Welcome!

Webinar #31:
Modelling M on N Systems

13 Feb 2019

Agenda:

* Introduction
* Modelling M on N systems in GTPM, Design and Simulation
* Modelling M on N systems in STPM, Design and Simulation
* Using TFX for modelling M on N systems: standalone, link or import
* Design a M on N plant in TFX with variable M and N using scripts
* Q & A Session

Presenter: IGNACIO MARTIN (SPAIN)
Support: Meritt Elmasri (U.S. HQ)

Thermoflow Training and Support

- Standard Training
- On site training course
- User's Meetings / Advanced Workshops
- Webinars when new version is released
- Help, Tutorials, PPT, Videos
- Technical Support

→ **Feature Awareness Webinars**

Feature Awareness Webinars

1- Assemblies in TFX, June 2016
2- Scripts in Thermoflow programs, GTP-GTM-TFX
3- Multi Point Design in GTP-GTM
4- Reciprocating Engines in TFX
5- TIME in GTM
6- Matching ST Perfromance in STP
7- Modeling Solar Systems in TFX
8- Combining THERMOFLEX & Application-Specific Programs
9- Methods & Methodology in GT PRO & STEAM PRO
10- Supplementary Firing & Control Loops in GT PRO & GT MASTER
11- The Wind Turbine Feature in Thermoflex
12- Modelling GT's in Thermoflow programas-1
13- Thermoflex for on line and off line performance monitoring
14- Tflow 27, what's new
15- Modelling GT's in Thermoflow programas-2
16- Multi Point Design in GTP-GTM
17- Total Plant Cost in TFX
18- Steam Turbine Tunning
19- User Defined Components in TFX
20- Cooling System Optimization

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31- Modelling M on N Systems

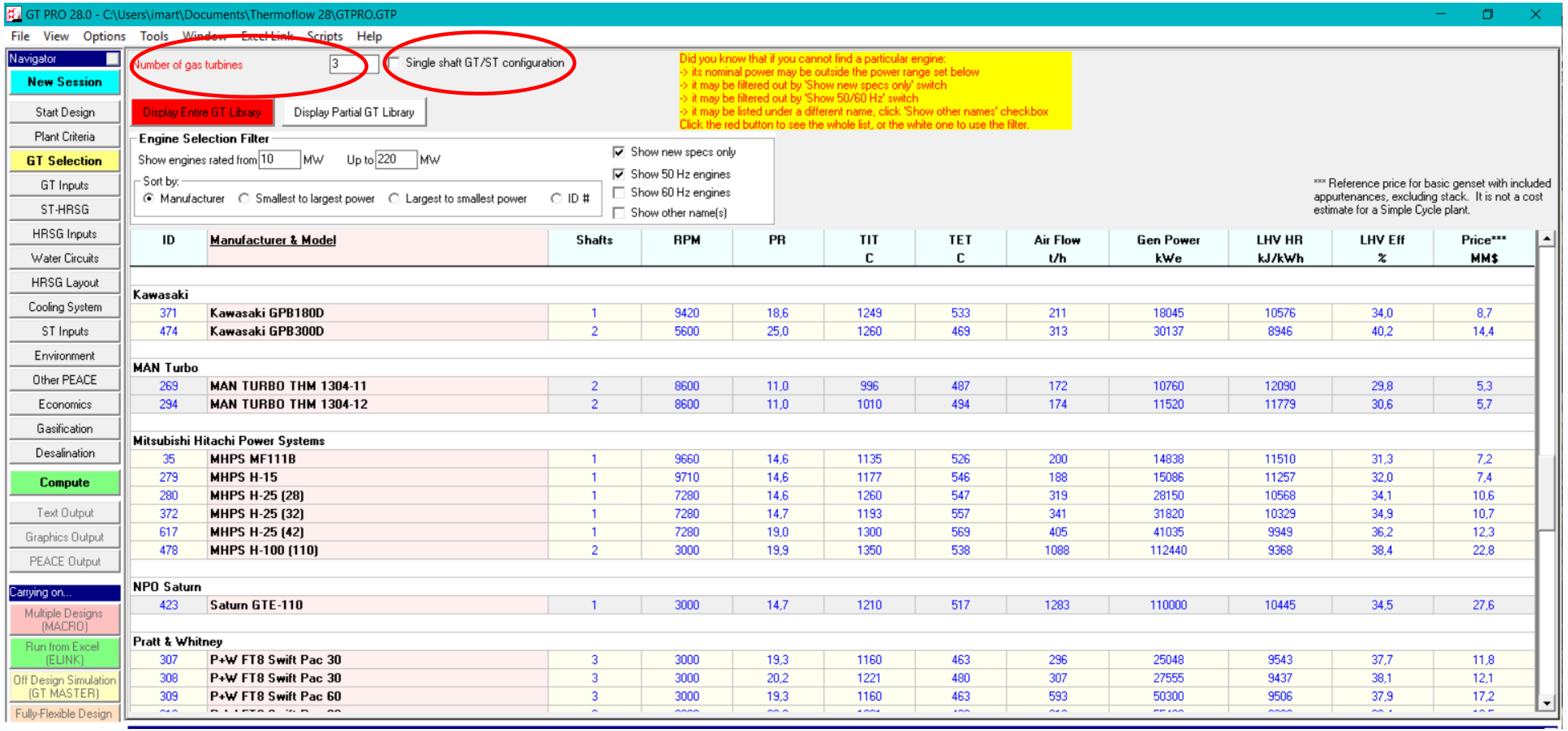
M on N Systems

- **GTPM**: **M** x Gas Turbine + **M** x HRSG + **N** x Steam Turbine-Cooling System
- **STPM**: **M** x Boiler + **N** x Steam Turbine-Cooling System
- **TFX**: Any Combination

Design M on N Systems in GT Pro

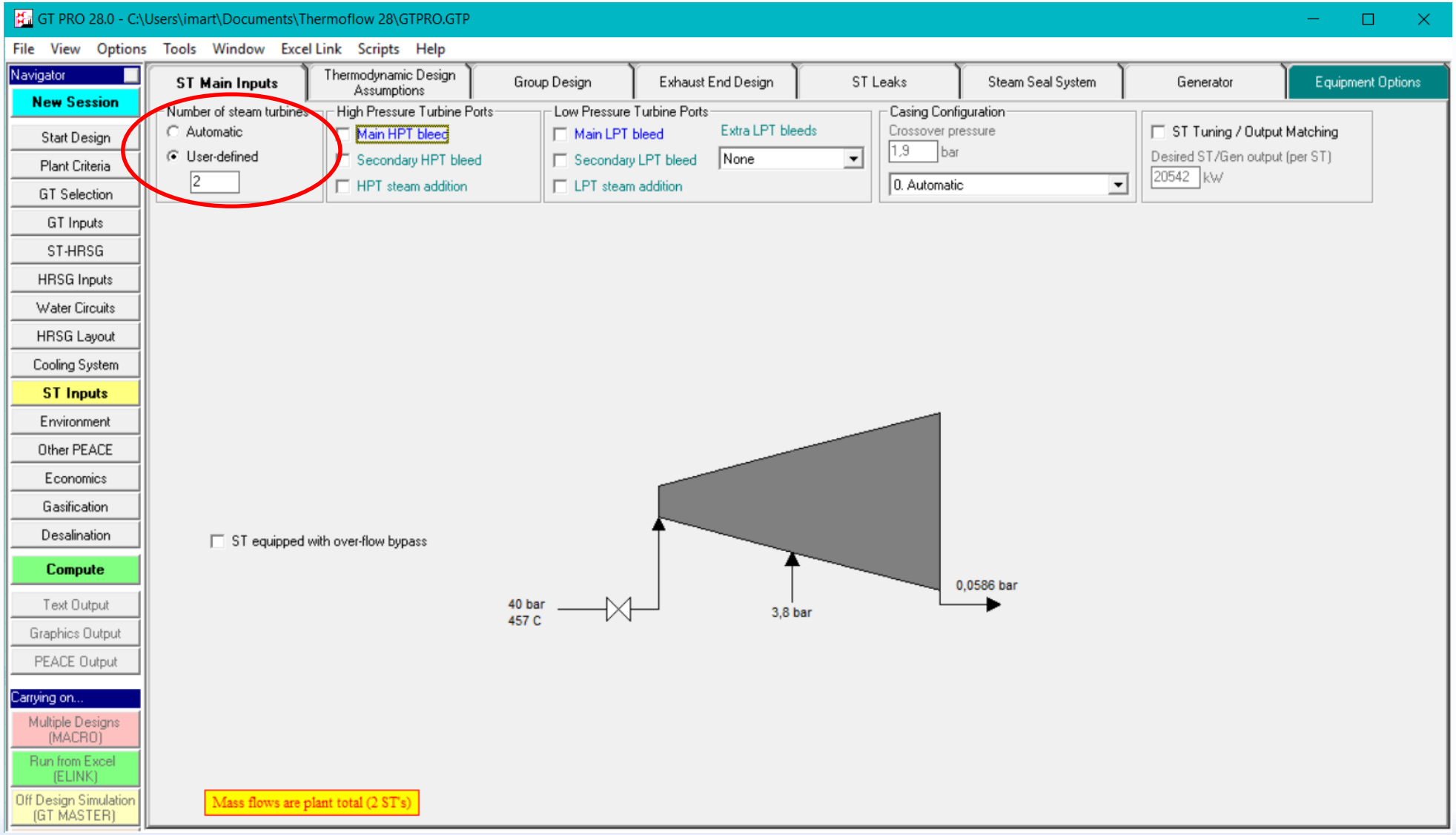
- In GT Pro the user can select:
  - A number of **M** GT units and equal number of HRSGs →GT-HRSG = 1 block
  - A number of **N** ST units and equal number of Cooling Systems
  - M and N can be different unless you select a “Single Shaft” Configuration
  - All the GT, HRSG, ST and Cooling Systems must be exactly the same: there is only one input for all the inputs related to them

Design M on N Systems in GT Pro, Inputs, Select M

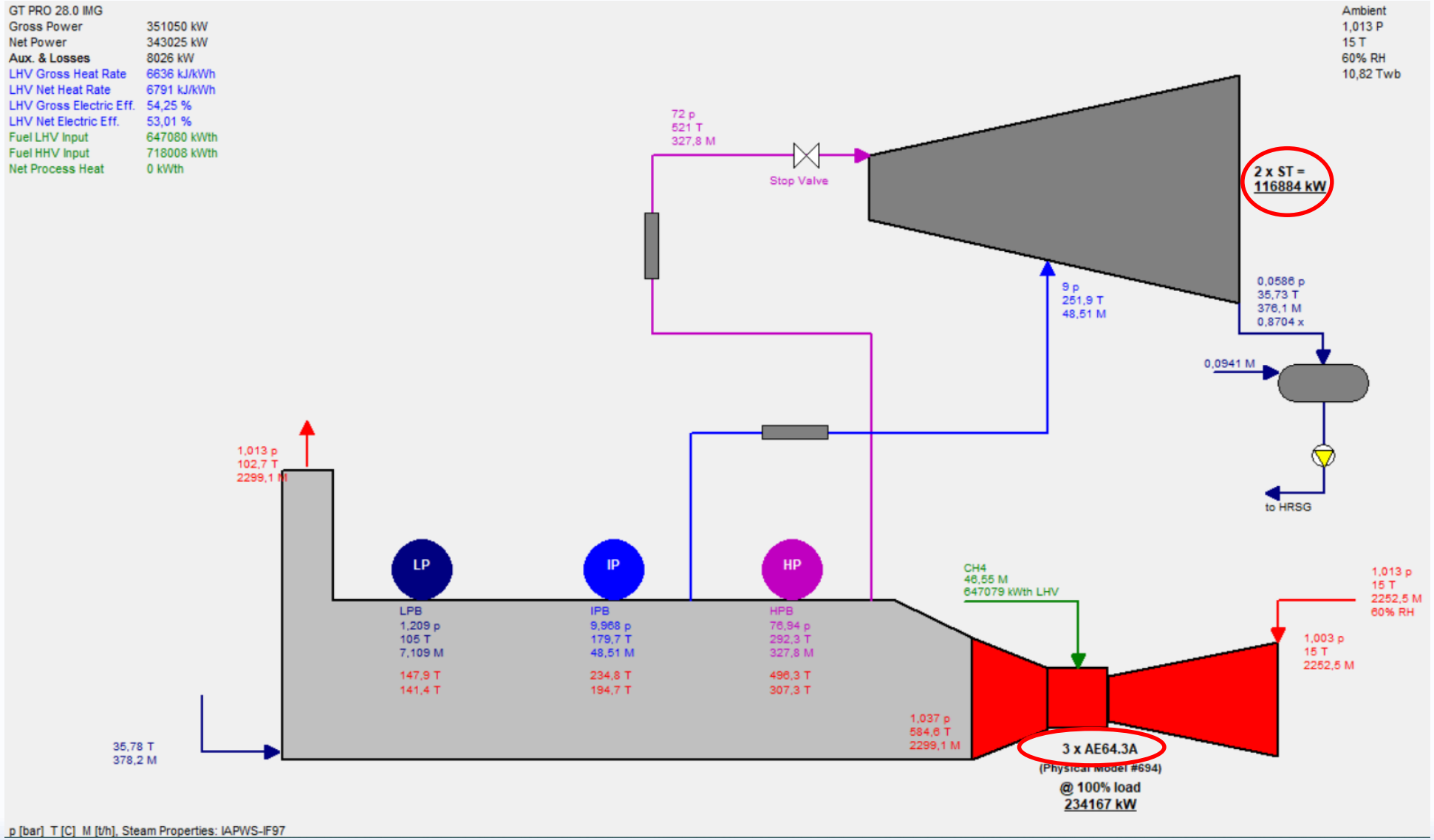


ID	Manufacturer & Model	Shafts	RPM	PR	TIT C	TET C	Air Flow t/h	Gen Power kWe	LHV HR kJ/kWh	LHV Eff %	Price*** MM$
Kawasaki											
371	**Kawasaki GPB180D**	1	9420	18,6	1249	533	211	18045	10576	34,0	8,7
474	**Kawasaki GPB300D**	2	5600	25,0	1260	469	313	30137	8946	40,2	14,4
MAN Turbo											
269	**MAN TURBO THM 1304-11**	2	8600	11,0	996	487	172	10760	12090	29,8	5,3
294	**MAN TURBO THM 1304-12**	2	8600	11,0	1010	494	174	11520	11779	30,6	5,7
Mitsubishi Hitachi Power Systems											
35	**MHPS MF111B**	1	9660	14,6	1135	526	200	14838	11510	31,3	7,2
279	**MHPS H-15**	1	9710	14,6	1177	546	188	15086	11257	32,0	7,4
280	**MHPS H-25 (28)**	1	7280	14,6	1260	547	319	28150	10568	34,1	10,6
372	**MHPS H-25 (32)**	1	7280	14,7	1193	557	341	31820	10329	34,9	10,7
617	**MHPS H-25 (42)**	1	7280	19,0	1300	569	405	41035	9949	36,2	12,3
478	**MHPS H-100 (110)**	2	3000	19,9	1350	538	1088	112440	9368	38,4	22,8
NPO Saturn											
423	**Saturn GTE-110**	1	3000	14,7	1210	517	1283	110000	10445	34,5	27,6
Pratt & Whitney											
307	**P+W FT8 Swift Pac 30**	3	3000	19,3	1160	463	296	25048	9543	37,7	11,8
308	**P+W FT8 Swift Pac 30**	3	3000	20,2	1221	480	307	27555	9437	38,1	12,1
309	**P+W FT8 Swift Pac 60**	3	3000	19,3	1160	463	593	50300	9506	37,9	17,2

