TEN METHODS FOR SAVING THOUSANDS IN THE BOILER ROOM

Developed by The American Society of Power Engineers (ASOPE™)

Nearly everyone involved in the operation of boilers, from the operator to the owner, realizes the considerable expense of operating steam generators and associated auxiliary equipment. What many do not realize however, is that there are many seemingly small and insignificant changes and/or modifications that can be implemented resulting in considerable savings.

Let's explore some methods for reducing operating expenses:

Efficiency Methods

1. **Boiler Efficiency Upgrades**
2. **Waterside Scale Prevention**
3. **Adequate Piping Insulation**
4. **Steam Trap Surveys**
5. **Limit Boiler Dynamic Operation**
6. **High Efficiency Motor Utilization**
7. **Repair Steam Leaks**
8. **Eliminate Water Losses**
9. **Install Removable Insulation**
10. **Train Your Employees**

√ Click to continue

Method Number 1

BOILER EFFICIENCY UPGRADES

By Judy Waive Crist

Boiler Efficiency

The formula for realized savings or losses resulting from changes in boiler efficiency can be expressed as follows:

$$\text{Savings} = \frac{\text{New Efficiency} - \text{Old Efficiency}}{\text{New Efficiency}}$$

Boiler Efficiency (cont)

Example 1:

Existing boiler efficiency is 74%. After a tune-up is performed on the boiler, efficiency has increased to 80%. Realized fuel savings would be calculated as follows:

$$\text{Fuel Savings} = \frac{80\% - 74\%}{80\%} = 7.50\%$$

Boiler Efficiency (cont)

Therefore in this example a 6% improvement in boiler efficiency results in a 7.5% savings in fuel expenses.

Illustrating practically: Your last annual fuel bill was $1,000,000. If a 6% efficiency tune-up was conducted on your boiler, realized fuel savings would have been:

$1,000,000 x 7.50% or:

$75,000/year

Boiler Efficiency (cont)

Example 2:

Existing boiler efficiency is 80%. After improper operation and maintenance, boiler efficiency has reduced to 73%, directly corresponding to a fuel efficiency loss of:

$$\text{Fuel Loss} = \frac{73\% - 80\%}{73\%} = -9.59\%$$

Boiler Efficiency (cont)

Therefore, as a result of a 7% decrease in boiler efficiency; a 9.95% increase in fuel expenses would be incurred.

Illustrating practically: Your last annual fuel bill was $1,000,000. If your boiler was not properly operated and maintained, increased fuel expenses would have been:

$1,000,000 x 9.59% or:

$95,900/year

Boiler Efficiency

Reference:

Combustion Efficiency Tables

Harry R. Taplin, Jr. P.E., C.E.M.

Method Number 2

WATERSIDE SCALE PREVENTION

By James Daugherty

Scale Prevention

Water Treatment in boilers today remains one of the most important items of energy conversation and savings.

Boiler waterside scale is mostly composed of the minerals calcium and magnesium. These are insoluble salts in water; meaning that they don't like to be in solution and will drop (plate) out as temperatures rise. This is what you often see in the bottom of hot water (tea/coffee) kettles at home.

Scale Prevention (cont)

