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The Reliability-Centered Maintenance Study at the Fast Flux Test Facility

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THE RELIABILITY-CENTERED MAINTENANCE STUDY AT THE FAST FLUX TEST FACILITY

INTRODUCTION

A reliability-centered maintenance (RCM) program was applied to two Fast Flux Test Facility (FFTF) systems to evaluate this method for improving the equipment reliability and reducing maintenance costs. This technique is a systematic approach to failure analysis and maintenance task development. The RCM method was originally developed by the airline industry to reduce maintenance costs and improve reliability and it has since been adopted by the military. The Electric Power Research Institute (EPRI) has completed two pilot studies with a third in progress to determine the RCM applicability to the commercial nuclear power industry. These studies showed that the RCM methodology could be beneficial to the nuclear power industry. The EPRI study performed at the McGuire nuclear power station (EPRI 1986) was used as the model for the FFTF study (Fig. 1).

SUMMARY

Four FFTF candidate systems were selected for RCM analysis based on a computer record of preventive maintenance (PM) and corrective maintenance (CM) work documents. Because the FFTF systems consist of several subsystems, it was decided to select either one specific subsystem or a group of subsystems with related functions for analysis. The importance of the system to reactor operation was also considered for system selection.

The first system selected was the compressed air system. The RCM analysis indicated that the maintenance program for this system was reasonably thorough and only a few changes were recommended. Two modifications to the EPRI method were developed from this analysis. The first was a table specifying major modifications that have been completed on the compressed air system. The second was the development of a system selection logic tree to prioritize the systems at FFTF based first on the system's impact on reactor operation or on safety and, second on the amount of maintenance (Fig. 2).

The second system selected was actually two subsystems with related functions, the sanitary and fire water system. This system and can have a direct effect on equipment protection and on the health and safety of personnel on the FFTF site. The RCM analysis of this system was used to develop several recommendations to improve the present maintenance program.

The application of RCM to both of these systems was effective for evaluating the effectiveness of the present FFTF PM program and indicated areas where improvements could be made. The study also indicated that the present PM program for these systems is thorough and effective.

The recommendations for the compressed air system are as follows:

- Delete two PM tasks
- Revise ten PM tasks
- Add four PM tasks
- Perform three design modifications.

The recommendations for the sanitary and fire water system include the following:

- Twenty-one PM task revisions
- Eleven PM task additions
- Five design modifications
- Additional training for the power operators.

Most of the added PM tasks were functional tests of equipment. The results of these functional tests would be used to determine if a maintenance action should be performed. The FFTF already has some maintenance actions that are performed as a result of functional tests or engineer inspections. The revised tasks would be added to these existing categories to be performed when required.

RCM APPLICATION TO THE COMPRESSED AIR SYSTEM

The compressed air system supplies operating air for instruments, valves, and equipment throughout the plant (Fig. 3). One of its most important loads is the dump heat exchanger (DHX) equipment that removes heat from the reactor secondary cooling system. A reactor scram is required if this system fails. Because of the importance of the compressed air system, a high priority is used for performance of both CM and PM tasks. The maintenance history of the compressed air system from January 1, 1986, to July 1, 1987, was evaluated for this study. The data were divided into two categories, corrective maintenance and preventive maintenance. The data analysis showed one recurring problem that required repeated repairs on the DHX backup air bottle regulators.

However, this problem was corrected by the cognizant engineer prior to the start of the RCM analysis. Thirteen specific recommendations resulted from using the RCM methodology on this system and are included in the system report. Figures 4 through 8 are included as examples of the RCM methodology.

The first modification to the EPRI methodology was adding a table to the compressed air analysis specifying major modifications completed on the system. This table will serve as a tool to explain significant changes in the maintenance history and to indicate FFTF Engineering's responsiveness to system problems.

The second modification to the EPRI methodology was the development of the system selection logic tree. The goal of using this logic tree is to prioritize the system so that the effect of a system failure on reactor operation, or on health and safety, is considered prior to the amount of maintenance activity. Using this logic tree, those systems whose operability requirements have a higher priority are analyzed first even though other systems may have more maintenance. This logic tree was used successfully in selecting the second system.

