# Section 4

# Steam System Assessment Tool – P2

Blowdown & Flash Steam
Steam Generation Conditions
Letdowns / PRVs
Deaerator
Heat Recovery Components
Condensate Recovery
Distribution Losses

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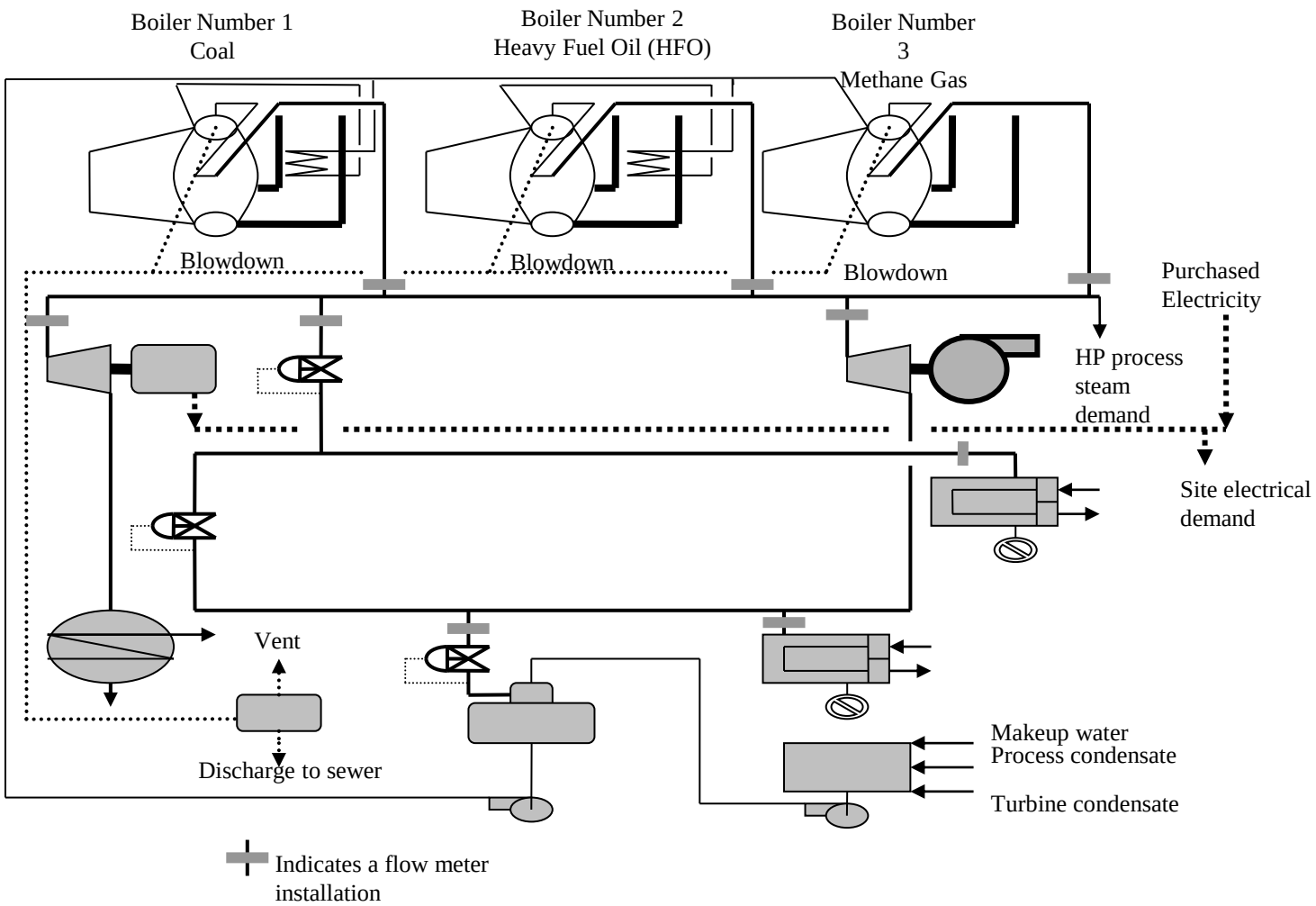
# Steam System

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# Blowdown & Flash Steam Recovery

| | | |
|---|---|---|
| Blowdown Rate (% of feedwater flow) | 5 % | |
| Do you have blowdown flash steam recovery to the LP system? | No | |

- Blowdown Rate is given as a percentage of feedwater flow
  - Typically refers to the continuous blowdown flow
  - Calculations were done in the “Boiler Efficiency” section

- Flash steam can be recovered at low pressure (or deaerator) level
  - Use pull-down menu to include it in the system

