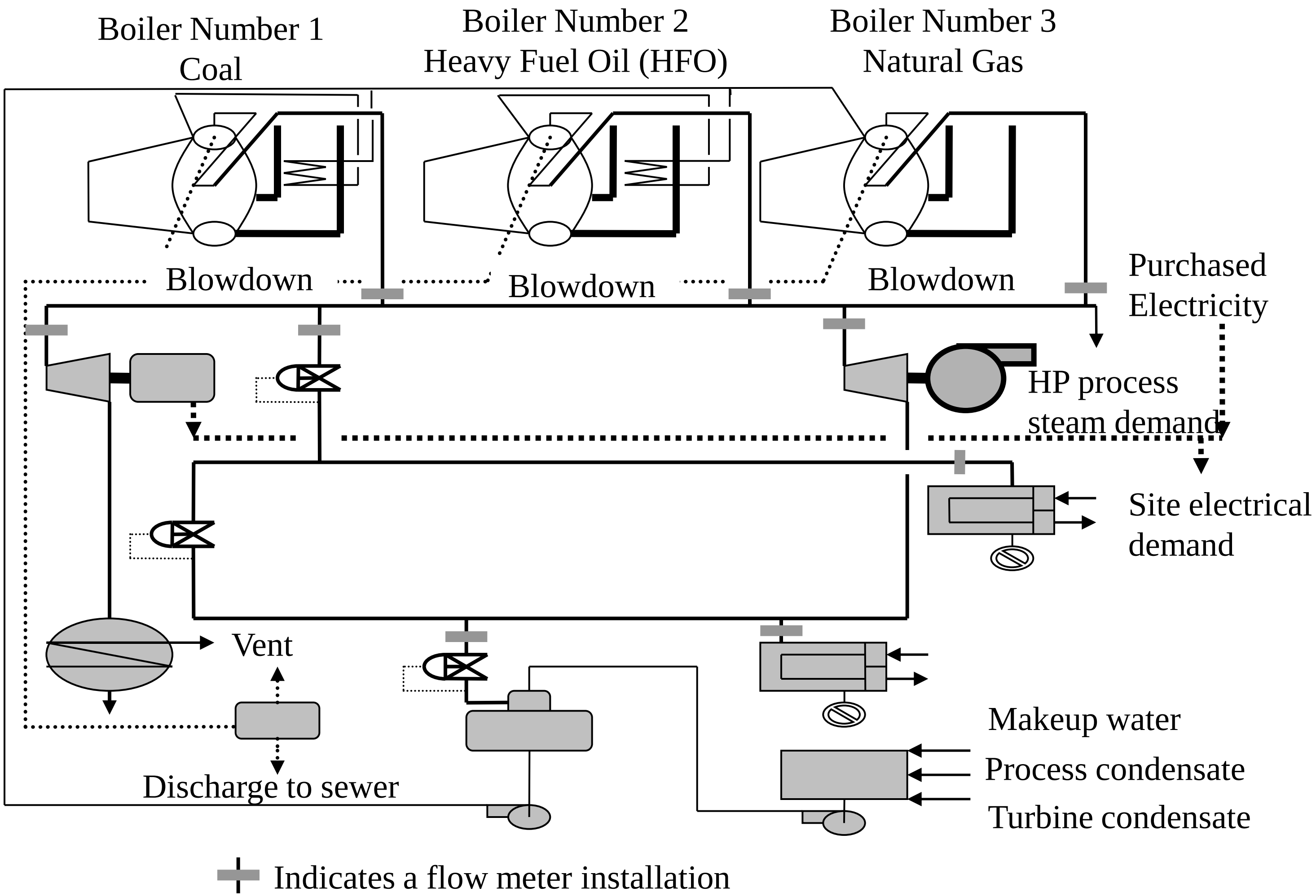
Section 4

Steam System Assessment Tool – P2

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

Steam System



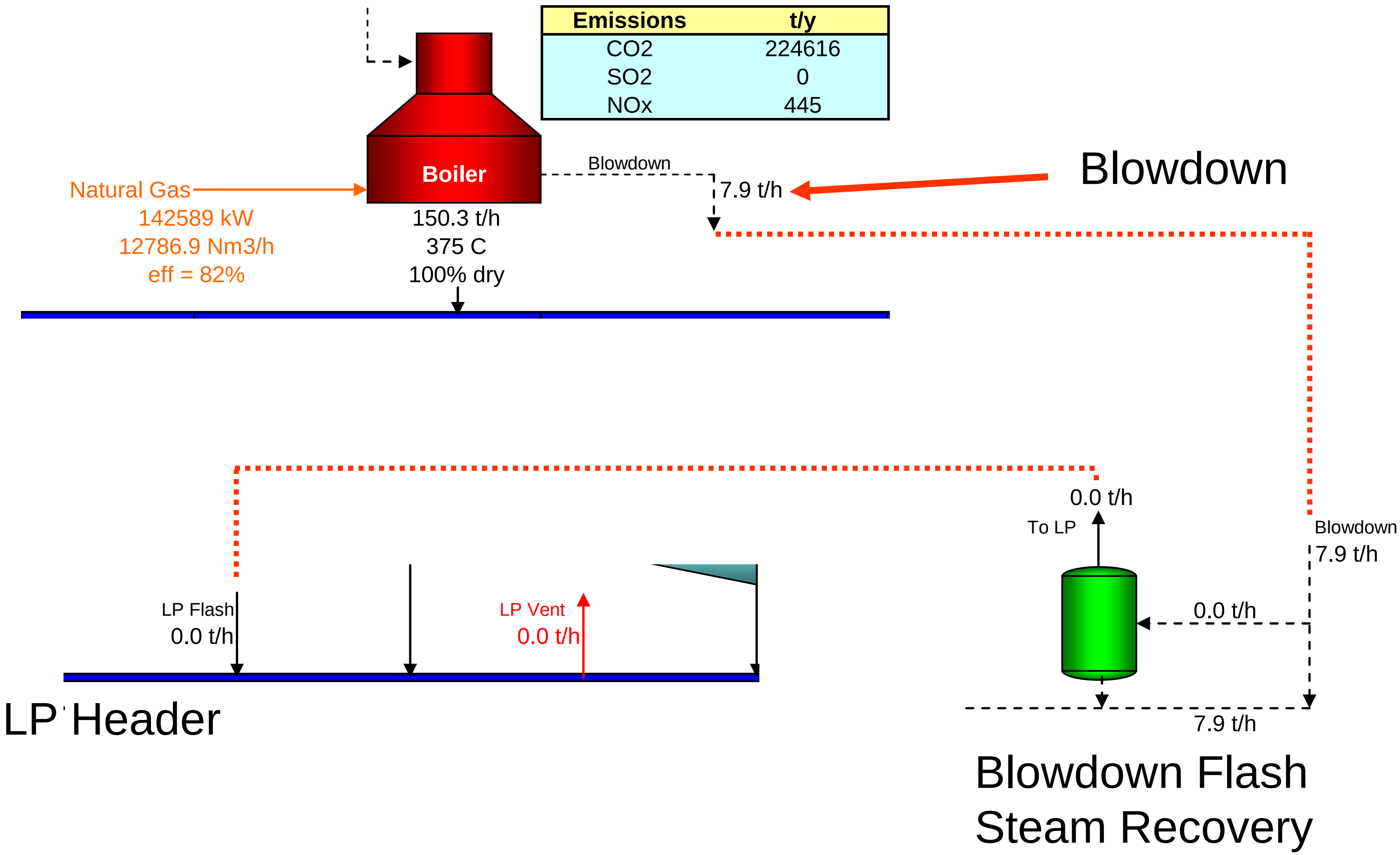
Blowdown & Flash Steam Recovery

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

Blowdown & Flash Steam Recovery



Emissions	t/y
CO_2	224616
SO_2	0
NOx	445

