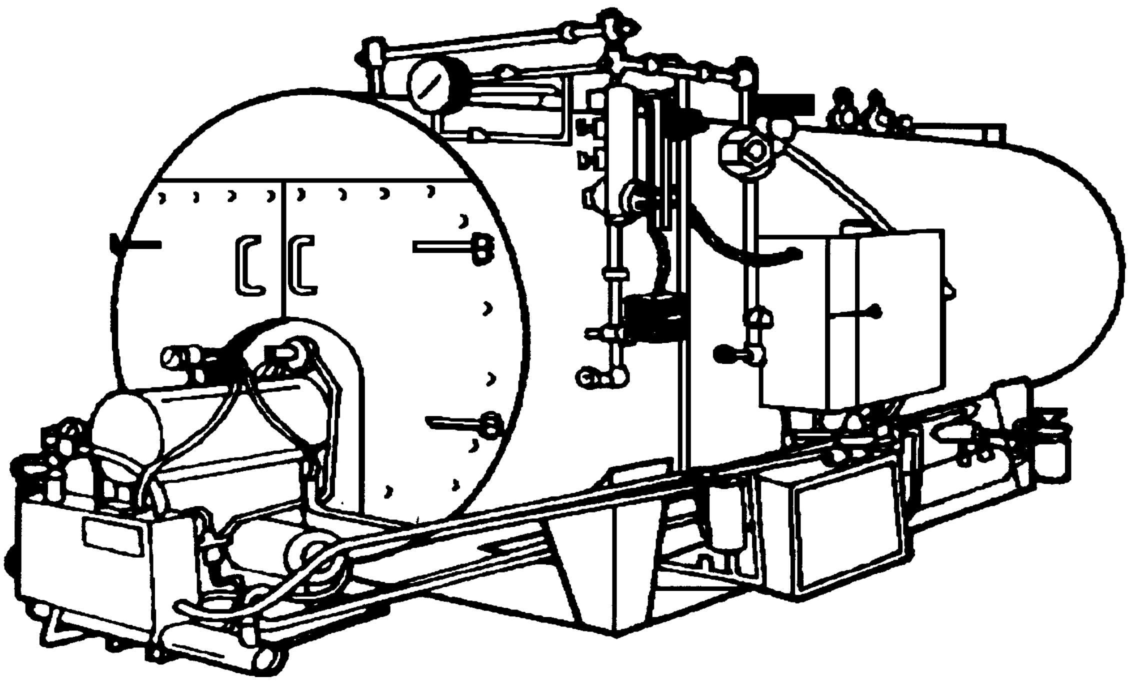

Drawing Courtesy of Kewanee Boiler Manufacturing

Improving Boiler Room Efficiencies

A Seminar on the ways and means of increasing boiler room efficiencies.

The Effect of System Pressure Reduction in the Boiler Plant

Presented by
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Rev 9/00

Contents

A Message from the speaker

Energy costs today are the highest in recent history. Gaining whatever efficiencies may be found in thermal processes can help to stabilize the effects of rising energy cost.

Today's economic and environmental demands dictate that we get the greatest practical efficiencies from our plants. To do this we must have a basic understanding of what those efficiencies are and how we may implement them.

My hope for you today is that you will leave this seminar with a clearer understanding of some of the economical and technically feasible opportunities you have to improve your steam plant.

Regards,
David C. Farthing
Industrial Sales Manager
Federal Corporation

Introduction

Improved efficiency has many connotations, everything from fuel savings, improved equipment operation and useful life span, to labor and manpower savings. This paper will focus on the effect of steam pressure reduction as a possible means of thermal optimization and energy savings. The strategy presented will have both technical and economic feasibility discussions presented with it.

