Maximize Boiler Heat Recovery with Condensing Economizers

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Outline

1. Review basic concepts of condensing heat recovery
2. Types of condensing economizers
3. Energy saving potential
4. Case studies
5. Potential applications
6. Key considerations
7. Major barriers to market penetration
8. Concluding remarks
Condensing Economizer Increases Boiler Efficiency Over 90%
When one molecule of CH$_4$ is burned, it produces 2 molecules of H$_2$O.

\[
\text{CH}_4 + 2\text{O}_2 + 7.52\ \text{N}_2 \rightarrow \text{CO}_2 + 2\text{H}_2\text{O} + 7.52\ \text{N}_2
\]

One lb of CH$_4$ produces 2.25 lb of H$_2$O

One lb of Natural Gas (1005 Btu/ft$^3$) produces 2.14 lb of water
Basic Concepts of Condensing Heat Recovery

- Water in products of combustion is vaporized due to heat of combustion
- Water vapors absorb about 10% of fuel input
- Energy lost to atmosphere with exhaust gases through stack
- Heat of vaporization can be recovered if flue gases are cooled below water dew point
- When water vapour condenses, it releases heat of vaporization
- Condensing economizer recovers both heat of condensation (latent heat) and sensible heat
Dew point varies with O2, CO2 and H2O in products of combustion

Example: For 4% O2, CO2 is 9.5%
Dew Point = 134 F

Source: North American Combustion Handbook
Available Heat Varies with FG Temperature Leaving Economizer

Heat of Condensation vs. Flue Gas Temperature
(Source: Sofame)

\[ y = -0.0001x^3 + 0.0134x^2 - 0.7686x + 108.23 \]

\[ R^2 = 0.9994 \]
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
- Excess air 15%
- Entering flue gas temp 450 F
- Exit Flue gas temp 105 F
- Efficiency w/o economizer 80%
- Efficiency with condensing economizer 95%

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
Types of Condensing Economizers

Indirect Contact

Direct Contact

Source: DOE Condensing Economizers Tip Sheets
Figure 1. Simplified Schematic of MENEX DCHR System
Energy Saving Potential with Condensing Economizer

Example

- Flue Gas 300 F
- Boiler FW 260 F
- Natural Gas 115,672 ft³/hr
- Boiler Excess O2: 4%
- Efficiency: 83%
- Steam Production 100,000 pph @ 100 psig
- Boiler Make-up Water 50%, (52,083 pph)
- Deaerator/Condensate Tank
- Condensate Return
- Steam 4%
- Boiler Blowdown 4%
- Condensing Economizer
- 300 F
- 55 F
- 200 F
- 115,672 ft³/hr
Available Heat Varies with FG Temp Leaving Condensing Economizer

Heat Available at FGT 75 F, 100 F, 125 F, 150 F
MUW T 55 F

Heat Available (MMBtu/hr)

- Flue Gas Temp Leaving Condensing Economizer (F)
- Latent Heat
- Sensible Heat

- 75 F: 6.46, 9.51 MMBtu/hr
- 100 F: 5.75, 7.00 MMBtu/hr
- 125 F: 5.03, 7.04 MMBtu/hr
- 150 F: 4.31 MMBtu/hr
Recovered Heat Depends on Heat Sink Size

- **Heat Available @ 100 F Exit Temp, 55 F MUW Temp**
- **Heat Recovered: MUW Rate 25%, 50%, 75%, 100%**
## Gas Saving Potential

<table>
<thead>
<tr>
<th>Description</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Steam production</td>
<td>100,000 pph</td>
</tr>
<tr>
<td>Make-up water flow rate</td>
<td>50%</td>
</tr>
<tr>
<td>Make-up water temperature entering condensing economizer</td>
<td>55 °F</td>
</tr>
<tr>
<td>Make-up water temperature leaving condensing economizer</td>
<td>200 °F</td>
</tr>
<tr>
<td>Flue gas temperature leaving condensing economizer</td>
<td>100 °F</td>
</tr>
<tr>
<td>Energy recovered</td>
<td>7.55 MMBtu/hr</td>
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<tr>
<td>Boiler operating hours</td>
<td>8000 hrs</td>
</tr>
<tr>
<td>Gas cost</td>
<td>$8/MMBtu</td>
</tr>
<tr>
<td>Energy cost savings</td>
<td>$582,000</td>
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</table>
Typical Applications

- Industries with steam boilers, requiring large amount of hot water such as make-up, washing, process, DHW
- Best Candidates:
  - Textile, commercial laundries
  - Food and beverage
  - Breweries
  - Non-integrated paper mills
  - Chemicals
  - District heating
  - Large hospitals
  - Green houses
Case Study: Indirect Condensing Economizer
Menu Foods – Pet Food Mfg, Toronto
Enbridge Customer

- Two 350 HP coil tube boilers, 105 psig saturated steam
- 100% boiler make-up water
- 5 day x 24 hr operation
- ConDex condensing economizer system installed on roof
- Pull exhaust from two stacks into one common duct feeding Condex
Case Study: Indirect Condensing Economizer
Menu Foods – Pet Food Mfg, Toronto
Enbridge Customer

System heats boiler make up water from 65 F up to 165 F

At maximum load the system recovers 2,541,000 Btu/hr

Projected Gas savings: $190,000

Payback: 1.4 yrs
Case Study: Indirect Condensing Economizer

W.O. Hospital, Greater Toronto Area
Enbridge Customer

ConDex Economizer installed to recover waste heat from 3 x 450 HP firetube boilers.

