A TEN-STEP PROGRAM FOR CLEAN, EFFICIENT INSTITUTIONAL STEAM PRODUCTION

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INTRODUCTION

Increasingly, institutional managers face fiscal challenges posed by aging mechanical systems, budget and staff reductions, and deteriorating maintenance. Facility engineers are often overburdened with multiple tasks, especially as engineering knowledge and manpower are lost through staff reductions. Steam systems, which are crucial to many institutional operations, often suffer from poor maintenance. These systems work harder and longer to compensate for lost efficiency. Resources are drained when more fuel inputs are demanded to compensate for efficiency losses. Also, combustion emissions rise with needless fuel consumption. Related issues include poor or uneven distribution of space heating within a building, typically evident when building occupants open windows in the middle of winter. When fuel expenditures become excessive, then program budgets are impacted and overall institutional effectiveness suffers. The situation is compounded by management plans that necessarily prioritize core programs over "support" functions like facility maintenance.

At the same time, public concern with global warming and resource management are impacting policy arenas and all sectors of the economy. The demand for "green" or environmentally friendly operating practices affects even public sector purchasing and contracting requirements. This is best evidenced in the White House's June 1999 Executive Order (E.O. 13123) that set management and accountability measures for implementing energy efficient systems and practices in federal facilities. As state and local legislatures embrace similar mandates for schools, hospitals, airports, and other institutional facilities in their jurisdictions, it is clear that the cumulative demand for effective energy efficiency practices can grow exponentially.

An example of localized demand for clean, efficient school environments is currently being played out in the state of New York. The Healthy Schools Network, Inc. (HSN) is a statewide organization of parents, environment, education, and public health groups dedicated to ensuring healthy school environments. That organization is encouraging the state to enact a "healthy school environments" bill designed to improve school air quality, improve school energy efficiency; reduce school pesticide use; and provide guidelines on school nontoxic supply purchasing.[1]

Increasingly, constituents demand environmentally safe and efficient use of energy in

[1] The Healthy Schools Network, *Neglected Buildings, Damaged Health: A 'Snapshot' of New York City Public School Environmental Conditions.* http://www.hsnet.org/getinvolved3.htm#report

their communities. Legislators are seeking meaningful and demonstrable ways to lead by example. Steam systems are a convenient place to start: steam is a common, pervasive, well-established technology that accounts for large volumes of energy consumption. The implementation of steam efficiency in local institutional settings allows community leaders to confidently demonstrate their support for energy efficiency. These very same efficiency applications can also serve as models to commercial and industrial operators in surrounding communities.

BACKGROUND

Institutions commonly rely on large mechanical (central plant) facilities for space conditioning, water heating, cooking and other housekeeping services. Data published by the Energy Information Administration describes the scope of institutional energy use.[2] Over 12,790 institutional sites (representing over 200,000 buildings) are served by central plant facilities—67 percent of which produce steam. The major energy consumers by volume in the institutional sector are education and health care. A large proportion of these structures (32% of all education, 70% of colleges and universities, 56% of hospitals) are arranged in multi-building facilities with a central plant for steam and related mechanical operations. Central plant energy requirements on multibuilding facilities represent annual energy consumption of 1.6 quadrillion Btu. That total, which is 28% of all commercial building energy usage, and 55% of all multibuilding facility usage, is equivalent to the aggregate energy demand of just over 14 million homes.

Schools and hospitals with central plant facilities consumed just over one quadrillion Btu in 1989. This consumption equates to six percent of all energy received by residential and commercial end-users in that year. A more telling statistic is that these central plants are on average 55 to 64 percent efficient in converting Btu inputs into useable heat. Additional losses occur in distribution from the central plant to buildings across the facilities.

WHAT TO EXPECT FROM STEAM EFFICIENCY

A primary reference on energy efficiency estimates the percentage loss (or alternatively, potential *gain*) in efficiency attributable to different aspects of system operations. This information is summarized in Table 1.

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[2] U.S. Department of Energy, Energy Information Administration. *Energy Consumption Series. Assessment of Energy in Multibuilding Facilities*, various pages.

