Section 9: Steam System Optimization – Condensate Recovery

Types of Steam Traps

Steam Trap Management Program

SSAT Evaluations & Economic Impacts

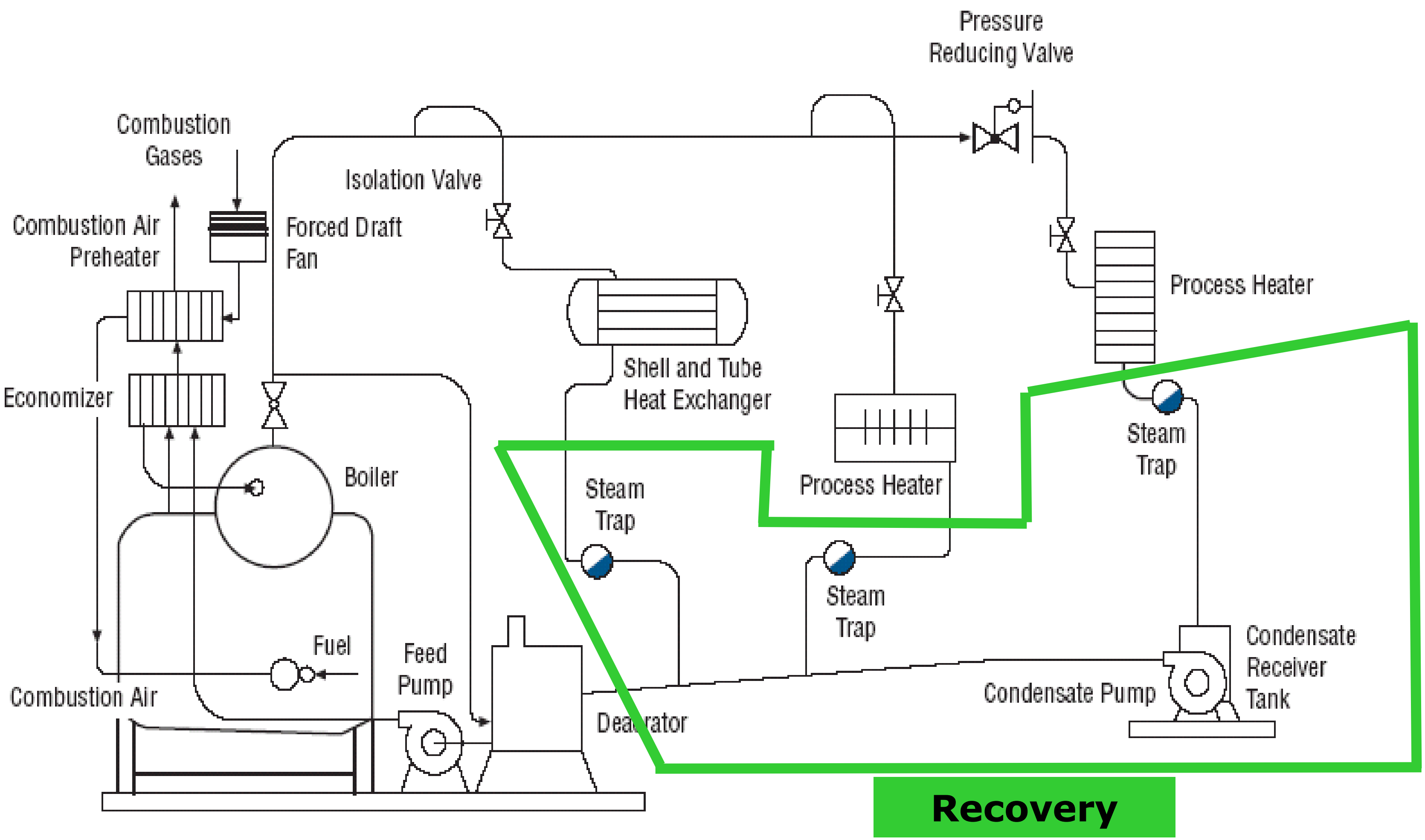
Evaluation of Condensate Recovery Systems

Condensate Flash Tanks

Condensate Tank Vents

SSAT Evaluations & Economic Impacts

Generic Steam System



Source: US DOE ITP Steam BestPractices Program

Steam Traps

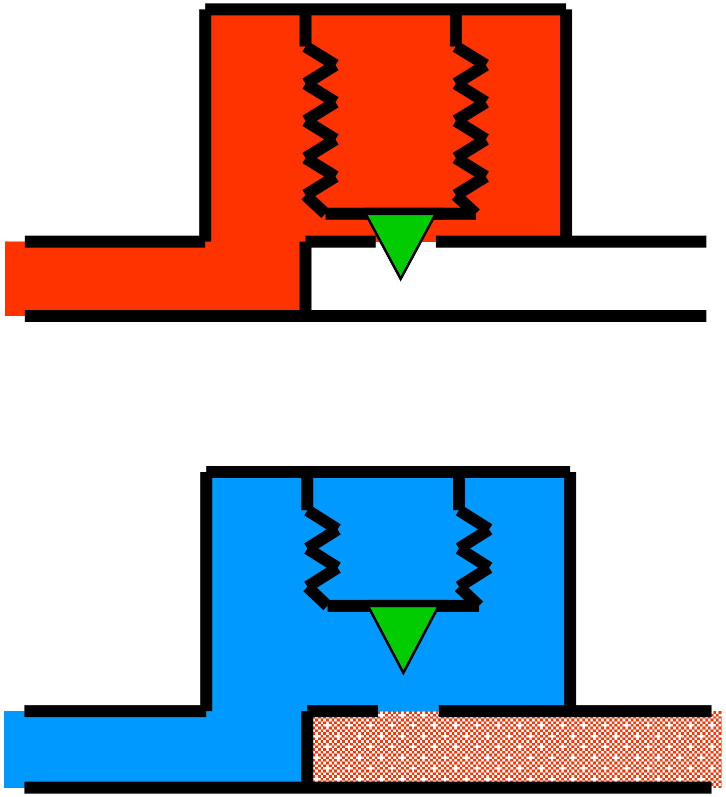
- ✓ Traps serve several vital operating functions for a steam system
  - During start-up, they allow air and large quantities of condensate to escape
  - During normal operation, they allow collected condensate to pass into the condensate return system, while minimizing (or eliminating) loss of steam
- ✓ There are different kinds of steam traps and hence, functionality and principles of operation must be understood
- ✓ All plants should have an effective steam trap management program
- ✓ Steam trap failures may not result in energy loss per se, but they will surely result in system operation problems and reliability issues

Types of Steam Traps

- ✓ Thermostatic Traps
  - Bellows*
  - Bimetallic*
- ✓ Mechanical Traps
  - Ball Float
  - Float and Lever
  - Inverted Bucket*
  - Open Bucket
  - Float and Thermostatic*
- ✓ Thermodynamic Traps
  - Disc*
  - Piston
  - Lever
- ✓ Orifice Traps
  - Orifice Plate
  - Venturi Tube

* - Most commonly used

Thermostatic Steam Traps

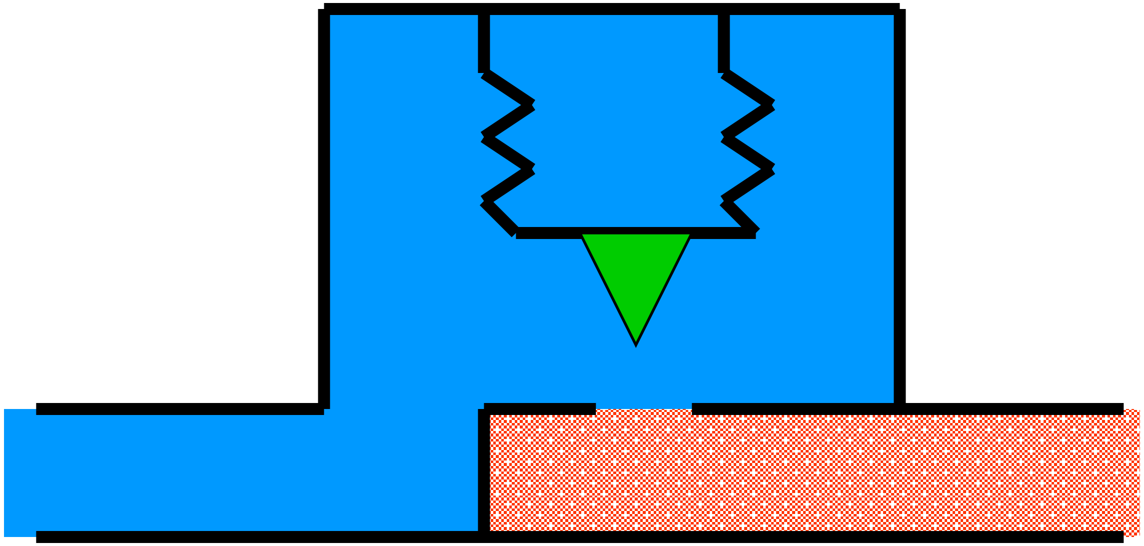


- ✓ Responds to temperature changes
- ✓ A bellows (with a volatile fluid) or a bimetallic strip closes the valve with high temperature steam
- ✓ When condensate (typically, sub-cooled) collects – the bellows contracts and opens the valve to let condensate drain out

