Better Plants
U.S. DEPARTMENT OF ENERGY

# Industrial Steam Systems
## Virtual INPLT Training & Assessment

Session 6
Friday – November 18, 2022
10 am – 12:30 pm

U.S. DEPARTMENT OF ENERGY

# Agenda – Session SIX

- Safety and Housekeeping
- Today's Content:
  - Discussion of Homework
  - Review of Session 5
  - Generation – Energy Efficiency & Savings Opportunities
    - Shell loss reduction
    - Other areas for optimization
  - Cogeneration – Areas of interest
  - Steam System Energy Assessment Standard
- Kahoot Quiz Game
- Q&A

Better Buildings is an initiative of the U.S. Department of Energy

# Safety and Housekeeping

- Safety Moment
  - Ensure all contractors, visitors, etc. that you are hosting at your plant follow all safety protocols
- Break points after each sub-section where you can ask questions
- When you are not asking a question, please MUTE your mic and this will provide the best sound quality for all participants
- We will be recording all these webinars and by staying on-line and attending the meeting you are giving your consent to be recorded
  - A link to the recorded webinars will be provided, afterwards

# Steam Virtual INPLT Agenda

- Week 1 (October 14) – Industrial Steam Systems Fundamentals and Introduction to SSST
- Week 2 (October 21) – Focus on Steam System Generation, Boiler Efficiency & Plant Efficiency
- Week 3 (October 28) – Introduction to DOE's MEASUR Tool & Cogeneration (CHP)
- Week 4 (November 3) – Steam System Distribution, End-Use & Condensate Recovery
- Week 5 (November 11) – Energy Efficiency Opportunities in the Generation Area
- **Week 6 (November 18) – Energy Efficiency Opportunities in Generation & Cogeneration (CHP) Area**
- **Week 7 (December 2) – EE Opportunities in Distribution, End-use and Condensate Recovery**
- **Week 8 (December 9) – Industrial Steam System VINPLT Wrap-up Presentations**

# Homework 5 Discussion

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# Homework #5

- Evaluate the opportunities to improve your steam generation efficiency by:
  - Reducing stack loss heat recovery (in the absence of feedwater economizer)
  - Comparing stack temperature to design conditions
  - Evaluating flue gas oxygen content and the control mechanism
- Evaluate implementation of blowdown control & energy recovery
  - Reduction of blowdown w/control
  - Flash tank heat recovery
  - Blowdown/Make-up water HX
- Save the file w/different scenarios on your computer and send us the .json file

# Session 5 – Review

# Better Plants Diagnostic Equipment Program (DEP)

**Better Plants®**
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## Diagnostic Equipment Program (DEP)

The Better Plants **Diagnostic Equipment Program (DEP)** allows partners to borrow over 22 different kinds of tools to collect energy data and improve equipment performance in their facilities.

Through this program, partners have the opportunity to test tools firsthand before deciding to purchase a piece of equipment on their own. This not only allows for the improved testing and collection of energy data, but also helps to demonstrate the value of certain tools in different applications throughout a facility.

### FULL SUITE OF DIAGNOSTIC TOOLS

- Anemometer
- Combustion Analyzer
- Conductivity Meter
- Current Transformer
- Digital Manometer
- Digital Thermometer
- Infrared Camera
- Infrared Thermometer
- Laser Distance Meter
- Light Meter
- Pitot Tube
- Power Logger
- Pressure Transducer
- Pyrometer
- Sonic Imager
- Strobe Tachometer
- Temp/RH logger
- Thermocouple
- Thermocouple Logger
- Time of Use Logger
- Ultrasonic Flow Meter
- Ultrasonic Leak Detector

### EXPLORE SOME OF THE TOOLS THAT YOU CAN BORROW THROUGH BETTER PLANTS:

**POWER LOGGER**

This device helps you directly measure energy consumption, which can be converted into costs. It also logs data to provide electric consumption trends.

**CURRENT TRANSFORMER**

Use this device with a data logger to quantify the electric current flowing to a component or system and identify wasted energy.

**COMBUSTION ANALYZER**

This analyzer quantifies excess oxygen in boilers and combustion process exhausts, helping you save fuel and heat energy.

**LEAK DETECTOR**

This device helps you identify leaks in compressed air or steam systems using high frequencies that are undetectable to the human ear.

betterbuildingssolutioncenter.energy.gov/better-plants/diagnostic-tools | @BetterPlantsDOE | linkedin.com/showcase/better-plants

### EXPLORE THE FULL SUITE OF DIAGNOSTIC EQUIPMENT AND SUBMIT AN APPLICATION:

Scan the QR Code above, or click here to download the DEP rental application.

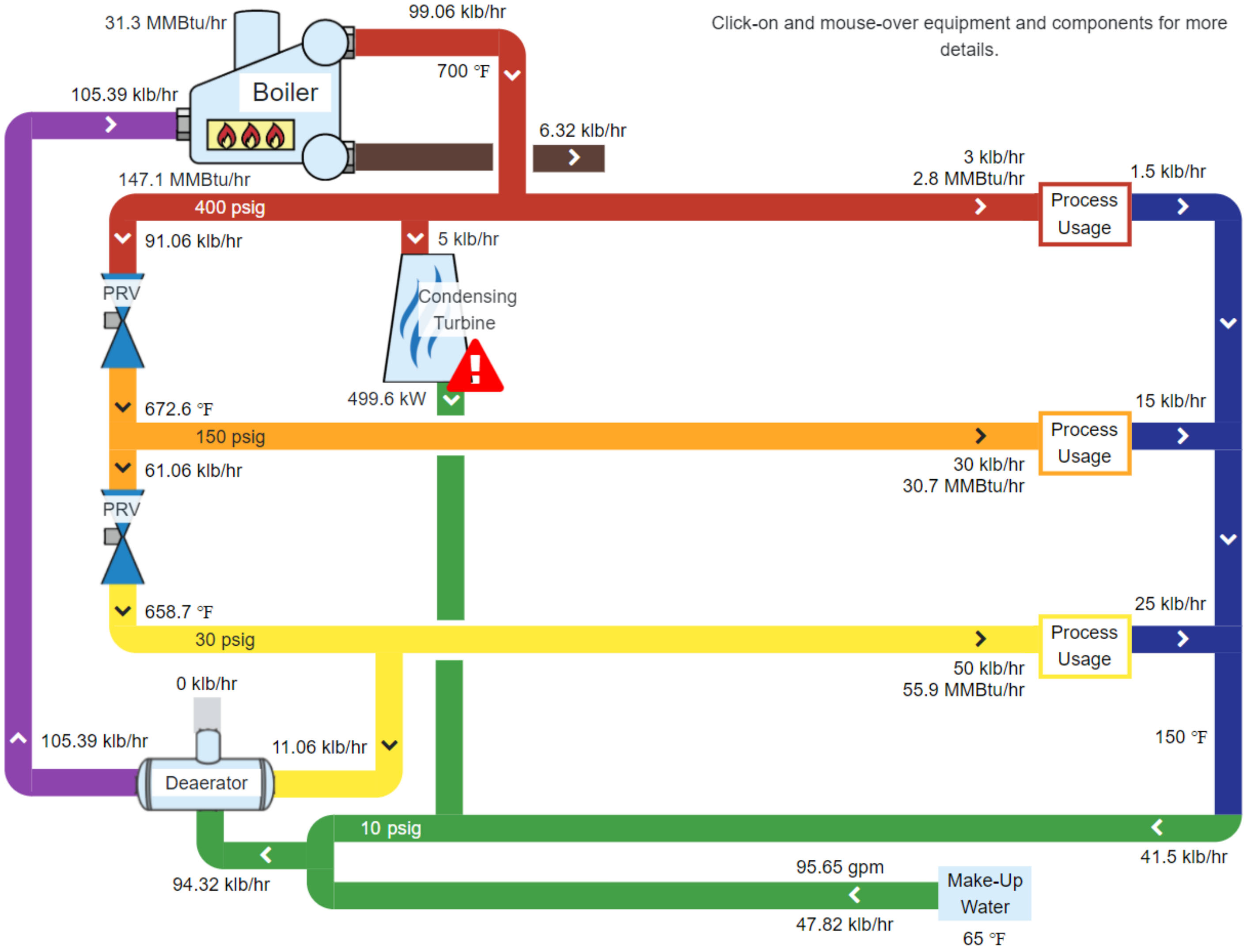
Send this completed form to the Better Plants Diagnostic Equipment Program Manager, Daryl Cox at coxdf@ornl.gov.

### HAVE QUESTIONS ABOUT BORROWING EQUIPMENT?

Scan the QR code above, or click here to email Daryl Cox, DEP Program Manager.

Daryl Cox has over 20 years of experience managing industrial technology and equipment and can help you find the right tool for your energy needs.

# MEASUR – Pulp & Paper Mill Model



# MEASUR – Pulp & Paper Mill Model

## COST SUMMARY

| Power Balance | |
|---|---|
| Generation | 499.6 kW |
| Demand | 5,499.6 kW |
| Import | 5,000 kW |
| Unit Cost | $0.05 /kWh |
| **Total $/yr** | $2,190,000 |

| Fuel Balance | |
|---|---|
| Boiler | 147.05 MMBtu/hr |
| Unit Cost | $5.00 /MMBtu |
| **Total $/yr** | $6,440,979 |

| Make-Up Water | |
|---|---|
| Flow | 95.65 gpm<br>50,272,661.49 gal |
| Unit Cost | $0.01 /gal |
| **Total $/yr** | $502,727 |

| Total Operating Cost |
|---|
| $9,133,705 |

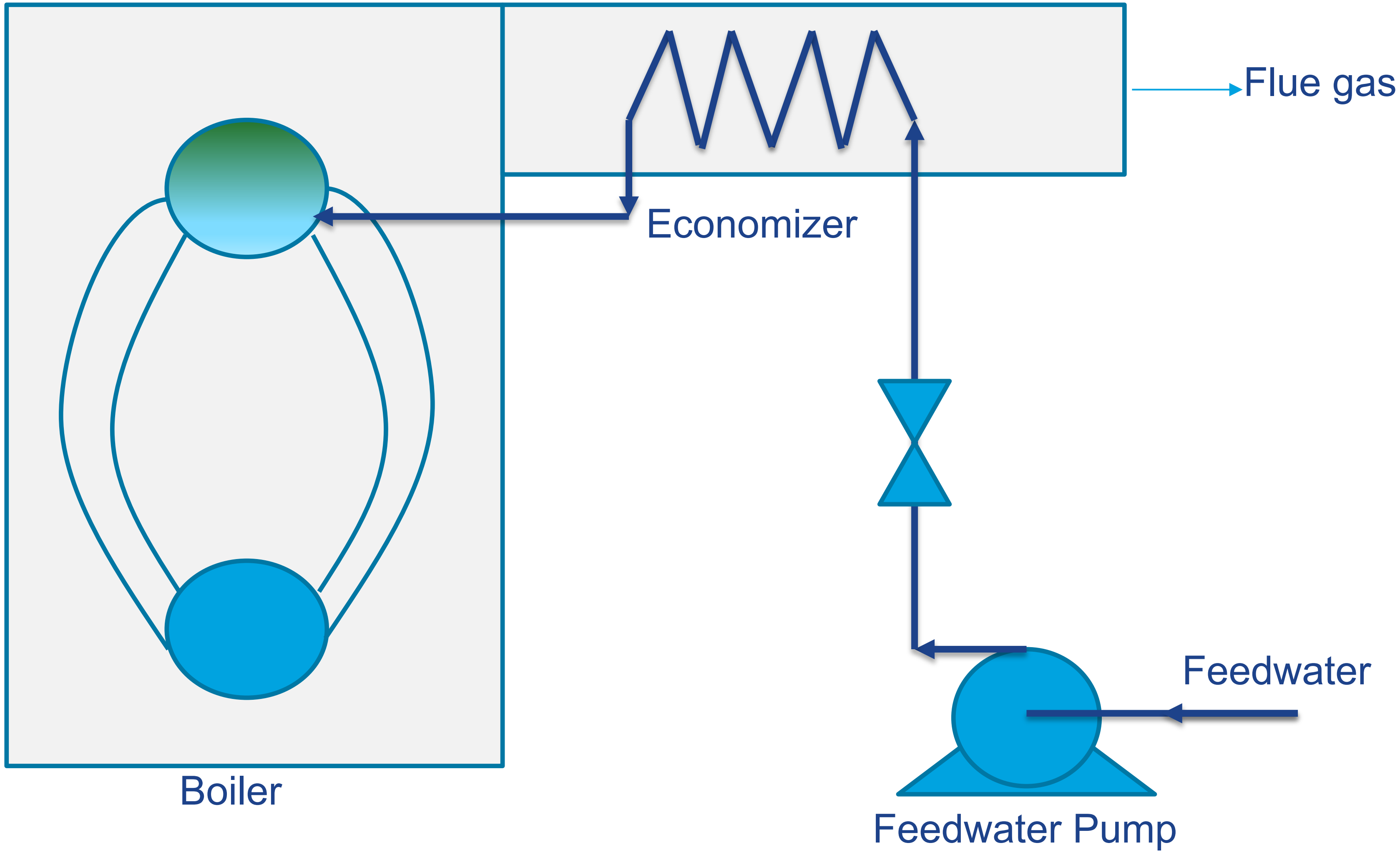
## MARGINAL STEAM COST

| | |
|---|---|
| High Pressure | $9.04 /klb |
| Medium Pressure | $9.04 /klb |
| Low Pressure | $9.04 /klb |

# Common BestPractices - Generation

- Minimize excess air
- Install heat recovery equipment
- Clean boiler heat transfer surfaces
- Improve water treatment to reduce boiler blowdown
- Recover energy from boiler blowdown
- Add/restore boiler refractory
- Minimize the number of operating boilers
- Optimize deaerator vent rate