TABLE 1: Boiler Plant Energy Losses

Energy Requirement/Loss	*Percent Increase in Plant Energy*	*Most Improvement Possible in:*
Unnecessary operation of equipment	0 to 200%	Facilities with non-continuous operations
Improper air-fuel ratio	0 to 20%	All boilers
Burner operation	0 to 1%	Large, heavy oil-burners
Forced draft and induced draft fans	0 to 0.7%	Large fans
Stand-by losses	0 to 10%	Atmospheric burners
Flue losses due to fouling	0.1 to 10%	All boilers
Flue losses due to inadequate heat transfer surface	0 to 40%	Old, cheap, & overdriven boilers
Flue losses due to unrecovered latent heat of water in flue gas	2 to 10%	Boilers with high blow-down rates
Condensate loss	0 to 10%	Facilities with old or missing condensate systems
Condensate system operation	0 to 0.2%	Systems with large pumps
Defective vacuum condensate system	0 to 50%	Vacuum condensate systems
Fuel oil heating	0 to 0.5%	Heavy oil burners
Fuel oil transfer	0 to 0.1%	Odd cases
Steam/hot water loss	0 to 50%	Old, large underground distribution systems
Steam trap leakage	0 to 20%	All systems with steam traps
Combustion air leakage	0 to 0.1%	Boilers with separate fans
Boiler plan radiation & conductive loss	0.3 to 4%	Medium-sized and older plants
Distribution system conduction loss	0.5 to 30%	Old distribution systems in damp soil

SOURCE: *Energy Efficiency Manual*, by D.R. Wulfinghoff, © 1999. Energy Institute Press, Wheaton, MD. Page 18. Reprinted with permission.

A series of steam efficiency case studies were presented in one seminal article.[3] The article was intended to illustrate the value of applying professional energy conservation standards as promulgated by the American Society of Heating, Refrigeration, and Air-Conditioning Engineers (ASHRAE). ASHRAE's institutional standard is straightforward:

> A preventative maintenance program should be established for each piece of equipment to ensure that it is properly maintained for maximum efficiency. This maintenance program should include written schedules for… boilers… heat exchangers… steam traps… strainers, insulation… heating specialties, piping, valves….[4]

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[3] Deacon, Walter T., January 1999. *Successful Steam System Operation Strategies*. ASHRAE Transactions: Symposia.

[4] ASHRAE, 1991. ANSI/ASHRAE Standard 100.5-1991. *Energy conservation in existing buildings—Institutional*. Atlanta: American Society of Heating, Refrigeration, and Air-Conditioning Engineers, Inc.

Application of the ASHRAE standard facilitates the attainment of optimal steam system operations. The results from several institutional-setting applications, presented in the Deacon article, are summarized here.

A 1,000-bed Ontario hospital. This facility used to purchase steam from the local utility and district steam system. A system survey identified leaks and misapplied steam fittings. A standardization program sought opportunities to reduce the number and variety of hardware fittings. The survey also established a metric that described heat consumption per bed, which permitted the quantitative monitoring, analysis, an improvement potential of energy consumption. The energy monitoring, plus the simplified inventory and maintenance attributable to hardware standardization, permitted the facility to save $305,000 ($U.S.). (Note: this is presumably an annual savings total; that is not clarified in the source material.)

An Illinois hospital. This moderate-sized facility consumed steam at a rate of 63,000 lbs./hr. The plant performed a system survey. The response addressed freeze-up and humidification problems while also replacing failed steam traps. The facility achieved an annual savings of $32,000 thanks to these efforts.

A university medical school. This facility consumed 203 million lbs./yr. of steam from a district heating system. Their efficiency effort began with a system survey and a one-time overhaul performed by an outside contractor. To preserve these improvements over subsequent seasons, a maintenance training program was implemented. The staff constructed their own steam hardware wagons for easily transporting replacement parts, fittings, and diagnostic tools throughout the facility. This combined effort of consultants and staff ingenuity netted the facility an annual savings of $300,000.

A Michigan hotel/office complex. This site consumed steam at a rate of 300,000 lbs./hr. A system survey permitted managers to construct a comprehensive database of the system's fittings. System components were tagged for easy inventory and post-installation identification. This in turn permitted the storage of periodic test data, which would be analyzed when failures occurred. The staff also developed maintenance kits for fast and easy correction of problems. Dramatic savings were achieved: the facility netted $170,000 in the first 40 days of this program.