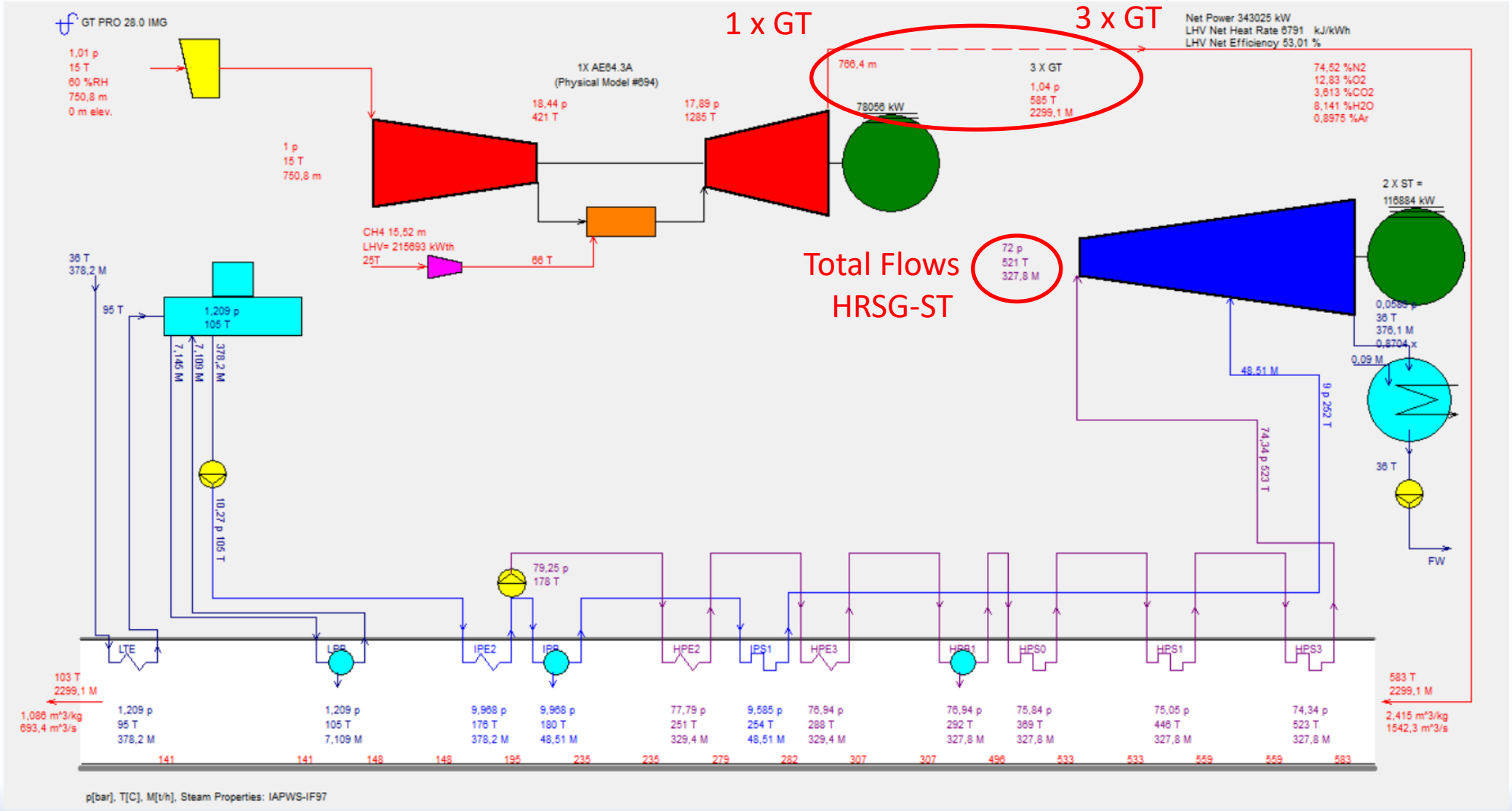
Design M on N Systems in GT Pro, Inputs, Select N



Design M on N Systems in GT Pro, Outputs



Design M on N Systems in GT Pro, Outputs



Design M on N Systems in GT Pro

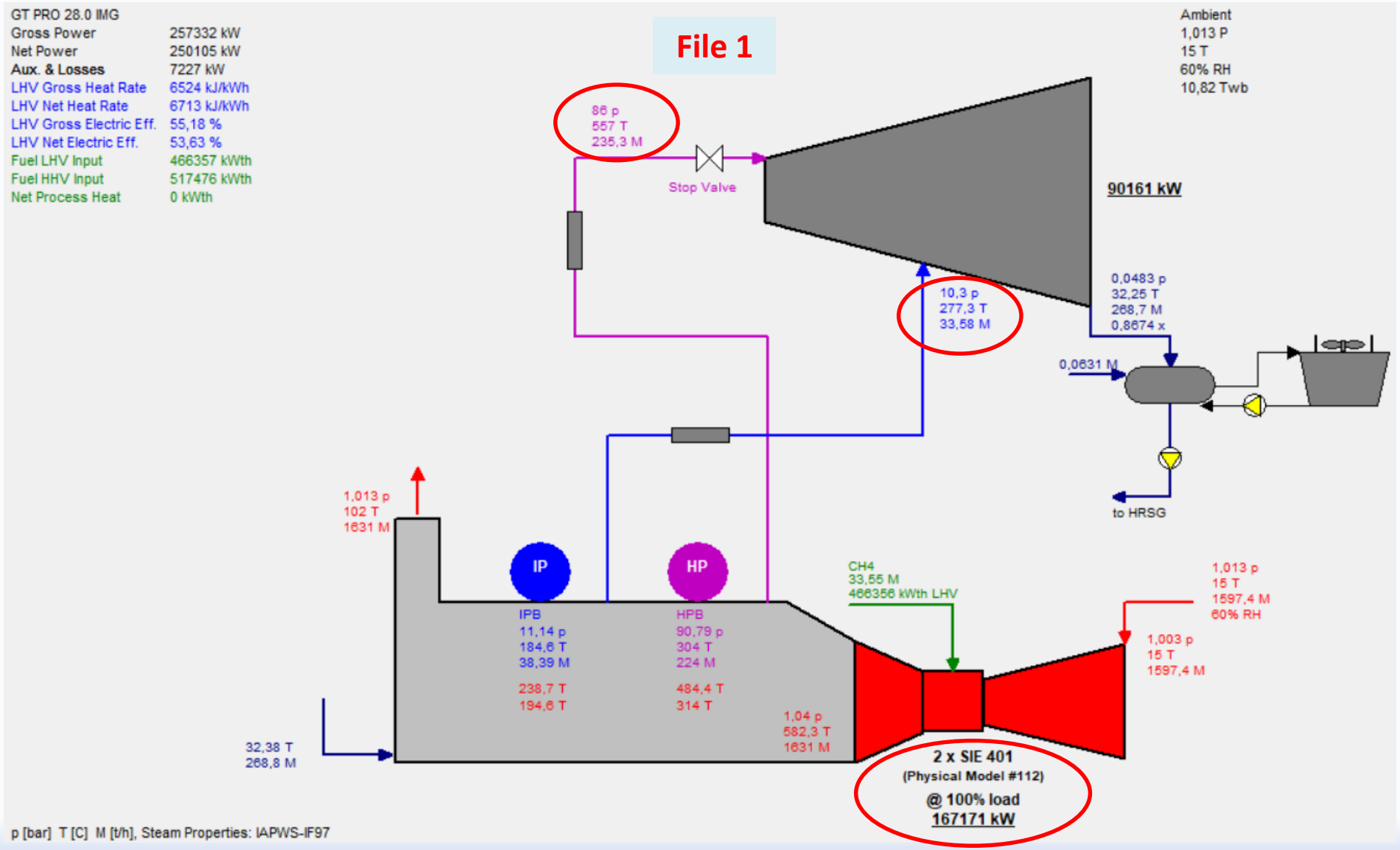
→ Example: How to design a system in GT Pro with **different Gas Turbine** models (2x1 2P combined cycle system, similar size GTs):

- Create 3 GT Pro files:
  - File 1: 2xGT (1)-HRSG (1) + 1xST
  - File 2: 1xGT (1)-HRSG (1)- ST(1)
  - File 3: 1xGT (2)-HRSG (2)

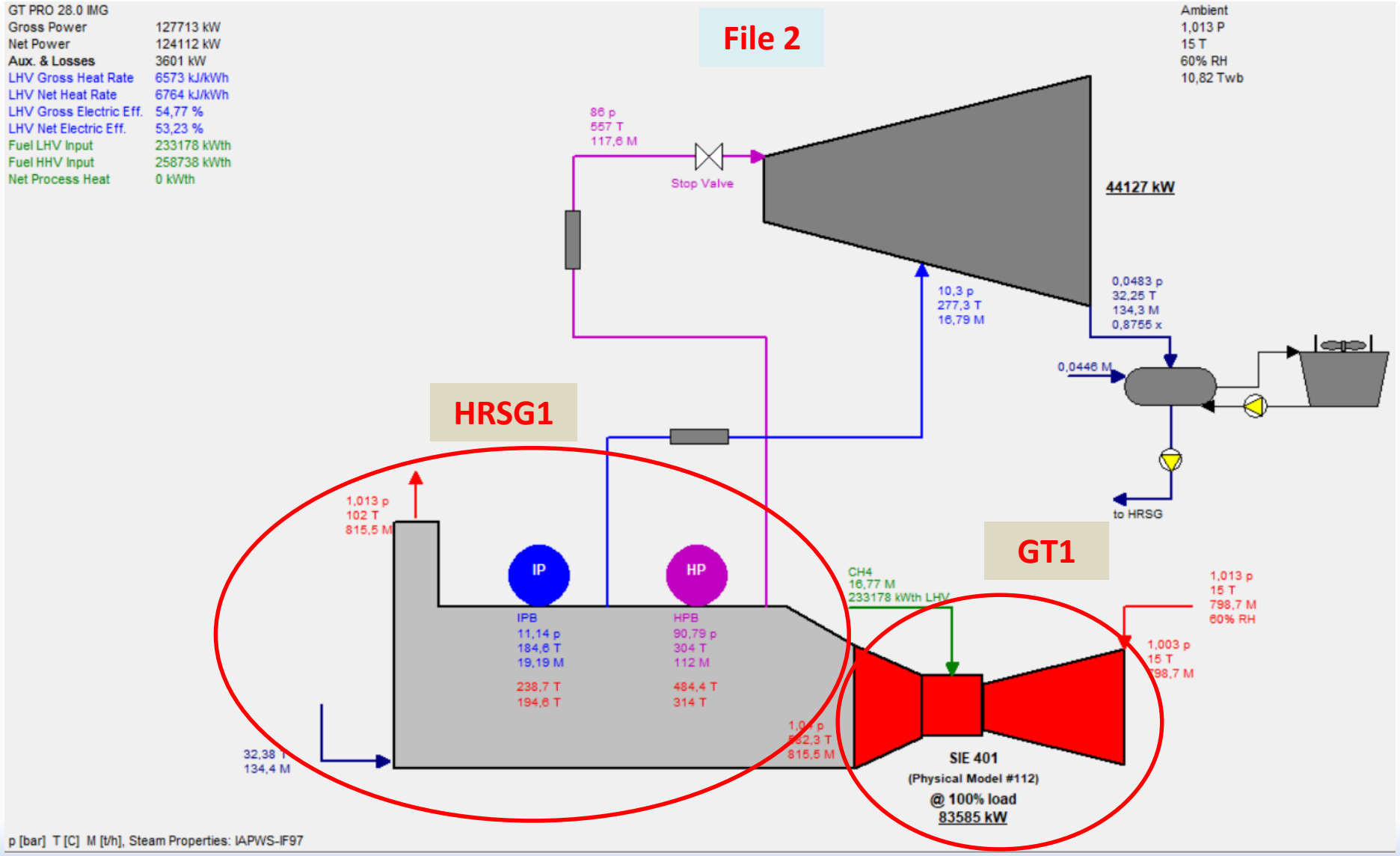
} → Check the Pinch & ST inlet *P* and *T*