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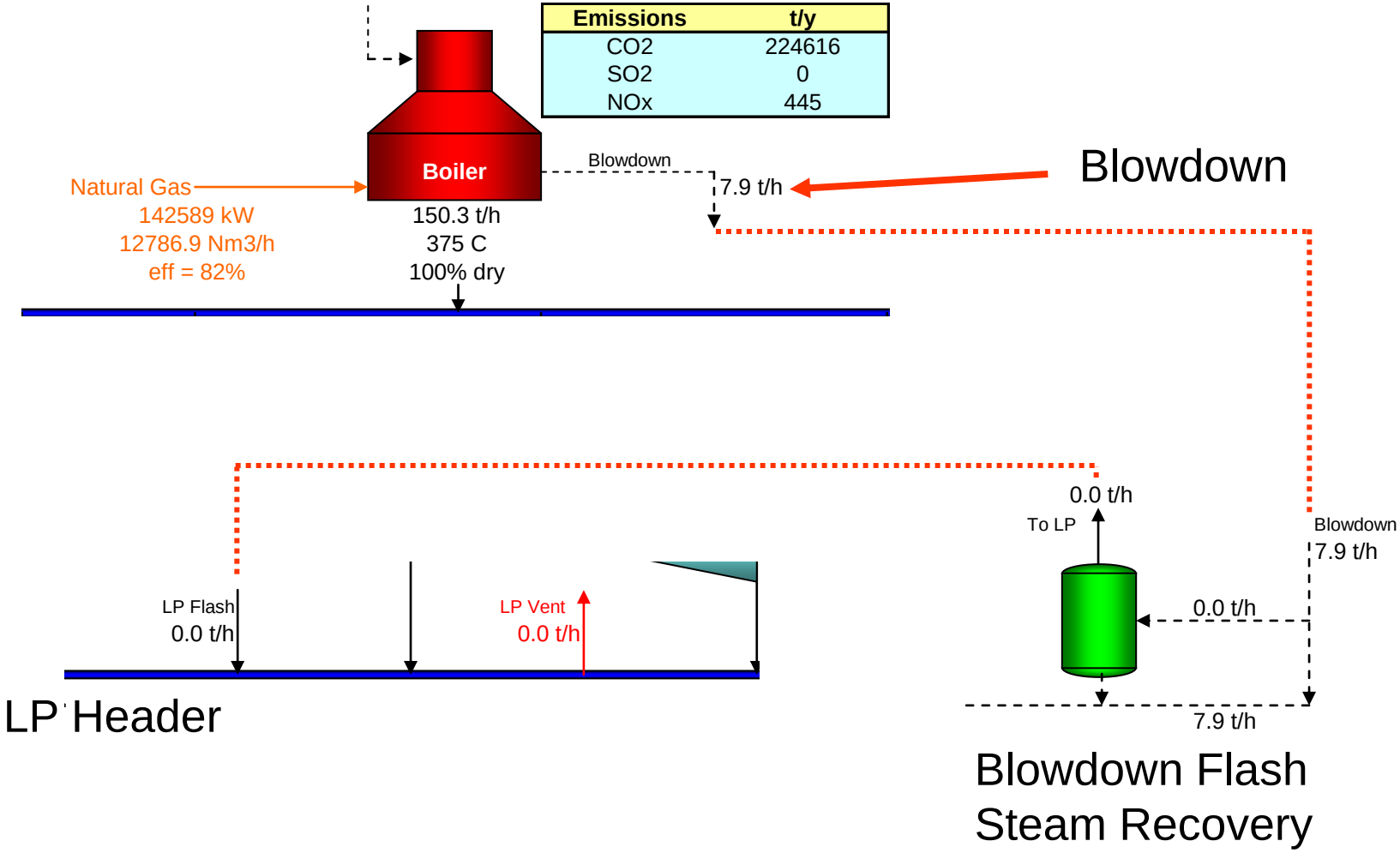
# Blowdown & Flash Steam Recovery

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# Steam Generation Conditions

Please select how you wish to define your HP generation condition and then provide supplementary information below if required:

| | |
|---|---|
| Method for specifying HP generation condition | Option 2 - User-defined superheated conditions |

Note: As a default, the model will use HP steam with 50°C of superheat. At HP pressure (25 barg), this corresponds to a temperature of 276°C

| | | |
|---|---|---|
| → **Option 2** - Enter temperature | 375 °C | ← |
| Option 3 - Enter thermodynamic quality | 99 % dry | |

- Boiler outlet steam condition can be set in SSAT
  - Steam condition can be
    - Superheated
    - Saturated steam dry
    - Saturated steam with a thermodynamic quality less than 100%
  - It is assumed the saturated mixture passes through the system
    - The liquid entering heat exchangers does not provide any energy transfer

$$Thermodynamic\ Quality = x = \frac{m_{vapor}}{\left(m_{liquid} + m_{vapor}\right)}$$

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# Saturated Mixture Steam Generation

- Boilers exporting carryover can result in significant operating problems
  - Energy loss as saturated liquid is discharged through the condensate system
  - Water hammer
  - Boiler water chemical loss
  - Turbine and valve erosion and deposits

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# Letdowns / PRVs

| Letdowns / PRVs | | |
|---|---|---|
| HP to MP - Is desuperheating water used? | | No (Model default) |
| If yes, enter control temperature | 190 °C | |

Note: Saturation temperature at specified MP pressure (10 barg) is 184°C

| | | |
|---|---|---|
| MP to LP - Is desuperheating water used? | | No (Model default) |
| If yes, enter control temperature | 140 °C | |

Note: Saturation temperature at specified LP pressure (2 barg) is 134°C

- Pressure Reducing Valves (PRVs) are most prevalent method of reducing pressure in a steam system
- A steam system will have one or more PRVs between two headers
- Not all PRVs maybe controlling header pressures

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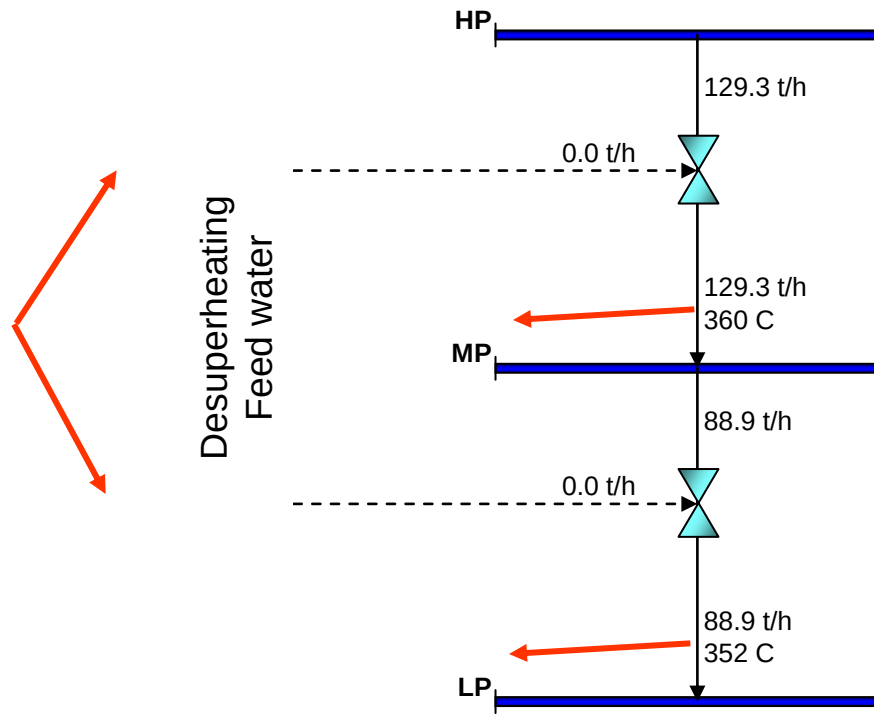
# Letdowns / PRVs