# Feedwater Economizer (Simplest Configuration)

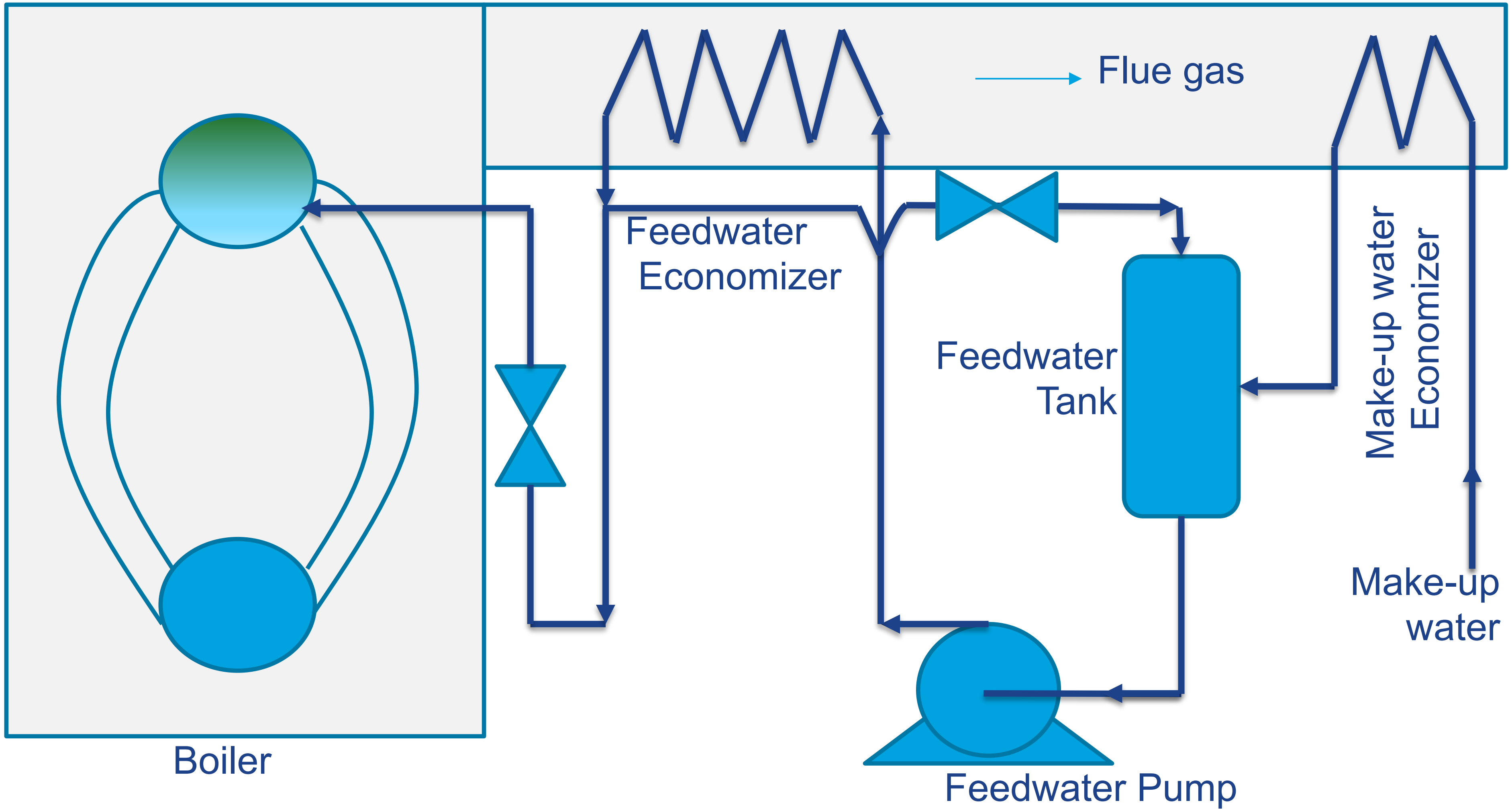


# Condensing Economizers

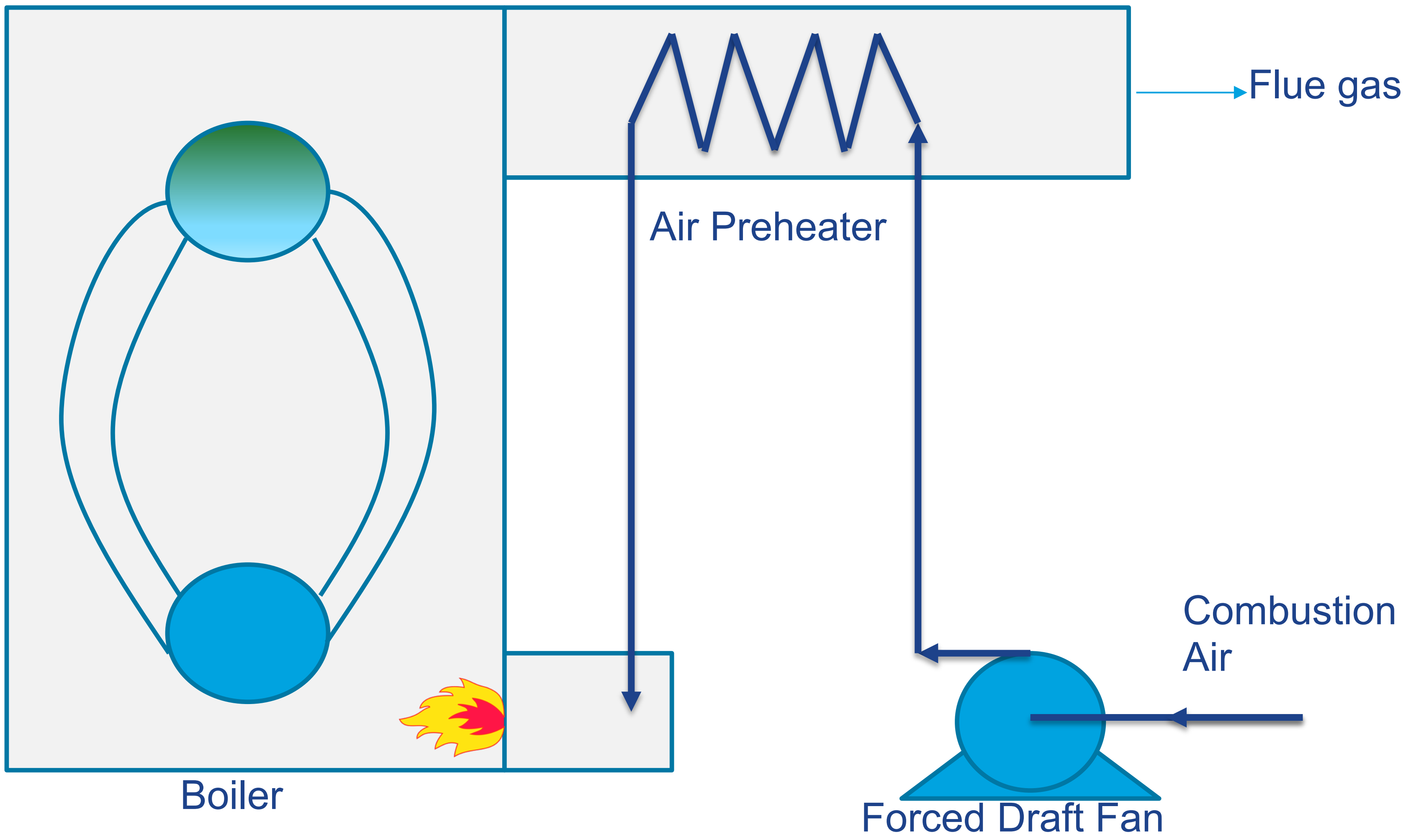
- **LARGE** amount of **LOW** temperature heat available

- Condensing Economizer applications include:
  - Boiler make-up water heating, especially in cases where there is NO condensate return
  - Industrial process water heating
  - Pre-heating for feed streams in process industries
  - Clean-up/wash-down water heating
  - Laundry wash water
  - Domestic water heating
  - Space heating (HVAC)
  - Central plant and District heating systems
  - Absorption / Adsorption chiller systems

# Feedwater & Make-up Water Economizer (Complex Configuration)



# Air Preheaters



# Temperature Loss Management - Summary

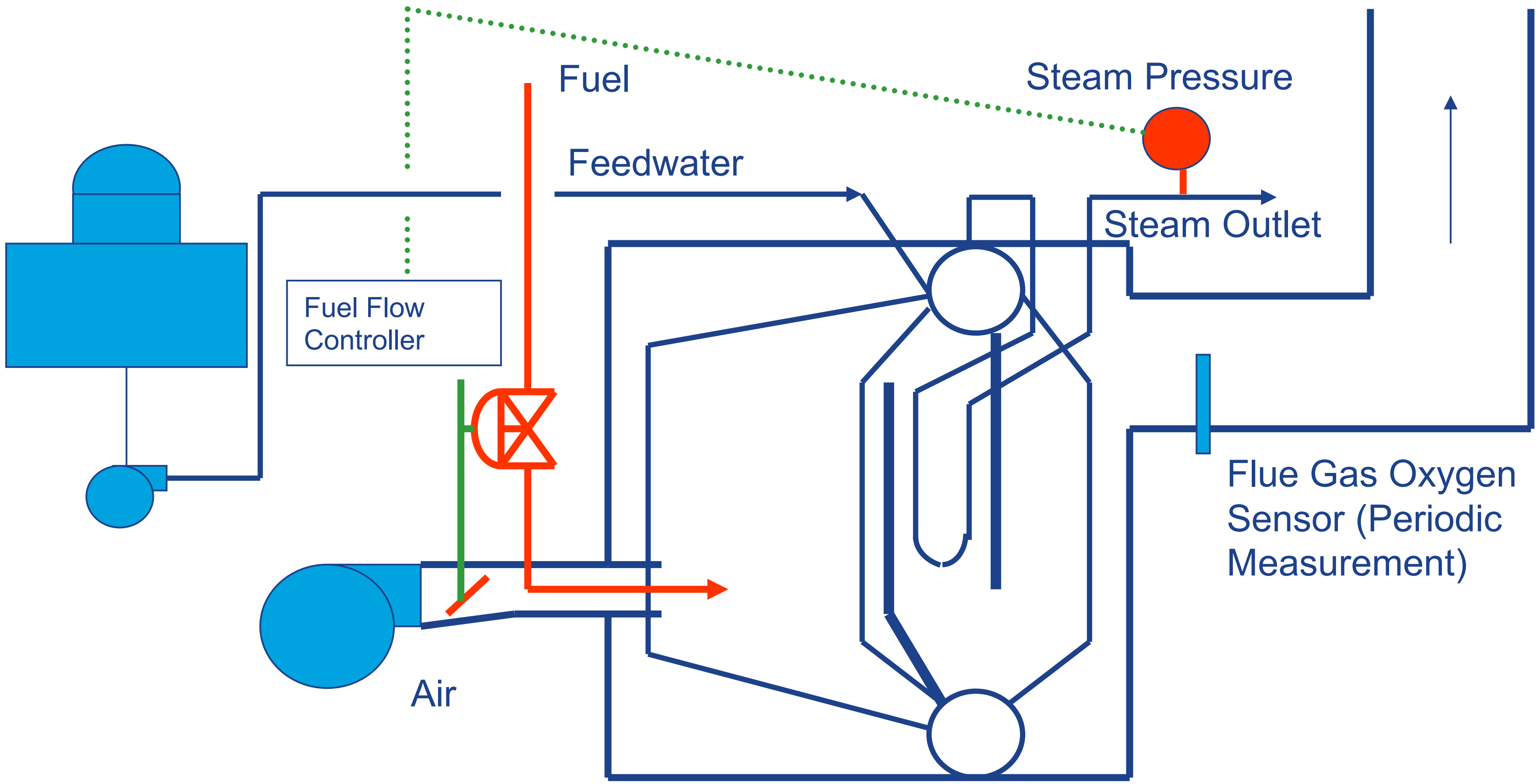
- Monitor and record flue gas temperature with respect to:
  - Boiler load
  - Ambient temperature
  - Flue gas oxygen content
- Compare flue gas temperature to previous, similar operating conditions
- Maintain appropriate fire-side cleaning
- Maintain appropriate water chemistry
- Evaluate heat recovery component savings potential

# Typical Flue Gas Oxygen Content Control Parameters

| Typical Flue Gas Oxygen Content Control Parameters | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Fuel | Automatic Control Flue Gas $O_2$ Content | | Positioning Control Flue Gas $O_2$ Content | | Automatic Control Excess Air | | Positioning Control Excess Air | |
| | Min. [%] | Max. [%] | Min. [%] | Max. [%] | Min. [%] | Max. [%] | Min. [%] | Max. [%] |
| Natural Gas | 1.5 | 3.0 | 3.0 | 7.0 | 9 | 18 | 18 | 55 |
| Numb. 2 Fuel Oil | 2.0 | 3.0 | 3.0 | 7.0 | 11 | 18 | 18 | 55 |
| Numb. 6 Fuel Oil | 2.5 | 3.5 | 3.5 | 8.0 | 14 | 21 | 21 | 65 |
| Pulverized Coal | 2.5 | 4.0 | 4.0 | 7.0 | 14 | 25 | 25 | 50 |
| Stoker Coal | 3.5 | 5.0 | 5.0 | 8.0 | 20 | 32 | 32 | 65 |

