Track: Industrial

Unit 10: Steam System Thermal Cycle

An overview of Steam System Thermal Cycle Efficiency and Energy Losses

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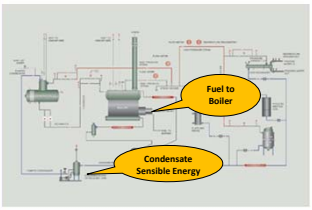
What is Steam System Thermal Cycle Efficiency?

- Energy input to the boiler(s)
- Minus all the energy losses in the system
- Energy recovered back to the boiler plant
  - Condensate
  - Not the deaerator water



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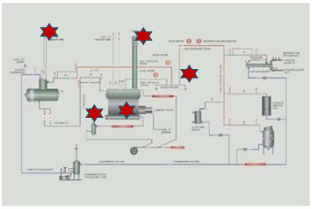
Where are the Losses in the Steam System?

- Boiler operation
  - Combustion efficiency
  - Flue gas losses
  - Deaerator
  - Boiler blow down
  - Radiation losses
  - Operating steam pressure



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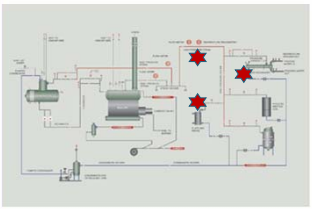
Where are the Losses in the Steam System?

- Steam distribution
  - Pressure reduction
  - Insulation
  - Steam leakage
  - Steam venting to atmosphere
  - Steam trap failures



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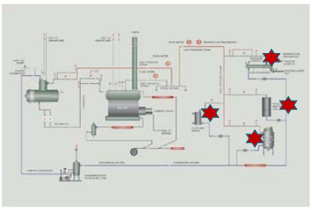
Where are the Losses in the Steam System?

- End users
  - Insulation
  - Steam leakage
  - Condensate loss
  - Steam trap failures



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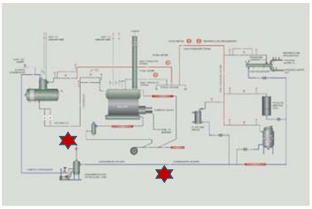
Where are the Losses in the Steam System?

- Condensate systems
  - Pumping issues – loss of condensate
  - Leakage
  - Low pressure systems vs. higher pressurized systems



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Boiler Operations Overview

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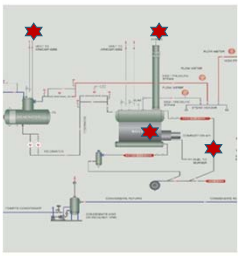
Steam Generation Operation Losses

- Large energy loss is in the flue gases leaving the boiler operation
- Combustion process
- Deaerator venting
- Boiler blow down
- Boiler radiation losses from the boiler surface area



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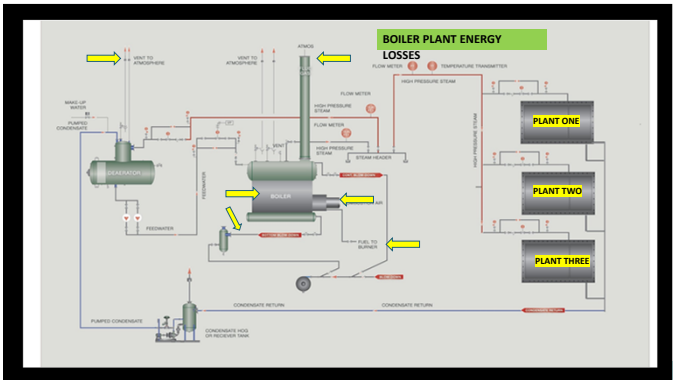

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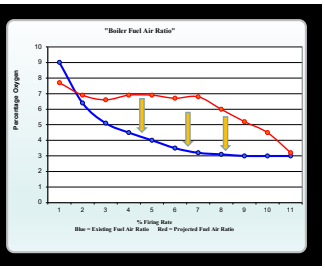
Combustion Testing and Efficiency Factors

