IMPROVEMENT OF AVAILABILITY OF PWR NUCLEAR
PLANTS THROUGH THE REDUCTION OF THE TIME
REQUIRED FOR REFUELING/MAINTENANCE OUTAGES

Contract #EY-76-C-02-2962 - 6

Phase 1
Final Report

August 1978

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ABSTRACT

The objective of this project, conducted by Commonwealth Research Corporation and Westinghouse Electric Corporation, is to identify improvements in procedures and equipment which will reduce the time required for refueling/maintenance outages at PWR nuclear power plants. The outage of Commonwealth Edison Zion Station Unit 1 in March through May of 1976 was evaluated to identify those items which caused delays and those work activities that offer the potential for significant improvements toward reducing its overall duration. Thus, the plant's availability for power production would be increased. Revisions in procedures and some equipment modifications were implemented and evaluated during the Zion Unit 2 refueling/maintenance outage beginning in January 1977. Analysis of the observed data has identified benefits available through improved refueling equipment and also areas where additional new, innovative refueling, or refueling-related equipment should be beneficial.

A number of specific design concepts are recommended as a result of Phase 1. In addition, a new master planning mechanism is described for implementation during subsequent planned outages at Zion Station. This final report describes the recommended conceptual designs and planning mechanism and assesses their impact upon future outages. Their effect on savings in refueling time, labor, and radiation exposure is discussed. The estimated economic payoff for these concepts was found to be of such significance that an additional phase of the program is warranted. During this extended phase, a more detailed engineering study should be undertaken to determine the cost of implementation along with more specific estimates of the benefits for PWR plants already in operation or under construction.

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LIST OF ABBREVIATIONS

A list of abbreviations used in this report is given below:

AEC	Atomic Energy Commission
ASME	American Society of Mechanical Engineers
AVT	All-Volatile Treatment
BWR	Boiling Water Reactor
CRDM	Control Rod Drive Mechanism
CRT	Cathode Ray Tube
DOE	Department of Energy
EC	Eddy Current
EHC	Electrohydraulic Control
FA	Fuel Assembly
FSAR	Final Safety Analysis Report
ft.	Feet
FW	Feedwater
in.	Inches
Kwh	Kilowatt-hours
LP	Low Pressure
LWA	Limited Work Authorization
Mr	Milliroentgen
Mrem	Millirem
MSIV	Main Steam Isolation Valve
MSR	Main Steam Return
MU	Middle-upper
MWe	Megawatt-electric
MWt	Megawatt-thermal
N ₂	Nitrogen
NRC	Nuclear Regulatory Commission
NSSS	Nuclear Steam Supply System
OOS	Out-of-Service
PRT	Pressurizer Relief Tank
PSAR	Preliminary Safety Analysis Report
psi	Pounds per Square Inch

PWR	Pressurized Water Reactor
QA	Quality Assurance
RCC	Rod Cluster Control
RCFC	Reactor Coolant Fan Cooling
RCPM	Reactor Coolant Pump Motor
RCS	Reactor Coolant System
rpm	Revolutions per Minute
RTD	Resistance Temperature Detector
RV	Reactor Vessel
RWST	Refueling Water Storage Tank
S/G	Steam Generator
SJAE	Steam Jet Air Ejectors
S/L	Sludge Lance
TC	Thermocouples
UI	Upper Internals
VCT	Volume Control Tank

SECTION 1

EXECUTIVE SUMMARY

The refueling and maintenance outage is historically the major individual contributor to nuclear plant unavailability. Many labor-intensive and lengthy refueling operations can be improved by the use of advanced refueling equipment technology. The current state of the art (third generation NSS Systems) includes advanced design concepts which more directly address operability and maintainability goals in addition to the traditional thermal, hydraulic, and safety design and performance objectives. The adaptation of this current refueling equipment technology to first and second generation operating NSS's appears to be both feasible and economically desirable. Phase 1 of this Department of Energy Program has identified the refueling and maintenance outage activities that were time-intensive. Phase 1 has also identified several adaptations of current refueling software, procedures, and equipment technology that conceptually should reduce the outage times at Zion. In addition, some new conceptual designs were identified and their development and use should reap similar benefits at Zion.

The expected results from the application of these advanced concepts is a significant reduction of refueling time, labor, and radiation exposure. These improvements have potential for significant economic benefits which must be weighed with the projected cost of the equipment application. The immediate follow-on to this Phase 1 would be to detail the design concepts identified in this report as having significant potential benefits at the Zion Station, procure and install those items with the highest potential return, monitor the actual improved activity times, and make recommendations for application to other plants.

A summary of expected benefits of refueling equipment modifications recommended are itemized in table 1.1. The first three of these modifications are state of the art refueling equipment requiring specific modifications design for application and installation at the Zion Site.

Assuming that all of the recommended modifications were installed at Zion Station the predicted refueling time is 20.4 days. The current minimum refueling time for Zion with existing equipment is approximately 39 days. However, due to the number of necessary plant modifications, improvements, and equipment problems during the early refueling outages Zion Station performance has not approached the minimum. See table 1.2 for a summary of Zion Refueling/Maintenance outages.

TABLE 1.1
SUMMARY OF BENEFITS OF REFUELING EQUIPMENT IMPROVEMENTS

	Radiation Exp. Improvement		Critical Path Time Improvement (Days)
	Man-Rem	% Reduction	
Integrated R.V. Head Assembly	5.26	84	2.41
Improved R.V. Closure System	13.51	47	2.31
Improved Refueling Machine Mast	9.04	58	3.33
Improved Refueling Machine Controls	5.98	57	2.25
Electrical Test Equipment	0.88	40	0.62
Improved TV System	0.20	33	0.08
Improved Cavity Cleaning Equip.	14.40	24	0.74
R.V. Head O-Ring Groove Cleaning Equipment	6.90	50	0
R.V. Stud Cleaning Equipment	0.24	30	0
Total Benefit	56.4	41	11.7

Two other areas of outage improvement have been identified: outage planning and scheduling and productivity improvements. The earliest returns can be realized through more effective preoutage planning and scheduling. Control of outage scope along with effective communications and constant monitoring will decrease nonproductive work time and allow key outage personnel to focus on critical path operations.

The other area, productivity improvement, was investigated and reported in an Interim Report^[1] as well as in this final report. Union relations, working conditions and work content must be addressed. New management tools and techniques can result in increased employee satisfaction and involvement, therefore improving productivity and the decreasing overall outage length.

TABLE 1.2
ZION STATION REFUELING/MAINTENANCE OUTAGE PERFORMANCE

Unit No.	Fuel Cycle	Date Started	Initial Outage Schedule, Days	Actual Outage Days	Major Problems
1	I-II	3/5/76	57	88	<ul style="list-style-type: none"> ■ (2) Unplanned Unit 2 Outages ■ Turbine Product Warranty Modifications ■ Unplanned Work Requests
2	I-II	1/8/77	71	80	<ul style="list-style-type: none"> ■ Spray Valve Modification Problems ■ Damaged Surveillance Capsule Basket ■ Leak Rate Test, Faulty Sensor ■ RC Pumps, Seal Problems
1	II-III	9/9/77	56	84	<ul style="list-style-type: none"> ■ Cavity Seal Modification Overrun ■ Pressurizer Spray Valve Overrun
2	II-III	2/3/78	56	70	<ul style="list-style-type: none"> ■ Boron Injection Valves Rework

1. Improvement of Availability of PWR Nuclear Plants through Reduction of the Time Required for Refueling/Maintenance Outages – Interim Report. April 1978, COO-2962-5/UC-78. Copies of this report may be obtained from the National Technical Information Service (NTIS), Springfield, VA 22161, USA.

SECTION 2

INTRODUCTION

The U.S. Department of Energy has established a refueling/maintenance outage improvement program to identify and demonstrate improved refueling, maintenance, and inspection procedures and equipment. This program is part of the Light Water Reactor Technology Program established by the Energy Research and Development Administration^[1] in 1976 to minimize consumption of oil and gas for electric power generation and to reduce dependence on foreign energy resources by making better use of existing nuclear capacity.

This project, as part of DOE's refueling outage program, is being conducted by Commonwealth Research Corporation in conjunction with Westinghouse Electric Corporation. Commonwealth Edison Company's Zion Nuclear Generating Station is being used for the observation and evaluation of refueling outages.

2.1 PROGRAM OBJECTIVES

The purpose of this program is to identify, evaluate, and demonstrate the improvements that can be made in the equipment, procedures, and management systems used in the refueling/maintenance outage of a typical PWR. The potential benefits of such improvements would be a significant reduction of the time required for refueling and maintenance outages (evaluated in terms of reduced cost and alternate fuel consumption for replacement power) and a reduction of the radiation exposure of plant personnel.

Analysis of utility records of scheduled and forced outages reveals that the annual refueling/maintenance outage constitutes one of the largest portions of nuclear plant nonavailability. Considerable time is expended and personnel radiation exposure incurred, particularly in preparing the reactor coolant system for fuel movement, during fuel movement, and in subsequently closing up the reactor coolant system. Reducing the duration of this type of outage, therefore, offers great potential for improving plant availability.

1. Now reorganized, with other federal energy activities, as the Department of Energy.

2.2 PROGRAM PLAN

As originally planned, the overall program consisted of three phases:

- Phase 1 – Plant Analysis/Conceptual Design
- Phase 2 – Detailed Design and Cost-Benefit Analysis
- Phase 3 – Procurement, Installation, and Evaluation of Modifications

Each phase had as its objective a complete analysis to present conclusions leading to decisions on whether to proceed with the next phase, and to what extent. This report presents the results of Phase I.

Phase I of the program was subdivided into the following tasks:

Task A – Development of an Improved Master Plan for the Refueling/Maintenance Outage

This task was begun with observations of the first refueling outage of Zion Unit 1 during March, April, and May of 1976. A detailed plan had been prepared by Commonwealth Edison for the scheduling and management of the outage. Comparison of this plan with the actual performance of the outage identified those items that caused unexpected delays.

A number of changes to procedures and a few equipment modifications were made to minimize these delays and to reduce the time required for other work items during subsequent outages.

Task B – Verification of the Improved Master Plan

The effects of the changes implemented in Task A were evaluated during the first refueling outage of Zion Unit 2 begun in January, 1977. The effects of these modifications and recommendations for further improvements are included.

Task C – Development of Improved Refueling Procedures

The 1976 refueling of Zion Unit 1, including preparatory operations such as degassing and draining of the reactor coolant system and removal of the reactor vessel head, was observed in detail and evaluated to develop procedural improvements and equipment modifications which could reduce the overall time required for the refueling portion of the outage.

The fuel movement operations were performed without serious delays, but a number of recommendations were developed for improving the preparatory procedures.

Task D – Verification of Improved Refueling Procedures

The results of the outage improvement efforts implemented during the observed outages are documented in this report. Procedural and equipment modifications are included to assist other plants in improving their refueling/maintenance outages.

Task E -- Phase I Final Report

An Interim Report, "Improvement of Availability of PWR Nuclear Plants Through the Reduction of the Time Required for Refueling/Maintenance Outages", WCAP-9215/COO-2962-5, was published in April 1978 and is referenced throughout this Final Report.

2.3 PARTICIPANTS

Commonwealth Edison is an investor-owned utility serving 2.8 million customers in northern Illinois within its approximately 11,525 square mile service territory, including Chicago (figure 2.1). Its generating plant consists of 5,453 Mwe nuclear, 8,962 Mwe fossil, and 1,857 Mwe fast-start gas turbine peaking units. The system record peak load of 13,932 Mwe was recorded on July 15, 1977.

The Company has been using nuclear power for electric generation since 1960. Its seven nuclear units currently in operation (table 2.1) together produced 26.6 billion kwh, or 42 percent, of Edison's output in 1977. This nuclear generation replaced alternate fuels equivalent to either 15 million tons of low-sulfur coal or 47 million barrels of residual oil and saved Edison's customers \$280 million in reduced fuel adjustment charges (compared to what such charges would have been if low-sulfur coal had been used instead of nuclear). Construction work is in progress on six more nuclear units at three sites which will boost the company's nuclear capacity to about 11,700 Mwe by the mid-1980's.

Westinghouse Electric Corporation's PWR Systems Division (PWRSD) is a leading nuclear steam supply system vendor and is holder of an ASME N Stamp as a design agency. Table 2.2 shows the status as of December 31, 1977, of all nuclear plants in the United States as compared to Westinghouse involvement in the commercial nuclear power industry.

Figure 2.1 Commonwealth Edison Company Service Territory

TABLE 2.1
COMMONWEALTH EDISON COMPANY NUCLEAR GENERATING STATIONS

Station Name	Reactor Type	Operation Date	Net Capability (Megawatts)	
			Unit	Station
Dresden Station				
Unit 1 (dual cycle)	BWR	1960	207	
Unit 2	BWR	1970	794	1795
Unit 3	BWR	1971	794	
Quad Cities Station				
Unit 1	BWR	1972	789	
Unit 2	BWR	1972	789	1183 ^(a)
Zion Station				
Unit 1	W -PWR	1973	1040	
Unit 2	W -PWR	1974	1040	2080
LaSalle County Station				
Unit 1	BWR	1979	1078	
Unit 2	BWR	1980	1078	2156
Byron Station				
Unit 1	W -PWR	1981	1120	
Unit 2	W -PWR	1982	1120	2240
Braidwood Station				
Unit 1	W -PWR	1981	1120	
Unit 2	W -PWR	1982	1120	2240

a. 75% of Quad Cities Station is owned by Commonwealth Edison Company, 25% by Iowa-Illinois Gas and Electric Company.

TABLE 2.2
STATUS OF DOMESTIC NUCLEAR POWER

December 31, 1977	Total		Westinghouse Plants
	Mwe	No. Plants	
Plants with Operating License	48,668	68	24
Plants with Construction Permits	87,504	81	39
Plants with LWA	13,840	13	—
Plants on Order	58,370	51	15
Total Commitments	208,382	213	78

Westinghouse has actively participated in most refuelings conducted for its reactors since 1969. This experience has been of great value in developing equipment and procedures to improve plant availability. These efforts have produced increased sophistication of refueling technology and provided a data base for improvements to both the process and the refueling equipment.

In 1975 Westinghouse developed a Rapid Refueling System that provided the potential benefits of improved plant availability, reduced operating costs, and reduced personnel radiation exposure. Rapid Refueling is an integrated system of mechanical and fluid systems design improvements coupled with a planned maintenance program aimed at reducing the annual refueling/maintenance outage time. Subsequently, additional improvements have been made in refueling technology and equipment. Appropriate third generation technological advances have been recommended for adaptation to an operating PWR plant.

Commonwealth Research Corporation (CRC) is a wholly owned subsidiary of Commonwealth Edison Company (CECO) for contract administration of major outside funded research and development contracts. In 1976, a Zion Refueling Outage Improvement Team was established under CRC lead as shown in figure 2.2. The CECO project team participants are shown in figure 2.3 and the corresponding PWRSD participants in figure 2.4.

2.4 ANALYSIS OF POTENTIAL BENEFITS

An analysis of benefits was presented in section 6 of the Interim Report where comparisons were made between the times required for refueling/maintenance in the Zion plant, with and without incorporation of the recommended equipment modifications.

Figure 2.2 Zion Refueling Outage Improvement Team

Figure 2.3 Commonwealth Edison Company Project Team

Figure 2.4 Westinghouse Refueling Project Outage Team

In this report, section 4, a second analysis focuses on the planning of a refueling/maintenance outage, including organization, preplanning, and planning/control techniques. This analysis is provided by the Zion station personnel involved in the initial outages of Zion station units 1 and 2. Benefit analyses for such factors are evaluated in a qualitative sense. To ascertain and quantify such benefits, an approach similar to that taken in Section 6 of the Interim Report might be used.

In the previous report a Time Utilization Factor, τ_U , was defined as the ratio of total productive work time to the total elapsed time. A Scheduled Time Factor, τ_S , was also defined as the ratio of scheduled work time to the total elapsed time. For the Zion refuelings the schedule was two 10-hour shifts per day with 1/2-hour lunch periods and 1/4-hour breaks each half shift.^[1] Given these work constraints at Zion Station, the maximum scheduled time factor per day was calculated as 0.75. Higher values of τ_S could be realized on specified tasks by minimizing the discretionary interruptions in the work in progress. For example a τ_S of 1.0 could be realized for a task that requires less time than the time between scheduled interruptions.

The time utilization factor, τ_U , has also been expressed in terms of productivity, P, and the schedule time factor, τ_S .

$$\tau_U = P \tau_S$$

Productivity is considered as a lumped parameter, although its factors may be simplified as follows:

- p_1 , planning (a measure of the effectiveness with which the coordination and allocation of resources was accomplished)
- p_2 , preparations (a measure of the adequacy of training, procedures, tooling, spare parts)
- p_3 , performance (the level of the workers skills and motivation. Also included is the effectiveness of outage coordination/communications for the work groups.)
- p_4 , problems (this is largely a function of the other three factors.) This does include the effect of equipment problems

where: $P = p_1 \times p_2 \times p_3 \times p_4$.

1. Such modifications as the number of shifts per day, the length of shifts, and the number of days per week could result in obvious benefits in the scheduled time factor, τ_S . However, cost-benefit analysis of such modifications was not attempted for this program. For planning purposes, Zion uses two 10-hour shifts per day and 6 days/week for most work tasks. Sundays are used to keep critical path items on or near schedule if problems arise.