Source: US DOE ITP Steam BestPractices Program

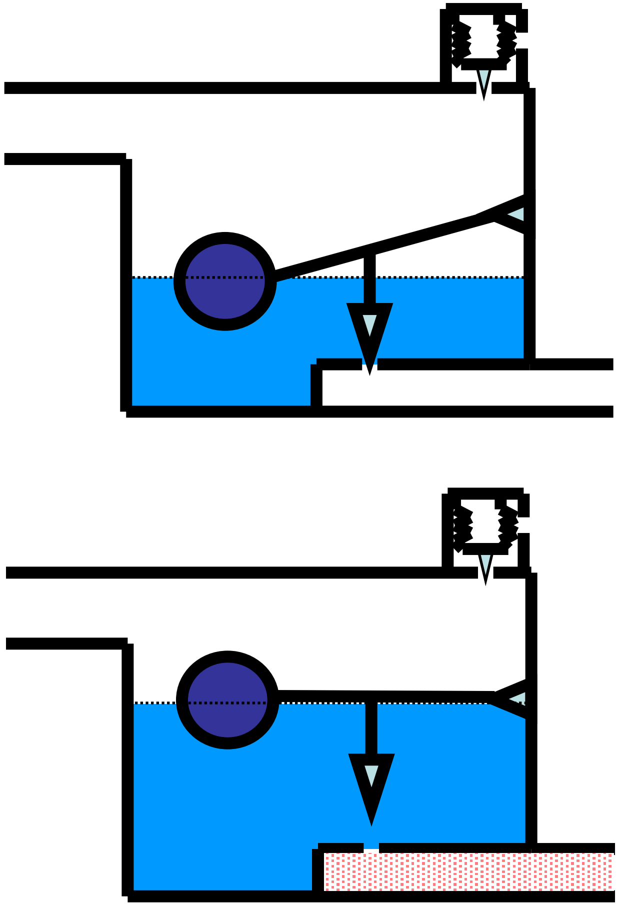
Thermostatic Steam Traps

- ✓ Opens to subcooled condensate
- ✓ Depending on subcooling can discharge condensate or condensate and flash steam
- ✓ Allows energy recovery from condensate
- ✓ Significant air removal capability



Source: US DOE ITP Steam BestPractices Program

Mechanical Steam Traps

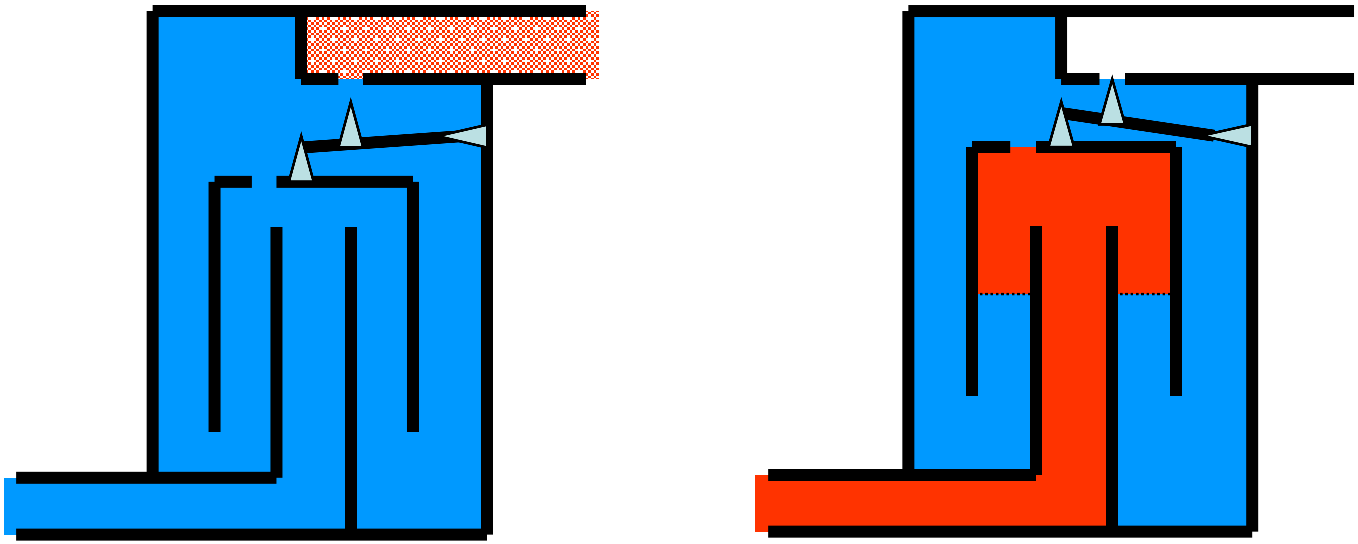


- Opens to saturated and/or sub-cooled condensate
- Will discharge condensate and flash steam
- Significant air removal and startup capabilities
- Modulating type operation

Float & Thermostatic Trap (F&T)

Source: US DOE ITP Steam BestPractices Program

Mechanical Steam Traps

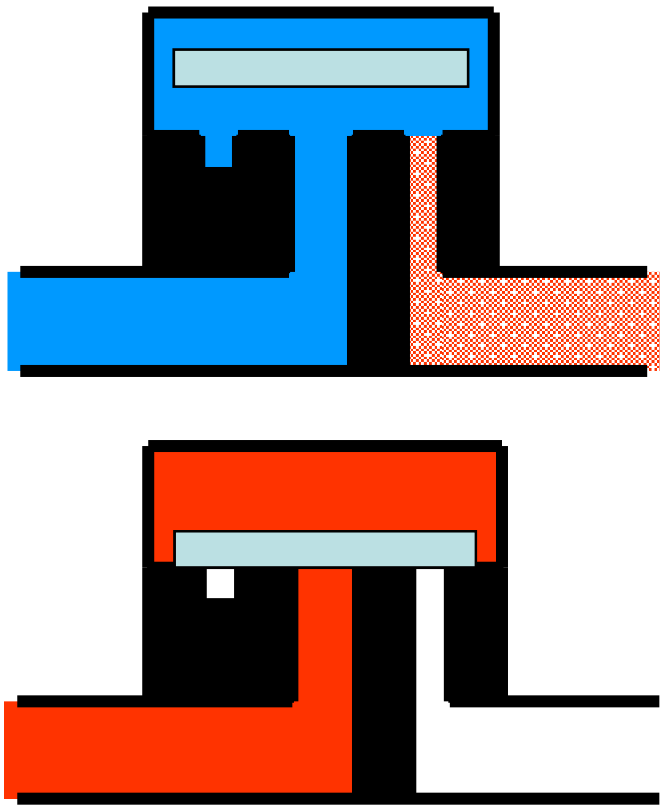


Inverted Bucket Trap (Open Float)

- Opens to saturated and/or sub-cooled condensate
- Will discharge condensate and flash steam
- Limited air removal and startup capabilities
- Application in superheated steam service should be questioned
- Intermittent operation

Source: US DOE ITP Steam BestPractices Program

Thermodynamic Steam Traps

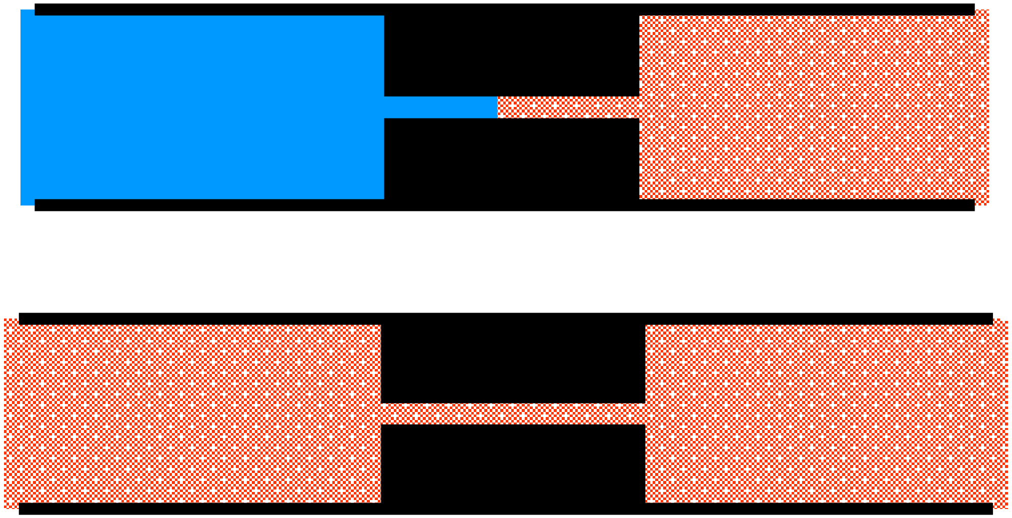


Disc Trap

- ✓ Works on the difference in kinetic energy (velocity) between condensate and steam to operate a valve
- ✓ Opens to saturated condensate
- ✓ Will discharge condensate and flash steam
- ✓ Intermittent operation
- ✓ Can be equipped with thermostatic element to improve air removal

