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INNOVATIVE ENGINEERING

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THIS IS AN INTERACTIVE PRESENTATION

PLEASE RAISE YOUR HAND AT ANY TIME TO ASK A QUESTION OR MAKE A COMMENT

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T-SHIRT HUMOR

CHEMICAL ENGINEERS

WE FIX PROBLEMS YOU DIDN'T KNOW YOU HAD

IN WAYS YOU DON'T UNDERSTAND

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Thermodynamic Laws are the foundation of Chemical Engineering
Environmental Laws regulate the byproducts of various processes in order to safeguard the public and our environment.

A subset of the both laws are guidelines, permits, and best practices to assist in designing processes and equipment to operate efficiently and to provide stewardship for our environment.

Guidelines provide a conservative approach to cover a wide range of operating conditions. In many situations, various plant equipment require different operating conditions for maximum efficiency and reliability. These needs offer opportunities for innovative engineering!
Permits are specific for each plant.
Best practices are applying both laws to a specific process and to overall plant operation, while maintaining safety and profitability.

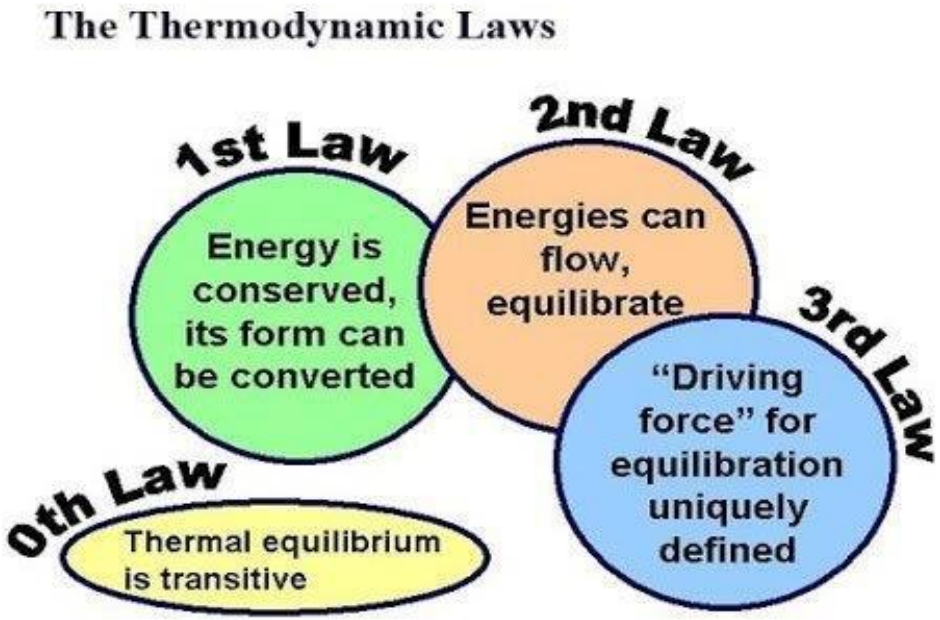
This presentation offers innovative ideas to best meet these goals.

The laws of Thermodynamics

1: You can't win, you can only break even.

2: You can only break even at T=0.

3: You can't reach T=0....



Discharge permits are required for every processing plant discharging industrial water to a city, regional district, or water body.
NPDES permit was created in 1972 to regulate point sources to all waters.
Generally, the permit identifies pH, TSS, TDS, Oil&Grease, BOD, COD and any specific contaminant attributable to the source (lead, zinc, mercury…).

188 air pollutants are identified -- heat is not one!!!

Best practices are derived from recognized guidelines and applied to specific equipment and operations.

Senior operators and managers provide excellent historical information to address challenges.

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CASE STUDIES:

BOILER/TURBINE OPERATION

COOLING/AIR COMPRESSOR AND OIL COOLER OPERATION

WASTEWATER/PROCESS PRODUCT RECOVERY

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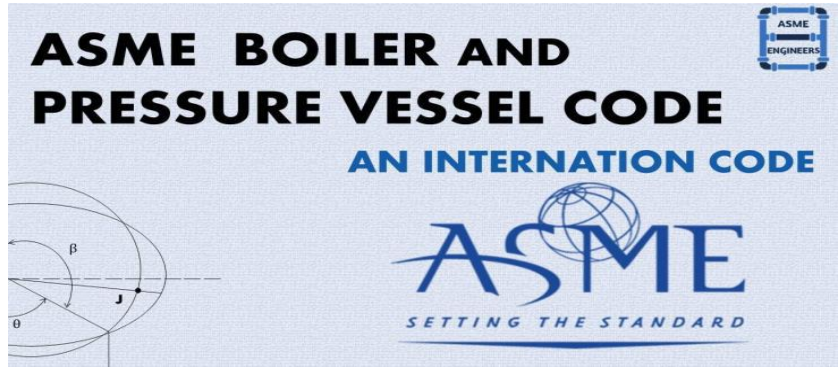
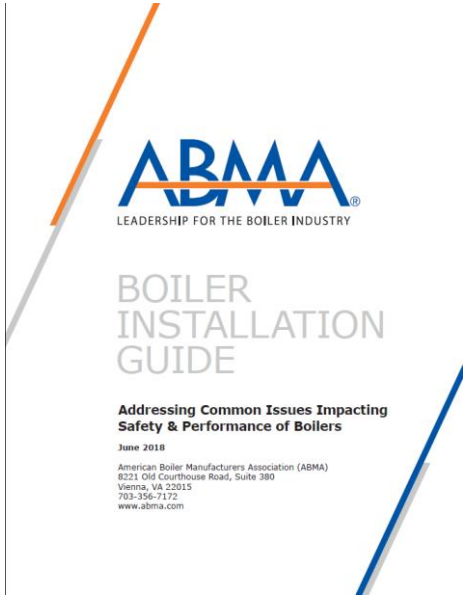


Engineering Standards and Guidelines

ABMA
ASME
NPDES



American Society of Mechanical Engineers
American Boiler Manufacturers Association
American Institute of Chemical Engineers

ASME standards regulate the design and construction of boilers and pressure vessels

ASME Research Committee on Water in Thermal Power Systems provides Boiler Feedwater and Boiler Water Guidelines

ABMA provides guidance on boiler water and steam quality

AICHE provides guidance on Steam Turbine Design and Analysis

HOW MANY ARE FAMILIAR WITH THE TERM

TURBINING TUBES??

USING ELLIOTT GAGES??

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TURBINING TUBES

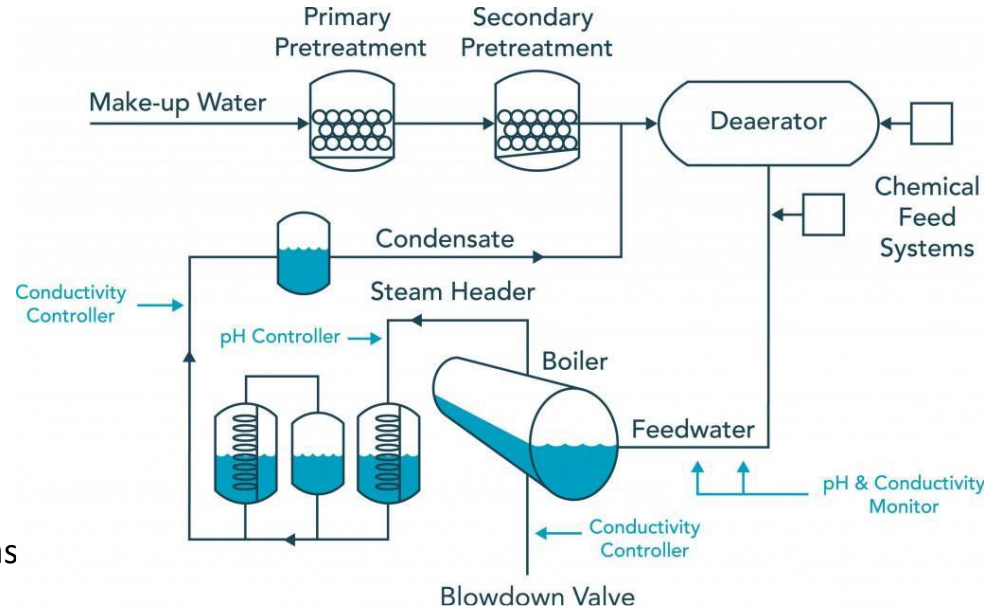
One old "Best practice" involved maintaining a thin scale on boiler tubes in order to minimize offline oxygen corrosion!!
Boilers are stored hot standby or cold (closed or open) off-line and susceptible to oxygen corrosion.
During maintenance shutdown, the scale was removed by turbining tubes.
The scale was collected in the mud drum and thickness was measured.

