Energy Efficiency

using

Direct Steam Injection

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WE BRING THE HEAT.

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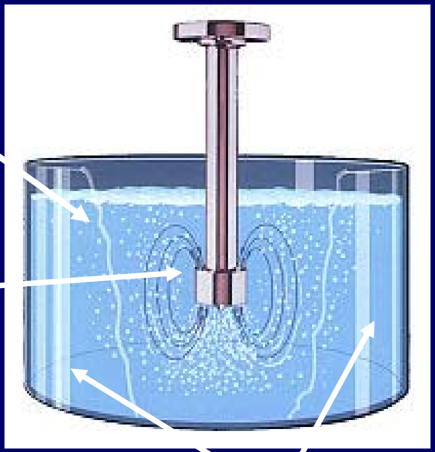
Heat Transfer Methods

Heat Exchangers

- Surface-contact transfer
- Difficult to control temperature
- High maintenance
- Energy losses significant



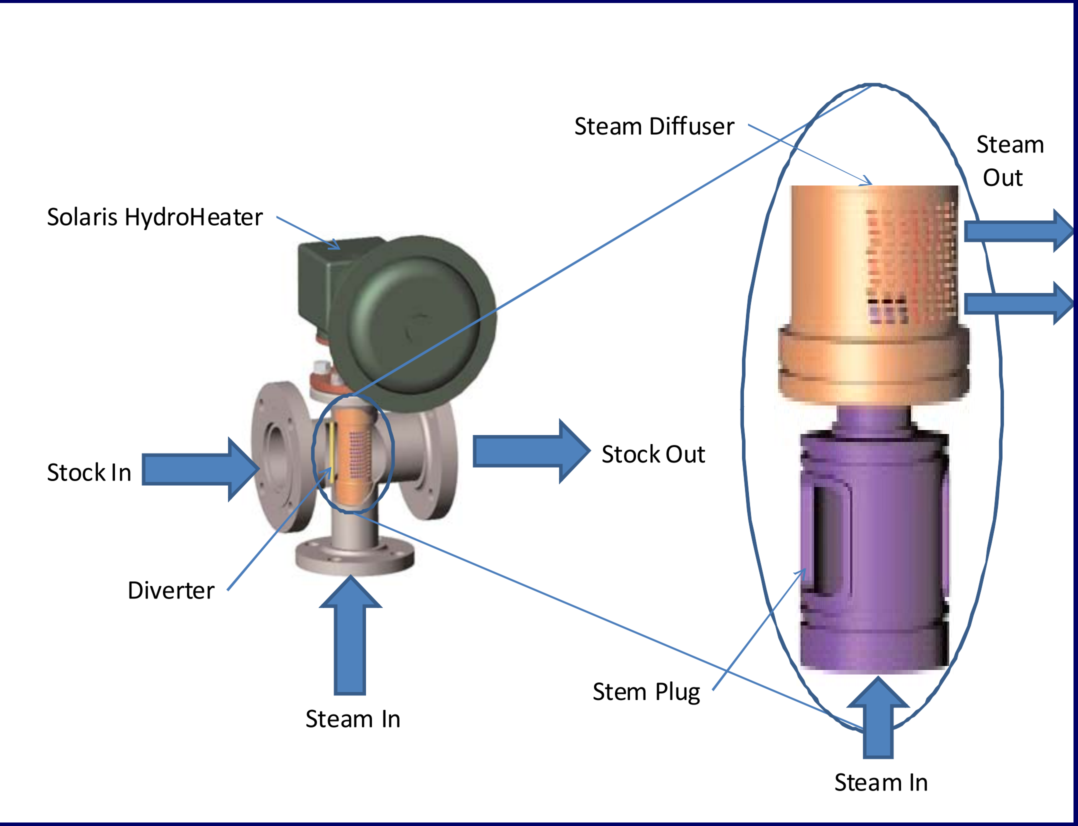
Spargers

- Uncontrolled forced steam
