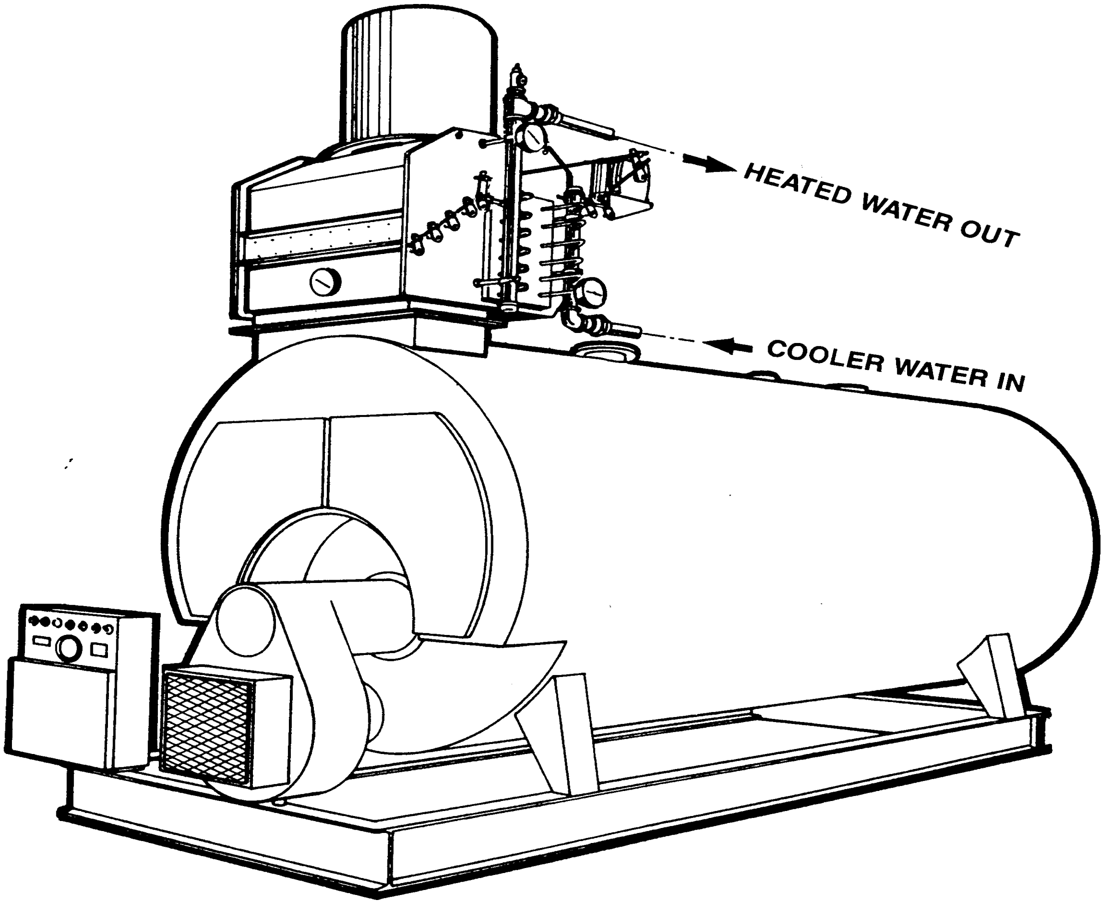
Tech Paper #901

# Improving Boiler Room Efficiencies

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




*Drawing Courtesy of Heatmizer Corporation*

# ECONOMIZERS

Presented by
**David C. Farthing**
**Federal Corporation**
A proud Oklahoma partner for over 80 years!
*Providing over 80 years of boiler and boiler room experience.*

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## 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 thermal optimization and energy savings through the use of thermal recovery equipment. The strategy presented will have both technical and economic feasibility discussions presented with it.

