Welcome!

Webinar #20: Cooling System Optimization

24 Jan 2018

Agenda:

* Introduction

- Cooling Systems in Thermoflow software
- CS at the design point
- Cooling System design optimization
- CS at off design
- Cooling System off design optimization
- Examples

* Q & A Session

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

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**

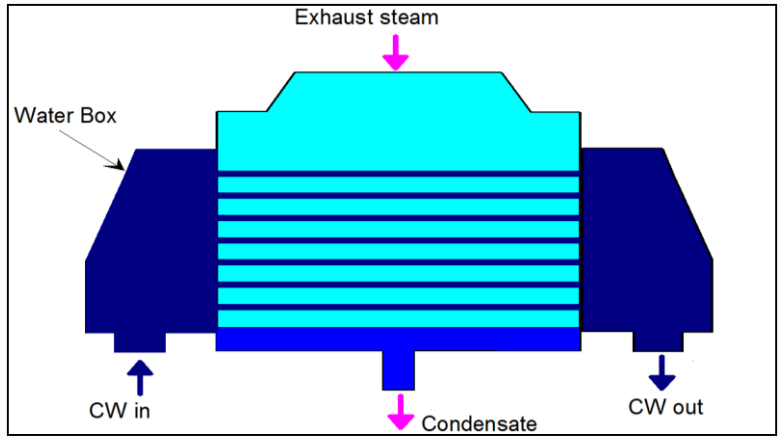
Feature Awareness Webinars

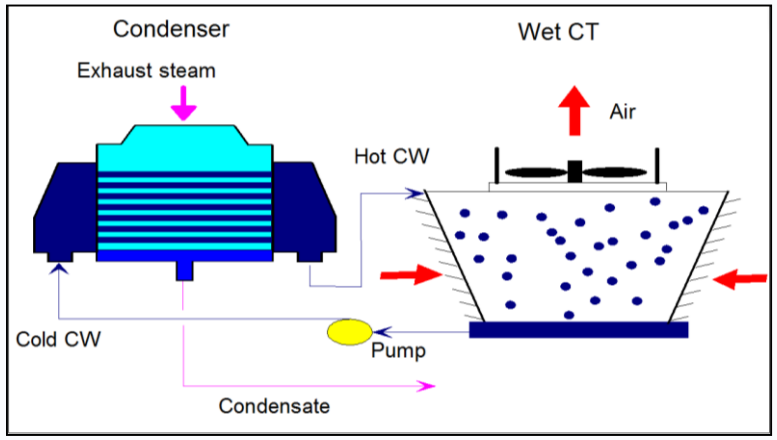
1- Assemblies in TFX
2- Scripts in Thermoflow programs, GTP-GTM-TFX
3- Multi Point Design in GTP-GTM
4- Reciprocating Engines in TFX
5- TIME in GTM
6- Matching ST Perfromance in STP
7- Modeling Solar Systems in TFX
8- Combining THERMOFLEX & Application-Specific Programs
9- Methods & Methodology in GT 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

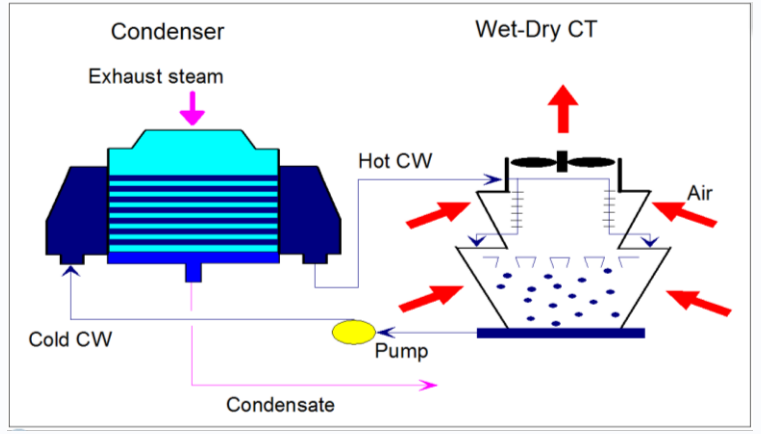
Cooling System @ the design point

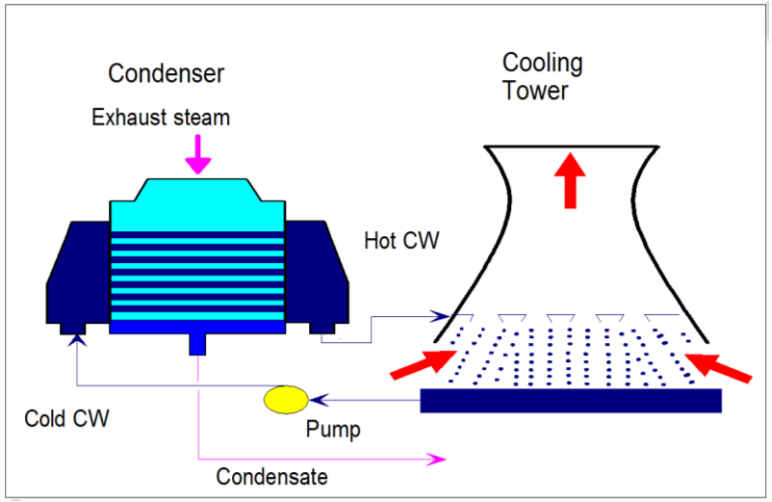
- Cooling Systems types in Thermoflow programs
- Main Inputs
- Automatic Design: Default Values (low cost- high efficiency) – GTP-STP
- Main Outputs
- Comparison of diferent systems performance & cost, automatic design → *Example 1a*
- Techno-Economic Optimization (ROI, NPV), via *Multiple Runs* or *Elink* - GTP-STP → *Example 1b*

