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Environmental Protection Technology Series

A Planned Maintenance Management System for Municipal Wastewater Treatment Plants

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The U. S. Environmental Protection Agency, as a subsequent action to the publishing of this report, may publish as a separate document, the entire group of Maintenance Procedure Sheets developed by this program for the Lower Potomac Wastewater Treatment Plant. If published, this supplemental publication will constitute a valuable source document for the adaptation of the Planned Maintenance Management System to other plants throughout the nation.

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A PLANNED MAINTENANCE MANAGEMENT SYSTEM FOR MUNICIPAL WASTEWATER TREATMENT PLANTS

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ABSTRACT

A Planned Maintenance Management System (PMMS) has been developed and successfully demonstrated at the 18-mgd Lower Potomac Wastewater Treatment Plant of Fairfax County, Virginia, establishing a model maintenance management program for wastewater treatment plants throughout the United States.

This PMMS provides for the specific maintenance needs of each item of plant equipment and reduces the maintenance of complex equipment to simple procedures. For each procedure, the PMMS details the methods, materials, tools and personnel required; schedules the task; and provides for data recording and feedback.

The success of this PMMS was measured during the 12-month demonstration phase by a steady downward trend in the malfunction of mechanical equipment. Incipient failures were detected in many cases and corrective action was taken to avoid breakdowns.

This report describes the PMMS in technical detail; discusses the installation of the PMMS, including acceptance by the mechanics and coordination with plant operations; and outlines the application of the PMMS to other wastewater systems.

This report was submitted in fulfillment of Project Number 11010 GWI by EnviroPlan, Incorporated, College Park, Maryland, under contract to the County of Fairfax, Virginia, and under the sponsorship of the United States Environmental Protection Agency. Work was completed as of July 1973.

CONTENTS

		Page
Abstract		ii
List of Figures		iv
List of Tables		v
Acknowledgements		vi
Sections		
I	Conclusions	1
II	Recommendations	3
III	Introduction	5
IV	Background of Maintenance Management	9
V	Description of the Planned Maintenance Management System	14
VI	Program Installation and Demonstration	46
VII	Application To Other Wastewater Treatment Plants	55
VIII	References	60
IX	Glossary	62
X	Appendices	63

FIGURES

No.		Page
1	Form M1, Equipment Reference Data	22
2	Form M1 (Reverse), Parts List	23
3	Form M2, Equipment Maintenance Record	30
4	Form M3, Preventive Maintenance Work Record	31
5	Form M3 (Reverse), Report of Trouble	31
6	Form M3X, Variation of Form M3	32
7	Form M4, Equipment Malfunction Report	33
8	Form M5, Corrective Maintenance Work Order	35
9	Form M6, Corrective Maintenance Work Order and Work Record	36
10	Form M7, Weekly Maintenance Summary Report	37
11	Form M7 (Reverse), Corrective Maintenance Summary	38
12	Corrections to Measured Insulation Resistance	44

Appendix II

A-1 through A-18	Examples of Maintenance Procedure Sheets (MPSs)	67

TABLES

No.		Page
1	Functional Number System	16
2	Samples From Equipment Configuration List	18
3	Samples From Equipment Data List	20
4	Samples From List of Additional Equipment Data	21
5	Sample From List of Maintenance Procedures	26
6	Example of Weekly PM Schedule	28

Appendix III

A-1	Equipment Type Classification	96
A-2	Indicators and Modifiers	97
A-3	Annual PM Manpower Requirement	98
A-4	Cross Reference To Equipment Configuration List	99
A-5	List of Maintenance Procedures For Remote Electrical Controls	103
A-6	Cross Reference, Alarm Sensors to Alarm Indicators	105
A-7	Incineration Equipment Which May Not Be Shut Down Arbitrarily	107
A-8	Maintenance Procedures in Category A	108
A-9	Maintenance Procedures in Category B	109
A-10	Estimated and Actual Time (Minutes) For PM Actions	111

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Credit for form layout and report editing is given to Ms. Marcia Kasow.

SECTION I

CONCLUSIONS

Since this Planned Maintenance Management System (PMMS) was initiated at Fairfax County's Lower Potomac Wastewater Treatment Plant, there has been a steady trend towards reduction of mechanical equipment malfunctions, bringing mechanical trouble to the lowest point since the start up of the plant.

The key to this PMMS is its extensive detail. The one-time effort of creating the basic equipment and maintenance data base, which provides for every maintenance need of every individual item of equipment in the plant, is a substantial task. Once in operation, however, the PMMS is a working, straightforward guide to the systematic, timely, safe and complete accomplishment of equipment care and inspection. The maintenance of numerous and complex installations is reduced to simple, specific procedures which are easily identified, followed and managed.

The PMMS, once installed, is easily operated and updated by plant personnel. In addition to the major mechanical and hydraulic equipment, the PMMS pays equal attention to the electrical equipment and controls, to the process measuring and read-out devices and to the alarm systems in the plant; in short, to every item in the plant necessary for continuous and optimum wastewater treatment.

Instead of complete reliance upon blanket recommendations of equipment manufacturers, the PMMS incorporates the environment and service duty of the equipment, the operational constraints upon equipment maintenance, and the skill levels and availability of personnel in defining the maintenance program.

The PMMS minimizes the paperwork burden for both the mechanics and the plant management. The paperwork is isolated so that it is performed by a clerk with or without the aid of data processing machinery. The mechanics are not required to understand or to use the internal numbering systems of the PMMS; all that is required is that they have the technical skills to perform the tasks with the aid of the step-by-step procedures furnished by the PMMS.

The PMMS has been developed as a model for nationwide application. It has been intentionally kept straightforward for use by small plants, and it is intentionally expandable to accommodate larger and/or more complex plants. The PMMS is also applicable to wastewater collection and pumping systems, fresh water treatment and pumping systems and storm water systems.

SECTION II

RECOMMENDATIONS

A significant recommendation is the effective introduction of the Planned Maintenance Management System (PMMS) to plant mechanics to enlist their cooperation and acceptance of the rather formal system. The PMMS must be presented as a vehicle for the mechanics to more effectively perform their jobs without undue paperwork, and to ensure that their observations and recommendations are recognized and followed.

The PMMS must be set up and conducted at a particular plant with full cooperation between the Maintenance and Operations Departments. Some unit operations cannot or should not be interrupted arbitrarily for servicing; conversely, operating schedules for parallel units should accommodate the maintenance requirements.

Well over half of the required preventive maintenance manpower requirement is in conducting routine and frequent tasks which might possibly be performed by regular operators rather than by assigned maintenance personnel. However, it is extremely desirable that the Maintenance Department perform these tasks since, in reality, they constitute a regular and frequent inspection of all of the plant's equipment by knowledgeable and observant mechanics. At the Lower Potomac Plant, many incipient malfunctions were detected before breakdowns occurred simply because assigned maintenance personnel made a thorough systematic inspection on a daily basis.

The monitoring task of scheduling, or recording, and of reporting is a continuing job which the PMMS isolates from both the mechanics and the plant management. For the 18-mgd Lower Potomac Plant, this task was performed manually by one Maintenance Technician, but only with some difficulty due to the large number of maintenance actions and the corresponding large volume of data. For smaller plants, a manual system may be installed; but for plants as large or larger than the Lower Potomac Plant, it is strongly recommended that some form of data processing system be utilized. The system may include, depending upon plant size, mechanical filing equipment, retrieval equipment or electronic data processing equipment.

The one-time task of tailoring the PMMS and creating a basic data base for the PMMS for a particular plant is substantial, simply because great detail is required to include each and every item of equipment into the PMMS. This one-time task should not be attempted by regular staff members on a part-time basis; it should have the full attention of an experienced staff maintenance engineer, or of a contractor experienced in wastewater systems maintenance management. Once installed, the PMMS can be operated and readily updated by regular plant personnel.

SECTION III

INTRODUCTION

PRIMARY OBJECTIVE

The primary objective of this program was to develop and demonstrate a Planned Maintenance Management System (PMMS) at the Lower Potomac Wastewater Treatment Plant of Fairfax County, Virginia, to establish a model maintenance management program for wastewater treatment plants throughout the United States, and to demonstrate increased plant reliability for the continuous protection of the quality and uses of the receiving waters.

DESCRIPTION OF THE LOWER POTOMAC PLANT

As a point of reference for those who may adapt this PMMS to other wastewater treatment plants, the Lower Potomac Plant is an 18-mgd secondary treatment plant which has been in service for approximately three years. It basically consist of:

1. An administration building (Area A).

2. A raw wastewater pumping station (Area B), with two parallel, mechanically cleaned bar screens upstream of three raw wastewater pumps (two-speed, constant-speed and variable-speed). Belt conveyors are used for the screenings.

3. Primary Treatment (Area C), with two parallel, three-bay rectangular settling tanks. There are three parallel primary sludge pumps and two parallel scum pumps in Area C.

4. Primary Sludge Degritting (Area H) with two cyclone-type units.

5. Secondary Treatment (Area D), consisting of two parallel three-pass aeration tanks for the step-aeration activated sludge process. The three air blowers are in Area E, along with three return sludge pumps, two excess (waste) sludge pumps and other major equipment items.

6. Secondary Clarification (Area F), with two circular clarifiers.

7. Chlorination (Area G).

8. Return Process Water Pumping Station (Area G), with two high-lift and four low-lift pumps.

9. Sludge Thickening (Area J), with two circular gravity thickeners, and four plunger pumps.

10. Sludge Processing (Area K), with a thickened sludge storage tank, three sludge plunger pumps, two sludge conditioning tanks with associated lime and ferric chloride feeding capability, and two vacuum filters. Dewatered sludge from other County plants is occassionally brought to Lower Potomac, and all dewatered sludge is conveyed to either of two multiple-hearth incinerators equipped with exhaust gas scrubbers and ash conveying and conditioning capability.

11. Plant shop and service building (Area L).

GOALS OF THE PLANNED MAINTENANCE MANAGEMENT SYSTEM (PMMS)

The PMMS was targeted towards achieving the highest level of plant performance by:

1. Providing a means for knowledgeable management of maintenance.

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

3. Increasing plant reliability by preventing equipment breakdown and by prolonging equipment life.

4. Minimizing maintenance manpower requirements.

5. Providing a complete record system and a system for feedback to management.

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

Prior to the development and demonstration of this PMMS, the state-of-the-art of maintenance management at wastewater treatment plants generally consisted of, in many cases, a set of guidelines for generic classes of equipment, such as "change the oil in all mechanical drives and reducers every six months or sooner." The application of such general guidelines to the actual effort of servicing each of the hundreds or thousands of individual items of equipment in the plant has been a restrictive condition for the following reasons:

1. Lack of a concise list, for example, of all the mechanical drives in the plant.

2. Lack of a precise time called out for servicing any specific item of equipment.

3. Lack of a document which was easily accessible to the mechanic that specified which type of oil to use, what special procedure was required, what special tools were required, what special safety precautions were to be taken, or what operational constraints existed.

4. Lack of coordination in combined servicing of a pump, motor, drive, controller, etc., which operate as a unit.

5. Lack of a prior estimate of what manpower was required, both in terms of time and type.

6. Lack of an easy way for anyone to analyze or summarize the maintenance records, assuming that maintenance records were kept. If adequate maintenance records were kept, the mechanics might have been spending too much time in paperwork.

The PMMS developed and demonstrated in this program bridges the gap between general guidelines and the actual item-by-item maintenance of plant equipment. It reduces the maintenance of complex and/or numerous and widely scattered equipment into simple procedures, specific for each equipment item and each task. These specific, simple procedures are directly useful to the mechanic on the job; they are also easily identified and managed. For each preventive maintenance work task, the PMMS identifies each task; describes the methods, materials, tools and personnel required; schedules the tasks; and provides for data recording and feedback.

Nationwide Applicability

The PMMS developed in this program has a dual purpose: to provide a maintenance management program specific to the Lower Potomac Wastewater Treatment Plant, and to provide a model program for other plants across the nation. This latter purpose required that, from the very start of the PMMS development, it be adaptable and flexible to make its usefulness as broad as possible. However, under no circumstances was the PMMS for the County of Fairfax to be degraded by a lack of specificity.

Manual- and Computer-Adaptable Systems

The PMMS developed and demonstrated by this program is a manual system, with all data handling, recordkeeping and reporting accomplished within the existing capabilities of the plant, i.e., without mechanical or electronic data processing equipment.

However, it was recognized from the start that data processing aids would eventually be utilized in conducting the PMMS either at the Lower Potomac Plant or in its application to other wastewater systems. Consequently, the PMMS was developed from the start so that computerization would be a straightforward task.

SYSTEM DEVELOPMENT AND DEMONSTRATION PHASES OF THE PROGRAM

The actual program was conducted in 16 months, concluding on April 6, 1973. The development of the PMMS was Phase I of the program, and was completed in the first four months. Phase II was a 12-month effort to monitor, evaluate, update and modify the PMMS during its actual use and demonstration at Fairfax County's Lower Potomac Wastewater Treatment Plant.

SECTION IV

BACKGROUND OF MAINTENANCE MANAGEMENT

GENERAL DISCUSSION OF MAINTENANCE

Maintenance is the function of sustaining or restoring equipment so that the equipment performs its intended job safely, effectively and economically. The three basic types of maintenance are:

1. Preventive—periodic tasks of care and inspection scheduled to prevent a breakdown or prolong the life of equipment.

2. Corrective—unscheduled tasks required to restore equipment to operational status after a breakdown or impending failure is discovered.

3. Overhaul—complete disassembly and reconditioning to like-new status.

The tasks of maintenance are combinations of inspection and care. Examples of inspection tasks are:

1. Looking or listening for wear or malfunction
2. Checking out electric circuits
3. Looking for cracks and tightness
4. Measuring clearance
5. Looking at corrosion protection.

Examples of equipment care tasks are:

1. Lubricating
2. Renewing seals and packings
3. Adjusting equipment
4. Sharpening cutting edges
5. Replacing worn parts; e.g., drive belts, safety pins, wear plates
6. Renewing corrosion protection
7. Restoring worn areas to an acceptable tolerance
8. Exercising seldomly used units.

The kinds and amounts of both inspection and care tasks are usually based upon extreme conditions. Review of these tasks should be made periodically to relate them to the actual service conditions, but this step is difficult because feedback from the operator and the maintainer are not easily coordinated.

PREVENTIVE AND CORRECTIVE MAINTENANCE

Preventive Maintenance (PM) is scheduled and regulated care intended to prevent a breakdown or to prolong the life of the equipment, coupled with intervals of recorded inspections can portray a trend or a deviation from operating standards. Any deviation must be presented to the controller in sufficient time to allow the care to be altered, thus eliminating the breakdown and a later need for Corrective Maintenance. The amount of care and inspection must be carefully considered so that time, effort or material is not wasted on over care.

The decision affecting quantity and quality of PM also should be governed by need. To satisfy the above conditions, it is necessary to have a realistic set of PM requirements, defined in a language all concerned can understand and published in a form useful to the person doing the work. Each work task must be assigned to a specific person, in writing and relative to when it was last accomplished and when it again falls due, to maintain the cycle.

A usable record of accomplished PM and Corrective Maintenance not covered by PM is necessary so that a history may be accumulated to justify relaxing some requirements or establishing new ones. This history must be relayed to a central point so that all similar activities can benefit through method improvements generated as a result of the feedback, and decisions can be made more rapidly.

Generally, PM requirements should not remove the equipment from an operationally ready status. This does not preclude the scheduled removal of components to accomplish the prescribed care during an idle period of the equipment. It is not always possible to configure equipment so that removal of parts for care will not interfere with the equipment's readiness to perform. Also, few pieces of equipment are required for continuous operation without a back-up. The back-up will require some operation to ensure reliability, therefore providing a relief for main equipment, at which time the maintenance can be performed. Any needed maintenance that can be scheduled for timely occurrence will then be classified as PM.

Corrective Maintenance (CM) is work that is required to restore a piece of equipment to an operational status after a breakdown or when the inspection cycle indicates a corrective task must be performed before further reliable use can be assured. The latter is similar to the PM requirement in that the prescribed inspection would monitor the questioned tolerance of an item until it nears out-of-limits. The task of correction is required when the equipment is found to be unsatisfactory to operate through another inspection cycle.

Overhaul means a complete disassembly of an item of equipment; removing it from an operationally ready status. Each piece is carefully inspected, restored to original operating characteristics and reassembled to start an operating cycle similar to a new piece of equipment.

MAINTENANCE MANAGEMENT SYSTEMS

The Federal Guidelines for the Design, Operation and Maintenance of Waste Water Treatment Facilities[1] specify that wastewater treatment plant designs must make equipment accessible for maintenance, that an effective equipment maintenance program is necessary and that sufficient funds must be provided for maintenance. The U.S. Environmental Protection Agency construction grant program requires that the grantee provide, for each grant-assisted plant, provisions for adequate maintenance in accordance with Section 35.935-12 of 40 CFR Part 35.

There are several comprehensive maintenance management systems which have been developed to satisfy the particular requirements of the armed services and of the aircraft industry. The Standard Navy Maintenance and Materiel Management System,[2] commonly referred to as the "3M System", takes cognizance of and offers remedial solutions to the increasing complexity of equipment being introduced into the U.S. Navy Fleet and the decreasing availability of skilled personnel to maintain them.

The Air Force Maintenance Management System,[3] commonly referred to as the 66-1 System, is applicable to all Air Force activities engaged in the maintenance of aircraft, missiles, munitions, aerospace ground equipment, training equipment, airborne communications-armament-electronics equipment and ground communications-electronics-meteorological equipment.

The general literature reveals the recognition of maintenance management as a key element of plant engineering. Vida[4] recommends

employing an outside consulting firm to gain management control of maintenance, with the installation of a PM system, a work order system, an inventory control system and personnel training. Kittner[5] is in favor of a formal PM system even for small plants, including such elements as work requests, schedules for PM and manpower requirements analyses. The advantages he gives include more effective scheduling of personnel, reduction of delays from lack of materials, reduction of travel time, better use of employee skills and better relationships with supervisors. Baronet[6] also is strongly in favor of formal scheduling, but feels that smaller plants are less in need of formality.

Carson and Mailhos[7] give a method for compiling a maintenance budget which involves breaking the services down into preventive maintenance, routine repairs and major repairs or alterations. Careful recording of costs leads to realistic budgets. Fuchs[8] outlines a work order system for a small plant, and argues that since maintenance problems are universal, small plants are not immune to such problems, and therefore need a system just as do large plants.

The idea of contract maintenance, or maintenance work performed by other than in-plant forces, was explained by Sullivan[9] and by Sarappo.[10] This system is geared for maintenance managers concerned with having an adequate quantity of skilled personnel available at the proper time. Sarappo's article contains a questionnaire aimed at evaluating whether or not a plant could effectively use contract maintenance.

A computerized maintenance management program in the Russian chemical industry was described by Antropov and Zuev,[11] with a mathematical treatment of optimum scheduling. Buttery[12] also described a computer-based system for maintenance recordkeeping of manpower, materials and equipment.

The organization of a maintenance department to clearly define responsibilities was the subject of James'[13] article and Hooper's[14] paper. Edmonson, et al.,[15] explained how management usually does not know the true cost of maintenance, since much of these costs are hidden in general plant overhead and in other items. Dodds[16] listed the features of a system to minimize the paperwork in a maintenance system by setting up job control centers throughout the plant.

Two studies by Michel, et al.,[17, 18] classified municipal wastewater treatment plants according to region, population served and type of equipment. Plant size is probably the most important single factor influencing the type of maintenance management system. Smaller plants,

of 10 mgd capacity or less, usually have very limited resources for maintenance in terms of number of employees, their special skills and the repair facilities available. They are generally unable to do any complex maintenance tasks and must look to outside help. Very large wastewater plants like the Hyperion Plant in Los Angeles, described by Garber,[19] have elaborate staffs and facilities and can be virtually self-sufficient. Garber also gave examples of the Hyperion work order and recordkeeping system.