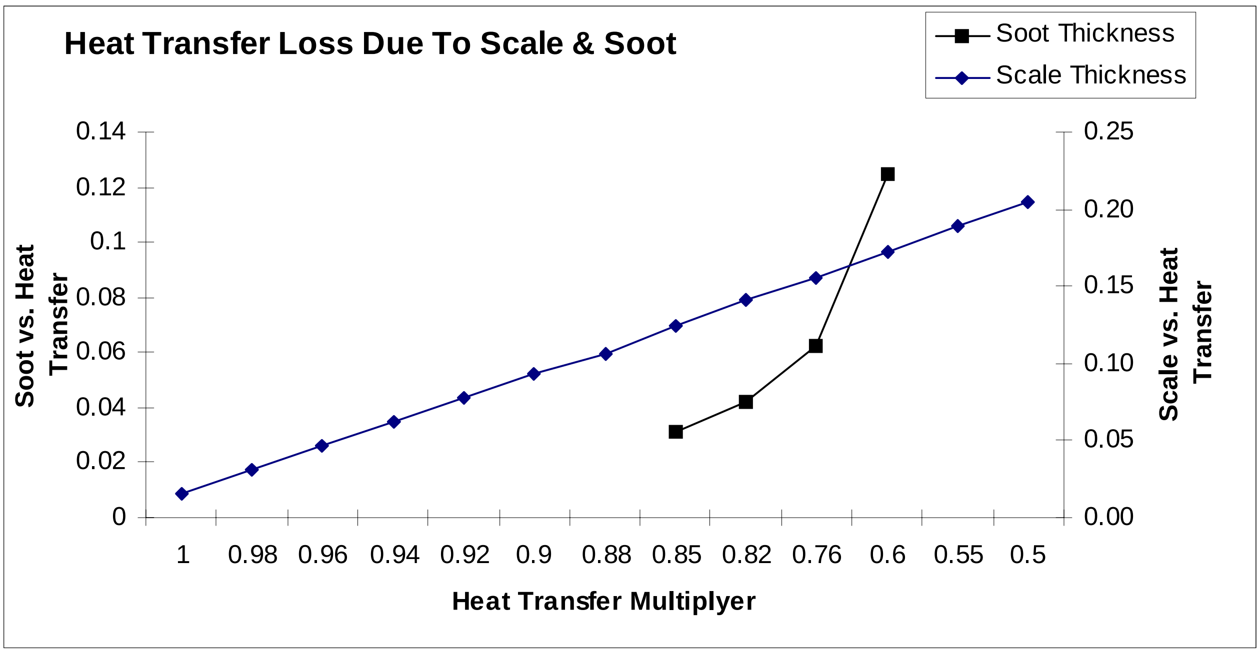
## Steam Plant Optimization & Automation

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.






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.

# Economizers

### *Economizers, What they are and how they work.*

Economizers are thermal mechanical apparatuses that scavenge the waste heat from thermal exhaust flue gases by passing the exhaust effluent through heat transfer surfaces to transfer some of the waste heat to a process media. In the boiler room most economizers transfer their waste heat to either the feedwater or combustion air pre-heaters. This paper focuses on feedwater economizers. A Feedwater Economizer is one of the most economic additions that can be made to any boiler room. The economizer's simple technology and lack of moving parts gives it a very long and relative maintenance free life cycle.

The preheating of boiler feedwater is the most common method of utilizing the waste heat captured from boiler flue gases. As the feedwater flow, the boiler load, and the flue gases generated are all in proportion, there is a ready 'heat sink' in the feedwater to absorb the recovered heat from the flue gases. It must be noted that economizers are used with modulating feedwater strategies to prevent overheating and sudden flashing, which would occur with on/off feedwater applications.

Boilers are rated from and at 212 degrees 'F'. If a boiler is provided with feedwater above 212 degrees then the firing rate required to meet horsepower is lessened resulting in fuel savings. Feedwater Economizers capture waste heat from the boiler stack gases and transfer it to the feedwater. This heat gain raises the temperature of the feedwater thus lowering the amount of BTU input required at the burner to accomplish rated horsepower. Note the example below.

### *Btu vs. Feedwater Tables*

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 |

The analysis below exemplifies the direct effect of feedwater temperature on boiler output. Note the factory rating at 212 degrees versus the original as observed feedwater temperature of 180 degrees. This sub-cooled feedwater temperature resulted in a loss of more than 3% of the boiler output, which directly relates to required input to gain operating horsepower.

By incorporating a heated deaerator and an economizer the user was able to recover the original losses and increase overall operating efficiencies.

