Welcome!

Webinar #9: METHODS & METHODOLOGIES
16 August 2017

<u>Agenda</u>:

* Introduction – Method & Methodology Fundamental Differences
* Examples illustrating the differences in Method used.
* Examples illustrating other fundamental differences arising from Method used
* Methodology – type 1, type 2, type 3 – meaning, examples etc.
* Methodology in STPro
* Q & A Session (pls. send Q's anytime during the presentation to both the presenter & host)

Presenter: STAN. KAVALE (CZECH REP.)
Support: Meritt Elmasri (U.S. HQ)

Thermoflow

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
5- Simplified Annual & TIME
6- Matching ST Performance
7- Modelling Solar Systems
8- Combining Thermoflex & Application Specific
9- Methods and Methodology explained

Introduction – Method & Methodology in GTPRO

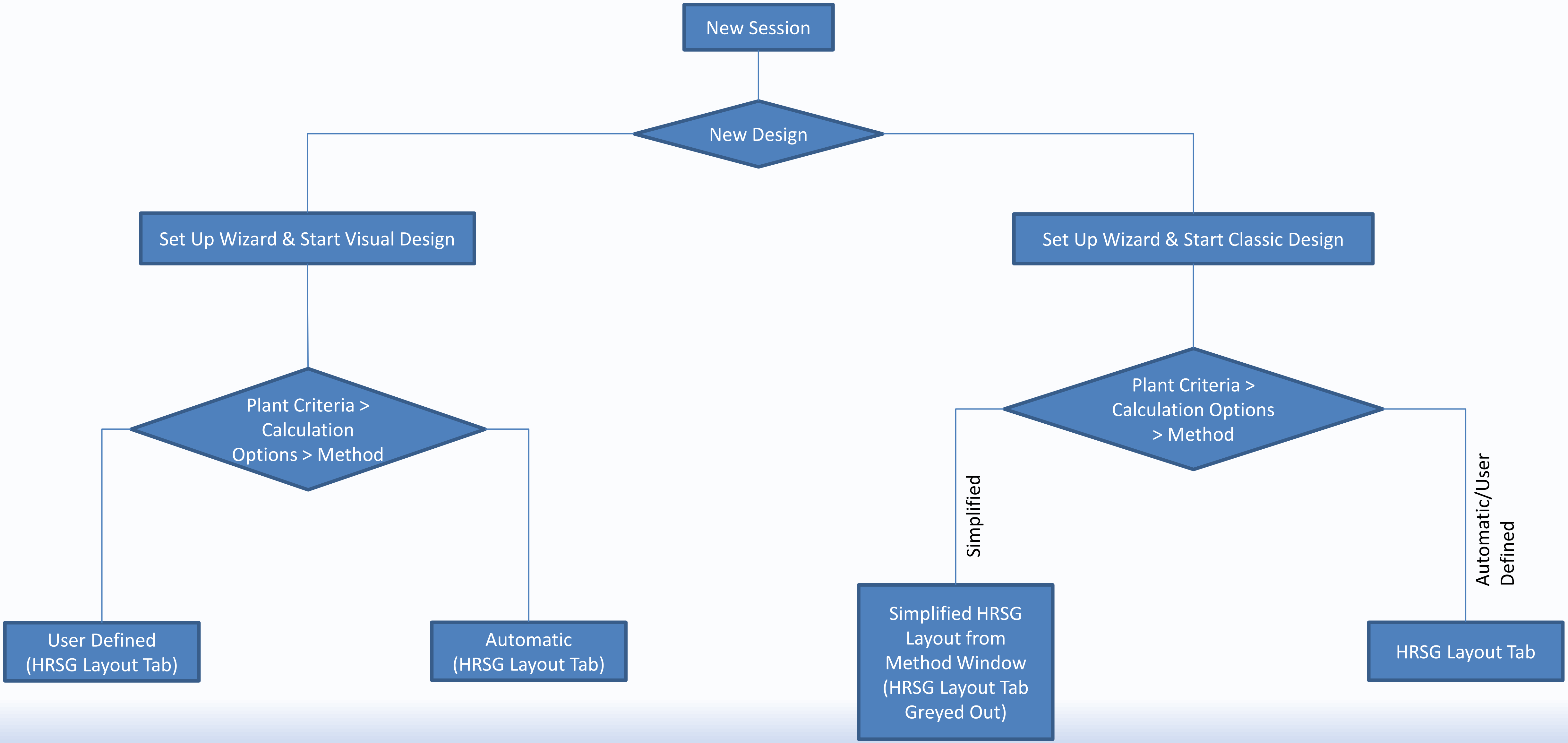
- Both Methods & Methodology feature at the early stage of model definiton.
- Each serve a completely different purpose.

Method : influences the method used for the HRSG design (either by the Simplified, the Automatic or the User Defined Method)

Note that since there is no HRSG in a Rankine plant, Method does not feature in Steam Pro.

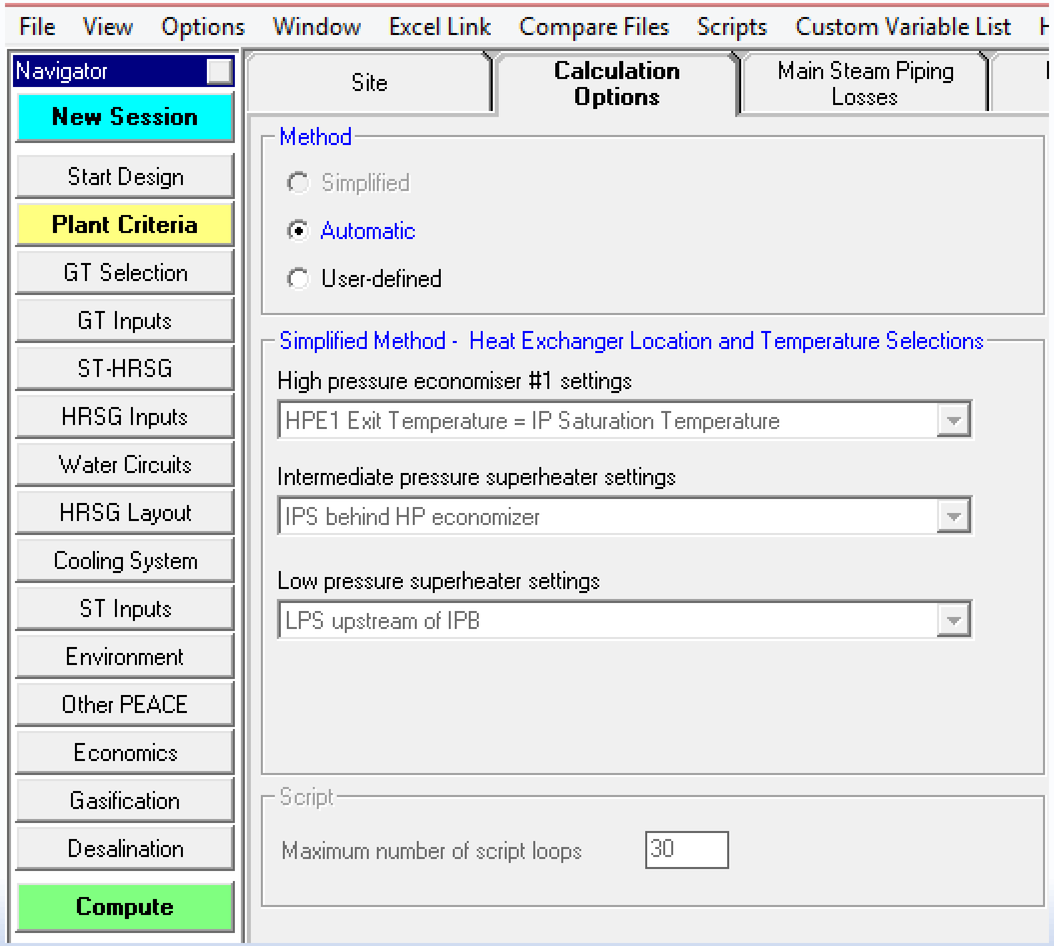
Methodology : allows the user to choose how the program applies effects of hardware determined from the initial calculation into subsequent calculation runs (either in GTPro or GTM)

Method (In Terms of a Flowchart)