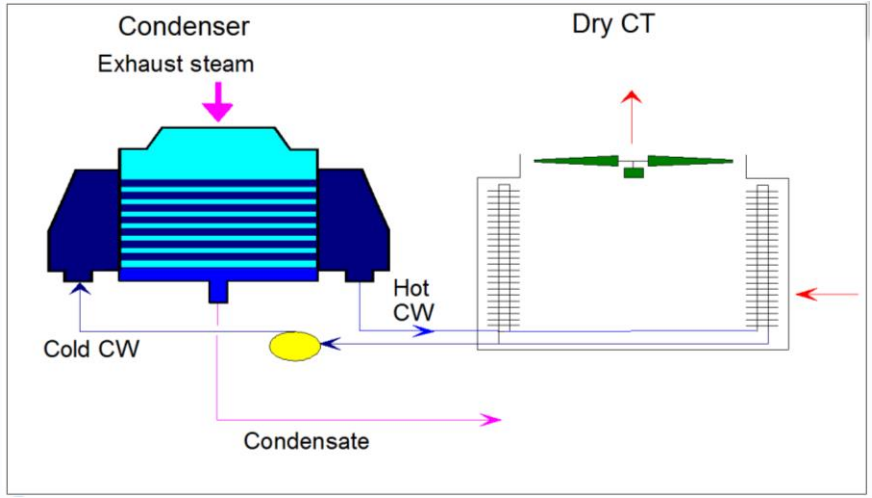
Cooling System types: Water Cooled



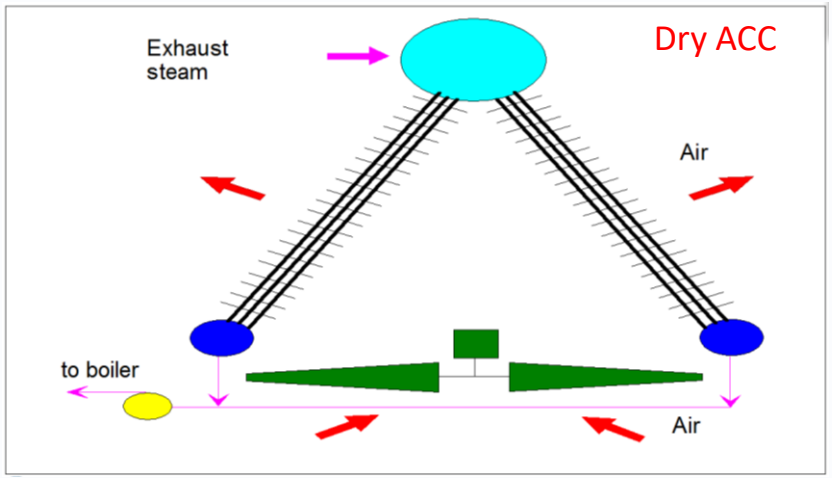


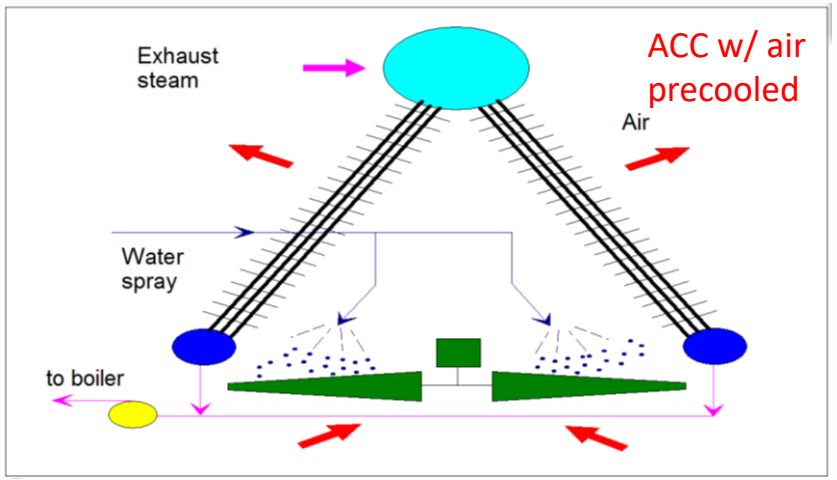


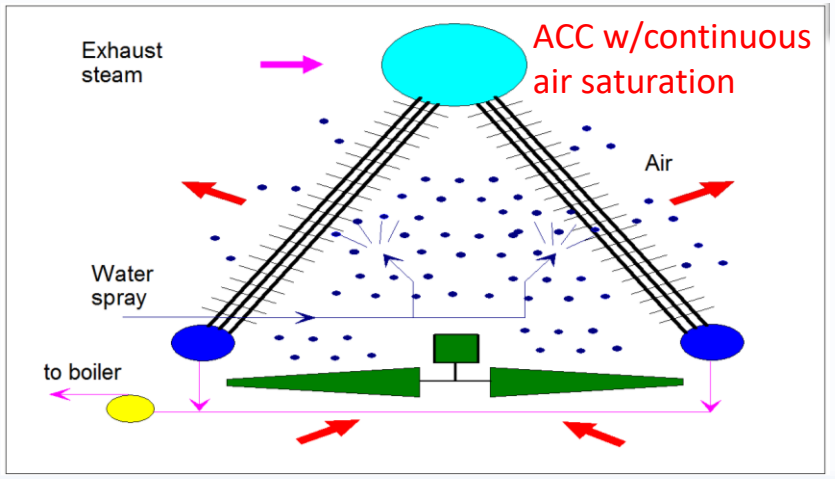


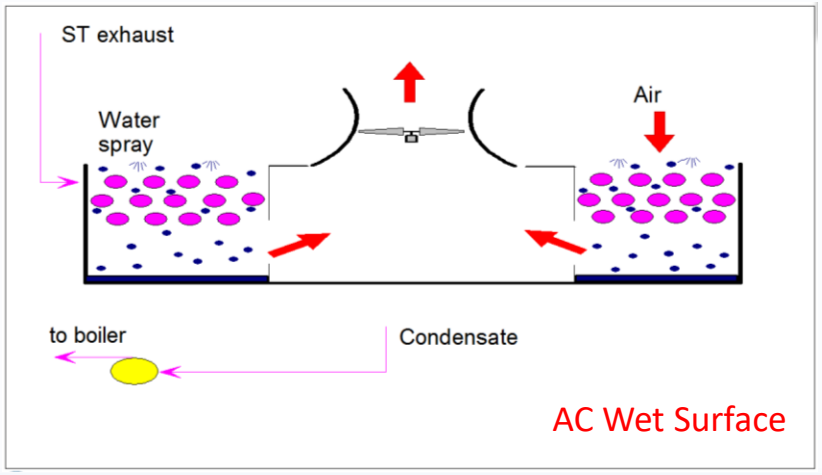