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

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

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

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

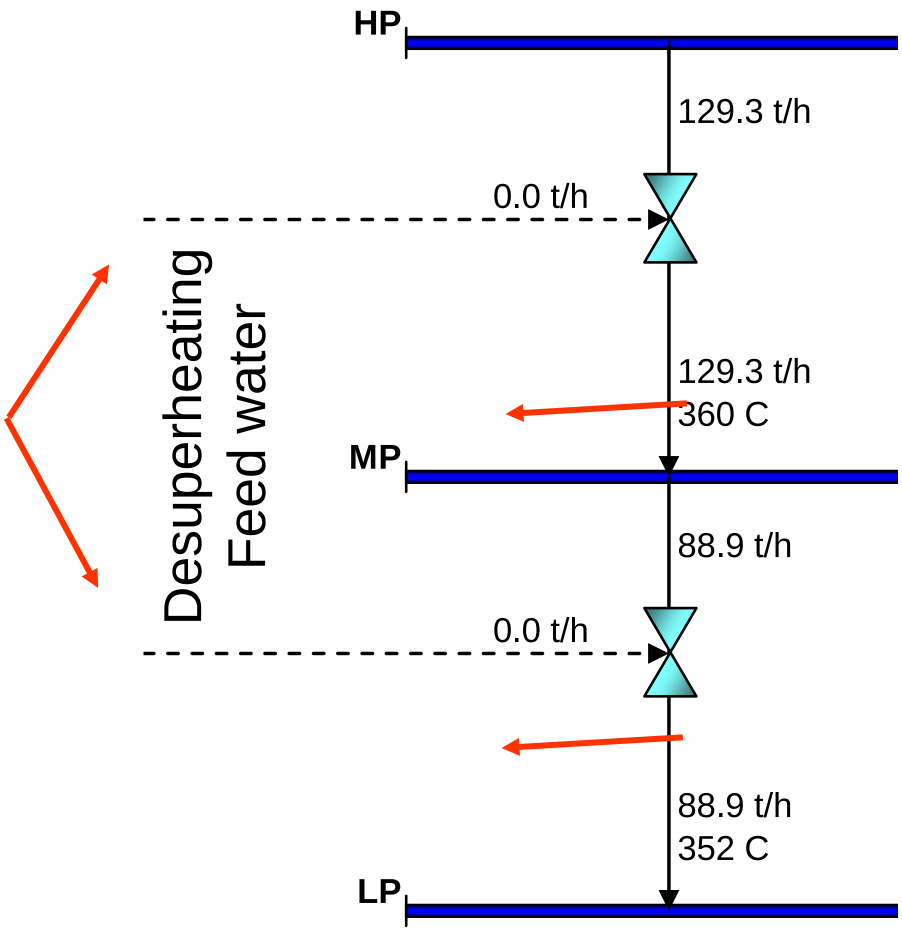
MP to LP - Is desuperheating water used?		No (Model default)
If yes, enter control temperature	140 °C	

