to assist the entire utility industry, we believe that if a plant implements these recommendations, similar savings could result.

By 1985, the total annual savings of 13 days from 23 nuclear power plants of B&W design will be approximately 299 days. Assuming this is critical path time, this results in a savings of $148,661,500 and an oil conservation of 11,328,000 barrels. As a result of the supplemental primary system recommendations presented in section 6, 16 hours of critical path time savings can be obtained. The 16 hours annual savings applied to the 23 B&W plants by 1985 could result in a total of 15 outage days savings. This produces an additional savings of $7,457,935 or 568,295 barrels of oil. These savings are based on an assumed nuclear operating capacity of 22,871 MWe supplied by these 23 plants.

As in the Phase 1 study, 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 can be 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 Videotapes
and Slides

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This appendix lists all the raw data recorded on videotapes and slides for the Maintenance Extension Studies conducted at Oconee 3 and Arkansas Nuclear One. The videotape effort produced approximately 25 hours of videotape. From these raw tapes, edited videotapes covering the following subjects were produced:

1. A 20-minute recommendation tape for Oconee 3.
2. A 20-minute recommendation tape for ANO.
3. A 10-minute applications tape for hydraulic bolting systems.
4. A 20-minute generic application tape.
5. A 40-minute BOP summary tape.

These tapes have proven useful in familiarizing management personnel with the problems that must be overcome in carrying out a secondary outage and training new personnel for BOP work.

1. Videotape and Slide Film Index for Oconee 3

1.1. Videotape Index

Tape No.	Footage	Description
1S	0-125	Unit 3 changeout room/RWPs
	125-546	MSRV Test
	546-676	Removing HP stud
2S	0-154	Removing HP stud
	154-240	Removing moisture separator reheater manway
	240-268	Removing HP studs
	268-301	Removing LP turbine cover
	301-339	Removing HP stud
	339-576	Removing HP turbine casing (rigging)
	576-588	Removing LP turbine cover
	588-601	Installing working platform for HP turbine
	601-604	Crane operator climbing down from overhead
	604-612	HP turbine work platforms
	612-631	Removing LP turbine cover
	631-637	Removing HP diaphragm bolts
	637-674	Removing LP turbine cover
3S	0-028	LP turbine general area

Tape No.	Footage	Description
3S (Cont'd)	028-040	Removing HP diaphragm bolts
	040-085	Removing coupling guard
	085-127	Removing BRG covers
	127-228	No. 6 diaphragm outer ring (HP)
	228-323	No. 5 diaphragm outer ring (HP)
	323-356	No. 6 diaphragm inner ring, center section (HP)
	356-398	No. 1 diaphragm, generator end, outer ring (HP)
	398-428	No. 1 diaphragm, generator end, scale buildup (HP)
	428-444	No. 1 diaphragm, generator end, inner ring (HP)
	444-524	No. 4 diaphragm, turbine end (HP)
	524-551	No. 3 diaphragm, turbine end (HP)
	524-589	No. 4 diaphragm, generator end (HP)
	589-613	No. 1 diaphragm, turbine end (HP)
	613-665	No. 6 diaphragm, turbine end (HP)
4S	0-088	General turbine shots
	88-203	Removing LP inner casing bolts
	203-370	Shots of HP top-half diaphragms and sandblasting tent
	370-425	LP "A" turbine disassembly work
	425-475	Rigging LP inner casing
	475-505	ARIS (outside)
	505-548	Removing LP inner casing
	548-553	Blank
	553-625	Turning LP rotor and closeup of rotor
	625-658	General floor shots
	658-End	Bearing cover removed
5S	0-142	Removing bearing housing
	142-218	Removing LP/HP coupling cover
	218-260	Removing bearing
	260-285	General turbine shots
	285-385	Uncoupling (and more general area shots)
	385-678	Diaphragm shots
	678-681	Rigging for HP turbine removal
6S	0-280	Lifting HP rotor

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Tape No.	Footage	Description
6S (Cont'd)	280-295	HP rotor being set down
	295-336	Bearing showing score marks
	336-365	General bearing shots
	365-408	HP bottom casing with HP rotor removed
	408-424	LP turbine rotor in bottom casing
	424-429	HP lower casing again
	429-442	Cleaning castellated nuts
	442-567	Removing LP diaphragm
	567-600	LP rotor in lower casing
	600-655	LP diaphragm
	655-682	General shots of turbine work
	682-684	HWP expansion joint
7S	0-320	HWP storage tank draining and expansion joint work
	320-423	Removing LP diaphragm
	423-646	Uncoupling A&B LP turbine (using crane, "Jenny Jack" in use from 525-646)
	646-678	Removing LP turbine rotor
8S	0-305	Removing LP rotor
	305-332	LP bottom casing — rotor removed
	332-410	HWP expansion joint
	410-465	Work on valve 3C-6, WR No. 22537
	465-478	General shots of HWPs and HWP area
	478-684	Valve work
9S	0-252	Work on valve 3C-6 (cont'd)
	252-305	Diaphragm inspection and repair
	305-332	Taking deposit samples off diaphragms for analysis
	332-426	Turbine bldg arrangement and laydown (view from above)
	426-473	Spare hot well pumps
	473-500	Crane broken down while carrying LP diaphragm
	500-547	Valve 3AS-98
	547-675	Intercept reheat control valve work
10S	0-428	Intercept reheat valve work
	428-456	Cleaning oil cooler 3AFWP
	456-516	HP rotor magnaflux — preparation and inspection

Tape No.	Footage	Description
10S (Cont'd)	516-537	Removing HP pin
	537-558	Magnafluxing HP rotor
	558-569	FWP oil cooler cleaning tool
	569-584	Moisture separator reheater
	584-601	HWP area and expansion joint
	601-638	Intercept reheat valves
	638-675	Feedwater valves
11S	0-189	Replacing HP turbine lower diaphragm
	189-262	LP turbine front bearing (No. 3)
	262-382	Valve work
	382-424	No. 10 bearing work
	424-512	FW control valve — general area shots
	512-541	FWPT coupling removed
	541-583	Oil cooler on FWP
	583-598	HWP expansion joint
	598-633	Preparation to enter hot well
	633-650	Valve work
	650-678	FW preheaters
12S	0-175	Removing No. 10 generator bearing (bent rig)
	175-460	Installing LP rotor
	460-560	Installing HP rotor
	560-628	Coupling stud stretching
	628-686	Removing hot well pump motor
13S	0-165	Removing hot well pump
	165-192	Hot well pump area after removal of pump "C"
	192-208	Hot well pump motor "C" in storage location
	208-253	Hot well pump
	253-322	Installing diaphragm on LP turbine
	322-328	Thrust bearings and shoes
	328-341	Replacing HP turbine front end component
	341-385	Installing LP turbine diaphragm
	385-402	Bearing work
	402-673	Installing LP inner casing
	673-End	Hot well pump

A

Tape No.	Footage	Description
14S	0-108	Hot well pump and turbine deck
	108-251	HP turbine
	251-288	LP turbine lagging
	288-308	Valve below surge tank on 6th level
	308-368	Shifting HP turbine to check thrust play
	368-430	Hot well pump area work
	430-465	Pipe work near hot well area
	465-498	EFWP and condensers
	498-530	Main steam lines below turbine
	530-546	Uncoupled valve (system was not completely drained)
	546-599	Tightening bolts on LP turbine lagging
	599-606	Coupling HP to LP turbine
	606-650	HP turbine outer casing
	650-676	Installing studs in HP turbine casing
15S	0-293	Alignment and coupling between LP and HP turbines
	293-388	Installing diaphragm on HP turbine
	388-426	Slug torquing coupling studs
	426-443	Applying linseed oil to diaphragm seating surface
	443-500	Installing diaphragm on HP turbine
	500-525	HP turbine inner casing
	525-585	Interference
	585-589	Steam pipe to HP turbine
	589-630	Thrust bearing cover being leveled
	630-648	Applying sealing compound to bearing cover seating surfaces
	648-678	Installing coupling cover end plate
16S	0-078	Installing thrust bearing cover
	078-131	Interference
	131-238	Installing HP turbine casing
	238-261	Applying "Never-Seize" to diaphragms
	261-293	Applying XXX linseed oil to casing
	293-619	Installing HP turbine cover casing
	619-636	Installing thrust bearing cover
	636-678	Installing remainder of HP turbine studs

Tape No.	Footage	Description
17S	0-431	Installing castle nuts on HP turbine
	431-570	Tightening castle nuts with impact wrench
	570-680	Placing insulation bags on HP turbine casing
18S	0-080	HP turbine gage panel
	080-112	General area shot after assembly
	112-179	Turning gear motor
	179-210	Brush rigging, etc. — Alterex
	210-263	More general area
	263-End	Blank

1.2. Oconee 3 Slide Film Index

Set No.	Description
1	Castellated nut support tool
	MSRH manway work
	Lifting HPT casing
	HPT without top half of casing
	HPT top half casing on support blocks
2	HPT diaphragm damage
3	HPT diaphragm damage
4	HPT diaphragm damage
5	LPT inner casing
	No. 1 bearing damage
	LP turbine diaphragms
	LP turbine A to LP turbine B coupling
	HPT rotor
6	Removing LP turbine rotor
	LP turbine casing
7	LP turbine lower diaphragm sections
8	LP turbine B bearing
	Intercept reheat control valve
	General valve work
	No. 5 bearing

A

Set No.	Description
8 (Cont'd)	LP turbine A to LP turbine B coupling
	Impact wrench
	Thrust bearing shoes
	HWP 3C removal
	HWP expansion joint
9	HWP 3C removal
	LP turbine inner casing
	HP turbine rotor
	No. 2 bearing and thrust bearing
	Intercept reheat control valve
	Front standard
	HWP 3C foundation
	HP turbine casing
	Generator housing and No. 10 bearing area
	Tightening LP turbine inner casing stud
	General valve work
	FWPT
	Feed booster pumps
	LPSW pump and motor
	Old 3C HWP
	HWP 3C replacement
10	HWP 3C replacement
	LP turbine A and HP turbine
	HP turbine to LP turbine A coupling
	Bearing installation
11	General valve work
	TIG welding and welding booth
	HWP strainer and expansion joints
	HWP 3C installed
12	HP turbine without casing
	Alterex without cover
	HP turbine casing
	Feedwater pump and turbine

Set No.	Description
12 (Cont'd)	HWP strainer and expansion joints
	Lake in basement
	LP turbine A outer casing bolt replacement
	HP turbine to LP turbine coupling work
	General valve work
13	LP turbine A to LP turbine B coupling
	HP turbine and front standard
	Cal-Rod heater stand
	Replacing HP turbine diaphragms
	HP turbine to LP turbine A coupling
	No. 1 bearing and labyrinth seal
14	HP turbine casing and turbine assembly
	No. 2 bearing work
	No. 3 bearing
	MSRH
15	HP turbine casing replacement
16	HP turbine casing installed
	Castellated nut replacement
	Front standard gage panel
	MSRH manway
	Turbine floor general area
17	Cal-Rod heater supply
	Condenser interior
	Feed system flow orifices
	Insulation replacement/repairs
	Rotor lifting beam
	Alterex slip ring
18	HP turbine lagging
	Turbine floor general area
	Alterex slip ring
	General shots of turbines

A

2. Videotape and Slide Film Index for Arkansas Nuclear One

2.1. Videotape Index

Tape No.	Footage	Description
1S	0-140	Slug torquing removal of HP turbine inlet flanges.
	141-215	Removing LP turbine crossover piping
	216-355	General HP turbine work (inlet flanges, insulation removal, etc.)
	356-415	General turbine bldg pan (main steam piping supports, crossover piping work, etc.)
	416-560	General HP turbine work (slug torquing inlet steam flanges)
	561-End	LP turbine crossover piping removal work (insulation removal, etc.)
2S	0-196	LP turbine crossover piping removal work (using air impact wrench to remove flange nuts)
	197-310	HP turbine casing bolts, detensioning operations
	311-365	Slug torquing HP turbine piping flanges
	366-565	HP turbine detensioning operations
	566-588	Slug torque removal of HP turbine inlet piping
	589-658	HP turbine detensioning unit in packing crate, lay-down area in front of turbine, moving second detensioning unit onto turbine, detensioning operations
	599-End	Removing oil and gland seal lines on HP turbine
3S	0-063	Removing oil and gland seal lines on HP turbine
	064-462	HP turbine detensioning operations
	463-492	Checkout of malfunctioning detensioning unit
	493-End	HP turbine detensioning operations
4S	0-064	HP turbine detensioning operations
	065-118	HP turbine inlet flange disassembly
	119-147	HP turbine detensioning operations
	148-253	General pan of turbine deck
	254-330	General HP turbine work area preparation (inlet flange disassembly)
	331-End	HP turbine detensioning operations
5S	0-End	HP turbine detensioning operations