Cooling System types: Air Cooled

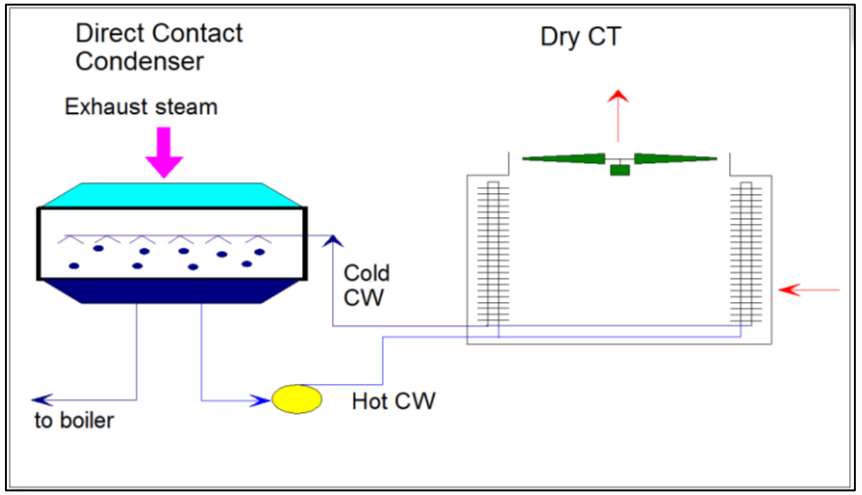




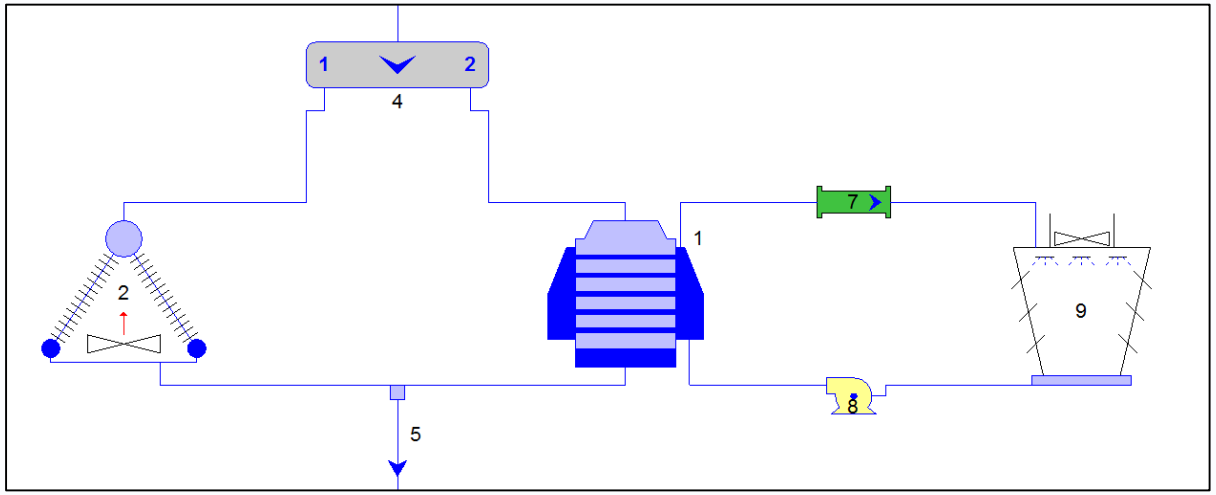




Cooling System types: Others

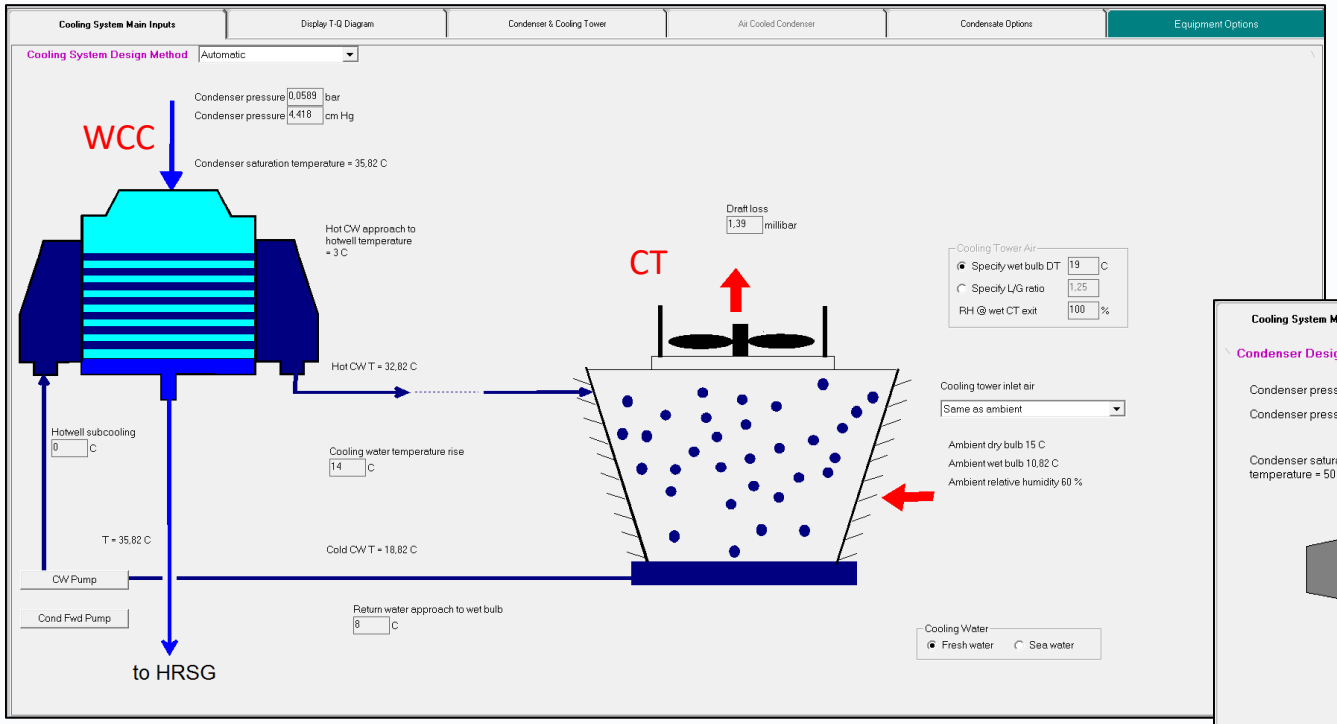


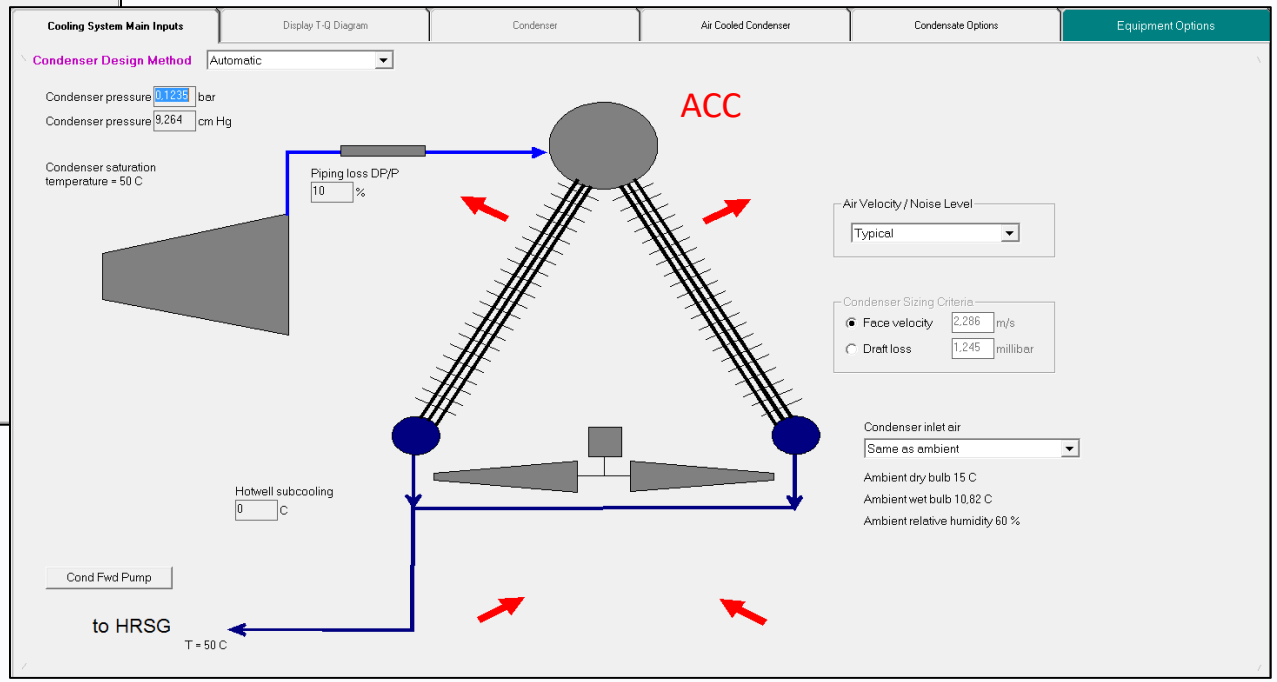
Heller System (GTP)