- Uneven heating
- Bubbles may damage equipment

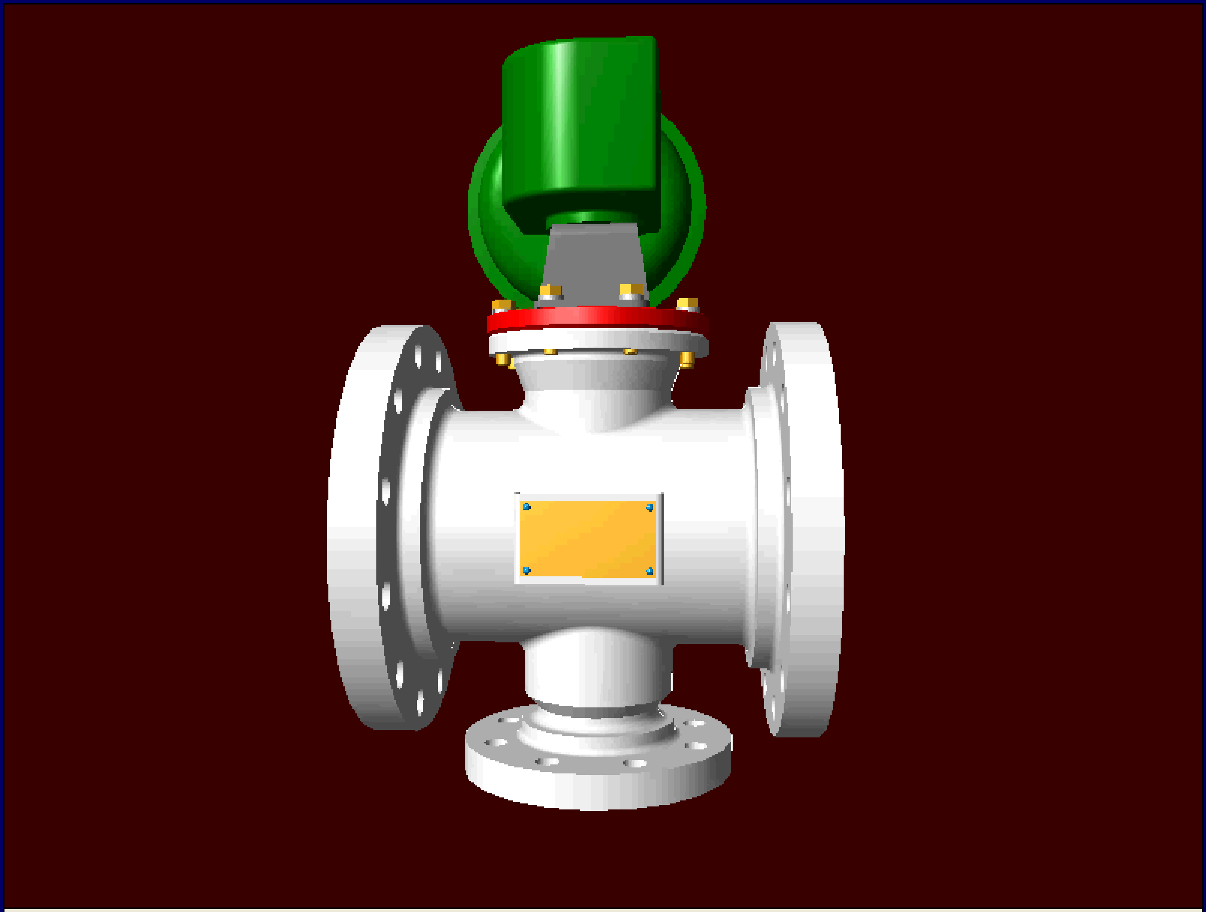
Heat Transfer Methods

Direct Steam Injection (DSI)

- Precisely controlled steam injection
- Sonic velocity
- Instant penetration and mixing
- Internal steam modulation keeps stock at precise temperature (± 1 ° F/ .5°C)



Cross Section – DSI Heater



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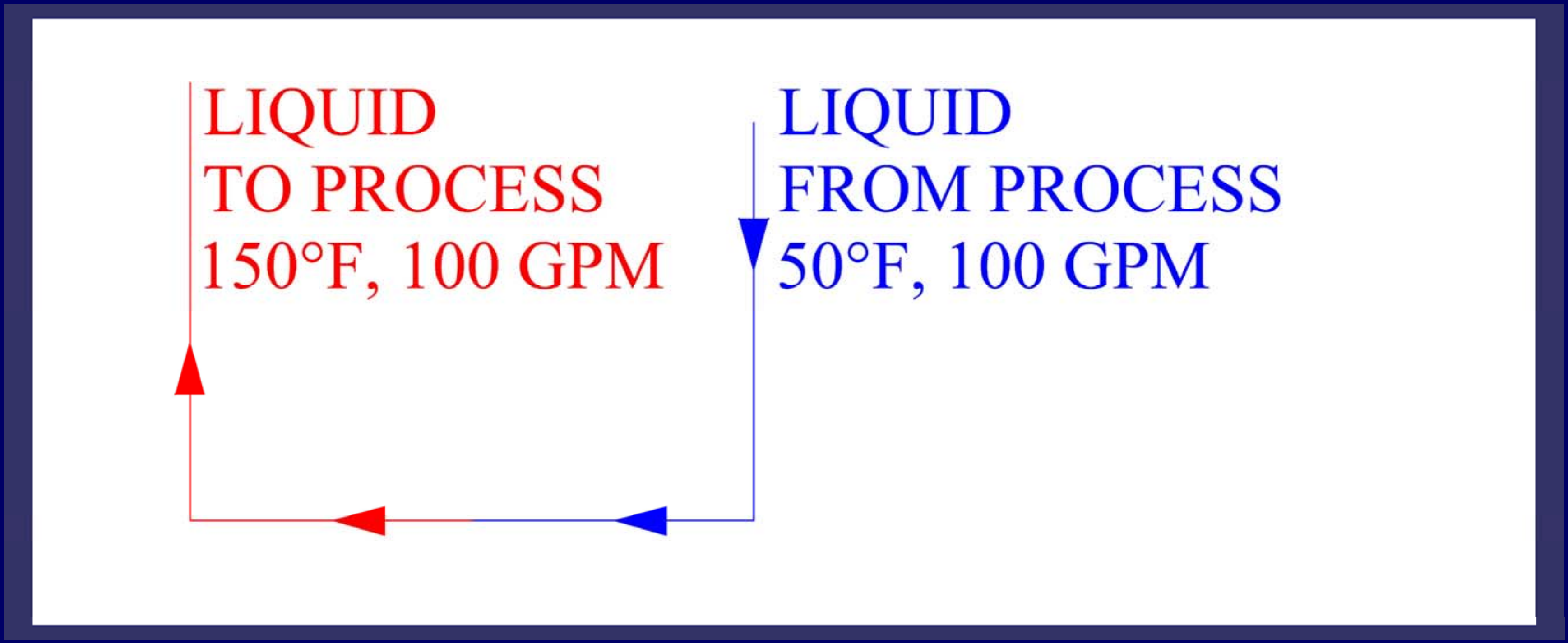
Energy Advantage

