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Heat Pumps and Beneficial Electrification in Industrial Facilities

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About Kinergetics LLC

- Provide energy investigations and engineering services to industrial customers in North America, South America and Europe.
- Operating energy recovery systems in four countries.
- Specialize in heat recovery and process improvement, including custom equipment design and fabrication.
- 2015/2016 Ameren Illinois Electric Program Trade Ally of the Year.



A Few Project Examples...



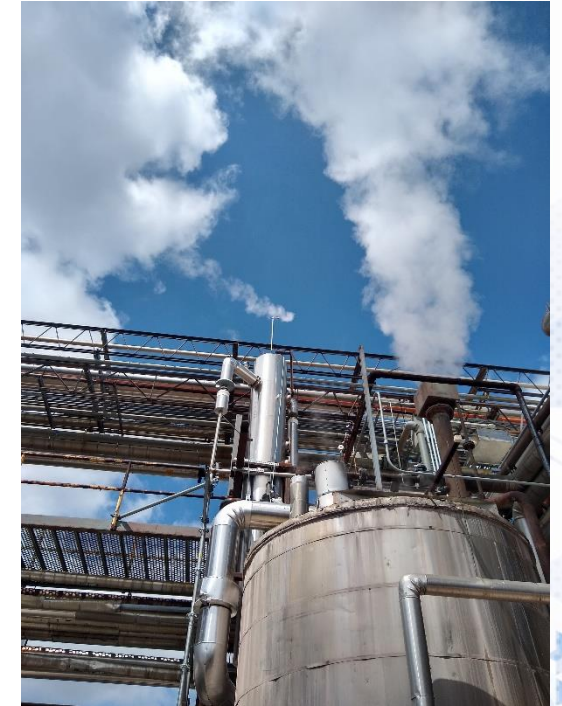
Wood-Fired Boiler
Exhaust Heat Recovery



Dryer-Cooler Exhaust from DTDC in
Soybean Oil Extraction



Scrubber Exhaust Heat for Makeup
Air Preheating



De-Aerator Column for
Feed/Makeup Water Preheating

Definitions

- **Electrification:** Simply replacing a natural gas or other fuel-based “appliance” with an all-electric version.
 - Common examples include electric boilers and electric water heaters.
- **Beneficial Electrification:** Combining waste recovery with electric components to enhance efficiency.
 - A common example is a heat pump. Some benefits of the heat pump will be briefly addressed.



Heat Pumps

- Makes an unusable lower-temperature waste heat source usable.
- Residential and commercial applications include using outdoor air at 40°F to provide building comfort heat at 70°F.
- Industrial applications include use of a waste liquid (like wastewater or process/boiler exhaust) to provide process heat at a higher temperature.
 - Steam generation can be included — more recently referred to as “steam-generating heat pumps.”