Source: US DOE ITP Steam BestPractices Program

Orifice Steam Traps

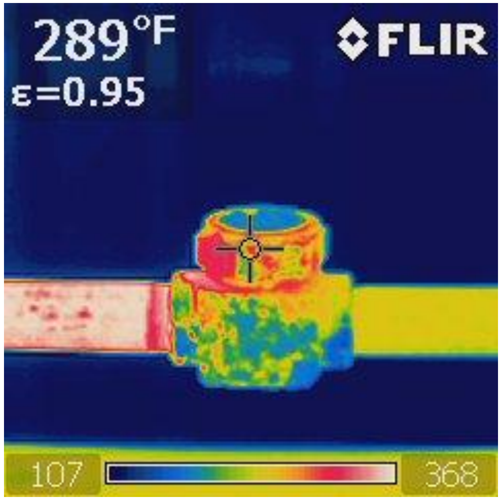


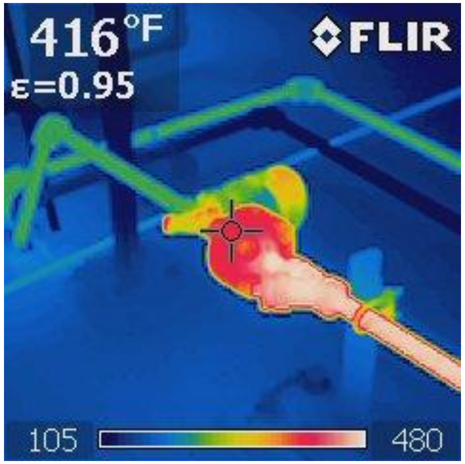
- ✓ Its designed for a specific amount of condensate removal
- ✓ If there is no condensate, then a small amount of steam leaks continuously

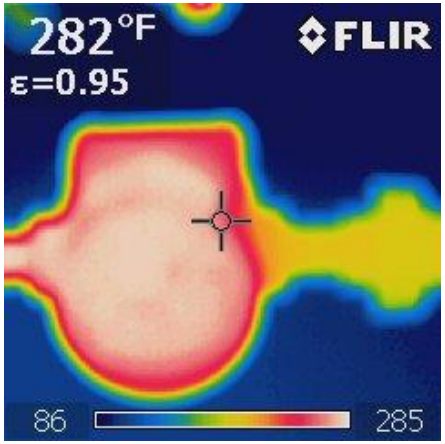
- ✓ No moving parts
- ✓ Continuous operation
- ✓ Common applications are steady loads
- ✓ Limited air removal capability due to orifice limitations

Source: US DOE ITP Steam BestPractices Program

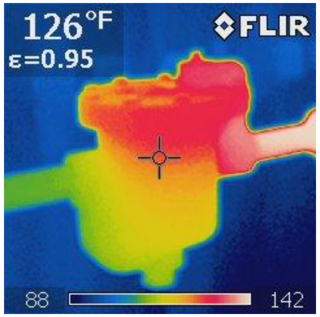
Steam Traps in the Field

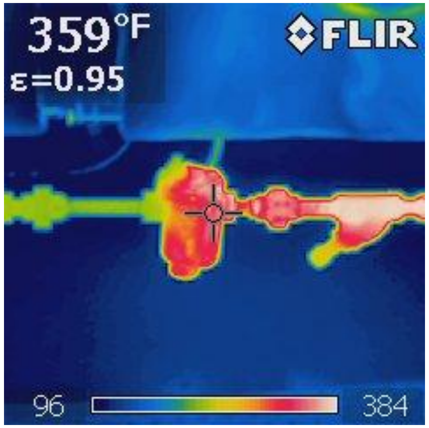


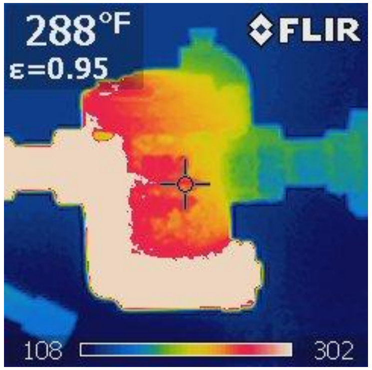


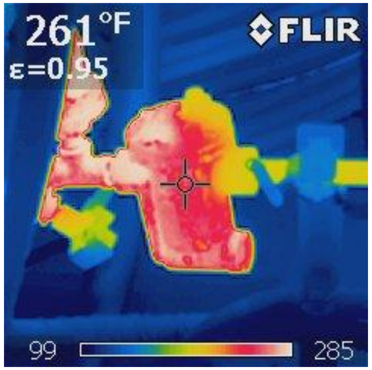


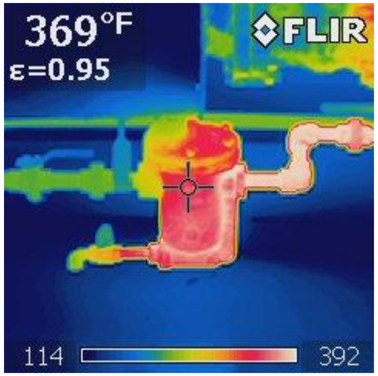
Steam Traps in the Field

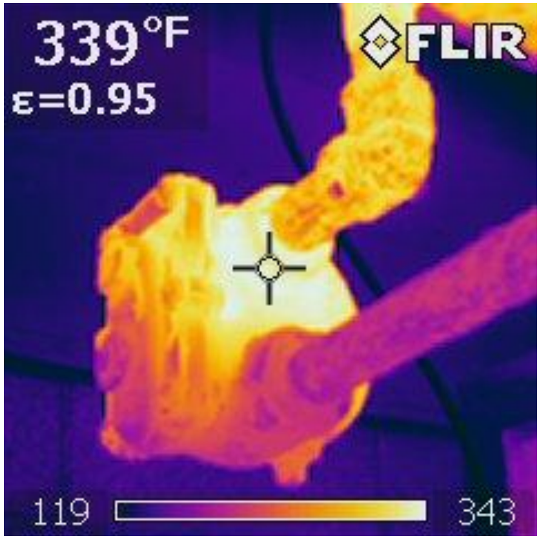


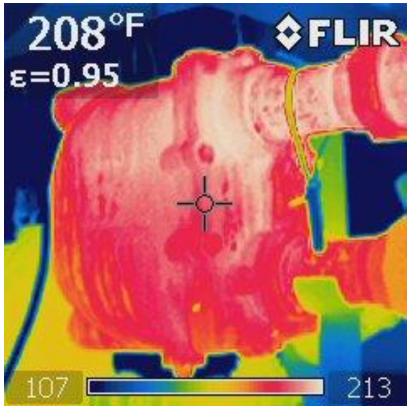












Steam Trap Failures

- ✓ There have been numerous studies in the industry and one of the more statistically accepted “rule of thumb” is that 10% of traps fail every year
- ✓ This depends on several factors and can be very industry specific also
- ✓ The main failure modes are:
  - Failed closed
  - Failed open
  - Failed partially leaking or partially closed
- ✓ Failed open and failed closed result in the greatest system impacts
  - These failure modes are the most readily recognized
  - These failures should be of first priority

Steam Trap Investigation for Performance

- ✓ There are several methods for investigating steam trap performance
  - Visual
  - Acoustic
  - Thermal
- ✓ Most times, using only one method maybe inconclusive – so the following is recommended
  - Combination of methods
  - Additional process or system information, is required
- ✓ New state-of-the-art in-trap (real-time) monitoring is available for some steam traps