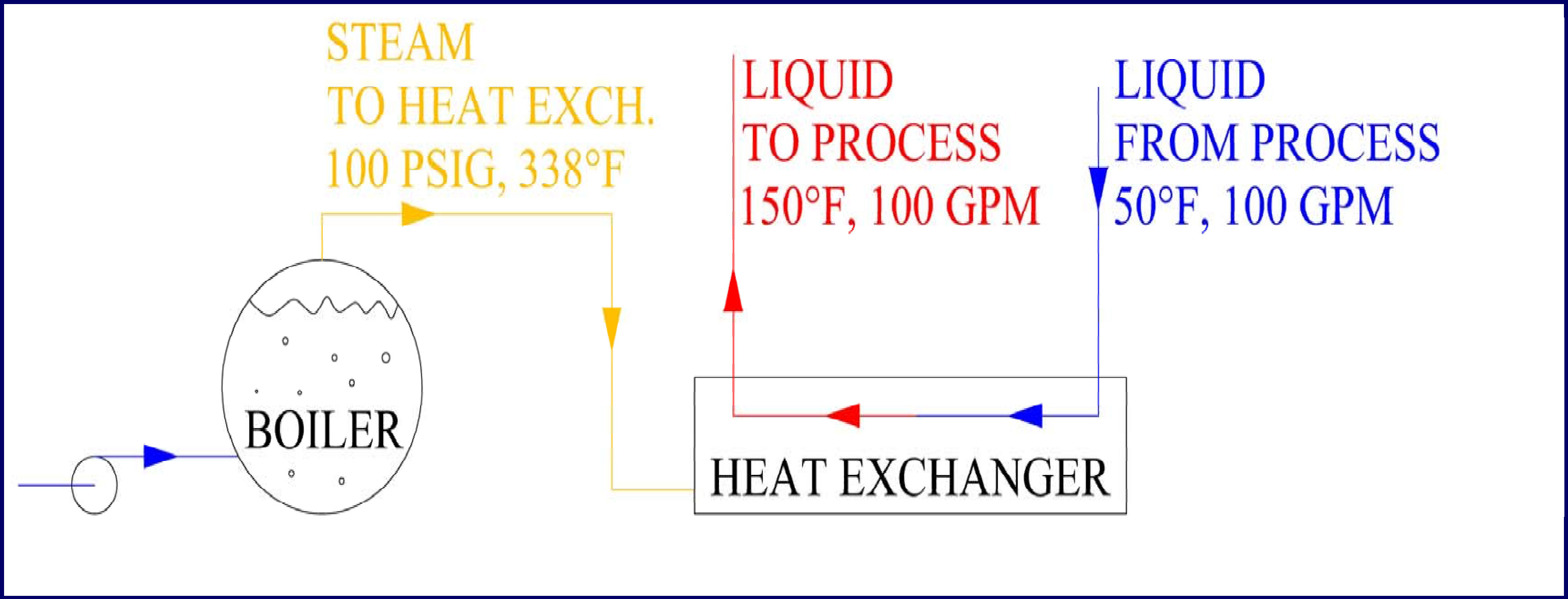
- Reduced steam consumption
  - Uses all of latent and sensible heat energy
  - Faster attainment of set-point / start-up
  - Precise temperature control
- Lower chemical use
- Time saver
  - No scaling or fouling