- Combustion testing
  - Operating at the peak efficiency
  - Qualified combustion testing person
  - Burner and control system engineer or technician
  - Excess air levels



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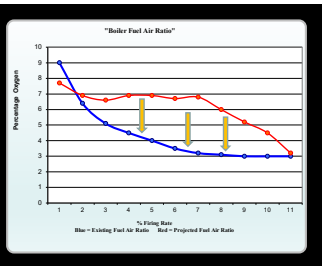
Combustion Testing and Efficiency Factors

- Oxygen vs. excess air
  - 7% oxygen level
    - 48% excess air
  - 2.6% oxygen level
    - 15% excess air
  - Lower excess air
    - Higher flame temperatures
    - Higher energy absorption in the boiler
    - Lower flue gas losses



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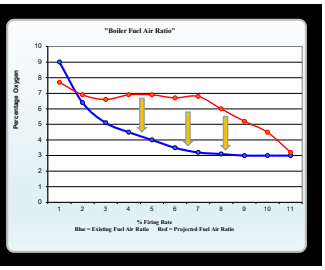
Combustion Testing and Efficiency Factors

- Low cost
- Excellent payback opportunity
- Combustion testing
  - Needs to be done every six months
  - Typically, a very high return



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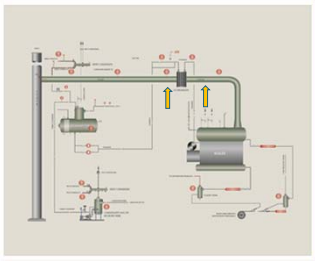
Boiler Plant Energy Improvements



- Standard economizer
  - Larger than 300 Bhp
  - Large number of vendors
  - Normally an easy installation
- Reducing the flue gas losses
  - Target temperatures: below 300°F

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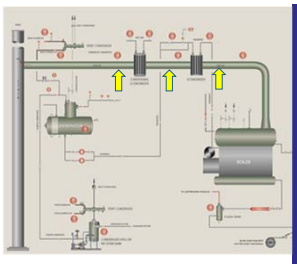
Boiler Plant Energy Improvements



- Condensing economizer
  - Very specialized
  - Need a large heat sink to lower flue gas temperature to 110°F or lower
  - High installation cost
  - Boiler efficiency can be higher than 96%
    - Significant gain

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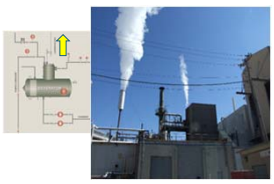
Boiler Plant Energy Improvements



- Deaerator venting
  - Most deaerators operate with excessive vented steam
  - Steam needs to be vented to remove non-condensable gases
  - Should be a very low volume – normally less than 125 lbs. per hour

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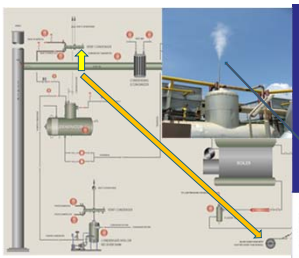
Boiler Plant Energy Improvements



- Deaerator venting
  - Simple test to operate the deaerator at 7 ppb dissolve oxygen or lower
  - Vent condenser or discharge to blow down heat recovery system
  - Even deaerator vent picture is too aggressive

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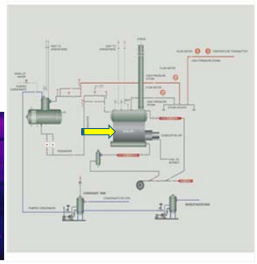
Boiler Plant Energy Improvements

- Boiler radiation losses
  - Firetube boiler back wall losses
  - Not a major issue on



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Boiler Plant Energy Improvements

- Blow down heat recovery system
  - Pre-heat the makeup water to the deaerator
  - No flash steam venting
  - Cooling the blow down for discharge to drain
- Surface blow down (easy to accomplish)
- Bottom blow down (larger boilers)