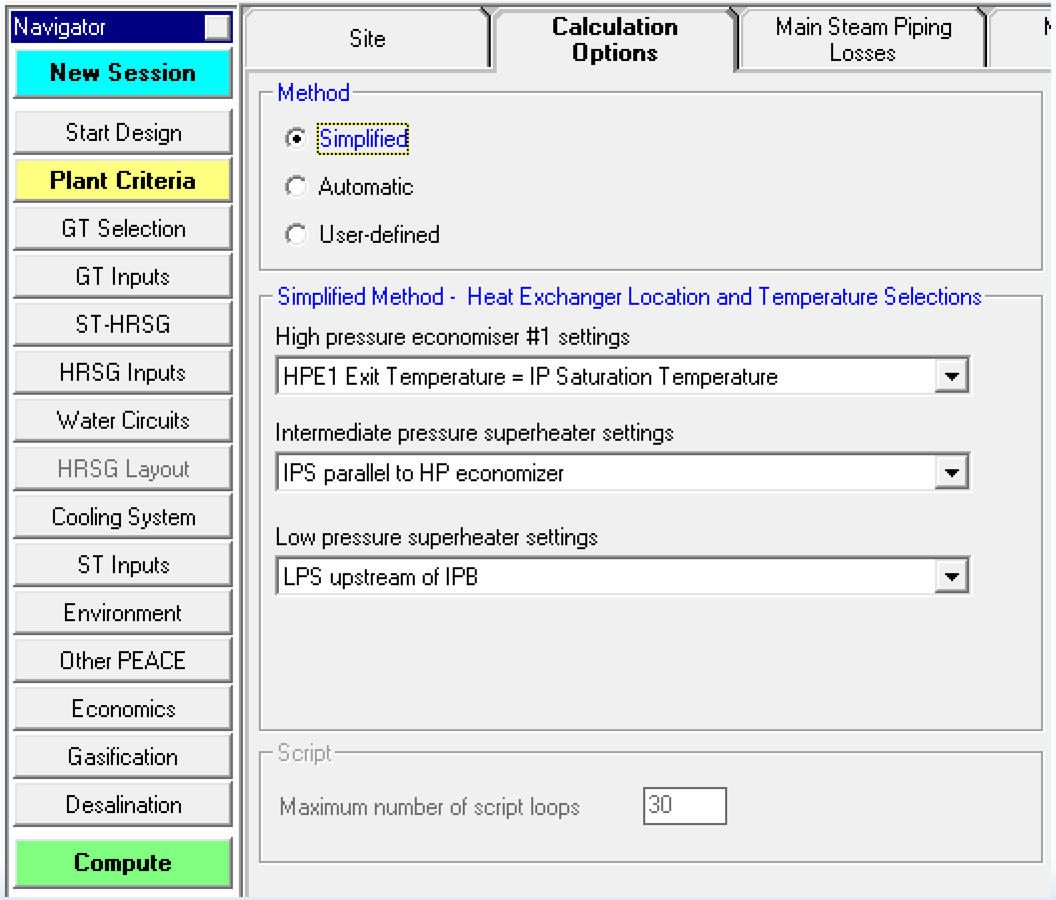


Differences in Representation – 2P HRSG, Condensing ST

Visual Method
Calculation Options > Automatic or User Defined only

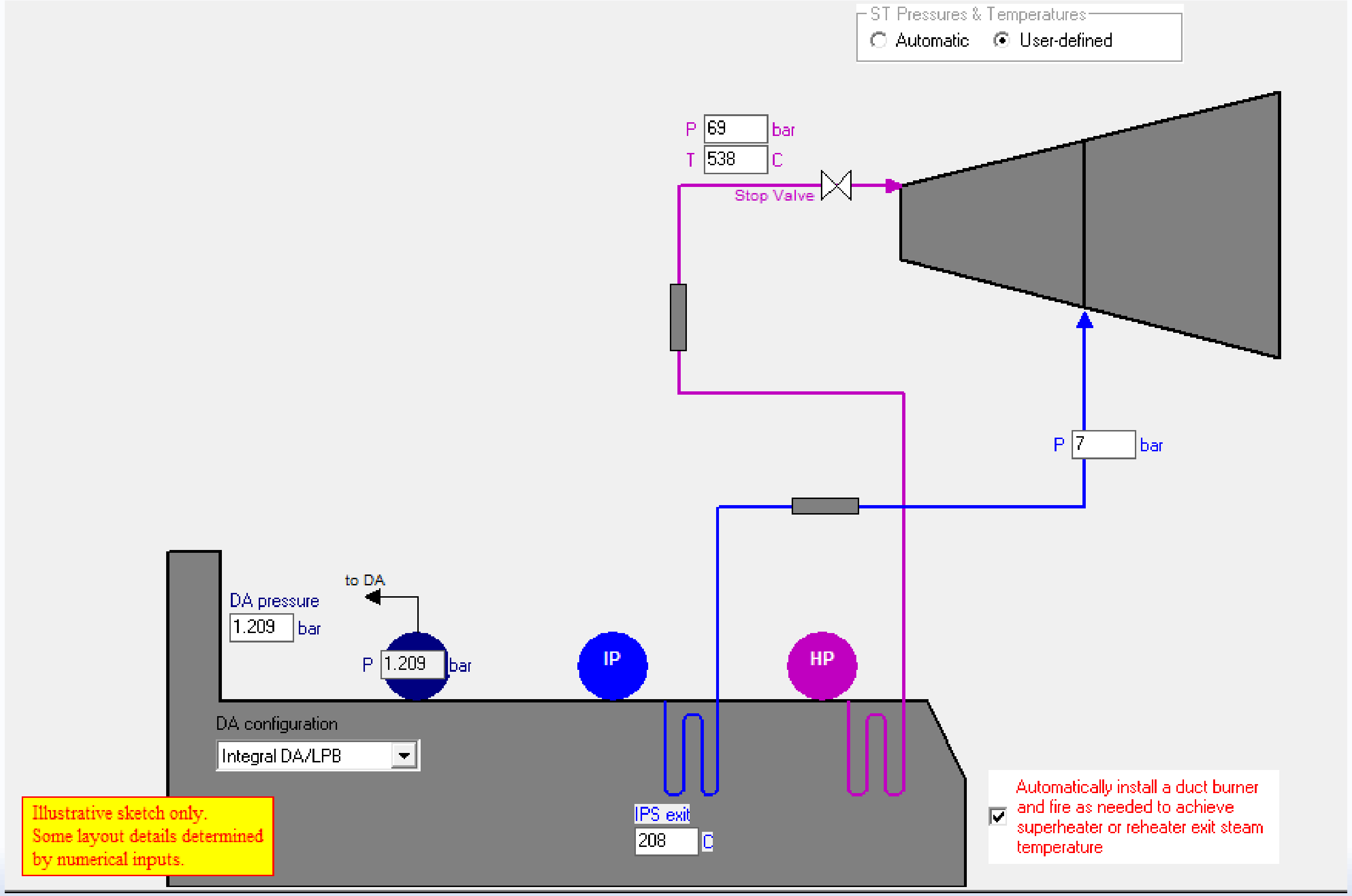


Classic Method
Calculation Options > Simplified Method Available

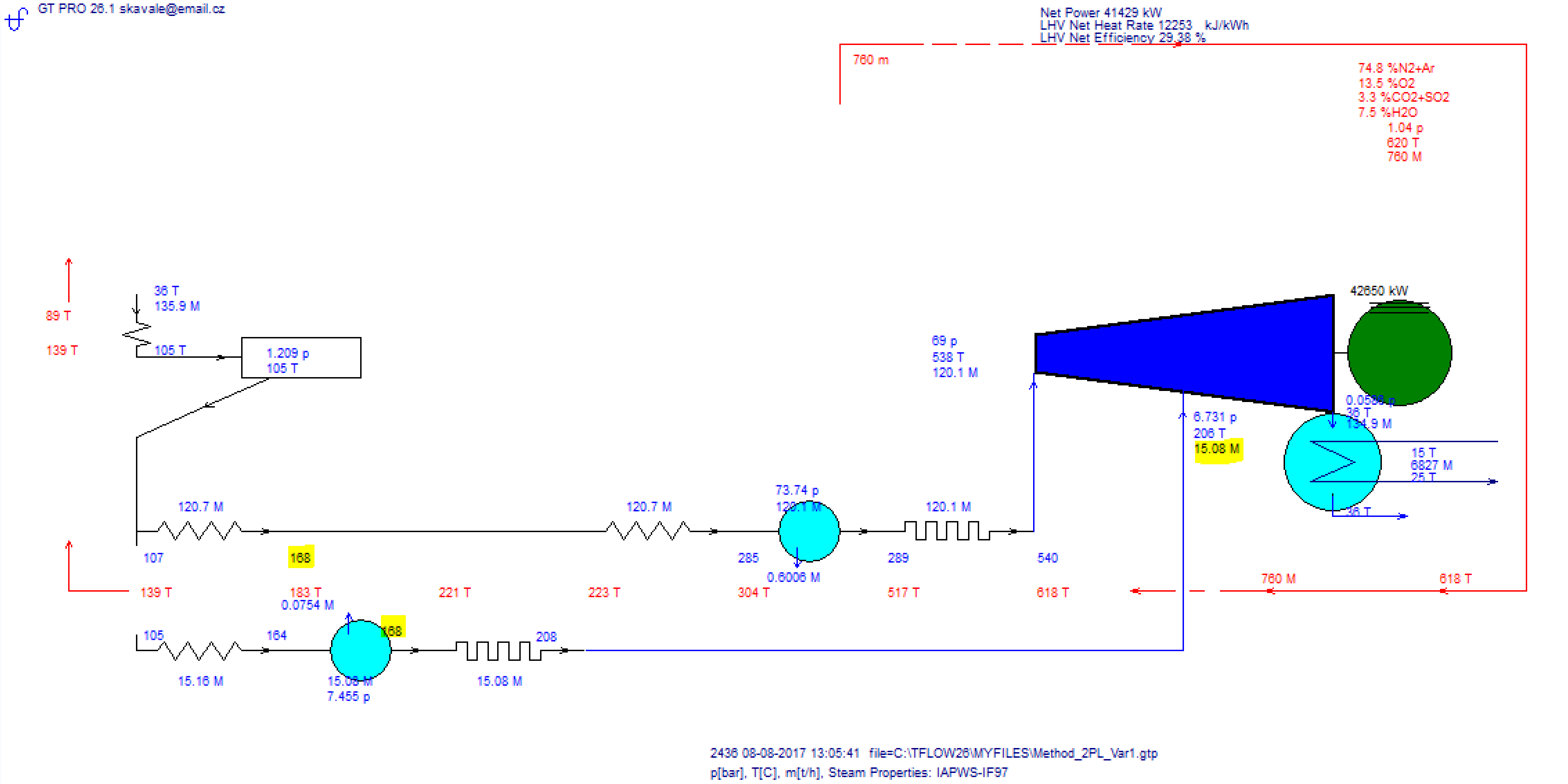


Example 1

- Consider a 2 PL HRSG being supplied with exhaust gas source, 760 t/hr @ 620 deg C
- HRSG Design Method = Simplified
- ST-HRSG conditions as shown, HP & IP Pinch @ 15degC, approach temp @ 4 degC

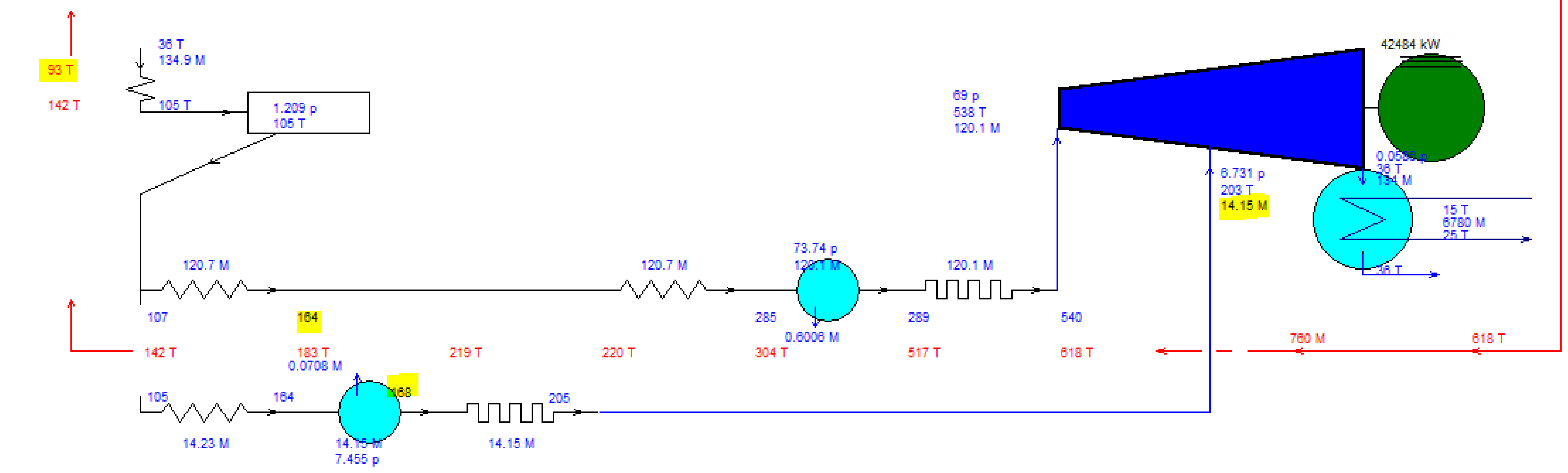


Example 1– GTPro Result/ HPE1 exit temperature = IP Saturation temperature



Example 2– GTPro Result/HPE1 exit temperature = IP saturation temperature - subcooling

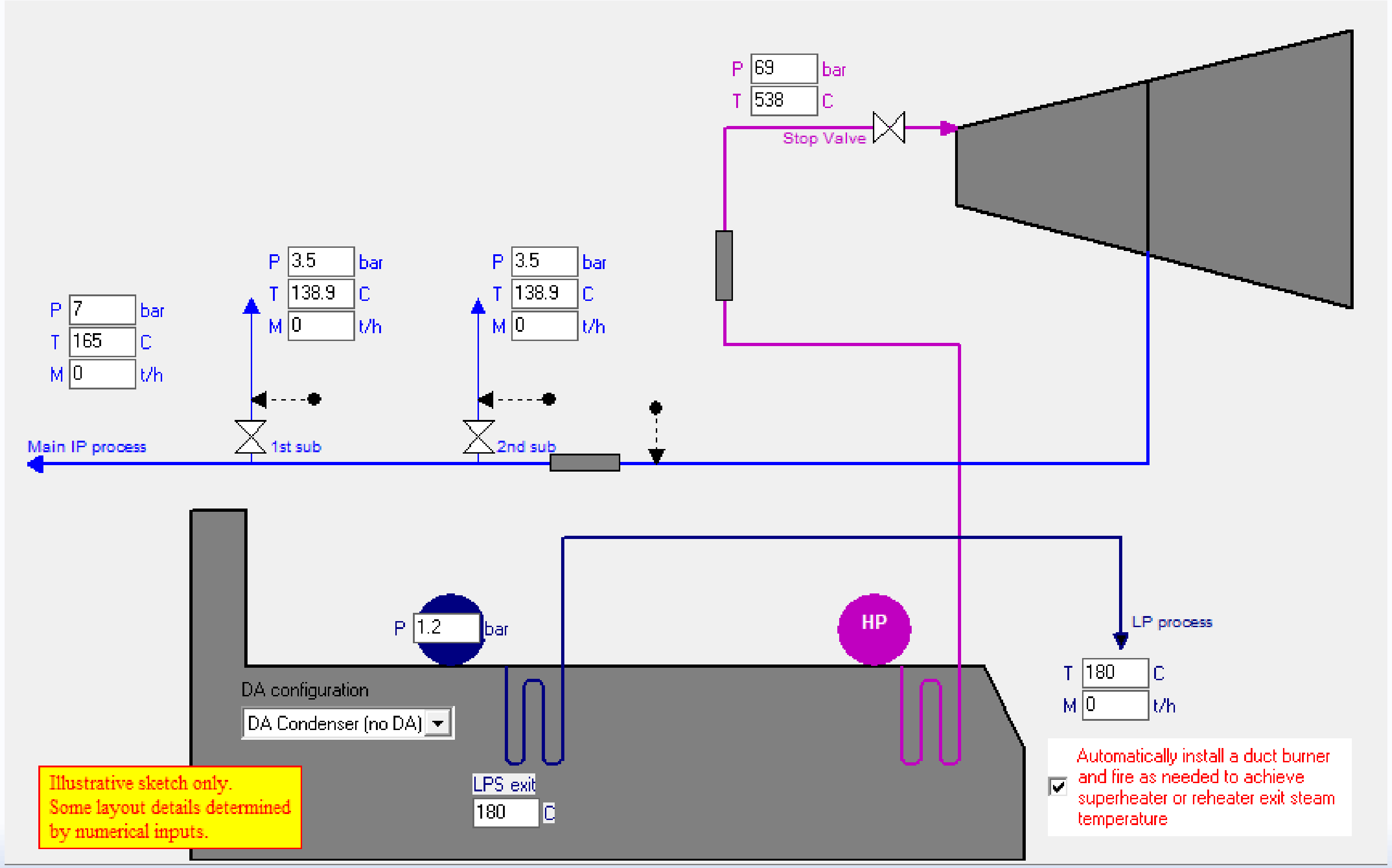
Worth Noting:
1st Design yields more IP steam generation with a lower stack temp and larger STG output. Potentially also allows the HPE1 and LPE1 to be combined into one unit since output temperatures for both the IP and HP streams are the same.



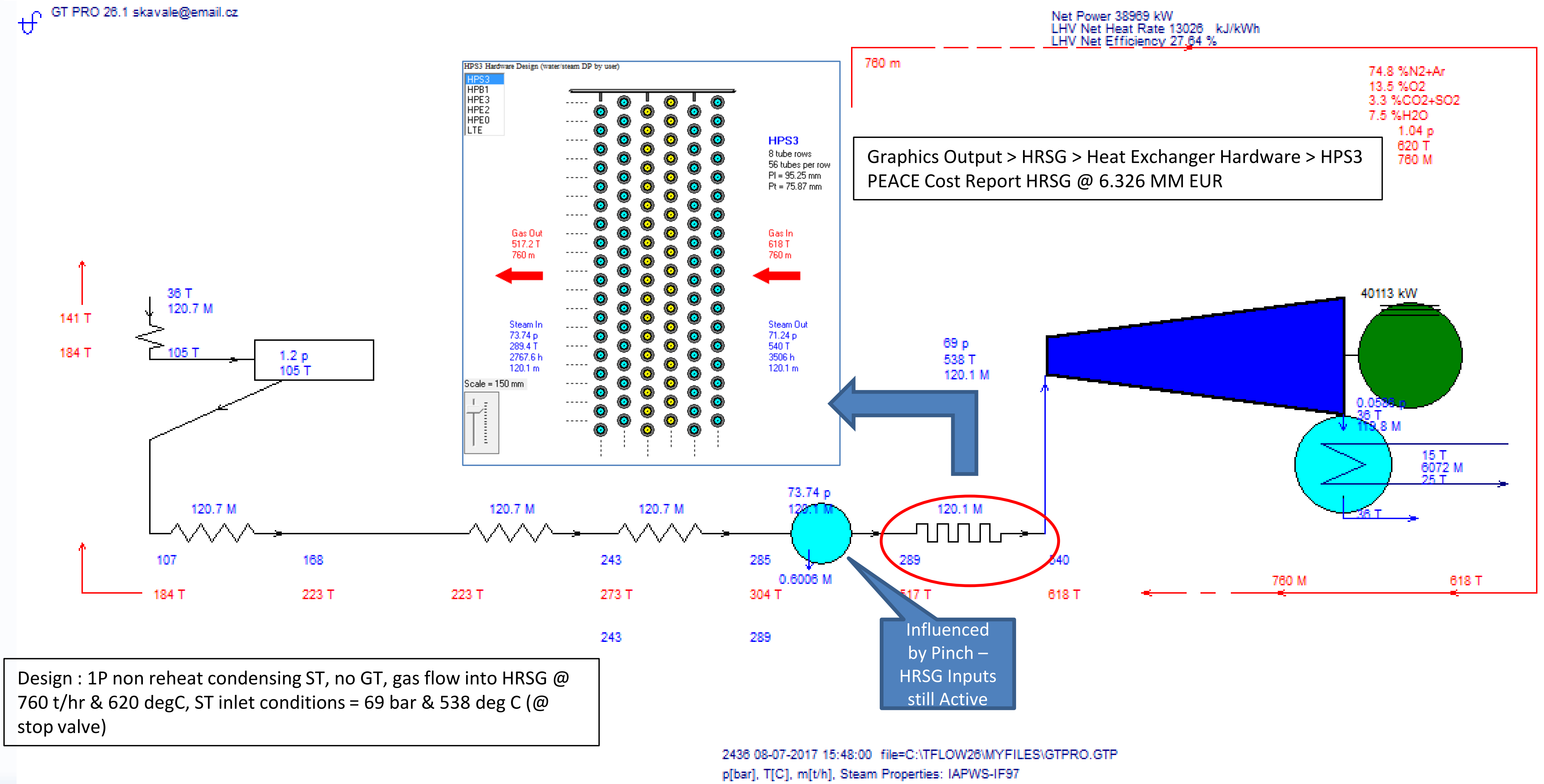
2436 08-08-2017 13:10:05 file=C:\TFLOW26\MYFILES\Method_2PL_Var2.gtp
p[bar], T[C], m[t/h], Steam Properties: IAPWS-IF97