Energy Usage Loop



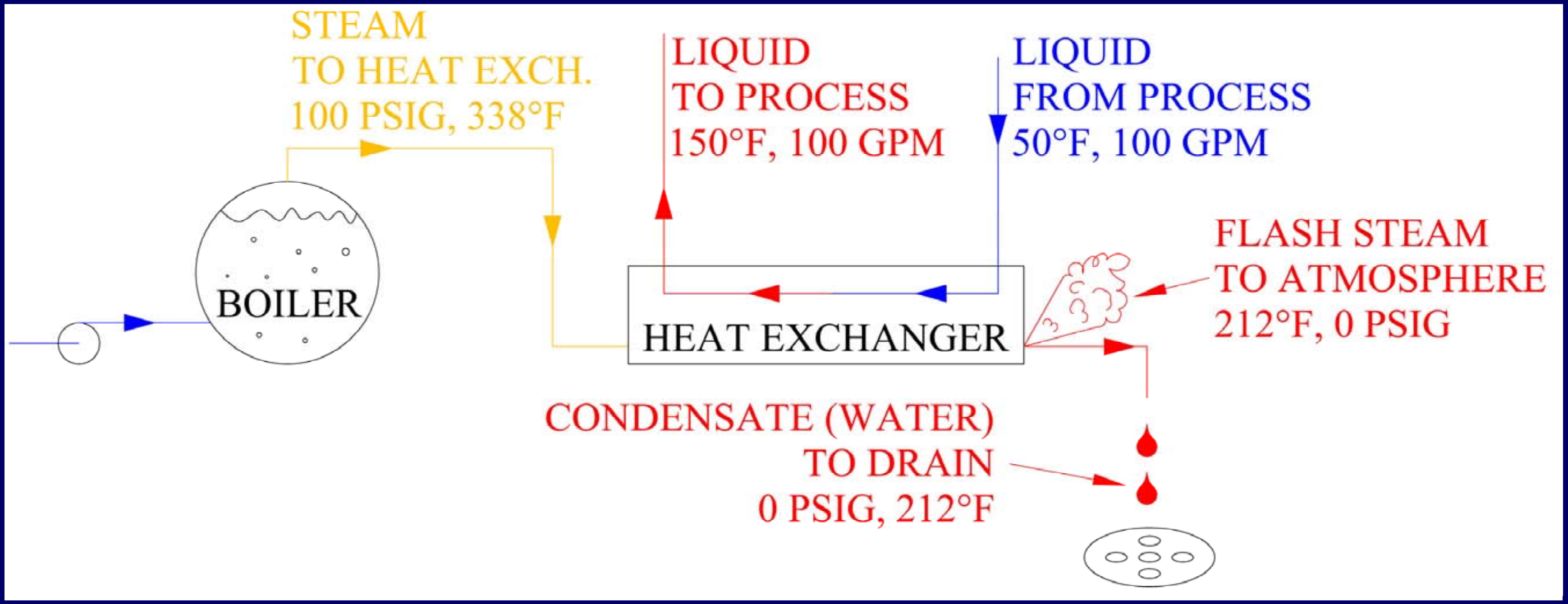
Condensate to drain

Energy Usage Loop



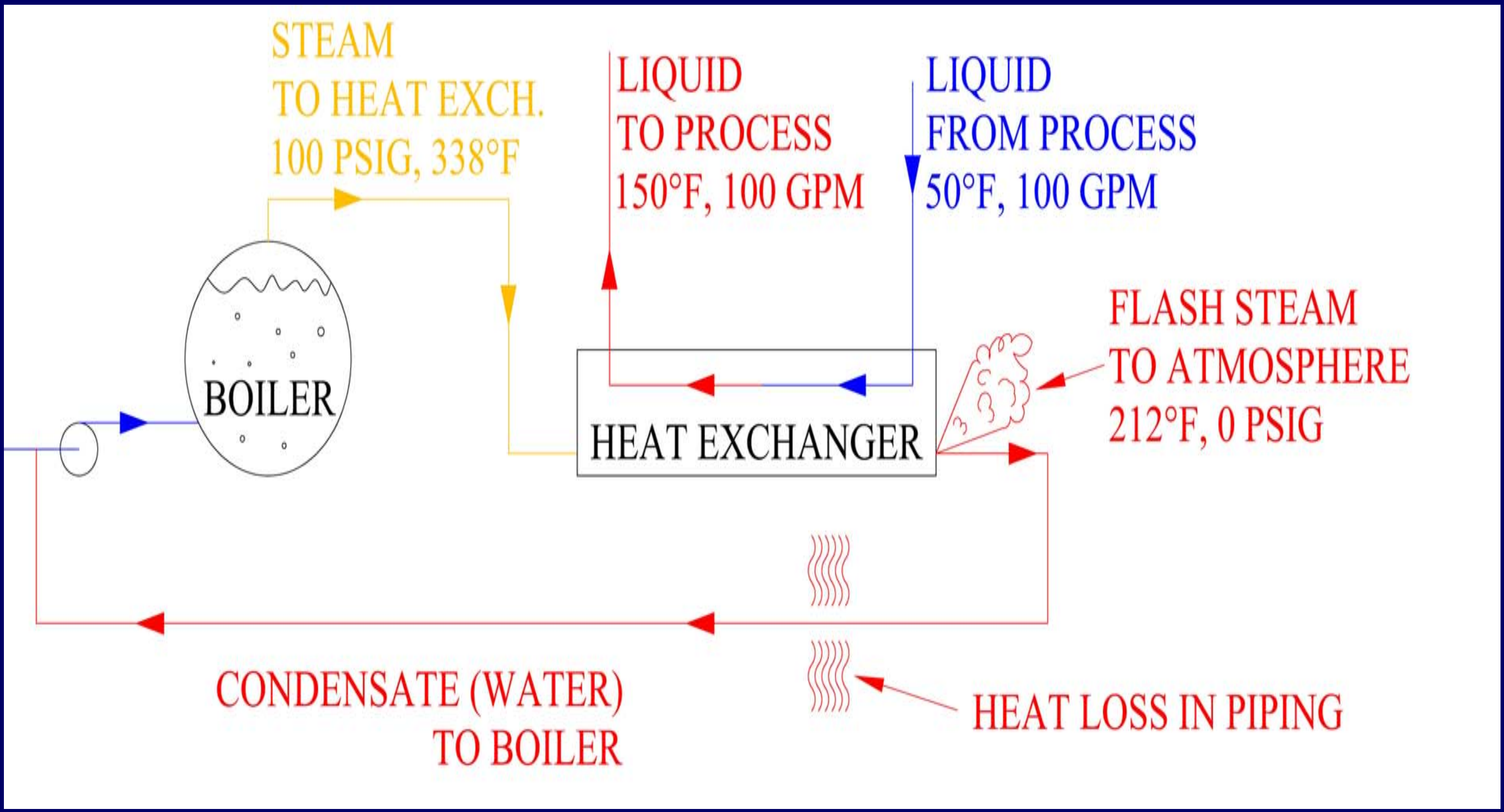
Condensate to drain

Energy Usage Loop



Condensate to drain

Energy Usage Loop



Condensate returned to boiler

Energy Usage
Heat Exchanger vs. DSI

Comparison of a well designed Heat Exchanger system vs Internally Modulated Direct Steam Injection

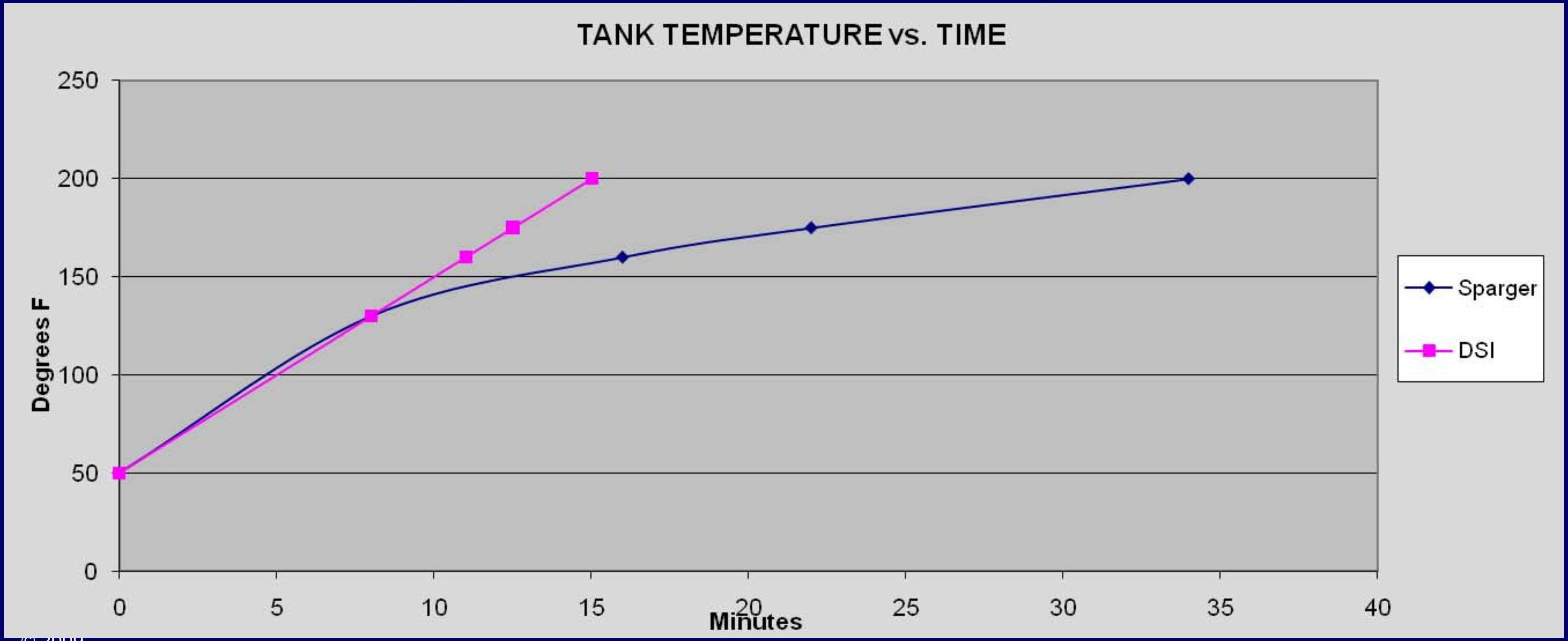
Process Flow Rate	600	Gallons per minute
Temperature of incoming water	98	°F
Required output temperature	150	°F
Header Steam Pressure	110	psig
Percent of Heat Exchanger Capacity	80	%
Boiler Efficiency	80	%
Percent of Condensate reclaimed to boiler	90	%
Percent of condensate heat lost during return	5	%
Condensate return line pressure	20	psig
Boiler Makeup water temperature	60	°F
Boiler Fuel Cost	12.00	$/Mbtu
Water treatment expense per 1000#/Steam	0.35	$/1000#
Average hours per day in use	24	Hours

