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NO MAINTENANCE - NO ENERGY EFFICIENCY

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## No Maintenance -- No Energy Efficiency

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### ABSTRACT

Field investigations illustrate that it is not realistic to expect new high-tech equipment to function for a full life expectancy at high efficiency without significant operations and maintenance (O&M). A simple walk-through inspection of most buildings reveals extensive equipment that is being operated on manual override, is incorrectly adjusted and operating inefficiently, or is simply inoperative. This point is illustrated with two examples at Robins Air Force Base, Georgia. The first describes development of a comprehensive, base-wide, steam trap maintenance program. The second describes a measured evaluation from a typical office building. The objective of both examples was to assess the importance of proper O&M. The proposed "O&M First" philosophy will result in more efficient building HVAC operation, provide improved services to the building occupants, and reduce energy consumption and unscheduled equipment repair/replacement. Implementation of a comprehensive O&M program will result in a 15-25% energy savings. The O&M foundation that is established will allow other energy conservation activities, such as demand side management or energy management and control systems, to achieve and maintain their expected energy savings.

### INTRODUCTION

Most Federal facilities have consistently focused on equipment upgrades as the source of energy conservation measures (ECMs), with an explicitly stated avoidance of changes to the operations and maintenance (O&M) process. High-tech equipment examples range from large computer-controlled energy management and control systems to small daylighting and occupancy controllers. Although the O&M process is known to be faulty, it is considered a separate issue that does not directly impact the calculated benefits of high-tech, high-efficiency, high-

cost equipment. Many new high-tech ECMs are expected to reduce overall O&M requirements. But basic O&M usually requires some training for new skills, which is not routinely included with the ECM purchase.

There is a long history of neglected operations and maintenance at Federal facilities. Examples discussed in [1] include equipment that is being operated on manual override, incorrectly adjusted, operating inefficiently, or is simply inoperative; widespread steam leaks; faulty or inoperative building control systems; and failed or damaged HVAC equipment. Although most of the O&M problems are obvious and the repair relatively simple for an experienced maintenance professional, it is clear that the local staff have not been able to fully address the problems. Some of the reasons are:

- Insufficient staffing for O&M procedures. The limited staff and funding resources are often directed toward quick fixes of the worst problems, with preventive maintenance receiving a low priority. This often results in more serious breakdowns and problems later which lead to more expensive repair or replacement of the existing equipment.
- Poorly trained and inexperienced staff. Staff at military bases are often young or inexperienced due to high turnover rates, experienced staff retirement, and frequent transfers between locations and job assignments. The result is limited opportunity for staff training or the assignment of specific equipment responsibilities.
- Inaccurate or broken monitoring and diagnostic equipment. The true operating state and the cause of problems is hidden behind incomplete or inaccurate information from diagnostic equipment.

- Missing, inaccurate, or incomplete documentation on existing equipment. It is very difficult to operate a facility without complete knowledge of the installed equipment, the equipment controls, and any special operating characteristics.
- Inadequate funding. Base facilities receive very low funding priority. The base facilities are not directly part of the mission, so "extra" funds are rarely directed toward facility improvements.
- No utility metering. With no significant utility submetering of facilities, there is no means to assess performance in terms of energy or maintenance costs and no means to establish appropriate incentives to lower those costs.
- Poor morale among O&M staff—for all of the above reasons.

The results of neglected O&M are increased fuel costs due to reduced operating efficiency, increased major maintenance, and increased capital costs due to shortened equipment life.

#### **"O&M FIRST" PHILOSOPHY**

The "O&M First" philosophy states that: 1) O&M improvement should be the first energy conservation measure evaluated, 2) the people responsible for O&M, not equipment, are key to success, and 3) new equipment must be appropriate for the O&M environment in which they will have to operate. The objectives of improved O&M is minimization of long-term operating costs and development of the solid foundation necessary for ECMs to achieve and maintain their expected energy savings. The expected benefits include:

- Increased energy conservation, both short-term and long-term, by improving facility energy efficiency,
- Reduction in call-backs to the facility, keeping occupants satisfied and allowing more time for scheduled maintenance,
- Less down time and unscheduled maintenance,
- Reduced capital costs for replacing equipment that failed prematurely,
- Realization of predicted savings from other energy conservation activities.