- Add the steam from HRSG (2) from File 3 to the ST(1) in File 2

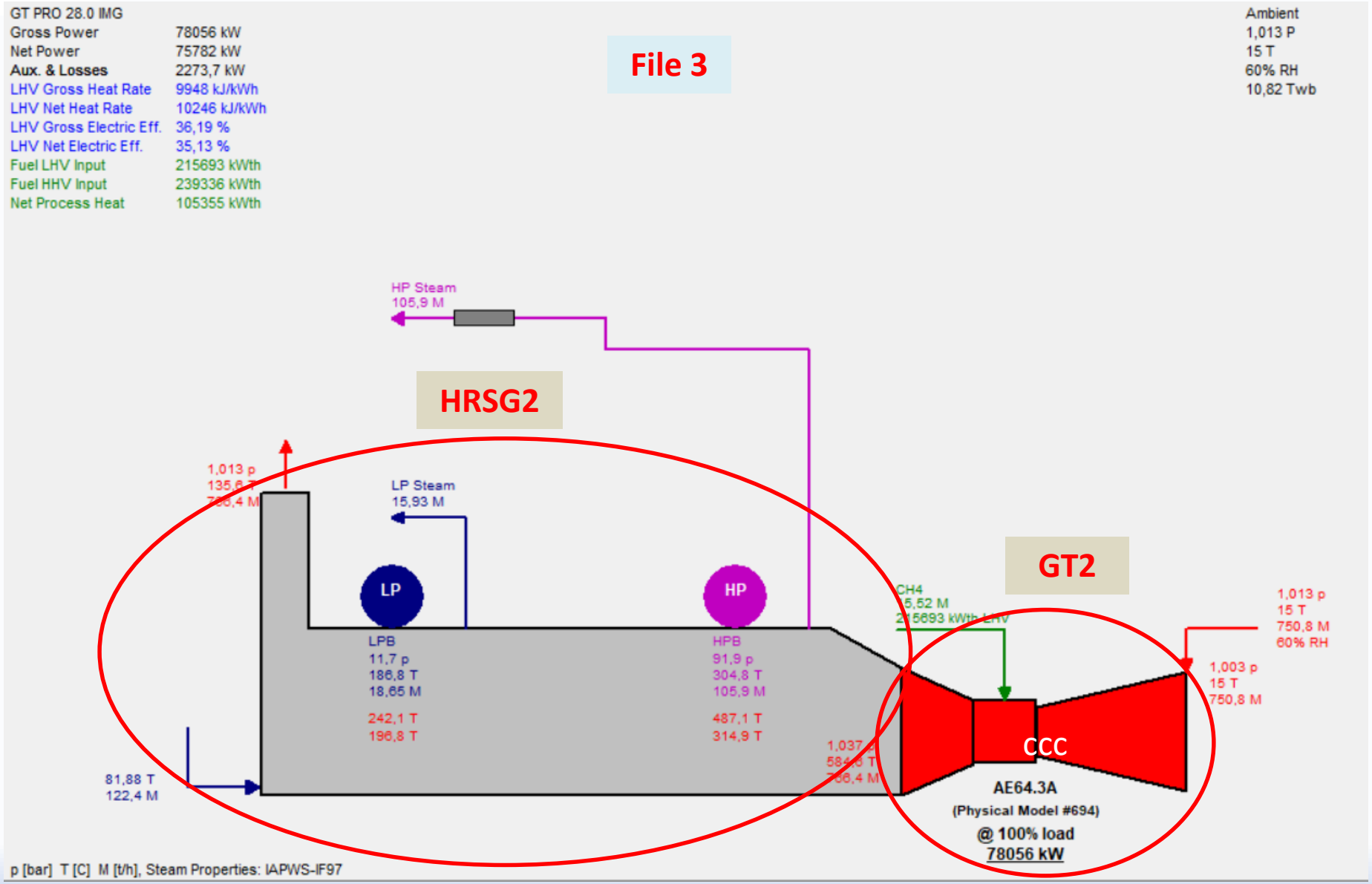
Example 2x1 System in GT Pro w/ different GT models



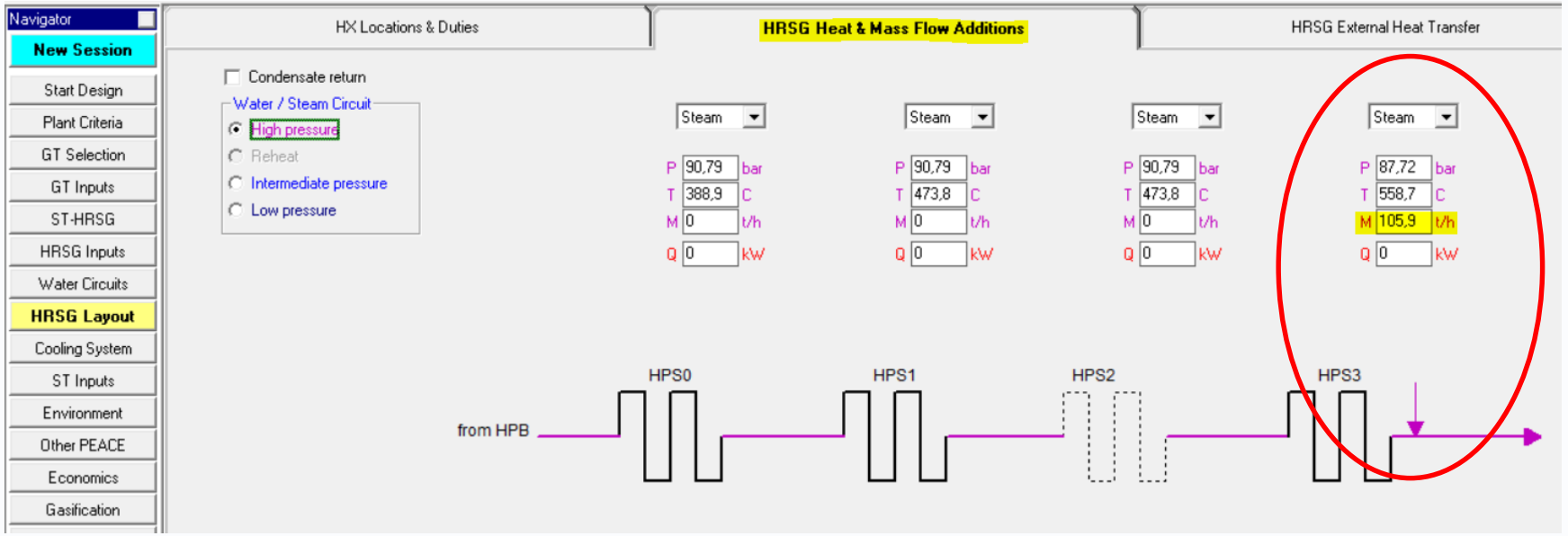
Example 2x1 System in GT Pro w/ different GT models

