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AFWL-TR-68-10

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68-10

# PM-1 FINAL SUMMARY REPORT

Milton H. Juister, Jr.
Capt USAF

John L. Singleton
SMSgt USAF

TECHNICAL REPORT NO. AFWL-TR-68-10

May 1968



AIR FORCE WEAPONS LABORATORY
Air Force Systems Command
Kirtland Air Force Base
New Mexico

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# FOREWORD

This report was prepared under Program Element 6.24.05.21.F, Project 2800, Task 280004. Inclusive dates of research were 1 November 1966 through 31 March 1967. The report was submitted 26 January 1968 by the Air Force Weapons Laboratory Project Officer, Captain Milton H. Juister, Jr. (WLDC).

This technical report has been reviewed and is approved.

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## ABSTRACT

(Distribution Limitation Statement No. 2)

This report evaluates the operation of the PM-1 nuclear power plant during the period from 1 November 1962 to 31 March 1967. The data in this report were extracted from the PM-1 Monthly Summary Reports, work orders, plant daily logs, chemistry logs, supply requests, and malfunction reports supplied by the 731 Radar Squadron, Sundance Air Force Station, Wyoming, and the 10 Air Force, Richards-Gebaur Air Force Base, Missouri. Plant administration, operations, process control, maintenance, and supply are analyzed and evaluated. Recommendations are made with the objective of cost reduction and improved plant availability. Supporting data for all recommendations are included in the text.

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# SECTION I

# INTRODUCTION

The PM-1 Final Summary Report of the Category III Test Program for the period of 1 November 1962 to 31 March 1967 is submitted in accordance with AFR 80-14 and Hq USAF (AFOCE-ES letter, dated 5 December 1961, subject: "Air Force Policy for Post Acceptancy Operation, Maintenance, and Support of the PM-1").

This report and the previous PM-1 Annual Summary Reports* published by the Air Force Weapons Laboratory (AFWL) form an operational history of the PM-1 nuclear power plant starting with Air Force acceptance on 31 October 1962. This is meant only as a final summary report and should be read in conjunction with the annual reports for a detailed view of the operation of the PM-1. Detailed information for the period of 1 November 1966 to 31 March 1967 is included in this report since it is not contained in the annual reports. To facilitate referring to the annual reports, this report maintains their basic structure and approach. Information contained within these previous reports is repeated only if it is important to the overall analysis of the plant.

The PM-1 was designed as an air-transportable packaged power plant for use in remote areas which have a cold climate and little precipitation. Warren Peak, Sundance, Wyoming, was selected as the PM-1 site because it provides these arctic-like conditions. The plant is designed to produce a net power output of 1 megawatt electric (Mw(e)), plus 7 x $10^6$ BTU/hr of process heat with 94 percent availability (i.e., 3 weeks down time per year). The unique design requirements of this system have led to many operational and maintenance problems not experienced by large central station commercial power reactors. Despite these obstacles the PM-1 presently holds the US record (4101.1 hours) for the longest continuous reactor power run.

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*AFWL TRs 65-54, 65-91, 66-42, and 67-5

## SECTION II

## RECOMMENDATIONS AND CONCLUSIONS

Hq USAF (AFOCE), Hq ADC (ADEEM), and AFWL mutually decided to formally end the PM-1 Category III Field Test Analysis 6 months after installation of the second core. This milestone was reached on 19 February 1967 (initial criticality of the second core was at 2130 on 19 August 1966). This report will be the final summary of the PM-1 Category III Field Test Analysis, and with the previous four annual summaries, constitutes a complete record of Air Force operation of the PM-1 from 1 November 1962 to 31 March 1967. Although AFWL is ending its evaluation of the PM-1, PM-1 and 10 Air Force personnel will continue publishing monthly and yearly summary reports of the plant operation. Since modifications are continually being made to the plant, evaluations of these will still be required. AFWL recommends that these follow-on evaluations be handled by the using agency (ADC) and/or the PM-1 Engineering Support Group at Fort Belvoir, Virginia. This arrangement is recommended for two reasons. First, it will result in a minimum manpower requirement; and second, these agencies are directly associated with the development of modifications, and therefore, are better suited to evaluate their performance.

In ending the AFWL Category III analysis of the PM-1, certain conclusions and recommendations are in order. These are as follows:

1. Many of the difficulties experienced in operating the PM-1 have stemmed from the congested nature of the plant. Although some compactness was necessitated by the design requirement of the plant being air transportable, the plant should have been designed first for ease of operation and maintenance and then for transportability. With the present design this first requirement was obviously sacrificed for the latter--as reflected in the operational history of the plant. In an attempt to correct some of these original design oversights, several modifications and additions have been made to the plant which have made it virtually a stationary plant. Consequently, the Air Force now has a plant that is neither portable nor easily maintainable or operable.

2. The PM-1 has never had to run for any extended periods of time at more than about 600 kw net electrical power output, although it was designed for 1000 kwe net output. In light of some of the problems encountered by the plant while running at reduced loads (e.g., the high turbine-generator (TG) pinion bearing oil temperature problems during July 1966), the design of the plant appears to be somewhat deficient to meet its design objectives.

3. Because of the above deficiencies, a completely redesigned plant would probably be necessary in any future Air Force nuclear power plant procurement. Although the primary (nuclear) portion of the PM-1 is far from perfect, most of its problems have been identified and corrected or are being corrected. The design and operations deficiencies mentioned are due primarily to the plant layout and compactness. In the future, very strong consideration should be given to stationary type plants which are well arranged for ease of maintenance and operation.

4. Running a nuclear plant requires well trained and experienced personnel. Presently, the PM-1 is the only Air Force nuclear power plant, and thus, it is very difficult to get trained personnel to operate it. This, plus the fact that the Navy sends many of their personnel to the PM-1 prior to duty on the PM-3A, tends to make the PM-1 more of a training plant than an operational plant. Although there is very little that can be done at the present time to correct this problem, it should be remembered while reviewing the plant history.

5. Recommendations and conclusions concerning specific items or systems in the plant or having to do with certain operational areas are reported in other sections of this report. Other deficiencies and limitation have been reported, with recommended solutions in previous AFWL PM-1 Annual Summary Reports. These reports should be reviewed with this present one.

# SECTION III

# PLANT PERFORMANCE

## 1. OPERATIONAL STATISTICS

### a. Plant Operating History

Figure 1 and tables I, II, III, and IV summarize and depict the operational history of the PM-1 from 1 November 1962 to 31 March 1967. Brief statistical histories of the PM-1 operation for the periods of 1 November 1962 to 31 March 1967 and 1 November 1966 to 31 March 1967 are listed in table I. Figure 1 graphically depicts PM-1 operations during the period of 1 November 1966 to 31 March 1967, and table II describes in chronological order the startup, shutdown, and scram events graphed in figure 1. Similar information for the period of 1 November 1962 to 31 October 1966 is contained in the previous PM-1 Annual Summary Reports.

Table III is essentially a chronological listing of those times when the PM-1 was not supplying full electrical power to the Sundance radar station. Some explanation of the terms and abbreviations used on the table is included here for clarification. The "TIME OUT" listed is usually the time of the event described (e.g., a scram time) or the time at which the PM-1 began dropping load in preparation for a shutdown. The "TIME IN" listed is usually the time the PM-1 was resynchronized with the site diesels and began picking up electrical load. The "TIME UNAVAILABLE" listed is the time of the outage and may cover more than one event. The "SITE OUTAGE" listing refers to whether or not the radar site experienced a power outage resulting from the PM-1 event listed. A "YES" means that there was a forced outage of the radar site; whereas, a "NO" means that none was experienced. "NOL" is an abbreviation indicating that the PM-1 was "not on line" at the time of the event described. The "SCRAM" column indicates whether a scram occurred during the outage and whether it was manual (M) or unintentional (U). A "U" or "M" followed by a number indicates that more than one scram occurred for the given reason between the time listed and the next listing.

Table III includes all periods from 1 November 1962 to 31 March 1967 when the PM-1 was not supplying the entire site electrical load. Although there are periods included when the PM-1 may have been available to provide

Table I

SUMMARY OF PM-1 PERFORMANCE

| Performance parameter | 1 November 1966 to 31 March 1967 | 1 November 1962 to 31 March 1967 |
|---|---|---|
| Gross reactor thermal output (kw-hr) | 24,785,520 | 185,792,880 |
| Gross electrical output (kw-hr) | 2,745,000 | 21,405,900 |
| Net electrical output (kw-hr) | 1,742,300 | 12,921,700 |
| Heat steam output (estimated electrical equivalent)(kw-hr) | 349,000 | 3,513,000 |
| Gross energy output (kw-hr) | 3,015,000 | 24,052,350 |
| Net energy output (kw-hr) | 2,091,300 | 16,434,700 |
| Average gross electrical demand (kw) | 770 | 722 |
| Average net electrical demand (kw) | 490 | 463 |
| Ratio of net to gross demand (percent) | 63 | 63 |
| Maximum gross electrical demand (kw) | 940 | 940 |
| Maximum net electrical demand (kw) | 580 | 590 |
| Maximum parasitic load (kw) | 360 | 360 |
| Period of report (hrs) | 3,624 | 38,688 |
| Generator run time (hrs:min) | 3,557:42 | 28,003:05 |
| Generator run time (Item 14/Item 13) (percent) | 97.7 | 72.4 |
| Downtime caused by secondary system (hrs:min) | 0 | 2,262:30 |
| Downtime caused by primary system (hrs:min) | 66:18 | 6,968:47 |
| Downtime for other reasons (hrs:min) | 0 | 1,507:48 |
| Total number of scrams | 5 | 148 |
| Unintentional scrams | 5 | 101 |
| Longest power run (hrs:min) | 4,101:08 | 4,101:08 |
| PM-1 operating costs | | |
| Nuclear fuel | $ 69,726 | $ 558,424 |
| Materials | 1,412 | 100,531 |
| Support contracts | 3,900 | 210,638 |
| Salaries (excluding training) | 79,316 | 668,818 |
| Total operating cost | $154,354 | $1,538,411 |
| Core II life (19 August 1966-31 March 1967) | | |
| Design life (MWD) | 8,760 | |
| Total burnup (31 Mar 67)(percent) | 17.2 | |

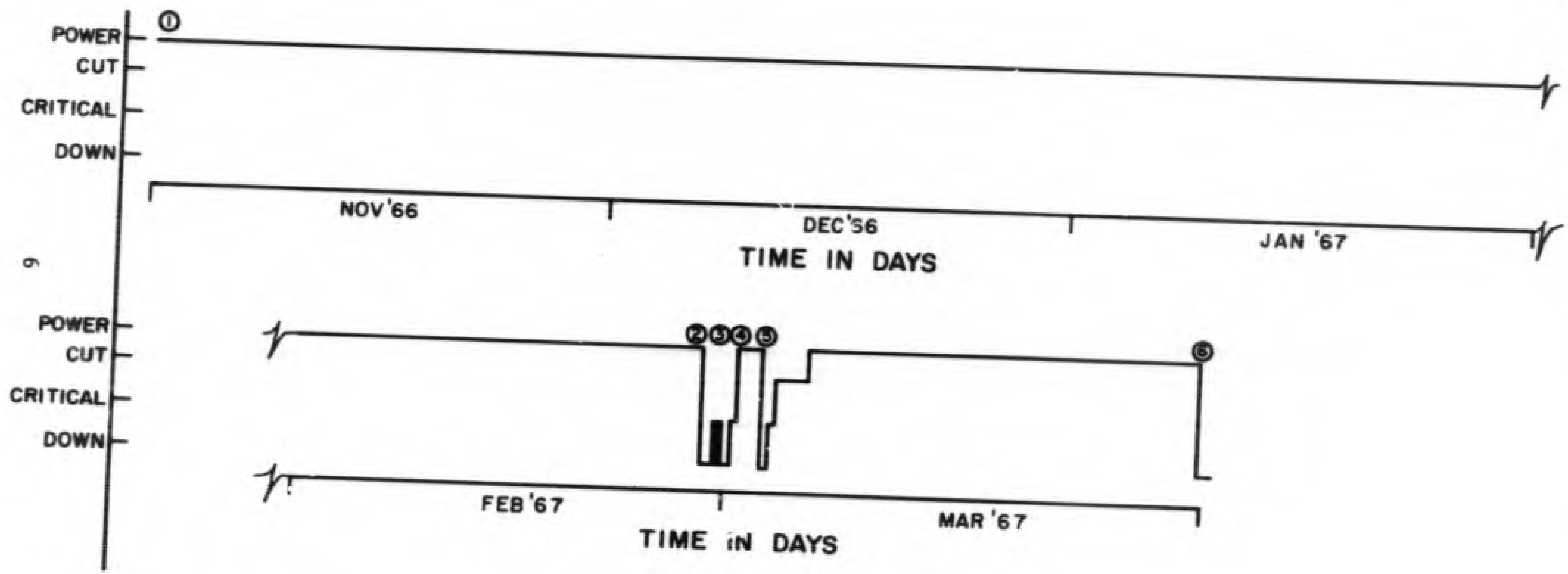


Figure 1. PM-1 Operating History (1 November 1966-31 March 1967)

Table II

KEY TO FIGURE 1

| Item | Date | Time | Event description |
|---|---|---|---|
| 1 | 1 Nov 66 | 0001 | At power; carrying full site heat and power loads. |
| 2 | 27 Feb 67 | 1238 | Scram: Transient periods on channels 1 and 2 resulted when channel 3 was placed in service from test positions; plant had been at power for 4,100 hours. |
| 3 | 28 Feb 67 | 0710 | Critical |
| | | 0715 | Scram: Lost hold power due to short period on channels 3 and 4; shutdown for maintenance. |
| | | 1238 | Critical; started heating up. |
| | | 1248 | Scram: Short period. |
| | | 1413 | Critical; heating up plant. |
| | | 1825 | Scram: Shutdown plant for maintenance on nuclear instruments. |
| 4 | 1 Mar 67 | 1022 | Critical. |
| | | 1441 | At power. |
| 5 | 3 Mar 67 | 0844 | Scram: Control rod No. 5 dropped due to moisture in a connector causing a low primary pressure scram. |
| | | 2209 | Critical. |
| | 4 Mar 67 | 0047 | At power; running isolated. |
| | 6 Mar 67 | 1046 | Assumed full site electrical load. |
| 6 | 31 Mar 67 | 2329 | Site load transferred to site diesel. |
| | | 2347 | Scram: Maintenance man inadvertantly moved channel 7 toward reactor, causing high power scram. |