| | Factory Design | As Observed | Deaerator First Recovery | Typical Economizer |
|---|---|---|---|---|
| **Name Plate Rated Boiler BHP** | 600 | | | |
| **Name Plate BTU Input** | 25,868,332.00 | | | |
| **Observed Feedwater Temp** | 212 | 180 | 225 | 264 |
| **Fuel Cost Per Therm** | $ 0.326 | | | |
| **Hours Day Operated** | 24 | 24 | 24 | 24 |
| **Days per Month** | 28 | 28 | 28 | 28 |
| **Name Plate BTU Output** | 20,079,000.00 | | | |
| **Calculated Efficiency (Input/Output)** | 77.62 | | | |
| **Calculated Bhp** | 600.00 | | | |
| **Rated Steam PPH at 100% Firing** | 20700 | | | |
| **BTU Lost/Gained Per Hour** | 0.00 | -662,400.00 | 269,100.00 | 1,076,400.00 |
| **Boiler HP Lost or Gained/ Hr.** | 0.00 | (19.79) | 8.04 | 32.16 |
| **Net Boiler Horsepower** | 600 | 580 | 608 | 632 |
| **Net Steam Output** | 20700.0 | 20017.1 | 20977.4 | 21809.7 |
| **Net Efficiency** | 77.62 | 75.06 | 78.66 | 81.78 |
| **Percent Increase/Decrease BHP** | 0.000% | -3.299% | 1.340% | 5.361% |

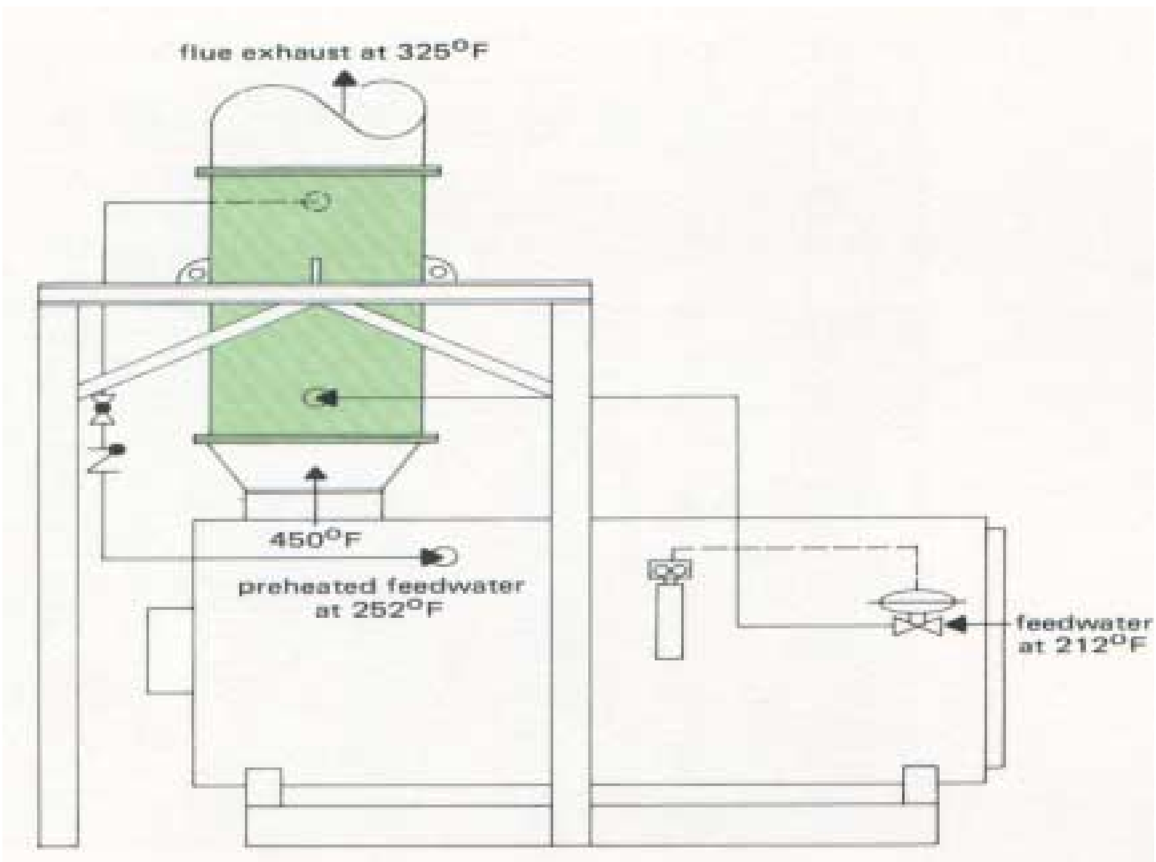


Economizers can save as much as 1-% fuel cost per 10-degree rise in feedwater temperature, and most economizers raise feedwater temperature by at least 20-30 degrees.

Economizers also lower stack temperatures, so be diligent in the selection and application of them. Don't make the mistake of implementing an economizer program to save fuel and wind up killing the stack and furnace. Proper economizer sizing is important to prevent the production of stack born acids.