A unique aspect of this philosophy is concentration on optimization of the "as designed" existing facilities. O&M is the first energy conservation measure—not new equipment. Field investigations have shown that most facility designs are basically sound, but either were not built as designed or do not operate as designed due to relatively minor equipment or control problems. The process of correcting problems which can impact the efficiency of new ECM projects is necessary, though not sufficient, to assure success of the ECM. In addition, the simple repairs, along with some minor re-design and equipment replacement, are expected to result in a 15-25% energy savings before implementation of the ECM.

It is clear that base O&M staff need assistance. Providing outside assistance to correct poorly operating or in-operative equipment will result in some short-term benefit, but does not address the root cause of the problem. Since the O&M neglect that caused the original equipment fault is not changed, failure of the repaired or new replacement equipment will likely be repeated.

Another unique aspect of this philosophy is that the people of the O&M staff are the key. Efficient facility operation and fault detection can be improved using high-tech automation, such as Energy Management and Control Systems (EMCS). However, the people of the O&M staff are responsible for both the facility and the EMCS. The EMCS, just like all other equipment, has to be understood by the O&M staff to be effective and will eventually require human interaction for maintenance. An EMCS is not useful if controls are bypassed, inoperable, or if systems are not maintained. The success or failure of all facility equipment ultimately rests on the training, experience, and motivation of the people of the O&M staff.

Equipment and controls must be appropriate for the O&M environment in which they will have to operate. Experience has shown that the installation of state-of-the-art, high-tech, sophisticated (usually electronic) controls generally have not provided the expected results. A simple, less effective but more easily understood, control system will often provide more net long-term benefit.

Expected energy savings from various energy conservation programs are listed in Table 1. (Note that because of interactions between programs, you can not simply add the expected energy savings from all active programs to calculate the total energy savings at a facility.) The magnitude of the energy savings expected from an O&M improvement program is as large as that for most high-tech equipment retrofits. Typically the expected savings values are calculated assuming that the existing O&M

program is capable of operating and maintaining the new energy conservation retrofits. Based on experience, appropriate O&M programs do not exist and the long-term benefits of the energy conservation programs are significantly less than expected.

Table 1. Range of expected energy savings from Energy Conservation Measures (ECMs).

Energy Conservation Measure	Energy Savings
Demand-Side Management Projects	20-30%
Energy Conscious Design of New Facilities	20-30%
Family Housing Self-Help and Incentives	15-25%
Other Energy Conservation Retrofits	5-15%
Energy Awareness and Incentive Programs	5-10%
Energy Management and Control Systems (EMCS)	10-20%
Operation and Maintenance Improvement Program	15-25%

**ROBINS AIR FORCE BASE**

Robins Air Force Base, Georgia, requested that Pacific Northwest Laboratory (PNL) assess the state of existing O&M activities and the value of an improved O&M program at the base. The results are illustrated with two examples. The first describes an attempt to develop of a comprehensive, base-wide, steam trap maintenance program. The second describes measured results from an office building in which an energy efficiency upgrade of the heating, ventilating, and air-conditioning (HVAC) system replaced the old, high maintenance, conventional pneumatic controls with a new, high-tech, digital control system. While the objective of the ECMs was to reduce facility operation costs by correcting existing faulty equipment and improving O&M procedures, the objective of this study was to assess the importance of developing a comprehensive O&M program.

Robins AFB is an 8,790-acre Air Force Materiel Command facility at Warner-Robins in central Georgia. The daytime population on the base averaged 19,920 in FY 1990. On-base housing supports 5,329 military personnel and dependents, with the remainder living in nearby off base towns. There are 646 commercial, industrial, and command buildings with a total floor area of 11.6M ft<sup>2</sup>.

The majority of the energy use is electricity and natural gas. There are two major and four minor central thermal loops. Three of the minor plants are located adjacent to the few buildings they serve, The remainder service a variety of buildings through approximately 9 miles of buried pipeline for steam and 0.74 miles of pipeline for chilled water.

The central Georgia climate zone has hot and humid summers and mild winters. Heating degree-days, based on a 65°F balance point, average 2,244 degree-days/yr, and cooling degree days, also based on a 65°F balance point, average 2,276 degree-days/yr.

**STEAM TRAP MAINTENANCE PROGRAM**

The central energy plants supply steam to numerous buildings and laboratories on base for space heating, reheating, and process loads. For many buildings, steam is supplied throughout the year. Leaking steam traps in the steam supply system represent a direct and significant utility cost. In addition, leaking or plugged steam traps cause numerous system problems, including excessive wear on pressure reducing valve orifices, condensate backup in coils, water hammer, coil freezing, reduction in equipment operating efficiency, excessive condensate return line pressures and temperatures, and loss of condensate. The problems add additional costs for inefficient use of energy and repair or replacement of damaged equipment.