Example 2

- Consider a 1 PL HRSG being supplied with exhaust gas source, 760 t/hr @ 620 deg C
- HRSG Design Method = Simplified/Automatic – what are the differences in terms of GTPro Output, PEACE results etc.
- ST-HRSG conditions as shown, HP & IP Pinch @ 15degC, approach temp @ 4 degC

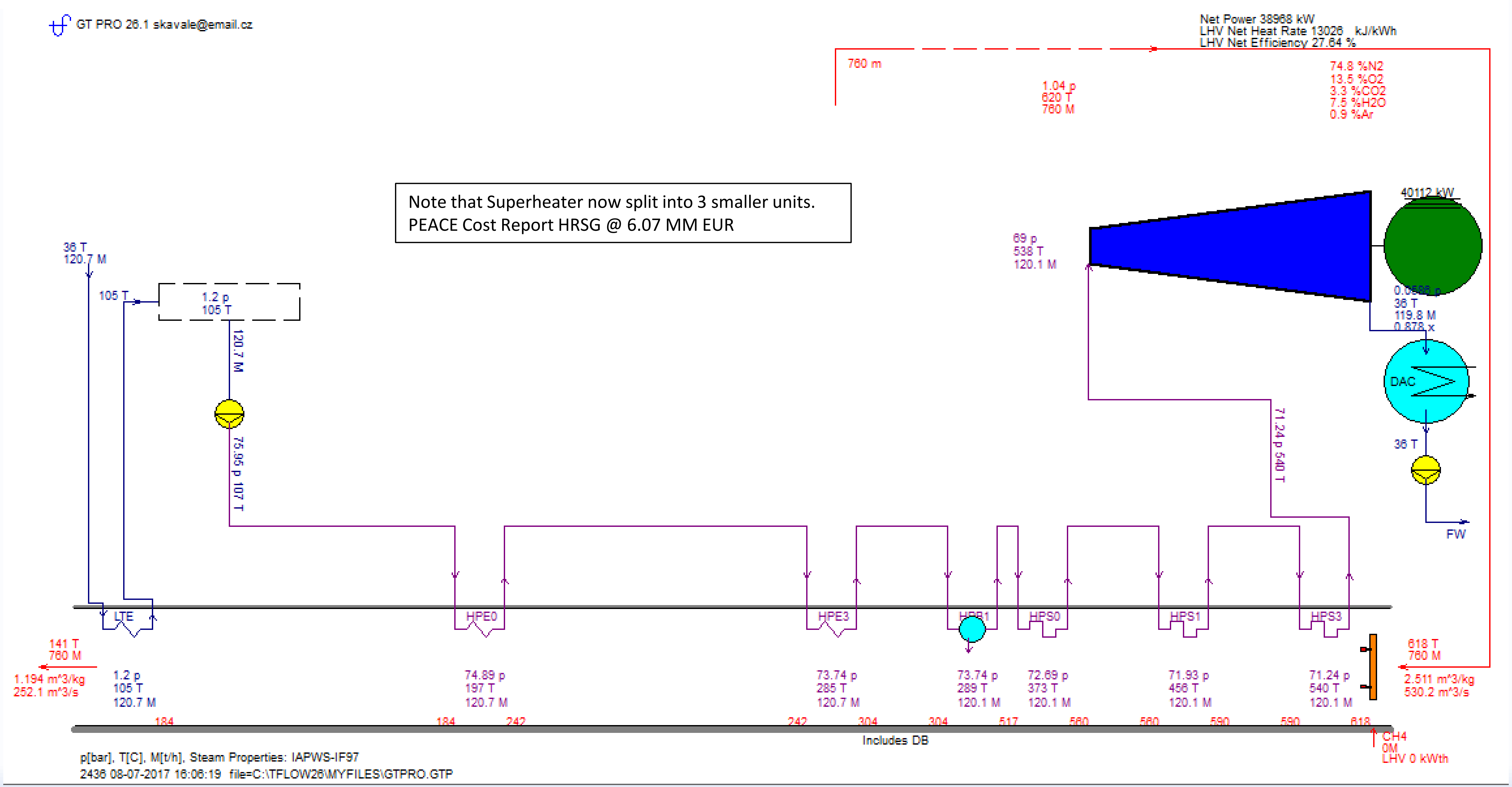


Cycle Flow Schematic – Simplified Method HRSG Spec



Design : 1P non reheat condensing ST, no GT, gas flow into HRSG @ 760 t/hr & 620 degC, ST inlet conditions = 69 bar & 538 deg C (@ stop valve)

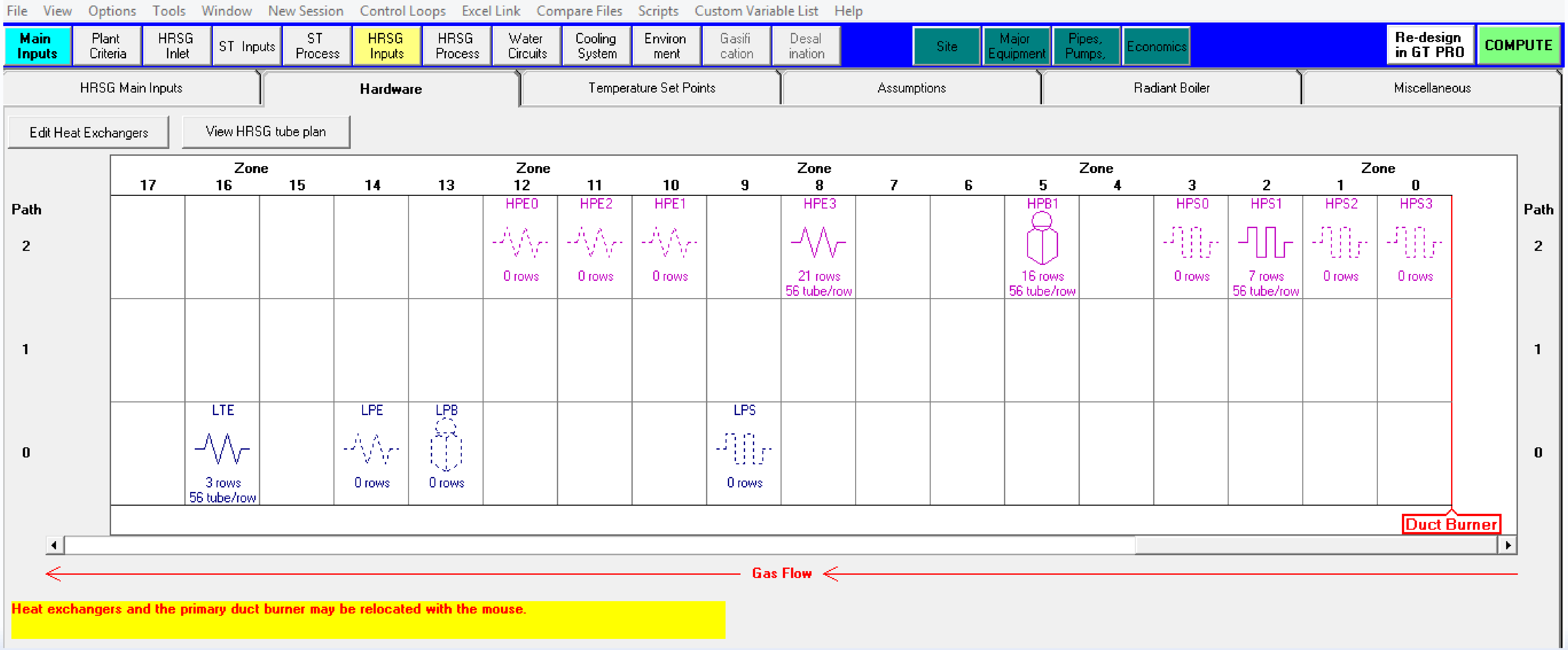
Cycle Flow Schematic – Automatic Method HRSG Spec



What Happens in GTM?

(Note: Method not available in GTM – since design is now fixed)

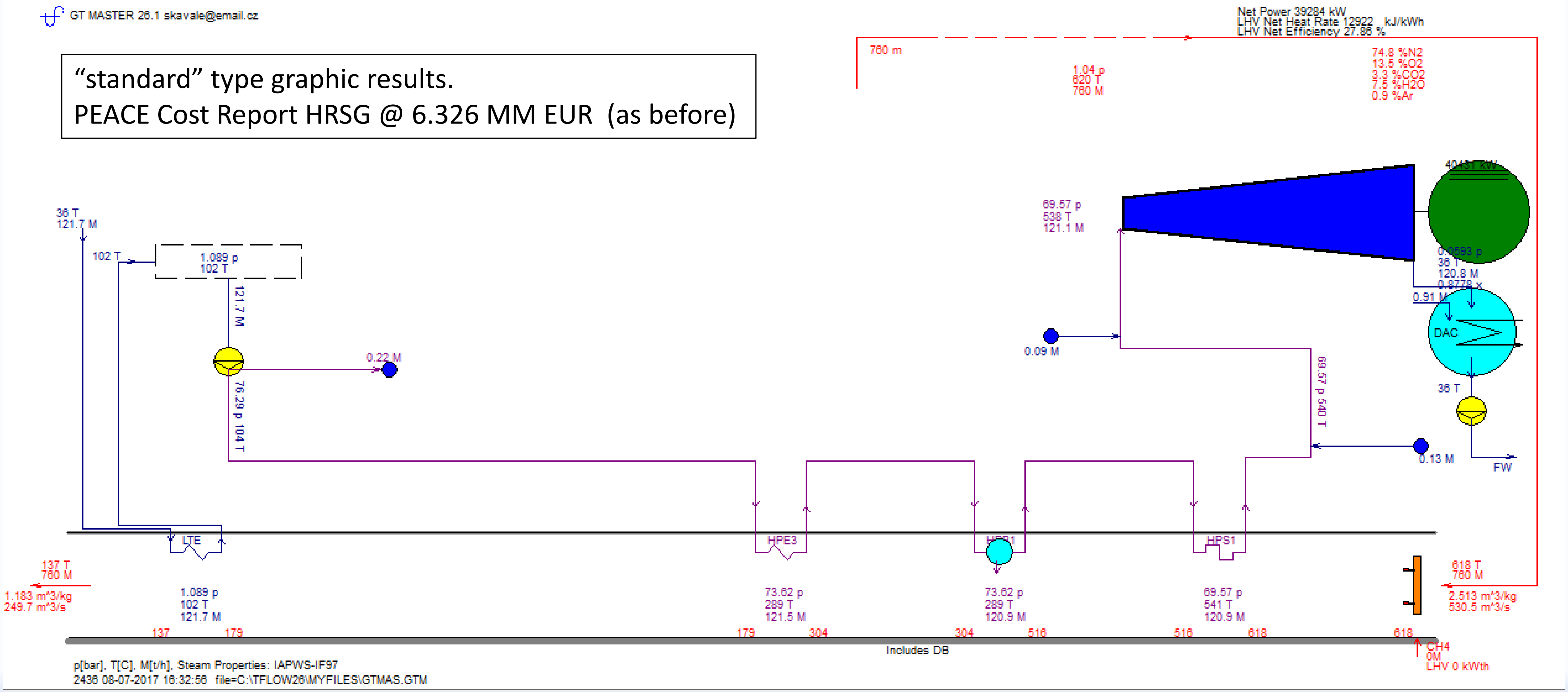
Transfer the Simplified Method Plant to GTM, Inspect the HRSG Inputs Screen
(Previously had 3 economisers – program has further simplified the design to just 1 equivalent Economiser)



GTM Output

(Method= Simplified in GTPro)

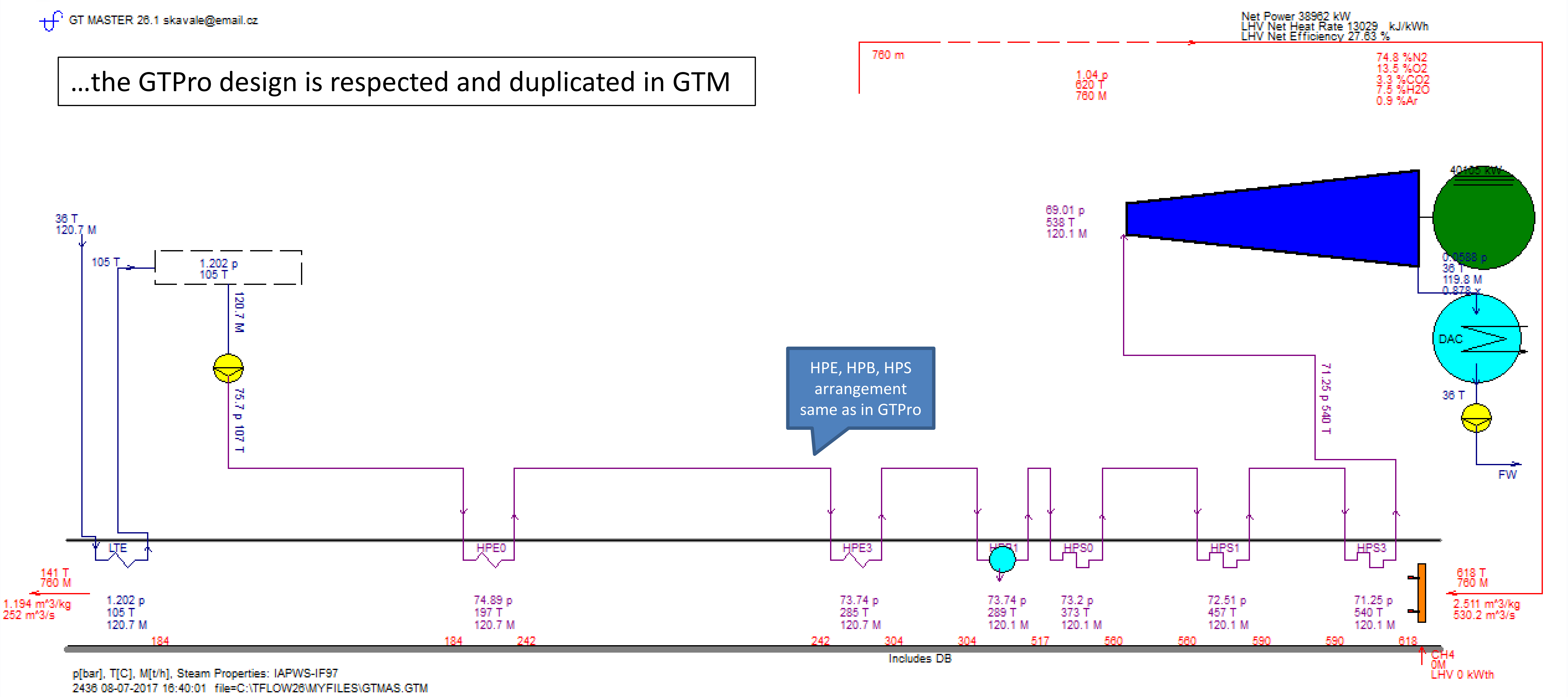
"standard" type graphic results.
PEACE Cost Report HRSG @ 6.326 MM EUR (as before)



GTM Output

(Method= Automatic in GTPro)

...the GTPro design is respected and duplicated in GTM



Conclusion

The Simplified Method of HRSG Specification is significantly different in its approach to the other two methods of HRSG specification
The Calculation code is a preserved version of the earlier calculation method for HRSG specification/design
Being a simpler & distinctly separate code, it may be a useful alternative to the other two HRSG specification methods in the event that these return error messages during calculation

The difference in design Method yields differences in HRSG heat transfer surface arrangements which may also yield subsequent differences in HRSG cost.