Visual Steam Trap Investigation

- ✓ Limited in applicability
  - Most condensate systems are closed
  - Safety and practicality limit the use of this method
- ✓ Individual trap operation and application must be understood
  - Intermittent
  - Continuous
- ✓ Several traps can return condensate via a cascaded condensate return system – condensate receiver vent becomes the point of visual inspection

Acoustic Steam Trap Investigation

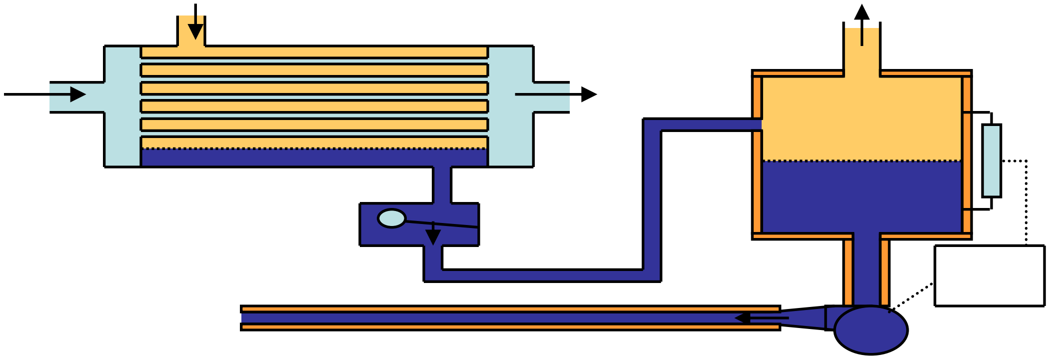
- ✓ Many instruments are available
  - Screw driver
  - Stethoscope
  - Ultrasonic devices
- ✓ Individual trap operation and application must be understood
- ✓ Ultrasonic sensing is typically the most practical
- ✓ Some manufacturers have tools that can take the acoustic signature of steam flow through the trap and use that information to detect failure

Thermal Steam Trap Investigation

- ✓ Many instruments are available
  - Temperature stick
  - Infra-red temperature gun
  - Infra-red thermography camera
- ✓ Individual trap operation and application must be understood
- ✓ Data can be inconclusive
  - Condensate and steam will take a temperature drop while going through an orifice – hence, difficult to say if trap is failed open!

Steam Trap Survey - Condensate Recovery Investigation

- ✓ Is condensate being recovered?
- ✓ Is the condensate recovered *to the boilers* with the greatest practical thermal energy?
- ✓ Does the condensate recovery system place excessive backpressure on the traps?
- ✓ Is flash steam recovery applicable?
- ✓ Design the condensate recovery system for the greatest effectiveness



Source: US DOE ITP Steam BestPractices Program

Steam Trap Installation

- ✓ Each trap must be installed properly
- ✓ Non-condensable gas and startup considerations must be targeted
- ✓ The condensate collection system must be considered
  - Backpressure considerations
  - Lift considerations
  - Two-phase flow considerations

Source: US DOE ITP Steam BestPractices Program

Effective Steam Trap Management Program

- ✓ Maintain a steam trap database
  - Type of trap, model number, size, etc
  - Application
  - Energy loss if failed open
  - Problems if failed closed
  - When was the last recorded failure, repair
- ✓ Prioritize repairs based on loss estimates and criticality of steam system and production operations
- ✓ Daily monitor receiver vents
- ✓ Inspect all traps at least once a year
- ✓ Trap maintenance training is essential

Steam Trap Savings Analysis

✓ 1st method

- Use SSAT to predict savings – preliminary estimate
- Number of traps & last maintenance done

✓ 2nd method

- Use SSAT to provide savings
- Number of failed traps

✓ 3rd method

- Use orifice size and calculate steam leak flow
- Use SSAT – Project 1 as demand savings
- Most accurate method – especially for cogeneration systems

SSAT Project 16 - Savings Analysis

✓ 1st method (Option 1)

- Use SSAT to predict savings – preliminary estimate
- Number of traps & last maintenance done
- Very GROSS Estimate

Project 16 - Steam Trap Losses
Losses calculated from user-defined data

Do you wish to model the impact of a maintenance program?	Option 1 - Yes, model to estimate new loss values

Note: For Option 1, the model estimates a new trap failure rate. The rate reported is for 6 months after the maintenance program is carried out

Option 2 - Trap failures on HP header	5	Failures > Current - Model will use 0
Option 2 - Trap failures on MP header	5	Failures > Current - Model will use 0
Option 2 - Trap failures on LP header	5	Failures > Current - Model will use 0

Note: Calculated values based on current user inputs are:-
HP header - Trap failures: 0, Loss per trap 0.034 t/h - Total trap loss = 0.00 t/h.
MP header - Trap failures: 0, Loss per trap 0.014 t/h - Total trap loss = 0.00 t/h.
LP header - Trap failures: 0, Loss per trap 0.003 t/h - Total trap loss = 0.00 t/h.

SSAT Project 16 - Savings Analysis

✓ 2nd method (Option 2)

- Use SSAT to provide savings
- Number of failed traps
- A GROSS estimate

Project 16 - Steam Trap Losses
Losses estimated automatically by model - Last maintenance program 3-5 years ago

Do you wish to model the impact of a maintenance program?	Option 2 - Yes, enter new number of failed traps

Note: For Option 1, the model estimates a new trap failure rate. The rate reported is for 6 months after the maintenance program is carried out

Option 2 - Trap failures on HP header	5
Option 2 - Trap failures on MP header	5
Option 2 - Trap failures on LP header	5

Note: Calculated values based on current user inputs are:-
HP header - Trap failures: 5, Loss per trap 0.034 t/h - Total trap loss = 0.17 t/h.
MP header - Trap failures: 5, Loss per trap 0.014 t/h - Total trap loss = 0.07 t/h.
LP header - Trap failures: 5, Loss per trap 0.003 t/h - Total trap loss = 0.02 t/h.

SSAT Project 1 - Steam Trap Savings Analysis

- ✓ 3rd Method – most accurate
- ✓ Work with open failed steam traps and prepare a list of traps failed at each pressure level

$$m_{steam} = 0.695 \times A_{orifice} \times P_{steam}$$

Project 1 - Steam Demand Savings (Changing the process steam requirements) Current use - HP: 25 t/h (12946 kW) MP: 50 t/h (27751 kW) LP: 100 t/h (57560 kW)		
Do you wish to specify steam demand savings?	Yes	
→ If yes, enter HP steam saving	0 t/h	←
→ If yes, enter MP steam saving	0 t/h	←
→ If yes, enter LP steam saving	0 t/h	←

Note: A negative saving can be entered to model an increase in steam demand

Note: The savings have been converted to heat duties of 0 kW (HP), 0 kW (MP) and 0 kW (LP) based on current header enthalpies

Note: These heat duties are then used to determine the actual flow change in the Projects Model based on the calculated header enthalpies

Key Points / Action Items

1. There are different kinds of steam traps and hence, functionality and principles of operation must be understood
2. Major steam trap failure modes - open / closed
3. An effective steam trap management program must be in place
4. There are several commercially available tools for steam trap investigations
5. Conduct a steam trap audit at least once a year and repair/replace defective traps
6. Steam trap manufacturers are a valuable resource

Condensate Recovery

- ✓ Condensate is produced after steam has transferred all its thermal energy and condensed into water
- ✓ Nevertheless, there is significant thermal energy in condensate
- ✓ Every unit of condensate returned implies one less unit of make-up required
- ✓ Returning condensate
  - Reduces energy (steam required) in deaerator
  - Reduces make-up water
  - Reduces chemicals for water treatment
  - Reduces quenching water
  - May reduce blowdown

