

# Welcome!

## Webinar #4: RECIPROCATING ENGINES & HEAT RECOVERY in TFX 05 JULY 2017

### Agenda:

- \* Introduction
- \* Reciprocating Engine component in TFX: Database or User Defined
- \* Available Heat from Exhaust Gas and Engine Cooling
- \* Heat Recovery for Hot Water, Steam and Chilled Water
- \* Multiple Engines
- \* Off Design Simulation
- \* Q & A Session

# Thermoflow Training and Support

- Standard Training
- On-site Training course
- Advanced Workshop
- Webinars when new version is released
- Help, Tutorials, PPT, Videos
- Technical Support

**→ Feature Awareness Webinars**

# Feature Awareness Webinars

1- Assemblies in THERMOFLEX

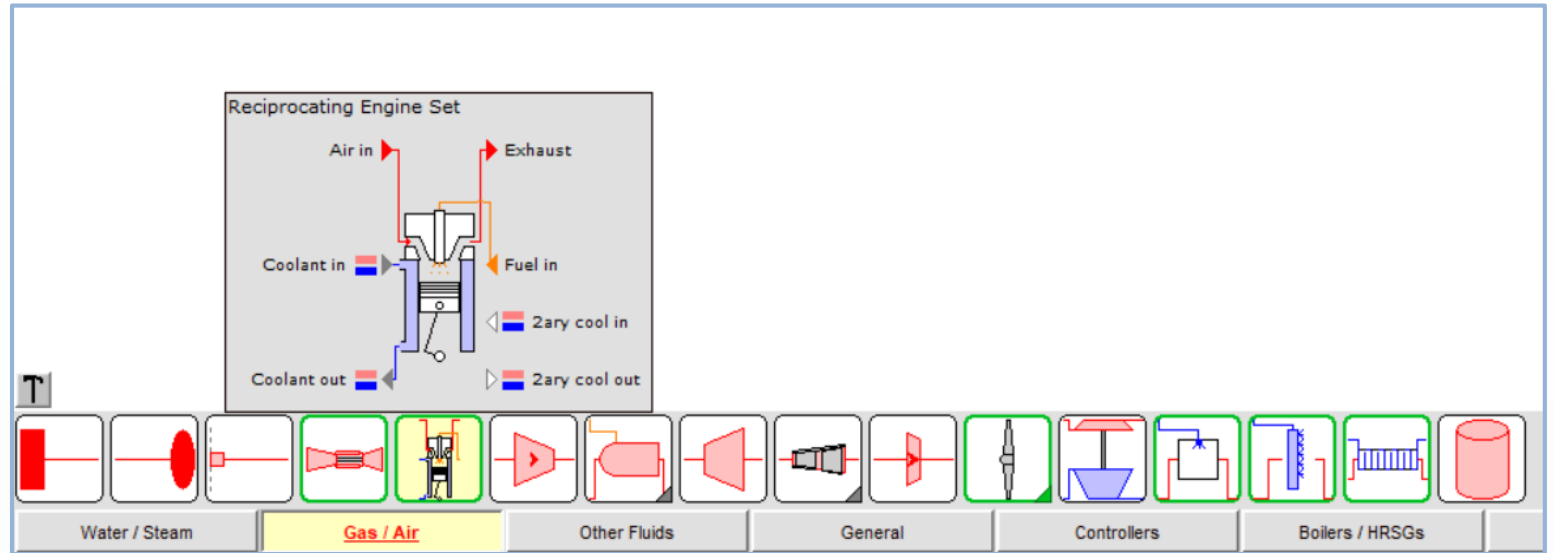
2- SCRIPTS in Thermoflow Programs

3- Multi Point Design

**4- Reciprocating Engines**

# Reciprocating Engine Component in TFX

- Database
- User Defined



# Reciprocating Engine Database

Reciprocating Engine Selection

File

Display entire reciprocating engine library

Engine Selection Filter

Smallest power  kW Largest power  kW

Sort

Manufacturer  Smallest to largest power  Largest to smallest power

Show 50 Hz engines  Show 60 Hz engines

Show gas engines  Show Diesel engines

| ID  | Model            | Fuel | Aspiration | Mode | RPM  | Freq. | Power | Texh | Exh. flow | Elec. Eff. |
|-----|------------------|------|------------|------|------|-------|-------|------|-----------|------------|
|     |                  |      |            |      |      | Hz    | kW    | C    | t/h       | %          |
| 338 | JEN JMS612GS-NLC | G    | TA         | P    | 1500 | 50    | 1464  | 410  | 8,83      | 41,6       |
| 345 | CUM QSV81-G      | G    | TA         | C    | 1500 | 50    | 1370  | 517  | 7,85      | 37,9       |
| 293 | DEU TBG620V16K   | G    | TA         | P    | 1500 | 50    | 1358  | 523  | 7,33      | 40,0       |
| 295 | DEU TBG620V16K   | G    | TA         | P    | 1500 | 50    | 1290  | 531  | 7,51      | 38,5       |
| 326 | MTU G16V4000     | G    | TA         | C    | 1500 | 50    | 1285  | 410  | 7,40      | 39,9       |
| 325 | MTU G16V4000     | G    | TA         | C    | 1500 | 50    | 1285  | 390  | 7,97      | 38,9       |
| 162 | CAT 3606E        | G    | TA         | C    | 1000 | 50    | 1265  | 465  | 9,43      | 35,9       |
| 272 | WAU 9500S        | G    | TA         | C    | 1000 | 50    | 1225  | 579  | 5,22      | 30,4       |
| 278 | WAU 9500L        | G    | TA         | C    | 1000 | 50    | 1225  | 354  | 7,94      | 33,8       |
| 163 | CAT 3606E        | G    | TA         | C    | 1000 | 50    | 1195  | 469  | 8,83      | 35,4       |
| 281 | WAU 9500L        | G    | TA         | C    | 1000 | 50    | 1175  | 357  | 7,56      | 34,0       |
| 275 | WAU 9500S        | G    | TA         | C    | 1000 | 50    | 1175  | 577  | 5,05      | 30,1       |
| 292 | DEU TBG620V12K   | G    | TA         | P    | 1500 | 50    | 1019  | 515  | 5,50      | 40,0       |
| 336 | JEN JMS320GS-NLC | G    | TA         | P    | 1500 | 50    | 972   | 515  | 5,55      | 38,1       |

Data source: Jenbacher Engineering Information 2001 CD  
 Date of last revision: 11/9/2001  
 Nox level: less than 500 mg/mn3  
 Applicable standards: Based on DIN-ISO 3046; Based on VDE 0530 REM with specified tolerance; Intake air temperature: 25 C; Barometric pressure: 1000

OK Cancel

# Reciprocating Engine User Defined

Input Menu - Edit Mode

File GTP/GTM/STM

Site Menu Components Miscellaneous Plant Assembly Non Flowsheet Economics Regional Costs OK Cancel

Reciprocating Engine Set [1]

**Main**

Genset Specification

Engine ID: 0

Manufacturer: TF

Model number: Example for

Engine RPM: 1500

Full load electrical power: 1500 kW

Full load generator eff.: 95,8 %

Full load exhaust temp.: 410 C

Full load exhaust flow: 2,452 kg/s

Primary heat recovery rate: 756,1 kW

2nd heat recovery rate: 0 kW

3rd heat recovery rate: 0 kW

4th heat recovery rate: 0 kW

Estimated other heat loss: 4,429 % Q fuel input (LHV)

Min. allowed part load: 25 %

Overall Size & Weight

Overall length: 7,3 m

Overall width: 2,5 m

Overall height: 2,8 m

Overall weight: 15900 kg

**Engine Parameters**

Genset Fuel Consumption

Rating LHV: 32,35 MJ/scm

Estimate part load data

100 % Load: 3523 kW (LHV)

75 % Load: 2811,1 kW (LHV)

50 % Load: 2098,8 kW (LHV)

25 % Load: 1386,5 kW (LHV)

Genset LHV Efficiency

100 % Load: 42,58 %

75 % Load: 40,02 %

50 % Load: 35,73 %

25 % Load: 27,05 %

Engine LHV Efficiency

100 % Load: 44,45 %

75 % Load: 41,95 %

50 % Load: 37,93 %

25 % Load: 30,01 %

Fuel Type:  Gas  Diesel

Frequency:  50 Hz  60 Hz

Rating: \_\_\_\_\_

NOx Level:  Unknown  < 250 mg/Nm3  < 500 mg/Nm3  > 500 mg/Nm3

Aspiration:  Turbocharged  Turbocharged/Aftercooled

**User-defined Engine**

Comments

Data source: TF

Last date revised: 5/07/2017

Other comment: Example for FAW4

Load User-defined Engine...