Hybrid Systems in TFX

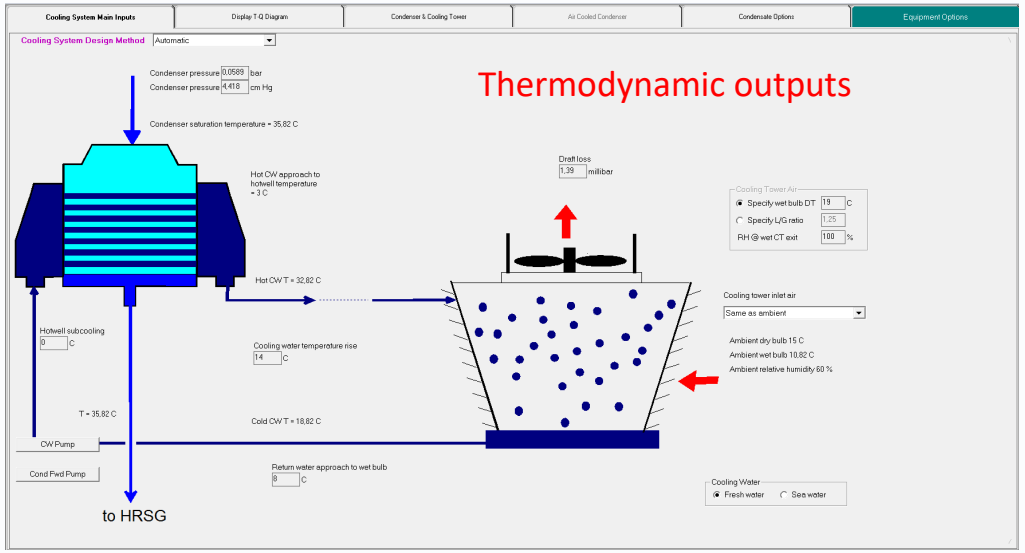
Cooling System @ Design: Main Inputs



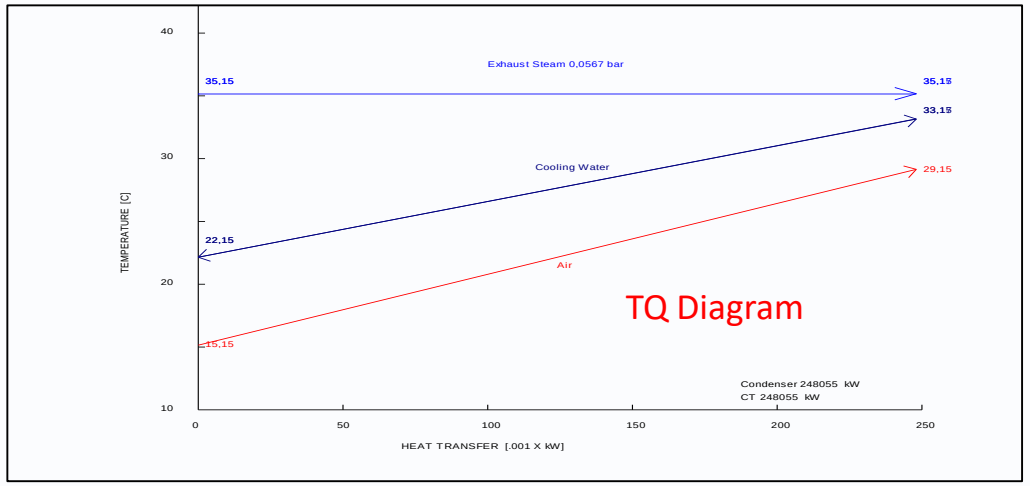


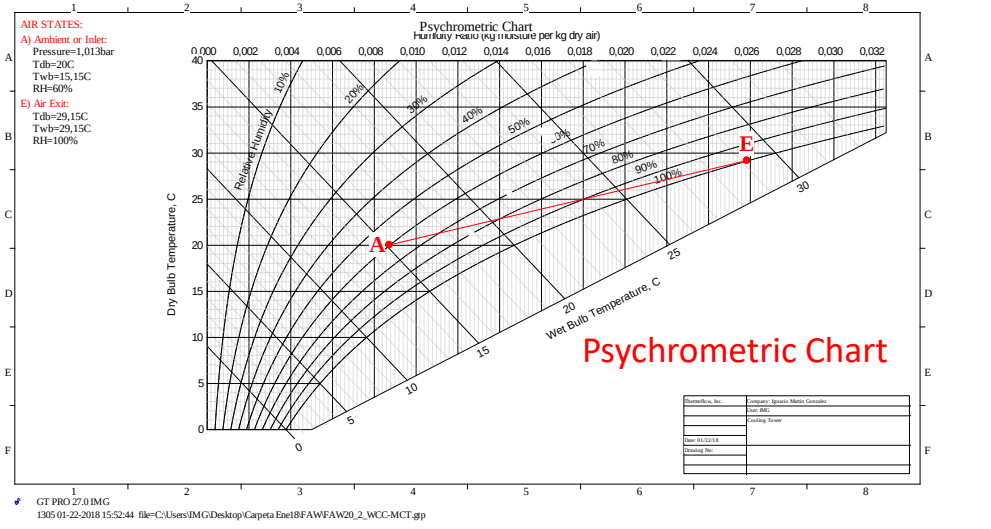
Default Values for Automatic Design (cost – eff)

Cooling System @ Design: Main Outputs



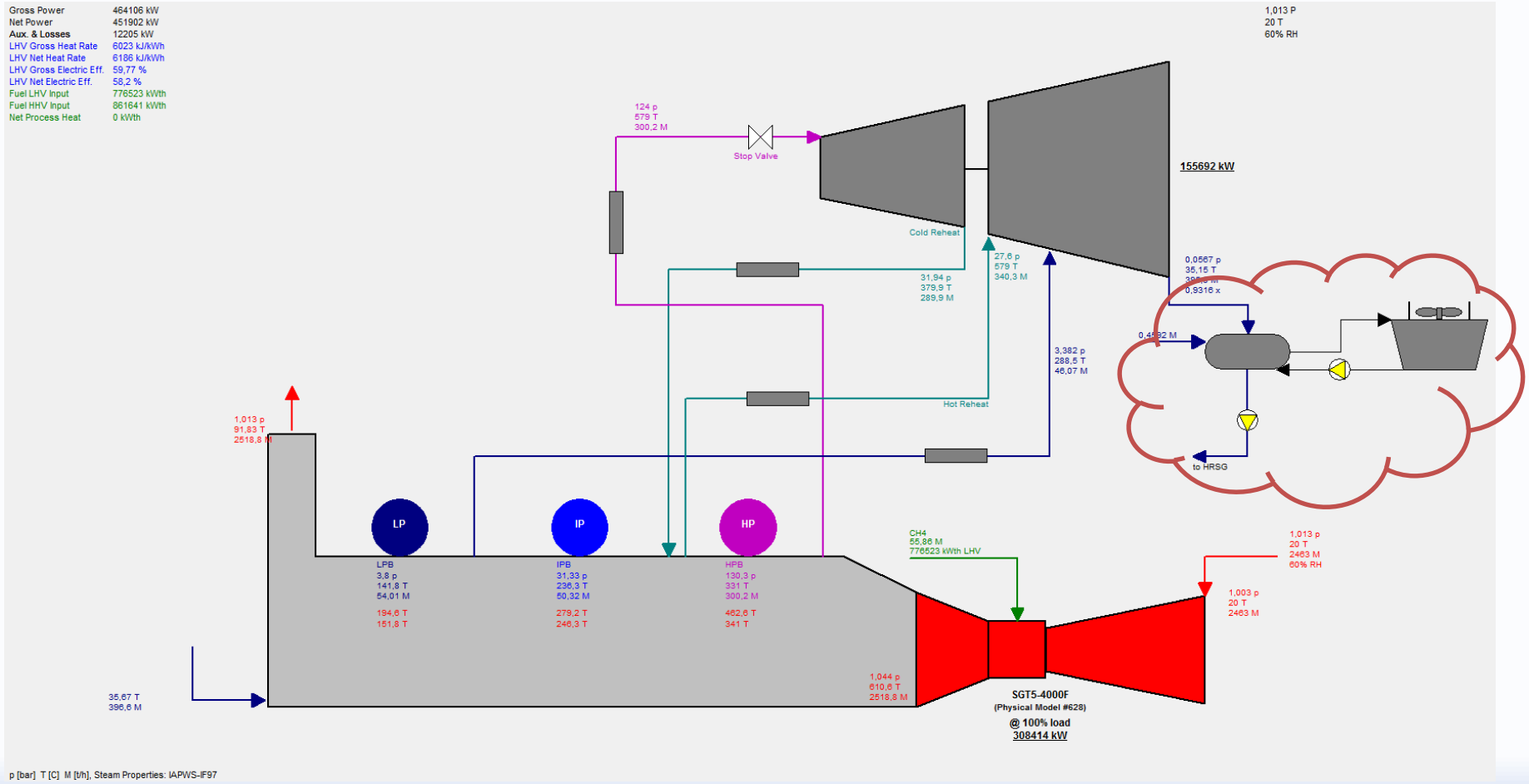
Estimated Condenser Data		
Number of Units	1	
Condenser Type	Shell & Tube	
Condenser Cost (per unit), Reference Basis	1.863.000	USD
1. Condenser Tube Description (per unit)		
Effective Surface Area	7.030	m^2
Number of Condenser Passes	2	
Tube Material	Stainless Steel (304)	
Number of Tubes	5981	
Tube Length	11,8	m
Tube Outside Diameter (O.D.)	31,75	mm
Tube Inside Diameter (I.D.)	30,33	mm
Tube Wall Thickness	0,7112	mm
Tube Weight, dry	39.220	kg
Tube Pitch	50,8	mm
2. Condenser Shell Description (per unit)		
Shell Material	Carbon Steel	
Nominal Shell Thickness	15,88	mm
Number Tube Support Plates	14	
Tube Support Plate Spacing	0,78	m