For the 5,000 steam traps throughout Robins AFB, maintenance is done primarily on an emergency-call basis. The exception is a scheduled annual mass replacement of steam traps in the distribution system and some selected areas--without testing and regardless of operating status. Consequently, many steam traps that are leaking or plugged continue to operate throughout the base and many good steam traps are replaced. The energy and equipment-related costs of the traps can be reduced or eliminated through a proper steam trap inspection and maintenance program.

PNL conducted the following four-step project to support development of a comprehensive steam trap testing and maintenance program.

- 1) Worked with the Civil Engineering staff to design a program tailored to their O&M staff.
- 2) Conducted classroom and field training including, hands-on live-steam testing of traps both on a test stand and in the field, for operational and failed steam traps.
- 3) Developed a steam trap documentation program which included tagging, data base, and maintenance scheduling.
- 4) Conducted an evaluation of the cost savings that could be achieved with the steam trap maintenance program.

Successful establishment of this program would provide Robins AFB with steam trap testing equipment, trained staff, and the maintenance program necessary for effective long-term impact on steam trap performance.

#### Test Equipment

A variety of ultrasound acoustic and temperature sensing tools can be used to help identify faulty steam trap operation. Trained and experienced personnel can successfully combine their knowledge of steam trap type and operating principles with an interpretation of the sound and temperature to determine fault modes. However, that diagnostic capability is beyond personnel that work on steam traps only part time. The test equipment sought for this program was an experienced and automated steam trap diagnostician-in-a-box.

The TrapMan, manufactured by TLV, is such a state-of-the-art computerized steam trap diagnostic and management system. The TrapMan system includes a portable hand-held test instrument that measures the operating temperature and ultrasound acoustic signal of an in-service steam trap and provides an on the spot automated diagnosis of steam trap functionality. This instrument is pre-programmed to diagnosis all generic types and most common steam trap models including TLV, Armstrong, Yarway, Spirax, Sarco, Gestra, Dunham Bush, Hoffman, Trane, and Illinois. The TrapMan system also includes a computer application software package and interface which allows field test data to be down-loaded and stored in a maintenance data base. The software serves as the maintenance log for a steam trap testing program, and provides graphical displays of survey results and failure analysis. PNL supplied two TrapMan systems for the proposed Robins AFB steam trap maintenance program.

#### Training Class

Dr. Thomas Burch of the Boiler Efficiency Institute (BEI) in Auburn, Alabama, was contracted to assist with

the classroom and field training. The BEI conducts numerous energy-related training sessions each year for DOE facilities across the country, and their expertise in steam systems and location in nearby Auburn made them an ideal resource for this project. BEI staff have a unique ability to provide both detailed technical information and real world experience at a level that talks to, not down to, typical O&M staff.

An agenda tailored to Robins AFB requirements and staff availability was developed in coordination with the base energy coordinator and BEI. Part of this agenda was a week-long training session which was targeted for the base heat shop maintenance supervisors and operation and maintenance personnel. The training included classroom work, a trap testing demonstration using a live-steam test stand, and field testing of in-service steam traps at the base.

The classroom portion of the program lasted the first one and one-half days and focused on how steam traps operate, types of steam traps that are used, steam trap failure modes, the pros and cons of various testing techniques, and setting up an effective steam trap testing and maintenance program. To complement the verbal discussion, each participant was given a manual on steam distribution and condensate systems [2].

A half day was spent at a steam trap test stand that was set up at the main central energy plant to demonstrate a variety of steam traps types and testing techniques using temperature and acoustic test methods. Class members were able to get hands-on experience in using these testing techniques on the test stand steam traps under a variety of condensate loadings. The test stand allowed the participants to use the various instruments while observing the discharge from the traps to get a feel for the effectiveness of each method. The TrapMan was just one of the set of testing instruments on which the class received training. Activities for the second day were concluded with practice testing of steam traps in two nearby buildings.

The third and fourth day were devoted to field testing steam traps in two buildings. However, each of these days began in the classroom to review activities from the previous day and to answer any questions. During the testing, the class was divided into two groups, each with a TrapMan and other traditional temperature and acoustic test equipment. Steam traps that were tested were numbered and tagged for later reference. At the conclusion of each day's testing, class members met with PNL staff in the Civil Engineering office to download test data stored in the TrapMan to an IBM compatible personal computer. Three of the more experienced

computer users in the class were shown how to operate the software to download data and develop a maintenance data base.