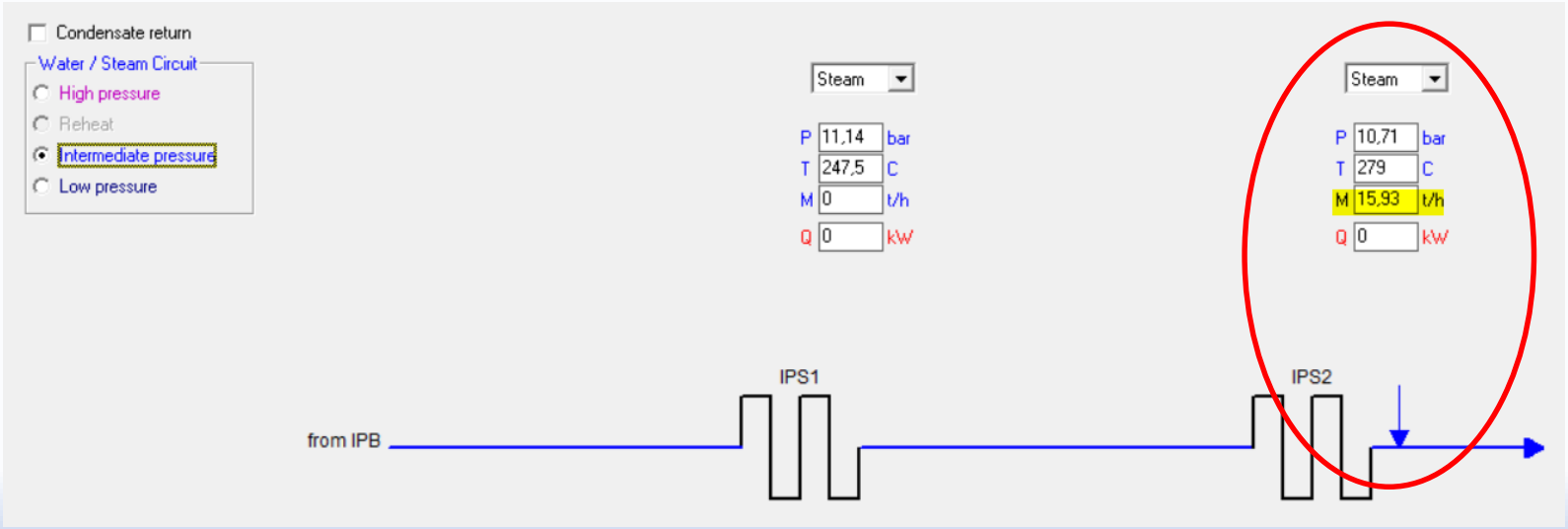


Example 2x1 System in GT Pro w/ different GT models

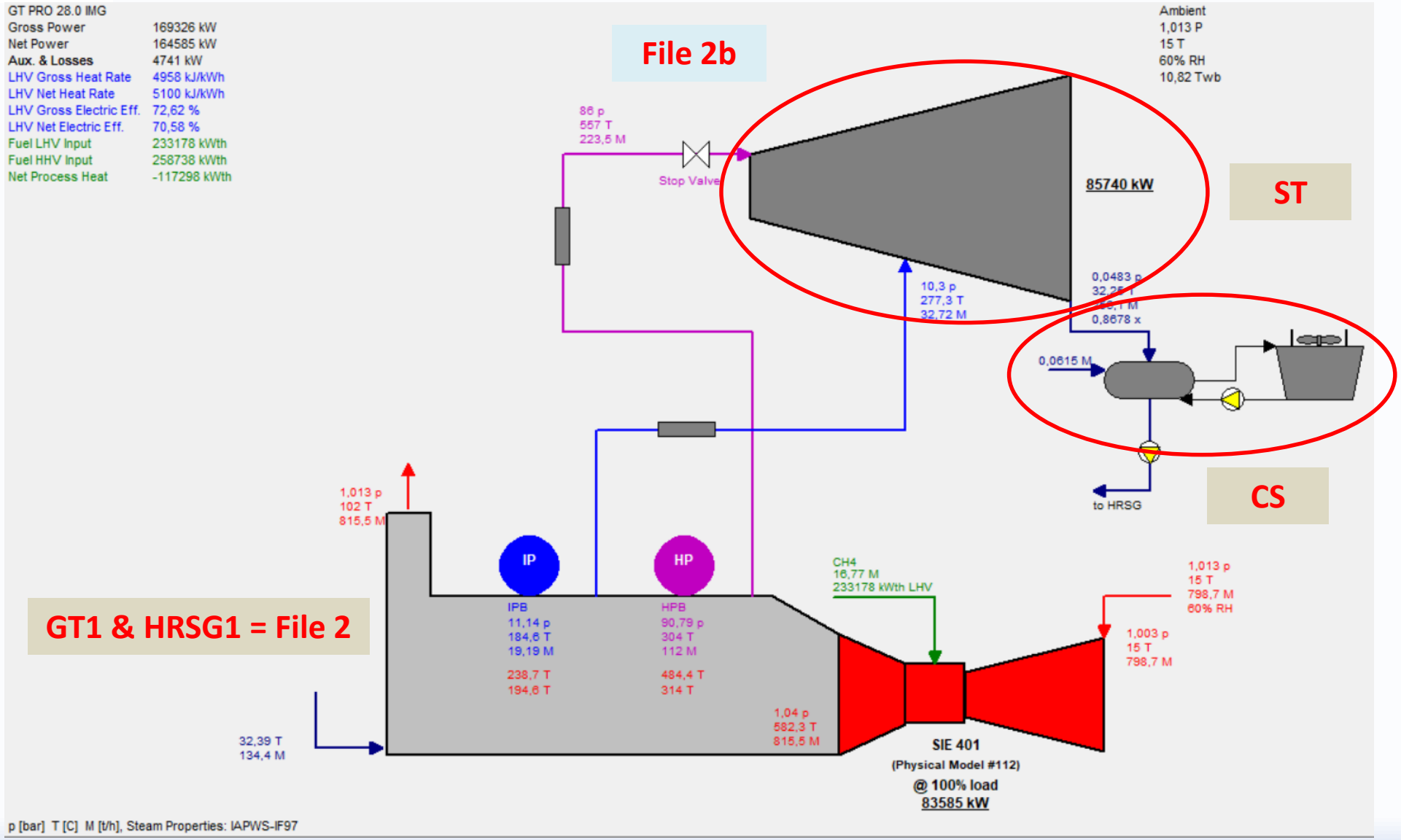


Example 2x1 System in GT Pro w/ different GT models

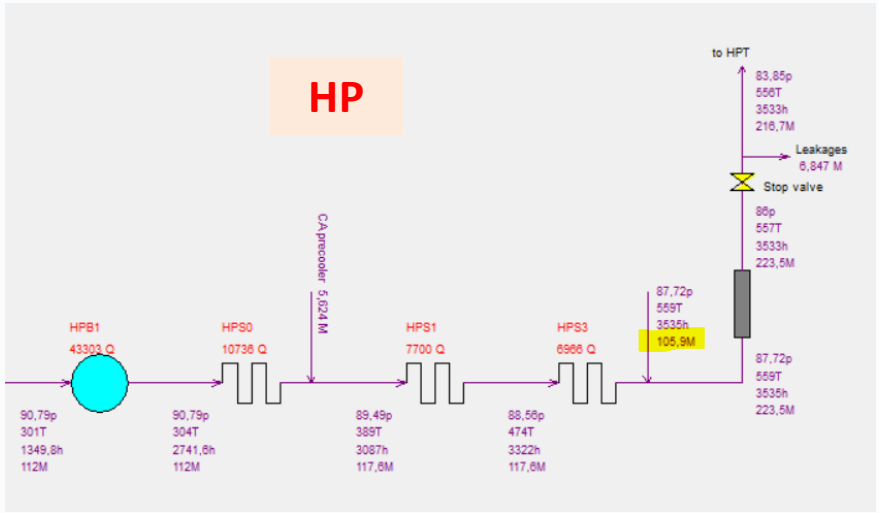


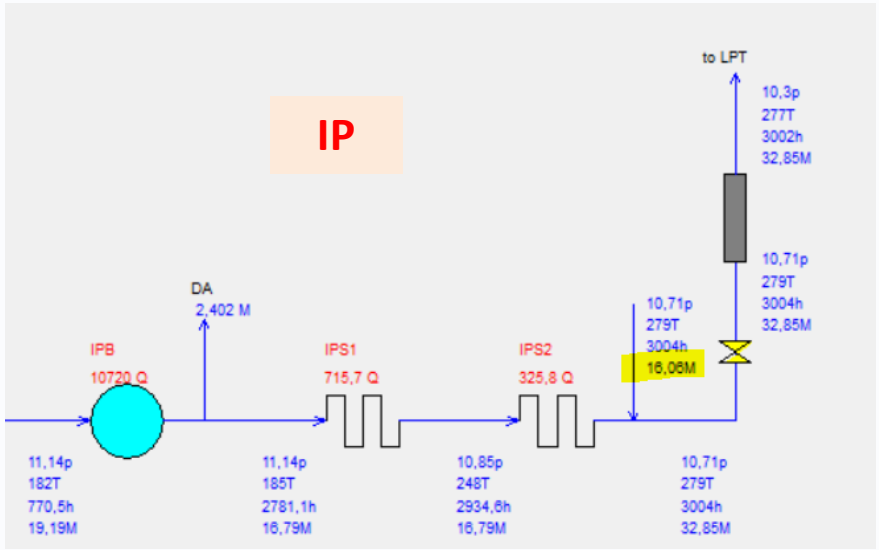


Example 2x1 System in GT Pro w/ different GT models

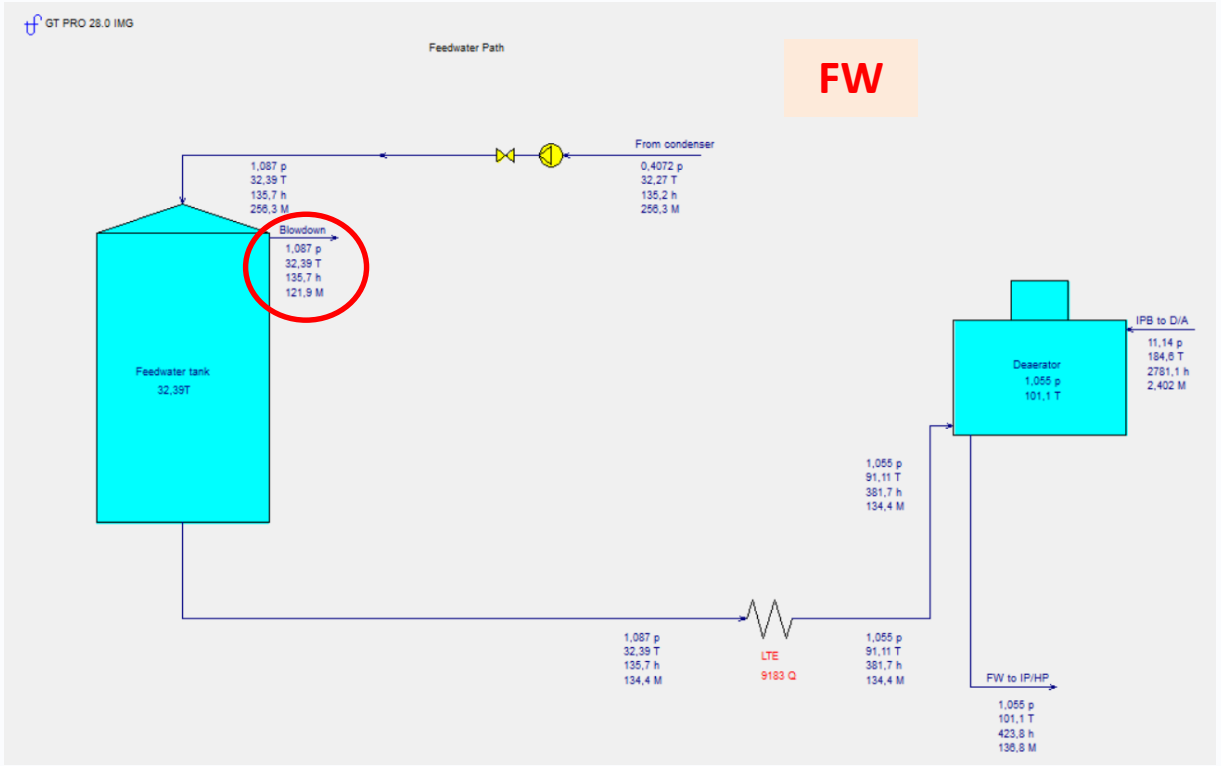


Example 2x1 System in GT Pro w/ different GT models





File 2b



Design M on N Systems in GT Pro

Components Design from each file

	GT	HRSG	ST	CS
File1	2xGT1	2xHRSG1	ST1	CS1
File2	1xGT1	1xHRSG1	ST2	CS2
File3	1xGT2	1xHRSG2		
File2b	1xGT1	1xHRSG1	ST	CS

Design M on N Systems in GT Pro

Integration of Results

- Gross Power
- Net Power - Auxiliaries
- Fuel consumption – Heat input
- Efficiency

- Plot
- Cost Estimation
- Financial

Design M on N Systems in GT Pro

Integration of Results, Energy

		Sum 2b+3	File 2b	File 3		File 1
Gross Power	kW	247.408				257.332
GT	kW		83.585	78.056		
ST	kW		85.767			
Auxiliaries **	kW	7.026	4.742	2.284		7.227
	% / GP	2,84%				2,81%
Net Power	kW	240.382				
Heat Input-LHV	kW	448.871	233.178	215.693		
Efficiency	%	53,55%				53,63%

Design M on N Systems in GT Pro

Integration of Results, Cost

		Total	Sum 2b+3	File 2b	File 3		File 1
Cost Estimation	M€		246,52	156,4	90,1		238,3
Net Power	MW		240	165	76		250
Specific Cost	USD/kW	?	1026	950	1190		953
Plot	Ha	?		2,066	1,351		2,508

Design M on N Systems in GT Pro

- Other Options
  - ELINK
  - Link in TFX
  - Import to TFX

Design M on N Systems in GT Pro using ELINK

File 2b

Computation Message ->		OK	OK
INPUT VARIABLE DESCRIPTION	**Units**	**Input**	Input
Addition/extraction @ HPS3 exit (plant total)	t/h	105,9	105,9
Addition/extraction @ IPS2 exit (plant total)	t/h	16,06	16,06
OUTPUT VARIABLE DESCRIPTION	**Units**	**Output**	Output
Plant gross output	kW	169.352	169.341
Plant net output	kW	164.611	164.600
Plant total fuel LHV chemical energy input (77F/25C)	kW	233.178	233.178
HPT pressure before stop valve	bar	86,0	86,0
HPT temperature before stop valve	C	557,0	557,0
HP/IP/LP Casing: Group LPTL - Group inlet pressure	bar	10,3	10,3
IP steam induction to LPT, after pipe Temperature	C	277,3	277,3

File 3

Computation Message ->		OK	OK
INPUT VARIABLE DESCRIPTION	**Units**	**Input**	Input
Main HP process pressure / HPT pressure before stop valve	bar	86,0	86,0
Main HP process temperature	C	557,0	557,0
Main IP process pressure / IP steam pressure @ turbine	bar	10,3	10,3
Main IP process temperature	C	277,3	277,3
OUTPUT VARIABLE DESCRIPTION	**Units**	**Output**	Output
Plant gross output	kW	78.056	78.056
Plant net output	kW	75.771	75.771
Plant total fuel LHV chemical energy input (77F/25C)	kW	215.693	215.693
HP superheater steam mass flow	t/h	105,9	105,9
IP superheater steam mass flow	t/h	16,06	16,06

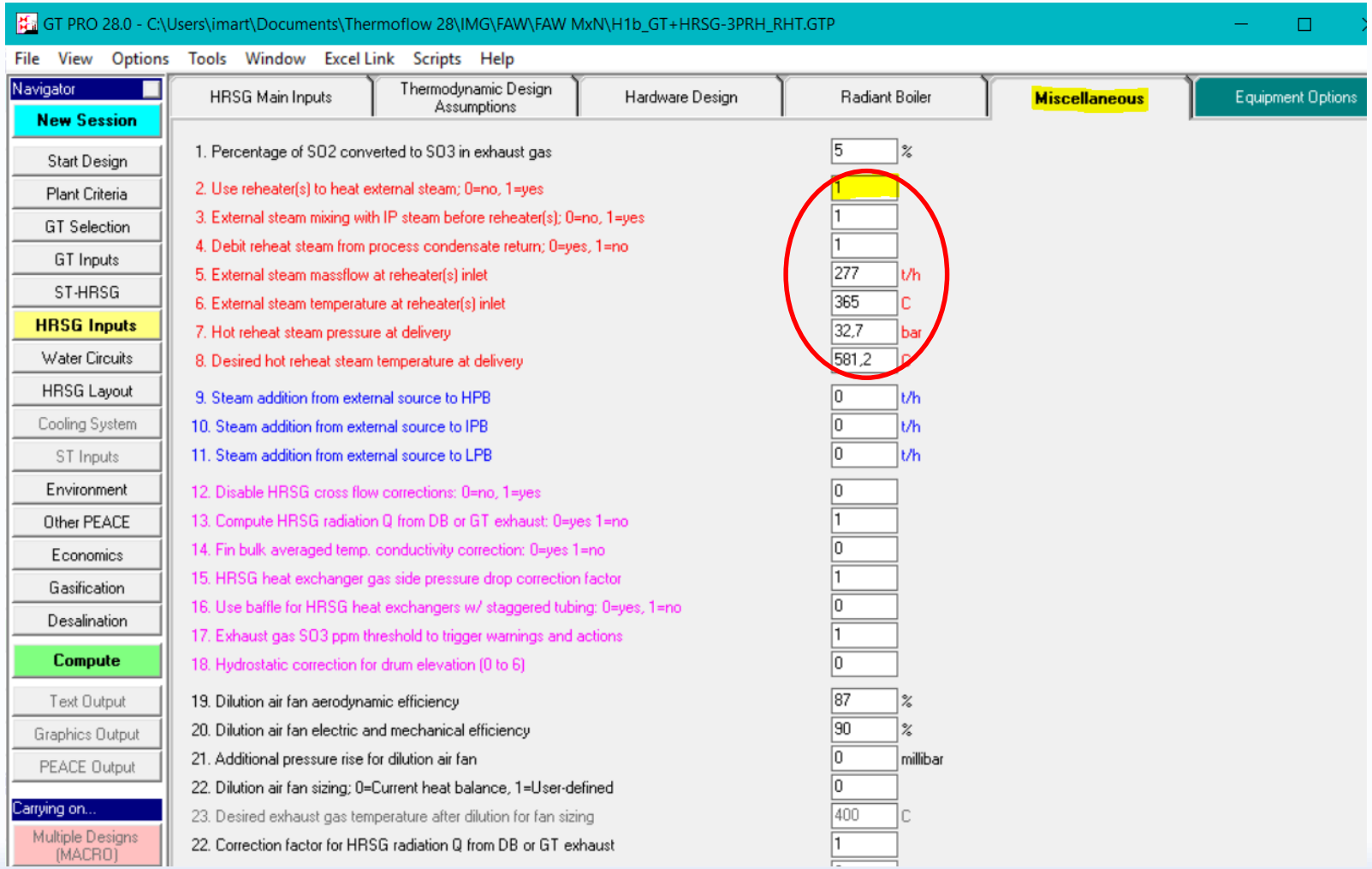
		Total	1	2
Gross P	kW	247.397	169.341	78.056
Net P	kW	240.371	164.600	75.771
Aux	kW	7.026	4.741	2.284
Heat Input LHV	kW	448.871	233.178	215.693
Net Eff LHV	%	53,6%	70,6%	35,1%

