EVALUATION OF MAINTENANCE MANAGEMENT SYSTEM AT LOWER POTOMAC WASTEWATER TREATMENT PLANT

FAIRFAX COUNTY
VIRGINIA

by

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DISCLAIMER

FOREWORD

ABSTRACT

The Planned Maintenance Management System (PMMS) installed at Lower Potomac Wastewater Treatment Plant of Fairfax County, Virginia was evaluated.

Descriptions are presented of the original manual system and the current computerized version. Although the current system is computerized, senior personnel are still required to make key decisions if the system is to work. The system, to work effectively, requires the cooperation and participation of all plant personnel.

The system is easy to use and only one person is required to code data for computer interface. The system can be enlarged to accommodate plant expansion, other plants within the County's jurisdiction, other utilities and other facilities.

The data collected are enumerated and the benefits of the PMMS are described. Data are analyzed to demonstrate some of the benefits of the system. Valuable data could be supplied to designers, equipment manufacturers, and purchasing agents.

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EXECUTIVE SUMMARY

A planned maintenance management system is one that makes use of a systematic approach to preventive and corrective maintenance. The system reduces the maintenance of a large number of equipment items, many of which are complex, to a set of explicit, simple tasks that can be easily scheduled, managed, performed and recorded. In addition, recordkeeping and feedback features provide for complete accounting of maintenance labor, material and contractor costs for management use in cost control and budget preparation. The Planned Maintenance Management System (PMMS) installed at the Lower Potomac Wastewater Treatment Plant, Fairfax County, Virginia is such a system.

Descriptions are presented of the original manual system and the current computerized version. Although the current system is computerized, senior personnel are still required to make key decisions if the system is to work. The system, to work effectively, requires the cooperation and participation of all plant personnel.

The system is easy to use and only one person is required to code data for computer interface. The system can be enlarged to accommodate plant expansion, other plants within the County's jurisdiction, other utilities and other facilities.

The data collected are enumerated and the benefits of the PMMS are described. Data are analyzed to demonstrate some of the benefits of the system. Valuable data could be supplied to designers, equipment manufacturers, and purchasing agents.

Preventive maintenance and corrective maintenance have been improved as a result of the PMMS. Senior plant personnel report that since the was installed in 1972, critical corrective maintenance has been diminished as evidenced by a reduction in emergency situations. The attitude of maintenance personnel has improved. More elective maintenance, which improves the appearance of the plant, is now carried out.

A number of deficiencies has been noted. There have been gaps in data input and there has been input of inaccurate data as a result of organizational difficulties. There is no computer terminal at the treatment plant, which causes an interface problem between maintenance staff and the computing center. The parts inventory component has not been implemented and the full manpower management component of the system is not utilized. Full use of the PMMS for cost control and budget preparation has not taken place. Thus the full potential of the installed PMMS has not been utilized as yet.

SECTION 1

INTRODUCTION

A planned maintenance management system was installed at the Lower Potomac Wastewater Treatment Plant in 1972. Two reports, (1) A Planned Maintenance Management System for Wastewater Treatment Plants by Sargent and Rudich - EPA-600/2-73-004, November 1973 and (2) Evaluation of a Preventive Maintenance Management System for Wastewater Treatment Plants - Prepared for U.S. Environmental Protection Agency, Contract No. 68-01-4164 by Enviro Plan, Incorporated, April 1977, have been prepared in this system and its effectiveness. The first report describes the PMMS in technical detail; discusses the installation of the PMMS, at the Lower Potomac Wastewater Treatment Plant, including acceptance by the mechanics and coordination with plant operations; and outlines the application of the PMMS to other wastewater systems. The second report provides an evaluation of the effectiveness of the PMMS at the LPWTP from its installation in 1972 through 1975. The name of the system is Planned maintenance Management System and is hereinafter referred to as the PMMS, although in the second report, the system was referred to as a Preventive Maintenance Management System.

The purpose of this report is to describe the system that was installed in 1972 and to describe the manner in which the system is presently being operated. When the system was installed in 1972 it was operated manually. The system was computerized in 1976. Documentation has been lacking as to how the system is being operated, the use to which the system is being put, and the cost-effectiveness of the installed system.

SECTION 2

CONCLUSIONS

The following conclusions are made for the evaluation of the PMMS installed at the Lower Potomac Wastewater Treatment Plant.

1. The PMMS as installed at the Lower Potomac Wastewater Treatment Plant has all of the components of an exemplary maintenance management system.

2. Both planned and corrective maintenance programs are being carried out in a satisfactory manner.

3. The feedback features of the PMMS, which could be useful to management in cost control and budget preparation, are being used only to a limited extent.

4. An organizational deficiency has existed that resulted in incomplete and inaccurate data entering the system.

5. The interface between plant maintenance personnel and the computing center needs improving, including the need for a computer terminal at the plant.

6. The information that can be derived from the PMMS is considerably greater than that required to carry out the physical and mechanical aspects of an effective preventive and corrective maintenance program.

7. Although the system is computerized, senior personnel are still required to make key decisions if the system is to work.

8. Quantification of the benefits of the PMMS such as cost-effectiveness is difficult although semi-quantitative and qualitative assessment, including subjective analysis of benefits, can be presented.

SECTION 3

RECOMMENDATIONS

1. The U.S. Environmental Protection Agency in cooperation with Fairfax County, Virginia should report to the wastewater treatment community-designers, plant operation and maintenance personnel, plant managers and executives, plant builders, educators and trainers, regulatory authorities, and governmental officials - on the successful and effective maintenance management system at the Lower Potomac Wastewater Treatment Plant.

SECTION 4

DESCRIPTION OF THE MANUAL SYSTEM

Based on a review of the two reports (see page 1) prepared on the PMMS and on interviews with the Fairfax Wastewater Treatment Plant (WWTP) personnel, the following describes the manual PMMS.

CAPABILITIES OF THE PMMS

The PMMS as installed in 1972 was capable of handling two types of maintenance procedures. These were:

1. Preventive Maintenance - those regularly scheduled procedures necessary for routine care and inspection of the equipment to prevent possible breakdowns and to insure proper operation and efficiency.

2. Corrective Maintenance - those procedures necessary to restore operation of the equipment after a breakdown or when a possible breakdown is anticipated.

The system is also capable of handling overhaul maintenance and elective maintenance.

The PMMS as installed consisted of five parts. These were:

1. The Equipment Configuration List
2. The Maintenance Procedures
3. The Preventive Maintenance Cycle Schedule
4. The Recordkeeping System
5. The Maintenance Data Feedback System

The Equipment Configuration List

This list was essential to the successful implementation of the PMMS and represented the complete inventory of all of the WWTP's equipment. This list displayed all of the electrical and mechanical equipment used in the treatment works, the utilities and services (laboratory).

Each item in the plant that could require maintenance was given a discrete five (5) digit number. The numbering system was developed in the following manner.

1. The first digit identified the major systems in the plant. An example of this is as follows:

   1 XXXX - Raw Wastewater Station
   2 XXXX - Primary Treatment
   3 XXXX - Secondary Treatment
   4 XXXX - Chlorination and Effluent Flow
   5 XXXX - Sludge and Scum Processing
   6 XXXX - Incineration
   7 XXXX - Utilities and Services

2. The second digit identified the subsystems within the major systems. Examples of this for the major system Sludge and Scum Processing (5XXXX) are as follows:

   51XXX - auxiliary services
   52XXX - sludge thickening
   53XXX - sludge storage and handling
   54XXX - scum handling
   55XXX - lime treatment
   56XXX - ferric chloride treatment
   57XXX - polymer treatment
   58XXX - sludge conditioning
   59XXX - vacuum filtration

3. The third digit identified the functional unit within the subsystem described in item 2 above. Examples using the sludge thickening (52XXX) subsystem are as follows:

   521XX - thickeners
   522XX - pumping
   523XX - flow measurement
   524XX - chlorination
   525XX - compressed air

4. The fourth digit identified a piece of electrical or mechanical equipment within the functional unit described in item 3 above. Examples for the thickeners (521XX) are as follows:

   5211X - sludge thickeners
   5212X - gear motors
   5213X - chain drives
   5214X - gear reducers
   5215X - ventilators
   5216X - controls

5. The fifth digit identified which parallel units were being specified. Thus, for the electrical and mechanical equipment itemized in item 4 above, the numbering system continued as described below:

   52111 - sludge thickener No. 1

52112 - sludge thickener No. 2
5212I - gear motor No. 1
5212Z - gear motor No. 2
5213I - chain drive No. 1
5213Z - chain drive No. 2
5214I - gear reducer No. 1
5214Z - gear reducer No. 2

In addition to the five-digit identification numbering system described above, the equipment configuration list also contained a two-digit number that indicated what that specific piece of equipment was used on or for. Some examples of this "type" numbering system are shown below.

Type Number	Equipment
10	Tanks and Equipment
11	Tanks, Channels, Bins
12	Slide gates, sluice gates
13	Sludge and scum collectors
14	Weirs
20	Pumps, Compressors, Blowers
21	Centrifugal pumps
22	Piston pumps
23	Gear, vane, screw, diaphragm pumps
30	Electrical equipment
31	Motors, motor and drive assemblies
32	Supply panels and boxes
33	Controls
40	Mechanical equipment

An example of the equipment configuration list is given in Figure 1. list was used for the assignment of identification numbers to each piece of electrical and mechanical equipment at the plant. This list was supplemented with an equipment data list, equipment reference data forms and other more detailed forms as necessary.

Information on Equipment Configuration List, Equipment Data List and Equipment Reference Data Forms--

These lists contained the following information:

Identification number
Common name
Equipment type number
Location
Manufacturer's name
Part or model number
Serial number

ID	Equipment Name	Type	Location		
520 SLUDGE THICKENING					
521 Thickeners					
52111	Sludge Thickener No. 1	11	J		N
52112	Sludge Thickener No. 2	11	J		S
52121	Gear Motor No. 1	31	J		N
52122	Gear Motor No. 2	31	J		S
52131	Chain Drive No. 1	41	J		N
52132	Chain Drive No. 2	41	J		S
52141	Gear Reducer, No. 1	41	J		N
52142	Gear Reducer, No. 2	41	J		S
52151	Ventilator, No. 1 Thickener	72	J		N
52152	Ventilator, No. 2 Thickener	72	J		S
52161	Control, No. 1	33	J		N
52162	Control, No. 2	33	J		S
522 Pumping					
52211	Duplex Plunger Pump No. 1	22	J	L	NW
52212	Duplex Plunger Pump No. 2	22	J	L	NE
52213	Duplex Plunger Pump No. 3	22	J	L	SW
52214	Duplex Plunger Pump No. 4	22	J	L	SE
52221	Motor, Pump No. 1	31	J	L	NW
52222	Motor, Pump No. 2	31	J	L	NE
52223	Motor, Pump No. 3	31	J	L	SW
52224	Motor, Pump No. 4	31	J	L	SE
52231	Variable Speed Reducer, No. 1	41	J	L	NW
52232	Variable Speed Reducer, No. 2	41	J	L	NE
52233	Variable Speed Reducer, No. 3	41	J	L	SW
52234	Variable Speed Reducer, No. 4	41	J	L	SE
52241	Gear Drive, No. 1	41	J	L	NW
52242	Gear Drive, No. 2	41	J	L	NE
52243	Gear Drive, No. 3	41	J	L	SW
52244	Gear Drive, No. 4	41	J	L	SE
52251	Reduction Gear No. 1	41	J	L	NW
52252	Reduction Gear No. 2	41	J	L	NE
52253	Reduction Gear No. 3	41	J	L	SW
52254	Reduction Gear No. 4	41	J	L	SE
52261	Control, No. 1	33	J	L	NW
52262	Control, No. 2	33	J	L	NE
52263	Control, No. 3	33	J	L	SW
52264	Control, No. 4	33	J	L	SE
523 Flow Measurement					
52311	Thickened Sludge Magnetic Flowmeter	61	J	L	
52321	Flow Transmitter	61	J	L	
52331	Influent Sludge Channel Level Recorder	63	J	O	W

Location areas (refer to pages 5 and 6):

J = sludge thickening
L = plant shop and service building
O = outside

Figure 1. Equipment configuration list.

ID	Manufacturer	Part Number	Serial Number
21 Centrifugal Pumps			
13112	Fairbanks Morse	5710	K2N1044068
13113	Fairbanks Morse	5710	K2N1044069
13114	Fairbanks Morse	5710	K2N1044070
22113	Wemco Torque Flow	Model G	6895610-3
22114	Wemco Torque Flow	Model G	6895610-2
22115	Wemco Torque Flow	Model G	6895610-1
23111	Wemco Torque Flow	Model E	6895610-4
23112	Wemco Torque Flow	Model E	6895610-5
35111	Fairbanks Morse	Model 5720	K2N1044071
35112	Fairbanks Morse	Model 5720	K2N1044071-1
35113	Fairbanks Morse	Model 5720	K2N1044071-2
35411	Fairbanks Morse	5423B-28	K2N1044073
36113	Fairbanks Morse	5424D	K2N1044072
36114	Fairbanks Morse	5424D	K2N1044072-1
42211	Eastern	U-34-C, 107-3	CJ8-0802
42212	Eastern	U-34-C, 107-3	CJ8-0801
42213	Eastern	U-34-C, 107-3	CJ9-1305
42311	Eastern	U-34-C, 107-3	CJ8-0797
42312	Eastern	U-34-C, 107-3	CJ8-0800
42313	Eastern	U-34-C, 107-3	CJ8-0798
43311	Fairbanks Morse	5414E	K2N1044075-1
31 Motors, Motor and Drive Assemblies			
32621	Westinghouse	TBDP	680B101G27-6807
32622	Westinghouse	TBDP	680B101G27-6807
33321	Sterling	FBNF-1	8A2528-2
33322	Sterling	FBNF-1	8A2528-1
34221	Fairbanks Morse	KZK, T1004-2	F291080
34241	Westinghouse	M	311P178-A
35121	US Varidrive	VEU	J1421251
35122	US Varidrive	VEU	J1421249
35123	US Varidrive	VEU	J1421250
35131	US Electrical	ERHB	B121781
35132	US Electrical	ERHB	B121781
35133	US Electrical	ERHB	B121781
35421	Fairbanks Morse	KZK, T1007-2	F-457875
36123	US Varidrive	VLUHVGS	P4177843
36124	US Varidrive	VLUHVGS	P4177842
36133	US Electrical	ERHP	121781
36134	US Electrical	ERHP	121781

Figure 1. (continued)

Additionally, pumps were listed separately with their head, capacity, size, impeller and RPM.

The equipment data list was grouped by equipment type (centrifugal pumps; motor; motor and drive assemblies; etc.) and specified for each piece of equipment, using the five-digit identification number, the manufacturer's name, the part or model number and the serial number.

The equipment reference data forms, prepared for each five-digit numbered item, contained all descriptive information on that piece of equipment taken from the manufacturer's catalogs, drawings, reference data, etc. The back of the reference data forms detailed the parts that would be needed for operation of that equipment. This information was used for the development of preventive maintenance (PM) and corrective maintenance (CM) procedures and for the development of a spare parts inventory. Additional forms that were developed, based on the five-digit identification number, gave other information such as the head-capacity-power data for pumps and the frame type, horsepower and current information for electric motors.

Thus, the equipment configuration list was used to group the equipment and assign identification numbers. The identification numbers were then used as catalog numbers to order other information necessary to facilitate a logical and systematic file on each piece of equipment.

The Maintenance Procedures (MPs)

The maintenance procedures (MP) for each item of equipment were detailed individually on a sheet called the maintenance procedure sheet. While each equipment item was identified by a five-digit identification number, the MP sheet carried the first four digits only and thus those maintenance procedures were applicable to all equipment items with those first four digits. A two-character, alpha-numeric code was added to the four-digit number. The first alpha character specified the frequency of the PM procedure (i.e., D=daily; W=weekly; M=monthly, etc.) and the second numeric character specified the num ber of MPs required for that piece of equipment at the specified frequency. For example, using the major sub-function number 520, sludge thickening, the MPs for the pumping equipment, 522, associated with sludge thickening, were numbered 5221 D1, 5221 W1, 5221 R1, 5221 M1 and 5221 M2. The first four digits identified the particular piece of equipment, in this case the duplex plunger pumps. The alpha-numeric codes D1, W1, R1 and M1 specified that those particular MPs were to be performed on a daily, weekly, as required and monthly basis, respectively, and that number one of a series of procedures is to be performed. The alpha-numeric code M2 specified that number two of a series of MPs were required for that piece of equipment on a monthly basis.

The maintenance procedure sheet specified in detail all of the tasks (steps) required for the successful completion of that MP. Additionally, the sheet detailed (a) the labor skill required (S1-electrician, S2-mechanic and S3-utility man); (b) the labor time required; (c) the name, identification number, nameplate data and location of that piece of equipment; (d) safety precautions to be observed; and (e) all parts, tools, materials and test equipment needed to accomplish that MP.

A summary MPs list was also prepared that displayed the MP number, a brief description of the PM task, the labor skill and labor time required and the week number that the PMMS was initiated for that MP. That initial week number was then updated based on the specified frequency of the MP. The week numbering system was used for scheduling the PM tasks. The PM tasks were scheduled for each of the 52 weeks in a year. All MPs with the alpha codes D and W were scheduled for daily and weekly assignments; those MPs with the alpha codes M, Q, S, and A were scheduled according to the week number for which the PMMS was implemented for that unit; and the MPs with the alpha code R were scheduled as required. For example, the summary sheet might have shown the following:

MP NO.	TASK DESCRIPTION	SKILL/MIN.	WEEK NO.
1111 D1	-	-	1
1111 D2	-	-	1
1111 M1	-	-	1
1122 M1	-	-	3
1122 Q1	-	-	3
1122 A1	-	-	3
1311 W1	-	-	1
1311 R1	-	-	(as required)
1311 S1	-	-	9
1311 S2	-	-	9

By using the initial week number MPs 1111 D1 and 1111 D2 would have been scheduled for daily attention; MP 1311 W1 would have been scheduled for each week; MP 1111 M1 would have been scheduled for weeks 1, 5, 9, 14, 18, 22, 27, 31, 35, 40, 44, and 48 and week 1 of the next year; MP 1122 M1 would have been scheduled for weeks 3, 7, 11, 16, 20, 24, 29, 33, 37, 42, 46, 50 and week 3 of the next year; MP 1122 Q1 would have been scheduled for weeks 3, 16, 29, 42 and week 3 of the next year; MPs 1311 S1 and 1311 S2 would have been scheduled for weeks 9, 35 and week 9 of the following year. This summary list was thus used to prepare the PM cycle schedule.

The Preventive Maintenance (PM) Cycle Schedule

The PM cycle schedule was prepared using the MPs summary list. PM actions were scheduled for each week and the list was ordered so that all PM tasks on a particular unit could be assigned to one team. Additionally, the MPs on the same unit, but different frequencies, were scheduled so that they could be accomplished during the same weeks that the unit was being worked on. Thus, MPs 1122 M1, 1122 Q1 and 1122 A1 were included on the PM cycle schedule for weeks 3 of the PMMS year and MPs 1122 M1 and 1122 Q1 were included on the PM cycle schedule for week 3, 16, 29 and 42 of the PMMS year. These items were scheduled in addition to all daily and weekly PMs required for MP 1122. However, the daily and weekly PM tasks were listed separately. The PM cycle schedule was generated on a weekly basis and the actual daily assignments were left to the foreman and plant management. As a means of facilitating with the daily assignments, the plant was sectioned into different areas and each area was scheduled for preventive maintenance on a particular day of the week. For example:

Monday - PM schedule for The Incinerator Building.
Tuesday - PM schedule for The Blower Building
Wednesday - PM schedule for The Chlorine Building
Thursday - PM schedule for The Chlorine Building
Friday - PM schedule for The Chlorine Building

A master PM schedule was prepared that displayed each PM task and frequency for each piece of equipment for the entire year. The master schedule assisted plant management in determining staffing requirements and also in making decisions concerning which PM tasks could be delayed in order to free personnel to attend to those PM tasks that had to be accomplished during that week without incurring overtime or having to add additional personnel. Rescheduling of PM tasks was done by plant management. This decision was based on the availability of personnel and the immediacy of the task.

The PM cycle schedule displayed on a weekly basis the PM procedures that should be accomplished during that week. The schedule listed by MP numbers all required MPs. The maintenance foreman made the decision as to which MPs would be performed each day. Upon completion of the task, the date, name and time were recorded on the back of the MP sheet. This information was used to adjust the time on the MP sheet for performing that task and to update the recordkeeping system.

The Recordkeeping System

The recordkeeping system of the PMMS was designed to maintain a permanent record for each item of equipment. This system included all records on the PM and CM work performed. In order to develop this system it was necessary to utilize six forms. These forms were:

1. Equipment Reference Data Form M1
2. The Equipment Maintenance Record Form M2
3. The Preventive Maintenance Work Record Form M3
4. The Report of Trouble Form M3X (this form was a variation of form M3)
5. Equipment Malfunction Report Form M4
6. Corrective Maintenance Work Order Form M5
7. Corrective Maintenance Work Order and Work Record Form M6.

These forms, including their reverse sides, are shown in Figures A1-A9 in Appendix A. The use and description of these forms have been previously described (1).

The recordkeeping system was designed to eliminate unnecessary paperwork from the maintenance personnel, yet maintain an updated maintenance record on each item of equipment. It was also used for generating weekly maintenance summary reports by providing information to update the Maintenance Data Feedback System.

The Maintenance Data Feedback System

The Maintenance Data Feedback System was developed to provide plant management with a weekly maintenance summary report. To accomplish this, the

Weekly Maintenance Summary Report Form M7 was completed by the maintenance technician using information from the recordkeeping system. The Weekly Maintenance Summary Report Form was comprised of three parts: a Work Load Summary and a Work Accomplished Summary on the front of the form, and a Corrective Maintenance Summary on the back.

The Work Load Summary included the maintenance workload that should have been accomplished during the week, what is actually accomplished and what the carryover (backlog) was for the following week. The maintenance actions were broken down into Preventive Maintenance and Corrective Maintenance and the man-hours by skill were also recorded. Management used the Work Load Summary to determine the number of preventive and corrective maintenance actions completed and the number of actions that were backlogged.

The Work Accomplished Summary summarized the total maintenance costs for the plant for each week. The Work Accomplished Summary was also broken down into Preventive and Corrective Maintenance, the number of actions completed, the actual man-hours expended per skill, the cost for labor, the cost for outside contractors, the cost of parts and materials, and the total costs.

The Corrective Maintenance Summary listed all CM work that was outstanding at the beginning of the week and that was initiated during the week. For each task the job number; the equipment name; the equipment identification number and the status code were recorded. The equipment status code indicated whether the equipment was operational, nonoperational or in a reduced capability mode. The Corrective Maintenance Summary also gave a description of the work to be done on each action, the work order date, and the completion date. Additional information was also provided, if necessary. Using this information a Priority Code was also established for each job. This code was as follows:

U - Urgent repairs to correct conditions that prevent the plant from operating or which involve the health and safety of personnel

N - Needed repairs to correct conditions that seriously impair plant efficiency or plant reliability

R - Routine repairs, tests and inspections

C - Convenience items.

This coding helped management with the scheduling of corrective maintenance jobs.

SUMMARY

The manual operation of the PMMS included both PM and CM procedures. Corrective maintenance was not, of course, planned, but occurred as a result of a breakdown or a noticed impending failure. Exhibit 1 summarizes the manual PMMS for PM and CM applications.

EXHIBIT 1

SUMMARY OF STEPS FOR PMMS FOR PREVENTIVE
MAINTENANCE AND CORRECTIVE MAINTENANCE APPLICATIONS

PREVENTIVE MAINTENANCE

1. The functional numbering system and equipment type numbering system were developed. This was a one-time accomplishment of the complete inventory of the plant's mechanical and electrical equipment. The equipment nameplate data was put on Form M1.

2. The inventory was restructured into the Equipment Configuration List by sorting into appropriate groupings the equipment related to each of the various plant unit treatment works, utilities and services.

3. The Equipment Data List was prepared. This list augmented the Equip ment Configuration List and was grouped by equipment type. Even more detailed data could have been tabulated if desired.

4. Maintenance Procedures (MP) for each piece of equipment included in the inventory, using manufacturer's information and drawings, and the expertise of personnel familiar with the equipment maintenance procedures were prepared.

5. A numbered (functional numbering system used) Maintenance Procedure Sheet (MPS) for each individual Maintenance Procedure (MP) was prepared.

6. A summary list of Maintenance Procedures was prepared.

7. Based on the summary list of Maintenance Procedures and the judgment of senior plant staff, PM actions were scheduled for each of the 52 weeks of the year. The actual work assignments on a daily basis were left to the discretion of the foreman and plant management.

8. When the PM task was completed, the maintenance personnel documented the task performed on Form M3 or M3X.

9. The PMMS technician used the data on Form M3 or M3X to prepare the permanent Form M2.

10. If the "trouble" box on Form M3 or M3X was not checked, the Form was discarded.

11. If the "trouble" box on Form M3 or M3X was checked, the form (after filling out Form M2) was returned to the Maintenance Department and Forms M5, CM work order, and M6 were filled out. Form M5 initiated the CM action.

12. Form M7, Weekly Maintenance Summary Report, was also completed.

CORRECTIVE MAINTENANCE

1. Corrective maintenance was initiated by the maintenance personnel that indicated trouble on the back of Form M3 or M3X. Additionally, CM could have also been initiated by the plant operators or anyone else that observed an equipment malfunction. In that situation, Form M4 was completed and returned to the Maintenance Department.

2. The Maintenance Department, after receipt of Form M3 or M3X, completed Form M5 and the top half of Form M6. Form M6 was given to the maintenance personnel.

3. The maintenance personnel completed the lower half of Form M6 when the CM task was completed.

4. The PMMS technician filled out Form M2 and discarded Form M5. Form M6 was kept as a permanent equipment file.

5. The PMMS technician then completed Form M7.

STAFFING

The PMMS is not a substitute for maintenance staff but rather a tool to be utilized by the staff. To be effective, the PMMS should be designed to meet the staff's needs to carry out a maintenance program. The staff must receive training and it is important that each of the staff's responsibilities be defined to assure a successful running system. One of the key personnel is the individual who, at the Lower Potomac Wastewater Treatment Plant, had the title Maintenance Technician.

