FEMP'S O&M Best Practices Guide A Guide to Achieving *Operational Efficiency*

Gregory P. Sullivan, PE, CEM
Aldo P. Melendez
Ray Pugh
(Pacific Northwest National Laboratory[1])

ABSTRACT

The Federal Energy Management Program's (FEMP's) Operations and Maintenance Best Practices Guide (O&M BPG) highlights O&M programs targeting energy efficiency, which are estimated to save 5 percent to 20 percent on energy bills without a significant capital investment. Depending on the federal site, these savings can represent thousands to hundreds of thousands of dollars each year, and many can be achieved with minimal cash outlays. In addition to energy/resource savings, a well-run O&M program will:

- Increase the safety of all staff because properly maintained equipment is safer equipment.
- Ensure the comfort, health, and safety of building occupants through properly functioning equipment, providing a healthy indoor environment.
- Confirm the design life expectancy of equipment is achieved.
- Facilitate compliance with federal legislation such as the *Clean Air Act* and the *Clean Water Act*.

[1]Pacific Northwest National Laboratory is operated for the U.S. Department of Energy by Battelle Memorial Institute under contract DE-AC06-76RL01830.

The focus of this guide is to provide the federal O&M/energy manager and practitioner with information and actions aimed at achieving these savings and benefits. The O&M BPG was developed under the direction of the Department of Energy's Federal Energy Management Program.

GUIDE DESIGN AND LAYOUT

This guide is intended to be a "living document," that is, one that is amended as things change. For this reason, a three-ring binder format was selected. In addition, the three-ring binder will provide storage room for newsletters, seminar announcements, and other supplementary information you may wish to include. Eventually, a web-based version is anticipated.

The guide currently consists of nine chapters. Chapter 1 provides an introduction and an overview. Chapter 2 provides the rationale for "Why O&M?" Chapter 3 discusses O&M management issues and their importance. Chapter 4 examines computerized maintenance management systems (CMMS) and their role in an effective O&M program. Chapter 5 looks at the different types of maintenance programs and definitions. Chapter 6 focuses on maintenance technologies, particularly the most accepted predictive technologies. Chapter 7 explores O&M procedures for the predominant equipment found at most federal facilities. Chapter 8 describes some of the promising O&M technologies and tools on the horizon to increase O&M efficiency, and Chapter 9 provides 10 steps to initiating an *operational efficiency* program.

The O&M environment is in a constant state of evolution, and the technologies and vocabularies are ever-expanding. Therefore, the guide contains a glossary of terms in Appendix A. Appendix B provides a list of federal contacts for training and assistance. Appendix C includes a list of organizations and trade groups that have interest or are related to O&M. And finally, Appendix D is a form that can be used to submit suggestions or revisions to the guide.

The goal of this article is to provide an overview of the O&M BPG, how and why it was developed, and present in highlight form some of its sections. Each highlighted section will be referenced in parentheses in this article's section title.

INTRODUCTION (O&M BPG Chapter 1)

Effective O&M is one of the most cost-effective methods for ensuring reliability, safety, and energy efficiency. Inadequate maintenance of energy using systems is a major cause of energy waste in both the federal government and the private sector. Energy losses from steam, water and air leaks, uninsulated lines, maladjusted or inoperable controls, and other losses from poor maintenance are often considerable. Good maintenance practices can generate substantial energy savings and should be considered a resource. Moreover, improvements to facility maintenance programs can often be accomplished immediately and at a relatively low cost.

The purpose of the O&M Best Practices Guide (O&M BPG) is to provide the operation and maintenance/energy manager and practitioner with useful information about O&M management, technologies, and cost-reduction approaches. To make this guide useful and to reflect the facility manager's needs and concerns, the authors met with O&M and energy managers via Federal Energy Management Program (FEMP) workshops. In addition, the authors conducted extensive literature searches and contacted numerous vendors and industry experts. The information and case studies that appear in the guide resulted from these activities.

It needs to be stated at the outset that the guide is designed to provide information on effective O&M as it applies to systems and equipment typically found at federal facilities. The guide ***is not*** designed to provide the reader with step-by-step procedures for performing O&M on any specific piece of equipment. Rather, the guide first directs the user to the manufacturer's specifications and recommendations. In no way should the recommendations in the guide be used in place of manufacturer's recommendations. The recommendations in the guide are designed to supplement those of the manufacturer, or, as is all too often the case, provide guidance for systems and equipment for which all technical documentation has been lost.

DEFINITIONS (Chapter 2)

Operations and Maintenance: Decisions and actions regarding the control and upkeep of property and equipment inclusive but not limited to the following: actions focused on scheduling, procedures, and work/systems control and optimization, and performance of routine, preventive, predictive, scheduled and unscheduled actions aimed at preventing equipment failure or decline with the goal of increasing efficiency, reliability, and safety.