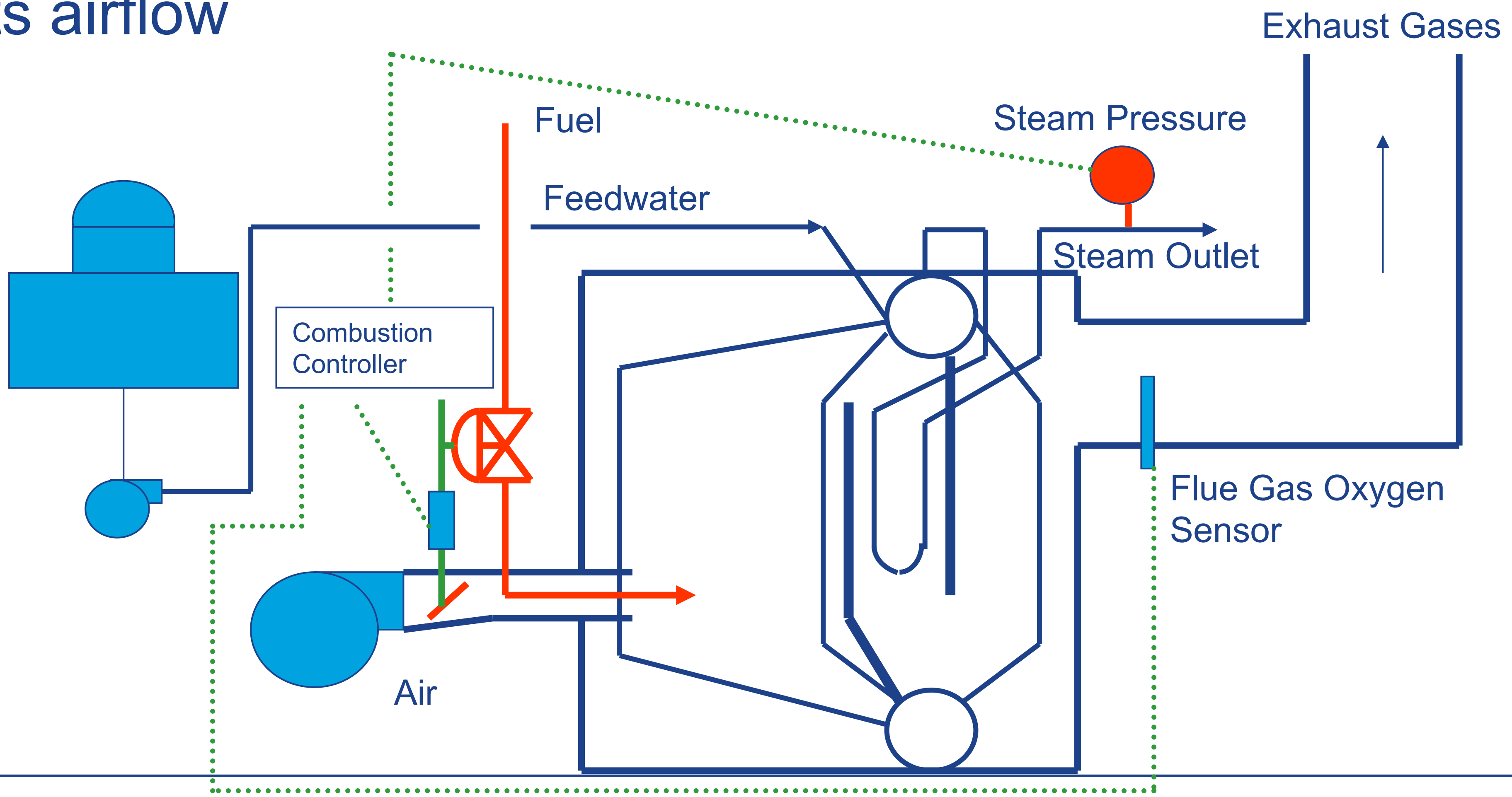
# Positioning Control

- *Positioning control* maintains a position relationship between the fuel and air flows



# Trim Control

- *<u>Trim</u>* or *<u>automatic control</u>* continuously monitors oxygen and adjusts airflow



# Combustion Management - Summary

- Combustion management principles:
  - Add enough oxygen to react all of the fuel
  - Minimize the amount of extra air to limit the energy loss
  - Monitor combustibles to identify problems

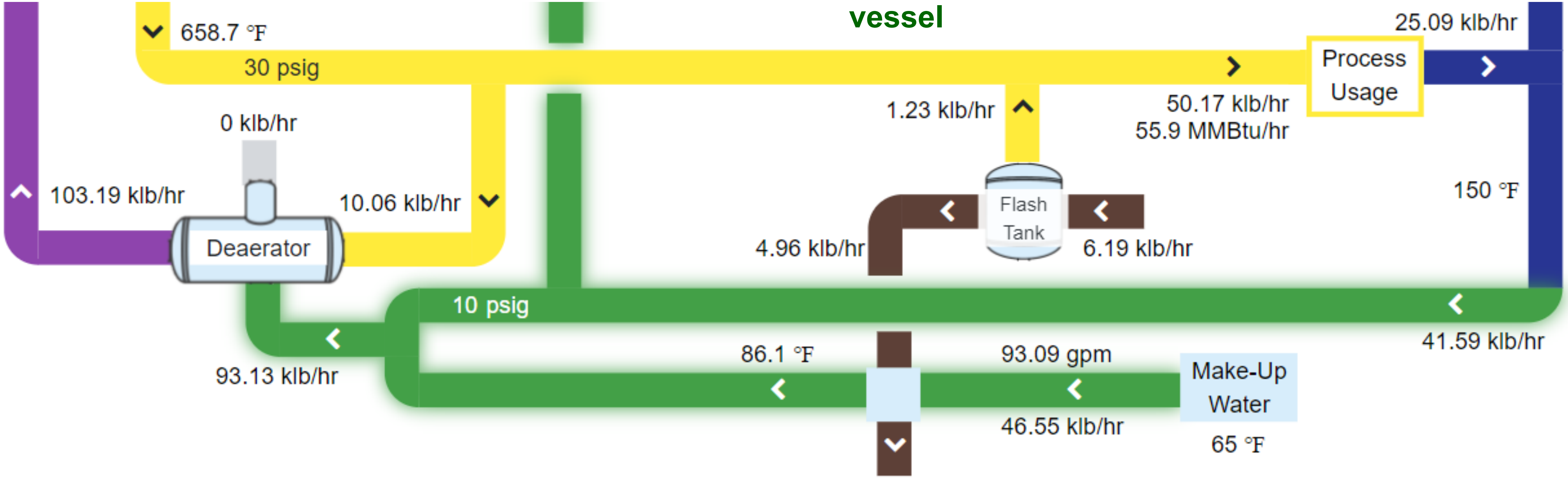
1. Measure the oxygen content of boiler exhaust gas
   a. Continuously
   b. Periodically
2. Control oxygen content within a minimum and maximum range
   a. Continuous-automatic control
   b. Positioning control
3. Challenge the control range
   a. Combustibles measurement
   b. Burner repair
   c. Control upgrade

# Blowdown Management

- Blowdown amount is primarily dependent on:
  - Water quality
  - Boiler operating pressure
- Blowdown management typically takes two forms:
  - Water quality improvement
  - Improved blowdown control
  - Heat recovery
- Blowdown management begins with *measurement*
  - Typically, blowdown amount is estimated from boiler water chemical analysis

# Example Steam System – Pulp & Paper Mill

**The amount of flash steam formed is dependent on the pressure of the boiler and the pressure of the flash vessel**



# Example Steam System – Pulp & Paper Mill

**Executive Summary** | Energy Summary | Losses | Diagram | Report Graphs | Input Summary | Facility Info | Sankey

| ($/yr) | Baseline | Economizer | Trim Control | Econ + Trim | Blowdown Control | Blowdown Flash + HX | BD Flash + HX + Control |
|---|---|---|---|---|---|---|---|
| Percent Savings (%) | — | 4.0% | 2.0% | 5.0% | 2.0% | 2.0% | 2.0% |
| Power Cost | $2,190,000 | $2,190,000 | $2,190,000 | $2,190,000 | $2,190,000 | $2,190,000 | $2,190,000 |
| Savings | — | $0 | $0 | $0 | $0 | $0 | $0 |
| Fuel Cost | $6,440,979 | $6,085,294 | $6,234,994 | $5,970,613 | $6,346,116 | $6,306,916 | $6,303,558 |
| Savings | — | $355,684 | $205,985 | $470,366 | $94,863 | $134,062 | $137,421 |
| Make-up Water Cost | $502,727 | $502,727 | $502,727 | $502,727 | $457,368 | $489,292 | $453,344 |
| Savings | — | $0 | $0 | $0 | $45,358 | $13,434 | $49,383 |
| **Annual Cost** | **$9,133,705** | **$8,778,021** | **$8,927,721** | **$8,663,339** | **$8,993,484** | **$8,986,209** | **$8,946,902** |
| **Annual Savings** | — | **$355,684** | **$205,985** | **$470,366** | **$140,221** | **$147,497** | **$186,804** |
| Implementation Cost | — | — | — | — | — | — | — |
| Payback Period (months) | — | — | — | — | — | — | — |
| Selected Energy Projects | — | Adjust Boiler Operations | Adjust Boiler Operations | Adjust Boiler Operations | Adjust Boiler Operations | Adjust Boiler Operations | Adjust Boiler Operations |
| Modifications | — | Boiler | Boiler | Boiler | Boiler | Boiler | Boiler |

## Energy Efficiency Opportunities (Generation)

- **Shell Loss Reduction**

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# Shell Loss - $\lambda_{shell}$

- The exterior surface of the boiler is not perfectly insulated resulting in shell loss
  - Radiation and convection heat transfer from the boiler surface result in the loss
- Shell loss is related to the integrity of the boiler insulation
- Shell loss is difficult to measure definitively
  - The loss is typically estimated

# Shell Losses

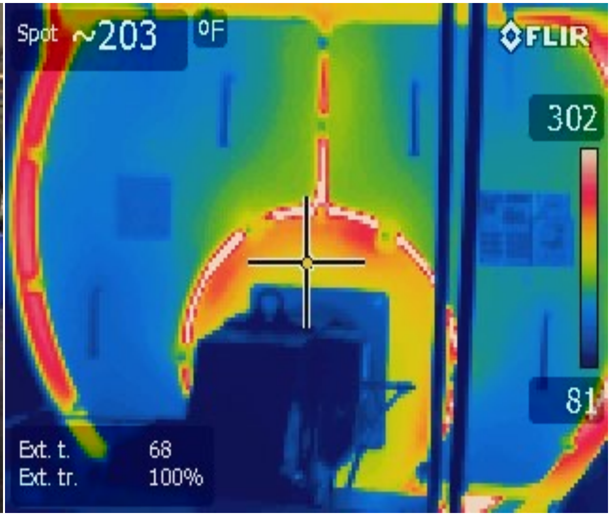
- Full-load radiation and convection losses are typically:
  - Less than 1.0%$_{fuel}$ for water-tube boilers
  - Less than 0.5%$_{fuel}$ for fire-tube boilers
- Shell loss *percentage* increases as boiler load decreases because shell loss magnitude is essentially constant
  - Shell loss of ~0.5%$_{fuel}$ *at full-load* will become ~2.0%$_{fuel}$ *at quarter-load*
  - The primary opportunity in this area is to reduce the number of boilers in operation to reduce the total site shell loss
    - Stack loss impacts must be considered

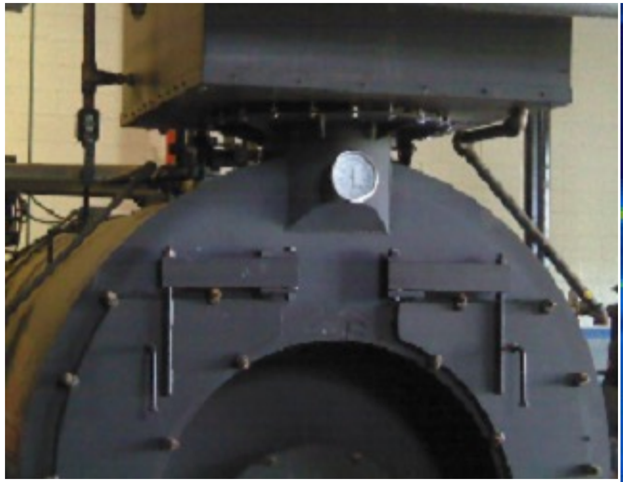
# Shell Loss

- Depends on:
  - Type of Boiler
  - Insulation
- Needed measurements –
  - Outer surface area of boiler
  - $\Delta T$ (Boiler Surface Temperature – Ambient Air Temperature)
  - Velocity of air around the boiler
- Improvement in insulation can reduce shell loss
- Minimal impact

# Shell Loss

- Boiler shell temperature
- Hot surfaces lose heat due to radiation and convection
- Shell loss is small (0.2 – 2%) and fixed in magnitude depending on size of the boiler






# Shell Loss Reduction - Summary

- Search for “hot spots”
- Measure boiler surface temperatures
  - Infrared
- Typical surface temperature should range between 120°F and 140°F
  - Personnel safety
- Repair refractory
- Monitor surface cladding integrity
- Reduced boiler load can present an opportunity

## Energy Efficiency Opportunities (Generation)

- Fuel Selection

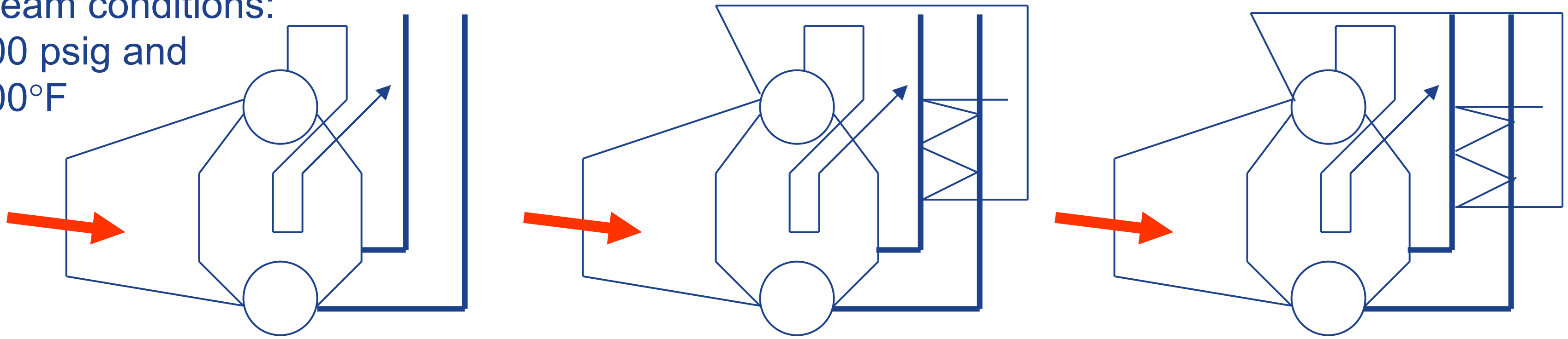
# Fuel Selection

- Fuel selection can provide significant reductions in operating costs due to differences in energy costs
  - Sometimes energy costs and maintenance expenditures are offsetting
  - *Interruptible* fuel pricing can provide great economic benefits
  - Environmental issues are a significant concern associated with fuel selection
  - Fuel efficiency will generally be an influencing factor when changing fuel