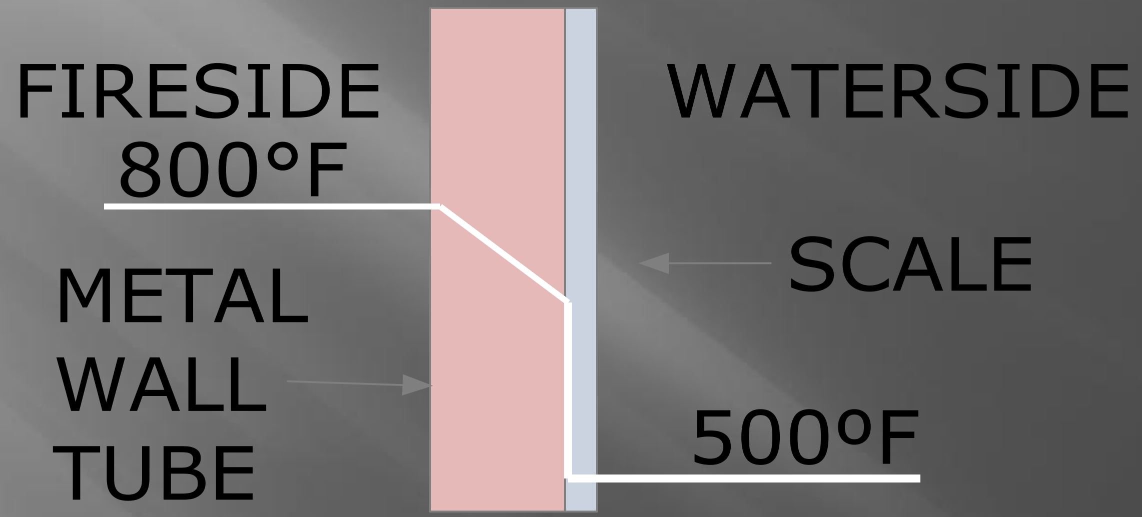
Deposition, or the 'plating out' of the calcium and magnesium on the boiler tube waterside reduces heat transfer from the boiler tube to the boiler water, resulting in an increase in tube metal temperature.

Tube overheating along with potential tube failure will eventually be the result of prolonged scale deposition.

The following charts illustrate the increased fuel expenses caused by scale deposition on the tubes.

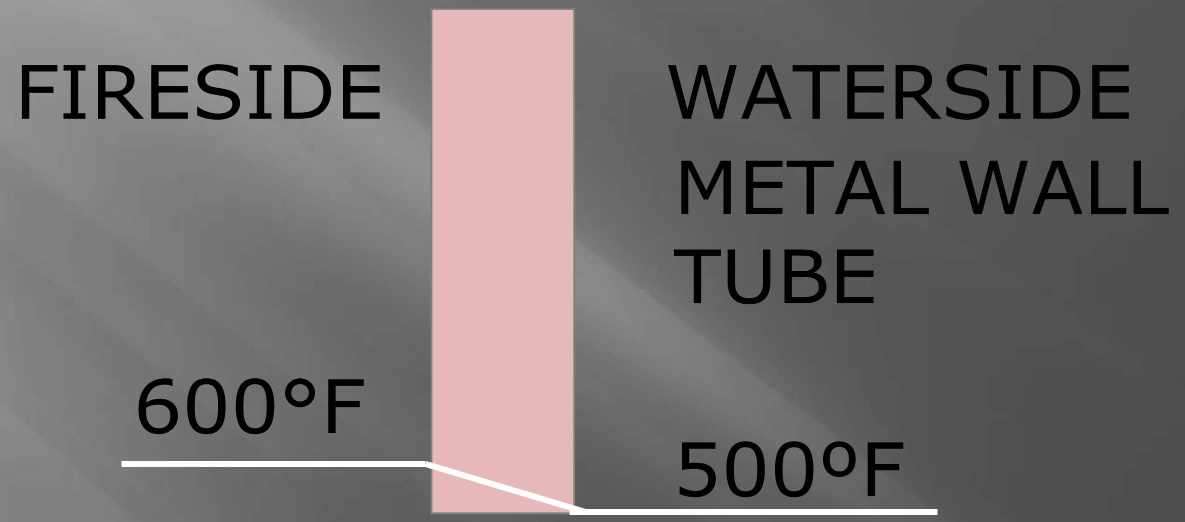
Note: There are many other extensive damages which can be caused by the same scale build-up.