In the Interim Report it was also shown that an average value of τ_U could be used for a given outage. For both Units 1 and 2, outage τ_U equaled an approximate value of 0.54, and since

$$P = \frac{\tau_U}{\tau_S}$$

a value of P for both outages was calculated.

$$P = \frac{\tau_U}{\tau_S} \text{ (optimum)} = \frac{0.54}{0.75}$$

$$P = 0.72$$

Productivity improvements can therefore be realized through improved planning, p_1 , preparations, p_2 , and performance p_3 (largely communications and skill/motivation).

SECTION 3

ZION NUCLEAR GENERATING STATION

3.1 DESCRIPTION

Zion Nuclear Generating Station (figure 3.1) houses the 6th and 7th nuclear units on the Commonwealth Edison system — two pressurized water reactor units with a total net capability of 2080 Mwe. The station is located on the shore of Lake Michigan in the city of Zion in the northeast corner of Illinois about midway between Chicago and Milwaukee.

Zion's two nuclear steam supply systems as well as the turbine-generator units were supplied by Westinghouse Electric Corporation on a nonturnkey basis. Sargent and Lundy is the station architect-engineer and Commonwealth Edison provided its own construction management.

The Zion reactor plants are four-loop PWRs with a licensed rating of 3250 Mwt, each located in spray-type containments. The turbine-generators are 1800 rpm, four-cylinder, tandem compound, sextuple flow, condensing units with a nameplate rating of 1085 Mwe. Condenser cooling is provided by a once-through cooling system to Lake Michigan.

The PSAR for the station was submitted in July of 1967, the FSAR in November, 1970, and the environmental report in May, 1971. Unit 1 fuel loading was begun on April 7, 1973, the reactor taken critical for the first time on June 19, and the generator initially synchronized to the Edison grid on June 28. Initial criticality for Unit 2 was achieved on Christmas Eve, 1973, with initial generation two days later.

The Zion units were among the first of the large, high-power-density reactor plants placed in operation, and were subjected to an extensive (and extended) startup testing and power escalation program. In addition, they were limited by the NRC (then AEC) to 85 percent of full power throughout the first core cycles until operating experience with 1000 Mwe reactor plants was gained and until the fuel could be examined visually at the first refueling. Unit 1 was taken off-system for its first refueling/maintenance outage on March 5, 1976, almost three years from core load.

Shortening refueling/maintenance outages, the goal of this program, is especially important for large generating units like those at Zion. A reduction in outage duration by one day can save Edison's customers approximately a quarter of a million dollars in replacement fossil fuel costs, and replaces alternate fuels equivalent to 14 thousand tons of low-sulfur coal or 44 thousand barrels of residual oil.

Figure 3.1 Zion Nuclear Generating Station

3.2 GENERAL ARRANGEMENT

Each of the units at the Zion station is a Westinghouse 4-loop pressurized water reactor of standard design. The reactor core contains 193 mechanically identical fuel assemblies. Each fuel assembly is a 15 x 15 array of fuel rods and is approximately 8.5 in. square and 13 ft, 4 in. long. The core also contains rod cluster control assemblies, burnable poison assemblies, neutron source assemblies, and plugging devices, all of which are inserted and removed from the core with the individual fuel assemblies in which they are positioned. The core assembly is supported inside the reactor pressure vessel by a removable internals structure.

The Westinghouse core uses the multi-region concept that usually requires only one-third of the core (64 assemblies) be replaced at each refueling. Additional fuel assemblies must be removed, however, to transfer core insert components and to be compatible with the requirements of the subsequent fuel cycle. Other fuel assemblies which do not require insert changes are shuffled to new core locations.

The reactor vessel is positioned in the containment so that only the vessel flange and head assembly protrude above the floor of the refueling cavity. The refueling cavity is a stainless-steel-lined reservoir which is kept flooded with borated water during refueling to a depth of about 24 feet to provide radiation shielding as fuel assemblies are moved to and from the reactor vessel. The cavity is large enough to provide space for the underwater storage of the reactor upper internals, control rod drive shafts, reactor head guide studs and various component handling tools. Space is also provided for the storage of the lower reactor internals, which are removed every 10 years as part of the reactor in-service inspection program.

The reactor vessel head laydown area is at one end of the cavity and is not submerged during refueling. A number of components associated with the reactor vessel head are identified here since they must be moved as part of the refueling operations. Large concrete missile shield blocks are supported on beams placed directly above the reactor vessel head assembly. The electrical cables of the control rod drive mechanisms (CRDMs), rod position instrumentation leads and core thermocouple leads are supported in a pivoted cable tray placed between the beams. The CRDM cooling fans and plenums are mounted on top of the missile shield.

Ducting connects the fan plenums to a cooling shroud surrounding the CRDMs mounted on the reactor vessel head. A seismic support platform mounted on the head provides restraint for the top ends of the CRDMs. Heavy adjustable lateral seismic support bars tie the platform to lugs in the cavity walls.

The remainder of the usable area on the main deck is taken up by the steam generators, pressurizer, fans and ductwork, and electrical penetrations. This leaves laydown space on the main deck for two reactor coolant pump motors, vessel stud storage and cleaning facilities, and miscellaneous tool boxes. Therefore, this space must be budgeted and used wisely throughout the

outage. Any additional laydown space must literally be constructed. For erection of the Westinghouse reactor vessel in-service inspection tool, two missile shield blocks are erected over a reactor coolant pump motor pull space. These are shored, and railings have been erected.

The crane is the polar variety with a main and auxiliary hook. This posed problems with cavity cleaning and stud removal. Unless the crane axis is parallel to the cavity walls, simple translation movements are not possible. Therefore a cavity bridge crane was constructed so that it moves parallel to the cavity wall like the refueling crane. This has speeded up head work and cavity cleaning in addition to freeing the polar crane for other uses.

Containment access is through a personnel hatch located in the equipment hatch. To enter or leave through the personnel hatch one must ascend up and down nine feet. This proved very inefficient for rapid access with workmen carrying tools and supplies. Therefore, the equipment hatch is removed at the beginning of an outage and installed only when containment integrity is necessary. A beam and trolley arrangement is also erected when the equipment hatch is removed. This facilitates the transportation of heavy loads between the fuel building crane and the polar crane.

Many permanent galleries have been constructed to eliminate scaffolding erection time and provide a solid and efficient work platform. Of particular use are the galleries for primary side manway removal on the steam generator, which are removed for eddy current inspections. These galleries, along with a special hoist rig and air-operated torque wrench speed removal and replacement.

A description of refueling operations is included in paragraph 3.1.1 of the Interim Report.

3.3 STATION ORGANIZATION

The Zion Nuclear Generating Station organization chart is shown in Figure 3.2. For refueling/maintenance outages, a project management approach is used and is described in more detail in section 4.

Figure 3.2 Zion Nuclear Generating Station Organization Chart

SECTION 4

DESCRIPTION OF PROGRAM

The Interim Report presents the results of this program from an equipment/hardware standpoint for the initial outages of both Zion Stations 1 & 2. This section describes the outage management and coordination activities by Zion Station personnel and documents the outage planning organization, preplanning, planning techniques, modifications made during and before the outages, and the key points of the outage.

4.1 ZION UNIT 1 OUTAGE

Zion Unit 1 fuel cycle I-II outage began at 12:02 a.m. on March 5, 1976 with reactor trip to cold shutdown and ended at 5:12 a.m. on May 31, 1976, more than 88 days into the outage. Evaluation of the key aspects of the outage are documented in section 4, Evaluation of 1976 Refueling of Zion Unit 1, of the Interim Report. It is the intent here to discuss in detail the task of coordinating or management of the refueling/maintenance outage at the Zion Station.

The description of the Outage Coordination of both Units 1 and 2 proceeds according to the following outline: Outage Organization, Pre-Outage Planning, Master Planning Technique, Modifications to Equipment, and Summary of the Outage. This discussion is presented for both units followed by an evaluation/critique.

4.1.1 Outage Organization

Basically, a form of matrix project management was used during the Zion Unit 1 outage, (figure 4.1) with the Assistant Superintendent as the project manager. For all outages, the Outage Coordinator reports directly to the Project Manager and is responsible for assuring that adequate preplanning is accomplished and that all operations occurring during the outage are monitored in relation to scheduled events and times. The Outage Coordinator or a member of his staff was on site whenever work relating to the outage was being performed. This was necessary to provide rapid awareness of problems or schedular revisions.

A daily outage meeting was conducted by the Coordinator at 10:00 a.m. each day for representatives of each station department and/or functional work group to provide proper communication of work status, problems/bottlenecks, and daily work plans. Details of the day's

Figure 4.1 Zion Unit 1 Refueling/Maintenance Outage Organization

operations were shown on the outage Planalog, figure 4.2. As necessary the Planalog was updated by the Planning Department and new daily work sheets were prepared and issued by 2:00 p.m. These daily meetings proved successful in communicating the overall status of the outage with emphasis on interrelationships and cooperation required among the work groups to keep the outage moving.

For each major work item a Work Segment Supervisor was named to assure adequate preplanning and availability of materials and procedures and to follow the progress and report any problems to the Outage Coordinator and Project Manager. This individual was chosen as someone not responsible for the work group performing the task in order to provide an independent source of review during the performance of critical operations.

The Work Segment Supervisor was generally selected from the site management staff with knowledge and experience in the area of the major work item. This was considered a task assignment in addition to the performance of normal job functions.

4.1.2 Preoutage Planning

Four months before the start of Unit 1 initial outage, meetings were held with all functional branches of the station to be involved in the outage to assign the scope of work for the outage. There was no attempt to limit the scope of work during this initial outage. Outage Job Planning Sheets, figure 4.3, were completed by the Planning Department with assistance from the departments performing the tasks to ascertain resource requirements including manpower and the expected duration of each task. An initial job list of major items was drawn up, and an attempt was made to track these items through the outage management approval chain. The initial turbine schedule was not developed until the first week of the outage due to contractual problems.

The work performed was divided into the following categories for ease of control and reporting:

- Refueling Preparation (Head Disassembly, etc.)
- Fuel Movements
- Surveillance and Inspections
- Modifications
- Turbine-Generator Maintenance

Figure 4.2 Outage Planalog

OUTAGE JOB PLANNING SHEET

ZION STATION UNIT 1
 JOB NO. _____ WR NO. _____

EPN IRC 100, 200, 300, 400	Work Group	Work Required	No. Men	Hrs. Reqd.	Shift Scheme
JOB DESCRIPTION: Sludge Lance	TS	Supervise	1	140	2-8's
Steam Generators	RP	Support	1	140	2-8's
REMARKS:	MM	Support	1	8	---
	CO	Contract Labor	4	140	2-8's
EQUIPMENT REQUIRED: Hose & Fittings					
Contractor to supply					
☐ ON SITE					
☐ ON ORDER, EST DELIVERY DATE:	SPECIAL INSTRUCTIONS OR PRECAUTIONS:				
MATERIAL REQUIRED:	1 Cannot conflict with Eddy Current Schedule				
Contractor to supply	2 Use flexible hose thru containment hatch				
☐ ON SITE					
☐ ON ORDER, EST DELIVERY DATE:					
PROCEDURE REQUIRED: Yes					
☒ ON HAND					
☐ NOT COMPLETE DUE DATE:					
EQUIPMENT REQUIRED O.O.S. All 4 steam generators drained					
☐ MOD.	PRIORITY ☒ ☒ ☒				
☒ SURV.	REQUIRED PLANT STATUS ☐ ☐ ☒ CYCLE: III-IV				
PREPARED BY: _____					

Figure 4.3. Outage Job Planning Sheet

- Physics Tests
- Maintenance Items (198 work requests)

4.1.3 Master Planning Technique

The initial refueling on Unit 1 was planned and monitored using two methods. A 33-foot Planalog (a manual, chip-mounted planning board), under the control of the Outage Coordinator, was laid out in the sequence of planned events for the entire outage. All major events and tasks were shown for each day of the schedule. The sequence of events was primarily generated by the Planning Staff with the departmental manager's concurring review and modifications. Since this was the first outage conducted by Zion personnel, a number of planned items had a weak basis for the time and resources forecast for their completion. Therefore, the daily outage planning meetings became the key to keeping the Planalog and the outage management team up to date.

A computer program known as PMS-IV^[1] was also loaded with all work items and 198 separate work requests, such as maintenance of leaking valves. Most work requests were issued within the final month before the start of this outage. Consequently, the first usable sequence of events using PMS-IV was not available until approximately two weeks before reactor shutdown.

During the Unit 1 outage, the Planalog board was the primary scheduling tool. Daily updates of the next day's work were issued to each department representative. This made the daily planning meetings important to the successful operation and control of the scheduled events. Initially, small work items, i.e., some of the 198 work requests, were also included in the schedule. However, this proved too fine a control and left little flexibility for the functional group supervisors. This problem was corrected during the outage.

4.1.4 Modifications to Equipment - Unit 1

The following equipment modifications were performed before the Unit 1 refueling outage, core cycle I-II. These modifications were made during planned shutdowns.

- Reactor head cable tray pivot pin. This pivot pin allows the tray to be raised after cable disconnection to an upright position next to the steam generators.
- Initial work on the steam generator primary manway access galleries. These galleries were designed for simplifying access to the primary manways to perform eddy current inspections.

1. PMS-IV is an IBM Proprietary Program

- Construction of a reactor vessel stud-handling tool which allows studs to be spun in and out of the vessel flange with an air motor. (See Interim Report, section 5.1.8)

During the subsequent outage of Unit 1 the following major equipment modifications were made.

- Completion of the steam generator primary manway access galleries.
- Installation of a reactor cavity filtration system designed to filter the refueling cavity during fuel movements. (See Interim Report, Section 5.7)
- Main steam isolation valve bypass line modification. This piping allows for primary system heatup with the mainstream isolation valves closed and allows equalization of temperature on the downstream side so that the isolation valves may be opened.

Table 4.1 is the Unit 1 refueling modification completion summary, including the modification number, description, and start/completion dates.

4.1.5 Summary of Unit 1 Outage

Zion Station Unit 1 was removed from service one day ahead of schedule at 12:02 a.m. on March 5, 1976 for its first refueling/maintenance outage. Initial scheduling predicted an outage duration of 57 days with a return to service on May 1, 1976. The refueling/maintenance outage was terminated at 5:12 a.m. on May 31, 1976 at 88 days with the reactor critical and the turbine rolling at synchronous speed. The unit was not brought on line due to indications of imminent problems with the 1C reactor coolant pump seals. On May 31, 1976 the unit went into a forced outage until it was returned to service at 10:50 a.m. on June 18, 1976. The total power-to-power duration of the combined outages was 106 days, or 7 weeks longer than initially scheduled. Also during this period Unit 2 experienced a 39-day outage for turbine generator bearing repair and a 12-day outage for repair of 2D reactor coolant pump seals.

During the refueling/maintenance portion of the outage, the following work was done:

- 60 spent fuel assemblies removed and replaced with new assemblies.
- 84 burnable poison rod assemblies removed.
- 37 modifications to existing systems (see Section 4.1.4 of this report).
- 1C L.P. turbine generator, governor valves, stop valves, intercept valves overhauled and 1C steam generator feedwater pump turbine disassembled and inspected.
- 643 work request jobs processed.
- In-service inspection of piping, welds and supports.
- 69 technical specification required refueling surveillances.