The Maintenance Technician was responsible for the running of the system. This position was essential to the successful implementation and development of the system. The duties of the Maintenance Technician required that he maintain and update equipment files; that he prepare working copies of the maintenance procedure sheets on a weekly basis; that he produce reports on equipment history, equipment conditions, maintenance history, maintenance cost and manpower requirements, when necessary to identify and implement improvements to the maintenance system. This position was usually given to a person that was quite familiar with the operational and maintenance history of the plant.

At the Lower Potomac Wastewater Treatment Plant three labor/skill categories were used for performance of the maintenance tasks. These were:

Skill 1 - Electrician
Skill 2 - Mechanic
Skill 3 - Utility Man

The duties of the electricians and the mechanics are self-explanatory. The utility man category required some familiarity with the repair and operation of electrical and mechanical equipment. This person assisted the electrician and mechanic as necessary.

SECTION 5

DESCRIPTION OF THE EXISTING SYSTEM

The maintenance management system presently installed at the Lower Potomac WWTP is a computerized version of the manual system that was described previously. The system was computerized in 1976 and has the capability of handling a comprehensive planned maintenance management program. However, the system has not been implemented to its complete extent. The five basic parts of the system as described in Section 1 have been computerized, but some of the operations are still manual.

Transition from Manual System to Computerized System

The transition from the manual system to the computerized system took place during a of 2 - to - 3 month period. This was possible because of two significant factors. One, the complete and detailed manner in which the manual PMMS had been prepared. Two, the computer software programs developed by personnel of the Fairfax County Government was prepared with full consultation with the LPWTP maintenance staff who were very knowledgeable about the PMMS.

The data and information obtained and stored in the present computerized system are essentially the same as those which were obtained and stored in the manual system.

The computer generates both PM and CM work orders, cyclical preventive, maintenance procedures, a monthly corrective maintenance summary and a work accomplished summary (summarizes PM and CM actions completed during the month). The computerized version of the PMMS requires 19 input documents, whereas the manual system required only 6 (Forms M1-M6). Of those 19 input documents, the maintenance staff only came in contact with 3 of them.

PREVENTIVE MAINTENANCE (PM)

To carry out the preventive maintenance program a number of files is necessary. These are the daily, weekly and cyclical Preventive Maintenance Files.

The Daily and Weekly Preventive Maintenance File, which is a non-computerized file consisting of all the Maintenance Procedure Sheets for the equipment requiring daily or weekly PMs, is maintained at the plant. This file is composed of five folders, one for each day of the week. The MPs are distributed among the five folders using the PM Cycle Schedule described in

Section 2 of this report and on a balanced work load. This file is developed using the Equipment File Maintenance and Maintenance Procedure File Maintenance Documents. Scheduling of the PM tasks is handled by the senior maintenance, operations, and PMMS personnel. This file is not maintained in the computer, but a ledger is kept for recording all daily and weekly preventive maintenance actions carried out on each item of equipment. The PMMS Technician summarizes these weekly PM actions and transmits them to the computing center. The daily and weekly PM actions are recorded by the computer and are printed out in one of the two monthly reports generated.

The Cyclical Preventive Maintenance File is designed to schedule only those items of equipment that require maintenance on a monthly, quarterly, semi-annual or annual basis or on the basis of hours of run-time of equipment. The file is developed using the Equipment File Maintenance, Maintenance Procedure File Maintenance and Meter Reading Card Documents. The scheduling of these actions is prepared by the senior maintenance, operations and PMMS personnel.

Preventive Maintenance Implementation

Each week, the computer prints out a list of all the PM actions scheduled for the following week. Exhibit 2 is a PM flow diagram. Since Maintenance Procedure Sheets are on file in the noncomputerized files for all items requiring weekly or daily maintenance, the computer only prints out "PM Work Orders" for equipment requiring cyclical maintenance. The "PM Work Orders" are delivered to the PMMS Technician for distribution, along with the corresponding Maintenance Procedure Sheets, to the appropriate daily folder described above. Completed PMs are reported back to the Computing Center via the PMMS Technician using the "PM Work Orders" for cyclical maintenance. Uncompleted PMs can be tracked by flagging the unreturned "PM Work Orders" and Maintenance Procedure Sheets that have not been filled out. Exhibit 3 summarizes the computerized version of the PMMS for the implementation of PM actions.

For the PM actions, the plant maintenance staff routinely use only two forms - the Maintenance Procedure Sheets and the "PM Work Orders". However, the following documents have to be utilized (prepared by senior maintenance, operations and PMMS personnel) in order to provide for file updating, maintenance scheduling and management reporting.

1. Equipment File Maintenance
2. Maintenance Procedure File Maintenance
3. Parts File Maintenance
4. Personnel File Maintenance
5. Meter Reading Card

The above forms are Figures B1, B2, B3, B6, and B15 of Appendix B.

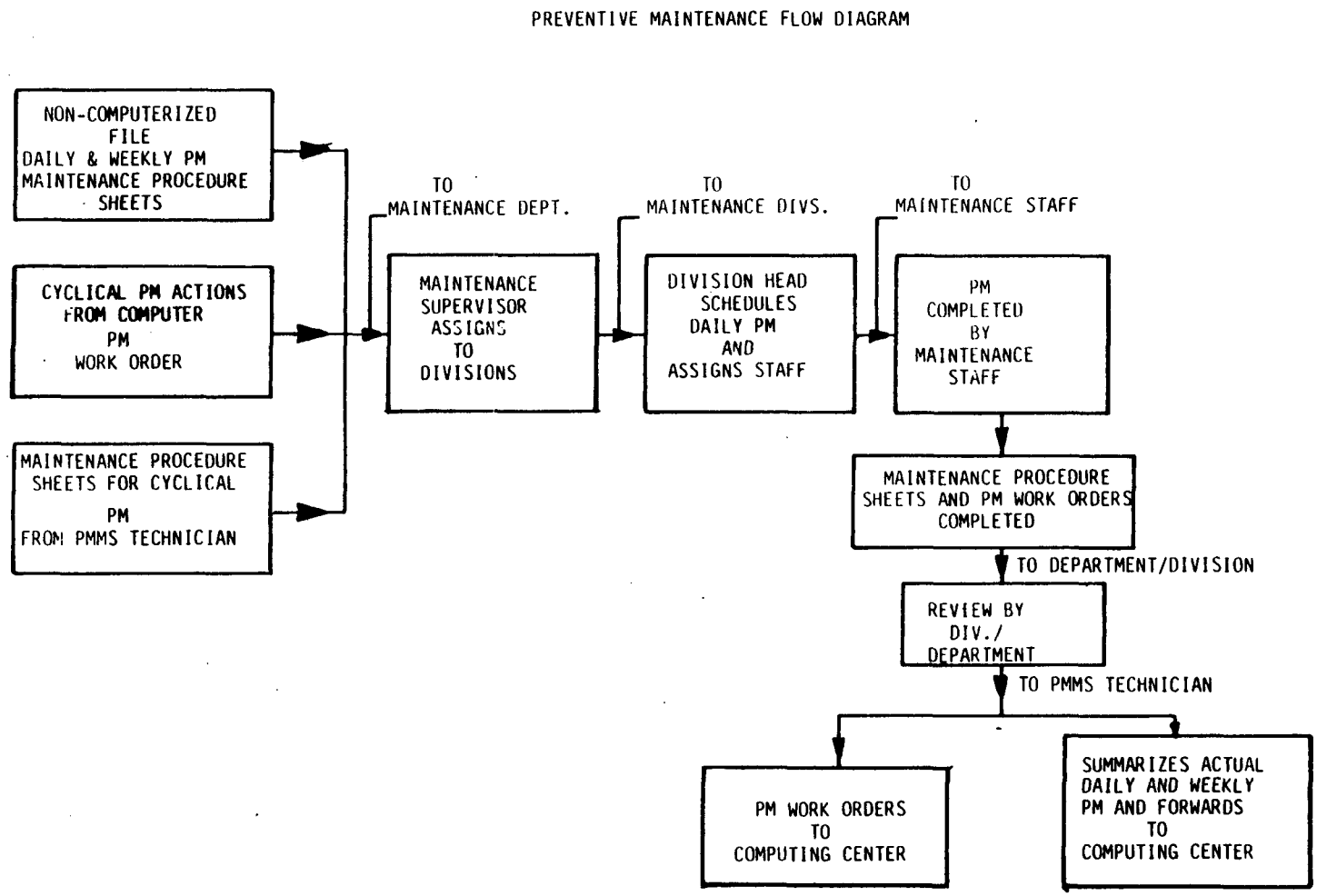

Exhibit 2. Preventive maintenance flow diagram.

EXHIBIT 3

SUMMARY OF STEPS FOR THE COMPUTERIZED PMMS FOR PREVENTIVE MAINTENANCE

1. A noncomputerized file of daily and weekly PMs is prepared by distributing the work among the 5 weekdays on the basis of the PM cycle schedule, a balanced work load and the judgment of the senior staff. This file consists of the daily and weekly Maintenance Procedure Sheets.

2. Cyclical PM actions are obtained from the computer center in the form of "PM Work Orders".

3. The Maintenance Procedure Sheets corresponding to the "PM Work Orders" generated are obtained by the PMMS Technician.

4. The weekly, daily and cyclical PM requirements are then sent to the Maintenance Department.

5. The maintenance supervisor sorts the PM actions received and assigns them to the responsible division (mechanical, electrical, instrumentation).

6. The division head schedules the daily PM activities and assigns the staff.

7. PM completed.

8. When the PM tasks are completed the maintenance personnel complete the information on "PM Work Orders" and Maintenance Procedure Sheets.

9. The two documents completed in step 8 are returned to the Department/Division.

10. The PM files are returned to the PMMS Technician.

11. The PMMS Technician returns the "PM Work Orders" to the Computing Center.

12. The PMMS Technician summarizes the actual daily and weekly PM performed and forwards to the Computing Center on a weekly basis.

CORRECTIVE MAINTENANCE

Three types of CM actions are recognized at the Lower Potomac Wastewater Treatment Plant - malfunction, incipient and elective. A malfunction is an actual breakdown or problem; an incipient problem, which is usually reported as part of PM work, is one that if not corrected will lead to breakdown; and elective is maintenance or construction that is nonfunctional in nature, e.g., painting, new safety features, change in location of meters or controls, etc.

A CM is classified as minor, major or emergency. A minor CM is one which can be corrected in less than one and one-half (1½) hours with parts costing less than fifteen dollars ($15). An emergency CM is one required to keep the plant, a major subsystem (e.g., aeration system), or a major piece of equipment (e.g., compressor) in operation. All other CMs, including elective, are considered major.

Corrective Maintenance Implementation

The Equipment Malfunction Report Documents are available in all locations of the plant where equipment is located and are readily accessible to all operations, maintenance and plant personnel. When a malfunction is discovered, that document (which consists of two copies) is filled out; one copy is posted on a notice board in the immediate vicinity of the equipment being reported on, and the original is delivered to the Shift Foreman. If the Shift Foreman determines that the malfunction is an "emergency," the Maintenance Department is notified immediately. The Maintenance Department may proceed to correct the malfunction without receiving a Corrective Maintenance Work Order. The PMMS Technician working with the Supervisor of the appropriate Maintenance Division has the responsibility of submitting the Equipment Malfunction Report and the CM Initiation Request to the Computer Center. The Computer Center generates the CM Work Order. When the malfunction has been corrected, the completed CM Work Order is returned to the Center. At the completion of the repair, the Equipment Malfunction Report Form that was posted on the notice board is removed and destroyed.

All other Equipment Malfunction Report Documents that are not determined to be an "emergency" are sent to the PMMS Technician who will refer them to the appropriate Maintenance Department Supervisor (electrical, mechanical, or instrumentation). If the CM action is a minor one, the CM action is completed by the Maintenance Department and no written record is kept. The labor time is billed to a standard work order, which is recorded at the Center. Upon completion of the CM, the copy of the Equipment Malfunction Report Document posted on the notice board is removed and destroyed.

If the CM action is determined to be major, the PMMS Technician sends the Equipment Malfunction Report Document to the Maintenance Department Supervisor. The Maintenance Department indicates on the Malfunction Report Document that a CM Work Order is needed and provides some information as to the nature of the repairs required. That document is sent to the PMMS Technician who prepares a CM Initiation Request, which is sent to the Computer Center. A CM Work Order is generated by the Center and returned to the Maintenance

Department via the PMMS Technician. At the completion of the CM action, the bottom half of the CM Work Order Document is completed by the Maintenance Department. The CM Work Order Document is then sent to the stockroom for cost data on the parts used before being returned to the Computer Center via the PMMS Technician. The copy of the Equipment Malfunction Report Document posted on the notice board is removed and destroyed.

If the CM action is elective, a Corrective Maintenance Initiation Request is prepared by the PMMS Technician upon authorization from the Maintenance Department. This request document is then sent to the Computer Center. A CM Work Order is prepared by the Center and returned to the Maintenance Department via the PMMS Technician. Upon completion of the CM action, the bottom half of the CM Work Order form is completed by the Maintenance Department and returned to the Computer Center via the PMMS Technician. Exhibit 4 is a flowchart for the PMMS implementation of corrective maintenance actions as described above.

DOCUMENTS USED FOR IMPLEMENTATION OF THE PMMS FOR CM ACTIONS

The plant maintenance staff routinely use only three documents for CM actions. These are the Equipment Malfunction Report, the Corrective Maintenance Initiation Request and the CM Work Order.

However, the following documents have to be utilized (prepared by senior maintenance, operations and PMMS personnel) in order to provide for file updating, maintenance scheduling and management reporting.

1. Equipment File Maintenance
2. Maintenance Procedure File
3. Parts File Maintenance
4. Standing Work Order File Maintenance
5. Personnel File Maintenance File
6. Action Codes File Maintenance
7. Description Code File Maintenance
8. Item Code File Maintenance

The scheduling of CM actions other than emergency repairs is done by the senior maintenance personnel and is determined on the basis of PM actions required, PM backlog, CM actions, CM backlog, personnel available, overtime to be utilized, contractor services that can be utilized and emergency repairs underway. Elective maintenance is also scheduled taking into account the above factors. A list of uncompleted (backlog) CMs can be printed out by the computer upon request.

DATA GENERATED BY THE EXISTING PMMS

The actual data on maintenance performed is provided by the maintenance staff and the Maintenance Technician, who fill in parts of the following five documents as shown in Table 1, that have been described and are shown in Appendix B:

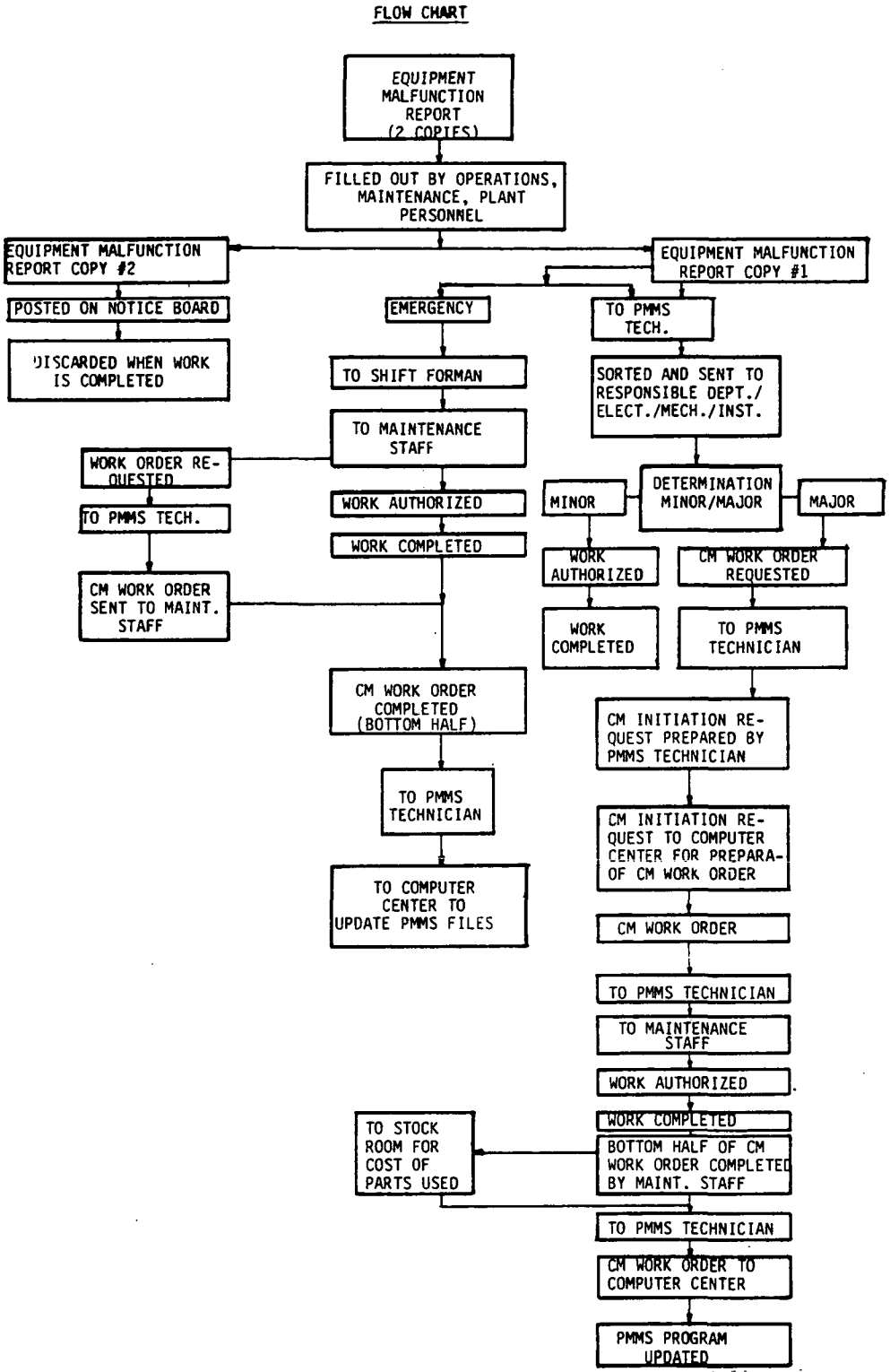

Exhibit 4. Corrective maintenance flowchart.

TABLE 1. INPUT DATA DOCUMENTS FOR EXISTING PMMS

Maintenance action	Document	Responsibility of maintenance staff
Preventive Maintenance	Maintenance Procedure Sheets	Sign and date after action completed
Preventive Maintenance	Preventive Maintenance Work Order	Sign and date after action completed
Corrective Maintenance	Equipment Malfunction Report	Indicate on document problem observed
Corrective Maintenance	Corrective Maintenance Initiation Request	Filled out by PMMS Technician
Corrective Maintenance	Corrective Maintenance Work Order	Sign and date after work completed

The data generated through the actual PMMS in use at the Lower Potomac Plant is itemized below.

Preventive Maintenance Data Generated

I. A. For every individual equipment item

(a) When maintenance took place (date)
(b) Who performed maintenance
(c) Parts and supplies utilized
(d) Cost of parts and supplies utilized
(e) Time required to perform maintenance
  (i) Regular hours
  (ii) Overtime hours
(f) Labor costs to perform maintenance
(g) Labor skills utilized for maintenance
(h) Outside contractor costs
(i) Total costs

B. For the plant as a whole

(a) Number of actions regularly scheduled during current week and estimated man-hours by skill
(b) Number of actions backlog from previous week and estimated man hours by skill
(c) Total number of outstanding actions for current week and estimated man-hours by skill

(d) Number of actions accomplished during current week and estimated man-hours by skill
(e) Number of actions backlog for next week and estimated man-hours by skill
(f) Labor costs for the week - regular time, overtime and total
(g) Outside contractor costs for the week
(h) Costs of parts and materials used during week
(i) Total costs for the week
(j) Number of actions completed during the month
(k) Number of hours utilized during month - regular time, overtime and total
(l) Labor costs for the month
(m) Parts and material costs for the month
(n) Outside contractor costs for the month
(o) Total costs for the month

Corrective Maintenance Data Generated

II. B. For every malfunction

(a) Malfunction report - who prepared
(b) Work order request - who prepared and who authorized, when requested
(c) Work order - who prepared and who authorized, when issued
(d) Time malfunction or trouble reported
(e) Nature of malfunction or trouble (description of symptoms)
(f) Identification of equipment (name and number)
(g) Job number
(h) Items needing repair
(i) Priority for repair
(j) Estimate of labor time and parts to repair
(k) Hours of running time for equipment (if applicable)
(l) Item repaired
(m) Labor time by skill - regular time, overtime, and total
(n) Labor costs by skill - regular time, overtime, and total
(o) Parts and materials used
(p) Costs of parts of materials
(q) Contractor costs
(r) Total costs to repair
(s) When job was complete

C. For the plant as a whole

(a) Number of actions regularly scheduled during current week and estimated man-hours by skill
(b) Number of actions backlog from previous week and estimated man hours by skill
(c) Total number of outstanding actions for current week and estimated man-hours by skill
(d) Number of actions accomplished during current week and man-hours by skill

(e) Number of actions backlog for next week and estimated man-hours by skill
(f) Labor costs for the week - regular time, overtime and total
(g) Outside contractor costs for the week
(h) Costs of parts and materials used during week
(i) Total costs for the week
(j) Number of actions completed during the month
(k) Number of hours utilized during month - regular time, overtime and total
(l) Labor costs for the month
(m) Parts and material costs for the month
(n) Outside contractor costs for the month
(o) Total costs for the month

The above list represents the actual data generated and does not represent the data that could be supplied by the PMMS. The recordkeeping and feedback capabilities of the PMMS represent a powerful management tool, which is underutilized at the present time. A complete accounting of maintenance labor, material and contractor costs for management use in cost control and budget preparation is available. Costs can be reported by plant area, functional subsystem, types of equipment and individual items of equipment. Life cycle costs can be determined. Actual performance of equipment can be compared to manufacturer or design specifications. The cause and responsibility for equipment failure can be assessed. Reliability of equipment, subsystems, and systems can be determined. Historical data as well as current data on PM and CM for each item of equipment are readily available.

MANAGEMENT REPORTS GENERATED

The only management reports that are now generated on a regular basis are the Monthly CM Summary and the Work Accomplished Summary. The Monthly CM Summary contains the following information:

- Date
- Plant
- Job Number
- Equipment Number
- Equipment Name
- Location
- Apparent Cause of Malfunction
- Completion Date
- Regular Hours
- Overtime Hours
- Labor Cost
- Parts Cost
- Contract Cost
- Grand Total Cost

The Work Accomplished Summary gives in tabular format the number of Preventive Maintenance actions completed and the number of Corrective Maintenance actions completed during that reporting period.

OPERATION OF THE EXISTING PMMS

The qualifications of the personnel required to operate the PMMS have been documented earlier. Exhibit 5 is a current table of organization for the operation and maintenance staff at the Fairfax Lower Potomac Wastewater Treatment Plant. The efficient utilization of the PMMS is dependant upon the availability of the following personnel categories:

1. Maintenance Technician (Engineering Technician on Table of Organization)

2. Senior staff who are responsible for the scheduling of the maintenance actions

3. Management personnel who utilize the generated data for planning evaluation and budgeting purposes

4. Maintenance personnel who must be cooperative and participate if the system is to work.

The training of the maintenance personnel is done on an ad hoc, informal basis, which appears to be adequate since the actual plant maintenance is being performed in a satisfactory manner.

There have been two major deficiencies in the operation and utilization of the system. One relates to the interface between the maintenance personnel and the Computer Center including the absence of a computer terminal at the plant. The other relates to the limited use that is being made of the data that are being collected and are available as data feedback.

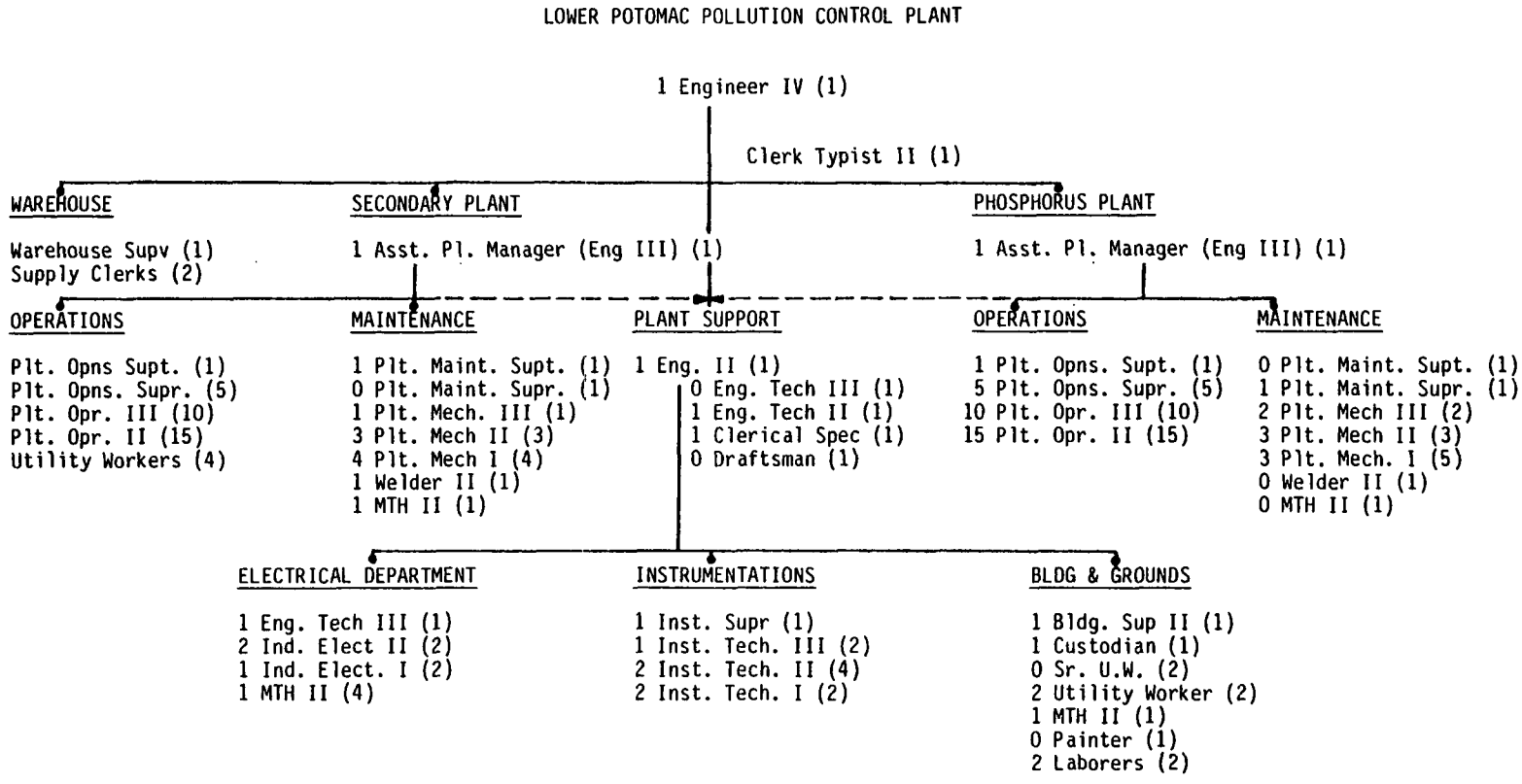

Exhibit 5. Organization of operation and maintenance staff.