The last half day was a short session to summarize the training and present the final results of the steam trap testing that the class had completed during days 2-4. The 10-15 individuals who had been able to attend the class for the entire week were initially somewhat skeptical about the value of the steam trap training, testing, and high-tech TrapMan diagnostic equipment. However, at the end of the training the participants felt like they had genuinely learned something, had successfully operated and now embraced the value of the TrapMan (to the exclusion of traditional methods), and were enthusiastic about setting up an steam trap maintenance program.

#### Steam Trap Testing Results

A total of 90 operating steam traps were tested by the students during two and one-half days of hands-on training in two buildings. Of these, 23 steam traps were identified as not in service. One of the buildings was typical of most buildings on base, whereas the second had been refitted with all new steam traps less than 2 years previously. Therefore, the sample of steam traps tested should include fewer failed traps than the general population. The TrapMan analysis identified 15% as low temperature (e.g., failed closed) and 3% as leaking, for a total failure rate of 18% (see Figure 1). Of particular importance is the backed up condensate related to the low temperature steam traps (15%) which can cause failure of other steam system components.

As an example of the significance of problems related to low temperature steam traps, in one of the buildings a failed drip-leg steam trap in a high-pressure line to a pressure-reducing valve (PRV) station was observed. The PRV had been replaced within the past year. The steam trap was 25 years old and had been allowing damaging condensate to flow through the PRV station for an unknown amount of time. There were no records to indicate how many times the PRV had been replaced over the 25 year period. A properly operating steam trap, costing \$100, could have prevented the repeated replacement of a \$1,000 PRV.

#### Comprehensive Maintenance Program

The status quo (no change) steam trap replacement policy and the impact on secondary equipment failures costs Robins AFB an estimated \$1,101K/yr. These costs are compared to the first- and second-year costs for a proposed aggressive new comprehensive O&M program in Table 2. Current prices for replacement traps, labor, and secondary equipment damage and the labor to replace this equipment are based on Civil Engineering data. These costs reflect a constant level of support for the program, and show anticipated cost savings from reductions in secondary equipment failure. Savings of \$35K is expected the first year of the program because of the costs to correct previous years of neglected maintenance. Subsequent savings are \$550K per year. Cost savings from more efficient use of steam services are anticipated and will add to the expected annual savings.

Table 2. Impact of comprehensive steam trap O&M program at Robins AFB.

Activity	Status Quo, Annual Cost	Proposed New O&M Program, Annual Costs	
		1st Year	2nd Year
Comprehensive O&M Program	N/A	\$170K	\$170K
Replacement Traps: Equipment Labor	\$80K \$55K	\$80K	\$80K
Secondary Failures: Equipment Labor	\$425K \$450K	\$350K \$375K	\$100K \$110K
Net Steam Trap O&M Cost	\$1,101K	\$975K	\$460K

A regular testing program would allow base personnel to develop familiarity with the types of steam traps used at Robins AFB. These personnel would become aware of which types of traps work best for a given application and which types fail frequently. Computerized record-keeping would allow automated identification of problem traps and areas. Some failures could be related to the brand of trap used or to system design problems at a given location. The experience gained from such a regimented program would allow informed purchases of replacement steam traps and system redesign justification. Also, inspection and identification of the failure mode of traps could point to additional system problems (i.e. if failure is due to residue buildup or wear). The training, software, and test instruments supplied to Robins AFB by PNL were designed for just such a program.

#### Post Training Analysis

As of January 1993, steam was still blowing out of a man hole cover in the street in front of the office of the Colonel responsible for establishing O&M priorities. This evidence was typical of the state of steam trap maintenance throughout Robins AFB. To date there is no evidence that any steam trap testing and maintenance program will be implemented at Robins AFB. In the mean time, maintenance staff levels have been cut since the training class was conducted and there is little attention given to any preventive maintenance activities.

The fact that PNL provided the O&M staff the required diagnostic equipment, software for automated maintenance management, training and genuine enthusiasm for participating in such a preventative maintenance program was not sufficient for development of a base wide steam trap maintenance program. All levels of management must buy into the concept, and they did not do so. In retrospect, perhaps what the program needs most is someone from Civil Engineering to be its champion. That person should be given the authority to set up the program and supervise personnel devoted to doing the testing, database management, and trap replacement. The concept remains very attractive because a comprehensive steam trap maintenance program would save Robins AFB \$550K a year.