Save User-defined Engine...

Notes ▲▼

# Reciprocating Engine User Defined - 2

Input Menu - Edit Mode

File GTP/GTM/STM

Site Menu Components Miscellaneous OK Cancel

Reciprocating Engine Set [1]

Main Engine Parameters User-defined Engine

**Primary Cooling**

Coolant Computation Method

- Compute outlet state
- Specify outlet state & compute CW flow
- Specify CW temperature rise & compute CW flow

Coolant Outlet Phase

- Subcooled liquid
- Saturated (2-phase)
- Superheated vapor

Cooling water temperature rise: 10 C

Cooling water outlet temperature: 90 C

Cooling water outlet quality: 0

Cooling water path dP/P: 10 %

**Secondary Cooling**

Coolant Computation Method

- Compute outlet state
- Specify outlet state & compute CW flow
- Specify CW temperature rise & compute CW flow

Coolant Outlet Phase

- Subcooled liquid
- Saturated (2-phase)
- Superheated vapor

Cooling water temperature rise: 10 C

Cooling water outlet temperature: 90 C

Cooling water outlet quality: 0

Cooling water path dP/P: 10 %

**Third Cooling Connection**

Choose Heat Adder No Heat Adder connected

**Fourth Cooling Connection**

Choose Heat Adder No Heat Adder connected

**Exhaust Temperature**

|            |     |   |
|------------|-----|---|
| 100 % Load | 410 | C |
| 75 % Load  | 405 | C |
| 50 % Load  | 396 | C |
| 25 % Load  | 388 | C |

**Generator Efficiency**

|            |       |   |
|------------|-------|---|
| 100 % Load | 95,8  | % |
| 75 % Load  | 95,4  | % |
| 50 % Load  | 94,21 | % |
| 25 % Load  | 90,12 | % |

**Genset LHV Efficiency**

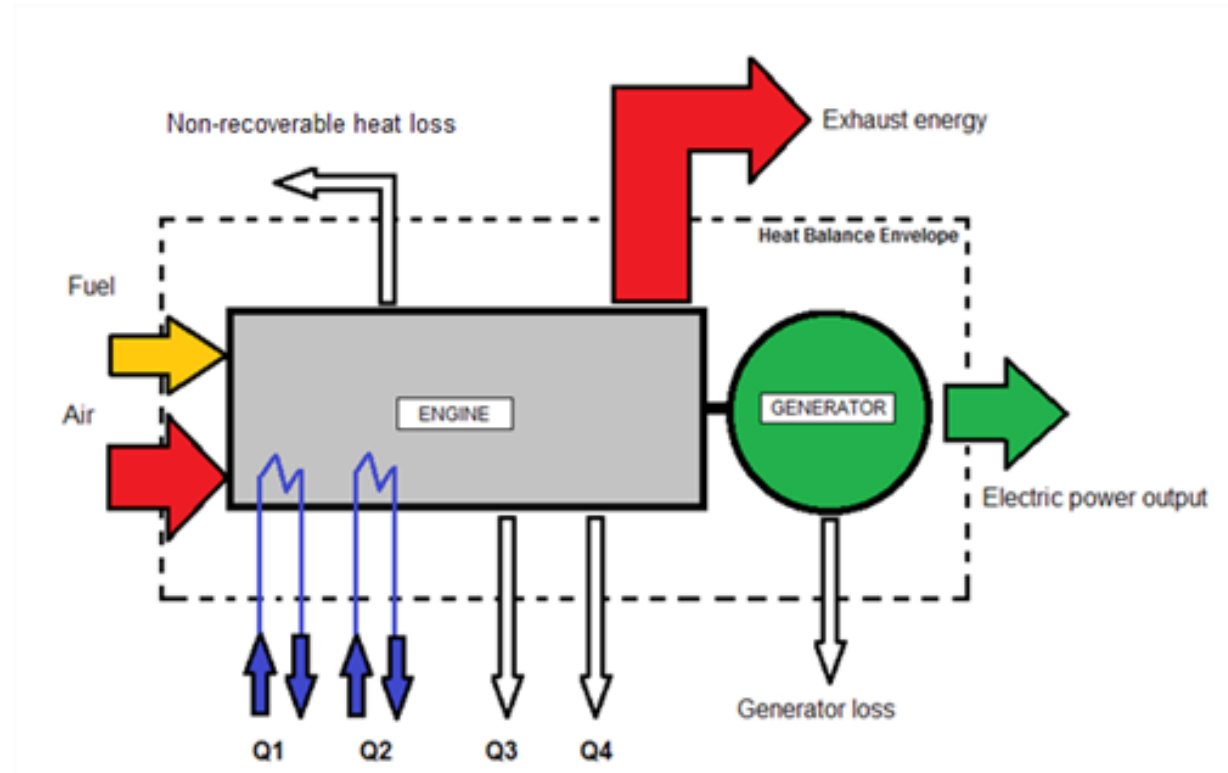
|            |       |   |
|------------|-------|---|
| 100 % Load | 41,56 | % |
| 75 % Load  | 39,06 | % |
| 50 % Load  | 34,88 | % |
| 25 % Load  | 26,4  | % |

**Engine LHV Efficiency**

|            |       |   |
|------------|-------|---|
| 100 % Load | 43,38 | % |
| 75 % Load  | 40,94 | % |
| 50 % Load  | 37,02 | % |
| 25 % Load  | 29,29 | % |

Notes

# Reciprocating Engine Heat Balance Envelope





- Q1:** Heat transfer from the cooling water jackets (primary cooling)
- Q2:** Heat transfer from a high temperature charge air cooler (secondary cooling)
- Q3:** Heat transfer from a low temperature charge air cooler
- Q4:** Heat transfer from the lube oil cooler