TABLE 4.1
UNIT 1 OUTAGE EQUIPMENT MODIFICATION SUMMARY

Mod. Number	Description	Date Start	Date Finished
M22-1-73-243	MSIV Bypass vlvs. Install conduit & wire from vlvs. to switches, also installed mechanical portion of mod	3-15-76	4-14-76
M22-1-74-12	Off gas-rad monitor installation	4-23-76	4-28-76
M22-1-74-48	MSIV oil pp. Status light start & stop switch installed	3-4-76	4-9-76
M22-1-74-113	Containment evac beacons installed	3-3-76	4-6-76
M22-1-74-116	Stator water cooling piping. Move tap off point of pipe 1CD255-1" N-N to vertical part of pipe 1CD 135-3"-N-N	5-1-76	5-17-76
M22-1-74-170	A.V.T. blowdown flow ind. Install orifice & ran lines both sides of orifice. No instrumentation installed.	3-15-76	4-1-76
M22-1-74-171	Blowdown sample lines, Reroute lines	3-24-76	4-27-76
M22-1-74	VCT piping reroute	4-3-76	4-19-76
M22-1-74-190	Reroute aux. FW containment drain line to condenser	3-9-76	4-27-76
M22-1-74-196	Break MSR partition drain line. Add a vlv. & cap at MSR, cap at condenser & at drain tank	3-29-76	3-31-76

TABLE 4.1 (cont)
UNIT 1 EQUIPMENT MODIFICATION SUMMARY

Mod. Number	Description	Date Start	Date Finished
M22-1-75-24	Tee in N ₂ piping to PRT to fill RC loops when draining N ₂ to PRT	4-12-76	4-19-76
M22-1-75-26	CW Discharge RTD's structural only	4-21-76	4-28-76
M22-1-75-30	CO ₂ bottle rack (incore) relocate	4-12-76	4-22-76
M22-1-75-32	FW reg. & bypass MOV. & piping. <u>Install</u> modified FW valve station	4-9-76	5-17-76
M22-1-75-43	EHC test connections <u>install</u> vlv's. & test conn. on EHC package	4-24-76	4-28-76
M22-1-75-48	ADD bypass around PP flow meters in containment	4-7-76	4-19-76
M22-1-75-64	Reroute MSIV cables	3-9-76	4-14-76
M22-1-75-80	Personnel Lock Drive Mod. Rebuild air lock drive	4-12-76	4-20-76
M22-1-75-83	Heater Drain Low Point Drain	3-22-76	3-31-76
M22-1-75-91	Reheat Turning Vane Mod. Brace 90° elbow turning vane & remove 65° T section.	4-12-76	5-4-76
M22-1-75-92	Raise 11 Htr Magnatrol	3-9-76	3-16-76
M22-1-76-5	1A Htr Dr Pp seal wtr piping reroute	3-16-76	4-19-76

TABLE 4.1 (cont)
UNIT 1 EQUIPMENT MODIFICATION SUMMARY

Mod. Number	Description	Date Start	Date Finished
M22-1/2-74-1	Off gas Iso valves. Put in additional valve to make both units independent	4-7-76	5-19-76
M22-1/2-74-87	VCT Ht trace; Install Ht. Trace & controls	4-3-76	4-17-76
M22-1/2-75-11	Condensate Storage Reroute	4-3-76	4-10-76
M22-1-75-50	G.S. cond. reroute. Put in 1" line from SJAE to the G.S. cond.	5-26-75	3-31-76
M22-1-75-99	RCPM COM 11 relay in parallel with present COM 5 relay	4-26-76	4-30-76
M22-1-76-11	CRD Chamfer Mod. Increase chamfer angle	4-6-76	4-9-76
M22-1-76-18	RCPM oil lift system and Thrust runner modification	3-30-76	5-4-76
M22-1-76-19	CW Discharge manways. Install 18" or 20" manway on line 1CW001-108" AFN halfway between discharge & cribhouse	3-6-76	5-4-76
M22-1-75-28	RC isolation valves. Limit open/close	4-29-76	5-24-76
M22-1-75-58	Aux. FW Dr. Reroute to Htr Dr. Tk seal coil Tk.	4-29-76	5-4-76
M22-1/2-75-113	RCPM zero speed indicators. Pull cable only		

TABLE 4.1 (cont)
UNIT 1 EQUIPMENT MODIFICATION SUMMARY

Mod. Number	Description	Date Start	Date Finished
M22-1-75-114	Cond/Recirc reroute	4-24-76	3-11-76
M22-2-76-13	S/G Galleries. Field fab. Expanded Galleries	4-19-76	5-17-76
M22-1-75-77	Relocate RWST MU level alarm	cancelled	
M22-1-73-128	RTD calib test setup	cancelled	
M22-1-75-10	CW water box nozzles	cancelled	

- Three reactor coolant pump motors disassembled and inspected.
- Eddy current inspection of 1A steam generator.
- Sludge lance of all 4 steam generators.

All work groups were on a two 10-hour/day shift scheme, six days/week with the exception of the Operating Department, which worked normal three 8-hour/day shifts, seven days/week. Critical path jobs often required modification of the schedules to include work on Sunday for one or two eight-hour shifts depending upon the outage status.

Prior to the Unit 1 outage both the Region III NRC inspector and the Staff inspector reviewed and discussed the content and conduct of the outage with station management. Upon their insistence, the Planning Coordinator issued a master refueling checklist/sign-off sheet. The effort was redundant to the other control mechanisms being used. This checklist was discontinued after the Unit 2 outage. During the outage there were NRC site audits of in-service inspections, steam generator eddy current inspections, refueling preparations, and documentation of maintenance performed during the outage.

4.2 EVALUATION OF UNIT 1 OUTAGE

The initial outage for Zion Station Unit 1 was completed in 31 days over the original 57-day schedule. No glaring reason or major problem could be associated with the overrun. However, in reviewing the initial schedule versus the actual as shown in the Interim Report, section 4, it can be seen that a significant number of tasks were underestimated due to a lack of experience as a basis for the initial schedule, minor problems involved in the coordinating of various work activities, the significant number of work requests, the substantial addition of work requests as the outage progressed, and the unplanned outage of Unit 2. See Appendix A for detailed problem matrix of Unit 1 outages as identified by the Project Team.

There were no significant problems related to the organization, but much was learned in relation to committing the major site resources versus using contractor personnel for various operations. This experience was compounded by the two forced outages of Unit 2 during the schedule. Because of such unanticipated problems as establishing human resource schedules and work load leveling, it was decided to commit only 50 percent of the site personnel for future planned outages so that those not participating can be available for normal operation and nonroutine occurrences on the operating unit.

Table 4.2 is a summary of major inaccuracies in the scheduling of the Unit 1 outage. Where no days are shown under the original estimate column, these operations were unanticipated. Where applicable, corrective actions are summarized for those operations in which modifications to planning or hardware could affect the future performance of an outage.

TABLE 4.2
MAJOR SCHEDULE ERRORS IN UNIT 1 OUTAGE

Item	Days Duration		Reason	Corrective Action
	(Est.)	(Actual)		
1. Turb/Gen Overhaul	42	80	Reblading & Bearing Work	See Interim Report Appendix A
2. Cavity Water Leakage	0	3	Cavity Not Watertight	Redesign Cavity Seal Plates
3. 1D RCP Motor Inspection	10	50	Scope Increased From 1 Motor to 3 Motors Causing Interference to Oil System Modification	Improve Preplanning
4. RCS Degas & Venting	1.5	6	Inexperience & Lack of Procedure Transmittal from Vendor	Procedure was written and Implemented
5. Cavity Cleaning	1	6	Inexperience & Lack of Procedure	Procedure written
6. Water Clarity During Refueling	0	1	Poor Scheduling - Filtration System Out of Service During Refueling	Filter RWST, Skimmer Pump Filtered RWST Before Refueling and Added Filter, Skimmer Pumps to Cavity
7. 1C RCP Seal	0	15	Seal Failure	Pump Seal Modification
8. 1AOV SI8880	0	5	Valve Jammed - Parts Unavailable	None
9. Radiation Protection Undermanned	0	0	R. P. Scope Increased - Noncritical Jobs Delayed - Lost Man Hours	Hired Contract Rad. Men
10. Containment Closed	0	2	Airborne Containment	Improved Housekeeping

Computer scheduling and load leveling was attempted by using an IBM program called PMS-IV. Although this program performs well for long-term projects where a microview is not required, there were difficulties discovered that prevented this from being an effective outage planning and control tool. Some of the problems experienced with this program are summarized below.

- PMS-IV has neither multicalendar nor micro scheduling capabilities; that is, with PMS-IV all work groups must be planned according to the same shift scheme and the minimum duration is 0.5 shift. Actual tasks often require odd hours; e.g., 5 hours, which cannot be entered in PMS-IV. The input of unrealistic times resulted in unrealistic schedule dates. The multicalendar problem prevented the scheduling of multiple shift schemes; e.g., mechanical maintenance worked two 10-hour, 6-day weeks and operating groups work three 8-hour, 7-day weeks. This shortcoming also produced unsatisfactory scheduler variations.
- The planning department was unable to process the schedule via PMS-IV from on-site, which meant that the program had to be run from the Chicago office. Updates were phoned into the Chicago office and outputs were mailed back to the site. A short report consisting of the following 15 shifts and the remaining critical path was received over the conversational programming system (CPS) terminal on the same day. The result of this procedure was that the computer lagged the actual work by an average of 24 hours.

Because of these problems, PMS-IV was used only as a historical document, but was not used to manage the outage. Therefore, the Planalog and the daily scheduling meetings became the principal planning/scheduling tools.

Working cycles were evaluated to determine the usefulness of the two 10-hour shifts/day. Several weeks into the outage it was determined that this scheme was self-defeating. Long periods of 10-hour days reduced productivity and made for dissatisfied personnel. This resulted in switching the contractors to a standard 40-hour week per man for the second Unit 1 outage. In some cases multiple shifts/day became necessary, depending on the job duration. Future outages are to be planned based on two 8-hour shifts/day, six-days/week with critical path work on two 10-hour shifts/day, six-days/week with two 8-hour shifts on Sunday.

4.3 ZION UNIT 2 OUTAGE

The Zion Unit 2 fuel cycle I-II outage began on January 8, 1977, and the reactor was returned to service on March 28, 1977. Evaluation of key aspects of the outage coordination and management are included in the following paragraphs.

4.3.1 Outage Organization

Two changes were made to the Zion Station outage team before the second outage. The first consisted of a split in the responsibility for the operating departments between the Assistant

Superintendent and the Administrative Assistant. Prior to this change, all departments reported to the Assistant Superintendent. As shown in figure 4.4, the Assistant Superintendent retained responsibility for outage coordination, maintenance engineering, and plant operation. The Administrative Assistant became responsible for the Technical Staff, Stores, Administration and Training Departments.

The second organizational change involved moving the Instrument Department from the Technical Staff to report to the Maintenance Engineer. This provided sole responsibility for maintenance under one management function.

Similar to the Unit 1 outage, daily meetings were held with representatives of each work group and served as a method to report job progress and potential problem areas, as well as to review the work schedule for the next 24 hours. As before, the daily meetings proved to be the most successful communication method for overall status and emphasizing the interrelations and support required among the work groups.

4.3.2 Preoutage Planning

Preoutage Planning was conducted in essentially a similar manner as for the Unit 1 outage. A greater amount of time was spent attempting to improve the work flow of planned activities and to analyze these activities for load leveling. Also, the outage planning group, with assistance of the other major departments, critically reviewed all work requests to screen out those of lower priority, those requiring high manpower resources, and those with a high potential for problems.

4.3.3 Master Planning Technique

The primary tool for planning and scheduling was the Planalog. Initially, about two months before the outage, the planned activities were posted on the Planalog board in the office of the Outage Coordinator. Each work group reviewed the layout and the most feasible schedule was developed. PMS-IV was then updated to reflect the final status, and bar charts were distributed to each work group. A status list was prepared for the first three days of the outage to detail each step or activity required to bring the plant to refueling conditions. Daily status lists were distributed during the outage to keep work groups informed of day-to-day changes.

Fifty percent of the available station manpower was committed to outage work, while the remaining 50 percent was used to contractor support, Unit 1 work, and as a contingency force. Extra radiation protection personnel were contracted for early in the outage, eliminating delays noted in the last outage due to manpower and cleanup shortages. This contract also covered fuel cavity cleanup/decontamination.

Figure 4.4 Zion Station Line Organization

Forty-six initial and retraining radiation protection classes were held for off-site personnel before and during the outage. A total of 167 persons required initial training and 170 were retrained. Retraining of all personnel on an annual basis is a Commonwealth Edison Company policy.

4.3.4 Modifications to Equipment – Unit 2

As a result of the Zion Unit 1 refueling analysis, equipment modifications were performed on Unit 2 prior to and during this initial outage. Before reactor shutdown, the following modifications were made during planned outages.

- Reactor head cable tray pivot pin, as performed on Unit 1
- Construction of a reactor vessel stud-handling tool as on Unit 1

The following major modifications were conducted during the outage:

- Steam Generator Primary Manway Access Galleries as performed on Unit 1
- Reactor Cavity Filtration System as performed on Unit 1
- Permanent Sludge Lance Piping. This piping eliminated the need to run temporary hose to sludge-lance the steam generator. Permanent piping was installed from the access hatch to the steam generator and from the emergency hatch to the Radioactive Waste Cleanup System.
- Reactor Cavity Nozzle Cover Sealing Arrangement. The nozzle cover seal surface was raised off the cavity floor to allow for an improved flange-type closure to insure watertightness.
- Improved Remote Vessel Level Indication. Remote level taps used to give control room indication of reactor vessel level from the centerline of the nozzles to the top of the refueling cavity.
- Reactor Cavity Hand Gear Bridge Crane. One-ton capacity bridge crane spanning the width of the refueling cavity to handle reactor vessel head studs, insulation, and cavity decontamination to free the polar crane.
- Instrument Port-Control Rod Drive Vent Shroud Access. Interference problems occurred when the hydraulic ram was used to make up the instrument port Conoseals. A removable section of CRD vent shrouding was made to improve access.
- Main Steam Isolation Valve Bypass Line as performed on Unit 1

Table 4.3 provides a summary of Unit 2 modifications and their start/complete dates.

4.3.5 Summary of Unit 2 Outage

Zion Station Unit 2 was removed from service as scheduled at 12:01 a.m. on January 8, 1977 for its first refueling/maintenance outage. Initial scheduling predicted an outage duration of

TABLE 4.3
UNIT 2 REFUELING CYCLE I-II MODIFICATION SUMMARY

Mod. #	Description	Date Started	Date Completed
22-2-74-207	DG 2A & 2B Pneumatic Tubing	2-10-77	3-04-77
22-2-75-36	DG 2A & 2B First-Out Annunciator	2-12-77	3-04-77
22-2-75-110	PP Purge Line Solenoid Valves	2-21-77	3-04-77
22-2-74-174	VCT Piping Reroute	2-06-77	3-07-77
22-2-76-50	VCT Heat Tracing	2-14-77	3-10-77
22-2-75-32	FW Reg. Valve Bypass Isol. Vlv.	1-19-77	3-14-77
22-1/2/76-77	FW Hand Hole at Flow Nozzle (Loop D)	2-04-77	3-12-77
22-2-76-36	MSR Vent Condenser	1-14-77	3-15-77
22-2-76-52	Cavity Filtration System	1-12-77	1-21-77
22-2-76-31	Rx Cavity Nozzle Cover	1-08-77	1-18-77
22-2-75-82	P-8 & P-13 ZA Test Relays	2-14-77	2-17-77
22-2-76-79C	Inst. Upgrade FW System	1-14-77	3-05-77
22-2-76-24	Dual Relays for Gen. Protection	2-10-77	3-18-77
22-2-75-26	CW Disch. RTD	1-10-77	3-12-77
22-2-76-63	S/L Permanent Piping	1-10-77	2-16-77
22-2-76-13	S/G Eddy Current Galleries	1-10-77	2-12-77
22-2-76-33	Aux. FW Piping Restraints	1-29-77	3-03-77
22-2-76-89	PZR Spray Valves	1-10-77	3-17-77
22-2-76-22	Relocate Remote S/D Panel Cables	1-24-77	1-28-77
22-2-75-80	Personnel Lock Drive	2-07-77	2-20-77
22-2-75-87	SJAE Loop Drain	1-26-77	1-31-77
22-2-75-43	EHC Test Connections	2-11-77	2-11-77
22-2-76-11	CRD Shaft Chamfer	2-06-77	2-08-77
22-2-76-67	T.O. Res. Fill Filter	3-04-77	-09-77
22-2-75-92	Raise 21 Htr. Magnetrols	1-31-77	2-02-77
22-2-76-95	Hi Velocity T.O. Flush Piping	2-04-77	2-25-77
22-2-76-56	Reactor Cavity Bridge Crane	1-10-77	3-05-77
22-2-77-13	Inst. Port CRD Vent Shroud Access	2-15-77	2-18-77
22-2-76-15	CW Pump Syntron Seals	1-18-77	3-04-77
22-2-76-14	SW Pump Shaft Sleeves	1-24-77	3-14-77
22-2-77-10	SW Pump BRG Flux Flush Conn.	2-24-77	3-10-77
22-2-74-157	CRD Booster Fan Grease Line	1-11-77	3-12-77
22-2-75-81	CRD Fan Plenum Access	3-10-77	3-12-77
22-2-75-91	MS Reheat Turning Vanes	1-18-77	3-09-77

TABLE 4.3 (cont)
UNIT 2 REFUELING CYCLE I-II MODIFICATION SUMMARY

Mod. #	Description	Date Started	Date Completed
22-2-76-90	NIS Drawer & Handle Latch	2-02-77	2-11-77
22-2-76-65	Gnd. on CR Logic Cabinet	1-19-77	1-19-77
22-2-76-29	RCFC Damper Counterweights	1-18-77	2-03-77
22-2-76-92	Δ T RTD Test Cabinet	2-15-77	2-28-77
22-2-75-28	RC LSIV Limit Switch	1-16-77	1-19-77
22-2-76-35	Hagan Controller Replacement	2-10-77	2-15-77
22-2-77-1	Circ. Water Regulator	2-28-77	3-10-77
22-2-77-15	Upper Seismic Support Hangers All/Steam Gen.	3-01-77	3-12-77
22-2-77-8	MSR Tube Bundle Hold-down Westinghouse	1-10-77	3-15-77
22-2-77-14	MSR Inst. Westinghouse	1-10-77	3-15-77
22-2-75-71	Computer Inputs		
22-2-77-2	Replace 3 T/C In-core Detectors	2-15-77	2-15-77

71 days with a return to service on March 19, 1977. The refueling/maintenance outage was terminated at 6:58 p.m. on March 28, 1977. The total power-to-power duration of the outage was 80 days, or 9 days longer than initially scheduled.

During this period Unit 1 remained on line, which allowed the maximum effort to be concentrated on Unit 2.