Operational Efficiency represents the life cycle cost-effective mix of preventive, predictive, and reliability centered maintenance technologies, coupled with equipment calibration, tracking, and computerized maintenance management capabilities, all targeting reliability, safety, occupant comfort, and system efficiency.

O&M POTENTIAL, ENERGY SAVINGS, AND BEYOND (Chapter 2)

It has been estimated that O&M programs targeting energy efficiency can save between 5 percent and 20 percent on energy bills without a significant capital investment [1]. From small to large sites, these savings can represent thousands to hundreds of thousands of dollars each year, and many can be achieved with minimal cash outlays. Beyond the potential for significant cost and energy/resource savings, an O&M program operating at its peak "operational efficiency" has other important implications:

- A well-functioning O&M program is a safe O&M program. Equipment is maintained properly, mitigating any potential hazard arising from deferred maintenance.

- In most federal buildings, the O&M staff are responsible for not only the comfort, but also the health and safety of the occupants. Indoor air quality (IAQ) issues within these buildings are of increasing productivity (and legal) concern. Proper O&M reduces the risks associated with development of dangerous and costly IAQ situations.

- Properly performed O&M helps ensure that the design life expectancy of equipment can be achieved, and in some cases, exceeded. Conversely, the costs associated with early equipment failure are usually not budgeted for, and often come at the expense of other planned activities.

- An effective O&M program aids in a facility's compliance with federal legislation, such as the *Clean Air Act* and the *Clean Water Act*.

- A well functioning O&M program is not always reactive (answering complaints); rather, it is proactive in its response, and corrects situations before they become problems. This model minimizes callbacks and keeps occupants satisfied while allowing more time for scheduled maintenance.

O&M MANAGEMENT (Chapter 3)

O&M management is a critical component of the overall program. The management function should bind the distinct parts of the program into a cohesive entity. From our experience, the overall program should contain five very distinct functions making up the organization [2]: **O**perations, **M**aintenance, **E**ngineering, **T**raining, and **A**dministration—OMETA.

Beyond establishing and facilitating the OMETA links, O&M managers have the responsibility of interfacing with other department managers and making their case against ever-shrinking budgets. Their roles also include project implementation functions, as well as the need to maintain the program and its goals.

Developing the Structure (Chapter 3)

Five well-defined elements of an effective O&M program include those presented above in the OMETA concept [2]. While these elements (operations, maintenance, engineering, training, and administration) form the basis for a solid O&M organization, the key lies in the well-defined functions each brings and the linkages between organizations. A subset of the roles and responsibilities for each of the elements is presented in the guide; further information is found in Meador [2].

Obtain Management Support (Chapter 3)

Federal O&M managers need to obtain full support from their management structure to carry out an effective maintenance program. A good way to start is by establishing a written maintenance plan and obtaining upper management approval. Such a management-supported program is very important because it allows necessary activities to be scheduled with the same priority as other management actions. Approaching O&M by equating it with increased productivity, energy efficiency, safety, and customer satisfaction are ways to gain management attention and support.

Measuring the Quality of Your O&M Program (Chapter 3)

Traditional thinking in the O&M field focused on a single metric, reliability, for program evaluation. Every O&M manager wants a reliable facility; however, this metric alone is not enough to evaluate or build a successful O&M program.

Beyond reliability, O&M managers need to be responsible for controlling costs, evaluating and implementing new technologies, tracking and reporting on health and safety issues, and expanding their program. To support these activities, the O&M manager must be aware of various indicators that can be used to measure the quality or effectiveness of the O&M program. Not only are these metrics useful in assessing effectiveness, but they are also useful in the justification of costs for equipment purchases, program modifications, and staff hiring.

Below are a number of metrics that can be used to evaluate an O&M program. Not all of these metrics can be used in all situations; however, a program should use as many metrics as possible to better define deficiencies and, most importantly, publicize successes. The O&M BPG describes each of these metrics in detail.

- capacity factor
- work orders generated/closed
- backlog of corrective maintenance
- safety record
- energy use
- inventory
- overtime worked
- environmental record
- absentee rate
- staff turnover.

Selling O&M to Management (Chapter 3)

To successfully interest management in O&M activities, O&M managers need to be fluent in the language spoken by management.

Projects and proposals brought forth to management need to stand on their own merits and be competitive with other funding requests. While evaluation criteria may differ, generally some level of economic criteria will be used. O&M managers need to have a working knowledge of economic metrics such as:

- ***Simple payback*—**The ratio of total installed cost to first-year savings.
- ***Return on investment*—**The ratio of the income or savings generated to the overall investment.
- ***Net present value*—**The present worth of future cash flows minus the initial cost of the project.
- ***Life-cycle cost*—**The present worth of all costs associated with a project.