Design M on N Systems in GT Pro

- Other Examples
  - Case of 3P-RH
  - GTs with different Exhaust T

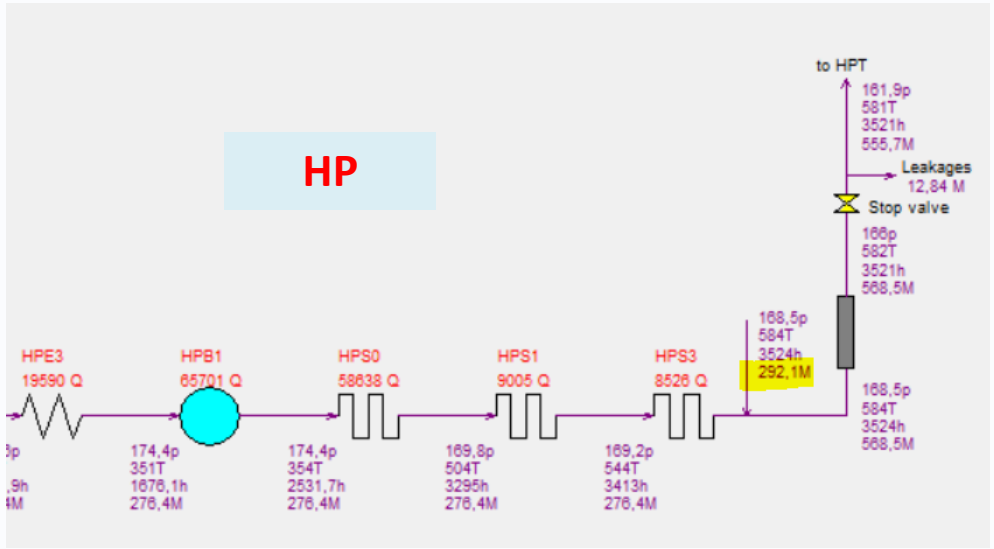
Design M on N Systems in GT Pro

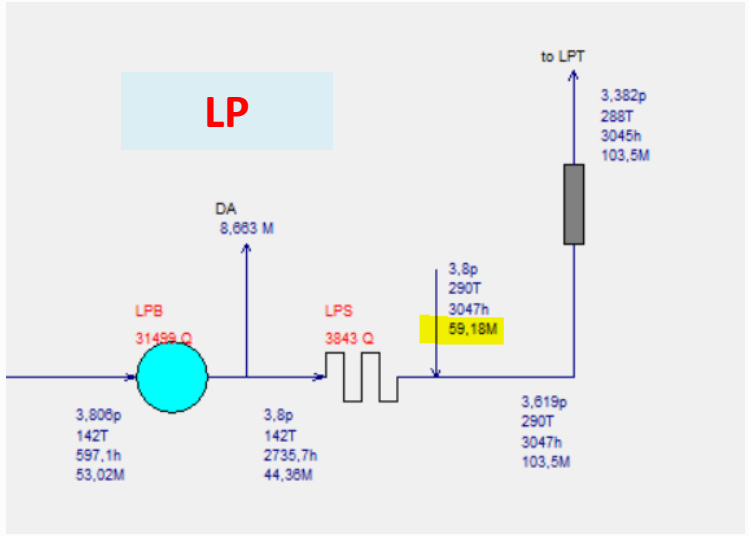
- Other Examples: RH Option

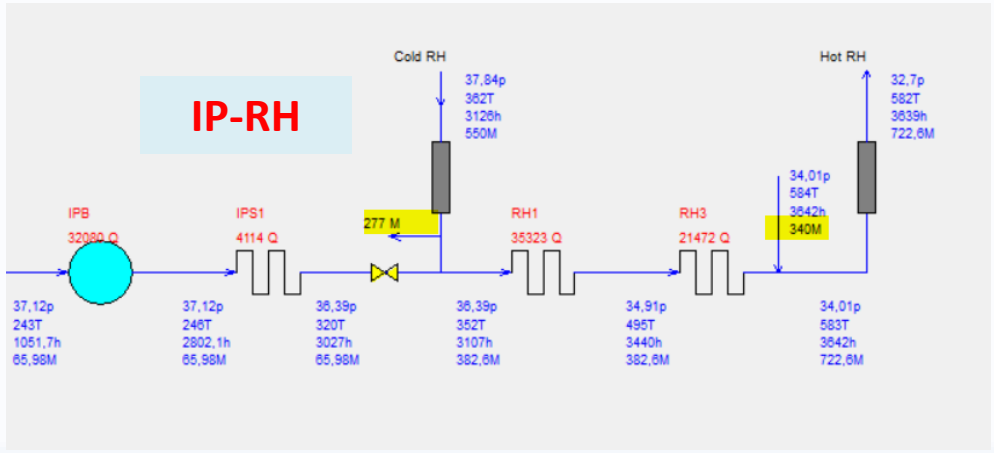


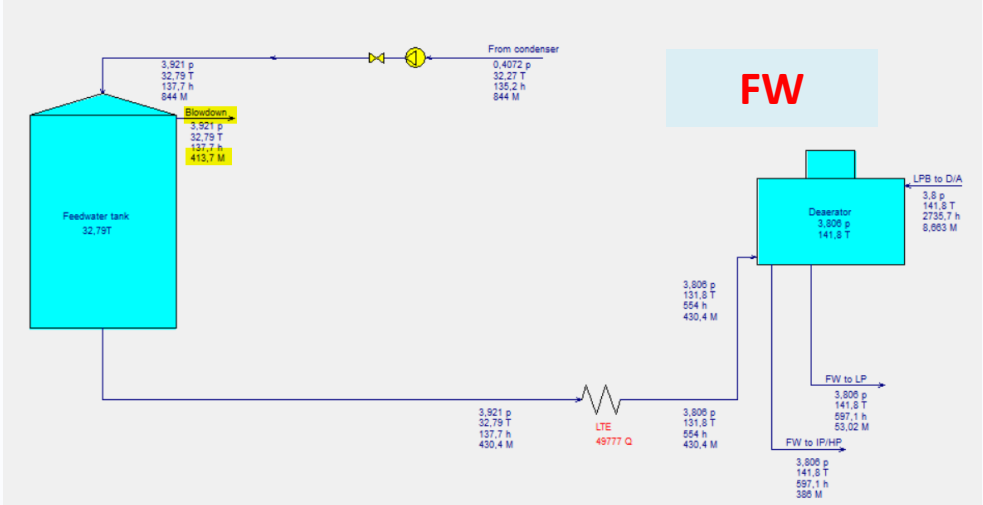
Design M on N Systems in GT Pro

- Other Examples: RH Option









Design M on N Systems in GT Pro

- Other Examples: Different Exhaust T
  - If the 2 GTs have a different exhaust T you can add a Duct Burner to the plant with a lower Tex, to match the final steam Temperatures
  - In GT Pro DB will come automatically to achieve the desired steam T
  - In GT Master you need to define a Control Loop to run the DB at any condition

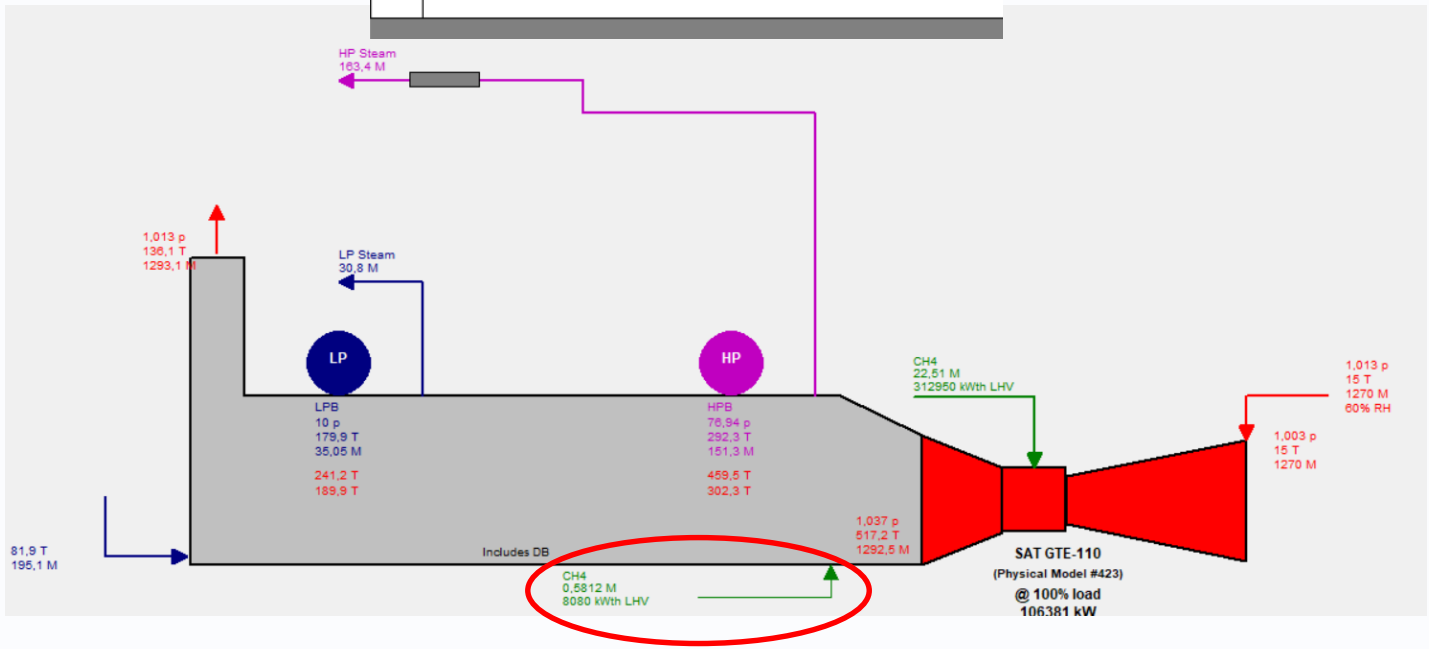
Design M on N Systems in GT Pro

GT Pro

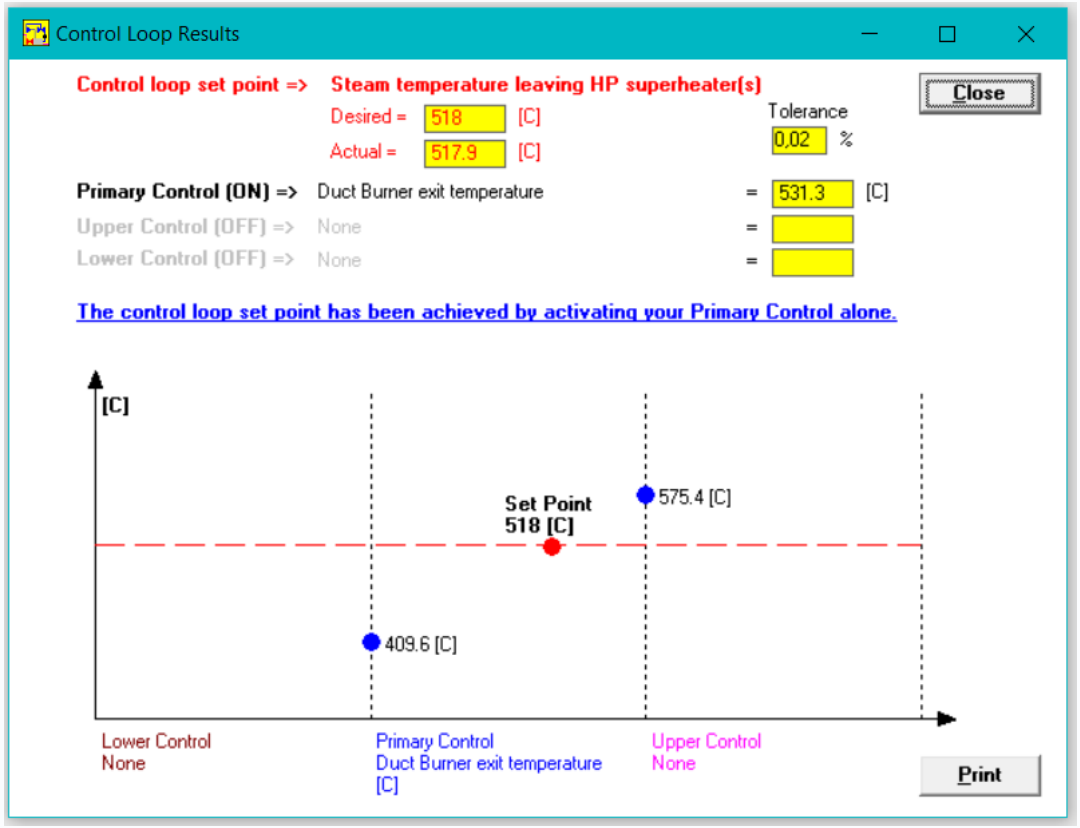
GT PRO Text Output - Messages

File Edit

	Warning Messages
	No warning messages
	Advisory Messages
	No advisory messages
	Remarks
1.	'You have selected 'No duct burner' on 'HRSG Main Inputs' tab.
	However, duct firing is needed to achieve current heat balance.
	GT PRO has included a duct burner for you.