The following work was accomplished during the refueling/maintenance outage:

- Sixty spent fuel assemblies removed and replaced with new assemblies.
- Sixty-nine burnable poison rod assemblies removed.
- Forty-six modifications to existing systems and plant structures, see paragraph 4.3.4.
- 2B & 2C LP turbines overhauled, all turbine bearings inspected and all bearing oil lines flushed. 2B steam generator feedwater pump turbine overhauled.
- Six hundred fifty-one work request jobs processed.
- In-service inspection of piping, welds, and supports.
- Technical specification required refueling surveillances.
- 2D reactor coolant pump motor disassembled and inspected.
- Eddy current inspection of the 2D steam generator.
- Sludge-lance of all four steam generators.
- Oil conversion to SHC 824 (synthetic oil) in 2B, 2C & 2D RCP motors.

The following fuel inspections were made during the outage:

1. A total of 37 assemblies was inspected (gamma-scanning) as part of a GE-EPRI program. Relative La-140 activity, which is reflective of recent power history, was measured on each assembly at 12 to 24 elevations. This effort was part of EPRI Project RP-130, "Nuclear Reactor Core Benchmark Data". The objective of the study was to provide power distribution benchmark data for verification of those methods used for predictive calculations and in-core monitoring of core power distributions. Results of these gamma scan measurements are reported in EPRI NP-509, "Gamma Scan Measurements at Zion Station Unit 2 Following Cycle 1," Final Report dated October 1977, by G. R. Parkos and G. F. Valby.

2. Approximately 140 assemblies were videotaped by the Technical Staff as they were removed from the core to verify structural integrity and to detect characteristics of abnormal fuel behavior. No abnormalities were observed.

A simplified outage milestone chart is shown in Figure 4.5. This schedule is expanded and described in detail in paragraph 4.4.

Radiation exposure averaged 300 mr per person, including contractors. This compares favorably to the exposure average for the Unit 1 outage of 338 mr, with the Unit 2 outage extending 8-days longer than the Unit 1 outage.

4.4 EVALUATION OF UNIT 2 OUTAGE

The initial outage for Zion Station Unit 2 was completed in 8 days over the original 72-day schedule. Significant problems and delays occurring during the outage are summarized in Table 4.4, along with future corrective action.

Several procedural changes were made during the Unit 2 outage to improve the coordination and flow of the work. The reactor vessel head degassing procedure was modified to sweep the head using an eductor with suction from the pressurizer vent. A method was established for recirculation and air mixing the RWST to clean the water for refueling. Steam generator primary side draining was speeded up by using N₂ overpressure to remove water from the U-tubes. Other procedural modifications were designed to achieve maximum volume control letdown for the duration of the fuel movements and to speed reactor cavity decontamination.

To control out-of-service requests, a form was developed for requesting the night shift to take equipment out-of-service for work scheduled during up-coming shifts. The Out-of-Service Request (OOS Request) was issued by the Outage Coordinator and approved by the operating engineer. This greatly increased efficiency by having equipment available at the start of the planned shift. A copy of OOS Request Form is shown in figure 4.6.

The computer manpower leveling feature of PMS-IV was determined to be inadequate for planning purposes. It was more selective to print histograms of resource usage with the resource level superimposed. Selective movement of tasks was accomplished wherever the resource usage exceeded that available. Such a manual scan of a manpower histogram was more efficient, reliable, and timely during this outage. The shortcoming of this code was the inability to shift jobs to a planner-preferred location since it lacks the information required to make such changes.

An expanded version of the planned-versus-actual schedule for work items and milestones for the Unit 2 outage is shown in Figure 4.7, Unit 2 Refueling/Maintenance Outage Milestones. The following is a critique of the outage with reference to this before and after schedule.

TABLE 4.4

LOST TIME DELAYS/PROBLEMS, ZION UNIT 2 OUTAGE

<u>Date</u>	<u>Problem/Delay</u>	<u>Lost Time, (hr)</u>	<u>Corrective Action</u>
1-23-77	Containment, Airborne Contamination	20	Roving permanent cleanup crews
1-25-77	Air Lock Broken	4	Modification to strengthen the Air Lock Mechanism
1-27-77	Air Lock Broken	2	
2-09-77	Specimen Plug Damaged	48 ^(a)	
3-04-77	Paint Vapors in Containment	4	Rescheduled painting in containment
	Leak Rate Test (Faulty sensor)	48	None
	Spray Valve Modification (pipe and weld problems)	120	None
3-17-77	Reactor Coolant Pumps	24	None
3-22-77	2VC8117 Valve Repair	24	None
3-28-77	2B & 2C Feedwater Pumps	24	Testing Scheduled on noncritical path time
(a) Not on Critical Path			
NOTE: Water clarity during refueling was poor and minor delays were noted. These delays were not directly on the critical path, but an investigation by Station Chemistry and Westinghouse is in progress to determine the cause and corrective action required.			

Zion Station

OOS Request Form

[illegible]

Date Issued _____ Page _____ Of _____

Figure 4.6 OOS Request Form

4:24

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Reactor shutdown and unit cooldown were completed as planned. Due to leakage of the cavity seal plates experienced during the Unit 1 outage, a seal plate of improved design was installed on Unit 2. Weld preparation and quality problems led to a three-shift delay. Welders had to be rescheduled from other critical path work.

Reactor Vessel head disassembly was completed on schedule and presented no major problems.

Parallel to this effort, eddy current tents were being erected. This job was delayed one shift due to a lack of manpower resources. The same work group installing the cavity seal plates had to pull men off the tent erection because weld preparation (cavity seal plates), required more men than scheduled.

Eddy current testing was delayed two shifts due to mechanical problems with the Combustion Engineering "finger walker" positioning device.

The time required to lift and place the upper internals in their laydown area was overestimated and was actually accomplished in less than a shift.

The fuel shuffle and inspection went well with a two-shift delay in the final shuffle due to miscellaneous equipment problems.

Head reassembly went well except for improper installation of the specimen plug holder (surveillance capsules). The holder was not seated fully and upon insertion of the upper internals it was bent. A replacement was obtained from another utility and installed. This accounted for a three-shift delay.

The control rod drive chamfer modification took one shift less than scheduled due to excellent procedure preparation and supervision by Westinghouse personnel.

Cavity decontamination had a one-shift delay due to polar crane scheduling problems. The polar crane was also needed at this time to remove secondary steam generator manways for an attempt to install J-tubes. This modification had not been scheduled and was eventually postponed.

Stud tensioning resulted in a three-shift overrun due to the need for multiple correction passes.

The containment leak rate test finished four-shifts behind schedule due to a faulty sensor that gave erroneous results 20-hours into the test and causing an extension. Investigation finally determined the faulty sensor and corrective calculations showed an acceptable leak rate allowing the test to be completed.

The largest percentage of outage extensions was due to welding not acceptable by the ASME code for the pressurizer spray valve modification. This modification involved extensive piping rerouting and substitution of ball valves for bellows valves. Numerous unacceptable welds had to be ground out and rewelded. This accounted for a five-day delay.

Mechanical problems, welding deficiencies, and unscheduled work resulted in a nine-day overrun for this outage.

SECTION 5

RECOMMENDATIONS

The observations made of the Zion Units 1 (1976) and 2 (1977) refueling outages were effective in identifying or confirming areas where important improvements could be made to reduce refueling time. The evaluations made during the program take into consideration that these were the first refuelings and improvement can be expected due to experience gained and problem resolution. See the Interim Report, section 5, for a complete description of the recommended equipment modifications.

The potential benefits of the recommended refueling equipment modifications are summarized in table 5.1. These benefits in terms of time savings in outage length, labor manhours, and radiation exposure reduction are appreciable.

The time expended in performing any task can be shortened through elimination or simplification of work steps, improvement of tools, and efficient time utilization. Analysis of most refueling equipment modifications proposed in this report shows potential for considerable benefit through the elimination and simplification of work steps. Time utilization primarily depends on planning effectiveness, training, and personnel motivation. A number of suggested equipment modifications do not have a direct impact on the refueling operation duration since they are not on the critical path. However, they should produce a vital indirect benefit upon the time utilization for critical path work activities through release of personnel for other tasks, reduction of radiation exposure of key personnel, and reduction of the total level of activity. While it is not possible to assign a numerical value to such indirect benefits, they are important.

The refueling outage length improvements of the magnitude predicted in this study must have a considerable effect on improvement of plant availability which is then an economic benefit to the utility and its customers through reduced requirements for replacement power. Implementation of similar improvements by other utilities will make an important contribution in our country's efforts to reduce the consumption of natural gas and petroleum fuels.

Recommendations resulting from this program are presented in the following sequence: software and procedural improvements, equipment modifications already implemented at the Zion Station, equipment modifications without further development, and equipment modifications requiring additional development. Although Westinghouse is continuously involved in development related to equipment improvements for future models, there were no results of this program which would fall into that category of recommendations

TABLE 5.1
SUMMARY OF BENEFITS OF REFUELING EQUIPMENT IMPROVEMENTS

Refueling Component	Work Time Improvement T_w = Hrs	Labor Improvement (Man-hours)	Radiation Exposure Improvement		Critical Path Time Improvement ($\tau_{\mu} = .54$) T_e = Days
			Man-Rem	(% Radiation)	
Integrated R.V. Head Assembly	36.1	176.6	5.26	84	2.41
Improved R.V. Closure System	30.0	280.0	13.51	47	2.31
Improved Refueling Machine Mast	68.2	384.2	9.04	58	3.33
Improved Refueling Machine Controls	44.1	245.0	5.98	57	2.25
Electrical Test Equipment	8.0	16.0	0.88	40	0.62
Improved T.V. System	1.0	5.0	0.20	33	0.08
Improved Cavity Cleaning Equip.	9.6	57.6	14.40	24	0.74
R.V. Head O-Ring Groove Cleaning Equipment	10.0	60.0	6.90	50	0
R.V. Stud Cleaning Equipment	16.2	48.6	0.24	30	0
Total Benefit	223.2	1273.0	56.4	41	11.7

5.1 SOFTWARE AND PROCEDURAL IMPROVEMENT

At this time Zion Station personnel are planning the fifth refueling maintenance outage at that site. Station personnel view the past outages as learning and growth experiences in which much was learned through trial and error. These recommendations are addressed for the benefit of those utilities planning their initial outages. However, most recommendations would be of interest/benefit to more experienced utilities in nuclear power production. There are two areas addressed: preplanning and outage management.

5.1.1 Preplanning Recommendations

- Selection and training of the Outage Coordinator and staff should be made one year prior to the initial refueling/maintenance outage.

A corollary to this recommendation is that preplanning for the next refueling/maintenance outage should begin as the last outage is completed. This is true because preplanning is the key to a smooth, efficient outage at any station. Particularly at a two-unit station such as Zion, the position of Outage Coordinator is a full-time job.

Training of the Outage Coordination Staff should begin one year before the initial refueling outage and should include the following items:

1. Project Management
2. Estimating and Planning
3. Refueling Outage Experience at Other Utilities.
4. Computer Planning Mechanisms.
5. Preparation of Short Outages.

Six months should be devoted to the above items, along with a team concept of job performance.

Preoutage planning should begin a minimum of six months before the initial outage.

All corporate departments, the NSSS vendor, and the turbine-generator vendor should submit a list of all known work items to the Outage Coordinator at this time. These work items are to be reviewed and accepted by an Outage Review Committee consisting of top station management. This review should eliminate from the outage all items except those absolutely required. Work that can be performed during the preoutage period should be scheduled as such. The following categories should be considered essential work:

1. Refueling
2. Surveillance
3. Periodic Tests
4. Valve Lineups
5. Preventive and Corrective Maintenance
6. Regulatory Commitments
7. Corporate Directives

With a list of approved work items, the Outage Coordinator can then begin to plan and perform a critical path analysis and manpower leveling analysis.

A listing of work items requiring contract award, modification approvals, work package procurement, and parts delivery should be made and monthly meetings held to determine if all necessary items will be ready by the time the outage begins. Cutoff dates should be established for work item preparation.

During this time, the initial schedule should have been generated by the Outage Coordinator.

The last month should be devoted to station review of the schedule with emphasis on anticipating problem areas.

- Outage planning and scheduling should be a continuous process with adequate tools provided for critical path analysis, manpower leveling, communication, and reporting.

Zion Station has a full-time Outage Coordinator and staff. Their office is located near the Control Room. This provides a central location for all work groups.

Zion Station uses two planning and scheduling mechanisms. The first is a 33-foot Planalog board, which is a visual representation of jobs and logic that reflects scheduling impacts and parallel activities. The Planalog is useful as a communicating/working tool during daily coordination meetings.

The second tool is a critical path planning mechanism including manpower leveling, hourly increments, site-controlled and updated with printout capability of overall master plan and functional group work plans on a daily or shift basis. The current tool being utilized at Zion is Project/2.^[1] This program as used at Zion is described in more detail in Appendix C.

- For a two-unit station, commit only 50 percent of the permanent work force to the refueling/maintenance outage.

At Zion only 50 percent of the station working groups and supervisors are committed during outage planning. This guideline was established after the Unit 1 initial outage when an unscheduled outage occurred on Unit 2. During the outage, the unscheduled 50 percent of the work force is used as support for contractors and as a contingency in case of an unscheduled outage or other problems.

5.1.2 Outage Management

- Daily planning meetings should be conducted with representatives of all functional groups to review scheduled and unscheduled events and to review the work plans for the next 24 hours.
- Update critical path information as a change occurs to advise the functional groups of task changes and to inform station management of outage status.
- The use of overtime should be evaluated where necessary to improve work continuity on critical path tasks and to minimize unplanned interruptions.

1. Project/2 is a program leased by Project Software & Development, Inc., Fourteen Stony Street, Cambridge, MA 02138.

For future outages Zion station will operate on two eight-hour shifts, six days per week with the seventh day used only for critical path tasks that are behind in schedule. It has been found that this improves morale and keeps work flowing on a regularly scheduled basis.

- Perform productivity reviews of all refueling operations with emphasis in the following areas:
 1. Improve work task planning to maximize concurrent work tasks.
 2. Continuously upgrade work procedures and tools.
 3. Insure the adequacy and availability of support personnel, such as quality control, health physics, contractors, etc.
 4. Perform preventive planning by disciplined adherence to procedures, improved communications (particularly between shifts), and prompt resolution of equipment and tooling problems.
 5. Provide contingency plans for unscheduled delays, interruptions, or opportunities.

5.2 EVALUATIONS OF MODIFICATIONS ALREADY IMPLEMENTED AT THE ZION STATION

A number of equipment and procedural modifications that are not yet in general use throughout the industry have already been implemented at the Zion Station. These changes were devised and implemented by the Zion staff independent of this program, but descriptions of these improvements are included in this report because of their benefit upon refueling/maintenance outages.

5.2.1 Improved Reactor Vessel Nozzle Cover Plate Sealing

During the 1976 refueling of Unit 1 a serious delay was caused by the leakage of water from the reactor cavity past the reactor vessel nozzle cover plate seals. The original design consisted of gaskets between each plate and the floor, with the plate bolted to threaded holes in the cavity floor. Irregular conditions of the floor prevented adequate sealing and bolts were broken when they were tightened in an attempt to improve the seal. A satisfactory seal was obtained using RTV compound to fill the gaps between the gaskets and the metal surfaces.

An improved seal design was implemented in time for the 1977 refueling of Unit 2 and proved to be very successful. The new design is based on C-Channel flanges welded to the floor around each opening to provide a flat sealing surface. Rubber gaskets are installed on top of the channels and the plates are clamped in place with bolts and nuts around the periphery.

5.2.2 Inflatable Reactor Vessel Seal

The original seal plate with gaskets for sealing the annular gap between the reactor vessel and the cavity was replaced at the Zion Station by a custom-molded inflatable seal. The seal has a T-shaped cross section to maintain proper position and utilizes the water head to enhance sealing. The seal is easily installed and inflated. Pressure in the seal is maintained by a nitrogen gas supply bottle and an inflation valve. The seal functioned very satisfactorily during the refueling outages at Zion.

5.2.3 Expandable Stud Hole Plugs

The threaded-metal stud hole plugs for the reactor vessel flange were replaced with expandable rubber washers squeezed between two plates by a screw/nut adjustment. Expansion of the rubber gasket seals the stud hole. Provision is made for filling stud hole with nitrogen gas, providing an easy method for detecting leakage. The nitrogen gas provides the added protection of maintaining a dry atmosphere in the stud hole throughout the refueling. These hole plugs have functioned very satisfactorily.

5.2.4 Pivoted Cable Tray

Support of the CRDM power and instrumentation cables at the Zion Station is provided by a cable tray pivoted at the steam generator wall on the cable run side of the reactor. During reactor operation, the cable tray is bolted in place between the missile shield support beams. The pivoted design provides some savings in time as compared with plants where the cable support structure must be lifted and moved to a storage position. The removal and replacement of the bolts which attach the tray to the support beam is still time-consuming. An alternate attachment method such as quick-disconnect "hooks and eyes" would provide further improvement through the reduction of disassembly, reassembly steps.

5.2.5 Reactor Vessel Stud Removal Tooling

At Zion, the use of a load-reducing device in tandem with the air-powered stud spinning tool is an excellent technique to ease the removal of studs. The spinner tool, however, appears to be underdesigned for the torque required. During the Unit 1 refueling a shaft was bent, and during the Unit 2 refueling, difficulty was experienced in achieving free spinning with several studs. A redesign or modification of this equipment would greatly enhance its effectiveness when high thread friction is experienced on studs where surface oxidation has occurred.