Cooling System different types comparison (automatic design)

Example 1a: GT Pro, Automatic Design, GT SGT5-4000F, 20 C, 3PRH, High Efficiency



Cooling System different types comparison (automatic design)

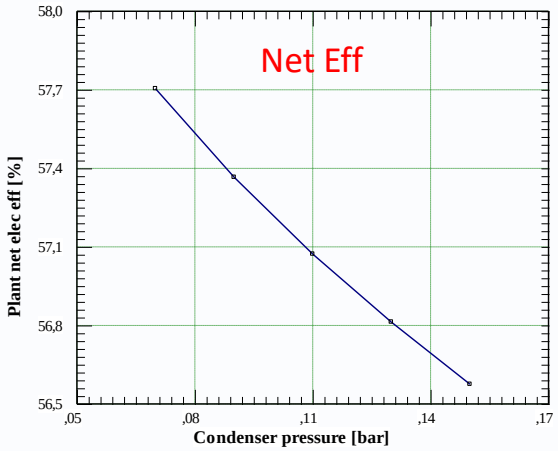
- Condenser Pressure
- DTs: Saturation-Cooling Water-DBT-WBT
- Gross, Net Power
- Net Efficiency
- Auxiliary Power associated to the CS
- Size: Condenser Surface Area, CT Number of Cells, Plot
- Cost: CS Cost (Condenser, CT, CWPump, CW Pipe, …) / Total Plant Cost
- Financial: ROI, NPV, LCOE

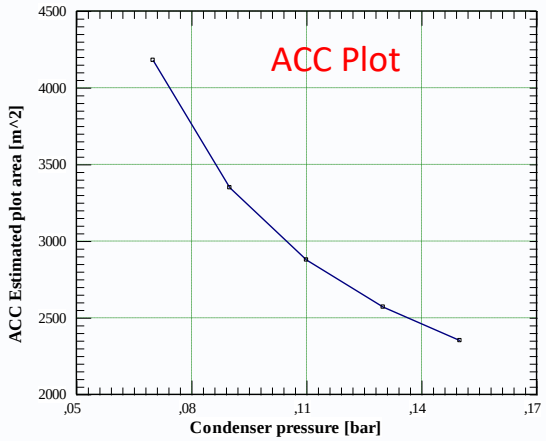
Cooling System different types comparison (automatic design)

Example 1a: GT Pro, Automatic Design, GT SGT5-4000F, 20 C, 3PRH, High Efficiency

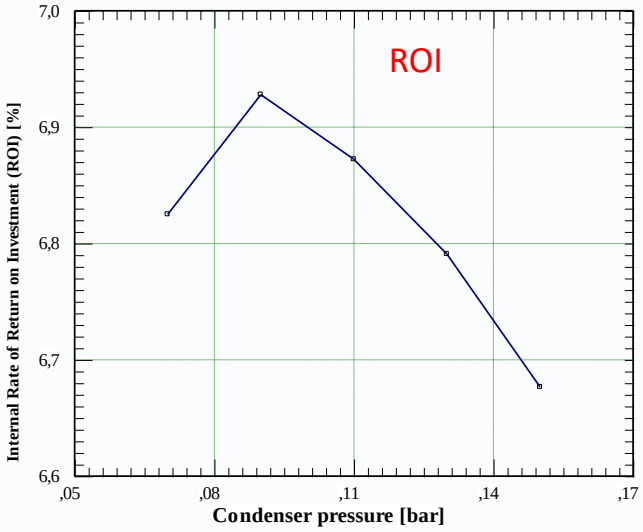
	Units	WCC OT	WCC MCT	WCC w-d CT	WCC NDCT	WCC dCT	ACC	ACC w/air prec	ACC w/air sat	ACC wet surface	Heller
Amb T	ºC	20	20	20	20	20	20	20	20	20	20
RH	%	60	60	60	60	60	60	60	60	60	60
WBT	ºC	15,1	15,1	15,1	15,1	15,1	15,1	15,1	15,1	15,1	15,1
Site CW	ºC	15	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Cond P	**mbara**	**48,3**	**56,7**	**83,8**	**56,7**	**83,1**	**123,5**	**96,7**	**96,7**	**96,7**	**83,1**
Sat T	ºC	32,2	35,1	42,4	35,1	42,2	50,0	45,1	45,1	45,1	42,2
DT-WBT	ºC	17,1	**20,0**	**27,3**	20,0	27,1	34,9	30,0	30,0	30,0	27,1
DT-Amb	**ºC**	**12,2**	**15,1**	**22,4**	**15,1**	**22,2**	**30,0**	**25,1**	**25,1**	**25,1**	**22,2**
Total CS Aux	**MW**	**1,2**	**2,9**	**2,2**	**1,7**	**5,3**	**1,7**	**1,7**	**1,2**	**0,6**	**4,6**
Cond surface	m2	7.029	13.850	9.123	13.850	14.517	537.320	540.785	376.521	32.026	
ACC plot	m2						2657	2676	1863	2654	
Water consumption	**t/h**	**0**	**372**	**335**	**372**	**0**	**0**	**79**	**394**	**384**	**0**
Net Power	**MW**	**455,4**	**451,9**	**448,0**	**453,1**	**444,5**	**441,8**	**445,0**	**445,5**	**446,1**	**445,2**
Net Eff	**%**	**58,65**	**58,20**	**57,69**	**58,35**	**57,24**	**56,89**	**57,30**	**57,36**	**57,45**	**57,33**
Total CS Cost	**MUSD**	**6,4**	**8,9**	**9,1**	**57,5**	**26,1**	**17,0**	**17,7**	**13,0**	**6,5**	**23,0**
Total Plant Cost	MUSD	321,1	326,4	320,5	369,8	354,6	334,5	339,8	328,6	321,6	347,8
Specific Cost	**USD/kW**	**705,2**	**722,3**	**715,5**	**816,2**	**797,7**	**757,1**	**763,6**	**737,7**	**720,9**	**781,3**
ROI ***	%	20,29	19,54	19,50	17,61	17,67	18,36	18,36	18,82	19,24	18,04

Cooling System Design Techno-Economic Optimization (GTP–STP)





Example 1b: *GT Pro, Automatic Design, GT SGT5-4000F, 20 C, 3PRH, High Efficiency,* ***ACC***



- Make the Cond P *user defined* in GTP/STP
- Use Multiple Runs or Elink to find the optimum ROI / NPV
- Effect of the Economic Assumptions
- Select the simple *Nameplate Mode* or more detailed *Annual Model* or *TIME*