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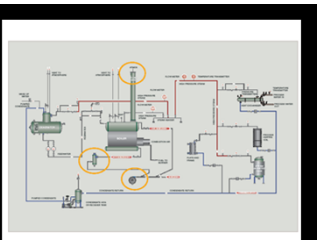
Steam Generation Estimated Energy Losses

- Boiler flue gas losses
  - Estimate on the average = 16.4%
- Combustion testing = 1.5%
- Boiler outer surface losses
  - Estimated on the average = 0.2%
- Surface blow down losses
  - Estimate on the average = 1.5%
- Bottom blow down losses
  - Estimated on the average = 0.7%



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Correction Methods Implemented – Estimated Energy Losses

- 14.2% Boiler operation
  - Heat recovery on the flue gas
- 0.8% Combustion testing and correction
- 0.2% Boiler outer shell surface
  - Not much can be done here
- 0.5% Surface blow down (boiler)
  - Blow down heat recovery
- 0.7% Bottom blow down (boiler)
  - Blow down heat recovery
  - Stayed the same

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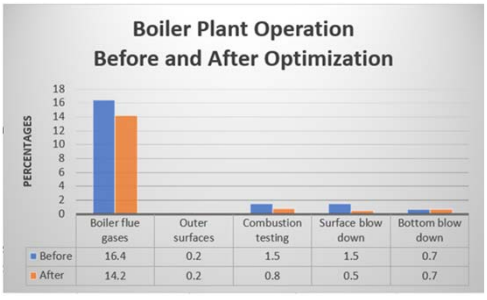
Overview of Boiler Operations



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Boiler Plant Energy Summary

- Existing conditions
  - Flue gases 17.4
  - Combustion testing 1.5
  - Outer surfaces 0.2
  - Surface blow down 1.5
  - Bottom blow down 0.7
  - Total: 21.3 %
    - Energy loss
- Energy opportunities reductions
  - Flue gases 2.2 %
  - Combustion testing 0.7 %
  - Outer surfaces 0.0 %
  - Surface blow down 0.75 %
  - Bottom blow down 0.0 %
  - Total: 3.9 %

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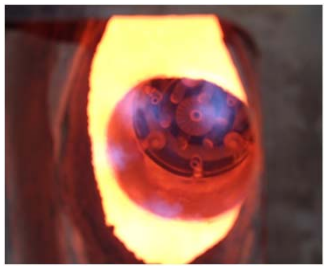
Boiler Plant Priorities



1 - Combustion testing
   Reduce excess air levels
2 – Deaerator dissolved oxygen testing
   Reduce steam venting from deaerator
3 - Surface blow down heat recovery
4 - Flue gas economizer

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Steam Distribution Systems

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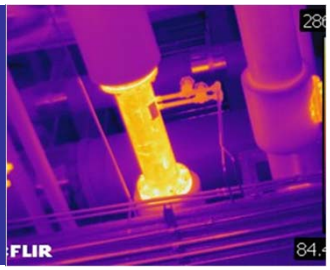
Steam Distribution System

- Steam venting
- Uninsulated steam lines
- Steam trap station failures
- Steam valves open to atmosphere
- Blow down valves open to atmosphere



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Steam Venting – No. 1 Energy Loss in the System

- Why do plants vent steam to atmosphere
  - Unbalance steam system
  - Flash steam
  - Excessive steam

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Steam Venting Cost

Steam cost per 1,000 lbs.	$8.45
Steam pressure	100
Steam loss (pph)	2,125
Cost/hr.	$11.69
Days/yr.	350
Cost/yr.	$98,204.00
CO_2 emissions/yr.	2,486
NO_x	1,945

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Steam Venting Cost

Steam cost per 1,000 lbs.	$4.90
Steam pressure	40
Steam loss (pph)	2,111
Cost/hr.	$10.36
Days/yr.	350
Cost/yr.	$87,050.00
CO_2 emissions/yr.	2,403,212
NO_X	1,822