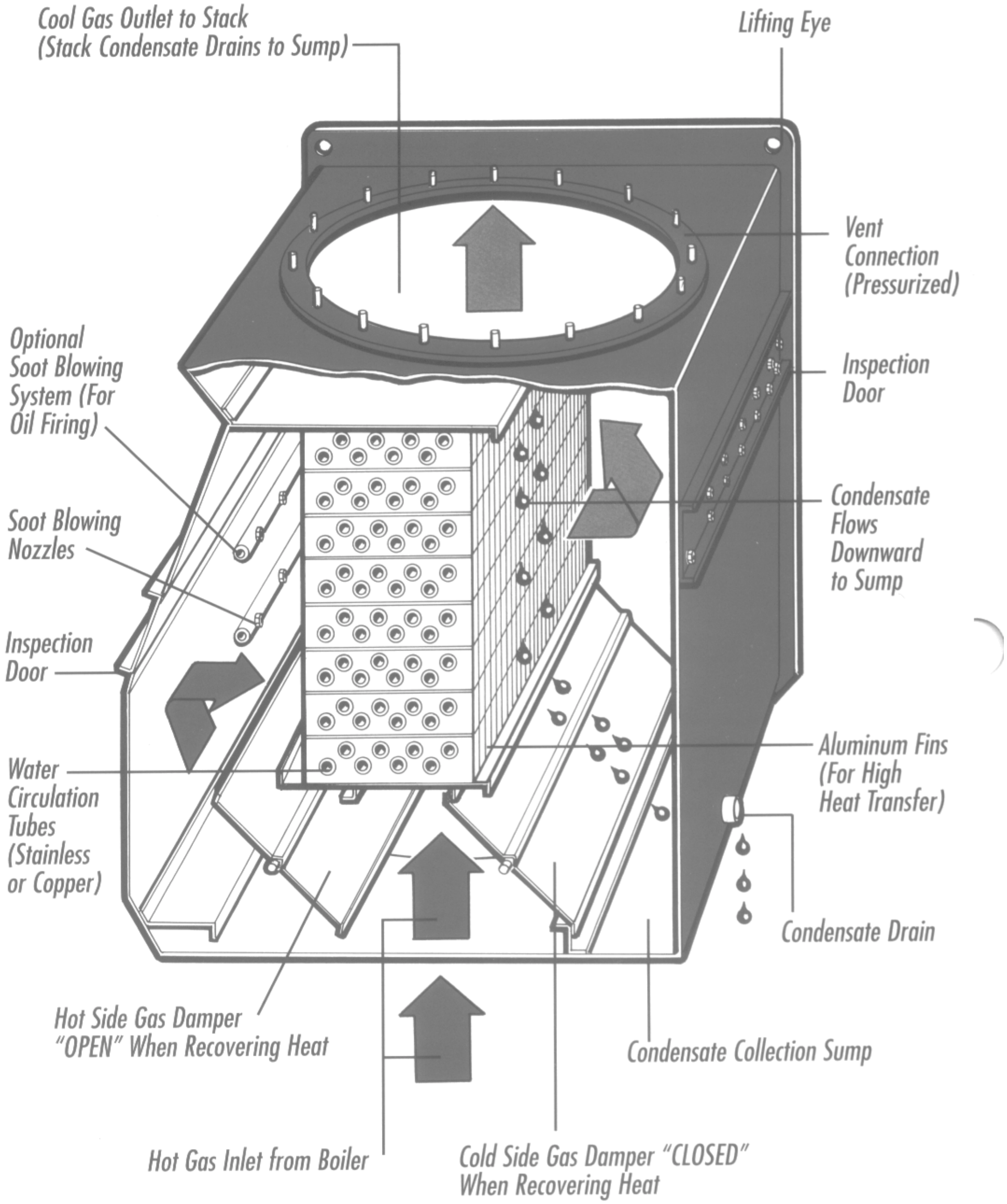
### ***Economizer Construction***

Economizers are designed in two basic construction configurations. The traditional economizer is constructed of steel boiler tubes passing through a tube sheet, much like a firetube boiler, or manifolded together like the radiator in your car. As the exhaust effluent passes through or around the tubes it transfers its heat to the feedwater in the shell side of the economizer. This design relates to an average efficiency of 45-75 percent. Rugged and heavy this design typifies most economizer installations.