Tape No.	Footage	Description
6S	0-450	HP turbine detensioning operations
	451-533	General turbine deck pan (moving rotor lifting cables, etc.)
	534-563	New LP turbine rotor and pan of unit 2 turbine deck
	564-576	Men in skip box being lifted by turbine bldg crane into place to work LP turbine crossover piping
	577-600	General turbine deck pan
	601-End	Attaching lifting cables to LP turbine crossover piping in preparation for lifting
7S	0-100	Attaching lifting cables to LP turbine crossover piping
	101-End	Not used
8S	0-608	Attaching lifting cables to LP turbine crossover piping
	609-645	Preparation for removing MSR outlet piping to repair leaking gasket (some general turbine deck pictures)
	646-End	Preparations of HP turbine rotor storage stand
9S	0-End	Preparation and lifting of No. 1 LP turbine crossover piping and storage on turbine deck
10S	0-476	Setting No. 1 LP turbine crossover over pipe down on turbine deck
	477-508	General turbine deck pictures (equipment arrangement, etc.)
	509-End	HP turbine detensioning operations
11S	0-124	HP turbine detensioning operations
	125-135	General turbine deck pictures
	136-170	Moving HP turbine throttle valve operator for storage
	171-228	HP turbine detensioning operations
	229-494	General turbine deck pictures (supports for LP turbine outer cylinder laydown, pan of Unit 2, new LP turbine rotor, LP turbine crossover piping laydown, LP turbine blade rings, and HP turbine rotor storage stand)
	495-555	HP turbine detensioning operations
	556-628	General turbine deck pictures
	629-End	HP turbine detensioning operations

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Tape No.	Footage	Description
12S	0-382	Preparation to remove steam inlet flange ring for No. 1 LP turbine
	383-426	HP turbine detensioning operations
	427-452	Removing solid block insulation from HP turbine
	453-468	No. 1 LP turbine outer cylinder in storage
	469-636	Preparations to remove No. 1 LP turbine inner cylinders (use of air impact tool to remove casing bolts), removing upper bearing caps on No. 1 LP turbine
	637-End	HP turbine detensioning operations
13S	0-030	Removing HP turbine gland seal steam piping
	031-085	General turbine deck pictures
	086-326	Slug torquing removal of turbine coupling bolts, use of drift punch and sledge hammer to remove bolts from coupling
	327-420	Lifting No. 1 LP turbine inner cylinder flange ring
	421-End	HP turbine detensioning operations
14S	0-100	Removing HP turbine monorail
	101-183	Blowing insulation dust off HP turbine
	184-275	General view of turbine deck, turbine rotor lifting beam in place over HP turbine.
	276-355	Preparing HP turbine rotor stand and storage area for HP turbine cover
	365-490	HP turbine lifting beam being maneuvered into place for lifting HP turbine cover, hooking up cables to the HP turbine cover and adjusting turnbuckles
	491-End	Lifting HP turbine cover
15S	0-End	Lifting HP turbine cover
16S	0-End	Lifting HP turbine cover
17S	0-End	Lifting and laying down HP turbine cover
18S	0-136	Laying HP turbine cover on turbine deck
	137-295	HP turbine lower casing and general equipment arrangement on turbine deck
	296-385	No. 1 LP turbine inner cylinder removal (bolt work)
	386-403	Cutting plywood plugs for HP turbine outlet piping holes in lower casing
	404-607	Moving detensioning unit into place on No. 1 LP turbine inner cylinder

Tape No.	Footage	Description
18S (Cont'd)	620-End	No. 1 LP turbine inner cylinder removal work (stud cleaning for detensioning), lowering detensioner into place
19S	0-End	Detensioning No. 1 LP turbine inner casing
20S	0-416	Work area support pictures (basement and other levels, valve work)
	417-432	MSR manways
	433-446	LP turbine work area
	447-460	No. 1 LP turbine inner cylinder and blade rings in storage on turbine deck
	461-481	No. 1 LP turbine rotor blades and inner cylinder in place, crossover piping in storage, general turbine deck pictures
	482-503	MSR relief lines over turbine deck area for condensate pump removal
	504-513	No. 1 LP turbine inner cylinder work
	514-523	HP turbine throttle valve and coupling work
	524-533	HP turbine cover and monorail on turbine work
	534-540	Turbine components in storage on turbine deck
	541-558	Pictures of HP turbine and area, HP turbine cover in storage on deck
	559-580	FW heaters and general area (valve arrangement)
	581-End	Not used
21S	0-385	Removal of HP turbine upper blade rings
	386-406	HP turbine casing bolt removal from HP turbine cover
	407-End	HP turbine upper blade ring removal
22S	0-121	HP turbine upper blade ring removal
	122-205	Removal of HP turbine blade ring bolt from HP turbine lower casing
	206-263	General pictures of No. 1 LP turbine deck, view of No. 1 LP turbine inner cylinder, new LP turbine rotor inside blast cleaning tent
	264-293	HP turbine upper bearing removal
	294-367	Taking HP turbine clearances
	368-440	No. 1 LP turbine journal bearing removal
	441-449	No. 1 LP turbine journal bearing pictures
	450-487	No. 1 LP turbine awaiting removal (closeups of turbine parts)

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Tape No.	Footage	Description
22S (Cont'd)	488-550	Preparations for HP turbine rotor removal
	551-568	Pictures of HP turbine storage stand
	569-End	Preparations for lifting HP turbine rotor
23S	0-249	Preparations for lifting HP turbine rotor
	250-End	Lifting of HP turbine rotor
24S	0-End	Lifting of HP turbine rotor
25S	0-178	Lifting of HP turbine rotor and setting down on storage stand
	179-220	HP turbine rotor in blast cleaning tent
	221-280	HP turbine and No. 1 LP turbine casing pictures (flange work on HP turbine), general turbine deck pictures
	281-297	Blast cleaning equipment
	298-367	Turbine lower casings, general turbine deck pictures
	368-375	New LP turbine rotor being rigged for lifting
	376-503	Turbine deck pan, blast cleaning equipment, new HP turbine casing bolts
	504-End	Not used
26S	0-071	Valve arrangement for maintenance
	072-141	Breaker arrangements, cleaning breaker cabinets
	142-182	Loading bay
	183-194	Electrical breakers
	195-234	Plant valve arrangements
	235-260	General pictures of turbine couplings, bearings, rotor
	261-282	Main feed pump pictures
	283-290	Turbine bolt pictures
	291-299	No. 1 LP turbine rotor and inner cylinder
	300-319	Main feed pump and general area pictures (LP turbine crossover piping)
	320-332	Main feed pump turbine and pump
	333-344	Breaker panel
	345-362	Turbine components in storage on turbine deck
	363-408	HP turbine rotor on storage stand, turbine bearings, and old LP turbine rotor
	409-417	Turbine components on turbine deck

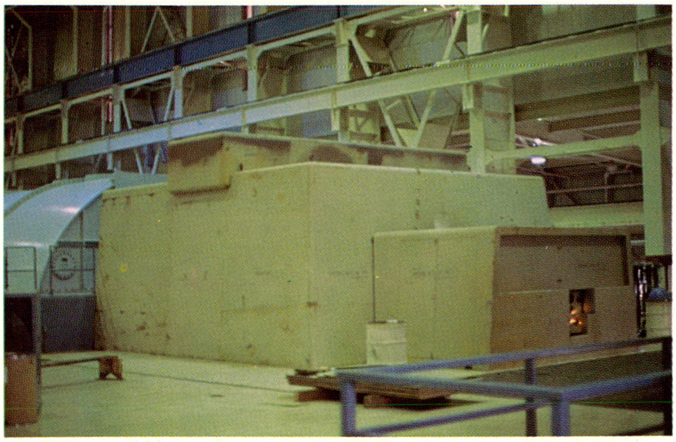
Tape No.	Footage	Description
26S (Cont'd)	418-506	Turbine components in storage on turbine deck, generator inspection, bearing caps, gland seal piping, casing bolts, blast cleaning machine
	507-536	B&W office
	537-669	ANO outside pictures
	670-End	Dardanelle Dam and Hydroelectric Station
27S	0-200	Dardanelle Hydroelectric Station
	201-222	ANO site from Mt. Nebo
	223-253	General pictures of blast cleaning
	254-296	HP turbine bearings, turbine couplings, turbine lower casings
	297-319	HP turbine blade rings and inter-stage packing
	320-336	MSR tube work
	337-387	Main feed pump disassembly
	388-400	General turbine deck pictures
	401-424	HP turbine governor valves
	425-End	Sand blasting turbine bolts and nuts
28S	0-End	Hydraulic bolting system demonstration
29S	0-End	Hydraulic bolting system demonstration
30S	0-End	ANO snubber work
31S	0-End	ANO snubber work
32S	0-End	Various RB pictures (fuel transfer tube, RCP seal area, etc.)
33S,34S,35S	0-End	New rotor for No. 1 LP turbine being lifted from loading bay onto turbine deck before outage

2.2. Slide Film Index

Set No.	No. of Slides	General Description
1	14	Arkansas Nulcear One, Unit 2
2	18	ANO outside laydown area
3	9	Reactor building and cooling tower
4	65	General turbine building work
5	213	HP and LP turbine disassembly and inspection

A

Set No.	No. of Slides	General Description
6	42	NSW select-a-torq hydraulic bolting system equipment
7	48	Hydraulic bolting system applications

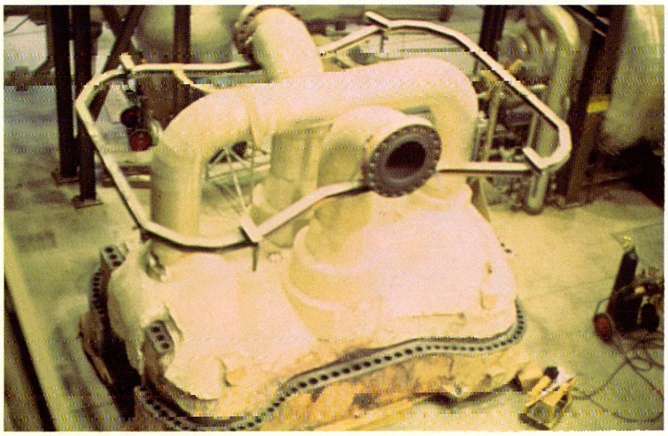


Slide 1

HP turbine outer shell fully assembled. Before actual turbine disassembly, many preparations can be made while the plant is cooling down before putting the turbine off the gear.

Slide 2

One such task is removal of the HP turbine outer shell. This component is stored as far away as possible to provide work space and prevent interference with work.



Slide 3

Another preparatory task is removing the HP turbine casing insulation pads. Although the turbine is still hot, performing this procedure now will prevent its being in the critical path and extending outage time.

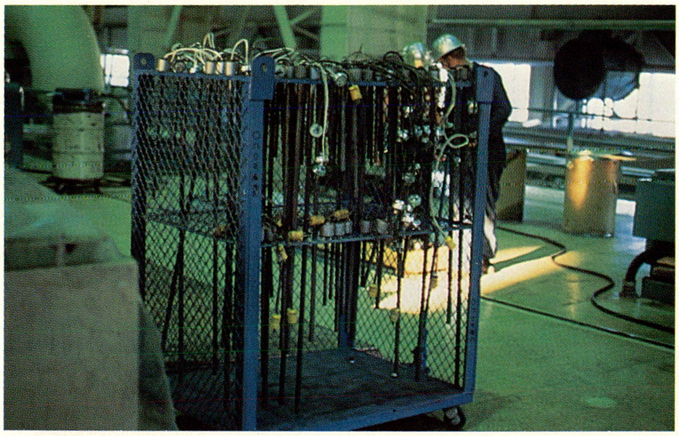
APPENDIX B

Oconee 3 BOP Maintenance, Inspection, and
Test Study — Photographic Summary

B

Slide 4

Work platforms must be built around the HP turbine (as shown here) for safety and easy access when removing the turbine casing stud nuts.