Cooling System @ off design

Off Design (GTM-STM-TFX OD)

- Main inputs, limits and controls
- Automatic Optimization to maximize Net power (GTM-STM)
- Use Searcher for Optimization (TFX)
- Use ELink for comparison
- Examples

Cooling System @ off design, Main Inputs

WCC

- Minimum / Maximum Condenser Pressure
- Prevent Choke option

} Limited by CW Flow / n. of operating CT cells

- CW Flow: User Defined / computed from Pump – number of CW Pumps running

WCT

- Number of Cells full speed / half speed, existing / operating
- CT shutdown
- Minimum Basin Temperature
- Air RH at exit
- CT water distribution: All Cells / Operating Cells

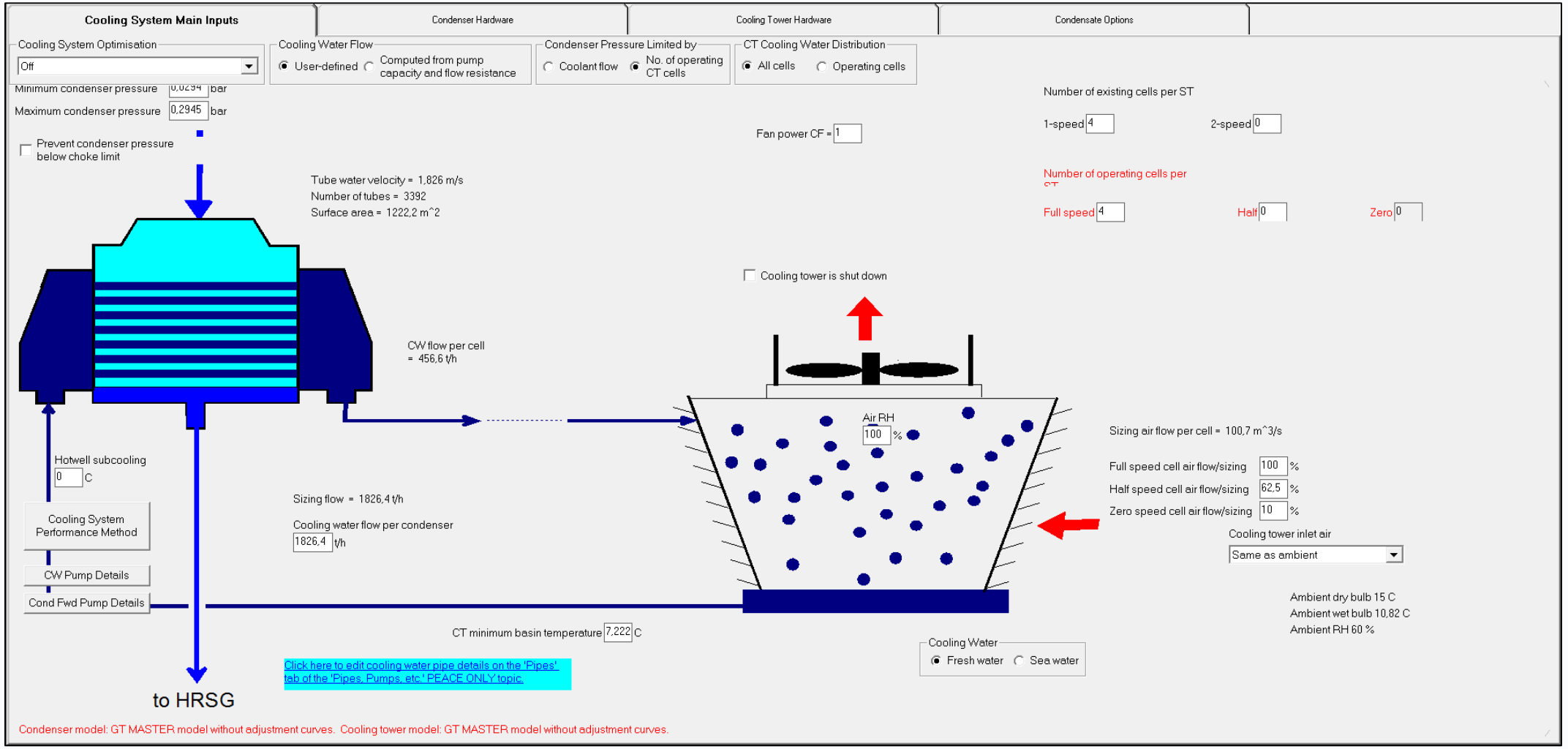
ACC

- Minimum / Maximum Condenser Pressure
- Prevent Choke option

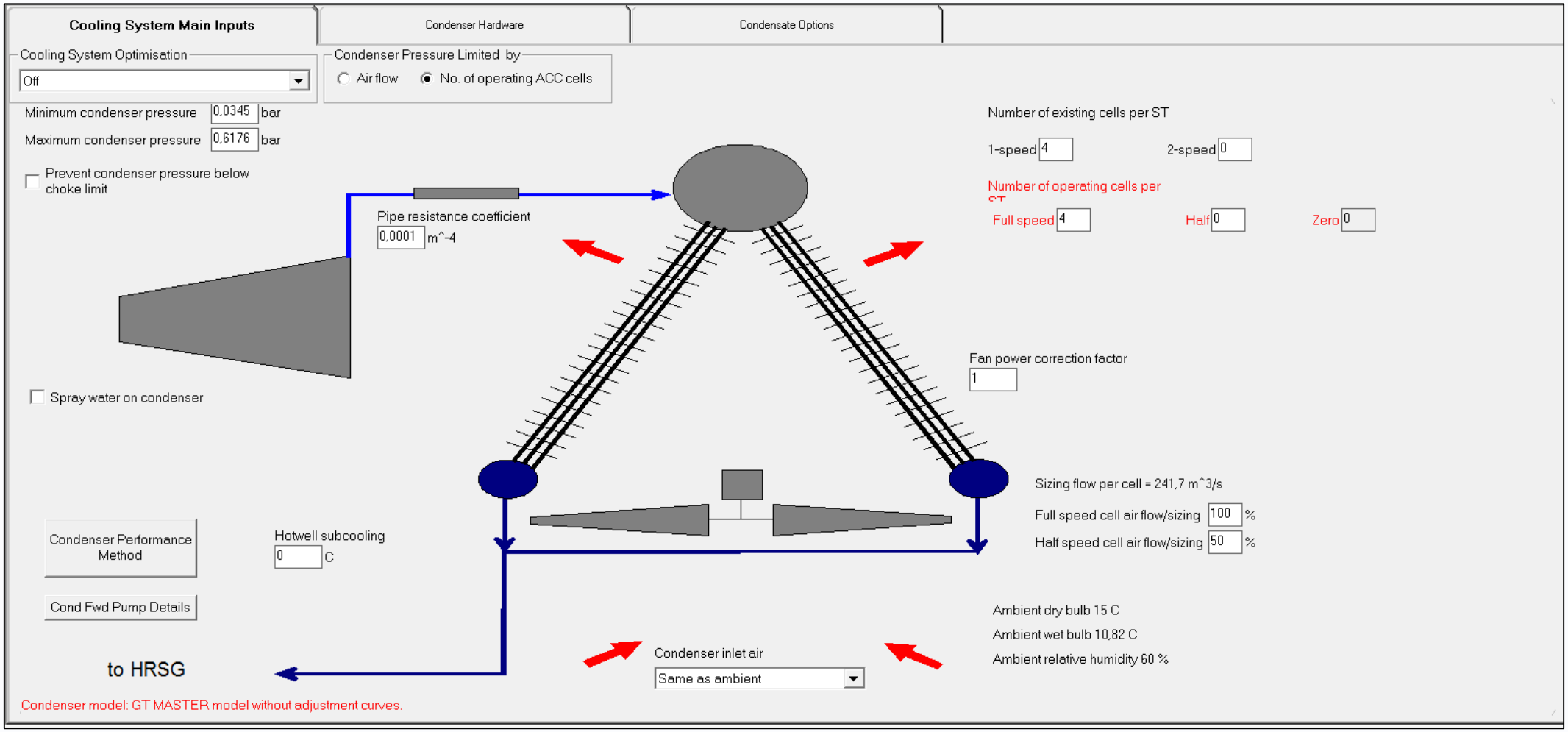
} Limited by Air Flow / n. of operating ACC cells