SECTION 6

METHODOLOGY FOR ASSESSING BENEFITS OF A MAINTENANCE SYSTEM

The primary methodology for assessing the benefits of a maintenance system in general, and the PMMS in particular, is to (1) identify the benefits; (2) quantify all actual or potential benefits; (3) consider alternative means for achieving those benefits; and (4) determine the costs and values (in monetary and nonmonetary terms) in achieving benefits.

The following are considered benefits for a maintenance system:

1. Improved plant performance.
2. Reduced number of plant, system, subsystem, equipment failures.
3. Improved reliability of system - reduce equipment downtime.
4. Reduced number of higher skilled staff.
5. Reduced overtime requirements for maintenance.
6. Number of maintenance backlog items at a level that does not increase malfunction potential.
7. Improved personnel morale.
8. Provision for cost control and budget preparation.
9. Provision of information for better design, construction and equipment evaluation for purchasing agents.
10. Reduced operational costs when compared to historical trends or comparable alternative systems.

Cost comparison among maintenance systems is extremely difficult because of the following considerations:

1. Costs must be normalized for different locations and time periods.
2. Institutional constraints can affect the numbers of personnel and skills required to be employed.

3. Total costs for a maintenance system should include startup costs, administrative costs and management costs.

4. Systems when installed have more capacity than can be utilized.

5. Maintenance costs affect life cycle costs that are not readily available.

6. Maintenance costs affect operating costs and these benefits are difficult to assess.

7. The need for outside contractors to assure a backup capability may require their use to assure their availability.

8. The method used for the allocation and accounting of the time of personnel - maintenance, operation, administrative, supervisory, management - varies from plant to plant.

There are two other approaches of assessing benefits other than the cost-effective approach described above. These are:

1. A statement of criteria for a system that, if met would provide positive benefits. These criteria are usually established by knowledgeable experienced experts in the field.

2. Direct comparison of systems -

   a. Systems that have been or will be in use at a particular plant (within plant comparison)
   b. Systems that have been used at comparable plants (between plant comparison)

CRITERIA AND GUIDELINES FOR MEASURING BENEFITS OF MAINTENANCE MANAGEMENT SYSTEM

Criteria for measuring the benefits of an effective maintenance management system were presented by Enviro Plan Incorporated (2). These included:

1. Reducing the maintenance of complex equipment to simple procedures that are easily identified and managed;

2. Defining the minimum requirements of preventive maintenance;

3. Scheduling and controlling the performance of work tasks, inspections and tests;

4. Describing the methods, materials, tools and personnel required;

5. Providing for the prevention or detection of impending malfunctions;

6. Providing a permanent record of equipment characteristics and a maintenance history;

7. Providing periodic maintenance summary reports to plant management;

8. Providing a means for knowledgeable management of maintenance;

9. Ensuring the systematic, timely, safe, standardized and complete accomplishment of equipment care and inspection;

10. Increasing plant reliability by preventing equipment breakdown and by prolonging equipment life;

11. Minimizing maintenance manpower requirements;

12. Providing a complete record system and a system for feedback to management;

13. Providing management with the information required for cost control, work load assessment and work assignment according to priority and urgency.

MAINTENANCE MANAGEMENT SYSTEM EVALUATION GUIDELINES

A report (3) on maintenance management systems prepared by an EPA contractor provided guidelines for evaluating a maintenance management system. Table 2 presents those evaluation guidelines and a rating system.

Those systems, which achieve a high rating would be expected to produce the most benefits. Each guideline may be assigned a numerical value up to the maximum as indicated in the "Maximum Rating" column. The columns "PMMS Potential" and "PMMS In Use" are numerical values assigned by PEER Consultants to the current PMMS at the Lower Potomac Wastewater Treatment Plant. It should be noted that the PMMS has the potential of receiving the maximum rating based on these guidelines.

SYSTEMS COMPARISON

A direct way of comparing systems would be to compare a new system such as the PMMS with a system or procedure in use prior to the introduction of the new system. The difficulty in obtaining quantitative data as to cost and to effectiveness of maintenance programs, particularly those which are not "planned maintenance management systems," negates or limits the use of the approach. However, a qualitative assessment based on comments of personnel and semi-quantitative assessments can be of use. Qualitative assessments could include appearance of plant, morale of personnel, number of emergencies or crises, backlogs, etc. Semi-quantitative data could include the size of the maintenance staff, number of breakdowns, number of hours of bypassing, etc.

Comparisons of systems, at different plants on the basis of costs to accomplish results, would be extremely difficult because of the problem of normalizing costs and differences in cost accounting. However, using the evaluation guidelines presented earlier in this section, interplant systems can be compared. Other comparisons that can be made include the following:

1. Cost of installing system (for an operating plant this could be difficult).

2. Problems in using system.

3. The extent to which the system is being used as contrasted to the systems potential.

TABLE 2. GUIDELINES FOR EVALUATING A MAINTENANCE MANAGEMENT SYSTEM

EVALUATION GUIDELINES	Maximum rating	PMMS potential	PMMS in use
Equipment Record System			
1. Equipment numbering or other identification system	20	20	20
2. System for maintaining nameplate data and other essential information	50	50	50
3. Preventive maintenance record system	30	30	30
4. Recording preventive maintenance work	20	20	20
5. Recording manpower, spare parts used	30	30	30
6. Recording cost data	30	30	30
7. Availability of maintenance related documents	20	20	20
Planning and Scheduling			
1. Schedule chart or list	20	20	20
2. Plan and schedule	30	30	30
a) PM frequency based on manufacturers and others	10	10	10
b) Integration of PM and CM organization	10	10	10
3. CM considered in planning	20	20	20
4. Work order system	30	30	30
5. Manpower management techniques	30	30	15

(continued)

TABLE 2. (continued)

EVALUATION GUIDELINES	Maximum rating	PMMS potential	PMMS in use
6. Labor standards	30	30	30
7. Contract maintenance	20	20	20
Storeroom and Inventory System			
1. Storeroom	40	40	40
2. Analysis of maintenance items needed	40	40	40
a) Monitor items in stock	20	20	20
b) Min. and max. requirements	20	20	10
c) Purchase order system	20	20	10
3. System for locating items	20	20	20
4. Index system	20	20	20
5. Withdrawal slip	20	20	20
Maintenance Organization and Personnel			
1. Organization chart	30	30	30
2. Update of chart	20	20	20
3. Job descriptions	30	30	30
4. Descriptions up to date	20	20	20
5. Analysis of job requirements	50	50	30
6. Training program	50	50	30

(continued)

TABLE 2. (continued)

EVALUATION GUIDELINES		Maximum rating	PMMS potential	PMMS in use
Cost and Budgets for Maintenance Operations				
1.	Breakdown of costs	50	50	50
2.	Labor and materials by jobs	40	40	40
3.	Maintenance cost history	30	30	30
4.	Compilation of cost information	50	50	20
5.	Contract maintenance costs	30	30	30

SECTION 7

DATA ANALYSIS

This section presents a number of examples of how the data being collected by the PMMS can be analyzed.

The validity of data analyses would, of course, depend on the accuracy of the data used for the analyses. The data collected by the maintenance staff and entered on the forms for input to the computer appear to be reliable and of sufficient accuracy. However, the interface activities between the maintenance staff and the computer has had problems that put in question some of the data coming out of the computer. Data from the forms have not been transcribed correctly, multiple entries of the same forms have been made, and not all the data have been entered into the computer. It should be pointed out that these deficiencies are not due to the PMMS but rather to an organizational problem and possibly because a computer terminal is not available at the treatment plant. Many of the deficiencies have now been corrected by the addition of a PMMS technician.

It should be further noted that in spite of what appears to be major deficiencies, the preventive and corrective maintenance activities are being carried out in a satisfactory manner due in a large measure to the PMMS. The system is considerably underused in that it does not have a complete and accurate record system that could be used by management for cost control and budget preparation and such optional features as quantitatively assessing the benefits of the system by analyzing such factors as life cycle costs, and providing information for better design, construction, and equipment evaluation and for purchasing agents.

Another major barrier to data analysis is that the records for the PMMS prior to its computerization have not been stored in a manner whereby they can be readily retrieved.

In spite of the data deficiencies enumerated above, an analysis of the data generated through the actual PMMS in use at the Lower Potomac Wastewater Treatment Plant is presented and some assessment of how benefits can be measured.

PLANT CAPACITY

The average flow at the plant has increased from 5 million gallons per day (MGD) in 1970 to 18 MGD in 1980 (over 19 MGD in 1979) - Figure 2; There has also been a corresponding increase in the influent BOD and suspended solids

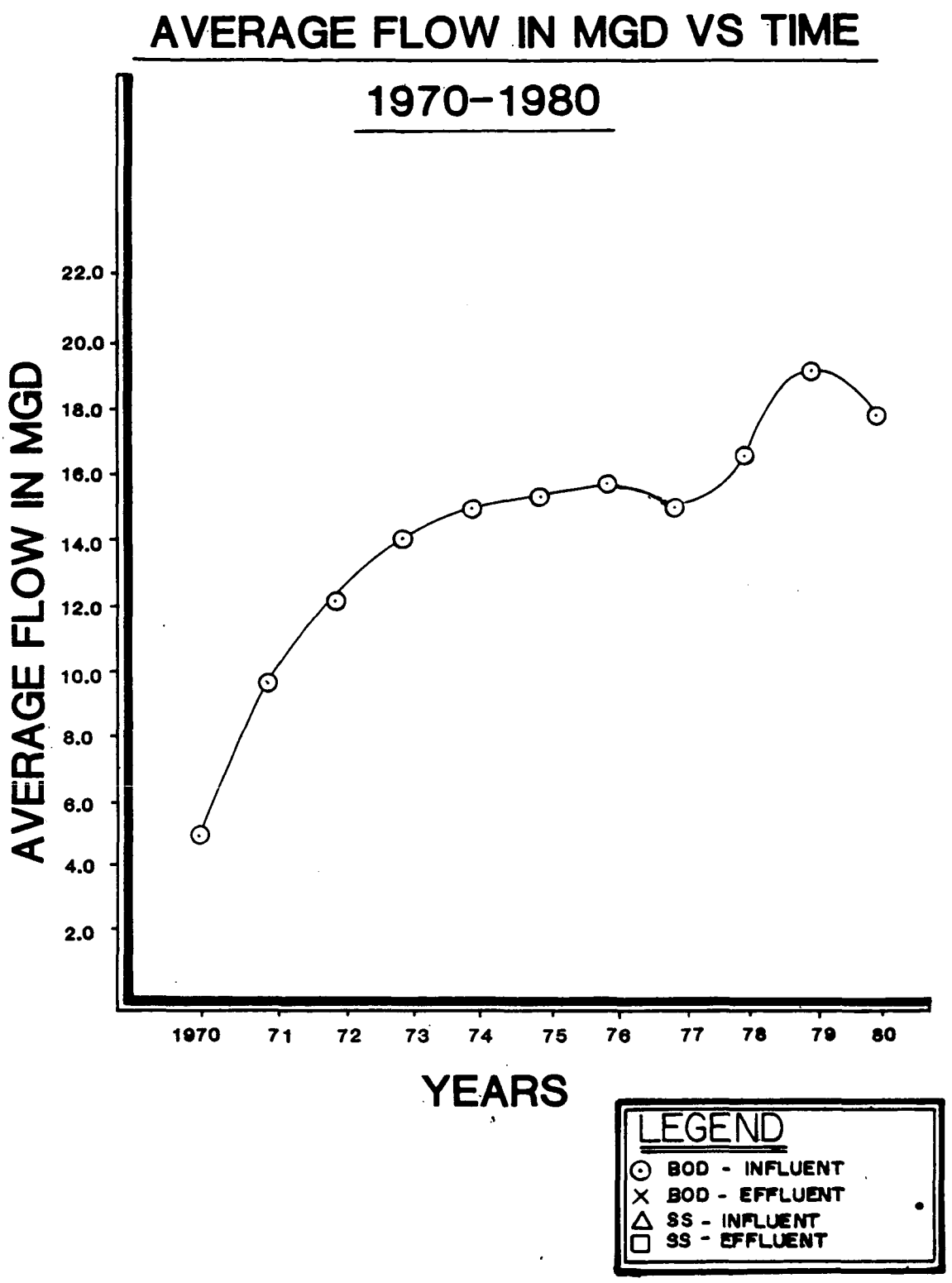

Figure 2. Average flow in MGD vs. time 1970-1980.

loading as shown in Figure 3. However, there has been a continuing improvement in plant performance, again illustrated by an actual reduction in effluent BOD and suspended solids quantities from 1972 through 1980 as also shown in Figure 3. In addition, phosphorus removal facilities were placed in operation in 1977, which increased the number of items requiring maintenance and added to the amount of solids handled at the plant.

DATA AVAILABLE FOR ANALYSIS

In the section entitled "Data Generated Through The Actual PMMS in Use," we have presented a summary of actual data generated. The only data generated regularly for data analysis are the "Monthly Corrective Maintenance Summaries" and the "Monthly Work Accomplished Summary." (See Section 5.)

These reports include the maintenance activities that are carried out at facilities other than the Lower Potomac Plant and any data analysis should take this into account.

However, in addition to the above two monthly reports, management can request a report of any or all data inputed in a wide variety of formats. To obtain this type of report may require the writing of a simple computer program.

MAINTENANCE ACTIONS AND COSTS

The number of maintenance actions taken or required and the costs associated with those actions should present a method for assessing the benefits or value of the PMMS.

The number of maintenance actions would be related to the size and age of plant, the amount of standby facilities, and the actual use of equipment.

Maintenance actions should be classified as preventive, corrective, elective (which does not necessarily relate to a malfunction or preventive maintenance), and general housekeeping. In the PMMS as now in use, elective maintenance and general housekeeping are included in corrective maintenance.

Labor costs depend on hourly rates, whether regular or overtime is used, overhead factors, and which functions, e.g., administrative, supervision, management, are charged to maintenance. Since labor rates change, the use of hours as the parameter would be a way of normalizing labor costs.

Maintenance Costs

The monthly preventive maintenance hours, standing work order hours, and corrective maintenance hours and parts costs (adjusted for noncorrective maintenance actions) are presented in Table 3.

The standing work orders include the following activities:

1. Custodial duties

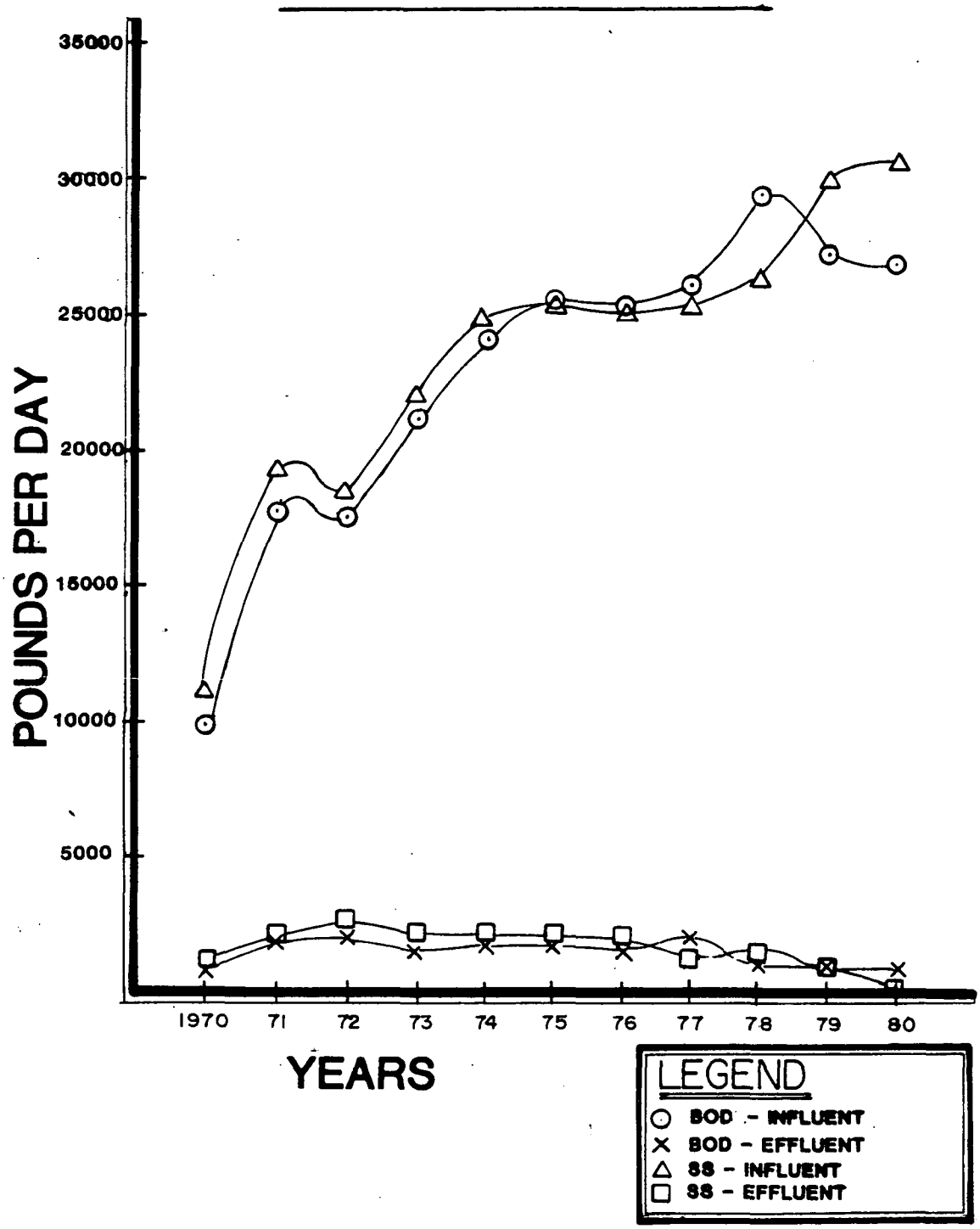

Figure 3. Influent and effluent of BOD and SS vs. time (1970-1980)

2. Supervision
3. Preparation of malfunction reports
4. Miscellaneous, buildings and grounds
5. Preventive maintenance management personnel and costs
6. Stock clerk
7. Training
8. Assist in start-up of new equipment
9. Minor maintenance
10. Clean up
11. Parts pick up

Management should be aware of the changes made against the standing work orders and should consider these categories in budgetary analysis of what is being included under maintenance costs and time.

The corrective maintenance hours and costs, which are developed for the "Monthly Corrective Maintenance Summary" and "Work Accomplished Summary," include all reported maintenance costs for a number of facilities other than the LPWTP. Before preparing Table 3, data were adjusted to include only LPWTP costs.

The reported corrective maintenance costs included certain repair and construction items that do not usually represent either preventive or corrective maintenance activities. These include such items as:

1. Moving up equipment that was installed in the wrong location.

2. Installation of new equipment.

3. Installation of safety devices and equipment not originally in stalled.

4. Modification necessary as a result of improper installations.

The reported corrective maintenance costs were adjusted by eliminating the above items from monthly totals. It is these adjusted corrective maintenance labor hours and parts costs that are presented in Table 3.

Table 4 contains monthly average maintenance data derived from Table 3 and uncorrected data from the plant records for the period of 1973 to 1975 inclusive. The following observations may be made:

1. There has been little change in preventive maintenance effort.

2. There has been a continuing increase in corrective maintenance effort. The increase generally follows the increase in plant flow. Most of the increase has taken place among the standing work orders.

3. For the period of 1976 to 1979 inclusive, overtime hours have continued to increase. However, the total overtime hours per month are approximately equivalent to one person.

TABLE 3. PM AND CM HOURS AT LPWTP 1976

	preventive maintenance			corrective maintenance									
				standing work orders			LPWTP			swo plus LPWTP			
	reg. hrs.	o.t. hrs.	total hrs.	reg. hrs.	o.t. hrs.	tot. hrs.	reg. hrs.	o.t. hrs.	total hrs.	reg. hrs.	o.t. hrs.	total hrs.	parts in $
Jan.	358	11	369	2015	16	2031	840	30	870	2855	46	2901	$2015
Feb.	244	43	287	1277	7	1284	744	38	782	2021	45	2066	1033
March	414	0	414	2254	17	2271	1193	23	1216	3447	40	3487	1800
April	432	9	441	1611	21	1632	1504	15	1519	3115	36	3151	2196
May	367	8	375	1704	25	1729	1248	15	1263	2952	40	2992	2574
June	375	0	375	2109	79	2188	1526	18	1544	3635	97	3732	3308
July	386	16	402	1653	59	1712	817	40	857	2470	99	2569	2279
Aug.	493	1	494	1347	42	1389	1530	12	1542	2877	54	2931	1799
Sept.	548	16	564	2596	77	2673	1487	24	1511	4083	101	4184	9920
Oct.	294	16	310	1264	45	1309	925	16	941	2189	61	2250	5697
Nov.	597	56	653	2466	138	2604	1521	58	1579	3987	196	4183	3585
Dec.	346	40	386	1633	33	1666	1212	49	1261	2845	82	2927	2515
1976 Monthly Average		18	423		47	1874		28	1240		75	3114	

(continued)

TABLE 3. (continued)

	preventive maintenance			corrective maintenance									
				standing work orders			LPWTP			swo plus LPWTP			
	reg. hrs.	o.t. hrs.	total hrs.	reg. hrs.	o.t. hrs.	tot. hrs.	reg. hrs.	o.t. hrs.	total hrs.	reg. hrs.	o.t. hrs.	total hrs.	parts in $
Jan.	372	0	372	1879	60	1939	1305	33	1338	3184	93	3277	$2924
Feb.	350	25	375	1814	81	1895	986	5	991	2800	86	2886	3031
March	650	13	663	1905	112	2017	1113	42	1155	3018	154	3172	4978
April	608	31	639	2553	71	2624	857	18	875	3410	89	3499	987
May	570	16	586	2484	19	2503	819	10	829	3303	29	3333	1562
June	438	26	464	2095	56	2151	1244	5	1249	3339	61	3400	3959
July	433	22	455	2201	57	2258	724	13	737	2925	70	2995	3167
Aug.	400	0	400	2147	28	2175	1021	2	1023	3168	30	3198	2383
Sept.	538	40	578	2374	109	2483	932	4	936	3306	113	3419	3471
Oct.	574	34	608	1931	76	2007	982	38	1020	2913	114	3027	5288
Nov.	437	42	479	1776	113	1889	1178	14	1192	2954	127	3081	4930
Dec.	522	32	554	2488	16	2504	1018	28	1046	3506	44	3550	4738
		23	514		67	2204		18	1032		85	3236	
1977 Monthly Average													

(continued)

TABLE 3. (continued)

	preventive maintenance			corrective maintenance									
				standing work orders			LPWTP			swo plus LPWTP			
	reg. hrs.	o.t. hrs.	total hrs.	reg. hrs.	o.t. hrs.	tot. hrs.	reg. hrs.	o.t. hrs.	total hrs.	reg. hrs.	o.t. hrs.	total hrs.	parts in $
Jan.	619	15	634	2270	14	2284	1669	165	1834	3939	179	4118	$7962
Feb.	581	30	611	2244	161	2405	895	45	940	3139	206	3345	2293
March	730	4	734	2919	128	3047	1042	63	1105	3961	191	4152	11813
April	683	32	715	3103	72	3175	1524	103	1627	4627	175	4802	7066
May	889	55	944	2931	105	3036	1578	34	1612	4509	139	4648	3637
June	420	0	420	1723	88	1811	1505	37	1542	3228	125	3353	13081
July	736	26	762	2442	43	2485	1162	81	1243	3604	124	3728	2957
Aug.	826	17	843	3258	81	3339	1283	119	1402	4541	200	4741	8730
Sept.	593	36	629	2487	101	2588	2155	55	2210	4642	156	4798	3080
Oct.	878	13	891	3337	135	3472	1239	41	1280	3576	176	3752	3553
Nov.	765	61	826	2455	50	2505	940	10	950	3395	60	3455	1843
Dec.	630	60	690	2317	64	2381	561	2	563	2878	66	2944	1299
1978 Monthly Average		29	725		87	2710		63	1359		150	4069	

(continued)

TABLE 3. (continued)

	preventive maintenance			corrective maintenance									
				standing work orders			LPWTP			swo plus LPWTP			
	reg. hrs.	o.t. hrs.	total hrs.	reg. hrs.	o.t. hrs.	tot. hrs.	reg. hrs.	o.t. hrs.	total hrs.	reg. hrs.	o.t. hrs.	total hrs.	parts in $
Jan.	1351	76	1426	4871	171	5042	1861	85	1946	6732	256	6988	$9090
Feb.	399	18	417	1445	55	1500	325	26	351	1770	81	1851	2137
March	694	52	746	2603	86	2689	1708	50	1758	4311	136	4447	9890
April	713	94	807	2440	69	2509	2811	474	3285	5251	543	5794	4166
May	160	8	168	592	8	600	619	74	693	1211	82	1293	2252
June	--	--	--	4778	190	4968	342	30	372	5120	220	5340	3555
		50	679		97	2885		123	1400		220	4285	
1979 Monthly Average													

TABLE 4. MONTHLY AVERAGE MAINTENANCE MANPOWER (MAN HOURS)

year	preventive maintenance		corrective maintenance					
			standing work orders		LPWTP		swo plus LPWTP	
	total hours	o.t. hours	total hours	o.t. hours	total hours	o.t. hours	total hours	o.t. hours
1973*	440	-	-	-	-	-	1706	-
1974*	695	-	-	-	-	-	2691	-
1975*	438	-	-	-	-	-	3178	-
1976	423	18	1874	47	1240	28	3114	75
1977	514	23	2204	67	1032	18	3236	85
1978	725	29	2710	87	1359	63	4069	150
1979	679	50	2885	97	1400	123	4285	220

* UNCORRECTED DATA - MANUAL SYSTEM

4. The data available for analysis must be carefully screened. As an example in March 1978, CM was charged with 342 hours of overtime for a single item. That item is for a new installation (elective maintenance) and could readily result in data misinterpretation. Note: The data that we have presented in Tables 3 and 4 have been adjusted for new installations.