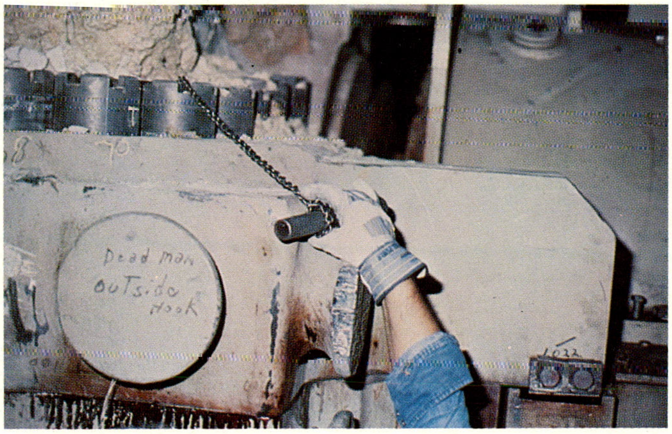


Slide 5

Cal-Rod heater elements and storage facility. These heaters are inserted through the HP turbine casing stud holes for detensioning and loosening the castellated nuts. It is important to check the heaters and associated power supplies completely before the outage to avoid delays caused by power supply failure.

Slide 6

After the turbine is off the gear, disassembly begins with detensioning the casing studs. This is done by inserting the Cal-Rod heater elements in the stud holes as shown and then heating until the lower nut is loose. (Note the two red-hot elements protruding through the bottom nuts.)



Slide 7

After the turbine is off the gear, HP turbine disassembly begins with detensioning the turbine casing studs. Shown here is the upper half of the special tool used by Duke's SSD turbine crew to support the HP turbine casing stud lower castellated nut during removal/replacement. The tool consists of a handle on the upper end and a support plate(s) on the lower end connected by a chain dropped through the center hole of the casing stud.

Slide 8

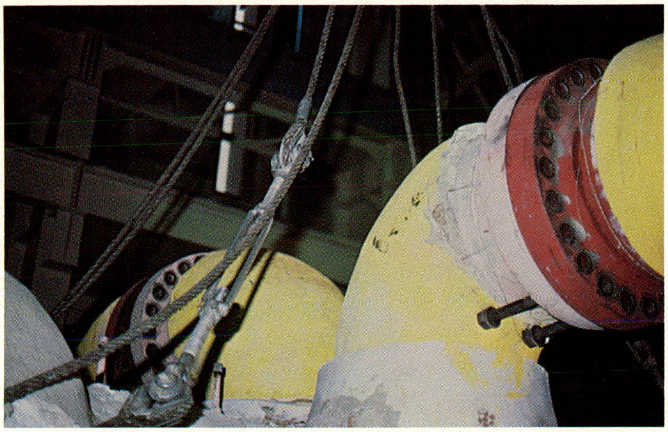
Lower half of the same tool, consisting of a support plate, after removing the lower HP turbine casing castellated nut. The plate is being unscrewed to allow removal of the chain.

Slide 9

Closeup view of lower half of the special tool. Extra plates are sometimes needed to hold larger castellated nuts. Note the small nut at the end of the threaded rod; this must be removed from the rod to shift to the next stud. A slight modification to the tool is recommended to eliminate this step and reduce removal time.

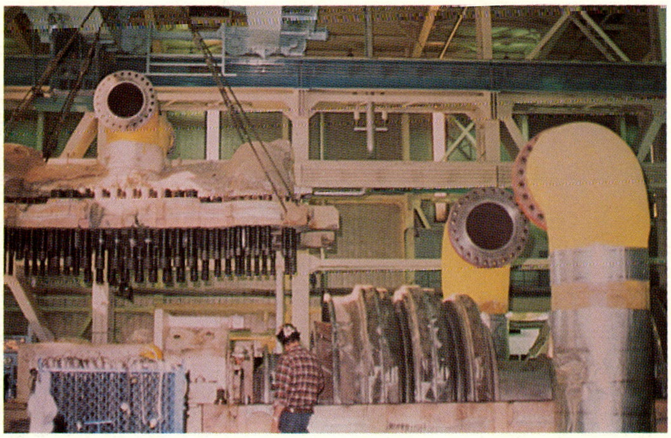
Slide 10

Closeup view of work area in Slide 9. Note chain extending down through stud hole. The cramped work area shows why the special tool is needed to support the weight of the castellated nut. Detensioning the HP turbine studs using Cal-Rod heaters and removing the castellated nuts took about 6 hours.



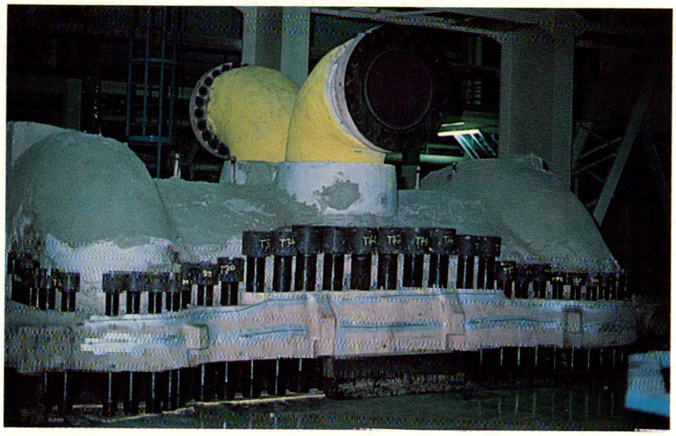
Slide 11

After removal of the HP turbine casing nut, the casing is ready to be lifted. Shown here is the rigging used to lift it. Load cells should be considered to balance the load with the overhead crane in lieu of "sounding" the wire ropes; this would be faster and more accurate.



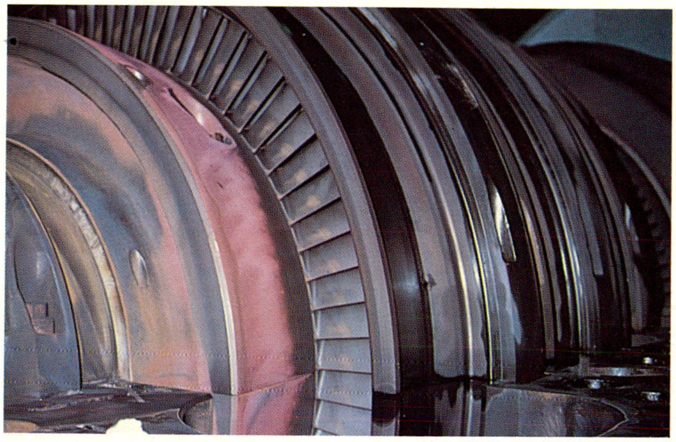
Slide 12

Shown here is the HP turbine casing being transported to a storage area. The upper diaphragm can be seen at the center of the photograph.



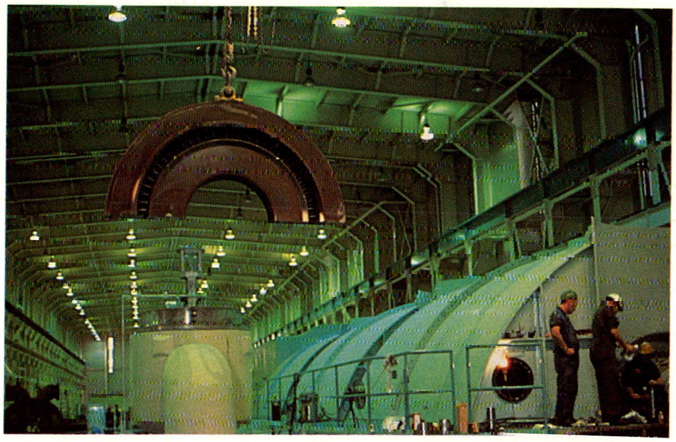
Slide 13

The HP turbine casing is laid down for inspection and cleaning. The studs are removed individually and cleaned. This is a parallel task that can be started now without affecting the critical path.



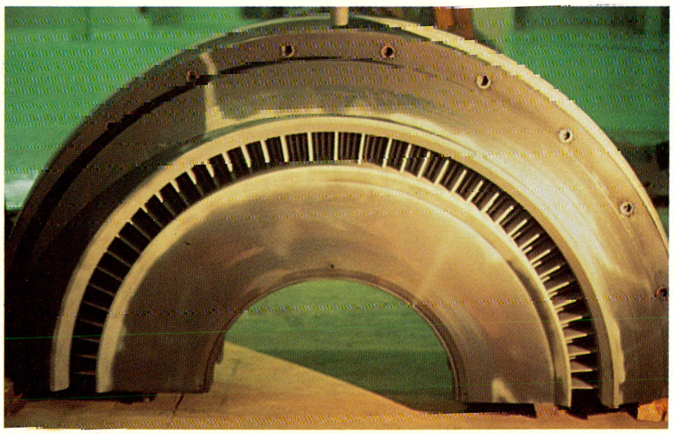
Slide 14

Closeup view of the HP turbine upper diaphragm in place. The bolts are unscrewed before the diaphragm is removed.



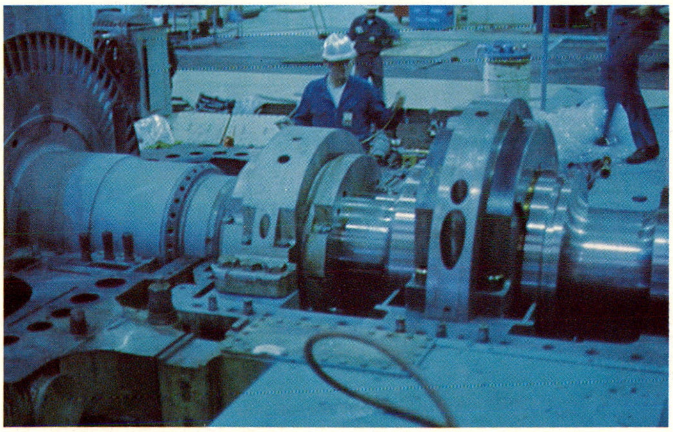
Slide 15

One of the HP turbine upper diaphragms being removed and transported to the work area for inspection and cleaning.



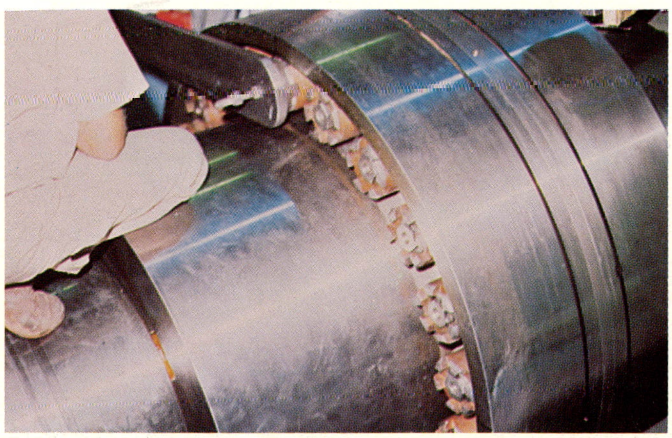
Slide 16

Turbine diaphragm after sandblasting. Prior to the outage, this diaphragm was to be shipped out for repair; during inspection it was determined that extensive repairs were not necessary.



Slide 17

Before lifting the rotor, several small jobs are done. For example, the packing heads and thrust bearing (shown here) are removed. Wheel readings are taken for thrust travel.

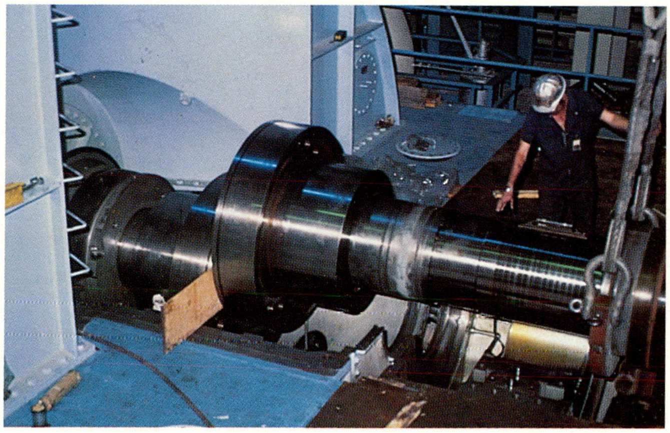


Slide 18

Another task includes unbolting the turbine shaft couplings, as shown here.

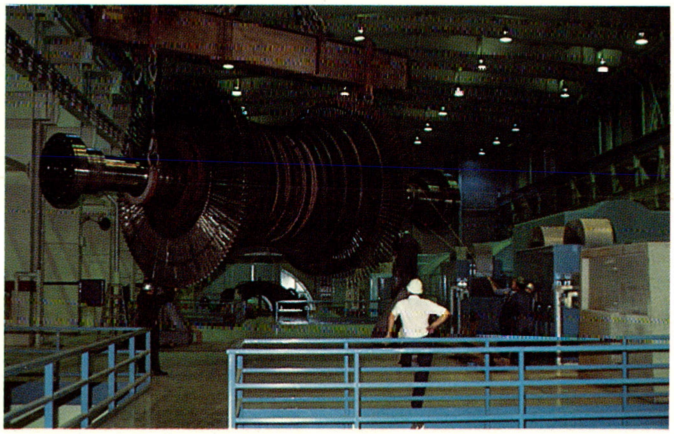
Slide 19

The HP turbine rotor is now ready to be lifted using a lifting beam hung from the overhead crane.