# Fuel Selection – Example System – Pulp & Paper Mill

**The Example Boiler (equipped with an economizer)**

Steam conditions: 400 psig and 700°F



Fuel: Green Wood
Fuel cost: $2.00/$10^6$Btu
Steam production: 80,000 lbm/hr
Efficiency: ~71.3%

Fuel: Natural gas
Fuel cost: $5/$10^6$Btu
Steam production: 100,000 lbm/hr
Efficiency: ~84.2%

Fuel: Number 6 oil *HS*
Fuel cost: $5/$10^6$Btu
Steam production: 80,000 lbm/hr
Efficiency: ~87.4%

- Modifications should be investigated to increase steam production from the wood boiler

# Fuel Selection Calculation

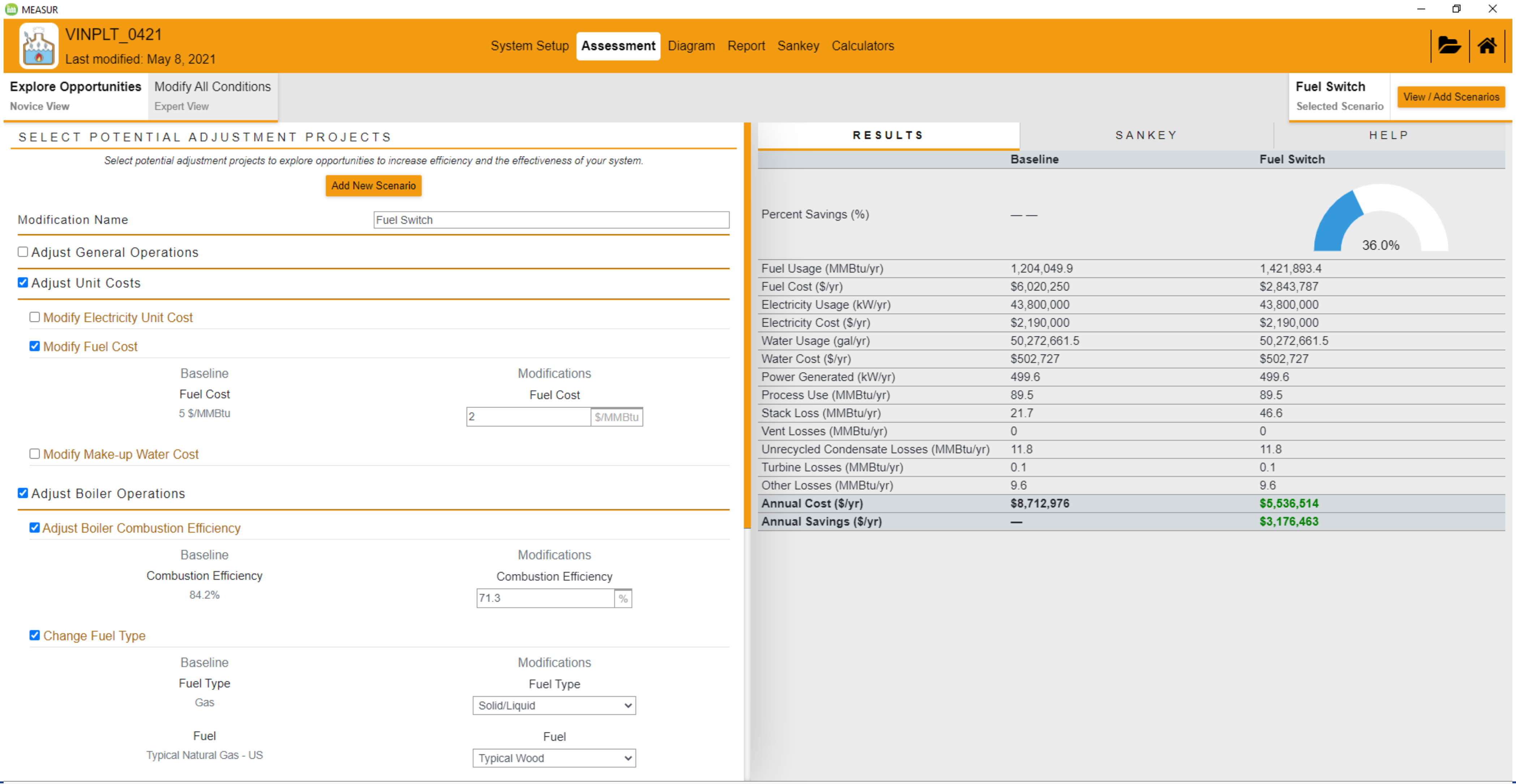
- What is the economic incentive associated with increasing steam production from the wood boiler by 1 klb/hr and decreasing steam production from the natural gas boiler by 1 klb/hr?

# Polling Question 1

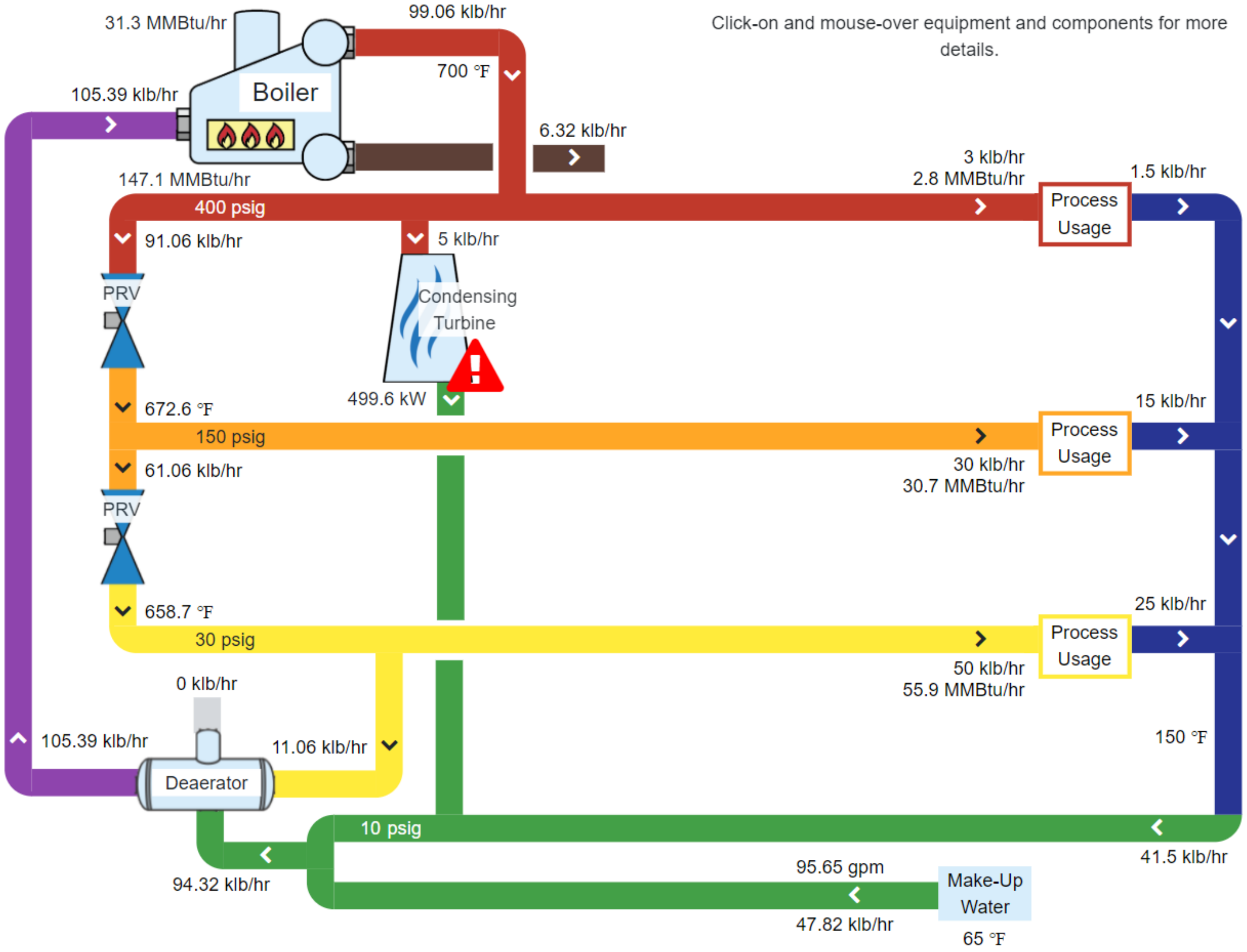
Polling Question

1) Do you believe there will be an economic incentive to switching fuel from natural gas to wood?
   A. Yes
   B. No
   C. Do not know

# Fuel Selection Calculation



# MEASUR – Pulp & Paper Mill Model



# Fuel Switching Calculations - MEASUR

- Can be modeled very easily but exercise caution and be very careful
- MEASUR calculates Fuel Switching energy and cost savings based on the FULL STEAM FLOW
- Real energy and cost savings are obtained by taking the results from MEASUR and dividing them by the steam flow rate to obtain results for 1 klb/hr
  - Annual savings for switching 1 klb/hr of steam from natural gas fired boiler to wood fired boiler = **3,176,463 / 99.06 = $32,000**

# Fuel Switching

- Many issues limit fuel switching capabilities
  - Environmental regulations
  - Fuel storage and handling issues
  - Boiler capabilities

- How should multi-fuel sites be operated and modeled?
  - Impact fuel cost should be utilized
    - The *impact fuel* is the fuel that will change consumption if steam demand changes
    - Typically the highest cost fuel in use is desired to be the impact fuel
    - "Blended costs" generally do not reflect actual system changes

# Energy Efficiency Opportunities (Generation)

- Optimizing Boiler Plant Operations

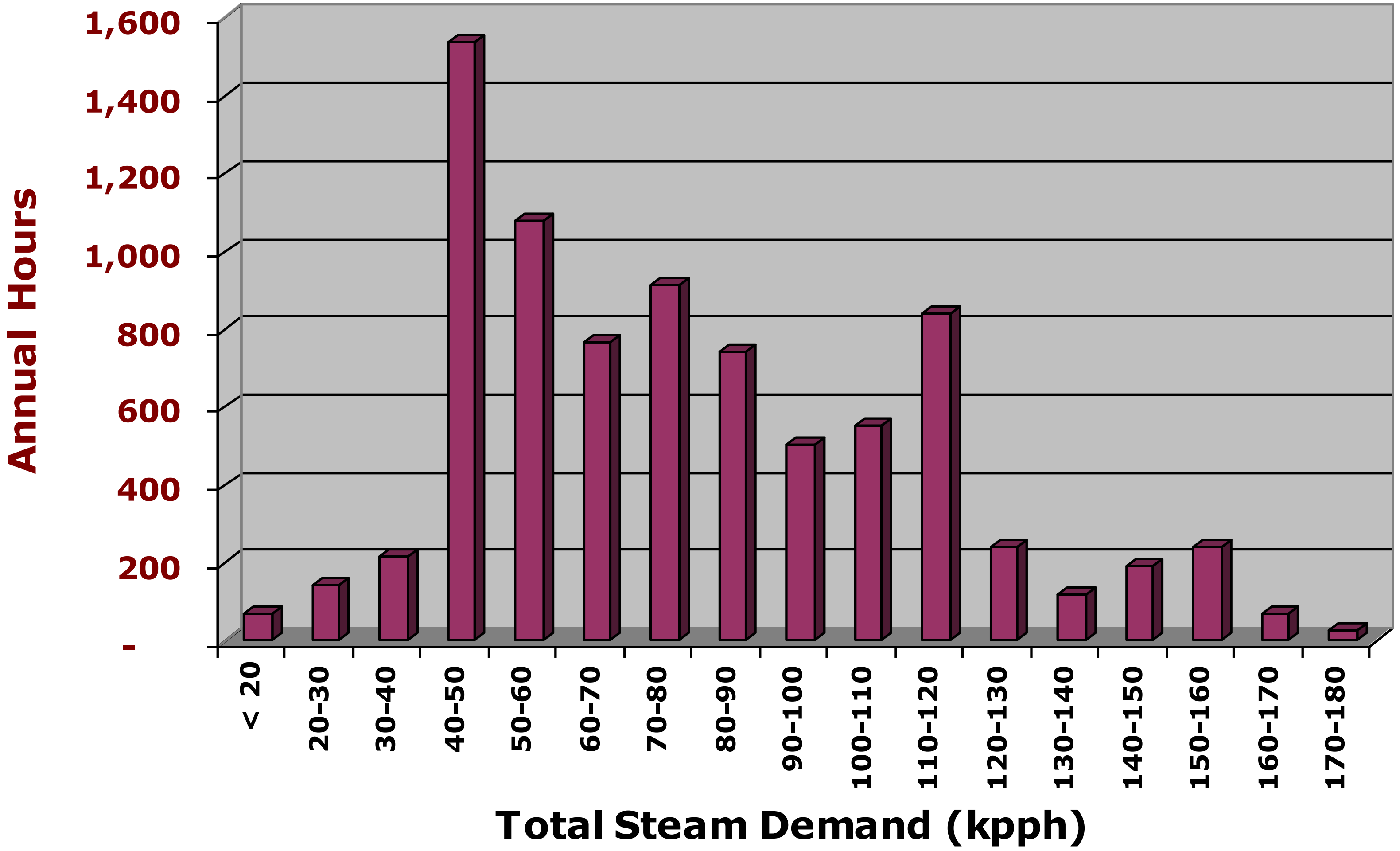
# Case Study – Chrysler Corporation

- Plant: St. Louis Assembly Plant, St. Louis, MO, USA
- Steam System Assessment & Optimization
- Boiler Plant Specifications
  - 4 Boilers
    - Total capacity: 415 klb/hr
    - Fuel: Natural gas & Land fill gas (originally – coal)
    - Pressure: 150 psig
    - Saturated steam production
  - 3 Condensing Turbines driving centrifugal chillers (4,300 RT each)