#### TYPICAL OFFICE BUILDING

Building 300 at Robins AFB is a brick structure that was built in the mid 1940's as a warehouse and later modified for use as office space. This type of renovated office space is typical of buildings at Robins AFB and of office space throughout U.S. military installations. The total floor area is 475,000 ft<sup>2</sup>, separated into 11 bays. Bays B and C, which are adjacent to each other on the east wing

of the "U" shaped building, were monitored in the study. The floor areas are approximately 45,000 ft<sup>2</sup> each. Each bay is divided down the center by a corridor into an east and a west half. There is a 300 ft<sup>2</sup> war contingency room in the east half of Bay C that is cooled with a dedicated package air conditioner, independent of the rest of the bay. Each half of each bay is configured as one large open-floor-plan office space, with a mean occupancy of approximately 500 people.

The east and west zones in each bay are conditioned by air handling units (AHU) located in the building's attic space. Each AHU is a single zone design which channels conditioning air first through a heating coil, then a cooling coil. Heating is provided by steam from a central steam plant. Cooling is provided by chilled water from the same plant. In operation, the air temperature in each half of each building bay is controlled by a single thermostat located in the return air duct of the air handler for that zone. Each thermostat provides a single pneumatic control signal which is used to modulate both the heating and the cooling valves on that zone's air handling unit. The thermostats are set between 74°F and 75°F to maintain inside comfort conditions.

An HVAC control system upgrade from pneumatic to a Johnson Controls Cybertronics electronic controls with a pneumatic actuator interface was installed in 1987. The upgrade retained use of the original pneumatic actuators for steam and chilled water valves control. New electro-hydraulic actuators were installed for air damper control. The controls system for each office bay featured an economizer cycle and time clock control of nighttime HVAC system shutdown. A manual override allowed occupant activation of HVAC operation during off hours.

A site inspection in October 1992 revealed that the electric actuators necessary to control the outdoor air dampers were broken, the time clocks were disabled, and many of the electronic controls had been removed. A simple pneumatic control system, similar to the system used before the 1987 upgrade, was controlling the HVAC system. The reasons given for removal of the controls were excessive moisture in the electro-pneumatic system, calibration problems with the electric to pneumatic transducers, and poor quality electro-hydraulic actuators.

Building 300 provides an example of building control systems that have failed because of lack of an effective O&M program. The magnitude of energy wasted due to ineffective maintenance of the building HVAC systems and controls was determined through a combination of walk-through audits and detailed monitoring.



### Observed O&M Problems

The following list of O&M problems were identified during the initial walk-through audits performed in March 1992. Investigation of all the other bays in this building confirmed that the listed observations are typical for all of building 300.

- All automatic damper actuators disconnected. All dampers manually set to a fixed position with clamps and wire, rendering air economizers inoperative.
- Electronic control system were disabled because of failed or missing components, or just turned off.
- Time clocks for nighttime HVAC shutdown disabled.
- The temperature measured for the chilled water supply to the building is 42°F, but the chilled water supply to the air handlers was 47°F. The cause is chilled water return back mixing into the chilled water supply line through a bad bypass valve.
- Leaks in the main supply ducts and access panels, allowing unconditioned air into the air handling units.
- Return air damper in closed position in bay C, East AHU and fully open on the West AHU.
- Outdoor air dampers were in closed position on 3 out of 4 air handler units in bay B and C. The 4th was in the minimum position setting. This results in low ventilation air for these building bays.
- The 15 ton (175,700 Btu/hr) package air conditioner serving the war contingency room ran with electric resistance reheat 24-hours a day because of a inappropriate relative humidity requirement.

### Test Procedure

The building electrical energy use was monitored from July 1992 through August 1993. Initial monitoring of thermal energy began in March 1993 and continued through August 1993. Data was recorded using two model C180 loggers, manufactured by Synergistics Control Systems. The C180 is capable of measuring 16 channels of real power, apparent power, and power factor as well as recording 16 digital and 15 analog channels. A one hour integration period was selected for recording of all time series records (TSRs). All electric power and analog channels were recorded as averages. The digital channels were recorded as an accumulated count of all pulses during the integration period. The data stored in the C180 logger's RAM memory were automatically

downloaded to a computer at PNL via telephone modem on a daily basis.