These examples illustrate the potential benefits of steam efficiency. The article that presented these cases does not, however, discuss the mobilization of resources that are necessary to pursue these results. The balance of this paper is intended to address that deficiency. Readers may wish to access more institutional steam efficiency case studies on the Internet at http://www.ase.org/programs/industrial/steam1.htm.

"TOTAL SYSTEM" APPROACH

The technical pursuit of steam efficiency requires a thorough understanding of all system components, as well as diligent monitoring and maintenance of operations. The "total-system" approach is offered as a framework for organizing this effort.

The best steam efficiency opportunities are incorporated in the blueprints of new construction buildings. But even when this is not the case, ongoing maintenance pays dividends in the form of operating cost containment. Boiler tune-ups, which are among the simplest opportunities, involve the optimization of air and fuel combustion mixtures and are a quick and virtually cost-free process. In general, financial decision-makers should realize that diligent steam system maintenance is a consistent and predictable expense, while the costs associated with poor maintenance are unpredictable and—in the case of a school, hospital, or nursing home—potentially catastrophic.

Steam efficiency is the product of an operations routine and discipline. It is also a focus on an entire steam system's functions—not just the boiler. Total steam system functionality can be generalized within four areas of operation: generation, distribution, end-use, and recovery. These four areas are the framework for (1) diagnosing efficiency opportunities and (2) organizing the elements of a maintenance discipline.

Generation refers to steam production in a boiler vessel. The primary task here for institutional steam operators is to balance system reliability and indoor comfort with fuel combustion, emissions release, and thermal loss. Proper burner design, maintenance, and system monitoring allow the steam operator to optimize combustion, all with direct impacts on system reliability and fuel consumption.

Distribution entails the routing of steam from its origin to (and within) buildings served by a steam loop. Distribution utilizes pressure differentials as steam branches into buildings and away from distribution mains. This in turn depends on the use of pressure-regulating valves, meters, steam traps, insulation, and interconnecting pipes. Leaks are an unavoidable consequence of utilizing such hardware, but their frequency and impact can be minimized through equipment standardization and maintenance routines. Leaks can be expressed as a negative cash flow, since additional inputs are required to make up for steam losses. Clearly, quality hardware pays for itself in terms of leak prevention. Similarly, heat loss that simply radiates from system pipes and hardware can be retarded by the proper use of pipe insulation, which pays for itself many times over in reduced fuel expenditures.

End-use involves transferring the latent heat of steam to interior spaces and into applications such as cooking, laundry, and sterilization. Invariably, these tasks are complicated several times over in an institutional environment. One dimension is the disparate heating demand coming from the many rooms and buildings served by one steam system. Well-planned installation and dedicated maintenance enables such a system to work effectively. Second, there is usually poor or no communication between facilities managers and building staff or residents about heat management. Sure evidence of this is a thermostat that resides under a locked cover, or exterior windows that are open in winter to moderate the effect of over-worked radiators.

Recovery stages of steam operations involve the recapture of heat present in condensate as well as treatment of combustion gases. Condensation discharge is a normal consequence of a complicated distribution system. Proper system design, however, maximizes usable heat as a proportion of boiler output. This also implies that excess or undeliverable heat is minimized. Another area for efficiency enhancement (beyond the scope of this paper) is the "scavenging" of excess heat for redirection into other mechanical system applications, including boosting inlet temperatures for water heating and recharging the desiccant materials used in humidity control systems. The optimization and recovery of thermal resources, including combustion heat, distribution surplus, and end-use optimization, all serve as a means for reducing expenditures on fuel and other steam inputs.

The total-system approach to steam efficiency—generation, distribution, end-use, and recovery—ensures a focus that is not piecemeal or counter productive. Intervention in one aspect usually has repercussions both upstream (toward the boiler) and downstream (toward the end-use applications). The total-system framework links the technical aspects of steam operations with equally important behavioral and managerial dimensions. Behavioral and plant managerial requirements include maintenance staff training, motivation, participation, and recognition of outcomes. Top-management responsibility includes clear communication of expectations to, and support for, the facility management and staff.