Table III

PM-1 UNAVAILABILITY AND SCRAM HISTORY

(For period of 1 November 1962 to 31 March 1967)

| Month | Time out* (hr/day) | Time in* (hr/day) | Time unavailable (hrs:min) | Site outage* | Scram* | Reason* |
|---|---|---|---|---|---|---|
| Nov 62 | 0000/01 | | | No | No | Down for miscellaneous maintenance |
| | 0247/01 | | | NOL | M | Ch 2 detector malfunction |
| | 0655/01 | 1326/02 | 37:26 | NOL | M | Losing primary pressure |
| | 2303/06 | 0800/07 | 8:57 | Yes | U | TG overspeed trip (governor malfunction) |
| | 0804/07 | 1745/07 | 9:41 | No | No | Main gen breaker opened (TG gov maint) |
| | 0910/12 | 1805/12 | 8:55 | Yes | U | TG overspeed trip (governor malfunction) |
| | 0549/15 | 0610/16 | 24:21 | No | No | Main gen breaker opened (TG gov maint) |
| | 1912/20 | 2135/20 | 2:23 | No | No | Main gen breaker opened (TG gov maint) |
| | 2256/20 | 1322/21 | 14:26 | No | No | Main gen breaker opened (TG gov maint) |
| | 2311/23 | | | Yes | U | Blown fuse in rod drive power supply |
| | 0131/24 | 0810/24 | 8:59 | NOL | U | Short period Ch 4 (came on too fast) |
| | 0827/24 | 1401/24 | 5:34 | No | No | Isolated (TG gov maint) |
| | 1637/24 | 2151/24 | 5:14 | No | No | TG tripped for gov modification |
| | 2332/24 | 0617/25 | 6:45 | Yes | U | Phase A transformer relay failure |
| | 0851/26 | 1208/26 | 3:17 | No | No | TG tripped (repair leak in gov oil sys) |
| | 1208/26 | 1440/26 | 2:32 | No | No | Cutback (TG gov problems) |
| | 1440/26 | 1754/26 | 3:14 | No | No | TG tripped (gov modifications) |
| | 1947/27 | 0246/29 | 30:59 | Yes | U | TG gov malfunction |
| Dec 62 | 1125/01 | | | Yes | U | Operator error (testing volt reg switch) |
| | 1914/06 | 1318/07 | 145:53 | NOL | U | Low primary press (failure of purification system relief valve) |
| | 1924/08 | 0210/09 | 6:46 | No | No | Sec shutdown (repair steam leak) |
| | 1945/13 | | | Yes | U | Operator error (accidently pushed TG manual trip button) |
| | 2200/13 | 0455/14 | 9:10 | NOL | M | Ch 1 not responding correctly |
| | 1130/17 | 1940/17 | 8:10 | No | No | Sec shutdown (repair FW heater and aux heater relief valve) |
| | 1050/30 | | | No | No | Sec shutdown (loss of air supply) |
| | 1115/30 | | | NOL | U | Short period Chs 1, 2, 3 during shutdown |
| | 0403/31 | 2400/31 | 37:10 | NOL | M | CR 1 (not indicating properly) |

*See text for explanations

Table III (cont'd)

| Month | Time out* (hr/day) | Time in* (hr/day) | Time unavailable (hrs:min) | Site outage* | Scram* | Reason |
|---|---|---|---|---|---|---|
| Jan 63 | 0000/01 | 0453/02 | 28:53 | No | No | CR 1 (not indicating properly) |
| | 1550/09 | | | Yes | U | Low primary press signal when switching press selector switch |
| | 2125/09 | 2150/10 | 30:00 | NOL | M | Ch 4 not responding during startup |
| Feb 63 | 1636/02 | | | No | No | Sec shutdown (repair steam leak) |
| | 2245/02 | 2158/03 | 29:22 | NOL | U | Short period Ch 4 (shorted cable) |
| | 1438/07 | 0331/08 | 12:53 | No | No | Sec shutdown (repair steam leak) |
| | 0918/12 | | | No | No | Sec shutdown (repair FW leak) |
| | 0947/12 | | | NOL | M | Training |
| | 1245/12 | | | NOL | M | Training |
| | 1725/12 | | | NOL | M | Training |
| | 1957/12 | 2258/12 | 13:40 | NOL | M | Training |
| Mar 63 | 2023/07 | | | No | No | Sec shutdown (repair turbine leak) |
| | 2205/07 | | | NOL | M | Training |
| | 2340/09 | 1408/20 | 305:45 | NOL | M | CR 4 not indicating |
| | 1035/22 | 1410/22 | 3:35 | No | No | Sec shutdown (repair turbine leak) |
| Apr 63 | 2147/02 | | | No | No | Sec shutdown (repair condenser leak) |
| | 2316/02 | | | NOL | M | Maintenance |
| | 2145/03 | 0550/0[illegible] | 32:03 | NOL | U | Short period Chs 1, 2 during startup |
| | 1246/09 | 1640/09 | 3:54 | No | No | Sec shutdown (repair FW heater leaks) |
| | 1005/16 | | | No | No | Sec shutdown (repair FW heater press relief valve) |
| | 1230/16 | 1722/16 | 7:17 | NOL | U | Short period Ch 4 (too rapid steam admission to sec) |
| | 0840/19 | 1345/19 | 5:05 | Yes | U | Unknown (RM switched off at same time) |
| | 1326/24 | | | No | M | IG operational test |
| | 2101/24 | | | NOL | U-2 | Short period Ch 3 during startups |
| | 0218/25 | 1116/25 | 21:50 | NOL | U | Short period Ch 3 (checking drawer) |
| | 2008/25 | | | No | U | Short period Chs 1, 2 (while shutting down to repair primary leak) |

*See text for explanations

Table III (cont'd)

| Month | Time out* (hr/day) | Time in* (hr/day) | Time unavailable (hrs:min) | Site outage* | Scram* | Reason |
|---|---|---|---|---|---|---|
| Apr 63 (cont'd) | 1204/27 | | | NOL | U | Fluctuating AC during startup |
| | 1440/27 | | | NOL | U | Bistable 8 malfunction |
| | 1734/27 | | | NOL | U-4 | Unknown (probably bistable 8 malfunctions) |
| | 1537/28 | | | NOL | U | Short period Chs 3, 4 (start FW pump) |
| | 1341/29 | | | NOL | U | Unknown |
| | 1549/29 | 2400/30 | 123:52 | NOL | M | Semiannual maintenance |
| May 63 | 0000/01 | | | No | No | Extended shutdown (CR 4 and NIS problems) |
| | 0931/08 | | | NOL | U-3 | NIS testing |
| | 2227/09 | | | NOL | M | Shutdown |
| | 1643/10 | | | NOL | U-4 | NIS testing |
| | 2046/12 | 2400/31 | 744:00 | NOL | M | Shutdown |
| Jun 63 | 0000/01 | 2400/30 | 720:00 | No | No | Extended shutdown (CR 4 maintenance) |
| Jul 63 | 0000/01 | 2021/09 | 212:21 | No | No | Extended shutdown |
| | 0836/10 | | | No | No | Sec shutdown (repair turbine steam leak) |
| | 2143/10 | | | NOL | U | Mechanic accidently tripped sec circuit breaker |
| | 0029/11 | | | NOL | U | Short period Chs 3, 4 (coming on too fast) |
| | 0255/11 | 1314/11 | 28:38 | NOL | U | Short period Ch 3 (mechanic positioning detector) |
| | 0843/12 | | | Yes | U | Low primary press (SG filling too rapidly)** |
| | 1123/12 | 1130/13 | 26:47 | NOL | U | Loose connector in NIS cabinet |
| | 1840/13 | 1954/14 | 25:14 | Yes | U | Blown fuse in rod hold power cabinet |
| | 1030/20 | 2020/20 | 10:10 | No | No | Cutback (high TG pinion bearing temp) |
| | 1144/21 | 0002/22 | 12:18 | No | No | Cutback (high TG pinion bearing temp) |
| | 1255/22 | 2215/22 | 9:50 | No | No | Cutback (high TG pinion bearing temp) |
| | 0725/26 | 1118/26 | 3:53 | No | No | Cutback (condensate pump failure) |

*See text for explanations

**Filling SG too rapidly can cause primary to cool and shrink; thus, causing drop in pressure.

Table III (cont'd)

| Month | Time cut* (hr/day) | Time in* (hr/day) | Time unavailable (hrs:min) | Site outage* | Scram* | Reason |
|---|---|---|---|---|---|---|
| Aug 63 | 2305/10 | | | Yes | U | Overheated PC pump thermal overload breaker |
| | 0850/11 | | | NOL | U | Overheated PC pump thermal overload breaker |
| | 1233/11 | | | NOL | M | Core physics testing |
| | 1540/14 | | | NOL | M | Rod 1 not indicating |
| | 0725/22 | | | NOL | M | Completed core physics testing |
| | 1532/27 | | | NOL | U | Unknown (attempting to sync with site) |
| | 2131/27 | | | NOL | U-2 | Station service breaker tripped |
| | 0748/28 | | | NOL | M | Shutdown (electrical maintenance) |
| | 1500/28 | | | NOL | U | PC pump low power (frequency fluctuations) |
| | 1735/28 | 0354/29 | 436:49 | NOL | U | Short period Ch 3 (shorted cable) |
| Sep 63 | 0659/07 | 1735/07 | 10:36 | No | No | Sec shutdown (Xenon buildup test) |
| | 1535/09 | 2400/30 | 512:25 | No | M | Hq ADC directed shutdown (check thimble corrosion) |
| Oct 63 | 0000/01 | 2400/31 | 744:00 | No | No | Hq ADC directed shutdown (check thimble corrosion) |
| Nov 63 | 0000/01 | 2320/24 | 575:20 | No | No | Hq ADC directed shutdown (check thimble corrosion) |
| Dec 63 | 1348/09 | 0135/10 | 11:47 | Yes | U | Overheated PC pump thermal overload breaker |
| | 1613/12 | 1852/12 | 2:39 | No | No | Cutback (PC pump high power alarm) |
| | 0823/19 | | | No | No | Planned shutdown (replace press relief valves) |
| | 0925/19 | 0142/20 | 17:19 | NOL | M | Planned shutdown (replace press relief valves) |
| Jan 64 | None | | | No | No | None |

*See text for explanations

Table III (cont'd)

| Month | Time out* (hr/day) | Time in* (hr/day) | Time unavailable (hrs:min) | Site outage* | Scram* | Reason |
|---|---|---|---|---|---|---|
| Feb 64 | None | | | No | No | None |
| Mar 64 | None | | | No | No | None |
| Apr 64 | 1610/07 | | | No | No | Scheduled shutdown (maintenance) |
| | 1614/07 | 2400/30 | 559:50 | NOL | M | Extended shutdown (thimble corrosion) |
| May 64 | 0000/01 | 2400/31 | 744:00 | No | No | Extended shutdown (thimble corrosion) |
| Jun 64 | 0000/01 | 2400/30 | 720:00 | No | No | Extended shutdown (thimble corrosion) |
| Jul 64 | 0000/01 | | | No | No | Extended shutdown (thimble corrosion) |
| | 0727/29 | 2400/31 | 744:00 | NOL | M | Completed core physics testing and maint |
| Aug 64 | 0000/01 | 2115/05 | 117:15 | No | No | Repair primary leak |
| | 1310/06 | | | Yes | U | TG static exciter malfunction |
| | 1525/06 | 2400/31 | 610:50 | NOL | M | CR 3 not indicating |
| Sep 64 | 0000/01 | | | No | No | Replace damaged can on CR 3 |
| | 1311/01 | 2140/02 | 45:40 | NOL | M | CR 3 unlatched |
| | 1322/03 | | | No | U | Reverse current trip (diesel plant operator error) |
| | 1525/03 | 2204/03 | 8:42 | NOL | U | Short period Chs 3, 4 |
| | 1445/10 | 0815/11 | 17:30 | Yes | U | Main steam stop valve solenoid failure |
| | 0815/11 | 0945/11 | 1:30 | No | No | Isolated (no reason) |
| | 1045/14 | 1500/17 | 76:15 | Yes | No | Tieline breaker tripped (repair man damaged line) |
| Oct 64 | 1215/16 | 1536/21 | 123:21 | Yes | U | FW pumps tripped off |
| | 1536/21 | 0830/22 | 16:54 | No | No | Isolated (DA press and level fluctuations) |
| | 0840/30 | 1550/30 | 7:10 | Yes | U | Spurious signals (NIS safety system) |
| | 1552/30 | 2052/30 | 5:00 | No | No | Isolated (no reason) |
| | 2052/30 | 1826/31 | 21:34 | NOL | M | Unable to drive rods |
| | 1827/31 | 2400/31 | 5:33 | No | No | Isolated (no reason) |

*See text for explanations

Table III (cont'd)

| Month | Time out* (hr/day) | Time in* (hr/day) | Time unavailable (hrs:min) | Site outage* | Scram* | Reason |
|---|---|---|---|---|---|---|
| Nov 64 | 0000/01 | 1715/01 | 17:15 | No | No | Isolated (no reason) |
| | 0910/08 | 1656/08 | 7:45 | No | No | Sec shutdown (repair steam leak) |
| | 0809/13 | 1400/13 | 5:51 | No | No | Sec shutdown (repair steam leak) |
| | 2030/27 | 1615/28 | 19:45 | No | No | Sec shutdown (repair steam leak) |
| | 1615/28 | 1746/28 | 1:31 | No | No | Isolated (no reason) |
| | 1447/30 | 1802/30 | 3:15 | No | No | Sec shutdown (sec maint) |
| Dec 64 | 1305/23 | 2056/23 | 7:51 | No | No | Sec shutdown (repair FW pump min flow line) |
| | 2025/25 | 2146/25 | 1:21 | No | No | TG overspeeding (manually tripped) |
| | 0829/26 | 1502/26 | 6:33 | Yes | U | SG level data column plugged |
| Jan 65 | 2245/01 | | | Yes | U | Spurious signals in safety circuits; extended for primary maint |
| | 0214/05 | | | NOL | U | Short period (filled SG too quickly) |
| | 0530/05 | 1505/05 | 88:20 | NOL | M | CR 2 sticking |
| | 1505/05 | 0818/06 | 17:13 | No | No | Isolated (no reason) |
| | 0600/07 | 1546/11 | 105:46 | Yes | U | Spurious signals in safety circuits; extended for maint |
| | 1546/11 | 0931/12 | 17:45 | No | No | Isolated (no reason) |
| | 0929/13 | 1544/13 | 6:15 | No | No | Sec shutdown (repair FW pump leak) |
| | 1544/13 | 2044/13 | 5:00 | No | No | Cutback (no reason) |
| | 1138/16 | 1531/16 | 3:53 | No | No | Sec shutdown (repair FW heater press relief valve) |
| | 1650/23 | 1919/23 | 2:29 | No | No | Isolated (training) |
| Feb 65 | None | | | No | No | None |
| Mar 65 | 1405/03 | 1418/04 | 24:13 | No | No | Cutback (repair condenser; fan motor arcing) |
| | 1358/16 | 1810/16 | 4:12 | No | No | Cutback (repair FW pump gage line leak) |
| | 0920/26 | 2400/31 | 134:40 | Yes | U | Safety circuit bistable failure (high ambient temp) |

*See text for explanations

Table III (cont'd)

| Month | Time out* (hr/day) | Time in* (hr/day) | Time unavailable (hrs:min) | Site outage* | Scram* | Reason |
|---|---|---|---|---|---|---|
| Apr 65 | 0000/01 | | | No | No | Extended shutdown (awaiting new selsyn for CR 6) |
| | 0538/09 | 2015/09 | 212:15 | NOL | M | SG relief valve (would not seat) |
| | 2230/10 | 0720/11 | 8:50 | Yes | U | Loss of rod holdpower (operator jarred rod drive cabinet) |
| | 0905/14 | | | No | M | IG (DNS) directed shutdown |
| | 1032/14 | | | NOL | U | Short period Chs 3, 4 (operator adjusting voltage) |
| | 1124/14 | 1444/14 | 5:39 | NOL | U | Short period Ch 1, 2 (operator adjusting voltage of Chs 3, 4) |
| | 1610/14 | 2030/14 | 4:20 | Yes | U | Low PC flow (bad PC flow relay contacts) |
| | 2030/14 | 1035/15 | 14:05 | No | No | Isolated (no reason) |
| | 2238/22 | 2345/22 | 1:07 | No | No | Turbine manually tripped (gov malfunction) |
| | 2345/22 | 0430/23 | 4:45 | No | No | Cutback (no reason) |
| May 65 | 1945/14 | 0112/19 | 101:27 | Yes | U | Faulty contact on scram button; extended for primary maint |
| | 0112/19 | 1458/19 | 13:46 | No | No | Isolated (no reason) |
| | 0422/21 | 1400/21 | 9:38 | Yes | U | Electrical transient in scram logic circuit (nearby arcing) |
| | 1400/21 | 0748/22 | 17:48 | No | No | Isolated (no reason) |
| | 0900/30 | | | Yes | U | Low press scram (TG low frequency fluctuation) |
| | 1446/30 | 2212/30 | 13:12 | NOL | U | Turbine throttle valve collett failed to latch |
| | 2212/30 | 0310/31 | 4:58 | No | No | Cutback (no reason) |
| Jun 65 | 0930/09 | | | No | No | Sec shutdown (check xenon buildup) |
| | 1250/09 | | | NOL | U | Short period Chs 3, 4 |
| | 1300/09 | 2306/09 | 13:36 | NOL | U | Short period Ch 4 (being calibrated) |
| | 1923/13 | 1511/29 | 379:48 | No | M-5 U-8 | Semiannual maint; extended (TG inspection) 13 scrams occurred during shutdown--5 manual, 8 for testing and calibration |