5.2.6 Auxiliary Cavity Crane

The use of an auxiliary cavity crane significantly reduces the scheduling limitations of the polar crane. An auxiliary crane is particularly useful in lifting studs and placing them in their storage boxes. For the 1976 Unit 1 refueling, a power hoist was installed mounted on a beam

which is stationary relative to the length of the reactor cavity. The hoist positioning was provided with a chain fall. A more versatile auxiliary crane has now been installed in Unit 2 but was not completed in time for its first refueling. This crane has a traveling beam supported from beams mounted on the steam generator compartment walls. Positioning of the power hoist across the pool and along the length of the pool are provided by separate chain fall drives. Loads can be handled from anywhere in the reactor cavity and deposited at the work deck elevation along the sides of the cavity.

5.2.7 Auxiliary Cavity Filtration System

An auxiliary cavity filtration system was used during both Unit 1 and Unit 2 refuelings. A portable system was used in Unit 1 while a built-in system was provided for Unit 2. The systems of similar design taking suction from the cavity pool passing through a strainer and pumping through a series of filters prior to return to the cavity at a distance from the reactor. The built-in system installed in Unit 2 had the added advantage of having the pump filter unit mounted behind the steam generator compartment walls, thus reducing the personnel exposure from contamination concentrated in the filters. Also, the increased work space at the side of the cavity pool was a significant advantage. A separate skimmer unit was provided for both units that included pumping and filtration equipment and a low-cost, swimming-pool-type skimmer. The value of these auxiliary filtration systems was clearly demonstrated when water turbidity problems caused delays during both refuelings.

5.2.8 Refueling Communication Systems

A three-way communication system was provided during the Zion refuelings between the manipulator crane (refueling machine) area, the control room, and the spent fuel building. The use of speakers instead of headphone sets was a notable advantage. All personnel performing the work were kept informed.

5.2.9 Fuel Transfer Tube Flange

A wall-mounted, swing-away davit has been provided in each Zion unit to support the heavy fuel transfer tube blind flange. This feature greatly aids in the removal and installation of the flange.

5.2.10 Cavity Cleaning

The time required to clean the cavity following refueling was significantly reduced by the use of a high-pressure water system during the 1977 refueling outage of Unit 2. The system used a high-pressure water jet to decontaminate the cavity walls; it was effective and required much less time than the wiping procedure used in the previous Unit 1 outage. Further improvements could be made to the work platform used that required the exclusive use of the polar crane. The auxiliary crane that has now been installed in Unit 2 should be adaptable for support of the platform.

5.3 EQUIPMENT MODIFICATIONS WITHOUT FURTHER DEVELOPMENT

The applicable modifications to refueling-related equipment proposed in the Interim Report should be considered for implementation at the Zion Station to demonstrate the predicted improvements in refueling time, radiation exposure, and manpower requirements. The initial step for implementation must be the development of the design concepts discussed in section 5 of that report to establish:

- the activities required for installation.
- the impact on the refueling outage(s) during which installation is anticipated.

Because of the long lead time for design, fabrication and installation of the proposed equipment modifications, other utilities should also promptly consider implementation in PWRs already in operation or under construction.

A concentrated effort should be made, through additional studies and modifications of planning, procedures, and equipment, to reduce the time required for other maintenance activities performed during the refueling outage. The goal is to complete the outage work within approximately the same time period as required for refueling. It should be noted that with a refueling outage of three weeks and a two-week allowance for forced outages during the year, nuclear plants could achieve an availability of 90 percent.

Equipment modifications as recommended in Section 5 of the Interim Report are briefly repeated in this Subsection and Subsection 5.4, although the order may be changed to reflect the amount of additional development or first-time design required for implementation.

The following recommendations are state-of-the-art retrofit modifications in which only first-time design effort is required to be implemented for an operating PWR or one under construction.

5.3.1 Integrated Vessel Head Assembly

Modifications to change one (or both) existing reactor vessel heads to the integrated vessel head assembly concept would be adapted. This would include incorporation of the following existing features:

- Control rod drive cooling system and shroud structure
- Integral lifting rig
- Integral missile shield
- Integral seismic platform

- Integral cable tray with quick disconnect cable feature
- Integral stud-handling system

5.3.2 Improved Reactor Vessel Head Closure System

The time required to detension, remove, insert, and tension the reactor vessel studs would be significantly reduced by implementation of a quick-disconnect stud-tensioning system and stud adapters.

5.3.3 Single Integrated Gripper Mast Assembly (SIGMA)

The manipulator crane (refueling machine) changes necessary for the incorporation of the SIGMA mast, which permits handling of fuel assemblies, RCC control rods, and thimble plugs by the mast should be implemented.

5.4 EQUIPMENT MODIFICATIONS REQUIRING ADDITIONAL DEVELOPMENT

The following recommendations are conceptual designs which require further development plus first-time design effort for implementation in an operating PWR or one under construction.

5.4.1 Improved Refueling Machine Control System

The application of the automatic X-Y positioning control system to the manipulator crane to permit rapid, accurate refueling machine positioning should be developed.

5.4.2 Improved Lighting System

An improved refueling cavity lighting system design should be developed, based on the latest underwater lighting technology.

5.4.3 Reactor Vessel Stud and Stud Hole Cleaning Equipment

Specification and design of a portable ultrasonic cleaning system for studs and general decontamination. Also, design of a portable, powered stud-hole cleaning system.

5.4.4 Reactor Vessel O-Ring Groove and Seal Surface Cleaning Equipment

Develop a powered O-ring groove and seal surface cleaning system to permit rapid, effective cleaning from a distance, resulting in low radiation exposure to maintenance personnel.

5.4.5 Refueling Cavity Access Equipment

Design a portable, freestanding cavity access power lift to provide rapid, safe transport of personnel and equipment into and out of the reactor cavity. Additional uses of the equipment for other in-containment maintenance tasks could be explored.

5.4.6 Improved Burnable Poison Handling Tool

Design a new burnable poison handling tool to permit handling and transfer of these components more quickly and reliably.

5.4.7 Control Rod Drive Mechanism Electrical Test Equipment

An electronic device should be designed to reduce the time required to perform the electrical testing and checkout of the multiple drive and positioning indication coils of the control rod drive mechanism.

5.4.8 Containment Access Material Handling Equipment

Conventional material-handling concepts should be reviewed and modified as recommendations for use in transporting bulky and massive materials into and out of the containment.

5.4.9 Improved Underwater TV System

An improved underwater viewing television system should be designed for use on operating and nonoperating plants.

5.4.10 Refueling Cavity Cleaning Equipment

Refueling cavity cleaning equipment concepts including the hydrolaser should be reviewed and a preferred concept developed.

SECTION 6

FUTURE PROGRAM DIRECTION

During Phase 1 of this program, an observation of refueling outages at the Zion Station was performed. Analysis of the observed data has identified benefits that are available through improved refueling equipment along with areas where additional new innovative refueling, or refueling-related equipment should be beneficial.

A number of specific design concepts have been recommended in this report and the Interim Report. The values of the proposed design concepts in terms of savings in refueling time, labor, and radiation exposure have also been reported. The estimated economic payoff for these concepts was found to be of such significance that an additional, Phase 2 of the program is warranted whereby a more detailed engineering study is undertaken to determine the cost of implementation.

6.1 PHASES 2 AND 3

As seen by Commonwealth Edison Company and Westinghouse, the specific objective of a follow-on Phase 2 would be as follows:

- Establish the detailed design configuration and estimated equipment cost of the proposed concepts for installation at the Zion Station.
- Establish a plan for the installation of the proposed concepts at the Zion Station compatible with planned shutdown schedules. Estimate the installation costs.
- Establish consequent station modifications and schedule perturbations associated with equipment installation and their cost effects.
- Evaluate relicensing requirements and associated cost estimates.
- List priorities of the concepts based upon a detailed cost benefit analysis.
- Prepare a decision-making document as a final report.

After appropriate decisions are made and such details as equipment ownership, etc., are worked out, Phase 3 would be developed with the following objectives:

- Implement those concepts which have highest priority.
- Monitor the actual performance and payoffs for those concepts implemented in a subsequent outage, report on the results, and make recommendations for application to other plants. Any Zion anomalies which would not be applicable to other plants will be identified.
- Make final recommendations for implementation of equipment designs at other operating/construction plants.

6.2 TECHNICAL APPROACH

The recommendations for equipment modifications resulting from Phase 1 fall into two categories: Equipment Modifications Without Further Development and Equipment Modifications Requiring Additional Development.

6.2.1 Equipment Modifications Without Further Development

Equipment modifications without further development are in the realm of current state of the art and are planned for implementation into new plants (third and fourth generation NSSS), but require additional design and engineering to evaluate the cost of manufacture and installation for application to operating plants (first and second generation NSSS).

Those recommendations from Phase 1 which deal with substantial changes to Zion equipment, will require the following activities.

- Review the design of the existing Zion equipment and facilities in the as-built condition.
 1. As-built or latest drawing revision review of affected equipment and facilities.
 2. On-site inspection of the affected equipment and facilities to assure correct documentation.
- Prepare layout design changes to accomplish the required modifications to implement the new design concepts to existing hardware.
- Perform required functional and structural analyses relative to the design changes.
- Prepare detailed design drawings and specifications required to implement the design concept.
- Prepare procedure to accomplish the installation of the modification.
- Estimate cost of hardware and installation.
- Perform economic benefit analysis.

6.2.2 Equipment Modifications Requiring Additional Development

Equipment modification requiring additional development are concepts which advance the state of the art and which require design and engineering to establish their special requirements.

Those recommendations from Phase 1 deal with design of new concepts (i.e., not previously supplied) where the following activities will be required.

- Establish performance criteria for the equipment.
- Prepare design requirement specifications.
- Perform layout and detailed designs of the equipment.
- Perform required functional and structural analyses.
- Prepare drawings and equipment specifications suitable for procurement.
- Plan implementation at site.
- Estimate cost of hardware and installation/implementation.
- Perform economic benefit analysis.
- Perform implementation decision process and configuration as well as their total cost of manufacture and installation.

The work under Phase 2 of this program would establish the equipment designs to such an extent as to permit accurate cost assessment, implementation planning, and estimation of the installation costs. The designs would be processed with sufficient detail to allow the initiation of a subsequent procurement phase (Phase 3) if a favorable decision to implement should be forthcoming.

Also installation planning and cost estimates for each concept would be processed with sufficient detail to allow expeditious implementation if a favorable decision is made.

APPENDIX A

**ZION UNIT 1 1976 REFUELING/MAINTENANCE OUTAGE
PROBLEM MATRIX**

ZION UNIT 1 - 1976 REFUELING/MAINTENANCE OUTAGE - PROBLEM MATRIX

Problem Description	Equipment/Procedure Involved	Field Expedient Handling	Time Loss
1. Containment access delayed. Suspected air-borne activity. [a]	Gas analyzer amplifier and back-up failure. Containment purge.	Repaired equipment. Extended containment purge time.	24 hours
2. One incore detector would not enter storage.	Incore Instrumentation System. Refueling Procedures.	Discovered an old stored instrument parked in location. Removed and disposed.	24 hours
3. Low pressure seals for seal table and instrument retracting tool misplaced. Vendor supplied seal replacements incorrently.	Bottom Mounted Incore Inst. Refueling Procedures	Borrowed retracting tool from different site. Made new seals in-house.	24 hours
4. Maintenance crew unavailable one shift due to emergency work on Unit 2. [a]	Outage management proced.	Curtailed outage activities.	10 hours
5. Secondary syst. maintenance delayed due to slow drain down.	Secondary drain, fill and vent procedure (SG & Blowdown valve)		24 hours
6. Auxiliary systems modification delayed due to conflicting Unit 2 operating req't.	Circulating Water System. Outage management proc.	Delayed until later	None
7. RV Guide stud keys not in place. [a]	Guide studs. Refueling procedures.	Replaced keys.	4 hours

a. Affected performance of Critical Path operation.

ZION UNIT 1 — 1976 REFUELING/MAINTENANCE OUTAGE — PROBLEM MATRIX (cont)

Problem Description	Equipment/Procedure Involved	Field Expedient Handling	Time Loss
8. Primary coolant system level indication, difficult, unreliable. New system designed but not installed.	RCS Drain, Fill and Vent procedures	Used Tygon tube recommended vendor procedures. New system with remote read-out installed later.	None
9. Initial cavity cleaning delayed by equipment and procedural problems. Problems mounting and operating equipment.	Hanging scaffold problems.	Hand wipe down of walls.	None
10. Installation and handling problems on new Auxiliary Cavity Crane.	Polar Crane and new Aux. Crane components. Erection procedure.	Used polar crane on an-available basis. Custom fitted crane support members.	None
11. Previous caustic spill required Missile Shield lifting lugs to be cleaned and dye checked.	Missile Shield lifting lugs. Q.A. & Safety procedures. Maintenance proc.	As described.	None
12. Double handling of Missile Shield Support Beams and R.V. Head Insulation. Not moved directly to assigned lay down area.	Polar crane, missile shield, R.V. head insulation. Reactor disassembly procedures and laydown area allocation.	Temporarily moved beam to permit Aux. Crane installation. Later moved to assigned storage. Head insulation in way of beam storage.	None
13. Seismic support bar removal delayed by polar crane work schedule.	Polar Crane, Seismic Support Bars Outage Procedure	Work done on polar crane availability basis.	None
14. Fuel inspection equipment problems. Switch failure, layout interference.	Fuel inspection rig.	New switch delivered to site. Equipment modified to eliminate interference.	None

ZION UNIT 1 - 1976 REFUELING/MAINTENANCE OUTAGE - PROBLEM MATRIX (cont)

Problem Description	Equipment/Procedure Involved	Field Expedient Handling	Time Loss
15. Difficulty in obtaining RV Head Gas sample delayed R.V. head disassembly. [a]	Head gas sampling equipment/procedure needed.	Progress delayed pending satisfactory sample.	60 hours
16. Delays of RV stud removal:			
a. Rad. protection - personnel exposure administration. [a]	Rad. protection procedures. Regulatory requirements	Crew assignments changed when dose limits reached. Checked at beginning of shift.	4 hours
b. Electrical repairs.	Stud tensioner handling crane.	Local repair.	1 hour
c. Low process air delivery to stud removal tool.	Shop air supply.	Used as available.	
d. One of three extractors failed in service (bent shaft)	Air driven stud extractors.	Completed job with two serviceable extractors	
e. Stud rack removal delayed	Polar crane.	Used crane as available.	
17. O-rings incorrect size.	Instrument Port Protection Sleeve.	Obtained new O-rings.	48 hours
18. Stripped bolts on cavity access ports. (Initial cavity flood preparation)	Sand box covers in cavity. Refueling Procedure	Drilled and tapped for larger bolt size.	10 hours
19. Fumes for RTV (sealant) created breathing hazard in reactor cavity.	Sand box covers in cavity. Refueling Procedure	Crew required to wear air packs.	None

a. Affected performance of Critical Path operation.

ZION UNIT 1 — 1976 REFUELING/MAINTENANCE OUTAGE — PROBLEM MATRIX (cont)

Problem Description	Equipment/Procedure Involved	Field Expedient Handling	Time Loss
20. Delays in RV Guide stud and bushing installation: ^[a]			
a. O-rings for bushing incorrect size	RV bushing O-rings	Fabricated correct size in-house.	1 hour
b. Guide stud lifting eye thd. mismatch with stud thd.	RV Guide Studs & lifting eyes.	Machined adaptor plug in-house.	1 hour
c. Interference with stud crane elec. conduit prevents true vertical lift and insertion of one stud (No. 12).	RV Head Assembly	Rocked into place	0.5 hour
21. Installation of Isolation Valves delayed by misplaced paper work.	Outage Coordination.		None
22. Cavity Crane removal delayed due to Polar Crane Unavailability	Polar Crane; Outage Coordination		None
23. Steam Generator, E/C test progress delayed by contract labor productivity	Steam Generator Inspection		None
24. Station Laundry capacity strained by outage demand	Radiation Protection Procedure, Regulatory Requirements		(Minor)

a. Affected performance of Critical Path operation.

ZION UNIT 1 - 1976 REFUELING/MAINTENANCE OUTAGE - PROBLEM MATRIX (cont)

Problem Description	Equipment/Procedure Involved	Field Expedient Handling	Time Loss
25. Auxiliary Filter location requires additional shielding	Auxiliary Cavity Filtration System; Radiation Protection Procedure	Temporary shielding erected	None
26. Excessive time required for R/V Head lift due to resistance bank overheating. All speeds not operable. [a]	Polar Crane	Auxiliary fan cooling provided to alleviate situation	(Minor)
27. Excessive Reactor Cavity leak required drain down; head installation & repair plus repeat of Head lift. Sump pump failure. [a]	Reactor Cavity, Sump Pump Refueling-Mechanical Maintenance Procedure	Lifted and resealed of all access port covers in cavity using gaskets and RTV.	87.5 hours
28. Containment access curtailed due to high airborne activity (3/18) [a]	Rad. Protection Procedure Regulatory Requirements		5 hours
29. Problems during the second R/V Head lift: [a]	Polar Crane, Dillon Load Indicator		
a. Dillon Load Indicator connector pins damaged		Removed pins and repaired	3.25 hours
b. Resistance banks overheated on Polar Crane		Used auxiliary cooling (fans). Stopped lift to cool down.	0.5 hours
c. Suspected reoccurrence of cavity leak		Stopped lift to investigate	0.5

a. Affected performance of Critical Path operation.