- Steam temperature at the outlet of the PRVs is controlled by feedwater (Desuperheaters)

- Mainly done for
  - Protecting equipment
  - Design conditions
  - Reducing pressure drop

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# Deaerator

- Oxygen, carbon dioxide and other gases are soluble in water
  - These chemicals are detrimental to the steam system
    - Oxygen results in corrosion generally in the form of pitting
    - Carbon dioxide results in corrosion generally from acidic condensate
- Open condensate receivers are a location where gases can become dissolved in condensate
- Makeup water usually contains significant amounts of dissolved gases
- The solubility of gases in water decreases as temperature increases
  - Deaeration is used to reduce the effects of dissolved gases

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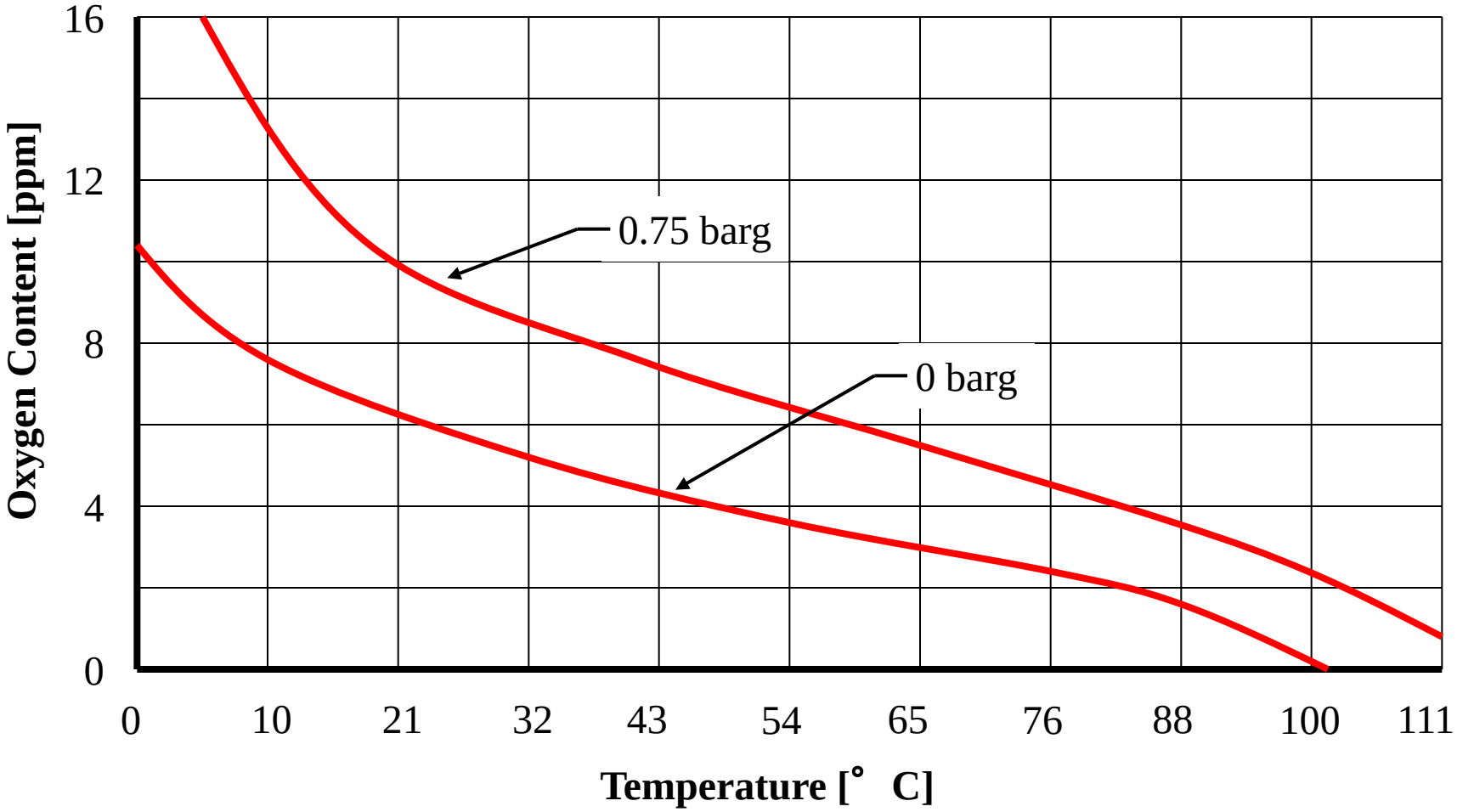
# Solubility of Oxygen in Water

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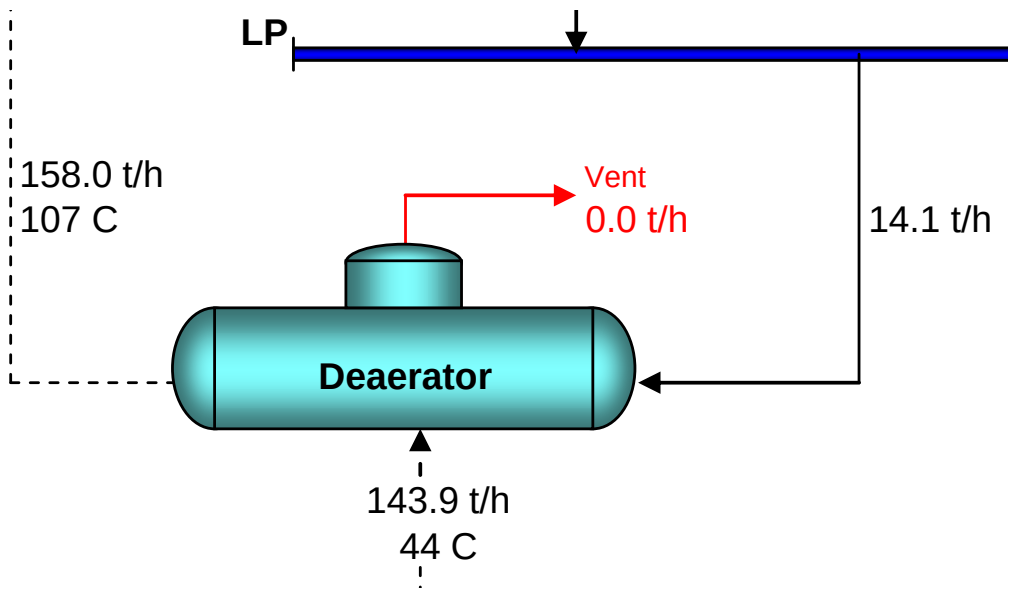
# Deaerator

| Deaerator | Input Data | Warnings |
|---|---|---|
| Vent (as % of boiler feedwater flow) | 0 % | |