Typical Vertical Counter Current Economizer, *Courtesy E-Tech Corporation*

An alternate economizer design gaining wide acceptance is the horizontal high-efficiency condensing economizer. This design is constructed of a stainless steel exhaust chest and thin-wall high tensile stainless heat transfer tubes. Water flowing through the tubes, which are mounted in the exhaust chest, absorbs the transient heat of the exhaust gases as it washes over the tubes. Condensing Economizers may reach efficiencies as high as 85% in very low velocity stacks. A condensate breech elbow and drain is required in condensing applications.



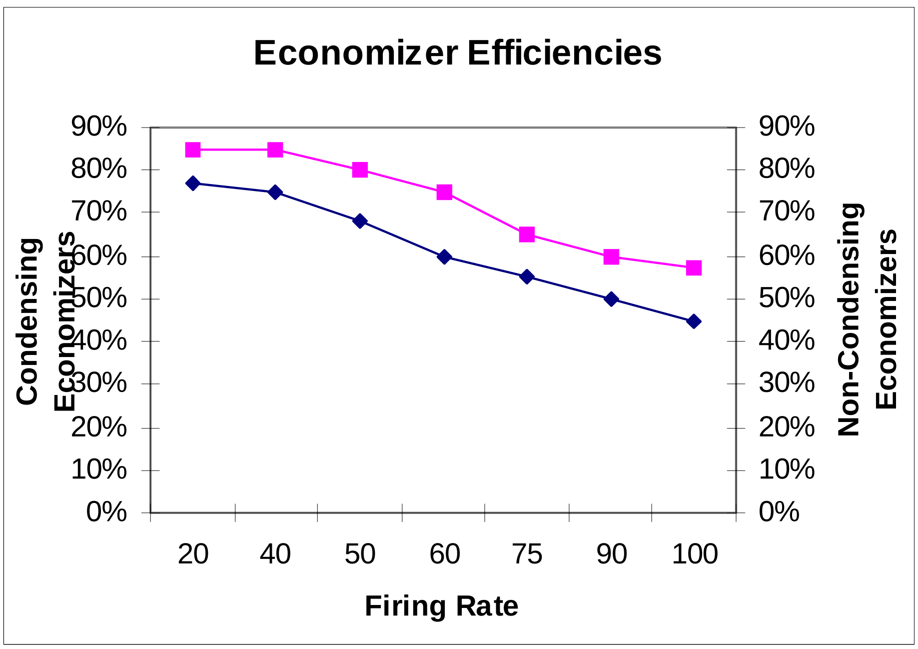

Typical Condensing Economizer schematic, *Courtesy Heatmizer Corporation*

### ***Economizer Efficiency***

Economizer Efficiency is in direct relationship to equipment design and stack gas velocities. While it is true that the relationship between feedwater flow, firing rate and stack gas flow is relatively proportional, what must be understood is the relationship between stack gas velocity and contact time with the economizer's heating surfaces.

Velocity <u>increases</u> through the stack as firing rate increases, which results in a <u>decrease</u> in contact time with the economizer heating surfaces. This decrease in contact time is a result of the increased velocity in the stack, which causes the exhaust gases to flow past the economizer faster than the heating surfaces can absorb the transient heat. This is due to the fact that more gases of combustion are passing through a fixed opening, the stack diameter, as the firing rate increases. Like any fixed orifice, as mass flow increases so does the velocity.

At lower firing rates the efficiency of the economizer may reach as high as 85 percent (condensing), while at normal firing rates it may be as low as 45 percent (vertical firetube). Because of the high efficiencies which can be reached at lower firing rates, entering feedwater temperatures must be maintained as high as possible to avoid condensing in the economizer. The chart below shows typical economizer efficiencies at different firing rates.






## Stack Temperature, Stack Height, and Acid Rain

An average dry-back three-pass firetube boiler will have an exhaust temperature at the breech of about 450 degrees 'F' at high fire, whereas a four pass wet back firetube could have an exhaust temperature of only 350 degrees. A typical water-tube boiler will have an exhaust temperature of about 550 degrees 'F''. These elevated temperatures are the perfect breeding ground for highly corrosive effluents.

The gases of combustion coming off of any fossil-fueled furnace contain oxygen, carbon dioxide, carbon monoxide, sulfur dioxide and free water. When carbon dioxide is combined with water, it turns to carbonic acid. Sulfur dioxide, when combined with water turns to sulfuric acid. This is the basis of acid rain. If these gases are allowed to condense in the stack, then they start producing acid rain in the stack and furnace of the fired device. End result... rotted-out stack, furnace and, in some very extreme cases, water and firetube corrosion damage.

