Boiler Energy Efficiency & Overview of Economizers

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Outline of Presentation

1. Steam System Overview
2. Energy Efficiency Opportunity Areas
3. Energy Efficiency Examples
4. Overview of Economizers
5. Further Sources of Information

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Issues for Boiler Plant Operators

1. **Increasing Cost of Fuel and Operation**

2. **Difficult to get funding for “long” payback projects**
3. **“Global Warming” – reduce GHG emissions**
4. **Other Environmental concerns – reduce NOx and other emissions**

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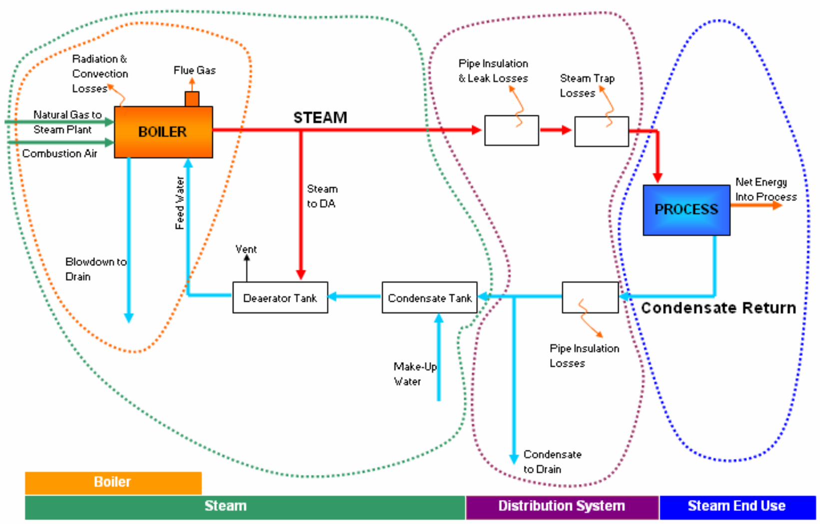
Steam System Schematic



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Key Savings Opportunities - Generation

Opportunity	Description
Minimize excess air	Reduces the amount of heat lost up the stack
Clean boiler heat transfer surfaces	Improves heat transfer from gases to the steam
Install heat recovery equipment	Recovers heat and transfers it back to the feedwater, combustion air or process water
Improve water treatment to minimize boiler blowdown	Reduces blowdown and lost energy
Recover energy from boiler blowdown	Transfers energy back to make-up water or into system
Optimize boiler selection in multiple-boiler plants	Results in operation of the most efficient boilers
Optimize deaerator vent rate	Minimizes lost steam

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Key Savings Opportunities – Distribution

Opportunity	Description
Repair steam leaks	Minimizes steam loss
Minimize vented steam	Minimizes steam loss
Pipe, valve, fittings insulation	Reduces energy loss
Steam trap maintenance program	Reduces live steam being passed into condensate system
Isolate steam from unused lines	Reduces energy loss
Utilize backpressure turbines instead of PRVs	More efficient use of energy in steam

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Key Savings Opportunities – Condensate

Opportunity	Description
Increase condensate return	Recovers the thermal energy in the condensate return as well as reducing costs for chemicals and make-up water
Use high-pressure condensate to make low pressure steam	Uses the available energy in the returning condensate

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Example: Distribution– Steam Trap

- Basis:
  - Trap with 1/8 inch diameter orifice
  - 100 psig steam
  - Operation: 8760 hours/year
  - Steam Cost: $ 8/ thousand lb steam
- Results:
  - Loses 53 lb/h steam
  - Annual value = $ 3,700 /year

Source: USDOE “Improving Steam System Performance”

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Example: Distribution – Steam Line Insulation

- Basis:
  - 8 in. diameter steam line; 100 ft.
  - 300 psig steam pressure
  - 8760 hours/year
  - $ 8/ thousand lb steam

- Results:
  - Bare Pipe Loss: 2030 MMBTU/yr
  - Savings with insulation: $ 14,600/yr (at 90 % effectiveness)

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Example: Generation– Combustion Efficiency

- Combustion Efficiency:

Excess Air (%)	Excess O2 (%)	Flue Gas T less Combustion Air T (oF)		
		200	400	600
9.5	2.0	85.4	80.8	76.0
15.0	3.0	85.2	80.4	75.4
28.1	5.0	84.7	79.5	74.0
44.9	7.0	84.1	78.2	72.1
81.6	10.0	82.8	75.6	68.2