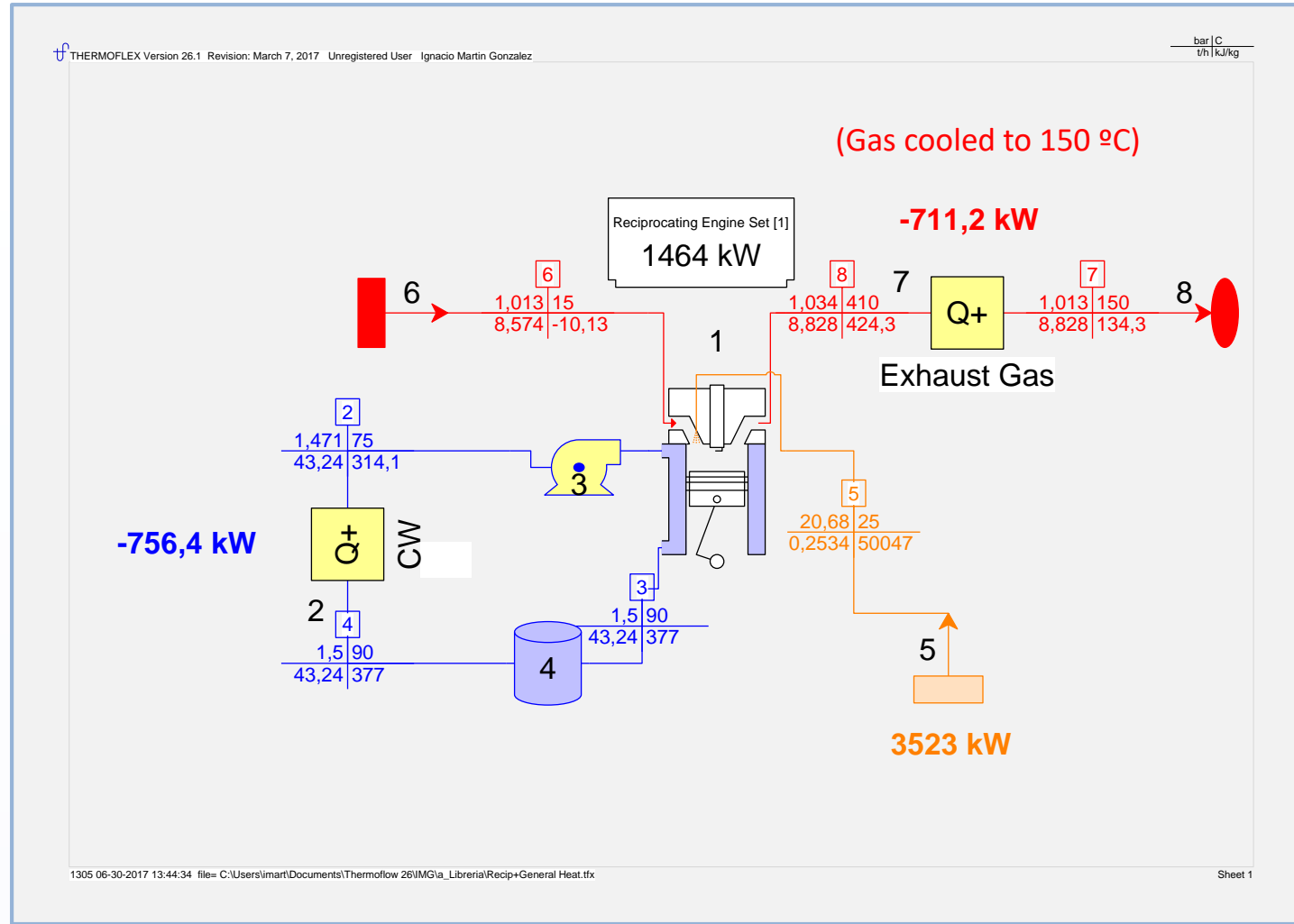
# Reciprocating Engine Inputs

|                  | NOMINAL            |                    | OFF DESIGN         |                    |
|------------------|--------------------|--------------------|--------------------|--------------------|
|                  | <i>Data Base</i>   | <i>User Def.</i>   | <i>Data Base</i>   | <i>User Def.</i>   |
| Power            | Defined / Computed | Inputs             | Inputs             | Inputs             |
| Efficiency       | Defined / Computed | Inputs             | Defined / Computed | Table              |
| Exhaust mf       | Defined / Computed | Inputs             | Defined / Computed | Defined / Computed |
| Exhaust T        | Defined / Computed | Inputs             | Table              | Table              |
| Generator Eff    | Inputs             | Inputs             | Table              | Table              |
| Heat Recovery-4  | Defined / Computed | Inputs             | Defined / Computed | Defined / Computed |
| CW T, DT         | Inputs             | Inputs             | Inputs             | Inputs             |
| Fuel Consumption | Defined / Computed | Defined / Computed | Defined / Computed | Defined / Computed |
| Air mf           | Defined / Computed | Defined / Computed | Defined / Computed | Defined / Computed |

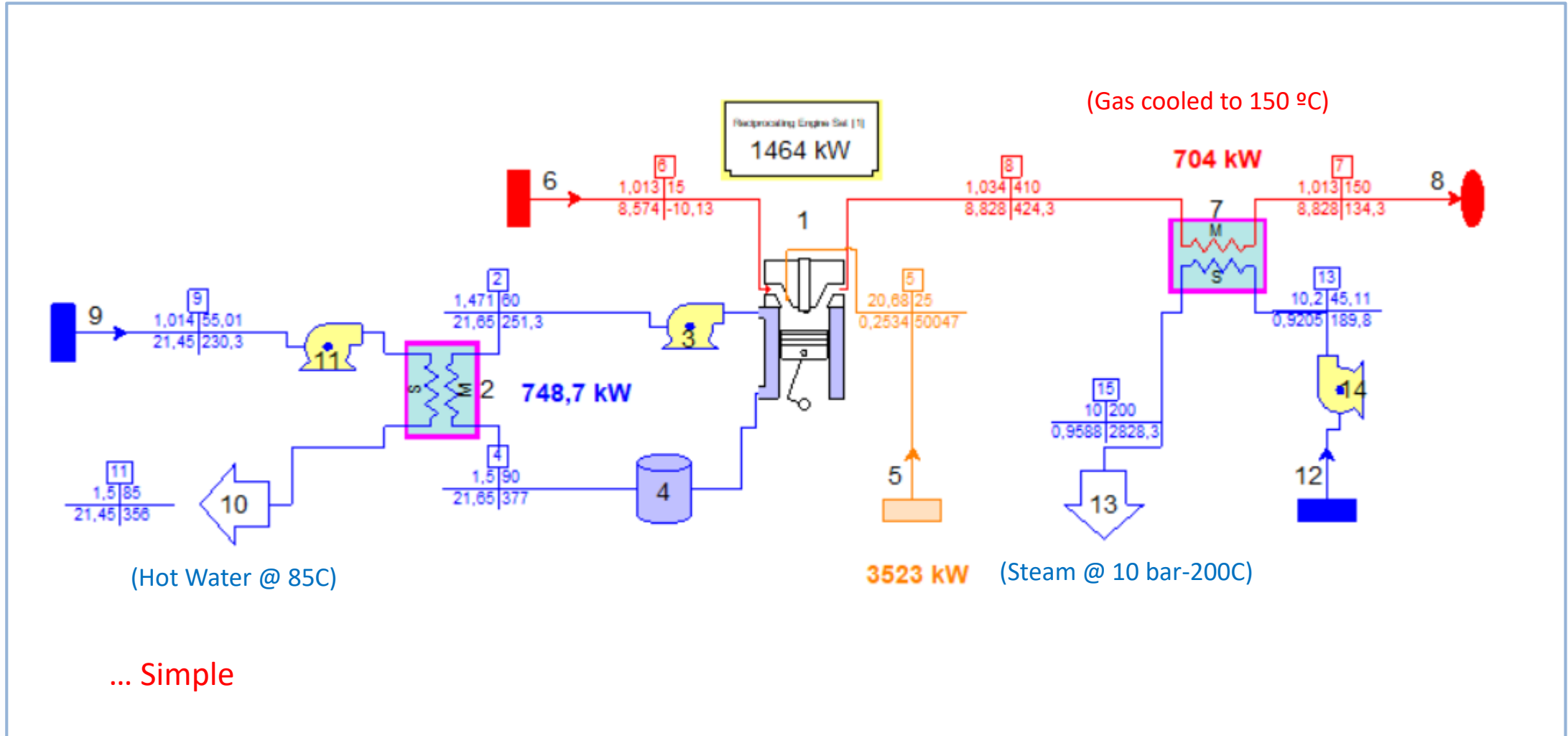
  

|  |                    |
|--|--------------------|
|   | Inputs             |
|  | Defined / Computed |