Scale Prevention (cont)



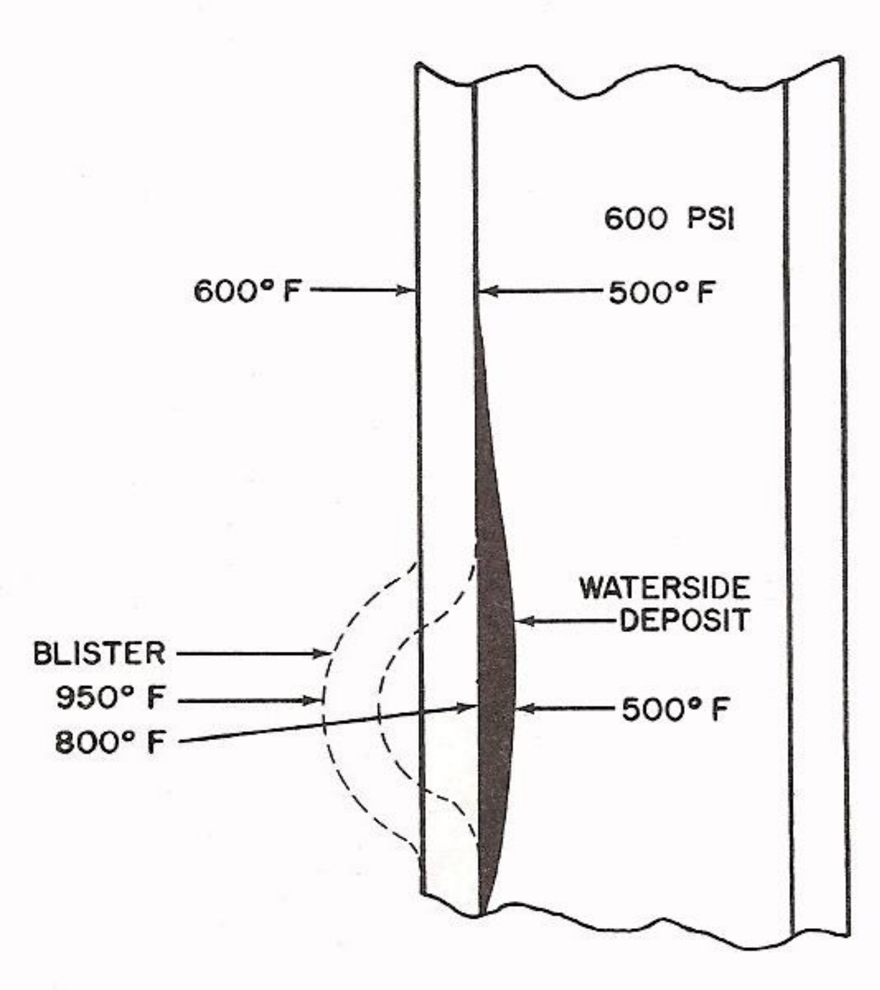
With the presence of scale, there exists a 300ºF heat loss through the tube.

Scale Prevention (cont)



With no scale present, there exists only a 100ºF heat loss through the tube.

Scale Prevention (cont)



Effects of waterside deposits on boiler tubes.

Scale Prevention (cont)

Thickness	Efficiency Reduction
0	0%
1/64	4%
1/32	7%
1/16	11%
1/8	18%
3/16	27%
1/4	38%
3/8	48%

This chart illustrates efficiency losses as scale thickness increases.

Scale Prevention (cont)

<u>Example:</u>

Your boiler's original efficiency was 80%.

Presently, there exists a scale layer of 3/16" on the tubes.

The resulting efficiency change caused by the scale layer is:

$$\text{New Efficiency} = 80\% - 27\%$$
$$= 53\%$$

Scale Prevention (cont)

Illustrating practically: Your last annual fuel bill was $30,000; with a layer of 3/16” scale formation, increased fuel expenses would be:

$30,000 + ($30,000 x 27%) =

$38,100

A loss of $8,100; along with the very real possibility that the boiler may not meet the steam production required as well.

Scale Prevention (cont)

Chemical Treatment and Control:

Feedwater Hardness (Calcium & Magnesium) prior to entering the boiler should typically be less than 1 ppm Total Hardness.

Hardness reduction is achieved by using RO units, Ion Exchange systems, and most importantly by maximizing condensate return recovery.

Typically, the more condensate return that is recovered, the less chemicals that will be required for the boiler, along with decreased fuel costs for preheating.

Scale Prevention (cont)

Chemical Treatment and Control (cont):

Water chemistry testing should be performed at least daily in order to ensure and maintain proper levels.

Calibration of all water chemistry meters is extremely important as well to ensure correct readings.