	Heat Exchanger	Internally modulated direct steam heater	
Required Energy Load	260364	260364	btu/min
Steam Flow Required	285.5	231.3	Lb/min
Energy Required at Boiler	354535	336457	btu/min
Water Treatment cost	$ 0.60	$ 4.86	per hour
Cost per hour of use	$ 255.87	$ 247.11	per hour
Cost per day	$ 6,140.76	$ 5,930.53	per day
Cost per week	$ 42,985.34	$ 41,513.71	per week
Cost per year	$ 2,235,237.47	$ 2,158,712.99	per year

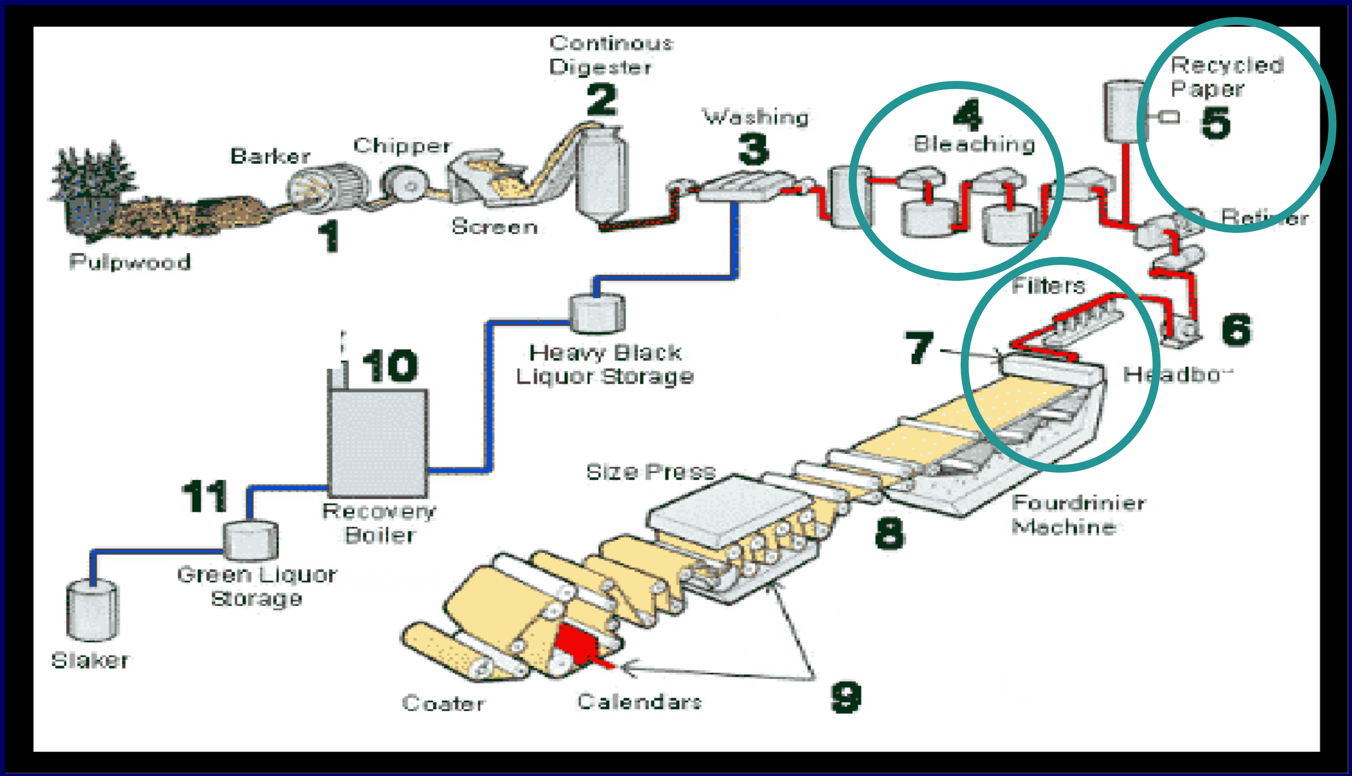
Estimated Annual Savings	**$ 76,524.48**
Estimated [redacted] Investment	$ 50,000.00
Estimated ROI in Months	**7.8**