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Savings from a Utility's Steam DSM Program

Project Type	# of Projects	% of Identified Savings	Average Simple Payback (years)
Combustion Improvements	89	12.4 %	0.5
Capital Projects	69	12.4	3.4
Heat Recovery, Economizer	137	30.4	0.9
Operating Practice Changes	37	14.4	0.9
Stm Distribution, Condensate Return Improvements	51	7.5	1.6
Bldg HV Improvements	14	4.9	0.6
Metering & Monitoring	20	3.1	0.9
Insulation Improvements	20	4.7	1.5
Steam Pressure Reduction	24	4.4	0.2
Others (incl. water chemistry)	30	5.5	1.5

Based on 92 detailed audits; $ 11.27/MMBTU; $ 43 million total identified savings

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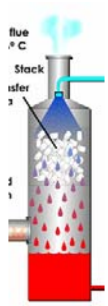
Overview of

ECONOMIZERS



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Economizers

- Flue gas temperature typically over 400 oF without economizers
- Economizers recover energy to preheat make-up or feedwater
- Sizing based on volume of flue gas, temperature, maximum allowable pressure drop, fuel chemistry, and amount of energy to be recovered

- Conventional: final stack temperature above dew point temperature (utilize sensible heat only)
- Condensing: recover energy from latent (primary) and sensible heat

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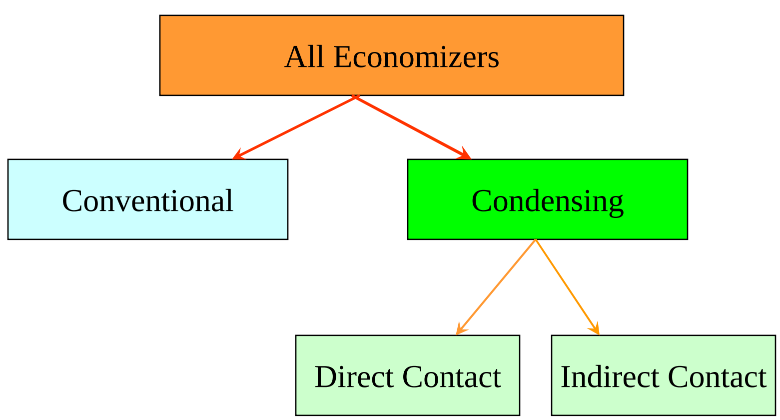
Economizer Types



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Economizers – Impact on Efficiency

System	Comb. Efficiency (@ 4% excess O2)	Stack Gas T (oF)
Boiler without economizer	78 – 83 %	350 – 550
Boiler with FW economizer	84 – 86 %	250 – 300
Boiler with FW and condensing economizers	92 – 95 %	75 – 150

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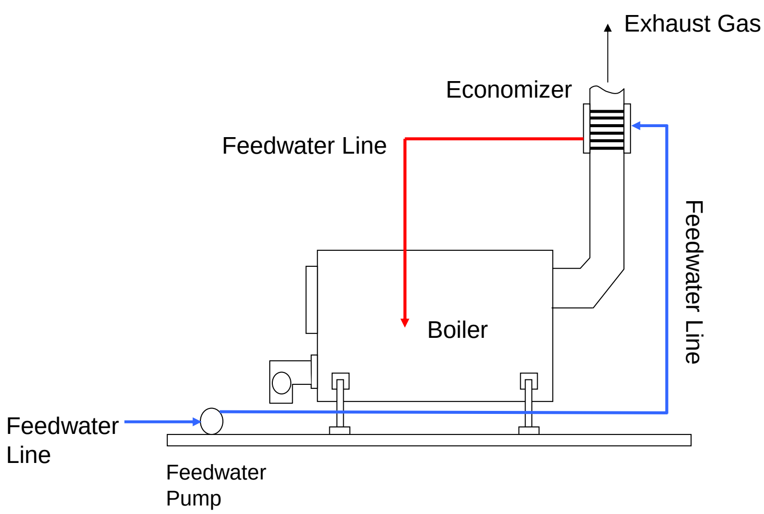
Feedwater Economizer



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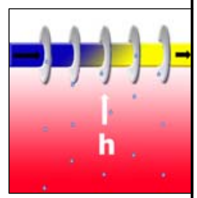
Condensing Heat Recovery Basics