Note: Values of around 0.1% are typical

| | | |
|---|---|---|
| Select the appropriate deaerator operating mode | | Option 2 - User-defined pressure |
| → **Option 2** - Specify pressure | 0.3 barg | ← |

Note: Deaerator uses LP steam. Specified LP pressure is 2 barg




- Vent flow is specified in SSAT as a percentage of boiler feedwater flow
- Deaerator receives low-pressure steam but can operate at a pressure lower than that

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# Heat Recovery Components

| Feedwater Heat Recovery System | | |
|---|---|---|
| Heat recovery exchanger on the condensate tank vent? | | No |
| If yes, enter approach temperature | 10 °C | |

Note: Approach temperature is defined as the minimum allowable temperature difference in the heat exchanger

| | | |
|---|---|---|
| Heat recovery exchanger on boiler blowdown? | | No |
| If yes, enter approach temperature | 10 °C | |

- There are two heat exchanger-based recovery components that can be modeled in SSAT
  - Condensate tank vent heat exchange
  - Boiler blowdown heat exchange

- Both these heat exchange components increase the make-up water temperature to the deaerator and thereby, reduce amount of deaerator steam requirement

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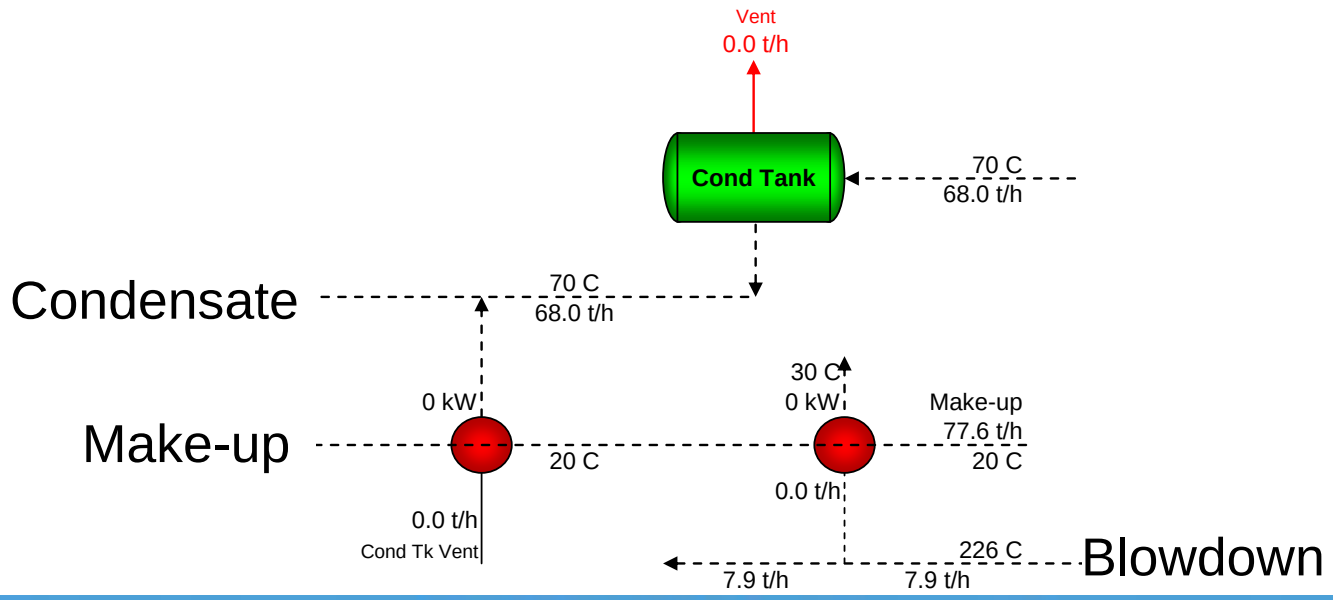
# Heat Recovery Components

| Feedwater Heat Recovery System | | |
|---|---|---|
| Heat recovery exchanger on the condensate tank vent? | | No |
| If yes, enter approach temperature | 10 °C | |

Note: Approach temperature is defined as the minimum allowable temperature difference in the heat exchanger

| | | |
|---|---|---|
| Heat recovery exchanger on boiler blowdown? | | No |
| If yes, enter approach temperature | 10 °C | |