Online operating efficiency loss was 5%!!

Cooling system heat exchangers have similar scale and turbining needs.

A TANK HEATING SYSTEM USES 15 PSIG STEAM INSIDE CLOSED PIPING WITH CONDENSATE TRAP TO ACHIEVE/MAINTAIN A PROCESS TEMPERATURE OF 140F IN AN OPEN TANK

HOW DOES CONDENSATE BECOME CONTAMINATED??



Boiler System Operating Conditions

60,000 to 80,000 #/hr steaming capacity at 200 psig -- 1 coal fired boiler, 2 gas

350 days per year operation 50,000 #/hr average steaming rate

Run of mine coal -- Truck Delivered stoker fired boiler -- 12,000 Btu/pound heating value -- $40/ton as received

3 makeup water options -- city, canal, or well water -- generally canal water due to expense

Hot Lime/Hot zeolite softening system

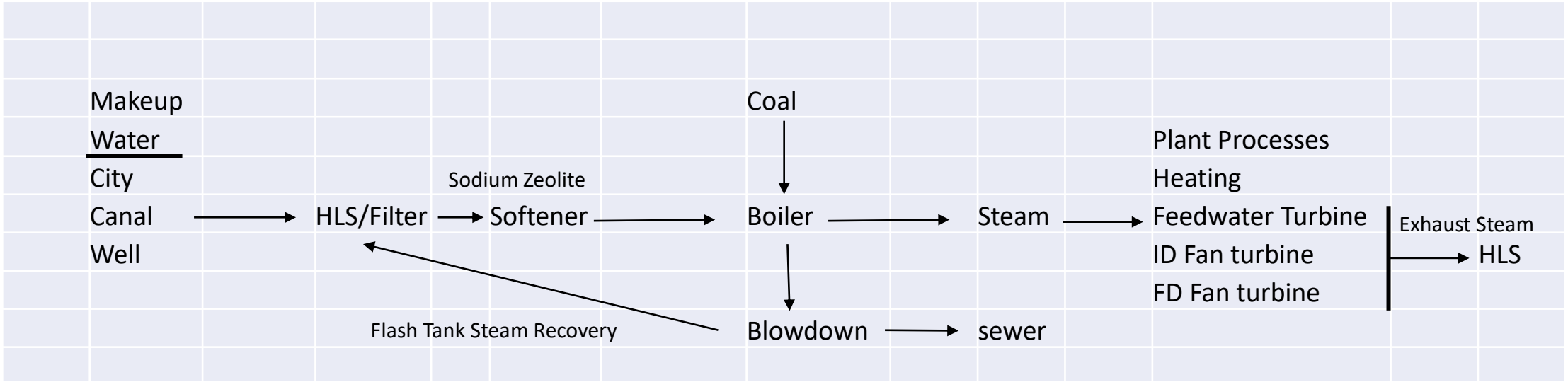
0% condensate return, no steam treatment

ID, FD, FW steam/electric driven motors

no power produced

Historical efficiency 7-8 pounds of steam per pound of coal burned (60-70% efficiency)
Historical fuel cost **$1.3 Million per year**

Boiler System



Boiler System Historical Fuel Costs

$ 40.00	Dollars per ton of coal Truck delivered
12000	Btu/# of coal
1150	avg Btu/# energy addition to make steam
10.4	# steam per # of coal at 100% fuel efficiency
6.5	Historical avg # steam per # coal
62%	Historical fuel efficiency
$ 0.020	per pound of coal
$ 3.08	per 1000 pounds of steam
50,000	#/hr average coal steaming rate
$ 154	fuel cost per hour
$ 1,292,308	fuel cost per year

Total Dissolved Solids is used interchangeably with conductivity

TDS is measured by evaporating a sample and determining the percentage of remaining solids.
This method is most accurate but too difficult to use on a daily basis

Conductance is measured by the ability of the sample to conduct electricity
This method is used due to simplicity - a conductivity meter is commonly used

