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OPERATION & MAINTENANCE MANUALS

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ABSTRACT

Technological and economical factors have created a trend toward operating larger and more complex power plants with fewer people. This trend is, therefore, making personnel ability an increasingly significant factor in overall plant performance. Operation and Maintenance (O&M) Manuals are a vital source of the information necessary to maintain and improve personnel ability. Therefore, a need exists for a well written set of integrated O&M Manuals.

This paper discusses some of the numerous reasons WHY there are O&M Manuals and WHAT a good set of O&M Manuals should include. A set of O&M Manuals cannot be a haphazardly thrown together document. The manuals require planning and thought. So, two other critical items in the development of manuals are addressed: WHO is writing them and WHEN should they be written. Another point of interest is WHERE are O&M Manuals headed in the future.

INTRODUCTION

Operation and Maintenance (O&M) Manuals have been around for quite awhile. They are supplied in the form of technical manuals with every piece of equipment from an abacus to a zymoscope. They come in a multitude of colors, sizes, and detail. They range in length from one page to several volumes. The titles of these manuals are as varied as the equipment. Some examples are: Service Manual, Technical Information, Instructions, Owners Manual, and Maintenance Instructions. Although they are vital to the successful performance of a power plant, the power plant manager and his O&M staff would be hard pressed to start up, let alone operate and maintain, a modern day power plant using the individual equipment technical manuals. Obviously, a need exists for integrated O&M Manuals. O&M Manuals that tie all of these individual technical manuals into one coherent package.

This paper is about developing these integrated O&M Manuals. Even though the importance of having O&M Manuals is generally recognized (there is inevitably a request for O&M Manuals in Bid Specifications), the amount of time O&M Manuals are even looked at depends entirely upon the personality of the user. Time and time again the cry goes up "Why do I have to use this book anyway? I have run this equipment so many times I could do it blindfolded. I am not going to use it because it will only slow me down and besides, you can see for yourself, it never gets used. Its covered with dust!" or "You don't need any operating procedures for this plant. It'll operate just fine all by itself. Just stop by occasionally an check to see if its still running." If this is indeed the prevailing attitude among owners, operators, and developers towards O&M Manuals, then why is there so much time and money spent on developing and updating the manuals? Why even have them at all?

WHY HAVE OPERATION AND MAINTENANCE MANUALS?

The successful operation of a power plant depends upon the ability of the O&M Staff to effectively utilize and maintain the equipment. Advances in technology have produced the ability to automate many of the functions formerly performed by operators. This automation combined with economic and practical considerations has created a trend toward operating larger and more complex power plants with fewer people. The impact of this trend on operability varies greatly with the plant's type, size and complexity. However, this "new" technology is creating a gap between the knowledge level of the O&M personnel and the knowledge level required to operate and maintain modern day power plants. Another aspect of the advances in design and technology is the variety of types of geothermal power plants; single flash, dual flash, binary, etc. The operational methods and the operating parameters for these plants can vary greatly. The combination of fewer personnel, the required increase in knowledge level, and the different operating characteristics has made personnel ability an increasingly significant factor in overall plant performance.

Source of Information

A major portion of personnel ability is knowledge. To improve personnel ability, the O&M Staff must be supplied with the information, procedures, and techniques necessary for proper job performance. The O&M Staff must be familiar with and comprehend the fundamentals of system interrelations, normal and abnormal plant conditions and the processes they are controlling and maintaining. These processes include the characteristics and behavior of power plant elements such as: steam, water, air, electricity, and non-condensable gases. The O&M Staff must understand the effects, and potential effects, that temperature, pressure, and flow have on safety, system operations and plant performance. They must also have knowledge which is specific to individual equipment layout and operation. This knowledge includes the physical location, configuration, and response of each display, control piece of equipment and safety device. Well written O&M Manuals supply this needed information and function as a very effective training tool for both new and experienced personnel.

Consolidation

The information contained in Vendor supplied technical manuals covers a large number of operating conditions and equipment combinations. A particular vendor technical manual may have three or four different operating procedures for the same piece of equipment depending on how it is to be used and what auxiliary components are on it. The O&M manual contains the operating procedure for the equipment layout as it applies to the plant. This procedure has been extracted from the Vendor technical manual and modified to fit the rest of the power plant conditions. This eliminates the time consuming procedure of jumping back an forth between pages.