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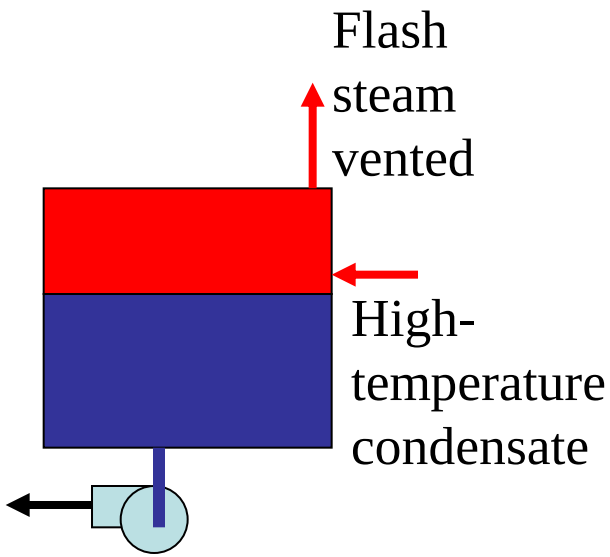
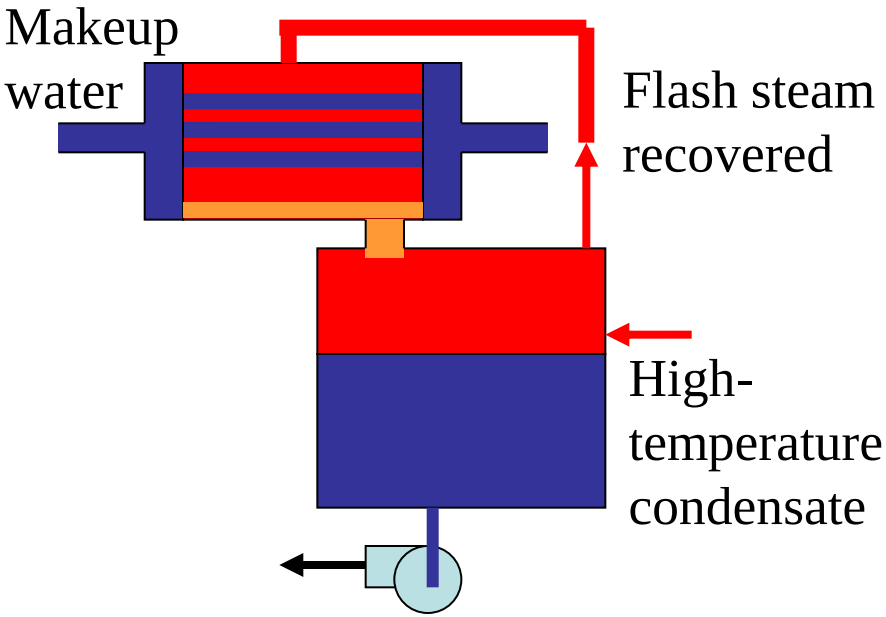
# Condensate Tank Vent Exchanger

- The condensate receiver operates at atmospheric pressure
  - Condensate entering the receiver with a temperature greater than atmospheric pressure saturation temperature (100°C) will flash
    - This flash steam can be recovered by make-up water energy recovery




**Condensate Receiver Vent Loss**




**Condensate Receiver Energy Recovery**

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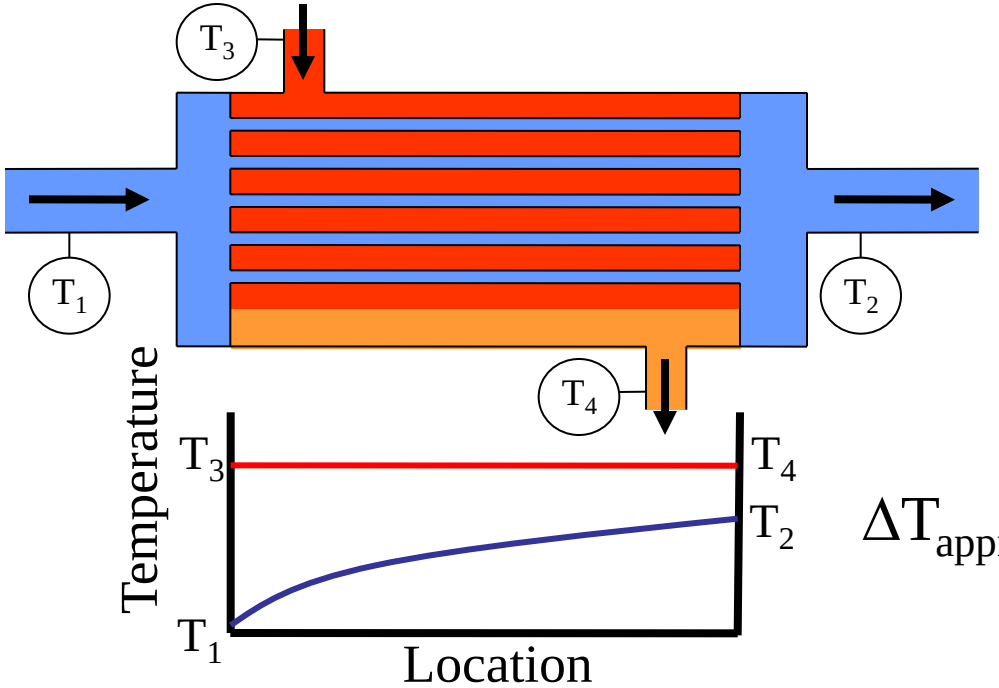
# Approach Temperature

- Heat exchanger approach temperature is defined as the **minimum allowable** temperature difference in the heat exchanger
  - This temperature difference will not be satisfied if the energy content of the recovered stream is insufficient
  - Typical values of approach temperature are 3°C to 10°C




$$\Delta T_{approach} = (T_4 - T_2)$$

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# Condensate Recovery / Flash Steam

| 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

| | |
|---|---|
| Do you flash condensate to MP steam? | No |
| Do you flash condensate to LP steam? | No |