Energy Usage – Sparger vs. DSI

- Reduced steam usage by 33%
  - 932 lbs (422 Kg) with spargers
  - 624 lbs (283 Kg) with DSI
- Time Savings
- Daily production increased by 32%



Case Studies



- Mill #1- Whitewater
- Mill #2 – Bleaching
- Mill # 3 – Green Liquor

Mill # 1 - Whitewater

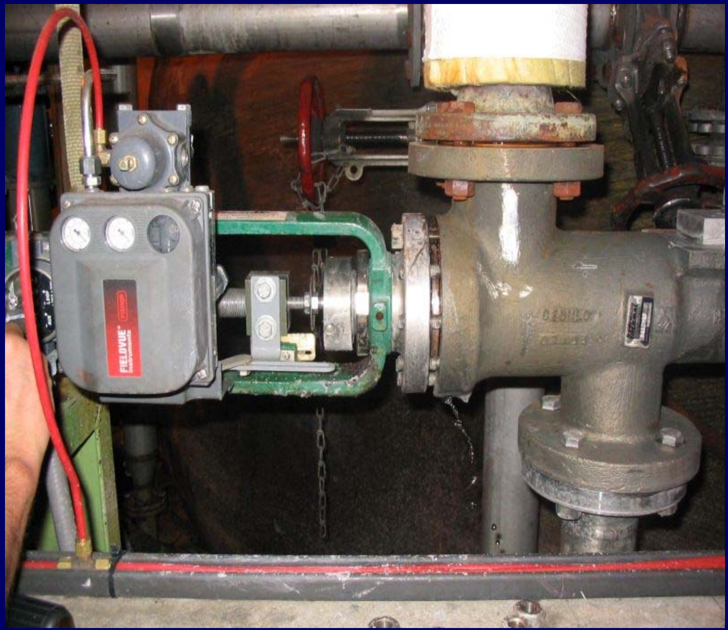
- Replaced sparger
  - Was well designed system
- 50K gallon system
- Reduced steam usage

Mill #2 – Case Study Bleaching Process

- Replaced energy hog mechanical mixer
- Reduced steam flashing
- Sonic velocity steam eliminated need for mixer
- 20% energy cost savings

Mill #3 – Case Study
Green Liquor Process

- Replaced Sparger
  - Needed to alleviate maintenance nightmare
  - Tanks suffering damage
- Reduced steam per hour - 3918 lbs to 3218 lbs
- Annual savings $70,000 USD



Where can DSI be used?

Save energy in these applications using direct steam injection

Application	Replaces
Black liquor	Sparging - heat exchanger
Bleach washing	Heat exchanger
Bleaching water	Heat exchanger
Boiler feed water	Heat exchanger
Boil-out	Sparging - heat exchanger
Brown stock washing	Heat exchanger
Chlorate car unloading	Heat exchanger
Cooking & PVOH	Batch cooking
Filter backwash	Heat exchanger
Green liquor	Sparging - heat exchanger
Hydro-pulping	Sparging
Log de-icing	Sparging
Protein cooking	Batch cooking
Secondary fiber	Sparging
Shower water	Hot water tank - heat exchangers - spargers
Silo heating	Sparging
Starch dilution	Batch cooking
Stock heating	Sparging - in-line auger
Tank heating	Sparging
Wash station	Heat exchangers - hot water tanks
Whitewater heating	Sparging

Process Conditions Needed to Properly Size Heater

- Fluid specific heat
- Fluid solids constant
- Presence of abrasive or corrosive products
- Automatic or manual temperature control
- Type of operation
  - Continuous
  - Intermittent
  - Variable
- Fluid density
- Fluid viscosity
- Flow rates
- Pipe size
- Inlet temperature
- Steam pressure

Summary - DSI Advantages

- Use to heat water miscible liquids/slurries
- Energy efficient
- Precise temperature
- Instant temperature
- Small footprint
- Less maintenance
- No condensate return needed
- May eliminate external mixers
- No hammering or vibration
- No scaling or fouling

Questions?