Proper chemistry levels in boilers under 300 psi include:

TDS	$<$ 3500 ppm after neutralization
Silica	$<$ 150 ppm
Phosphate	20-40 ppm
Sulfite	30-60 ppm
Hydroxide	300-600 ppm

Scale Prevention (cont)

Chemical Treatment and Control (cont):

Scale forming conditions in the boiler can also be a significant contributing factor for Carryover (moisture in steam) to occur.

Carryover can cause down stream scaling in process piping, equipment, or on steam turbine blading.

Cooling System Scale

Cooling system scaling is a little different than boiler scaling in that hot areas do not need to be present for scale deposition to occur. Cooling system scale typically occurs when the solubility of the water is exceeded (concentration cycles too high).

As in boilers, heat transference is inhibited along with proper flow.

Unlike boilers, microbiological growth can cause the same problems.

Cooling System Microbiological

Cooling systems are ideal for microscopic life due to the temperatures as well as food sources in the air.

Bacteria:

- Can attack both once-through systems and recirculating systems.
- Can be aerobic (air breathing) or anaerobic (non air breathing).

Algae:

- There are many types of algae. Algae is a plant that requires sunlight for growth.
- Like bacteria, different types of algae will live in different pH's and temperatures.

Cooling System Microbiological (cont)

<u>Fungi:</u>

- Has 2 forms, Mold and Yeast.
- Yeast will form slime in abundance.

Biofilms formed by microbiological growth are 25 to 200 times more resistant to conduction than many metals.

1mm of Biofilm on mild carbon steel is equivalent to a wall thickness of 80 mm.

Method Number 3

ADEQUATE PIPING INSULATION

By Carroll Hooper

Piping Insulation

Energy losses from both insulated and uninsulated piping can be gathered, calculated, and quantified using standard industry tables, charts and software.

The number of hours that the piping is in service is multiplied by the condensation rate in pounds per hour (lb/hr) to derive the total Steam Loss.

Since the cost of the steam is normally given in dollars per thousand pounds of steam, the loss per year is then divided by 1000 and multiplied by the cost of steam. This determines the cost of the heat loss and may be used to justify the cost of insulating the pipe.

Piping Insulation (cont)

<u>Example:</u>

A plant has identified 100 feet of uninsulated 6" steam piping used for 180 psig steam. The piping is in service 24 hr/day, 365 days/yr. The piping is inside a building and is surrounded by still air at 70ºF.

The amount of condensation can be determined from the following table:

NOTE: (Charts and tables are available from The American Society of Heating, Refrigeration and Air Conditioning Engineers and the National Insulation Association).

Piping Insulation (cont)

The number 1.85 is found at the intersection of row 6″ piping and the column for 180 psig steam.

UNINSULATED PIPE CONDENSATION RATE*									
Pipe Size		15	30	60	125	180	250	450	600
Pipe Size	**Area***	**Pounds of Steam Condensed per Hour Per Linear Foot**							
1	0.344	0.19	0.22	0.26	0.33	0.37	0.41	0.51	0.57
2	0.622	0.32	0.40	0.47	0.59	0.66	0.74	0.91	1.04
3	0.916	0.47	0.58	0.70	0.87	0.97	1.09	1.35	1.52
4	1.178	0.56	0.75	0.90	1.11	1.25	1.40	1.73	1.96
6	1.735	0.82	1.10	1.32	1.64	1.85	2.06	2.55	3.89
8	2.260	1.04	1.44	1.72	2.14	2.40	2.69	3.32	3.76

* Carrying saturated steam in still air at 70ºF

Piping Insulation (cont)

This means that 1.85 lb of steam will condense per hour per foot of uninsulated pipe due to loss of radiant heat from the piping. Since the uninsulated section of piping is 100′ in length, the steam loss will be 185 lb/hr (1.85 X 100 = 185).