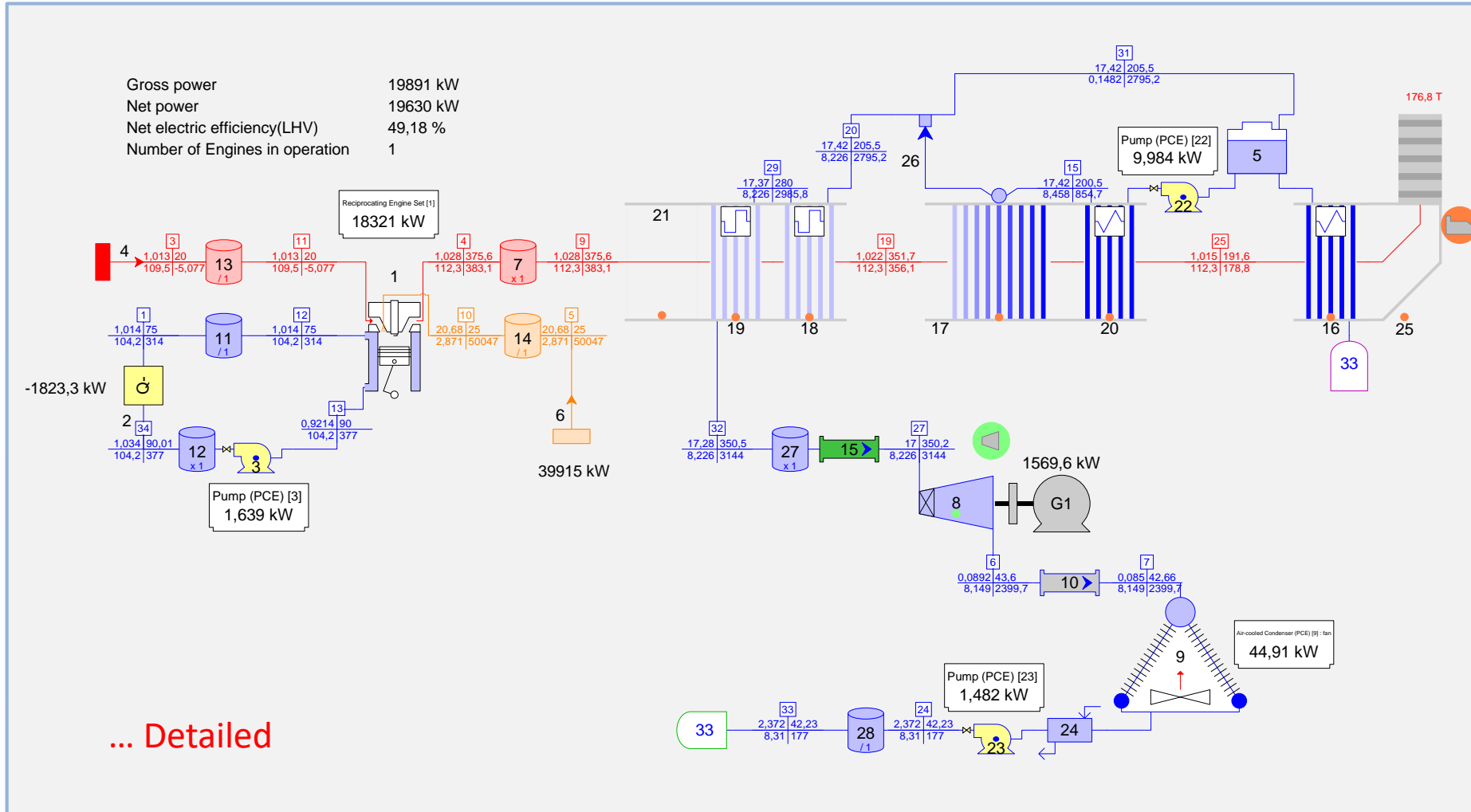
# Heat Balance: Available Heat Recovery



# Available Heat Recovery, Hot Water & Steam



# Exhaust Heat Recovery - Combined Cycle



# Cooling Water Circuit: 4 Heating Sources

Input Menu - Edit Mode  
File GTP/GTM/STM

Site Menu **Components** Miscellaneous

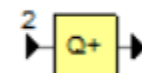
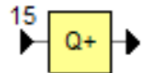
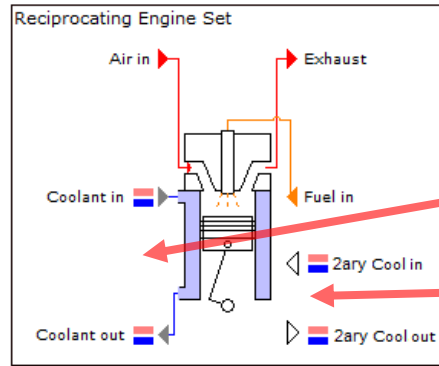
Reciprocating Engine Set [1]

| Main  | Engine Parameters   | User-defined Engine   |
|---|---|---|
| <b>Genset Specification</b><br>Engine ID: 0<br>Manufacturer: JEN<br>Model number: JMS612GS-NLC<br>Engine RPM: 1800<br>Full load electrical power: 1413 kW<br>Full load generator eff.: 95,79 %<br>Full load exhaust temp.: 409 C<br>Full load exhaust flow: 7500 kg/h<br><br>Primary heat recovery rate: 337 kW<br>2nd heat recovery rate: 93 kW<br>3rd heat recovery rate: 342 kW<br>4th heat recovery rate: 177 kW<br>Estimated other heat loss: 1,718 % Q fuel input (LHV)<br>Min. allowed part load: 25 %<br><br><b>Overall Size &amp; Weight</b><br>Overall length: 8,699 m<br>Overall width: 2,5 m<br>Overall height: 2,8 m<br>Overall weight: 17300 kg | <b>Genset Fuel Consumption</b><br>Rating LHV: 9,9 kWh/Nm3<br><input type="checkbox"/> Estimate part load data<br>100 % Load: 3374 kW (LHV)<br>75 % Load: 2585 kW (LHV)<br>50 % Load: 1795 kW (LHV)<br>25 % Load: 1200 kW (LHV)<br><br><b>Genset LHV Efficiency</b><br>100 % Load: 41,88 %<br>75 % Load: 41 %<br>50 % Load: 39,36 %<br>25 % Load: 29,44 %<br><br><b>Engine LHV Efficiency</b><br>100 % Load: 43,72 %<br>75 % Load: 42,98 %<br>50 % Load: 41,78 %<br>25 % Load: 32,68 % | <b>Comments</b><br>Data source: Jenbacher Engineering Information 2001 CD<br>Last date revised: 11/9/2001<br>Other comment:<br>Applicable standards: Based on DIN-ISO 3046; Based on VDE 0530 REM with specified tolerance; Intake air temperature: 25 C; Barometric pressure: 1000 mbar; Relative humidity: 30%; Gas flow pressure 80 - 200 mbar |

Fuel Type:  Gas  Diesel  
 Frequency:  50 Hz  60 Hz  
 Rating:  Prime  Continuous  
 NOx Level:  Unknown  < 250 mg/Nm3  < 500 mg/Nm3  > 500 mg/Nm3  
 Aspiration:  Turbocharged  Turbocharged/Aftercooled  Naturally aspirated

Buttons: Load User-defined Engine... Save User-defined Engine...