Slide 20

During removal of the rotor, a board is placed between the coupling faces to prevent damage to these surfaces during rotor removal.

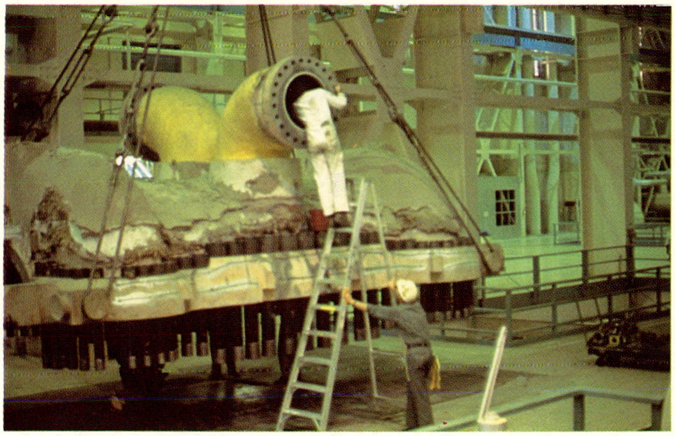


Slide 21

Rotor being transferred to a laydown area for inspection and cleaning. Note the excellent space available for storage of large components.

Slide 22

After the rotor is removed, the lower-half diaphragms can be lifted out as is being done here.

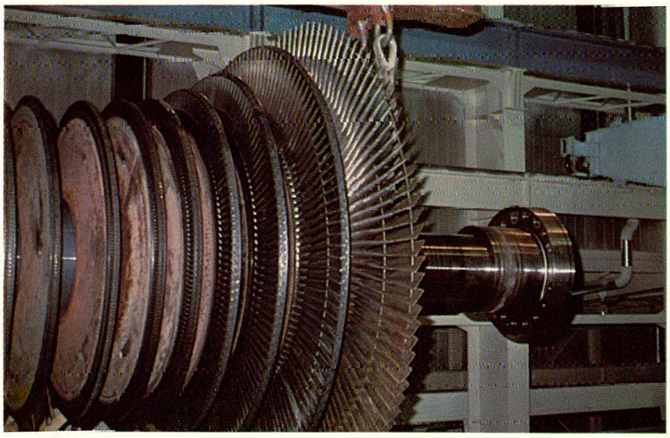


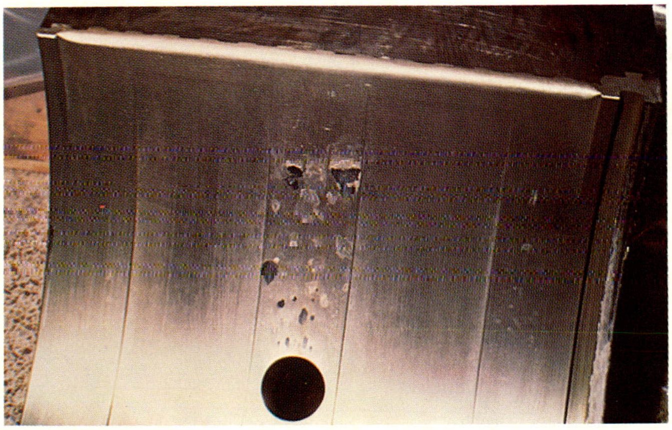
Slide 23

At this point, all HP turbine parts are inspected and cleaned, e.g., inspection and cleaning of the HP turbine upper casing shown here.

Slide 24

The rotor is also inspected by magnafluxing and is sandblasted.



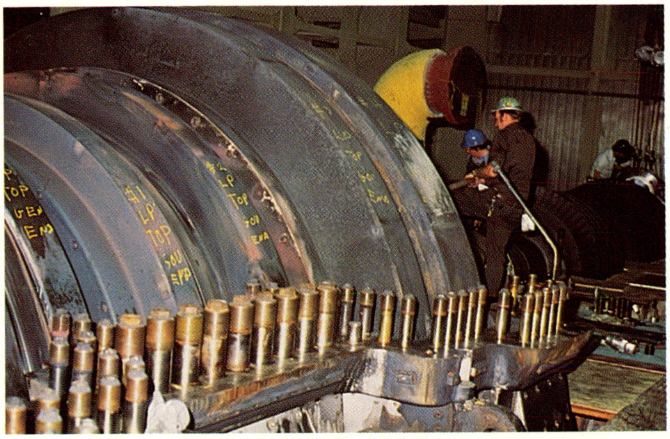


Slide 25

Closeup view of No. 1 turbine bearing half showing damage found during inspection. The bearing was sent to the vendor for repair, which slowed down other turbine work. To avoid unnecessary delays, spare bearings should be purchased. The concept of "remove, replace, repair" applies here.

Slide 26

During inspection and cleaning of the HP turbine parts, the LP turbine is being disassembled. Shown here are the upper-half diaphragms of LP turbine A after the inner casing has been removed.

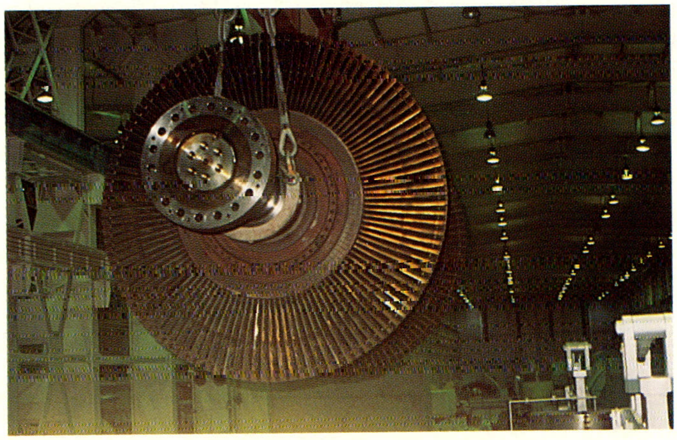


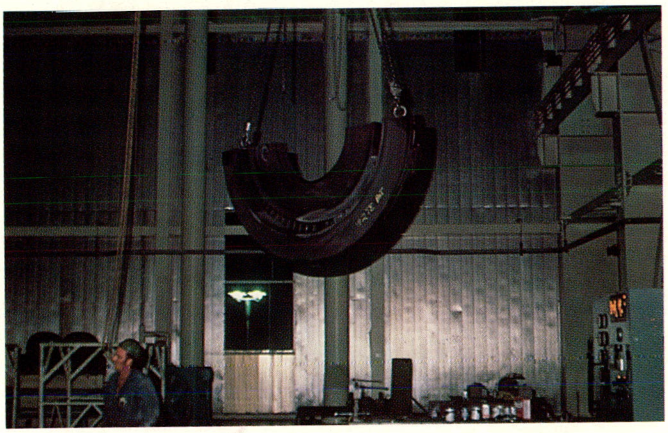
Slide 27

After removal of the upper-half diaphragms, the turbine rotor is lifted.

Slide 28

LP turbine rotor being transported to laydown area for cleaning and inspection.



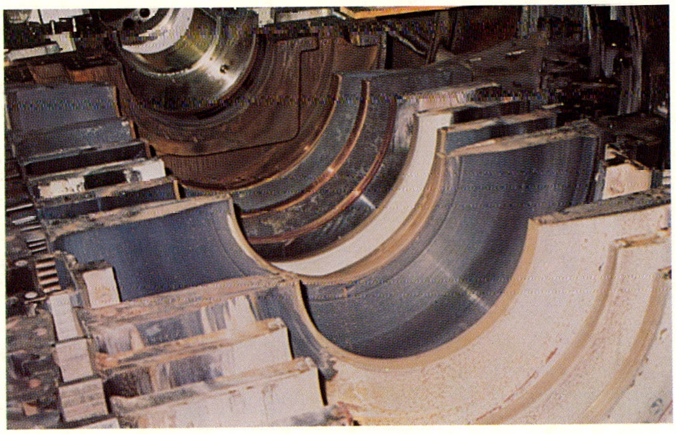


Slide 29

LP turbine lower-half diaphragms can now be removed for cleaning and inspection.

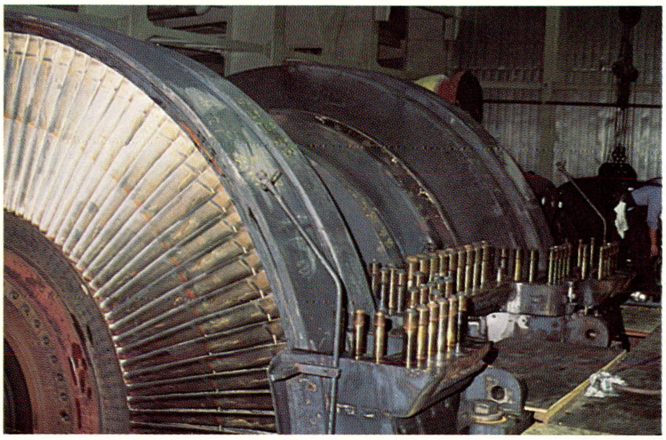
Slide 30

After inspection and cleaning, the turbine parts can be reassembled.



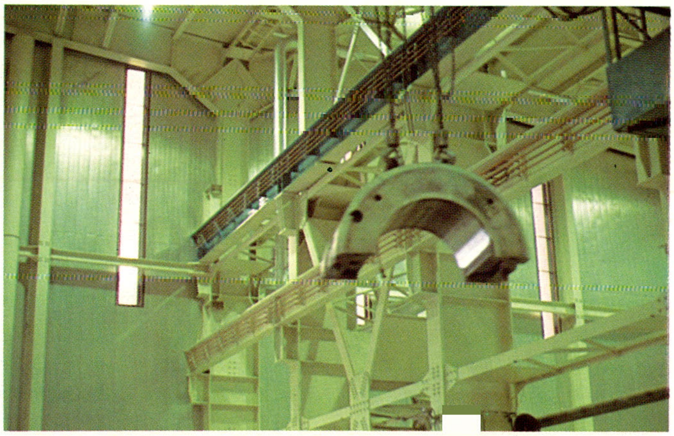
Slide 31

LP turbine rotor being set after the lower-half diaphragms are installed.



Slide 32

View of the LP turbine with upper-half diaphragm assembled.

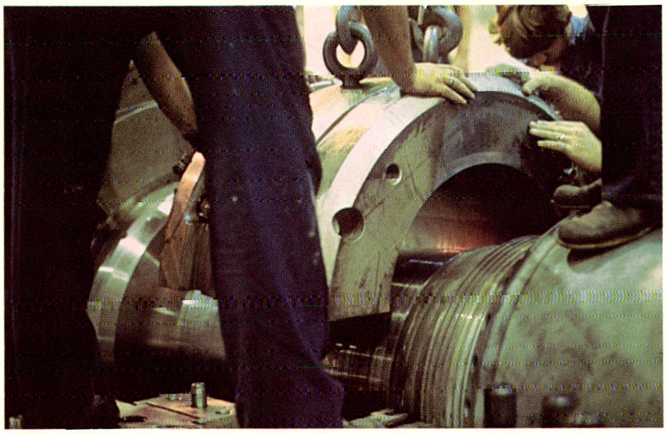


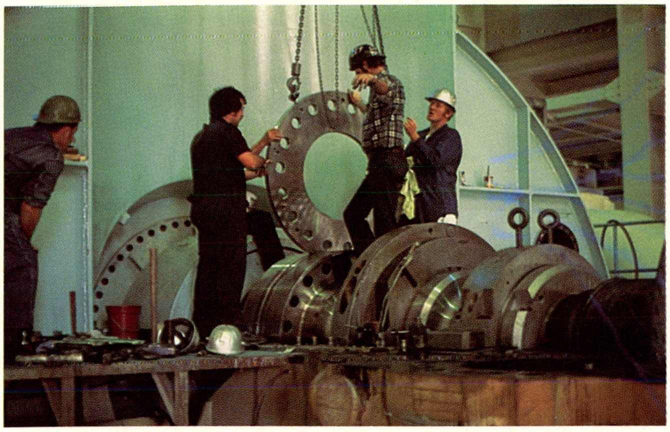
Slide 33

Reassembly of the HP turbine begins now. Shown here is a turbine bearing half being transported by an overhead crane.

Slide 34

The same bearing being set in place. Installation and removal of smaller components, such as this bearing, caps, and covers, could be handled by cherry-pickers or fork lifts. This would free the turbine crane for other activities that must be handled in that manner.