Sequencing System

O&M Manuals provide for the sequencing of power plant procedures. This is true even for the "totally automated" plants. Valves have to be open or shut, equipment has to filled with water or oil, the computer has to be programmed, and somebody needs to push the start button. Another, critical aspect of power plants is that when they aren't running the owner doesn't make any money. If the computer should fail, O&M Manuals give all necessary procedures to manually operated the plant.

Now that the 'why' has been explored lets look at what constitutes an O&M Manual.

WHAT ARE OPERATION AND MAINTENANCE MANUALS?

The term O&M Manuals refers to a set of manuals containing all the information necessary to operate and maintain a power plant. This information is presented in different formats depending on the application required of a particular manual. For the purpose of clarity, this paper will address four different manuals; Plant Description Manual, Maintenance Manual, Operation Manual, and Technical Information Manual.

Plant Description Manual

The Plant Description manual is written in text format. The manual is broken down by chapters with appendices when required. Generally, the fist chapter is the general plant description and the succeeding chapters are system descriptions.

General Plant Description

The general plant description covers all of the unique information pertaining to the power plant such as location, flow rates, power output, and plant performance parameters. A simple description of each system is given to identify how each system interrelates with the other systems. An overall plant schematic shows all of the major components and systems and how they tie together.

System Descriptions

The system descriptions provide a complete functional description of each system. Each component, valve, and instrument is briefly discussed with regards to each item's physical characteristics and operation. The system controls are explained and the effects upon the system from the different plant operational modes are explained. The system schematics contain all the controls, valves, instruments, and components with their associated numbers. Any crossconnects or inter-ties with other systems are also shown on the system schematics. If a system schematic is too crowded to show component details, then component schematics can be placed in the appropriate chapter.

Maintenance Manual

Regardless of the maintenance system being used (books, cards, computerized), the mainte-

nance manual provides a structured guide to be used as a management tool for maintenance planning. This planning involves not only when to do the maintenance but also what spare parts to order and determining what extra personnel may be required.

Vendor supplied manuals cover the specific maintenance requirements for each piece of equipment. Therefore, the maintenance manual need not contain any detailed technical information on particular pieces of equipment, only when the maintenance should be done, what maintenance needs to be done, and provide references as to where detailed information can be found.

Depending upon the maintenance system, the Maintenance Manual may only exist in a computer and not as a manual. Different Maintenance Systems used different formats but the methodology is primarily the same. The following are examples of one type of system are used simply to demonstrate the planning capability of a well organized and integrated Maintenance Manual.

Scheduling

Maintenance Action Index: The Maintenance Action Index is a list of all the maintenance requirements extracted from vendor information and from experience for a particular piece of equipment.

Maintenance Action Guide: The Maintenance Action Guide refers to a specific maintenance action on a particular piece of equipment. The guide lists any special tools, safety precautions, and any related maintenance which can be accomplished simultaneously. The guide may have a procedure and required spare parts for the easier maintenance actions or provide references to the appropriate technical manuals for the more complex actions.

Yearly: The Yearly Maintenance Schedule is used to project the required maintenance for a full year and is derived from the information contained in the Maintenance Action Indexes and Maintenance Action Guides. This allows for scheduling maintenance based on the projected operational requirements. The schedule is divided into months and covers annual, simi-annual, quarterly, and situation requirement maintenance.

Monthly: The Monthly Maintenance Schedule is divided into days (1-31) and covers only one month at a time. The maintenance requirements on this schedule correspond to the associated month on Yearly Maintenance Schedule.

Weekly: The Weekly Maintenance Schedule is divided into days of the week and covers only one week at a time. The maintenance requirements on this schedule correspond to appropriate seven days on the Monthly Maintenance Schedule and any additional weekly and daily requirements.

Parts List Index

The Parts List Index is a detailed list of vendor technical manuals with their associated parts list page numbers.

Equipment Specification Sheets

This section is an appendix to the Maintenance Manual and is used as a master library of all the equipment specification sheets

Operation Manual

An operators memory greatly impacts his ability to carry out his duties effectively. An experienced operator can perform routine operations without any difficulty. However, this same operator may experience startup, shutdown, or an emergency situation on vary rare occasions. Yet he is expected to handle all situations in the safest and most efficient manner. The Operation manual gives all the proper steps required to startup, shutdown and operate under normal and emergency conditions.