The steam loss number may now be multiplied by the cost of steam at the facility to determine the value of the lost steam. As an example, if the cost of steam is $9.00/1000 lb, the cost of the lost steam can be calculated as follows:

Piping Insulation (cont)

$$Cost = \frac{W_w}{1000} x\ steam\ \mathrm{cost}$$

$$where$$

$$\mathrm{cos}t = \mathrm{cost\ of\ lost\ heat\ (in\ \$)}$$

$$W_w = \mathrm{weight\ of\ steam\ lost\ (in\ lb/hr)}$$

$$steam\ \mathrm{cost} = \mathrm{cost\ of\ steam\ (in\ \$/lb)}$$

$$\mathrm{cos}t = \frac{185}{1000} x\, 9.00$$

$$\mathrm{cos}t = 0.185\, x\, 9.00$$

$$\mathrm{cos}t = \$1.66/\mathrm{hr}$$

\$1.66/hr x 24 hr/day x 365 day/yr = **\$14,542 / yr**

Piping Insulation

Reference:

American Technical Publishing (ATP)

Boiler Operator's Workbook

3rd Edition

Method Number 4

STEAM TRAP SURVEYS

By Carroll Hooper

Steam Traps

Steam Traps, like all other pieces of mechanical equipment, will fail in time. They may fail closed, restricting the flow; or they may fail open, freely passing steam. In order to fully appreciate the cost consequences of malfunctioning steam traps one must first go through some basic arithmetic.

Consider a plant with 2000 steam traps and a reasonably good maintenance program. Experience dictates a conservative assumption that at least 10% have failed in the ‘open’ position and are ‘blowing through’, wasting steam.

Steam Traps (cont)

Example:

200 steam traps, losing 20 pounds of steam per hour per unit, for twenty-four hours, are losing 96,000 lbs of steam each day. While steam generating costs vary from plant to plant, a conservative estimate of $9.00 per 1000 lbs. can be used for today's energy climates.

2000 traps x 10%	=	200 failed traps
200 failed traps x $9.00/1,000 lb	=	96,000 lb/day
96,000 lb/day x $9.00/1,000 lb	=	$864/day
$864/day x 365 day/year	=	**$315,360 per year!**

Steam Traps (cont)

Note that it is not necessary to have several thousand steam traps in order to have very large steam and dollar losses. Several failed large capacity traps can also significantly contribute to costly steam losses.

Costs resulting from steam traps that have failed in the closed position are not considered in the preceding example. These types of failures are much more difficult to quantify but are no less real. Losses from closed traps typically result from reduced productivity or quality as well as higher rates of equipment damage due to corrosion, water hammer, and freeze ups.

Steam Traps (cont)

An article on Steam Trap Maintenance as a Profit Center for Strategic Planning from *Energy and the Environment Vol. 16, No 3-1997* sums what we have been saying in the preceding slides:

The article describes a survey where, out of 260,000 steam traps in 40 large steam using industrial plants, an average of only 58% were working correctly. If steam costs were $9.00 per thousand lbs. in today's energy climate, the average manufacturing facility with 2000 steam traps can be throwing away $750,000 per year and never be aware of these losses.

Steam Traps

References:

The Industrial Steam Trapping Handbook

The Strategic Planning for Energy and the Environment

Mr. Carroll Hooper's Private Library on Industrial Engineering

Method Number 5

LIMIT BOILER DYNAMIC OPERATION (CYCLING)

By Larry Tarvin

Boiler Cycling

The following describes two types of dynamic (cycling) boiler operation:

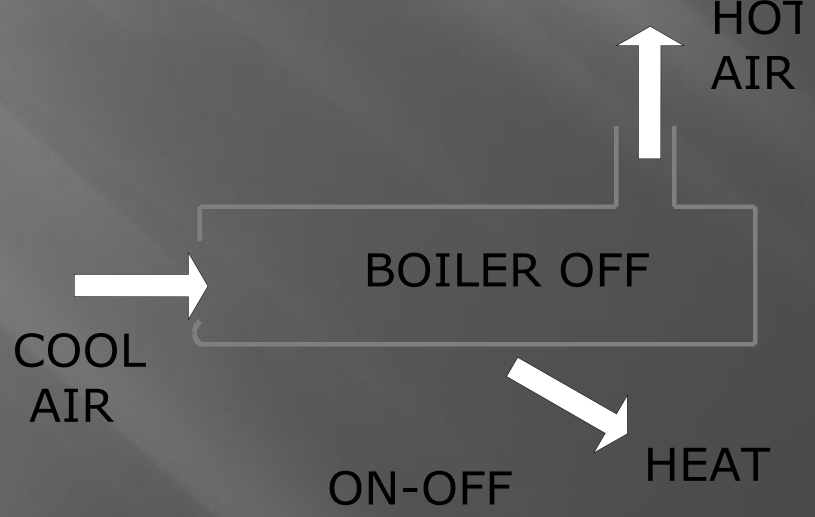
1. On/Off Cycling: Boiler will come on for a few minutes and then be off for several minutes.