An additional element to be understood at the managerial level is the life-cycle cost performance that is inherent in total-system steam management. Life-cycle costing captures the sum total of expenses and benefits accruing over the economic lifespan of an investment. That time period may be 10, 15 or even 30 years. Life-cycle cost accounting, when performed for several alternative solutions, will suggest the best economic selection to be pursued. As a comprehensive accounting of an investment option, the life-cycle cost analysis for a steam efficiency measure would include projections of:

- search and selection costs for seeking an engineering implementation firm (if any)
- initial capital costs, including installation and costs of borrowing
- maintenance costs
- supply and consumable costs
- energy costs over the economic life of the implementation
- search and verification costs related to deregulated energy market purchases
- depreciation and tax impacts
- scrap value or cost of disposal at the end of the equipment's economic life, and
- impacts on production such as product quality and downtime.

One revelation that typically emerges from this exercise is that fuel costs represent the majority of a boiler system's life-cycle costs, while the initial capital outlay and maintenance costs are much smaller. These findings are true for boilers with a long (20-years or longer) economic life operating at high rates of capacity utilization. Clearly, any measure that reduces fuel consumption (while not impacting reliability and productivity) will certainly yield positive financial impacts.

Top management must ensure that all stakeholders understand and aspire to a steam efficiency program on a basis of life-cycle costs and benefits. Stakeholders include budget and procurement officers who usually focus on expenditures for one year at a time.

TEN-STEP PROGRAM FOR EFFICIENT INSTITUTIONAL STEAM

What follows is offered as a step-by-step blueprint for engaging technical, behavioral, and managerial resources in the pursuit of steam efficiency.

1. Identify your options.

Action	*Impact*
Inventory the components of the steam system and the service that it is intended to provide (number of rooms, beds, square feet, or similar metric). Survey the system's energy usage, including purchased fuel inputs through each of the four stages of the "total-system" framework. Recognize opportunities to standardize hardware applications, especially steam traps, valves, and other consumable items.	Know the system, its limitations, the nature of the demands made on it. This is a key prerequisite for recognizing, understanding, and pursuing efficiency opportunities. Standardization reduces the complexity and expense of inventory control while also helping to avoid the cost and disruption attributable to misapplication of hardware.

2. Prioritize the options.

Action	*Impact*
Don't try to do it all at once. The energy survey will reveal a variety of opportunities, some of which are easier to accomplish than others. Start by pursuing the options that provide the most "bang-for-the-buck": those that give the largest ratio of benefits to costs. Insulation applied to pipes and fittings provides a very quick return on investment.	This allows implementation to proceed in phases. The returns from one phase generate savings that pay for the next phase. Phases also allow facility managers and staff to progress on the learning curve.

3. Determine a dollar impact for the best options.

Action	*Impact*
Using the findings of the system's energy survey and the potential savings that it recognizes, calculate the concurrent dollar savings attributable to efficiency implementation. Expression of results should include such metrics as net expenses avoided (or net contribution to operating income), return on investment, and payback.	The expression of efficiency savings as dollars and cents is a common denominator that will be well understood by facility managers, staff, and top management. Dollars are also a benchmark for establishing the goals and management accountability aspects of any efficiency implementation effort.

4. Ensure support from above and within.

Action	*Impact*
Top-management should assure the plant manager that it has the resources it needs to pursue efficiency implementation. Communicate the expected effort and benefits. Issue incentives that reward initiative.	Ensure buy-in and motivation at all levels.

5. Train staff and offer incentives for achieving results.

Action	*Impact*
Establish criteria that link results to staff accomplishments. Training is critical. So is initiative and recognition for positive results. Rewards can be derived from the very savings that staffs generate.[5]	Incentives should greatly assist in achieving the buy-in of staff that is necessary to make implementation work. Savings shared between the central plant and the program office also facilitate the buy-in and support of top-level management.

6. Develop a maintenance discipline.

Action	*Impact*
Using the system overview provided by the energy survey, prepare a schedule for testing, verification, and replacement.	This becomes the driver of maintenance duties and discipline. It is also a tool for planning inventory purchases and labor utilization.