Smith[20] tabulated in detail O&M cost data which can serve as starting points in constructing a guideline for a wastewater treatment plant budget.

SECTION V

DESCRIPTION OF THE PLANNED MAINTENANCE MANAGEMENT SYSTEM

The objective of the Planned Maintenance Management System (PMMS) is to reduce the preventive maintenance of a large number of equipment items, many of which are complex, to a set of explicit, simple tasks which can be easily scheduled, managed, performed and recorded. The system:

1. Reduces the maintenance of complex equipment to simple procedures which are easily identified and managed.
2. Defines the minimum requirements of planned maintenance.
3. Schedules and controls the performance of work tasks, inspections and tests.
4. Describes the methods, materials, tools and personnel required.
5. Provides for the prevention or detection of impending malfunctions.
6. Provides a permanent record of equipment characteristics and a maintenance history.
7. Provides periodic maintenance summary reports to plant management.

Although the PMMS is aimed at ensuring the systematic, timely, safe and complete accomplishment of equipment care and inspection, two factors must be emphasized.

1. PMMS is a tool of management rather than a substitute for a manager.
2. No system can substitute for the actual technical ability required of personnel who direct and perform the upkeep of equipment.

It is important to appreciate the scope of the PMMS. For it to be effective in achieving the highest continuous level of plant performance, all of the plant equipment must be included in the PMMS. It is not sufficient to merely attend to the mechanical and hydraulic equipment; the PMMS must pay equal attention to electrical equipment, electrical controls, electrical supply substations, measuring devices, meters and recorders, alarm sensors and alarm indicators.

The detailed description of the PMMS is contained in the remainder of this Section. First, the five basic parts of the PMMS are described, and then a number of special considerations (for municipal wastewater treatment plants) are discussed.

BASIC PARTS OF THE PMMS

The five basic parts of the PMMS are:

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

The initial step in the development of the PMMS is the one-time accomplishment of a complete inventory of plant mechanical and electrical equipment, including a take-off of nameplate data utilizing Form M1, shown in Figures 1 and 2 on pages 22 and 23. The resultant inventory list is then restructured into the Equipment Configuration List by sorting into appropriate groupings, equipment related to each of the various plant unit process functions. Within each grouping, equipment is oriented by a numbering system described below. Table 2 is a sample page from the Equipment Configuration List of the Lower Potomac Plant.

Each item of equipment in the plant is assigned a unique five-digit identification (ID) number. The first three digits identify the function of the equipment. Table 1 is the functional numbering system for the 18-mgd Lower Potomac Wastewater Treatment Plant of Fairfax County, Virginia. The first digit identifies one of the major systems in the plant, the second identifies the subsystem and the third identifies the particular function. For example, referring to Table 1, 522 refers to all sludge pumping equipment in the sludge thickening area. The digit 5 refers to Sludge and Scum Processing; the second digit, 2, refers to Sludge Thickening; and the third digit, 2, refers to Pumping. This functional numbering system was designed to be expandable both vertically, for more complex plants with more systems, subsystems and functions, such as AWT; and horizontally, for larger plants with more parallel items of equipment, or for plant expansion.

The fourth and fifth digits of the ID number specify exactly and uniquely each item of equipment, as illustrated in Table 2. The fourth digit identifies the piece of equipment within the functional unit—the drive, for example, in a pump-motor-drive-controller unit; and the fifth digit identifies which

Table 1. FUNCTIONAL NUMBER SYSTEM

100 Raw Wastewater Station
- 110 Screening
  - 111 Bar Screens
  - 112 Conveyors
- 120 Grinding
  - 121 Grinders
- 130 Wastewater Flow
  - 131 Pumping
  - 132 Valves and Gates
  - 133 Wet Well Level Control
  - 134 Flow Measurement
  - 135 Pump Seal Water
  - 136 Compressed Air
- 140 Auxiliary Services
  - 141 Sump Pumping
  - 142 Ventilation
  - 143 Hoists
  - 144 Electrical Supply

200 Primary Treatment
- 210 Primary Settling
  - 211 Tanks and Gates
  - 212 Sludge Collectors
  - 213 Scum Launders
- 220 Sludge Handling
  - 221 Pumping
  - 222 Pump Seal Water
  - 223 Flow Measurement
  - 224 Sludge Degritting
- 230 Scum Handling
  - 231 Pumping
  - 232 Pump Seal Water
  - 233 Scum Well Level Control
- 240 Auxiliary Services
  - 241 Sump Pumping
  - 242 Ventilation
  - 243 Hoists
  - 244 Electrical Supply

300 Secondary Treatment
- 310 Aeration
  - 311 Tanks and Gates
  - 312 Adjustable Weirs
  - 313 Tank Air Diffusers
  - 314 Incremental Feed Channel Air Diffusers
  - 316 Tank and Feed Channel Water Sprays
  - 316 Mixed Liquor Flow Measurement
  - 317 Diffuser Sock Washing
- 320 Air Delivery
  - 321 Filters
  - 322 Blowers
  - 323 Flow Measurement
  - 324 Pressure Relief
  - 325 Channel Sparger Air Delivery
  - 326 Compressed Air
- 330 Secondary Clarifiers
  - 331 Mixed Liquor Channel Air Spargers
  - 332 Mixed Liquor Channel Water Sprays
  - 333 Clarifier Mechanism and Gates
- 340 Chemical Treatment
  - 341 Flocculant Mixing
  - 342 Flocculant Pumping
- 350 Return Sludge
  - 351 Pumping
  - 352 Pump Seal Water
  - 353 Return Sludge Wet Well Level
  - 354 Dewatering
  - 355 Flow Measurement
- 360 Excess Sludge
  - 361 Pumping
  - 362 Pump Seal Water
  - 363 Flow Measurement
  - 364 Dilution
- 370 Scum
  - 371 Scum Well Level Control
  - 372 Scum Pumping
- 380 Auxiliary Services
  - 381 Sump Pumping
  - 382 Ventilation
  - 383 Hoists
  - 384 Electrical Supply

400 Chlorination and Effluent Flow
- 410 Chlorination
  - 411 Chlorine Handling and Weighing
  - 412 Evaporation
  - 413 Chlorinators
  - 414 Chlorine Detection and Venting
  - 415 Injectors and Diffusers
  - 416 Contact Chambers
- 420 Residual Chlorine Analysis
  - 421 Analyzers
  - 422 Influent Sampling
  - 423 Effluent Sampling
- 430 Effluent Water
  - 431 Weirs and Gates
  - 432 Level Measurement
  - 433 Return Water Pumping, High Lift
  - 434 Return Water Pumping, Low Lift
  - 435 Pump Seal Water
- 440 Auxiliary Services
  - 441 Sump Pumping
  - 442 Ventilation
  - 443 Hoists
  - 444 Electrical Supply

Table 1 (continued). FUNCTIONAL NUMBER SYSTEM

500 Sludge and Scum Processing
- 510 Auxiliary Services
  - 511 Sump Pumping
  - 512 Ventilation
  - 513 Hoists
  - 514 Electrical Supply
- 520 Sludge Thickening
  - 521 Thickeners
  - 522 Pumping
  - 523 Flow Measurement
  - 524 Chlorination
  - 525 Compressed Air
- 530 Sludge Storage and Handling
  - 531 Sludge Storage Tank
  - 532 Screw Feeders
  - 533 Pumps
  - 534 Conveyors
  - 535 Flow Measurement
  - 536 Flushing Water
  - 537 Hydraulic Power
  - 538 Sump Pumping
- 540 Scum Handling
  - 541 Weir Control
  - 542 Pumping
- 550 Lime Treatment
  - 551 Dry Lime Storage Tank
  - 552 Level Indication
  - 553 Vibration
  - 554 Dust Collection
  - 555 Dry Lime Feeding
  - 556 Lime Mixing
  - 557 Lime Slurry Pumping
- 560 Ferric Chloride Treatment
  - 561 Storage Tanks
  - 562 Compressed Air Supply
  - 563 Day Tanks
  - 564 Pumping
- 570 Polymer Treatment
  - 571 Mixing
  - 572 Pumping
- 580 Sludge Conditioning
  - 581 Conditioning Tanks
- 590 Vacuum Filtration
  - 591 Vacuum Pumping
  - 592 Filtering
  - 593 Filter Agitation
  - 594 Filtrate Pumping

600 Incineration
- 610 Incinerators
  - 611 Mechanisms
- 620 Gas Supply
  - 621 Oil Supply
  - 631 Shutoff
  - 632 Filtration
  - 633 Pumping
  - 634 Flow Rate
- 640 Air Supply and Foul Gases
  - 641 Cooling Air
  - 642 Combustion Air
  - 643 Four Gas Delivery
- 650 Scrubbing
  - 651 Scrubbers
  - 652 Flush Water
  - 653 Exhaust Fans
- 660 Ash Handling
  - 661 Elevators
  - 662 Conveyors
  - 663 Storage
  - 664 Conditioning
  - 665 Feeding
- 670 Auxiliary Services
  - 671 Sump Pumping
  - 672 Ventilation
  - 673 Hoists
  - 674 Electrical Supply

700 Utilities and Services
- 710 Recorders and Meters
  - 711 Flow
  - 712 Pressure
  - 713 Level
  - 714 Concentration
  - 715 Electrical and Position
- 720 Laboratory Facilities
  - 721 Lab Equipment
- 730 Plant Service Equipment
  - 731 Plant Water
  - 732 Heating
  - 733 Hot Water
  - 734 Lighting
- 740 Outside Utility Supply
  - 741 Electricity
  - 742 Gas
  - 743 County Water
- 750 Maintenance & Repair Facilities
  - 751 Machine Shop
  - 752 Mechanical Shop
  - 753 Electrical Shop
- 760 Buildings and Grounds
- 770 Safety Equipment
  - 771 Fire Extinguishers
  - 772 Hydrants
  - 773 Emergency Lighting
  - 774 First Aid Equipment

Table 2. SAMPLES FROM EQUIPMENT CONFIGURATION LIST

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

of the parallel units is being specified. The numbering system permits all similar parallel units to be grouped by the first four digits, and it permits all equipment which operates together as a unit to be grouped by the first, second, third and fifth digits.

The Equipment Configuration List, based upon this numbering system, identifies all of the equipment in the plant. In addition to the identification number and the common name, other information is provided. An equipment type number tells what the equipment item is; for example, 33 means electric controls, regardless of the function of the item in the plant (Table A-1 of Appendix III is the list of equipment type numbers for the Lower Potomac Plant). The location tells the area in the plant, the level within the area (upper, middle, lower), the location within the area (N.W., S.E., etc.) and the relative location with respect to similar or parallel items.

The Equipment Data List (illustrated by Table 3) augments the main Equipment Configuration List and is grouped by equipment type. For each item of equipment, identified by its five-digit ID number, the Equipment Data List contains the manufacturer's name, the part or model number and the serial number.

The Equipment Data List, with the equipment type number, is useful for grouping equipment with similar maintenance requirements and with similar spare parts requirements. This list is extremely useful in searching for replacement units or parts in the event of a breakdown leading to an emergency situation.

Even more detailed data are tabulated in a similar fashion to augment the Equipment Configuration List. Table 4, a sample list from the Lower Potomac Plant, shows how pumps are separately listed with their head, capacity, size, impeller and RPM; and how electric motors are separately listed with their horesepower, frame, RPM, voltage, amperage and number of phases.

In addition to these tabular equipment inventory lists, which should be kept at a central location, the pertinent data for each item of equipment is also recorded on a single sheet of paper, Form M1, for easy reference (close to the equipment).

Form M1, "Equipment Reference Data," is an 8-1/2 x 11-inch permanent record for each item of equipment. Figures 1 and 2 show both sides of Form M1. All descriptive data from manufacturer's catalogs, drawings, bulletins and reference documents are transcribed onto Form M1. This form has three special blocks for data should the item of equipment be an electric motor, a pump or a drive or reducer. For items of equipment

Table 3. SAMPLES FROM EQUIPMENT DATA 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

Table 4. SAMPLES FROM LIST OF ADDITIONAL EQUIPMENT DATA

ADDITIONAL DATA FOR PUMPS					
	TDH	GPM	SIZE	IMP	RPM
13112	27.5	19200	24	24 3/8	585
13113	25.5	14000	24	22 1/4	585
13114	27		20	20 5/8	665
22113	35	100	4X4		800
22114	35	100	4X4		800
22115	35	100	4X4		800
23111	8	100	4X9	9	600
23112	8	100	4X9	9	600
35111	29	4200	12	12 3/8	1170
35112	29	4200	12	12 3/8	1170
35113	29	4200	12	12 3/8	1170
35411	25	1000	6	12	875
36113	16.5	1250	8	14	640
36114	16.5	1250	8	14	640
43311	160	1500	5X8	13 7/8	1750
43312	160	1500	5X8	13 7/8	1750
43411	60	1200	5	9 7/8	1750
43412	60	1200	5	9 7/8	1750
43413	60	1200	5	9 7/8	1750
43414	60	1200	5	9 7/8	1750

ADDITIONAL DATA FOR ELECTRIC MOTORS						
	HP	FRAME	RPM	VOLTS	AMPS	PH
42221	0.5	M48	3450	115/230	6.8/3.4	1
42222	0.5	M48	3450	115/230	6.8/3.4	1
42223	0.5	M48	3450	115/230	6.8/3.4	1
42321	0.5	M48	3450	115/230	6.8/3.4	1
42322	0.5	M48	3450	115/230	6.8/3.4	1
42323	0.5	M48	3450	115/230	6.8/3.4	1
43321	100	445UP	1770	230/460	228/114	3
43322	100	445UP	1780	230/460	228/114	3
43421	30	A326UPY	1800	230/460	72.7/36.4	3
43422	30	A326UPY	1800	230/460	72.7/36.4	3
43423	30	A326UPY	1800	230/460	72.7/36.4	3
43424	30	A326UPY	1800	230/460	72.7/36.4	3
43521	5	213	3180	230/460	13.8/6.8	3
43522	5	213	3180	230/460	13.8/6.8	3
44121	0.75	56C	1725	230/460	3.1/1.55	3
44221	0.5	J56	1140	220/440	1.9/0.95	3
44222	0.17	F48	1725	115	3.4	1

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		

Electric Motor		Pump		Drive or Reducer
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	

Electric Motor	Pump	Drive or Reducer
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 1. Form M1, Equipment Reference Data

PARTS LIST

Name of Part	Manufacturer	Cat. No.	Local Supplier	Cost

Form M1 Reverse)-5/72

Figure 2. Form M1 (Reverse), Parts List

not falling into one of these common categories, the data is entered in the block at the bottom of the form. The reverse side of Form M1 is for listing parts which are likely to be replaced. The basic purpose of Form M1 is to provide an accessible file of manufacturer's data for use in the event of a breakdown, or a proposed modification or replacement. The data on the form is also useful for generating an equipment inventory list and for planning a spare parts inventory.

The Maintenance Procedures

Each individual Maintenance Procedure (MP) is detailed on a numbered Maintenance Procedure Sheet (MPS), and:

1. Defines the maintenance task in terms that allow all concerned to know what is required, who must perform, estimate of time required and how often.

2. Standardizes the procedure and sequence for doing a job in the best known way.

3. Expedites the accomplishment of the task by stating the tools and materials needed and the safety precautions to be observed.

4. Provides a concise and complete work instruction to the maintenance personnel in the work space. The basic objective of the MPS is to be all inclusive. References to other publications are not required since availability of outside references other than instructions posted on or near the equipment cannot be assured.

For each equipment item in the plant, an MPS is included for each PM action. Since the maintenance requirements for parallel units are identical, the MPS is identified by the first four digits only and is applicable to all equipment items with those first four digits.

Each MPS has an additional two-character code. The first character specifies the required frequency for the particular maintenance according to the following list:

D - Daily	Q - Quarterly
W - Weekly	S - Semiannually
M - Monthly	A - Annually
R - As required	

The second character is the designated number of MPs to be performed at the specified frequency.

Examples of some MPSs are included in Appendix II as Figures A-1 through A-18. A variety of MPSs are included to show the type and extent of the information included for different classes of equipment and maintenance actions. Each MPS contains:

1. The number, the descriptive title and the frequency of the maintenance action to be performed.

2. The skill level required to perform the maintenance.

3. An average time required to perform the maintenance, not including "make ready" and "put away" time.

4. The complete title, identification number, nameplate data and location of the equipment to avoid any ambiguity over which item of equipment is to be serviced.

5. The specific safety precautions to be observed when performing the maintenance action(s).

6. A list of tools, parts, materials and test equipment required.

7. The individual step-by-step instructions for the maintenance action. The instructions are specific, stating which type of lubricant to use, or what torque to use for tightening bolts, etc. The first instruction is always a repetition of the safety precautions.

A concise summary list of Maintenance Procedures (MPs) was generated to enable the Maintenance Engineer to rapidly identify the PM actions for each unit in the plant. Table 5 is a sample page of the summary list of Maintenance Procedures for the Lower Potomac Plant. This summary lists the operating unit, the description of the work to be performed for each Maintenance Procedure, the frequency of each PM task, the manpower requirement by skill and time in minutes for each PM task, and a key which initiates the schedule for performing each PM task. This key is simply the first scheduled week number, not necessarily January 1, but the week selected for PMMS start up, from which all other scheduled week numbers automatically follow.

1. Daily and weekly MPs are, of course, scheduled for every week from one to fifty-two.

2. For monthly MPs, add to the key number: 0, 4, 8, 13, 17, 21, 26, 30, 34, 39, 43, 47.

Table 5. SAMPLE FROM LIST OF MAINTENANCE PROCEDURES
(keyed to Maintenance Procedure Sheets [MPSs])

MP No.	Task Description	Skill/Minutes 1	2	3	Week No.
*1111	2 Bar Screen Mechanical Cleaner				
1111 D1	Lubricate bar screen		20	20	1
1111 D2	Inspect rake assembly and chain		15	15	1
1111 M1	Inspect counterweight shock absorbers			18	1
*1112	2 Motor, Bar Screen Cleaner				
1112 Q1	Clean motor and perform elec. inspection	18		18	1
1112 A1	Lubricate motor			30	1
*1113	2 Drive, Bar Screen Cleaner				
1113 W1	Check oil level			12	1
1113 Q1	Change oil		30		1
*1114	2 Control, Bar Screen Cleaner				
1114 A1	Clean and inspect controller	48		48	1
1114 A2	Clean and inspect remote control switch	30			1
*1121	3 Conveyor, Bar Screen Cleanings				
1121 W1	Inspect and lubricate conveyor		24		1
*1122	3 Motor, Conveyor, Bar Screen Cleanings				
1122 M1	Inspect drive belt(s) tension		12		3
1122 Q1	Clean motor and perform elec. inspection	18		18	3
1122 A1	Lubricate motor			24	3
*1123	3 Drive, Conveyor, Bar Screen Cleanings				
1123 W1	Check oil level			12	1
1123 S1	Change oil		30		3
*1124	3 Control, Conveyor, Bar Screen Cleanings				
1124 A1	Clean and inspect controller	48		48	3
1124 A2	Clean and inspect remote control switch	30			3
*1211	2 Grinder, Bar Screen Cleanings				
1211 W1	Lubricate grinder			18	1
1211 M1	Inspect drive belt(s) tension		18		2
1211 M2	Inspect grinder		90	180	2
*1212	2 Motor and Drive, Grinder, Bar Screen Cleanings				
1212 Q1	Clean motor and perform elec. inspection	18		18	6
1212 A1	Lubricate motor			30	6
*1213	2 Control, Grinder, Bar Screen Cleanings				
1213 A1	Clean and inspect controller	48		48	6
1213 A2	Clean and inspect remote control switch	30			6
*1311	3 Raw Wastewater Pump A				
1311 W1	Inspect packing gland adjustment		12		1
1311 R1	Renew packing		180		
1311 S1	Lubricate pump bearings			12	9
1311 S2	Lubricate coupling			6	9

*Equipment name

3. For quarterly MPs, add to the key number: 0, 13, 26, 39.

4. For semiannual MPs, add to the key number: 0, 26.

5. For annual MPs, the key number is the scheduled week number.

The Preventive Maintenance (PM) Cycle Schedule

The PM actions are scheduled for each of the 52 weeks of the year. Table 6 is a sample listing of the Maintenance Procedures (MPs) scheduled for a particular week at the Lower Potomac Plant. The list is generally organized so that all MPs for a single unit in the plant are listed together for the purpose of assigning them to a single team at a time. Hence, the unit need be removed from service only once. Furthermore, the schedule was generated to group MPSs on the same unit, although of differing frequencies, during the same weeks.