The general relationship is that TDS equals 0.7 times conductance

Source: Nalco Water Handbook Second Edition

TABLE 39.8 Optimum Boiler Water Control Limits*

Drum-type boilers using softened (not deionized) feed waters

	Pressure, lb/in²			
	150	300	600	900
TDS (max.)	4000	3500	3000	200
Phosphate (as PO_4)†	30–60	30–60	20–40	15–2
Hydroxide (as $CaCO_3$)	300–400	250–300	150–200	120–
Sulfite	30–60	30–40	20–30	15–
Silica (as SiO_2) mas.‡	100	50	30	1
Total iron (as Fe) max.	10	5	3	
Organics	70–100	70–100	70–100	50–

Source: Nalco Water Handbook Second Edition

Boiler Water			
Drum Pressure (psig)	Silica (ppm SiO_2)	Total Alkalinity (ppm $CaCO_3$)	Specific Conductance (micromhos/cm)
0-300	150	700	7000
301-450	90	600	6000
451-600	40	500	5000
601-750	30	400	4000
751-900	20	300	3000
901-1000	8	200	2000
1001-1500	2	0	150
1501-2000	1	0	100

Figure 17-6. General guidelines for avoiding chemical carryover.

Source: Betz Handbook of Industrial Water Conditioning Seventh Edition

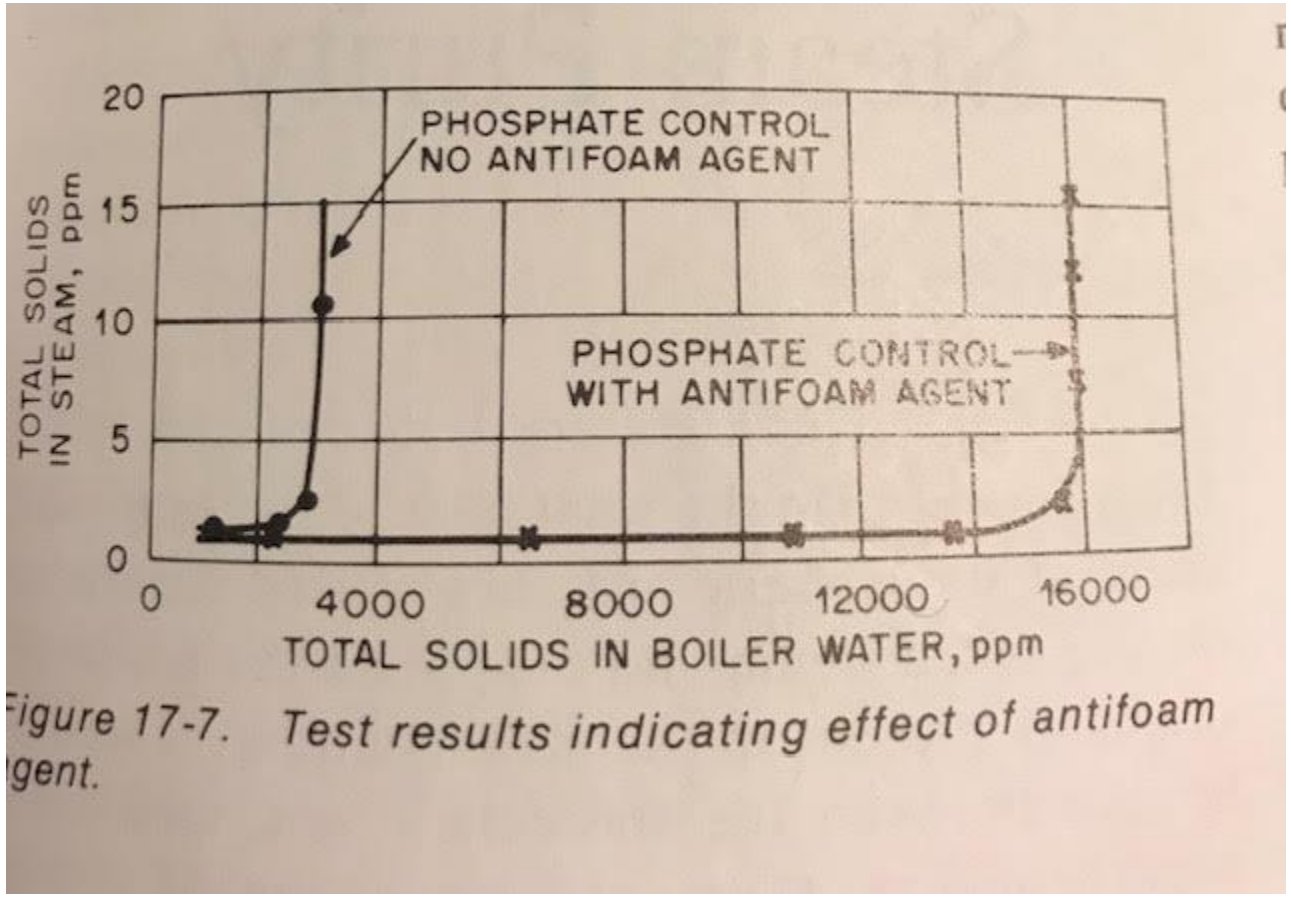
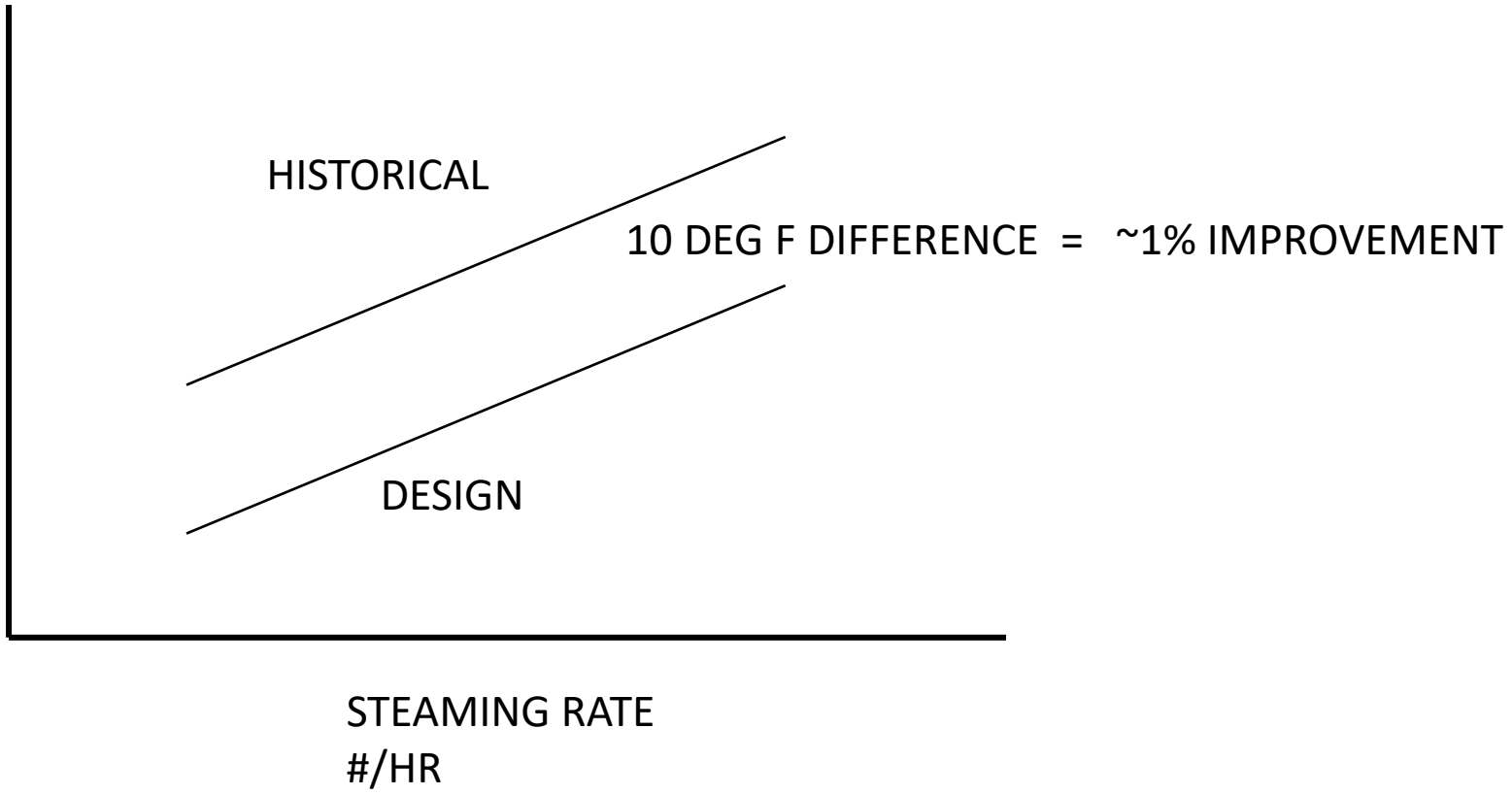


Figure 17-7. Test results indicating effect of antifoam agent.