*See text for explanations

Table III (cont'd)

| Month | Time out* (hr/day) | Time in* (hr/day) | Time unavailable (hrs:min) | Site outage* | Scram* | Reason |
|---|---|---|---|---|---|---|
| Jul 65 | 0945/13 | 2148/13 | 12:03 | No | No | Cutback (foreign object damage to condenser) |
| | 2148/13 | 0514/15 | 31:26 | No | M | Plant shutdown (sec maint in 02 tank) |
| | 0514/15 | 0634/15 | 1:20 | No | No | Isolated (no reason) |
| | 0634/15 | | | NOL | U | Main station secondary breaker malfunction |
| | 0916/15 | 1329/15 | 6:55 | NOL | M | No reason (probably testing scram button) |
| | 1329/15 | 1345/15 | 0:16 | No | No | Isolated (no reason) |
| | 1345/15 | 2100/15 | 7:15 | NOL | U | Main station secondary breaker malfunction |
| | 2100/15 | 1720/16 | 20:20 | No | No | Isolated (no reason) |
| | 1720/16 | | | No | No | Sec shutdown (repair steam leak) |
| | 1735/16 | 0624/17 | 13:04 | NOL | U-2 | Short period Chs 1, 2, 3, 4 (while shutting down and starting up) |
| | 0624/17 | 1544/17 | 9:20 | No | No | Isolated (no reason) |
| | 1320/20 | 0014/21 | 10:54 | Yes | U | Unknown (NIS maint in progress at time) |
| | 0014/21 | 0700/21 | 6:46 | No | No | Isolated (no reason) |
| Aug 65 | 0833/13 | 1755/13 | 9:22 | Yes | U | Maint error (maint man grounded vital AC) |
| | 1755/13 | 1501/14 | 21:06 | No | No | Preparing for AFWL Cat III test |
| | 0318/16 | 1001/16 | 6:43 | Yes | M | Main gen brushes arcing; could not get diesels on line |
| | 1001/16 | | | No | M | Shutdown (AFWL Cat III test) |
| | 0730/20 | 0537/21 | 115:36 | NOL | U | Operator error (opened pri trans breaker during test) |
| | 0537/21 | 1855/23 | 53:18 | NOL | M | Shutdown (pri and sec maint) |
| | 1855/23 | 0300/24 | 8:05 | No | No | Cutback and isolated (no reasons) |
| Sep 65 | 1510/07 | 0015/08 | 9:05 | Yes | M | Fire in roof of bldg (caused by contract welders) |
| | 0015/08 | 0826/08 | 8:11 | No | No | Isolated (no reason) |
| | 1740/29 | | | No | M | Shutdown (pri maint on CR 6 transformer) |
| | 1525/30 | 2400/30 | 30:20 | NOL | M | Testing |

*See text for explanations

Table III (cont'd)

| Month | Time out* (hr/day) | Time in* (hr/day) | Time unavailable (hrs:min) | Site outage* | Scram* | Reason |
|---|---|---|---|---|---|---|
| Oct 65 | 0000/01 | 1506/01 | 15:06 | No | No | Maint on CR 6 |
| | 1506/01 | 1806/01 | 3:00 | No | No | Isolated (no reason) |
| | 2312/03 | 0434/04 | 5:22 | Yes | U | Operator error (bumped sec breaker cabinet) |
| | 0830/25 | | | Yes | U | MS stop valve solenoid failure |
| | 1825/25 | | | NOL | U | Operator error (improper sync with diesels) |
| | 1927/25 | 2315/25 | 14:45 | NOL | U | Loss of power from diesel plant |
| Nov 65 | 0930/02 | 1513/02 | 5:43 | No | No | Cutback (live mission) |
| | 0935/03 | 1455/03 | 5:20 | No | No | Cutback (repair "B" condenser) |
| | 0913/05 | 1612/05 | 6:59 | No | No | Cutback (live mission) |
| | 2106/09 | 0742/10 | 10:36 | Yes | U | Unknown |
| | 0742/10 | 1446/10 | 7:04 | No | No | Isolated (no reason) |
| | 1445/12 | 1600/13 | 25:15 | No | No | Cutback (live mission) |
| Dec 65 | 0758/07 | 0916/07 | 1:18 | No | No | Isolated (tieline breaker maint) |
| Jan 66 | 2040/24 | 2155/24 | 1:15 | No | No | Cutback (losing vacuum, "B" condenser tubes frozen) |
| | 0921/26 | 1720/26 | 7:59 | No | No | Cutback (exceeding capacity of three condensers) |
| | 1354/29 | 1925/31 | 53:31 | Yes | U | Switch VAC to standby (faulty under voltage relay |
| | 1925/31 | 2400/31 | 4:35 | No | No | Isolated (no reason) |
| Feb 66 | 0000/01 | 1131/01 | 11:31 | No | No | Isolated (no reason) |
| | 1131/01 | | | NOL | U | NIS bistable 5 malfunction when Ch 3 put into operation |
| | 0203/02 | 0725/02 | 19:54 | NOL | No | Sec shutdown (repair FW pump seal leak) |
| | 0725/02 | 0817/02 | 0:52 | No | No | Isolated (no reason) |
| | 2050/04 | 1348/05 | 16:58 | No | No | Sec shutdown (repair FW line leak) |

*See text for explanations

Table III (cont'd)

| Month | Time out* (hr/day) | Time in* (hr/day) | Time unavailable (hrs:min) | Site outage* | Scram* | Reason |
|---|---|---|---|---|---|---|
| Mar 66 | 1320/02 | 1826/02 | 5:06 | No | No | Cutback (maint on "C" condenser) |
| | 1406/03 | 1505/03 | 0:59 | No | No | Cutback (thaw some frozen primary lines) |
| | 1845/03 | 0225/04 | 7:40 | Yes | U | Low pri press (TG low frequency fluctuation) |
| | 0225/04 | 0942/05 | 31:17 | No | No | Isolated (no reason) |
| | 1655/05 | 0420/06 | 11:25 | No | No | Cutback (frozen tubes on "C" condenser) |
| | 0838/07 | 1707/09 | 56:29 | No | No | Cutback (maint on "C" condenser) |
| | 1045/10 | 1610/10 | 5:25 | No | No | Cutback (high condenser pressure) |
| | 0700/11 | | | No | No | Sec shutdown (repair steam leak) |
| | 0750/11 | 2050/11 | 13:50 | NOL | U | Ch 1 put in test causing scram |
| | 2219/20 | 0930/21 | 11:11 | Yes | U | R-20 relay failure (R-20 annunciates, trips TG etc. on scram) |
| | 0930/21 | 1300/21 | 3:30 | No | No | Isolated (no reason) |
| | 0923/22 | 1544/22 | 6:21 | No | No | Cutback (weather conditions) |
| | 1459/24 | 1115/25 | 20:16 | No | No | Isolated (no reason) |
| Apr 66 | 0933/08 | 1333/08 | 4:00 | No | No | Cutback (oscillating turbine exhaust pressure) |
| | 0934/20 | 1542/20 | 6:08 | No | No | Cutback (live mission) |
| | 1025/28 | 1100/28 | 0:35 | No | No | Cutback (repair steam leak) |
| May 66 | 0812/02 | | | No | No | Cutback (core I life extension through 8 Aug) |
| | 0810/20 | 1046/20 | 2:36 | No | No | Cutback (unstable exhaust vacuum) |
| Jun 66 | 1320/14 | 1448/14 | 1:28 | No | No | Cutback (repair steam leak) |
| | 1145/27 | 1950/27 | 8:05 | No | No | Cutback (repair condenser leak) |
| | 1115/28 | 2145/28 | 10:30 | No | No | Cutback (high TG pinion bearing oil temp--carrying 225 kw) |
| Jul 66 | See last column | | | No | No | Numerous cutbacks (high TG pinion bearing oil temperature occurred during month)** |

*See text for explanations

**Since plant was already in cutback condition to extend life of core I, full extent of high TG bearing oil temp problem remained hidden. However, during the month, there were at least 8 additional cutbacks, lasting up to 12 hours which were attributed to this problem.

Table III (cont'd)

| Month | Time out* (hr/day) | Time in* (hr/day) | Time unavailable (hrs:min) | Site outage* | Scram* | Reason |
|---|---|---|---|---|---|---|
| Aug 66 | 0456/08 | | | No | M | Shutdown (refuel and maint) |
| | 1116/10 | | | NOL | U | Short period Chs 3, 4 during startup for testing |
| | 2258/10 | | | NOL | M | Completed core physics test of core I |
| | 2115/20 | 0655/21 | 313:59 | NOL | M | Hot rod scram test of core II |
| | 0705/21 | 1144/21 | 4:39 | No | No | Isolated (no reason) |
| | 0315/23 | 1120/23 | 8:05 | No | No | Cutback (live mission) |
| | 1431/24 | 1550/24 | 1:26 | No | No | Cutback (maint on "B" condenser) |
| | 0609/25 | 1341/25 | 7:32 | No | M | Pri shutdown (align purification economizer properly) |
| | 0501/31 | 1347/31 | 8:46 | No | No | Cutback (no reason) |
| Sep 66 | 0447/02 | 1000/02 | 5:13 | No | No | Cutback (live mission) |
| | 0946/06 | | | Yes | U | CR 5 fell (due to drift in signal gen) |
| | 0112/08 | 0926/08 | 47:40 | NOL | U | Erratic period on Ch 4 |
| | 0926/08 | 1044/08 | 1:18 | No | No | Isolated (no reason) |
| | 1345/09 | 1530/09 | 1:45 | No | U | Short period Ch 2 (shutdown for pri align) |
| | 1011/10 | 2056/10 | 10:45 | No | No | Cutback (high TG bearing oil temp) |
| | 1346/12 | 1753/12 | 4:07 | No | No | Cutback (high TG bearing oil temp) |
| | 0256/15 | 1143/15 | 8:47 | No | No | Cutback (no reason) |
| | 0003/26 | 0400/26 | 3:57 | No | No | Cutback (no reason) |
| Oct 66 | 0800/10 | 0406/12 | 44:06 | No | No | Cutback (live mission) |
| | 0905/18 | 1340/18 | 4:35 | No | No | Cutback (change pri purification sys resin) |
| Nov 66 | 0602/07 | 0820/08 | 26:18 | No | No | Cutback ("C" condenser fan failure) |
| Dec 66 | 0125/10 | 0200/10 | 0:35 | No | No | Cutback (repair steam leak in DA tank line) |
| Jan 67 | None | None | None | No | No | None |

*See text for explanations

Table III (cont'd)

| Month | Time out* (hr/day) | Time in* (hr/day) | Time unavailable (hrs:min) | Site outage* | Scram* | Reason |
|---|---|---|---|---|---|---|
| Feb 67 | 1238/27 | | | Yes | U | Short period Chs 1, 2 (connecting Ch 3) |
| | 0715/28 | | | NOL | U-2 | Short period Chs 3, 4 (on startups) |
| | 1825/28 | 2400/28 | 35:22 | NOL | M | NIS and primary maint |
| Mar 67 | 0000/01 | 1441/01 | 14:41 | No | No | NIS and primary maint |
| | 0844/03 | 0046/04 | 16:02 | Yes | U | Low pri press (CR 5 drop due to moisture in connector) |
| | 0046/04 | 1046/06 | 58:00 | No | No | Isolated (no reason) |
| | 0858/20 | 1200/20 | 3:02 | No | No | Isolated (no reason) |
| | 0905/23 | 1510/23 | 6:05 | No | No | Isolated (no reason) |
| | 2329/31 | 2347/31 | 0:18 | No | No | Isolated (failure of Ch 6) |
| | 2347/31 | 2400/31 | 0:13 | NOL | U | High power scram (operator moved Ch 7 detector toward reactor) |

*See text for explanations

Table IV

SUMMARY OF PM-1 UNAVAILABILITY

(Period of 1 November 1962 to 31 March 1967)

| | |
|---|---|
| **Time** | |
| Total time not at full power | 11,656 hrs |
| Total time at reduced load or isolated* | 933 hrs |
| Total time not producing any electrical power | 10,723 hrs |
| Time not at full power chargeable to: | |
| Directed shutdowns, nonroutine testing, scheduled maintenance, waiting for parts, inspections | 7,721 hrs |
| Primary system and associated components | 2,295 hrs |
| Nonprimary systems and associated components | 991 hrs |
| Human error | 117 hrs |
| Unknown causes | 532 hrs |
| **Outages** | |
| Total number of radar site outages due to PM-1 | 40 |
| Number of site outages caused by: | |
| Primary system and associated components | 17 |
| Nonprimary system and associated components | 14 |
| Human error | 6 |
| Unknown causes | 3 |

*Includes period of AFWL Category III test during August 1965.

the full site load and did not for policy or other reasons (e.g., the live mission cutbacks), the table still gives a good indication of the overall availability of the plant. Summing the "TIME UNAVAILABLE" listings in table III gives 11,656 hours. Since there were 38,688 hours in the report period, this gives an overall availability of 69.9 percent for full power production.

Since table III includes periods when the PM-1 was not supplying full electrical load to the radar site for many different reasons, some consolidation of the periods according to cause is meaningful. Thus, table IV is included to summarize the information contained in table III. In formulating table IV, certain assumptions had to be made because the length of an outage may have been due to several causes. An attempt was made to divide all periods of unavailability into their component parts.

About 70 percent of the PM-1 unavailability has been due to nonoperational causes. If this time is eliminated from consideration, the PM-1 availability increases to 87.3 percent. Although much better than 69.9 percent (the availability before removing nonoperational downtime), this is still somewhat below the design availability of 94.3 percent.