The actual work assignment on a daily basis is left to the discretion of the foreman and plant management, since operational constraints, corrective maintenance work loads and employee absenteeism cannot be fully anticipated.

During one week in each quarter of the year, only daily and weekly PM is scheduled. The remaining time may be used by the plant to catch up on delayed preventive and corrective maintenance, and may also be used to allow for periods of high absenteeism (vacations, Easter week, Christmas week, etc.).

In addition to a list of MPs for each week of the year, the schedule lists the daily and weekly tasks separately. To augment the lists for each of the weeks, a master schedule displays the individual PM tasks for each operating unit in the plant for the entire year. This master schedule is part of the summary of Maintenance Procedures described previously (Table 5). An optional display in the form of a wall chart would enable the Maintenance Engineer to see at a glance what the PM work load will be, or alternately, to see when PM is to be performed on any particular unit.

The Recordkeeping System

The recordkeeping system of the PMMS consists of six forms. Forms M1 and M2 are permanent records for each item of equipment, containing reference data and cumulative maintenance data. Form M3 is a temporary record of preventive maintenance actions, and Forms M4, M5 and M6 are temporary records of corrective maintenance actions.

Table 6. EXAMPLE OF WEEKLY PM SCHEDULE

Week 1		
1111 M1	2133 M1	5222 Q1
1112 Q1	2133 Q1	5224 Q1
1112 A1	2242 M1	5225 Q1
1113 Q1	2332 M1	5312 M1
1114 A1	2332 M2	5564 M1
1114 A2	2332 M3	5571 M1
1334 M1	2332 Q1	5573 M1
2112 M1	2332 S1	5581 M1
2131 M1	2332 S2	5583 M1
2132 Q1	5221 M1	5711 Q1
2132 Q2	5221 M2	5712 Q1

Perform these plus all Daily and Weekly Maintenance Procedures (MPs), keyed to Maintenance Procedure Sheets (MPSs).

Form M1, "Equipment Reference Data," was described previously and is shown in Figures 1 and 2.

Form M2, the "Equipment Maintenance Record," provides an historical file of all PM and CM performed on a particular item of equipment. This 8-1/2 x 11-inch permanent record, shown in Figure 3, will be useful in the event of a breakdown or an impending breakdown, and for an examination of trends and of any indications of equipment deterioration with time. Each time a maintenance action is performed an entry is made on Form M2. The MPS number or the job number specifies, respectively, whether the action is PM or CM. The "Labor" entry is for recording the skill level, the initials of the mechanic and the actual manhours expended. The "Observations" entry is coded according to the list of Indicators and Modifiers, which is included as Table A-2. In addition to this coded entry, a descriptive statement can be made, when necessary, in the "Remarks and Data" column. The "Volts," "Amps" and "Megohms" entries are reserved for maintenance on electric motors.

Forms M3, M4 and M5 are temporary 5 x 8-inch records. Form M3, Figures 4 and 5, is a "Preventive Maintenance Work Record," which the mechanic uses while on the job to document that the PM work has been done and to record the labor expended and the measurements made. The checklist on Form M3 is used by the mechanic to indicate whether there was any indication of trouble during the routine PM and inspection. If any of the "Trouble" boxes are checked, the reverse side of Form M3, "Report of Trouble," is used by the mechanic to provide a detailed explanation.

Form M3X, a variation of Form M3, is shown in Figure 6. This format is used for daily and weekly actions, and conserves the amount of paper handled by having multiple entries on one form. In practice, this form is printed on the back of the 8-1/2 x 11-inch Maintenance Procedure Sheet, on heavy card stock, which is used repetitively until the available spaces are filled or until the card is mutilated. At that point, a replacement is made.

Whichever of the two Form M3 formats is used, and whether or not any of the "Trouble" boxes are checked, the data from Form M3 is transcribed onto the permanent Form M2. If there is no "Trouble," Form M3 can be discarded once the PM data have been recorded. If trouble has been spotted, Form M5 must be filled out to initiate CM action.

Form M4, the "Equipment Malfunction Report," shown in Figure 7, serves a similar purpose as the "Report of Trouble" side of M3, except that M4

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 Ohm's			Remarks and Data
		Skill	Initials	Hours	Ind.	Mod.	Leg 1	Leg 2	Leg 3	Leg 1	Leg 2	Leg 3	Leg 1	Leg 2	Leg 3	

Form M2-5/72

Figure 3. Form M2, Equipment Maintenance Record

PREVENTIVE MAINTENANCE WORK RECORD

Equipment Name and Number		I. D. No.	Date
INCINERATOR NO. K			
MPS No. 6 1 1 1 – D 1	Name of Procedure CHECK OIL LEVEL - SIGHT FEEDER - TOP-BOTT. CENTER SHAFT	Work Completed (Signatures)	

Mechanic's Name	Reg. Hrs	OT Hrs	Volts	Leg 1	Leg 2	Leg 3
			Amps	Leg 1	Leg 2	Leg 3
			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

Form M1-5/72

Figure 4. Form M3, Preventive Maintenance Work Record

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 ☐

Form M3(reverse)-5/72

Figure 5. 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 6. Form M3X, Variation of Form M3*

*Summary of listing on reverse side of various maintenance procedure sheets.

EQUIPMENT MALFUNCTION REPORT

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

Date of Trouble	Time	Reported by	Foreman

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 ☐
_____	

Form M4-5/72

Figure 7. Form M4, Equipment Malfunction Report

is intended for use by plant operators or anyone else noticing a malfunction (M3 is intended for use by maintenance mechanics while performing PM). Completed Forms M4 should, of course, be promptly delivered to the Maintenance Department. Pads of blank M4 Forms should be in convenient locations throughout the plant.

Forms M5 and M6, shown in Figures 8 and 9, are for initiating CM whenever the "Trouble" side of Form M3 or Form M4 has been received by the Maintenance Department. Form M5, a 5 x 8-inch "Corrective Maintenance Work Order," is prepared with cost and downtime estimates when analysis indicates that corrective action is required. This information is automatically reproduced, by the use of carbon or NCR-type paper, onto the top of Form M6. The combined forms then are signed, and a job number is issued, allowing the CM work to be initiated. At this point, the forms are separated; Form M5 is retained as an open work order, while Form M6 is used by the field maintenance personnel.

The lower half of M6, which is an 8-1/2 x 11-inch form, is used to record the labor, parts and materials used, descriptions and recommendations, equipment status and spare parts availability, and actual corrective maintenance costs and downtime. The maintenance foreman and the requestor sign off on the completed work. At this time, Form M5 may be discarded. An appropriate entry is made on Form M2, and Form M6 is kept in the permanent equipment file with the M1 and M2 forms.

The Recordkeeping System has been constructed to segregate the coding and the paperwork from the mechanics. The mechanics are given appropriate MPSs which explicitly identify both the equipment and procedure in common language. The mechanics fill out Forms M3 (or M4) and M6, which are designed as simple checklists. No other paperwork burden is placed upon the mechanics.

The Maintenance Data Feedback System

Form M7, shown as Figures 10 and 11, is a weekly maintenance summary report which is prepared by the Maintenance Technician for plant management. There are three parts to Form M7: 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 corresponds to the balance sheet in a financial report. The new work load for the week is added to the old backlog for the total outstanding work; from this total is subtracted the work accomplished during the week to establish the new backlog for the following week.

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
- ☐ 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 _____

Corrective Work Requested _____

Estimated Costs

Labor _____

Parts _____

Contractors _____

Total _____

Estimated Down-Time

Approved by	Date	Job No.

Form M5-5/72

Figure 8. 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

Recommendation for avoiding repeated failure

Equipment Status at Completion

- Fully operational
- Non-operational
- Reduced capability
- Awaiting spare parts

Spare Parts Availability

- In stock
- Obtained locally
- Delay in procuring
- Length _____

Outside Contractor Used

Reason

Actual Costs

Labor _____
Parts _____
Contractors _____
Total _____

Total Down-Time

Work Completed

Date _____ Maint. Foreman _____

Work Accepted

Date _____ Requestor _____

Form M6-5/72

Figure 9. 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 10. 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 11. Form M7 (Reverse), Corrective Maintenance Summary

A separate balance sheet is included for PM and for CM, and the new total backlog is shown. For the Work Load Summary, all manhours are expressed as "estimated" manhours.

The Work Accomplished Summary corresponds to the income statement in a financial report. The objective is to show the actual labor and the actual costs incurred during the week.

The Corrective Maintenance Summary lists all CM work orders (Form M5) that were outstanding at the beginning of the week and those that were initiated during the week. Those items that were completed during the week are noted by an entry in the "Completion Date" column. For plant management to decide which jobs to attack first, this Summary lists an Equipment Status Code and a Priority Code for each job. The "Remarks" column should be used for comments such as "awaiting spare parts."

The weekly maintenance summary report is prepared for plant management by the Maintenance Technician. The report is generated directly from the data in the Recordkeeping System. Aside from providing management with timely important data, the Feedback System is designed to relieve management of any paperwork burden.

SPECIAL CONSIDERATIONS IN THE PMMS

The Maintenance Technician

The permanent records, the Indicators and Modifiers Code, the PM Cycle Schedule, and the Equipment Configuration numbering system do not concern the mechanics in the performance of their work. All of the scheduling and monitoring for the PMMS is performed by a Maintenance Technician. His efforts may be strictly manual in smaller plants, or he may use computers or other data processing devices in medium-to-large plants.

The Technician position is essential to the successful implementation of the PMMS. It is the intention of the PMMS to remove the paperwork burden from the mechanics and from plant management, and to concentrate the paperwork and coordination of details upon the Technician.

The duties of the Maintenance Technician are:

1. To maintain and update a file for each item of equipment in the plant. The Technician records, on a continual basis, each preventive maintenance action taken. The data recorded includes the date, a code describing what was done, the initials and labor

category of the mechanic(s), the labor hours consumed, readings or measurements taken, and a coded entry of observations the mechanic will make regarding equipment condition. The Technician relieves the mechanics of any formal record-taking by transcribing his freestyle comments onto a permanent record. The Technician should therefore be familiar with equipment and with maintenance procedures to effectively communicate with the mechanics, and should be capable of using codes for recording and retrieval purposes.

2. To record corrective maintenance actions and equipment modifications in the equipment file. For corrective maintenance actions, the record will include labor hours, spare parts and purchased services, a cost for each item and for the total, the reasons for the breakdown, and suggestions for preventing similar breakdowns. The Technician is expected to understand and summarize the inputs from engineers and mechanics.

3. To maintain and update a file on equipment data, which will include type, model number, serial number, size, capacity, spare parts numbers, etc.

4. To prepare, on a weekly basis, the working copies of the MPSs (for planned PM actions) from a schedule and from a master file of sheets.

5. To retrieve and summarize data on equipment history, equipment condition, maintenance history, maintenance costs, and manpower requirements for the use of plant management. The Technician should be capable of providing meaningful summaries to relieve management of the burden of examining large quantities of data items.

6. To identify and implement improvements to the maintenance system.

Skills of Field Personnel

Three categories of labor are involved under the PMMS:

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

Appendix I contains detailed job descriptions for these three labor categories.

In very small plants, a single individual generally performs all maintenance (possibly in addition to plant operations), so that this individual should have overall capability. Conversely, there is some trend today even in large plants to train maintenance personnel to perform both electrical and mechanical tasks, so that when a unit is taken out of service it may be completely attended to by a single man. This philosophy also aids in diagnosing malfunctions, where the precise cause of trouble is not readily apparent. This PMMS was developed to differentiate between skills; however, it is useful whether or not a wastewater treatment plant differentiates between skills.

For some plants, a separate instrumentation mechanic may be on the staff. To be most widely useful, this model PMMS did not assume that a separate skill existed for maintaining measurement devices and meters and recorders, but assigned these tasks as appropriate to either Skill 1 or Skill 2. In actual practice at the Lower Potomac Plant of Fairfax County, an Instrumentation Technician was added to the staff midway through the demonstration phase of the program. The PMMS was readily adaptable to this change without formally changing the PMMS paperwork. When the week's PM tasks were given to the maintenance foreman, he easily identified those appropriate to the Instrumentation Technician.

The Skill 3 category is labeled "Utility Man," and it indicates a lower level of experience than either Skill 1 or Skill 2. This distinction is extremely important in conserving the skilled manpower available for those tasks requiring the higher experience. Table A-3, the PM manpower requirement for the Lower Potomac Plant, shows that well over 50 percent of the total PM manhours is in the Skill 3 category, the category where personnel should be more available and of lower cost.

Consistent with the philosophy of this program to make the model PMMS most useful on a nationwide basis, no attempt was made to further break down Skill 3 into sub-skills perculiar to any plant or organization.

In actual practice at the Lower Potomac Plant, the bulk of the Skill 3 work has been accomplished by mechanics' helpers within the Maintenance Department. Several exceptions were made, with Operations personnel performing time-consuming tasks such as cleaning the sludge belt conveyors (prior to Skill 2 inspection and lubrication) and draining and cleaning primary settling tanks, secondary aeration tanks and chlorination contact chambers (prior to Skill 2 inspection).

Many of the Skill 3 tasks consist of routine repetitive PM actions requiring a minimum of judgement or special skills. At the option of the plant utilizing the PMMS, much of the Skill 3 workload may be accomplished

by plant operators, rather than by assigned personnel from the Maintenance Department. There are two sides to this question. In favor of such a division is the potentially significant cost and manpower savings, since Skill 3 tasks comprise well over 50 percent of the overall work load. Against such a division are:

1. A division is made in pride and responsibility; i.e., in the sense of "ownership" of equipment by regular maintenance mechanics which was evident at Lower Potomac.

2. An important feature of the routine repetitive PM actions is that maintenance personnel get around the plant on a regular daily basis and are therefore quick to spot any signs of impending trouble. Conversely, a shift operator may not be trained well enough to either notice the abnormality or to assign proper significance to it.

Judging by the tangible positive results at the Lower Potomac Plant, it is recommended that the Maintenance Department perform as much of the PMMS as is feasible within the very real constraints of the personnel available and the budget.

Cross Reference With Design Engineer's Code

When an existing, operating plant such as the Lower Potomac Plant installs a PMMS, the PMMS must take into account that the design engineer's equipment names and codes have become commonly used means for identifying equipment. The introduction of a new nomenclature via the PMMS does not change the commonly used nomenclature overnight. Hence, the PMMS must be structured so that the common names of equipment are retained in the lists, procedures, schedules, etc.

To correlate this dual nomenclature, a concise cross-reference list was prepared. Table A-4, for the Lower Potomac Plant, includes the design engineer's code for pumps, measurement transmitters and measurement receivers. Additional pumps in Area K are also included in Table A-4 for completeness.

Cross References for Remote Electrical Controls and Remote Alarm Indicators

In addition to measurement receivers (meters and recorders), which were covered in the previous section, there are two other instances where an equipment item may be quite remote from its functionally operating unit. One instance is the remote electrical controls. Table A-5 lists

the MPS numbers corresponding to the operating functional unit ID number, cross referenced to one or more remote controllers. Table A-6 cross references alarm operating functional numbers to one or more remote alarm indicators.

These cross-reference lists are to be used, of course, with the basic Equipment Configuration List, which provides data and location for each equipment item.

These cross references have been incorporated into the appropriate Maintenance Procedure Sheets. The remote electrical controllers are scheduled to be serviced at the same time as the PM on the process unit, while it is out of service. Observers are stationed at alarm indicators while malfunctions or abnormal conditions are simulated at the operating locations.

Insulation Resistance of Electric Motors

Since the insulation resistance of electric motors is very highly temperature dependent, a means for standardizing measured values is needed. There are two reasons why these insulation resistance measurements must be made when the motor is at ambient temperature: first, to avoid any appreciable temperature gradients, either spatial or temporal; and second, there is generally only the capability of measuring a constant ambient temperature. Once the insulation resistance at a measured ambient temperature is known, Figure 12 may be used to correct this value to a standard 70 deg F value.

Repainting of Plant Equipment

The PMMS includes a detailed MPS for repainting plant equipment and piping. No formal schedule or manhour estimate is associated with this MPS since requirements depend largely upon location, service, climate, etc.; and since the need for repainting is readily apparent.

Preventive Maintenance for Incineration

The sludge incineration and auxiliary process equipment require special attention in scheduling and performing preventive and corrective maintenance. The plant design provided redundant incinerator systems. Each incinerator system and its related equipment must be operated as a unit except for the induced draft fans which can be temporarily bypassed.

Table A-7 is a list of the sensitive equipment requiring special attention in the maintenance management system. Two categories of special preventive maintenance have been identified:

INSULATION RESISTANCE CORRECTION—multiply measured resistance correction factor

Minimum corrected resistance:

Class A insulation, 40 megohms
Class B insulation, 6 megohms

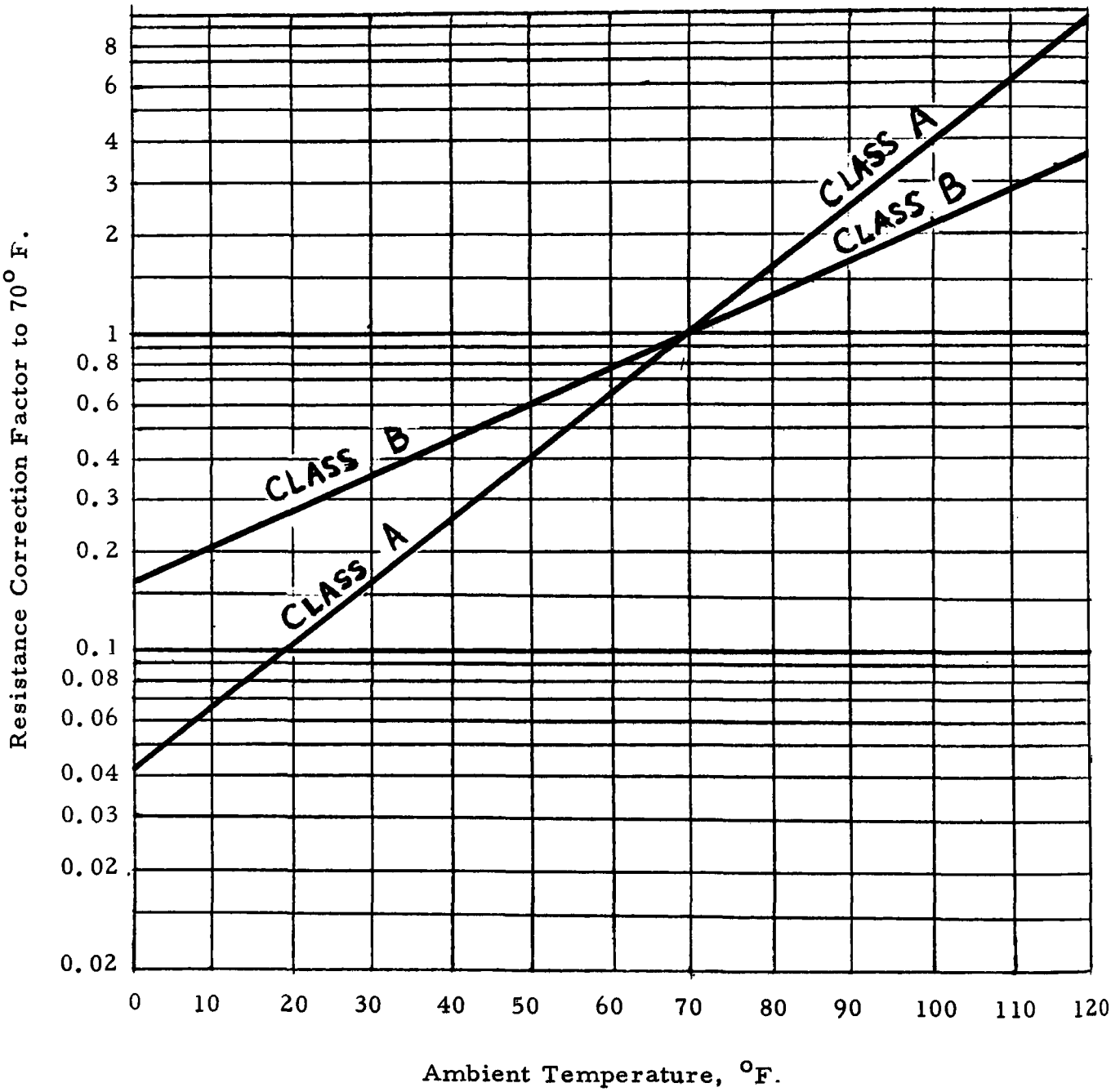

Figure 12. Corrections to Measured Insulation Resistance

1. Category A—The MP is to be performed without shutting down the equipment.

2. Category B—The MP is to be performed with the equipment taken out of service, but it must be scheduled to coincide with a shutdown of the entire incinerator by coordination between Maintenance and Operations.