- Number of Cells full speed / half speed, existing / operating
- Spray Water option / exit Air RH

Cooling System @ off design, Inputs WCC+MCT



Cooling System @ off design, Inputs ACC

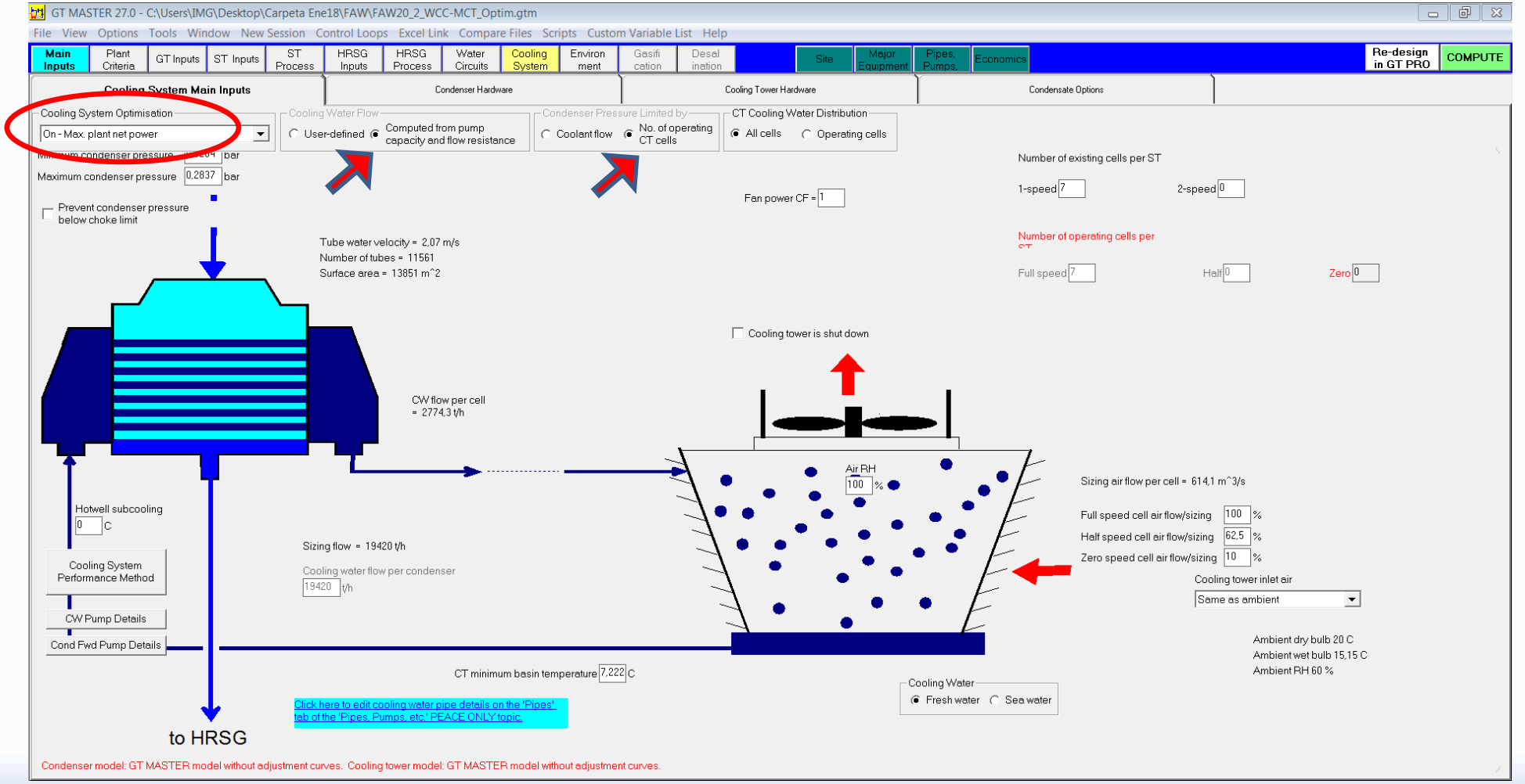


Cooling System @ off design Optimization

- Automatic Optimization to maximize Net Power (WCC-CT-ACC) / (GTM-STM) → *Example 2*
- Spray Water to ACC to increase output at peak conditions (GTM-TFX) → *Example 3*
- CT n. of cells optimization to maximize Net Power using Searcher (TFX) → *Example 4*
- Hybrid Condenser in TFX, link to GTP/GTM → *Example 5*

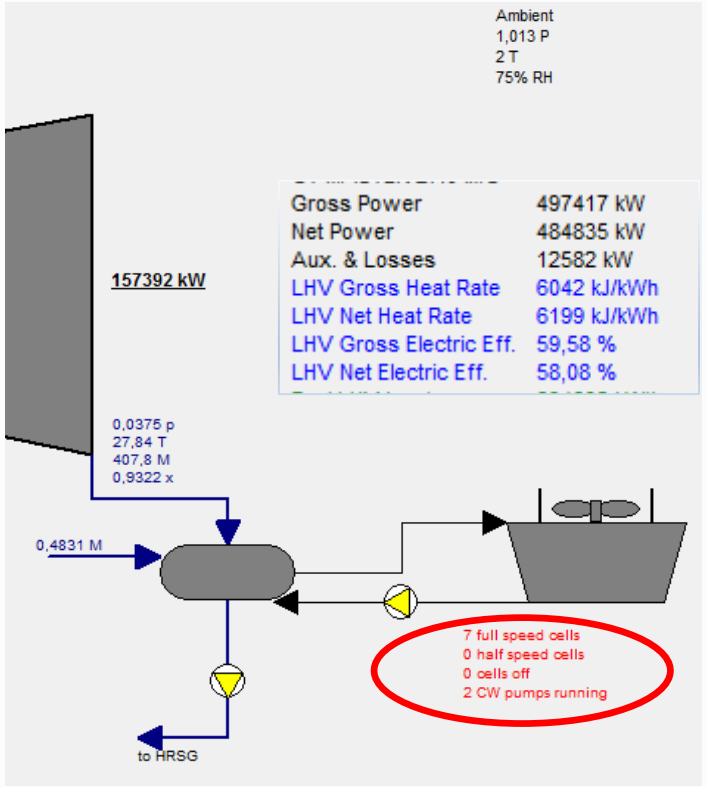
Automatic Optimization to maximize Net Power

Example 2: GT Master, GT SGT5-4000F, 3PRH, WCC+WCT, 2 CWP-7 CT Cells. ***Optim. @ 2 ºC***