Program Implementation (Chapter 3)

Developing or enhancing an O&M program requires patience and persistence. Guidelines for initiating a new O&M program will vary by agency and management situation; however, some steps to consider are presented below:

- ***Start small*—**Choose a project that is manageable and can be completed in a short period of time, 6 months to 1 year.
- ***Select troubled equipment*—**Choose a project that has visibility because of a problematic history.
- ***Minimize risk*—**Choose a project that will provide immediate and positive results. This project needs to be successful, and therefore, the risk of failure should be minimal.
- ***Keep accurate records*—**This project needs to stand on its own merits. Accurate, if not conservative, records are critical to compare before and after results.
- ***Tout the success*—**When you are successful, this needs to be shared

with those involved and with management. Consider developing a "wall of accomplishment" and locate it in a place where management will take notice.

- ***Build off this success***—Generate the success, acknowledge those involved, publicize it, and then request more money/time/resources for the next project.

O&M Contracting (Chapter 3)

Approximately 40 percent of all non-residential buildings contract maintenance service for heating, ventilation, and air conditioning (HVAC) equipment [3]. Discussions with federal building managers and organizations indicate this value is significantly higher in the federal sector, and the trend is toward increased reliance on contracted services. The O&M BPG explores this trend further and offers guidance on O&M contracting.

COMPUTERIZED MAINTENANCE MANAGEMENT SYSTEMS (Chapter 4)

A computerized maintenance management system (CMMS) is a type of management software that performs functions in support of management and tracking of O&M activities. CMMS systems automate most of the logistical functions performed by maintenance staff and management. CMMS systems come with many options and have many advantages over manual maintenance tracking systems. The O&M BPG presents the major capabilities, benefits, and potential pitfalls of CMMS.

TYPES OF MAINTENANCE PROGRAMS (Chapter 5)

What is maintenance and why is it performed? Past and current maintenance practices in both the private and government sectors would imply that maintenance is the actions associated with equipment repair after it is broken. The dictionary defines maintenance as follows: "The work of keeping something in proper condition; upkeep." This would imply that maintenance is actions taken to prevent a device or component from failing or to repair normal equipment degradation experienced with the operation of the device to keep it in proper working order. Unfortunately, data obtained in many studies over the past decade indicate that most private and government facilities do not expend the necessary resources to maintain equipment in proper working order. Rather, they wait for equipment failure to occur and then take whatever actions are necessary to repair or replace the equipment. Nothing lasts forever, and all equipment has some predefined life expectancy or operational life. For example, equipment may be designed to operate at full design load for 5,000 hours and may be designed to go through 15,000 start and stop cycles.

The design life of most equipment requires periodic maintenance. Belts need adjustment, alignment needs to be maintained, proper lubrication on rotating equipment is required, and so on. In some cases, certain components need replacement (e.g., a wheel bearing on a motor vehicle) to ensure the main piece of equipment (in this case a car) lasts for its design life. Anytime maintenance activities intended by the equipment's designer are not performed, we shorten the operating life of the equipment. But what options do we have? Over the last 30 years, different approaches to how maintenance can be performed to ensure equipment reaches or exceeds its design life have been developed in the United States. In addition to waiting for a piece of equipment to fail (reactive maintenance), we can utilize preventive maintenance, predictive maintenance, or reliability centered maintenance.

The O&M BPG provides a detailed description of each major maintenance program type (reactive, preventive, predictive, and reliability centered), including each program's advantages and disadvantages.

PREDICTIVE MAINTENANCE TECHNOLOGIES (Chapter 6)

Predictive maintenance attempts to detect the onset of a degradation mechanism with the goal of correcting that degradation prior to significant deterioration in the component or equipment.

The diagnostic capabilities of predictive maintenance technologies have increased in recent years with advances in sensor technologies. These advances, breakthroughs in component sensitivities, size reductions, and most importantly, costs have opened up an entirely new area of diagnostics to the O&M practitioner.

As with the introduction of any new technology, proper application and ***TRAINING*** is of critical importance. This is particularly true in the field of predictive maintenance technology, which has become increasingly sophisticated and technology driven. Most industry experts would agree (as well as most reputable equipment vendors) that this equipment should not be purchased for in-house use if there is not a serious commitment to proper implementation, operator training, and equipment upkeep. If such a commitment cannot be made, a site is well advised to seek other methods of program implementation—a preferable option may be to contract for these services with an outside vendor and rely on their equipment and expertise.

Chapter 6 presents a detailed description and applications for predictive technologies including: thermography, oil analysis, ultrasonic analysis, vibration analysis, motor analysis, and performance trending.