Condensate Recovery

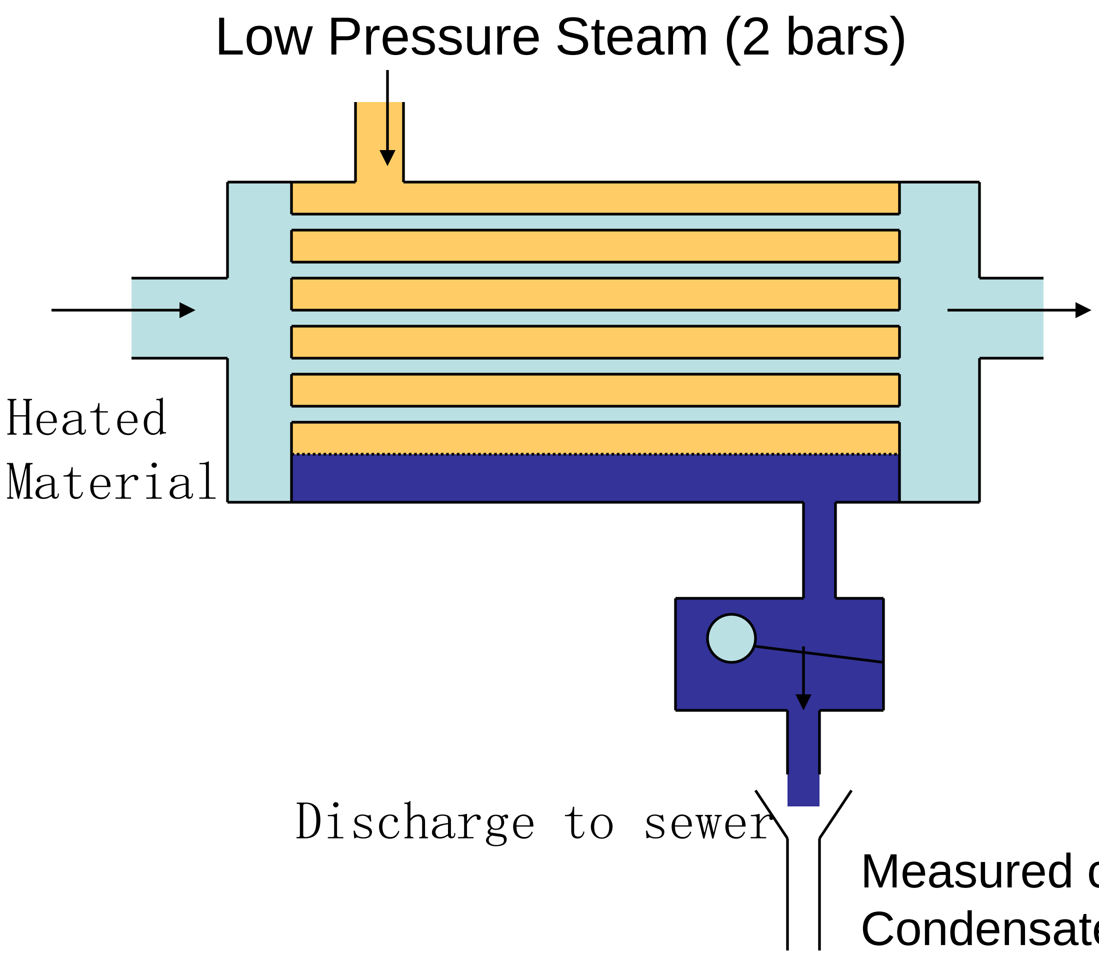
- Condensate typically has worth
  - Energy
  - Make-up water reduction
    - This generally improves feedwater quality
      - Resulting in a reduction in boiler blowdown
  - Chemical
- Condensate recovery costs generally center on the recovery system piping
  - Recovery equipment
  - Return piping

Condensate Recovery

- ✓ Condensate receivers serving "areas" can reduce project costs
- ✓ Condensate receivers and flash tanks serve to reduce the amount of steam entering the condensate return piping reducing flow restriction problems
- ✓ Contaminated condensate is a critical issue
- ✓ Receiver vents are indicative of trap failures
- ✓ Pump NPSH issues must be investigated

Source: US DOE ITP Steam BestPractices Program

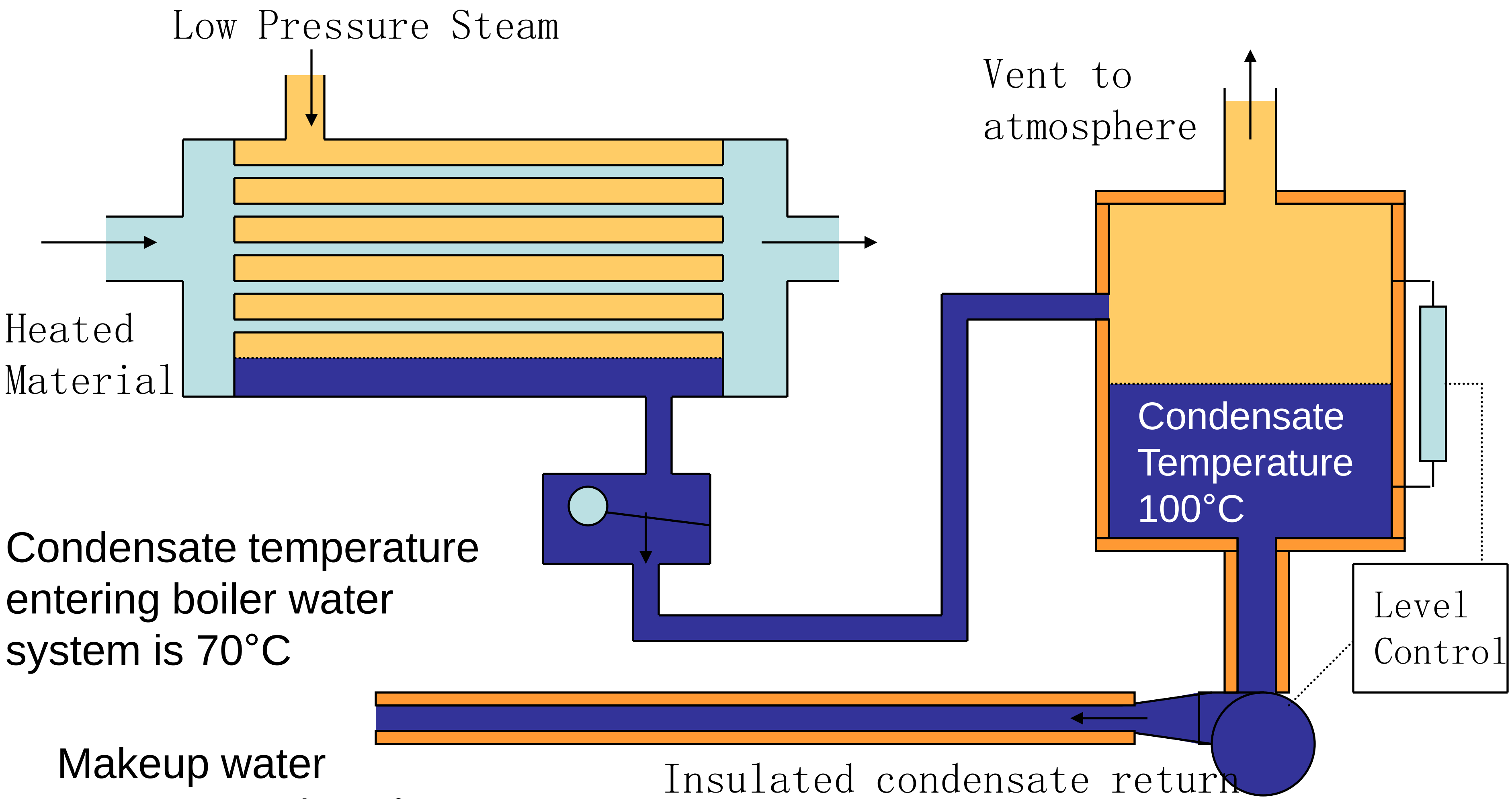
Condensate Return Example



Measured condensate temperature 100°C. Condensate flow measured by bucket and stopwatch (mass and energy balance is also a common method) to be 50 litres/minute

Source: US DOE ITP Steam BestPractices Program

Condensate Return Example



Condensate temperature entering boiler water system is 70°C

Makeup water temperature is 20°C

Source: US DOE ITP Steam BestPractices Program

Condensate Return Example

- ✓ Enthalpy of condensate: 293.1 kJ/kg
- ✓ Enthalpy of make-up: 83.9 kJ/kg
- ✓ Condensate flow rate: 50 litres/min

} From Steam Tables

$$m_{condensate} = 50 \times 977.8 \times \frac{1}{1000} \times \frac{1}{60} = 0.81 \frac{kg}{s}$$

$$Q_{condensate} = m_{condensate} \times \left(h_{condensate} - h_{makeup}\right)$$

$$Q_{condensate} = 0.81 \times \left(293.1 - 83.9\right) = 169.5\, kW$$

$$Q_{system} = Q_{condensate} \times \frac{1}{\eta_{boiler}} = 169.5 \times \frac{1}{0.80} = 212\, kW$$