# Cooling Water Circuit: 4 Heating Sources



Input Menu - Edit Mode  
File GTP/GTM/STM

Site Menu Components Miscellaneous

Reciprocating Engine Set [1]

Main Engine Parameters User-defi

**Primary Cooling**

Coolant Computation Method

- Compute outlet state
- Specify outlet state & compute CW flow
- Specify CW temperature rise & compute CW flow

Coolant Outlet Phase

- Subcooled liquid
- Saturated (2-phase)
- Superheated vapor

Cooling water temperature rise: 10 C

Cooling water outlet temperature: 90 C

Cooling water outlet quality: 0

Cooling water path dP/P: 10 %

**Secondary Cooling**

Coolant Computation Method

- Compute outlet state
- Specify outlet state & compute CW flow
- Specify CW temperature rise & compute CW flow

Coolant Outlet Phase

- Subcooled liquid
- Saturated (2-phase)
- Superheated vapor

Cooling water temperature rise: 10 C

Cooling water outlet temperature: 44,5 C

Cooling water outlet quality: 0

Cooling water path dP/P: 10 %

**Third Cooling Connection**

Choose Heat Adder Heat Adder [2]

**Fourth Cooling Connection**

Choose Heat Adder Heat Adder [3]

**Exhaust Temperature**

|            |       |
|------------|-------|
| 100 % Load | 409 C |
| 75 % Load  | 410 C |
| 50 % Load  | 410 C |
| 25 % Load  | 410 C |

**Generator Efficiency**

|            |         |
|------------|---------|
| 100 % Load | 95,79 % |
| 75 % Load  | 95,38 % |
| 50 % Load  | 94,2 %  |
| 25 % Load  | 90,09 % |

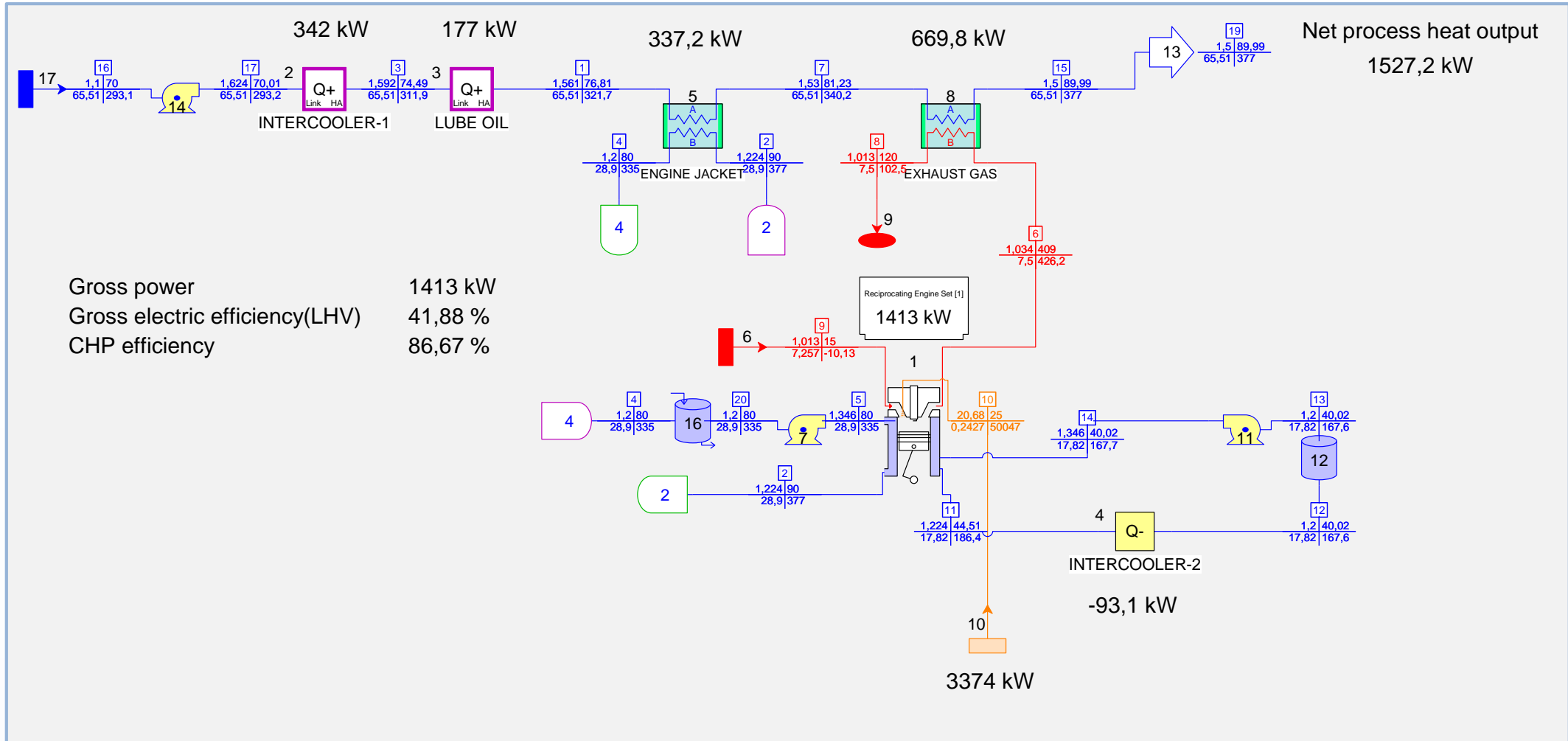
**Genset LHV Efficiency**

|            |         |
|------------|---------|
| 100 % Load | 41,88 % |
| 75 % Load  | 41 %    |
| 50 % Load  | 39,36 % |
| 25 % Load  | 29,44 % |

**Engine LHV Efficiency**

|            |         |
|------------|---------|
| 100 % Load | 43,72 % |
| 75 % Load  | 42,98 % |
| 50 % Load  | 41,78 % |
| 25 % Load  | 32,68 % |