ZION UNIT 1 – 1976 REFUELING/MAINTENANCE OUTAGE – PROBLEM MATRIX (cont)

Problem Description	Equipment/Procedure Involved	Field Expedient Handling	Time Loss
30. Problems during Drive Rod unlatching: ^[a]			
a. Hold for administrative approval to proceed	Refueling Procedures Regulatory Requirements	Control Room approval obtained	0.5 hours
b. Delay to inspect for cause of suspected cavity leak		Inspected sand box covers and rubber seal ring with TV	0.5 hours
c. Adjust Drive Rod latching tool	Drive Rod Latching Tool	Performed adjustment	0.25 hours
d. Last two rows of drive rods cannot be unlatched due to interference between Manipulator Crane and stored internals lift rig.	Internals Lift Rig; Manipulator Crane; Internals Storage Stand, Reactor Cavity Design	Raised lift rig with Polar Crane permitting correct positioning of Manipulator Crane for unlatching last two rows of Drive Rods.	0.75 hours
e. Drive rod unlatching requires air pressure in excess of manufacturer specs value (100 psi). Required shaking of tool in many cases to release RCC	Drive Rod Latching Tool	Air bottle at pressure of ~200 psi used to operate tool	~1.0 hours
31. Intermittent operating problems with Guide Tube Cover Tool	Guide Tube Cover Removal Tool	Continued use.	1.0 hours
32. Upper Internals lift delays: ^[a]			
a. Fill cavity to 24 ft elevation	RWST System		2.0 hours
b. Lift held until next shift	Reactor Disassembly Procedure		2.0 hours
c. Trouble releasing Lift Rig from Polar Crane	Internals Lift Rig		0.5 hours

a. Affected performance of Critical Path operation.

ZION UNIT 1 -- 1976 REFUELING/MAINTENANCE OUTAGE -- PROBLEM MATRIX (cont.)

Problem Description	Equipment/Procedure Involved	Field Expedient Handling	Time Loss
33. RV Head O-Ring removal: ^[a] a. Inner & Outer O-rings stuck in groove b. No container for storing old O-ring pieces	R/V Head and O-rings	Pried out and cut into pieces Obtained 55 gal drum	See No. 35
34. Clean O-ring grooves and install new O-rings Difficult to remove baked on Boric Acid	R/V Head; O-rings	Scraped with rubber stone and cus cloth. Wiped with spot cleaner and alcohol using lint free rags.	See No. 35
35. Clean O-ring grooves and install new O-ring (cont.) Threaded fasteners to retain O-ring broken while adjusting	R/V Head, O-ring retainer clips and screws	Filed down, not replaced since sufficient number remained	~40.0 hours total No. 34 and 35 not on critical path.
36. Fuel Shuffle delays: ^[a] a. Steam Generator blow-down valves disassembled; needed for containment integrity. No replacement parts on hand. b. Waiting for cavity water level adjustment c. Fuel assembly lowered out of position on upender in spent fuel building	Tech. Spec and Refueling procedures RWST systems & Refueling procedures Spent Fuel Bridge Hoist	Repair parts obtained from valve in storage Trip limit switch and repeat operation	10.5 hours Included Above 0.5 hours

a. Affected performance of Critical Path operation.

ZION UNIT 1 — 1976 REFUELING/MAINTENANCE OUTAGE — PROBLEM MATRIX (cont)

Problem Description	Equipment/Procedure Involved	Field Expedient Handling	Time Loss
d. Thimble plug not inserted in F.A. nozzle in refueling canal	Thimble Plug Tool	Installed T.V. for viewing, Installed B/P Insert plate in RCC change fixture. Made hook tool to lift Thimble plug and installed	3.0 hours
e. Leaning F.A. in core, difficult latching	Manipulator Crane; Fuel Assembly	Installed light for viewing, lower RHR flow, repeated operation	1.0 hours
f. Fuel Assembly lowered on top of another in core. RCC in F/A damaged; hub bent	Manipulator Crane; Refueling Procedures, Fuel Assembly	Installed T.V. on Manipulator Mast; Inspect assembly, Removed assembly to Spent Fuel Pit. Made to lift damaged RCC; Removed and Installed new RCC.	3.0 hours
g. Assembly would not enter core; water clarity bad.	Manipulator Crane; Auxiliary Filtration System, Fuel Assembly	Installed T.V. on Manipulator Crane to inspect. Removed adjacent assembly; loaded working assembly	2.5 hours
h. Assembly would not enter core; water clarity bad	Manipulator crane; Auxiliary Filtration System; Fuel Assembly	Installed T.V. on manipulator crane to inspect; Worked new assembly in	0.75 hours
i. Work on lights on Spent Fuel Pit Bridge	Spent Fuel Bridge lighting		1.0 hours
j. Spent Fuel Pit Bridge making moves for fuel evaluation inspection (3 items)	Spent Fuel Bridge		2.0 hours
k. Bent finger on Thimble Plug would not enter Fuel Assembly	Thimble Plug & handling tool	Made tool to straighten finger. Repair and repeat operation	0.6 hours

ZION UNIT 1 — 1976 REFUELING/MAINTENANCE OUTAGE — PROBLEM MATRIX (cont)

Problem Description	Equipment/Procedure Involved	Field Expedient Handling	Time Loss
l. Waiting for Radiation Protection coverage	Radiation Protection procedures, Regulatory requirements		0.7 hours
m. Manipulator Crane pulley developed high friction	Manipulator Crane	Remove pulley, polish bore and shaft surface	0.5 hours
n. Fuel assembly would not enter core. Water clarity bad	Manipulator Crane, Auxiliary Filtration System; Fuel Assembly	Install T.V. on Manipulator Crane to inspect, reindex manipulator crane, repeat operation	
o. Manipulator Crane Pulley again developed high friction	Manipulator Crane	Removed parts from Unit 2 crane and installed on Unit 1	1.1 hours
p. Fuel assembly would not enter core. Water clarity bad.	Manipulator Crane; Auxiliary Filtration System, Fuel Assembly	Installed T.V. on manipulator crane. Removed adjacent assembly; loaded working assembly	3.0 hours
q. Fuel assembly would not enter core. (continued)	Manipulator Crane; Fuel Assembly	Removed adjacent assembly. Installed working assembly; replaced adjacent assembly	4.25 hours
r. Manipulator Crane gripper latched over vacant basket in RCC Change Fixture. Safety feature would not permit unlatching	Manipulator Crane	Installed plate in change fixture. applied pressure on gripper w/plate overcoming safety lock. Removed plate; proceeded with operation	0.6 hours
s. Fuel assembly would not enter core	Manipulator Crane; Fuel Assembly	Removed adjacent assembly. Installed working assembly; replaced adjacent assembly	2.0 hours
t. Waiting for Radiation Protection coverages			0.5 hours
u. Fuel assembly would not enter core	Manipulator Crane; Fuel Assembly		0.5 hours

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ZION UNIT 1 - 1976 REFUELING/MAINTENANCE OUTAGE - PROBLEM MATRIX (cont)

Problem Description	Equipment/Procedure Involved	Field Expedient Handling	Time Loss
v. Assembly lowered on top of upender basket. Limit switch safety feature had to be tripped to permit lifting for repositioning	Spent Fuel Bridge		
w. One finger came out of engagement with combs	Source-B/P Ass'y; B/P Handling Tool	Re-engage finger	
x. Containment radiation monitor failed during shuffle requiring delay of operations.	Rad. Monitor; Rad. Protection Procedures Regulatory Requirements	Repaired monitor	2 hours
37. Fuel Inspection:			None
a. Number of assemblies inspected was reduced by delay of fuel shuffle, commitment of equipment to another site and impending teamster's strike			
b. Brake shoe engaged locking vertical travel of TV scan.	Fuel inspection equipment	Swelling of lining caused seizure when immersed. Shoe removed to permit operation.	22 hours
c. Inspection requires use of S/F Bridge for handling F.A.'s. This conflicts with B/P change of refueling	S/F Bridge and Hoist	B/P Tool & Fuel Handling tool alternately mounted on single hoist to support both inspection and refueling operations.	0.5 hours
d. Inspection had minor delays awaiting Rad. Protection coverage	Rad. Protection Procedures, Regulatory Requirements		

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ZION UNIT 1 — 1976 REFUELING/MAINTENANCE OUTAGE — PROBLEM MATRIX (cont)

Problem Description	Equipment/Procedure Involved	Field Expedient Handling	Time Loss
38. Incorrect sling selected for removal of surveillance capsule hole plugs. Rerigging was required. [a]	Rigging	Rerigged with longer sling	0.5
39. Delay waiting Radiation Protection coverage for RCC inspection	Rad. Protection Procedures Regulatory Requirements		0.6 hours
40. Delay waiting Radiation Protection coverage for R/V Head Baffle Plate removal			0.5 hours
41. Difficulty installing T/V on manipulator crane for Core Mapping [a]	Manipulator Crane TV System (CECO)		1.25 hours
42. Installation of Upper Internals [a] a. Polar Crane diverted to handle equipment for Drive Rod modification b. Delayed to retrieve unidentified disc on R/V flange	Polar Crane	Wait for crane release Installed T.V. to view object and core. Retrieved object using suction line from Aux. Filtration System. Tried unsuccessfully to identify object.	1.25 hours 10.0 hours

a. Affected performance of Critical Path operation.

ZION UNIT 1 — 1976 REFUELING/MAINTENANCE OUTAGE — PROBLEM MATRIX (cont)

Problem Description	Equipment/Procedure Involved	Field Expedient Handling	Time Loss
c. Delay awaiting water drain down	RWST System/Refueling Procedures		1.0 hours
d. Difficulty getting dimensional check for internals seating	Refueling Procedure	Waited for next shift to remove	4.0 hours
43. Modification of Drive Rods:			
a. Delay waiting for polar crane and identification of disc on vessel flange (see 42.b)	Polar Crane		6.5 hours
b. Mod. crew waiting for drive rod removal			2.7 hours
c. Stop gage used for determination of chamfer dimension bound on drive rod (twice)	Drive Rod Modification	Removed from rod, decontaminated, modified in Zion machine shop	4.25 hours
d. Procedure check and waiting for supervision			0.8 hours
44. Removal of Guide Tube covers: ^[a]			
a. Difficulty latching G.T. covers	Guide Tube Cover Removal Tool	Adjust tool and proceed	1.75 hours
b. Removal of last two rows of G.T. covers — interference between Man. Crane & U.I. lift rig. (same as 31.d.)	Internals Lift Rig; Manipulator Crane; Internals Storage Stand	Raise Lift Rig with Polar Crane, position Manipulator Crane	0.25 hours

a. Affected performance of Critical Path operation.

ZION UNIT 1 -- 1976 REFUELING/MAINTENANCE OUTAGE -- PROBLEM MATRIX (cont)

Problem Description	Equipment/Procedure Involved	Field Expedient Handling	Time Loss
45. Difficulties encountered aligning of load cell and lift rig for Head Installation. ^[a]	Polar Crane, Head Lift Rig Reactor Assembly Procedure		0.6 hours
46. Waiting for cavity water drain down during RV Head Installation. ^[a]	Refueling Water System		2.25 hours
47. Cavity Cleaning: ^[a]			
a. Motorized Scaffold -- many problems with fit of curb hanging clamps. Drive motors required repair several times.	Motorized Hanging Scaffold	Repair in place	Unaccounted
b. Difficulties with wall mounted hangers interfering with motion of the scaffold	Racks and equipment stored	Work around physical	Unaccounted
c. Work interrupted by other tasks going on concurrently			
d. Deposit (bath-tub ring) formed on wall. Difficult to remove	Auxiliary Cavity Filtering System		
e. Heavy particulate matter deposit on cavity floor		"Squeegeed" to drain	Unaccounted
f. South end drain pipe small size, plugged up. Little or no floor slope to drain	Cavity drain system	Cleaned drain line after plugging at top with rubber stopper.	Unaccounted
g. Rubber stopper drawn into drain			
h. Efforts hampered by need of procedure and equipment			

a. Affected performance of Critical Path operation.

ZION UNIT 1 — 1976 REFUELING/MAINTENANCE OUTAGE — PROBLEM MATRIX (cont)

Problem Description	Equipment/Procedure Involved	Field Expedient Handling	Time Loss
48. Waiting for Rad. Protection to cover installation of Part Length Conoseals ^[a]	Rad. Protection Procedures Regulatory Requirements		0.25 hours
49. Installation of R/V Head studs:			
a. Delay for work place meeting			1.0 hours
b. Protective clothing shortage due to strained capacity ^[a]	Protective Clothing/Radiation Protection Procedure, Regulatory Requirements		0.75 hours
c. Delay due to high airborne activity-stud hole plugs not placed in container. (purge system status not certain-may have been off).	Radiation Protection Procedures, Regulatory Requirements	Containment closed until Radiation Protection Clearance	10.0 hours
d. Rad. Protection instruction on Protective clothing required	Radiation Protection Procedures		0.5 hours
e. Prepare spacer blocks to prevent stud & vessel thread damage	R/V Closure Studs/Reactor Assembly Procedures	Wooden blocks fabricated in Zion Machine Shop to hold studs out of contact until ready to thread in	1.0 hours
f. Problem starting one stud on threads	R/V Closure Stud	Run tap into stud hole of R/V flange. Clean-up top two threads	3.0 hours
g. Problem operating one stud tensioner-hand wheel lowering of stud engagement nut.	Stud Tensioner	Release pressure, remove stud tensioner, repeat engagement trial.	1.5 hours
h. Problem mounting tensioner on Stud No. 54-interference with Stud No. 1 & No. 53	R/V Studs and Stud Tensioner	Release studs No. 1 & 53 and two pass companion studs. Tighten No. 54 and companions.	6.75 hours

a. Affected performance of Critical Path operation.

ZION UNIT 1 -- 1976 REFUELING/MAINTENANCE OUTAGE -- PROBLEM MATRIX (cont)

Problem Description	Equipment/Procedure Involved	Field Expedient Handling	Time Loss
50. Misplaced Cable Tray Supports Pin ^[a]	Cable Tray	Rig cable tray temporarily until support pin found	2.0 hours
51. Rivets pulling out of R/V Head insulation joint to lifting angle ^[a]	R/V Head Insulation/Reactor Assembly Procedure	Handle using sling	0.5 hours
52. Missile Shield Installation: ^[a]			
a. Difficulties lining up holes in Missile Shield Blocks with holes in support beams	Missile Shield blocks and Support Beams/Reactor Assembly Procedure	Uses hydraulic jacks to spread beams to line up holes for tie down bolt installation	2.75 hours
b. CRDM Blower Housing stored on Missile Shield Block	CRDM Blower, Missile Shield Laydown-Storage Procedure	Double handle CRDM blower housing for missile shield handling	0.7 hours
53. CRDM Cooling System Installation: ^[a]			
a. Auxiliary Cavity Crane interfered with cooling system installation	CRDM Cooling System; Auxiliary Cavity Crane	Move cavity crane beams to permit CRDM Cooling System installation	0.7 hours
b. One bolt lost	CRDM Cooling System	Obtain new bolt	0.3 hours
c. Electrical hook up and check out		Only one shift worked on this task	
d. Electricians stopped work due to reaching daily dose limit	Rad. Protection Procedure, Regulatory Requirements	No replacement crew provided	6.0 hours
54. Cavity Access Port Cover Installation:			
a. Need procedure to start			2.0 hours
b. Polar Crane not available	Polar Crane		7.0 hours

a. Affected performance of Critical Path operation.

ZION UNIT 1 - 1976 REFUELING/MAINTENANCE OUTAGE - PROBLEM MATRIX (cont)

Problem Description	Equipment/Procedure Involved	Field Expedient Handling	Time Loss
c. Interference with cavity cleaning and crew assigned to other tasks at times			
d. Difficult to remove RTV sealant-broke tap in threaded hole in one instance			4.5 hours
55. In-service Inspection delayed by lack of craft support-carpenters or build scaffolding, grinders for indication removal	In-Service Inspection Procedures. ASME Section XI Code acceptance requirements		NA
56. Reactor Coolant Pump Motor modification;	RCP Motors, Polar Crane		
a. Laydown and work-space problem in containment		Pull two motors at a time one rotor at a time	40.0 hours
b. Remachined parts delivery problem		Staggered delivery to maintain progress	
c. Difficulty balancing RCP motor due to dynamic instrument problems		Resolved by service representative advising on correct light sensitive target to be used.	NA
57. Paperwork and Tech Staff support caused minor delays of maintenance and modification work			

ZION UNIT 1 – 1976 REFUELING/MAINTENANCE OUTAGE – PROBLEM MATRIX (cont)

Problem Description	Equipment/Procedure Involved	Field Expedient Handling	Time Loss
58. Interference between non-independent maintenance work tasks developed. (Possibly due to schedule slip)			NA
59. Scheduling of work without going through Outage Coordinator caused conflict between outage-non-outage work. Also caused problems in scheduling of Radiation Protection coverage.			NA
60. Preparation of 100% power NRC license review had impact on overall supervision of outage			NA
61. Regulatory and Tech. Spec paperwork was a significant burden during the outage			NA
62. Nitrogen fill valve failure delayed return to service (containment integrity) No spare parts on site [a]	N ₂ valves/spare parts Proc., Regulatory Requirements	Replacement parts flown in	40.0 hours

a. Affected performance of Critical Path operation.