Another very interesting aspect of tables III and IV is the amount of trouble experienced with the conventional (nonprimary) systems and components in the PM-1. Although the unavailable time charged to these systems and components is less than half that charged to the nuclear (primary) systems and components, the number of incidents of trouble with the conventional components is about one and one-half times that for the nuclear components. Looking to the number of radar site power outages chargeable to the PM-1, the conventional and nuclear systems are about even. Thus, it would appear that nuclear power plant R&D should concentrate as much on improving the conventional aspects of these plants as the nuclear aspects. Considering the number of years that steam turbine systems have been in existence, it appears that perhaps another approach is necessary to get highly reliable nuclear power plants.

b. Scram History

Table V contains a listing of all scrams from 1 November 1962 to 31 March 1967. A chronological listing of these scrams can be obtained from table III along with some pertinent facts concerning the cause of the scram. Scrams just for the period of 1 November 1966 to 31 March 1967 are

Table V

SCRAM HISTORY

| Month | Primary system | Secondary system | Nuclear instru- mentation | Electrical | Operator error | Main- tenance error | Total uninten- tional scrams | Manual scrams | Total scrams |
|---|---|---|---|---|---|---|---|---|---|
| Nov 62 | 1 | 0 | 1 | 4 | 0 | 0 | 6 | 2 | 8 |
| Dec 62 | 1 | 0 | 1 | 0 | 2 | 0 | 4 | 2 | 6 |
| Jan 63 | 1 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 2 |
| Feb 63 | 0 | 0 | 1 | 0 | 0 | 0 | 1 | 4 | 5 |
| Mar 63 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 2 |
| Apr 63 | 0 | 1 | 13 | 0 | 1 | 0 | 15 | 3 | 18 |
| May 63 | 0 | 0 | 7 | 0 | 0 | 0 | 7 | 2 | 9 |
| Jun 63 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Jul 63 | 1 | 0 | 3 | 0 | 0 | 2 | 6 | 0 | 6 |
| Aug 63 | 3 | 0 | 2 | 2 | 0 | 0 | 7 | 4 | 11 |
| Sep 63 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 |
| Oct 63 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | 7 | 1 | 28 | 6 | 3 | 2 | 47 | 21 | 68 |
| Nov 63 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Dec 63 | 1 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 2 |
| Jan 64 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Feb 64 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Mar 64 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Apr 64 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 |
| May 64 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Jun 64 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Jul 64 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Aug 64 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 1 | 1 |
| Sep 64 | 0 | 1 | 1 | 0 | 1 | 0 | 1 | 1 | 2 |
| Oct 64 | 0 | 1 | 1 | 0 | 0 | 0 | 2 | 1 | 3 |
| | 1 | 2 | 2 | 1 | 1 | 0 | 7 | 6 | 13 |

Table V (cont'd)

| Month | Primary system | Secondary system | Nuclear instru-mentation | Electrical | Operator error | Main-tenance error | Total uninten-tional scrams | Manual scrams | Total scrams |
|---|---|---|---|---|---|---|---|---|---|
| Nov 64 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Dec 64 | 0 | 1 | 0 | 0 | 0 | 0 | 1 | 0 | 1 |
| Jan 65 | 0 | 0 | 2 | 0 | 1 | 0 | 3 | 1 | 4 |
| Feb 65 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Mar 65 | 0 | 0 | 1 | 0 | 0 | 0 | 1 | 0 | 1 |
| Apr 65 | 2 | 0 | 0 | 0 | 2 | 0 | 4 | 2 | 6 |
| May 65 | 1 | 0 | 1 | 2 | 0 | 0 | 4 | 0 | 4 |
| Jun 65 | 0 | 0 | 4 | 4 | 0 | 0 | 8 | 5 | 13 |
| Jul 65 | 0 | 0 | 3 | 2 | 0 | 0 | 5 | 2 | 7 |
| Aug 65 | 0 | 0 | 0 | 0 | 1 | 1 | 2 | 3 | 5 |
| Sep 65 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 3 | 3 |
| Oct 65 | 0 | 1 | 0 | 1 | 1 | 1 | 4 | 0 | 4 |
| | 3 | 2 | 11 | 9 | 5 | 2 | 32 | 16 | 48 |
| Nov 65 | 0 | 0 | 1 | 0 | 0 | 0 | 1 | 0 | 1 |
| Dec 65 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Jan 66 | 0 | 0 | 0 | 1 | 0 | 0 | 1 | 0 | 1 |
| Feb 66 | 0 | 0 | 1 | 0 | 0 | 0 | 1 | 0 | 1 |
| Mar 66 | 0 | 0 | 1 | 2 | 0 | 0 | 3 | 0 | 3 |
| Apr 66 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| May 66 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Jun 66 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Jul 66 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Aug 66 | 0 | 0 | 1 | 0 | 0 | 0 | 1 | 4 | 5 |
| Sep 66 | 1 | 0 | 2 | 0 | 0 | 0 | 3 | 0 | 3 |
| Oct 66 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | 1 | 0 | 6 | 3 | 0 | 0 | 10 | 4 | 14 |

Table V (cont'd)

| Month | Primary system | Secondary system | Nuclear instru-mentation | Electrical | Operator error | Main-tenance error | Total uninten-tional scrams | Manual scrams | Total scrams |
|---|---|---|---|---|---|---|---|---|---|
| Nov 66 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Dec 66 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Jan 67 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Feb 67 | 0 | 0 | 3 | 0 | 0 | 0 | 3 | 1 | 4 |
| Mar 67 | 1 | 0 | 0 | 0 | 0 | 1 | 2 | 0 | 2 |
| | 1 | 0 | 3 | 0 | 0 | 1 | 5 | 1 | 6 |
| Overall totals | 13 | 5 | 50 | 19 | 9 | 5 | 101 | 48 | 149 |

indicated in figure 1. They are al listed in table II. During this latter period, a total of six scrams occurred--two of them resulting in radar site power outages. The first of these scrams (at 1238 on 27 February 1967) should not have occurred had the nuclear safety circuits been designed and built correctly. Since this is the second time this particular sequence of events has led to an unnecessary scram, action should be taken to get the appropriate circuitry corrected as soon as possible. Except for the last scram (at 2347 on 31 March 1967) the others were due to normal scram causes. The last one occurred because of a failure in one of the three power channels (No. 6) and the inadvertant moving of one of the other power channels (No. 7) towards the reactor by one of the maintenance men. Normally, high readings on two of the three power channels is required for a scram. However, if one channel is out of service, either one of the remaining channels can scram the reactor.

## 2. REACTOR CORE PERFORMANCE

### a. Scram Time Test

During the period of 1 November 1966 to 31 March 1967, testing of the PM-1 second core was limited to rod drop times. The results of this testing are shown in table VI. The rod drop times recorded are within the permissible limits and are comparable to previous tests. Results of these previous tests are contained in past AFWL Annual Summary Reports.

### b. Core Life and Fuel Burnup

Figure 2 shows the average rod bank position as a function of core burnup for cores I and II. Information on core II is plotted through 21 August 1967, which is the first anniversary of the core. Based on a design life of 875 effective full power days (EFPD) and an expended life of 251 EFPD, 29 percent of core II was expended during this first year of operation. I should be noted that the curve is somewhat higher than the predicted one--which may indicate an actual life of something less than 875 EFPD. This higher trend has continued up to the publication of this report.

## 3. SYSTEMS EVALUATION

This section evaluates all subsystems, denotes maintenance problem areas, and makes recommendations where applicable. Table VII summarizes the number of mainenance requirements, manhours expended, and supply costs of each system. A more detailed handling of each system follows.

Table VI

CONTROL ROD DROP TIMES

| Rod no. | Temp (°F) | Initial rod position (in) | Position indicator (in) | Drop distance (in) | Drop time (millisec) |
|---|---|---|---|---|---|
| 1 | 434 | 30.00 | 10.01 | 19.99 | 350 |
| 2 | 430 | 30.04 | 10.01 | 20.03 | 367 |
| 3 | 407 | 30.01 | 10.01 | 20.00 | 367 |
| 4 | 412 | 30.03 | 10.01 | 20.02 | 335 |
| 5 | 411 | 29.95 | 10.01 | 19.94 | 367 |
| 6 | 408 | 30.01 | 10.01 | 20.00 | 334 |

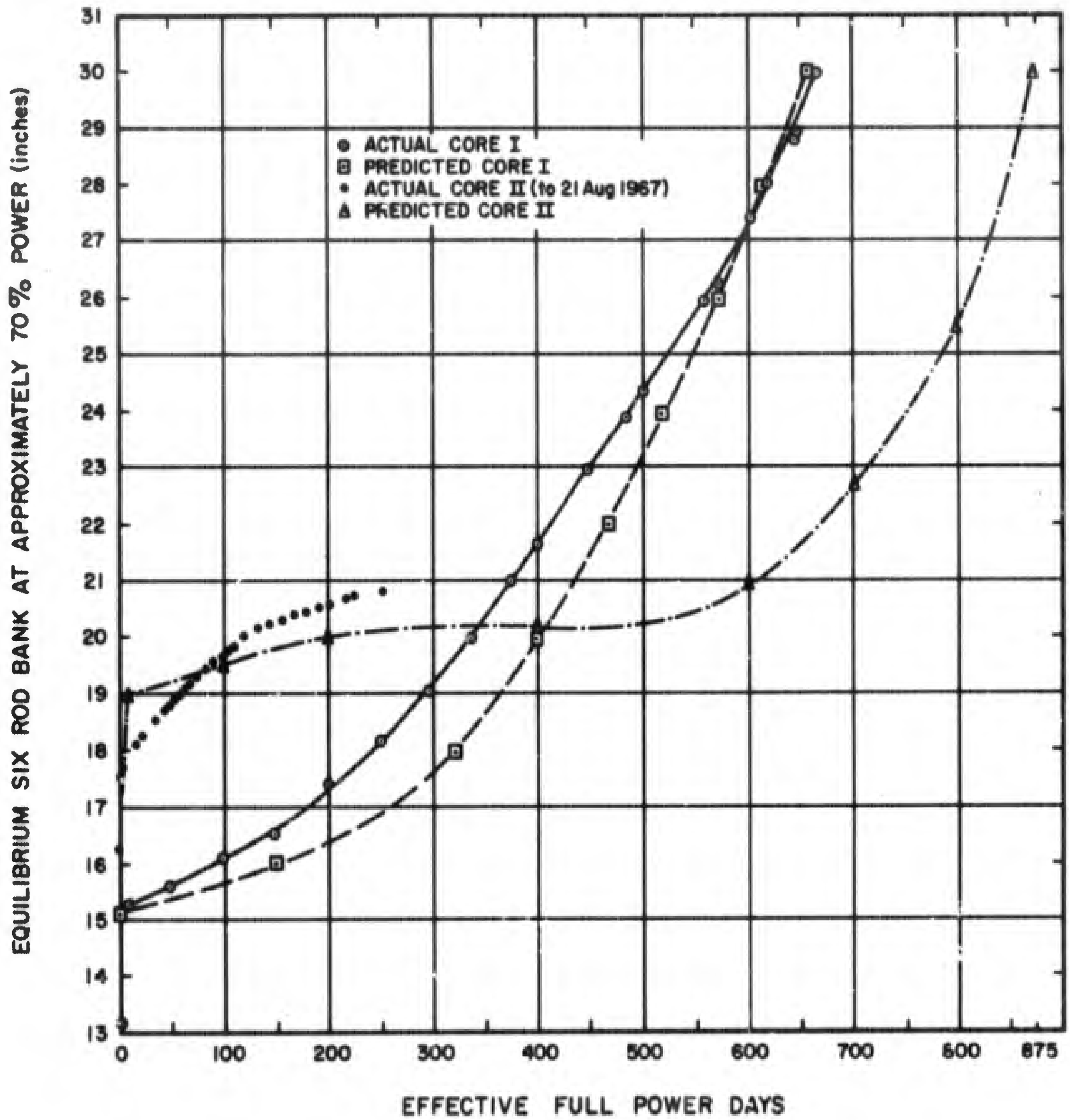


Figure 2. Core Life versus Six-Rod Bank, PM-1, Cores I and II

Table VII

EVALUATION OF CORRECTIVE MAINTENANCE, MODIFICATIONS, AND CONTRACT MAINTENANCE
(For period of 1 November 1962 to 31 October 1966)

| System | Description | Req'd no. actions | Man-hours | Parts costs |
|---|---|---|---|---|
| 1-PIP | Primary instrumentation and control | 35 | 263 | $ 853.25 |
| 1-PIS | Secondary instrumentation and control | 69 | 637 | 3,938.31 |
| 1-PIF | Fluid sampling | 29 | 132 | 436.10 |
| 1-PIC | Communication | 15 | 278 | 391.46 |
| 1-PIA | Control console annunciator | 37 | 236 | 1,347.99 |
| 2-NI | Nuclear instrumentation | 88 | 1,435 | 10,009.26 |
| 3-RR | Reactor control rod drive | 66 | 2,619 | 47,798.12 |
| 4-RS | Reactor safety | 4 | 45 | 135.80 |
| 5-RM | Radiation monitoring | 131 | 759 | 2,727.69 |
| 6-RC | Reactor coolant | 4 | 36 | 44.82 |
| 7-PR | Pressure relief and pressurizer | 19 | 190 | 1,934.65 |
| 8-CC | Coolant charging | 7 | 29 | 67.10 |
| 9-DV | Coolant discharge and vent | 9 | 246 | 367.65 |
| 10-CP | Coolant purification | 8 | 55 | 96.00 |
| 11-CA | Coolant chemical addition | 4 | 228 | 146.67 |
| 12-DH | Decay heat removal | 3 | 27 | 4.89 |
| 13-SW | Shield water | 23 | 363 | 1,352.92 |
| 14-HC | Reactor plant heating and cooling | 1 | 7 | 0.00 |
| 15-FC | Fuel cask and cooling | 2 | 90 | 0.00 |
| 16-WD | Radioactive waste disposal (RWDS) | 64 | 734 | 2,048.23 |
| 17-PC | Plant container (01, 02, 22 tks) | 4 | 56 | 380.90 |
| 18-MS | Main and auxiliary steam | 45 | 337 | 412.32 |

Table VII (cont'd)

| System | Description | Req'd no. actions | Man-hours | Parts costs |
|---|---|---|---|---|
| 19-TG | Main turbine and generator unit | 30 | 708 | $ 175.63 |
| 20-MC | Main condenser and condensate | 74 | 1,378 | 1,976.89 |
| 21-FW | Feedwater | 47 | 1,165 | 6,602.96 |
| 22-ES | Extraction steam | 12 | 136 | 136.57 |
| 23-CW | Cooling water | 7 | 124 | 849.51 |
| 24-TD | Main station transformer and distribution | 16 | 257 | 1,050.36 |
| 25-SS | Station service | 2 | 16 | 5.28 |
| 26-LS | Lighting and DC emergency lighting | 29 | 240 | 316.61 |
| 27-DC | Vital AC and DC | 14 | 80 | 25.77 |
| 28-EP | Emergency power | 14 | 107 | 561 12 |
| 29-WT | Water treating | 31 | 586 | 1,213.24 |
| 30-MU | Condensate make-up | 40 | 410 | 386.49 |
| 31-FP | Fire protection | 11 | 252 | 552.52 |
| 32-TE | Turbine exhaust | 1 | 2 | 0.00 |
| 33-HV | Plant heating, air conditioning, and ventilating | 81 | 1,167 | 2,979.61 |
| 34-PB | Primary building and grounds | 15 | 235 | 89.64 |
| 35-SB | Secondary building and grounds | 44 | 1,110 | 1,366.90 |
| 36-DB | Decontamination building and grounds | 42 | 522 | 417.09 |
| 37-MT | Maintenance items and tools | 43 | 246 | 492.18 |
| 38-IA | Instrument air | 23 | 209 | 510.34 |
| 39-MISC | Miscellaneous items | 37 | 1,745 | 134.39 |
| | Subtotal | 1,280 | 19,497 | $ 94,337.23 |
| Contract | Phase I (AF 39(601)-2487) | 6 | 165 | 22,598.44 |
| | Total | 1,286 | 19,662 | $116,935.67 |

a. Plant Instrumentation (Primary System) (1-PIP)

| | Req'd no. actions | Manhours | Parts cost |
|---|---|---|---|
| 1962-63 | 16 | 79 | $ 161.50 |
| 1963-64 | 11 | 117 | 177.00 |
| 1964-65 | 8 | 67 | 514.75 |
| 1965-66 | 0 | 0 | 0.00 |
| | 35 | 263 | $ 853.25 |

The primary instrumentation system operated less than satisfactorily during the first 4 years of operation, but has shown a marked improvement since 1965. The majority of the servicing action has been limited to minor adjustment and repairs that fit normally into the preventive maintenance category.

b. Plant Instrumentation (Secondary System) (1-PIS)

| | Req'd no. actions | Manhours | Parts cost |
|---|---|---|---|
| 1962-63 | 20 | 220 | $ 1,900.70 |
| 1963-64 | 22 | 216 | 1,774.00 |
| 1964-65 | 24 | 189 | 224.93 |
| 1965-66 | 3 | 12 | 38.68 |
| | 69 | 637 | $ 3,938.31 |

The secondary instrumentation system is rated satisfactory although the data for the first 2 years show excessive costs. The major problem area was with the original Foxboro M-62 controllers, which proved to be inadequately designed. Foxboro redesigned these controllers, and the improved model seems to be functioning reasonably well. Another factor in reduction of failure rates was an aggressive in-house preventive maintenance program that put the controllers under regular observation to prevent unnecessary failure.