The Operation Manual contains the integrated procedures for the operation of the power plant. These procedures include the following:

Plant Startup

The plant start-up procedure contains the sequential steps to take the power plant from "cold iron" to putting electricity on the grid. This procedure ensures that all the different systems, compressed air, vacuum, auxiliary cooling water, etc. have been aligned for operation. Whether the plant is manually or automatically started, this procedure will guide the operator through the startup sequence. The operator can then monitor the key setpoints and parameters which indicate a successful start-up. If something goes wrong with the start-up the procedure tells the operator what actions to take.

Normal Operating Evolutions

This section of the Operation Manual will contain all the procedures which apply to the

plant while it is running. These procedures inform the operator on how to due evolutions such as: shift running equipment, crossconnet systems, conduct blowdowns, and take oil and water samples.

Normal Plant Shutdown

The plant shut down procedure contains the sequential steps to take the power plant from putting electricity on the grid to "cold iron". This procedure ensures that the turbine generator has the proper cool down time prior to stopping the other running equipment. This procedure also contains the proper shut down valve line ups for all the different auxiliary systems.

Alarms

The alarms procedures inform the operator what to do when an alarm sounds. The operator should know what immediate action to take. This procedure supplies the operator with the supplemental and alternative actions needed to correct the problem.

Automatic Shut Downs

The automatic shut down procedures inform the operator what to do when the plant suffers ann automatic shut down. The operator should know what immediate action to take to place the plant in a "safe" condition. This procedure supplies the operator with the supplemental and alternative actions needed to safely complete the shut down and to investigate the problem.

Technical Information Manual

This manual is the collection of all the vendor information. The information is placed in alphabetical order by manufacturer. Some of the information such as the turbine books do not lend them selves to additional binding and should be left as stand alone manuals.

Because these manuals change in format, the use of names and terminology should be consistent. If something is called "Number 1 Liquid Ring Vacuum Pump Suction Valve" on page 1 then it should be called "Number 1 Liquid Ring Vacuum Pump Suction Valve" throughout all the manuals. Of course, it would be simpler to give the valve a number (V-123) and refer to the number throughout the manuals. This technique will allow for easy transition between different procedures and manuals. Another aspect of prime importance is the use of good indexes and the emphasizing of safety precautions through out the manuals.

Indexes

Indexes show the user the organization of the manuals and the relative location of the different parts, such as descriptive information, operating procedures, maintenance procedures and emergency procedures. The manuals should be straightforward, so that the indexing is not too complex. They should also be easy to use. If the information cannot be found without a great deal of searching, the user may stop using the manual. An index also gives the user an overview of the manual. If there is more than one volume, then the user can quickly determine which is the proper volume.

One of the better forms of indexing is accomplished through the use of a table of contents and tabs.

Table of Contents

The Table of Contents located in the front of the manual is basically an outline of the manual. There should be a list containing the number, title and page number for each of the following: chapters and subheadings, tables, drawings, figures, and appendices.

For multi volume manuals, each volume should contain a copy of the complete Table of Contents. This will enable the user to find the location of the desired information without having to refer to Volume 1.

Tabs

Tabs allow the user to get to the desired section quickly and easily. Tabs should be labeled with the chapter title/number or appendix title/letter. A good practice to follow, when tabs are also used to identify subheadings, tables, or drawings, is to make the chapter tabs a different color then the subheading tabs. This helps the user wade through a potential forest of tabs.

Safety Precautions

Any practices, procedures, and conditions which could lead to injury or equipment damage, should be brought to the user's attention. This is easily accomplished through the use of Safety

Precautions. Safety Precautions can be general or specific and pertain to people or equipment.

General Safety Precautions

General Safety Precautions are applicable at any time during a procedure. They should be observed prior to a particular operation or maintenance procedure. Therefore, they are located at the beginning of the associated chapter or section.

Example:

To ensure safe operation of turbine, do not operate with a protective function disabled.

Specific Safety Precautions

Specific Safety Precautions are applicable to a particular procedural step and appear within the procedures as Warnings, Cautions or Notes. To be the most effective, Warnings, Cautions and Notes should be short and placed just before and used as many times as the procedural step to which they apply.

Warnings: Warnings are precautionary measures which apply to ensure the safety of all personnel involved. Failure to observe these warnings could result in personnel injury or loss of life.

Example:

WARNING

Prior to performing maintenance procedures when the plant is shut down, ensure that controls are tagged to prevent inadvertent energizing of system, that pressures are relieved, that electrical power is removed, and that parts have cooled.