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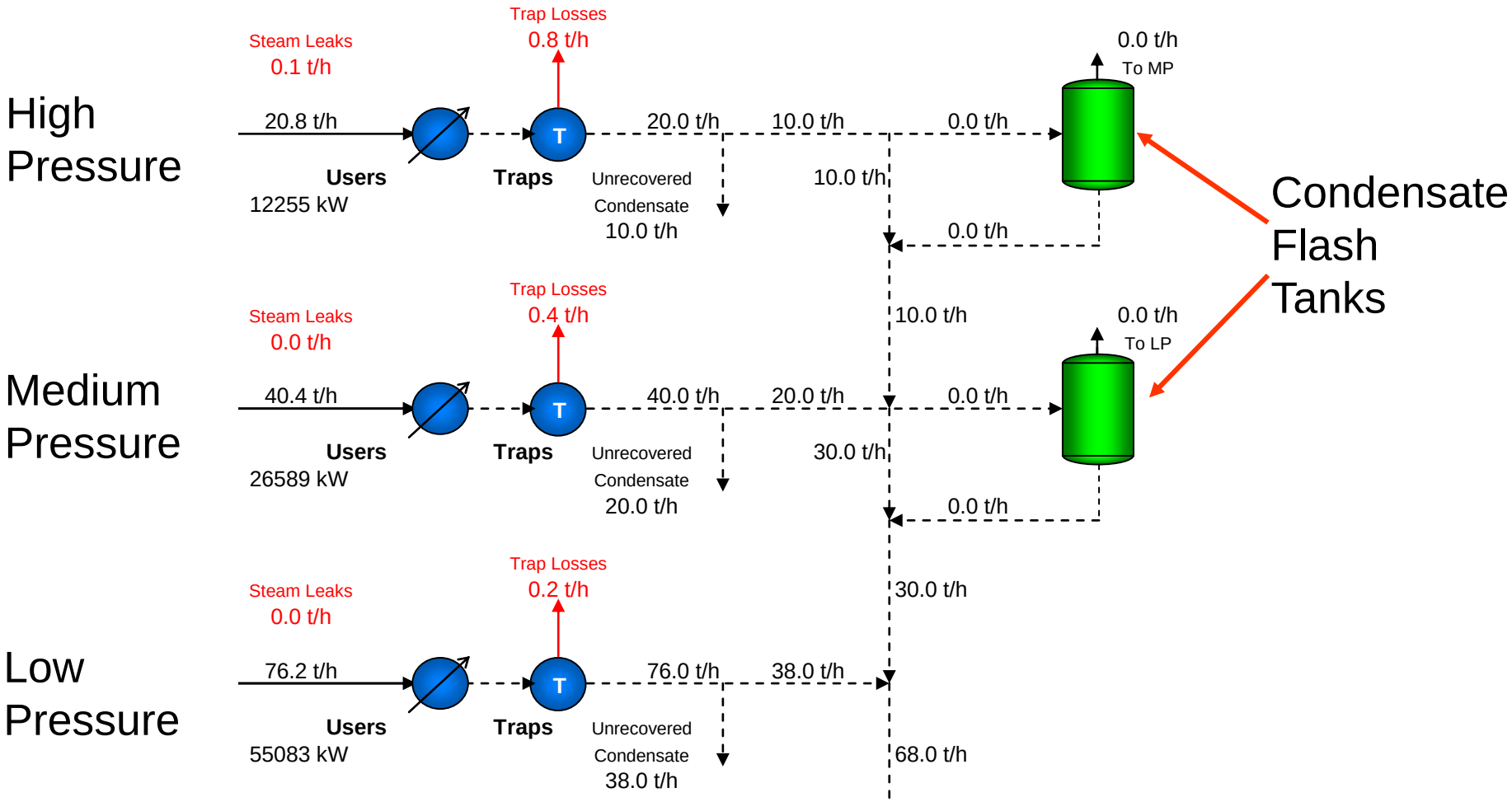
# Condensate Recovery / Flash Steam

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# Process Condensate

- SSAT condensate receiver operates at atmospheric pressure
- SSAT condensate return temperature provides an indication of the energy loss associated with the condensate return system
  - SSAT condensate exits a process heat exchanger as a saturated liquid at the pressure of the heat exchanger

- Condensate recovery percentage describes the amount of *process steam* recovered in the condensate system
- Flash steam recovery systems allow recovered condensate to flash steam into lower-pressure steam systems
- Makeup water temperature impacts condensate related projects

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# Steam Trap losses and Steam Leaks

| Steam Trap Losses and Steam Leaks | |
|---|---|
| Choose a method for estimating steam losses | Option 1 - Losses automatically estimated by model (Model default) |

| Option 2 - Specify number of failed traps at each pressure level | | Warnings |
|---|---|---|
| Trap failures on HP header | 10 traps | |
| Trap failures on MP header | 10 traps | |
| Trap failures on LP header | 10 traps | |

| Option 2 - Specify number of steam leaks at each pressure level | | Warnings |
|---|---|---|
| Steam leaks on HP header | 10 leaks | |
| Steam leaks on MP header | 10 leaks | |
| Steam leaks on LP header | 10 leaks | |

Note: Calculated values for current loss and leak rates based on current user inputs are:-
HP header - Trap failures: 25, Loss per trap 0.034 t/h - Total trap loss = 0.85 t/h. Steam leaks: 10, Loss per leak 0.008 t/h - Total leaks = 0.08 t/h.
MP header - Trap failures: 30, Loss per trap 0.014 t/h - Total trap loss = 0.42 t/h. Steam leaks: 12, Loss per leak 0.003 t/h - Total leaks = 0.04 t/h.
LP header - Trap failures: 50, Loss per trap 0.003 t/h - Total trap loss = 0.16 t/h. Steam leaks: 20, Loss per leak 0.001 t/h - Total leaks = 0.02 t/h.

- Two methods to specify trap losses & leaks
  - Model default – losses estimated by model
  - User specifies number of traps failed open & leaks

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# Steam Trap losses and Steam Leaks

- SSAT allows the number of known steam trap failures to override the initial steam trap failure gross estimate
  - Each trap reported as failed is assigned a leak amount
    - The leak amount is based on a theoretical flow analysis for a general orifice (3.2 mm diameter)
      - A blockage factor of 50% is applied to the theoretical analysis
      - This is the same analysis applied in the initial data input
      - The number of failed closed traps should not be included

- Steam leak estimates are based on a 1.6 mm diameter orifice and a 50% blockage factor

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# SSAT Steam Trap Model

- The SSAT steam trap model assumes that all failed traps discharge steam to the atmosphere
  - The condensate collection system must be considered in this evaluation
    - In reality, failed open steam traps discharging to a closed condensate collection system with flash steam act as a pressure reducing valve
      - The steam is not lost from the system

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# Example System - SSAT Steam Trap & Steam Leaks Model

| Steam Trap Losses and Steam Leaks | |
|---|---|
| Choose a method for estimating steam losses | Option 2 - Losses calculated from user-defined data |

| Option 2 - Specify number of failed traps at each pressure level | | Warnings |
|---|---|---|
| Trap failures on HP header | 0 traps | |
| Trap failures on MP header | 0 traps | |
| Trap failures on LP header | 0 traps | |

| Option 2 - Specify number of steam leaks at each pressure level | | Warnings |
|---|---|---|
| Steam leaks on HP header | 0 leaks | |
| Steam leaks on MP header | 0 leaks | |
| Steam leaks on LP header | 0 leaks | |

Note: Calculated values for current loss and leak rates 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. Steam leaks: 0, Loss per leak 0.008 t/h - Total leaks = 0.00 t/h.

