Reducing Inefficiency and Wastes from Boilers and Compressed Air Systems

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Summary

- Boiler
  - Types
  - Improving efficiency
  - ECM’s

- Air Compressors
  - Types
  - Wastes & inefficiencies
  - ECM’s
Boiler Heating Systems

Types

- Steam or Hot Water
- Fuels – natural gas, diesel oil or solid fuel
- Local or central plant
- Condensing boilers
Boiler Heating System

- Uses boiler to burn fuel to heat water for building and process needs

- System components
  - Boilers
  - Fans
  - Pumps
  - Controls
  - Coils and heat exchangers
  - Valves
  - Piping
Boiler Fundamentals

- Fuel burned in an insulated chamber lined with water pipes
- Heat goes into water and combustion gases
- Boiler efficiency range 80% - 85% at full load under peak performance

<table>
<thead>
<tr>
<th>Boiler Loss</th>
<th>Energy Loss, % of Heat Input</th>
</tr>
</thead>
<tbody>
<tr>
<td>Raising Combustion Gas Temperature</td>
<td>8% - 12%</td>
</tr>
<tr>
<td>Raising Water Temperature Caused by Combustion</td>
<td>4% - 7%</td>
</tr>
<tr>
<td>Boiler Shell Radiation Loss</td>
<td>0.25% - 2%</td>
</tr>
<tr>
<td>Unburned Carbon</td>
<td>0% - 0.5%</td>
</tr>
<tr>
<td>Raising Temperature of Water in Combustion Air</td>
<td>0.1% - 0.4%</td>
</tr>
</tbody>
</table>
Boiler Loss Reduction

1. Reduce stack temperature
   - 40 F reduction = 1% efficiency improvement
2. Minimize excess air for combustion
3. Increase water temperature to boiler
4. Raise combustion air temperature to burner

Items 1& 3 utilize an economizer heat exchanger
Item 2 requires low excess air burner and proper combustion controls
Reducing Excess Air

Standard burner on package boiler designed to provide 15% to 20% excess air at high fire only (3% to 4% oxygen in stack gases)

High performance burner will deliver 12.5% to 15% excess air from midfire to high fire

Burners need to be field tuned to accomplish

Desire to reduce NO\textsubscript{x} or CO emissions lead to increasing excess air amounts

Have combustion control system that can react
Impact of Excess Air on Combustion Efficiency

Combustion Efficiency of Burning natural Gas

Percent of CO2 in Flue Gas

Combustion Efficiency, %
Combustion Controls

- Per ASME PTC 4.1 boiler efficiency guarantee assume firing at 100%, a steady state and no ambient condition changes
- Fully metered combustion control systems monitors air & fuel flow makes adjustments to keep rates constant
- Add oxygen trim to better control excess air
- Parallel-positioning combustion controls with oxygen trim offer low cost control that can be applied to small boilers
Part Load Boiler Efficiency

- Typical boiler has 6:1 turndown firing natural gas and 4:1 turndown firing oil.
- At low heat demands, the burner will shut off, and energy losses occur during combustion chamber purge at firing end and purge before firing.
- High performance burners have 10:1 turndown firing gas and 8:1 turndown firing oil, which offers less cycling.
Types of Boilers

- Condensing – Up to 3.0 million Btuh
- Firetube – Up to 50 million Btuh
- Small Watertube – Up to 10 million Btuh
- Large Watertube – 10 million Btuh to 10 billion Btuh

Solid fuel types – stoker grate, fluidized bed, pulverized coal
Condensing Boiler

- Able to recover latent heat from water formed by combustion
- Need to have low enough return water temperature
- Corrosion resistant materials required
Firing Efficiency

![Graph showing combustion efficiency vs. flue gas temperature](image)
Need Low Temperature Return Water

- Requires larger heat exchangers to obtain higher efficiency
  - AHU Coils
  - Room convectors
Fire Tube Boiler

- Water in boiler shell & hot gases flow through tubes
- Efficiency increases with more passes of the combustion gases
- Simple, low cost
Water Tube Boilers

- Good for making steam
- Used for very high pressure
- Complicated design, more expensive
Stoker Burner

- For burning solid fuels
- Coal burned on grate at boiler bottom
- Combustion air supplied under and over grate
Steam Boilers

A steam system is complicated

- Making steam requires extra heat to vaporize water, 881 Btu for 100 psig steam which is 338 F at saturated conditions
- Steam is condensed at points of use & steam trap allows condensed water to pass but not steam
- Condensate is pumped back to boiler room, enters the deaerator and the boiler feed pump sends the water to the boiler
Typical Operating Parameters of Central Heating Systems

- **Boiler output**
  - Steam - 60 to 125 psig
  - Hot water –
    - High temperature - 280 F to 400 F
    - Medium temperature – 180 F to 270 F