RCM APPLICATION TO THE SANITARY AND FIRE WATER SYSTEM

Unlike the compressed air system, the sanitary and fire water system does not directly effect reactor operation (Fig. 9), however, loss of the system function will lead to a plant shutdown for administrative reasons. The amount of time between system failure and reactor shutdown is several hours, compared with minutes for a failure of the compressed air system. The sanitary and fire water system is operated by Support Services instead of Reactor Operations. System problems are reported in a timely manner, but their priority is lower than that for the compressed air system due to the delayed effect on reactor operation. Because this system supplies water for fire fighting, it is required to be maintained in an operable status for personnel and equipment safety. The maintenance history for the sanitary and fire water system from January 1, 1983, to October 1, 1987, was evaluated in this study. The data were analyzed in the same way as that for the compressed air system. The results of the analysis indicated that the maintenance on this system is effective, but it can be improved. There were two significant recurring problems noted in this system: chlorinator failures and fire pump packing failures. The maintenance engineer reported that the chlorinator failures may have been corrected by clearing a clogged elbow on the chlorinator discharge line. The problem with the fire pump packing appeared to be due to lack of operator training instead of a mechanical problem with either the pump or the packing. Nineteen recommendations for improving plant maintenance are included in the system report.

RCM STUDY FINDINGS

The compressed air system had a significantly higher level of maintenance than the sanitary and fire water system. This difference appeared to be due to the system function and the effect on reactor operation if failure should occur.

The results of the studies indicate that the present PM/CM maintenance program for the two systems surveyed at FFTF is effective and thorough, however, it can be improved. Both systems had several time-directed tasks that could be changed to condition-directed tasks. A condition directed task is based on the results of a functional test of the equipment or is performed when a specific operational limit is exceeded. The RCM study revealed the need for more functional testing to determine the criteria for performing maintenance work. The most significant observation from the RCM studies was the need for design modifications. The compressed air system had several major design modifications implemented during the time for which data were analyzed. The improved system reliability is evident by the reduction of CM items during the past 18 mo (Fig. 10), therefore, only a few design modifications were recommended. The sanitary and fire water system study recommended several design modifications to reduce maintenance on the chlorinators. In addition, the study recommended that the power operators be given training on the operation of the fire pumps that have been operated with improperly adjusted packing glands, which resulted in damage to the pump shafts. The data also indicate that the overall reliability of the sanitary and fire water system is deteriorating (Fig. 11). Recorded maintenance manhours spent on corrective maintenance for the past 5-yr period totaled 1020. During the final 21 months of the analysis period, the recorded maintenance manhours totaled 562.

COST BENEFIT

It is difficult to accurately predict the cost benefit of implementing the RCM program for either system. A potential savings of approximately $8,000 over a 1-1/2 yr period for the compressed air system and approximately $10,000 over a 5-yr period for the sanitary water system are rough estimates based on maintenance manhours that would have been saved if the RCM program had been in use. The charge rate for crafts was assumed to be $40/hr. No material costs were available, and the time spent on these problems by Operations or Engineering personnel are not known. Therefore, these figures could vary significantly.

IMPLEMENTATION

The actual implementation of these recommendations will be determined by the cognizant engineer and management. Implementation of the recommendations would require writing the following:

- Engineering Change Notices (ECNs) for design modifications and the PM/ICR data base
- Field Change Notices (FCNs) to change maintenance and operating procedures
- Work packages to install design modifications.

LIMITATIONS

The RCM analysis has limitations and it cannot predict some types of failures. For example, the sticking check valve that caused the P-61 fire pump to run backwards would not have been analyzed as a failed check valve until it occurred on at least two separate occasions. Since this type of failure had not been reported with other system check valves the RCM analysis would indicate only the need to periodically inspect the check valve for P-61. The cognizant engineer's investigation revealed that the check valves were made of material not approved for use in water systems. The RCM analyses will not take the place of the engineer in predicting and resolving specific system failures.

CONCLUSIONS

The RCM methodology can be an effective tool to analyze and develop maintenance programs at FFTF. This approach appears to achieve the goals of improving system reliability and reducing maintenance costs. The RCM method does not replace the engineer, but can be used to assist the engineer to develop or refine a maintenance program.

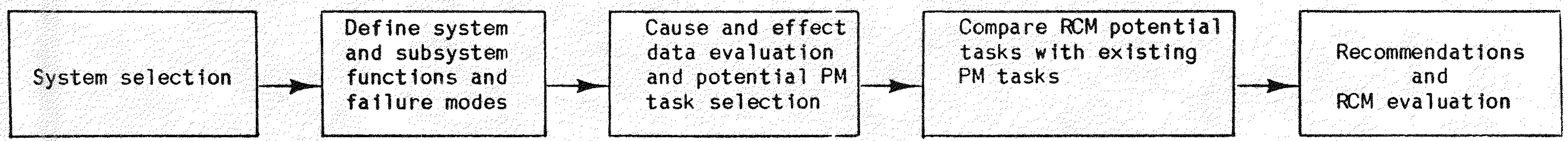
The reliability of the compressed air system is improving as a result of design modifications developed in response to system problems. The reliability of the sanitary and fire water system appears to be deteriorating due to system age.