Antifoam is generally not used due to inconvenience of feeding it separately from other boiler water treatment chemicals.

Source: Betz Handbook of Industrial Water Conditioning Seventh Edition

Boiler System



Boiler System

BACKGROUND

Review Boiler Equipment Systems

Pretreatment – HLS, Filters, Softeners

Boiler – Internal Treatment, Fireside

Turbines Operation -- ID, FD, and FW units

Internal Water Treatment

Review Boiler and Turbine inspection reports

CHANGES

Install canal water quality monitor – conductivity meter with alarm

Initiate operator training for HLS, Filters, and softener operation

Eliminate caustic addition to boiler water for pH control -- increase pH through higher conductivity

Add antifoaming chemical

Install steam quality monitor to determine optimum boiler water conductivity limit

Monitor and improve fireside deposits -- exit gas temperature vs steam load

Boiler System Improved Fuel Costs

$ 40.00	Dollars per ton of coal Truck delivered
12000	Btu/# of coal
1150	avg Btu/# energy addition to make steam
10.4	# steam per # of coal at 100% fuel efficiency
8.5	Historical avg # steam per # coal
81%	Historical fuel efficiency
$ 0.020	per pound of coal
$ 2.35	per 1000 pounds of steam
50,000	#/hr average coal steaming rate
$ 118	fuel cost per hour
$ 988,235	fuel cost per year

$304,000 Yearly Savings

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THANKS TO JOE YURKO FOR

PEER CHECK/RECOMMENDATIONS

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- QUESTIONS/COMMENTS ??

COOLING SYSTEM REVIEW

THIS DISCUSSION WILL COVER SYSTEMS USING COOLING TOWERS

- COOLING TOWERS REMOVE PROCESS HEAT THROUGH EVAPORATION AND PROVIDE COOLING WATER AROUND 15F ABOVE THE BACKGROUND WET BULB TEMPERATURE.
  - ABOUT 80% OF THE HEAT REMOVED IS THROUGH EVAPORATION
  - THE REMAINDER IS REMOVED THROUGH SENSIBLE AIR HEAT TRANSFER

- FOR NE OHIO AREA THE RANGE OF COOLED WATER 40 TO 90F
  - -- 90F IS USED TO DESIGN PROCESS EQUIPMENT

- Q = U A DELTA T LOG MEAN

- USERS
  - AIR COMPRESSORS
  - OIL COOLERS
  - POWER PLANT CONDENSERS
  - AIR CONDITIONING

AIR COMPRESSORS

- Types of air compressors
  - Reciprocating
  - Rotary/Screw
  - Centrifugal

AIR COMPRESSORS

MULTI STAGE AIR COMPRESSORS

- Typical plant air pressure is 90-100 psig
- A 4-stage air compressor would have a single shaft with gears running interstage units
  - The outlet air temperature of each stage is closely controlled
  - Each stage must run in unison to minimize imbalance
- Each stage has an air inlet/outlet and water inlet/outlet
- Air outlet of each stage can be about 300F and is the inlet to the next stage -
  the mass flow needs to be constant and is temperature controlled ~110F
- As noted, interstage coolers are designed for worst case cooling water temperature of 90F
- Typical water velocity through heat exchangers is about 7 ft per second.

AIR COMPRESSORS

Cooling tower operation

- Under summer conditions, 90F cooling water is design temp and available
- 110 F outlet air temperature is required
- 105F outlet temperature is the design temperature for the heat exchanger
- 15F rise for water
  - for 1 million BTU/HR heat removal, 67,000 #/hr or 133 gpm at 7 fps

- Under winter conditions, 40F cooling water is design temp and available
- 110 F outlet air temperature is required
- 105F outlet temperature is the design temperature for the heat exchanger
- 65F rise for water
  - for 1 million BTU/HR heat removal, 15,000 #/hr or 31 gpm at ~1.6 fps

Water control valves close to maintain air interstage temperatures

Equipment inspections confirmed scale and corrosion

AIR COMPRESSORS

OPERATING CHANGES

- Other cooling processes were all designed for 90F – no process improvements were achieved with colder cooling water.
- The cooling tower operation was modified to bypass water across the tower during winter conditions.
- A return cooling water temperature of 75F was chosen as the operating set point in order to achieve an exchanger water velocity of about 3.5 fps – 50% of design.