GT Master



Design M on N Systems: Simulation in GT Master

- M on N Systems, same GT Models:
  - Only 1 input for GT / HRSG: all of them run on the same condition
  - You can:
    - Operate on simple cycle
    - Switch off some of the GTs
  - Use TFX if you need to run the GTs at different condition

- M on N Systems, different GT Models:
  - Run the 2 Files 2b & 3 separately, iterative process on Pressures-mass flows, then integrate the results
  - Use Thermoflex

Modelling M on N Systems in Steam Pro – Steam Master

- In **Steam Pro** the user can select:
  - For Conventional Boilers **M** units →Boiler-ST = 1 unit
  - For CFB-BFB and Grate Boilers: **M** units comprised by **N** Boilers + **1** ST
  - You **cannot link** STP files with TFX
  - You can import STP files into TFX
    → Be carefull, only 1 Unit can be imported from STP into TFX
- In **Steam Master** you can:
  - For Conventional Boilers run **M** units
  - For CFB-BFB and Grate Boilers you can switch off Boilers of each Unit
  - STM files can be linked to TFX
  - STM files **cannot be imported** into TFX

Modelling M on N Systems in Steam Pro – Steam Master

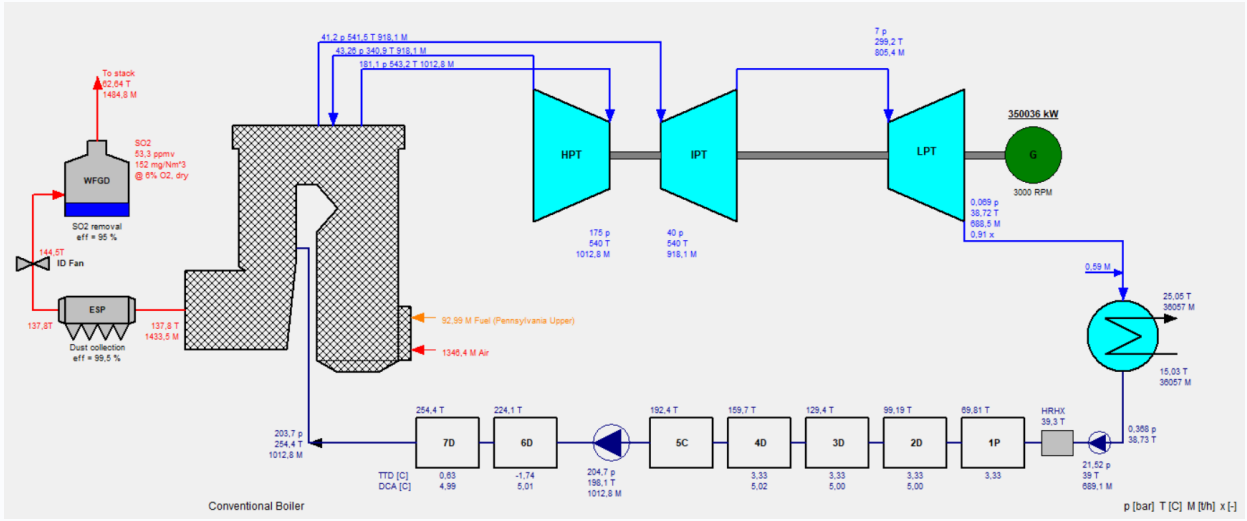
→ Example: How to create a plant with **2 different Boilers** feeding 1 ST:

- Create 2 STP files:
  - File 1: Boiler (1) + ST (1) + FWHS (1) + CS (1) → HP1 flow
  - File 2: Boiler (2) + ST (2) (no FWH, no CS) → HP2, cRH2, hRH2 and FW2 flows
- Add / Extract the steam flows from File 2 to File 1 at appropriate locations
  - Steam Cycle specification to Steam Flow (HP1 + HP2)
  - Steam Addition to Port 0 (SPHR), massflow = HP2
  - Steam Extraction (Process) from Port 1 (HPTex), mf = cRH2
  - Steam Addition to Port 2 (IPTin), mf = hRH2
  - Water Extraction “after FWH8”, mf = FW2
- Run and save as File 1b

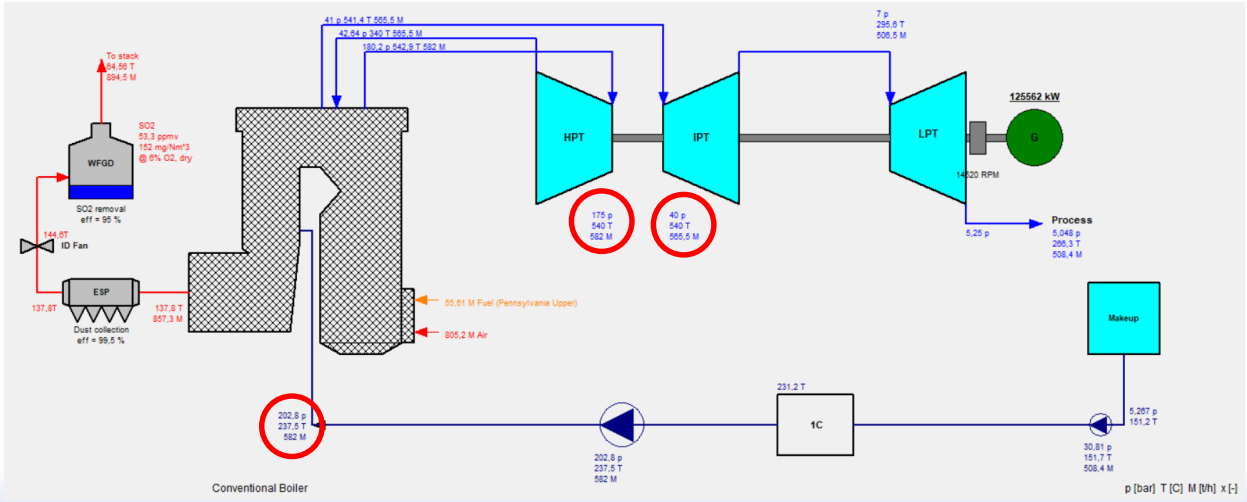
Modelling M on N Systems in Steam Pro – Steam Master

- Example: How to create a plant with 2 different Boilers feeding 1 ST:

File 1

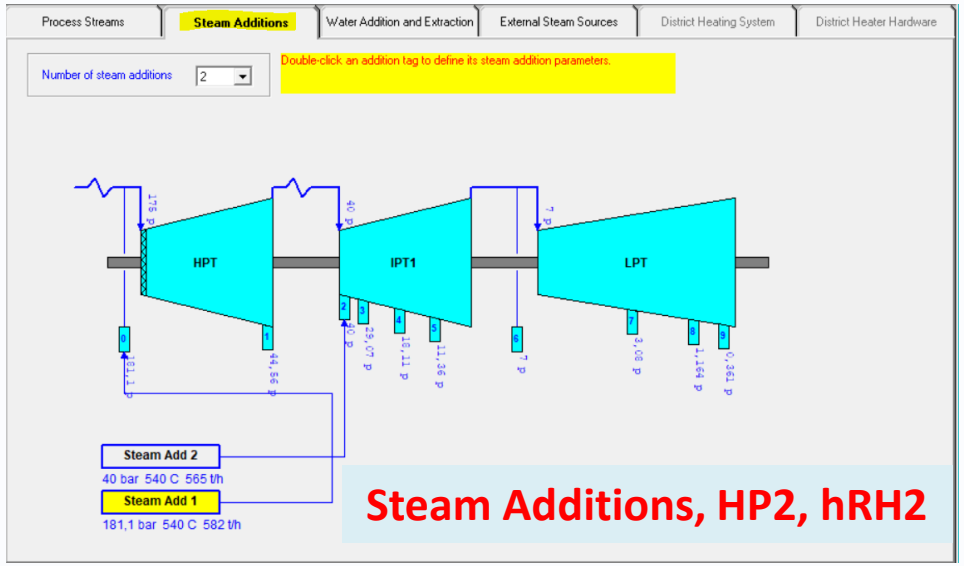


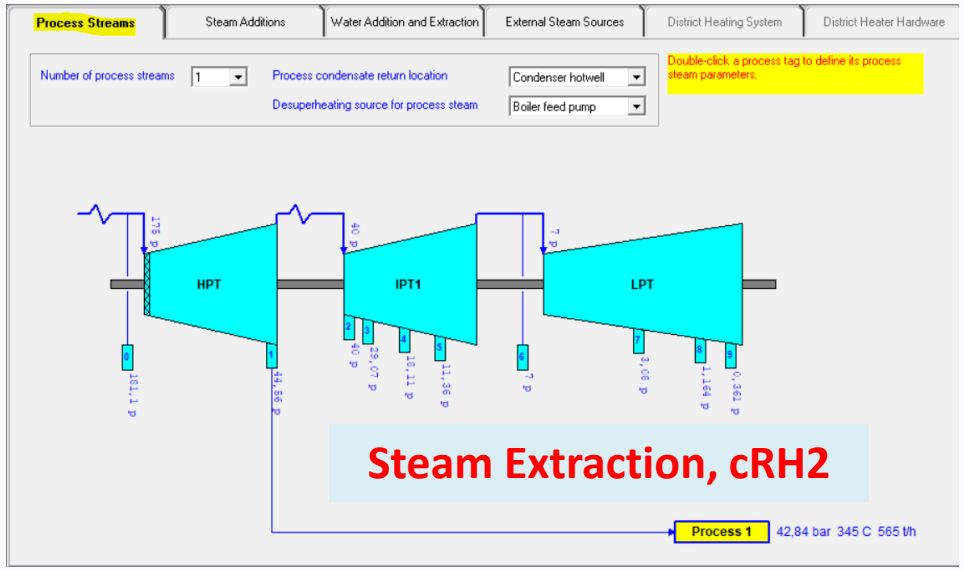
File 2

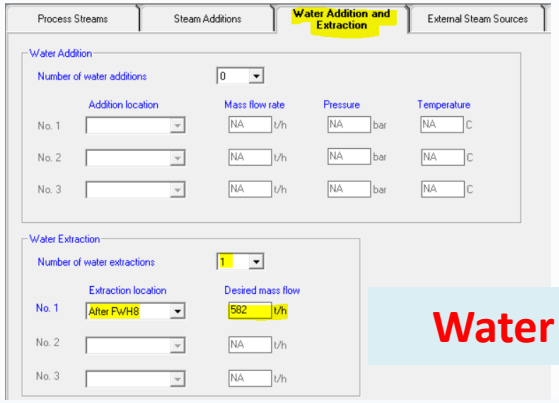


Modelling M on N Systems in Steam Pro – Steam Master

- Example: How to create a plant with 2 different Boilers feeding 1 ST:

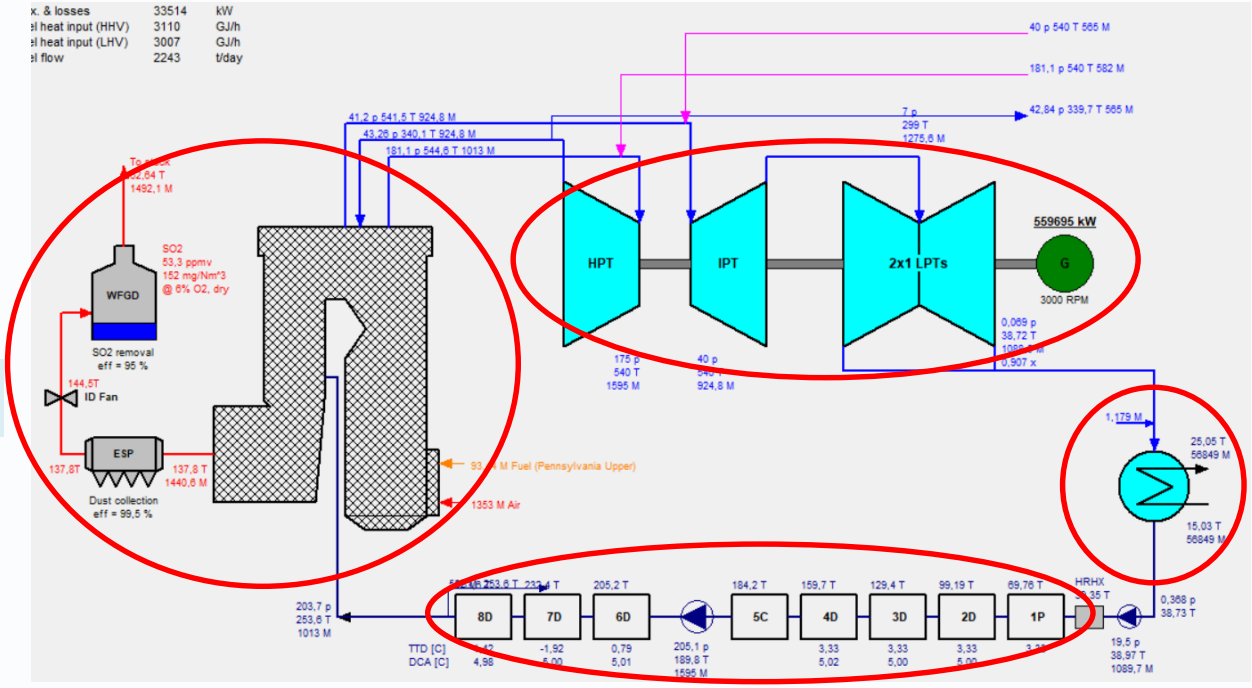




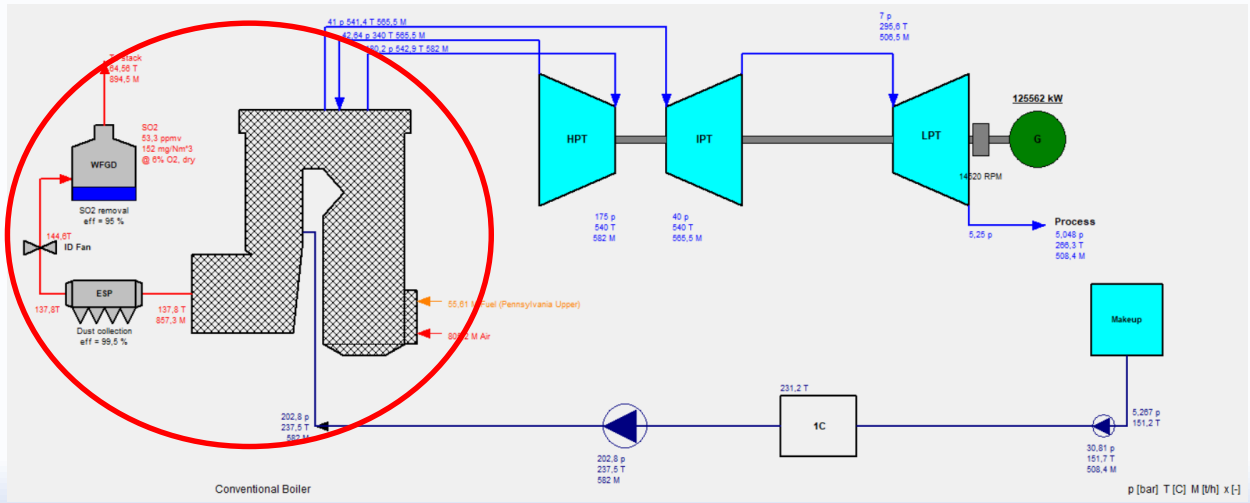


Modelling M on N Systems in Steam Pro – Steam Master

File 1b



File 2



Modelling M on N Systems in Steam Pro – Steam Master

- Example: How to create a plant with 2 different Boilers feeding 1 ST:

Components Design from each file

	Boiler	ST	FWHS	CS
File1	Boiler 1	ST 1	FWHS 1	CS 1
File2	Boiler 2	ST 2		
File1b	Boiler 1	ST	FWHS	CS

Integration of Results

		Total	File 1b	File 2
Gross Power	MW	559,7	559,7	125,6
Auxiliaries **	MW	?	24,4	12,8
Net Power	MW	?		
Heat Input-HHV	MW	1.378,0	863,9	514,1
Gross Efficiency	%	40,6%		
Cost Estimation	MUSD	?	940,8	489,0

Modelling M on N Systems in Steam Pro – Steam Master

- Example: How to create a plant with 2 different Boilers feeding 1 ST:

  Integration of Results:
  - Auxiliaries associated to the Boilers should be OK in File 1b and File 2
  - Auxiliaries associated to the Steam Cycle:
    - Remove the CFP and BFP from File 2, depending on the pumps configuration
    - Check the Additional PEACE and Miscellaneous
  - Cost Estimation:
    - Remove the cost associated to the steam cycle in File 2
    - Check the cost of the general and auxiliary equipment, Tanks, Buildings, …

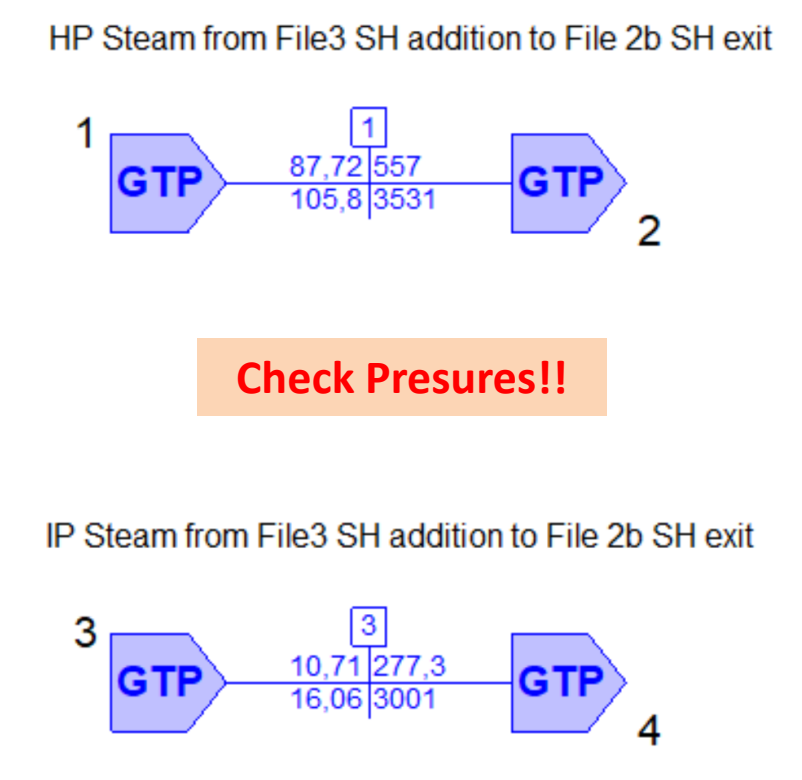
Design M on N Systems in Thermoflex

- In THERMOFLEX the user can:
  - *Standalone*: Any combination of GTs-HRSGs-Boilers-STs-Cooling Systems, …
  - *Link* with Files with GTP-GTM-STM
  - *Import* Files from GTP-GTM-STP

→ Example: Design M on N Combined Cycle plant with variable M and N using scripts → Sample (S2-37)

Design M on N Systems using THERMOFLEX

→ Link GTP-TFX, only “connections”

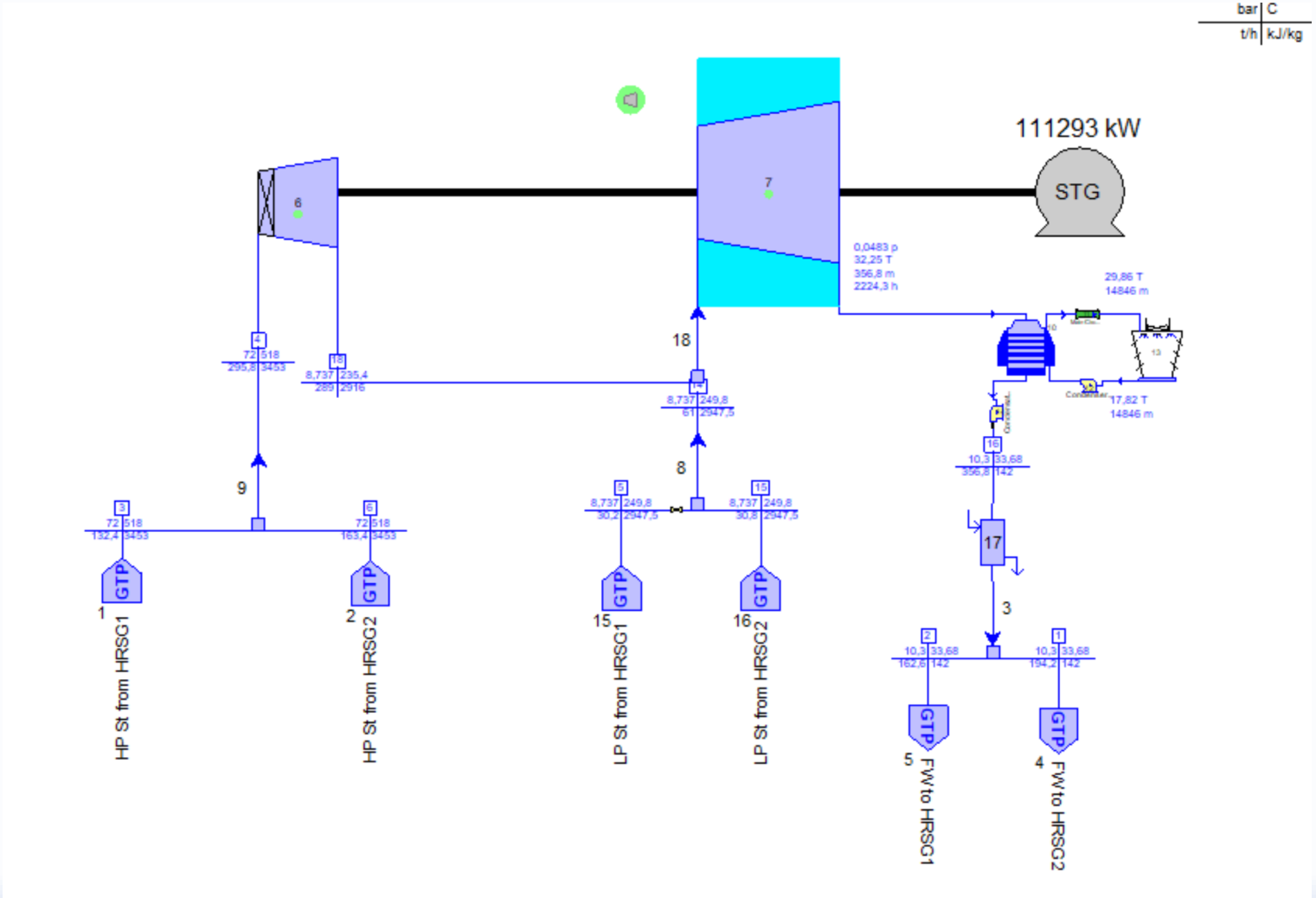


Summary of TFX & Linked Files						
	Gross power	Net power	Net HR	Net Eff	Fuel input	[kW]
File name	[kW]	[kW]	[kJ/kWh]	[%]	LHV	HHV
F2_1XGT1-HRSG1-ST.GTP	169299	164559	5101	70,57	233178	258738
F3_1XGT2-HRSG2.GTP	78056	75758	10250	35,12	215693	239336
THERMOFLEX						
Totals	247355	240317	6724	53,54	448871	498074

Performance of Gas Turbines in GT PRO Files							
			Gross Power	Gross LHV eff	Gross LHV HR	Exh. Flow	Exh. Temp.
File name	GT name	Units	[kW]	[%]	[kJ/kWh]	[t/h]	[C]
F2_1XGT1-HRSG1-ST.GTP	SIE 401	1	83585	35,85	10043	815,5	582,3
F3_1XGT2-HRSG2.GTP	AE64.3A	1	78056	36,19	9948	766,4	584,6

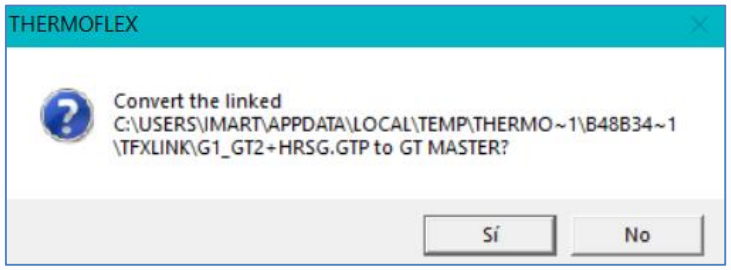
Design M on N Systems using THERMOFLEX

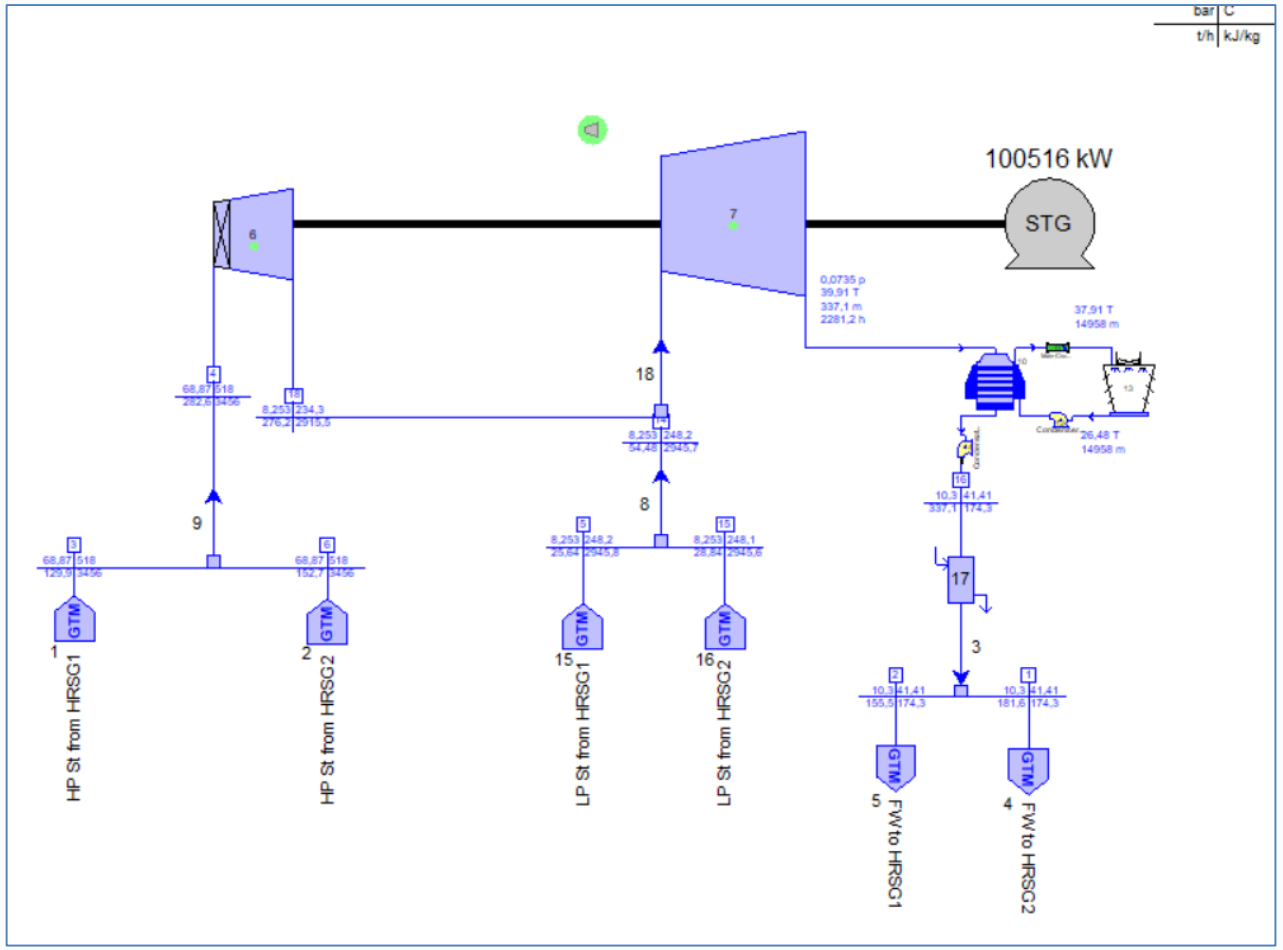
→ Link GTP-TFX, GT-HRSG in GTP, ST-CS in TFX