RECOMMENDATIONS

- The RCM recommendations for both the compressed air system and sanitary fire water system should be implemented.
- The program should be reviewed periodically to evaluate its effectiveness on system performance.
- Cognizant engineers should be encouraged to perform RCM analysis on other FFTF systems.

REFERENCE

EPRI, 1986, "Use of Reliability Centered Maintenance for the McGuire Nuclear Station Feedwater System," EPRI NP-4795, Electric Power Research Institute, Palo Alto, California, September.



System selection

1. Maintenance history collection
2. System description
3. Data collection
   - a) procedures
   - b) OMM's
   - c) SDD's
   - d) OTM's
   - e) prints
4. Define system boundaries and interfaces
5. Break the system into functional subsystems

Define system and subsystem functions and failure modes

1. Identify functionally significant items
2. Define specific subsystem functions and functional failures
3. Identify the dominant failure modes of the functional failures
4. Establish cause and effect data

Cause and effect data evaluation and potential PM task selection

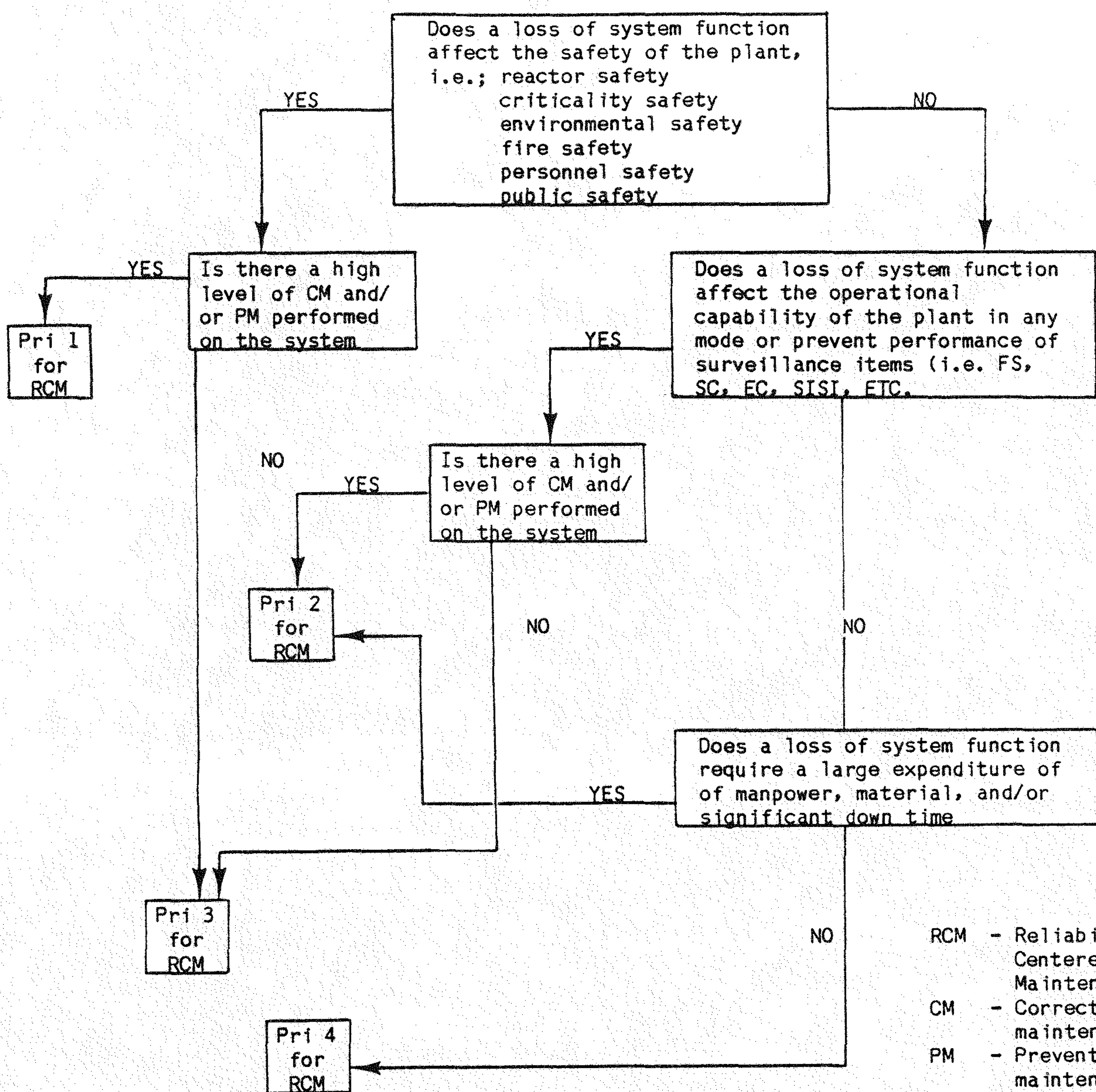
1. Apply RCM decision logic tree
2. Identify potential PM tasks
3. From the potential PM tasks, select applicable and effective tasks
4. Establish task intervals
5. Identify potential design modifications