Analysis of Corrective Maintenance Histories

As described previously, data from the corrective maintenance actions are entered into the computer. These data can then be retrieved in a number of formats to facilitate analysis and evaluation.

A history of corrective maintenance actions can be assembled by (1) major system, e.g., secondary treatment, (2) subsystem, e.g., air delivery, (3) functional unit, e.g., blowers, (4) type of equipment, e.g. air blower motor or (5) specific piece of equipment, e.g. air blower motor unit No. 3.

Each of the corrective maintenance histories could include any or all of the following information:

1. Equipment identification number
2. Equipment name
3. Job number
4. Labor hours - regular, overtime and total
5. Labor costs
6. Parts and material costs
7. Contractor costs
8. Total job costs
9. Date equipment taken out of service
10. Date corrective action completed
11. Total hours equipment has run since it was installed
12. What was wrong
13. What caused the malfunction
14. What was done to correct malfunction
15. What specific item was repaired or replaced.

Thus an analysis of a corrective maintenance history could yield the following types of beneficial information:

1. Cause of malfunction
2. Repeated malfunction of same item
3. Cost of corrective maintenance for each piece of equipment or for the cost for a major system

4. A quantitative record of where most corrective maintenance takes place

5. Cost of corrective maintenance related to age of equipment, cyclic operation, equipment loading, general operating environment, preventive maintenance, manufacturer

6. Life cycle costs
7. Frequency of corrective maintenance actions
8. Downtime of equipment for corrective maintenance
9. Optimizing parts inventory
10. Able to anticipate failure due to normal use or wear
11. Reliability of systems, equipment, etc.

Figures 4 and 5 are examples of corrective maintenance histories that can be obtained from the computer.

In utilizing the corrective maintenance data for analysis, there are a number of major factors that must be taken in account. Maintenance required by breakdown or incipient failure must be distinguished from elective or nonbreakdown maintenance. Records must be complete and accurate. There must be sufficient data (or corrective maintenance actions) for the analyses to be statistically sound.

To illustrate how data from corrective maintenance histories can be analyzed to assist maintenance and management personnel in improving plant performance, CM histories for a number of equipment items were analyzed. The equipment items are:

1. Incinerators - ID No. 6111__.
2. Sludge Plunger Pumps - ID No. 5221__.
3. Air Blowers - ID No. 3221__.
4. Vacuum Pump Motors - ID No. 5912__.
5. Chlorinators
6. Low Lift Pumps - ID No. 4341__.
7. Sludge Conveyors - ID No. 5341__.
8. Secondary Clarifiers - ID No.

For each equipment item, CM histories were analyzed and corrected for non-CM actions. The data and computed values for the following factors were tabulated:

1. Hours of equipment run
2. Period of equipment use
3. CM labor hours for hours run
4. Number of CM during hours run
5. Parts cost during hours run
6. CM labor hours during period of equipment use
7. Number of CM actions during period of equipment use
8. Parts cost during period of equipment use
9. Run hours per hour of CM
10. Run hours between CM actions
11. Run hours per $ of CM part
12. Number of hours of CM per CM action
13. $ of CM parts per CM action
14. Time interval between CM actions in months
15. CM hours per month.

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ID NO	EQUIP NAME		JOBNO	ITEM WRONG	ITEM WRONG	DESCP WRONG	DESCP WRONG	ACTN DONE	ACTN DONE	ITEM DONE	ITEM DONE	JOBYRCMP	RUN HOURS
6333106	DUPLX SLUDGE PLUNGER PUMP NO 6	020	002214					2066		2040	4071	76	
6333105	DUPLX SLUDGE PLUNGER PUMP NO 5	020	002213					2066		2040	4071	76	
6333104	DUPLX SLUDGE PLUNGER PUMP NO 4	020	002212					2066		2040	4071	76	
6333106	DUPLX SLUDGE PLUNGER PUMP NO 6	020	003194					1022		1024		76	
6333105	DUPLX SLUDGE PLUNGER PUMP NO 5	020	003193					1022		1024		76	
6333104	DUPLX SLUDGE PLUNGER PUMP NO 4	020	003192					1022		1024		76	
6333101	DUPLX SLUDGE PLUNGER PUMP NO 1	020	002635	2046		070		2025		2053		76	4.309
6333101	DUPLX SLUDGE PLUNGER PUMP NO 1	020	002615					2045		2046		76	4.701
6333103	DUPLX SLUDGE PLUNGER PUMP NO 3	020	002506	2187	2303	093		2012		2303		76	4.117
6333103	DUPLX SLUDGE PLUNGER PUMP NO 3	020	002455	2068		112		2014	2045	2241	2068	76	4.117
6333101	DUPLX SLUDGE PLUNGER PUMP NO 1	020	002412	2046		018		2045		2046		76	4.186
6333102	DUPLX SLUDGE PLUNGER PUMP NO 2	020	004928	2046		070		2025				76	9.054
6333103	DUPLX SLUDGE PLUNGER PUMP NO 3	020	004800	2144		049		2019	2053	2144		76	4.971
6333105	DUPLX SLUDGE PLUNGER PUMP NO 5	020	004645	2046		070		2025				76	7
6333104	DUPLX SLUDGE PLUNGER PUMP NO 4	020	004644	2046		070		2025				76	682
6333106	DUPLX SLUDGE PLUNGER PUMP NO 6	020	004539			060		1024		1074		76	749
6333105	DUPLX SLUDGE PLUNGER PUMP NO 5	020	004538			060		1024		1074		76	7
6333104	DUPLX SLUDGE PLUNGER PUMP NO 4	020	004537			060		1024		1074		76	682
6333104	DUPLX SLUDGE PLUNGER PUMP NO 4	020	004297					2015		2112		76	322
6333101	DUPLX SLUDGE PLUNGER PUMP NO 1	020	004180	2046		070		2025		2053		76	5.100
6333102	DUPLX SLUDGE PLUNGER PUMP NO 2	020	004178	2046		070		2025		2053		76	8.544
6333101	DUPLX SLUDGE PLUNGER PUMP NO 1	020	003786	2069	2197	070		2003	2066	2187	2197	76	4.779
6333102	DUPLX SLUDGE PLUNGER PUMP NO 2	020	003672	2267		093		2015		2267		76	8.294
6333101	DUPLX SLUDGE PLUNGER PUMP NO 1	020	003671					2014		2241		76	4.701
6333103	DUPLX SLUDGE PLUNGER PUMP NO 3	020	003670	2191		070		2066		2191		76	4.654
6333103	DUPLX SLUDGE PLUNGER PUMP NO 3	020	003431	1001		064		2015	2003	1001		76	4.654
6333103	DUPLX SLUDGE PLUNGER PUMP NO 3	020	003274					2025		2053		76	4.654
6333103	DUPLX SLUDGE PLUNGER PUMP NO 3	020	007659	2069	2046	070		2066	2025	2069		76	7.223
6333104	DUPLX SLUDGE PLUNGER PUMP NO 4	020	007349	2199		038		2053	2040	2199	2211	76	1.109
6333103	DUPLX SLUDGE PLUNGER PUMP NO 3	020	006693					2027		2046		76	6.694
6333101	DUPLX SLUDGE PLUNGER PUMP NO 1	020	005889					2025				76	6.537
6333103	DUPLX SLUDGE PLUNGER PUMP NO 3	020	005788	2069	2046	057	070	2025	2015		2069	76	6.023
6333102	DUPLX SLUDGE PLUNGER PUMP NO 2	020	005671					2012		2069		76	9.744
6333102	DUPLX SLUDGE PLUNGER PUMP NO 2	020	005575					2012		2053		76	9.744
6333101	DUPLX SLUDGE PLUNGER PUMP NO 1	020	005421					2025		2053		76	5.953
6333103	DUPLX SLUDGE PLUNGER PUMP NO 3	020	005113	2046	2068	070	093	2025	2015	2068	2002	76	5.382
6333102	DUPLX SLUDGE PLUNGER PUMP NO 2	020	011947					2015	2012	2179		77	11.104
6333106	DUPLX SLUDGE PLUNGER PUMP NO 6	020	011945	1068		070		1037		1068		77	1.916
6333103	DUPLX SLUDGE PLUNGER PUMP NO 3	020	011404	2069	2002	070		2015		2069	2002	77	9.825
6333103	DUPLX SLUDGE PLUNGER PUMP NO 3	020	010626	2053		078		2019	2049		2049	77	9.042
6333102	DUPLX SLUDGE PLUNGER PUMP NO 2	020	010625	2046		112		2027		2046		77	11.019
6333101	DUPLX SLUDGE PLUNGER PUMP NO 1	020	010624	2046	2260	070	043	2025	2015	2053	2260	77	9.948
6333106	DUPLX SLUDGE PLUNGER PUMP NO 6	020	010507	2046		070		2025				77	1.328
6333105	DUPLX SLUDGE PLUNGER PUMP NO 5	020	010415					2015		2112		77	896
6333104	DUPLX SLUDGE PLUNGER PUMP NO 4	020	009350					2019	2012	2211		77	1.945
6333103	DUPLX SLUDGE PLUNGER PUMP NO 3	020	009131	2046		070		2025				77	7.986
6333102	DUPLX SLUDGE PLUNGER PUMP NO 2	020	008851	2046		070		2025		2053		77	11.019
6333101	DUPLX SLUDGE PLUNGER PUMP NO 1	020	008598	2046		070		2025		2053		77	8.120
6333103	DUPLX SLUDGE PLUNGER PUMP NO 3	020	008402			036	119	2066		2298	2295	77	7.708
6333104	DUPLX SLUDGE PLUNGER PUMP NO 4	020	008380			119		2066				77	1.572
6333102	DUPLX SLUDGE PLUNGER PUMP NO 2	020	013525	2046		070		2025				77	11.104
6333101	DUPLX SLUDGE PLUNGER PUMP NO 1	020	013468	2046		070		2025				77	13.053

Figure 4. Corrective maintenance history no. 141 - 1976.

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ID NO	EQUIP NAME		JOBNO	REG HR	OT HR	LABOR COST	PART COST	TOTAL JOB COST	MNTH	YR
522103	DUPLX SLUDGE PLUNGER PUMP NO 3	020	007874	80.0	.0	41.72	.00	41.72	01	77
JOBNO TOTAL				80.0	.0	41.72	.00	41.72		
522101	DUPLX SLUDGE PLUNGER PUMP NO 1	020	013000	8.0	.0	44.40	.00	44.40	11	77
JOBNO TOTAL				8.0	.0	44.40	.00	44.40		
522102	DUPLX SLUDGE PLUNGER PUMP NO 2	020	010651	8.0	.0	38.98	.00	38.98	06	77
JOBNO TOTAL				8.0	.0	38.98	.00	38.98		
522101	DUPLX SLUDGE PLUNGER PUMP NO 1	020	010650	12.0	.0	57.36	.00	57.36	07	77
JOBNO TOTAL				12.0	.0	57.36	.00	57.36		
522104	DUPLX SLUDGE PLUNGER PUMP NO 4	020	010648	3.0	.0	18.78	.00	18.78	07	77
JOBNO TOTAL				3.0	.0	18.78	.00	18.78		
522101	DUPLX SLUDGE PLUNGER PUMP NO 1	020	010647	2.0	.0	12.52	.00	12.52	07	77
JOBNO TOTAL				2.0	.0	12.52	.00	12.52		
522104	DUPLX SLUDGE PLUNGER PUMP NO 4	020	010130	16.0	.0	83.30	.00	83.30	07	77
JOBNO TOTAL				16.0	.0	83.30	.00	83.30		
522104	DUPLX SLUDGE PLUNGER PUMP NO 4	020	015903	31.0	.0	174.58	.00	174.58	05	78
JOBNO TOTAL				31.0	.0	174.58	.00	174.58		
522104	DUPLX SLUDGE PLUNGER PUMP NO 4	020	015468	25.0	.0	151.60	360.00	511.60	04	78
JOBNO TOTAL				25.0	.0	151.60	360.00	511.60		
522103	DUPLX SLUDGE PLUNGER PUMP NO 3	020	014267	8.0	.0	44.40	.00	44.40	02	78
JOBNO TOTAL				8.0	.0	44.40	.00	44.40		
522101	DUPLX SLUDGE PLUNGER PUMP NO 1	020	013725	12.0	.0	57.40	81.20	138.60	01	78
JOBNO TOTAL				12.0	.0	57.40	81.20	138.60		
522103	DUPLX SLUDGE PLUNGER PUMP NO 3	020	019070	16.0	.0	103.44	9.46	112.90	09	78
JOBNO TOTAL				16.0	.0	103.44	9.46	112.90		
522103	DUPLX SLUDGE PLUNGER PUMP NO 3	020	018968	20.0	.0	129.80	948.46	1,078.26	09	78
JOBNO TOTAL				20.0	.0	129.80	948.46	1,078.26		
522103	DUPLX SLUDGE PLUNGER PUMP NO 3	020	018039	2.0	.0	13.64	.00	13.64	08	78
JOBNO TOTAL				2.0	.0	13.64	.00	13.64		
522104	DUPLX SLUDGE PLUNGER PUMP NO 4	020	023172	16.0	.0	109.36	21.31	130.67	03	79
JOBNO TOTAL				16.0	.0	109.36	21.31	130.67		
522102	DUPLX SLUDGE PLUNGER PUMP NO 2	020	024350	2.0	.0	11.40	.00	11.40	05	79
JOBNO TOTAL				2.0	.0	11.40	.00	11.40		
522102	DUPLX SLUDGE PLUNGER PUMP NO 2	020	024179	1.0	.0	5.70	.00	5.70	04	79
JOBNO TOTAL				1.0	.0	5.70	.00	5.70		
522101	DUPLX SLUDGE PLUNGER PUMP NO 1	020	023471	2.0	.0	11.40	.00	11.40	03	79
JOBNO TOTAL				2.0	.0	11.40	.00	11.40		

Figure 5. Corrective maintenance history cost 1976.

The results of the analyses are presented in Tables 5 through 20 inclusive. A comparison among the various units within each equipment category can be readily made.

A summary of analyses of corrective maintenance histories is presented in Tables 21 and 22. A comparison among various equipment categories can be readily made.

Use of Data Analyses

The purpose of analyzing maintenance data is to obtain the benefits that were discussed in Section 6. These benefits could include the following:

1. Decreased downtime of equipment
2. Decreased costs of maintenance
3. More effective use of PM
4. Manufacturing, installation, or design defect identification
5. Improved plant performance
6. Determination of life-cycle costs
7. Reduction in spare parts inventory
8. Equipment evaluation
9. Effective use of maintenance personnel

The analyzed data should be of considerable value to management and maintenance personnel. However, IT IS ESSENTIAL THAT SOMEONE BE ASSIGNED THE RESPONSIBILITY OF ANALYZING THE DATA THAT ARE BEING COLLECTED. Furthermore, the results of the analysis should be implemented by modifying any necessary maintenance procedures.

TABLE 5. ANALYSIS OF CORRECTIVE MAINTENANCE HISTORY 1976-1980

INCINERATORS ID NO. 6111

Unit no.	Hrs. run	Labor hrs. for hrs. run	No. of CM during hrs. run	Parts cost during hrs. run	Labor hrs. during time int.	No. of CM during time int.	Parts cost during time int.
No. 1	1273	279	9	$ 1117	317	10	$ 1117
No. 2	4556	296	8	1703	376	10	1703
No. 3	34847	1679	54	21860	1691	57	21860
No. 4	32577	965	33	13342	973	33	13346
TOTAL	73253	3219	104	$ 38022	3357	110	$ 38026

TABLE 6. ANALYSIS OF CORRECTIVE MAINTENANCE HISTORY 1976-1980

INCINERATORS ID NO. 6111__

Unit no.	Run hrs. per hr. of CM	Hrs. of run between CM actions	Hrs. of run per $ of CM part	No. of hrs. of CM per CM action	$ of CM parts per CM action	Time internal between CM actions months	CM hrs. per month
Incinerator No. 1	4.6	141	1.1	3.2	$ 110	4.8	6.6
No. 2	15	570	2.7	38	170	4.8	7.8
No. 3	21	645	1.6	30	384	1.0	28
No. 4	34	990	2.4	29	404	1.6	16
All equip* in category	23	700	1.9	31	$ 345	0.5	56

* Based on 60 months.

TABLE 7. ANALYSIS OF CORRECTIVE MAINTENANCE HISTORY 1976-1980

SLUDGE PLUNGER PUMPS ID NO. 5221__

Unit no.	Hrs. run	Labor hrs. for hrs. run	No. of CM during hrs. run	Parts cost during hrs. run	Labor hrs. during time int.	No. of CM during time int.	Parts cost during time int.
No. 1	10085	288	23	$ 789	288	24	$ 789
No. 2	2810	116	12	738	127	13	745
No. 3	14133	233	20	1022	241	21	1022
No. 4	14743	222	22	863	242	23	877
No. 5	11680	30	7	83	40	8	97
No. 6	3380	37	9	208	49	10	231
TOTAL	56831	926	113	$ 3703	987	99	$ 3761

TABLE 8. ANALYSIS OF CORRECTIVE MAINTENANCE HISTORY 1976-1980

SLUDGE PLUNGER PUMPS ID NO. 5221__

Unit no.	Run hrs. per hr. of CM	Hrs. of run between CM actions	Hrs. of run per $ of CM part	No. of hrs. of CM per CM action	$ of CM parts per CM action	Time internal between CM actions months	CM hrs. per month
Plunger Pump No. 1	35	438	13	12	$ 33	2.5	4.8
No. 2	24	122	3.6	9.8	57	4.6	2.1
No. 3	61	710	13.8	11	49	2.9	4.0
No. 4	65	660	17	11	38	2.6	4.0
No. 5	390	1670	141	5	12	7.5	0.7
No. 6	91	375	16	5	23	6	0.8
All Equip. in category	61	500	15	10	$ 38	0.6	16.5

TABLE 9. ANALYSIS OF CORRECTIVE MAINTENANCE HISTORY 1976-1980

AIR BLOWERS ID NO. 3221__

Unit No.	Hrs. run	Labor hrs. for hrs. run	No. of CM during hrs. run	Parts cost during hrs. run	Labor hrs. during time int.	No. of CM during time int.	Parts cost during time int.
1							
2	7902	18	2	$ 0	26	3	$ 0
3	14100	67	5	410	65	6	423
4	9941	384	7	73	392	8	78
5	15029	154	11	521	168	12	521
TOTAL	46972	623	25	$1004	625	26	$1022

TABLE 10. ANALYSIS OF CORRECTIVE MAINTENANCE HISTORY 1976-1980

AIR BLOWERS ID NO. 3221__

Unit no.	Run hrs. per hr. of CM	Hrs. of run between CM actions	Hrs. of run per $ of CM part	No. of hrs. of CM per CM action	$ of CM parts per CM action	Time internal between CM actions months	(60 Months) CM hrs. per month
Blower No. 3	21	2820	35	13	$ 11	10	1.1
No. 4	26	26	136	55	49	7.5	6.5
No. 5	98	98	29	14	14	5	2.8
No. 2	439	3950	--	9	--	--	--
All Equip. in category	75	1880	47	24	$ 39	2.3	10.4

TABLE 11. ANALYSIS OF CORRECTIVE MAINTENANCE HISTORY 1976-1980

VACUUM PUMP MOTORS ID NO. 5912

Unit no.	Hrs. run	Labor hrs. for hrs. run	No. of CM during hrs. run	Parts cost during hrs. run	Labor hrs. during time int.	No. of CM during time int.	Parts cost during time int.
1	--				93	2	$ 760
3	15438	141	5	$ 230	165	6	505
4	13264	40	6	0	55	7	130
TOTAL	28702	181	11	$ 230	313	15	$ 760

TABLE 12. ANALYSIS OF CORRECTIVE MAINTENANCE HISTORY 1976-1980

VACUUM PUMP MOTORS ID NO. 5912__

Unit no.	Run hrs. per hr. of CM	Hrs. of run between CM actions	Hrs. of run per $ of CM part	No. of hrs. of CM per CM action	$ of CM parts per CM action	Time internal between CM actions months	CM hrs. per month
1				47	$ 63		
3	109	3090	67	28	64		
4	332	2210	--	8	19		
All equip. in category	159	2610	125	21	$ 51		

TABLE 13. ANALYSIS OF CORRECTIVE MAINTENANCE HISTORY 1976-1980

CHLORINATORS

Unit no.	Hrs. run	Labor hrs. for hrs. run	No. of CM during hrs. run	Parts cost during hrs. run	5 Labor hrs. during time int.	6 No. of CM during time int.	7 Parts cost during time int.
1 Prechlor.					54	2	$ 746
2 East					114	10	234
3 Standby					106	6	182
4 West					85	7	145
5 Gravity					15	3	15
TOTAL					374	28	$1322

TABLE 14. ANALYSIS OF CORRECTIVE MAINTENANCE HISTORY 1976-1980

CHLORINATORS

	Run hrs. per hr. of CM	Hrs. of run between CM actions	Hrs. of run per $ of CM part	No. of hrs. of CM per CM action	$ of CM parts per CM action	Time internal between CM actions months	CM hrs. per month
Pre.				27	$ 370	30	0.9
East				11	23	6	1.9
Standby				18	30	10	1.8
West				14	21	9	1.4
Gravity				5	5	20	0.4
All equip. in category				13	$ 47	2.1	6.2

Assume 60 months

TABLE 15. ANALYSIS OF CORRECTIVE MAINTENANCE HISTORY 1976-1980

LOW LIFT PUMPS ID NO. 4341

Unit no.	Run hrs. per hr. of CM	Hrs. of run between CM actions	Hrs. of run per $ of CM part	No. of hrs. of CM per CM action	$ of CM parts per CM action	Time internal between CM actions months	CM hrs. per month
Low Lift Pump No. 1	250	3590	230	13	$ 14	4.8	2.8
Low Lift Pump No. 2	78	860	89	10	9	5.3	1.9
Low Lift Pump No. 3	184	900	127	6	6	4.4	1.4
Low Lift Pump No. 4	18	260	5	14	48	3.7	3.8
All equip. in category	116	1320	56	11	$ 21	1.1	9.8

TABLE 16. ANALYSIS OF CORRECTIVE MAINTENANCE HISTORY 1976-1980

LOW LIFT PUMPS ID NO. 4341__

Unit no.	Hrs. run	Labor hrs. for hrs. run	No. of CM during hrs. run	Parts cost during hrs. run	Labor hrs. during time int.	No. of CM during time int.	Parts cost during time int.
1	32325	130	9	$ 138	134	10	$ 138
2	6887	88	8	77	90	9	77
3	8998	49	10	71	67	11	71
4	3137	177	12	626	181	13	629
TOTAL	51347	444	39	$ 912	472	43	$ 915

TABLE 17. ANALYSIS OF CORRECTIVE MAINTENANCE HISTORY 1976-1980

SLUDGE CONVEYORS ID NO. 5341__

Unit no.	Hrs. run	Labor hrs. for hrs. run	No. of CM during hrs. run	Parts cost during hrs. run	Labor hrs. during time int.	No. of CM during time int.	Parts cost during time int.
1							
2	6199	313	21	$ 4198	313	22	$ 4198
3							
4	5694	6514	22	4191	654	23	$ 5124
5	41047	159	12	1103	300	13	1103
6	24346	115	15	1991	115	16	1991
7	12097	613	27	4598	613	28	4598
8	6883	272	10	354	272	11	354
TOTAL	96266	1986	107	$ 16435	2539	113	$ 17368

TABLE 18. ANLAYSIS OF CORRECTIVE MAINTENANCE HISTORY 1976-1980

SLUDGE CONVEYORS ID NO. 5341__

Unit. no.	Run hrs per hrs. of CM	Hrs. of run between CM actions	Hrs. of run per $ of CM part	No. of hrs. of CM per CM action	$ of CM parts per CM action	Time internal between CM actions months	CM hrs. per month
1							
2	20	295	1.5	14	$ 191		
3							
4	11	260	1.4	2.8	222		
5	258	3420	37	23	85		
6	212	1620	12	7	124		
7	20	450	2.6	22	164		
8	25	688	19	25	32		
All equip. in category	48	900	5.9	22	$ 154		

TABLE 19. ANALYSIS OF CORRECTIVE MAINTENANCE HISTORY 1976-1980

SECONDARY CLARIFIERS

Unit no.	Hrs. run	Labor hrs. for hrs. run	No. of CM during hrs. run	Parts cost during hrs. run	Labor hrs. during time int.	No. of CM during time int.	Parts cost during time int.
1	22591	139	15	$ 268	139	15	$ 268
2	25492	38	5	47	40	6	60
3	5659	147	15	165	157	16	165
4	16694	254	16	388	264	17	388
TOTAL ALL UNITS	70436	578	51	$ 868	600	54	$ 881

TABLE 20. ANALYSIS OF CORRECTIVE MAINTENANCE HISTORY 1976-1980

SECONDARY CLARIFIERS

No. of unit	Run hrs. per hr. of CM	Hrs. of run between CM actions	Hrs. of run per $ of CM part	No. of hrs. of CM per CM action	$ of CM parts per CM action	Time internal between CM actions months	CM hrs. per month
Clarifier No. 1	163	1510	84	9.2	$ 18	3.2	2.9
Clarifier No. 2	670	5100	670	6.7	10	8.0	0.8
Clarifier No. 3	38	377	34	10	6	3.0	1.2
Clarifier No. 4	66	1040	43	16	23	2.8	5.5
All equip. in category	122	1380	81	11	$ 16	0.9	12.5

TABLE 21. SUMMARY OF ANALYSES OF CORRECTIVE MAINTENANCE HISTORIES

Equipment category	No. of units	Run hrs. per hr. of CM	Hrs. of run between CM actions	Hrs. of run per $ of CM part	No. of hrs. of CM per CM action	$ of CM parts per CM action	Time internal between CM actions months	CM hrs. per month
Clarifiers	4	122	1380	81	11	16	0.9	12.5
Low Lift Pumps	4	116	1320	56	11	21	1.1	9.8
Incinerator	4	23	700	2	31	345	0.5	56
Chlorinators	5				13	47	2.1	6.2
Plunger Pumps	6	61	500	15	10	38	0.6	16.5
Sludge Conveyors	6	48	900	6	22	154		
Vacuum Pump Motors	3	159	2610	125	21	51		
Air Blowers	4	75	1880	47	24	39	2.3	10.4

TABLE 22. SUMMARY OF ANALYSES OF CORRECTIVE MAINTENANCE HISTORIES

Equipment category	Labor hrs. per CM		Part costs $ per CM		Total CM labor hours	Total no. of CM	Total CM parts $
	Aver	Max	Aver	Max	-----	---------	------
Clarifiers	11	71	$ 16	$ 278	600	54	$ 881
Low Lift Pump	11	50	21	285	472	43	915
Incinerator	31	597	345	9454	3357	110	38026
Chlorinator	13	35	47	684	374	28	1322
Plunger pump	10	67	38	400	987	99	3761
Air Blowers	24	340	39	436	625	26	1022
Sludge Conveyors	22	148	154	3511	2539	113	17368
Vacuum Pump Motors	21	80	51	275	313	15	760

Data Analysis

The performance of the treatment plant since the introduction of the PMMS in 1972 has yielded a satisfactory effluent (Figure 3) while the flow has nearly doubled (Figure 2).