Other problem areas such as frozen lines to D-P cells were reduced through extensive maintenance to the facility as well as to individual systems.

c. Fluid Sampling System (1-PIF)

| | Req'd no. actions | Manhours | Parts cost |
|---|---|---|---|
| 1962-63 | 2 | 31 | $ 38.82 |
| 1963-64 | 11 | 42 | 0.00 |
| 1964-65 | 12 | 49 | 254.83 |
| 1965-66 | 4 | 10 | 142.45 |
| | 29 | 132 | $ 436.10 |

The fluid sampling system was generally satisfactory for the first 4 years of operation. It was necessary to redesign the fluid sampling cabinet initially to provide proper control of the system. The major problems have been caused by clogging and leaking of the inline sampling equipment. Certain portable equipment, especially the pH meters, received above normal attention. Some improvements in equipment functioning have been obtained through a better preventive maintenance program.

d. Communication System (1-PIC)

| | Req'd no. actions | Manhours | Parts cost |
|---|---|---|---|
| 1962-63 | 7 | 246 | $ 278.96 |
| 1963-64 | 1 | 1 | 0.00 |
| 1964-65 | 4 | 19 | 27.89 |
| 1965-66 | 3 | 12 | 84.61 |
| | 15 | 278 | $ 391.46 |

The communication system within the plant has operated satisfactorily, although certain modifications were necessary initially to bring the system into acceptable operating condition. An enlargement of the system was necessary to provide additional speakers for the building expansion and to fill in blind areas in the plant. Additional alarm systems were also provided for emergency signalling and for disaster control.

e. Annunciator and Scan System (1-PIA)

| | Req'd no. actions | Manhours | Parts cost |
|---|---|---|---|
| 1962-63 | 16 | 56 | $ 110.78 |
| 1963-64 | 5 | 22 | 12.94 |
| 1964-65 | 6 | 53 | 23.69 |
| 1965-66 | 10 | 105 | 1,200.58 |
| | 37 | 236 | $ 1,347.99 |

This system has operated satisfactorily during the first 4 years of operation. The high cost in the fourth year was due primarily to the addition of a sequential analyzer to the annunciator system. The maintenance in general consisted of minor adjustments and replacement of parts.

f. Nuclear Instrumentation (2-NI)

| | Req'd no. actions | Manhours | Parts cost |
|---|---|---|---|
| 1962-63 | 20 | 780 | $ 7,534.22 |
| 1963-64 | 21 | 198 | 1,287.33 |
| 1964-65 | 31 | 277 | 520.74 |
| 1965-66 | 16 | 180 | 666.97 |
| | 88 | 1,435 | $10,009.26 |

As indicated by the above data, the performance of this system has been substandard during the 4 years of plant operation. Many improvements have been made through modifications of the system to provide dry wells for the detectors and cable extensions for high flux areas. Although the system has improved with respect to maintenance cost, it still remains a problem area since many plant scrams are caused by its extreme sensitivity and over-sophistication (for a field plant).

Numerous studies and safeguards requirements have led to an over-complication of the instrumentation system to a point where plant reliability has suffered. Until complete overhaul of these standards is made, bringing them into perspective for a field system, the plant will continue being plagued by unneccesary scrams from this system.

g. Rod Drive (3-RR)

| | Req'd no. actions | Manhours | Parts cost |
|---|---|---|---|
| 1962-63 | 14 | 908 | $26,997.58 |
| 1963-64 | 17 | 865 | 18,950.80 |
| 1964-65 | 17 | 343 | 433.32 |
| 1965-66 | 18 | 503 | 1,416.42 |
| | 66 | 2,619 | $47,798.12 |

This system has not performed satisfactorily during the first 4 years of operation although there have been reductions in the cost of maintenance during the second 2 years. There have been several recurring problem areas: failure of control rod cable, failure of rod position indicator sensing elements internal to the magnetic jack can, cans sticking on thimbles, and thimble corrosion. Several things have been done to help alleviate these problems. They include nickle-plating of the 403 SS section of the thimbles, in-house retermination of cables, specification changes on shield water, and splitting the cans between the magnetic jacks and servo-mechanisms to allow repair of the rod position indicator sensing elements while maintaining the reactor at power.

h. Reactor Safety (4-RS)

| | Req'd no. actions | Manhours | Parts cost |
|---|---|---|---|
| 1962-63 | 0 | 0 | $ 0.00 |
| 1963-64 | 2 | 26 | 16.50 |
| 1964-65 | 1 | 6 | 23.00 |
| 1965-66 | 1 | 13 | 96.30 |
| | 4 | 45 | $ 135.80 |

From a maintenance standpoint, this system has been quite satisfactory.

i. Radiation Monitoring (5-RM)

| | Req'd no. actions | Manhours | Parts cost |
|---|---|---|---|
| 1962-63 | 40 | 172 | $ 265.52 |
| 1963-64 | 31 | 189 | 877.10 |
| 1964-65 | 38 | 240 | 502.56 |
| 1965-66 | 22 | 158 | 1,082.51 |
| | 131 | 759 | $ 2,727.69 |

The operation of the radiation monitoring system is considered satisfactory for the first 4 years of operation. The failure rate at first glance seems relatively high when compared to other systems, but it must be realized that this system includes numerous portable monitors that receive fairly rough treatment. Also, since these are outfitted with batteries and are often exposed to the weather, corrosive damage can occur. However, as preventive maintenance programs become better defined for these items, corrective maintenance should show continued improvement.

This conclusion is borne out by the reduction in failures of certain counting equipment that had a history of numerous recurring failures in the initial year of operation.

j. Reactor Coolant (6-RC)

| | Req'd no. actions | Manhours | Parts cost |
|---|---|---|---|
| 1962-63 | 0 | 0 | $ 0.00 |
| 1963-64 | 4 | 36 | 44.82 |
| 1964-65 | 0 | 0 | 0.00 |
| 1965-66 | 0 | 0 | 0.00 |
| | 4 | 36 | $ 44.82 |

The performance of this system was very satisfactory during the first 4 years of operation.

k. Pressure Relief and Pressurizer System (7-PR)

| | Req'd no. actions | Manhours | Parts cost |
|---|---|---|---|
| 1962-63 | 7 | 40 | $ 145.18 |
| 1963-64 | 5 | 51 | 202.00 |
| 1964-65 | 3 | 35 | 315.05 |
| 1965-66 | 4 | 64 | 1,272.42 |
| | 19 | 190 | $ 1,934.65 |

Except for the problem of leaky pressure relief valves, the pressure relief and pressurizer system has performed satisfactorily during the first 4 years of operation. Although there have been many modifications made to the piping and supporting structures around these relief valves, and changes in operating procedures (minimizing back pressure at the expansion tank), the improvements gained were only temporary. As a final fix, work is progressing to install rupture discs upstream of the relief valves to give a positive seal against leakage.

l. Coolant Charging (8-CC)

| | Req'd no. actions | Manhours | Parts cost |
|---|---|---|---|
| 1962-63 | 2 | 4 | $ 0.00 |
| 1963-64 | 1 | 10 | 3.60 |
| 1964-65 | 2 | 8 | 63.50 |
| 1965-66 | 2 | 7 | 0.00 |
| | 7 | 29 | $ 67.10 |

System performance was satisfactory during the first 4 years of operation.

m. Coolant Discharge and Vent (9-DV)

| | Req'd no. actions | Manhours | Parts cost |
|---|---|---|---|
| 1962-63 | 1 | 7 | $ 0.00 |
| 1963-64 | 2 | 140 | 76.25 |
| 1964-65 | 4 | 51 | 62.70 |
| 1965-66 | 2 | 48 | 228.70 |
| | 9 | 246 | $ 367.65 |

From a maintenance standpoint this system is satisfactory; however, from an operational standpoint the system has proven unsatisfactory. The problem has been due primarily to the inability of the system to condense any vented steam and subsequent failure to dry the off-gases. As a result this steam has been freezing and damaging the monitors and flow equipment. A modification to install a water-cooled condenser, an improved monitor, and an improved filter has been planned to alleviate this problem. When this modification is accomplished, the operational performance of the system should improve markedly.

n. Coolant Purification System (10-CP)

| | Req'd no. actions | Manhours | Parts cost |
|---|---|---|---|
| 1962-63 | 3 | 17 | $ 0.00 |
| 1963-64 | 4 | 22 | 96.00 |
| 1964-65 | 1 | 16 | 0.00 |
| 1965-66 | 0 | 0 | 0.00 |
| | 8 | 55 | $ 96.00 |

System performance was satisfactory during the first 4 years of operation.

o. Coolant Chemical Addition (11-CA)

| | Req'd no. actions | Manhours | Parts cost |
|---|---|---|---|
| 1962-63 | 2 | 72 | $ 16.10 |
| 1963-64 | 1 | 155 | 128.42 |
| 1964-65 | 1 | 1 | 2.15 |
| 1965-66 | 0 | 0 | 0.00 |
| | 4 | 228 | $ 146.67 |

System performance was satisfactory during the first 4 years of operation.

p. Decay Heat (12-DH)

| | Req'd no. actions | Manhours | Parts cost |
|---|---|---|---|
| 1962-63 | 2 | 21 | $ 1.19 |
| 1963-64 | 1 | 6 | 3.70 |
| 1964-65 | 0 | 0 | 0.00 |
| 1965-66 | 0 | 0 | 0.00 |
| | 3 | 27 | $ 4.89 |

System performance was satisfactory during the first 4 years of operation.

q. Shield Water (13-SW)

| | Req'd no. actions | Manhours | Parts cost |
|---|---|---|---|
| 1962-63 | 6 | 67 | $ 89.00 |
| 1963-64 | 6 | 134 | 362.28 |
| 1964-65 | 7 | 89 | 34.96 |
| 1965-66 | 4 | 73 | 866.68 |
| | 23 | 363 | $ 1,352.92 |

This system has been satisfactory during the first 4 years from a maintenance standpoint. Although the original shield water cooling system was undersized for the required cooling load, the installation of a new Radioactive Waste Disposal System (RWDS) having its own cooling system should alleviate this condition.

r. Reactor Plant Heating and Cooling (14-NC)

| | Req'd no. actions | Manhours | Parts cost |
|---|---|---|---|
| 1962-63 | 1 | 7 | $ 0.00 |
| 1963-64 | 0 | 0 | 0.00 |
| 1964-65 | 0 | 0 | 0.00 |
| 1965-66 | 0 | 0 | 0.00 |
| | 1 | 7 | $ 0.00 |

The performance of this system was very satisfactory during the first 4 years of operation.

s. Fuel Cask (15-FC)

| | Req'd no. actions | Manhours | Parts cost |
|---|---|---|---|
| 1962-63 | 0 | 0 | $ 0.00 |
| 1963-64 | 0 | 0 | 0.00 |
| 1964-65 | 2 | 90 | 0.00 |
| 1965-66 | 0 | 0 | 0.00 |
| | 2 | 90 | $ 0.00 |

The performance of this system was quite satisfactory during the first 4 years of operation.

t. Radioactive Waste Disposal System (16-WD)

| | Req'd no. actions | Manhours | Parts cost |
|---|---|---|---|
| 1962-63 | 31 | 245 | $ 531.49 |
| 1963-64 | 12 | 220 | 158.15 |
| 1964-65 | 15 | 157 | 824.29 |
| 1965-66 | 6 | 112 | 534.30 |
| | 64 | 734 | $ 2,048.23 |

This system has been unsatisfactory both from a maintenance and an operational standpoint during the first 4 years. The failure of this system to meet specifications is well documented, and no further analysis is necessary. At present a skid-mounted waste disposal system has been installed and is being tested at the site by the Atomic Energy Commission. If this new system proves satisfactory, AFWL recommends that it be retained for use at the PM-1 to establish its reliability for future plant adaption.

u. Plant Container (01, 02, and 22 tks)

| | Req'd no. actions | Manhours | Parts cost |
|---|---|---|---|
| 1962-63 | 2 | 24 | $ 0.90 |
| 1963-64 | 0 | 0 | 0.00 |
| 1964-65 | 0 | 0 | 0.00 |
| 1965-66 | 2 | 32 | 380.00 |
| | 4 | 56 | $ 380.90 |

The plant container system (consisting of the three basic tanks that house the primary system, spent fuel storage, and steam-generating equipment) is rated satisfactory from the data received after 4 years of operation.

v. Main Steam System (18-MS)

| | Req'd no. actions | Manhours | Parts cost |
|---|---|---|---|
| 1962-63 | 22 | 163 | $ 62.54 |
| 1963-64 | 6 | 45 | 53.53 |
| 1964-65 | 9 | 47 | 56.00 |
| 1965-66 | 8 | 82 | 240.25 |
| | 45 | 337 | $ 412.32 |

This system has been satisfactory during the first 4 years of operation. The majority of the problems experienced were steam leaks and valve failures. There are no trends that would indicate the failure of the integrity of the system. The only problem area with regard to operation of the plant has been associated with the operating (electrical) coils on the main steam stop valves. This recurring failure, causing a number of unscheduled scrams (at least four), does point to an existing deficiency. AFWL therefore recommends that action be taken to purchase operating coils sufficiently large and well insulated to withstand the ambient temperatures and loads to which these coils are exposed.

w. Main Turbine and Generator Unit (19-TG)

| | Req'd no. actions | Manhours | Parts cost |
|---|---|---|---|
| 1962-63 | 13 | 138 | $ 34.72 |
| 1963-64 | 1 | 4 | 25.00 |
| 1964-65 | 11 | 476 | 46.86 |
| 1965-66 | 5 | 90 | 69.05 |
| | 30 | 708 | $ 175.63 |

This system, from a maintenance standpoint, has performed satisfactorily during the first 4 years of operation. However, operationally the governing and oil systems have presented some problems. The main problem has been insufficient cooling capacity in the oil coolers. When outside temperatures have exceeded 80°F, the governor and/or the TG bearings have caused numerous shut downs for maintenance and adjustments due to poor oil conditions or high bearing temperatures. A significant improvement has been the installation of an additional oil cooler. This cooler should provide adequate cooling in the hottest months, and with proper attention given to removing the suspended particles, water, and air from the oil system, the problems with the TG system should be greatly reduced.

x. Main Condenser and Condensate System (20-MC)

| | Req'd no. actions | Manhours | Parts cost |
|---|---|---|---|
| 1962-63 | 31 | 538 | $ 688.15 |
| 1963-64 | 12 | 306 | 293.96 |
| 1964-65 | 14 | 134 | 632.51 |
| 1965-66 | 17 | 400 | 362.27 |
| | 74 | 1,378 | $ 1,976.89 |

This system has been satisfactory during the first 4 years and the maintenance requirement has remained relatively constant as is shown by the data. The major problem area, which has occurred with increasing frequency, is the freezing of condenser tubes. To eliminate this problem, an intermediate condenser employing a glycol loop to the air coolers is required. This factor is noted as a consideration for future design. It is recommended that more care be exercised with the present system to prevent freezing of condenser tubes; and that an investigation be made to determine how to achieve balanced cooling for the four condensers as temperature and winds change, and to determine if there are other factors that may set up the condition that allows the tubes to freeze.

y. Feedwater System (21-FW)

| | Req'd no. actions | Manhours | Parts cost |
|---|---|---|---|
| 1962-63 | 20 | 595 | $ 3,213.16 |
| 1963-64 | 9 | 164 | 1,441.62 |
| 1964-65 | 10 | 264 | 1,333.71 |
| 1965-66 | 8 | 142 | 614.47 |
| | 47 | 1,165 | $ 6,602.96 |