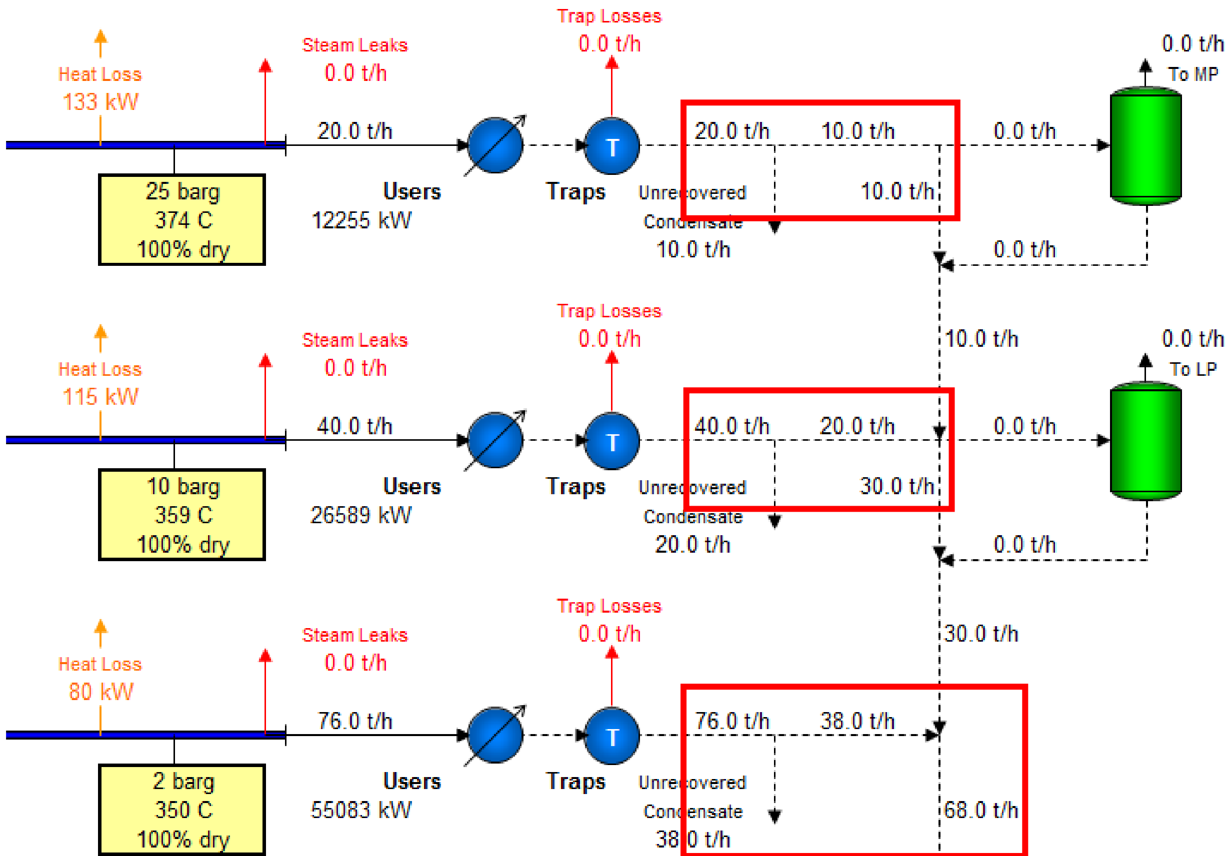
$$Energy\, Savings = 212 \times 3{,}600 \times \frac{2.10}{40{,}144} \times 8{,}760 \approx EGP\, 349{,}700$$

PARTNER FOR PROSPERITY

SSAT Project 13 - Condensate Return Savings

Process Condensate	Input Data	Warnings
Condensate return temperature to tank	70 °C	
HP condensate recovery	50 %	
MP condensate recovery	50 %	
LP condensate recovery	50 %	

Note: Condensate recovery specified as the percentage of steam supplied to the processes at each level



SSAT Project 13 – Condensate Return Savings

- ✓ Note that SSAT requires condensate return input as a percent of steam supplied to the process at each header level
  - Manual calculations will be needed to get to the new value of condensate returned
    - Steam demand on LP = 76 Tph
    - Current condensate returned = 50%
    - Current condensate returned = 38 Tph
    - Additional condensate = 0.81 kg/s = 2.92 Tph
    - New condensate return = 38 + 2.92 = 40.92 Tph
    - New condensate return = 40.92 / 76 = 53.84%

SSAT Project 13 – Condensate Return Savings

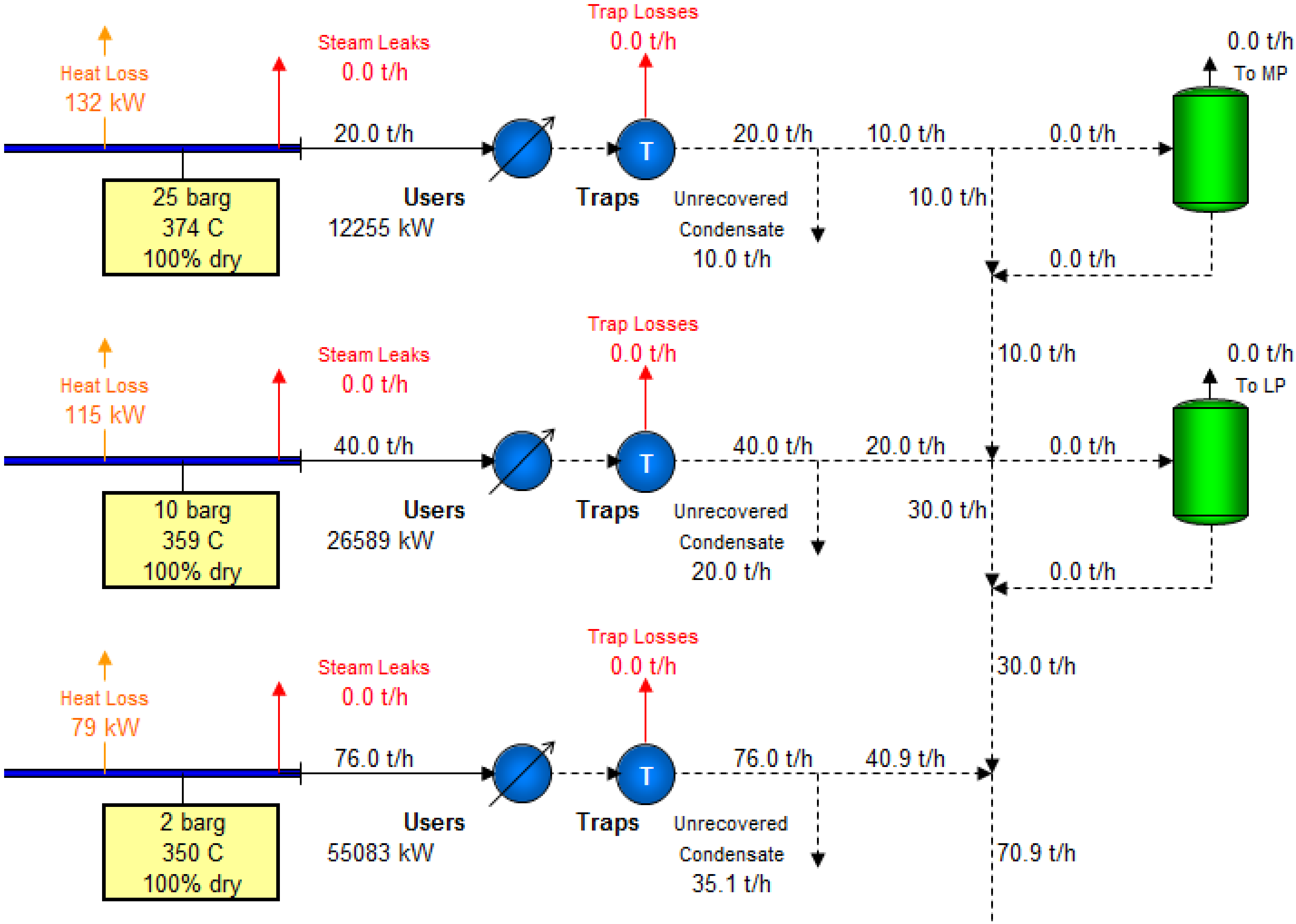
Project 13 - Condensate Recovery Currently recover 50% of HP, 50% of MP and 50% of LP at 70°C	
Do you wish to specify new condensate recovery rates?	Yes

If yes, enter new HP condensate recovery	50 %
If yes, enter new MP condensate recovery	50 %
If yes, enter new LP condensate recovery	53.84 %

Note: Condensate return temperature will be assumed to be 70°C as for the current operation

- ✓ Note that SSAT needs information of condensate recovery on all the headers even though the project being modeled is only on one of the headers
  - Other headers should have the same numbers as the "Input" page