The increase in overtime hours has been minimal. The maintenance staff reports that the frequency of emergency corrective maintenance actions has decreased, impending failures have been identified and prevented, additional elective maintenance can be performed with available staff and the general appearance of the plant continues to improve.

Much of the above benefits can be attributed to the PMMS. However, considerably more benefits could be obtained by the analysis and use of data that are currently being stored in the computer. The following are examples of how these data may be used.

Manpower and Costs--

Table 4 - Monthly Average Maintenance Manpower - summarizes the actual reported manpower utilized for preventive and corrective maintenance. PM has been 425 to 725 man-hours per month, which is approximately 15 to 25 percent of CM. Over the years, CM has increased but the major position of that increase has been in the Standing Work Orders (from 1870 to 2885 man-hours per month from 1976 to 1979). The hours devoted to PM has not changed significantly over the year. Overtime hours, although increasing from 93 to 270 man-hours per month from 1976 to 1979, have remained relatively low. These data, particularly the time reported as Standing Work Orders, should be analyzed by management in detail to determine if data are being correctly recorded, personnel are correctly assigned, personnel can be more effectively utilized, etc.

Corrective Maintenance Histories--

Tables 5 through 22 provide examples of how data can be analyzed to bring about a reduction in downtime of equipment and costs (man-hours and parts). Tables 5 and 6 present an analysis of data related to the four incinerators for the period of 1976-80 and is used to illustrate how data may be analyzed. Each of the following points should be reviewed by maintenance and management personnel to determine the reasons for the variability of the data and whether any changes in maintenance procedures or frequencies are in order.

1. Hours run per incinerator ranged from 1273 to 34,847, with two of the incinerators in use most of the time.

2. The CM labor hours ranged from 279 to 1679 per incinerator. Although the higher CM labor hours were associated with the incinerators that were operated for longer periods, incinerator no. 3 required 1679 CM hours while incinerator no. 4 required only 965 hours. Parts costs were $21,860 and $13,346, and the number of CM actions were 57 and 33, respectively for no. 3 and no. 4.

3. The average number of hours run per hour of CM was 23 but the range was 5 to 34.

4. The average number of hours run between CM actions was 700 but the range was 141 to 990.

5. The hours of run per dollar of CM part averaged 1.9 with a range of 1.1 to 2.4.

6. The average number of hours of CM per CM action was 31 with a range of averages of 3.2 to 38. Note: The maximum for a single CM was 597 (Table 22).

7. The average cost of parts per CM action was $345 with a range of averages $110 to $404. Note: The maximum for a single CM was $9454 (Table 22).

8. The average time interval between CM actions ranged from 1.0 to 4.8 months.

9. The average CM hours ranged from 6.6 to 28 hours per month.

In addition to the analysis of specific pieces of equipment, e.g., incinerators, a comparison among groups of equipment within the plant can also be made. Table 22 presents a summary of CM data for that comparison.

An analysis of Table 22 indicates that the incinerators and sludge conveyors had extremely high CM labor and parts, 3357 and 2539 man-hours and $38,026 and $17,368, respectively, during 1976 to 1980. Plunger pumps also require frequent CM and costly parts.

The experience of other plants with the same equipment would make a valuable comparison but those data are not as yet readily available.

It is important to note that there was no change in PM procedures or frequencies during the period for which data are presented.

An even more detailed analysis, which should be carried out on a regular basis, should attempt to determine why some units need more frequent and more costly CM. Are there particular parts that are failing? Could additional PM reduce CM? Would additional PM be cost-effectiveness? Is excessive CM due to poor installation? Is proper equipment being used? Are there sufficient data to determine expected life of part and provide for replacement before actual failure? Etc.

Based on the data presented in Table 22, is the distribution of PM effort among the various equipment appropriate?

Thus, by an analysis of data and, if necessary, a review of each CM action as reported in the CM Work Order Request, steps can be taken to (1) revise PM procedures, (2) assure proper installation of equipment, and/or (3)

have properly sized and specified equipment. These steps would then provide for obtaining the full benefits of the PMMS that have been previously discussed.

APPENDIX A

FORMS FOR PMMS AS ORIGINALLY INSTALLED

Forms

M1 - Equipment Reference Data - Figure A1
Reverse side - Parts List - Figure A2

M2 - Equipment Maintenance Record - Figure A3

M3 - Preventive Maintenance Work Record - Figure A4
Reverse side - Report of Trouble - Figure A5

M3x - Preventive Maintenance Work Record (ALT) - Figure A6

M4 - Equipment Malfunction Report - Figure A7

M5 - Corrective Maintenance Work Order - Figure A8

M6 - Corrective Maintenance Work Order and Work Record - Figure A9

M7 - Weekly Maintenance Summary Report - Figure 10
Reverse side - Corrective Maintenance Summary - Figure A11

M8 - Maintenance Procedure Sheet - Figure A12
Reverse side - Figure A13

In addition to the above forms, the system requires a functional numbering and an equipment type number.

EQUIPMENT REFERENCE DATA

Equipment Name and Number	Type No.	ID No.	Plant Area	Level	Location in Area	Rel. Location

Manufacturer	Local Representative	Part or Model Number	Serial Number

Reference Drawing	Reference Catalog	Instruction Book	Date Put in Service

Electric Motor			Pump			Drive or Reducer		
HP	Frame	RPM	Capacity	TDH	RPM	HP	RPM In	RPM Out
Volts	**Amps**	**Phase**	**Impeller**		**Packing**	**Ratio**		

Type	Specification	Type	Installation	Type
☐ Series	☐ Open	☐ Centrifugal	☐ Horizontal	☐ Gear
☐ Shunt	☐ Exp. proof	☐ Plunger	☐ Vertical	☐ V-Belt
☐ Synchronous	☐ Drip proof	☐ Diaphragm	☐ Submerged	☐ Chain
☐ Induction	☐ Totally enclosed	☐ Gear	Lubrication	☐ Varidrive
☐ _____	☐ _____	☐ Screw	☐ Water	
		☐ _____	☐ Oil	
			☐ Grease	

Bearings	Bearings	Bearings
☐ Sleeve ☐ Ball ☐ Roller	☐ Sleeve ☐ Ball ☐ Roller	☐ Sleeve ☐ Ball ☐ Roller
Lubricant	**Lubricant**	**Lubricant**

Other Equipment
Type, Speed, Size, Capacity, Range
Bearings, Lubricant
Other Features

Form M1-5/72

Figure A1. Form M1, equipment reference data.

PARTS LIST

Name of Part	Manufacturer	Cat. No.	Local Supplier	Cost

Form M1 Reverse)-5/72

Figure A2. Form M1 (reverse) parts list.

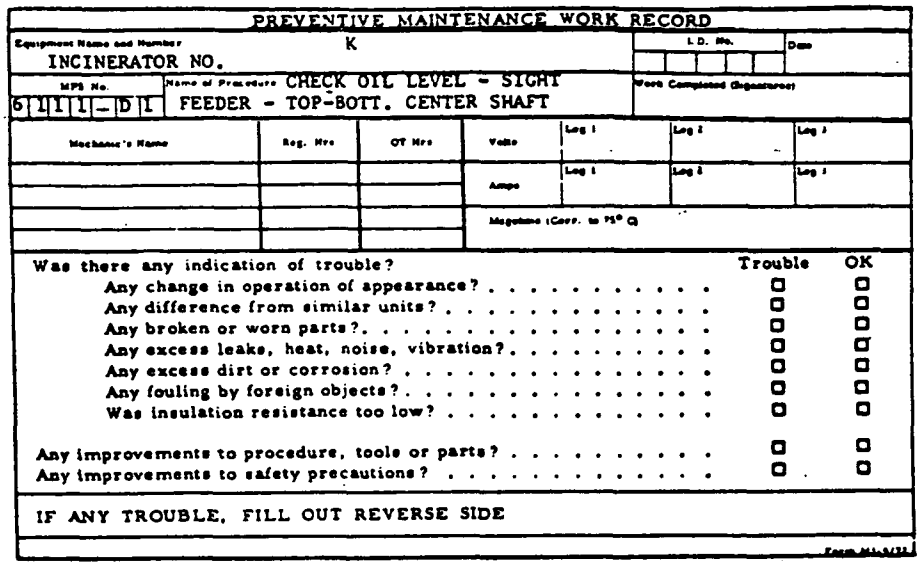
EQUIPMENT MAINTENANCE RECORD

Equipment Name and Number	I. D. No.	Serial No.	Location	Record Sheet No.

Date	MPC No. or Job No.	Labor			Observations		Volts			Amps			Meg Ohms			Remarks and Data
		Skill	Initials	Hours	Ind.	Med.	Leg 1	Leg 2	Leg 3	Leg 1	Leg 2	Leg 3	Leg 1	Leg 2	Leg 3	

Form M2-5/72

Figure A3. Form M2, equipment maintenance record.



PREVENTIVE MAINTENANCE WORK RECORD

Equipment Name and Number: INCINERATOR NO. K

I.D. No. | Date

MPS No.: 6 1 1 1 – D 1

Name of Procedure: CHECK OIL LEVEL - SIGHT FEEDER - TOP-BOTT. CENTER SHAFT

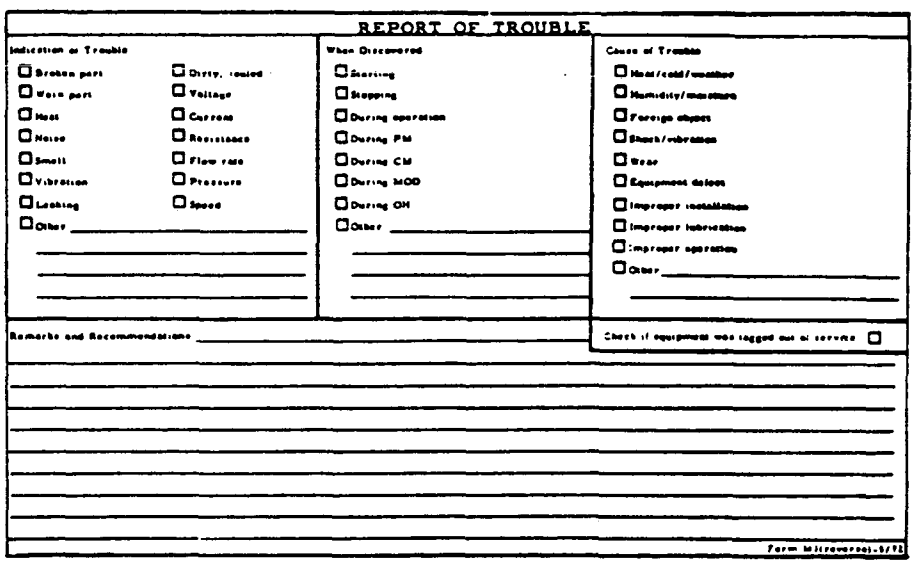
Work Completed (Signature)

Mechanic's Name	Reg. Hrs	OT Hrs		Log 1	Log 2	Log 3
			Volts			
			Amps			
			Megohms (Corr. to 75° C)			

Was there any indication of trouble?	Trouble	OK
Any change in operation of appearance?	☐	☐
Any difference from similar units?	☐	☐
Any broken or worn parts?	☐	☐
Any excess leaks, heat, noise, vibration?	☐	☐
Any excess dirt or corrosion?	☐	☐
Any fouling by foreign objects?	☐	☐
Was insulation resistance too low?	☐	☐
Any improvements to procedure, tools or parts?	☐	☐
Any improvements to safety precautions?	☐	☐

IF ANY TROUBLE, FILL OUT REVERSE SIDE

Figure A4. Form M3, preventive maintenance work record.



REPORT OF TROUBLE

Indication of Trouble

☐ Broken part ☐ Dirty, soiled
☐ Worn part ☐ Voltage
☐ Heat ☐ Current
☐ Noise ☐ Resistance
☐ Smell ☐ Flow rate
☐ Vibration ☐ Pressure
☐ Leaking ☐ Speed
☐ Other _____

When Discovered

☐ Starting
☐ Stopping
☐ During operation
☐ During PM
☐ During CM
☐ During MOD
☐ During OH
☐ Other _____

Cause of Trouble

☐ Heat/cold/weather
☐ Humidity/moisture
☐ Foreign object
☐ Shock/vibration
☐ Wear
☐ Equipment defect
☐ Improper installation
☐ Improper lubrication
☐ Improper operation
☐ Other _____

Remarks and Recommendations _____

Check if equipment was tagged out of service ☐

Figure A5. Form M3 (reverse) report of trouble.

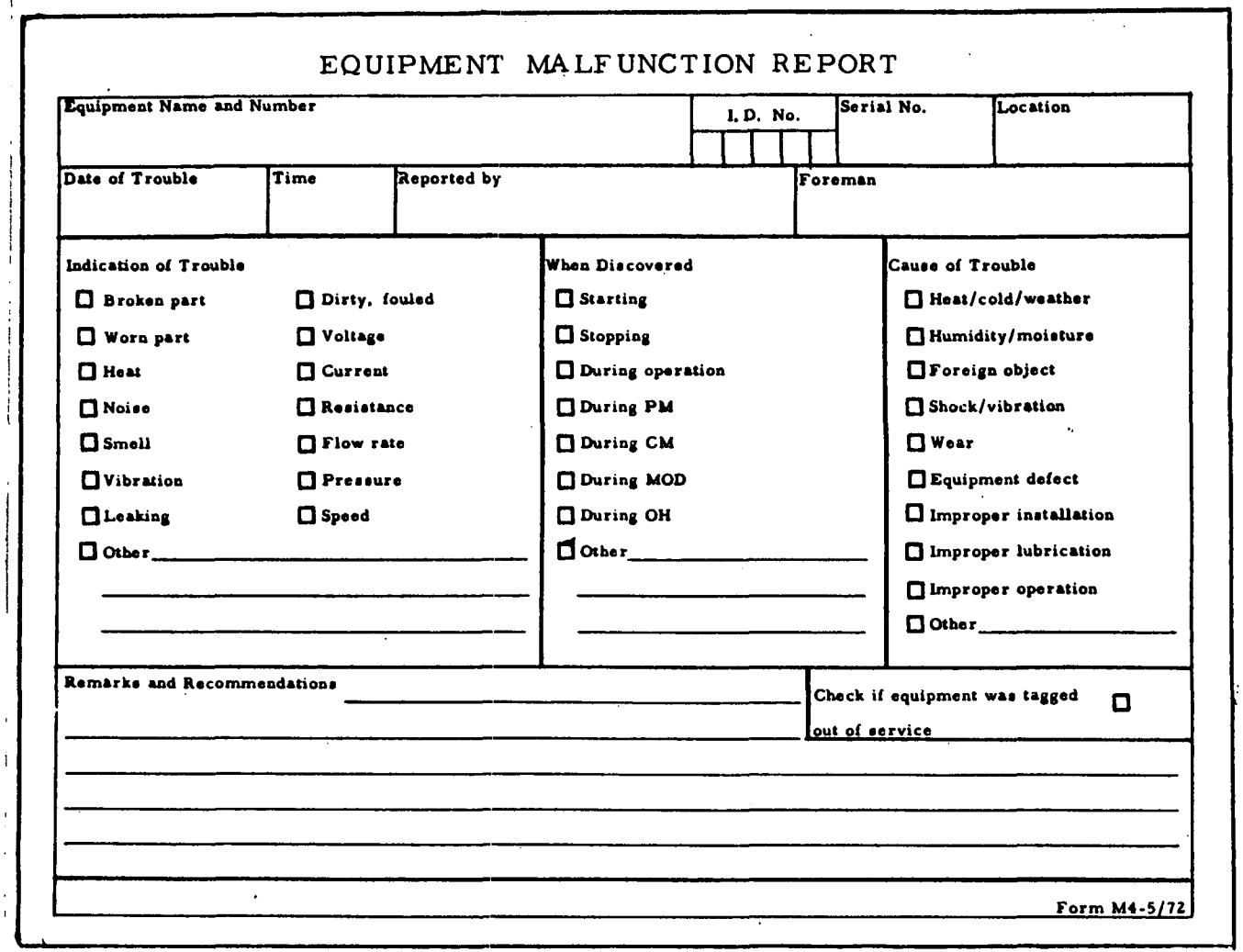
Date	Mechanic's Name	Reg.Hrs	OT Hrs	Date	Mechanic's Name	Reg.Hrs	OT Hrs

REPORT OF TROUBLE

INDICATION OF TROUBLE		WHEN DISCOVERED	CAUSE OF TROUBLE
_Broken part	_Dirty, fouled	_Starting	_Heat/Cold/weather
_Worn part	_Voltage	_Stopping	_Humidity/moisture
_Heat	_Current	_During operation	_Foreign object
_Noise	_Resistance	_During PM	_Shock/vibration
_Smell	_Flow rate	_During CM	_Wear
_Vibration	_Pressure	_During MOD	_Equipment defect
_Leaking	_Speed	_During OH	_Improper installation
_Other		_Other	_Improper lubrication
			_Improper operation
			_Other

Remarks and Recommendations	Check if equipment was tagged out of service

Figure A6. Form M3X, preventive maintenance record (ALT).



EQUIPMENT MALFUNCTION REPORT

Equipment Name and Number	I. D. No.	Serial No.	Location

Date of Trouble	Time	Reported by	Foreman

Indication of Trouble

- ☐ Broken part
- ☐ Worn part
- ☐ Heat
- ☐ Noise
- ☐ Smell
- ☐ Vibration
- ☐ Leaking
- ☐ Dirty, fouled
- ☐ Voltage
- ☐ Current
- ☐ Resistance
- ☐ Flow rate
- ☐ Pressure
- ☐ Speed
- ☐ Other _____

When Discovered

- ☐ Starting
- ☐ Stopping
- ☐ During operation
- ☐ During PM
- ☐ During CM
- ☐ During MOD
- ☐ During OH
- ☐ Other _____

Cause of Trouble

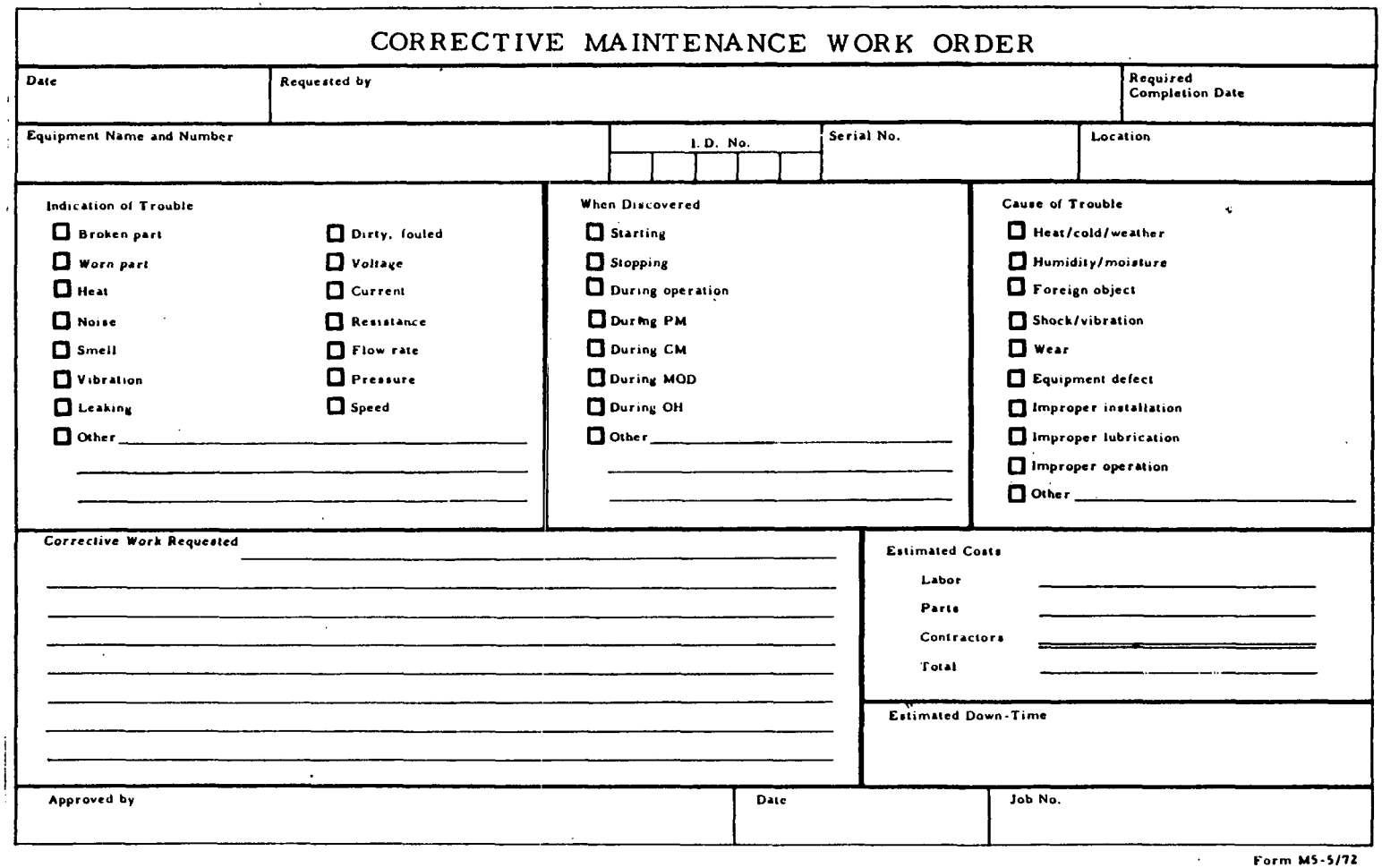
- ☐ Heat/cold/weather
- ☐ Humidity/moisture
- ☐ Foreign object
- ☐ Shock/vibration
- ☐ Wear
- ☐ Equipment defect
- ☐ Improper installation
- ☐ Improper lubrication
- ☐ Improper operation
- ☐ Other _____

Remarks and Recommendations _____

Check if equipment was tagged out of service ☐

Form M4-5/72

Figure A7. Form M4, equipment malfunction report.



CORRECTIVE MAINTENANCE WORK ORDER

Date | Requested by | Required Completion Date

Equipment Name and Number | I. D. No. | Serial No. | Location

Indication of Trouble

- ☐ Broken part
- ☐ Worn part
- ☐ Heat
- ☐ Noise
- ☐ Smell
- ☐ Vibration
- ☐ Leaking
- ☐ Other _____
- ☐ Dirty, fouled
- ☐ Voltage
- ☐ Current
- ☐ Resistance
- ☐ Flow rate
- ☐ Pressure
- ☐ Speed

When Discovered

- ☐ Starting
- ☐ Stopping
- ☐ During operation
- ☐ During PM
- ☐ During CM
- ☐ During MOD
- ☐ During OH
- ☐ Other _____

Cause of Trouble

- ☐ Heat/cold/weather
- ☐ Humidity/moisture
- ☐ Foreign object
- ☐ Shock/vibration
- ☐ Wear
- ☐ Equipment defect
- ☐ Improper installation
- ☐ Improper lubrication
- ☐ Improper operation
- ☐ Other _____

Corrective Work Requested _____

Estimated Costs

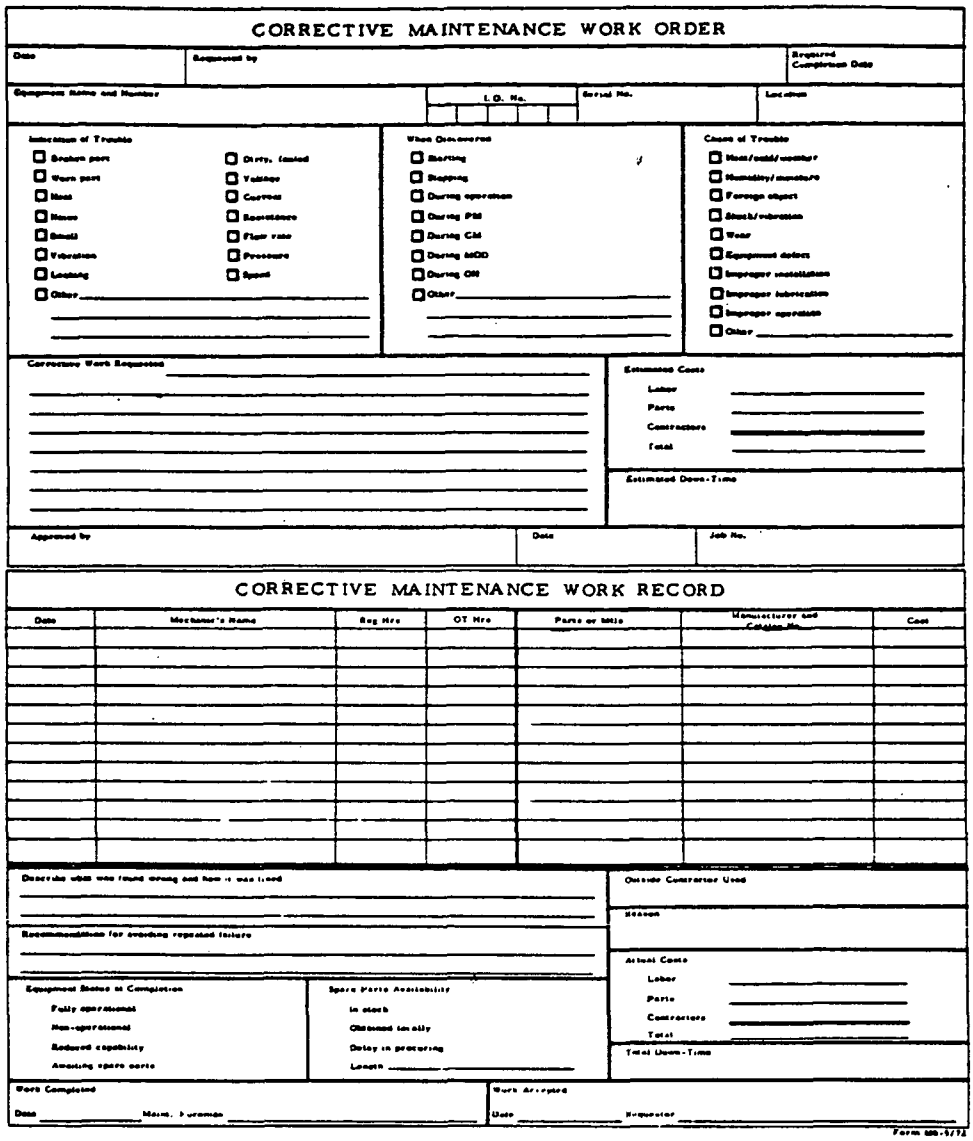
- Labor _____
- Parts _____
- Contractors _____
- Total _____

Estimated Down-Time

Approved by | Date | Job No.