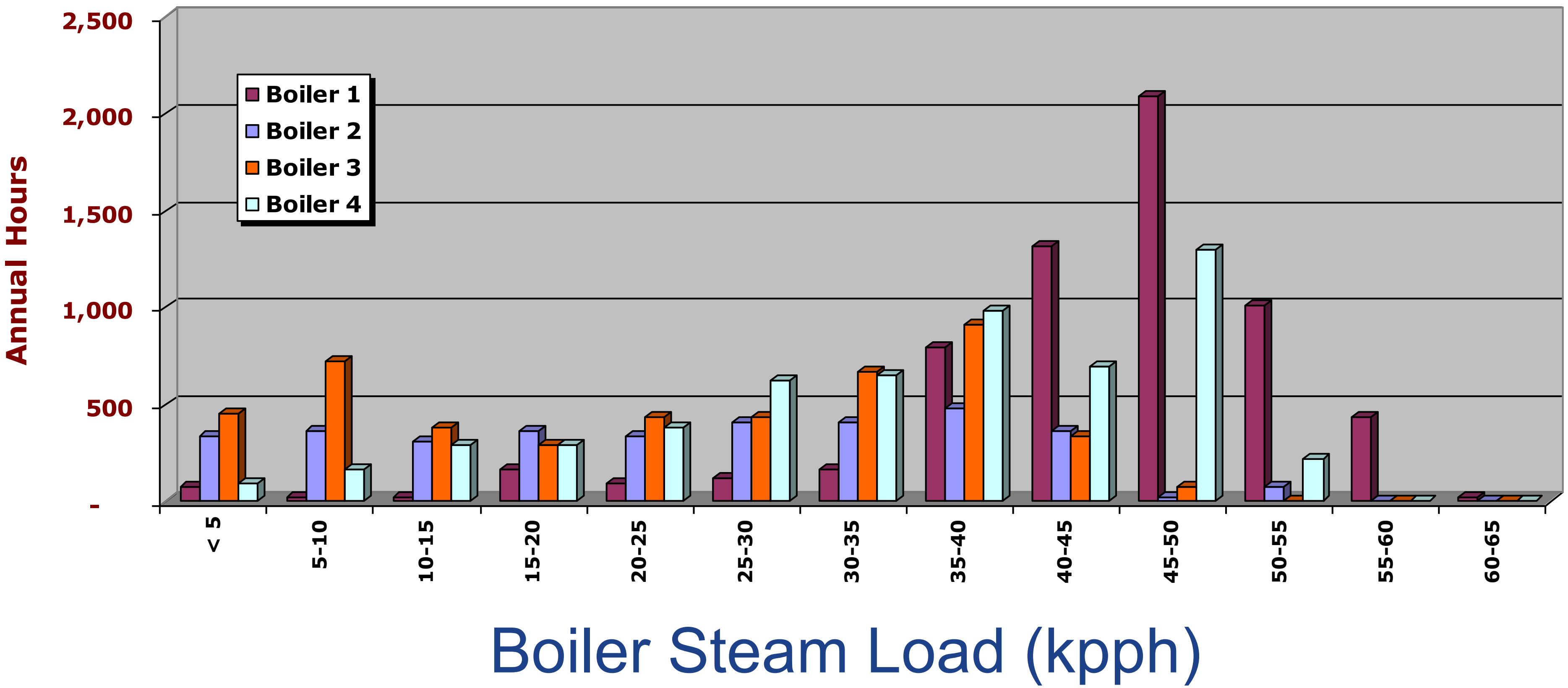
# Optimizing Boiler Plant Operations

- Develop an optimized boiler operation and load management strategy
  - Minimize number of boilers that operate
    - Without sacrificing reliability
  - Part-load vs. full load efficiency
  - Optimize use of landfill gas (fuel switching)
  - Tasks
    - Data analysis – 2.5 years
    - Development of load scenarios and how to manage the loads
    - Risk assessment
    - Management and business case study
    - Transition Oversight
    - Training for operators
    - Monitoring and Verification protocol

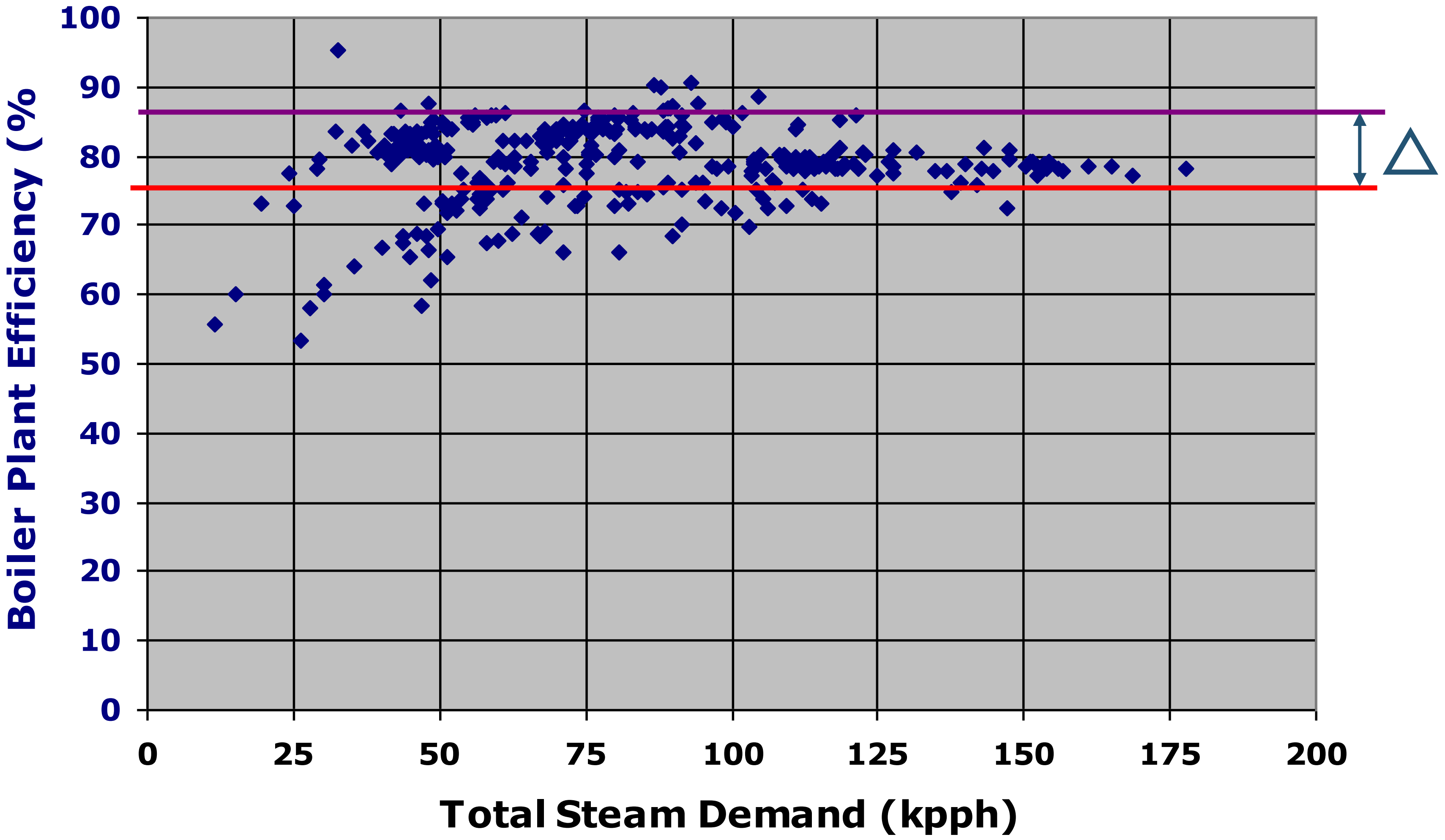
# Load Profile



# Load Profile



# Overall Boiler Plant Efficiency



# Optimization Strategy

- Load management
  - Use all the landfill gas that is available
  - Use the most efficient boilers
    - Mainly applies to low load conditions <70 klb/hr
  - Ensure that operational reliability exists in all scenarios
  - Level of redundancy (n+1)

- Maintain a warm standby boiler at all times
  - Eliminates boiler operation at low loads
  - Similar to a “spinning reserve”
  - Maintain at least 250°F in flue gas chamber
  - Operate standby boiler for a short period (15-20 minutes) to regain temperatures in boiler

# Optimization Strategy

| Steam Load (kpph) | Boiler #1 | Boiler #2 | Boiler #3* | Boiler #4 |
|---|---|---|---|---|
| 0 - 50 | STB | OFF | OFF | ON |
| 50 - 70 | ON | OFF | OFF | STB |
| 70 - 120 | ON | STB | OFF | ON (NG)** |
| 120 - 150 | ON | ON | STB | OFF |
| 150 - | ON | ON | ON | STB |

* Boiler #2 and #3 can be substituted for one another
** Indicates operation with natural gas only

# Save Energy Now Assessment Implementations

| ENERGY SAVINGS SUMMARY INFORMATION | | | | | |
|---|---|---|---|---|---|
| Implemented Opportunities | Savings/yr | | | | |
| | $ | kWh | MMBtu | Fuel Type | |
| Optimized boiler operation and load management strategy | 430,000 | 0 | 48,000 | Natural gas | |
| | | | | | |
| Reduced flue gas oxygen in Boiler #1 | 84,000 | 0 | 9,400 | Natural gas | |
| | | | | | |
| Reduced boiler blowdown | 24,000 | 0 | 3,000 | Natural gas | |
| | | | | | |
| Implemented a steam trap management program | 89,000 | 0 | 10,000 | Natural gas | |
| | | | | | |

# Case Study – Success Story



Industrial Technologies Program

Case Study

Save ENERGY Now

The powerhouse at Chrysler's St. Louis Assembly Complex provides steam, chilled water, and compressed air to both the north and south plants.

## Chrysler: Save Energy Now Assessment Enables a Vehicle Assembly Complex to Achieve Significant Natural Gas Savings

**Benefits**

- Achieves annual energy savings of $627,000
- Achieves annual natural gas savings of more than 70,000 MMBtu
- Yields a simple payback of just over 2 months

**Summary**

In July 2006, a Save Energy Now plant energy assessment was conducted for Chrysler at the company's truck and minivan assembly complex in St. Louis, Missouri. The main purpose of the assessment was to analyze the complex's steam system and identify opportunities for

Plant Energy Champion: Ken Peebles

## Energy Efficiency Opportunities (Generation)

- Thermal Energy Storage (Steam Accumulators)

# Polling Question 2

Polling Question

2) Do you have one (or multiple) boiler(s) which short-cycle or frequently turn ON/OFF?

A. Yes

B. No

C. Do not know

# Steam Accumulators

- Primary purpose - Thermal Energy Storage

- Significant impact on operations
  - Boiler plant capacity
  - Energy efficiency
  - Water savings
  - Environmental issues

- Classic applications
  - Batch operations
  - Intermittent high and low steam demands
  - Periods of very small high peaks of steam demand

# Steam Accumulators

- Typical examples in industry
  - Food and Beverage
  - Specialty chemical plants
  - Pharmaceutical industry
  - Textile plants
  - Rubber Tire manufacturing
  - Others…..

- Look for periodic short-cycling of steam demand
  - Longer periods (12 hours or more) may not be cost-effective