- **Boiler efficiency** = 75% to 80%

- **Make-up water (steam system only)** = 3% – 5%

- **Distribution losses** = 5% to 15%

- **Stack temperatures** = 250 F to 400 F
Design Considerations

- Operating temperature and pressure
- Fuel type & reliability
- Emissions control
- Systems served
  - Constant or variable flow
  - Seasonal & daily requirements
Things to Check

- Boiler load profile data
- Flue gas temperature
- Percent oxygen/carbon dioxide in flue gas
- Percent make-up water
- Return water/condensate temperature
- Temperature & pressure at remote locations of distribution system
Energy Waste – Boilers Systems

- Burners – dirty or poor control
- Boiler tubes not cleaned in 2 years
- Damaged/missing refractory
- Leaks at valves, gaskets
- Too high pressure/temperature
- Excessive boiler blowdown
Energy Waste – Boiler Systems Continued

- Steam traps leaks
- Failure to return condensate
- Poor water treatment
- Distribution system leaks
- Steam line serving unused areas
- Excessive venting of steam
- Condensate receiver pumps need repair
Energy Inefficiencies – Boiler Systems

- More than 20% excess oxygen in flue gas
- Flue gases > 150 F than leaving hot water or steam
- Damper control of air flow
- Boiler surface temperature > 125 F
- Boiler cycling on and off
- Boiler efficiency < 70%
Energy Inefficiencies - Boiler Systems Continued

- No automatic stack damper
- Blowdown water > 140 F
- Use of inefficient steam turbines (< 65%)
- Continuous lit pilots
- Steam atomization of oil
- High pressure pumps instead of booster pump use
- Variable flows with constant speed pumps
Steam Traps

Thermostatic

Float & Thermostatic
Bucket Trap  Condensate Receiver & Pump
ECM – Improve Combustion Efficiency

- Excess oxygen or combustible gas in boiler flue gas
- Add combustion controls that monitors flue gases and adjusts burner
- Replace burner and combustion controls
- Improved control of combustion air flow with variable speed fans
ECM – Boiler Heat Recovery

Flue gas systems
- Preheat combustion air or make-up water
- Thermal wheel - 60% to 80% efficient
- Run-around coil - 40% to 60% efficient
- If sulfur present in fuel don’t go below 250 F to avoid condensing SO$_2$ gas
FUEL CONSERVATION WITH HEAT RECOVERY ECONOMIZER

Minimum Flue Gas Temperature, Flue Gas Dew Point, Recommended Minimum Feedwater Temperature, Versus Fuel Sulphur Content

ASSUMPTIONS:
1. 10 to 35% Excess Air
2. Constant 4% Conversion of Fuel Sulphur to SO2
ECM – Boiler Heat Recovery

Blowdown water

- Preheat make-up water
- Use shell and tube heat exchanger
- Blow down water needs to be cooled to 140 F before discharge into sewer
ECM – Avoid Boiler Cycling

- Difficult for boiler to operate at less than 25% capacity.
- On/off operation wasteful since air purging of boiler is required before and after each firing.
ECM – Insulate Distribution Piping

- Hot pipes with inadequate insulation waste heat
- It often is not cost effective to add additional insulation
- Need good moisture barrier if outside
ECM – Fix Steam Traps

- Open steam traps allow steam to enter condensate return system.
- Energy lost up vent in condensate receivers
- Can cause early failure of condensate pumps
- Very cost effective maintenance program to adopt
- Trap monitors are available
ECM – Eliminate Steam Leaks

- Loss similar to leak at steam trap
- Also lose condensate and chemical treatment investment
- Disrupts service downstream from leak
- If underground, location difficult to find and costly to repair
- Can be caused by poor installation or poor pipe selection
ECM – Switch from Steam Heat

- Unitary systems
  - Energy efficient
  - Higher maintenance than central plant hot water
- Central hot water system
  - Greater fuel choices & flexibility
  - Lower fuel costs
  - Longer equipment life
- Topic in later discussion
ECM – Reduce Steam Pressure or Hot Water Temperature

- Determine actual building requirements.