SSAT Project 13 – Condensate Return Savings



SSAT Project 13 – Condensate Return Savings

Results Summary

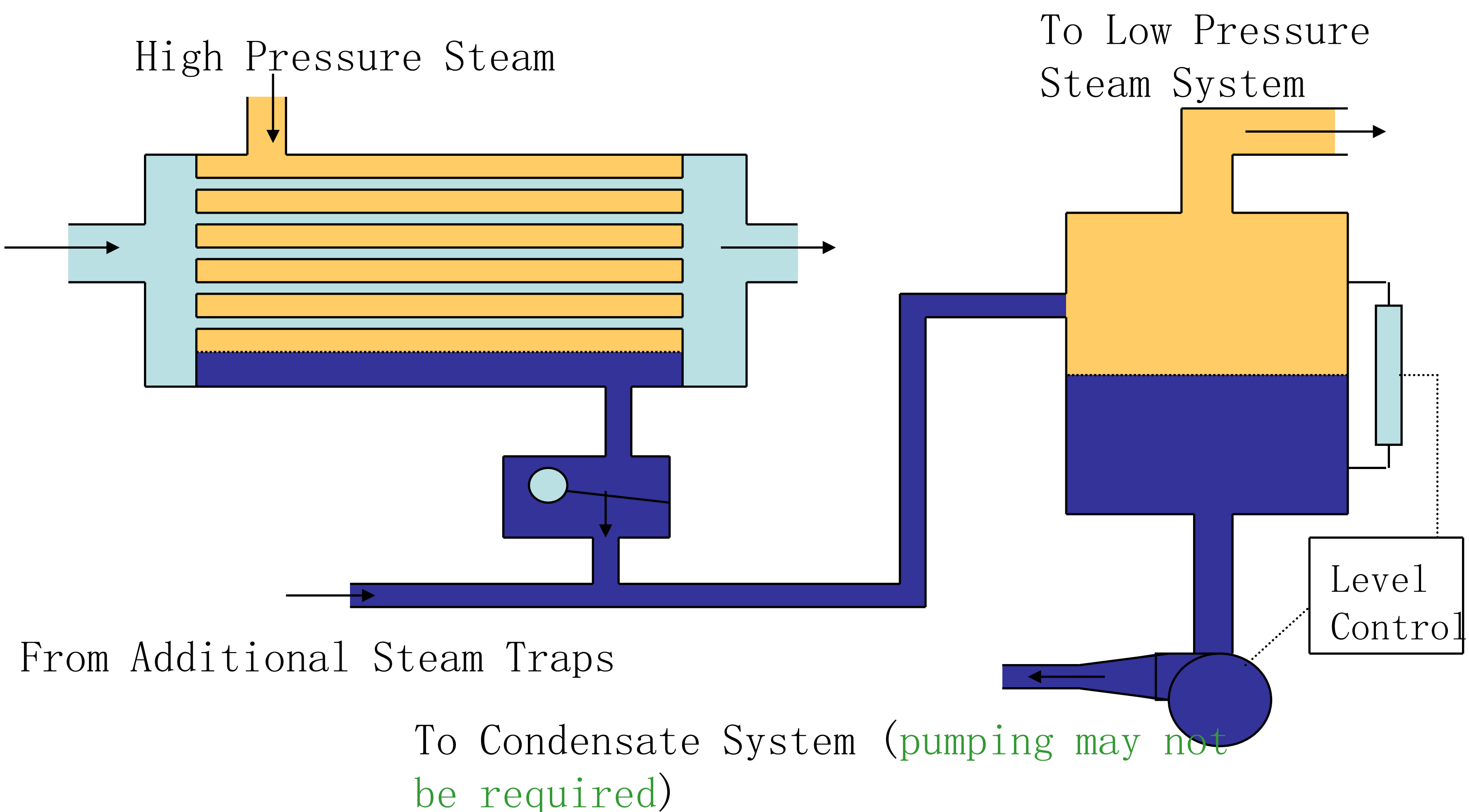
SSAT 3 Header Metric Model for User Training Egypt

Model Status : OK

Cost Summary ($ '000s/yr)	Current Operation	After Projects	Reduction	
Power Cost	33,726	33,726	0	0.0%
Fuel Cost	231,305	230,992	313	0.1%
Make-Up Water Cost	3,897	3,746	150	3.9%
Total Cost (in $ '000s/yr)	**268,928**	**268,464**	**464**	**0.2%**

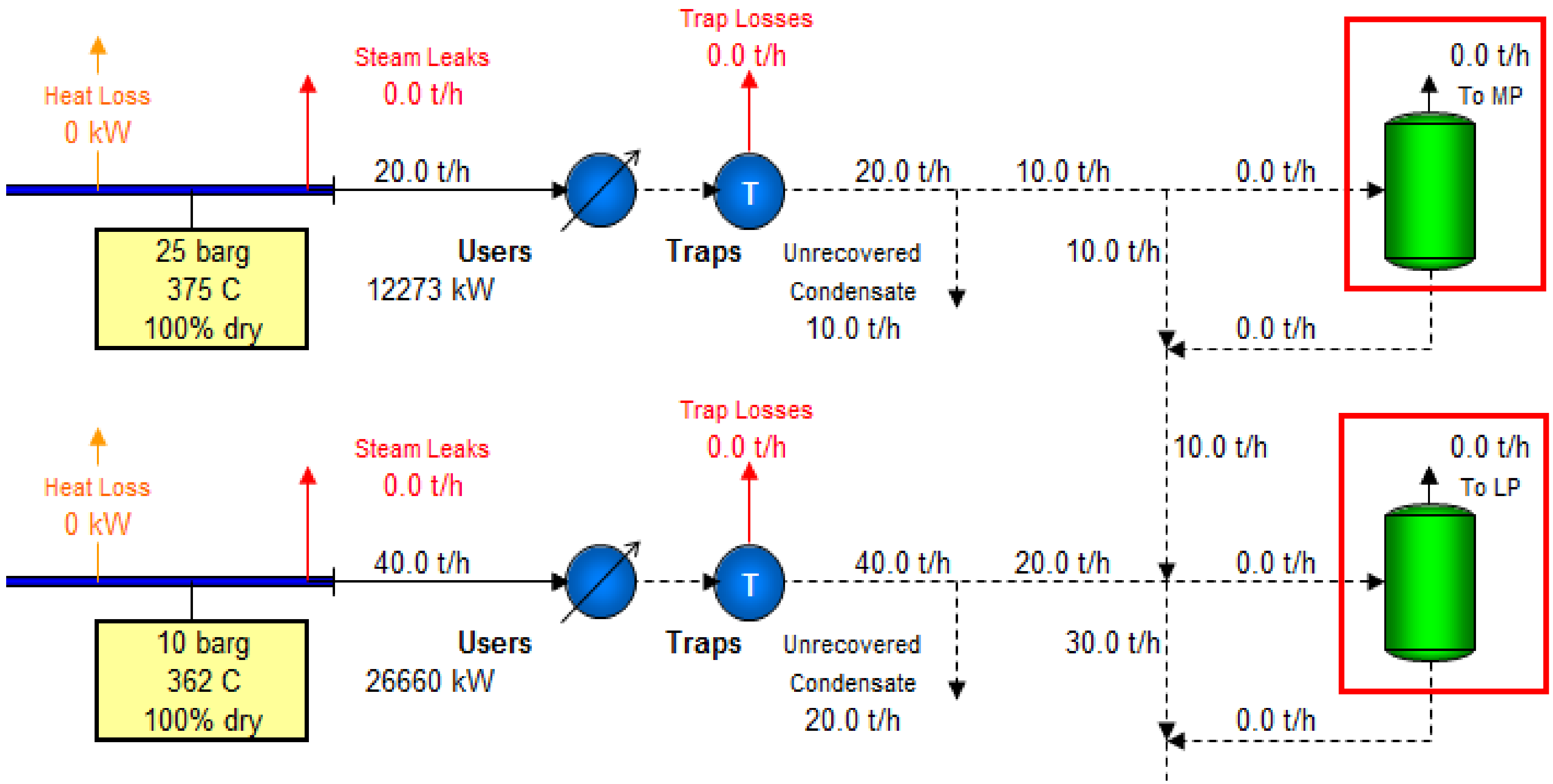
Utility Balance	Current Operation	After Projects	Reduction	
Power Generation	0 kW	0 kW	-	-
Power Import	5000 kW	5000 kW	0 kW	0.0%
Total Site Electrical Demand	5000 kW	5000 kW	-	-
Boiler Duty	140212 kW	140022 kW	190 kW	0.1%
Fuel Type	Natural Gas	Natural Gas	-	-
Fuel Consumption	12573.7 Nm3/h	12556.6 Nm3/h	17.1 Nm3/h	0.1%
Boiler Steam Flow	150.1 t/h	149.9 t/h	0.2 t/h	0.1%
Fuel Cost (in $/MWh)	188.32	188.32	-	-
Power Cost (as $/MWh)	770.00	770.00	-	-
Make-Up Water Flow	76 m3/h	73 m3/h	3 m3/h	3.9%