Corrective maintenance may or may not require complete shut down of the affected incinerator and the auxiliary equipment. A judgement must be made by the Maintenance Department and coordinated with Operations. In addition, should one unit not be in service for an extended period, the unit and its auxiliary equipment should be exercised under full Maintenance/Operations coordination.

Table A-8 is a list of the MPSs in Category A, and Table A-9 is a list of the MPSs in Category B. Table A-9 should be used as a checklist to ensure that all scheduled MPSs are accomplished when the incinerator is shut down.

On each of the MPSs corresponding to Table A-8, there is a notation that, "This procedure is to be performed without shutting down the equipment." On the MPSs corresponding to Table A-9, the notation reads, "This procedure is to be performed only when the entire incinerator has been shut down."

SECTION VI

PROGRAM INSTALLATION AND DEMONSTRATION

INITIATION OF CYCLE SCHEDULING

The Planned Maintenance Management System (PMMS) has been in effect at Fairfax County's Lower Potomac Plant since May 25, 1972. The system was installed gradually to enable the maintenance personnel to become familiar with the work requirements and with the format of the maintenance procedures, work orders and other forms without the full burden of the work load of the entire system.

There are two options for gradually installing the system. At the Lower Potomac Plant, the daily procedures and the weekly procedures were started first. These maintenance actions are an effective vehicle for familiarizing the personnel with the system simply because they are frequently repeated. The other option is to start the full system in only one area or building of the plant, adding additional areas later on. This second option may be appropriate for a very large wastewater system.

ACCEPTANCE BY THE MECHANICS

Great care was taken at Lower Potomac to effectively introduce the wastewater treatment plant mechanics to a formal PMMS. The success of a PMMS depends primarily upon the cooperation and acceptance by the personnel. The PMMS was presented as a vehicle for the mechanics to more effectively perform their jobs and to have their observations and recommendations recognized and followed. If the PMMS is viewed by the mechanics with hostility as another time-motion study or as a paperwork burden, then the PMMS will be doomed.

The Plant's Maintenance Engineer and Maintenance Foreman conducted an initial introductory meeting with the mechanics to explain the program's purpose and how it works. During the initial effort, the mechanics were frequently interviewed while on the job to ask their opinions and recommendations for improving the PMMS. This yielded valuable comments which were incorporated into the system, and it helped convince the mechanics that the PMMS was <u>their</u> program.

The initial acceptance and workability of the PMMS was so complete that the full preventive maintenance cycle schedule, including monthly, quarterly, semiannual and annual actions, in addition to the initial daily and weekly actions, was adopted by the maintenance personnel at Lower Potomac on June 5, 1972, only seven full working days after the original inception of the partial PMMS.

During the first four weeks of operation of the system, the following observations were made:

1. The system was enthusiastically accepted by the mechanics right from the start.

2. The personnel needed little convincing that preventive maintenance was a worthwhile endeavor. Since a prime objective of the system is to make preventive maintenance possible, feasible and effective; the system was by definition a worthwhile endeavor.

3. The Lower Potomac mechanics did indeed use the system as a vehicle for passing on their observations and recommendations.

4. The mechanics found little difficulty is using and following the Maintenance Procedure Sheets (MPSs). These step-by-step procedures appeared to be near the optimum level of detail—they were written so that the tasks could be effectively and properly performed, yet did not burden or insult the mechanics by including too much instruction.

COORDINATION OF PREVENTIVE MAINTENANCE WITH OPERATIONS

The PM Program at Lower Potomac was conducted entirely by the Maintenance Department. There was an early coordination problem which eventually was ironed out—some scheduled PM could not be accomplished because the units could not be removed from service by Operations, and some PM procedures had to be modified so that a limited amount of maintenance could be accomplished while a unit was running. A particular case concerned the vacuum filters. Once a good cake has been built up, the filters should not be shut down arbitrarily for PM. Since only one of the two filters is normally in operation, the solution was for Operations to alternate units in cooperation with the Maintenance Department.

Some procedures were divided so that Operations and Maintenance can each have separately defined tasks. An example is the maintenance on conveyors in K Building. Operations was made responsible for cleaning, and Maintenance for the inspection and lubrication.

It was possible in some cases for units to be taken out of service for PM with the cooperation of Operations. In other cases, Operations was unable to comply. An example of the latter is the incinerators in K Building, where daily PM must be performed without shutting down the rotating mechanism.

Another problem area identified was that, although the formal PM Program was being conducted entirely by the Maintenance Department, Operations had been performing informal PM on the same equipment. Operators had been lubricating machinery and adding oil without the benefit of a planned schedule and without the benefit of the detailed procedures (which specify the recommended lubricant). Instances of gross over-greasing and of using the wrong grade of oil were confirmed by the Maintenance personnel. Just as Maintenance must consult with Operations before removing a unit from service for PM, Operations must consult with Maintenance before servicing equipment.

EARLY RESULTS

Observations that were made on the workability and the effectiveness of the program during the first four weeks are presented in the following paragraphs.

The first few weeks of the program demonstration uncovered a problem in work assignments, due to a misunderstanding. The weekly PM schedule was intentionally constructed so that as many tasks as possible on the same unit are accomplished in the same week to minimize the number of times a unit must be removed from service. However, the individual PM tasks on the same unit were not grouped for assignment. The result was that different mechanics were working on the same piece of equipment at different times during the week. This was not only a waste of time, resulting in the mechanics getting in each other's way, but was directly contrary to the intent of the schedule. To resolve this problem, the PM actions for each week were grouped by unit (easily accomplished with the equipment numbering system, as described on Page 15), and assigned as a package to a single mechanic.

Several of the original labor estimates were quickly reduced. For example, the weekly tasks on the sludge plunger pumps in J and K Buildings originally called for 36 minutes per pump, which included running the pump for a while to inspect for packing leaks and to adjust the sight feed oiler. Since there are four pumps in J Building and three in K Building, significant time is saved by letting one pump run for observation while accomplishing work on the adjacent unit.

Similarly, needed revisions to the original PM schedule were quickly implemented. An example is the weekly tasks on the bar screens, calling for lubrication and inspection of the rake assembly and chain. Since Operations only uses one of the two bar screens at a time and rotates between the two on a weekly basis, there was obviously no need to perform weekly PM on both bar screens. Another suggestion on the bar screens was that lubrication should be daily instead of weekly, based on experience and also that bearing designs are such that overlubrication cannot be harmful.

The value of the Planned Maintenance Management System to the Lower Potomac Plant was quickly proven within less than four weeks of demonstration; numerous potential trouble spots were uncovered and corrected, thus preventing equipment breakdowns and the resulting "fire drills" in the future. The following list is a sampling of mechanics' comments:

1. Incinerators, K Building. Buckets on chain drive in poor condition, two new shear pins added. No. 2 shear pin had no snap ring.

2. Sludge pumps, J Building. Found wrong oil in oil cups. No. 4 needs new belt. Order balls and seats. No. 3 needs repacking.

3. Air filter, E Building. Filter status indicator has reversed and erratic readings—request manufacturer repair man to correct.

4. Vacuum filters, K Building. The varidrives for No. 1 drum and for the No. 1 agitator are noisy at high speeds. Repair kits are needed. No. 2 filter needs a drum seal. Both filters had too much oil and grease. Both vacuum lines to filters are out of alignment. No. 2 vacuum gauge line was plugged with dirt.

5. Hydraulic power unit, K Building. A 2,000 psi gauge is needed.

6. Ferric pumps, K Building. No. 1 needs new link pins; No. 3 has a broken rod and needs two new link pins. Need new studs on all three pumps.

7. Raw wastewater pump controllers, B Building. Changed contacts, A-4, and tightened a loose ground connection.

8. Sludge screw feeders, K Building. Both drives were empty, had to fill with oil.

The value of the system is aptly demonstrated by this list of early field results. The skill and motivation of the mechanics at Lower Potomac were basically responsible for discovering and correcting potentially disastrous equipment deterioration. The formal program of PM is the vehicle by which the mechanics can find the trouble spots, can express and record their observations and recommendations, and can undertake corrective maintenance where needed. With the formal program, all equipment needs are attended to on a timely basis.

LONG-TERM EXPERIENCE

During June 1972, the flooding caused by Hurricane Agnes demanded a great deal of corrective maintenance at the Lower Potomac Plant. Because of the extraordinary CM workload, the scheduled PM program was suspended for approximately two weeks. As soon as the critical repairs were accomplished, however, the PM program was back in full operation.

During the entire year of operation, the preventive maintenance program for the entire plant proceeded smoothly. The enthusiasm of the mechanics for the program was consistent, and did not wane appreciably after the initial installation of the program. Conversely, the mechanics became fully familiar with their duties, the cycle schedule, procedures and recording system, so that the PM program was conducted with increasingly higher efficiency.

A pickup truck was designated for the plant's preventive maintenance, with all of the tools and lubricants readily available. This action significantly reduced the dead time between PM actions.

Each equipment unit was prominently labeled with large reflective red stick-on numerals on a painted black background, easily seen even at night. This action eliminated any chance of ambiguity over which of the parallel units was to be serviced.

Attention was brought to the necessity for alternate cycling of parallel units when all units are not required to run continuously. A schedule was set up by Operations to ensure that no unit remains idle for great lengths of time while other units run extensively. Running-time meters were installed to aid in this objective.

After the system had been in operation for about six months, a lengthy walking inspection of the plant revealed many significant accomplishments. Some improvements were very readily apparent, such as the appearance of the ash conditioner and the sludge conveyors in K Building, the running-time meters to promote equal use of parallel equipment, and the general

cleanliness of the plant. The visible effects were, however, just the tip of the iceberg; the improved mechanical condition of the equipment is the major goal of this program. Six months previously, there was an almost continuous occurrence of equipment breakdowns which completely occupied the time and attention of the mechanics in a series of "fire drills" to avoid disaster. Now, the mechanics have the additional time to systematically improve the plant through modifications and additions to the original equipment.

Since this program was initiated, there has been a steady trend towards reduction of the malfunction reports on mechanical equipment because of the systematic action of the preventive maintenance program. Incipient failures are being detected in many cases and prompt corrective action is accomplished. This has brought mechanical troubles caused by the lack of preventive maintenance to its lowest point since the start up of the plant.

Several recommendations were made to the County to maintain the effectiveness of the system over the long haul. The importance of keeping preventive maintenance actions going continuously should be emphasized even when the plant is in apparently good mechanical condition. Of special importance are the daily procedures, which have the beneficial effect of a daily inspection of virtually the entire plant by mechanics trained to spot any impending problems. Non-urgent CM and less frequent PM tasks may be delayed if necessary; daily PM tasks cannot be delayed and should not be bypassed. Periodic meetings should be held with the mechanics to reinforce morale for the PM system which may suffer from the repetitive nature of the work. Management should ensure that the mechanics' suggestions are being considered and incorporated into the system. The mechanics should feel that the system is flexible enough to be improved and that it is <u>their</u> vehicle for instituting needed changes.

MAINTENANCE MANPOWER REQUIREMENTS

Each preventive maintenance task is accompanied by a nominal manpower requirement of a certain skill. These skill and manhour requirements for the individual MPs are used to generate the total annual manpower requirements for the plant by skill level. Table A-3 is a list of manpower required for PM at the Lower Potomac Plant, organized by major systems in the plant.

Early experience has indicated that a man-day is limited to approximately 6.5 manhours of "hands-on" time, not counting the time required to gather tools and materials or get to and from the equipment. Hence, a man-year

contains approximately 1,625 manhours. The total annual PM requirement at the Lower Potomac Plant of 7,934 manhours is therefore equivalent to 4.9 full-time maintenance personnel.

An analysis was made of the preventive maintenance data gathered during the year-long demonstration phase of the Lower Potomac Program. Each PM action has been recorded, with an entry of the time consumed. Table A-10 lists some representative PM actions, with a comparison between the originally estimated time and the range of actual times.

Both types of times shown in Table A-10 are "hands-on" times for actual maintenance work. On the average for the Lower Potomac Plant, a man-day consists of approximately six to six and a half hours of hands-on time. However, this Plant is relatively compact, and the time consumed in getting to and from the operating units is small.

The first observation made from the actual times in Table A-10 is that there is a great variability for any PM action. A statistical analysis has shown that the span of times containing 90 percent of the entries for a given PM action is approximately twice the value of the mean time—in other words, any entry can reasonably be plus or minus 100 percent of an "average" time (the distribution is obviously skewed since no entry can be less than zero).

From a practical standpoint, it is well understood in the maintenance field that a great variation in performance time is to be expected. The job is always a little different, depending upon in what condition the mechanic finds the equipment. Maintenance is not a production line, where each task is well defined and may be quantified more easily. Many other factors enter into the recorded time for a particular maintenance action that add to the variability. More or less experienced personnel will consume different amounts of time. The recorded time is only an estimate of the actual time, since no effort was made to require the mechanic to precisely measure elapsed time. The times are usually documented in even increments, i.e., 20 or 30 minutes rather than 23 or 27 minutes. No attempt has been made, nor is any suggested, to ask the mechanics to account for all of the eight hours in a shift; this alone introduces a level of expected inconsistency in the data records.

The comparison in Table A-10 shows that for the most part, the original estimates are as valid as any other estimate in light of the great variability of the actual data. If anything, the original estimates were somewhat more conservative (higher) than some actual "averages." No justification was seen, therefore, to revise the original estimates of nominal time. The strong recommendation is made, however, to treat these times and all

manpower requirement conclusions derived from these times, with temperance commensurate with the observed variability in the actual data.

The preventive maintenance manpower requirement must, of course, be augmented by the manpower requirements for corrective maintenance and for equipment modifications or additions. The PMMS provides the necessary methods and records for documenting and analyzing the manpower and cost data for corrective maintenance and equipment modifications. However, any prediction of these requirements was beyond the scope of this program. The manpower requirements for corrective maintenance and equipment modifications depend to a great extent upon the age and condition of the equipment, the type of processes and equipment employed, and the adequacy of the plant's hydraulic capacity and treatment efficiency. It is, of course, the objective of the PMMS to significantly increase the plants reliability by reducing the requirements for corrective maintenance, and this has been demonstrated at the Lower Potomac Plant.

The actual manhours expended by skill level for both PM and CM are summarized by the PMMS and can be compared to the original estimates. The estimates can be modified to become more realistic so that the schedule can be revised. Conversely, the maintenance tasks that consume large amounts of labor can be examined to see if improvements in the procedure can safely conserve labor. These data are directly useful to plant management in planning and justifying the size of the labor force.

MAINTENANCE COSTS, SPARE PARTS INVENTORY AND EQUIPMENT CONDITION

The recordkeeping and feedback features of the PMMS provide for the complete accounting of maintenance labor, material and contractor costs, for management's use in cost control and budget preparation. The costs can be reported by plant area, functional subsystem, types of equipment and individual equipment items, so that cost control measures can be directed in a rational manner. In addition to current costs, management can retrieve historical data for any desired period of time.

The PMMS provides the basis for a spare parts inventory control system in three ways:

1. An integral part of the Equipment Configuration List is a listing of spare parts for each item of equipment, with the emphasis on parts likely to be replaced, such as bearings, drive belts, filter elements, etc.

2. The Equipment Configuration List may be organized according to the equipment type code, which immediately offers data on commonality of parts, regardless of the function or the location of the operating unit within the plant.

3. The corrective maintenance work record, an integral part of the recording system, provides a current tally on parts usage.

The recordkeeping and data feedback features of the PMS are also useful in evaluating equipment condition. The complete maintenance history of each item of equipment is in a single place in the file, readily accessible for analysis in the event of a breakdown or preferably before a breakdown occurs. This historical data record will prove invaluable in analyzing how well the equipment is performing its function and when a major overhaul or replacement, if indicated, should be made. Conversely, the historical record may indicate that the mode of operation needs to be changed. In addition, an analysis of the historical data record will permit the preventive maintenance frequency to be adjusted, making more frequent PM actions for equipment which deteriorates or goes out of adjustment rapidly, thus preventing breakdowns; and making less frequent PM actions for equipment which shows little deterioration, saving PM costs.

SECTION VII

APPLICATION TO OTHER WASTEWATER TREATMENT PLANTS

FLEXIBILITY AND EXPANDABILITY OF THE PMMS

One of the primary objectives of the effort described in this report was that the PMMS be directly applicable on a nationwide basis to all types of wastewater systems, including both treatment plants and collection systems.

The equipment ID numbering system is designed to be expandable both vertically, for more complex plants with more systems, subsystems and functions, such as AWT; and horizontally, for larger plants with more parallel items of equipment, or for plant expansion. Additional digits can be added preceding the first five digits to specify to which of several locations or plants the equipment belongs. The other elements of the system, such as the Equipment Configuration List, the Maintenance Procedures, the PM Cycle Schedule, the Recordkeeping System, and the Data Feedback System, are general and are not constrained by either the size of the plant or the type of treatment.

The key to the flexibility and adaptability of the Planned Maintenance Management System is that it is at a level of detail to accomplish one task at a time on a particular item of equipment by a single maintenance crew. Any wastewater operation is made up of such individual maintenance tasks; hence, any wastewater operation may utilize the PMMS.

TAILORING TO PLANT REQUIREMENTS

The geographical distribution of facilities and personnel is an important consideration for each application of the PMMS. The Fairfax County Lower Potomac Plant is a rather compact operation, with all of the maintenance personnel and shops based at the plant. One centralized recordkeeping center at the plant serves both purposes: to have the necessary information readily accessible to the mechanics on the job; and to enable centralized overview, control, reporting and analysis.

More widespread systems may require a different approach. Examples of other systems are:

1. More than one treatment plant in the same municipal organization, with maintenance personnel based at one or several locations.

2. A widespread sewage collection system, including pumping stations, in which travel time of maintenance personnel is an appreciable factor.

3. A very large treatment plant with separate maintenance groups for various parts of the plant.

For these situations, a dual recordkeeping system would likely be called for to accomplish both local accessibility to the mechanics and centralized control, analysis and reporting. This dual system could be implemented with the use of copying machines and simple filing aids.