Design M on N Systems using THERMOFLEX

→ Off Design, GTP Links converted to GTM





Design M on N Systems using THERMOFLEX

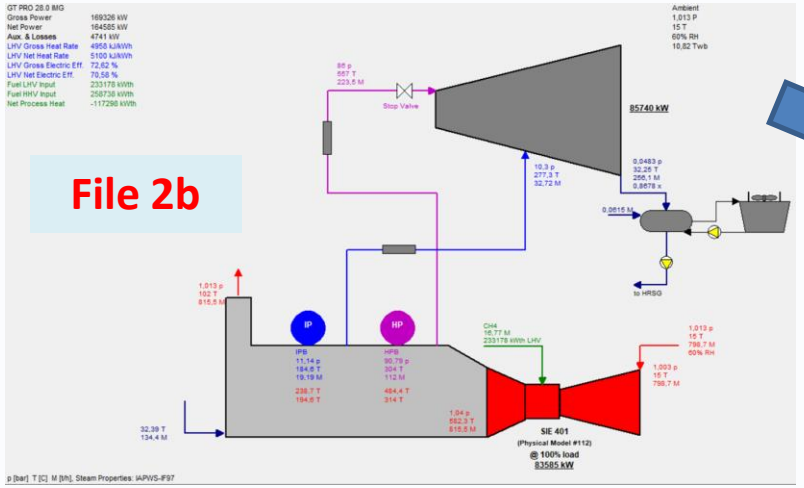
→ Import from GTP (GTM) into TFX
- Import File 2b
- Import File 3
- Copy All in File 3 and Paste it into File 2b
- Change sources / sinks / process by connections & add Mixers /Splitters:
  - HP steam from HRSG2: mix with HP steam from HRSG1, before ST
  - IP steam from HRSG2: mix with IP steam from HRSG1, before ST
  - Feedwater from Condensate Pump: Split to HRSG2
- Run in design mode, TD-ED
- Run in Off Design mode

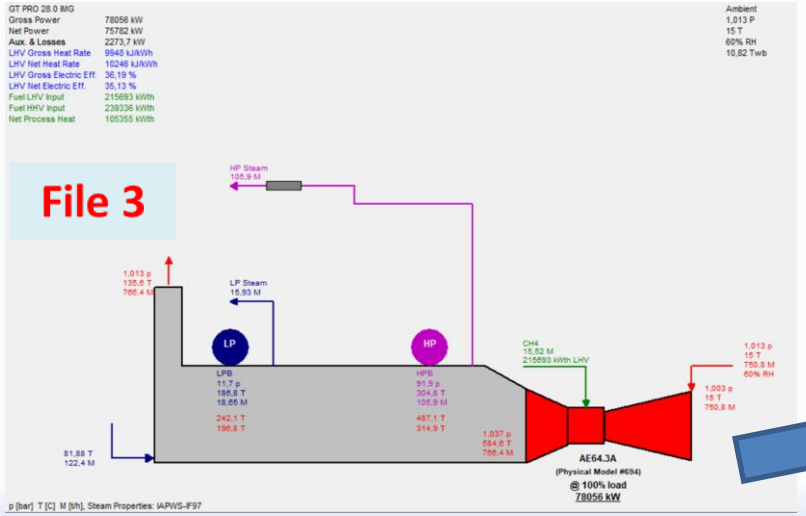
→ Import from GT Pro: redesign

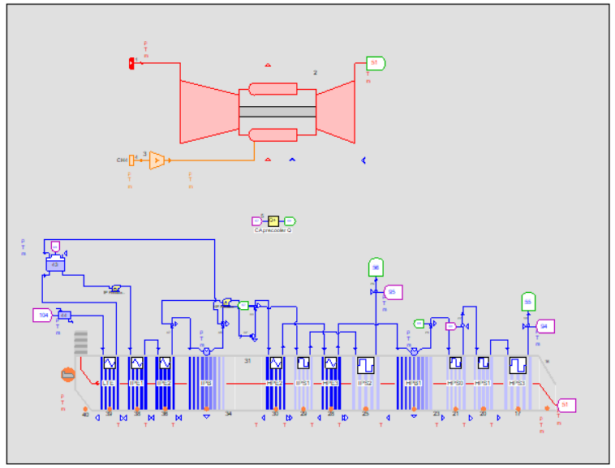
→ Import from GT Master: hardware fixed, simulation

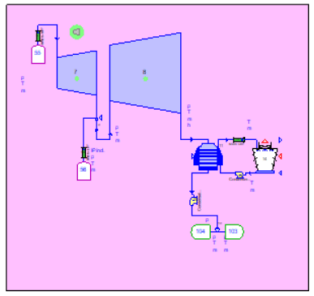
Design M on N Systems using THERMOFLEX

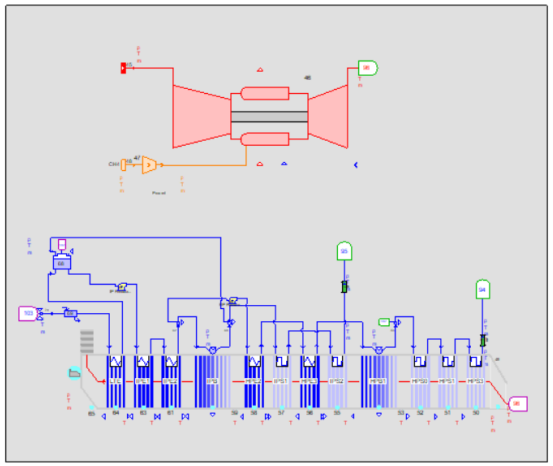
→ Import from GTP (GTM) into TFX











Design M on N Systems using THERMOFLEX

→ Import from GTP (GTM) into TFX

Final Plant Results

	Unit	LHV	HHV
Net fuel/energy input	[kW]	448933	498142
Gross heat rate	[kJ/kWh]	6539	
Net heat rate	[kJ/kWh]	6721	7458
Gross electric efficiency	[%]	55,05	
Net electric efficiency	[%]	53,56	48,27
CHP efficiency	[%]	53,56	
PURPA efficiency	[%]	53,56	
Gross power	[kW]	247138	
Net power	[kW]	240459	
Total auxiliaries and transformer losses	[kW]	6679	
Net process heat output	[kW]	0	

POWER DEVICE(S)

Generator	Component	Shaft	Shaft [kW]	Eff [%]	Multiplier	Gen [kW]	Accounted [kW]
	ST Assembly [1]: ST Group [7]		33657				
	ST Assembly [1]: ST Group [8]		53269,3				
ST Assembly [1] generator			86926,3	98,52	1	85635,6	85635,6
Gas Turbine (GT PRO) [2] generator			86559,7	96,47	1	83505,5	83505,5
Gas Turbine (GT PRO) [46] generator			80491,7	96,9	1	77997,2	77997,2
Total Generator(s)						247138,2	**247138,2**

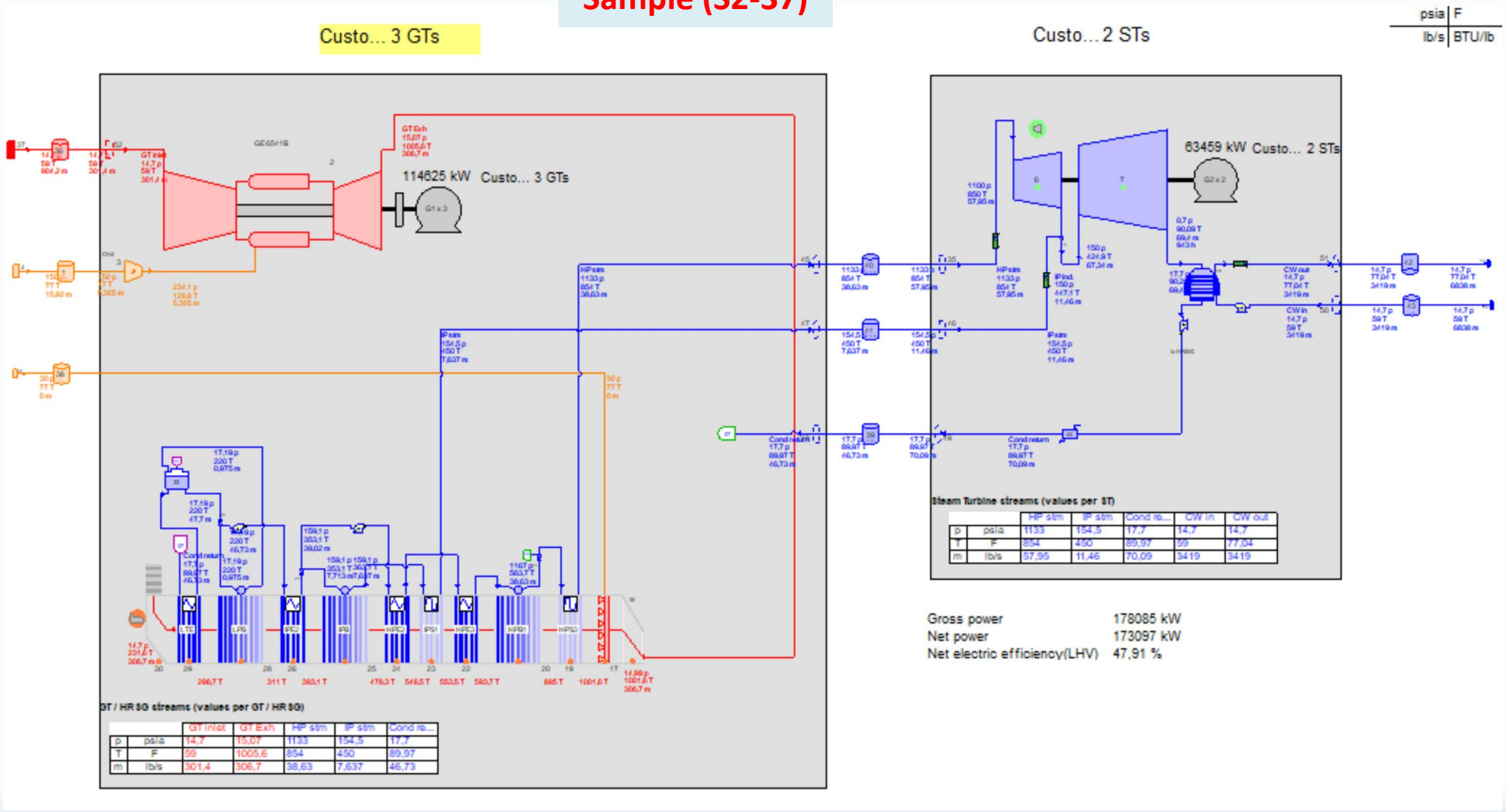
Project Cost Summary (USD)	Reference Cost	Estimated Cost	
Power Plant			
I. Specialized Equipment	93.832.000	98.524.000	USD
II. Other Equipment	7.945.000	8.342.000	USD
III. Civil	11.994.000	13.625.000	USD
IV. Mechanical	14.777.000	17.345.000	USD
V. Electrical Assembly & Wiring	4.978.000	5.855.000	USD
VI. Buildings & Structures	6.711.000	7.718.000	USD
VII. Engineering & Startup	13.900.000	13.921.000	USD
VIII. Linked Files & Other Systems	0	0	USD
Subtotal - Contractor's Internal Cost	154.136.000	165.329.000	USD
IX. Contractor's Soft & Miscellaneous Costs	41.001.000	46.877.000	USD
Contractor's Price	195.137.000	212.205.000	USD
X. Owner's Soft & Miscellaneous Costs	17.562.000	19.098.000	USD
Other Standalone Plants (Owner's Cost)	0	0	USD
Total - Owner's Cost	212.700.000	231.304.000	USD
Nameplate Net Plant Output	240	240	MW
Price per kW - Contractor's	811,5	882,5	USD/kW
Cost per kW - Owner's	884,6	961,9	USD/kW
* Cost estimates as of September 2018.			

Financial Summary | Cash Flow

These results are based on simplified annual model defined by the user.		
Annual Electricity Exported	1.580	10^6 kWh
Annual Heat Exported	0	TJ
Annual Fuel Imported	10.618	TJ LHV
Annual Water Imported	1.430	10^6 l
Annual CO2 Emission	582	ktonne
Annual Desal Water Exported	0	MM imperial gal.
Annual Hydrogen Exported	0	TJ LHV
Annual Syngas Exported	0	TJ LHV
Annual CO2 Captured	0	ktonne
Annual Limestone Consumed	0	ktonne
Annual Lime Consumed	0	ktonne
Annual CO2 Capture Solvent Consumed	0	ktonne
Annual Combustion Waste Production	0	ktonne
Annual FGD Waste/Byproducts Production	0	ktonne
Annual Activated Carbon Consumed	0	ktonne
Total Investment	231.304.000	USD
Specific Investment	961,9	USD per kW
Initial Equity	69.391.180	USD
Cumulative Net Cash Flow	535.235.600	USD
Internal Rate of Return on Investment (ROI)	13,339	%
Internal Rate of Return on Equity (ROE)	24,429	%
Years for Payback of Equity	4,707	years
Net Present Value	111.567.400	USD
Break-even Electricity Price @ Input Fuel Price (i.e. Levelised Cost of Electricity)	0,0557	USD/kWh
Break-even Fuel LHV Price @ Input Electricity Price	7,073	USD/GJ

Design M on N Systems in Thermoflex

Sample (S2-37)



Modelling M on N Systems

→ Conclusions: Which Option to choose?

- Programs you have licenced
- Your ability with the programs GTPM-TFX, …
- Stage of Project: feasibility, conceptual, matching a HB, vendor data, …
- Level of details you need
- Plant complexity
- Flexibility you require
- …

Q & A Session

- Please forward your questions on the WebEx Chat
- Further questions by email to: **info@thermoflow.com**

- PP Presentation will be available on the Website / Tutorials
- Video will be available on the Service Center

Thank you!

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