ZION UNIT 1 - 1976 REFUELING/MAINTENANCE OUTAGE - PROBLEM MATRIX (cont)

Problem Description	Equipment/Procedure Involved	Field Expedient Handling	Time Loss
63. Problem with disposal or storage of bulky contaminated equipment in containment	Failed ex-core detector w/shielding, stuck filter on Auxiliary Cavity Filter, Large RCP motor work stands, etc.	Lashed to structural supports in Containment to eliminate missile problems	NA
64. Interference of Conoseal Seating tool with CRDM Cooling Shroud (Instrument Port Column to RV Head)	R/V Head Installation Penetration and Installation Port Column	Permanent modification of shroud panel by making quick removal sub-panel	NA
65. Secondary System Maintenance:			
a. Preparation and planning hampered by late contract award			
b. Auxiliary steamline break interfered with turbine work	Steamline-floor penetration	Contractor personnel repaired steamline	4.0 hours
c. Stud Heaters for generator cover removal incorrect size (vendor supplied)	Main Unit Generator	Borrowed heaters from another site	
d. L.P. Turbine design for access & disassembly very inconvenient	L.P. Turbine		
e. Scope of work increased to include Unit 2 feed-water pump	Feedwater pump		
f. Turbine blader arrived on site without required tools		Field supplied tools	

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ZION UNIT 1 - 1976 REFUELING/MAINTENANCE OUTAGE - PROBLEM MATRIX (cont)

Problem Description	Equipment/Procedure Involved	Field Expedient Handling	Time Loss
g. Unit 2 trip due to turbine bearing problem had strong impact on Unit 1 turbine general maintenance work	Unit 1 & 2 turbines	Maintenance personnel diverted for Unit 2 repair. Unit 1 bearings diverted for Unit 2 repair.	
h. Rework of new turbine bearing required because of incorrect thermocouple location.	Turbine bearing and thermocouple couple	Modify in Zion machine shop	
i. Replacement turbine bearings required re-machining for proper fit after delivery to site.	Turbine bearings	Sent out for machining	
j. Frozen shaft on Unit 2 turbine lift oil pump	Turbine Lift Pump	Sent out for repair	
k. Turbine bearing thermocouple found to be faulty after bearing installation	Turbine bearings	Disassembly and repair	
l. Hydrogen leak through generator, radial leads discovered after assembly	Unit 1 Main Generator	Disassemble and repair radial leads	
m. Turbine cross-over piping leaked after reassembly	Unit 1 Steam Piping	Disassemble, realign flanges, replace gaskets	
66. RCP seal flow problem	RCP	Repair seals	NA
67. RCP Motor Oil Reservoir minor leak	RCP-Motor	Repair	NA

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APPENDIX B

FURTHER EVALUATION OF ZION UNITS 1 & 2 INITIAL OUTAGES

(This information originally intended for Appendix B
has been incorporated into section 5 of the
main body of this report.)

APPENDIX C

ZION STATION MASTER PLAN

A revised master plan for Zion Station NSSS has been produced using a software package known as PROJECT/2.^[1] For purposes of this study only work items that pertain to the NSSS and/or generic items have been included. Items such as surveillance, periodic tests, turbine-generator and other secondary side work, valve lineups, and maintenance requests have been deleted since these operations are not typical.

PROJECT/2 is a full multicalendar, microscheduling program with a matched hardware system which can easily be installed on site. The hardware package consists of a CRT terminal, floppy diskette system, line printer and a graphic plotter. This system gives the Zion Station the capability to handle scheduling and updates in a timely manner. The program is executed by submitting a relatively small update to a stored network (schedule) to the host computer located in Chicago via a phone connection. Printed output is returned to the site within 15 to 20 minutes and can be distributed to work groups in such time as to provide up-to-date scheduling information. Field status communications have been greatly improved to the working level and to all site management.

To develop an outage plan incorporating all planned operations an Outage Planning Group needs only to "overlay" these operations onto the Master Plan. The Master Plan reproduced for this report assumes that all jobs proceed 24 hours/day, seven days/week with no resource limitations. All of these data inputs can be modified to match the constraints at any station. For example, Zion Station modifies these inputs to two eight-hour shifts per day, six days/week. Also, the capability exists to overlay different work schedules for multiple groups; e.g., maintenance on two 8-hour shifts and refueling operations on two 10-hour shifts.

Figure C-1 is a printout of the Zion Station Master plan by line item. Time duration in hours for each item are shown as estimated by station personnel for the refueling equipment as of Units 1 and 2 initial refueling/maintenance outages. With those times, the job duration is 931 hours, or approximately 39 days. This is the minimum current refueling/maintenance duration anticipated on a Zion Unit without further modifications to equipment or work schedules.

It should be noted that a minimum of three sorting codes are available to sort and run sub-routines for microdisplays of the stored data.

Figure C-2 is a bar chart presentation of refueling activities showing scheduled work on a daily basis including total activity float. Similiar charts may be printed showing zero float for all operations for distribution to the work location. Figure C-3 is a typical working schedule for the Technical Staff group (Technical Specification items).

1. PROJECT/2 is a proprietary program by Project Software & Development, Inc., 14 Story Street, Cambridge, MA 02138.

The entire master plan is shown, printed by the graphic plotter, in figure C-4. The critical path is printed in red lines and boxes. Critical path items can also be identified by the operations with zero float. In each box, the top number is the job duration and the bottom number indicates the total float in hours.

Zion Station personnel believe that this master planning mechanism provides for maximum flexibility for the Outage Planning staff while providing for smooth operations and on-time communications of status and changes.

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*   PROJECT SOFTWARE & DEVELOPMENT, INC.   *
*   14 STORY STREET                         *
*   CAMBRIDGE MASSACHUSETTS 02138        *
*                                           *
*   TEL 617-661-1444                       *
*                                           *
*   7753 27 APR 1978 CDES                  *
*   7753 27 APR 1978 MDES                  *
*                                           *
*   DATA FOOT INCREMENT 8176 BYTES       *
*****

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MONTH TO DATE STATISTICS FOR PASSWORD *2ICN* (EXCLUSIVE OF THIS RUN).

ENTRIES	65
COMPLETIONS	65
RECORDED CPL TIME	11MIN 22 SEC
RECORDED EXCFS	26215

THIS PROJECT/2 SYSTEM IS LEASED FROM
PROJECT SOFTWARE & DEVELOPMENT, INC
FOR THE EXCLUSIVE USE OF,

COMMONWEALTH EDISON COMPANY

ALL OTHER RIGHTS ARE RESERVED. USE OF
THIS PROJECT/2 SYSTEM BY UNAUTHORIZED
PERSONS OR ORGANIZATIONS IS PROHIBITED.

ALTHOUGH PROJECT/2 HAS BEEN TESTED BY
PSCI, NO WARRANTY, EXPRESS OR IMPLIED
IS MADE BY PSCI AS TO THE ACCURACY AND
FUNCTIONING OF PROJECT/2 AND RELATED PROGRAM
MATERIAL NOR SHALL THE FACT OF DISTRIBUTION
CONSTITUTE ANY SUCH WARRANTY AND NO
RESPONSIBILITY IS ASSUMED BY PSCI
IN CONNECTION THEREWITH.

Figure C-1

96

ACTIVITY NUMBER(S)	D E S C R I P T I O N	CLRA- TION	A CCDE	B CCDE	C CCDE	EST'D CCST (\$)
1002	BREAK CONTAINMENT INTEGRITY	1	0	0	0	0
1003	SET CONTAINMENT INTEGRITY	3	0	0	0	0
1004	REMOVE FUEL TRANSFER TEE FLANGE	5	0	0	0	0
1005	REPLACE TRANSFER TEE FLANGE	6	0	0	0	0
1010	MAIN STEAM SAFETY VALVE TEST	5	0	0	0	0
1011	REMOVE AND SEAL INCRE THIMBLES	20	0	0	0	0
1012	REPLACE INCRE THIMBLES	10	0	0	0	0
1013	REMOVE THERMOCOUPLE CONNSEALS; INSTALL SLEEVES	20	0	0	0	0
1014	REMOVE SLEEVES AND REPLACE THERMOCOUPLE CONNSEAL	20	0	0	0	0
1022	REMOVE CONTROL ROD DRIVE VENT FANS AND CLCTS	20	0	0	0	0
1023	REMOVE REACTOR BEAMS AND RAISE CRD CABLE TRAY	10	0	0	0	0
1024	REMOVE PART LENGTH CONNSEALS	10	0	0	0	0
1025	REMOVE HEAD INSULATION AND SEISMIC SUPPORTS	16	0	0	0	0
1026	INSTALL NOZZLE COVERS	10	0	0	0	0
1027	INSTALL HEAD LIFT RIG AND PLACE NEW C-RINGS	10	0	0	0	0
1028	LOWER DETENSICING EQUIPMENT INTO CAVITY	10	0	0	0	0
1029	DETENSICION AND REMOVE STDS	30	0	0	0	0
1030	INSTALL STD HOLE PLUGS AND GUIDE STDS	30	0	0	0	0
1031	INSTALL CAVITY SEAL BOOT	10	0	0	0	0
1032	CLEAN AND INSPECT STDS	80	0	0	0	0
1033	REMOVE STDS, DETENSICING EQUIPMENT FROM CAVITY	20	0	0	0	0
1034	LIFT HEAD TO 132 INCHES; INSPECT AND STORE	5	0	0	0	0
1035	FULL LOWER INTERNALS	8	0	0	0	0
1036	INSTALL NEW REACTOR HEAD C-RINGS	10	0	0	0	0

ACTIVITY NUMBER(S)	D E S C R I P T I O N	DURA- TION	A CODE	B CODE	C CODE	EST'D CCST (\$)
1037	INSTALL UPPER INTERNALS	8	0	0	0	0
1038	LOWER HEAD TO 132 INCHES; INSPECT AND SEAT	2	0	0	0	0
1039	LOWER TENSIONING EQUIPMENT AND STUDS TO CAVITY	10	0	0	0	0
1040	REMOVE STUD HOLE PLUGS, GUIDE STUDS AND ECCT	30	0	0	0	0
1042	CLEAN STD HOLES	20	0	0	0	0
1043	INSTALL STUDS	20	0	0	0	0
1044	TENSION STUDS	10	0	0	0	0
1045	REPLACE PART LENGTH COACSEALS	10	0	0	0	0
1046	REMOVE STD TENSIONING EQUIPMENT FROM CAVITY	10	0	0	0	0
1047	REMOVE NOZZLE COVERS	10	0	0	0	0
1049	LOWER CABLE TRAY AND INSTALL BEAMS	10	0	0	0	0
1050	REPLACE MISSILE BLOCKS	10	0	0	0	0
1051	REPLACE HEAD INSULATION AND SEISMIC RESTRAINTS	20	0	0	0	0
1052	REPLACE CDM FANS AND ELCTS	20	0	0	0	0
1100	EQUALIZE STUDS TO REACTOR TEMPERATURE	24	0	0	0	0
1200	SET CONTAINMENT INTEGRITY	1	0	0	0	0
1300	BREAK CONTAINMENT INTEGRITY	1	0	0	0	0
1301	REMOVE MISSILE BLOCKS	10	0	0	0	0
2000	DISCONNECT T/C, FULL AND PART LENGTH CABLES	20	0	0	0	0
2001	CONNECT T/C, FULL AND PART LENGTH CABLES & TEST	20	0	0	0	0
2005	INSPECT CONTAINMENT LIGHTING	16	0	0	0	0
3001	INSTALL SPARE SOURCE RANGE DETECTOR	10	0	0	0	0
3003	INSTALL REMOTE RCS LEVEL INDICATOR SYSTEM	8	0	0	0	0
4015	DRAIN STEAM GENERATORS (SECONDARY SIDE)	16	0	0	0	0

ACTIVITY NUMBER (C)	D E S C R I P T I O N	DURA- TION	A CODE	B CODE	C CODE	EST'D CCST (\$)
4021	PARK INCCRES AT TCP OF CORE	1	0	0	0	0
4022	INCCRES TO STORAGE	1	0	0	0	0
4023	RLN IN INCCRE DETECTORS	1	0	0	0	0
4025	UNIT OFF LINE; SHUTDOWN REACTOR	5	0	0	0	0
4026	REDUCE H ₂ CONCENTRATION AND DEGAS RCS	0	0	0	0	0
4027	CCCL REACTOR COOLANT SYSTEM TO 100 F	8	0	0	0	0
4028	REACTOR COOLANT SYSTEM LEAK SURVEY	4	0	0	0	0
4029	DRAIN REACTOR COOLANT SYSTEM TO NOZZLES	24	0	0	0	0
4032	FLCCD CAVITY TO 16 FEET	4	0	0	0	0
4033	FLCCD CAVITY TO TCP	8	0	0	0	0
4034	DRAIN CAVITY TO 16 FEET	4	0	0	0	0
4035	DRAIN CAVITY TO FLANGE	4	0	0	0	0
4036	PRIMARY VALVE LINEUPS	168	0	0	0	0
4039	FT-10 SAFEGUARDS ACTUATION TEST	40	0	0	0	0
4053	FILL RWST, AIR MIX, DEMINERALIZE AND RECIRC	0	0	0	0	0
4060	UNIT ON LINE	1	0	0	0	0
4069	VENT REACTOR COOLANT SYSTEM	8	0	0	0	0
4070	DEGAS REACTOR COOLANT SYSTEM	16	0	0	0	0
4075	INSPECT UNDER REACTOR VESSEL IF NEEDED	20	0	0	0	0
4100	REACTOR CRITICAL	1	0	0	0	0
4114	REACTOR COOLANT SYSTEM HEATUP	24	0	0	0	0
4200	FILL STEAM GENERATORS	16	0	0	0	0
4500	PERFORM PRE-REFUELING CHECKLISTS HERE	0	0	0	0	0
5006	SILUGE LANCE STEAM GENERATORS	72	0	0	0	0

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ACTIVITY NUMBER(S)	DESCRIPTION	DURA- TION	A CODE	E CODE	C CODE	EST'D COST (\$)
	5026 CCLE ROD DPCF TEST	8	0	0	0	0
	5027 FCT RCD DPCF TEST	8	0	0	0	0
	5035 ECOS ACTUATION TEST	20	0	0	0	0
	5051 ZERO POWER PHYSICS TESTING	16	0	0	0	0
	5100 SLUDGE LANCE APPARATUS SETUP	16	0	0	0	0
	5101 COMPLETE ZERO POWER PHYSICS TESTING	56	0	0	0	0
M	5500 PERFORM CONTAINMENT LEAK RATE TEST HERE	0	0	0	0	0
M	5501 PERFORM INTERNAL REACTOR VESSEL ISI HERE	0	0	0	0	0
M	5505 START ISI TOOL ERECTION HERE	0	0	0	0	0
	6000 EDDY CURRENT INSPECTION (CAE STEAM GENERATOR)	70	0	0	0	0
	6100 REMOVE MANWAYS FOR EDDY CURRENT INSPECTION	20	0	0	0	0
	6101 INSTALL STEAM GENERATOR MANWAYS	20	0	0	0	0
	6102 EDDY CURRENT TEST CLEANUP	40	0	0	0	0
	6200 EDDY CURRENT TEST AND APPARATUS SETUP	25	0	0	0	0
	7003 FLL CONTAINMENT SAMPLE AND ANALYZE	8	0	0	0	0
	8000 FUEL TRANSFER SYSTEM AND EQUIPMENT CHECKOUT	20	0	0	0	0
	8001 UNLATCH FART LENGTH RCDs	8	0	0	0	0
	8002 UNLATCH FLL LENGTH RCDs	8	0	0	0	0
	8003 LATCH FLL LENGTH RCDs	8	0	0	0	0
	8004 LATCH FART LENGTH RCDs	8	0	0	0	0
	8005 VERIFY CCRE	4	0	0	0	0
	8011 FUEL SHUFFLE	140	0	0	0	0
	8012 REACTOR CAVITY DECONTAMINATION	36	0	0	0	0
TOTAL \$						0