TAILORING TO EXISTING METHODS AND PERSONNEL

The PMMS should take every advantage of the existing knowledge, experience and modes of operation. Instead of arbitrarily creating a PMMS in a vacuum, the program should incorporate all of the valuable background that the personnel have to offer. It is recognized that systems with varying degrees of formality may have been built up over the years, and the PMMS should take full advantage of these systems. This approach includes, of course, the existing forms, filing methods, scheduling methods and recordkeeping methods of management; but it emphasizes the practical know-how of maintenance mechanics and foremen. For long-existing operations, equipment maintenance characteristics may have been documented, including subtle differences between nominally identical units. This type of data is priceless, and must certainly become an important part of the PMMS.

Large wastewater operations which may have been built up piecemeal over the years may show a diversity of maintenance organizations and systems. Some portions of the organization may have been run over the years by maintenance teams which have independently developed procedures, schedules, filing systems and records for their areas of responsibility. The system used by one team may be significantly different from the systems of other teams. Some systems may be more formal and detailed than others. Some may be so unique that they are almost totally dependent upon the individual who originated them.

In creating a PMMS for such a system, the largest challenge will be to balance the desire for a unified system covering all aspects of the operation with the alternate desire of preserving and strengthening those effective maintenance systems which have evolved over the years. The former desire is based upon the advantages of commonality of parts, procedures, forms and personnel; with the overriding advantage that good maintenance techniques are used by all of the personnel on all of the equipment. The latter desire may be based upon the pride and effectiveness in portions of the operation.

The intention should be to satisfy both desires whenever feasible, instead of making changes just for the sake of change. Something very simple like a numbering order for parallel units should be retained rather than revised (unless there is a fundamental ambiguity or error). In every way possible, any transition that people will have to make to a unified PMMS should be eased.

From a technical viewpoint, the maintenance engineering staff will form the backbone of the maintenance requirements and procedures in the PMMS. Technical judgements should be made objectively, with the full benefit of all available knowledge, and should not presume to eliminate or supercede arbitrarily the contributions of the personnel already within the system.

In essence, then, the approach toward creating a PMMS should be to delicately preserve the best of what exists, and incorporate these best parts into the entire PMMS, utilizing the technical capabilities and the experience of the plant's personnel, and adding or innovating where required.

AUTOMATION OF DATA HANDLING

The PMMS in operation at Fairfax County's Lower Potomac Plant is a manual system. A full-time Maintenance Technician is employed at this 18-mgd plant for the express purpose of relieving all of the paperwork burden from both the mechanics and the plant management.

For a much larger plant, some level of automation of the data handling task would be anticipated. From the very start, the manual system was developed with the requirement that it be directly amenable to computerization. The following items of a manual system are directly useful, without change, to an automated system.

1. Equipment Configuration List. All items of equipment have a five-digit identification number which permits all similar parallel units of equipment to be grouped by the first four digits; and permits all

equipment items which operate together as a unit to be grouped by the first, second, third and fifth digits.

2. Equipment Data List. The two-digit numbering system specifying types of equipment, regardless of function. This is useful for grouping equipment with similar maintenance requirements and with similar spare parts requirements.

3. Preventive Maintenance Cycle Schedule. The Maintenance Procedure numbering system includes a specification of frequency and the scheduled week numbers, which is directly useful for computerization.

4. Maintenance Personnel. The numbered Skill Code, with job descriptions for each skill level, is directly useful in a computerized system. A manual system can identify each mechanic by his initials, but a computerized system would simply use an employee number instead.

5. Indication of Trouble. The numbered coding system, which describes observations by mechanics or operators, is directly useful in a computerized system.

6. Reasons for Breakdowns. The numbered coding system is directly useful in a computerized system.

7. Work Order, PM Work Records, CM Work Records, Reports of Trouble, and Equipment Malfunction Reports. All forms used by plant personnel should utilize checklists wherever possible. These forms can be used for machine coding.

The computerized system should be identical to the manual system from the viewpoint of the mechanics. They would use the same maintenance procedures, perform work under the same preventive maintenance schedules, use the same forms for recording their observations and PM actions and for initiating corrective maintenance, and use the same forms for recording corrective maintenance actions. The computerized system should be designed so that the maintenance mechanics would not be at all affected by any computer-related requirements.

In addition to full computerization using electronic data processing equipment, the Planned Maintenance Management System could also utilize less sophisticated (and less expensive) machines for portions of the system, or for auxiliary use in remote locations in the event that dual records must be maintained.

CREATION OF A BASIC DATA BASE

As is readily apparent from the description of the PMMS, the day-to-day operation of the PMMS is dependent upon a detailed Equipment Configuration List, a set of Maintenance Procedures and a Preventive Maintenance Cycle Schedule. These items may be called the basic data base for the PMMS.

A wastewater treatment plant, system or organization wishing to apply this PMMS must create, on a one-time basis, this basic data base. There is no substitute for the detail, since the success of the PMMS operation is due to the specific maintenance attention given each and every item of equipment in the plant.

The creation of this data base may be relatively straightforward, as in the case of a plant under construction where every item of equipment will have designer's specifications and the actual purchase orders available, and where the equipment manufacturer's drawings and instruction bulletins are available immediately upon receipt of the equipment.

In the case of an older, operating plant, the creation of a data base is also relatively straightforward if a good filing system of equipment drawings and bulletins has been conscientiously maintained and if later equipment replacements or changes have been documented. Moreover, an older plant may have accumulated actual equipment maintenance data and specific observations and comments; both of which are extremely valuable.

In every case, regardless of the condition of the equipment paperwork, an actual item-by-item check against the equipment nameplates must be performed. In older plants, this may require removing layers of paint from nameplates. The equipment that is actually installed in the plant and as modified must be known and verified.

This one-time effort of creating the basic data base for the PMMS must be the primary assignment of either a staff maintenance engineer, or an outside maintenance management firm experienced in wastewater systems. It is very strongly recommended that this effort not be attempted by regular staff members who have continuing day-to-day responsibilities; the creation of a basic data base is a full-time effort. Once this is accomplished, the system is easily updated and operated by plant personnel.

SECTION VIII

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SECTION IX

GLOSSARY

CM	Corrective Maintenance
MP	Maintenance Procedure
MPS	Maintenance Procedure Sheet
PM	Preventative Maintenance
PMMS	Planned Maintenance Management System

SECTION X

APPENDICES

Table of Contents

Appendix		Page
I	Job Descriptions for Maintenance Personnel	64
II	Figures A-1 through A-18, Examples of Maintenance Procedure Sheets.	67
III	Table A-1 through A-10.	95

APPENDIX I

JOB DESCRIPTIONS FOR MAINTENANCE PERSONNEL

SKILL I. ELECTRICIAN

Inspects, repairs and maintains electrical and/or electronic operating and control systems, equipment, fixtures and instruments; including wiring and lighting systems, electrical control equipment, meters, outlets and panels. Uses standard and special electrical tools and equipment, such as voltmeters, ammeters, ohmmeters, meggers and synchroscopes. Interprets oral and written instruction, specifications, procedures, wiring diagrams, schedules and codes. Exercises independent judgement in solving normal work problems under general supervision; and is able to recognize abnormally functioning electrical equipment and to describe, both orally and in written form, the indications of trouble to his supervisor.

Performs ordinary arithmetical procedures involving fractions, decimals and percentages. Has thorough knowledge of electrical systems, equipment and fixtures; and of approved methods, practices, code requirements and safety standards.

A list of maintenance procedures assigned to Skill 1 is:

- Test insulation resistance of motor
- Clean motor
- Clean and inspect controller
- Clean and inspect remote control switch
- Clean ionizer and inspect ionizer wires.

SKILL 2. MECHANIC

Performs preventive maintenance, inspections and repairs on mechanical and electromechanical machinery and equipment. Lubricates equipment and checks for malfunctions. Replaces packing in pumps or valves. Replaces bearings in motors, pumps and other equipment. Adjusts and cleans equipment, cleans out pipes and performs other plumbing and pipefitting tasks as required. Uses standard and special mechanical tools. Interprets oral and written instructions, technical manuals, drawings, specifications, layouts, blueprints and schematics. Exercises

independent judgement in solving normal work problems under general supervision; and is able to recognize abnormally functioning mechanical equipment and to describe, both orally and in written form, the indications of trouble to his superior. Is capable of independently disassembling and reassembling mechanical equipment and of replacing defective parts. Performs ordinary arithmetical procedures involving fractions, decimals and percentages. Has thorough knowledge of wastewater treatment machinery and equipment.

A representative list of maintenance procedures assigned to Skill 2 are:

- Inspect rake assembly and chain on bar screen
- Inspect counterweight shock absorbers on bar screen
- Clean, inspect and lubricate flexible coupling
- Change oil
- Inspect and lubricate conveyor
- Inspect drive belt tension
- Inspect packing gland adjustment
- Renew packing
- Inspect oil level, check automatic start and stop, blow down receivers on air compressor
- Clean and inspect pump
- Inspect aeration tank, clean and inspect swing diffusers
- Check oil condition and oil level
- Check oil and grease pinion bearing; clean and repack pinion bearing
- Clean and inspect chlorinators
- Clean and inspect fan
- Inspect packing, adjust sight feed oiler, lubricate plunger packing and crosshead on sludge plunger pump
- Clean vacuum filter subsystem, check tine bar and spring alignment, inspect spray nozzles on vacuum filter
- Lubricate disk assembly, lubricate ball oiler, lubricate slide shifting screw, adjust high and low speed stops on incinerator.

SKILL 3. UTILITY MAN

Assists maintenance mechanics and electricians in maintaining and repairing equipment, under direct supervision of Skill 1 or Skill 2 personnel. Assists in removing, repairing and replacing equipment as directed. Carries or holds materials, supplies or tools to assist mechanics or electricians. Is familiar with standard safety procedures and precautions.

Also, independently and without direct supervision performs routine cleaning and lubrication, and checks oil levels where no equipment disassembly, adjustment or significant element of judgement is involved. Is able to understand and follow oral and written instructions. Is familiar enough with plant equipment to locate grease fittings or oil fill and drain ports, or to locate and read sight gauges. Is able to use a variety of hand and power tools and equipment. Is capable of recognizing abnormally operating equipment and or making verbal and written notification of abnormalities and indications of trouble to his supervisors.

Assists mechanics or electricians in performing some of the maintenance procedures listed for Skill 1 and Skill 2. Skill 3 also performs the following maintenance procedures by himself from written instructions.

- Lubricate motor
- Check oil level
- Lubricate pump bearings
- Lubricate and exercise sluice and slide gates
- Inspect foundation bolt tightness
- Clean and inspect strainer
- Lubricate sludge collector
- Inspect oil for water
- Lubricate roller chain on sludge thickener
- Check sight feed oiler, lubricate pillow block bearings on sludge plunger pump
- Lubricate conveyor and check chain oil level
- Lubricate trunion bearings, aligning roll and discharge roll bearings, and chain on vacuum filter
- Lubricate master gear and pinion on incinerator
- Lubricate conveyor
- Clean and lubricate ash conditioner.

APPENDIX II

FIGURES A-1 THROUGH A-18,

Examples of Maintenance Procedure Sheets (MPSs)

MAINTENANCE PROCEDURE SHEET	Page 1 of 3	MPS No. 4131 A1

EQUIPMENT NAME Chlorinator			Average Time S-1 _____ min. S-2 480 min. S-3 _____ min.
Plant Area G	Level U	Location	

MAINTENANCE DESCRIPTION

Clean and inspect chlorinator.

SAFETY PRECAUTIONS

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

TOOLS, PARTS, MATERIALS, TEST EQUIPMENT

Safety tag
Soft rags
Adjustable wrench
Set of gaskets
Wood alcohol
Muriatic acid (dilute hydrochloric acid)

PROCEDURE

Preliminary—1. Close the gas supply valve.
2. Continue to operate dispenser until the gas pressure gauge and flow meter readings drop to zero, indicating that gas supply line has been evacuated.
3. Close gas supply shut-off valve at dispenser.
4. Remove test plug from vacuum regulator stack, allowing air to be pulled in. Operate the dispenser on air for a few minutes to purge gas from dispenser components.
5. Stop booster pump (is used) and close ejector water supply valve.
6. Close valves in chemical solution line.
7. If dispenser uses automatic control(s), deactivate the control system(s).
8. Connect the test plug back on vacuum regulator.
9. Turn off power to electrical heater. De-energize circuit and tag "out of service."

NOTE 1: Use wood alcohol to remove any accumulated organic residues from gas dispenser parts. The parts being cleaned may be dipped in the wood alcohol or wiped with a cloth wetted with the solvent, whichever is more convenient. Muriatic acid (dilute hydrochloric acid) can be used to remove accumulated mineral deposits from parts. Dip the part into the muriatic acid, being careful that the acid does not come into contact with the skin or clothing.

To clean vacuum regulating valve and gas filter:

1. Remove the gas filter block by disconnecting the gas line and the coupling nut at bottom of vacuum regulator. Be careful to catch the spring, spring retainer and valve plug at the regulator.

(Continued)

Page 1 of 3 MPS No. 4131 A1

Figure A-1

PROCEDURE (continued)

2. Clean the valve plug. Use a soft cloth and reach into the inlet fitting to clean the seat. Inspect seat surfaces thoroughly for any scratches or roughness. Replace if defective.

3. Unscrew the bottom nut, then remove the end plug.

NOTE 2: When removing or tightening the end nut, be sure to hold the gas filter block steady with a wrench.

4. Clean gas filter.

5. Inspect "O" rings and replace if required.

6. On reassembly, be sure to replace all gaskets at gas filter block and gas line connections. Tighten these connections with a wrench.

To clean and inspect flowmeter:

1. Remove metering tube assembly by grasping tube with both hands, the heel of one hand pressing down on the lower adaptor while bringing the upper adaptor forward with the other hand.

NOTE 3: Do not use excessive force on the tube itself.

2. Disassemble and clean all parts. Inspect all parts for wear or damage and replace if necessary. Replace any "O" rings showing signs of brittleness, cuts or abrasion.

3. Reassemble. Lubricate "O" rings sparingly.

4. Insert metering tube assembly into dispenser, holding the tube the same as in the first step. Makr sure adaptor "O" rings are properly seated.

To clean and inspect flowrater valve:

1. Disconnect and remove piping from top of flowrater valve.

2. Remove orifice tube by pulling it straight up while holding adaptor place.

3. Remove orifice plug by pulling it straight up, being careful not to drop plug or it may be damaged.

4. Pull out tube adaptor (if used) and remove "O" rings.

5. Clean orifice plug and adaptor. Inspect plug for roughness or damage. Replace if necessary. Inspect "O" rings and replace if necessary.

6. On reassembly, lubricate "O" rings sparingly. Make sure "O" rings are properly seated and orifice plug, tube and adaptor are "bottomed".

To clean vacuum stabilizing valve:

1. Disconnect vacuum line from upper valve body. Disconnect piping from lower valve body.

2. Remove bolts and separate valve body halves, prying loose if necessary.

(Continued)

Figure A-1 (Cont)

PROCEDURE (continued)

3. Remove diaphragm, spring, sleeve and valve plug from the body as one assembly. Inspect diaphragm for cracks or weakness. Replace if necessary.
4. Mark position of valve seat assembly in body. Unscrew valve seat assembly by using a steel or plastic strip to fit the 3/16-inch slots.
5. Clean valve seat and plug. Inspect for roughness or damage. Replace if necessary. Renew "O" rings if necessary.
6. On reassembly, screw the valve seat assembly to original position marked.

NOTE 4: Clearance between plug and seat must be 1/4-inch. A 1/4-inch drill should just fit between plug and seat.

To clean vacuum relief valve:

1. Disconnect the tubing from vacuum relief valve.
2. Unscrew nuts at mounting bracket and remove valve from dispenser.
3. Unscrew coupling nut and separate the valve body halves. Pry loose, if necessary, and remove spring.
4. Clean valve seat and plug. Inspect contacting surfaces for scratches, nicks or roughness. Inspect diaphragm for cracks or weakness. Replace parts if necessary.
5. Unscrew plug on upper valve body and remove dampening ball. Clean the ball and inspect it for chips or cracks. Replace if necessary.
6. Reassemble vacuum relief valve.

To clean drain relief valve:

1. Remove piping from bottom of drain relief valve. Unscrew coupling nut at the tee and remove valve.
2. Remove bolts from valve body. Separate the body halves, prying loose, if necessary.
3. Clean valve seat and plug. Inspect contacting surfaces for scratches, nicks or roughness. Inspect diaphragm for cracks or weakness. Replace any defective parts.
4. Reassemble drain relief valve.

To inspect all hose lines:

1. Inspect all hose lines for cracks or weak spots that may develop with aging. Faulty lines should be replaced. Hose should be protected from strain, freezing or any mechanical damage.
2. Restart chlorinator in accordance with current instructions. Remove safety tag.

NOTE 5: Calibrate flowrater valve (zero adjustment) before resuming normal operation.

Figure A-1 (Cont)

MAINTENANCE PROCEDURE SHEET	Page 1 of 1	MPS No. 4221 M1

EQUIPMENT NAME Sampling Pump M, Chlorination Influent			Average Time S-1 _____ min. S-2 12 min. S-3 _____ min.
Plant Area	Level	Location	

MAINTENANCE DESCRIPTION

Inspect packing gland adjustment.

SAFETY PRECAUTIONS

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

TOOLS, PARTS, MATERIALS, TEST EQUIPMENT

Rags
Flashlight
Safety tag
7/8-inch combination wrench
Flexible rule or steel rule with holder

PROCEDURE

Preliminary— De-energize circuit and tag "out of service."

To inspect packing gland adjustment:

NOTE 1: Damage to shaft sleeve or shaft occurs when:
(1) Rings are added to stop leakage rather than repacking.
(2) Gland nuts are not adjusted evenly.
(3) Gland is improperly adjusted for lubrication.
(4) Packing becomes hard and gland is overtightened to stop leakage.

1. Ensure gland nuts have been adjusted evenly and properly.

2. Measure distance packing gland can be moved before contact is made with housing. Distance should be greater than 1/4-inch; if not, renew stuffing box packing as described on MPC R-1.

3. Remove safety tag and energize circuit.

Page 1 of 1
MPS No. 4221 M1

Figure A-2

MAINTENANCE PROCEDURE SHEET	Page 1 of 1	MPS No. 4221 R1

EQUIPMENT NAME Influent Sampling Pump M			Average Time S-1 _____ min. S-2 180 min. S-3 _____ min.
Plant Area G	Level L	Location	

MAINTENANCE DESCRIPTION

Renew packing.

SAFETY PRECAUTIONS

Observe standard safety precautions
De-energize circuit and tag "out of service"
Wire suction and discharge valves shut and tag "do not open"

TOOLS, PARTS, MATERIALS, TEST EQUIPMENT

Rags
Knife
Wire brush
Safety Tags
Packing
6-inch Slip Joint Pliers
24 Gauge Wire
Packing Puller
Combination Wrench

PROCEDURE

NOTE 1: Accomplish when packing gland has been tightened to within 1/4-inch of pump housing.

Preliminary—De-energize circuit and tag "out of service".
Wire suction and discharge valves shut and tag "do not open".

To renew packing:

1. Remove packing gland.
2. Remove old packing.
3. Remove lantern ring.
4. Remove remaining packing.
5. Clean stuffing box and sleeves; inspect for wear.
6. Clean packing gland and bolts with wire brush.

NOTE 2: Angle cut packing ends and stagger joints around shaft while installing.

7. Install rings of packing (2 rings required).
8. Reinstall lantern ring.
9. Install rings of packing (2 rings required).
10. Reinstall packing gland and tighten packing gland nuts handtight.
11. Remove wire and safety tags; open suction and discharge valves.
12. Remove safety tag and energize circuit.
13. Operate pump for two hours to "run-in" the packing; adjust packing gland nuts for greater than normal leakage during this "run-in"
14. Readjust packing until there is a slight leakage.
15. Stop pump if not needed for service.