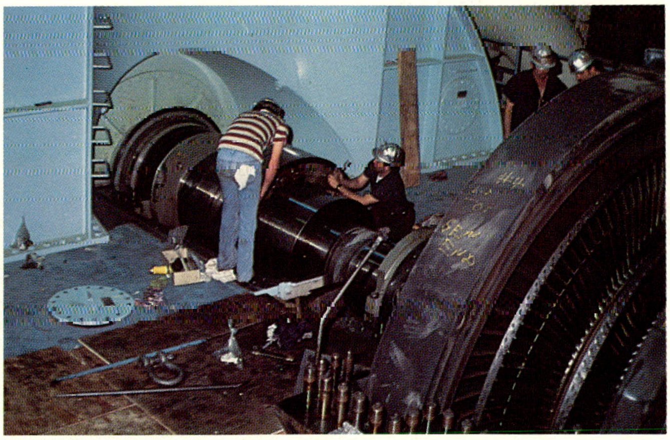


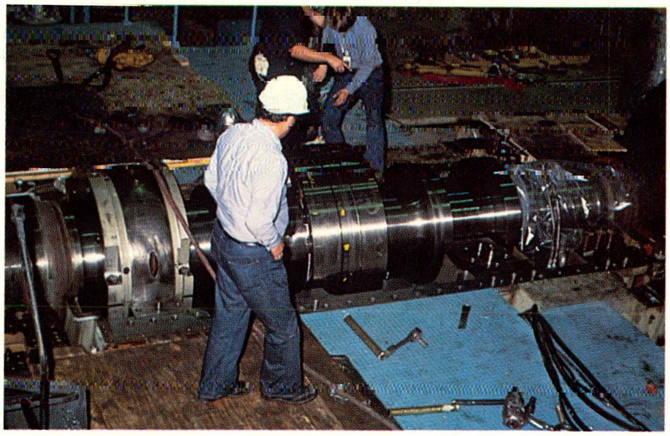
Slide 35

Coupling spacer between the A and B LP turbines being installed. Again, small components like this could be handled by a cherry-picker so as not to tie up the crane.

Slide 36

LP turbine coupling being bolted using a manual wrench and torque using the 25-ton crane. An HBS is recommended for breaking out and making up the coupling bolts in lieu of the present method. The HBS is faster and safer to use.



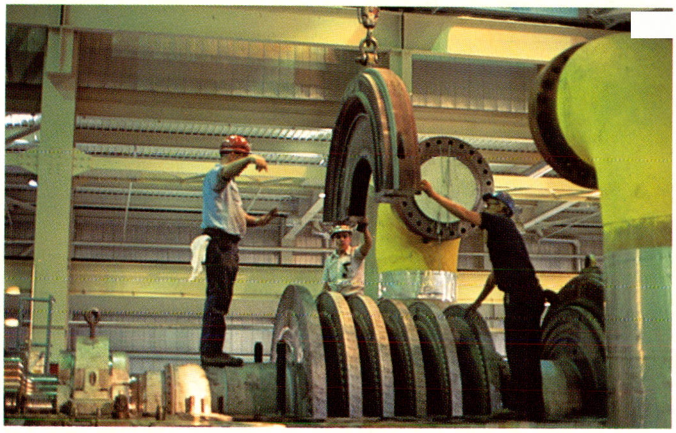


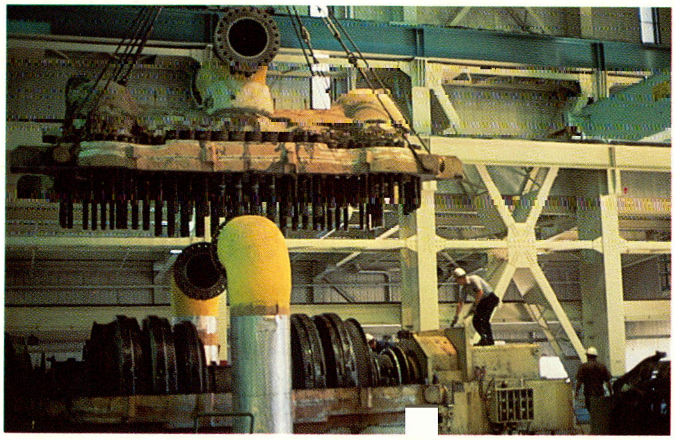
Slide 37

Taking measurements of bearing clearances, wheel readings, and turbine alignment (a time-consuming task).

Slide 38

After installation of the HP turbine lower-half diaphragms and the rotor, the upper-half diaphragms are installed as shown here (being lowered into place).



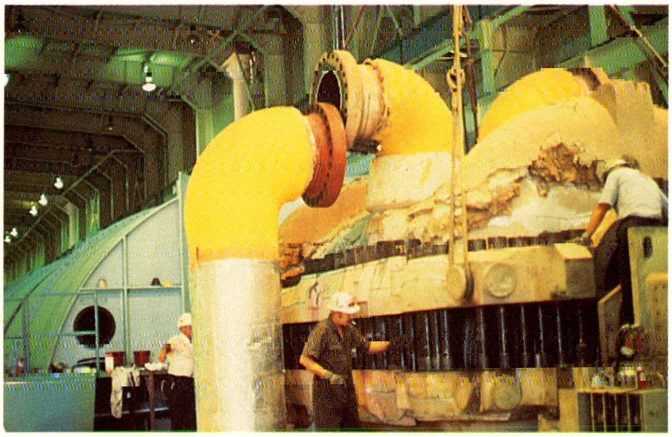


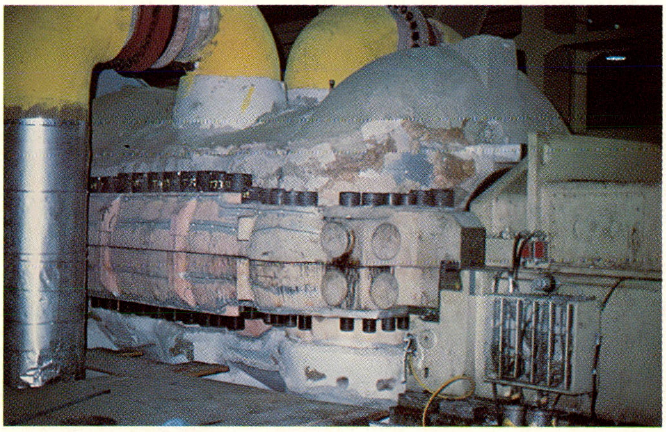
Slide 39

The HP turbine casing is installed next (shown here being lowered into place).

Slide 40

HP turbine casing almost seated.



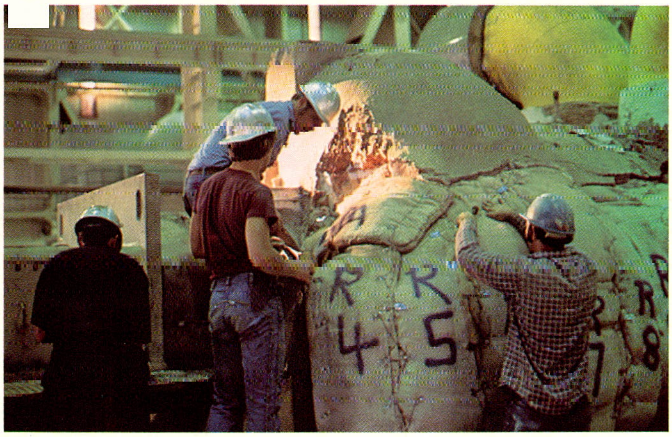


Slide 41

After the HP turbine is fully seated as shown, the lower casing castellated nuts are installed.

Slide 42

HP turbine casing studs being cold-torqued. An air-impact wrench is used, supported by the overhead crane. A portable, free-standing frame is recommended to support this tool and free the crane for other jobs, saving time.

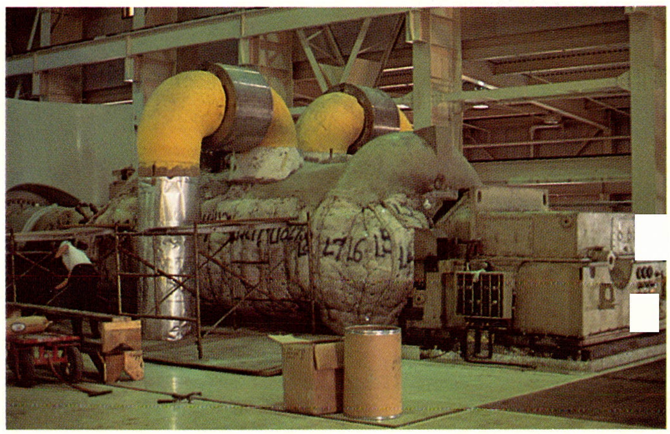


Slide 43

Installing the HP turbine casing insulation. Removal and installation of this insulation requires several hours. Using preformed metal insulation should be investigated as an alternative to reduce the time expended here.

Slide 44

Completing HP turbine insulation replacement. The number of sections of insulation mud used can lead to lost/damaged sections (as was the case during this outage), causing delays. This is another good reason for investigating preformed insulation.

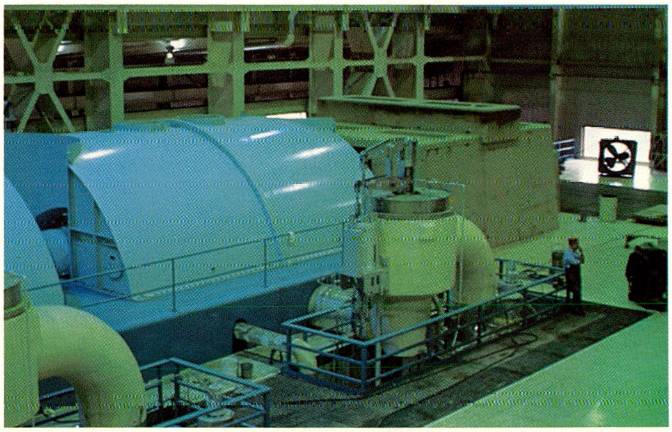


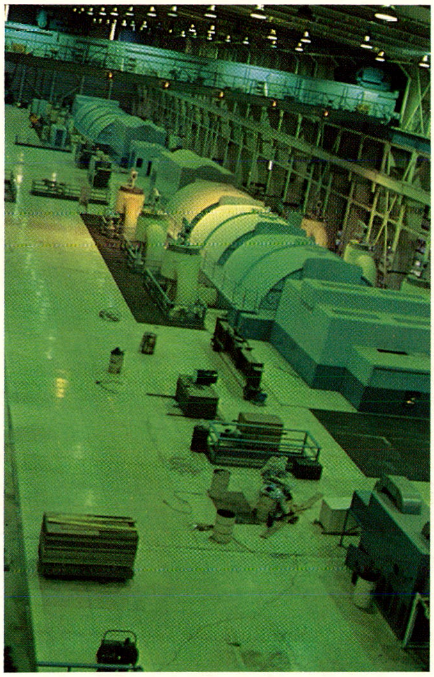
Slide 45

After the LP turbine outer shell is in place, the bolts are tightened.

Slide 46

General view of LP turbine A, the HP turbine, and the intercept reheat control valve after completion of turbine reassembly. These valves were disassembled, inspected, and cleaned during the outage.





Slide 47

General laydown area for inspection and cleaning of turbine parts. It is important to have adequate work space, as shown, to allow activities to proceed concurrently and without interference. The excellent laydown space at Oconee is evident since three units are housed in the same building.

Slide 48

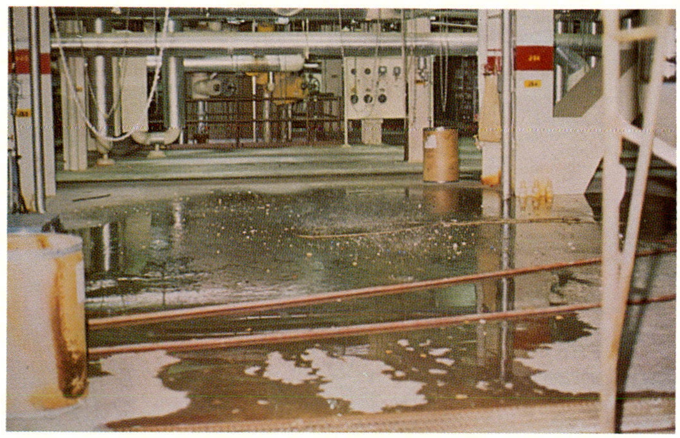
During the turbine outage other BOP work is done in parallel. One such task is modification of the MSRs. Entry into the MSRs requires removal of the manways by arc-gouging the seal weld on manway as shown. (The seal weld is necessary to prevent leakage during startup and operation.)