Steam Plant Optimization & Automation

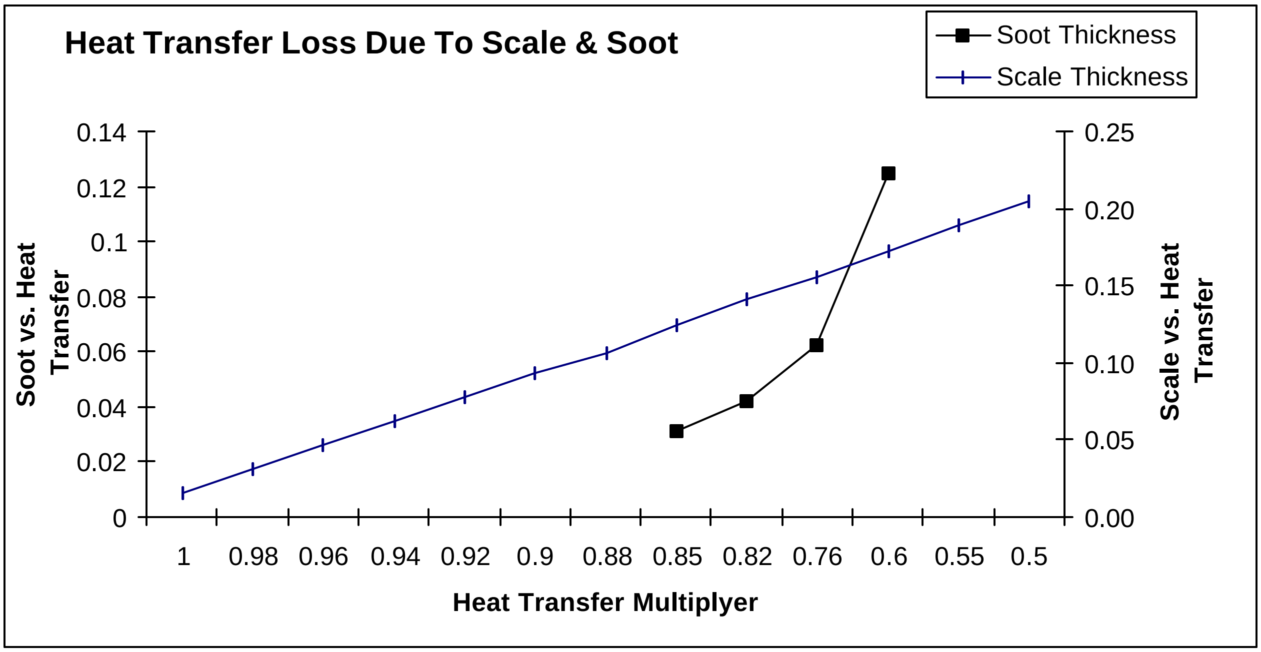
Steam plant optimization is the overall improvement of the plant's operation. The most common strategies used to accomplish this task include, and generally focus on the improvement of primary equipment operating efficiency, i.e. fuel and energy savings. In heavy commercial and industrial boiler applications these efficiencies are normally found in the application of waste heat recovery equipment, systems and process automation, and improved operating practices.

Keeping It Clean

One of the myths that need's to be cleared-up before we go forward is the effect of boiler and plant cleanliness on improving efficiency. Keeping boiler furnace and watersides clean does not improve efficiency. Keeping these surfaces clean maintains the factory delivered efficiency of the equipment. That is the efficiency rating the equipment *was designed to have*. Allowing these surfaces to become dirty or scaled lowers the original design efficiency, thus requiring more energy to accomplish the same amount of work.

As can be seen in the chart below, a waterside scale build-up of .03 inch can result in a 2% loss of efficiency. Increase the scale thickness to 0.095 inch and you can expect losses of 10% or greater.

© David Farthing's TechStuff Rev 9.12 'The effect of Scale & Soot Build-up on Heat Transfer in Boilers'



Conversely soot build-up in the furnace of .02 inch can result in as much as a 15% loss in thermal efficiency. Keeping these fireside and waterside surfaces in good order is paramount to efficient operations.

Additionally a clean plant lowers the risk of accidents and allows the operating staff more efficient access to equipment and operating environments. It's just plain common sense and good practice. It is also the first place to look when implementing any thermal efficiency improvement program.