The overall rating of the feedwater system is unsatisfactory, both from cost of maintenance and expended manhours. Due to excessive maintenance, an electric-driven feedwater pump was installed to replace the original steam-driven pump. The steam-driven pump had a series of failures which were probably due to deficiencies in the support structure. To allow for operation of the plant using two electric-driven pumps, an emergency gas-driven pump was installed to ensure a safe shutdown in case of an emergency. These items have improved the operation of the feedwater system, and by the end of the fourth year the system had improved sufficiently to be rated satisfactory. It is anticipated that this system will continue to require above normal maintenance since the pumps are still mounted on a skid that, through this analysis, indicates a deficiency in support structure.

z. Extraction Steam (22-ES)

| | Req'd no. actions | Manhours | Parts cost |
|---|---|---|---|
| 1962-63 | 4 | 28 | $ 14.40 |
| 1963-64 | 2 | 20 | 47.48 |
| 1964-65 | 3 | 81 | 46.12 |
| 1965-66 | 3 | 7 | 28.57 |
| | 12 | 136 | $ 136.57 |

From a maintenance standpoint, this system was satisfactory during the first 4 years of operation.

aa. Cooling Water System (23-CW)

| | Req'd no. actions | Manhours | Parts cost |
|---|---|---|---|
| 1962-63 | 1 | 1 | $ 0.00 |
| 1963-64 | 4 | 94 | 832.98 |
| 1964-65 | 0 | 0 | 0.00 |
| 1965-66 | 2 | 29 | 16.53 |
| | 7 | 124 | $ 849.51 |

System performance was satisfactory during the first 4 years of operation. The high cost of the second year was due to installation of additional equipment and enlargement of the original installation.

bb. Main Station Transformer and Distribution System (24-TD)

| | Req'd no. actions | Manhours | Parts cost |
|---|---|---|---|
| 1962-63 | 7 | 86 | $ 8.00 |
| 1963-64 | 4 | 68 | 265.36 |
| 1964-65 | 4 | 101 | 350.00 |
| 1965-66 | 1 | 2 | 427.00 |
| | 16 | 257 | $ 1,050.36 |

The station transformer and distribution system was satisfactory during the first 4 years of operation.

cc. Station Service (25-SS)

| | Req'd no. actions | Manhours | Parts cost |
|---|---|---|---|
| 1962-63 | 0 | 0 | $ 0.00 |
| 1963-64 | 1 | 14 | 5.28 |
| 1964-65 | 1 | 2 | 0.00 |
| 1965-66 | 0 | 0 | 0.00 |
| | 2 | 16 | $ 5.28 |

This system was satisfactory during the first 4 years of operation.

dd. Lighting and DC Emergency Lighting (26-LS)

| | Req'd no. actions | Manhours | Parts cost |
|---|---|---|---|
| 1962-63 | 12 | 100 | $ 210.56 |
| 1963-64 | 12 | 63 | 78.78 |
| 1964-65 | 1 | 8 | 4.50 |
| 1965-66 | 4 | 69 | 22.77 |
| | 29 | 240 | $ 316.61 |

The performance of this system is rated satisfactory, based on the first 4 years of operation. The maintenance requirements shown were primarily for additions and rearrangements of equipment to establish compatibility with the total plant. Barring future plant expansion, maintenance requirements should diminish except for regularly scheduled preventive maintenance.

ee. Vital AC and DC (27-DC)

| | Req'd no. actions | Manhours | Parts cost |
|---|---|---|---|
| 1962-63 | 3 | 16 | $ 0.00 |
| 1963-64 | 3 | 7 | 1.85 |
| 1964-65 | 4 | 32 | 3.20 |
| 1965-66 | 4 | 25 | 20.72 |
| | 14 | 80 | $ 25.77 |

From a maintenance standpoint, this system is rated satisfactory for the first 4 years of operation. However, operationally, the system has failed to meet its specifications and to operate as designed. For future consideration, the vital AC portion of any new nuclear power plants should be more rugged, not so sensitive to temperature changes, have a faster responding frequency control on the motor-generator set, and provide better voltage regulation. The DC portion of the vital AC-DC system is considered satisfactory.

ff. Emergency Power (28-EP)

| | Req'd no. actions | Manhours | Parts cost |
|---|---|---|---|
| 1962-63 | 5 | 24 | $ 0.00 |
| 1963-64 | 2 | 25 | 59.56 |
| 1964-65 | 4 | 32 | 36.57 |
| 1965-66 | 3 | 26 | 464.99 |
| | 14 | 107 | $ 561.12 |

The emergency power system is considered satisfactory except for the emergency standby diesel. The diesel is too small for a plant startup without additional power from the site diesels. Although the diesel is capable of running at overload for the time required to start up the plant, it is incapable of taking the load swings required to put the feedwater system in operation.

gg. Water Treating System (29-WT)

| | Req'd no. actions | Manhours | Parts cost |
|---|---|---|---|
| 1962-63 | 17 | 401 | $ 951.52 |
| 1963-64 | 12 | 160 | 147.80 |
| 1964-65 | 0 | 0 | 0.00 |
| 1965-66 | 2 | 25 | 113.92 |
| | 31 | 586 | $ 1,213.24 |

Because of excessive maintenance requirements, this system was unsatisfactory during the first 4 years of operation. However, an extensive remodeling and simplification of the system, accomplished during 1966, should measurably improve the system both in operation and maintenance. It is recommended that this system be reevaluated as soon as sufficient experience is gained in its present status.

hh. Condensate Makeup (30-MU)

| | Req'd no. actions | Manhours | Parts cost |
|---|---|---|---|
| 1962-63 | 11 | 89 | $ 178.81 |
| 1963-64 | 12 | 160 | 147.80 |
| 1964-65 | 9 | 125 | 5.89 |
| 1965-66 | 8 | 36 | 53.99 |
| | 40 | 410 | $ 386.49 |

From a maintenance standpoint this system has been satisfactory. However, there have been numerous operating problems during the first 4 years, especially with $CO_2$ carry-over and methods of treating the makeup water. A scrubber-preheater was installed on the evaporator in November 1966 which alleviated some of these problems. Subsequent testing in December 1966 proved satisfactory. It is believed that this new feature will improve the water makeup in addition to eliminating the problems of water treatment. AFWL recommends that an analysis be made on this system as soon as sufficient data is obtained on its operation.

ii. Fire Protection (31-FP)

| | Req'd no. actions | Manhours | Parts cost |
|---|---|---|---|
| 1962-63 | 1 | 2 | $ 0.00 |
| 1963-64 | 3 | 210 | 539.00 |
| 1964-65 | 4 | 30 | 6.50 |
| 1965-66 | 3 | 10 | 7.02 |
| | 11 | 252 | $ 552.52 |

This system has performed satisfactorily during the first 4 years of operation. The high cost for 1964 was the result of a scheduled modification to meet expansion of facilities and plant requirements.

jj. Turbine Exhaust System (32-TE)

| | Req'd no. actions | Manhours | Parts cost |
|---|---|---|---|
| 1962-63 | 0 | 0 | $ 0.00 |
| 1963-64 | 0 | 0 | 0.00 |
| 1964-65 | 1 | 2 | 0.00 |
| 1965-66 | 0 | 0 | 0.00 |
| | 1 | 2 | $ 0.00 |

The performance of this system has been satisfactory during the first 4 years of operation.

kk. Plant Heating, Air Conditioning, and Ventilating (33-HV)

| | Req'd no. actions | Manhours | Parts cost |
|---|---|---|---|
| 1962-63 | 31 | 565 | $ 1,129.16 |
| 1963-64 | 25 | 344 | 1,564.93 |
| 1964-65 | 18 | 203 | 170.57 |
| 1965-66 | 7 | 55 | 114.95 |
| | 81 | 1,167 | $ 2,979.61 |

The performance of this system was unsatisfactory during the first 4 years of operation. In addition to the manhours and cost shown above, $22,598.44 was spent under Air Force Contract No. AF 39(601)-2487, Phase I, which improved the facility and the ventilation system. Two design deficiencies have been primarily responsible for the unsatisfactory performance of this system. First, the basic housing was poorly selected for a steam plant since it allowed equipment to freeze up in the winter and overheat in summer. And second, due to the compactness of the installed equipment and the low building ceiling, there was essentially no internal circulation of air. The forced ventilation system installed under the above mentioned contract has improved the ventilation within the secondary building but has added to the already overcrowded condition. Although little can be done now to further improve the system other than learning to make the best of the existing conditions, it is highly recommended that in future plants consideration be given to providing an adequate facility of a more permanent nature.

The auxiliary boiler accounts for the highest failure rate and cost of any single item within this particular system. Its substandard performance can be attributed to a lack of ruggedness and capacity for the job required. Presently, the entire system can be rated as marginally satisfactory.

ll. Primary Building and Grounds (34-PB)

| | Req'd no. actions | Manhours | Parts cost |
|---|---|---|---|
| 1962-63 | 3 | 8 | $ 0.00 |
| 1963-64 | 6 | 191 | 65.95 |
| 1964-65 | 2 | 18 | 17.11 |
| 1965-66 | 4 | 18 | 6.58 |
| | 15 | 235 | $ 89.64 |

From a maintenance standpoint, this system was satisfactory. However, as discussed in subsection kk, the primary building design is unsatisfactory from a heating and ventilation viewpoint.

mm. Secondary Building and Grounds (35-SB)

| | Req'd no. actions | Manhours | Parts cost |
|---|---|---|---|
| 1962-63 | 1 | 3 | $ 26.40 |
| 1963-64 | 24 | 544 | 821.17 |
| 1964-65 | 8 | 331 | 147.80 |
| 1965-66 | 11 | 232 | 371.53 |
| | 44 | 1,110 | $ 1,366.90 |

This building was unsatisfactory both from excessive maintenance requirements and ventilation as discussed in subsection kk.

nn. Decontamination Building and Grounds (36-DB)

| | Req'd no. actions | Manhours | Parts cost |
|---|---|---|---|
| 1962-63 | 16 | 235 | $ 42.70 |
| 1963-64 | 9 | 112 | 156.85 |
| 1964-65 | 5 | 31 | 95.10 |
| 1965-66 | 12 | 144 | 122.44 |
| | 42 | 522 | $ 417.09 |

This system was satisfactory from a maintenance standpoint. However, the ventilation and equipment accessibility within the building was unsatisfactory. See comments in subsection kk.

oo. Maintenance Items and Tools (37-MT)

| | Req'd no. actions | Manhours | Parts cost |
|---|---|---|---|
| 1962-63 | 8 | 60 | $ 40.50 |
| 1963-64 | 14 | 104 | 74.35 |
| 1964-65 | 9 | 50 | 67.15 |
| 1965-66 | 12 | 32 | 310.18 |
| | 43 | 246 | $ 492.18 |

The maintenance requirement for this system is satisfactory.

pp. Instrument Air System (38-IA)

| | Req'd no. actions | Manhours | Parts cost |
|---|---|---|---|
| 1962-63 | 9 | 55 | $ 30.50 |
| 1963-64 | 5 | 34 | 80.61 |
| 1964-65 | 5 | 57 | 224.35 |
| 1965-66 | 4 | 63 | 174.88 |
| | 23 | 209 | $ 510.34 |

The instrument air system was generally satisfactory as shown by the data presented. However, at times the air compressors are below capacity since both compressors are required to perform certain operations. This is due to increased air demands that have been added under contracted modifications and equipment additions. This condition of the system is undesirable because if one air compressor is out for maintenance certain plant operations must be postponed until the second compressor is repaired.

qq. Miscellaneous Items (39-Misc)

| | Req'd no. actions | Manhours | Parts cost |
|---|---|---|---|
| 1962-63 | 28 | 1,276 | $ 68.90 |
| 1963-64 | 2 | 449 | 0.00 |
| 1964-65 | 1 | 2 | 1.74 |
| 1965-66 | 6 | 18 | 63.75 |
| | 37 | 1,745 | $ 134.39 |

Certain jobs, such as reviewing specifications for plants, up-dating as-built prints, and maintenance on items that do not fit into the regular plant systems and yet require maintenance assistance fit into this category and do not require evaluation. This is only an accounting item used to identify expended manhours associated with the maintenance section.

## 4. PLANT MODIFICATIONS

A summary of plant modifications is listed in table VIII. The relative effectiveness is rated either satisfactory or unsatisfactory--where satisfactory indicates the system has proven adequate through operational experience. Systems showing deficiencies which require further explanations are listed below. Major modifications that are being implemented or planned for the near future are rupture disks for the pressurizer relief valves, off-gas monitor, and split-coil cans for rod actuator control (now in progress). For complete information on these particular items, it is recommended that the PM-1 project office at Nuclear Power Field Office (NPFO) be contacted.

a. Nuclear Instrumentation

The nuclear detector modification providing sealed cans for the nuclear detectors and cables exposed to high radiation field near the reactor core has proven marginally satisfactory. At present, dry wells are being

Table VIII

PLANT MODIFICATIONS
(For period 1 November 1962 to 31 March 1967)

| System | Modification description | Parts costs | Manhours | Effectiveness |
|---|---|---|---|---|
| 1-PIP | Pressurizer heater cutoff. Rewired to operate on either level control switch. To prevent shutdown if one switch failed. | $ 0.00 | 2 | Satisfactory |
| 1-PIS | Control actuators to main condenser butterfly valves. Reinforced aluminum mountings which were being deformed under operating pressure and preventing full control of the butterfly valve. | 0.00 | 80 | Satisfactory |
| 1-PIS | Wind velocity indicator--mounted on console. | 0.00 | 10 | Satisfactory |
| 1-PIS | MS24-TF2, flow transmitter D/P cell; relocated for ease of maintenance. | 0.00 | 10 | Satisfactory |
| 1-PIS | FW06-TF, flow transmitter D/P cell; relocated for ease of maintenance. | 0.00 | 12 | Satisfactory |
| 1-PIS | MC06-TL1, flow transmitter D/P cell; relocated to prevent clogging; ease of maintenance. | 0.00 | 8 | Satisfactory |
| 1-PIF | Water sampling cabinet. Repiped so inline instrumentation would operate properly; installed modified sample cooler. | 0.00 | 280 | Satisfactory |
| 1-PIC | Intercom for PM-1. Installed 4 new speakers; adjusted to obtain maximum effectiveness. | 122.90 | 35 | Satisfactory |
| 1-PIC | Sound powered phone and door interlock installed for admittance to plant via radar site walkway. | 6.50 | 10 | Satisfactory |
| 1-PIC | Speaker (PIC 24-Sp) installed in office and lunch area. | 84.61 | 6 | Satisfactory |

Table VIII (cont'd)

| System | Modification description | Parts costs | Manhours | Effectiveness |
|---|---|---|---|---|
| 1-PIA | Sequential analyzer (PIA 04-AN) installed for analyzing first out annunciation at scram. | $ 900.00 | 14 | Satisfactory |
| 2-NI | Nuclear detectors; fabricated aluminum cans for protecting cables and detectors against radiation damage. | 151.00 | 283 | Unsatisfactory |
| 2-RR | Thimble corrosion; corrosion and pitting between thimble and actuator can; honed inside of can, outside of 403 SS section of thimbles to remove corrosion; thereby increased clearance between can and thimble; 4 "V" slots cut in flared ID section of coil 90° apart to increase circulation; replaced damaged parts. | 25,040.17 | 630 | Unsatisfactory |
| 2-RR | Control rod drive indicator; elongated slot cut in slider contact rail to prevent bowing from heat; required opening each can and seal welding. | 0.00 | 90 | Unsatisfactory |
| 3-RR | Magnetic jacks (RR 01-MJ); 403 SS section replaced with nickel-plated section. | 97.66 | 96 | Satisfactory |
| 4-RS | Reactor safety system--fail-safe modifications | 16.50 | 24 | Satisfactory |
| 5-RM | Off-gas monitor; relocated to lower radiation field to reduce background radiation levels and to allow installation of new building. | 35.44 | 24 | Satisfactory |
| 6-RC | Installed temperature compensated overload protection for primary coolant pump. | 32.40 | 15 | Satisfactory |
| 7-PR | Pressurizer heaters; reconnect 3 heaters from bank C to bank A to improve heater control. | 0.00 | 8 | Satisfactory |