Recommendations and RCM evaluation

1. Recommend task revisions
2. Recommend design modifications
3. Evaluate the usefulness of the RCM methodology
   - a) Modifications for use at the FFTF

RCM - Reliability-Centered Maintenance
PM - Preventive maintenance
OMM - Operation and maintenance manual
SDD - System design description
OTM - Operations training manual

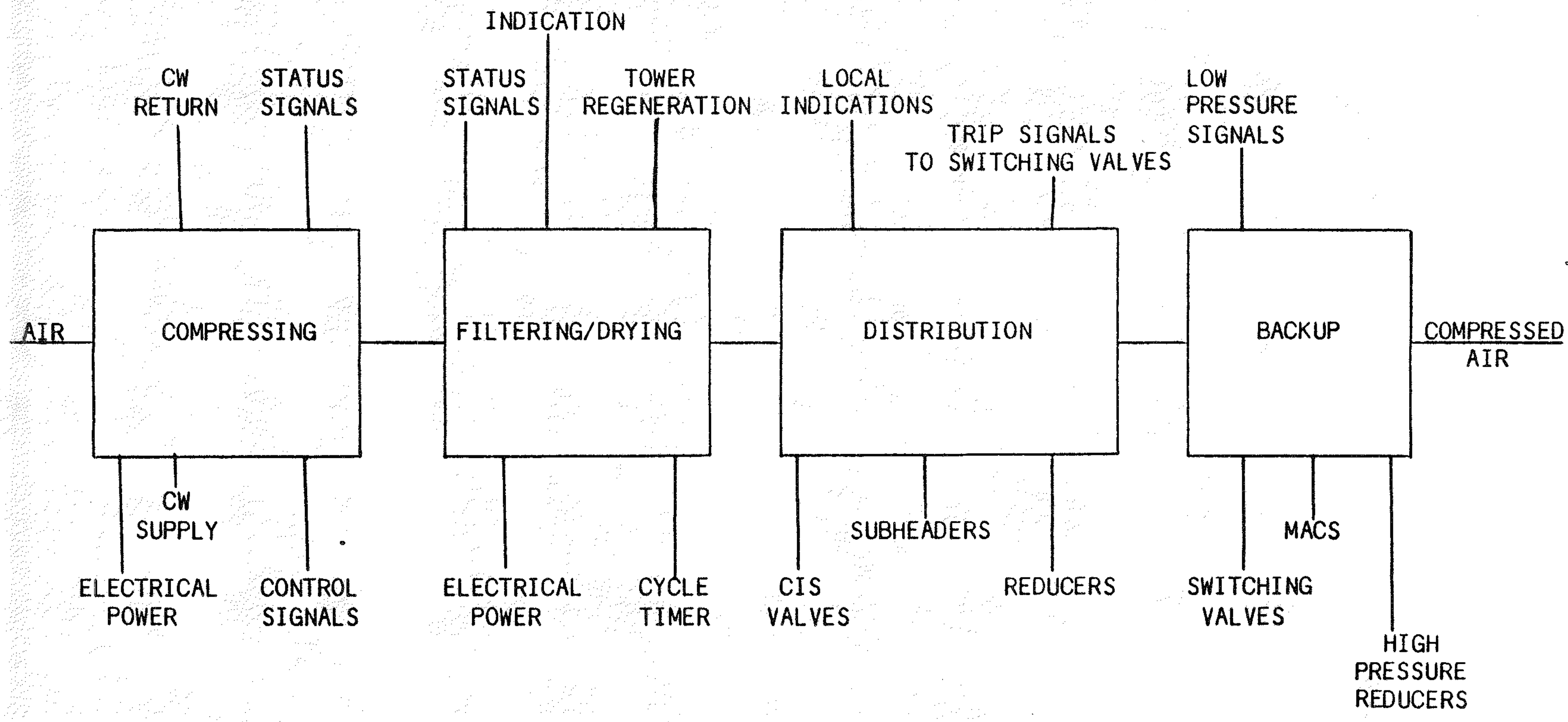
FIGURE 1. Reliability-Centered Maintenance Method.