- Water in products of combustion is vaporized and absorbs energy
- Latent heat represents approximately 10% of the energy content of the input fuel
- Heat of vaporization can be recovered if flue gases are cooled below water dew point (condensing conditions)
- Condensing economizer recovers both heat of condensation (latent heat) and sensible heat
- Water chemistry must be considered to avoid carbonic acid corrosion (condensed vapor)



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Basic Concepts of Condensing Heat Recovery

When one molecule of CH4 is burned, it produces 2 molecules of H2O

$$CH_4 + 2O_2 + 7.52\,N_2 \Rightarrow CO_2 + 2H_2O + 7.52\,N_2$$

CH_4 ↓ 16 lb, 1 lb

$2H_2O$ ↓ 36 lb, 2.25 lb

One lb of CH_4 produces 2.25 lb of $2H_2O$

One lb of Natural Gas (1005 Btu/ft3) produces 2.14 lb of water

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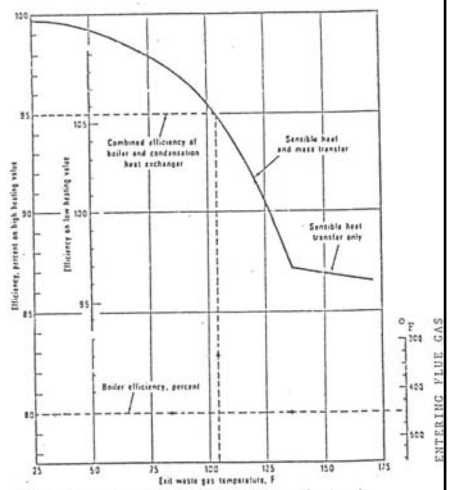
Efficiency Varies with FG Temperature Leaving Economizer

- X-axis: Exit Flue Gas Temp
- Y-axis: Efficiency – percent of high heating value
- Latent heat transfer starts at 137 F



2 Condensation heat exchanger performance in terms of exit waste gas temperatures. Based on natural gas from the Lacq source in France burned with 15 percent excess air.

Heating/Piping/Air Conditioning, October 1974

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Condensing Economizers - Types

- Indirect
  - Shell and tube or tubular heat exchangers
  - Must be designed to withstand corrosion from condensed water vapor
- Direct Contact
  - Concurrent spray chamber
  - Liquid droplets cool the stack gas, condense and disentrain the water vapor
  - Chamber may have a packing to improve contact surface area
  - Mist eliminator required to prevent carry-over of small droplets

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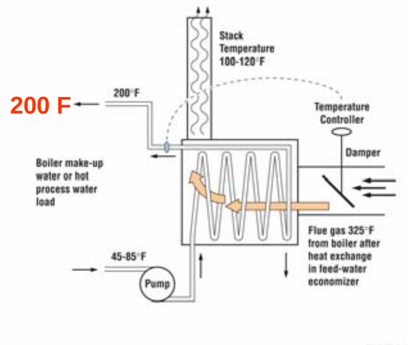
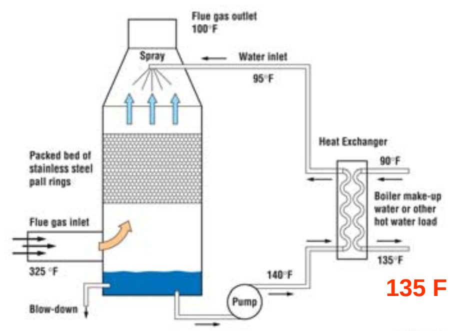
Types of Condensing Economizers

Indirect Contact



Direct Contact



Source: DOE Condensing Economizers Tip Sheets

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Additional Sources of Information

- Energy Solutions Center: www.CleanBoiler.org
- U.S. Department of Energy – Industrial Technologies Program
  - “Improving Steam System Performance – A Sourcebook for Industry”
  - Website: http://www1.eere.energy.gov/industry/bestpractices/for_technical.html