These gases can start condensing at temperatures as high as 200 degrees 'F'. Thus, most furnace and boiler manufacturers specify exhaust temperatures not to fall below 325 degrees 'F'. As an economizer can readily extract 20-30 degrees of temperature from a stack, economizer sizing and thermal efficiencies are real considerations in product selection.

### *Acid Dewpoint Tables*

Acid Dewpoint Temperature of Various Fuels

| Fuel | Acid Dewpoint Temperature | Minimum Allowable Stack Temperature | Minimum Allowable Feedwater Inlet Temp. |
|---|---|---|---|
| Natural Gas | 150 | 250 | 210 |
| #2 Oil | 180 | 275 | 210 |
| Low Sulfur Oil | 200 | 300 | 220 |

*Courtesy of* Kewanee Boiler Manufacturing

### *Economizer Location and Draft Considerations*

The location of the economizer in the stack is critical, as stack gases tend to cool as they approach the stack outlet. This cooling is due to thermal loses in the stack and the mixing of fresh air in the stack discharge. Thus economizers should be installed as close to the furnace breech as is practical.

It should be noted that the installation of an economizer places certain flow restrictions on the furnace resulting in higher furnace pressures. This increase in furnace pressure is normally 2-4 inches of water column. Sufficient draft is needed to overcome the resistance caused by the economizer. On some very large forced-draft applications and in some condensing economizers an induced draft fan is used to create the necessary draft. Suffice it to say that all atmospheric burner/boiler applications and unsealed power-burner applications must incorporate an induced draft fan to insure safe and efficient removal of the combustion gases.

## Example of a Typical Economizer Application

| | |
|---|---|
| **Boiler Rated Horsepower** | 600 |

| | |
|---|---|
| **Boiler Rated Efficiency** | 77.60% |
| Max. Boiler Fuel Input at Rated Eff. | 25,875,000 |
| **Normal Firing Rate (NFR)** | 88.0% |
| **BTU Output @ NFR** | **17,669,520.00** |
| Flue Gases Mass Flow #/Hr @100% | 25,329.04 |
| **Flue Gases Mass Flow #/Hr @ NFR** | **22,289.55** |
| **Entering Feedwater Temperature** | 225 |
| **Net Operating Efficiency** | **78.64%** |
| **Entering Stack Temperature** | 475 |
| Temperature Rise Across Econ. | 250 |
| **Economizer Efficiency @ NFR** | **60%** |
| **Flue Gas Specific Heat @ NFR** | **0.2715** |
| **Net BTU Recovered/Hr** | **907,742.05** |
| **Exiting Feedwater Temperature** | **264** |
| **Exiting Stack Temperature** | **434** |
| **Gain in Efficiency** | **3.51%** |
| **New Net Calculated Efficiency** | **82.15%** |
| **Fuel Cost per Therm** | **$ 0.326** |
| Fuel Savings/Hr | **$ 2.96** |
| **Hours/Day Operation** | 24 |
| **Days/Month Operation** | 22 |
| **Total Annual Savings** | **$ 18,749.74** |
| Economizer Equipment Cost | $ 26,800.00 |
| Economizer Estimated Installation | $ 10,720.00 |
| **Simple Pay-Back in Years** | **2.00** |

## Financial Analysis of Typical Economizer Installation

**Financial Analysis of a Project**

| | |
|---|---|
| Project Name | **600 HP Economizer 88% Firing Rate** |
| Initial Cost of Investment Materials | **$ 26,800.00** |
| Initial Cost of Investment Installation | **$ 10,720.00** |
| Annual Pay Back Expected from this investment | **$ 18,749.74** |
| Base Line Years to Payout | **2.00** |
| Fixed Cost of Money in percent to be used for this exercise | **6.85%** |
| How many Years will the Project be Amortized over? | **5** |
| First Year Cost of Money | **$ 1,285.76** |
| Second Year Cost of Money | **$ 642.88** |
| Third Year Cost of Money | **$ 428.59** |
| Fourth Year Cost of Money | **$ 321.44** |
| Fifth Year Cost of Money | **$ 257.15** |
| Estimated Cost of Perishables during first five years of ownership | **$ -** |
| **NET Years to Payout** | **2.16** |
| **Expected Life Span of Investment** | **25.00** |
| ***Total Dollars Returned Over Life of Investment** | **$ 428,287.67** |

## Conclusion

As you can see from the example we have evaluated, increasing plant efficiencies does pay back. It is important however, to do a total financial analysis of the project for the actual payback period. This is especially important when the cost of the total project; materials, installation, and documentation is to be considered.

## *About the Author*

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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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