Table VIII (cont'd)

| System | Modification description | Parts costs | Manhours | Effectiveness |
|---|---|---|---|---|
| 8-CC | None | | | |
| 9-DV | Primary coolant discharge recirculating system to contain tritiated water for reuse in primary loop. | $ Unknown | Unknown | Satisfactory |
| 9-DV | Off-gas vent condenser; fabricated, installed in expansion tank vent to eliminate moisture in off gas. | 154.45 | 33 | Unsatisfactory |
| 10-CP | None | | | |
| 11-CA | Hydrogen addition system; added 1500-pound test tank into primary makeup line to allow feed of hydrogen to primary loop safely. | 0.00 | 56 | Satisfactory |
| 11-CA | Primary sample sink for $H_2$ and $O_2$ analysis. | 128.42 | 155 | Satisfactory |
| 12-DH | None | | | |
| 13-SW | None | | | |
| 14-HC | None | | | |
| 15-FC | None | | | |
| 16-WD | Waste disposal condensate; installed sample line to allow continued flow while sampling. | 0.00 | 2 | Satisfactory |
| 16-WD | Waste disposal steam line; installed root valve for maintenance while at power. | 30.00 | 12 | Satisfactory |
| 16-WD | Flowmeter installed in condensate line for test and monitor operation. | 250.00 | 51 | Satisfactory |
| 16-WD | Waste disposal condensate; installed additional valve on condensate discharge line to prevent discharge of radioactive water to sewer. | 10.50 | 2 | Satisfactory |

Table VIII (cont'd)

| System | Modification description | Parts costs | Manhours | Effectiveness |
|---|---|---|---|---|
| 16-WD | RWDS steam line; replaced leaky flange with socket-weld valve. | $ 48.00 | 16 | Satisfactory |
| 16-WD | Steam condensate line to DA tank. | 19.93 | 16 | Unsatisfactory |
| 16-WD | Waste disposal entrance shed removed to facilitate new building installations. | 0.00 | 6 | Satisfactory |
| 16-WD | In-line filter fabricated and installed from RWDS sump tank to evaporator. | 87.32 | 53 | Unknown |
| 16-WD | Drain lines installed in new RWDS building. | 436.23 | 48 | Satisfactory |
| 16-WD | Installed new RWDS skid built by AMF for testing at PM-1. | 0.00 | 0 | Unknown |
| 17-PC | None | | | |
| 18-MS | Main steam lines to turbine-driven pumps; turbine pumps removed under modification; lines moved; no longer needed. | 0.00 | Credit to another system | Satisfactory |
| 18-MS | Steam generator blowdown line repiped beneath primary floor to prevent freezing or physical damage to line. | 0.00 | 2 | Satisfactory |
| 19-TG | Turbine control; eliminated air from governor control; vented servo-motor pilot relay and cavity for servo-motor piston; baffle screens added to reduction gear housing; orifice vent installed in high-pressure oil line; accumulator added to control line; suction, discharge lines to oil conditioner reversed. | Contract | Unknown | Satisfactory |
| 19-TG | Main generator tachometer; installed meter on control console. | 403.00 | 39 | Satisfactory |

Table VIII (cont'd)

| System | Modification description | Parts costs | Manhours | Effectiveness |
|---|---|---|---|---|
| 20-MC | Condenser freeze protection; installed heater on air ejector line. | $ 0.00 | 12 | Satisfactory |
| 20-MC | Condenser condensate headers; installed drain lines. | 28.75 | 32 | Satisfactory |
| 20-MC | Condensate pump PP2; replaced turbine with electric motor. | 318.54 | 77 | Satisfactory |
| 20-MC | Installed mercoid switch for auto-control of motor-driven condensate pump. | 75.00 | 12 | Satisfactory |
| 20-MC | Condenser freeze protection; condenser air offtake section. | 197.87 | 232 | Satisfactory |
| 20-MC | Changed signal tubing to D/P cell for MC06-TL2; relocated valve MC06-VL22 between sample line, condensate storage tank. | 4.12 | 7 | Satisfactory |
| 20-MC | Added drain valve to condensate storage tank. | 0.00 | 4 | Satisfactory |
| 21-FW | FW pump PP2; replaced turbine driver with electric motor. | 1,476.33 | 218 | Satisfactory |
| 21-FW | Mercoid switch, auto control; installed switch to automatically realign motor on low pressure. | 150.00 | 12 | Satisfactory |
| 21-FW | Portable feedpump; installed gas-driven feedpump for safety in shutdown (DNS requirement). | 1,359.24 | 24 | Satisfactory |
| 22-ES | ES06-VFC1; deaerator dump valve; relocated for ease of maintenance. | 13.58 | 64 | Satisfactory |
| 23-CW | Cooling water recirculation system | 664.35 | 70 | Satisfactory |
| 24-TD | Main generator breaker; added time totalizer | 0.00 | 2 | Satisfactory |
| 25-SS | None | | | |

Table VIII (cont'd)

| System | Modification description | Parts costs | Manhours | Effectiveness |
|---|---|---|---|---|
| 26-LS | Outside light; installed weather-proof light outside decontamination package, at air blast cooler | $ 6.39 | 24 | Satisfactory |
| 26-LS | Exit light installed at "inclement weather" entryway. | 38.52 | 18 | Satisfactory |
| 26-LS | 10 kva transformer installed; installed lighting panel to provide additional lighting circuits. | 157.00 | 16 | Satisfactory |
| 26-LS | Lighting fixtures for decontamination annex. | 30.80 | 10 | Satisfactory |
| 26-LS | Spare exit-light fixture moved from decontamination building to condenser exit. | 0.00 | 12 | Satisfactory |
| 26-LS | Lighting panel (LS05-LP); transferred circuits from 1B to 1C panel; installed spare cable to instrument shop. | 0.00 | 28 | Satisfactory |
| 27-DC | Vital AC cabinet; installed cooling fans. | 56.37 | 57 | Unsatisfactory |
| 28-EP | Diesel generator set; installed electric heater to engine cooling system. | 30.00 | 6 | Satisfactory |
| 28-EP | Diesel exhaust louvers. | 55.54 | 10 | Satisfactory |
| 29-WT | Inline sample cabinet; modified entire sampling system. | 708.24 | 200 | Satisfactory |
| 29-WT | Chemical addition; replaced 3-way flushing valve with 2 solenoid valves; modification designed to prevent dilution of tank during flushing cycles. | 44.00 | 12 | Satisfactory |
| 29-WT | Water softener; installed deionizer to provide high quality make-up water. | 410.00 | 96 | Satisfactory |
| 29-WT | Phosphate feed selector switch | 0.45 | 4 | Satisfactory |

Table VIII (cont'd)

| System | Modification description | Parts costs | Manhours | Effectiveness |
|---|---|---|---|---|
| 29-WT | Water treatment system; deleted regular feeding of sulfite to allow extraneous feed controls to be replaced by simple manual controls and simplified piping; repiped for 1 sulfite and 2 phosphate tanks. | $ 113.92 | 25 | Satisfactory |
| 29-WT | Modified sample cabinet, in-line process control instrumentation. | 0.00 | 80 | Unsatisfactory |
| 30-MU | Installed condensate transfer pump between storage tank and auxiliary hotwell. | 151.15 | 34 | Satisfactory |
| 30-MU | Deionizer; raw water filter installed. | 82.08 | 5 | Satisfactory |
| 30-MU | Trap station beneath evaporator relocated for ease of maintenance. | 0.00 | 86 | Satisfactory |
| 30-MU | Evaporator level D/P cell; relocated for ease of maintenance. | 0.00 | 13 | Satisfactory |
| 31-FP | Air evacuation horn installed; air tank provided; accessories provided by PM-1. | 64.81 | 119 | Satisfactory |
| 31-FP | Evacuation horn air tank; tie into instrument air system so rechargeable from PM-1 air supply. | 10.65 | 7 | Satisfactory |
| 31-FP | Emergency alarm (klaxon horn) supplied; installed (PM-1 supply for accessories); installed emergency power supply to klaxon horn. | 27.27 | 40 | Satisfactory |
| 31-FP | PM-1 interalarm system; add alarm station in RWDS tank housing, at doorway to secondary building, near air blast cooler, at top of RWDS tank. | 60.00 | 38 | Satisfactory |

Table VIII (cont'd)

| System | Modification description | Parts costs | Manhours | Effectiveness |
|---|---|---|---|---|
| 31-FP | Disaster control alarm provided for entire site. | $ 520.00 | 196 | Satisfactory |
| 31-FP | Push-button station for alarm system at RWDS tank. | 19.00 | 12 | Satisfactory |
| 32-TG | None | | | |
| 33-HV | Heaters in primary building; installed additional heating units below primary floor; relocated heaters to provide maximum heat utilization. | 288.00 | 152 | Satisfactory |
| 33-HV | Auxiliary boiler hotwell; enlarged with 55-gallon drum to provide surge capacity. | 10.00 | 16 | Unsatisfactory |
| 33-HV | Heating condensate return; installed flowmeter to measure condensate return from site for calculating heating steam requirement. | 168.86 | 10 | Satisfactory |
| 33-HV | Auxilary boiler hotwell enlarged. | 146.25 | 249 | Satisfactory |
| 34-PB | Emergency push-button station for primary building connected to emergency light power. | 1.13 | 4 | Satisfactory |
| 34-PB | Installed "Reactor On" sign at entrance to primary building (safety requirement). | 17.11 | 8 | Satisfactory |
| 34-PB | Primary entrance control lock and "Power On" sign moved to new entrance. | 0.14 | 22.5 | Satisfactory |
| 35-SB | Constructed tool cabinet. | Supplied by Civil Engineering | 63 | Satisfactory |
| 35-SB | Instrument shop (SB04-SUS) enlarged; isolated from control room. | 311.39 | 133.5 | Satisfactory |
| 35-SB | Eye washer moved from latrine; installed in decon building for safety reasons. | 5.52 | 12 | Satisfactory |

Table VIII (cont'd)

| System | Modification description | Parts costs | Manhours | Effectiveness |
|---|---|---|---|---|
| 36-SB | Moved decontamination shower to decontamination annex to allow passage for stretcher cases through decon building. | 19.60 | 97 | Satisfactory |
| 36-DB | Tritium sampler installed for analyzing airborne levels of tritium in plant complex. | $ 10.72 | 15 | Satisfactory |
| 36-DB | Decon annex (DB03-SUS) modified, rewired for health physics lab; moved shower to new RWDS building; wired for 115 volts AC; latrine fixtures removed to provide counting area. | 91.09 | 115 | Satisfactory |
| 37-M1 | Source well for instrument calibration. | 10.55 | 28 | Satisfactory |
| Phase I | Contract AF 39(601)-2487 | 22,589.44 | 165 | Unsatisfactory |
| Phase II | Contract AF 39(601)-2599 (construction) | 98,000.00 | | |
| | PM-1 assistance to contract | 103.23 | 278 | Satisfactory |

installed to see if further improvements can be made in the life of detector cable and connectors in the vicinity of the reactor. AFWL recommends that this modification be fully tested and, if satisfactory, that a remodification be made to provide dry wells for all nuclear detectors and cables.

b. Rod Drive System

The thimble corrosion problem has gone through a number of developmental stages to attain the present system condition. The first attempt (increasing circulation with "V" slats) did not measurably decrease the corrosion rate. Later, the addition of dry hole adapters (using forced air between the can and thimble) proved insufficient because the moisture content of the air could not be controlled. A final solution was the installation of nickel-plated 403 SS sections provided by the Nuclear Power Field Office, Fort Belvoir, Virginia. At present this system is operating satisfactorily.

The control rod drive indicator problem has been somewhat improved by the elongated slot. However, due to the high failure rate a new modification which separates the coil drive and the indicator sections is being completed by SAAMA. At present, one of these modified "split-can" coil cans is installed at the PM-1 and is operating satisfactorily.

c. Off-Gas Monitor

The original off-gas monitoring system is being replaced by a new approved system that employs water cooling of the effluent, a constant flow pump to regulate the off-gas flow, and an improved monitoring system which will ensure more accurate reading of the off-gas activity.

d. Waste Disposal System

A new skid-mounted waste disposal system is being tested at the PM-1. If this system proves satisfactory, AFWL recommends the Air Force utilize it and salvage the components from the old waste disposal system.

e. Vital AC-DC System

The vital AC system continues to present an operational problem during hot weather. The installation of fans has improved the operation of the controls, but there are still evidences of dead spots in the air circulation patterns.

## SECTION IV

## PERSONNEL AND TRAINING

### 1. PERSONNEL

On 31 March 1967 the PM-1 was manned by two officers and 37 enlisted men. The enlisted personnel included four from the Navy and seven from the Army. In addition, a nuclear safety officer is assigned to the squadron.

Keeping the plant manned by qualified technicians has been a continual problem at the PM-1. The Air Force lost six qualified operators during the report period through transfers, and had a gain of three reactor technicians (002X0's). The new arrivals were immediately placed in training status; however, a minimum of 3 months is required before they are considered productive, plus an additional 3 months before they are fully qualified.

The Army and Navy technicians have remained relatively constant even though the Navy personnel remain for a shorter time period. Navy technicians are used for manning crews on the Navy's sister plant, PM-3A, at McMurdo Sound, Antarctica, and are assigned primarily to receive training provided at the PM-1.

Table IX presents a breakdown of enlisted losses and gains for all three services from 1 November 1966 to 31 March 1967.

During the 8-month period from 1 November 1966, the Plant Superintendent, Operations Chief, Maintenance Chief, and Health Physics Chief had been transferred. Although there were sufficient qualified personnel to replace them at the PM-1 by elevating men to these higher positions, the middle line of supervision has suffered.

### 2. TRAINING

Training in most part has remained of high quality. However, a tendency to expedite training to meet requirements caused by unplanned losses still presents problems at the PM-1. As noted in the previous paragraph, there were 12 new Air Force personnel plus additional arrivals of Army and Navy personnel who will require immediate training. Training becomes a major factor in maintaining qualified operators and maintenance personnel. During the 5-month

Table IX

ENLISTED PERSONNEL, GAINS AND LOSSES

| | Air Force | | | | Navy | | | | Army | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Specialty | 1 Nov 66 | Gain | Loss | 31 Mar 67 | 1 Nov 66 | Gain | Loss | 31 Mar 67 | 1 Nov 66 | Gain | Loss | 31 Mar 67 |
| Electrical | 7 | 1 | 2 | 6 | 3 | 0 | 0 | 3 | 1 | 0 | 0 | 1 |
| Mechanical | 8 | 1 | 2 | 7 | 1 | 0 | 0 | 1 | 1 | 0 | 0 | 1 |
| Instrumentation | 6 | 1 | 2 | 5 | 2 | 0 | 0 | 2 | 1 | 1 | 1 | 1 |
| Process control | 7 | 0 | 0 | 7 | 1 | 0 | 0 | 1 | 1 | 0 | 0 | 1 |
| Administration and supply | 2 | 0 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Totals | 30 | 3 | 7 | 26 | 7 | 0 | 0 | 7 | 4 | 1 | 1 | 4 |

period of this report, a total of 2,044 manhours were expended for training purposes at a cost of $8,246. These figures include only that time spent in training and upgrading new personnel. They do not include the administration time spend in upgrading and supervision of these trainees.