2. "Hunting": Boiler stays on, but firing rate is continually adjusted to satisfy a stringent requirement to maintain boiler pressure.

Boiler Cycling (cont)

On/Off Mode:

There are large energy losses due to purging, free convection through the boiler, and skin heat transfer losses. All of these remove useful heat from the boiler.



Boiler Cycling (cont)

<u>Hunting Mode:</u>

This figure shows that excess air levels are much higher while the boiler is “hunting” than in steady operation. Of course, high excess air means low efficiency.

Boiler Cycling (cont)

- Any boiler which either stays off a significant amount of time or continually varies in firing rate can be changed to improve efficiency.
- For boilers which operate on and off, it may be possible to leave it on and reduce the firing rate instead. If so, excess air must be maintained at the same or lower level.
- Another approach is to not allow the boiler to move to high fire, but rather, fire at an intermediate rate. This will allow the boiler to stay on longer. However, excess air must be carefully controlled. Usually, the economic action is to purchase a small boiler for when limited amounts of steam are required.

Boiler Cycling (cont)

For Boilers that “hunt”, control system potentiometers (sets the sensitivity of firing rate to boiler pressure) can be adjusted so that the boiler changes firing rate only under relatively large deviations from boiler pressure setpoint.

This will result in large steam pressure fluctuations. However, typical “hunting” modes of operation do not require exact control of pressure.

Typical annual savings of ~10% on some boilers:

$23,000 on 100 HP

$266,666 on 40,000 lb/hr

Boiler Cycling

References:

David F. Dyer, Glennon Maples, and Timothy T. Maxwell

Professors of Mechanical Engineering

Auburn University, Auburn, Alabama

Method Number 6

HIGH EFFICIENCY MOTOR UTILIZATION

By Byron Nichols

HIGH EFFICIENCY MOTORS

When new motors are identified for purchase or when older motors require replacement, it is wise to consider the purchase of high efficiency motors.

The efficiency of a motor is the ratio of the energy output (mechanical power produced) vs. the energy input (electricity required).

It may be expressed simply as:

EFFICIENCY = OUTPUT/INPUT

HIGH EFFICIENCY MOTORS (cont)

Design changes, better materials, and manufacturing improvements reduce motor losses, making premium or energy efficient motors more efficient than standard motors.

Reduced losses basically mean that an energy efficient motor produces a given amount of work using less energy than a standard motor.

HIGH EFFICIENCY MOTORS (cont)

Assuming a constant motor speed; the formula to calculate cost savings is expressed as:

$$S = hp \times 0.746 \times L \times C \times N \times [(100/E\ std) - (100/E\ ee)]$$

<u>Where:</u>

S	= $ Savings (annual)
Hp	= Motor horsepower
L	= % Load
C	= Energy Cost ($/kWh)
N	= Operating hours (annual)
E std	= % Efficiency of standard motor
E ee	= % Efficiency of high efficiency motor

HIGH EFFICIENCY MOTORS (cont)

Example:

A 100 hp boiler feedwater pump runs continuously at 85% load with an electrical cost of \$0.065/kWh. What would be the annual savings when replacing this standard efficiency (90.2%) motor with a high efficiency (93%) motor?

S = hp x 0.746 x L x C x N x [(100/E std) – (100/E ee)]

S = 100 x 0.746 x 0.85 x 0.065 x 8760 x [(100/90.2) – (100/93.0)]

S = **\$1,205 / year**

Extending this figure out by projecting a 10 year motor life, we can expect a savings of **\$12,050** by replacing the standard efficiency motor with a high efficiency for the ten year period.