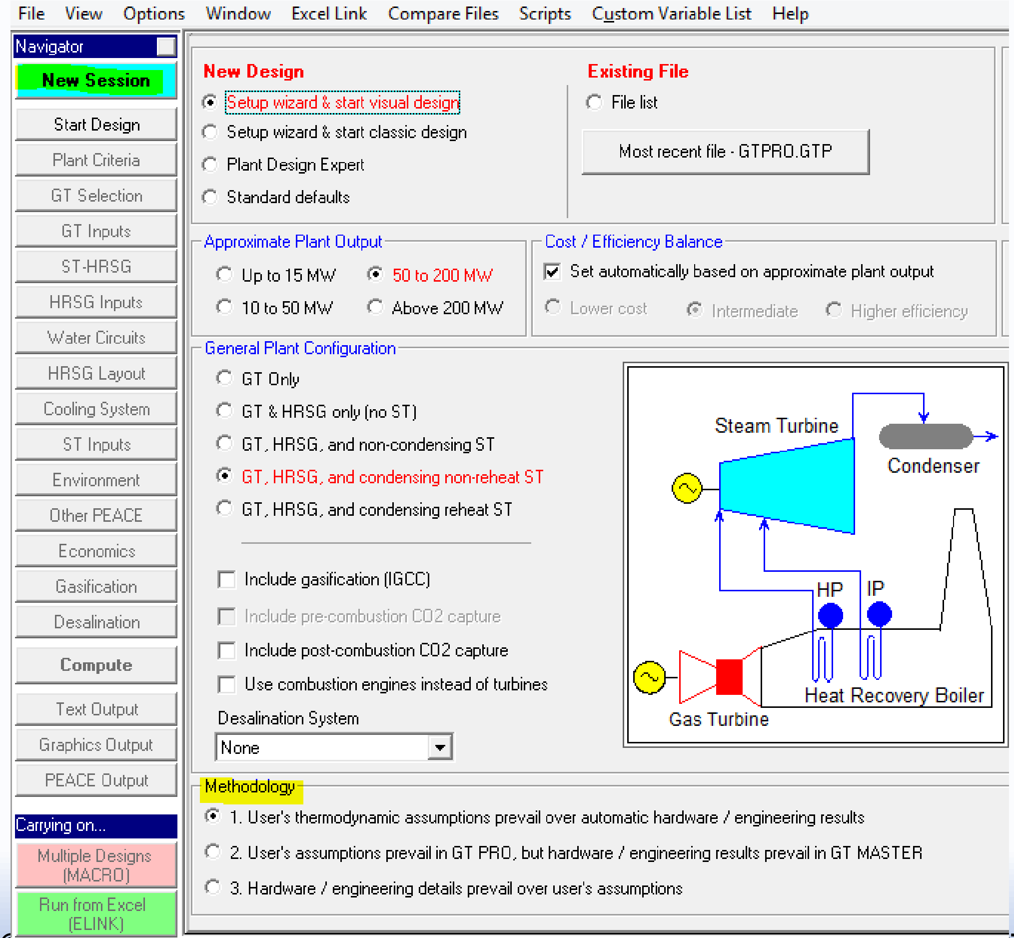
Further information is provided in the Help Menu, GTPro ch. 4.2.1 and GTPro ch.20

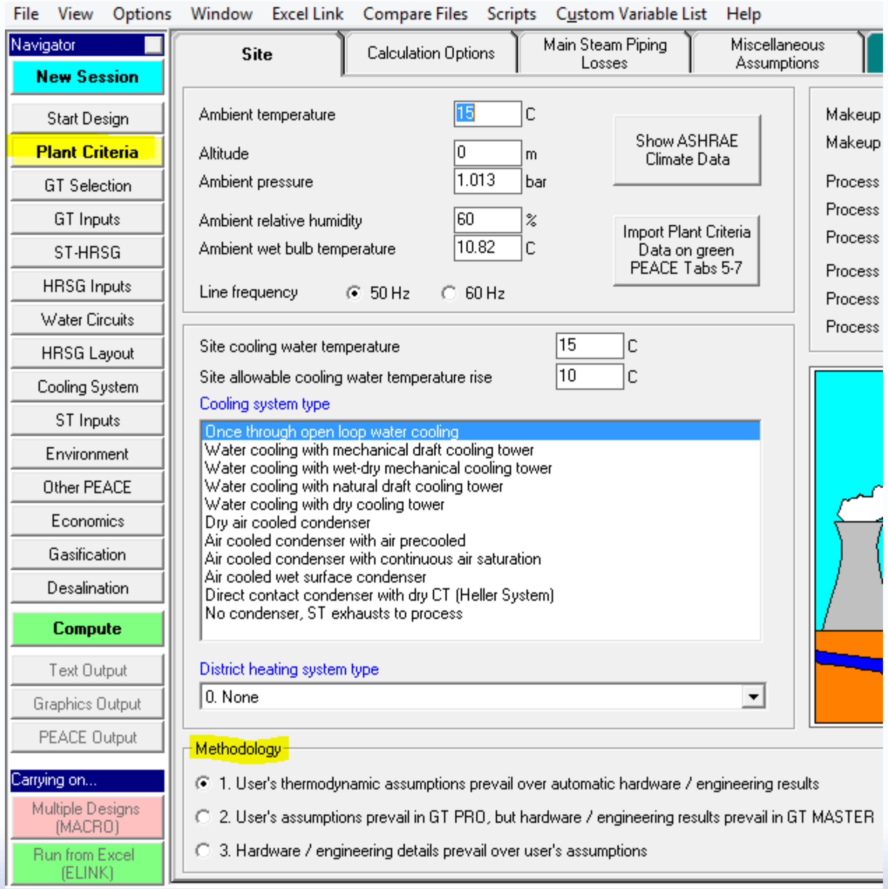
Method	HPE1 Setting	Intermediate Pressure Superheater Settings	HP Steam t/hr	IP Steam t/hr	MWe	Stack Temp degC
Simplified	HPE1 exit temperature = IP saturation temperature	IPS behind HP economiser	120.1	14.15	42.484	93
Automatic	HPE1 common with IPE	IPS1 behind HPE3, IPS2 behind HPB	120.1	12.16	41.956	100
Auto. Mimic of Simplified	HPE1 common with IPE	IPS behind HP economiser	120.1	12.16	41.955	100

Methodology

(As Applicable to GTPro)

Can be specified at the New Session or Plant Criteria tab
Is available for both the "Setup Wizard and Start Visual Design" as well as the "Setup Wizard and Start Classic Design" method of plant specification
Unavailable for the PDE and Standard Defaults Method of Plant Design.





Methodology 1

(As Applicable to GTPro)
Ref GTPro Help 2.4.5

"Users thermodynamic assumptions prevail over automatic hardware/engineering results."

This means that: **Method 1** is the default and results in the shortest computation times. The heat balance results in GT PRO and GT MASTER rely on the assumptions used to create the hardware. The hardware characteristics do not feed back into the heat balance automatically. For example, the pressure drops in the heat balance pipes are computed directly from assumptions made at the **Plant Criteria** topic, §4.3. Those assumptions are also used by PEACE to size the pipes. In GT MASTER, a resistance coefficient derived from the GT PRO heat balance is used to scale the pressure drops at off design. Thus, under identical flow conditions the pressure drops in GT PRO and GT MASTER will be identical, but are not computed using the hardware definition of the piping system shown in the PEACE outputs.

	Methodology		
GT PRO Defaults	1	2	3
1. Pipe dp	Udf	Udf	PHW
2. HRSG water-side dp	Udf	Udf	PHW
3. Stack loss	No	No	Yes
4. Rad q from GT/DB	No	No	Yes
5. Hydrostatic corr.	No	No	Yes
6. PEACE aux HX q to CT	No	No	Yes
GT MASTER Defaults	1	2	3
1. Pipe dp	RC	PHW	PHW
2. HRSG water-side dp CF	GTP	1	1
3. Stack loss	GTP	Yes	Yes
4. Rad q from GT/DB	GTP	Yes	Yes
5. Hydrostatic corr.	GTP	GTP	GTP
6. PEACE aux HX q to CT	GTP	GTP	GTP
7. Cooling water flow	Udf	PHW	PHW

Udf: User-defined, PHW: PEACE Hardware (if licensed)
RC: Resistance coefficient

Site | Calculation Options | **Main Steam Piping Losses** | Miscellaneous Assumptions

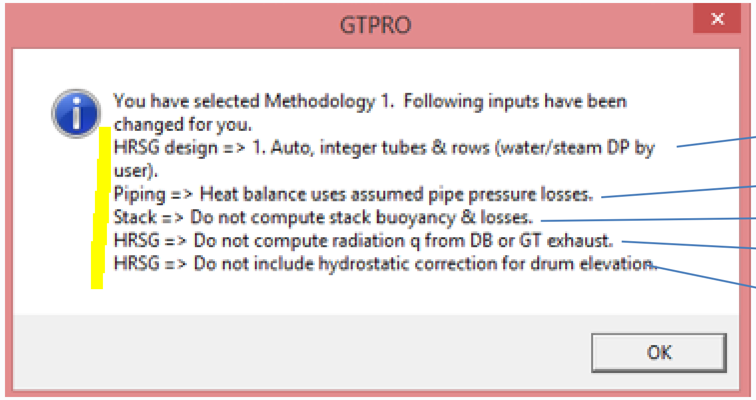
- (•) Heat balance uses assumed pipe pressure losses below
- ( ) Heat balance uses hardware-based pressure drops from PEACE pipe results

1. Pressure loss in HP piping (DP/P)	3.25	%
2. Pressure loss in HPT piping (DP/P)	3.75	%
3. Pressure loss in hot RH piping (DP/P)	6.5	%
4. Pressure loss in cold RH piping (DP/P)	6.5	%
5. Pressure loss in IP piping (DP/P)	6.5	%
6. Pressure loss in LP piping (DP/P)	9	%
7. Pressure loss in LPT piping (DP/P)	9	%
8. Enthalpy drop in HP piping	2.5	kJ/k
9. Enthalpy drop in HPT piping	2.5	kJ/k
10. Enthalpy drop in hot RH piping	2.5	kJ/k
11. Enthalpy drop in cold RH piping	2.5	kJ/k
12. Enthalpy drop in IP piping	2.5	kJ/k
13. Enthalpy drop in LP piping	2.5	kJ/k
14. Enthalpy drop in LPT piping	2.5	kJ/k

Methodology 1

(As Applicable to GTPro Ref GTPro Help 2.4.5)

On leaving Plant Criteria Screen, note the below message advising of changes to selections made by the program to various aspects of the plant hardware



From HRSG Inputs > Hardware Design Tab

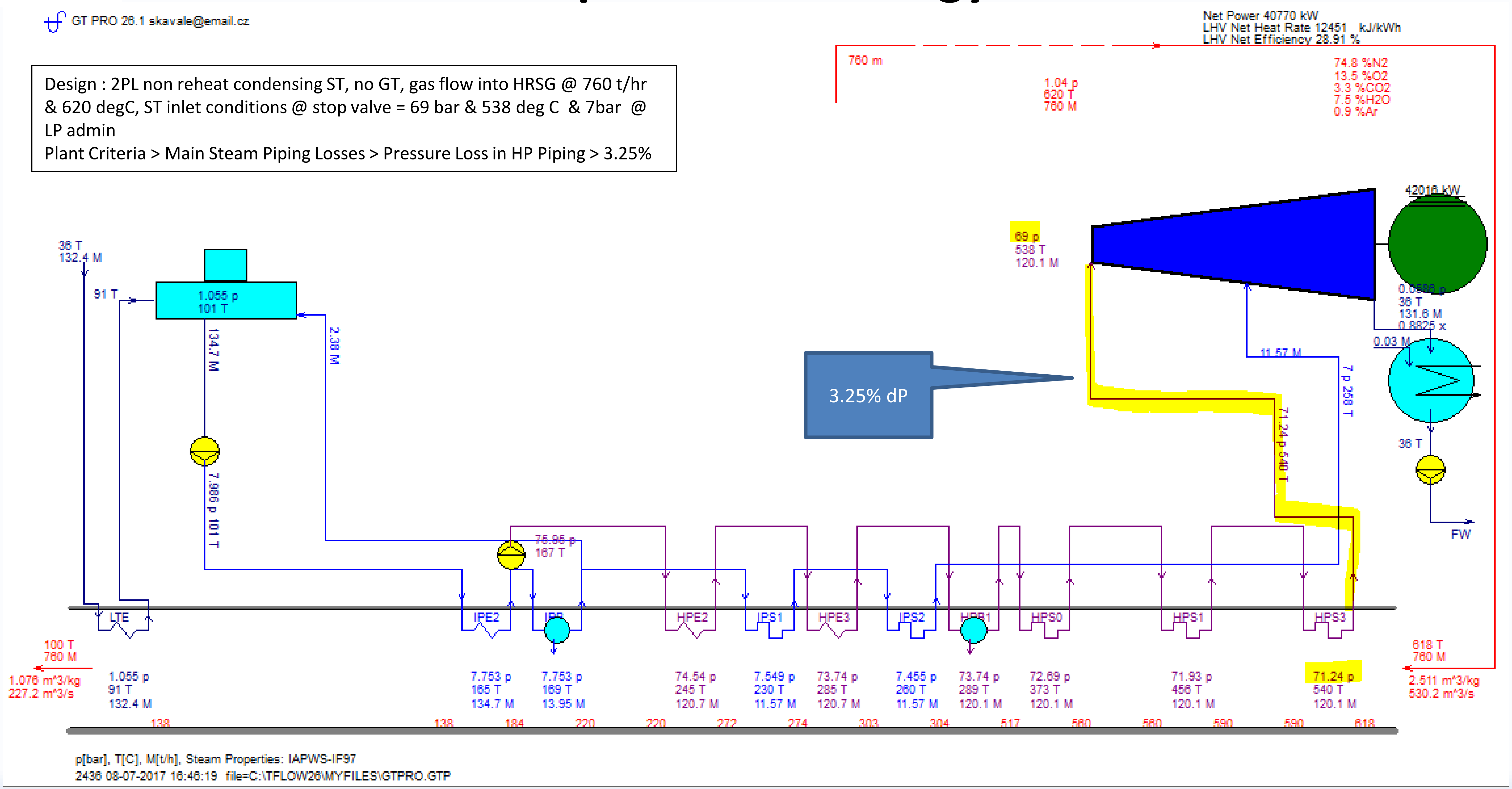
From Plant Criteria > Main Steam Piping Losses Tab