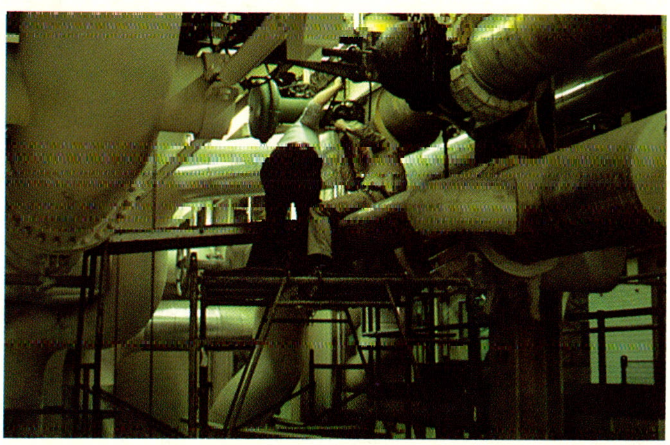
Slide 49

MSR manway after partial arc-gouging of seal weld. Many manhours are spent restoring areas damaged by seal welding and arc-gouging. Improvement of the MSR to eliminate seal welding while maintaining an airtight seal is recommended.

Slide 50

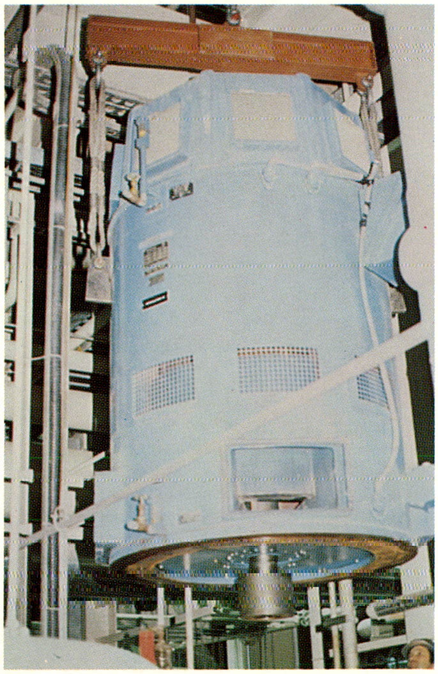
Draining/isolating the system should proceed with proper planning and coordination to prevent spillage as shown. This view shows the turbine building basement where contaminated water was spilled.





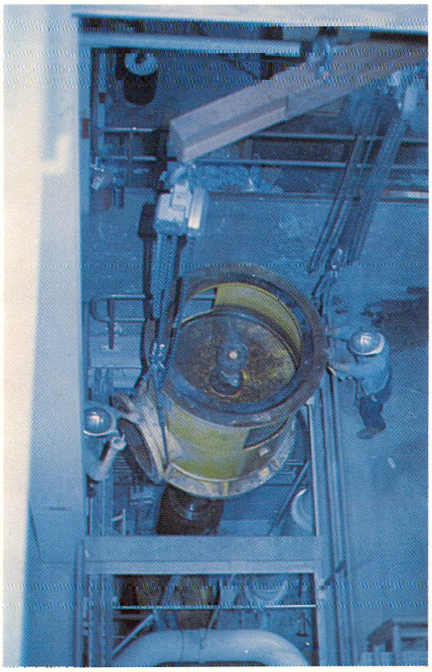
Slide 51

Valve maintenance work consumes many hours and resources during the outage. Proper planning, coordination, application of PM practices, and the use of sufficient scaffolding are key ingredients in preventing valve work from becoming critical path items.



Slide 52

Non-critical-path BOP activities include hot well pump removal/replacement. Here the motor is being moved from the basement using a special lifting beam.

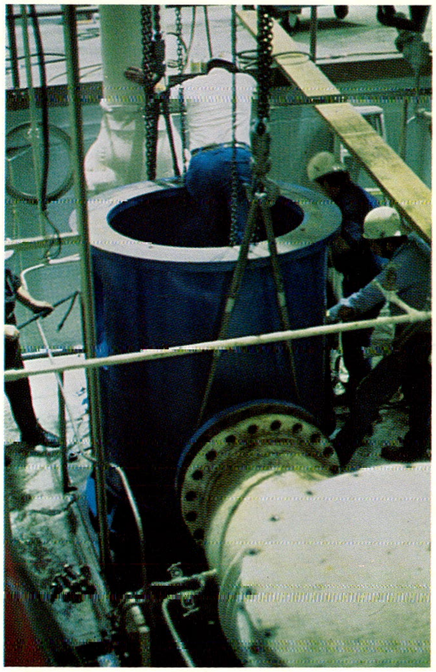


Slide 53

After the hot well pump motor is removed, the defective pump is lifted as shown.

Slide 54

The defective hot well pump is being laid down on the turbine floor. The motor rests on storage blocks in the foreground.



Slide 55

New hot well pump being set in place and aligned with piping flanges using the overhead crane. The "remove, replace, repair" concept, as shown here, should be implemented whenever possible since this allows defective parts to be repaired at the utility's convenience, thus avoiding potential delays during the outage.

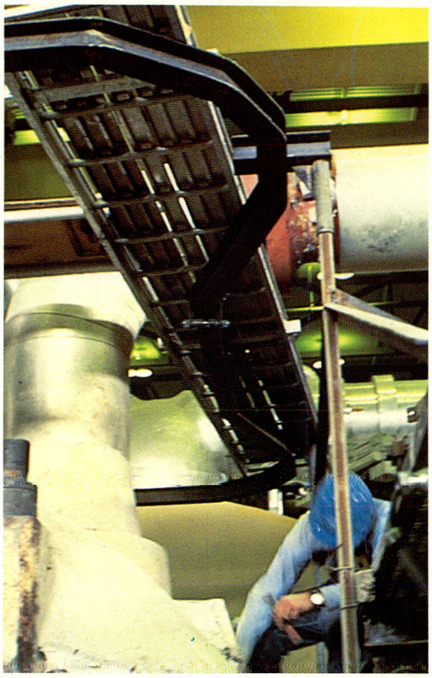
Slide 56

View of turbine deck after all work has been completed. The turbine outage, which included the disassembly of the HP turbine and LP turbine A, took 18 days from turning gear-to-turning gear. This excelent performance can be attributed to good planning, coordination, excellent laydown area, and the availability of well-trained, experienced personnel from the Duke SSD group.

APPENDIX C

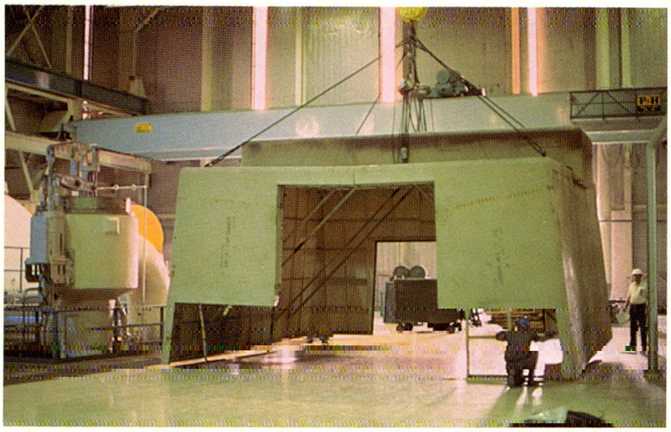
ANO-1 Recommendations — Illustrative Photographs

C



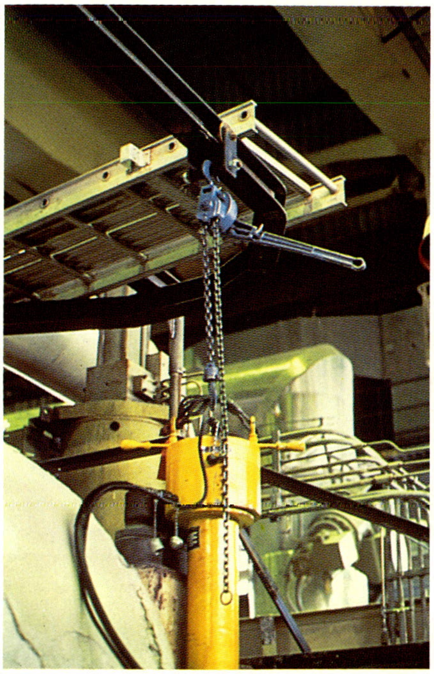
Slide 1

Section of HP monorail in position on HP turbine casing. Adding this monorail at ANO has saved at least 48 hours critical path time by allowing two tensioners to be used and freeing the building crane for other critical activities.



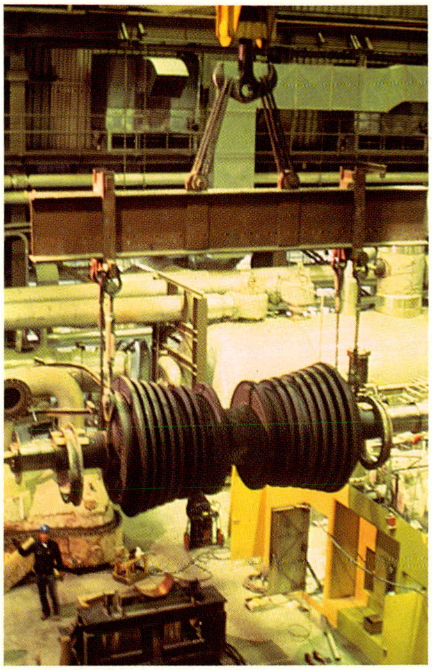
Slide 2

Bird's-eye view of monorail segment over HP turbine casing.



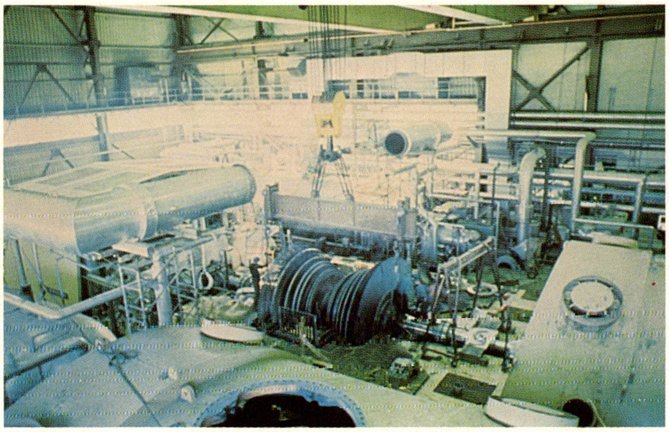
Slide 3

The HP turbine bolt detensioning unit is supported from the monorail. Using two detensioning units will speed up the process and allow the turbine crane to be used for other critical path activities.



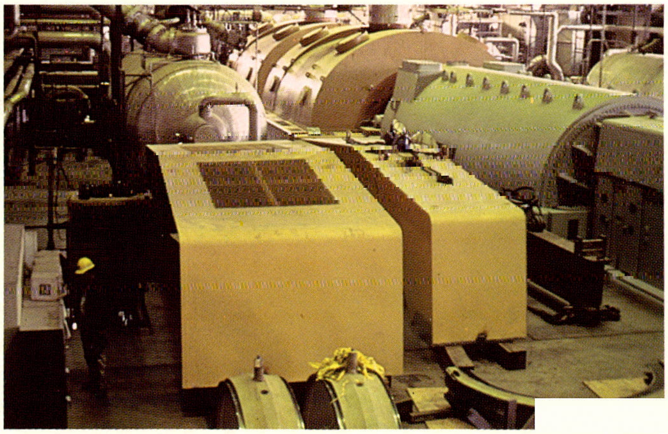
Slide 4

HP turbine rotor being removed using heavy equipment. When rigging and lifting large components such as the rotor and turbine casings, load cells or hydrosets should be used to verify equal loads and thus speed up this work effort.



Slide 5

No. 1 LP turbine rotor being removed for inspection. Note the congestion and poor access for laydown of large components.