Cautions: Cautions are generally precautionary measures which apply to ensuring the safety of equipment involved. They are to provide a basis for minimizing equipment downtime. Failure to observe these cautions could result in damage to or destruction of equipment.

Example:

CAUTION

When changing controller setpoint (indicated by green bar on display) do not allow the setpoint to exceed upper limit of safe operating range (indicated by yellow bar on display).

Notes: Notes provide additional information which may be required to clarify an operation. Failure to observe these notes could result in confusion and improper operator actions.

Example:

NOTE

An acknowledged alarm is indicated by a sold arrowhead next to the alarm's name. A new alarm is indicted by a flashing arrowhead next to the alarm's name. Do not press Alarm Acknowledge key until alarm display is completely on the monitor or 'new' and 'old' alarms cannot be distinguished.

Consistency

The gathering, sorting, and writing of all the various pieces of information required for the O&M Manuals is not a simple task. So our next question is, who should write these manuals?

WHO SHOULD WRITE THE OPERATION AND MAINTENANCE MANUALS?

The maintenance procedures supplied by the vendors vary from none to fairly complete. So some or all of the maintenance for a particular piece of equipment may have to be based on experience. This is especially true in situations where the vendors recommended maintenance is " as operating conditions or experience dictate".

The operating procedures supplied by the vendors are generally going to require some major overhaul. The primary reason for this is that

the equipment operating procedures are written as if the piece of equipment is the center of the world. Plus the vendor's procedures are generic in nature and cover similar but yet different model variations. This is understandable since a piece of equipment can be used in a variety of situations. For example: Liquid Ring Vacuum Pump procedures cover pumps/compressors with; closed or open seal water systems; automatic or manual make up water systems; and motor or turbine drives.

The individual responsible for integrating the Liquid Ring Vacuum Pump procedure into the overall plant O&M procedures needs to determine which variation applies to the project. This is true for all the major components, control valves, and instrumentation. Therefore, the O&M Manuals should be written by experienced individuals who have a good overall knowledge of equipment operation and power plant system interrelations.

The various components of the O&M Manuals can be very time consuming in their development. So when should these manuals be written?

WHEN SHOULD THE OPERATION AND MAINTENANCE MANUALS BE WRITTEN?

The O&M Manuals writing should begin as early in the design development phase as possible. This helps to lessen the last minute panic over manual development. The ability to start writing the manuals hinges directly on three items; the equipment selection, receipt of vendor information, and drawing completion. A good place to start the writing is after the clients acceptance of the 35% design submittal.

Individual operating procedures can be written and maintenance requirements can be established for each component as the information becomes available. When the majority of the vendor information is received and the drawings are approaching completion, then the O&M procedures become more integrated.

The development of these procedures provides a good means of design review, especially from the operability and maintainability stand point. If it doesn't work on paper then it surely isn't going to work in reality.

Example:

> The air compressors are required to run when the power plant is shut down to supply service air for the pneumatic tools. Obviously, the air compressors will require cooling water. The design calls for the Auxiliary Cooling Water System to use the Circulating Water System for the source of water. Let's further suppose that the plant is shut down to conduct cooling tower maintenance and the tower is drained. Since the Circulating Water System is the motive force for water through the cooling tower, it is also shutdown. Therefore, the air compressors do not have any cooling water. Do the air compressors have an alternate source of water? If so, then a procedure has to be written to cover this evolution. If not, then an alternate source of water must be added to the design.

Unfortunately, just because it does work on paper doesn't guarantee that it will work in reality. So the O&M manuals will require modifications right through the start-up phase, and even at this point the writing is not over. Numerous changes will take place in equipment and operational procedures throughout the life of the plant. These changes will occur for a multitude of foreseen and unforeseen reasons. In order to keep a viable set of O&M manuals, they will require updating on a continuous basis.

WHERE ARE OPERATION AND MAINTENANCE MANUALS HEADED?

Power plants are becoming more automated and the role of the O&M Staff is becoming that of a caretaker. The equipment is becoming more reliable and easier to maintain. However, as the sophistication of the equipment increases so does the knowledge required to operate and maintain it. The need for instant access to this knowledge is becoming a critical aspect of day to day operation, especially when something goes wrong. O&M Manuals in the form of books may give way to computerization, but they will continue to be a vital part of power plant O&M.

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