From HRSG Inputs > Equipment Options (PEACE) Tab

From HRSG Inputs > Miscellaneous Tab (item 13)

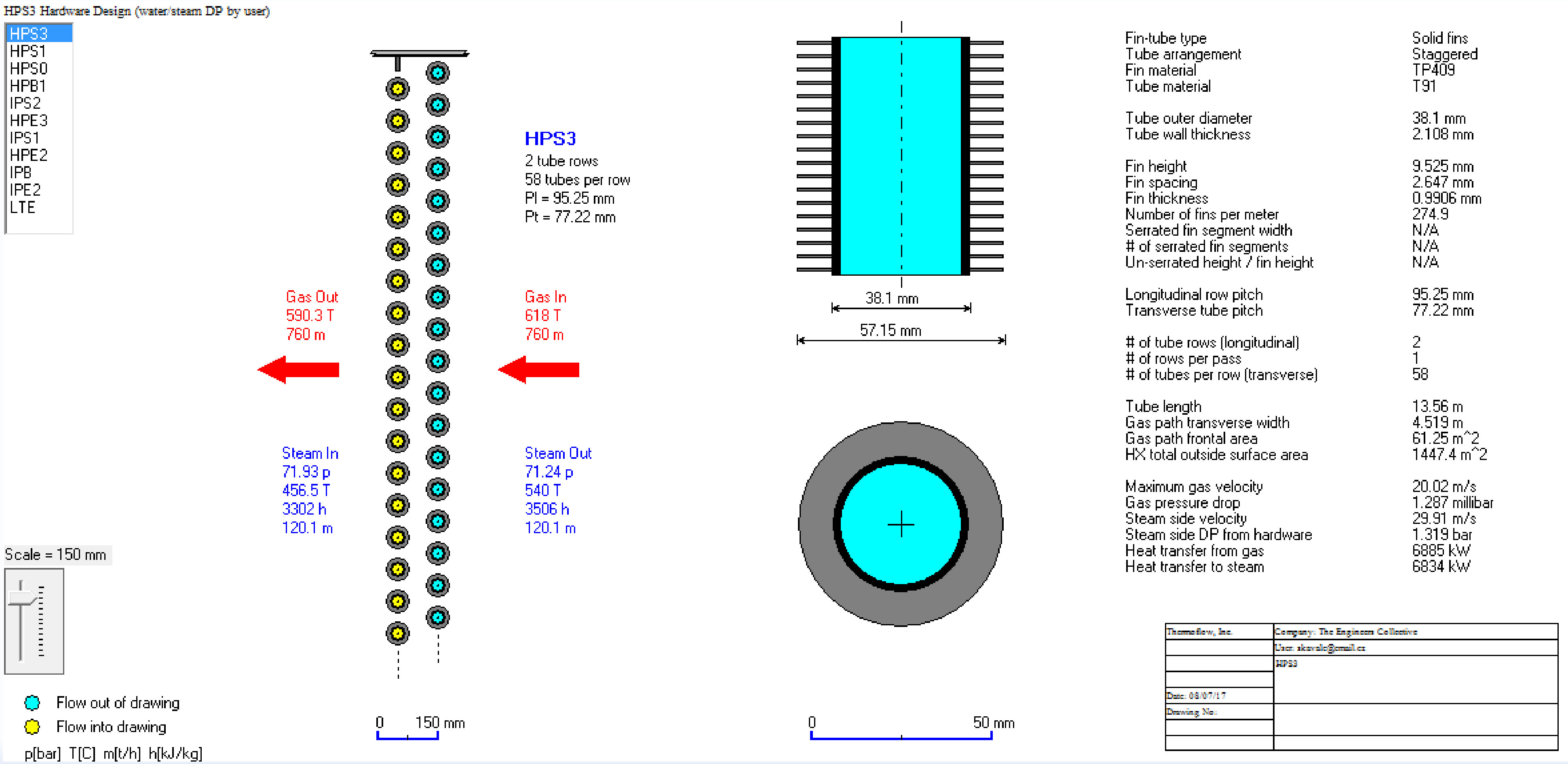
From HRSG Inputs > Miscellaneous Tab (item 18)

Example: Methodology 1



Example: Methodology 1 (cntd)

Note that Hardware has been calculated and can be determined from the GTPro calculated outputs- but these details have not been fed back into the model .



Methodology 1 – GTM Input Screen

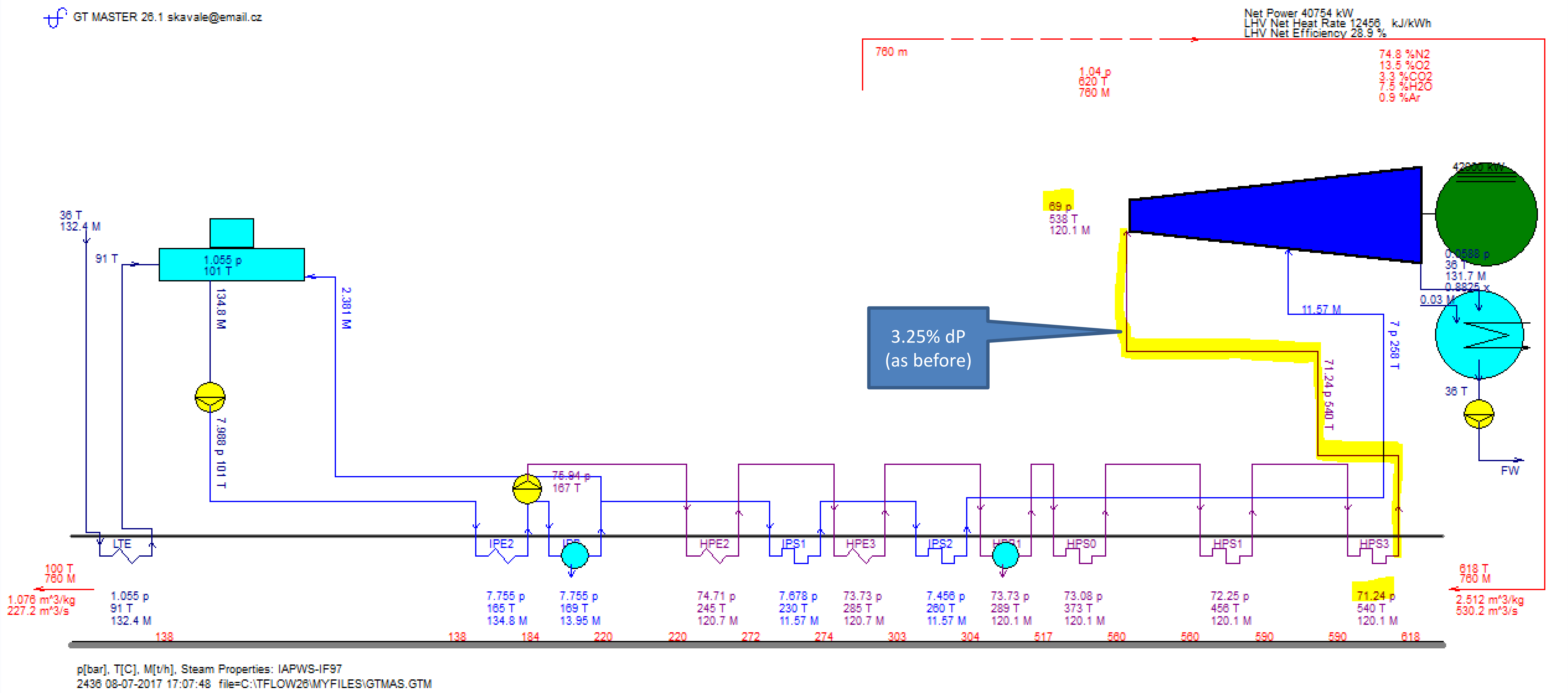
Main Inputs | Plant Criteria | HRSG Inlet | ST Inputs | ST Process | HRSG Inputs | HRSG Process | Water Circuits | Cooling System | Environ ment | Gasifi cation | Desal ination

Site | Calculation Options | Main Steam Piping Losses | Misce

	Resistance coefficient		Enthalpy loss		Pressure drop model	
1. HPB to HPT	0.8518	m^-4	2.5	kJ/kg	Use resistance coefficient	Click to edit pipe details...
2. IPB to LPT	2.863	m^-4	2.5	kJ/kg	Use resistance coefficient	Click to edit pipe details...
3. Hot reheat to HPT	0	m^-4	2.5	kJ/kg	Use resistance coefficient	Click to edit pipe details...
4. Cold reheat pipe	0	m^-4	2.5	kJ/kg	Use resistance coefficient	Click to edit pipe details...
5. LPB to LPT addition	0	m^-4	2.5	kJ/kg	Use resistance coefficient	Click to edit pipe details...
6. HP process	0	m^-4	2.5	kJ/kg	Use resistance coefficient	Click to edit pipe details...
7. IP process	0	m^-4	2.5	kJ/kg	Use resistance coefficient	Click to edit pipe details...
8. HPT extraction for process	0	m^-4	2.5	kJ/kg	Use resistance coefficient	Click to edit pipe details...
9. LPT extraction for process	0	m^-4	2.5	kJ/kg	Use resistance coefficient	Click to edit pipe details...

GTM- Methodology 1- Pressure Drop Model = Resistance Co-Efficient

Methodology 1 – GTM Output



Methodology 2

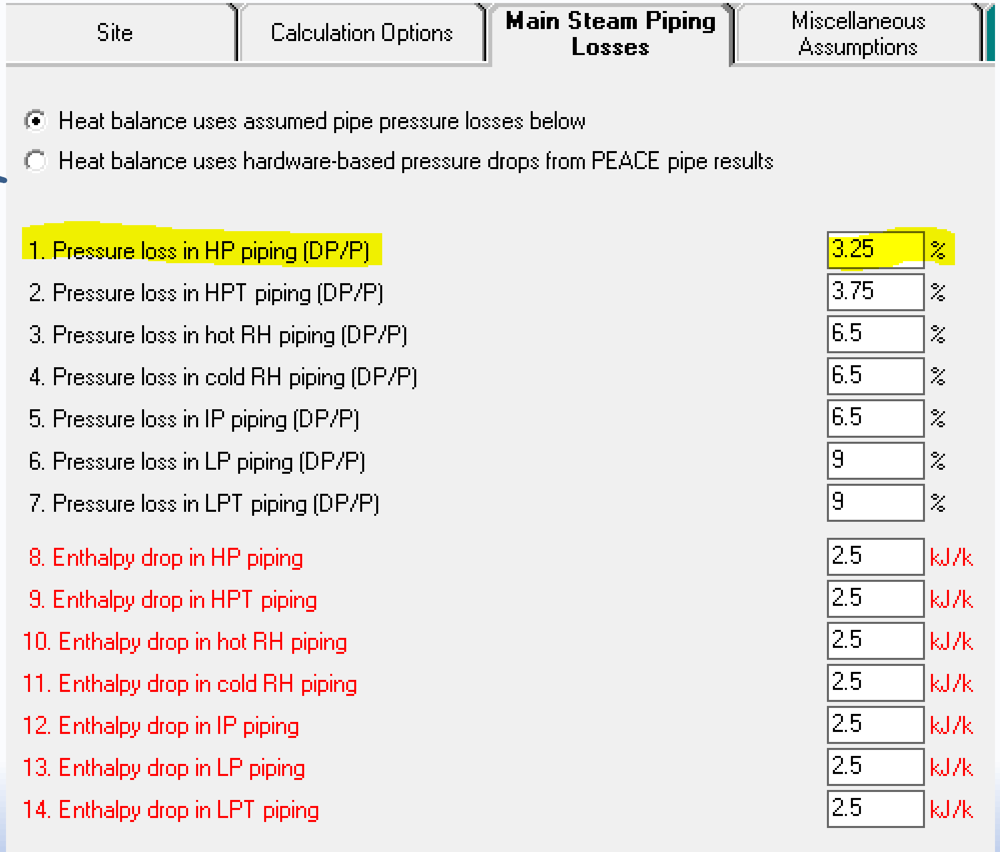
(As Applicable to GTPro)
Ref GTPro Help 2.4.5

"Users assumptions prevail in GTPro, but hardware/engineering results prevail in GTMaster."
This means that: Essentially there is no difference to Methodology 1 when in GTPro, however once the user enters GTMaster for off design calculations, the physical hardware parameters calculated/defined in GTPro now dominate in subsequent GTMaster calculations.