- Consider alternative energy sources for -
  - Steam turbine driven devices
  - Cooking operations
  - Washing operations
  - Space humidification
  - Heating domestic hot water
  - Pressing clothes
Heat Recovery

- Using waste heat to reduce energy use in some system
- There must be a heat source to recover
- There must be a simultaneous heat use
- It must be cost effective
Compressed Air Systems
Compressed Air System

Components:

- Compressors & motors
- Dryers – remove moisture
- Filters – remove particulate & oil
- Receivers – air storage to smooth out compressor operation
- System Cooling – cooling tower or air cooled
Air Compressors Types

- **Reciprocating**
  - Up to 30 hp
  - 3.5 to 4 CFM/Hp

- **Rotary Screw**
  - 7.5 to 100 hp
  - 3.6 to 4.4 CFM/Hp
  - Oil free compressed air
  - Noisy – need sound enclosure

- **Centrifugal**
  - 200 hp & larger
  - 4 to 5.4 CFM/Hp
  - Good base load unit, poor part load performance
Air Quality

Air contaminants

- Solid particulates – remove by filter
- Moisture – use a dryer or separator
- Oil droplets – control by
  - compressor selection – lower efficiency, higher cost & greater maintenance
  - Coalescing filters – consume energy
Air Dryers

- **Desiccant**
  - -40 F dew point air discharged
  - Consumes some compressed air to recharge (dry) desiccant = 0.8 kW/100 cfm
  - Raises compressed air temperature

- **Refrigerated**
  - 38 F dew point - minimum temperature
    - lower temperature could cause frost on coil
  - Uses electrical energy = 0.8 kW/100 cfm
Typical Army Operations

- **Air requirements**
  - Flow rate = less than 200 CFM
  - Normal operating pressure = 90 to 125 psig
- **Air or water cooled compressors**
- **Uses**
  - Hand Tools
  - Clamping devices in machine tools
  - Cleaning operations
  - Controls and instrumentation
  - Motors & pumps
  - Hoists
Design Issues

- Flow rate
  - Sum of average uses

- Air pressure
  - Pipe losses
  - Process requirements

- Air Dryness
  - Moisture will condense in compressed air line unless air is dried well
  - Use remote dryers for more demanding requirements
  - Some users – painting, instruments & controls need dry air
Energy Waste

- Leaks at gaskets, fittings and valves – can be up to 30%, 5% is acceptable
- Running standby dryer
- Dirty heat exchangers
- Fouled air/oil separators
- System pressure greater than required by users – For 100 psi system a 2 psi reduction provides 1 % energy savings & up to 1% lower leaks
Energy Waste

- Dirty air filters
- Continuous air bleeds
- Providing compressed air to unused areas
- Inappropriate compressed air uses such as for cooling, agitating liquids, moving product or drying
- Inoperable, uncalibrated or poorly adjusted controls
Energy Inefficiencies

- Use of oversized equipment
- Use of modulation-controlled air compressors at part load
- Lack of compressor system control system
- Use of warm building air for compressors air intake, 5 F temperature reduction obtains 1% increase in performance
ECM – Reduce Inappropriate Uses

- Air cleaning – blowing off work benches
- Cooling – 100 psi air when rapidly expands results in 40 F temperature
- Drying – removing moisture with air jets
- Air powered tools
- Air powered motors
ECM – Replace Compressed Air Tools with Electrical Tools

- Electric Tools are
  - Less expensive
  - Less energy intensive
- Compressed air tools are
  - Lighter
  - More powerful
  - Faster acting
  - Non-sparking
  - Can stall load

<table>
<thead>
<tr>
<th>Tool</th>
<th>Air Use CFM</th>
<th>Equivalent watts</th>
<th>Electrical Tool Use, watts</th>
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<tbody>
<tr>
<td>Drill</td>
<td>4 for 15 sec</td>
<td>750</td>
<td>840</td>
</tr>
<tr>
<td>Impact Wrench, ¾”</td>
<td>9.5 for 15 sec</td>
<td>1780</td>
<td>900</td>
</tr>
<tr>
<td>Sander</td>
<td>16</td>
<td>3000</td>
<td>240</td>
</tr>
<tr>
<td>Screwdriver</td>
<td>3 for 15 sec</td>
<td>560</td>
<td>744</td>
</tr>
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</table>
ECM - Reduce Air Pressure

Determine if compressed air users require high pressure

- Clamping functions
- Motors

- Lower operating pressure saves energy – obtain information from air compressor manufacturer

- Lower pressure reduces loss through leaks

- Adjustment of compressor control required to reduce operating pressure
Leaks in the compressed air system are controlled by a constant inspection and repair program.

To find the leaks, it is best to inspect the system during off hours (Sundays, nights, etc.).

Leaks can best be heard when the building is quiet.

Can use an ultrasonic detector to sense air leaks.

Look at hose fittings, valves, and devices that are pressurized.
ECM – Heat Recovery

- Heat needs to be removed from the air compressor and dryers so that they will continue to perform. These systems can be either water or air cooled.
- For water cooled systems the heat can be used to preheat domestic hot water if there is a high enough demand.
- For air cooled systems the warm air can be used for building heat in the winter time. A 50 Hp unit can provide approximately 126,000 Btuh of heat.
Thank You

Questions?