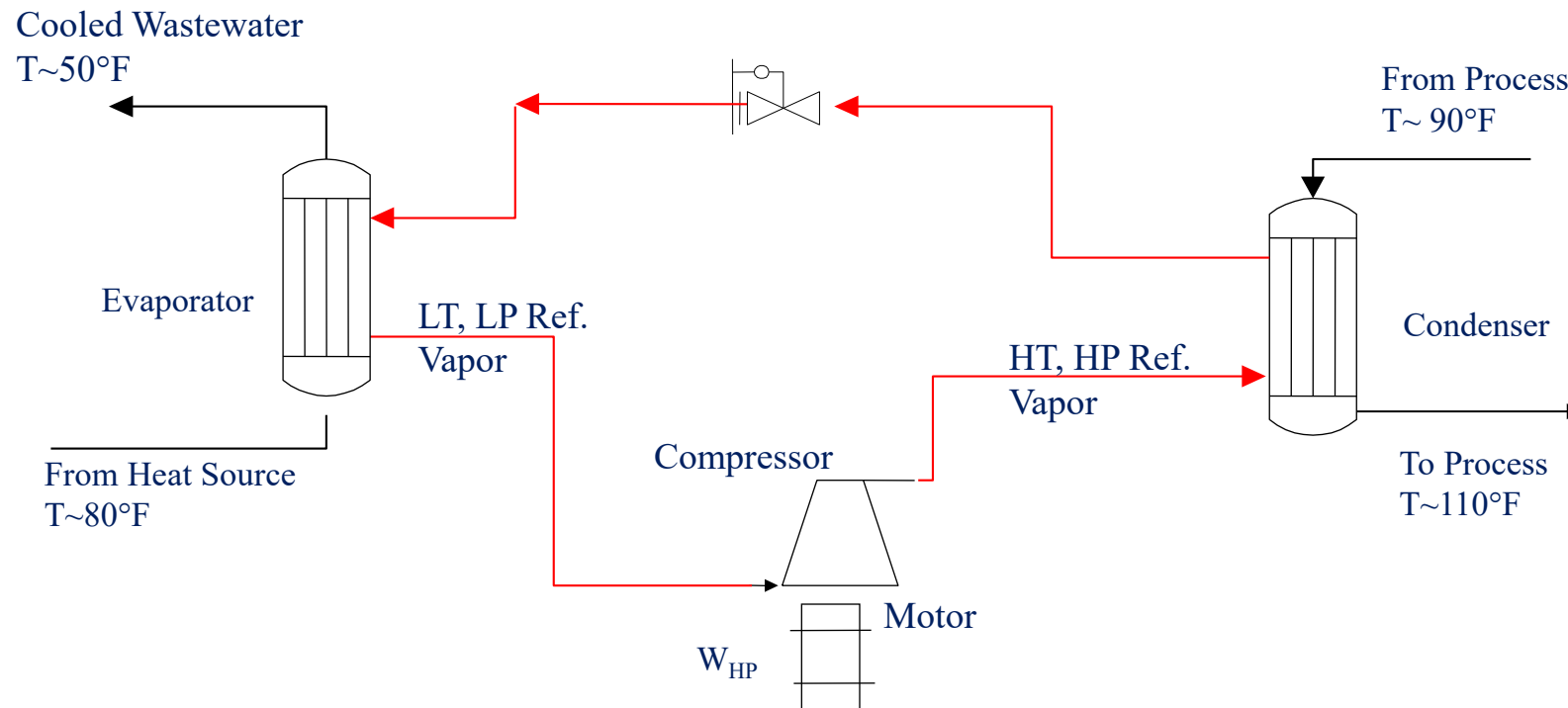


Common Heat Pump Types

- The **closed cycle heat pump** is often provided as a “packaged” unit for liquid or air source heat recovery.
 - Tends to be somewhat smaller.
- The **semi-open cycle heat pump** is more often a “custom” application involving a low-temperature vapor waste heat source.
 - Tends to be somewhat larger.

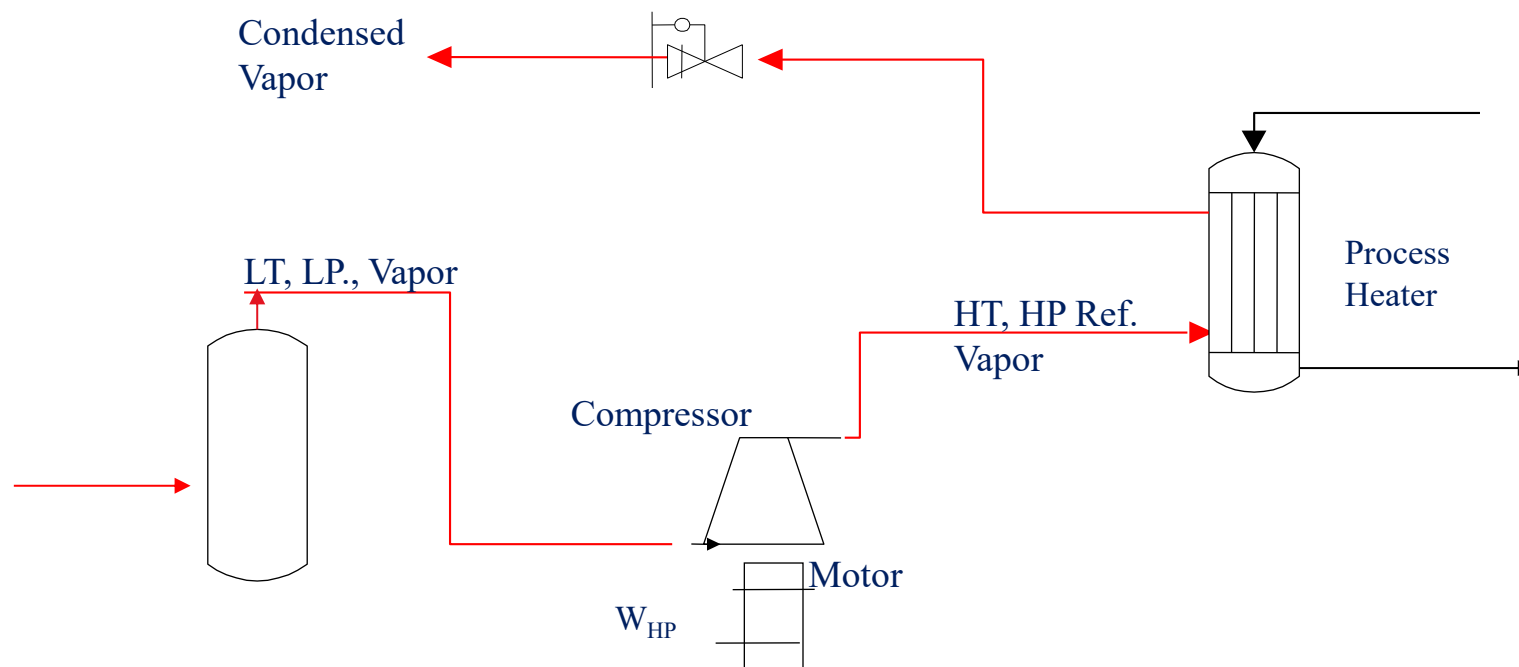


Simplified Closed-Cycle Heat Pump



Refrigerant is contained in a circuit bound by heat exchangers on the low and high temperature sides.