Form M5-5/72

Figure A8. Form M5, corrective maintenance work order.



CORRECTIVE MAINTENANCE WORK ORDER

Date | Requested by | Required Completion Date

Equipment Name and Number | I.D. No. | Serial No. | Location

Indication of Trouble
- Broken part
- Worn part
- Heat
- Noise
- Smell
- Vibration
- Leaking
- Other
- Dirty, fouled
- Voltage
- Current
- Resistance
- Flow rate
- Pressure
- Speed

When Discovered
- Starting
- Stopping
- During operation
- During PM
- During CM
- During MOD
- During OH
- Other

Cause of Trouble
- Heat/cold/weather
- Humidity/moisture
- Foreign object
- Shock/vibration
- Wear
- Equipment defect
- Improper installation
- Improper lubrication
- Improper operation
- Other

Corrective Work Requested

Estimated Costs
- Labor
- Parts
- Contractors
- Total

Estimated Down-Time

Approved by | Date | Job No.

CORRECTIVE MAINTENANCE WORK RECORD

Date	Mechanic's Name	Reg Hrs	OT Hrs	Parts or Mtls	Manufacturer and Catalog No.	Cost

Describe what was found wrong and how it was fixed

Recommendations for avoiding repeated failure

Outside Contractor Used

Reason

Actual Costs
- Labor
- Parts
- Contractors
- Total

Total Down-Time

Equipment Status at Completion
- Fully operational
- Non-operational
- Reduced capability
- Awaiting spare parts

Spare Parts Availability
- In stock
- Obtained locally
- Delay in procuring
- Length

Work Completed
Date ____ Maint. Foreman ____

Work Accepted
Date ____ Requester ____

Form M6-5/73

Figure A9. Form M6, corrective maintenance work order and work record.

Fairfax County Lower Potomac Pollution Control Plant

MAINTENANCE SUMMARY REPORT FOR WEEK ENDING_____

WORK LOAD SUMMARY

Line	Item	Number of Actions	Estimated Manhours			
			Skill 1	Skill 2	Skill 3	Total
	Preventive Maintenance					
A	Backlog from previous week					
B	Regularly scheduled for this week					
C	Total outstanding work (A&B)					
D	Accomplished this week					
E	Backlog for next week (C-D)					
	Corrective Maintenance					
F	Backlog from previous week					
G	New work orders, this week					
H	Total outstanding work (F&G)					
I	Accomplished this week					
J	Backlog for next week (H-I)					
K	Total backlog for next week (E&J)					

WORK ACCOMPLISHED SUMMARY

Item	Preventive Maintenance	Corrective Maintenance	Total Maintenance
Number of Actions Completed			
Actual manhours expended			
Skill 1			
Skill 2			
Skill 3			
Total			
Labor costs			
Regular			
O.T.			
Total			
Outside contractor costs			
Cost of parts and materials			
Total costs			

Form M7-5/72

Figure A10. Form M7, weekly maintenance summary report.

CORRECTIVE MAINTENANCE SUMMARY

Job No.	Equipment Name	Equip. I. D.	Status Code*	Description of Work To Be Done	Priority Code**	Work Order Date	Completion Date	Remarks

*Equipment Status Code
- O - Operational
- N - Nonoperational
- R - Reduced capability

**Priority Code
- U - Urgent repairs to correct conditions which prevent the plant from operating or which involve the health and safety of personnel
- N - Needed repairs to correct conditions which seriously impair plant efficiency or plant reliability
- R - Routine repairs, tests and inspections
- C - Convenience items

Form M7 (Reverse)-5/72

Figure A11. Form M7 (reverse), corrective maintenance summary.

MAINTENANCE PROCEDURE SHEET		Page 1 of 1	MPS No.
EQUIPMENT NAME			Average Time S-1_____min S-2_____min S-3_____min
Plant Area	Level	Location	

MAINTENANCE DESCRIPTION

SAFETY PRECAUTIONS

Observe standard safety precautions
De-energize unit and tag "out of service"

TOOLS, PARTS, MATERIALS, TEST EQUIPMENT

PROCEDURE

Figure A12. Form M8, maintenance procedure sheet.

Date	Mechanic	Reg Hrs	OT Hrs	Date	Mechanic	Reg Hrs	OT Hrs

REPORT OF TROUBLE

INDICATION OF TROUBLE		WHEN DISCOVERED	CAUSE OF TROUBLE
__Broken part	__Dirty, fouled	__Starting	__Heat/Cold weather
__Worn part	__Voltage	__Stopping	__Humidity/moisture
__Heat	__Current	__During operation	__Foreign object
__Noise	__Resistance	__During PM	__Shock/vibration
__Smell	__Flow rate	__During CM	__Wear
__Vibration	__Pressure	__During MOD	__Equipment defect
__Leaking	__Speed	__During OH	__Improper installation
__Other		__Other	__Improper lubrication
			__Improper operation
			__Other

Remarks and Recommendations	Check if equipment was tagged out of service

Figure A13. Form M8 (reverse), maintenance procedure sheet.

APPENDIX B

INPUT DOCUMENTS FOR PMMS NOW IN USE

The Users Manual prepared by the Community Development Branch, Office of Research and Statistics, County of Fairfax for The Lower Potomac Planned Maintenance Management System consists of detailed instructions for every input document in the system. All file updating, maintenance scheduling and management reporting can be accomplished by utilizing these document:

1. Equipment File Maintenance (M-1 Form)(includes Maintenance Procedure Scheduling Criteria) - Figure B1
2. Maintenance Procedure File Maintenance - Figure B2
3. Parts File Maintenance - Figure B3
4. Job File Maintenance Change Transactions - Figure B4
5. Standing Work Order File Maintenance - Figure B5
6. Personnel File Maintenance - Figure B6
7. Action Codes File Maintenance - Figure B7
8. Description Code File Maintenance - Figure B8
9. Item Code File Maintenance - Figure B9
10. Equipment Malfunction Report - Figure B10
11. Malfunction Delete - Figure B11
12. Corrective Maintenance Work Order - Figure B12
13. Corrective Maintenance Initiation Request - Figure B13

14. Manpower Available Parameter (currently not used) - Figure B14

15. Meter Reading Card - Figure B15

16. Preventive Maintenance Work Order - Figure B16

17. Initiate a PM Action Out of Scheduling Cycle - Figure B17

18. PM and CM Request to Reprint a Work Order - Figure B18

19. PM Delete, CM Delete, and CM or PM Priority or Work Order Status Change - Figure B19

In addition to the above documents, Maintenance Procedure Sheets (Figure 20) for each piece of equipment requiring weekly and less-than-weekly preventive maintenance are kept on file at the plant.

Each piece of equipment is given (1) a unique six (6) digit identification number based on a functional numbering system; and (2) a two (2) digit number which indicates the type of equipment. This has been described in the original installed system.

EQUIPMENT FILE MAINTENANCE (B1)

The Equipment File Maintenance Form or M-1 Form is completed for each item in the plant identifying the item with its equipment identification number from the functional numbering system and the equipment type number.

The Equipment File Maintenance (M-1 Form) contains the following information:

Equipment I.D.

Equipment Name

Equipment Type

Building Number

Building Level

Location in Area

Relative Location (optional)

Manufacturer/Local Representative

Part or Model Number

Serial Number

Instruction Book File Number

Date Put in Service

Electric Motor Data (if applicable)

Pump Data (if applicable)

Drive or Reducer Data (if applicable)

Daily Preventive Maintenance Time

Weekly Preventive Maintenance Time

Equipment Status

Meter Code

Maintenance Procedure Scheduling Criteria

Run Time and Downtime of Equipment

Number of PMs Missed

Total PM Actions

Lifetime CM Actions

Total CM Actions

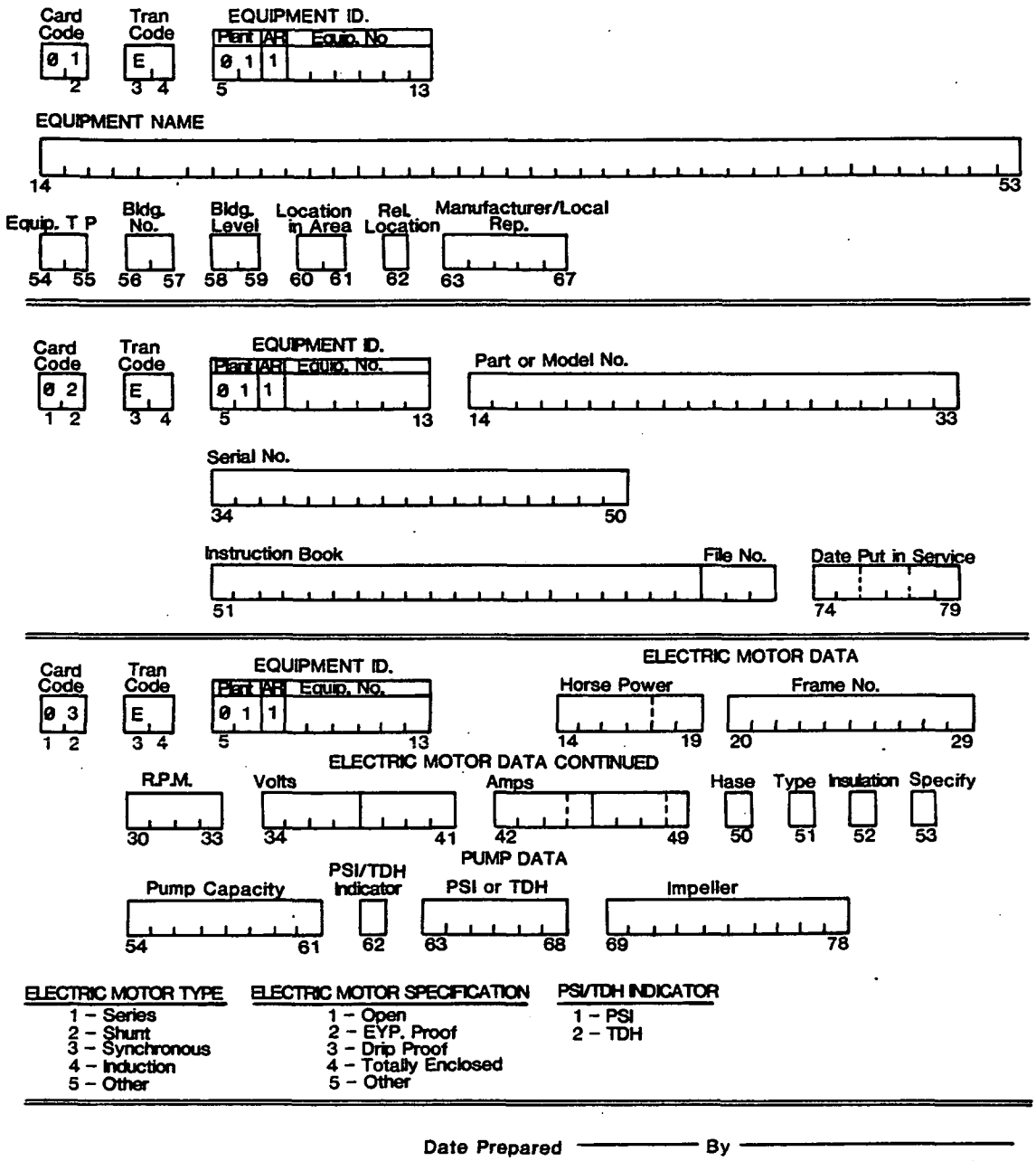
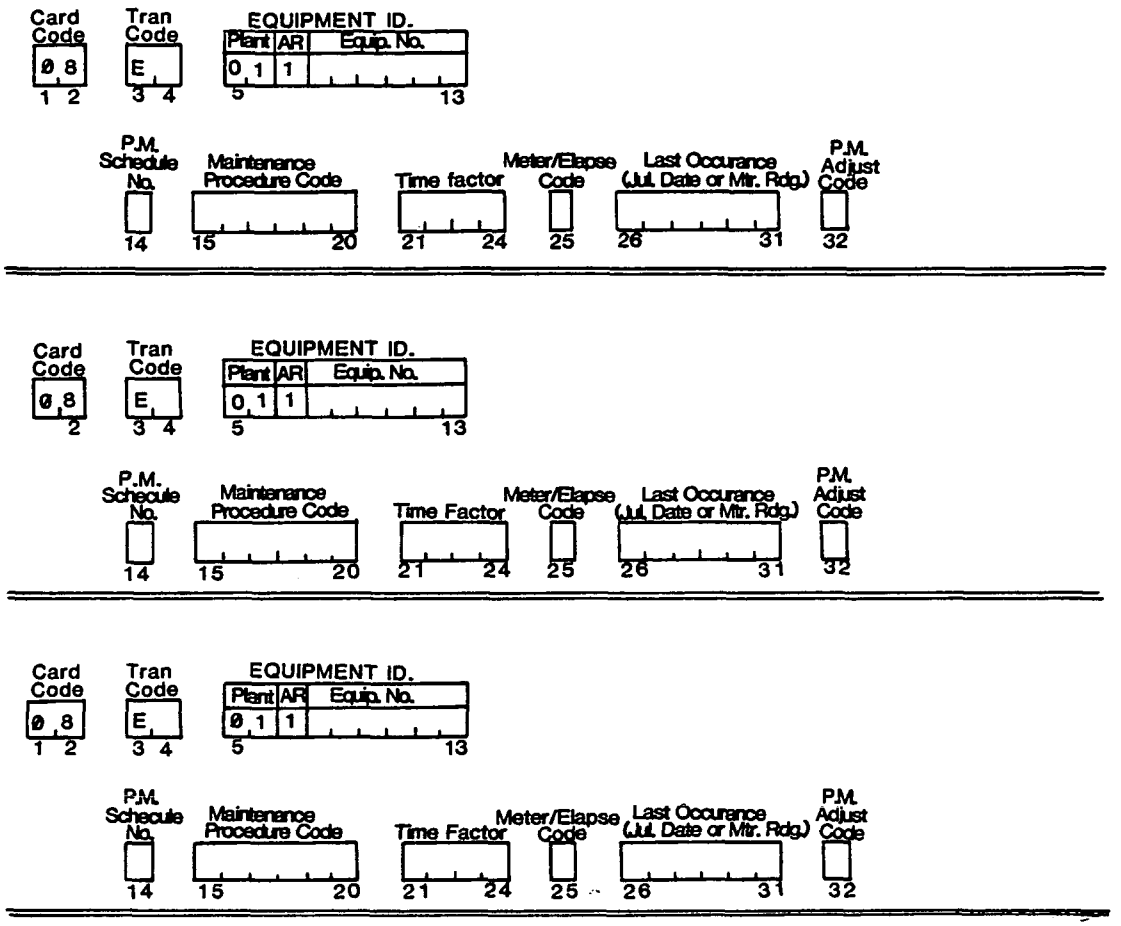
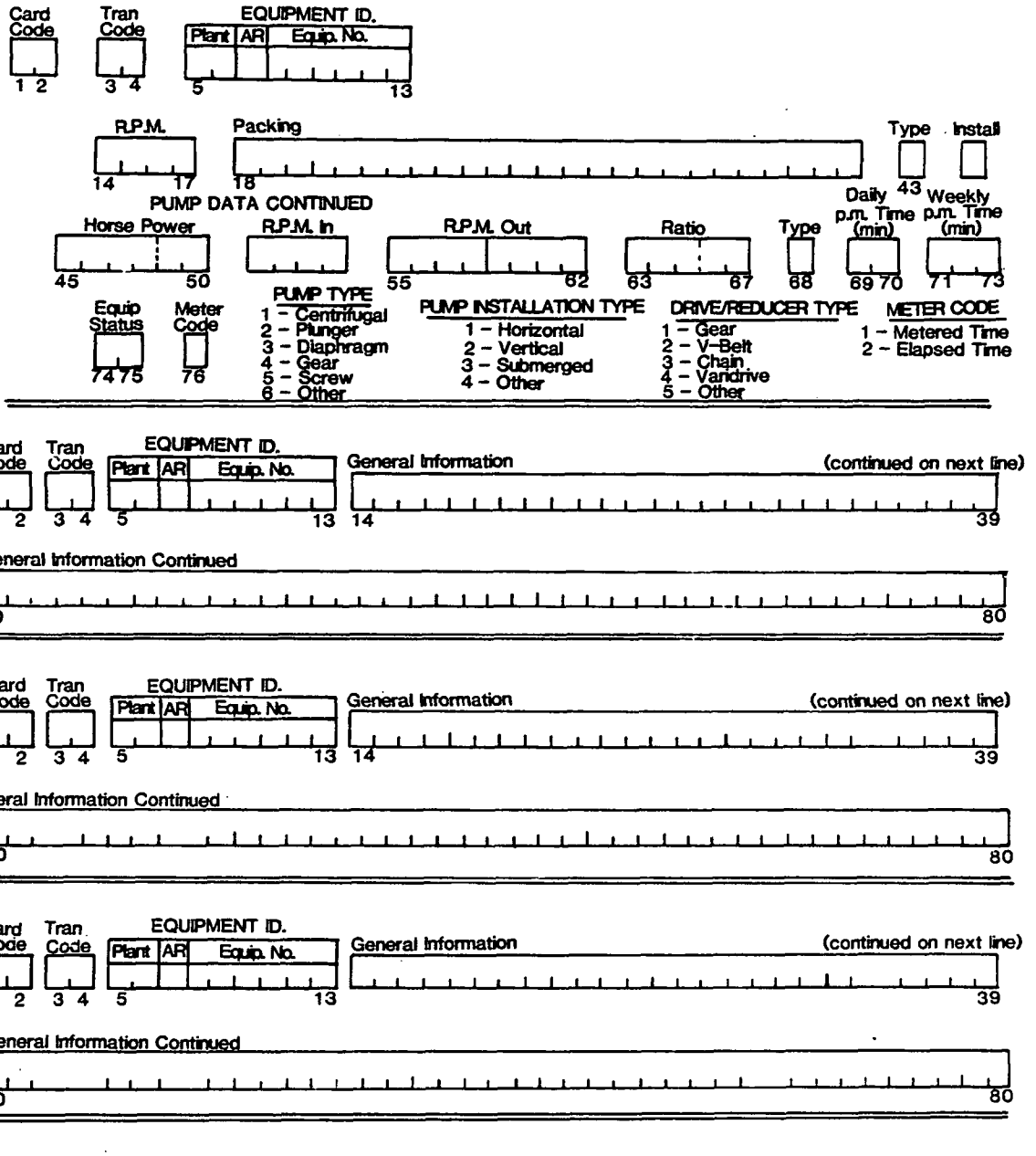


Figure B1. Equipment file maintenance (M-1 Form) (includes maintenance procedure scheduling criteria).



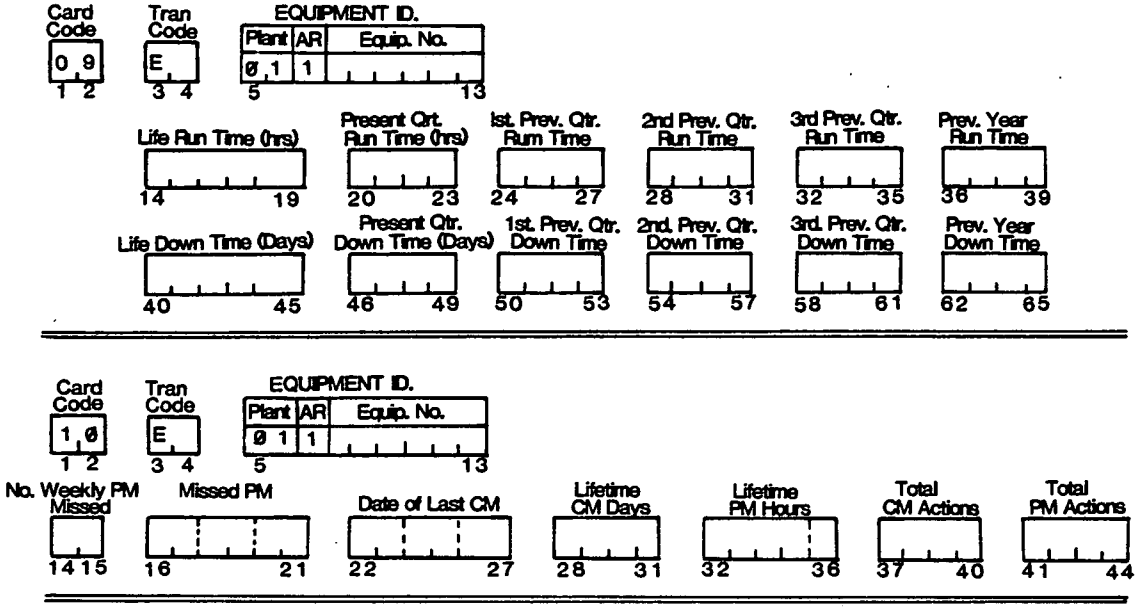
Date Prepared _____ By _____

Figure B1. (continued)



Date Prepared _____ By _____

Figure B1. (continued)



Date Prepared _____ By _____

Figure B1. (continued)

THE MAINTENANCE PROCEDURE FILE FORM (B2)

The Maintenance Procedure File form is used for the additions, corrections, and deletions to the Planned Maintenance Management System Maintenance Procedure File.

The Maintenance Procedure File form contains the following information:

Maintenance Procedure Code

Description

Instruction Book

File Number

Primary Skill Code

Estimated Time (Min.)

Fairfax County Inventory Number (FCIN)

Quantity

Unit of Measure

PARTS FILE MAINTENANCE FORM (B3)

The Parts File Maintenance form is used for additions, changes, or deletions to the Parts Master File when Preventive and Corrective Maintenance jobs are competed.

The Parts File Maintenance form contains the following information:

Job number

Fairfax County Inventory Number (FCIN)

Parts Status

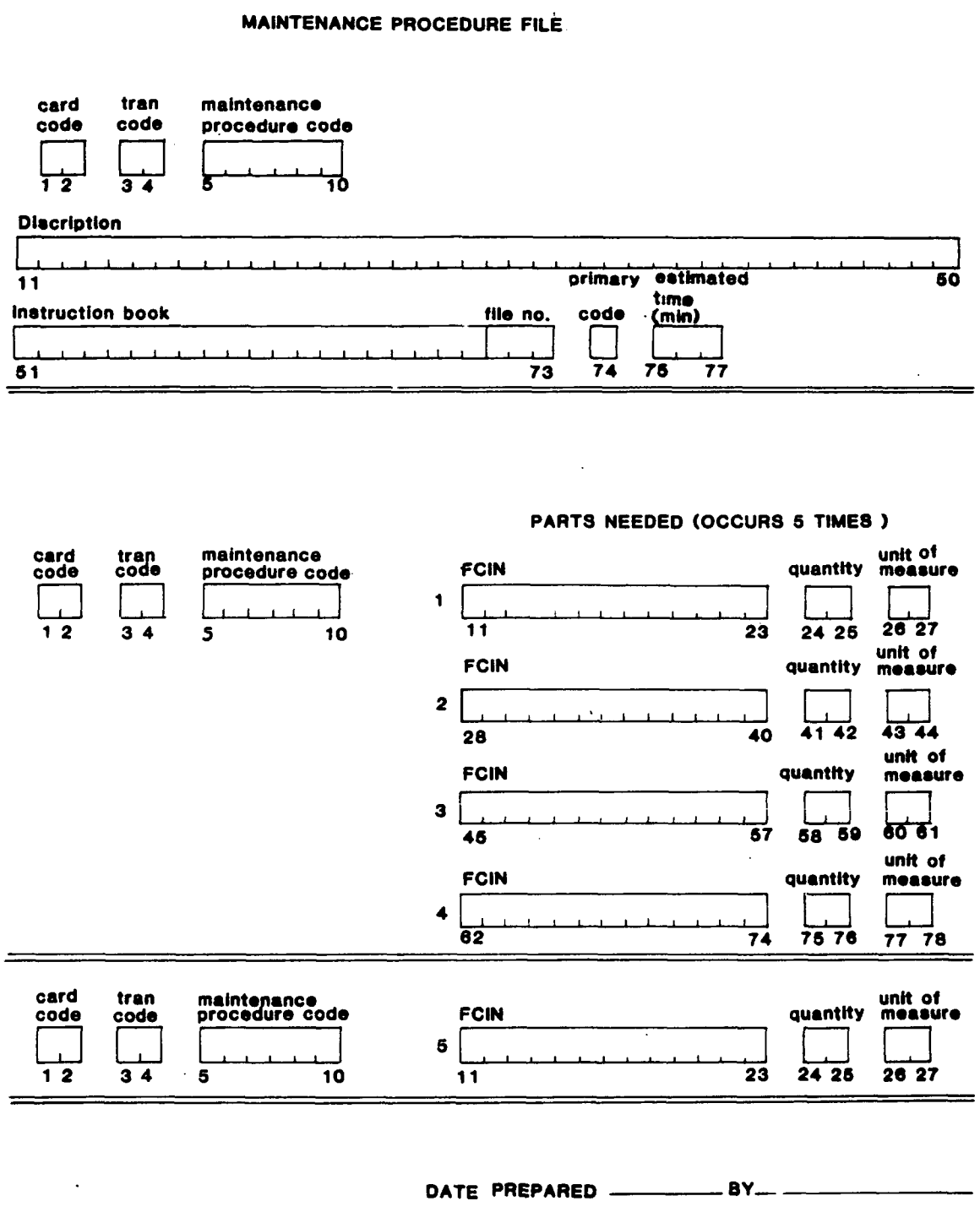


Figure B2. Maintenance procedure file.