One C180 logger was installed in the HVAC mechanical space above each bay. Each logger recorded the total three phase power and total steam and chilled water energy supplied to its respective bay. Additional detail in monitoring of bay B included the total three phase fan power for the supply and return fans on each AHU, supply, return, and mixed air temperatures for each AHU, and economizer/outside air temperature.

### Building Energy Use

Monitoring was necessary to quantify the current energy use of building 300 because there was no submetering. The monitored data was used to develop simple regression models of the buildings energy use as a function of outdoor air temperature. These models allowed estimation of the building energy use under conditions beyond those observed during the period of study. Monitoring also allowed identification of system operation problems not immediately apparent with visual inspections or spot measurements (using handheld diagnostic equipment) of the system.

Analysis of the metered data showed that the buildings heating and cooling usage is predominantly a function of outdoor air temperature. Typical operation included chilled water for cooling that is left on all year long and steam heat that is turned off in the spring and turned back on in late fall. The heating schedule is determined by the weather. The steam is turned off after there have been 10 consecutive days with daily minimum temperatures above 50 degrees. The steam is turned back on in the fall when requested by the building occupants. This energy use strategy was reflected in our calculations.

Monitoring revealed two additional operating problems not observed in the walk-through audits. These problems were coincident heating and cooling in the HVAC system and faulty operation of the building time clocks. A detailed discussion of these problems and their energy impacts are provided below.

### Coincident Heating and Cooling

Monitoring in bays B and C showed times of coincident heating and cooling during the months of March and April, 1993. This is illustrated for bay B in Figure 2. This problem was reported to Robins AFB staff. The steam flow to that AHU was manually shut off on April 10, 1993 as a solution to the problem. Coincident heating and cooling continued in bay C. Monitoring showed that

the steam flow in bay C was constant between April 10 and May 10. This steam usage is likely due to leaking steam valves in bay C. The steam was shut off for all of the building on May 10, 1993. The leaking steam valves were not scheduled for repair.

The likely source of the coincident heating and cooling in bay B was overlapping valve activation control air pressure ranges. The pneumatic control signal for the heating and cooling valves in bay B comes from a single thermostat. The steam valve is closed at control air pressures below 9 PSI. Air pressures between 9 and 13 PSI modulate the valve from full closed to full open. The chilled water valve is set normally open at zero air pressure and modulates to fully closed at 8 PSI.

A steam valve design which allows steam pressure to force open the steam valve results in a control response that is sensitive to steam supply pressure. When the steam supply pressure is too high, there is an overlap between the steam and chilled water control air pressure ranges, resulting in both valves being partially open and coincident heating and cooling. In an attempt to overcome this difficulty, adapters had been installed on the control air lines to the steam valve to reduce the control air pressure. This corrected the problem for certain steam pressure conditions but not others, and can only be considered a partial solution.

By examining hours of coincidental heating and cooling it was possible to estimate the savings due to fixing both the steam control problem in bay B and the leaking steam valve in bay C. The amount of excess heating energy is approximately equal to the lower value of heating or cooling energy usage for all coincidental hours (see Figure 2). This assumes that both heating and cooling are not required during a one-hour time period. It should be noted that for any hour for which there is excess heating there is an extra, equal amount of cooling energy needed to offset the excess amount. Coincidental heating and cooling has a double energy penalty.

Table 3 shows the annual amount of coincident heating and cooling that would occur in bays B and C. Estimated values were calculated by multiplying the average amount of coincident heating and cooling that occurred during the monitored time period by the number of days in which steam is supplied to the building. High internal heat gains and the mild climate result in cooling requirements throughout most of the year. Examination of Typical Mean Year weather data and discussions with site staff suggested that the steam would typically be supplied to the building between November 15 and May 15, resulting in a total of 181 days. The estimate of whole building impact, 1,229 MBtu/yr, is based on

observations that indicate that the AHUs in bays B and C are representative of all the AHUs in building 300.

Table 3. Estimated annual energy waste due to coincident heating and cooling in building 300.

Building Area: Type of Problem	Coincident Heating & Cooling MBtu/yr
Bay B: Overlap of Control Air Pressure Ranges	696
Bay C: Leaking Steam Valve	533
<b>Building 300 Total</b>	<b>1,229</b>

#### Time Clock Operation

Air handlers in all building bays were equipped with time clocks which could turn on and off the AHU fans at specified times of the day. The steam and chilled water valves remained active to prevent potential coil freezing. These time clocks are not capable of separate weekday and weekend schedules. All of the time clocks in the building had been disabled for at least a year prior to the beginning of the monitoring period in July 1992. In February 1993, PNL encouraged maintenance personnel to re-connect and activate the time clocks. Only one time clock, in bay B west, was activated. Monitoring showed that the time setting on the clock was shifted by 12 hours (AM instead of PM), resulting in an HVAC system that was off during the day and on at night. After Robins AFB staff were informed of this problem in early March 1993, the time clocks were turned off.