# Steam Accumulators

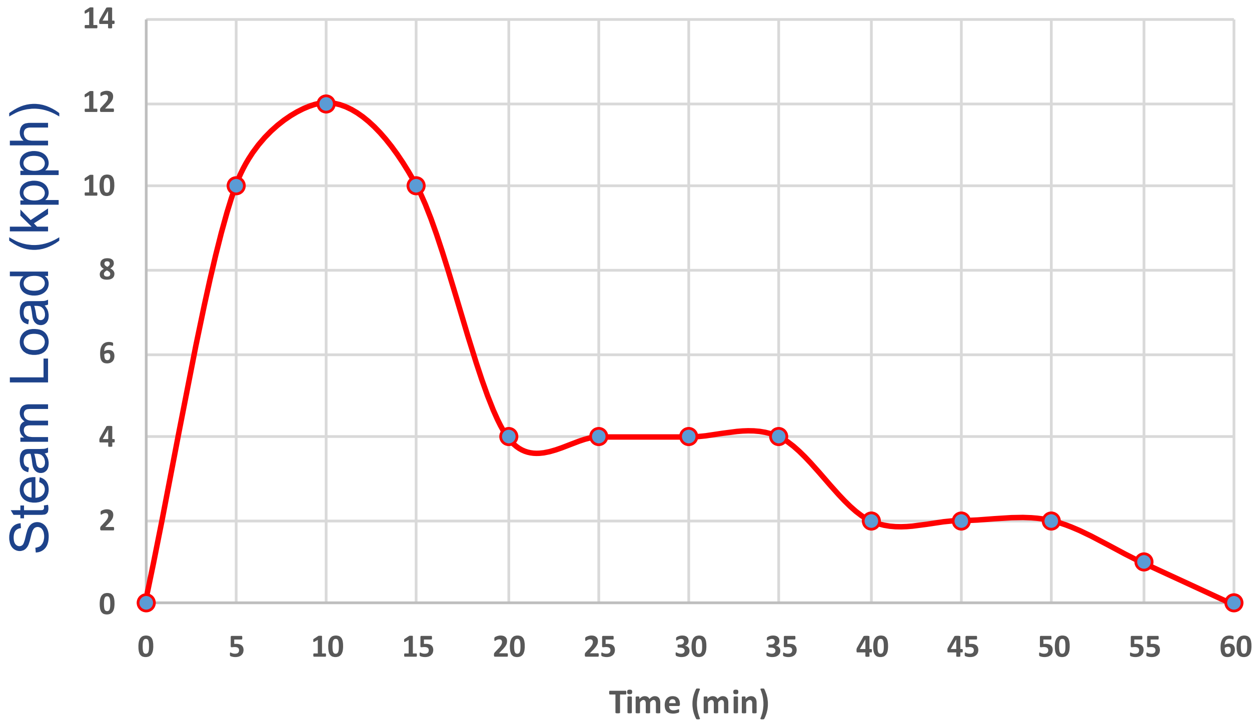
Batch Operation

Venting – Difficult Boiler Control

Accumulate Excess Steam

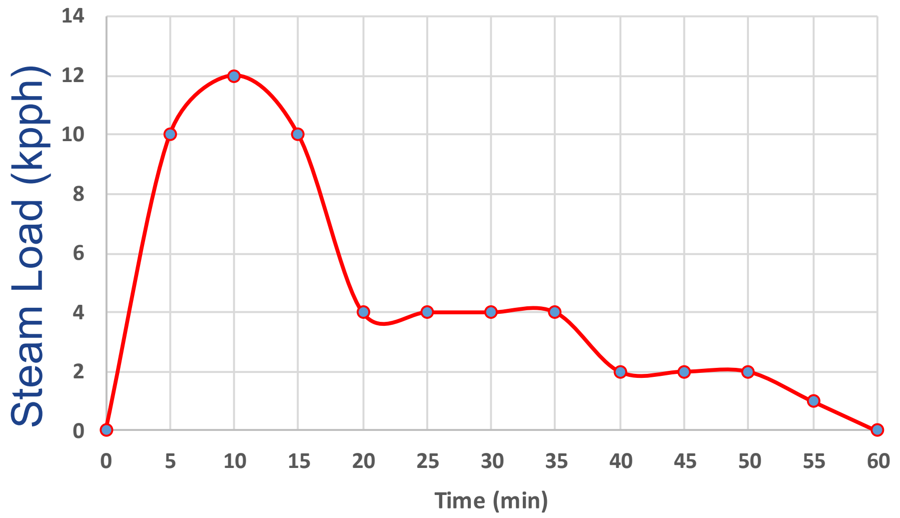
# Steam Accumulators

## Steam Load Profile: Cycle time



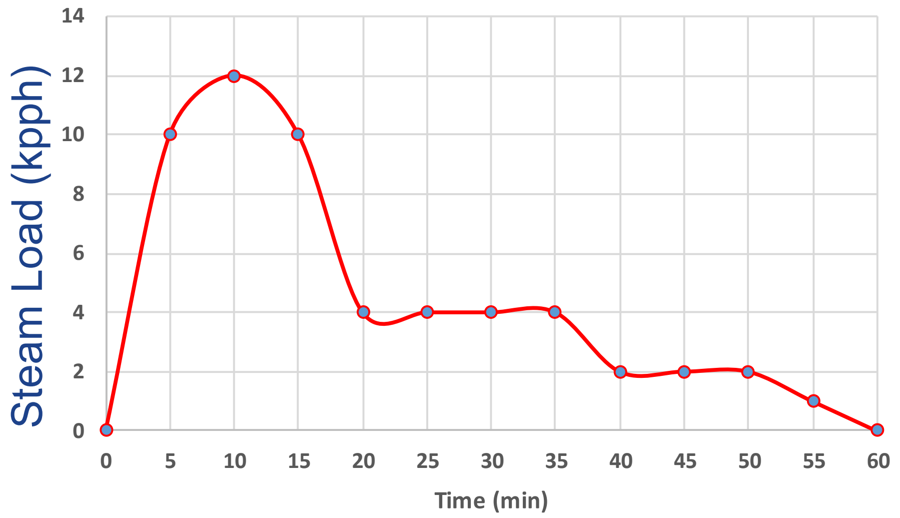
# Steam Accumulators

- Current Boiler Operation
  - Ramp up for 15 minutes
  - Slow down for 25 minutes
  - Low-fire or vent steam for 20 minutes
  - Pressure swings
  - Level control issues
  - Fuel / Air ratio issues
  - Manual versus automatic
  - Problems magnified with solid / biomass fuels

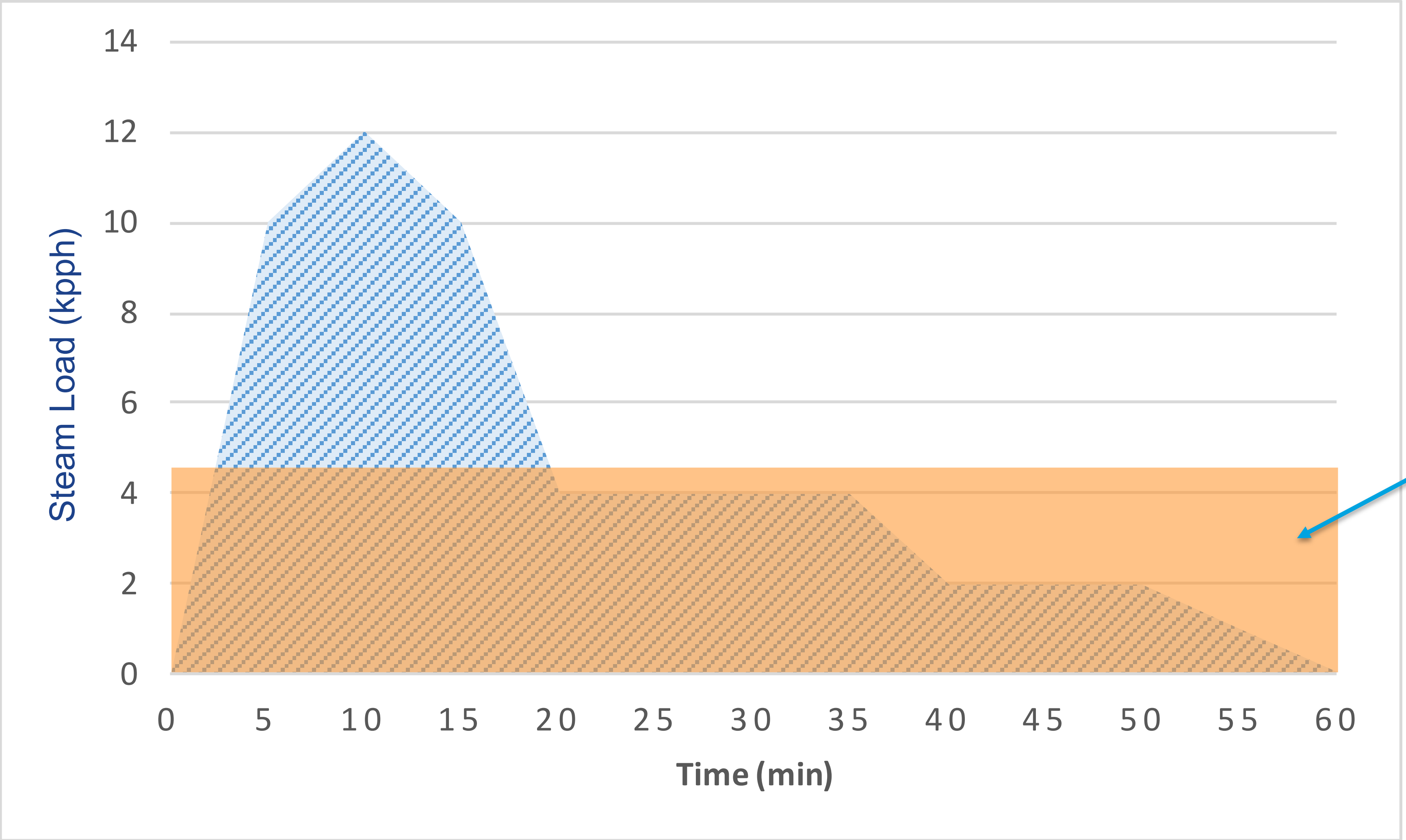


# Steam Accumulators

- Add a properly sized steam accumulator
- Maintain boiler at steady state operations
- Ramp up time for 15 minutes
  - Steam from boiler and accumulator
- Slow down for 25 minutes
  - Steam from boiler and/or accumulator
  - Steam supply to accumulator
- Next 20 minutes
  - Steam from boiler
  - Steam supply to accumulator



# Steam Accumulators




Fixed Boiler Operation

# Steam Accumulators

- Boiler runs a steady load of 4.6 klb/hr
- Total steam supplied in an hour = 4.6 klb
- Area under the profiles is the same
- Plant benefits
  - Energy savings due to better boiler efficiency
    - Zero purging since continuous boiler operation
  - Operating minimum number of boilers
  - No steam venting
  - Higher reliability of operations
  - Other system optimization opportunities may become options to consider

## Energy Efficiency Opportunities (CoGeneration)

- **Back Pressure Turbines**

# Classic Cogeneration Analysis

- The classic cogeneration analysis answers the following questions:
  - What is the true economic impact of cogeneration?
  - When is it viable?
    - To operate or shut down
    - To install
  - What changes, if any, will be required on the steam system?
  - What changes, if any, will be required for the electrical utility system and grid interconnects?

# Backpressure Turbine Evaluations

- It is important to understand the impact of turbines on the steam system
  - The following investigation is designed to emphasize the physical interactions within the steam system
    - The interactions are modeled in MEASUR
- The primary factors impacting the analysis are:
  - Impact electrical cost
  - Impact fuel cost
  - Boiler efficiency
  - Steam turbine efficiency
  - Steam demand

# Backpressure Turbine Economics

- Most industrial systems require **thermal energy** (not mass flow of steam)

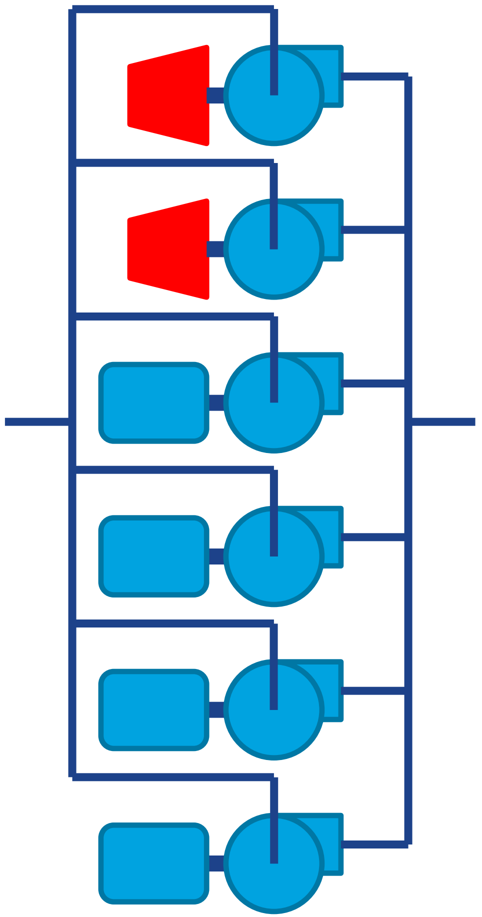
- The turbine will extract energy from the steam and convert it into shaft energy
  - The steam will exit the turbine with a reduced temperature

- The result will be an increased mass flow of steam required to satisfy the thermal demand

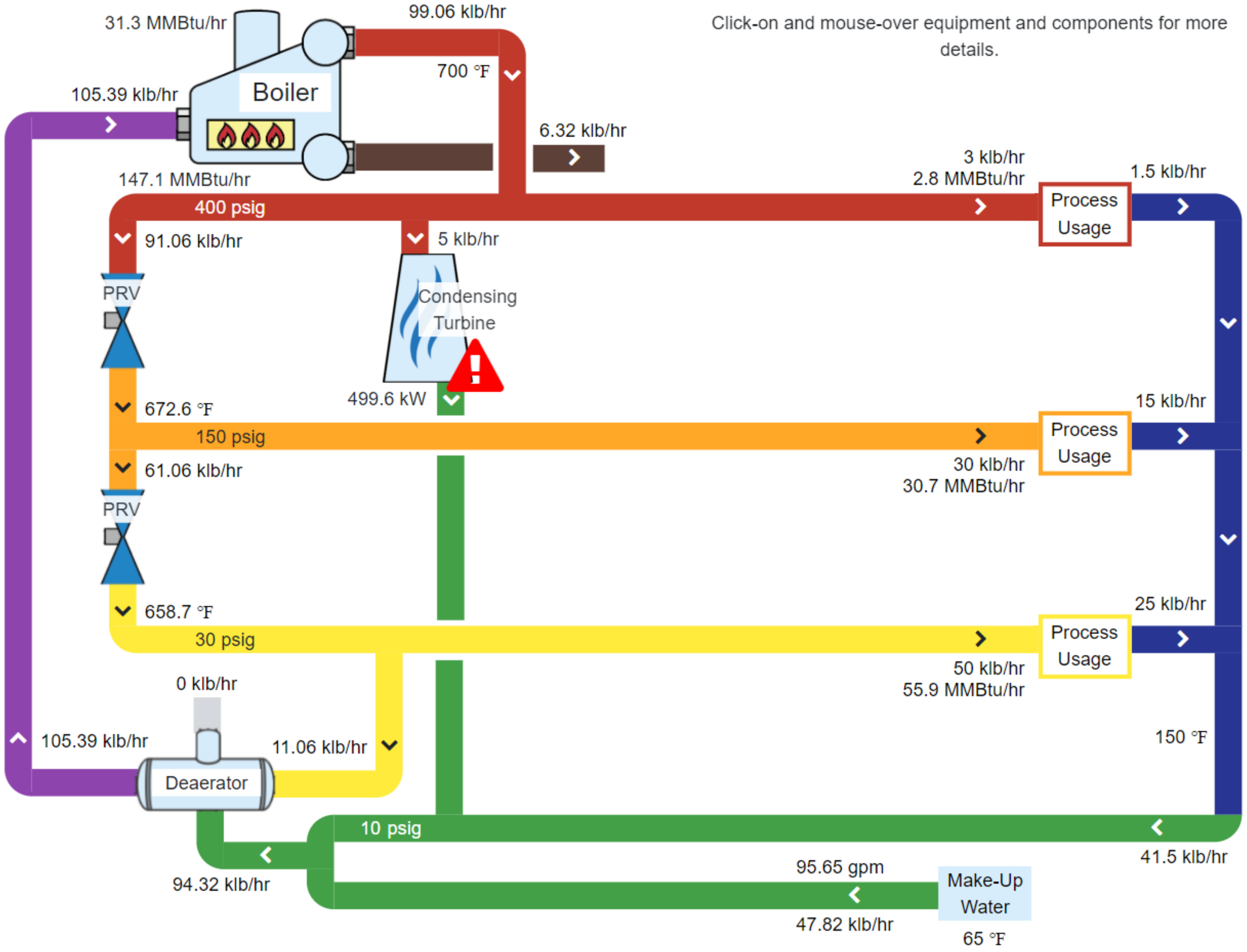
# Example Turbine-PRV Evaluation

- A process unit is equipped with 6 identical pumps (100 hp) that are installed in parallel
  - Only 3 of the 6 pumps are required to operate continuously
    - The remaining pumps are spare (backup) units
  - Electric motors drive 4 of the pumps and steam turbines drive 2 of the pumps
    - None of the steam turbine-driven pumps is being used at this time