Rating Boiler Horsepower

Boilers are rated from and at 212 degrees 'F' and zero PSIG pressure. Additional Btu input is required as steam pressure is increased. Operating pressure is a function of the end process's heat requirements and the piping restrictions of the distribution system. The obvious consideration, being the overall cost of the distribution system during the original installation. In the initial analysis it is normally less costly to lay-up a smaller distribution line and run at elevated pressures, than a larger line which would allow the boiler to operate at a lower pressure. The chart below shows the theoretical addition of Btu required to increase steaming pressure based on feedwater temperatures.

Btu vs. Feedwater Tables at Design Pressure

Additional BTU Required to Develop 1 Boiler Horsepower vs. Feedwater Temperature

Feedwater	Boiler Operating Pressure										
Temperature	0	25	50	75	100	125	150	175	200	225	250
50	5,766	7,664	8,733	9,492	10,113	10,631	11,079	11,459	11,838	12,149	12,459
100	4,041	5,939	7,008	7,767	8,388	8,906	9,354	9,734	10,113	10,424	10,734
125	3,179	5,076	6,146	6,905	7,526	8,043	8,492	8,871	9,251	9,561	9,872
150	2,316	4,214	5,283	6,042	6,663	7,181	7,629	8,009	8,388	8,699	9,009
175	1,454	3,351	4,421	5,180	5,801	6,318	6,767	7,146	7,526	7,836	8,147
200	591	2,489	3,558	4,317	4,938	5,456	5,904	6,284	6,663	6,974	7,284
212	177	2,075	3,144	3,903	4,524	5,042	5,490	5,870	6,249	6,560	6,870
225		1,626	2,696	3,455	4,076	4,593	5,042	5,421	5,801	6,111	6,422
230		1,454	2,523	3,282	3,903	4,421	4,869	5,249	5,628	5,939	6,249
240		1,109	2,178	2,937	3,558	4,076	4,524	4,904	5,283	5,594	5,904
250		764	1,833	2,592	3,213	3,731	4,179	4,559	4,938	5,249	5,559
260		419	1,488	2,247	2,868	3,386	3,834	4,214	4,593	4,904	5,214
270		74	1,143	1,902	2,523	3,041	3,489	3,869	4,248	4,559	4,869
275			971	1,730	2,351	2,868	3,317	3,696	4,076	4,386	4,697
280			798	1,557	2,178	2,696	3,144	3,524	3,903	4,214	4,524

Determining Boiler Operating Pressure

As previously mentioned, boiler operating pressure is a function of the process's total heat requirement and the restrictions in the distribution line. Most firetube and watertube boilers are designed to have discharge velocities less than 5,000 feet per minuet. This limitation is to prevent priming or carryover of the liquids in the water/steam separation drum, which might occur at higher velocities. Carryover occurs when the surface pressure at the water/steam interface is reduced below operating pressure by the negative pressure effect of accelerated velocities. The physical properties of the water/steam interface dictate the boiler's drum and discharge nozzle size at specific operating pressures to maintain these velocity limitations.

When the boiler operates outside of the limits the water/steam interface rises in level, thus reducing the surface area, which in turn increases the velocity effect. This only serves to amplify the problem and can result in the feedwater pumps failing to keep up with feed demand due to very high amounts of carryover.

Determining Distribution Operating Pressure

Distribution Operating Pressure is a function of how much and how far. This is to say, how much heat energy is required at the end point and how far does it have to travel to get there. The heat energy available is in direct relationship to volume of steam and steaming pressure. However, the issue we are concerned with in determining the operating pressure of the distribution system is the volume of steam to be delivered.

The steam volume required to be transported from the boiler to the point of use heavily impacts distribution operating pressure. The physical properties of steam prove that steam has a different specific volume for each temperature/pressure phase it exists in. As an example 15 PSIG steam has a specific volume of about 13.85 cubic feet per pound, while 100 PSIG steam has a specific volume of only 3.89 cubic feet per pound; a difference of 356%. Thus if I wanted to move equal volumes of 15 PSIG steam as I was 100 PSIG steam at the same pressure drop in the distribution line, it would require a line with 356% greater volume.

Steam velocity also increases as its specific volume or mass increases in the distribution line. Velocities over 5,000 feet per minuet become very audible and should be avoided in occupied spaces without proper hearing protection. It should be noted that some process piping velocities reach as high as 12,000 ft/min. in highly industrialized environments. Thus the steam line environment also helps to determine acceptable velocities.