Page 1 of 1
MPS No. 4221 R1

Figure A-3

MAINTENANCE PROCEDURE SHEET	Page 1 of 1	MPS No. 5214 W1

EQUIPMENT NAME
Gear Reducer, Sludge Thickener

Plant Area	Level	Location
J		

Average Time
S-1 _____ min.
S-2 42 min.
S-3 _____ min.

MAINTENANCE DESCRIPTION

Check oil condition and oil level.

SAFETY PRECAUTIONS

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

TOOLS, PARTS, MATERIALS, TEST EQUIPMENT

Rags
Safety tag
Container
Lock jaw pliers or pipe wrench
Lubricant—AGMA No. 8 EP or AGMA No. 5 EP
Flashlight
Allen wrench

PROCEDURE

Preliminary— De-energize unit and tag "out of service".

To check oil condition and oil level:

1. Remove cover.
2. Loosen drain plugs on lower reservoir and drain off any accumulated water and foreign matter. Draw off a small amount of additional oil in a clean container and check its condition; tighten drain plug.
3. Loosen drain plug on drive head and drain off any accumulated water and foreign matter. Draw off a small amount of additional oil in a clean container and check its condition; tighten drain plug.
4. Check oil level (sight glass) of the drive head and the lower reservoir

NOTE 1: The oil level marks are located as follows:
(A) Drive head—1-inch above the centerline of the connection nipple.
(B) Lower reservoir—3 7/16-inch above the centerline of the connection pipe.

5. Refill to level marks if necessary.

NOTE 2: Reservoir is filled from the top of the drive head.
NOTE 3: The following lubricant should be used:
(A) Ambient temperature 0-125 deg. F., use AGMA No. 8 EP.
(B) Ambient temperature 0-40 deg. F., use AGMA No. 5 EP.

6. Replace cover.
7. Remove safety tag and energize unit.

Page 1 of 1
MPS No. 5214 W1

Figure A-4

MAINTENANCE PROCEDURE SHEET	Page 1 of 1	MPS No. 5214 Q1

EQUIPMENT NAME			Average Time
Gear Reducer, Sludge Thickener			S-1 _____ min.
Plant Area J	Level	Location	S-2 90 min.
			S-3 _____ min.

MAINTENANCE DESCRIPTION

Change oil and grease pinion bearing.

SAFETY PRECAUTIONS

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

TOOLS, PARTS, MATERIALS, TEST EQUIPMENT

Rags	Allen wrench
Safety tags	Lubricant
Container	Grease gun filled with Lubriplate No. 630AA or equivalent
Pipe wrench	
Combination wrench	
Flashlight	

PROCEDURE

Preliminary— De-energize unit and tag "out of service."

To change oil and grease pinion bearing:

1. Remove split cover.
2. Remove fill plugs on drive head cover (2 heads).
3. Remove pipe cap on drive head and drain out oil.
4. Remove 1/2-inch drain plug on drive head and drain out oil.
5. Remove drain plug and drain lower reservoir (located at end of sight glass piping).
6. Replace drain plug on lower reservoir.
7. Replace drain plug on drive head.
8. Replace pipe cap on drive head.
9. Fill with lubricant.

NOTE 1: Both reservoirs are filled from the top of the drive head.

NOTE 2: The following lubricant should be used:
(a) Ambient temperature 30-125 degrees F, use AGMA No. 8 EP.
(b) Ambient temperature 0-40 degrees F, use AGMA No. 5 EP.

NOTE 3: Turntable base oil capacity including drive head is 8 gallons.

10. Lubricate pinion bearings using the grease gun.
11. Check oil levels.
12. Replace split cover.
13. Remove safety tag and energize unit.

Page 1 of 1
MPS No. 5214 Q1

Figure A-5

MAINTENANCE PROCEDURE SHEET	Page 1 of 2	MPS No. 5342 Q1

EQUIPMENT NAME Motor, Sludge Belt Conveyor			Average Time S-1 18 min. S-2 _____ min. S-3 18 min.
Plant Area K	Level	Location	

MAINTENANCE DESCRIPTION

Clean motor and perform electrical inspection.

SAFETY PRECAUTIONS

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

TOOLS, PARTS, MATERIALS, TEST EQUIPMENT

Safety tags	Thermometer
500 volt megger	Rags
Voltmeter	Non-flammable solvent (LIX Cleaning Solvent or equivalent)
Ammeter	
Ohmmeter	
Screwdriver	

PROCEDURE

Preliminary— De-energize unit and tag "out of service."
Allow motor to cool to ambient temperature

To clean motor:

1. Clean exterior of motor of all foreign matter. For open or drip-proof motors, make note of extreme dirty condition and take corrective action if necessary.

To test insulation resistance:

1. Turn circuit breaker at Motor Control Console to "off."
2. Turn local electrical control (at motor) to "on". Measure the ambient temperature at the motor in degrees Fahrenheit.
3. Remove access panel at the very bottom of the Motor Control Console, exposing terminals.
4. Meg the motor circuits at these terminals, after application of a 500-volt direct current for one minute.

NOTE 1: Use an ohmmeter on those circuits which would be damaged by a 500-volt megger.

5. Correct the insulation resistance measurement to a standard 75° F. and record the corrected reading on the PM Work Record.

NOTE 2: If the corrected reading shows a significant drop from previous readings, or if the corrected reading is less than 40 megohms (Class A) or 8 megohms (Class B), corrective action should be taken.

(Continued)

Page 1 of 2 MPS No. 5342 Q1

Figure A-6

MAINTENANCE PROCEDURE SHEET	Page 2 of 2	MPS No. 5342 Q1

PROCEDURE (continued), "*Clean motor and perform electrical inspection.*"

To measure voltage and current:

1. After ensuring the unit may be operated, energize the unit by turning breaker at Motor Control Console to "on."
2. At the terminals at the very bottom of the Motor Control Console, measure the voltage and current for each of the three legs (for 3-phase motors). Record these readings on the PM Work Record.

NOTE 3: Take corrective action should any discrepancies be observed.

3. De-energize unit at the local electrical controller.
4. Replace access panel on the Motor Control Console.

Remove safety tag and return unit to service.

Page 2 of 2 MPS No. 5342 Q1

Figure A-6 (Cont)

MAINTENANCE PROCEDURE SHEET	Page 1 of 1	MPS No. 5344 A1

EQUIPMENT NAME			Average Time
Control, Sludge Belt Conveyor			S-1 48 min.
Plant Area K	Level	Location	S-2 ____ min.
			S-3 48 min.

MAINTENANCE DESCRIPTION

Clean and inspect controller.

SAFETY PRECAUTIONS

Observe standard safety precautions
Tag "out of service".

TOOLS, PARTS, MATERIALS, TEST EQUIPMENT

Rags	Vacuum cleaner--non-metallic nozzle
Flashlight	1/4 inch drive socket set
Safety tag	500 volt megger
Dusting brush	Contact dressing file
Voltage tester	Ohmmeter
Screwdriver	

PROCEDURE

Preliminary— Tag "out of service".

To clean and inspect controller:

1. Open access to controller.
2. Remove controller assembly.

NOTE 1: Caution. Avoid the energized lead.

3. Remove arc chutes where applicable. Inspect for carbonizing. Scrape clean or renew as necessary.
4. Inspect all contacts. If main line contacts are rough, burned or pitted, dress with contact dressing file.

NOTE 2: The brown discoloration found on silver and silver-plated auxiliary or relay contacts is harmless and need not be removed.

5. Inspect components and wiring for evidence of overheating.
6. Inspect and tighten all connections as necessary.
7. Clean controller assembly.
8. Vacuum and clean inside of panel; avoid the energized leads.
9. Manually check for binding in moving parts.
10. Meg circuits to ensure insulation resistance is satisfactory.

NOTE 3: Use an ohmmeter on those circuits which could be damaged by a 500 volt megger.

11. Replace controller assembly.
12. Close controller and remove safety tags.
13. Observe for proper operation.

Page 1 of 1 MPS No. 5344 A1

Figure A-7

MAINTENANCE PROCEDURE SHEET	Page 1 of 1	MPS No. 5344 A2

EQUIPMENT NAME			Average Time
Control, Sludge Belt Conveyor			S-1 30 min.
Plant Area K	Level	Location	S-2 _____ min.
			S-3 _____ min.

MAINTENANCE DESCRIPTION

Clean and inspect remote control switch.

SAFETY PRECAUTIONS

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

TOOLS, PARTS, MATERIALS, TEST EQUIPMENT

Screwdriver	Rags	Spare indicator lights
Flashlight	Dusting brush	Spare fuses
Safety tags	Vacuum cleaner (non-mettalic nozzle)	Spare overload heaters
Voltage tester	Contact dressing file	Spare contacts
500 volt megger		
Ohmmeter	1/4-inch drive socket set	

PROCEDURE

Preliminary— De-energize unit and tag "out of service".
Tag any alternate switches in other locations.

To clean and inspect remote control switch:

1. Open door or remove cover.
2. Test with voltage tester to ensure circuit is de-energized.
3. Remove accumulated dust and dirt with brush, soft cloth or vacuum cleaner.
4. Wipe all bus insulators and bus barriers.
5. Inspect bus joints and bus supports and tighten if necessary.
6. Check all wiring for deterioration of insulation and tighten all connections.
7. Inspect components and wiring for evidence of overheating.
8. Inspect overload heater for distortion; replace as required.
9. Inspect contacts. If beads have formed due to arcing, or where rough, burned or pitted, replace contacts or dress with contact dressing file.
10. Remove draw-out units and check stabs and wiring. Remove accumulated dust from barriers and in area of stabs.
11. Manually check for binding in all moving parts.
12. Megger all terminals and circuits to ensure insulation resistance is adequate.

NOTE: Instruments or control devices sensitive to megger voltage should be isolated from circuit, or an ohmmeter should be used.

13. Check all indicating lights and replace as required.
14. Check unit door interlock for proper operation.
15. Check door or cover gasket and replace as required.
16. Close door or replace cover.

Perform this procedure on any alternate switches in other locations.
Remove safety tags and energize unit.

Page 1 of 1
MPS No. 5344 A2

Figure A-8

MAINTENANCE PROCEDURE SHEET	Page 1 of 1	MPS No. 5364 W1

EQUIPMENT NAME Flowrate, Flushing Water (N1)			Average Time S-1 _____ min. S-2 12 min. S-3 _____ min.
Plant Area K	Level L	Location	

MAINTENANCE DESCRIPTION

Clean flow tube, adjust purge rates, bleed air.

SAFETY PRECAUTIONS

Observe standard safety precautions

TOOLS, PARTS, MATERIALS, TEST EQUIPMENT

PROCEDURE

1. Clean flow tube orifices using manual vent cleaners on both high and low pressure sides.
2. Check purge water flow rates on both high and low sides using sight flow indicators. Adjust flow if indicators are off the red reference marks.
3. Slowly open air vent valve on high pressure side. Rap mercury well and test pipe to dislodge air bubbles. Close air vent valve.
4. Repeat for air vent valve on low pressure side.

Page 1 of 1
MPS No. 5364 W1

Figure A-9

MAINTENANCE PROCEDURE SHEET	Page 1 of 2	MPS No. 5364 S1

EQUIPMENT NAME Flowrate, Flushing Water (NI)			Average Time S-1 48 min. S-2 _____ min. S-3 _____ min.
Plant Area K	Level L	Location	

MAINTENANCE DESCRIPTION

Inspect, lubricate, and index flow transmitter.

SAFETY PRECAUTIONS

Observe standard safety precautions

TOOLS, PARTS, MATERIALS, TEST EQUIPMENT

Adjustable wrench
Pipe wrench
Screwdriver
Marking crayon or pen
Rags
Lithium-base grease type lubricant, Molykote G or equal
Automatic precision electrical interval timer, accurate to 0.01 seconds

PROCEDURE

To inspect transmitter:

1. Check for excessive accumulation of water or flooding in area.
2. Check for leaks in piping and fittings both outside and inside the transmitter. Eliminate any leaks.
3. Check for loosened mounting, cracked or broken cover, damaged mechanism, loosened electrical connections, or other damage.

To lubricate cam:

1. Clean and re-lubricate the face of the cam and the cam gear stud bearing with a grease type lubricant (Molykote G or equal).

NOTE—Do not lubricate any other points in the mechanism.

To index transmitter:

1. Close high and low pressure needle valves at the transmitter.
2. Ensure bypass valve is shut between high and low pressure lines.
3. Remove both air vent valves from top of test pipe and from low pressure pipe.
4. Slowly fill test pipe and low pressure pipe with additional water if necessary. Rap mercury wells and test pipes with fist to remove air bubbles. Level off water at top of pipes.
5. Attach the electrical interval timer to terminals 10 and 11 of the terminal strip.

(Continued)

Page 1 of 2
MPS No. 5364 S1

Figure A-10

PROCEDURE (continued)

6. Wait four revolutions of the cam and then measure the time with the interval timer for the trip arm to ride on the cam face (which moves the magnet on the trip lever away from the mercury switch).
7. Compare this time with the standard time taken from the data plate on the transmitter under test head-signal seconds. If they do not agree to within 0.02 seconds, adjustment should be made as follows to the trip arm position:
   - Caution—do not change the adjustment of the link lever slide. Red paint was put on at the factory to seal its position.
   - Mark the knurled head of the trip arm micrometer screw to enable approximation of amount of turning.
   - Carefully back off clamping screw.
   - Reposition the micrometer screw a small amount—to increase time reading, turn screw so trip arm moves towards center of cam.
   - Wait four revolutions of cam and take time interval reading.
   - Repeat adjustment if necessary to make time agree with standard.
   - Tighten clamping screw, wait four revolutions, and take final time interval reading, which should agree with standard to within 0.02 seconds.
8. Remove interval timer from terminal strip.
9. Replace both air vent valves.
10. Open high and low pressure needle valves at the transmitter.

Page 2 of 2 | MPS No. 5364 S1

Figure A-10 (Cont)

MAINTENANCE PROCEDURE SHEET	Page 1 of 1	MPS No. 5621 A1

EQUIPMENT NAME
Air Compressor, Area K

Plant Area K	Level M	Location E

Average Time
S-1 _____ min.
S-2 _____ min.
S-3 30 min.

MAINTENANCE DESCRIPTION

Inspect foundation bolt tightness.

SAFETY PRECAUTIONS

Observe standard safety precautions
Deactivate unit and tag "out of service"

TOOLS, PARTS, MATERIALS, TEST EQUIPMENT

Torque wrench
Safety tags

PROCEDURE

Preliminary— Deactivate unit and tag "out of service."

To test foundation bolt tightness on wetwell blower:

1. Test tightness of foundation bolts with torque wrench.

CAUTION: Improper torqueing of foundation bolts may cause misalignment of internal parts.

2. Tighten loose bolts (see standard steel bolt and nut specifications below)
3. Remove safety tag and activate unit.

NOTE: Observe torque value for applicable bolts from following list.

Standard steel bolt and nut torque specifications

Size nut or bolt/ No. threads per inch	Torque (ft-lbs)	Size nut or bolt/ No. threads per inch	Torque (ft-lbs)
1/4-20	7-9	1/2-20	83-93
1/4-28	8-10	9/16-12	90-100
5/16-18	13-17	9/16-18	107-117
5/16-24	15-19	5/8-11	137-147
3/8-16	30-35	5/8-18	168-178
3/8-24	35-39	3/4-10	240-250
7/16-14	46-50	3/4-16	290-300
7/16-20	57-61	7/8-9	410-420
1/2-13	71-75	7/8-14	475-485

Page 1 of 1
MPS No. 5621 A1

Figure A-11

MAINTENANCE PROCEDURE SHEET	Page 1 of 2	MPS No. 5921 W1

EQUIPMENT NAME Sludge Vacuum Filter			Average Time
Plant Area K	Level U	Location	S-1 _____ min. S-2 150 min. S-3 150 min.

MAINTENANCE DESCRIPTION

Clean vacuum filter subsystem, check tine bar and spring alignment, inspect spray nozzles.

SAFETY PRECAUTIONS

Observe standard safety precautions
Tag unit "out of service"

TOOLS, PARTS, MATERIALS, TEST EQUIPMENT

Rags
Safety tag
Water hose
Pipe wrench

PROCEDURE

Preliminary— Tag unit "out of service."

To clean vacuum filter subsystem:

1. Put unit into operation.
2. Stop sludge feed to the filter.
3. Stop the sludge conditioning feeder.
4. Stop the conditioning tank.
5. Open the conditioning tank drain valve.
6. Stop the filter agitator when the sludge level is way down.
7. Operate the filter until the filter vat sludge level is too low for filtering.
8. Stop vacuum pump and filtrate pump.
9. Open the filter vat drain valve.
10. Stop the belt conveyor.
11. Turn on valve to top wash water spray pipe for cleaning springs.
12. Hose down filter, conditioning tank and vat.
13. Replace conditioning tank drain cap; fill conditioning tank with water and allow it to rotate while hosing down the rest of the equipment.
14. Stop filter drum and shut valves to wash water sprays.
15. Remove conditioning tank drain cap and drain tank.
16. Replace conditioning tank drain cap.
17. Drain vat; hose down as required to clean vat.

To Check Tine Bar Alignment:

1. Check Tine bar alignment; adjust as necessary to center tines between the coil springs.

(Continued)

Page 1 of 2 MPS No. 5921 W1

Figure A-12

MAINTENANCE PROCEDURE SHEET	Page 2 of 2	MPS No. 5921 W1

PROCEDURE (continued) Clean vacuum filter subsystem, check tine bar and spring alignment, inspect spray nozzles.

To Check Spring Alignment:

1. Check spring alignment; adjust as necessary.

NOTE 1: Proper alignment means that the centers of the end grooves on the upper aligning roll (small upper roll nearest drum) are equidistant from the outer surface of the drum head (a straight-edge on this cleaned surface is the best point to measure from).

CAUTION: Do not shorten springs to remove sag. Do not overstretch springs.

To Inspect Spray Nozzles:

1. Inspect spray nozzles for clogging; clean as required.
2. Remove safety tag and return unit to service.

Page 2 of 2 MPS No. 5921 W1

Figure A-12 (Cont)

MAINTENANCE PROCEDURE SHEET	Page 1 of 2	MPS No. 5921 R1

EQUIPMENT NAME			Average Time
Sludge Vacuum Filter			S-1 _____ min.
Plant Area K	Level U	Location	S-2 120 min.
			S-3 120 min.

MAINTENANCE DESCRIPTION

Acid wash springs and drum.

SAFETY PRECAUTIONS

Observe standard safety precautions
Tag unit "out of service"

TOOLS, PARTS, MATERIALS, TEST EQUIPMENT

Rags
Safety tags
Scraper
Drums of Oakite CPD No. 32.
Rubber protective clothing and eye goggles
Brush

PROCEDURE

NOTE 1: To be performed when scale deposits become excessive. A positive indication is spring sag between the take-off point on the drum and the discharge roll.

Preliminary—Tag unit "out of service."
Clean drum, springs and vat. See MPC W-1 procedure 1 for proper cleaning procedure.

To acid wash springs and drum:

1. Clean vat; if heavy deposits exist on the vat agitator, raise agitator out of vat and scrape off deposits. Return agitator to normal position and use to mix the acid and the water.
2. Wet the springs and the drum sruface thoroughly with water.
3. Run 300 gallons of water and 100 gallons (5 drums) of acid—CA 36% HCL (Oakite CPD No. 32)—into vat.
4. CAUTION: Always add acid to water. Do not add water to the acid.

NOTE 2: An additional drum of acid will be required for makeup.