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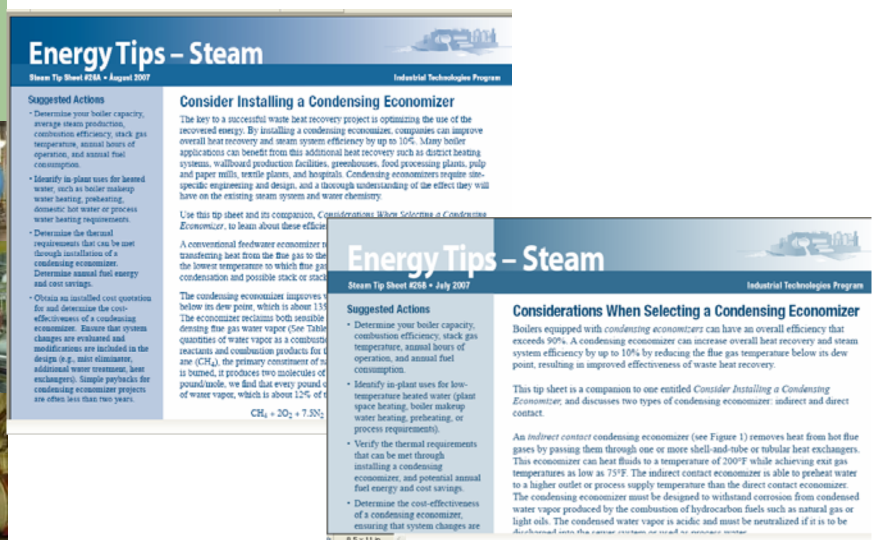
Additional Sources of Information – DOE Best Practices Steam Tip Sheets



Energy Tips – Steam

Steam Tip Sheet #26A • August 2007

Industrial Technologies Program

Suggested Actions

- Determine your boiler capacity, average steam production, combustion efficiency, stack gas temperature, annual hours of operation, and annual fuel consumption.
- Identify in-plant uses for heated water, such as boiler makeup water heating, preheating, domestic hot water or process water heating requirements.
- Determine the thermal requirements that can be met through installation of a condensing economizer. Determine annual fuel energy and cost savings.
- Obtain an installed cost quotation for and determine the cost-effectiveness of a condensing economizer. Ensure that system changes are evaluated and modifications are included in the design (e.g., mist eliminator, additional water treatment, heat exchangers). Simple paybacks for condensing economizer projects are often less than two years.

Consider Installing a Condensing Economizer

The key to a successful waste heat recovery project is optimizing the use of the recovered energy. By installing a condensing economizer, companies can improve overall heat recovery and steam system efficiency by up to 10%. Many boiler applications can benefit from this additional heat recovery such as district heating systems, wallboard production facilities, greenhouses, food processing plants, pulp and paper mills, textile plants, and hospitals. Condensing economizers require site-specific engineering and design, and a thorough understanding of the effect they will have on the existing steam system and water chemistry.

Use this tip sheet and its companion, *Considerations When Selecting a Condensing Economizer*, to learn about these efficie

A conventional feedwater economizer r
transferring heat from the flue gas to the
the lowest temperature to which flue gas
condensation and possible stack or stack

The condensing economizer improves w
below its dew point, which is about 13
The economizer reclaims both sensible
densing flue gas water vapor (See Table
quantities of water vapor as a combusti
reactants and combustion products for t
ane (CH_4), the primary constituent of n
is burned, it produces two molecules of
pound/mole, we find that every pound o
of water vapor, which is about 12% of t

$CH_4 + 2O_2 + 7.5N_2$

Energy Tips – Steam

Steam Tip Sheet #26B • July 2007

Industrial Technologies Program

Suggested Actions

- Determine your boiler capacity, combustion efficiency, stack gas temperature, annual hours of operation, and annual fuel consumption.
- Identify in-plant uses for low-temperature heated water (plant space heating, boiler makeup water heating, preheating, or process requirements).
- Verify the thermal requirements that can be met through installing a condensing economizer, and potential annual fuel energy and cost savings.
- Determine the cost-effectiveness of a condensing economizer, ensuring that system changes are

Considerations When Selecting a Condensing Economizer

Boilers equipped with *condensing economizers* can have an overall efficiency that exceeds 90%. A condensing economizer can increase overall heat recovery and steam system efficiency by up to 10% by reducing the flue gas temperature below its dew point, resulting in improved effectiveness of waste heat recovery.

This tip sheet is a companion to one entitled *Consider Installing a Condensing Economizer*, and discusses two types of condensing economizer: indirect and direct contact.

An *indirect contact* condensing economizer (see Figure 1) removes heat from hot flue gases by passing them through one or more shell-and-tube or tubular heat exchangers. This economizer can heat fluids to a temperature of 200°F while achieving exit gas temperatures as low as 75°F. The indirect contact economizer is able to preheat water to a higher outlet or process supply temperature than the direct contact economizer. The condensing economizer must be designed to withstand corrosion from condensed water vapor produced by the combustion of hydrocarbon fuels such as natural gas or light oils. The condensed water vapor is acidic and must be neutralized if it is to be

8.5 x 11 in

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