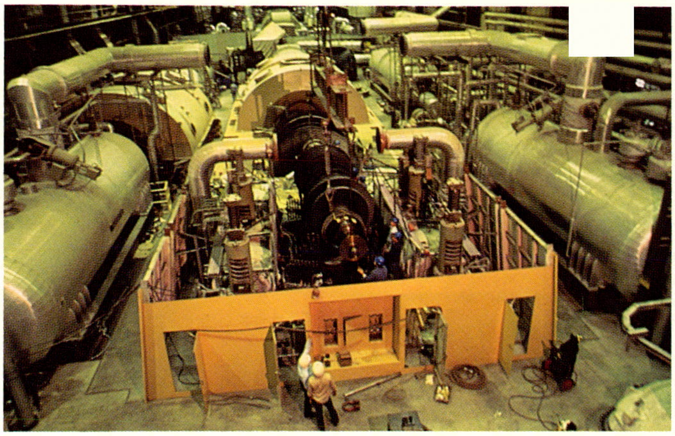


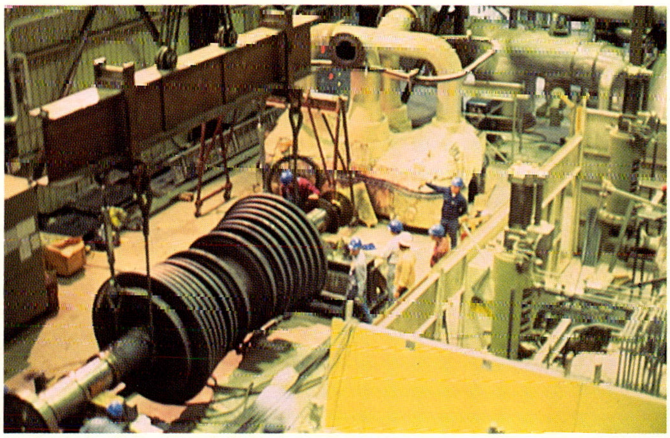
Slide 6

Turbine floor with HP turbine metal lagging in storage. The lack of laydown space is apparent in this photograph.

Slide 7

Overall view of ANO-1 turbine floor during removal of the HP turbine rotor. The upper turbine casing is shown in the lower left-hand corner of this view. Again, note lack of space.



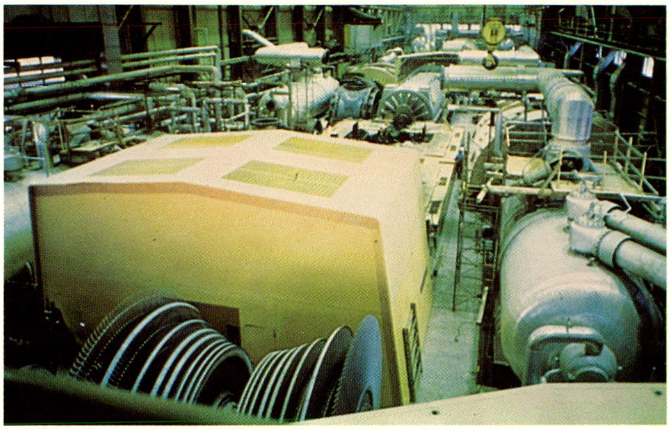


Slide 8

HP turbine rotor being removed for cleaning and inspection. All these area shots indicate the need to improve the laydown area in the turbine deck either by building an extension or modifying the roof to make it removable, thus allowing large components to be removed and stored outside.

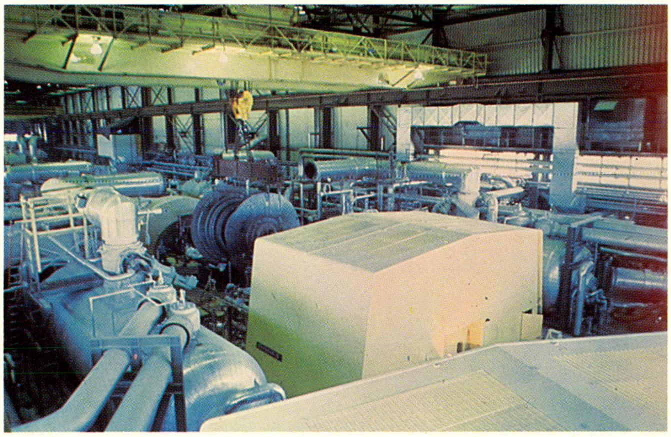
Slide 9

Area outside the turbine building where large turbine components could be laid down for storage, making room in the turbine deck for work space. Note the HP turbine metal lagging in storage.



Slide 10

HP turbine metal lagging is shown in place. The lagging is partially removed before turbine disassembly.

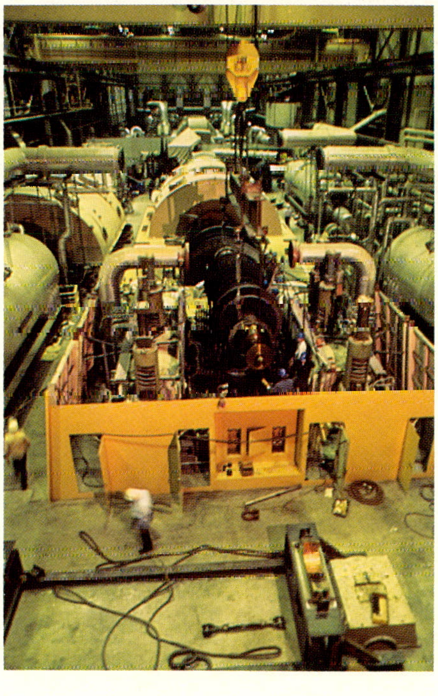


Slide 11

HP turbine metal lagging with portions removed. The laydown of this large component causes interference with movement of other turbine parts. For this reason the lagging was stored outside the building.

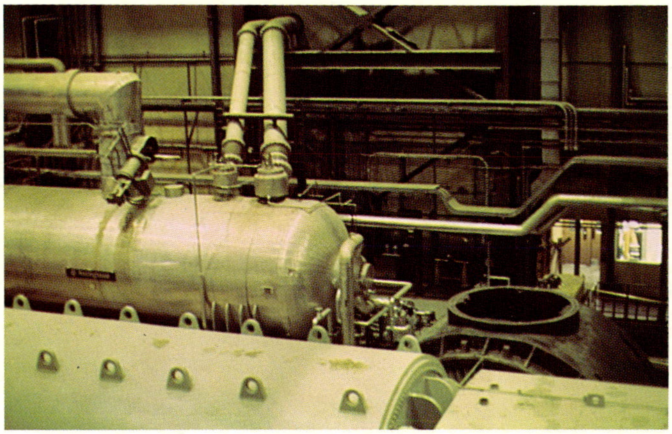
Slide 12

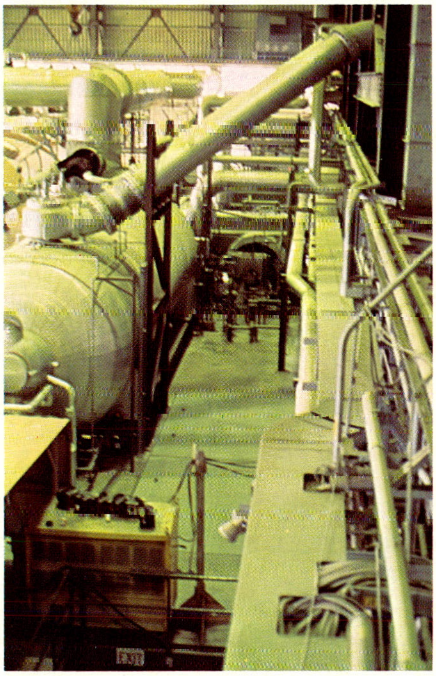
Lower portion of the HP turbine metal lagging, which is left in place during all the turbine work. This interferes with the smooth flow of work in the vicinity of the HP turbine. ANO should consider removing the entire metal lagging permanently since it serves no real purpose.



Slide 13

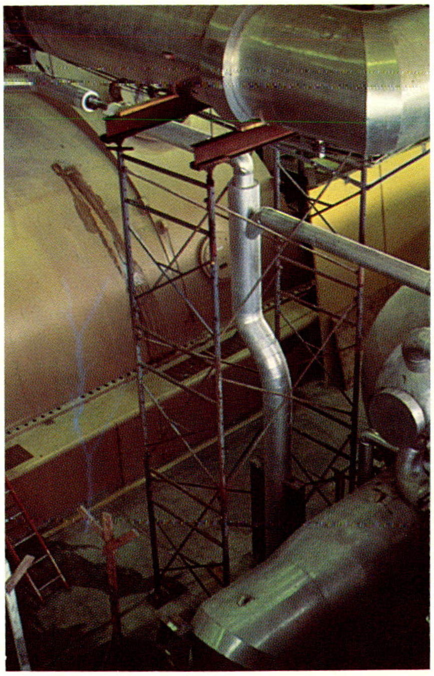
To work on a condensate pump, it must be lifted up from the basement and laid down on the turbine deck. However, the MSR relief lines are in the way, as shown here. Rearranging these lines would allow all three condensate pumps to be removed and overhauled during plant operation.





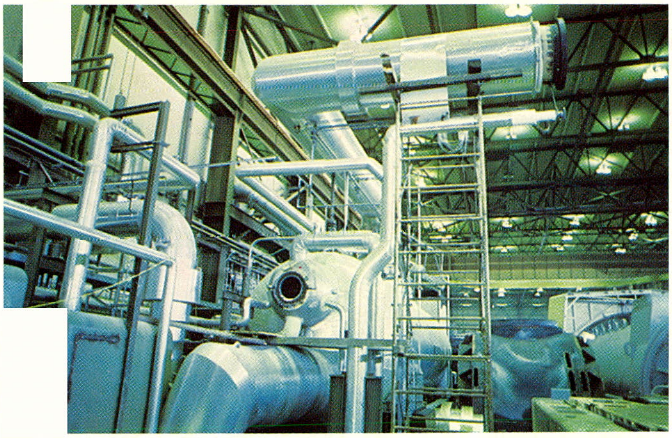
Slide 14

Another view of the MSR relief lines running over the removable deck through which the condensate pumps must be removed.



Slide 15

This overhead main steam line running above the turbine deck formerly had to be removed for turbine disassembly. If the line is supported by scaffolding, it does not have to be removed, thus allowing work to proceed sooner on turbine disassembly.

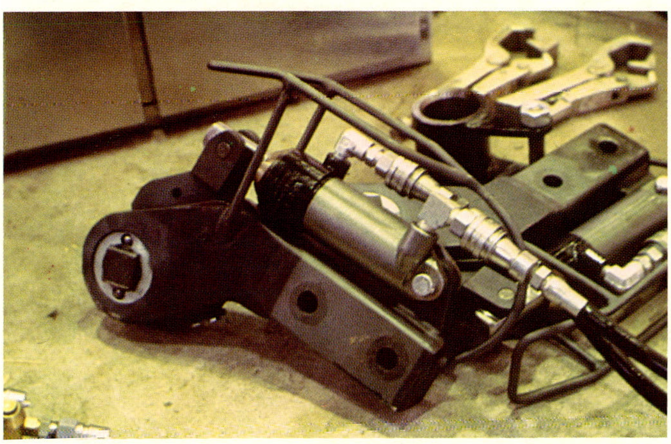


Slide 16

Another view of the steam line support, which saved many critical path hours.

Slide 17

The next six views show the N-S-W hydraulic bolting system units. This view is the N-S-W Select-A-Torq HBS 5000 EPP unit. The HBS can be used for a wide range of applications in the secondary plant and is estimated to save at least 100 hours critical path time.

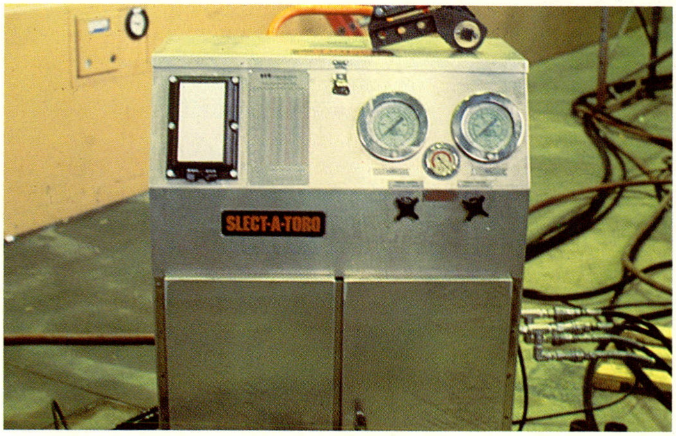


Slide 18

Medium-range HBS ratcheting head. The unit weighs 39 lb (17.7 kg), and its stud range is 1.25-3 in. (30-72 mm).

Slide 19

HBS main cabinet containing pump, gages, controls, and power controls.