5. Start all wash water sprays.
6. Rotate drum intermittently so that each section remains immersed about 5 minutes.

NOTE 3: As the alkaline carbonate scale is being removed, the acid will be neutralized and will slow down the scale removal. Check acid strength with a Titraion Kit. Acid should not be allowed to go below 9% of Oakite No. 32 or 3% HCL. Add more acid to vat as required.

(Continued)

Page 1 of 2 MPS No. 5921 R1

Figure A-13

PROCEDURE (continued)

NOTE 4: Scale removal can be hastened by brushing the springs and scraping the drum.

CAUTION: Care should be taken to hose off discharge rolls and galvanized piping to prevent acid damage.

7. When scale has been removed, drain vat and thoroughly wash down all equipment exposed to the acid with water.
8. Immediately resume sludge dewatering so that any residual acid will be neutralized.
9. Remove safety tag.

Page 2 of 2 | MPS No. 5921 R1

Figure A-13 (Cont)

MAINTENANCE PROCEDURE SHEET	Page 1 of 1	MPS No. 6531 Q2

EQUIPMENT NAME			Average Time
Exhaust ID Fan, Incinerator			S-1 _____ min.
Plant Area K	Level U	Location	S-2 24 min.
			S-3 _____ min.

MAINTENANCE DESCRIPTION

Inspect drive belt(s) tension.

SAFETY PRECAUTIONS

Observe standard safety precautions
De-energize unit and tag "out of service".
NOTE: This procedure is to be performed only when the entire incinerator has been shut down.

TOOLS, PARTS, MATERIALS, TEST EQUIPMENT

Combination Wrench
Screwdriver
Safety Tags

PROCEDURE

Preliminary— De-energize circuit and tag "out of service".

To inspect drive belt(s) tension:

1. Remove drive belt guard, if installed.
2. Inspect drive belt for cracks, fraying or evidence of unusual wear.
3. Depress drive belt by hand in a central location between pulleys. Belt should depress from 1/2 to 3/4 of an inch.
4. Caution: Do not tighten drive belt to have less than 1/2-inch depression.

NOTE 1: When renewal of one belt of a multiple V-belt drive is necessary, a complete new set of matched belts should be installed.

5. Reinstall belt guard, if installed.
6. Remove safety tag; energize circuit.

Page 1 of 1
MPS No. 6531 Q2

Figure A-14

MAINTENANCE PROCEDURE SHEET	Page 1 of 1	MPS No. 7151 A1

EQUIPMENT NAME			Average Time
9 Recorders, Blower Building Console			S-1 270 min.
Plant Area E	Level U	Location SW	S-2 _____ min.
			S-3 _____ min.

MAINTENANCE DESCRIPTION

Clean and calibrate recorder.

SAFETY PRECAUTIONS

Observe standard safety precautions
De-energize unit

TOOLS, PARTS, MATERIALS, TEST EQUIPMENT

Mild Non-abrasive Soap
Warm Water
Alcohol
Clean Cloth or Tissue
Soft Brush
Small Screwdriver
Strand of 6 mil Wire

PROCEDURE

Preliminary— De-energize unit.

NOTE 1: Under no circumstances should internal mechanism be lubricated. Do not tamper unnecessarily with internal mechanism.

To clean recorder:

1. Clean dials and chart plate with a mild non-abrasive soap and warm water.
2. Remove dust from gears with a soft brush.
3. Clean pen point with strand of 6 mil wire, and flush with water or alcohol. Clean outside of pen by wiping the pen from the body toward and beyond the point.

To calibrate recorder:

1. Re-energize the unit.
2. Check pen carriage alignment so that the pen will track a chart time line. Adjust if necessary.
3. Check indicator and pen zero position. Adjust if necessary.

Return unit to service.

Page 1 of 1
MPS No. 7151 A1

Figure A-15

MAINTENANCE PROCEDURE SHEET			Page 1 of 1	MPS No. 7700 Q1
EQUIPMENT NAME Alarm Annunciators				Average Time S-1 60 min. S-2 _____ min. S-3 _____ min.
Plant Area B, E, G, J, K	Level	Location		

MAINTENANCE DESCRIPTION

Test Annunciator Operation.

SAFETY PRECAUTIONS

Observe standard safety precautions

TOOLS, PARTS, MATERIALS, TEST EQUIPMENT

PROCEDURE

To test annunciator operation:

1. Push Annunciator Test Buttons and check for proper operation of both horn and light. The following annunciators are to be checked:

I. D.	Area	Level	Location	No. of Annunciators
77200	B	U		11
77300	E	U	SW	30
77400	G	U	S	4
77500	J	U		2
77600	K	U	S	8
77700	K	M	S	10

Page 1 of 1 MPS No. 7700 Q1

Figure A-16

MAINTENANCE PROCEDURE SHEET	Page 1 of 3	MPS No. 7700 S6

EQUIPMENT NAME			Average Time
Alarm Systems – Area K (Incineration Operations)			S-1 60 min. S-2 60 min. S-3 60 min.
Plant Area K	Level	Location	

MAINTENANCE DESCRIPTION

Test alarm systems by simulating alarm conditions

SAFETY PRECAUTIONS

Observe standard safety precautions

TOOLS, PARTS, MATERIALS, TEST EQUIPMENT

3 copies of this MPS

PROCEDURE

Preliminary—Station observers at these alarm indicator (annunciator) locations: 77300 (Area E) and 77700 (Area K, Incinerator Room). Each observer should check off proper operation of the alarm indicators at his location.

To test alarm systems:

NOTE: The following steps are temporary tests. Normal operation should be resumed promptly.

1. To simulate a stopped shaft for each of the incinerators, turn off the incinerator mechanism for approximately 60 seconds (to exceed the normal time delay of 55 seconds for one revolution). Do not allow shaft to be stopped for any longer period of time.
2. To simulate a clogged condition for each of the flushing water strainers, hand-trip the appropriate mercury switch.
3. Simulate a high-level alarm for the ash bin by removing the sensor assembly from the bin and holding the propeller by hand, preventing it from turning.
4. Simulate a high temperature for each of the incinerators by lifting the contact bar on the appropriate strip chart recorder.
5. Simulate a high temperature for each of the ID fans by lifting the contact bar on the appropriate strip chart recorder.

Page 1 of 3
MPS No. 7700 S6

Figure A-17

MAINTENANCE PROCEDURE SHEET	Page 2 of 3	MPS No. 7700 S6

PROCEDURE (continued)

6. Simulate a flame failure in the sludge building boiler by shutting off the pilot light.

7. Simulate an electrical failure in the incinerator area by pulling the main breaker in the motor control console.

Page 2 of 3 MPS No. 7700 S6

Figure A-17 (Cont)

MAINTENANCE PROCEDURE SHEET

Page 3 of 3

MPS No. 7700 S6

PROCEDURE (continued)

MPS Step Number	Operating Unit and Sensor					Alarm Condition	Alarm Indicators			
	ID	Name	Area	Level	Loc		ID	Area	ID	Area
1	61161	Incinerator No. 1	K	L	N	Shaft Stopped	77702	K		
1	61162	Incinerator No. 2	K	L	S	Shaft Stopped	77706	K		
2	65211	Flushing Water to Scrubber No. 1	K	U	N	Strainer Clogged	77704	K		
2	65212	Flushing Water to Scrubber No. 2	K	U	S	Strainer Clogged	77708	K		
3	66331	Ash Bin	K			Ash Bin Full	77709	K		
4	71851	Temp. Recorder, Incinerator No. 1	K	M	S	High Incinerator Temp.	77701	K		
5	71851	Temp. Recorder, Incinerator No. 1	K	M	S	High ID Fan Temp.	77703	K		
4	71852	Temp. Recorder, Incinerator No. 2	K	M	S	High Incinerator Temp.	77705	K		
5	71852	Temp. Recorder, Incinerator No. 2	K	M	S	High ID Fan Temp.	77707	K		
6	73212	Sludge Building Boiler	K			Flame Failure	77710	K	77315	E
7	79500	Sludge Incineration	K	M	S	Electrical Failure	77311	E		

Page 3 of 3

MPS No. 7700 S6

Figure A-17 (Cont)

MAINTENANCE PROCEDURE SHEET	Page 1 of 2	MPS No. 7700 A1

EQUIPMENT NAME			Average Time
Alarm Systems—Electrical Substations			S-1 30 min.
Plant Area	Level	Location	S-2 _____ min.
B, E, K			S-3 120 min.

MAINTENANCE DESCRIPTION

Test alarm systems by simulating alarm conditions

SAFETY PRECAUTIONS

Observe standard safety precautions

TOOLS, PARTS, MATERIALS, TEST EQUIPMENT

5 copies of this MPS

PROCEDURE

Preliminary—Station observers at these alarm indicator (annunciator) locations: 77100 (Area L, 77200 (Area B), 77300 (Area E) and 77600 (Area K, Filter Room). A VEPCO service man is required to perform Step 2 of this MPS.

To test alarm systems

NOTE: The following steps are temporary tests. Normal operation should be resumed promptly.

1. For each of the four electrical substations, simulate an emergency power failure by transferring from normal to emergency power, and simulate a ground fault by transferring power.
2. Simulate a failure of emergency power at Electrical Substation No. 1 by having the VEPCO service man de-energize the emergency power.

Page 1 of 2 MPS No. 7700 A1

Figure A-18

MAINTENANCE PROCEDURE SHEET

Page 2 of 2

MPS No. 7700 A1

PROCEDURE (continued)

MPS Step Number	Operating Unit and Sensor					Alarm Condition	Alarm Indicators					
	ID	Name	Area	Level	Loc		ID	Area	ID	Area	ID	Area
1	74111	Electrical Substation No. 1	B		O	Emergency Power On	77101	L	77210	B	77323	E
1	74111	Electrical Substation No. 1	B		O	Ground Fault	77211	B	77324	E		
2	74111	Electrical Substation No. 1	B		O	Emergency Power Failure	77212	B				
1	74112	Electrical Substation No. 2	K			Emergency Power On	77102	L	77325	E	77606	K
1	74112	Electrical Substation No. 2	K			Ground Fault	77326	E	77607	K		
1	74113	Electrical Substation No. 3	E			Emergency Power On	77103	L	77327	E		
1	74113	Electrical Substation No. 3	E			Ground Fault	77328	E				
1	74114	Electrical Substation No. 4	E			Emergency Power On	77104	L	77329	E		
1	74114	Electrical Substation No. 4	E			Ground Fault	77330	E				

Page 2 of 2

MPS No. 7700 A1

Figure A-18 (Cont)

APPENDIX III

TABLE A-1 THROUGH A-10

Table A-1. EQUIPMENT TYPE CLASSIFICATION

10	Tanks and Tank 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
24	Air Compressors
25	Air Blowers
26	Sump Pumps
27	Submersible Pump/Drive Assemblies
28	Vacuum Pumps
30	Electrical Equipment
31	Motors, Motor and Drive Assemblies
32	Supply Panels and Boxes
33	Controls
34	Transformers, HV Power Supplies
35	Delays, Relays, Timers
40	Mechanical Equipment
41	Drives and Bearings
42	Hoists and Cranes
43	Conveyors
44	Special Equipment
50	Hydraulic and Pneumatic Components
51	Strainers, Filters, Screens
52	Heat Exchangers, Evaporators
53	Diffusers, Injectors, Nozzles
54	Valves, Dampers
55	Pressure Reducers, Relief Devices
56	Silencers, Scrubbers
57	Mixers, Agitators, Vibrators
58	Chlorinators, Feeders
59	Hydraulic Power Components
60	Measurement and Control
61	Flowrate Transducers
62	Pressure Transducers
63	Level Transducers and Controls
64	Analyzers
65	Scales
66	Meters, Alarms, Recorders
67	Float, Pressure, and Limit Switches
70	Plant Service Equipment
71	Fire Extinguishers
72	Heaters, Ventilators
73	Laboratory Equipment

Table A-2. INDICATORS AND MODIFIERS

Indicators	
11	Start/Turn on
12	Stop/Turn off
13	Open
14	Shut/Close
15	Tune, adjust, align, calibrate
16	Safety hazard
17	Defective material
18	Broken, cracked, bent
22	Corroded/Rusted
23	Dirty/Fouled
24	Leaking
25	Vibration
26	Alignment/Fit
31	Smell
32	Heat/Temperature
33	Noise
34	Smoking/Arcing
41	Flow rate
42	Speed/Rotation
43	Frequency
44	Pressure
45	Suction/Vacuum
51	Current
52	Voltage
53	Resistance
54	Power

Modifiers	
1	No, none, fails to
2	Poor, improper
3	Unstable, unbalanced
4	Difficult to
5	High, fast, excessive
6	Low, slow, too little
7	Intermittent, erratic, uncontrollable
8	Drifting, shifting, fluctuating
9	Steady
0	No modifier required

Table A-3. ANNUAL PM MANPOWER REQUIREMENT

System		Annual Manhours Required			
ID	Name	Skill 1	Skill 2	Skill 3	Total
110	Screening	15	211	189	415
120	Grinding	6	43	108	157
130	Wastewater flow	12	124	65	201
210	Primary settling	12	27	121	160
220	Sludge handling	13	11	94	118
230	Scum handling	5	33	12	50
240	Auxiliary services	6	14	5	25
310	Aeration	2	6	111	119
320	Air delivery	21	99	260	380
330	Secondary clarifiers	6	90	70	166
340	Chemical treatment	3	4	6	13
350	Return sludge	12	74	75	161
360	Excess sludge	6	25	6	37
370	Scum	6	2	5	13
380	Auxiliary services	12	28	10	50
410	Chlorination	0	56	6	62
420	Residual chlorine analysis	18	14	24	56
430	Effluent water	24	62	60	146
440	Auxiliary services	3	7	2	12
510	Auxiliary services	15	18	13	46
520	Sludge thickening	18	272	617	907
530	Sludge storage and handling	32	224	954	1,210
540	Scum handling	3	2	3	8
550	Lime treatment	--	--	--	--
560	Ferric chloride treatment	9	84	282	375
570	Polymer treatment	4	3	4	11
580	Sludge conditioning	6	1	99	106
590	Vacuum filtration	24	378	984	1,386
610	Incinerators	6	540	490	1,036
620	Gas supply	0	12	0	12
630	Oil supply	9	0	6	15
640	Air supply and foul gases	15	37	56	108
650	Scrubbing	6	26	28	60
660	Ash handling	18	128	167	313
100	Raw wastewater station	33	378	362	773
200	Primary treatment	36	85	232	353
300	Secondary treatment	68	328	543	939
400	Chlorination & effluent flow	45	139	92	276
500	Sludge & scum processing	111	982	2,956	4,049
600	Incineration	54	743	747	1,544
	Total for plant	347	2,655	4,932	7,934

Table A-4. CROSS REFERENCE TO EQUIPMENT CONFIGURATION LIST

Design Engineering Code	Pump	Area	ID Number
A2	Raw Wastewater	B	13112
A3	Raw Wastewater	B	13113
A4	Raw Wastewater	B	13114
B1	Return Sludge (RA-1)	E	35111
B2	Return Sludge (RA-2)	E	35112
B3	Return Sludge (RA-3)	E	35113
C3	Excess Sludge	E	36113
C4	Excess Sludge	E	36114
D1	Dewatering	E	35411
E1	Low Lift	G	43411
E2	Low Lift	G	43412
E3	Low Lift	G	43413
E4	Low Lift	G	43414
F1	High Lift	G	43311
F2	High Lift	G	43312
G3	Primary Sludge	C	22113
G4	Primary Sludge	C	22114
G5	Primary Sludge	C	22115
H1	Primary Scum	C	23111
H2	Primary Scum	C	23112
J1	Secondary Scum Well	F	37121
J2	Secondary Scum Well	F	37122
K1	Sludge Plunger	J	52211
K2	Sludge Plunger	J	52212
K3	Sludge Plunger	J	52213
K4	Sludge Plunger	J	52214
L1	Scum Pit	K	54211
M1	Influent Sampling	G	42211
M2	Influent Sampling	G	42212
M3	Influent Sampling	G	42213
N1	Effluent Sampling	G	42311
N2	Effluent Sampling	G	42312
N3	Effluent Sampling	G	42313
O1	Sump	B	14111
O2	Sump	B	14112
P1	Sump	C	24111
P2	Sump	C	24112
Q1	Sump	E	38111
Q2	Sump	E	38112
Q3	Sump	E	38113
Q4	Sump	E	38114

Table A-4 (Continued)

Design Engineering Code	Pump	Area	ID Number
R1	Sump	G	44111
S1	Sump	J	51111
T1	Sump	K	53811
T2	Sump	K	53812
U1	Sump	H	24113
V1	Seal Water	G	43511
V2	Seal Water	G	43512
W1	Meter Purge Water	K	53611
W2	Meter Purge Water	K	53612
X1	Sump	D	38115
X2	Sump	D	38116
--	Sludge Plunger	K	53311
--	Sludge Plunger	K	53312
--	Sludge Plunger	K	53313
--	Ferric Chloride	K	56411
--	Ferric Chloride	K	56412
--	Ferric Chloride	K	56413
--	Lime (Screw)	K	55711
--	Lime (Plunger)	K	55811
--	Vacuum	K	59111
--	Vacuum	K	59112
--	Filtrate	K	59411
--	Filtrate	K	59412
--	Oil	K	63311
--	Oil	K	63312
--	Oil	K	63313
--	Hydraulic Fluid	K	53741

Table A-4 (Continued)

Design Engineering Code	Transmitter	Area	ID Number
A3	Mixed Liquor From No. 3	E	31613
A4	Mixed Liquor From No. 4	E	31614
B3	Return Sludge to No. 3	D	35513
B4	Return Sludge to No. 4	D	35514
D	Excess Sludge to Thickeners	E	36311
E	Total Flow to Thickeners	E	36321
F1	Primary Sludge to No. 1 Degrit	H	22311
F2	Primary Sludge to No. 2 Degrit	H	22312
G2	Blower No. 2 Output	E	32312
G3	Blower No. 3 Output	E	32313
G4	Blower No. 4 Output	E	32314
H4	Air to 3A and 3B	E	31343
H5	Air to 3C and 4C	E	31340
H6	Air to 4A and 4B	E	31344
K	Chlorine Residual in Effluent	G	42123
L	Return Sludge Well Level	E	35321
N1	Flushing Water	K	53640

Table A-4 (Continued)

Design Engineering Code	Receiver	Area	ID Number
A3	Mixed Liquor Flow From No. 3	E	71525
A4	Mixed Liquor Flow From No. 4	E	71526
A7	Total ML Flow (A3 and A4)	E	71511
A7	Total ML Flow (A3 and A4)	L	71111
B3	Return Sludge to No. 3	E	71523
B4	Return Sludge to No. 4	E	71524
B7	Total Return Sludge (B3 & B4)	E	71512
B7	Total Return Sludge (B3 & B4)	L	71112
C3	Wastewater to No. 3 (A3 - B3)	E	71521
C4	Wastewater to No. 4 (A4 - B4)	E	71522
C7	Total Wastewater (C3 and C4)	E	71513
D	XS Sludge to Thickeners	E	71514
D	XS Sludge to Thickeners	L	71113
E	Total Flow to Thickeners	E	71515
F1	Primary Sludge to No. 1 Degrit	H	71411
F2	Primary Sludge to No. 2 Degrit	H	71412
F4	Total Primary Sludge (F1 & F2)	E	71516
F4	Total Primary Sludge (F1 & F2)	C	71311
G2	Blower No. 2 Output	E	71534
G3	Blower No. 3 Output	E	71535
G4	Blower No. 4 Output	E	71536
G6	Total Blower O'put (G2& G3& G4)	E	71518
H4	Air to 3A and 3B	E	71531
H5	Air to 3C and 4C	E	71532
H6	Air to 4A and 4B	E	71533
H10	Total Air to Aerators (H4, 5&6)	E	71519
H10	Total Air to Aerators (H4, 5&6)	L	71115
K	Chlorine Residual	E	71581
K	Chlorine Residual	L	71116
K	Chlorine Residual	G	71613
L	Return Sludge Well Level	E	71527
N1	Flushing Water Flow	K	71811
O1	Raw W'water Flow (C7-E-N1)	E	71517
O1	Raw W'water Flow (C7-E-N1)	L	71114
O1	Raw W'water Flow (C7-E-N1)	A	71121
O1	Raw W'water Flow (C7-E-N1)	B	71211
O1	Raw W'water Flow (C7-E-N1)	G	71612