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

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

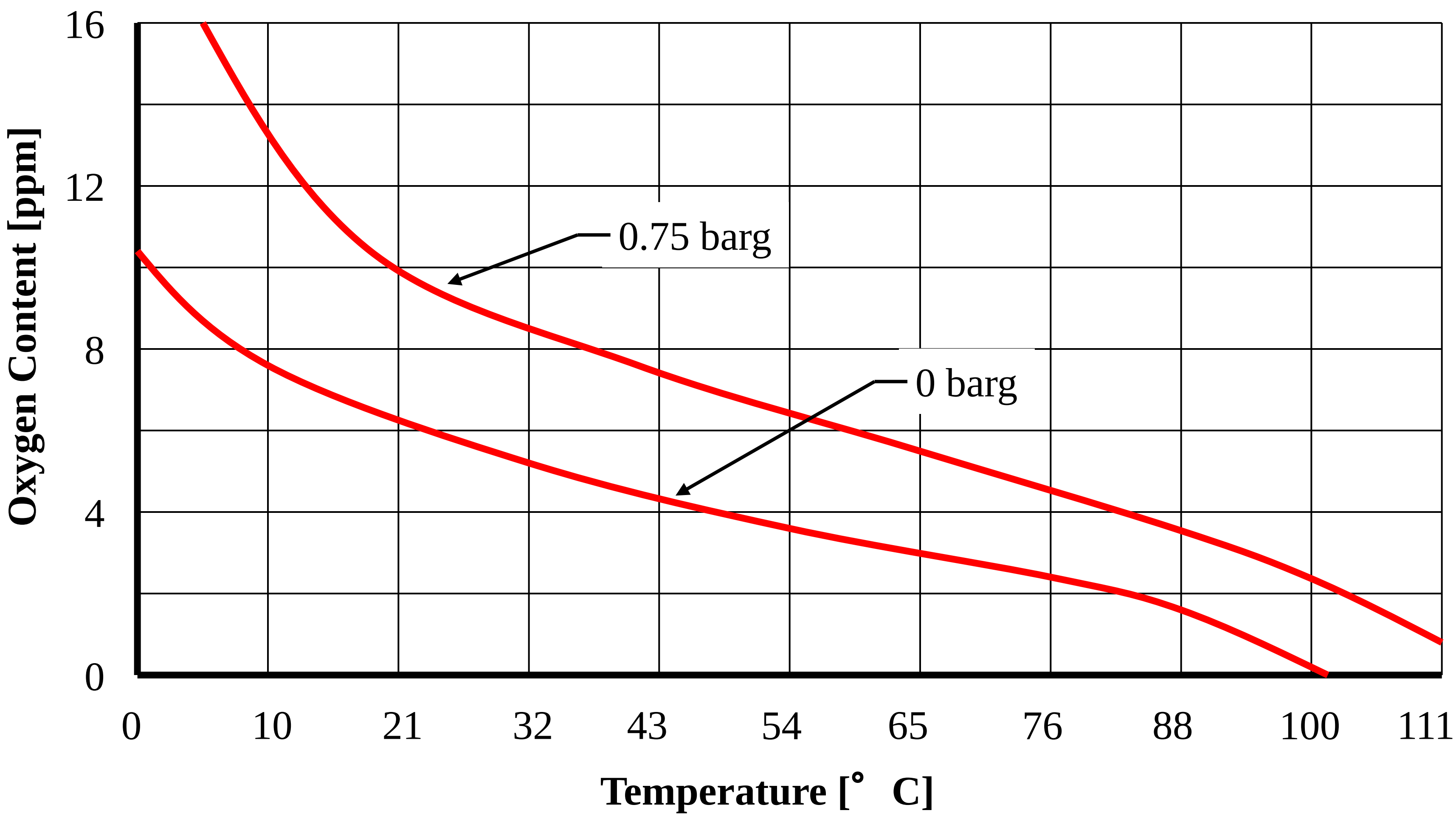


Deaerator

- 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

Solubility of Oxygen in Water