Other Plant System Considerations

Other considerations in the plant are items such as pressure reducing valves and steam trap capacities at reduced operating pressures. While most steam traps are sized for double the normal operating capacity, pressure reducing stations and flow control valves are not. As an example a 2.0 inch pressure reducing station operating with an inlet pressure of 125 PSIG and reducing to 25 PSIG has a capacity of 7,300 PPH steam. This same valve operating with an inlet pressure of 100 PSIG has a capacity of only 6,000 PPH, a process reduction of 17.80 percent. Smaller valves can suffer even higher loses.

The additional moister content of the steam media may also require the addition of inline steam/water separators in the distribution and process lines. This helps protect the lines and process equipment from damage due to water hammer or erosion from the high velocity water droplets in the wet steam.

Example of System Pressure on Steam Velocity

Steam Velocity is calculated as

$$V = 2.4Q * Vs / A$$

Where V= Velocity
Q= Mass Flow in Pounds Per Hour Steam Flow
Vs = Specific Volume of Steam at the Flowing Pressure
A = The area of the diameter of the pipeline or nozzle

Analysis of a 125 PSIG Design System

Designed Velocity Across the Boiler Outlet			
Rated Boiler Horsepower		**600**	
Boiler Outlet Diameter		**7**	
Current Operating Pressure		**125**	
Feedwater Temperature		**212**	
Steam Volume Cft/#		**3.23**	
Boiler Outlet Velocity		**4170.4228**	Ft./Min.
Nozzle Velocity OK			

Design Velocity in the distribution line	
Distribution line Diameter	**7**
Distribution Velocity Ft./Min.	**4170.4228**
Distribution Velocity OK	

Analysis of 125 PSI Design System operating at 75 PSIG

New Velocity Across the Boiler Outlet			
New Operating Pressure		**75**	
Steam Volume Cft/#		**4.91**	
New Boiler Outlet Velocity		**6339.5591**	Ft./Min.
Danger Outlet Nozzle Velocity Above Safety Limits - Priming and Carry Over Will Occur!			

Distribution Velocity Ft./Min.	**6339.5591**	
Caution Distribution Velocity Abnormally High!		

Analysis of 125 PSI Design System operating at 105 PSIG

New Velocity Across the Boiler Outlet			
New Operating Pressure		**105**	
Steam Volume Cft/#		**3.74**	
New Boiler Outlet Velocity		**4828.9106**	Ft./Min.
Caution Outlet Nozzle Velocity Abnormally High – Priming May Occur!			

Distribution Velocity Ft./Min.	**4828.9106**
Distribution Velocity OK	

As can be seen from the example the 125 PSIG designed system can be readily lowered to operate at 105 PSIG. This is a reduction of approximately 518 Btu per boiler horsepower. As our example is based on an operational load of 600 boiler horsepower this equates to 518Btu/Hr. X 600Bhp = 310,800 BTU per hour of operation.

4,524	BTU @ New Pressure
5,042	BTU @ Current Pressure
(518)	Btu @ Horsepower/Hr Differential

Financial Analysis

Theoretical Savings from Lowering Operating Pressure			
Btu Differential			**(518)**
Boiler Horsepower			**600**
Cost of Fuel			**3.26**
Hrs/Day Operation			**16**
Days/Month/Operation			**22**
$$ Saved or Expended/Mth.			**$ 356.30**
$$ Saved or Expended/Yr.			**$ 4,275.66**

Conclusion

As you can see from the example we have evaluated, decreasing plant operating pressure can help to reduce operating cost, but not without some draw backs. It is important to do a total plant system analysis so that all possible repercussions are addressed.

About the Author

David C. Farthing

Mr. Farthing combines his twenty-eight years of experience in thermal processes with a degree in General Engineering Technology from Oklahoma State University as well as a degree in Business from the University of Central Oklahoma. He is both a practitioner and academic in the field of boilers and thermal process control systems, as Sales Manager for Federal Corporation and adjunct instructor of '*Boiler Construction, Operations, and Maintenance'* for Oklahoma State University, Oklahoma City campus.

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