- Identify the economic incentive associated with operating a steam turbine-driven pump
  - Compared to operating an electric motor driven pump and passing steam through a Pressure reducing Valve (PRV) to satisfy the low pressure demands



# Example – Pulp & Paper Mill Steam System



# Example – Pulp & Paper Mill Steam System

MEASUR

VINPLT_0421
Last modified: May 8, 2021

System Setup | **Assessment** | Diagram | Report | Sankey | Calculators

**Explore Opportunities** Novice View | Modify All Conditions Expert View

**BackPressure Turbine** Selected Scenario | View / Add Scenarios

Modification Name: BackPressure Turbine

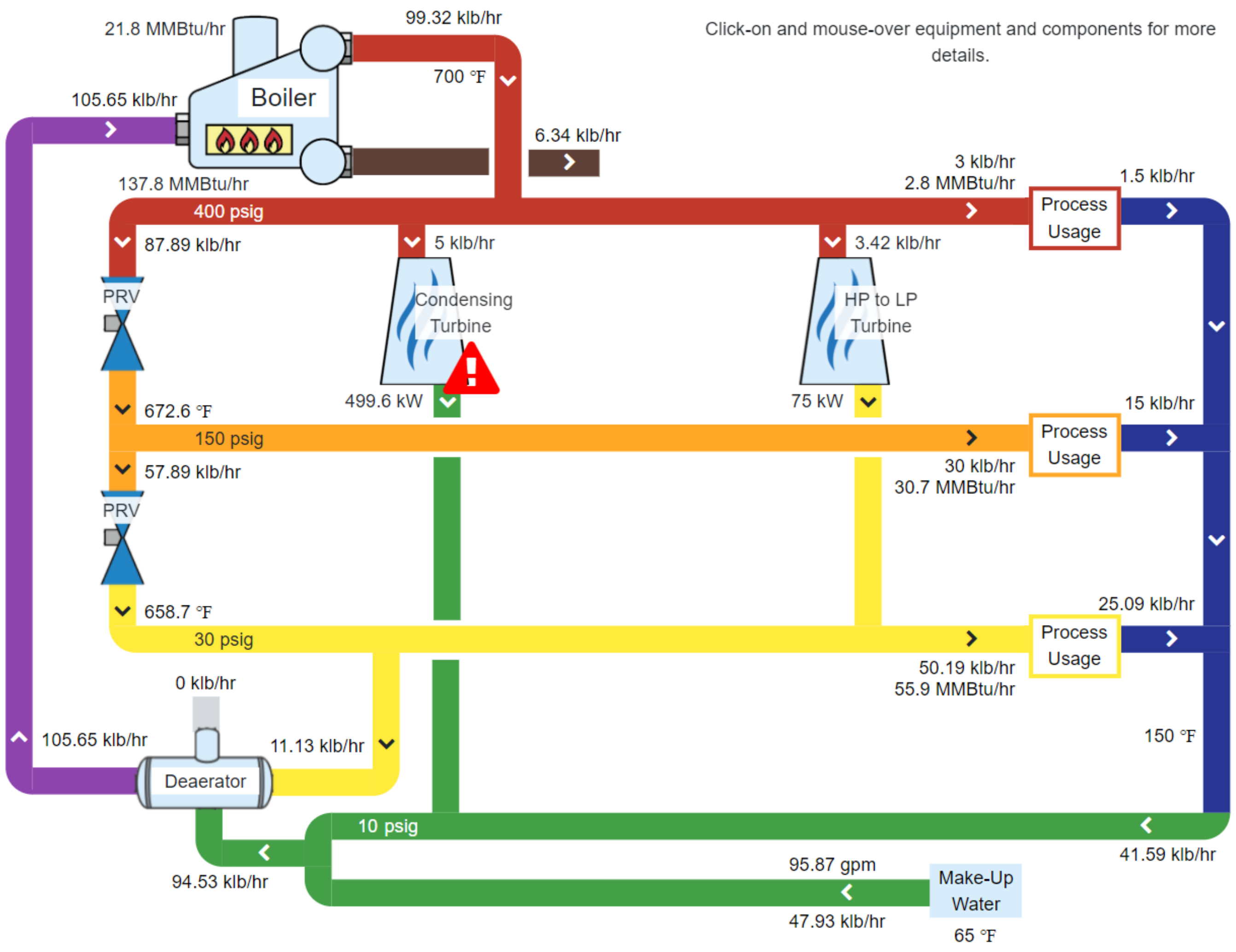
- [ ] Adjust General Operations
- [ ] Adjust Unit Costs
- [ ] Adjust Boiler Operations
- [ ] Adjust Condensate Handling
- [ ] Adjust Heat Loss Percentages
- [ ] Adjust Steam Demand/Usage
- [ ] Modify High Pressure to Condensing Steam Turbine
- [x] Modify High to Low Pressure Steam Turbine

| Baseline | Modifications |
|---|---|
| Turbine Status: Off | Turbine Status: On |
| | Isentropic Efficiency: 35 % |
| | Generator Efficiency: 100 % |
| | Operation Type: Power Generation |
| | Fixed Power: 75 kW |

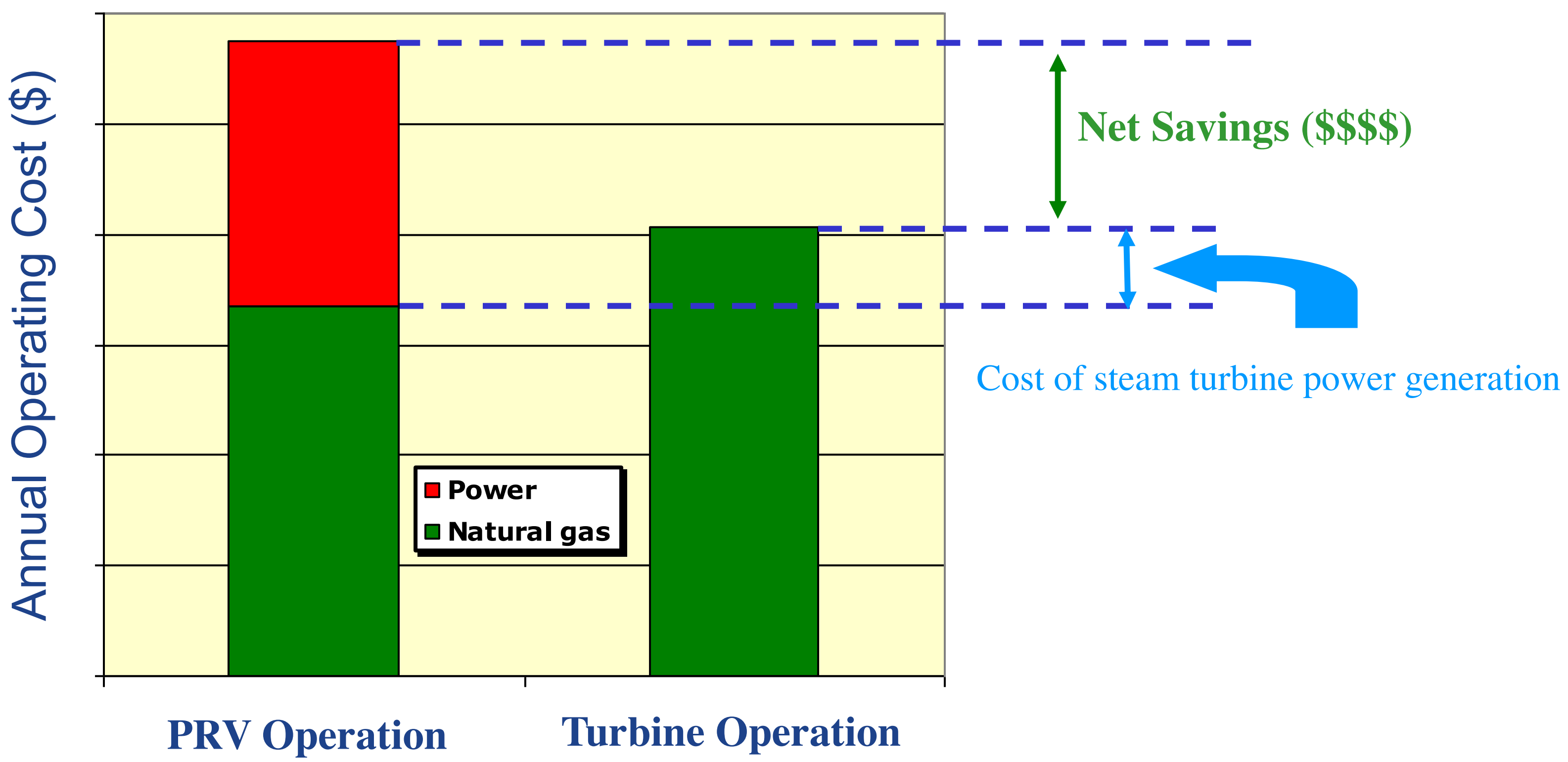
RESULTS | SANKEY | HELP

| | Baseline | BackPressure Turbine |
|---|---|---|
| Percent Savings (%) | — — | |
| Fuel Usage (MMBtu/yr) | 1,204,049.9 | 1,207,105.7 |
| Fuel Cost ($/yr) | $6,020,250 | $6,035,528 |
| Electricity Usage (kW/yr) | 43,800,000 | 43,143,000 |
| Electricity Cost ($/yr) | $2,190,000 | $2,157,150 |
| Water Usage (gal/yr) | 50,272,661.5 | 50,387,971.6 |
| Water Cost ($/yr) | $502,727 | $503,880 |
| Power Generated (kW/yr) | 499.6 | 574.6 |
| Process Use (MMBtu/yr) | 89.5 | 89.5 |
| Stack Loss (MMBtu/yr) | 21.7 | 21.8 |
| Vent Losses (MMBtu/yr) | 0 | 0 |
| Unrecycled Condensate Losses (MMBtu/yr) | 11.8 | 11.8 |
| Turbine Losses (MMBtu/yr) | 0.1 | 0.1 |
| Other Losses (MMBtu/yr) | 9.6 | 9.6 |
| **Annual Cost ($/yr)** | **$8,712,976** | **$8,696,558** |
| **Annual Savings ($/yr)** | **—** | **$16,418** |

# Example – Pulp & Paper Mill Steam System



# Backpressure Turbine Economics



# Variables for Industrial Applications

- Constant steam flow
- High pressure supply steam
- Existing Pressure Reducing Valve (PRV)
- Multiple steam header system
- Simultaneous steam and electric (power) demand
- High run hours

## Energy Efficiency Opportunities (CoGeneration)

- Back Pressure Turbines – A case study

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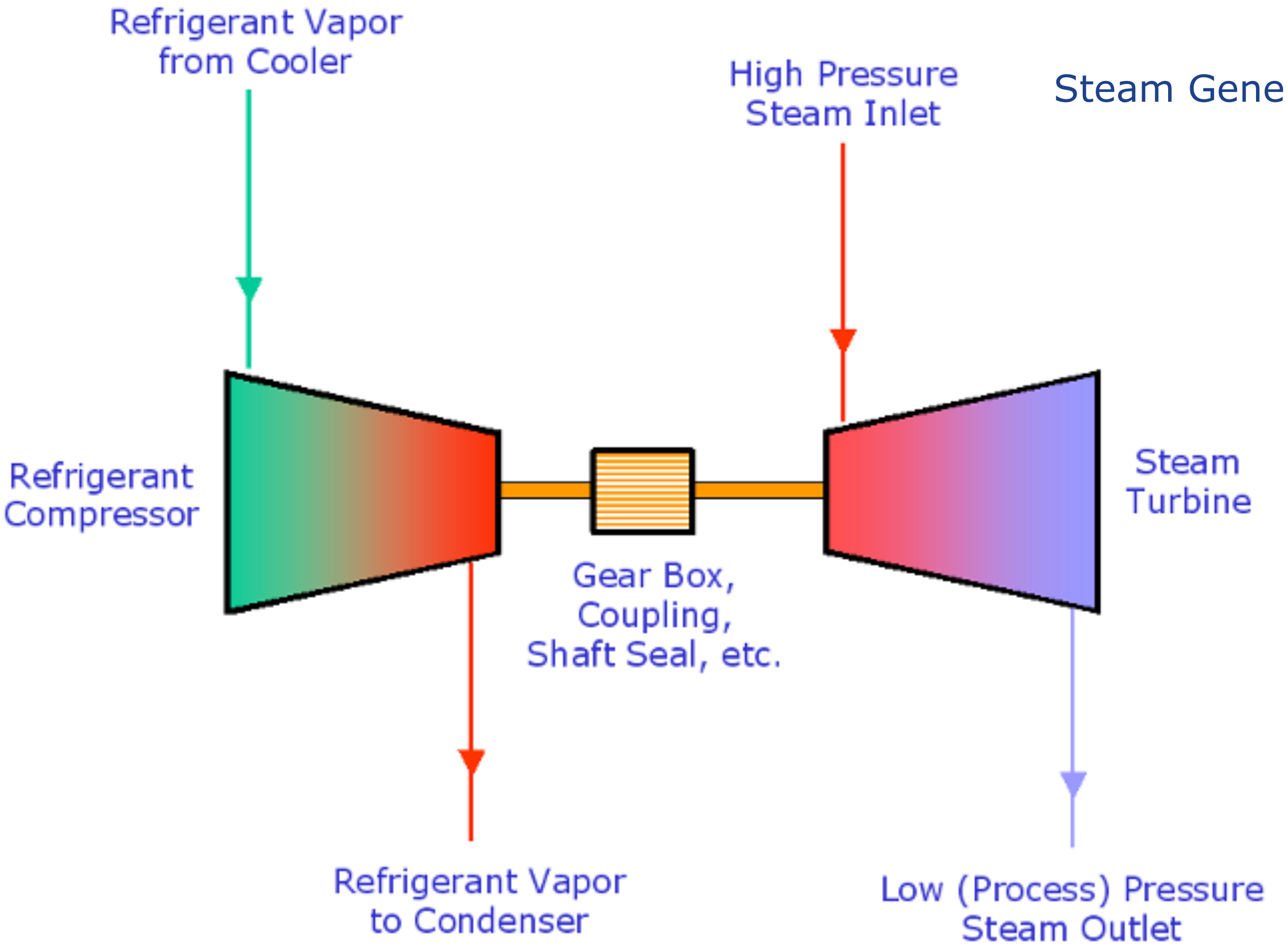
# Steam Turbine-driven Topping Cycle