Simplified Semi-Open Cycle Heat Pump



Heat Pump Examples



Closed-Cycle

*Photo courtesy of
Greg Walthers, Affiliated Steam*



2,500 HP MVR Evaporator
(Electric Semi-open)

Heat Pump Examples



Steam-Generating Heat Pump under construction
("WHIR" System)



Case Study Example #1



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Replace Hot Water Boiler with an Electric Boiler

Category: Electrification



Case Study: Electric Boiler

- During an assessment, we were asked to make savings and cost secondary to “environmental benefits” and to electrify heat production.
- For this example, 3 MMBTU/Hr of steam or hot water output is assumed.
- 500 tons of refrigeration were in use during normal operation.
- Plant was in Wisconsin, so EIA emission factors apply.



Case Study: Electric Boiler

- Estimated gas with 83% fuel to heat efficiency use:
 - **$3 \text{ MMBTU/Hr} \div 83\% = 3.6 \text{ MMBTU/Hr}$**
- Assume ~6% loss for electric boiler, so “fuel” to heat efficiency is 94%.
- Electric supply required:
 - **$3 \text{ MMBTU/Hr} \div 94\% \times 10^6 \text{ BTU/MMBTU} \div 3,412 \text{ BTU/Hr-kW}_e = 938 \text{ kW}_e$**



Case Study: Electric Boiler

Electric supply required:

$$3 \text{ MMBTU/Hr} \div 94\% = 3.2 \text{ MMBTU/Hr}$$

$$3,200,000 \text{ BTU/Hr} \div 3,412 \text{ BTU/Hr-kW}_e = \mathbf{938 \text{ kW}_e}$$

Cost for electric boiler operation:

$$938 \text{ kW}_e \times 6,000 \text{ Hr/Yr} \times \$0.080/\text{kWh} = \mathbf{\$450,240/Yr}$$



Case Study: Electric Boiler

Cost for gas boiler operation:

$$3.6 \text{ MMBTU/Hr} \times 6,000 \text{ Hr/Yr} \times \$6.00/\text{MMBTU} \\ = \$129,600/\text{Yr}$$

- Electric boiler is ~3.5 x more costly to operate.
- Simple payback: Why bother? The answer is never.
- What about GHG emissions?



Case Study: Electric Boiler

Gas boiler CO₂ emissions:

$$3.6 \text{ MMBTU/Hr} \times 6,000 \text{ Hr/yr} \times 116.65 \text{ LB-CO}_2/\text{MMBTU} \div 2,000 = \mathbf{1,260 \text{ Ton-CO}_2/\text{yr}}$$

Electric boiler CO₂ emissions:

$$0.938 \text{ MW} \times 6,000 \text{ Hr/yr} \times 1,246 \text{ LB-CO}_2 \div 2,000 \text{ LB/Ton} \\ = \mathbf{3,506 \text{ Ton-CO}_2/\text{yr}}$$

- Electric boiler CO₂ emissions are ~2.8 x greater than the gas-fired appliance.



Case Study Example #2

**Keep Gas Boiler as Backup and Use
Heat Pump as Primary Heat Source**

Category: Beneficial Electrification



Case Study: Electric Heat Pump

- Chiller is waste heat source.
- Chiller load is 60% on average:
 - $500 \text{ TR} \times 60\% = 300 \text{ TR}$
 - $300 \text{ TR} \times 12,000 \text{ BTU/HR-TR} = 3,600,000 \text{ BTU/Hr}$
 - Assume chiller refrigerant vapor is available at 90°F.
- Estimated $\text{COP}_{\text{HP}} = 5.4$ {energy out ÷ energy in}
- Electrical power with 95% efficient motor = 172 kW_e



Case Study: Electric Heat Pump

Cost for heat pump operation:

$172 \text{ kW}_e \times 6,000 \text{ Hr/Yr} \times \$0.080/\text{kWh} = \$82,560/\text{Yr}$
(~\$47,000/Yr less than gas boiler)

Heat pump CO₂ emissions:

$0.172 \text{ MW} \times 6,000 \text{ Hr/yr} \times 1,246 \text{ LB-CO}_2 \div 2,000 \text{ LB/Ton}$
 $= 643 \text{ Ton-CO}_2/\text{yr}$
(~50% of the gas boiler and 18% of the electric boiler)





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Questions?

“Any fool can know. The point is to understand.”

- Albert Einstein



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