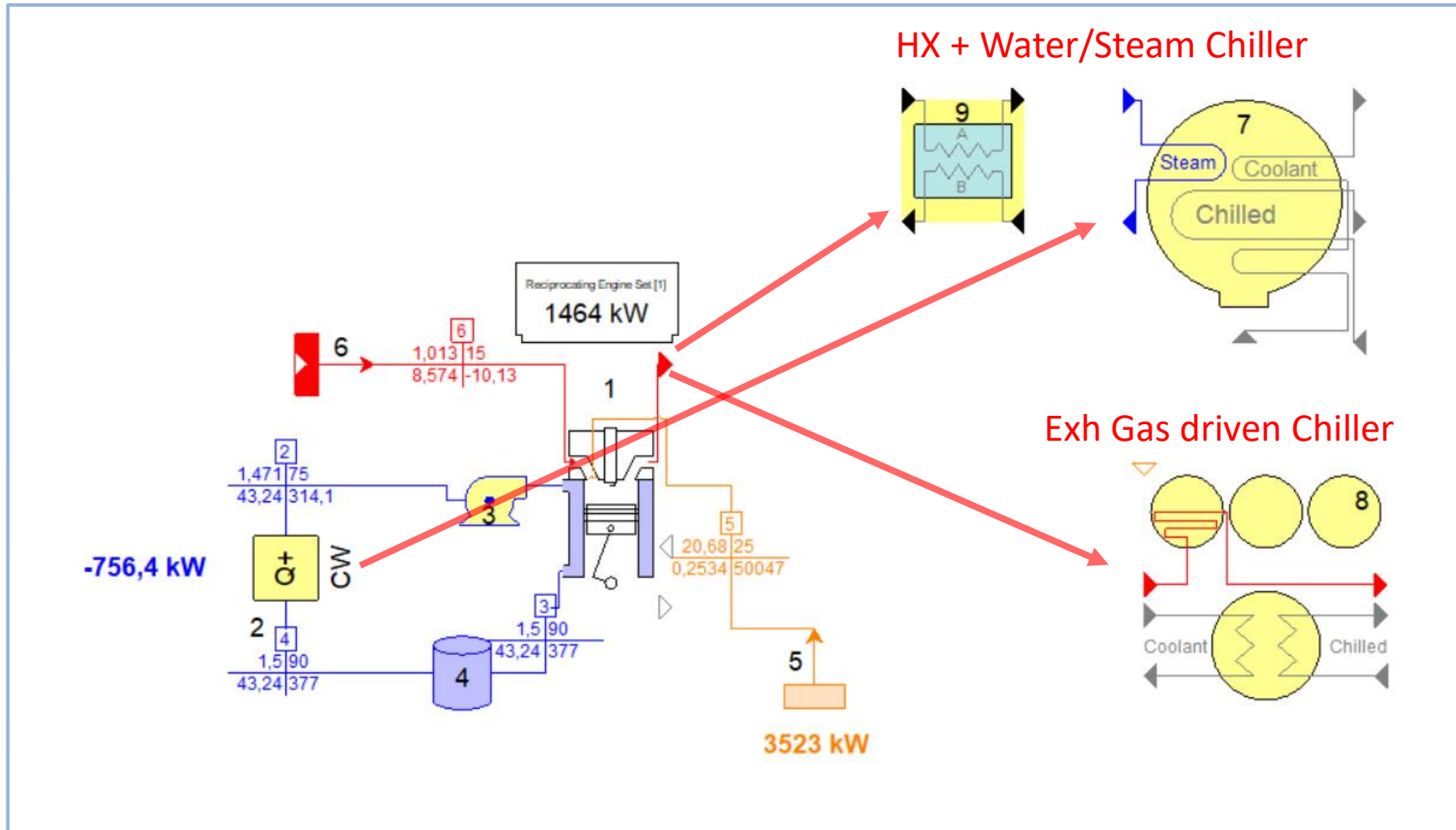
# Cooling Water Circuit







# Heat Recovery, Chillers





# Water / Steam Absorption Chillers

Input Menu - Edit Mode

File GTP/GTM/STM

Site Menu Components Miscellaneous Fix Pressure Plant Assembly Non-Flowheat Economics Regional Costs

Absorption Chiller (PCE) [13] Thermodynamic Design

Chiller Type

- Single-stage using hot water Nameplate COP 0,67
- Single-stage using low pressure steam Nameplate COP 0,67
- Two-stage using medium pressure steam Nameplate COP 1,1

Chiller Load Chiller load set by network-determined heating flow

Chiller load 1000 ton

Auxiliary load / chiller load 0,005

Price of chilled output (as Process) 0 USD/GJ

heating steam or hot water

1st Generator

2nd Generator

Condenser

Evaporator

Absorber

Chilled water

Cooling water

Chilled water exit temperature 7 C

Chilled water pressure drop 0,6895 bar

Cooling Water

- Chiller dictates cooling water flow
- Cooling Water Flow Priority
  - Strong
  - Weak
- CW temperature rise (range) 10 C
- CW pressure drop 0,6895 bar

Chiller Performance Corrections

- Automatic
- User-defined

Edit Data

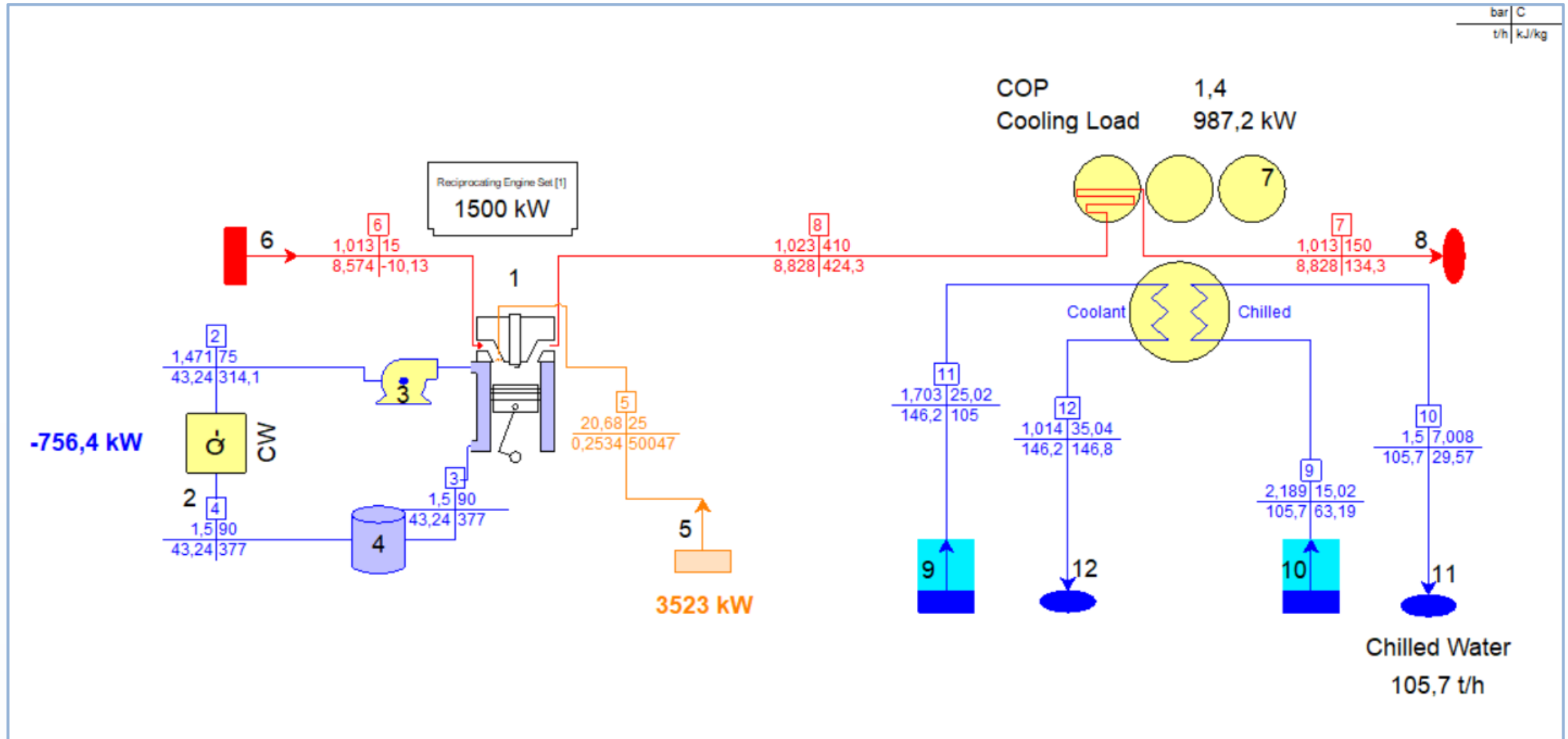
Steam condensate subcooling 0 C

Standard conditions:

- 1) 44 F (6.67 C) chilled water exit temperature
- 2) 85 F (29.4 C) cooling water supply temperature
- 3) Steam source pressure of 20 psia (1.4 bar) for single-stage units, and 130 psia (9 bar) for two-stage units

Notes

# Heat Recovery, Exhaust Gas driven Absorption Chillers



# Exhaust Gas-driven Absorption Chillers

Input Menu - Edit Mode  
File: GTP/GTM/STM

Site Menu | **Components** | Miscellaneous | Plant Assembly | Non-Flowheat | Economics | Regional Costs

Absorption Chiller, Exhaust-Driven (PCE) [7] | Thermodynamic Design

**Exhaust Flue Gas Chiller Design Parameters**

Single-stage Nameplate COP: 0.8 Gas exit temp.: 110 C  
 Two-stage Nameplate COP: 1.4 Gas exit temp.: 150 C

**Chiller Load**: Inlet flue gas energy dictates chiller load

Chiller load: 1000 ton  
 Auxiliary load / Chiller load: 0.005  
 Price of chilled output (as Process): 0 EURO/GJ