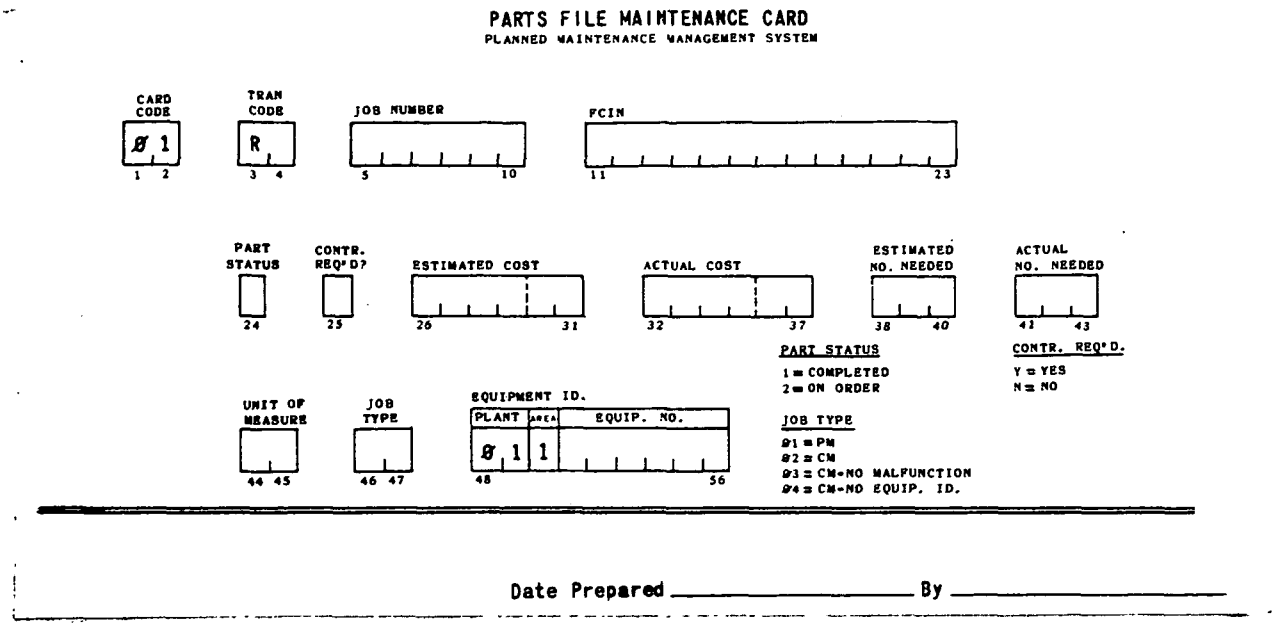


Figure B3. Parts file maintenance.

Contractor Requested

Actual Costs

Actual Number Needed

Unit of Measure

Job Type

Equipment Identification

JOB FILE MAINTENANCE CHANGE TRANSACTIONS FORM (B4)

The Job File Maintenance Change Transactions form is used to change data on the Job Master File.

The Job File Maintenance Change Transactions form contains the following information:

Job Number

Date Requested

Out-of-Service

Work Completed Date

Requested By

Indication of Trouble

When Discovered

Cause of Problem

Effect of Problem

Corrective Work Requested

What Was Found Wrong

Work Done

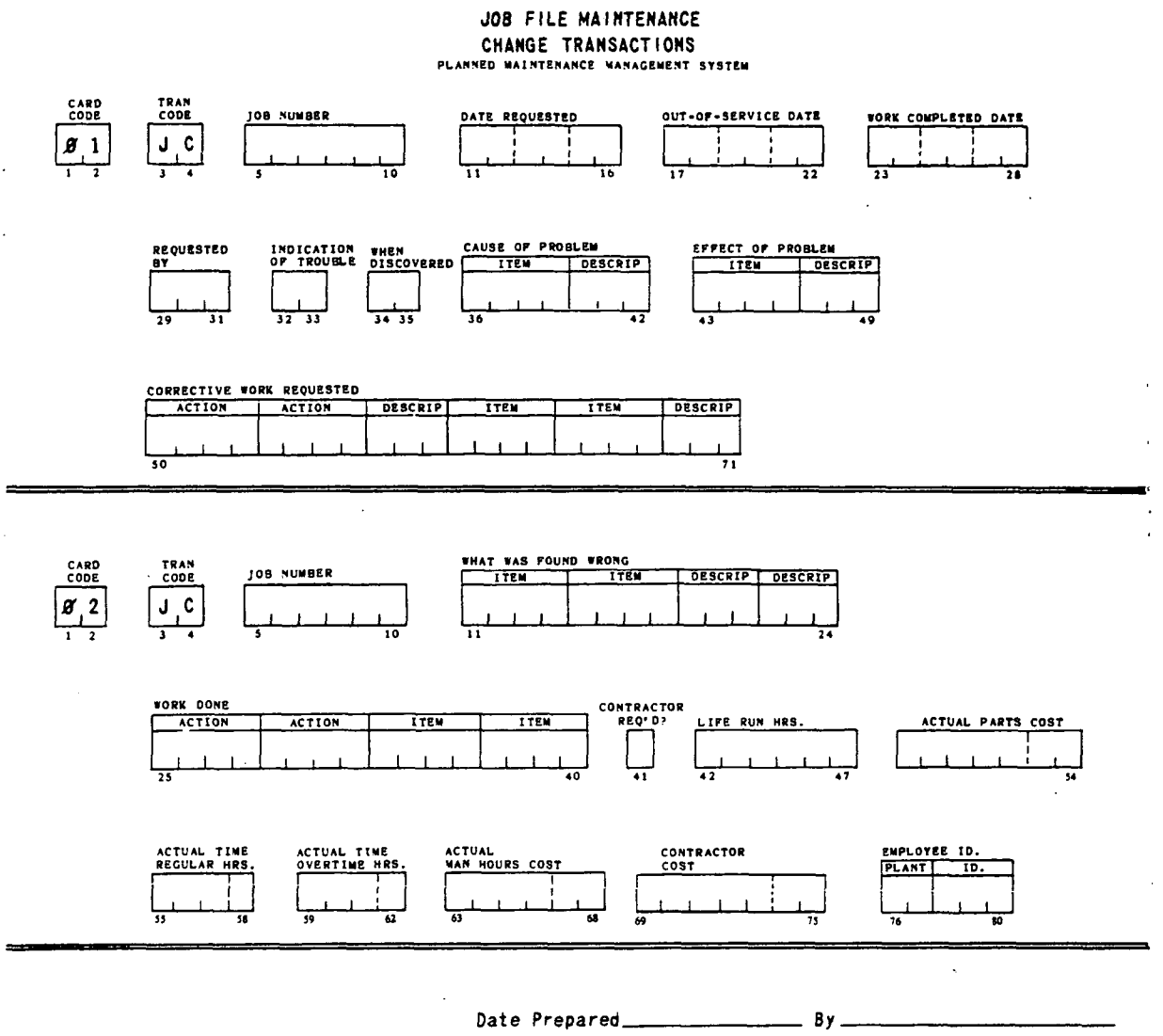


Figure B4. Job file maintenance change transactions.

Contractor Requested

Life Run Hours

Actual Parts Cost

Actual Time Regular Hours

Actual Time Overtime Hours

Actual Man-Hours Cost

Contractor Cost

Employee Indentification

STANDING WORK ORDER FILE MAINTENANCE (B5)

The Standing Work Order File Maintenance form is used to provide for the addition or change of a Standing Order.

The Standing Work Order File Maintenance form contains the following information:

Standing Work Order Number

Description

PERSONNEL FILE MAINTENANCE CARD (B6)

The Personnel File Maintenance Card is used to provide for the additions, changes, and deletions to the Planned Maintenance System Personnel File.

The Personal File Maintenance Card contains the following information:

Social Security Number

Employee Identification

Employee Status Code

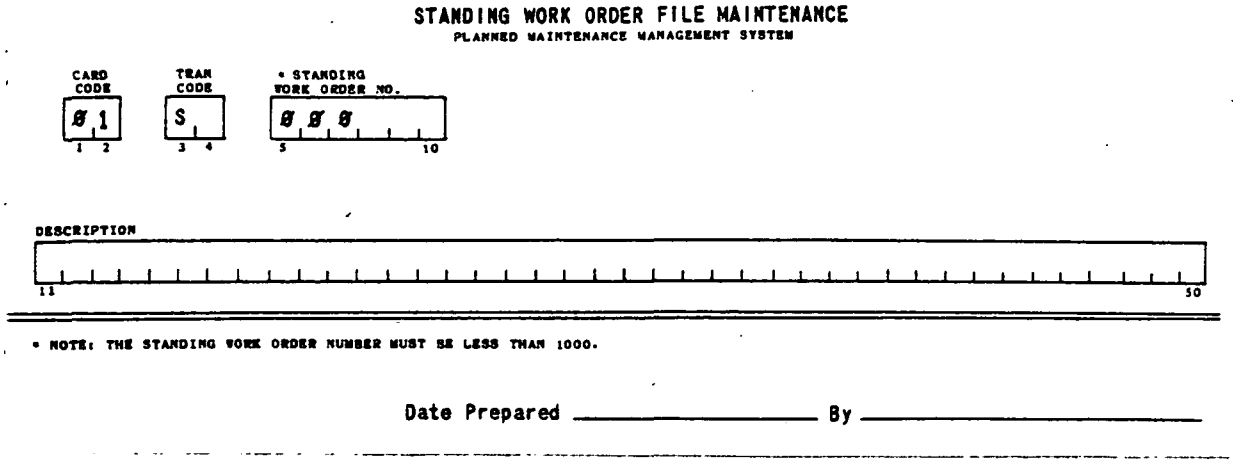


Figure B5. Standing work order file maintenance.

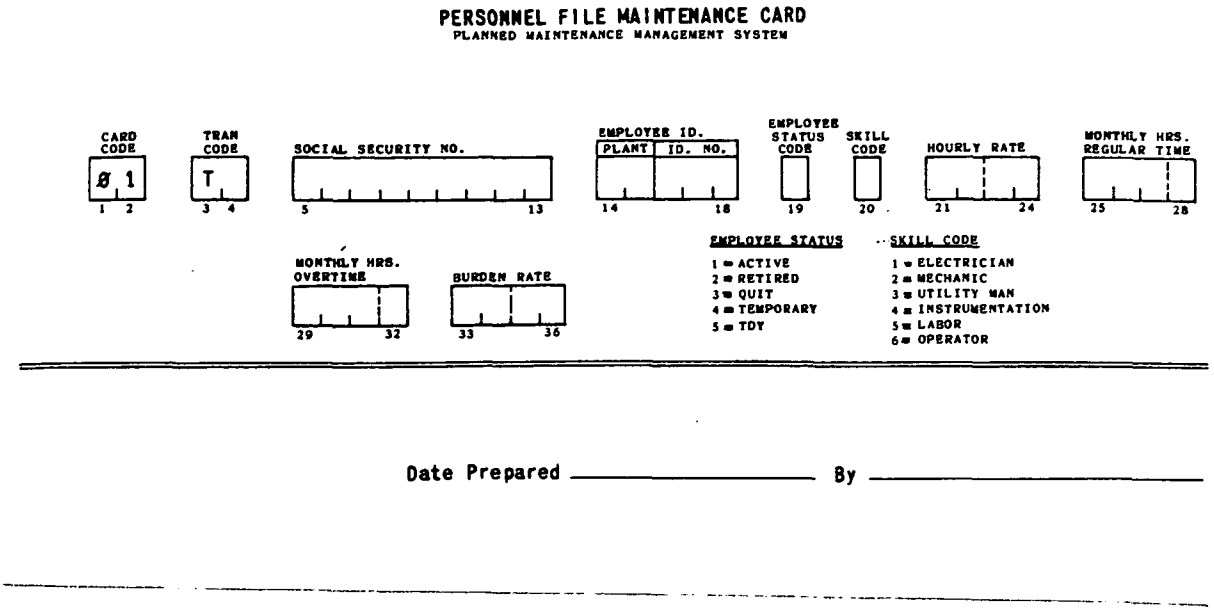


Figure B6. Personnel file maintenance.

ACTION CODES FILE MAINTENANCE
PLANNED MAINTENANCE MANAGEMENT SYSTEM

CARD CODE	TRAN CODE	ACTION CODE	DESCRIPTION
Ø1	A		
1 2	3 4	5 8	9 33

CARD CODE	TRAN CODE	ACTION CODE	DESCRIPTION
Ø1	A		
1 2	3 4	5 8	9 33

CARD CODE	TRAN CODE	ACTION CODE	DESCRIPTION
Ø1	A		
1 2	3 4	5 8	9 33

CARD CODE	TRAN CODE	ACTION CODE	DESCRIPTION
Ø1	A		
1 2	3 4	5 8	9 33

Date Prepared ______________________ By ______________________

Figure B7. Action codes file maintenance.

Skill Code

Hourly Rate

Monthly Hours Regular Time

Monthly Hours Overtime

Burden Rate

ACTION CODES FILE MAINTENANCE (B7)

The Action Codes File Maintenance form provides for the additions or changes of records on the Action Code Master File.

The Action Codes File Maintenance form contains the following information:

Action Code

Description

DESCRIPTION CODE FILE MAINTENANCE (B8)

The Description Code File Maintenance form provides for additions and changes to the Description Code Master File.

The Description Code File Maintenance form contains the following information:

Description Code

Description

ITEM CODE FILE MAINTENANCE (B9)

The Item Code File Maintenance form provides for additions and changes to the Item Code Master File.

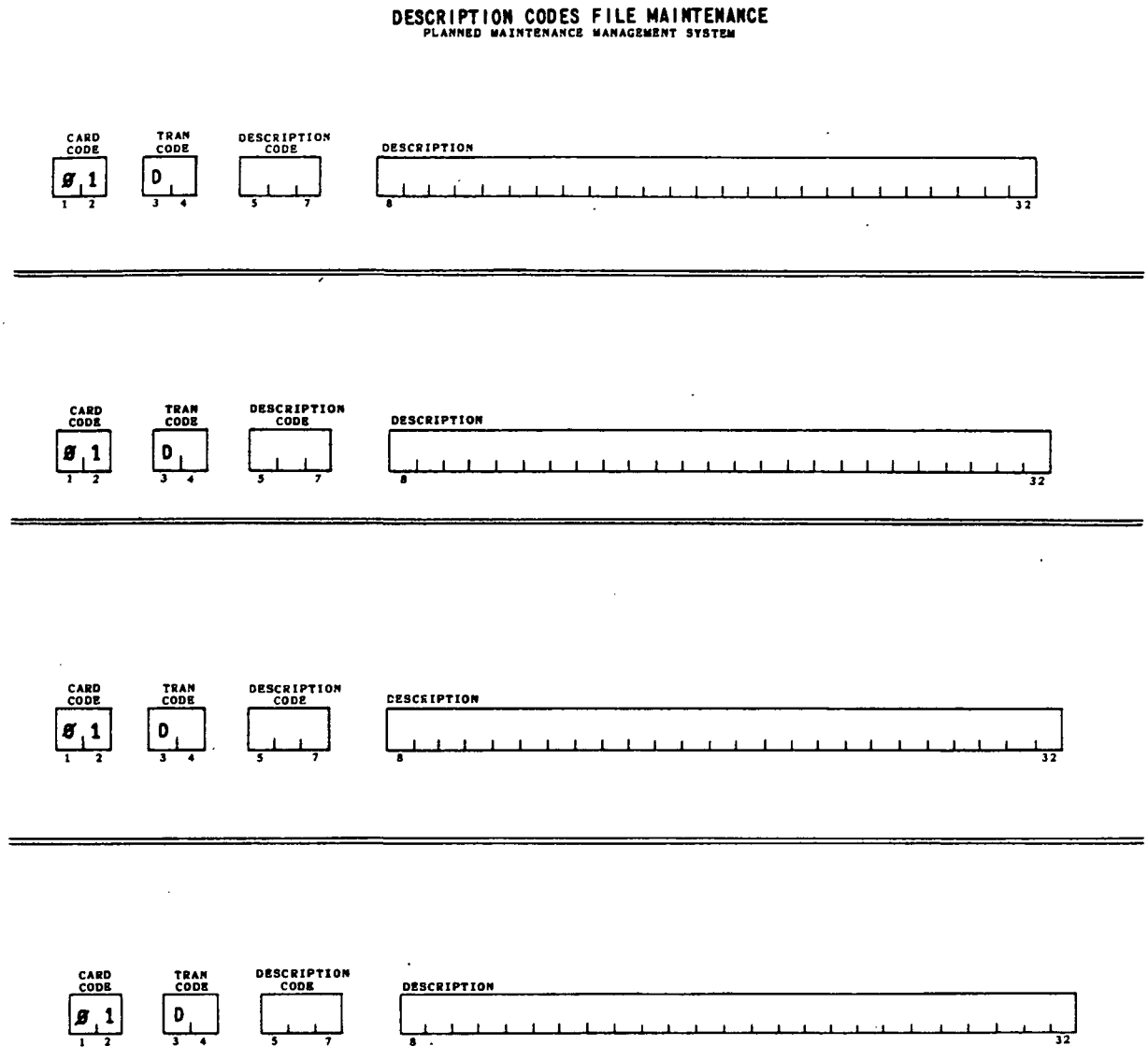


Figure B8. Description code file maintenance.

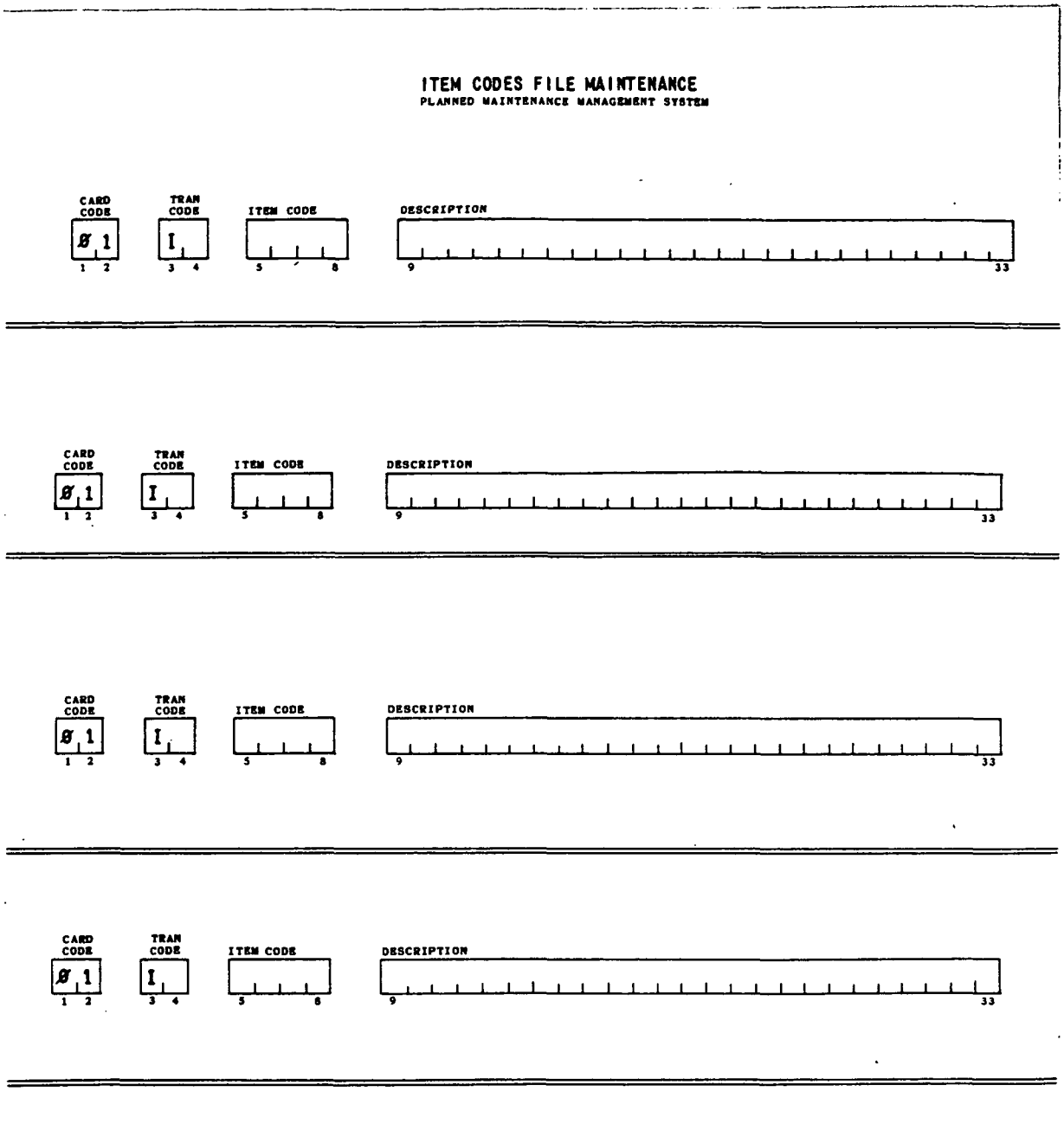


Figure B9. Item code file maintenance.

The Item Code File Maintenance form contains the following information:

Item Code

Description

EQUIPMENT MALFUNCTION REPORT (B10)

The Equipment Malfunction Report form is used to initiate a malfunction report by providing a malfunction number for the Malfunction Register until it is deleted as a Corrective Maintenance Initiation Request is processed against it.

The Equipment Malfunction Report form contains the following information:

Equipment Name and Number

Identification Number

Building Number

Date of Trouble

Time

Reported By

Foreman

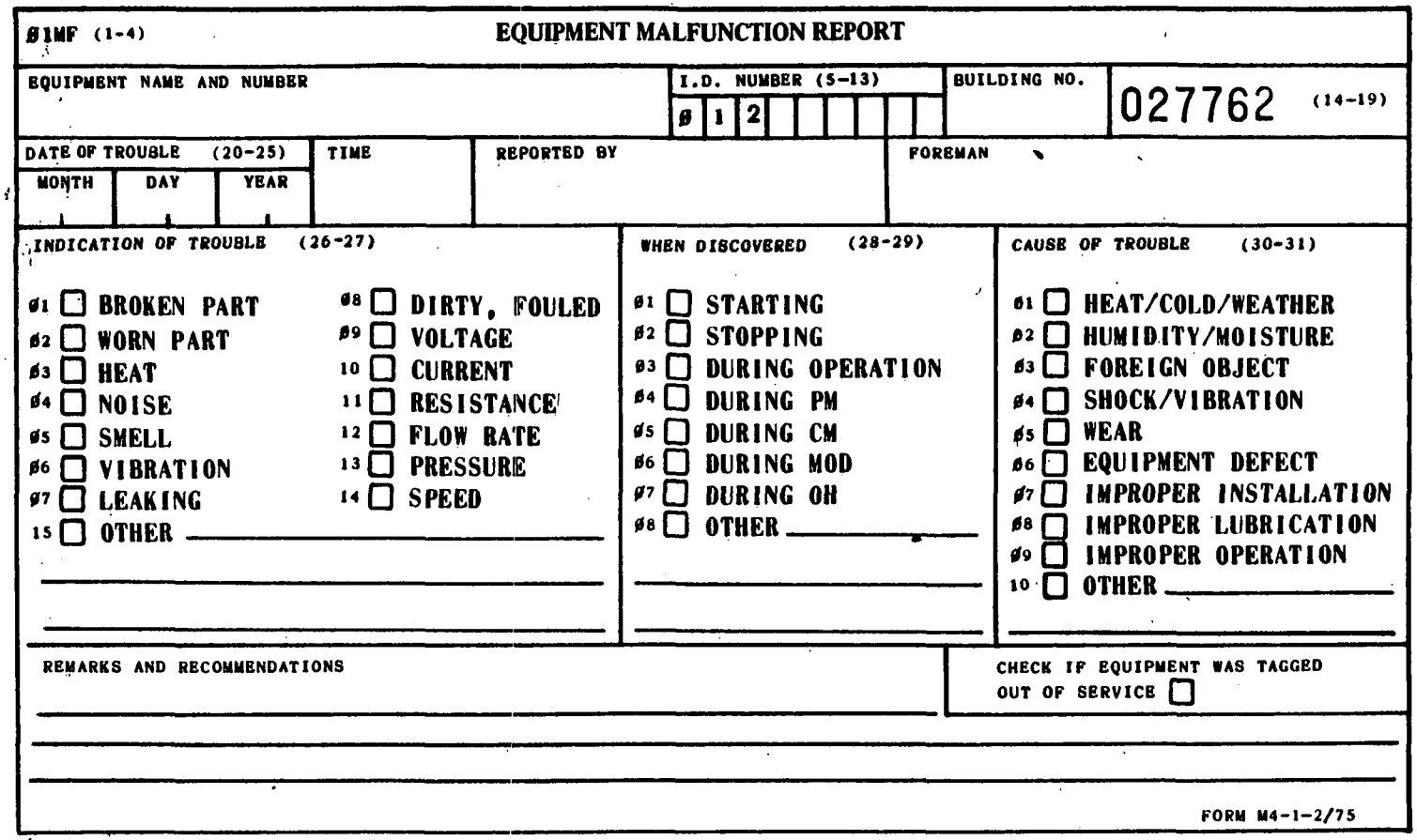
MALFUNCTION DELETE (B11)

The Malfunction Delete form is used to provide for the deletion of a malfunction record off the Malfunction Master File.