In July 1993 PNL requested that the time clocks be activated again (with correct time settings) to allow measurement of their effect on building energy consumption. Difficulties in getting the time clocks to function correctly postponed the start of this period of time clock operation until Aug 12, 1993. In bay C, one time clock broke on August 25 and was not repaired or replaced by the O&M staff. The period from August 12 till August 24 represents the only available period of proper time clock operation for that bay. Monitoring of the system in bay B showed proper time clock operation through September 7.

The time clocks in both bays were set to turn on the HVAC systems between 5:00 AM and 6:00 PM, seven days a week. Measurement of HVAC fan operation verified that the HVAC system was off 46% of the time. Figure 3 shows the thermal energy use for a typical day with and without time clock control. The energy use during time clock control and 24-hour-a-day operation was compared during similar outdoor temperatures (between 81.6°F and 83.1°F).

The estimated daily energy use and savings, presented as an average of bays B and C, are presented in Table 4. The average savings are 32% thermal and 43% electric. The chilled water savings for the separate bays varied from 24% for bay B to 41% for bay C. The lower savings for bay B is due to a 29% higher daytime cooling load, with no difference in nighttime cooling load, compared to bay C. The higher daytime cooling load in bay B was due to a higher staff and equipment loading. The magnitude of the energy savings due to HVAC time clock control will vary with outside air temperature, with the largest savings during the hottest days.

Table 4. Energy savings with HVAC time clock control, presented as an average of bays B and C.

Time Clock Status & Operating Hours	Chilled Water Btu/day	HVAC Fan kWh/Day
Without Time Clock: 24 hr/day	14.0M	355
With Time Clock: 13 hr/day	9.5M	204
Energy Savings	32%	43%

The time clocks were not properly activated during the heating season, preventing the measurements necessary to analyze the energy impact. However, the percent electric savings for the AHU fan will remain 43%, and the steam savings are expected to be similar to that calculated for the cooling season.

## CONCLUSIONS

Although an "O&M First" philosophy was embraced by a few Civil Engineering staff who understood the long-term value, it was not promoted by Robins AFB facilities management. The reasons include the fact that facilities management is consumed by mission related activities (e.g., new or remodeled building design and construction oversight to support mission activities), and the top military management have base facility responsibilities for only a few years before being re-assigned. Despite federal legislation that requires an energy usage reduction to 80% of the 1985 baseline by the year 2000, energy conservation is not a high priority. Preventing the high cost of future facility and equipment failures is not a high priority because the cost comes from a facilities, not mission, budget and it will probably occur after those responsible have moved to another assignment. Experience with other military and federal installations shows that Robins AFB is typical, not the exception.

The proposed steam trap program was not implemented because of facility management resistance. The O&M staff were provided the necessary diagnostic equipment, trained on steam trap operating fundamentals and operation of the diagnostic equipment, and were enthusiastic to start. Management was briefed on the cost savings potential of implementing a comprehensive steam trap maintenance program, and were offered continued support under the existing funded project. The opportunity cost of not having an "O&M First" philosophy is \$550K/yr.

The upgraded electronic control system in building 300 was not cost effective because it operated less than one year before being abandoned. A coordinated effort between the different O&M shops could have prevented the original problems. Known problems, including the coincident heating and cooling, and time clock operation should be corrected as an interim solution. The electronic control systems are now in such bad condition and have so many missing components that repair is not feasible. A new system will have to be designed, purchased, and installed. The cost of not having an "O&M First" philosophy is the premature replacement of all the HVAC controls (approximately \$200K), excess energy use (approximately \$50K/yr), and an uncomfortable office space. The resulting reduced office productivity does affect the mission.

The existing O&M program is continuously doing emergency repairs and complaint management, instead of preventative maintenance. These examples at Robins AFB illustrate the value of a comprehensive O&M program. Switching to an "O&M First" philosophy could

produce a 15-25% energy savings and a larger reduction in replacement of prematurely failed equipment.

#### ACKNOWLEDGMENTS

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#### REFERENCES

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- [2] USACERL 1990, Special Report E-90/03, Volume X, January 1990.