NOTE: All systems are assumed to be the minimum operable equipment level as specified in PN-1

RCM - Reliability-Centered Maintenance
CM - Corrective maintenance
PM - Preventive maintenance
FS - Fire surveillance
SC - System compliance
EC - Environmental compliance
SISI - Surveillance & in-service inspection

FIGURE 2. The Reliability-Centered Maintenance Method System Selection Logic Tree.



CW - Cooling water
CIS - Containment isolation system
MACS - Mobile air compressors

FIGURE 3. Compressed Air Functional Block Diagram.

1. SWS/SUBSYS SWBS NUMBER	2. SYSTEM/SUBSYSTEM NOMENCLATURE		SH	OF
23J	COMPRESSED AIR		1	1

3. PREPARED BY	4. REVIEWED BY	5. APPROVED BY	6. REVISION
DATE	DATE	DATE	DATE

7. SWBS NUMBER	8. NOMENCLATURE
23J	COMPRESSED AIR
23J-1	COMPRESSING SUBSYSTEM
23J-2	FILTERING/DRYING SUBSYSTEM
23J-3	DISTRIBUTION SUBSYSTEM
23J-4	BACKUP AIR SUBSYSTEM

FIGURE 4. Functionally Significant Items Index.

1. SWBS NUMBER 23J-3	2. NOMENCLATURE COMPRESSED AIR DISTRIBUTION SUBSYSTEM	SH 1 OF 1

3. SOURCES OF INFORMATION		
A. SDD-23	B. OTM 23J/P	C.

4. DESCRIPTION

This subsystem consists of the piping and valves which distribute the 120 psig air through the various subheaders to the loads.

Redundancy: The system is designed in a loop such that an individual subheader may be isolated without effecting the operation of any other subheader.

Protection: Relief valves.

Trips: None

5. FUNCTIONS AND OUT INTERFACES

1. Distribute 120 psig air to loads.
2. Maintain system integrity.

6. IN INTERFACES

1. Receive 120 psig air from the drying towers.
2. Receive air from the backup air system.

7. FUNCTIONAL FAILURES

1.1 Loss of air pressure

FIGURE 5. Functional Failure Analysis.

1. SWBS NUMBER	2. NOMENCLATURE	SH	OF
23J-1	COMPRESSING SUBSYSTEM	1	5

3. FUNCTION(S)	4. FUNCTIONAL FAILURES	5. DOMINANT FAILURE MODES	6. FAILURE EFFECTS A. LOCAL	6. FAILURE EFFECTS B. SUBSYS/SYS	6. FAILURE EFFECTS C. PLANT	7. LTA* (YES/NO)
1. Provide compressed air at 120 psig to subsystem 23J-2	1.1 No pressure	1.1.1 Compressor loss	All three compressors trip	Backup system comes on line	Scram (1)	Yes
		1.1.2 All pressure switches fail	Compressors do not load	Backup system comes on line	Scram (1)	Yes
	1.2 Low pressure	1.2.1 #1 compressor trips a) High vibration b) Low oil level c) High oil temperature d) High discharge air temperature e) Low oil pressure f) High discharge air pressure g) Aftercooler high air temperature h) Electric fault i) After cooler high condensate level	#2 compressor starts	Pressure cycles between 110 and 120 psig	None	No
		1.2.2 #1 and #2 compressors trip for any of the above reasons	#3 compressor starts	Pressure cycles between 90 and 125 psig	Scram if #3 compressor not available (1)	Yes

*LTA: LOGIC TREE ANALYSIS
(1) The scram is a "manual scram" required by Tech Specs at 70 psig in the instrument air header.

FIGURE 6. Failure Modes and Effects Analysis.