MP header - Trap failures: 0, Loss per trap 0.014 t/h - Total trap loss = 0.00 t/h. Steam leaks: 0, Loss per leak 0.003 t/h - Total leaks = 0.00 t/h.

LP header - Trap failures: 0, Loss per trap 0.003 t/h - Total trap loss = 0.00 t/h. Steam leaks: 0, Loss per leak 0.001 t/h - Total leaks = 0.00 t/h.

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# Insulation Energy Loss

| Insulation Heat Losses | Input Data | Notes/Warnings |
|---|---|---|
| Choose a method for specifying heat losses | | Option 2 - Percentage heat loss on each header (Model default) |
| Option 1 - Heat loss on HP header | 30 kW | |
| Option 1 - Heat loss on MP header | 30 kW | |
| Option 1 - Heat loss on LP header | 30 kW | |
| → Option 2 - % of heat lost on HP header | 0.1 % | ← |
| → Option 2 - % of heat lost on MP header | 0.1 % | ← |
| → Option 2 - % of heat lost on LP header | 0.1 % | ← |

Note: Losses calculated as the percentage of heat flow entering each header

Note: Current values for heat entering headers are: HP 132770 kW, MP 114161 kW, LP 78369 kW - These may change when the model is updated

- Two methods in SSAT for insulation energy losses
  - Specify heat loss (kW) on each header
  - Specify percent heat lost on each header
- 3rd Method
  - Use 3EPlus

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# Example System - SSAT Insulation Loss Model

| Insulation Heat Losses | Input Data | Notes/Warnings |
|---|---|---|
| Choose a method for specifying heat losses | | Option 2 - Percentage heat loss on each header (Model default) |
| Option 1 - Heat loss on HP header | 30 kW | |
| Option 1 - Heat loss on MP header | 30 kW | |
| Option 1 - Heat loss on LP header | 30 kW | |
| → Option 2 - % of heat lost on HP header | 0 % | ← |
| → Option 2 - % of heat lost on MP header | 0 % | ← |
| → Option 2 - % of heat lost on LP header | 0 % | ← |

Note: Losses calculated as the percentage of heat flow entering each header

Note: Current values for heat entering headers are: HP 132630 kW, MP 114959 kW, LP 79615 kW - These may change when the model is updated

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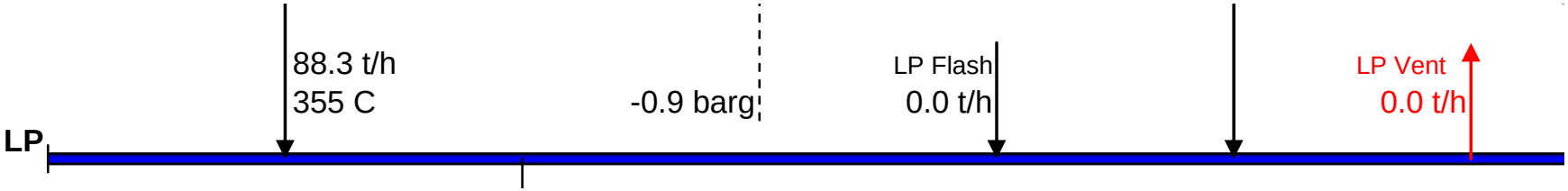
# Low-pressure Header Vent




- The low-pressure header can operate in an “unbalanced” state
  - This can develop in steam systems by:
    - Operating more backpressure turbines than necessary
    - Poor control strategies
  - The low-pressure vent should always be a point of investigation
    - From the physical site operations standpoint
    - From the SSAT model standpoint

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# SSAT 3-Header Model Student Exercise

- Using the example system with the methane gas boiler as the impact boiler, build a model to accurately reflect steam flows, steam impact (marginal) costs and economic benefits of saving 1 Tph of steam
- Steam generated ~150 Tph in the plant
- Steam conditions: 25 bars, 375°C
- Make up water: 20°C