The Malfunction Delete form contains the following information:

Equipment Identification Number

Malfunction Number



ØIMF (1-4)

EQUIPMENT MALFUNCTION REPORT

EQUIPMENT NAME AND NUMBER

I.D. NUMBER (5-13) Ø 1 2

BUILDING NO. 027762 (14-19)

DATE OF TROUBLE (20-25) MONTH DAY YEAR

TIME

REPORTED BY

FOREMAN

INDICATION OF TROUBLE (26-27)

Ø1 ☐ BROKEN PART
Ø2 ☐ WORN PART
Ø3 ☐ HEAT
Ø4 ☐ NOISE
Ø5 ☐ SMELL
Ø6 ☐ VIBRATION
Ø7 ☐ LEAKING
15 ☐ OTHER _____
Ø8 ☐ DIRTY, FOULED
Ø9 ☐ VOLTAGE
10 ☐ CURRENT
11 ☐ RESISTANCE
12 ☐ FLOW RATE
13 ☐ PRESSURE
14 ☐ SPEED

WHEN DISCOVERED (28-29)

Ø1 ☐ STARTING
Ø2 ☐ STOPPING
Ø3 ☐ DURING OPERATION
Ø4 ☐ DURING PM
Ø5 ☐ DURING CM
Ø6 ☐ DURING MOD
Ø7 ☐ DURING OH
Ø8 ☐ OTHER _____

CAUSE OF TROUBLE (30-31)

Ø1 ☐ HEAT/COLD/WEATHER
Ø2 ☐ HUMIDITY/MOISTURE
Ø3 ☐ FOREIGN OBJECT
Ø4 ☐ SHOCK/VIBRATION
Ø5 ☐ WEAR
Ø6 ☐ EQUIPMENT DEFECT
Ø7 ☐ IMPROPER INSTALLATION
Ø8 ☐ IMPROPER LUBRICATION
Ø9 ☐ IMPROPER OPERATION
10 ☐ OTHER _____

REMARKS AND RECOMMENDATIONS

CHECK IF EQUIPMENT WAS TAGGED OUT OF SERVICE ☐

FORM M4-1-2/75

Figure B10. Equipment malfunction report.

MALFUNCTION DELETE
PLANNED MAINTENANCE MANAGEMENT SYSTEM

CARD CODE	TRAN CODE	EQUIPMENT I.D. PLANT	AREA	EQUIP. NO.	MALFUNCTION NO.
02	MF	01	1		
1 2	3 4	5		13	14 19

Date Prepared_____ By _____

Figure B11. Malfunction delete.

CORRECTIVE MAINTENANCE WORK ORDER (B12)

The Corrective Maintenance Work Order form is used to capture data while completing a corrective maintenance action for the updating of the Job Master, Equipment Master, and Parts Master files. This form also serves as an indicator to the automated system that a corrective action has been completed.

The Corrective Maintenance Work Order form contains the following information:

Date Printed

Date Requested

Requested By

Equipment Name and Number

Part or Model Number

Serial Number

Instruction Book/File Number

Skill Code

Job Number

Unit of Measure

How Was It Fixed

Outside Contractor Required

Date Out of Service

Date Job Completed

Contractor Cost (if applicable)

CORRECTIVE MAINTENANCE WORK ORDER

Date printed _____ JOB NUMBER _____
Date requested _____ Priority _____
Requested by _____ Malfunc. no. _____
EQUIP. NAME & NO. _____ Plant area _____
Part or model no. _____ Bldg. no. _____
Serial No. _____ Level _____
INSTRUCTION BOOK/FILE NO. _____ Loc. in area _____
SKILL CODE _____ Rel. location _____
Electric motor data:
HP _____ Frame no. _____ Volts _____ Amps _____
Pump packing: _____
GENERAL INFO: _____

Indication of trouble _____ When discovered _____
Apparent cause _____
Effect _____
CORRECTIVE WORK REQUIRED:

Sketch required? _____ Estimated cost _____ Estimated time _____
REMARKS _____

Card code 01 (1-2) Tran. code RA (3-4) Job no. _____ (5-10) Type job _____ (46-47) Equip. ID _____ (48-56)

Parts used:	Offce use only: FCIN (11-23)	Contr. Reqd.? (25)	Estimated Cost (26-31) OR	Actual Cost (32-37)	Estimated #Needed (38-40) OR	Actual #Needed (41-43)	Unit of Measure (44-45)

Card code 01 (1-2) Tran. code CC (3-4) Job no. _____ (5-10) Equip. ID _____ (11-19)
What was found wrong? _____ How was it fixed? _____

Office use only:
Item code _____ (20-23)(24-27) Descr. code _____ (28-30)(31-33) Action code _____ (34-37)(38-41) Item code _____ (42-45)(46-49)

Outside contractor required? Yes No (50) Date cut of service _____ Mo. Day Yr. (51-56) Date job completed _____ Mo. Day Yr. (57-62)
Contractor cost _____ (63-69)

_____ Requestor

_____ ID no. _____ (70-74)
Mechanic

_____ Maint. Foreman

Figure B12. Corrective maintenance work order.

Mechanic

Identification Number (from employee file)

Requestor

Maintenance Foreman

CORRECTIVE MAINTENANCE INITIATION REQUEST (B13)

The Corrective Maintenance Initiation Request form is used to initiate a Corrective Maintenance Action.

The Corrective Maintenance Initiation Request form contains the following information:

Equipment Identification

Building Number

Date Requested

Out-of-Service Date

Requested By

Priority

Job Type

Cause of Problem

Effect of Problem

Corrective Work Requested

Estimated Time (Hours)

Estimated Cost

Malfunction Number

Remarks

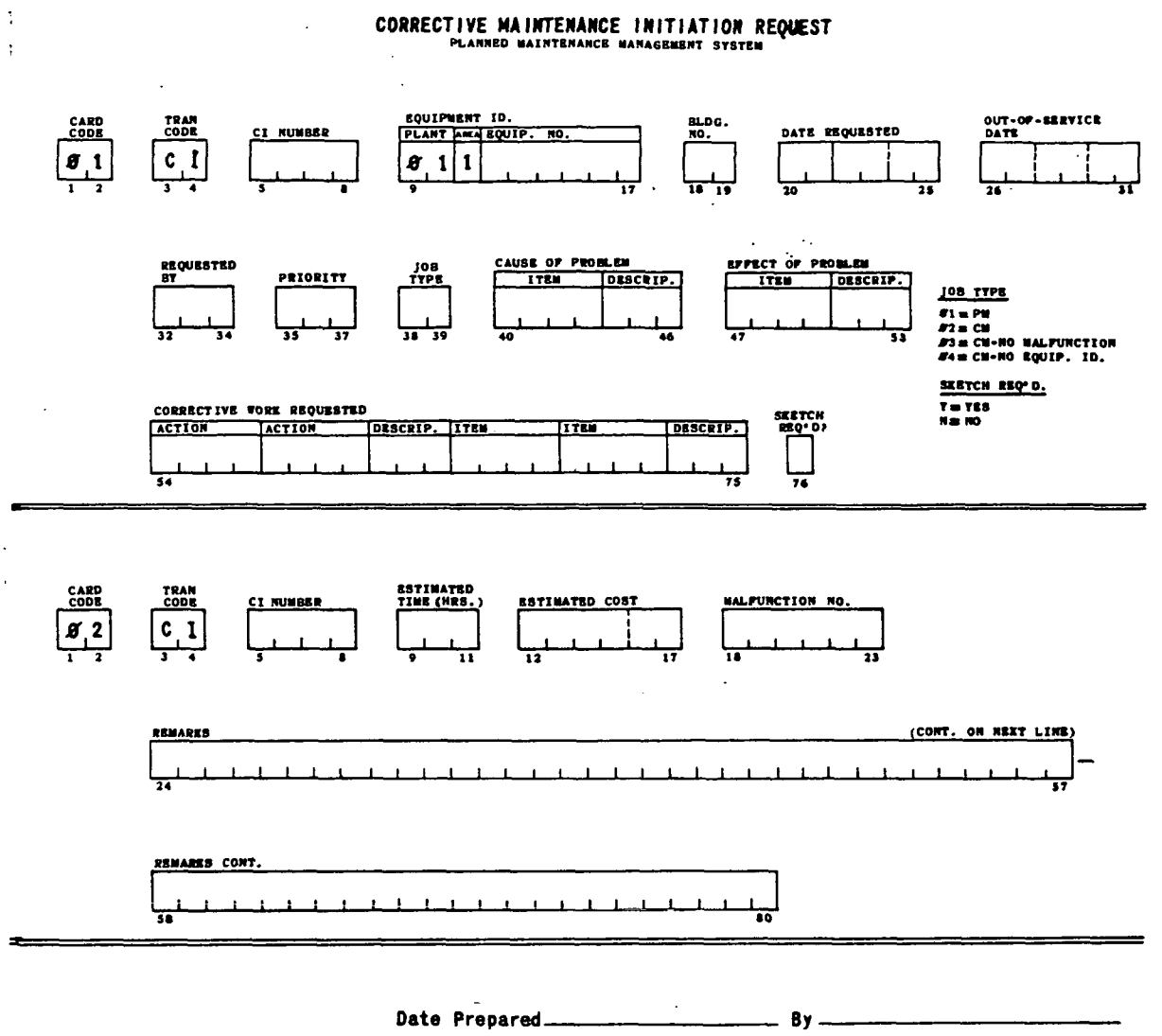


Figure B13. Corrective maintenance initiation request.

MANPOWER AVAILABLE PARAMETER (B14)

The Manpower Available Parameter form provides for the entering of available manpower into the weekly Preventive Maintenance Scheduling Cycle thereby determining which preventive maintenance action will be released to the schedule for the upcoming week.

The Manpower Available Parameter form contains the following information:

Available Man-Hours (pm skill)

METER READING CARD (B15)

The Meter Reading Card is used for placing a meter into service for a piece of equipment, which has never been metered; for recording the first reading when replacing a meter; for placing a repaired meter back into service and for reporting the current meter reading on an existing meter.

The Meter Reading Card contains the following information:

Equipment Identification

Current Meter Reading

New Meter Reading (in case or repair)

Accept Code

PREVENTIVE MAINTENANCE WORK ORDER (B16)

The Preventive Maintenance Work Order form is used to capture data while completing a preventive maintenance action for the updating of the Job Master, Equipment Master, and Parts Master file.

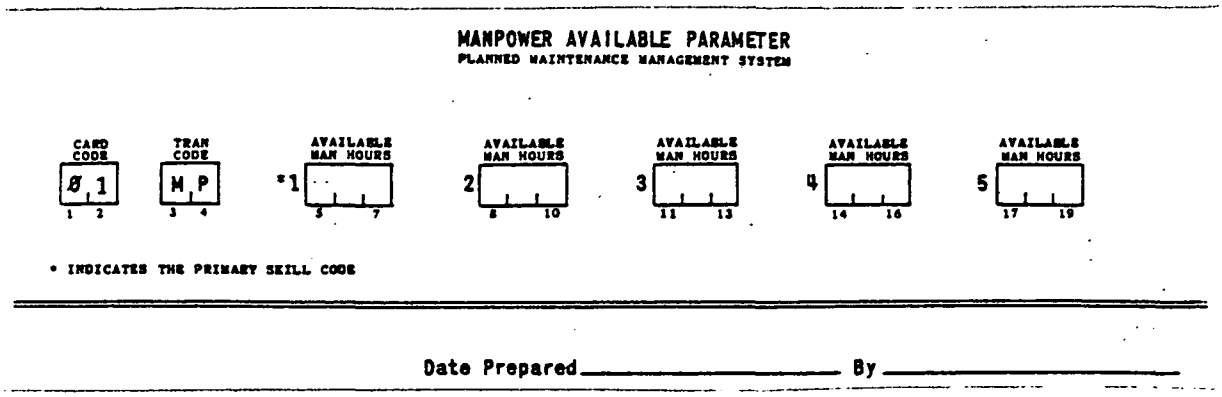


Figure B14. Manpower available parameter (currently not used).

METER READING CARD

PLANNED MAINTENANCE MANAGEMENT SYSTEM

CARD CODE	TRAN CODE	EQUIPMENT ID. PLANT	AREA	EQUIP. NO.	CURRENT METER READING	NEW METER READING (IN CASE OF REPAIR)	ACCEPT CODE*
Ø 1	M R	Ø 1					
1 2	3 4	5		13	14 19	20 25	26

* A "1" SHOULD BE FILLED IN HERE IF THE CURRENT METER READING IS TO BE ACCEPTED AS IS. NO CHECK WILL BE MADE ON THE NUMBER OF ELAPSED HOURS.

Date Prepared _____ By _____

Figure B15. Meter reading card.

PREVENTIVE MAINTENANCE WORK ORDER

JOB NO. _____
Date printed _____
Building no. _____
Building level _____
Location in area _____
Rel. location _____

EQUIPMENT ID _____
Equipment name _____
Part or model no. _____
Serial no. _____

ELECTRIC MOTOR DATA:
HP _____ Amps _____ Volts _____ Frame no. _____ RPM _____

PUMP DATA:
Type _____ Installation _____

DRIVER OR REDUCER DATA:
Type _____

MAINTENANCE PROCEDURE CODE _____
DESCRIPTION _____
Instruction book/file no. _____
PRIMARY SKILL CODE _____
Estimated time _____

Card code 01 (1-2) Tran. code RC (3-4) Job no. _____ (5-10)

Parts required/used:	FCIN (11-23)	Description	Estimated Quantity (38-40)	Quantity Used 41-43	Unit of Measure (44-45)
[]					
[]					
[]					
[]					
[]					

Card Code 01 (1-2) Tran. Code PC (3-4) Job no. _____ (5-10) Equip. ID _____ (11-19) Maint. Proc. code _____ (20-25)
Leg 1: Volts ____ (26-29) Amps ____ (30-33) Leg 2: Volts ____ (34-37) Amps ____ (38-41) Leg 3: Volts ____ (42-45) Amps ____ (46-49)
_____ Megohms (50-52) Time, in minutes, to complete job _____ (Only if different than est time (53-55)
Job completed by:

Employee ID no: _____ (56-60) _____ Signature _____ Maint. Foreman

Figure B16. Preventive maintenance work order.

The Preventive Maintenance Work Order form contains the following information:

Job Number

Date Printed

Building Number

Building Level

Location in Area

Relocation

Equipment Identification

Equipment Name

Part or Model Number

Serial Number

Electric Motor Data (if applicable)

Pump Data (if applicable)

Drive or Reducer Data (if applicable)

Maintenance Procedure Code

Description

Instruction Book/File Number

Primary Skill Code

Estimated Time

Parts Required/Used

Time in minutes to complete the job (Only if different than estimated time)

Employee Identification Number

Signature

Maintenance Foreman

INITIATE A PM ACTION OUT OF SCHEDULING CYCLE (B17)

The Initiate a P.M. Action Out of Scheduling Cycle form is used to provide for the initiation of preventive maintenance actions out of the normal scheduling cylce.

The Intiate a P.M. Action Out of Scheduling Cycle form contains the following information:

Equipment Identification

Maintenance Procedure Code

PM AND CM REQUEST A WORK ORDER (B18)

The PM and CM Request a Work Order form is used to provide for the reprinting of a Corrective or Preventive Maintenance Work Order.

The PM and CM Request to Reprint a Work Order form contains the following information:

Job Number

Equipment Identification

Job Type Code

PM DELETE, CM DELETE, AND CM OR PM PRIORITY OR WORK ORDER STATUS CHANGE (B19)

The PM Delete, CM Delete, and CM or PR Priority or Work Order Status Change form is used to provide for the deletion of a Preventive Maintenance Work Order or a Corrective Maintenance Work Order and to change the Work

Order status or priority of a Corrective of Preventive Maintenance Work Order.

The PM Delete, CM Delete, and CM or PM Priority or Work Order Status Change form contains the following information:

Job Number

Equipment Identification

Maintenance Procedure Code

Priority

Work Order Status

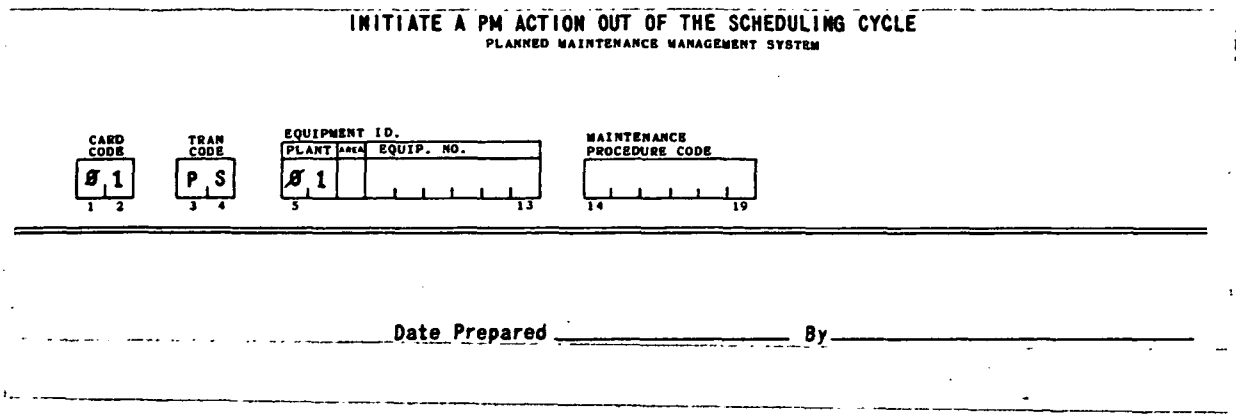


Figure B17. Initiate a PM action out of scheduling cycle.

PREVENTIVE AND CORRECTIVE MAINTENANCE
REQUEST TO REPRINT A WORK ORDER
PLANNED MAINTENANCE MANAGEMENT SYSTEM

CARD CODE	TRAN CODE	JOB NUMBER	EQUIPMENT ID. PLANT	AREA	EQUIP. NO.	JOB TYPE CODE
Ø1	RP		01			
1 2	3 4	5 10	11		19	20 21

JOB TYPE
01 = PM
02 = CM
03 = CM-NO MALFUNCTION
04 = CM-NO EQUIP. ID.

Date Prepared _____ By _____

Figure B18. PM and CM request to reprint a work order.

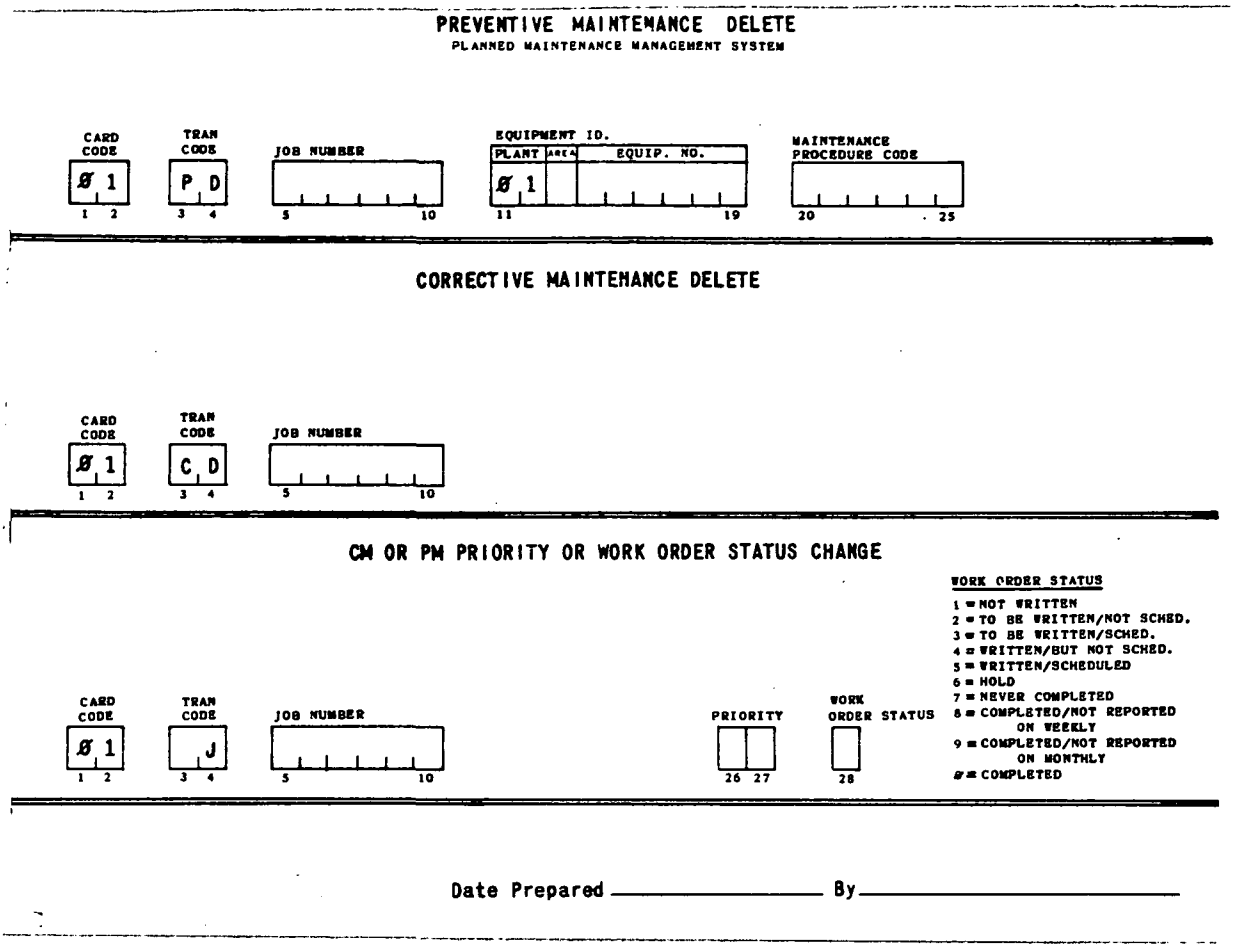


Figure B19. PM delete, CM delete, and CM and PM priority or work order status change.

MAINTENANCE PROCEDURE SHEET		Page 1 of 1	MPS No.
EQUIPMENT NAME			Average Time S-1_____min S-2_____min S-3_____min
Plant Area	Level	Location	

MAINTENANCE DESCRIPTION

SAFETY PRECAUTIONS

Observe standard safety precautions
De-energize unit and tag "out of service"

TOOLS, PARTS, MATERIALS, TEST EQUIPMENT

PROCEDURE

Figure B20. Maintenance procedure sheet.

Date	Mechanic	Reg Hrs	OT Hrs	Date	Mechanic	Reg Hrs	OT Hrs

REPORT OF TROUBLE

INDICATION OF TROUBLE		WHEN DISCOVERED	CAUSE OF TROUBLE
__Broken part	__Dirty, fouled	__Starting	__Heat/Cold/weather
__Worn part	__Voltage	__Stopping	__Humidity/moisture
__Heat	__Current	__During operation	__Foreign object
__Noise	__Resistance	__During PM	__Shock/vibration
__Smell	__Flow rate	__During CM	__Wear
__Vibration	__Pressure	__During MOD	__Equipment defect
__Leaking	__Speed	__During OH	__Improper installation
__Other		__Other	__Improper lubrication
			__Improper operation
			__Other

Remarks and Recommendations	Check if equipment was tagged out of service

Figure B21. Maintenance procedure sheet (reverse).

REFERENCES

1. Federal Guidelines, Design, Operation and Maintenance of Wastewater Treatment Facilities. U.S. Department of Interior, Federal Water Pollution Control Administration. U.S. Government Printing Office. Washington, D.C. Report No. 0-406-409. September 1970.

2. Environmental Protection Agency. A Planned Maintenance Mangement System for Municipal Wastewater Treatment Plants. U.S. Government Printing Office, Washington, D.C. Report No. EPA-600/2-73-004.

3. Tuxbury D.C. and B.E. Srite. Laboratory Services Series a Programmed Maintenance System.

TECHNICAL REPORT DATA
(Please read Instructions on the reverse before completing)

1. REPORT NO.	2.	3. RECIPIENT'S ACCESSION NO.

4. TITLE AND SUBTITLE
EVALUATION OF MAINTENANCE MANAGEMENT SYSTEM AT LOWER POTOMAC WASTEWATER TREATMENT PLANT FAIRFAX COUNTY VIRGINIA

5. REPORT DATE
May,1981 (issuing date)

6. PERFORMING ORGANIZATION CODE

7. AUTHOR(S)
Lilia A. Abron-Robinson, Ph.D.
Leon W. Weinberger, Sc.D., P.E.

8. PERFORMING ORGANIZATION REPORT NO.

9. PERFORMING ORGANIZATION NAME AND ADDRESS
PEER Consultants, Inc.
1160 Rockville Pike, Suite 202
Rockville, Maryland 20852

10. PROGRAM ELEMENT NO.

11. CONTRACT/GRANT NO.
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16. ABSTRACT

The Planned Maintenance Management System (PMMS) installed at Lower Potomac Wastewater Treatment Plant of Fairfax County, Virginia was evaluated.

Descriptions are presented of the original manual system and the current computerized version. Although the current system is computerized, senior personnel are still required to make key decisions if the system is to work. The system, to work effectively, requires the cooperation and participation of all plant personnel.

The system is easy to use and only one person is required to code data for computer interface. The system can be enlarged to accommodate plant expansion, other plants within the County's jurisdiction, other utilities and other facilities.

The data collected are enumerated and the benefits of the PMMS are described. Data are analyzed to demonstrate some of the benefits of the system. Valuable data could be supplied to designers, equipment manufacturers, and purchasing agents.

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17. KEY WORDS AND DOCUMENT ANALYSIS

a. DESCRIPTORS	b. IDENTIFIERS/OPEN ENDED TERMS	c. COSATI Field/Group
Maintenance systems, preventive maintenenace, corrective maintenance, planned maintenance, evaluation, effectiveness	Wastewater treatment, sewage treatment, maintenance, operations, treatment costs, treatment effectiveness, management	

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