7. Monitor operations.

Action	*Impact*
Put into daily practice the schedule of maintenance duties. Empower staff to follow this program. Operational progress should document system performance along with concurrent fuel consumption, demand load, weather, and mechanical conditions that impact performance.	Records generated through diligent, operationalized maintenance eventually pay for themselves. Such data can "fingerprint" the conditions that precede system failures. After collecting a season's worth of data, facility managers can begin to spot problems before they occur. Benchmarks for "normal" performance begin to emerge.

[5] One question that this might raise: How does one generate staff incentives for the second year of implementation, assuming that most efficiencies and savings were captured in the first year? For one answer, see step nine, "Recognize and Reward."

8. Demonstrate results.

Action	*Impact*
Record and demonstrate to top managers the savings and related benefits brought by the efficiency implementation. Document net savings on fuel expenditures. Fuel savings should more than counter any increase in O&M costs incurred by more intensive maintenance. Account for, or at least recognize, indirect savings as well. Utilize financial measures such as ROI to illustrate the impact.	Note the full range of potential value: • fuel consumption savings • increased facility productivity due to prevented system failures and avoided "down-time" • reduced costs of misapplication thanks to better training and standardized component selection • avoided costs related to health and safety issues. Well-run steam facilities also qualify for reduced hazard insurance premiums. • emissions compliance, when applicable. Note the tremendous public relations value in demonstrating compliance to a "green" agenda.

9. Reward those who make the results possible.

Action	*Impact*
Reward staff for generating positive results. Bonuses can come from the very savings they helped to generate. Awards and recognition before one's peers is an equally strong motivator. After the energy survey's opportunities have all been met, reward key staff by giving trade organization membership (such as ASHRAE).	Bonuses, rewards, and recognition help to retain staff while ensuring continued capture of efficiency opportunities. Dues paid to trade associations are an investment that ensures continual education while providing the staff with opportunities to convene with peers. Association conferences in Florida are always a perk!

10. Share the news.

Action	*Impact*
Document and report savings to top management, directorship boards, and to the surrounding community.	The demonstrable savings provided by steam efficiency will resonate positively with taxpayers or shareholders. Facility staff and clients appreciate the concurrent benefits of productivity, safety, and comfort. The electorate who demand a real effort to curb pollutants and greenhouse gas emissions will similarly applaud the effort.

CONCLUSION

Institutional steam users are distributed across the country, at all levels of government, and in private and non-profit functions. This population of steam systems presents countless opportunities for achieving more efficient and economical energy usage. These facilities are also positioned to demonstrate efficient technologies and practices for the benefit of commercial and industrial steam users in their surrounding communities.

The potential for energy expense savings gives administrators the incentive to embrace steam efficiency. The total-system approach to steam system surveys is offered here as a fundamental blueprint for identifying and prioritizing opportunities to implement efficiency measures. The ten-step program is then suggested as a tool for organizing the technical, behavioral, and managerial roles that make implementation effective.

By obtaining the steam resources freely offered by the BestPractices program, facility managers can access valuable information. Facility managers that do so will hopefully demonstrate operational improvements and financial benefits to their top-level management audience. Public-purpose institutions are subject to legislative oversight, so policy makers can be exposed to the BestPractices Steam program as a practical way to advance clean, efficient energy practices. Legislators can then replicate the initiative among other institutions within their jurisdictions, thus multiplying the eventual impact of steam efficiency. The benefits are most immediate in the form of economic savings and institutional effectiveness. As an added value, state and local governments can confidently demonstrate their response to a growing public demand for clean, efficient energy use.

FOR MORE INFORMATION…

The BestPractices Steam program is co-managed by the U.S. Department of Energy and the Alliance to Save Energy, a Washington, D.C.-based non-profit that supports national energy management initiatives. Industrial end users, equipment suppliers, and resource organizations act together to help industry stay competitive and promote the comprehensive upgrade of industrial steam systems. Contact the DOE Office of Industrial Technology Clearinghouse at:

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See also the BestPractices Steam website: www.oit.doe.gov/bestpractices/steam
Institutional Steam Case Studies: www.ase.org/programs/industrial/steam1.htm