	Methodology		
GT PRO Defaults	1	2	3
1. Pipe dp	Udf	Udf	PHW
2. HRSG water-side dp	Udf	Udf	PHW
3. Stack loss	No	No	Yes
4. Rad q from GT/DB	No	No	Yes
5. Hydrostatic corr.	No	No	Yes
6. PEACE aux HX q to CT	No	No	Yes
GT MASTER Defaults	1	2	3
1. Pipe dp	RC	PHW	PHW
2. HRSG water-side dp CF	GTP	1	1
3. Stack loss	GTP	Yes	Yes
4. Rad q from GT/DB	GTP	Yes	Yes
5. Hydrostatic corr.	GTP	GTP	GTP
6. PEACE aux HX q to CT	GTP	GTP	GTP
7. Cooling water flow	Udf	PHW	PHW

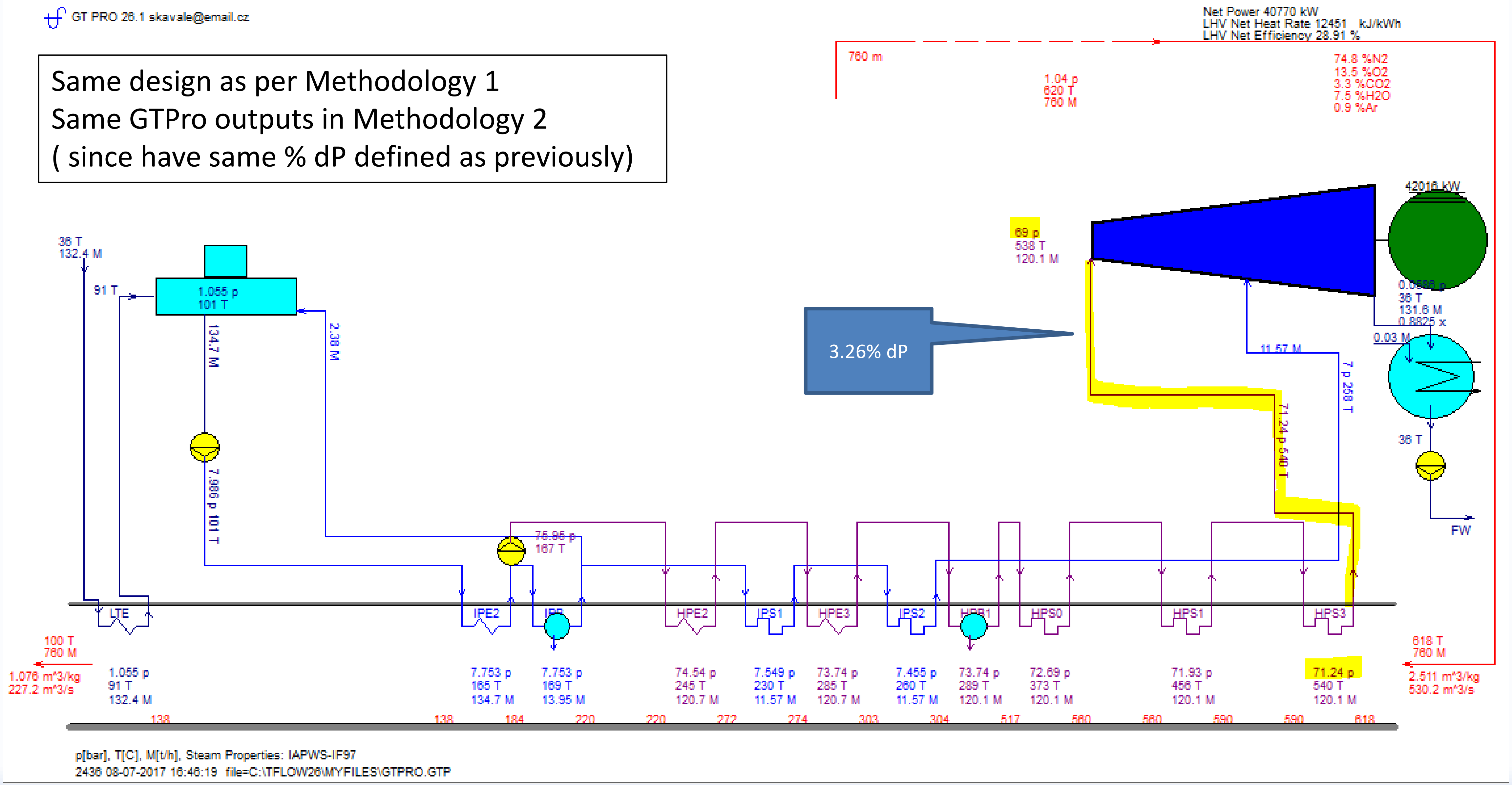
Udf: User-defined, PHW: PEACE Hardware (if licensed)
RC: Resistance coefficient

...same defaults in GTPro M2 as in M1



Example: Methodology 2

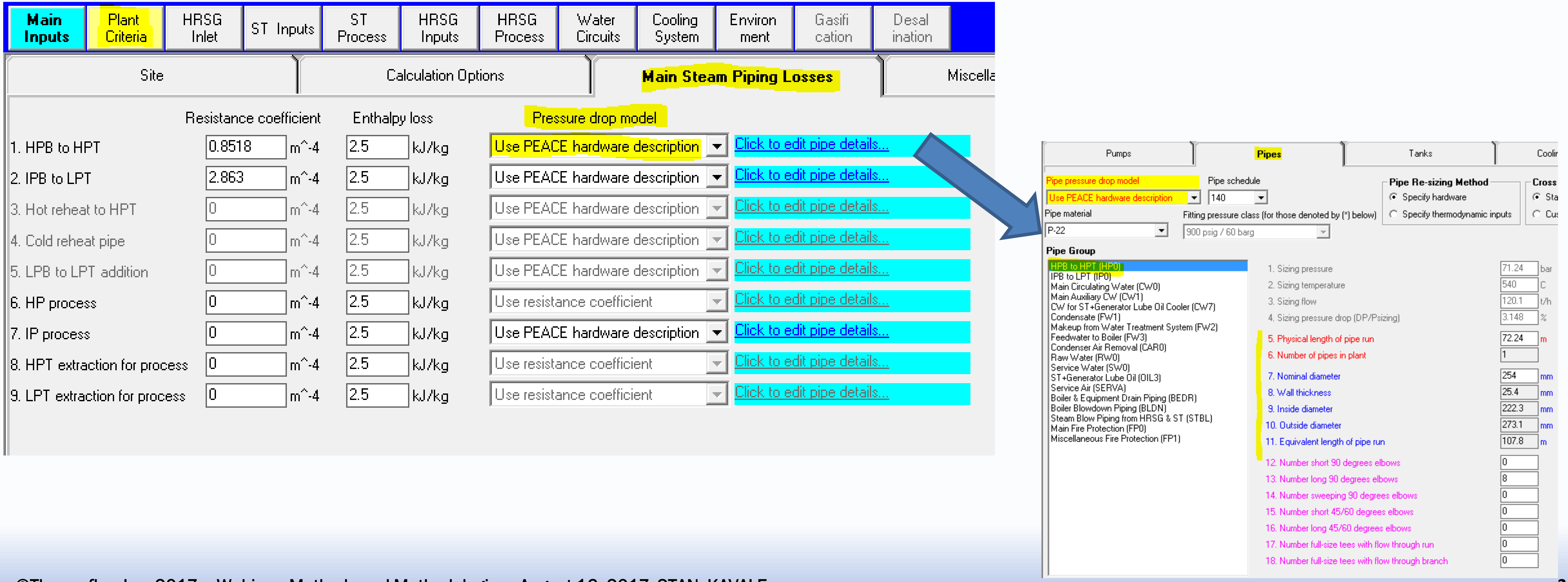
Same design as per Methodology 1
Same GTPro outputs in Methodology 2
(since have same % dP defined as previously)



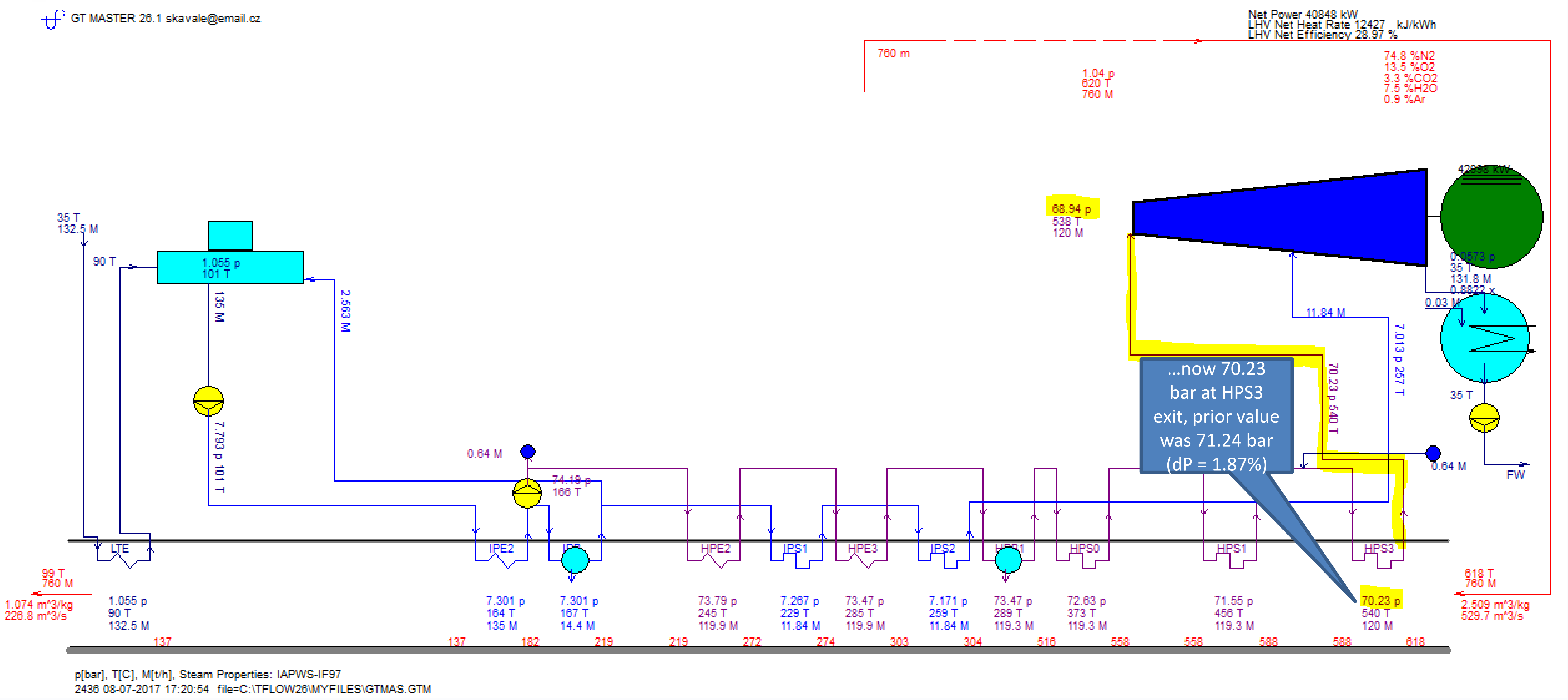
Methodology 2 – GTM Input Screen

Note the difference: in prior example with Methodology 1, the GTM input screen had Main Steam Piping Losses/Pressure Drop Model as "Use Resistance Co Efficient", with Methodology 2, this is now "Use PEACE hardware description. Model calculation is therefore based on the hardware characteristics calculated previously in GTPro.

Also- could have "manually" switched on Methodology 2 in prior example by manually changing the pressure drop model in this screen.



Methodology 2 – GTM Output



Methodology 3

(As Applicable to GTPro Ref GTPro Help 2.4.5)

"Hardware/engineering details prevail over users assumptions."

Method 3 results in a heat balance most tightly coupled to the hardware characteristics of the designed plant. In this mode, the GT PRO and GT MASTER heat balances are very similar, and most consistent with the PEACE description of the plant. Outputs from both GT PRO and GT MASTER are consistent with hardware definitions of the components, rather than on the assumptions used to create those hardware definitions. Consider the procedure used with this method as it applies to the pipes described above. The assumed pressure drops in the main piping (§4.3) are applied in the initial GT PRO heat balance. Those initial heat balance results are used by PEACE to design the piping systems. The resulting piping system pressure drop characteristics are used in a second GT PRO heat balance calculation. The second (final) GT PRO result is based on pressure drops computed using the hardware characteristics of the piping system shown in the PEACE outputs. In GT MASTER, changing the piping system design will affect the computed pressure drops (and plant cost) automatically.

	Methodology		
GT PRO Defaults	1	2	3
1. Pipe dp	Udf	Udf	PHW
2. HRSG water-side dp	Udf	Udf	PHW
3. Stack loss	No	No	Yes
4. Rad q from GT/DB	No	No	Yes
5. Hydrostatic corr.	No	No	Yes
6. PEACE aux HX q to CT	No	No	Yes
GT MASTER Defaults	1	2	3
1. Pipe dp	RC	PHW	PHW
2. HRSG water-side dp CF	GTP	1	1
3. Stack loss	GTP	Yes	Yes
4. Rad q from GT/DB	GTP	Yes	Yes
5. Hydrostatic corr.	GTP	GTP	GTP
6. PEACE aux HX q to CT	GTP	GTP	GTP
7. Cooling water flow	Udf	PHW	PHW

Udf: User-defined, PHW: PEACE Hardware (if licensed)
RC: Resistance coefficient

...same defaults in GTPro M3 as in M1

Site | Calculation Options | **Main Steam Piping Losses** | Miscellaneous Assumptions

(•) Heat balance uses assumed pipe pressure losses below
( ) Heat balance uses hardware-based pressure drops from PEACE pipe results

1. Pressure loss in HP piping (DP/P)	3.25	%
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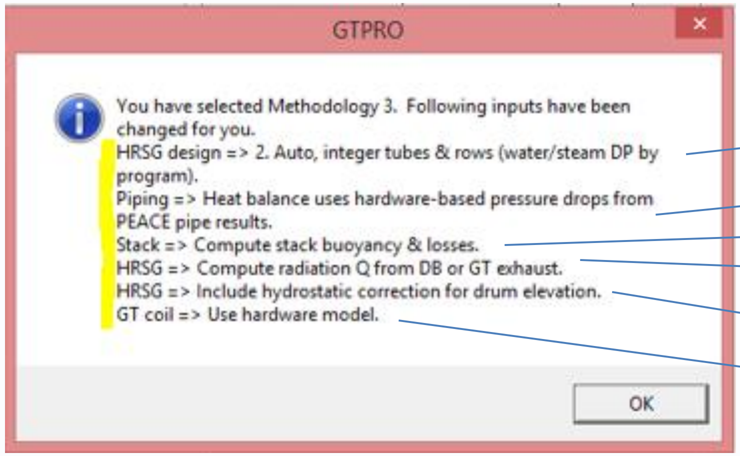
4. Pressure loss in cold RH piping (DP/P)	6.5	%
5. Pressure loss in IP piping (DP/P)	6.5	%
6. Pressure loss in LP piping (DP/P)	9	%
7. Pressure loss in LPT piping (DP/P)	9	%
8. Enthalpy drop in HP piping	2.5	kJ/k
9. Enthalpy drop in HPT piping	2.5	kJ/k
10. Enthalpy drop in hot RH piping	2.5	kJ/k
11. Enthalpy drop in cold RH piping	2.5	kJ/k
12. Enthalpy drop in IP piping	2.5	kJ/k
13. Enthalpy drop in LP piping	2.5	kJ/k
14. Enthalpy drop in LPT piping	2.5	kJ/k

Methodology 3

(As Applicable to GTPro Ref GTPro Help 2.4.5)

On leaving Plant Criteria Screen, note the below message advising of changes to selections made by the program to various aspects of the plant hardware