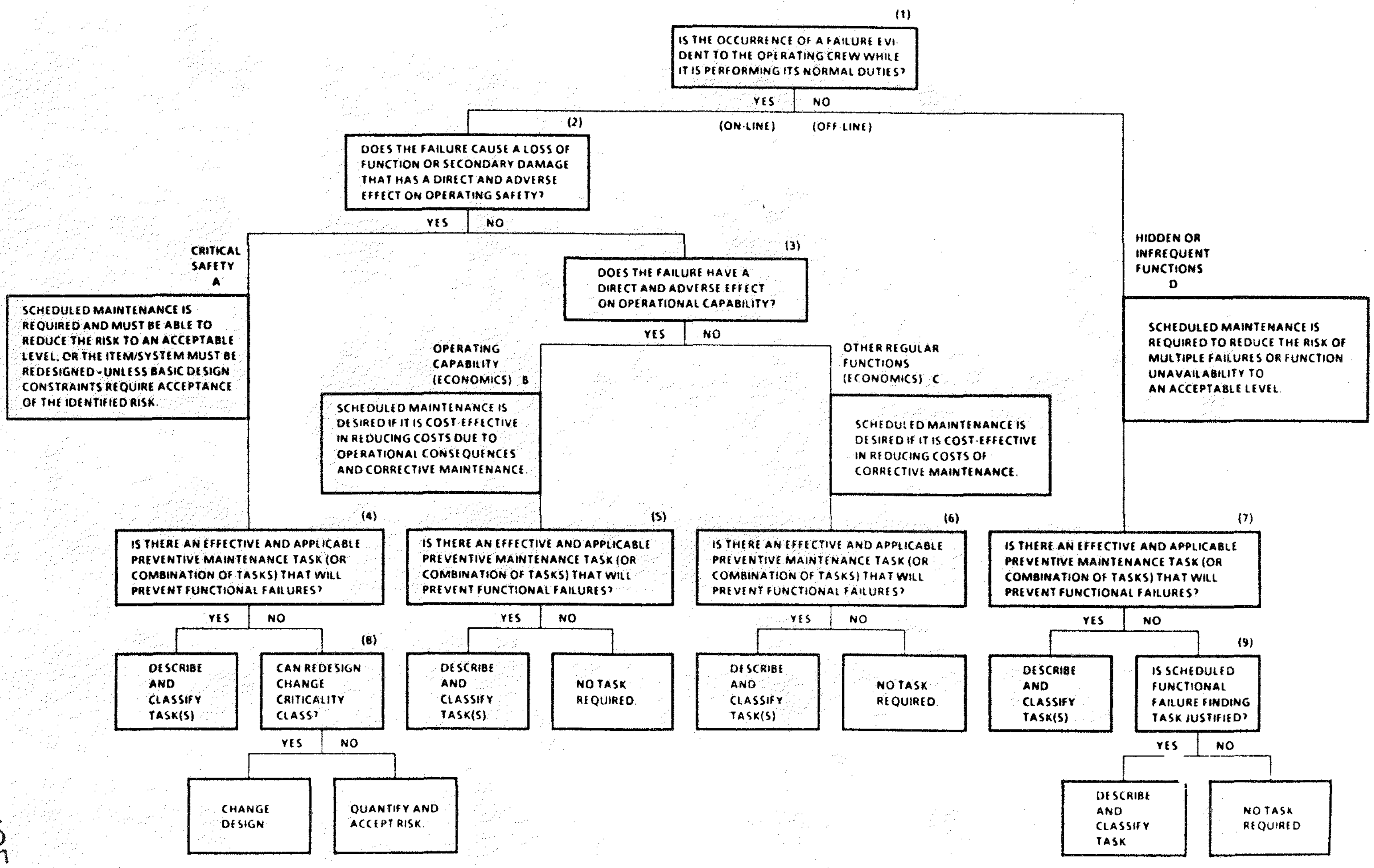


FIGURE 7. The RCM Decision Logic Tree. (Reprinted with permission, from EPRI NP-4795, "Use of Reliability Centered Maintenance for the McGuire Nuclear Station Feedwater System," p. 3-9, copyright© 1986 by the Electric Power Research Institute, Palo Alto, California.)

1. SWBS NUMBER	2. NOMENCLATURE	SH	OF
23J-1	COMPRESSING SUBSYSTEM	1	5

3. FUNCTIONAL FAILURE/ FAILURE MODE	4. CRITICALITY ANALYSIS (YES/NO) (1)	(2)	(3)	5. CRITICALITY CLASS (A, B, C, OR D)	6. PM TASK (YES/NO)	7. FAILURE FINDING (8)TASK (YES/NO)	8. REDESIGN REF.NO.7	9. TASK DESCRIPTIONS OR DESIGN CHANGES	10. PERIODICITY
<u>1.1 NO PRESSURE</u>									
1.1.1 Compressor Loss	Y	N	Y	B	Y			Check compressor alignment and mounting	CD
								Check oil level	TD Shiftly
								Check cooling water flow	TD Shiftly
								Calibrate temperature instruments	TD 3 Years
								Calibrate pressure instruments	TD 3 Years
1.1.2 All pressure switches fail	N			D	Y	Y		Calibrate pressure switches	CD
								Functionally test pressure switches	FF Annually

*FOR DEFINITION OF ABBREVIATIONS. REFERENCE RCM DECISION LOGIC TREE DIAGRAM

FIGURE 8. Logic Tree Analysis.