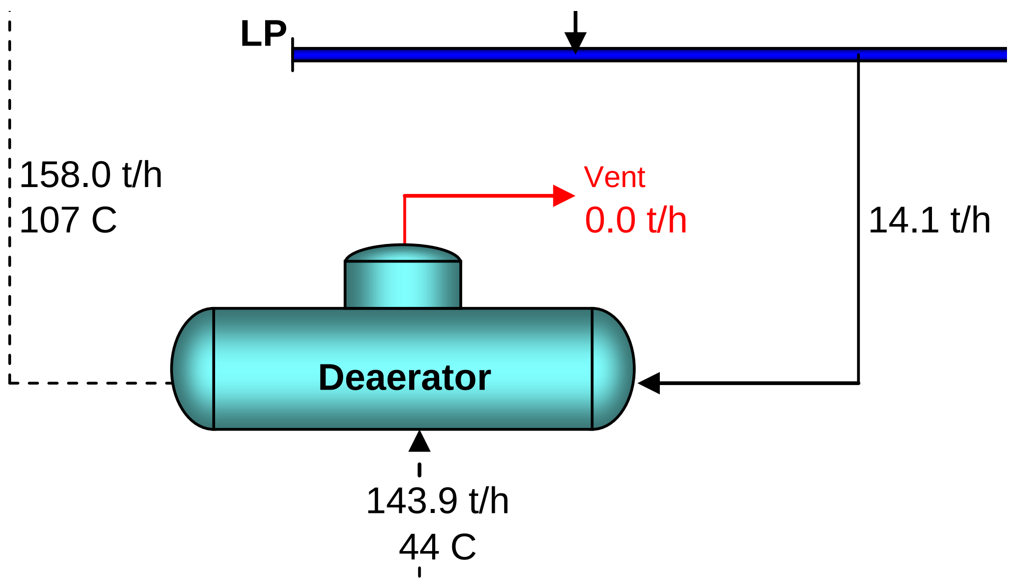
Deaerator

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

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

Heat Recovery Components

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