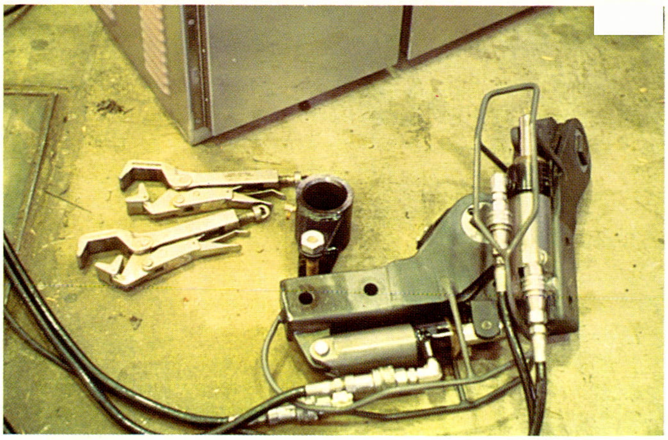


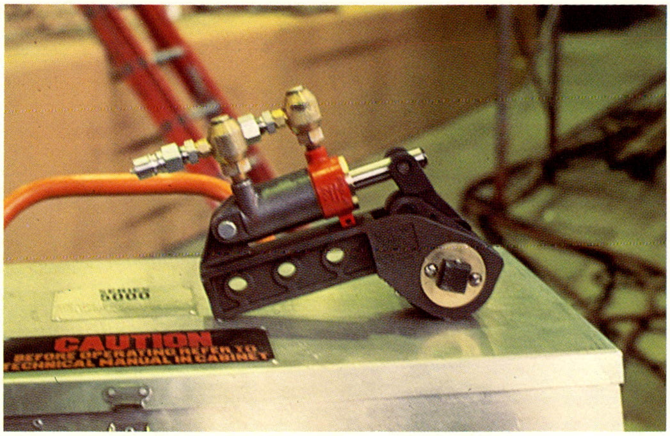
Slide 20

Some of the standard tooling available with the N-S-W HBS.

Slide 21

Medium-range ratcheting head with back-anchor and adjustable backing wrenches.



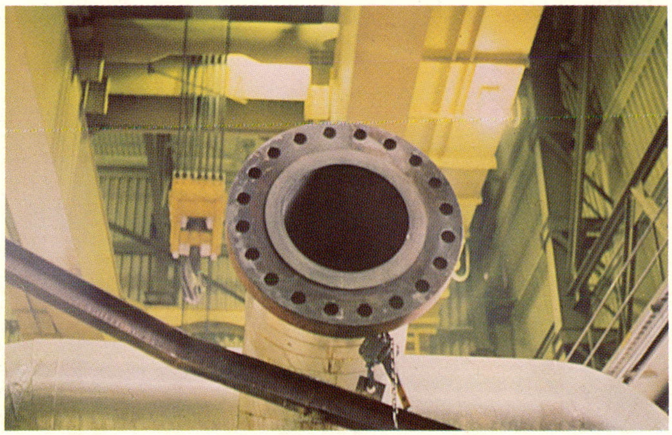


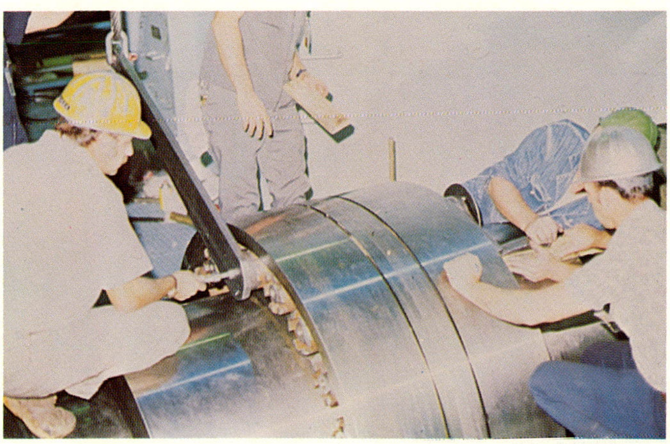
Slide 22

HBS light-weight ratcheting head. Weight 14 lb, stud size 0.75 to 1.75 inches.

Slide 23

The next series of slides shows the various applications of the HBS. The main steam piping flange for the HP turbine (shown here) can be worked with the HBS in approximately 25% of the time that was formerly required.



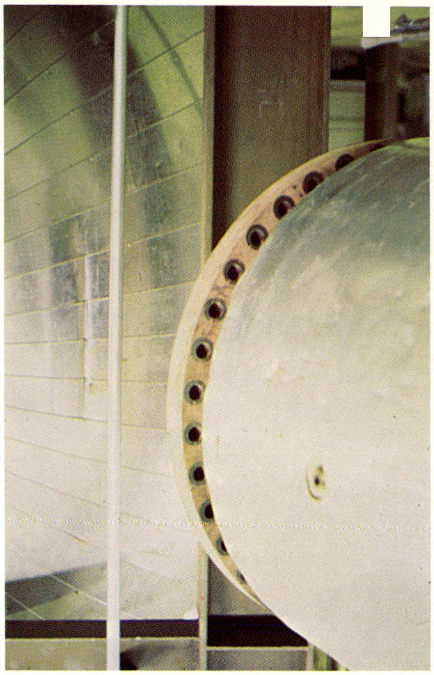


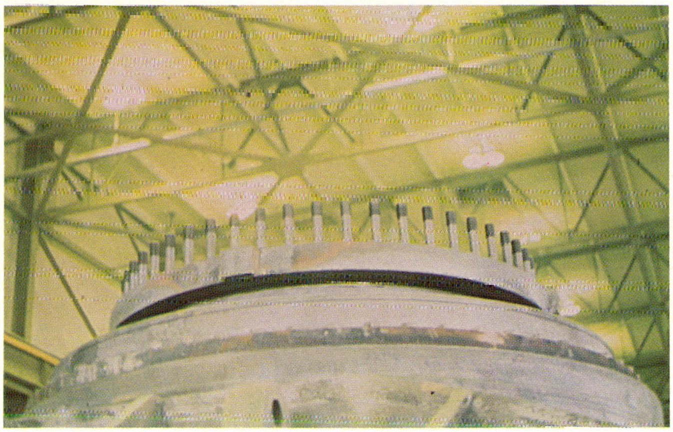
Slide 24

Main turbine couplings are excellent examples of effective HBS applications.

Slide 25

Closeup view of a large main steam line flange that will allow the HBS to be used to reduce makeup and breakout time. More than 90% of all steam line flanges can be worked by an HBS.



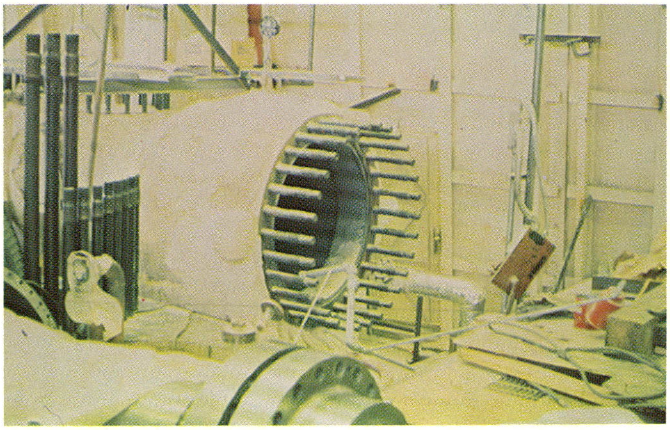


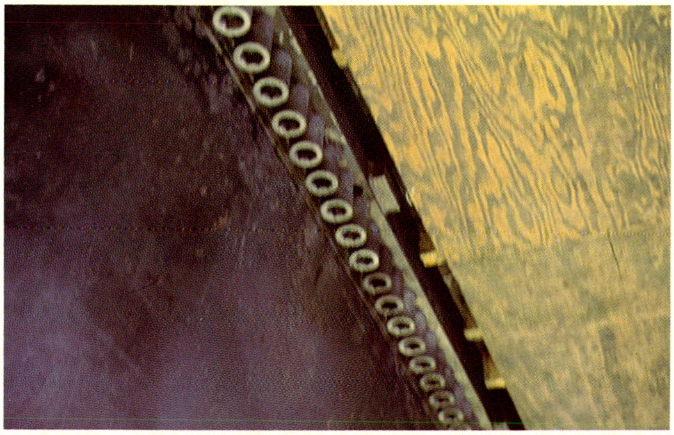
Slide 26

Disassembly and reassembly of the LP turbine inner casing flanges is another HBS application.

Slide 27

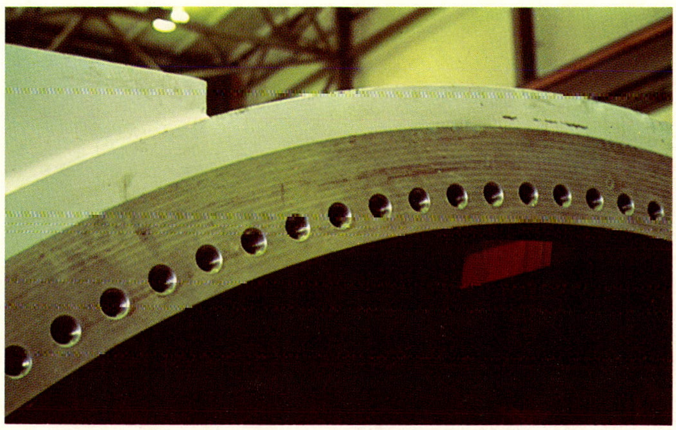
HP turbine throttle valve work is another large time-consumer readily worked with an HBS.





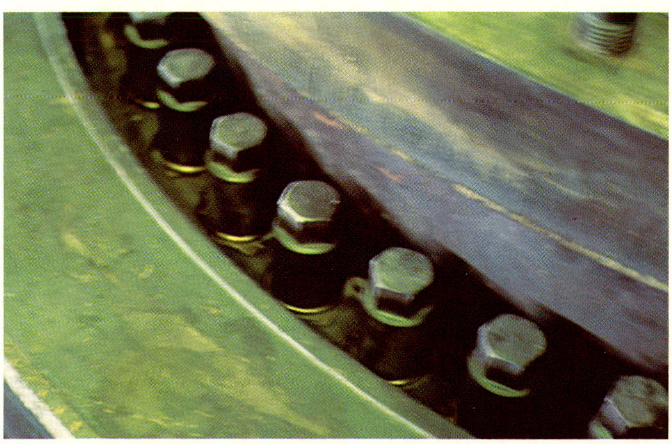
Slide 28

Typical LP turbine inner casing bolts that can be worked with an HBS.



Slide 29

An example of the bolt pattern on the main electrical generator end bell. This pattern can easily be worked with an HBS with standard tooling.

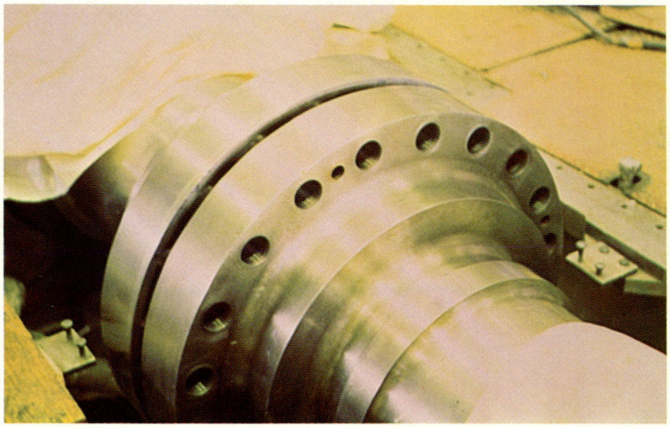


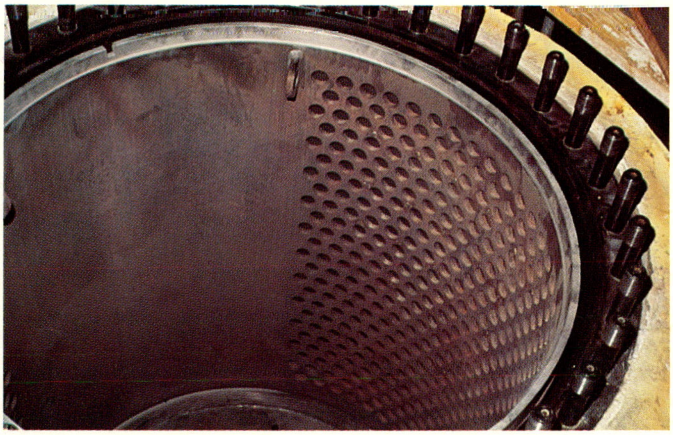
Slide 30

Large main steam piping flanges can be worked with an HBS.

Slide 31

The main turbine coupling can be worked with an HBS in less than half the time required by the old slugging wrench methods.





Slide 32

View of the HP turbine governor valve body bolts that can be worked with an HBS at significant time savings.