Method Number 7

REPAIR STEAM LEAKS

By Larry Tarvin

Steam Leaks

Steam is a high-value commodity; the higher the pressure, the higher the equipment expenses. Make every effort to repair steam leaks as soon as they occur.

In addition to wasting energy, steam leaks waste boiler water and chemicals, and can be dangerous to people and equipment. The longer the steam leaks the bigger the leak will get.

Steam Leaks (cont)

<u>Example:</u>

A sharp edge orifice leak of 9.5/1000 lb pressure @ 150 psig @ 500ºF:

Leak Size	Monthly Energy Cost	Total Cost per Year
1 in	$26,083.00	$312,996.00
3/4	$14,668.00	$176,016.00
1/2	$6,519.00	$78,228.00
1/4	1,630.00	$19,560.00
1/8	$409.00	$48,108.00

Steam Leaks

Reference:

Steam System Survey Guide

ORNL/TM-2001-263. P 6-2

Method Number 8

ELIMINATE WATER LOSSES

By Ron Nuoffer

Eliminate Water Losses

Water and steam leaks are a major source of hidden costs. Each valve, piping flange, or drain that leaks, impacts the facility by increasing make-up water expenses.

A pipe flange or a valve's packing that leaks 1 drop of water per second will lose 6 ounces of water per hour and 34 gallons per month. Initially, that may not sound like much, but if there are 10 valves or pipe connections dripping; water losses add up to 340 gallons per month.

Eliminate Water Losses (cont)

If the leak increases from a drop to a 1/16" steady stream, the result will be 84 gallons of lost water each day. Accordingly, every month that the leak continues, 2,520 gallons of water are lost.

Not only is lost water expensive to replace directly, but the facility will also incur 'indirect' expenses in the form of equipment and metal erosion in valves and piping. Additional expenses will also be realized in water chemistry treatment for the replacement water.

Eliminate Water Losses (cont)

Drain valve leak-through is another major source of water loss. Most drains discharge to flash or blowdown tanks; so if a valve is leaking by, this water is lost from the overall steam/water cycle. By monitoring the amount of makeup water added to the steam/water cycle, water loss rates can be determined.

Pay back for proper packing adjustment or valve and pipe fitting replacement would be a few days and will keep the facility running efficiently.

NOTE: A pound of water equals a pound of steam, and a pound of steam equals a pound of water. There are 8.33 pounds of water in a gallon.

Method Number 9

INSTALL REMOVABLE INSULATION ON VALVES AND FITTINGS

By Larry Tarvin

Valves and Fittings Insulation

During maintenance, insulation that covers pipes, valves, and fittings is often damaged or removed and not replaced. Pipes, valves, and fittings that are not insulated can be safety hazards and major sources of heat loss.

Removable and reusable insulating pads are available to cover almost any surface. Pads are made of noncombustible outer layers with insulating material inside. The outer layers are made to resist tears, abrasion, oil, and water. Pads also come with straps and buckles hold them in place.

Valves and Fittings Insulation (cont)

Reusable insulating pads are commonly used for insulating flanges, valves, expansion joints, heat exchangers, pumps, turbines, tanks, and other irregular surfaces.

These pads are flexible, are vibration resistant, and can be used with equipment that is horizontally or vertically mounted or is difficult to access. All high-temperature piping or equipment should be insulated to reduce heat/energy loss, to reduce emissions, and to ensure personnel safety.

Valves and Fittings Insulation (cont)

As a general rule, any surface that reaches temperatures above 120°F should be insulated to protect personnel. Insulating pads can be easily removed for periodic inspection or maintenance, and are replaced as needed. Insulating pads may also contain built-in acoustical barriers to help control noise.

The following table illustrates insulating valve cover energy savings for various valve sizes and operating temperatures. These values were calculated using a computer program meeting the requirements of *ASTM C 680-Heat Loss and Surface Temperature Calculations*.