From HRSG Inputs > Hardware Design Tab

From Plant Criteria > Main Steam Piping Losses Tab

From HRSG Inputs > Equipment Options (PEACE) Tab

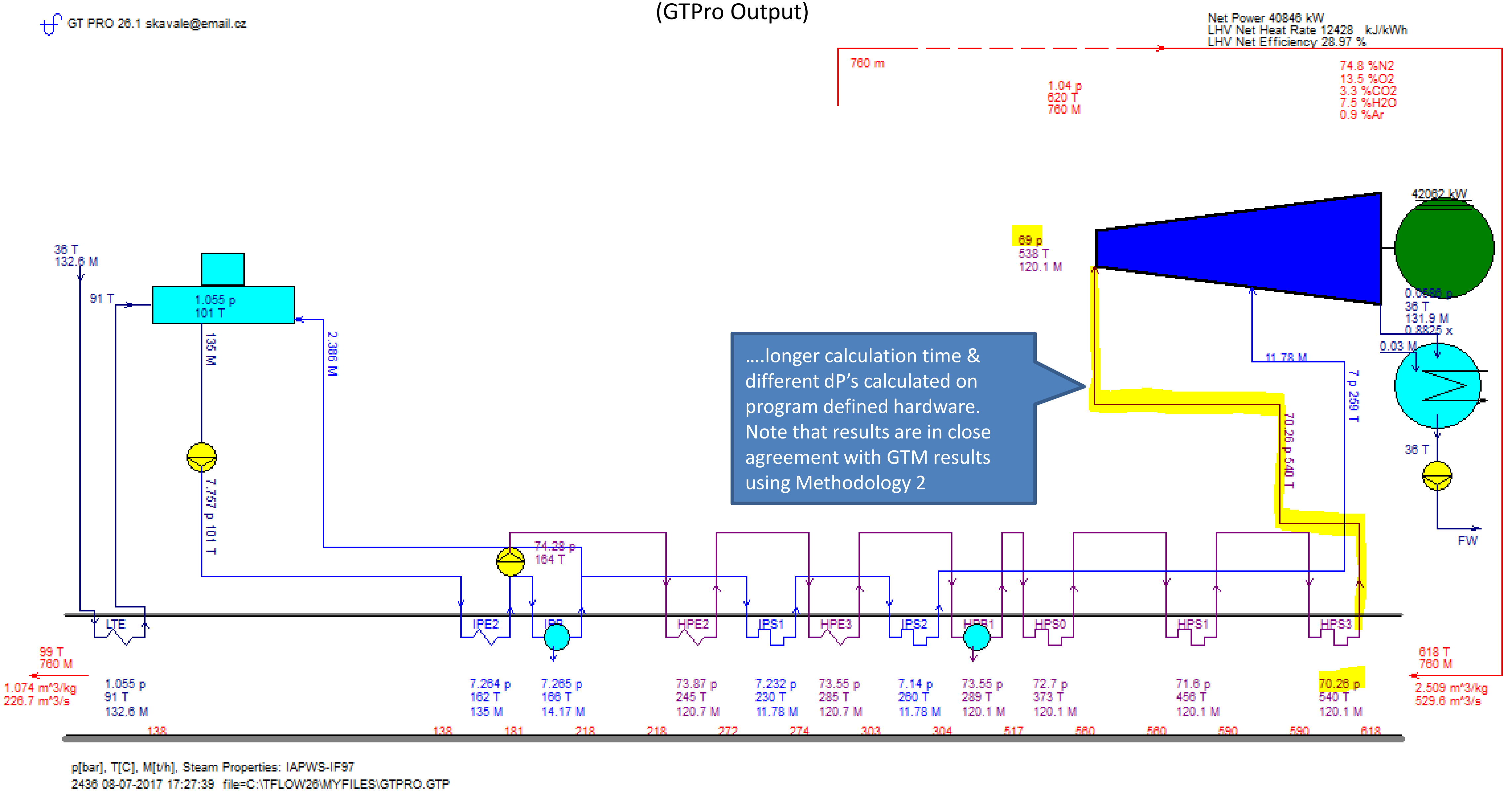
From HRSG Inputs > Miscellaneous Tab (item 13)

From HRSG Inputs > Miscellaneous Tab (item 18)

From GT Inputs > Inlet Heating & Cooling > Coil Tab

Example: Methodology 3

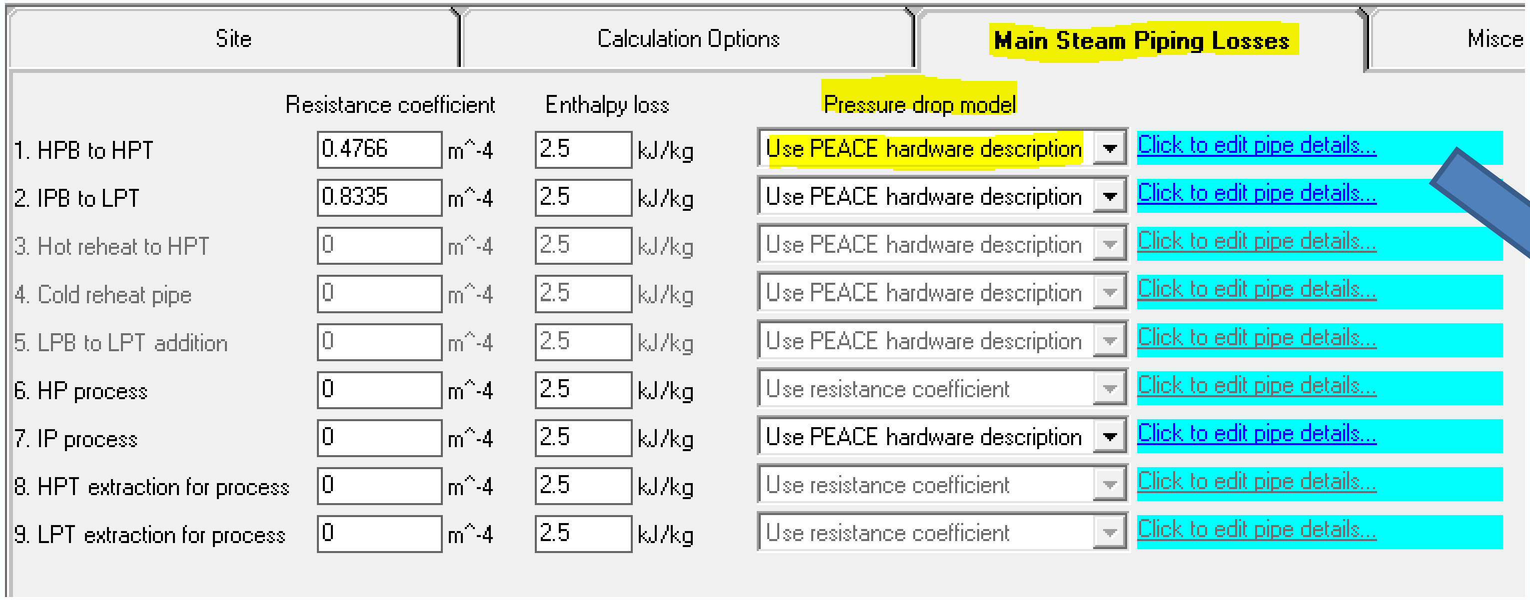
(GTPro Output)

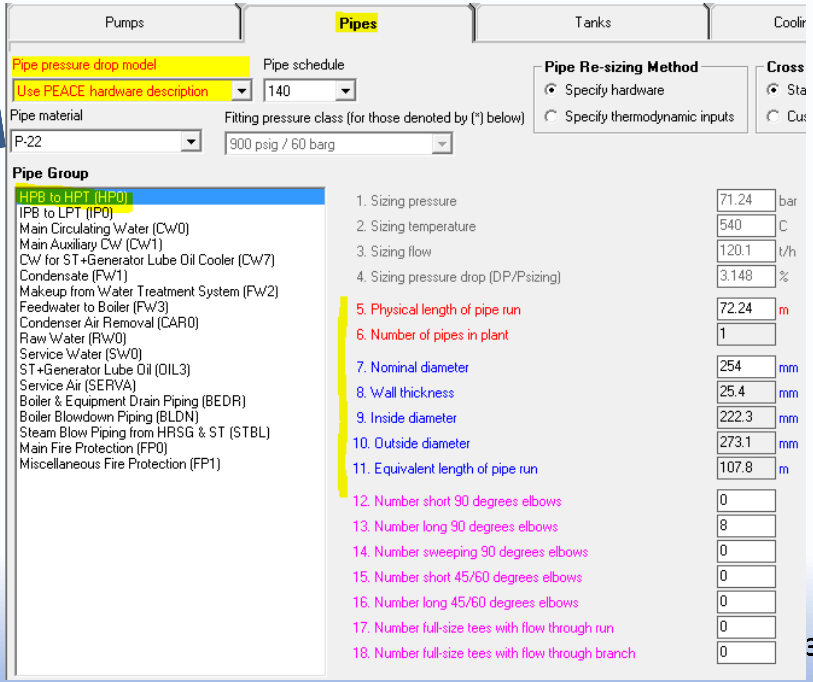


....longer calculation time & different dP's calculated on program defined hardware. Note that results are in close agreement with GTM results using Methodology 2

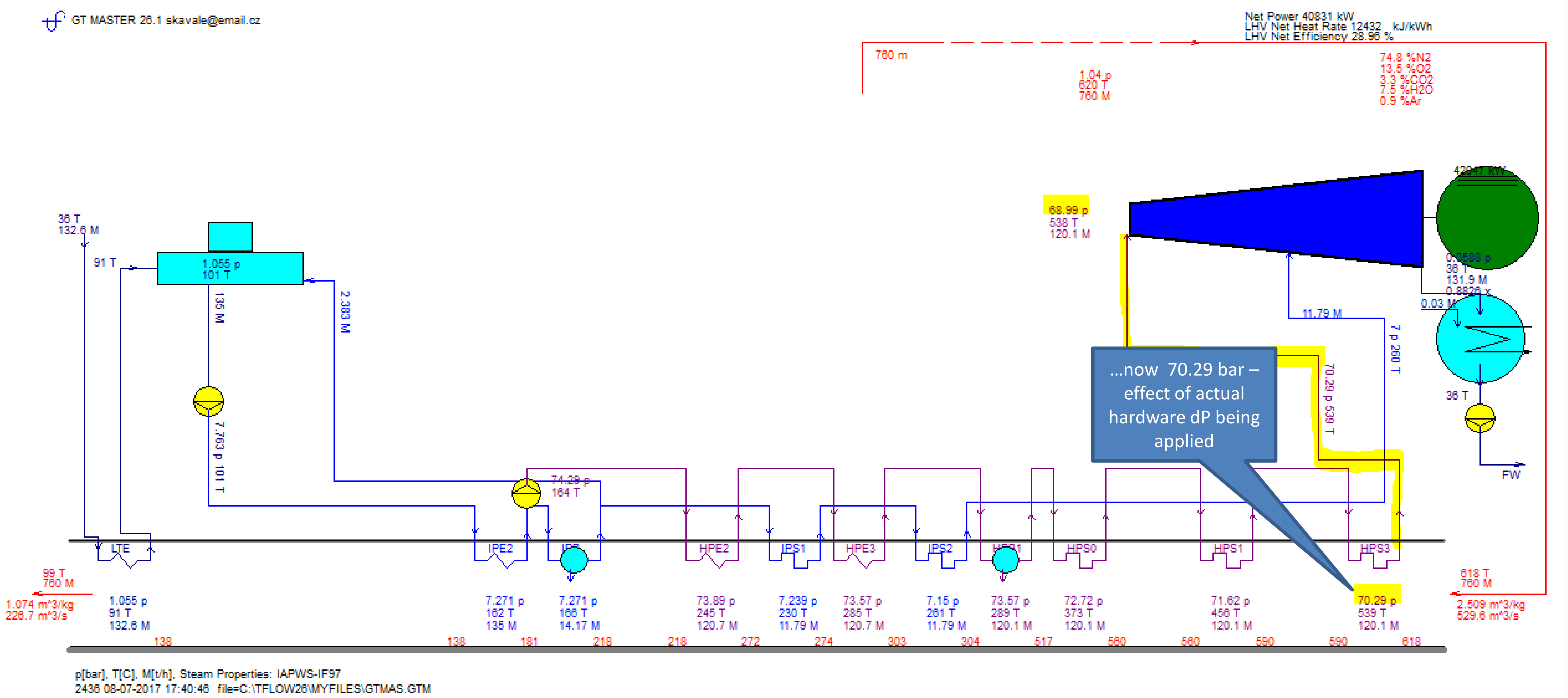
Methodology 3 – GTM Input Screen

Note the difference in Resistance Co- Efficients between the Methodology 2 & Methodology 3 GTM Input screens… reason = ???





Methodology 3 – GTM Output



Methodology – Conclusions

Methodology 1- Most likely use when the design of a new plant is required.
Methodology 3- Appropriate when are replicating an existing plant design and many of the physical parameters for pipe runs and heat transfer areas can be replicated in GTPro

	Method 1	Method 2	Method 3
GT PRO Defaults			
Water-side pressure drop in HRSG heat exchangers	User-defined	User-defined	Hardware
Water-side pressure drop correction factor in HRSG heat exchangers	Computed	Computed	1
Switch to include radiation heat transfer from GT or DB exhaust to downstream heat exchanger	Off	Off	On
Pressure drop in heat balance pipes	User-defined	User-defined	Hardware
Switch to estimate buoyancy and pressure losses in HRSG stack	Off	Off	On
Switch to include hydrostatic correction for HRSG drum elevation	Off	Off	On
Switch to add heat rejected from auxiliary heat exchangers to the main plant cooling tower thereby increasing its size	Off	Off	On
GT MASTER Defaults			
HRSG heat exchanger water-side pressure drop correction factor	From GT PRO	1	1
HRSG heat exchanger gas-side pressure drop correction factor	From GT PRO	From GT PRO	From GT PRO
HRSG heat exchanger gas-side convective h.t.c. correction factors	From GT PRO	From GT PRO	From GT PRO
Switch to include radiation heat transfer from GT or DB exhaust to downstream heat exchanger	From GT PRO	On	On
Switch to include hydrostatic correction for drum elevation	From GT PRO	From GT PRO	From GT PRO
Calculation of pressure drop in heat balance pipes	Resistance Coefficient	PCE Hardware	PCE Hardware
Method to determine cooling water flow rate	User-defined	PCE Hardware	PCE Hardware
Switch to estimate buoyancy and pressure losses in HRSG stack	From GT PRO	On	On
Switch to add heat rejected from auxiliary heat exchangers to the main plant cooling tower thereby increasing its size	From GT PRO	From GT PRO	From GT PRO

Methodology in STP/M

- Define at the New Session window
- In contrast to GTP, have fewer parameters impacted

	Methodology		
STEAM PRO Defaults	1	2	3
1. Pipe dp	Udf	Udf	PHW
2. Conv. HX water dp	Udf	Udf	PHW

STEAM MASTER Defaults	1	2	3
1. Pipe dp	RC	PHW	PHW
2. Conv. HX water dp CF	STP	1	1
3. Cooling water flow	Udf	PHW	PHW