Two Stages of separate heat recovery sections heat:
- bldg heating loop water (160 to 190 F)
- boiler make up water (45 up to 175 F)

Energy saving: 4,293,800 Btu/hr

Annual cost savings: $421,900

Installed payback: 8.5 months
Case Study: Indirect Condensing Economizer
Bunge North America, USA

- ConDex System heats 183 GPM of boiler make up water from 60 F up to 185 F.
- Exit flue gas temperature cooled to 105 F.
- System recovers avg. 11,200,000 Btu/hr
- Annual savings delivered: $1,035,000.00
- Fuel saving: 8.75% of fuel cost
- Payback less than 6 months

Source: Combustion and Energy System, Canada
Menex system installed on two 75,000 pph 800 psig saturated steam boilers

Steam Production
- 95,000 pph summer
- 130,000 pph winter

Installed after existing FW economizer

Preheat boiler make-up water to 135 F

Installed cost: $600,000

Annual savings: $400,000

Payback: 1.5 yrs

Source: Menex Inc., Canada
Case Study: Direct Contact Condensing Economizer
Dial Corporation, Chicago area

Source: Menex Inc., Canada
Key Considerations

- Establish how much heat is available
  - Existing FW economizer, Flue gas temp, excess O2, steam production, gas consumption, hours of operation
- Is there sufficient heat sink available
  - Boiler make-up water,
  - Domestic hot water
  - Process water
- Entering temperature of heat sink must be below dew point to cause condensation
- Evaluate impact on existing system including blow down, flash steam, DA, water treatment etc.
- Fuel used
Key Considerations

- Space for installation, stacks, icing due to plume impingement, indoor outdoor installation etc.
- Cost savings, installed cost, payback
- Direct versus Indirect?
  - site specific
  - customer preference
  - Cost
  - temp requirement
  - Application
  - heat sink etc.
Major Barriers for Market Penetration

- Not an “off-the-shelf” technology. Each application is an engineered solution
- Requires good understanding of technology and its application
- Needs a suitable heat sink. Small amounts of make-up water (25%) capture only a small portion of available heat
- Project approval faces same issues as any other steam and boiler energy efficiency related projects. Steam is considered a “necessary evil” and does not get same attention as production and product quality
- Initial work conducted in 80’s carries stigma related to Sulfur induced corrosion which is not an issue with natural gas
Concluding Remarks

• Condensing heat recovery is a proven, commercially available cost effective technology

• Offers significant un-tapped energy saving potential for boiler applications. Could be applied to recover latent heat from paper machine hoods, dryers and gas turbine/HRSG exhaust.

• Natural gas prices above $5 per MMBtu offer attractive payback

• Need to increase awareness of technology and its applications.
Concluding Remarks

- Need to include condensing economizer as part of a standard steam plant assessment
- Organizations such as ESC, DOE, NRCan, natural gas utilities can help increase awareness
- ESC workshops and DOE condensing economizer tip sheets offer significant help to increase awareness
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.

A conventional feedwater economizer reduces steam boilertwater heat from the flue gas to the boiler feedwater. The lowest temperature to which flue gas can be cooled is the condensation point for steam (atmospheric pressure). Above this temperature, steam can be condensed into water without removing any heat. Below this point, there is a temperature range between the condensation point and the dew point, during which the flue gas contains heat that can be recovered.

The condensing economizer improves waste heat recovery below the dew point, which is about 135°F for products of combustion that are mostly nitrogen, and 160°F for products of combustion that contain carbon. The economizer reduces both sensible heat from the flue gas and latent heat of water vapor (See Table 1). All water vapor reactants and condensation products are the same as (CH₄), the primary constituent of natural gas. When water vapor is burned, it produces two molecules of water vapor. With this information, we find that every pound of methane fuel corresponds to 2 pounds of water vapor, which is about 12% of the total enthalpy.

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 a tube and tube bundle heat exchangers. This economizer can heat flue gases 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 discharged into the waste system or used as process water.
## Major Manufacturers

### Indirect Contact Economizers
- **Combustion and Energy System, Toronto, Canada**
  - [www.combustionandenergy.com](http://www.combustionandenergy.com)
- **CHX Corporation, Clifton Park, NY**
  - [www.chx.com](http://www.chx.com)
- **Sidel System USA, California**
  - [www.sidelsystems.com](http://www.sidelsystems.com)

### Direct Contact Economizers
- **Direct Contact Inc. Renton, WA**
  - [www.dciheat.com](http://www.dciheat.com)
- **Kemco System**
  - [www.kemcosystems.com](http://www.kemcosystems.com)
- **Menex, Toronto, Canada**
  - Ph: (905) 276-1774
- **Sofame, Montreal, Canada**
  - [www.sofame.com](http://www.sofame.com)
- **Thermal Energy System, Ottawa, Canada**
  - [www.thermalenergy.com](http://www.thermalenergy.com)