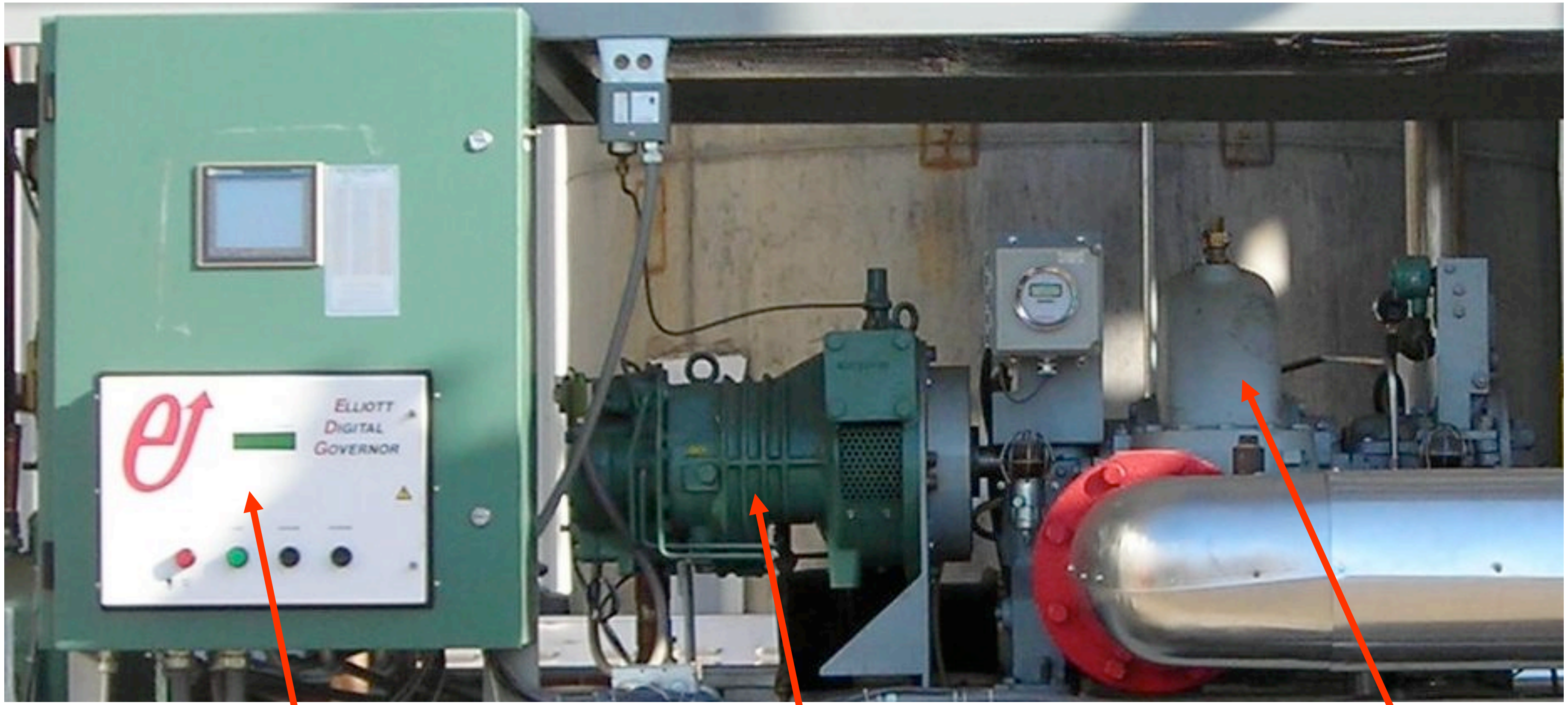

Steam Generation = 150 psig

Process use = 50 psig

# Equipment Specifications

- A steam turbine (Elliott 2BYRT: 65 kW; 4000 rpm; 10 klb/hr) is directly coupled to a screw chiller (Bitzer 86 ton refrigeration capacity)
- Plant boiler (150 psig) provides steam to turbine with the low pressure exhaust (50 psig) providing steam to operations and retorts

# Equipment Specifications




Control Panel

Screw Compressor

Steam Turbine

# Project Cost-Benefits Summary

- Cost Summary
  - Steam turbine and controls: $30,000
  - Bitzer Chiller and Controls: $56,000

- Savings Summary
  - Steam turbine-driven chiller vs electric unit: 104 kW and 540,000 kWh (in-season)
  - Natural gas net increase of 2,100 MMBtu due to an increase in steam generation to offset the steam enthalpy change across the steam turbine
  - Net annual savings: $45,000

# Common BestPractices –Turbines

- Process and utility integration leads to overall energy optimization of the plant
- Install backpressure turbines in parallel with pressure letdown stations and minimize flow through letdown stations
- Evaluate backpressure turbine applications for direct mechanical drives
- Evaluate condensing turbines and optimize their operations to maintain design conditions
- Condensing turbines can serve as a system balance mechanism especially, in industries which have significant waste heat steam generation

**Source: US DOE BestPractices Steam System Sourcebook**

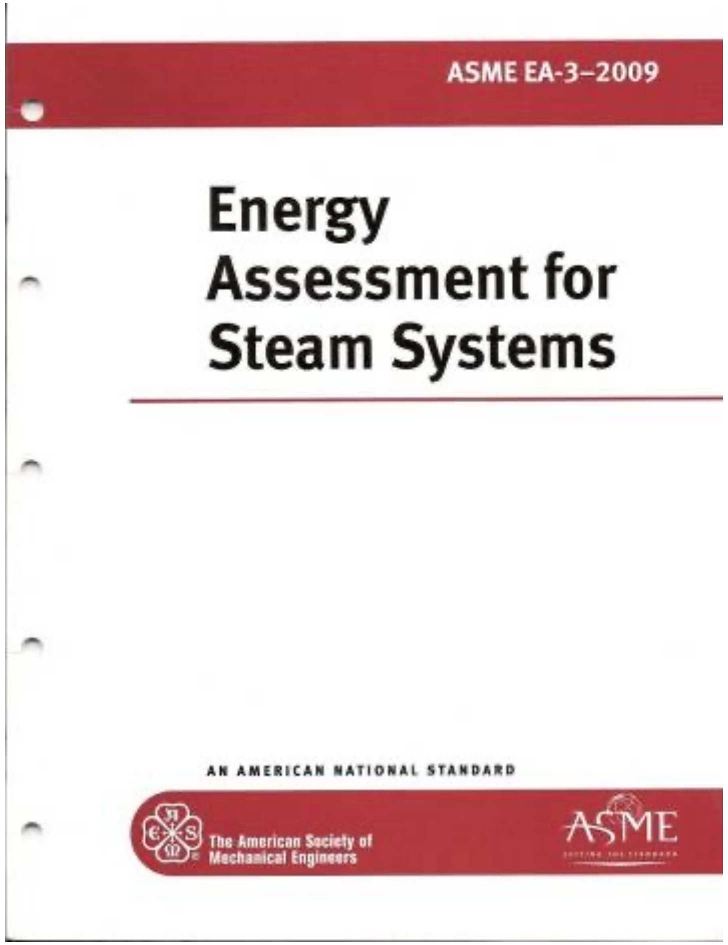
## Steam System Industrial Energy Assessment

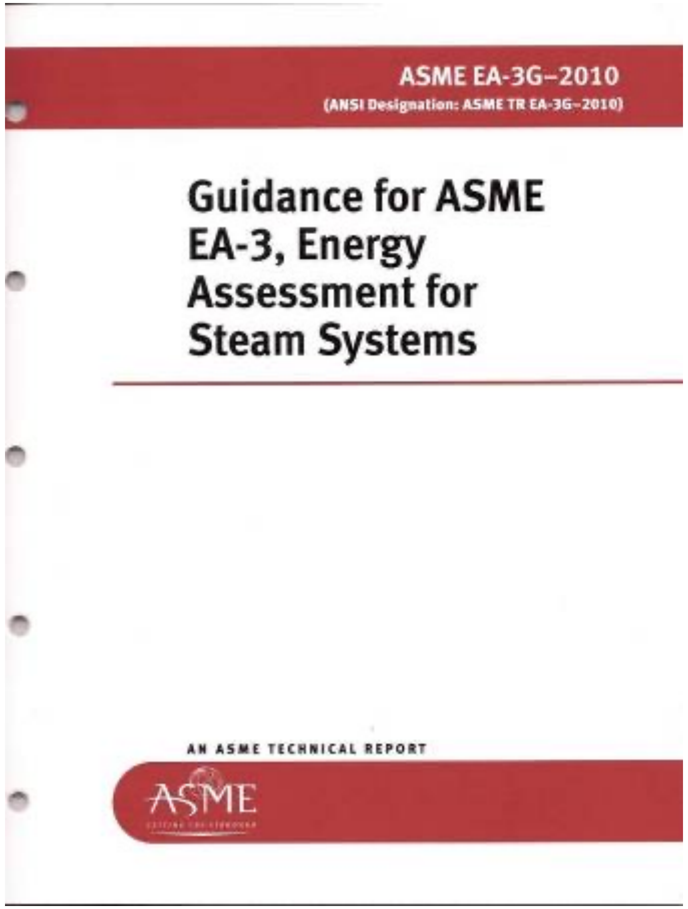
- Preparation for Group Discussion (December 9)

# Industrial Energy Assessment

- There are several levels of industrial plant energy assessments (audits)
  - Overall plant-wide
  - System focused – steam, compressed air…..
  - 1-day, 3-day……
- But the overall goal is typically, focused on reductions in energy usage (and/or intensity)
- Identification of energy savings opportunities and path to implementation
- Expectations vary significantly between plant personnel and energy auditor

# Energy Assessment Standard for Steam Systems




http://www.asme.org/products/codes---standards/energy-assessment-for-steam-systems

# Energy Assessment Standard for Steam Systems

- Scope
  - Covers steam systems containing steam generator(s) or other steam source(s), a steam distribution network, end-use equipment and recovery
  - Cogeneration and power generation components may be included
  - Sets the requirements for conducting and reporting the results of a steam system energy assessment that considers the entire system, from energy inputs to the work performed as the result of these inputs
  - Resulting assessment will identify the major opportunities for improving the overall energy performance of steam system
  - Designed to be applied primarily at industrial facilities, but most of the specified procedures can be used in other facilities such as those in the institutional and commercial sectors

# Energy Assessment Standard for Steam Systems

- Use of this Standard and accompanying Guidance Document should increase the quantity and quality of energy assessments performed, with significant potential savings in implemented energy costs

- **Intended for** energy managers, facility managers, plant engineers, energy consultants, maintenance managers, plant managers, EH&S managers, across a broad range of industries

# Energy Assessment Standard for Steam Systems

- The standard clearly identifies the processes, protocols and deliverables of a steam assessment
- The sections of the steam assessment standard are:
  - Scope & Introduction
  - Definitions
  - References
  - Organizing the Assessment
  - Conducting the Assessment
  - Assessment Data Analysis
  - Report & Documentation
  - Appendix A – Key References
- An accompanying guide provides more detailed information for each of the sections

# Typical Project Areas in a Steam System Assessment

- Boiler efficiency improvement
- Fuel switching
- Boiler blowdown thermal energy recovery
- Steam demand reduction
- General turbine operations
- Thermal integration
- Process/Utility integration
- Turbine-PRV operations
- Condensing turbine operations
- Thermal insulation
- Condensate recovery
- Flash steam recovery
- Steam leaks management
- Steam trap management
- Waste heat recovery

# Energy Saving Opportunities

| | Near-Term | Mid-Term | Long-Term |
|---|---|---|---|
| **Definition** | Improvements in operating and maintenance practices | Require purchase of additional equipment and/or system changes | New technology or confirmation of performance in plant |
| **Capital Expense** | Low cost actions or equipment purchases | Rules of thumb estimates can be made | Additional due-diligence required |
| **Payback** | Less than one year | One to two year | Two to five-year |
| **Examples of Projects** | • Boiler combustion tuning<br>• Insulation<br>• Steam leaks and trap management | • Automatic combustion control<br>• Blowdown energy recovery<br>• Feedwater economizer | • Combined Heat & Power<br>• Steam turbine driven process components<br>• Boiler fuel switching |

# Homework #6

- Evaluate the opportunities we talked about in the VINPLT today
- Pick one (or more) applicable scenarios and apply it to your plant by modeling it in your MEASUR plant model
- Save the file w/different scenarios on your computer and send us the .json file
- As you undertake your energy assessment, provide me with one project that you would want to present on December 9 in the group discussion

**Thank You all for attending today's webinar.**

**See you all on Friday – December 2, 2022 – 10 am ET**

**If you have specific questions, please stay online and we will try and answer them.**

**Alternately, you can email questions to me at rapapar@c2asustainable.com**

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