Valves and Fittings Insulation (cont)

Energy Savings* from Removable Insulated Valve Covers (Btu/hour)						
Operating Temperature, ºF	Valve Size (inches)					
	3	4	5	6	7	8
200	800	1.090	1,500	2,200	2,900	3,300
300	1.710	2,300	3,300	4,800	6,200	7,200
400	2,900	3,400	5,800	8,300	10,800	12,500
500	4,500	6,200	9,000	13,000	16,900	19,700
600	6,700	9,100	13,300	19,200	25,200	29,300

*Based on a 1-inch thick insulating pad on an ANSI 150-pound class flanged valve, with an ambient temperature of 65ºF and zero wind speed.

Valves and Fittings Insulation (cont)

Energy savings are defined as the difference in heat loss between uninsulated and insulated valves operating at the same temperature.

<u>Example:</u>

Using the table, calculate annual savings from installing a 1″ thick insulating pad on an uninsulated 5″ gate valve in a steam line operating at 300°F (about 50 PSI saturated steam). Assume continuous operation with natural gas at a boiler efficiency of 80% and a fuel price of $6 per million British thermal units (MMBtu).

Valves and Fittings Insulation (cont)

Energy Savings* from Removable Insulated Valve Covers (Btu/hour)						
Operating Temperature, ºF	Valve Size (inches)					
	3	4	5	6	7	8
200	800	1.090	1,500	2,200	2,900	3,300
300	1.710	2,300	3,300	4,800	6,200	7,200
400	2,900	3,400	5,800	8,300	10,800	12,500
500	4,500	6,200	9,000	13,000	16,900	19,700
600	6,700	9,100	13,300	19,200	25,200	29,300

Valves and Fittings Insulation (cont)

Annual Fuel Savings:

3,300 Btu/hr X 8,700 hours/year x 1/0.80 =

36.1 MMBtu/year

Annual Dollar Savings:

36.1 MMBtu/year x $9.50/MMbtu =

$216 per 5-inch gate valve

Valves and Fittings Insulation

References:

US Department of Energy, Energy Efficiency and Renewable Energy

Method Number 10

TRAIN YOUR EMPLOYEES!

By Dave Preston

Train Your Employees

It's people, not just equipment or processes that make the difference between a well run facility and one with never ending problems.

Whether it's how they respond to abnormal operating conditions, how careful they are with plant chemistry, how well they test and maintain critical components, or how they operate the boiler; it's training that makes the difference.

Train Your Employees (cont)

According to industry statistics, power generation facilities will lose between 30% and 50% of their most experienced workers over the next five years.

Employees who leave take valuable experience and knowledge with them and, according to an EPRI survey of 21 power companies, only 30 percent have a formal plan to capture the knowledge lost.

Train Your Employees (cont)

The power generation industry has changed significantly over the past several years and there is little doubt the industry will continue to evolve as the benefits and challenges of deregulation are further debated.

Over the past decade, most power generation companies have transformed themselves into leaner and more competitive companies. Further aggravating the situation has been the purchase and sale of generation assets, creating mixed employee unions, corporate cultures and operating philosophies.

Train Your Employees (cont)

Industry keeps saying a major issue for many power companies is the challenge to locate, hire and train a well-qualified workforce. To meet this challenge, leading power companies are offering their employees various types of "blended learning".

Blended learning simply means the combining of multiple training methods (for example, OJT from retired workers being hired back, classroom training, self study training, Web-based training, and others). This type of learning tends to produce a more effective training program. The blended approach has shown that costs are reduced, levels of knowledge comprehension are higher, and time required to complete training is shorter.

Train Your Employees (cont)

For facilities in the market for new equipment, don't forget to include personnel training in the RFP (Request for Proposal). The most cost effective time to train employees on new items purchased is when these items are installed and tested.

So if you want to save "Thousands in your Boiler Room", stop and take a good hard look at how your employees operate and maintain the equipment you have. Operating Procedures, System Descriptions, Lesson Plans, JPMs (Job Performance Measures) are all training tools in your operating tool kit that need to be "sharpened" (reviewed and updated) periodically.

Train Your Employees (cont)

Effective and efficient use of your employees is your #1 cost savings tool.

Special Thanks To:

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