			SORT E START																PAGE 2	
ACTIVITY DESCRIPTION	MCDE=C/F		26JUN78				6JUL78				16JUL78				26JUL78					
			MTWTFSSMTWTFSSMTWTFSSMTWTFSS				MTWTFSSMTWTFSSMTWTFSSMTWTFSS				MTWTFSSMTWTFSSMTWTFSSMTWTFSS				MTWTFSSMTWTFSSMTWTFSSMTWTFSS					
			I	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I		
LOWER CABLE TRAY AND INSTALL BEAMS			X																	
C 1045	TF= 0		I	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I		
CONNECT 1/4, FULL AND PART LENGTH CABLES & TEST			X-																	
2001	TF= 10		I	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I		
REPLACE MISSILE ELDOCKS			X																	
C 1050	TF= 0		I	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I		
REPLACE CROW FANS AND ELCTS			XX																	
C 1052	TF= 0		I	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I		
PERFORM CONTAINMENT LEAK RATE TEST HERE			-----																	
5000	TF= 325		I	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I		
PRIMARY VALVE LINEUPS			XXXXXXXX																	
C 4026	TF= 0		I	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I		
COLD ROD DROF TEST					X															
C 5026	TF= 0		I	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I		
PT-10 SAFEGUARDS ACTIVATION TEST					XXX															
C 4035	TF= 0		I	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I		
SET CONTAINMENT INTEGRITY					X															
C 1003	TF= 0		I	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I		
REACTOR COOLANT SYSTEM HEATLF					XX															
C 4034	TF= 0		I	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I		
ACT ROD DROF TEST					X															
C 5027	TF= 0		I	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I		
ZERO POWER PHYSICS TESTING					XX															
C 5051	TF= 0		I	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I		
REACTOR CRITICAL					X															
C 4100	TF= 0		I	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I		
COMPLETE ZERO POWER PHYSICS TESTING					XXX															
C 5101	TF= 0		I	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I		
UNIT ON LINE					X															
C 4060	TF= 0		I	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I		
			I	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I		
ACTIVITY DESCRIPTION	MCDE=C/F		26JUN78				6JUL78				16JUL78				26JUL78					
			MTWTFSSMTWTFSSMTWTFSSMTWTFSS				MTWTFSSMTWTFSSMTWTFSSMTWTFSS				MTWTFSSMTWTFSSMTWTFSSMTWTFSS				MTWTFSSMTWTFSSMTWTFSSMTWTFSS					

Figure C-2

VERIFY CODE																			
C	8000	TF= 0	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I
SLUDGE LANCE AFFAIRATLS SETLF																			
C	5100	TF= 135	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I
INSTALL LFER INTERNALS																			
C	1037	TF= 0	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I
INSTALL NEW REACTOR HEAD C-RINGS																			
C	1036	TF= 36	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I
DRAIN CAVITY TO 16 FEET																			
C	4034	TF= 0	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I
LATCH FULL LENGTH RDDS																			
C	8003	TF= 0	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I
SLUDGE LANCE STEAM GENERATORS																			
C	5006	TF= 135	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I
DRAIN CAVITY TO FLANGE																			
C	4025	TF= 24	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I
REACTOR CAVITY DECONTAMINATION																			
C	8012	TF= 0	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I
LOWER HEAD TO 123 INCHES; INSPECT AND SEAT																			
C	1038	TF= 24	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I
REPLACE TRANSFER TUBE FLANGE																			
C	1005	TF= 426	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I
REPLACE INCCRE THIMPLES																			
C	1012	TF= 157	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I
RLN IN INCCRE DETECTORS																			
C	4023	TF= 157	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I
REMOVE STD HOLE PLUGS, GLICE STILES AND ECCT																			
C	1040	TF= 0	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I
LOWER TENSIONING EGLIFFENT AND STILES TO CAVITY																			
C	1025	TF= 40	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I
FILL STEAM GENERATORS																			
C	4000	TF= 135	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I
CLEAN STD H-CLES																			
C	1042	TF= 0	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I
INSTALL STILES																			
C	1043	TF= 0	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I
EGLALIZE STILES TO REACTOR TEMPERATURE																			
C	1100	TF= 0	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I
LATCH PART LENGTH RDDS																			
C	8004	TF= 36	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I
REPLACE PART LENGTH CONNSEALS																			
C	1045	TF= 36	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I
TENSION STILES																			
C	1044	TF= 0	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I
REPLACE HEAD INSULATION AND SEISMIC RESTRAINTS																			
C	1051	TF= 0	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I
REMOVE NOZZLE COVERS																			
C	1047	TF= 70	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I
REMOVE STD TENSIONING EGLIFFENT FROM CAVITY																			
C	1046	TF= 70	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I
REMOVE SLEEVES AND REPLACE THERMOCOUPLE CONNSEAL																			
C	1014	TF= 0	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I

ACTIVITY DESCRIPTION

PCDE=O/F

3JUN78 13JUN78 23JUN78 3JUL78 13JUL78 23JUL78
SSPTWTFSSPTWTFSSPTWTFSSPTWTFSSPTWTFSSPTWTFSSPTWTFSS

1026 TF= 134
 REMOVE CONTROL ROD DRIVE VENT FANS AND CLCTS
 C 1022 TF= 0
 VENT REACTOR COOLANT SYSTEM
 4069 TF= 6
 REMOVE AND SEAL INCORE THIMBLES
 1011 TF= 56
 REMOVE MANWAYS FOR EDDY CURRENT INSPECTICA
 6100 TF= 13
 REMOVE MISSILE BLOCKS
 1301 TF= 10
 REMOVE HEAD INSULATION AND SEISMIC SUPPORTS
 1025 TF= 24
 REMOVE THERMOCOUPLE COOLSEALS; INSTALL SLEEVES
 C 1013 TF= 0
 EDDY CURRENT INSPECTICA (CAE STEAM GENERATOR)
 6000 TF= 13
 REMOVE REACTOR BEAMS AND RAISE CRE CABLE TRAY
 C 1023 TF= 0
 LOWER DETENSIGNING EGLIPMENT INTO CAVITY
 C 1028 TF= 0
 REMOVE PART LENGTH COOLSEALS
 1024 TF= 62
 DETENSION AND REMOVE SILDS
 C 1025 TF= 0
 UNLATCH PART LENGTH RCDs
 8001 TF= 62
 REMOVE SILDS, DETENSIGNING EGLIPMENT FROM CAVITY
 1023 TF= 20
 INSTALL STD HOLE PLUGS AND GLIDE SILDS
 C 1020 TF= 0
 INSTALL STEAM GENERATOR MANWAYS
 6101 TF= 13
 CLEAN AND INSPECT STUCS
 1022 TF= 214
 INSTALL HEAD LIFT RIG AND PLACE NEW C-FINGS
 C 1027 TF= 0
 INSTALL CAVITY SEAL PCOT
 C 1021 TF= 0
 EDDY CURRENT TEST CLEANUP
 6102 TF= 602
 LIFT HEAD TO 133 INCHES; INSPECT AND STORE
 C 1024 TF= 0
 FLOOD CAVITY TO 16 FEET
 C 4022 TF= 0
 UNLATCH FULL LENGTH RCDs
 C 8002 TF= 0
 PULL UPPER INTERNALS
 C 1025 TF= 0
 FLOOD CAVITY TO TCP
 C 4023 TF= 0
 PERFORM PRE-REFUELING CHECKLISTS HERE
 4500 TF= 109
 PERFORM INTERNAL REACTOR VESSEL ISI HERE
 5501 TF= 109
 SET CONTAINMENT INTEGRITY
 C 1200 TF= 0
 FUEL SHUFFLE
 C 8011 TF= 0
 BREAK CONTAINMENT INTEGRITY
 1200 TF= 2

I	I	I	I	I	I	I	I	I	I	I	I	I	I	I
XX	I	I	I	I	I	I	I	I	I	I	I	I	I	I
I	X-	I	I	I	I	I	I	I	I	I	I	I	I	I
I	I	I	I	I	I	I	I	I	I	I	I	I	I	I
XX----	I	I	I	I	I	I	I	I	I	I	I	I	I	I
I	I	I	I	I	I	I	I	I	I	I	I	I	I	I
X--	I	I	I	I	I	I	I	I	I	I	I	I	I	I
I	I	I	I	I	I	I	I	I	I	I	I	I	I	I
X-	I	I	I	I	I	I	I	I	I	I	I	I	I	I
XX	I	I	I	I	I	I	I	I	I	I	I	I	I	I
I	I	I	I	I	I	I	I	I	I	I	I	I	I	I
XX	I	I	I	I	I	I	I	I	I	I	I	I	I	I
X*XX-	I	I	I	I	I	I	I	I	I	I	I	I	I	I
I	I	I	I	I	I	I	I	I	I	I	I	I	I	I
X	I	I	I	I	I	I	I	I	I	I	I	I	I	I
I	I	I	I	I	I	I	I	I	I	I	I	I	I	I
X	I	I	I	I	I	I	I	I	I	I	I	I	I	I
I	I	I	I	I	I	I	I	I	I	I	I	I	I	I
X---	I	I	I	I	I	I	I	I	I	I	I	I	I	I
I	I	I	I	I	I	I	I	I	I	I	I	I	I	I
XXX	I	I	I	I	I	I	I	I	I	I	I	I	I	I
I	I	I	I	I	I	I	I	I	I	I	I	I	I	I
XX--	I	I	I	I	I	I	I	I	I	I	I	I	I	I
I	I	I	I	I	I	I	I	I	I	I	I	I	I	I
X*	I	I	I	I	I	I	I	I	I	I	I	I	I	I
I	I	I	I	I	I	I	I	I	I	I	I	I	I	I
XX	I	I	I	I	I	I	I	I	I	I	I	I	I	I
I	I	I	I	I	I	I	I	I	I	I	I	I	I	I
X--	I	I	I	I	I	I	I	I	I	I	I	I	I	I
I	I	I	I	I	I	I	I	I	I	I	I	I	I	I
XXXX-----	I	I	I	I	I	I	I	I	I	I	I	I	I	I
I	I	I	I	I	I	I	I	I	I	I	I	I	I	I
X	I	I	I	I	I	I	I	I	I	I	I	I	I	I
I	I	I	I	I	I	I	I	I	I	I	I	I	I	I
X	I	I	I	I	I	I	I	I	I	I	I	I	I	I
I	I	I	I	I	I	I	I	I	I	I	I	I	I	I
X	I	I	I	I	I	I	I	I	I	I	I	I	I	I
I	I	I	I	I	I	I	I	I	I	I	I	I	I	I
X	I	I	I	I	I	I	I	I	I	I	I	I	I	I
I	I	I	I	I	I	I	I	I	I	I	I	I	I	I
XX	I	I	I	I	I	I	I	I	I	I	I	I	I	I
I	I	I	I	I	I	I	I	I	I	I	I	I	I	I
M-----	I	I	I	I	I	I	I	I	I	I	I	I	I	I
I	I	I	I	I	I	I	I	I	I	I	I	I	I	I
M-----	I	I	I	I	I	I	I	I	I	I	I	I	I	I
I	I	I	I	I	I	I	I	I	I	I	I	I	I	I
X	I	I	I	I	I	I	I	I	I	I	I	I	I	I
I	I	I	I	I	I	I	I	I	I	I	I	I	I	I
XXXXXXXX	I	I	I	I	I	I	I	I	I	I	I	I	I	I
I	I	I	I	I	I	I	I	I	I	I	I	I	I	I
X	I	I	I	I	I	I	I	I	I	I	I	I	I	I
I	I	I	I	I	I	I	I	I	I	I	I	I	I	I

BAR CHART LEGEND

PLANNING SCHEDULE

XX = SCHEDULED WORK
M = MILESTONE
A = WORKING DATE
C = CN/EEFCRE RANGE START
D = CN/AFTER RANGE FINISH
T = TOTAL FLCAT
L = LATE START

Figure C-3.

REFUELING MASTER PLAN

COMMONWEALTH EDISON COMPANY

RLN DATE 09JUN78 0724HRS

P L A N N I N G S C H E D U L L E

PROJECT START 20JUN78

PROJECT Z-MASTER ZION GENERATING STATION

BASE COMPLETION 11JUL78

SCRT E START

PAGE 1

ACTIVITY	DESCRIPTION	PCE=C/F	SSMTWTFSSMTWTFSSMTWTFSSMTWTFSSMTWTFSSMTWTFSS											
			20JUN78	21JUN78	22JUN78	23JUN78	24JUN78	25JUN78	26JUN78	27JUN78	28JUN78	29JUN78	30JUN78	01JUL78
REDUCE H ₂ CONCENTRATION AND DEGAS RCS			I	I	I	I	I	I	I	I	I	I	I	I
C 4026	TF= 0		I	I	I	I	I	I	I	I	I	I	I	I
FILL RWST, AIR MIX, DEMINERALIZE AND RECIRC			I	I	I	I	I	I	I	I	I	I	I	I
C 4053	TF= 0		I	I	I	I	I	I	I	I	I	I	I	I
UNIT OFF LINE; SHUTDOWN REACTOR			X	I	I	I	I	I	I	I	I	I	I	I
C 4025	TF= 0		I	I	I	I	I	I	I	I	I	I	I	I
MAIN STEAM SAFETY VALVE TEST			X	I	I	I	I	I	I	I	I	I	I	I
C 1010	TF= 0		I	I	I	I	I	I	I	I	I	I	I	I
PARK INCREASE AT TOP OF CORE			X-----	I	I	I	I	I	I	I	I	I	I	I
C 4021	TF= 141		I	I	I	I	I	I	I	I	I	I	I	I
DEGAS REACTOR COOLANT SYSTEM			X*	I	I	I	I	I	I	I	I	I	I	I
C 4070	TF= 25		I	I	I	I	I	I	I	I	I	I	I	I
PULL CONTAINMENT SAMPLE AND ANALYZE			X-	I	I	I	I	I	I	I	I	I	I	I
C 7003	TF= 13		I	I	I	I	I	I	I	I	I	I	I	I
INSPECT LATER REACTOR VESSEL IF NEEDED			XX-----	I	I	I	I	I	I	I	I	I	I	I
C 4075	TF= 141		I	I	I	I	I	I	I	I	I	I	I	I
ECCS ACTIVATION TEST			XX	I	I	I	I	I	I	I	I	I	I	I
C 5025	TF= 0		I	I	I	I	I	I	I	I	I	I	I	I
INSPECT CONTAINMENT LIGHTING			X*-	I	I	I	I	I	I	I	I	I	I	I
C 2005	TF= 26		I	I	I	I	I	I	I	I	I	I	I	I
REACTOR COOLANT SYSTEM LEAK SURVEY			X*	I	I	I	I	I	I	I	I	I	I	I
C 4026	TF= 13		I	I	I	I	I	I	I	I	I	I	I	I
INCREASE TO STORAGE			X-----	I	I	I	I	I	I	I	I	I	I	I
C 4022	TF= 141		I	I	I	I	I	I	I	I	I	I	I	I
COOL REACTOR COOLANT SYSTEM TO 100 F			X	I	I	I	I	I	I	I	I	I	I	I
C 4027	TF= 0		I	I	I	I	I	I	I	I	I	I	I	I
DRAIN STEAM GENERATORS (SECONDARY SIDE)			XX*-	I	I	I	I	I	I	I	I	I	I	I
C 4015	TF= 53		I	I	I	I	I	I	I	I	I	I	I	I
DISCONNECT T/C, FULL AND PART LENGTH CABLES			XX	I	I	I	I	I	I	I	I	I	I	I
C 2000	TF= 0		I	I	I	I	I	I	I	I	I	I	I	I
INSTALL REACTOR RCS LEVEL INDICATOR SYSTEM			X*	I	I	I	I	I	I	I	I	I	I	I
C 3003	TF= 24		I	I	I	I	I	I	I	I	I	I	I	I
BREAK CONTAINMENT INTEGRITY			X*	I	I	I	I	I	I	I	I	I	I	I
C 1002	TF= 15		I	I	I	I	I	I	I	I	I	I	I	I
DRAIN REACTOR COOLANT SYSTEM TO NOZZLES			XX	I	I	I	I	I	I	I	I	I	I	I
C 4025	TF= 8		I	I	I	I	I	I	I	I	I	I	I	I
START ISI TOOL ERECTION HERE			I-----	I	I	I	I	I	I	I	I	I	I	I
C 5505	TF= 852		I	I	I	I	I	I	I	I	I	I	I	I
INSTALL SPARE SOURCE RANGE DETECTOR			XX-----	I	I	I	I	I	I	I	I	I	I	I
C 3001	TF= 134		I	I	I	I	I	I	I	I	I	I	I	I
REMOVE FUEL TRANSFER TUBE FLANGE			X-----	I	I	I	I	I	I	I	I	I	I	I
C 1004	TF= 125		I	I	I	I	I	I	I	I	I	I	I	I
EDDY CURRENT TEST AND APPARATUS SETUP			X*-	I	I	I	I	I	I	I	I	I	I	I
C 6200	TF= 15		I	I	I	I	I	I	I	I	I	I	I	I
FUEL TRANSFER SYSTEM AND EQUIPMENT CHECKOUT			XX-----	I	I	I	I	I	I	I	I	I	I	I
C 8000	TF= 125		I	I	I	I	I	I	I	I	I	I	I	I
INSTALL NOZZLE COVERS			X-----	I	I	I	I	I	I	I	I	I	I	I

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RLA DATE 18 JUL 78 1042HFS

W C R F I A E S C H E D L E

PROJECT START 15SEF78

PROJECT REFUEL21 REFUELING/MAINTENANCE CYCLE CORE CYCLE III-IV

EASE COMPLETION 5 NOV 78

[illegible]

Figure C-4. Graphic Plot of Zion Station Refueling Master Plan, Project/2, (Sheet 1 of 5)

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Figure C-4. Graphic Plot of Zion Station Refueling Master Plan, Project/2, (Sheet 2 of 5)

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Figure C-4. Graphic Plot of Zion Station Refueling Master Plan, Project/2, (Sheet 3 of 5)

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Figure C-4. Graphic Plot of Zion Station Refueling Master Plan, Project/2, (Sheet 5 of 5)

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