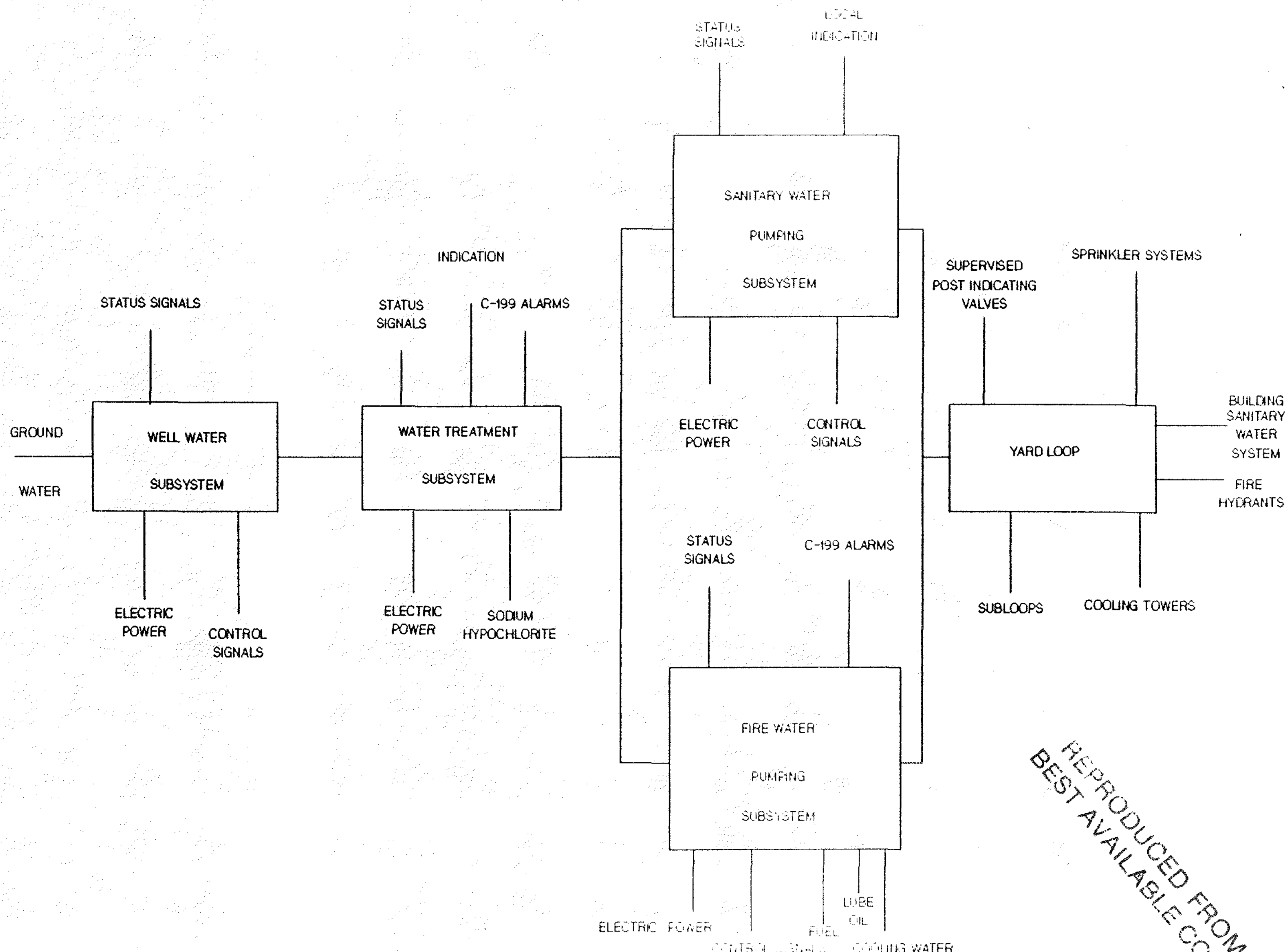


FIGURE 9. Sanitary and Fire Water Functional Block Diagram.