FIGURE 1

### Steam Trap Testing Results Robins AFB, Buildings 640 & 645, August 12-13, 1992

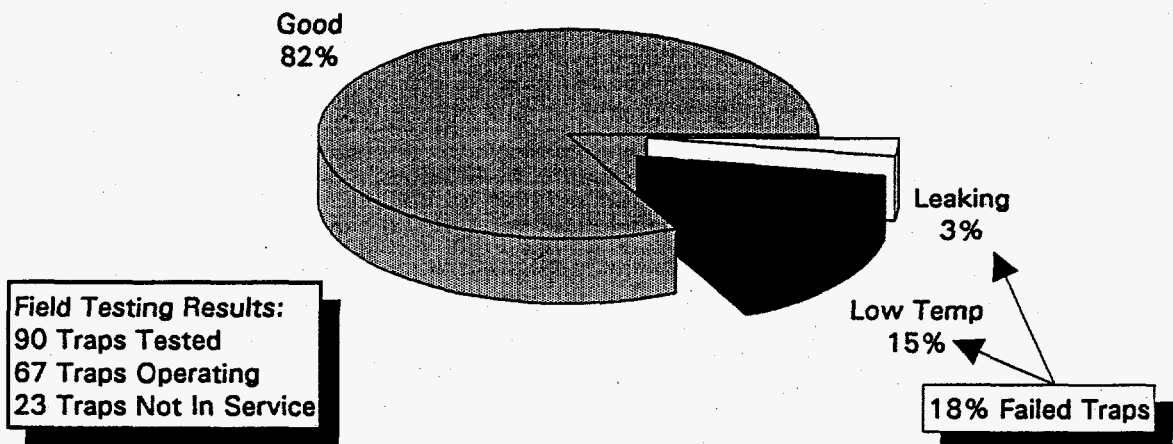


FIGURE 2

Coincidental Heating and Cooling  
Robins AFB, Building 300, Bay B

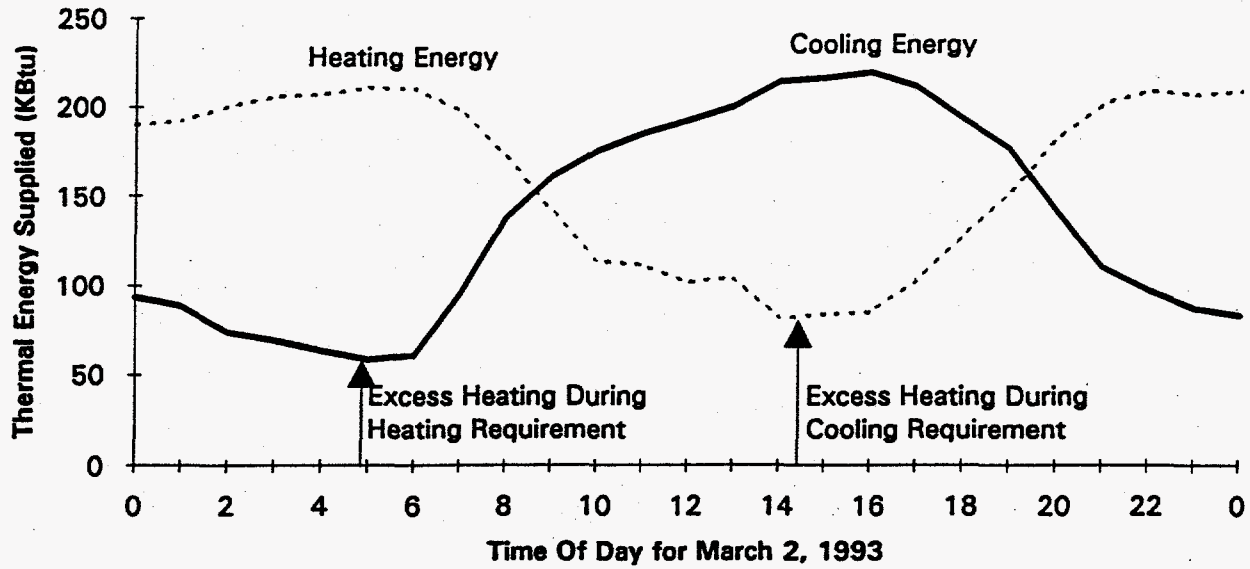


FIGURE 3

Impact Of Time Clock Operation On Cooling Energy  
Robins AFB, Building 300, Bay B