Table A-5. LIST OF MAINTENANCE PROCEDURES FOR REMOTE ELECTRICAL CONTROLS

MPS No.	Equipment Controlled	Remote Control ID	Remote Control ID
1114 A2	Bar Screens	7811	
1124 A2	Bar Screen Conveyors	7812	
1213 A2	Grinders	7813	
1316 A2	Raw Wastewater Pumps A	7816	
1364 A1	Control, Air Compressor	7814	
1411 A1	Sump Pump O	7815	
2124 A2	Sludge Collectors, A&B	7821	
2134 A2	Sludge Collectors, C & Cross	7822	
2213 A2	Primary Sludge Pumps G	7824	7833
2245 A2	Grit Classifiers	7831	
2313 A2	Primary Scum Pumps H	7823	
2333 A1	Motor, Air Compressor	7826	
2414 A2	Sump Pumps P, U	7825	7832
3214 A1	Air Damper Motor DM-FAI	7849	7853
3228 A2	Blowers	7854	7861
3264 A1	Pressure Switch, Air Compressor	7847	
3337 A2	Secondary Classifiers	7841	7851
3514 A2	Return Sludge Pumps B	7842	
3543 A2	Dewatering Pump D	7844	7852
3614 A2	Excess Sludge Pumps C	7843	
3641 A1	Motor Valve, XS Sludge Dilution	7846	
3814 A2	Sump Pumps Q, X	7848	
4121 A2	Chlorine Evaporator	7876	7883
4123 A1	Chlorine Pressure Reducing Valve	7881	
4131 A2	Chlorinator	7885	
4141 A1	Chlorine Gas Detector	7886	
4211 A1	Chlorine Analyzer	7884	
4224 A2	Influent Sampling Pumps M	7875	
4234 A2	Effluent Sampling Pumps N	7882	
4333 A2	High Lift Pumps F	7871	
4343 A2	Low Lift Pumps E	7872	
4353 A2	Seal Water Pumps V	7873	
4414 A2	Sump Pumps R	7874	
5114 A2	Sump Pump S	7894	
5123 A2	Dome Fan, Thickeners	7895	
5216 A2	Sludge Thickeners	7892	
5226 A2	Sludge Plunger Pumps K	7891	
5253 A1	Pressure Switch, Air Compressor	7893	
5314 A2	Compressor, Sludge Storage Tank	7922	7942
5336 A2	Sludge Plunger Pumps	7911	7931
5344 A2	Sludge Belt Conveyors	7961	

Table A-5 (Continued)

MPS No.	Equipment Controlled	Remote Control ID	Remote Control ID
5363 A2	Meter Purge Water Pumps W	7921	7941
5423 A2	Scum Pump L	7923	7943
5544 A2	Lime Dust Collector Fan	7928	7948
5547 A2	Lime Dust Collector Vibrator	7929	7949
5551 A1	Lime Gravimetric Feeder	7940	
5563 A2	Lime Slurry Tank Mixer	7927	7947
5574 A2	Lime Slurry Pump No. 1 (Screw)	7925	7945
5584 A2	Lime Slurry Pump No. 2 (Plunger)	7926	7946
5624 A1	Control, Air Compressor	7914	7937
5633 A1	Motor, Ferric Chloride Tank Mixer	7919	7939
5644 A2	Ferric Chloride Feed Pumps	7918	7938
5814 A2	Sludge Conditioning Tanks	7912	7932
5913 A2	Vacuum Pumps	7915	7935
5925 A2	Vacuum Filter Drums	7913	7933
5934 A2	Filter Agitators	7914	7934
5943 A2	Filtrate Pumps	7916	7936
6117 A2	Incinerator Mechanisms	7951	
6413 A2	Cooling Air Fans	7952	
6423 A2	Turbo Blowers	7953	
6433 A2	Foul Air Fan	7954	
6533 A2	Exhaust ID Fans	7955	
6614 A2	Ash Bucket Elevators	7956	
6624 A2	Ash Screw Conveyors	7957	
6644 A2	Rotary Ash Conditioner	7958	
6654 A2	Ash Vane Feeder	7959	
6711 A1	Sump Pump T	7924	7944

Table A-6. CROSS REFERENCE, ALARM SENSORS TO ALARM INDICATORS

Operating Unit and Sensor					Alarm Condition	Alarm Indicators					
ID	Name	Area	Level	Loc		ID	Area	ID	Area	ID	Area
11111	Bar Screen No. 1	B	U	N	High Differential	77202	B				
11112	Bar Screen No. 2	B	U	S	High Differential	77203	B				
13122	Motor, Raw Wastewater Pump A2	B	U	N	Power Failure	77206	B				
13123	Motor, Raw Wastewater Pump A3	B	U	M	Power Failure	77207	B				
13124	Motor, Raw Wastewater Pump A4	B	U	S	Power Failure	77208	B				
13311	Raw Wastewater Wet Well Control	B	U		Low Level	77204	B	77301	E		
13311	Raw Wastewater Wet Well Control	B	U		High Level	77205	B	77302	E		
13511	Strainer, Pump Seal Water	B	L		Strainer Clogged	77201	B				
32212	Blower No. 2	E	U	W	Low Oil Pressure	77320	E				
32213	Blower No. 3	E	U	M	Low Oil Pressure	77321	E				
32214	Blower No. 4	E	U	E	Low Oil Pressure	77322	E				
32640	Blower Building Compressors	E	L	S	Instrument Air Failure	77314	E				
33311	Secondary Clarifier No. 1	F		NW	Overload	77312	E				
33312	Secondary Clarifier No. 2	F		NE	Overload	77313	E				
35221	Strainer, Pump Seal Water	E	L	W	Strainer Clogged	77319	E				
35321	Return Sludge Wet Well	E	U	S	Low Level	77303	E				
35321	Return Sludge Wet Well	E	U	S	High Level	77304	E				
38115	Cross-Tunnel Sump Pump X-1	D	L	W	Sump Pump Failure	77317	E				
38116	Cross-Tunnel Sump Pump X-2	D	L	E	Sump Pump Failure	77318	E				
41221	West Evaporator	G	U	W	High Water Temperature	77401	G				
41222	East Evaporator	G	U	E	High Water Temperature	77402	G				
41230	Chlorine Pressure Reducing Valves	G	U		Motor Valve Failure	77403	G				
52111	Scraper Drive, Thickener No. 1	J		N	Overload	77501	J	77601	K		
52112	Scraper Drive, Thickener No. 2	J		S	Overload	77502	J	77601	K		
53121	Sludge Storage Tank Air Compressor	K	O	N	Electrical Failure	77605	K				
55211	Lime Storage Bin	K	U		High Level	77602	K				
55212	Lime Storage Bin	K	L		Low Level	77603	K				

Table A-6 (Continued)

Operating Unit and Sensor					Alarm Condition	Alarm Indicators					
ID	Name	Area	Level	Loc		ID	Area	ID	Area	ID	Area
55641	Lime Slurry Tank	K	L		Low Level	77604	K				
61161	Incinerator No. 1	K	L	N	Shaft Stopped	77702	K				
61162	Incinerator No. 2	K	L	S	Shaft Stopped	77706	K				
65211	Flushing Water to Scrubber No. 1	K	U	N	Strainer Clogged	77704	K				
65212	Flushing Water to Scrubber No. 2	K	U	S	Strainer Clogged	77708	K				
66331	Ash Bin	K			Ash Bin Full	77709	K				
71851	Temp. Recorder, Incinerator No. 1	K	M	S	High Incinerator Temp.	77701	K				
71851	Temp. Recorder, Incinerator No. 1	K	M	S	High ID Fan Temp.	77703	K				
71852	Temp. Recorder, Incinerator No. 2	K	M	S	High Incinerator Temp.	77705	K				
71852	Temp. Recorder, Incinerator No. 2	K	M	S	High ID Fan Temp.	77707	K				
73211	Blower Building Boiler	E			Flame Failure	77316	E				
73212	Sludge Building Boiler	K			Flame Failure	77710	K	77315	E		
73213	Raw Wastewater Station Boiler	B	M		Flame Failure	77209	B	77315	E		
74111	Electrical Substation No. 1	B		O	Emergency Power On	77101	L	77210	B	77323	E
74111	Electrical Substation No. 1	B		O	Ground Fault	77211	B	77324	E		
74111	Electrical Substation No. 1	B		O	Emergency Power Failure	77212	B				
74112	Electrical Substation No. 2	K			Emergency Power On	77102	L	77325	E	77606	K
74112	Electrical Substation No. 2	K			Ground Fault	77326	E	77607	K		
74113	Electrical Substation No. 3	E			Emergency Power On	77103	L	77327	E		
74113	Electrical Substation No. 3	E			Ground Fault	77328	E				
74114	Electrical Substation No. 4	E			Emergency Power On	77104	L	77329	E		
74114	Electrical Substation No. 4	E			Ground Fault	77330	E				
77400	Alarm Systems	G			Power On	77404	G				
77600	Alarm Systems	K			Power On	77608	K				
78100	Raw Wastewater Pumping Station	B			Electrical Failure	77305	E				
78200	Primary Sludge Pumping Station	C			Electrical Failure	77306	E				
78500	Blower Air Intake Filter	E			Electrical Failure	77307	E				
78700	Chlorine Building	G			Electrical Failure	77308	E				
78900	Thickener Building	J			Electrical Failure	77309	E				
79100	Sludge Filtration	K	U	S	Electrical Failure	77310	E				
79500	Sludge Incineration	K	M	S	Electrical Failure	77311	E				

Table A-7. INCINERATION EQUIPMENT WHICH MAY NOT BE SHUT DOWN ARBITRARILY

ID Number	Equipment
6111	Incinerator mechanism
6112	Motor
6113	Drive
6115	Gear reducer
6116	Limit switch
6117	Control
6411	Cooling air fan
6412	Motor
6413	Control
6421	Turbo blower
6422	Motor
6423	Control
6511	Scrubber
6531	Exhaust ID fan
6532	Motor
6533	Control
6611	Ash bucket elevator
6612	Motor
6613	Drive
6614	Control
6621	Ash screw conveyor
6622	Motor
6623	Drive
6624	Control

Table A-8. MAINTENANCE PROCEDURES IN CATEGORY A*

MPS No.	Equipment	Maintenance
6111 D1	Incinerator mechanism	Check oil level
6111 M1	Incinerator mechanism	Lubricate master gear & pinion
6113 M1	Drive, incinerator mechanism	Lubricate disk, oiler, screw
6115 D1	Gear reducer, incinerator mechanism	Check oil level
6116 M1	Limit switch, incinerator mechanism	Check switch operation
6411 W1	Cooling air fan	Lubricate fan
6611 W1	Ash bucket elevator	Lubricate elevator
6613 W1	Drive, ash bucket elevator	Check oil level
6621 W1	Ash screw conveyor	Lubricate conveyor
6623 W1	Drive, ash screw conveyor	Check oil level

*These procedures are to be performed without shutting down the equipment.

Table A-9. MAINTENANCE PROCEDURES IN CATEGORY B*

MPS No.	Equipment	Maintenance
6111 Q1	Incinerator mechanism	Change oil, inspect & lubricate
6111 Q2	Incinerator mechanism	Inspect incinerator
6111 Q3	Incinerator mechanism	Inspect shear pin
6112 Q1	Motor, incinerator mechanism	Clean and perform electrical inspection
6112 S1	Motor, incinerator mechanism	Lubricate motor
6113 S1	Drive, incinerator mechanism	Adjust Hi & Lo speed stops
6115 S1	Gear reducer, incinerator mechanism	Change oil
6117 A1	Control, incinerator mechanism	Clean and inspect controller
6117 A2	Control. incinerator mechanism	Clean and inspect remote control switch
6411 Q1	Cooling air fan	Clean and inspect fan
6411 Q2	Cooling air fan	Inspect drive belt tension
6412 Q1	Motor, cooling air fan	Clean & perform electrical inspection
6412 Q2	Motor, cooling air fan	Lubricate motor
6413 A1	Control, cooling air fan	Clean and inspect controller
6413 A2	Control, cooling air fan	Clean & inspect remote control switch
6421 S1	Turbo blower	Clean and inspect blower
6422 Q1	Motor, turbo blower	Clean and perform electrical inspection
6422 S1	Motor, turbo blower	Lubricate motor
6423 Q1	Control, turbo blower	Check oil and gas interlocks
6423 A1	Control, turbo blower	Clean and inspect controller
6423 A2	Control, turbo blower	Clean and inspect remote control switch
6511 Q1	Scrubber	Clean and inspect scrubber
6531 Q1	Exhaust ID fan	Lubricate fan bearings
6531 Q2	Exhaust ID fan	Inspect drive belt tension
6531 S1	Exhaust ID fan	Clean and inspect fan
6531 S2	Exhaust ID fan	Inspect foundation bolt tightness
6532 Q1	Motor, exhaust ID fan	Clean and perform electrical inspection
6532 S1	Motor, exhaust ID fan	Lubricate motor

Table A-9 (Continued)

MPS No.	Equipment	Maintenance
6533 A1	Control, exhaust ID fan	Clean and inspect controller
6533 A2	Control, exhaust ID fan	Clean and inspect remote control switch
6611 A1	Ash bucket elevator	Clean and inspect elevator
6612 Q1	Motor, ash bucket elevator	Clean and perform electrical inspection
6612 Q2	Motor, ash bucket elevator	Lubricate motor
6612 S1	Motor, ash bucket elevator	Clean and inspect coupling
6613 S1	Dirve, ash bucket elevator	Change oil
6614 A1	Control, ash bucket elevator	Clean and inspect controller
6614 A2	Control, ash bucket elevator	Clean and inspect remote control switch
6622 Q1	Motor, ash screw conveyor	Clean and perform electrical inspection
6622 Q2	Motor, ash screw conveyor	Lubricate motor
6622 Q3	Motor, ash screw conveyor	Inspect drive belt tension
6623 S1	Drive, ash screw conveyor	Change oil
6624 A1	Control, ash screw conveyor	Clean and inspect controller
6624 A2	Control, ash screw conveyor	Clean and inspect remote control switch

*These procedures require the equipment to be taken out of service—they must be performed when the entire incinerator is shut down.

Table A-10. ESTIMATED AND ACTUAL TIME (Minutes) FOR PM ACTIONS

MP No.	Equipment	PM Action	Estimated Time	Range of Actual Time
1111 D1	Bar Screen	Lubricate Bar Screen	24	10-36
1111 D2	Bar Screen	Inspect Rake Assy. & Chain	48	5-20
1311 W1	Raw Wastewater Pump	Inspect Packing Gland Adjustment	12	4-10
1312 W1	Motor, Raw Wastewater Pump	Check Oil Level	6	4-10
2123 W1	Reduction Gear, Sludge Collector	Check Oil Level	12	10-20
2211 W1	Primary Sludge Pump	Inspect Packing Gland Adjustment	12	4-20
2211 W2	Primary Sludge Pump	Check Bearing Oil Level	12	4-10
2311 M1	Primary Scum Pump	Inspect Packing Gland Adjustment	12	5-20
2312 M1	Motor, Primary Scum Pump	Lubricate Motor Base Adjusting Screw	6	5-30
2312 Q1	Motor, Primary Scum Pump	Clean & Perform Electrical Inspection	18	20-36
3511 W1	Return Sludge Pump	Inspect Packing Gland Adjustment	12	4-20
3512 W2	Motor, Return Sludge Pump	Lubricate Motor Bearings	24	7-20
3512 A1	Motor, Return Sludge Pump	Lubriflush Varidrive Motor	30	20-36
3514 A1	Control, Return Sludge Pump	Clean & Inspect Controller	48	30
3514 A2	Control, Return Sludge Pump	Clean & Inspect Remote Control Switch	30	24-30
4342 Q1	Motor, Low Lift Pump	Clean & Perform Electrical Inspection	36	36
5221 D1	Sludge Plunger Pump	Check Sight Feed Oiler, Lube Pillow Block Bearings	12	3-10
5221 W1	Sludge Plunger Pump	Inspect Packing, Adjust Oiler, Lube Plunger Packing	36	5-30
5221 R1	Sludge Plunger Pump	Renew Packing	120	120
5221 M1	Sludge Plunger Pump	Inspect Valve Balls & Seats, Check Conn. Rod	36	5-30
5221 M2	Sludge Plunger Pump	Inspect Drive Belt Tension	18	5-40
5222 Q1	Motor, Sludge Plunger Pump	Clean & Perform Electrical Inspection	36	48
5222 S1	Motor, Sludge Plunger Pump	Lubricate Motor	18	5-15
5223 W1	Variable Reducer, Sludge Plunger Pump	Lube Varidrive Gear Motor, Cycle Handwheels	54	5-40
5224 W1	Gear Drive, Sludge Plunger Pump	Check Oil Level	12	5-20
5224 Q1	Gear Drive, Sludge Plunger Pump	Change Oil	30	15-60
5225 W1	Reduction Gear, Sludge Plunger Pump	Check Oil Level	12	5-20
5225 Q1	Reduction Gear, Sludge Plunger Pump	Change Oil	30	15-60
5226 A1	Control, Sludge Plunger Pump	Clean & Inspect Controller	48	30
5226 A2	Control, Sludge Plunger Pump	Clean & Inspect Remote Control Switch	30	24-30
5341 W1	Sludge Belt Conveyor	Clean Conveyor	60	40-540
5341 W2	Sludge Belt Conveyor	Lubricate Conveyor	42	10-40
5341 M1	Sludge Belt Conveyor	Inspect Conveyor, Check Chain Oil Level	36	10-30
5342 Q1	Motor, Sludge Belt Conveyor	Clean & Perform Electrical Inspection	36	36
5343 W1	Drive, Sludge Belt Conveyor	Check Oil Level	12	5-10

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4. Title A PLANNED MAINTENANCE MANAGEMENT SYSTEM FOR MUNICIPAL WASTEWATER TREATMENT PLANTS

5. Report Date April 1973

6.

8. Performing Organization Report No. FR 90060

7. Author(s) Sargent, Donald H., Rudich, David A.

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16. Abstract A Planned Maintenance Management System (PMMS) has been developed and successfully demonstrated at the 18-MGD Lower Potomac Plant of Fairfax County, Va., establishing a model maintenance management program for wastewater treatment plants throughout the United States.

This PMMS provides for the specific maintenance needs of each item of plant equipment and reduces the maintenance of complex equipment to simple procedures. For each procedure the PMMS details the methods, materials, tools and personnel required; schedules the task; and provides for data recording and feedback.

The success of this PMMS during the 12-month demonstration phase was measured by a steady downward trend in the malfunction of mechanical equipment. Incipient failures were detected in many cases and corrective action was taken to avoid breakdowns.

This report describes the PMMS in technical detail; discusses the installation of the PMMS, including acceptance by the mechanics and coordination with plant operations; and outlines the application of the PMMS to other wastewater systems.

This report was submitted to fulfill Project Number 11010 GWI by EnviroPlan, Inc., College Park, Maryland, under contract to the County of Fairfax, Virginia, under the sponsorship of the Environmental Protection Agency. Work was completed as of July 1973.

17a. Descriptors *Waste Water Treatment, *Maintenance, *Management, *Scheduling, *Manpower, Operation and Maintenance, Maintenance Costs, Equipment, Mechanical Equipment, Hydraulic Equipment, Electrical Equipment, Instrumentation, Warning Systems, Control Systems

17b. Identifiers

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