A practical solution for manning and training would be to provide replacements on a quarterly basis, i.e., have two technicians assigned to the PM-1 at intervals of 3 months. Then, as these become qualified, allow the transfer of the most eligible on a voluntary basis, keeping in mind the needs of the PM-1. The past forecast and bulk deployment method has created tremendous gaps in qualified personnel at each changeover. In addition, many other unpredicted losses have added to the plight.

The question of safety versus training requirements for field plant operation has come up from time to time. Certain aspects of this problem (regarding inspections) place excess pressure on the operationg group by forcing the crew into long hours of training while trying to keep abreast of plant operations and maintenance. AFWL recommends that this demonstration of skill be handled either by (1) DNS inspection being conducted at the training facility at Fort Belvoir, Virginia, for Air Force personnel prior to their transfer to Sundance AFS, or (2) by allowing the PM-1 to have a training period when the plant is shutdown for approximately 1 week prior to DNS inspection.

The first suggestion is the most practical since Fort Belvoir is geared to an academic situation; whereas, the PM-1 is designed as a field plant. A field plant, after operating 6 months, needs certain adjustments and recalibration before returning to an extended power run. By attempting to combine this maintenance requirement with certification, the crew is pressed into overtime, and pressures are created that might prove unsafe. It is therefore recommended that demonstrations of bringing the reactor critical, plant startups, nuclear capability and understanding, and the ability to operate under simulated adverse conditions be done at the training site. A final DNS certification as to plant knowledge, safety, and operating ability should be ascertained by oral interviews and written tests to be made after operating personnel have been plant certified by the operating group. If the PM-1 is to improve its performance, some changes must be made to decrease problems in the assignment and training area.

# SECTION V

# MAINTENANCE AND SUPPLY

The maintenance requirement over the past 4 years has been excessive due to the number of modifications required, poorly designed equipment, and the improper selection of equipment for the jobs required. Another problem that has seriously hindered the progress of maintenance has been the lack of a clear-cut policy or understanding as to the function of maintenance and definition of maintenance to be performed at the PM-1. Finally, the type of maintenance required on certain equipment had to be gained through experience since data on these items was lacking.

Generally speaking, each of these areas has been brought into perspective by the operating crew through research and organization. And as each of these areas was explored, a clear-cut maintenance program has evolved, which has brought the maintenance within the standards of Civil Engineering.

As discussed in the previous section under Systems, most of the recommended modifications are being completed and thus, no future problem with modifications is anticipated that would become an excessive burden to maintenance. There are still some problems in proper selection of equipment, such as fans, transformers, temperature-effected solenoids (steam trip valve), and electrical control (vital AC). However, as each of these is corrected, maintenance requirements are being improved.

Another problem area has been in the assignment of maintenance technicians. Since operations are usually given precedence over maintenance requirements, there has been an unhealthy tendency on the part of PM-1 supervisory personnel to neglect these maintenance requirements and assign technicians to operations, rather than maintenance. AFWL recommends that this practice be corrected and that technicians be assigned strictly to maintenance after going through a minimum training program to equipment operator. By doing this, required maintenance could be performed on a scheduled basis instead of by the present haphazard method. In addition, only the most experienced enlisted members should be fully qualified as operators and technicians--these being assigned to shift supervisor and above positions. All other personnel should be assigned to either operations or maintenance, but be capable of performing in either function under proper supervision of the first line supervisors. At present, the maintenance functions are well defined in ADCM 400-3, current PM-1 SOPs, and scheduling of periodic, corrective, and modifying maintenance is in accordance with Air Force civil engineering regulations. Therefore, no problem should exist as to the responsibility for the maintenance program. The only problem is in implementing these procedures and regulations.

One last point still in question is the maintenance required on new items. The new control rod thimbles, split coil cans, waste-disposal system, and off-gas monitoring system have not been in operation long enough to determine the frequency of maintenance required. However, as experience is gained on these modifications, a maintenance program should unfold as it has with previous equipment at the PM-1.

Manning requirements for maintenance are shown in table X for 4 years of operation. The final period from 1 November 1966 to 30 June 1967 reflects a better estimate of maintenance requirement since there were no major modifications being made during this period. The increased manhours of 1965 and 1966 can be directly related to modifications or equipment relocations. Although ADCM 400-3 shows only a total of six personnel in maintenance and process control, overmanning (including Army and Navy personnel) figures into these hours requiring more man years to be expended than authorized. This manpower requirement is realistic since it reflects both supervisory and technician level requirements, and takes into account leave time, holidays, sickness, and additional duties. Additional manpower is required for training requirements in upgrading 3- and 5-level maintenance personnel. Since each individual assigned to the PM-1 is a qualified technician in one of the specialties--electrical, mechanical, instrument or process control--the training requirement does not present a great problem, provided the maintenance technician remains in this one maintenance section the entire length of his tour. However, if the maintenance section receives a high turnover rate of personnel, then training does present a significant problem to manning.

Table X

RECOMMENDED MANNING LEVELS (Maintenance)

| Maintenance specialty | Period 1964 Man years | 1965 Man years | 1966 Man years | 1967* Man years |
|---|---|---|---|---|
| Electrical | 1.5 | 1.5 | 1.5 | 1.5 |
| Mechanical | 2.5 | 2.5 | 3.5 | 2.0 |
| Instrumentation | 1.5 | 2.0 | 2.5 | 1.5 |
| Process control | 3.5 | 3.5 | 3.5 | 3.5 |
| Totals | 9.0 | 10.0 | 11.0 | 8.5 |

*These figures are based on 8 months of data extrapolated to approximate a year.

A minimum of three operations personnel are required per shift: one shift supervisor, one control room operator, and one equipment operator. In general, these are qualified to one step above their assigned position so that a backup is maintained at all times. Likewise, the maintenance technician has a minimum qualification of equipment operator to back up the assigned shift equipment operator. For a four-shift operation, the minimum number of operators is 12. An operations chief brings the total assigned in operations to 13. To account for leave, squadron duty, training, etc., an additional three men must be added to make a detail of 16 assigned to operations, which agrees with ADCM 400-3.

This gives a total requirement for operations, maintenance, and process control of 25 personnel compared to ADCM 400-3s manning of 23. This difference in manning is only slight and through proper management and better use of personnel, compatibility could be achieved. First, during shutdown periods, the crew on cold iron watch can be reduced to just a shift supervisor and control room operator since all functional requirements are reduced. Other shift personnel can then be used in performance of preventive and corrective maintenance. Second, by improved scheduling, preventive maintenance and minor corrective measures can be performed by the operating crew and trainees during regular operating shifts. By accomplishing an average of 4 hours of maintenance a shift, the PM-1 could more than make up the deficit between its present manning and the ADCM 400-3 requirements. Also, special assignments, such as manual revision, manual writings, supply, clerical work, full-time safety NCO, civil engineer, etc. (which have pulled men from the PM-1 crew in the past), should be eliminated. Manning at the squadron level is presently authorized to perform these functions, and the use of highly trained technicians for these tasks should not be tolerated. Only when the mission of the site is in jeopardy should this policy be deviated from.

Because of overmanning, excessive outside assignments, and the additional training imposed on the PM-1 crew, a realistic manning requirement is hard to define. If these external requirements were minimized, the manning levels reported in ADCM 400-3 would be close to those required. In remote areas (such as the Arctic or Antarctic), after initial checkout has been accomplished, further reductions in manning could be made. For example, leave time would be eliminated along with many of the additional duties that are part of a larger military operation.

## SECTION VI

## SAFETY

The PM-1 is now in its fifth year of safe operation, which testifies to the inherently safe design of the reactor as well as the effectiveness of the continuing safety program. Since the Air Force take-over of the PM-1, AFWL has kept close cognizance of the PM-1 safety program. Although AFWL has not maintained a formal safety inspection status, it has maintained a close watch of reports emanating from the PM-1 and other agencies that have formal inspection responsibility. Considering the information obtained from these reports, plus personal contact at the field plant, it can be stated that the PM-1 type of nuclear power plant is safe. There are many potential hazards associated with plants like the PM-1 (e.g., radiation release, electrical, steam, or moving equipment accidents), and unless the crew maintains a high state of readiness and training, any of these could become disastrous.

It is recommended that present administrative control be retained at the PM-1, and that research continue in the field of nuclear instrumentation to minimize the amount of safety devices required to give maximum safety. Administrative control is primarily vested in the operating agency, Air Defense Command (ADC), and its subordinate units, 10 Air Force and 731 Radar Squadron. The plant nuclear safety program is under the direction of a nuclear safety officer who reports directly to the station commander. Under routine inspections, the nuclear safety officer ensures that safe procedures are maintained and that on-the-spot corrections to potential problems are made. A Nuclear Safety Committee, which is made up of Sundance AFS personnel, provides a first line review of prodecural, personnel, or design changes to provide maximum control of in-house policies regarding both nuclear and industrial safety.

A nuclear safety council at Hq ADC also reviews safety matters pertaining to the PM-1. The Directorate of Nuclear Safety (DNS), headquartered at Kirtland AFB, also conducts safety surveys of PM-1 operations and equipment changes. In addition to keeping a watch on procedures, the DNS inspection checks the qualifications of individual operators on nuclear and plant knowledge. Since the PM-1 is an operating field plant, it does not lend itself to frequent startups and does not have the flexibility of a test or training reactor. At present, the DNS policy of certifying new operators is to require them to demonstrate their knowledge and nuclear ability by plant startups, shutdowns, etc. This type of testing is not in keeping with the initial requirements placed on nuclear power plants by the Air Force, and poses a question as to the reliability of the training provided by the Nuclear Power Field Office (NPFO) at Fort Belvoir, Virginia.

# SECTION VII

# COST ANALYSIS

## 1. SUMMARY OF COSTS

PM-1 original investment costs, as well as subsequent yearly operating costs, have been tabulated and are presented below. Figures were obtained from previous AFWL Annual Summary Reports and PM-1 Monthly Summary Reports.

a. Original investment through 31 October 1962

| | |
|---|---|
| (1) Est cost, Contract AT (30-1)-2345 | $ 5,387,450 |
| (2) Final cost, Contract AT (30-1)-2345 | 10,252,750 |
| (3) Military labor | 178,500 |
| (4) Fuel cycle costs | 25,400 |
| (5) Total | $10,456,650 |

b. Operating cost, 1 November 1962 to 31 October 1963

| | |
|---|---|
| (1) Material | $ 43,986 |
| (2) Labor | 143,604 |
| (3) Nuclear fuel | 90,500 |
| (4) Support contracts | 121,371 |
| (5) Total | $ 399,461 |

c. Operating cost, 1 November 1963 to 31 October 1964

| | |
|---|---|
| (1) Material | $ 21,494 |
| (2) Labor | 125,424 |
| (3) Nuclear fuel | 89,300 |
| (4) Support contracts | 40,214 |
| (5) Total | $ 276,432 |

d. Operating cost, 1 November 1964 to 31 October 1965

| | |
|---|---|
| (1) Material | $ 15,878 |
| (2) Labor | 157,264 |
| (3) Nuclear fuel | 149,600 |
| (4) Support contracts | 17,650 |
| (5) Total | $ 340,392 |

e. Operating cost, 1 November 1965 to 31 October 1966

| | | | |
|---|---|---|---|
| (1) | Material | $ | 17,761 |
| (2) | Labor | | 163,210 |
| (3) | Nuclear fuel | | |
| | Core I | | 124,758 |
| | Core II | | 34,540 |
| (4) | Support contracts | | 27,503 |
| (5) | Total | $ | 367,772 |

f. Operating cost, 1 November 1966 to 31 March 1967

| | | | |
|---|---|---|---|
| (1) | Material | $ | 1,412 |
| (2) | Labor (including modification) | | 79,316 |
| (3) | Nuclear fuel | | |
| | Core amortization | | 53,010 |
| | Fuel process | | 16,716 |
| (4) | Support contracts | | 3,900 |
| (5) | Total | $ | 154,354 |

g. Aggregate total, 1 November 1962 to 31 March 1967 (53 months)

| | | | |
|---|---|---|---|
| (1) | Material | $ | 100,531 |
| (2) | Labor | | 668,818 |
| (3) | Fuel | | 558,424 |
| (4) | Support contracts | | 210,638 |
| (5) | Total | $ | 1,538,411 |

h. Additional capital investment, Contract AF 39(601)-2487, Phase II — $ 98,000

i. Total investment and operational costs for PM-1 through 31 March 1967 — $ 12,093,061

2. BASIS FOR EVALUATION

The following definitions of each cost item were used in this evaluation for determining operating costs.

a. Material

Material includes all spare parts and expendable supplies used with in-house maintenance. Administrative and utilities supplies furnished through squadron supply are not reported.

b. Labor

Labor charges are based on the current Civil Engineering standard man-hour costs as outlined in AFM 177-101. These figures are obtained from the PM-1 Monthly Summary Report, published by 10 Air Force, Richard-Gebaur AFB, Missouri. Training, squadron duties, leaves, etc., are not included as part of this cost.

c. Nuclear Fuel

Fuel cycling costs are based on the original core fabrication cost plus fuel recovery costs for the spent core. Core I costs were based on 16.6 megawatt years (MWY) life with a total cost of $479,558.

Core II cycling costs are based on a fuel process charge of $12 per gram of fuel consumed plus amortization of the fabrication cost of $450,000 over a 24-MWY life.

3. DISCUSSION

During the period of 1 November 1966 to 31 March 1967, a total of 2,091,300 kw-hr(e) of energy was supplied to the site. This includes 349,000 kw-hr (electrical equivalent) of heating steam. Excluding plant capital investment costs, an operating cost of $154,354 was required, giving a unit cost of $0.0767/kw-hr (net electrical). The operating cost of Core II is somewhat lower than that for Core I since fabrication costs are significantly lower per MWY design output life.

During the 4 years and 5 months the Air Force has operated the PM-1 plant, a total net energy of 16,434,700 kw-hr has been produced at an operating cost of $1,538,411 (for a unit energy cost of $0.0936/kw-hr). Based on net electrical energy output only, this unit cost increases to $0.1191/kw-hr. These costs do not include any plant depreciation or capitol investment charges. Since the original cost of the PM-1 included many R&D charges, it is practically impossible to determine a true plant cost, and thus, this has been omitted.

Factors that have resulted in this high cost of power production are numerous; however, many of these costs could be reduced or brought into a realistic value by equating a plant such as the PM-1 to a compatible mission. The problems such as overmanning, excessive modification requirement, training requirement due to the policy of giving maximum training to the majority of the crew members, loss of personnel by premature transfers, operating the plant below capacity, and excessive down time (especially during the first 2 years of operation for design improvement) have all added up to present a dim economical picture of nuclear power production.

Stationary field nuclear-steam plants could evolve from the present portable concept of the PM-1 to become a prime source of military power by employing a series of identical plants in the range of 1500 to 2000 kw net load, by optimizing crew sizes and tenure, and by eliminating training requirements. However, for portable plants of 1000 kw net and below, steam-nuclear plants as presently exist, do not readily adapt to military requirements due to their complexity and large manning requirements.

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| 11. SUPPLEMENTARY NOTES | 12. SPONSORING MILITARY ACTIVITY |
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13. ABSTRACT

(Distribution Limitation Statement No. 2)

This report evaluates the operation of the PM-1 nuclear power plant during the period from 1 November 1962 to 31 March 1967. The data in this report were extracted from the PM-1 Monthly Summary Reports, work orders, plant daily logs, chemistry logs, supply requests, and malfunction reports supplied by the 731 Radar Squadron, Sundance Air Force Station, Wyoming, and the 10 Air Force, Richards-Gebaur Air Force Base, Missouri. Plant administration, operations, process control, maintenance, and supply are analyzed and evaluated. Recommendations are made with the objective of cost reduction and improved plant availability. Supporting data for all recommendations are included in the text.

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| PM-1 cost analysis | | | | | | |
| PM-1 performance | | | | | | |