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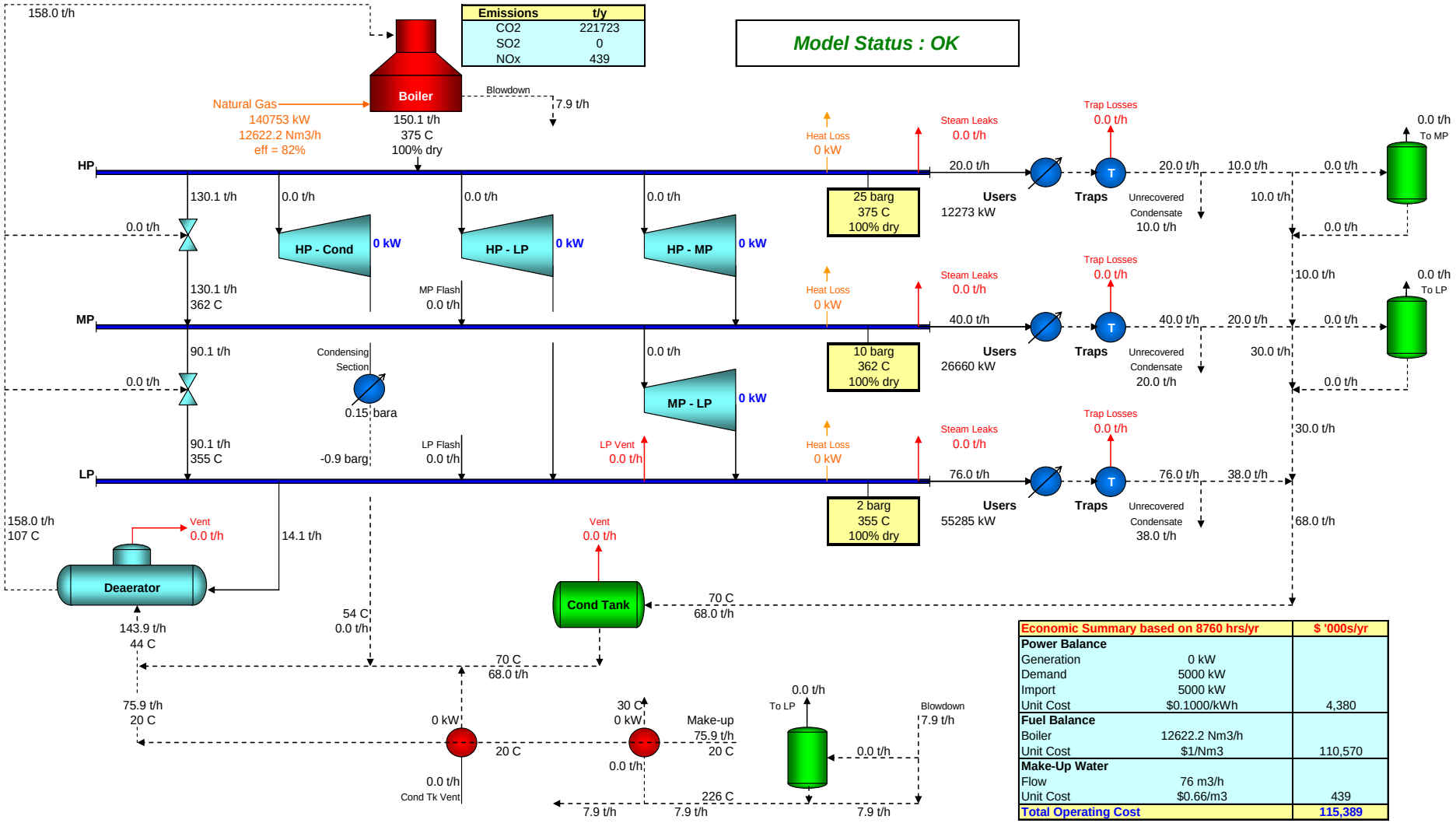
**Steam System Assessment Tool**

# SSAT 3 Header Experts Training Example

**Current Operation**

| Emissions | t/y |
|---|---|
| CO2 | 221723 |
| SO2 | 0 |
| NOx | 439 |

***Model Status : OK***




| Economic Summary based on 8760 hrs/yr | | $ '000s/yr |
|---|---|---|
| **Power Balance** | | |
| Generation | 0 kW | |
| Demand | 5000 kW | |
| Import | 5000 kW | |
| Unit Cost | $0.1000/kWh | 4,380 |
| **Fuel Balance** | | |
| Boiler | 12622.2 Nm3/h | |
| Unit Cost | $1/Nm3 | 110,570 |
| **Make-Up Water** | | |
| Flow | 76 m3/h | |
| Unit Cost | $0.66/m3 | 439 |
| **Total Operating Cost** | | **115,389** |

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# Results Summary

## SSAT 3 Header Experts Training Example

***Model Status : OK***

| Cost Summary ($ '000s/yr) | Current Operation | After Projects | Reduction | |
|---|---|---|---|---|
| Power Cost | 4,380 | 4,380 | 0 | 0.0% |
| Fuel Cost | 110,570 | 110,570 | 0 | 0.0% |
| Make-Up Water Cost | 439 | 439 | 0 | 0.0% |
| **Total Cost (in $ '000s/yr)** | **115,389** | **115,389** | **0** | **0.0%** |

| On-Site Emissions | Current Operation | After Projects | Reduction | |
|---|---|---|---|---|
| CO2 Emissions | 221723 t/yr | 221723 t/yr | 0 t/yr | 0.0% |
| SOx Emissions | 0 t/yr | 0 t/yr | 0 t/yr | N/A |
| NOx Emissions | 439 t/yr | 439 t/yr | 0 t/yr | 0.0% |

| 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 | 140753 kW | 140753 kW | 0 kW | 0.0% |
| Fuel Type | Natural Gas | Natural Gas | - | - |
| Fuel Consumption | 12622.2 Nm3/h | 12622.2 Nm3/h | 0 Nm3/h | 0.0% |
| Boiler Steam Flow | 150.1 t/h | 150.1 t/h | 0.0 t/h | 0.0% |
| Fuel Cost (in $/MWh) | 89.68 | 89.68 | - | - |
| Power Cost (as $/MWh) | 100.00 | 100.00 | - | - |
| Make-Up Water Flow | 76 m3/h | 76 m3/h | 0 m3/h | 0.0% |

| Turbine Performance | Current Operation | After Projects | Marginal Steam Costs | |
|---|---|---|---|---|
| HP to LP steam rate | Not in use | Not in use | (based on current operation) | |
| HP to MP steam rate | Not in use | Not in use | HP ($/t) | 93.18 |
| MP to LP steam rate | Not in use | Not in use | MP ($/t) | 93.18 |
| HP to Condensing steam rate | Not in use | Not in use | LP ($/t) | 93.18 |

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# Marginal Steam Costs

| Marginal Steam Costs | |
|---|---|
| (based on current operation) | |
| HP ($/t) | -----> |
| MP ($/t) | -----> |
| LP ($/t) | -----> |

Press this button if marginal costs are not shown

- Marginal costs are determined based on supplying an additional 1 Tph of additional steam from a header
  - The marginal cost is the actual impact cost of a steam demand
  - The calculation is based on
    - Input data
    - Input configuration

- It is important to not interrupt the Marginal Steam Cost calculation
  - SSAT will abort the calculation if interrupted

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# Marginal Steam Costs

- Marginal steam costs are typically used when analyzing
  - Steam leaks
  - Process changes
  - Elimination or institution of nominal steam use

- Marginal steam costs are impacted by condensate return
  - Amount
  - Temperature

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# Comparison of Results from SSAT 1-Header & SSAT 3-Header Student Exercises

- Steam generated was different in the two cases
- Marginal costs of steam were identical in both cases
- Economic benefits of saving 1 Tph of steam was identical
- Most often, its best to use the 3-Header model because it is the superset of 1 and 2-header models
- Much more complex systems can be modeled with the 3-Header model and more projects can be simulated

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