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Heat recovery exchanger on boiler blowdown?		No
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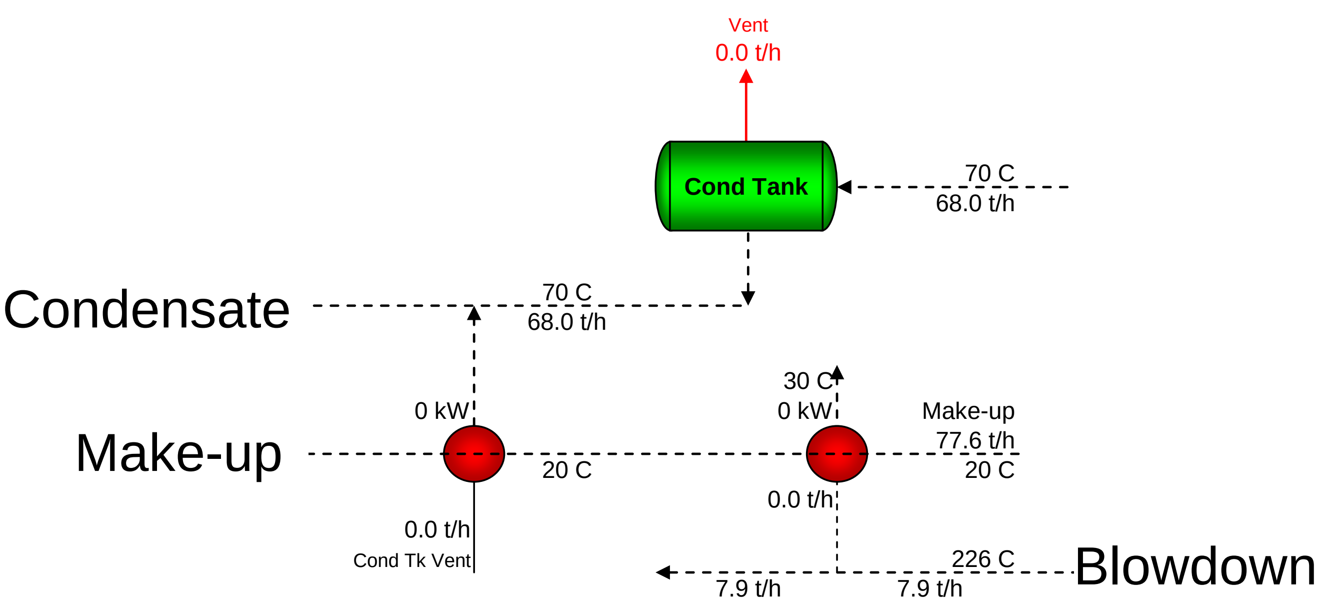
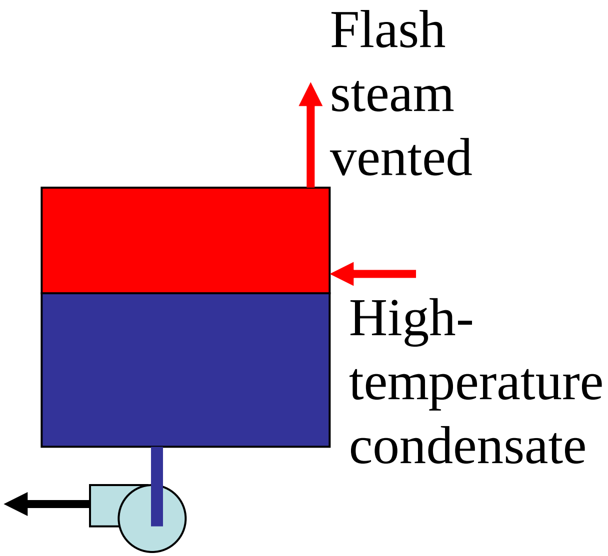
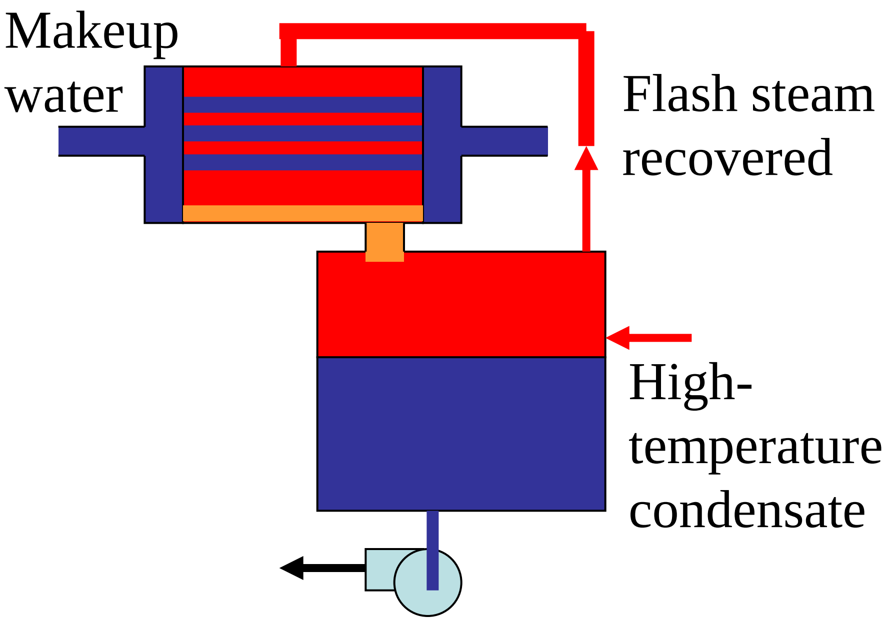