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Steam Venting Eliminated

- No steam venting
- Today, there is no reason to vent steam to atmosphere

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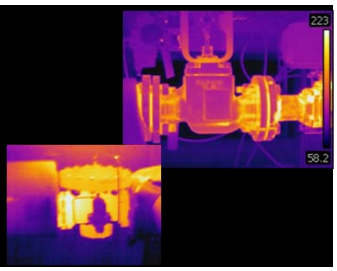
Steam Distribution Energy Losses

- Insulation
  - All components need to be insulated
  - Conduct thermal scans of the system
  - Set roadmap for corrections
  - Safety, 140°F surface require personnel protection



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Steam Distribution Energy Losses

- Steam trap station failures
- What are the losses?
  - Energy loss, only if the steam trap is discharging into a vented to atmosphere condensate tank
  - Any steam trap survey must determine steam trap condensate discharge
- Energy loss is added into the steam venting calculation

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Steam Distribution Leakage

- Steam venting
  - Flash steam, excessive steam, steam trap failure
  - Estimated at **14.6%**
- Lack of proper insulation
  - Valves, steam lines, other components
  - Estimated on the average = **7.4%**
- Steam leakage
  - Valves, flanges, threaded connections
  - Estimated on the average = **3.5%**
- Steam trap failures
  - Discharging to a vent condensate tank system
  - Losses calculated into the vent steam estimation
- **Total estimates = 25.5 %**

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Mechanical Energy Losses

- Pressure reduction done by control valves instead of steam turbines
- Loss of mechanical energy
  - Not added into the loss calculations

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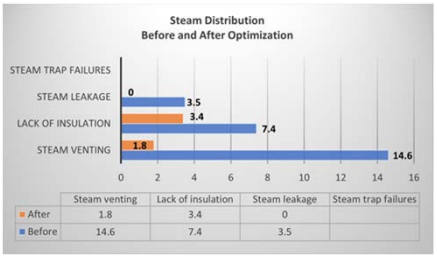
Steam Distribution – Before and After Optimization



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Steam Distribution Energy Summary

- Existing conditions
  - Steam venting 14.6 %
  - Insulation 7.4 %
  - Steam leakage 3.5 %
  - Total: 25.5 %
    Energy loss
- Energy opportunities- estimated energy losses after corrections
  - Steam venting 1.8 %
  - Insulation 4 %
  - Steam leakage 0.0 %
  - Steam trap failures
  - Total Reduction: 20.3 %

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Steam Distribution Priorities

Steam venting
Steam leakage
Insulation
Steam trap stations

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End Users

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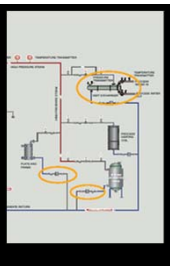
End Users

- **Insulation**
  - Heat transfer outer surfaces are not insulated
  - Steam piping to the end users not insulated
- **Steam leaks**
  - Flange leakage
  - NPT connections
- **Steam trap station failures**
  - Average steam trap station failures rate 18%
  - Estimated energy loss = 3.6%
  - Steam trap station - failure rates should be less than 3%



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End Users Energy Summary

- Existing conditions
  - Steam trap station failures
    - Already in our calculations
  - Insulation
    - Already in our calculations
  - Steam leakage
    - Already in our calculations
- Energy opportunities
  - Steam traps (Inc.)
  - Insulation (Inc.)
  - Steam leakage (Inc)

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Condensate Systems

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Condensate System Losses

- Not returning condensate
  - No. 2 major energy loss
- Why?
  - Pump failures
    - Failure to specify the correct pumping system
  - System issues
    - High condensate system pressures – improper operation or improperly operated
  - Contamination

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Condensate System Energy Losses

- Condensate recovery system target
  - 90% or higher
  - If steam injection is not used in the plant

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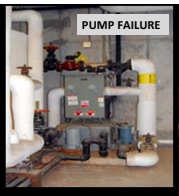
Condensate System Energy Losses

- Condensate pumping issues (major issue in the steam system)
- Not specifying the operating conditions
  - Operating temperature: 211ºF
  - Standard condensate pumps do not have the NPSH to handle this temperature, therefore pump cavitation and failure
- End-result – loss of condensate