EQUIPMENT/CM	1986				1987			
	1 - 3	4 - 6	7 - 9	10 - 12	1 - 3	4 - 6	7 - 9	TOTAL
Air compressor, mechanical	2	9(a)				1		12
Air compressor, electrical	1	1			3			5
Drying tower, mechanical	1	1		1				3
Drying tower, electrical		1	1	1	1		1	5
Regulator repair	5	4(b)	1	2	1			13
Transfer valve repair		3						3
Relief valves	1					1		2
B/U air bottles				1		1		2
Check valves		1						1
Pressure switches		1		1	1	2		5
General valve/piping			1			6		7
Filter repairs				2				2
Control panel repair		2						2
Pressure indicator						1		1
Compressor instrumentation	2		1		1			3

(a) Modification performed installing dry air to the air compressor unloader valves.
(b) E-15 regulator replaced.

FIGURE 10. Summary of Corrective Maintenance (CM).

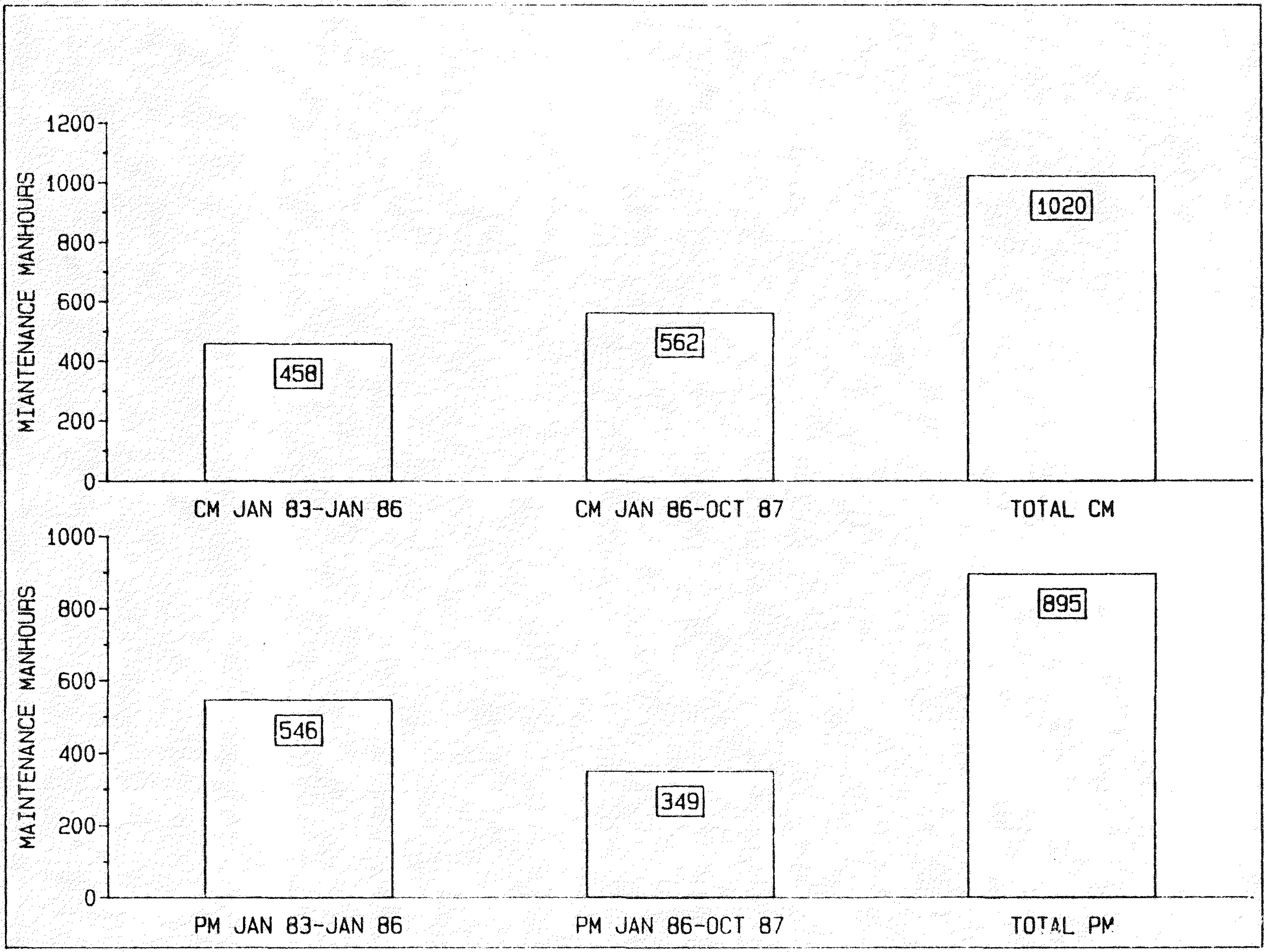


FIGURE 11. Sanitary and Fire Water System Maintenance Manhours, January 1, 1983 through October 1, 1987.

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