Condensate Tank Vent Exchanger

- 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



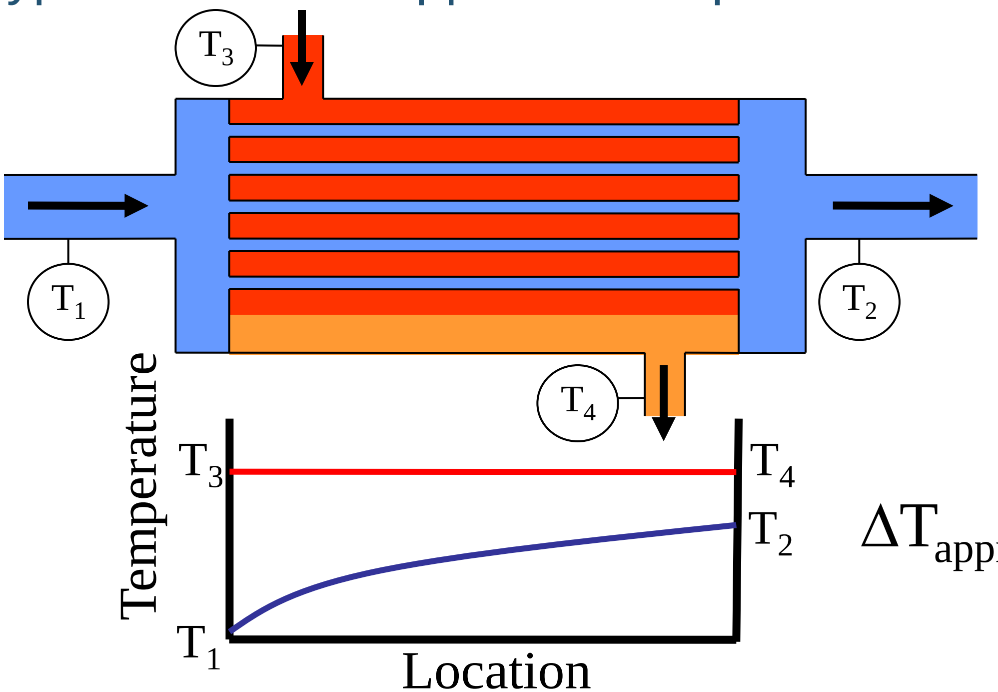
Condensate Receiver Vent Loss



Condensate Receiver Energy Recovery

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



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

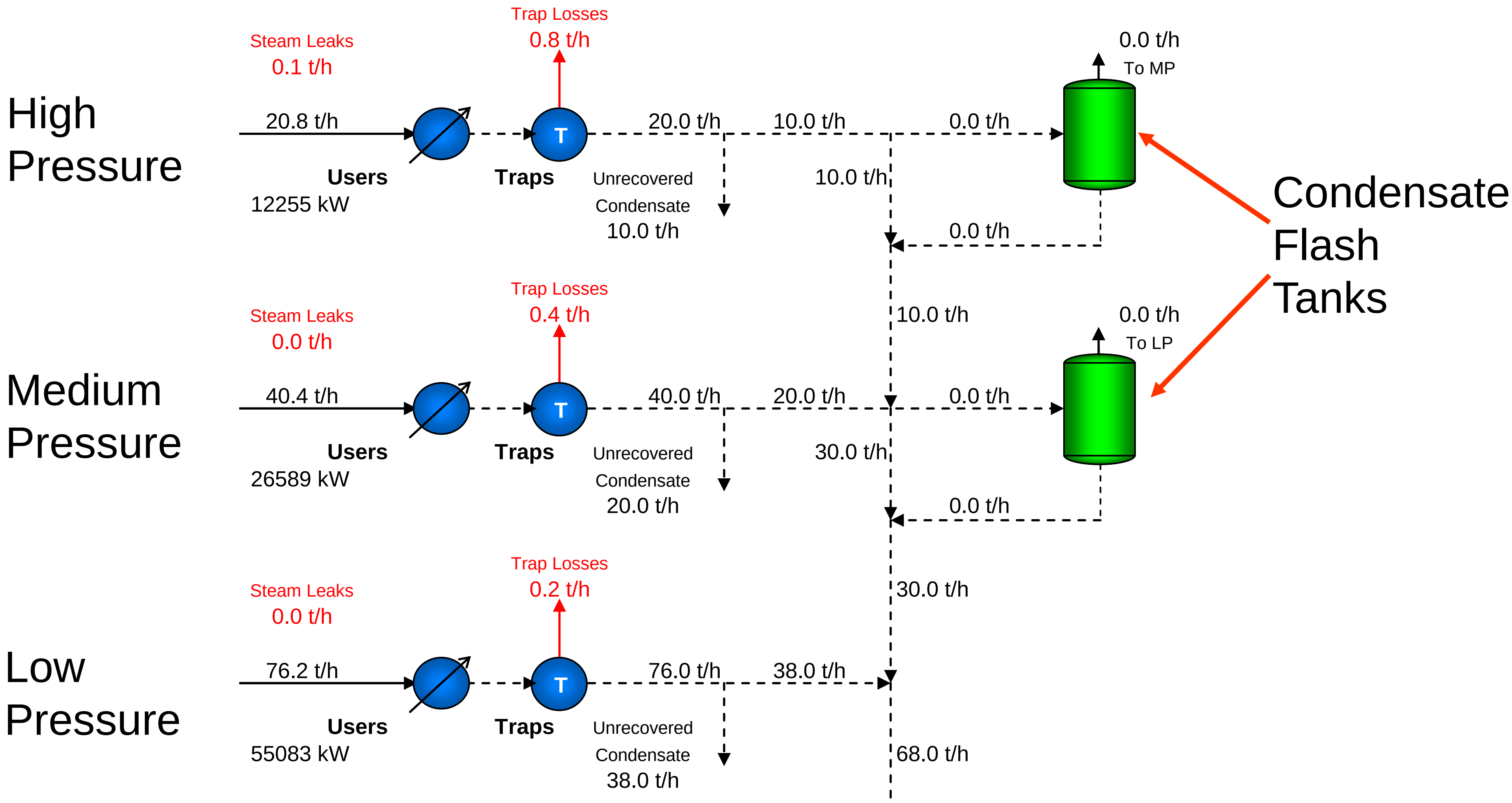
Condensate Recovery / Flash Steam

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

Condensate Recovery / Flash Steam



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

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

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

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

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.

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

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)

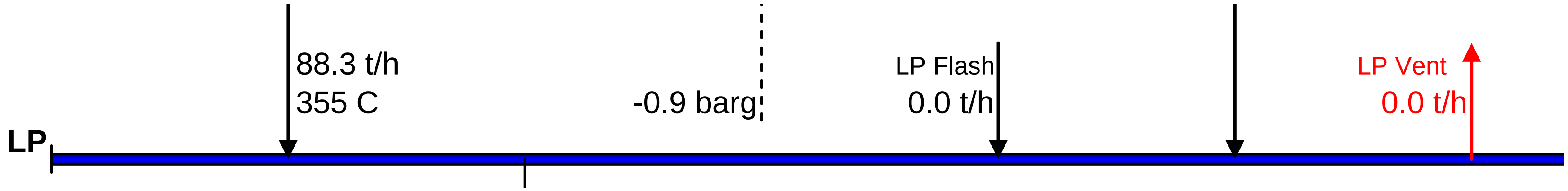
Option 1 - Heat loss on HP header	30 kW	
Option 1 - Heat loss on MP header	30 kW	
Option 1 - Heat loss on LP header	30 kW	