**Cooling Water**

Chiller dictates cooling water flow

**Cooling Water Flow Priority**

Strong  Weak

CW temperature rise (range): 10 C  
 CW pressure drop: 0.6895 bar

**Chiller Performance Corrections**

Automatic  User-defined [Edit Data](#)

**Standard Conditions:**

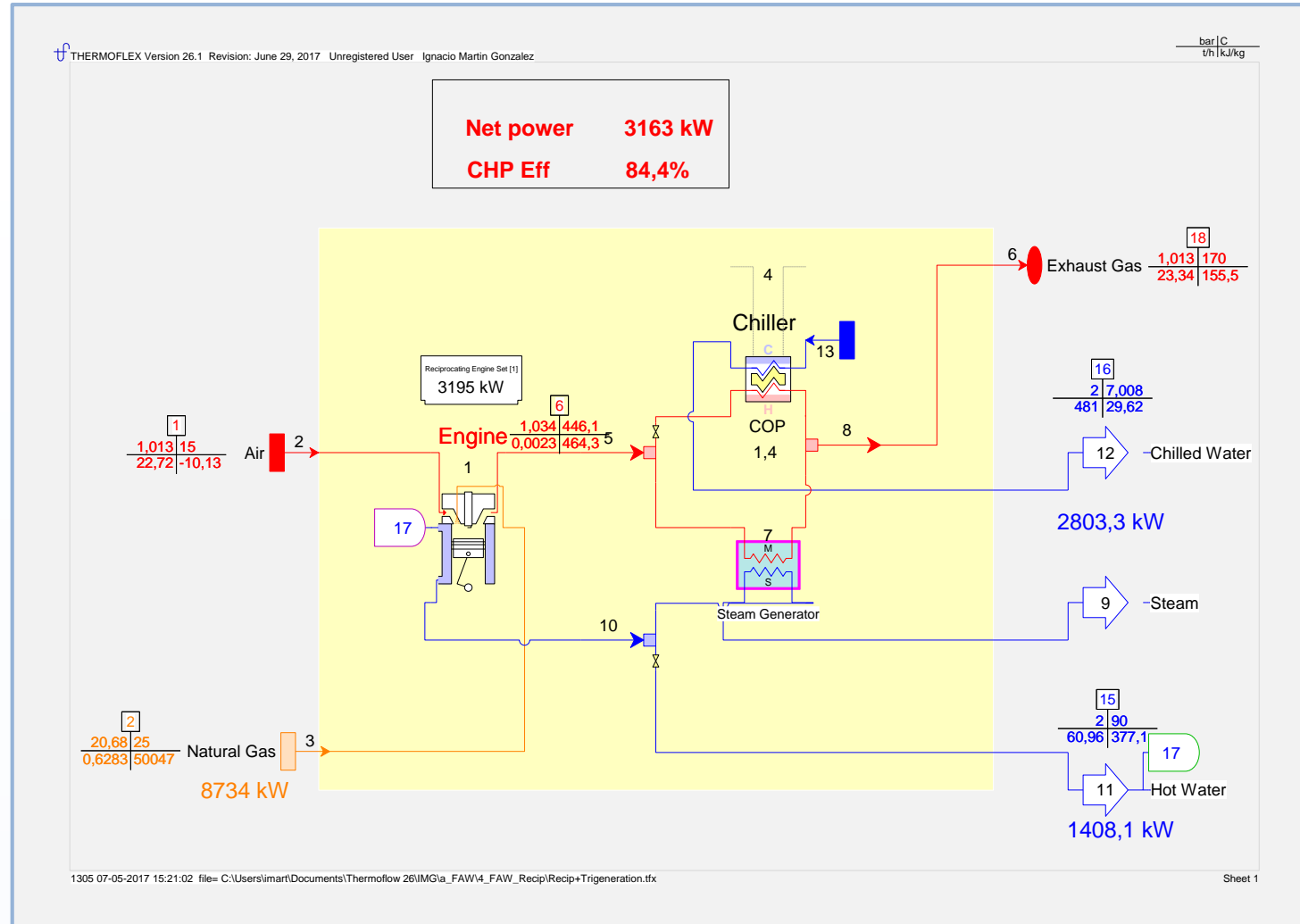
- 1) 44 F (6.67 C) chilled water exit temperature
- 2) 85 F (29.4 C) coolant supply temperature
- 3) 347 F (175 C) flue gas exhaust temperature

Chilled water exit temperature: 7 C

Chilled water pressure drop: 0.6895 bar

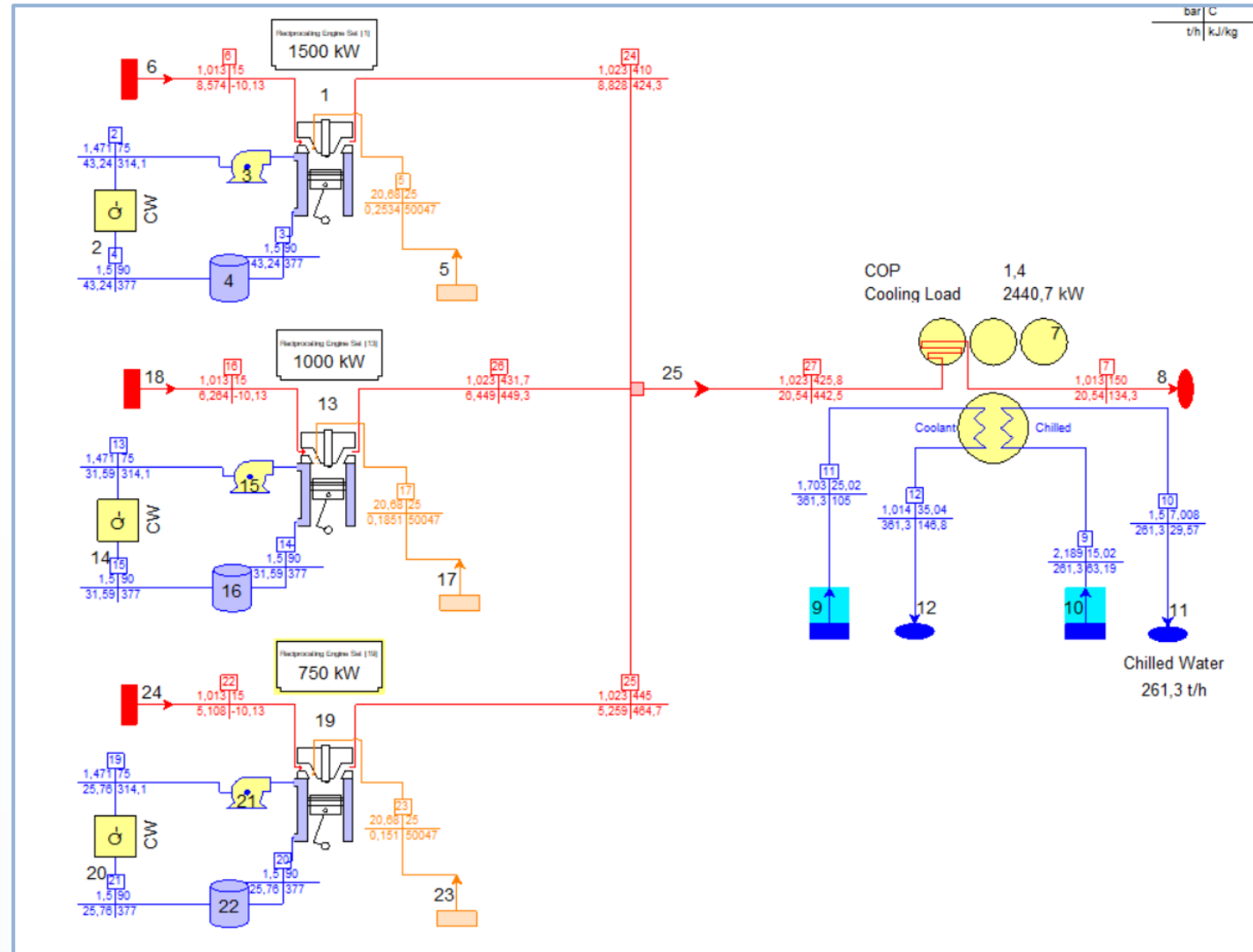
Primary generator draft loss: 9.963 millibar