Cascade Condensate Systems



Source: US DOE ITP Steam BestPractices Program

SSAT Projects 14 & 15 – Condensate Flash Tanks



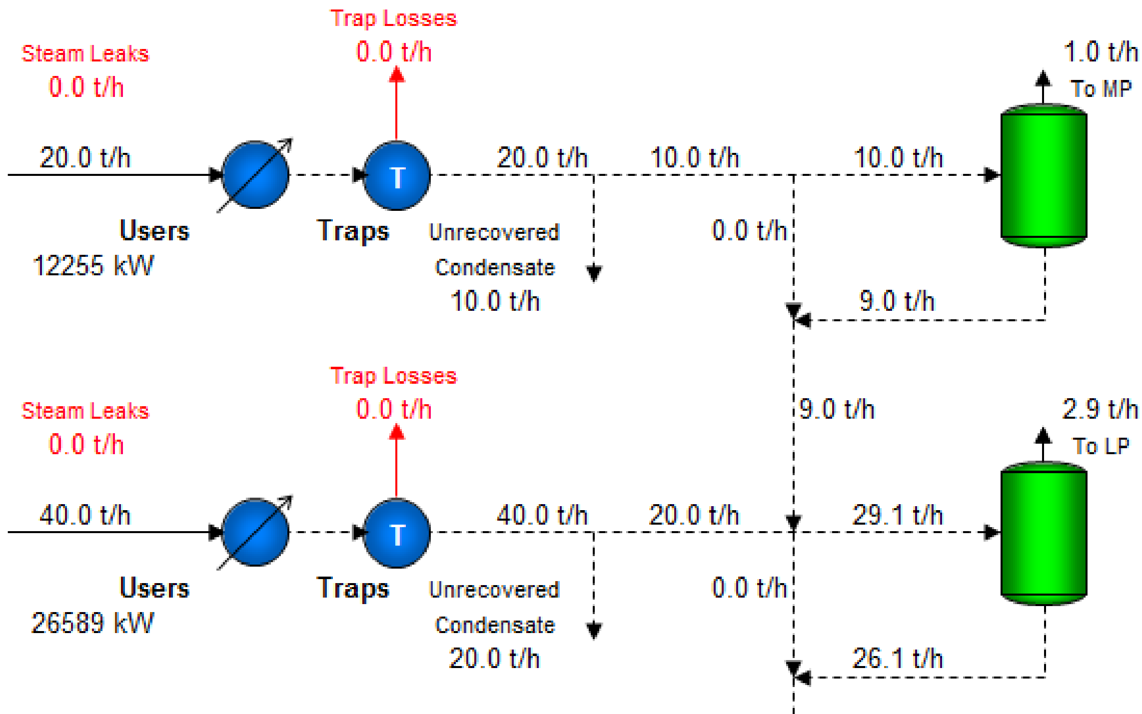
SSAT Projects 14 & 15 - Condensate Flash Tanks

Project 14 - Condensate Flash to MP
Not currently installed

Do you wish to modify the MP condensate flash system?	Yes, install condensate flash to MP

Project 15 - Condensate Flash to LP
Not currently installed

Do you wish to modify the LP condensate flash system?	Yes, install condensate flash to LP



SSAT Project 14 & 15 – Condensate Flash Tanks

Results Summary

SSAT 3 Header Metric Model for User Training Egypt

Model Status : OK

Cost Summary ($ '000s/yr)	Current Operation	After Projects	Reduction	
Power Cost	33,726	33,726	0	0.0%
Fuel Cost	231,305	225,989	5,316	2.3%
Make-Up Water Cost	3,897	3,902	-5	-0.1%
Total Cost (in $ '000s/yr)	**268,928**	**263,617**	**5,311**	**2.0%**

On-Site Emissions	Current Operation	After Projects	Reduction	
CO2 Emissions	220871 t/yr	215794 t/yr	5076 t/yr	2.3%
SOx Emissions	0 t/yr	0 t/yr	0 t/yr	N/A
NOx Emissions	437 t/yr	427 t/yr	10 t/yr	2.3%

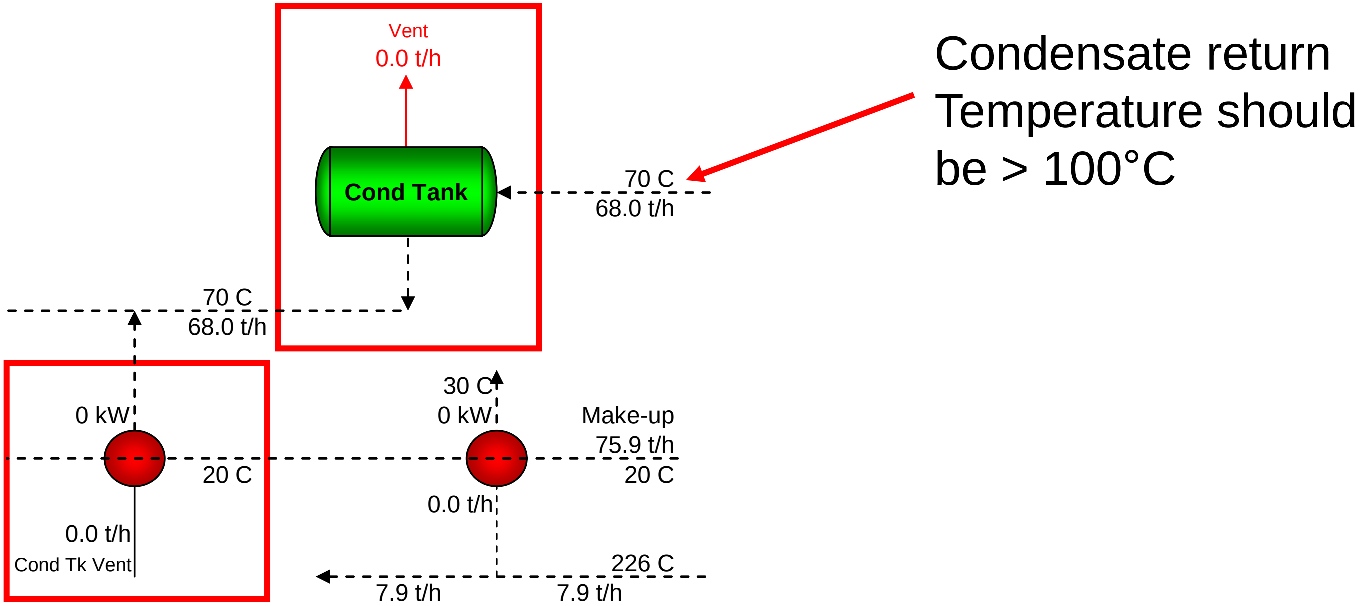
Utility Balance	Current Operation	After Projects	Reduction	
Power Generation	0 kW	0 kW	-	-
Power Import	5000 kW	5000 kW	0 kW	0.0%
Total Site Electrical Demand	5000 kW	5000 kW	-	-
Boiler Duty	140212 kW	136989 kW	3223 kW	2.3%
Fuel Type	Natural Gas	Natural Gas	-	-
Fuel Consumption	12573.7 Nm3/h	12284.7 Nm3/h	289 Nm3/h	2.3%
Boiler Steam Flow	150.1 t/h	146.6 t/h	3.4 t/h	2.3%
Fuel Cost (in $/MWh)	188.32	188.32	-	-
Power Cost (as $/MWh)	770.00	770.00	-	-
Make-Up Water Flow	76 m3/h	76 m3/h	0 m3/h	-0.1%

SSAT Project 11 – Condensate Tank Vent HX

Project 11 - Feedwater Heat Recovery Exchanger using Condensate Tank Vent
Not currently installed

Modify the condensate tank vent heat recovery system?	No

Note: An approach temperature of 10°C will be assumed for a new exchanger



- ✓ Note that this Project is possible ONLY with condensate return temperatures > 100°C

Key Points / Action Items

1. Returning condensate
   - Reduces energy
   - Reduces make-up water
   - Reduces chemicals for water treatment
   - Reduces quenching water
   - May reduce blowdown
2. Condensate recovery is often neglected but it can provide significant energy savings
3. Quantify the amount of condensate being recovered in a plant using a simple mass balance on the entire steam system
4. Identify potential areas of condensate recovery

Common BestPractices - Recovery

- ✓ Implement an effective steam-trap management and maintenance program
- ✓ Recover as much as possible of available condensate
- ✓ Recover condensate at the highest possible thermal energy
- ✓ Flash high-pressure condensate to make low-pressure steam

Source: US DOE BestPractices Steam System Sourcebook