→ **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

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

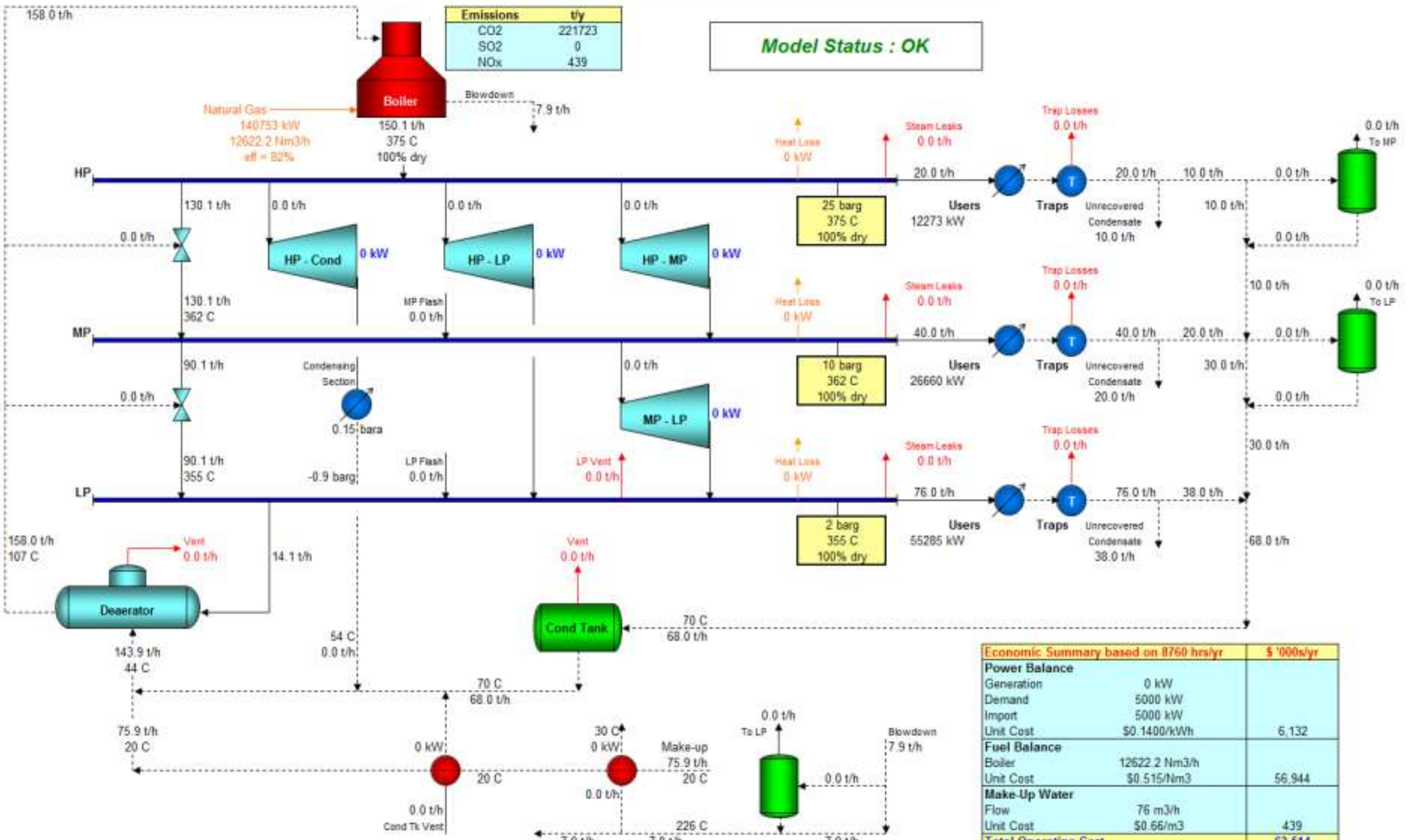
SSAT 3-Header Model Student Exercise

- 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

Steam System Assessment Tool

SSAT Default 3 Header Metric Model Moldova Ex2

Current Operation



Economic Summary based on 8760 hrs/yr		$ '000s/yr
Power Balance		
Generation	0 kW	
Demand	5000 kW	
Import	5000 kW	
Unit Cost	$0.1400/kWh	6,132
Fuel Balance		
Boiler	12622.2 Nm3/h	
Unit Cost	$0.515/Nm3	56,944
Make-Up Water		
Flow	76 m3/h	
Unit Cost	$0.66/m3	439
Total Operating Cost		63,514

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

Results Summary

SSAT Default 3 Header Metric Model Moldova Ex2

Model Status : OK

Cost Summary ($ '000s/yr)	Current Operation	After Projects	Reduction	
Power Cost	6,132	6,132	0	0.0%
Fuel Cost	55,285	55,285	0	0.0%
Make-Up Water Cost	439	439	0	0.0%
Total Cost (in $ '000s/yr)	**61,856**	**61,856**	**0**	**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)	43.04	43.04	-	-
Power Cost (as $/MWh)	140.00	140.00	-	-
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 ($/t)	44.92
MP to LP steam rate	Not in use	Not in use	MP ($/t)	44.92
HP to Condensing steam rate	Not in use	Not in use	LP ($/t)	44.92

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

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