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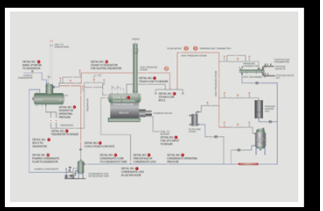
Pressurized Condensate Systems

- Recovery condensate under in a pressurized condensate system
  - Increases the thermal cycle efficiency
  - Eliminates the steam venting
  - Reduces energy to heat up make up water and atmosphere condensate



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Condensate System Losses

- Venting flash steam to atmosphere
  - Condensate tanks venting
  - Flash tanks venting
  - Failed steam traps
- Insulation of components
  - Condensate lines and components
  - Pumping units

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Condensate Losses

- Loss condensate = 4.6 %
- Steam losses to atmosphere
  - Already added into calculations
- Insulation
  - Already added into calculations
- Total condensate losses = 4.6 %

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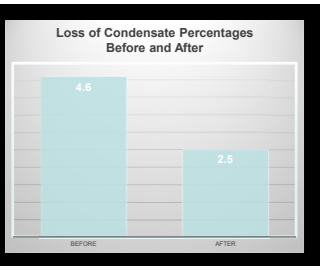
Condensate Loss – Before and After

- Corrections
  - Correct pumping units
  - Electrical pumps vs. steam motive
    - Electric condensate pumps have lower energy consumption than steam motive
    - Electric pumps are far more reliable
  - Correct all leakage



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Condensate System Energy Summary

- Existing conditions
  - Loss of condensate
    Estimated: 4.6
  - Insulation
    - Already in our calculations
  - Steam leakage
    - Already in our calculations
  - Total: 4.6
    Energy loss

- Energy losses after corrections
  - Recovery condensate 2.5 %
  - Insulation (Inc.)
  - Steam leakage (Inc)
- Total Reduction: 2.1 %

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First Step in Optimization - Steam Balancing

One or two page drawing
Providing key information on the steam system

Steam balance is always the first step in any steam system optimization and management program

- Efficient way to gain knowledge
  - steam generation
  - distribution
  - end users
  - condensate-recovery systems.

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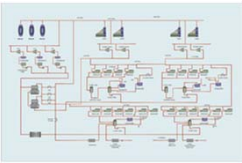
What Are The Expected End Results To A Steam Balance Program



Dashboard for the steam and condensate system
Information to drive the steam system efficiently
Provides the necessary knowledge to increase steam system thermal cycle efficiency

Every plant needs to achieve the highest steam thermal cycle efficiency possible

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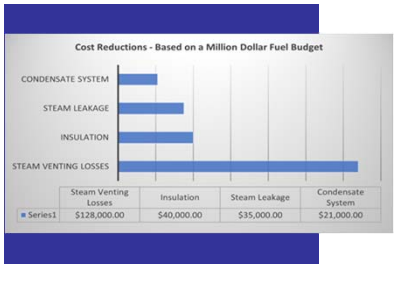
What Are The Top Four Major Opportunities in Steam and Condensate Systems Based on Million Dollar Energy Cost?



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Summary of Losses vs. Achievable Savings

- Estimated energy losses
  - Thermal cycle efficiency
    - 49.7 %
  - Loss energy
    - 50.3 %
- Opportunities to improve
  - Thermal cycle efficiency
    - 78.9 %
  - Loss energy
    - 21.1 %
- Achievable savings: 29.2 %

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Roadmap To Success

- Benchmark existing steam system thermal cycle efficiency
- Set roadmap to achieve above a 74.0% steam system cycle efficiency

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Inveno Engineering LLC Our Approach

Long Term Impact

- Implementation engineering
- Project designs, project management,
- Full engineering support for Steam System changes

Partnerships

Short Term Impact

- Steam System Engineering Assessments
- Steam System Balancing
- Steam System Reliability
- Steam System Engineering Training

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Thank you …

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