Speaker

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- 14 years R&D and process engineering various industries
- BSME and BS Mathematics – University of Wisconsin, Madison, WI

Mill #? – Case Study Bleaching Process Chemicals

- Car unloading – needed homogenous heating
- Raise chlorine dioxide temp by 46° F
- Decreased chemical usage by 10%
- ROI 4 mos.

DSI mass and Energy balance

- Ms+Ml=Mt (Mass balnce)
- Ml x Hl + Ms + Hs=Mt x Ht (Energy balance)
- (Mt – Ms) x Hl + Ms x Hs = Mt x Ht
- Mt x Hl – Ms x Hl +Ms x Hs = Mt x Ht
- Ms x Hs x Ms x Hl = Mt x Ht – Mt x Hl
- Ms x (Hs – Hl) = Mt x (Ht-Hl)
- Ms = Mt x ((Ht-Hl)/(Hs – Hl))

DSI steam flow req'd

- Ms = Mt x ((Ht –Hl)/(Hs-Hl))
- Ms = 600 x 8.34 x ((118.2 – 66.2)/(1192 – 66.2))
- Ms = 231 lbm/min

Energy req'd to produce steam

- 231 lbm/min – Steam flow
- 60º F, H=28.1 btu/lbm – Boiler feedwater
- 80% - Boiler efficiency

- Q = Ms x (Hs – Hb) x 1/(h)
- Q = 231 x (1192 – 28.1) x (1/0.8)
- Q = 336462 btu/min

Heat exchanger energy load

- Q =Cp x Ml x (Hhot – Hcold)
- Q = 600 x 8.34 (118.2-66)
- Q = 260364 btu/min

Heat exchanger % capacity

Log Mean Temperature Difference (LMTD)

DTlm = (DT1 – DT2)/Ln(DT1/ DT2)

DT1 = 344.4 - 150 = 194.4

DT2 = 344.4 – 98 = 264.4

DTlm = (194.4 – 264.4)/Ln(194.4/264.4)

DTlm = 219.4 ºF

Heat exchanger % capacity

- Solve for Heat exchanger UA' @ 100% capacity:
- UA'= Q/LMTD
- UA'= 260208/219.4
- UA'= 1186 btu/ºF min (UA for 100% capacity)

- Calculate UA for 80% capacity Heat exchanger:
- UA= UA'/h
- UA=1186/.8 = 1483 btu/ºF min

Calculate LMTD @80% Capacity

- Q/UA = LMTD
- 260208/1483 = 175.5 ºF

Calculate DT1, DT2

$$175.5 = (DT1 - DT2)/\text{Ln}(DT1/DT2)$$

$$175.5 = \frac{(Ts - 150) - (Ts - 98)}{\text{Ln}((Ts - 150)/(Ts - 98))}$$

$$\text{Ln}((Ts - 150)/(Ts - 98)) = -52/175.5 = -.2963$$

$$(Ts - 150)/(Ts - 98) = e^{-.2963} = .7436$$

Calculate DT1, DT2

- $(T_s - 150)/(T_s - 98) = .7436$
- $T_s - 150 = .7436 \times (T_s - 98)$
- $T_s - 150 = .7436 \times T_s - 72.86$
- $.2564 \times T_s = 77.13$
- $T_s = 301^{o}F$ (Steam temp in 80% cap HE)
- Saturation pressure for 301ºF = 53 psig

Calculate HE steam consumption

- M = Q/(DT)
- M = 260208/909.7 = 286 lbm/min
- Condensate enthalpy @ 53psig:
  - 271 btu/lbm
- Condensate return line pressure:
  - 20 psig
- Condensate enthalpy @ 20 psig:
  - 226 btu/lbm

Calculate HE boiler load

- Flash steam loss at trap:
  - Q=M x (DH)
  - Q = 286 x (271 – 226)
  - Q = 12786 btu/min
- Mass of flash steam:
  - M = Q/DH
  - M = 12786/940.5 = 13.59 lbm/min

Calculate HE boiler load

- Calculate mass of remaining condensate:
  - 286 – 13.6 = 272.4 lbm/min
- Calculate boiler feedwater temp:
  $(T_C-(T_C - 70) \times K_{LOSS}) \times K_{LEAK} + T_{BF} \times (1-K_{LEAK})$
- (259 – (259 – 70) x .05) x .9 + 60 x (1-.9)
- Boiler feed temp = 230.6ºF

Calculate HE boiler load

- Calculate energy req’d to generate HE steam:
- Q = M (DH)/h
- Q = 286 x (994.6)/.8
- Q = 355600 btu/min

Calculation Summary

- DSI Energy load = 336462 btu/min
- HE Energy load = 355600 btu/min
- Difference: = 19138 btu/min
- = 1.15×10^6 btu/hr