O&M IDEAS FOR MAJOR EQUIPMENT TYPES (Chapter 7)

At the heart of all O&M lies the equipment. Across the federal sector, this equipment varies greatly in age, size, type, model, fuel used, condition, etc. While it is well beyond the scope of this guide to study all equipment types, we tried to focus our efforts on the more common types prevalent in the federal sector. The objectives of this chapter in the guide are:

- Present general equipment descriptions and operating principles for the major equipment types.
- Discuss the key maintenance components of that equipment.
- Highlight important safety issues.
- Point out cost and efficiency issues.
- Provide recommended general O&M activities in the form of checklists.
- Where possible, provide case studies.

The major equipment types covered in Chapter 7 include boilers, steam traps, chillers, cooling towers, energy management/building automation systems, pumps, fans, motors, air compressors, and lighting. At the end of each section in Chapter 7, a checklist of suggested O&M activities is provided. These checklists are not presented to replace activities specifically recommended by equipment vendors or manufacturers. In most cases, these checklists represent industry standard best practices for the given equipment. They are presented here to supplement existing O&M procedures, or to serve as reminders of activities that should be taking place.

O&M FRONTIERS (Chapter 8)

As old a topic as O&M is, there are a number of new technologies and tools targeting the increased efficiency of O&M. As with most new technology introduction, these tools are in various stages of commercialization; for up-to-date information on each tool, contact information is provided. This chapter serves to highlight some of the more promising technologies targeting improved O&M and efficiency.

TEN STEPS TO *OPERATIONAL EFFICIENCY* (Chapter 9)

As defined, operational efficiency is the life cycle cost-effective mix of preventive, predictive, and reliability-centered maintenance technologies, coupled with equipment calibration, tracking, and computerized maintenance management capabilities, all targeting reliability, safety, occupant comfort, and system efficiency. Chapter 9 presents 10 simple steps to begin the path toward improved O&M and ultimately *operational efficiency.*

APPENDICES

Four appendices are provided in the O&M BPG. These are: Appendix A, a glossary of common terms; Appendix B, the FEMP staff contact list; Appendix C, a variety of O&M resources including relevant trade organizations and web sites; and Appendix D, a form to submit offering suggestions for the next version of the O&M BPG.

CONCLUSIONS

As FEMP starts up its O&M program, the O&M BPG will provide valuable guidance to federal building managers, O&M program managers, and building operations staffs. This guidance provides a starting point for establishing clear objectives and understanding benefits. It also can be used to: 1) establish an effective long-range plan that involves all O&M related staff functions, 2) measure existing program performance, 3) review and upgrade existing practices, and 4) plan for the future. This guide will ultimately assist federal building managers in realizing significant cost-effective energy savings and improved occupant satisfaction.

For More Information

To obtain information on the FEMP Operations and Maintenance Best Practices Guide visit the FEMP home page at http://www.eren.doe.gov/femp/

References

1. PECI. 1999. *Operations and Maintenance Assessments*. Prepared by Portland Energy Conservation, Inc. for the U.S. Environmental Protection Agency and U.S. Department of Energy, Washington, D.C.
2. Meador, RJ. 1995. "*Maintaining the Solution to Operations and Maintenance Efficiency Improvement*." World Energy Engineering Congress, Atlanta, Georgia.
3. PECI. 1997. *Energy Management Systems: A Practical Guide*. Portland Energy Conservation, Inc., Portland, Oregon.

ABOUT THE AUTHORS

Greg Sullivan is a senior research engineer with Pacific Northwest National Laboratory (PNNL). His research interests include resource efficiency, operations and maintenance, end-use metering, and technology evaluation. He received his Bachelor of Science in physics from the University of Oregon, Bachelor of Science in mechanical engineering from Oregon State University, and Masters of Science in building engineering from the Massachusetts Institute of Technology. Greg is a registered Professional Engineer in the state of Washington and a Certified

Energy Manager.

Ray Pugh is a senior development engineer for Pacific Northwest National Laboratory and has been involved in facility operations and maintenance for over 27 years. His early career was spent aboard a U.S. Navy fast attack submarine as a reactor operator. During this time, Mr. Pugh was involved in operation and maintenance of steam and electrical plant equipment and components. After his Navy tour, Mr. Pugh work at a 4000 MW_t DOE-owned nuclear plant in Washington State, where he wore various hats involved with directing facility operations and maintenance activities. Since his reactor-associated days, Mr. Pugh has worked at the Pacific Northwest National Laboratory, where his job duties required certification as a licensing examiner for the Nuclear Regulatory Commission on Westinghouse and combustion engineering reactor plant designs. In addition, Mr. Pugh has been involved in a program aimed at increasing the safety of Russian nuclear facilities through the transfer of predictive maintenance technologies

Aldo Melendez is a research engineer with the Pacific Northwest National Laboratory. His research interests include energy efficiency and energy technologies, health and risk analysis, and mechanical behavior of materials. He received his Bachelor of Science in engineering and Masters of Science in mechanical engineering from the University of Akron (Ohio). Aldo is a former Submarine Nuclear Propulsion Plant Supervisor/Operator in the U.S. Navy.