AIR COMPRESSORS

OPERATING IMPROVEMENTS

- REDUCED COOLING TOWER FAN OPERATION --- 100 HP = ABOUT $15,000 – 6 MONTHS
- SIGNIFICANT IMPROVEMENT OF COMPRESSOR AVAILABILITY DURING SUMMER
- SIGNIFICANT REDUCTION IN MAINTENANCE COSTS/CLEANING

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- QUESTIONS/COMMENTS ??

EXAMPLES OF WASTEWATER/PROCESS PRODUCT RECOVERY

LAWS AND GUIDELINES

CLEAN WATER ACT

(1972) The Clean Water Act (CWA) **establishes the basic structure for regulating discharges of pollutants into the waters of the United States and regulating quality standards for surface waters**. ... Industrial, municipal, and other facilities must obtain permits if their discharges go directly to surface waters.

The Water Quality Standards program acts as a road map for achieving the goals of the Clean Water Act by doing three specific things:

1. **Designating uses of each water body in the state,**
2. **Establishing numeric, biological, and narrative criteria to protect those uses, and**
3. **Protecting levels of good water quality in waters**

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EXAMPLES OF WASTEWATER/PROCESS PRODUCT RECOVERY

LAWS AND GUIDELINES

EPA - The Environmental Protection Agency is an independent executive agency of the United States federal government tasked with environmental protection matters. This includes water, air, and solids.

NPDES - A discharging sewage treatment systems treats and then discharges treated effluent to a stream, ditch or other surface water body. A National Pollutant Discharge Elimination Systems (NPDES) permit must be obtained from the Ohio Environmental Protection Agency (Ohio EPA) Division of Surface Water whenever there is a discharge of treated or partially treated water to a surface water of the State. NPDES permits exist to regulate wastewater discharges by placing limitations on the quantity of pollutants that may be discharged and to establish monitoring requirements and other conditions. Federal regulations, Ohio water quality standards and NPDES permits were written to protect public health and the aquatic environment.

NEORSD The Northeast Ohio Regional Sewer District **protects public health and the environment by leading effective wastewater and stormwater management**.

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EXAMPLES OF WASTEWATER AND PROCESS PRODUCT RECOVERY

Wastewater is generally regarded as an integral part of most processes

Recovery of wastewater components can provide a positive value

1. Oil or Water Based paint overspray is captured, treated and then sent to a land fill.
   Special pigments are part of the paint and can be separated and recycled as a primer paint

2. Chemical dispersants are especially challenging for wastewater treatment.
   Typically, solids are added to the wastewater to capture the dispersant, creating a low solids sludge.
   The sludge is then sent to a landfill.

3. A waste water stream contains high chlorides and fluorides that require non-traditional municipal treatment. Separation of the fluorides allows concentration of chlorides to produce a salable product

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EXAMPLES OF WASTEWATER/PROCESS PRODUCT RECOVERY

Waste Heat is An overlooked process product that offers significant opportunity for innovative engineering

Most plants have boilers for process and comfort heating
- Exhaust gas discharge temperature is 300-400F

Some plants also have process furnaces
- Exhaust gas discharge temperature is 200-400F
- Water sprays are sometimes used

Most plants have overhead doors to allow trucks and large material access
- The overhead doors require extensive heating in the winter

Hot exhaust gases can replace gas or electric heaters for overhead doors
The gases can also be used to preheat water or process components

EXAMPLES OF WASTEWATER/PROCESS PRODUCT RECOVERY

Waste Heat is An overlooked process product that offers significant opportunity for innovative engineering

Most plants have air compressors

Interstage or final stage exit temperature can be 200-300F

Closed loop heat exchangers can be used to transfer heat to water or other process components

SUMMARY

Boiler, cooling and plant processes are integral components of plant operation

Initial plant design uses thermodynamic laws and good engineering practice to address a wide range of operating conditions

Typical plant operation focuses on safe production, producing a profit and fulfilling environmental laws as good stewards

There is significant opportunity to use innovative engineering to meet these goals

- THANK YOU!!
- QUESTIONS/COMMENTS ??