# Recip Engine Trigeneration



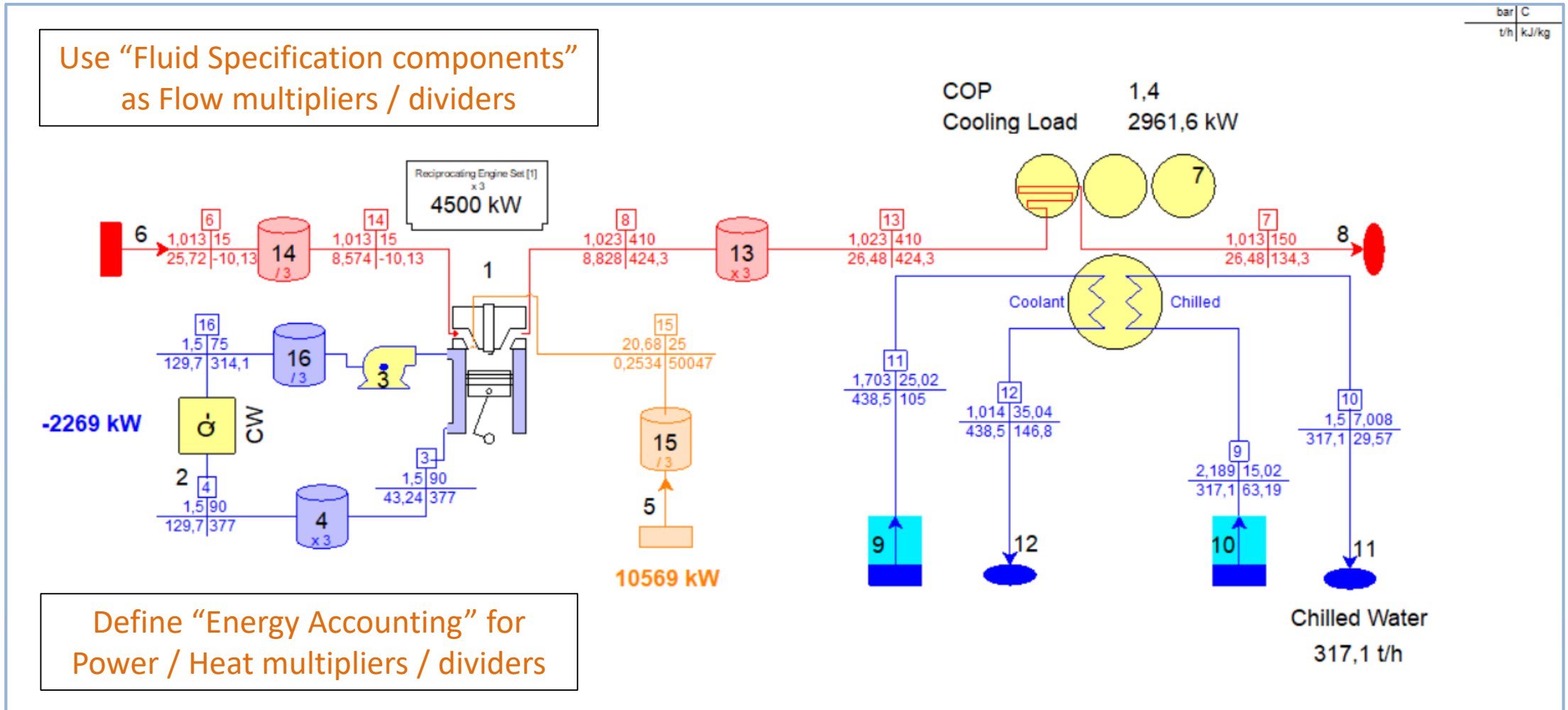
# Multiple Engines

... if different Engine models or running at different loads



# Multiple Engines

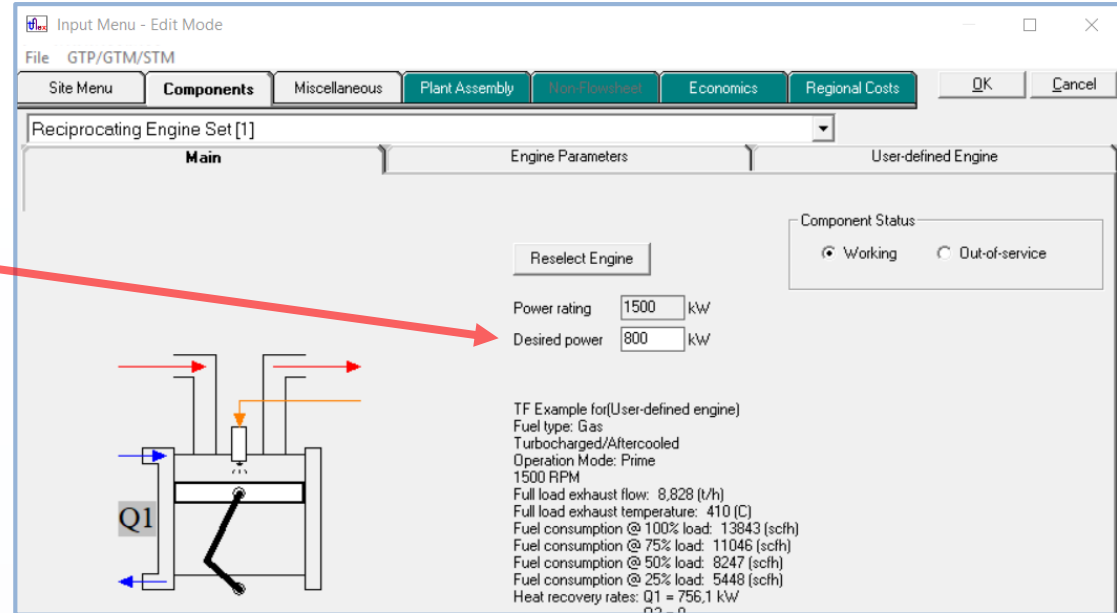
... or





# Recip Engines Off-Design Simulation

Recip Engines “modeless”  
Just enter the “desired power”  
to simulate part load



OD calculations from the Tables

| Exhaust Temperature |       | Generator Efficiency |         | Genset Fuel Consumption                                     |                           |
|---------------------|-------|----------------------|---------|---|---------------------------|
| 100 % Load          | 410 C | 100 % Load           | 95,8 %  | Rating LHV  | 32,35 MJ/scm              |
| 75 % Load           | 410 C | 75 % Load            | 95,4 %  | <input checked="" type="checkbox"/> Estimate part load data |                           |
| 50 % Load           | 410 C | 50 % Load            | 94,21 % | 100 % Load  | 42,58 Efficiency(%) (LHV) |
| 25 % Load           | 410 C | 25 % Load            | 90,12 % | 75 % Load   | 40,02 Efficiency(%) (LHV) |
|                     |       |                      |         | 50 % Load   | 35,74 Efficiency(%) (LHV) |
|                     |       |                      |         | 25 % Load   | 27,05 Efficiency(%) (LHV) |

Rest of the parameters computed  
“User define” your part load case to match the Engine specs