Udf: User-defined
PHW: PEACE Hardware (if licensed)
RC: Resistance coefficient

Resistance Coefficient vs Actual Hardware (GTM)

3.3.1 Pipe Pressure Drop Calculation - Resistance Coefficient Method

This finds the off-design pressure drop from the equation:

$$\Delta P = R\, v\, m^2$$

where

- ΔP = pipe pressure loss
- R = pipe resistance coefficient
- v = average steam specific volume
- m = steam mass flow rate

3.3.2 Pipe Pressure Drop Calculation - PEACE Hardware Method

This method is only available in combined GTM/PCE mode. It uses the actual pipe hardware description, such as diameter, length, number of fittings of each type, and a wall roughness commensurate with the pipe's material. It computes friction factor as a function of Reynolds Number and wall roughness, to find pressure drop from the equation:

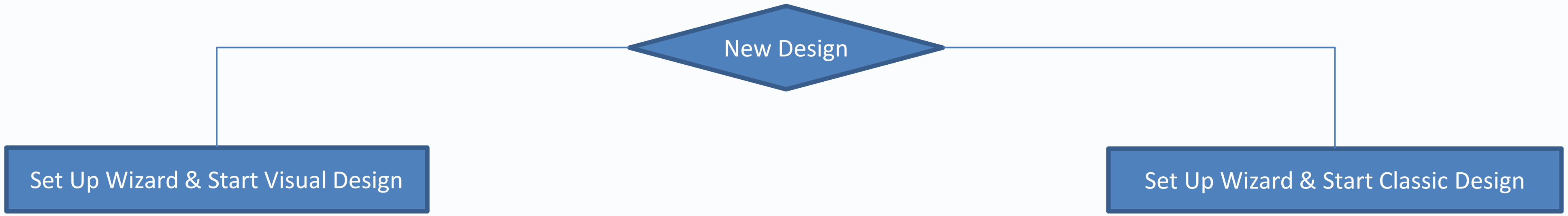
$$\Delta P = f\{ (L+\Sigma L_e)/D \}\ ½\ \rho\ V^2 \qquad (3\text{-}2)$$

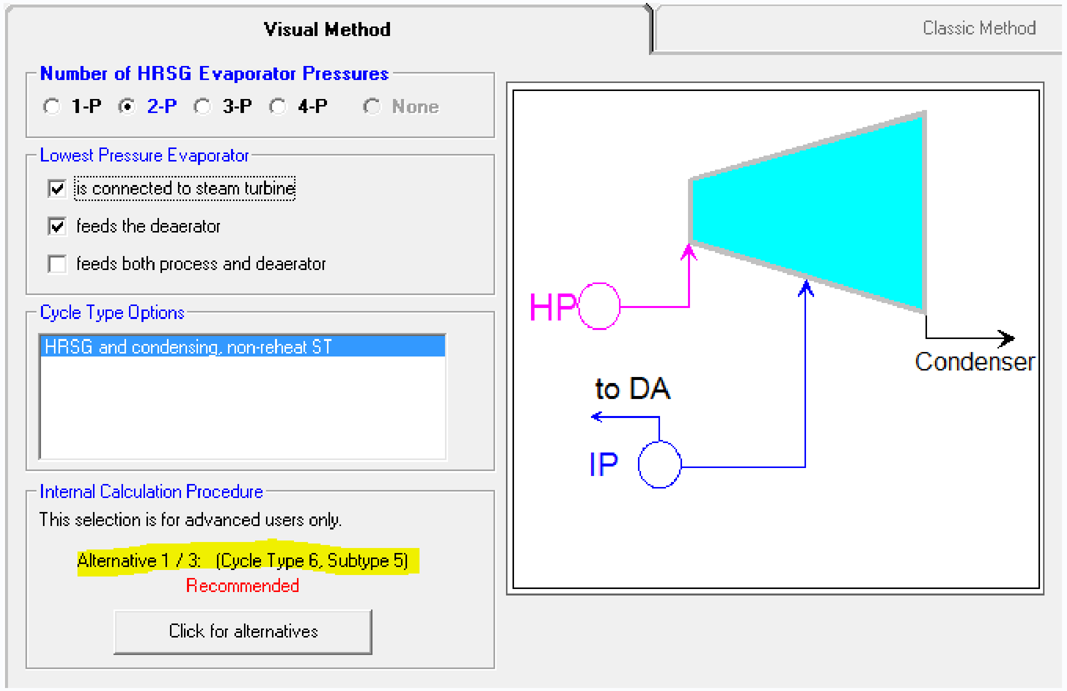
where

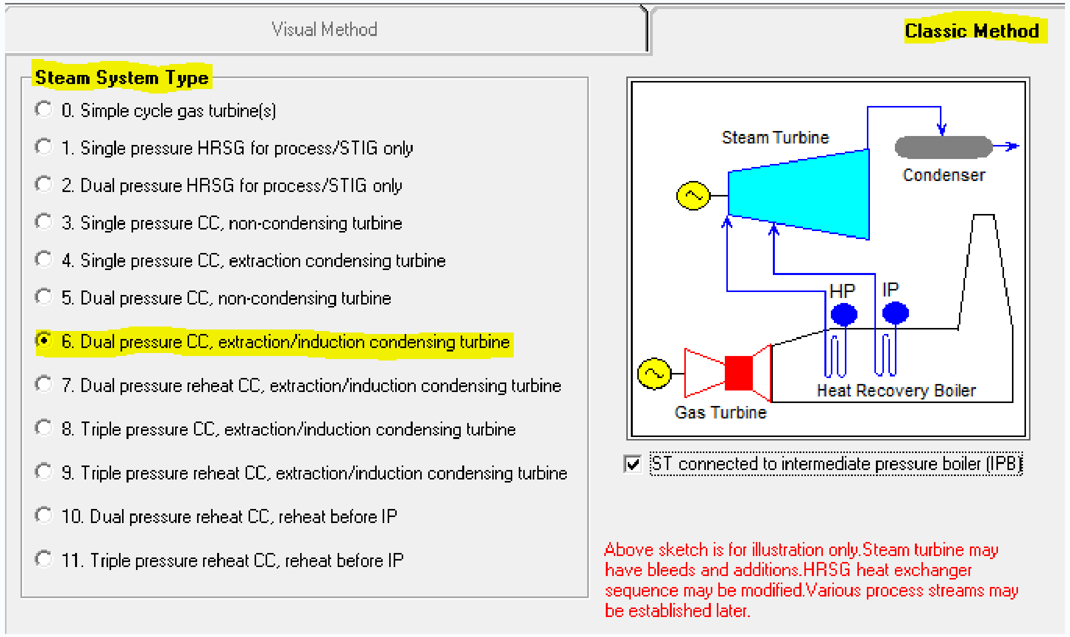
- ΔP = pipe pressure loss
- f = pipe friction factor, a function of Reynolds Number and pipe wall roughness
- L = pipe length
- ΣL_e = sum of equivalent lengths for all fittings (elbows, valves, etc.) in the pipe
- D = pipe diameter
- ρ = steam or water density, averaged between pipe inlet and exit states
- V = steam or water velocity, averaged between pipe inlet and exit states

Thermoflow

….further to the NEW DESIGN topic….







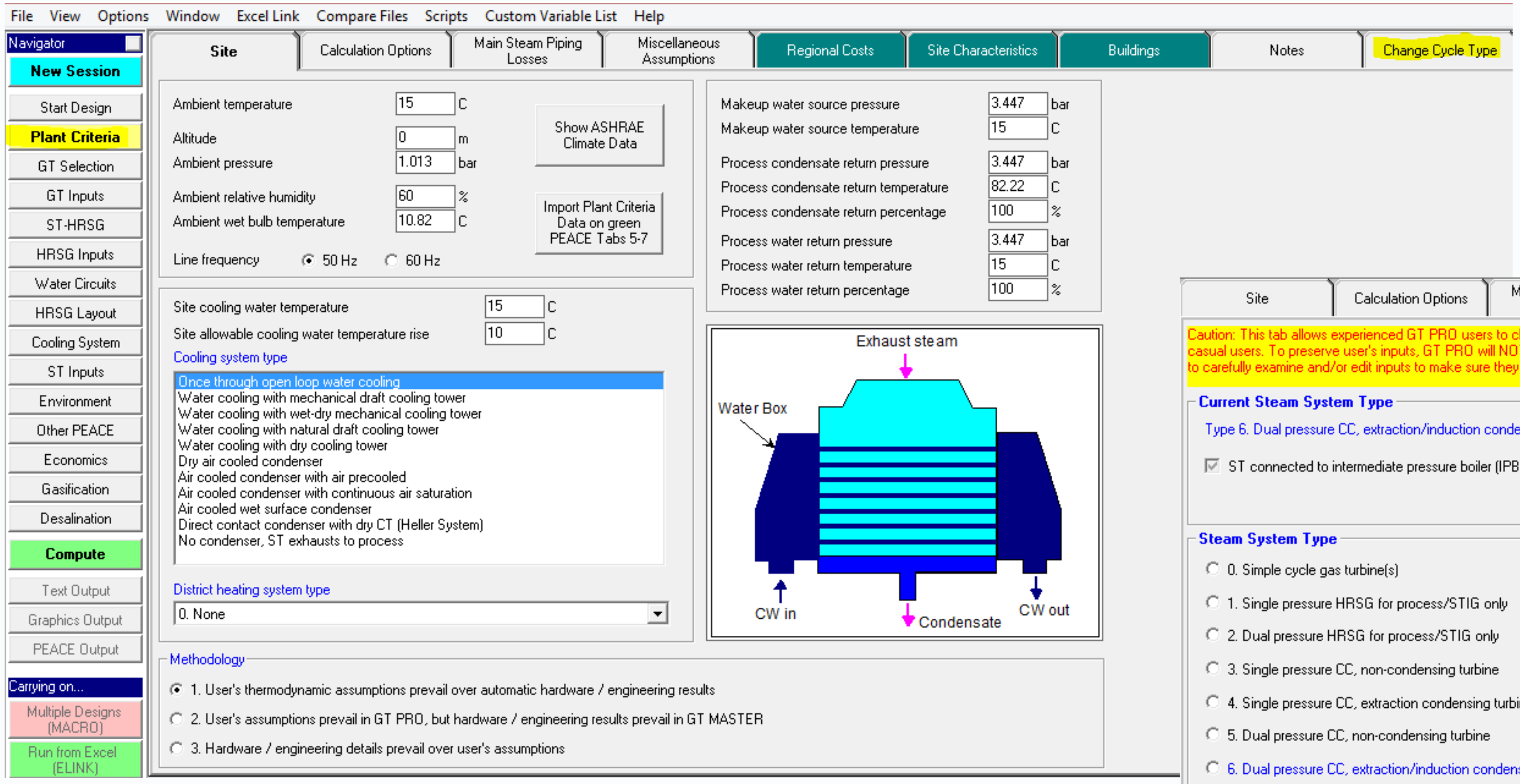
….further to the NEW DESIGN topic (continued)….

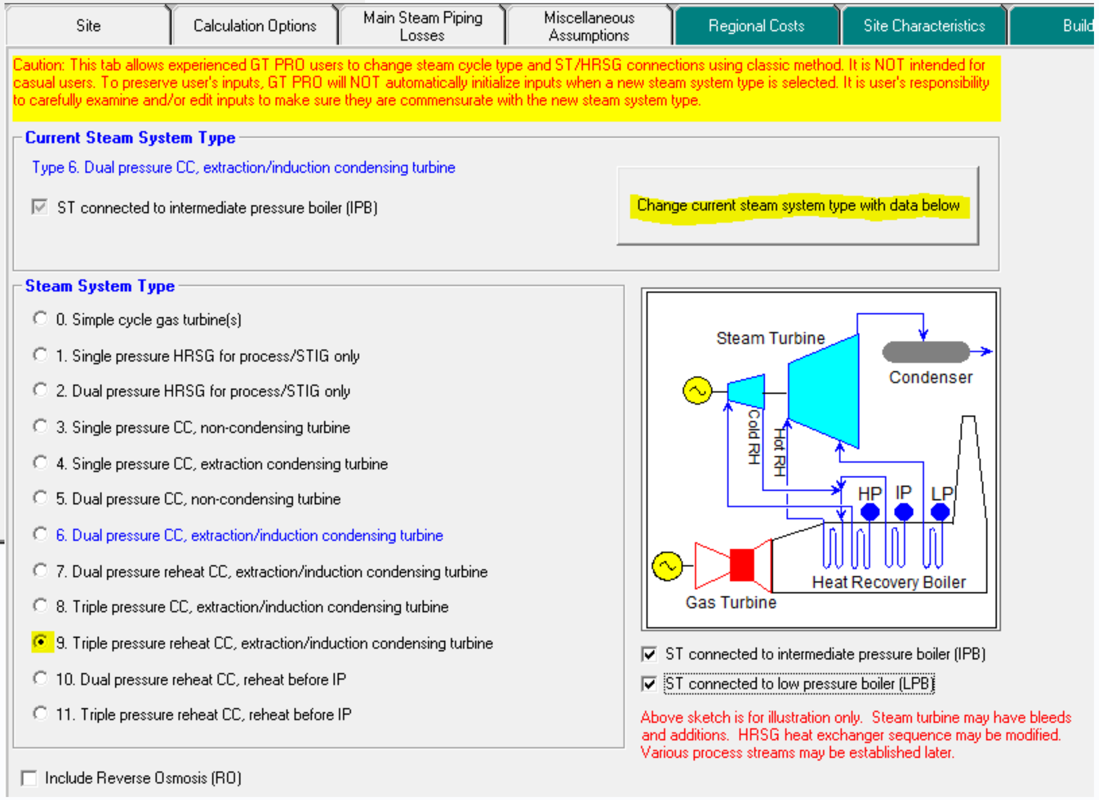
Setup Wizard & Start Visual Design – this is the recommended method of starting a new design. Ref Help > GTPro > Ch.2 & Ch.3. This start method is intended for less experienced users and provides more internal mechanisms to ensure that a sound thermodynamic model results.

Setup Wizard & Start Classic Design – this is the alternative method of starting a new design. Ref Help > GTPro > Ch.2 & Ch.3. This start method has more flexibility in the design and so requires more experience on the part of the user to ensure that a sound design results

Changing the Cycle Type

If required, the design (once defined in Visual Method say) can be changed at the Plant Criteria Screen/Change Cycle Type Tab. This then opens the Classic Method type options as shown below.





In this case the design was initially defined by the Visual Method (2 PL, non reheat). The design was then changed to a Type 9 (3 PL, non reheat). Note the cautionary highlighted test. Once the new design is chosen, confirm the new design by clicking on the "Change Current Steam System Type With Data Below" in order for the changes to take effect.

Q & A Time….