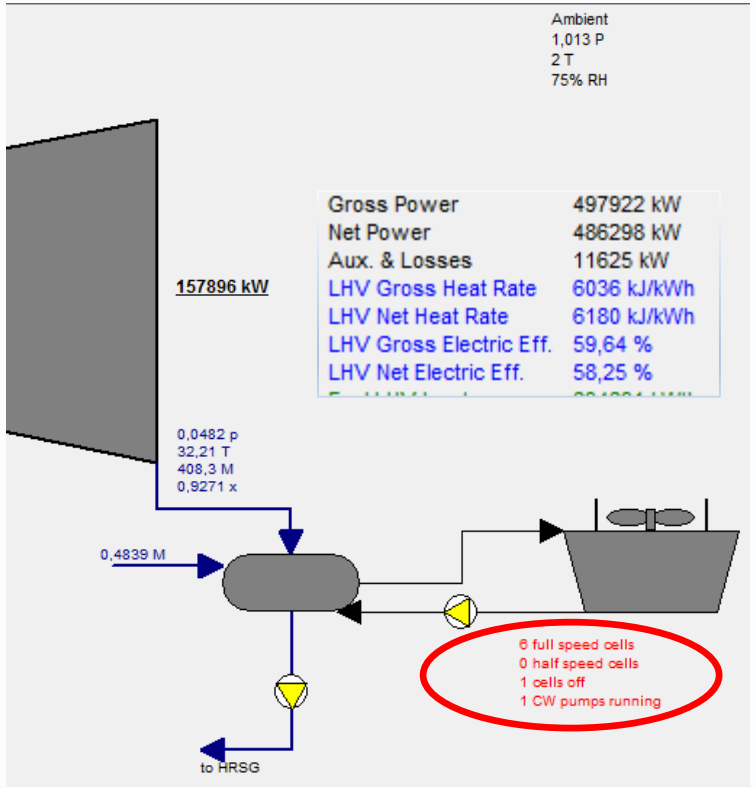


Automatic Optimization to maximize Net Power

Optimization OFF

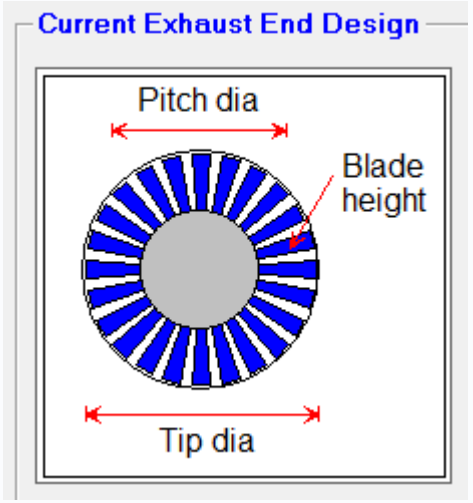


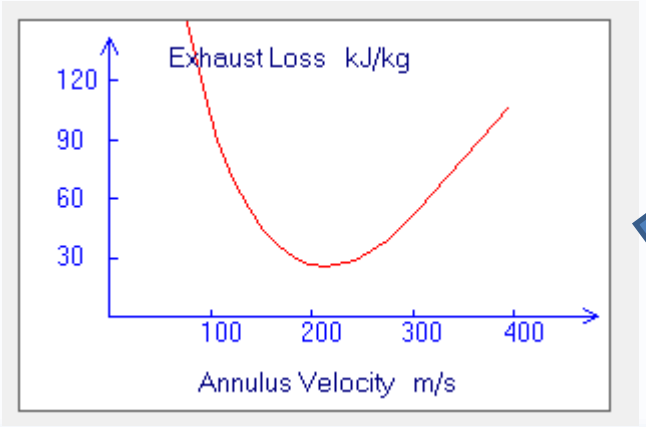
Optimization ON



Automatic Optimization to maximize Net Power

Effect of Exhaust End design and Exhaust Loss calculation on optimization !!!

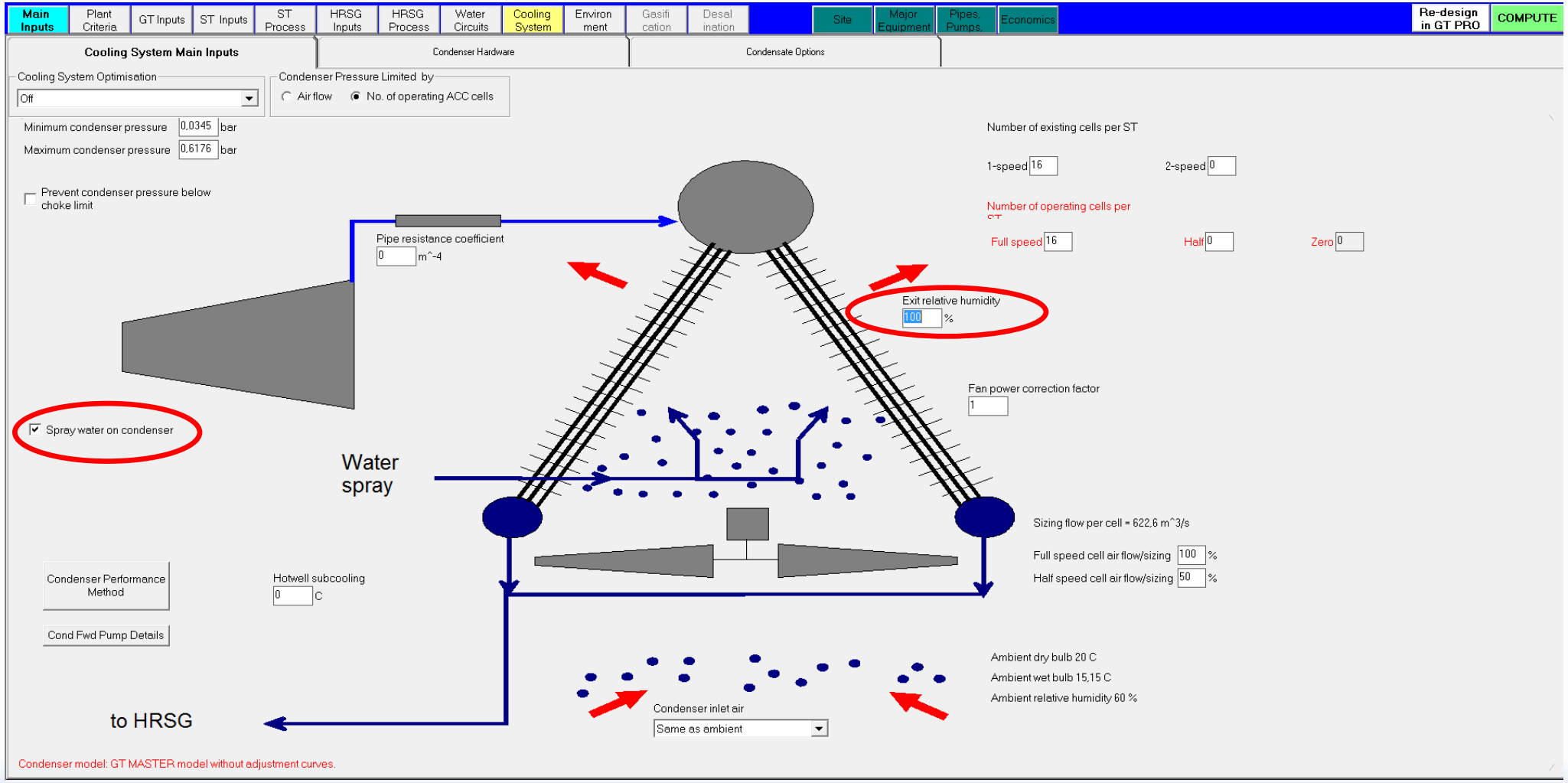




	Optimization		Cond P	Net P
	N. CT Cells	N. CW Pumps	mbara	MW
EL = Auto	6	1	49,0	486,3
EL =1/2 Auto	7	1	41,6	488,9
No EL	7	2	36,8	492,4

Spray Water to ACC to increase output at peak conditions

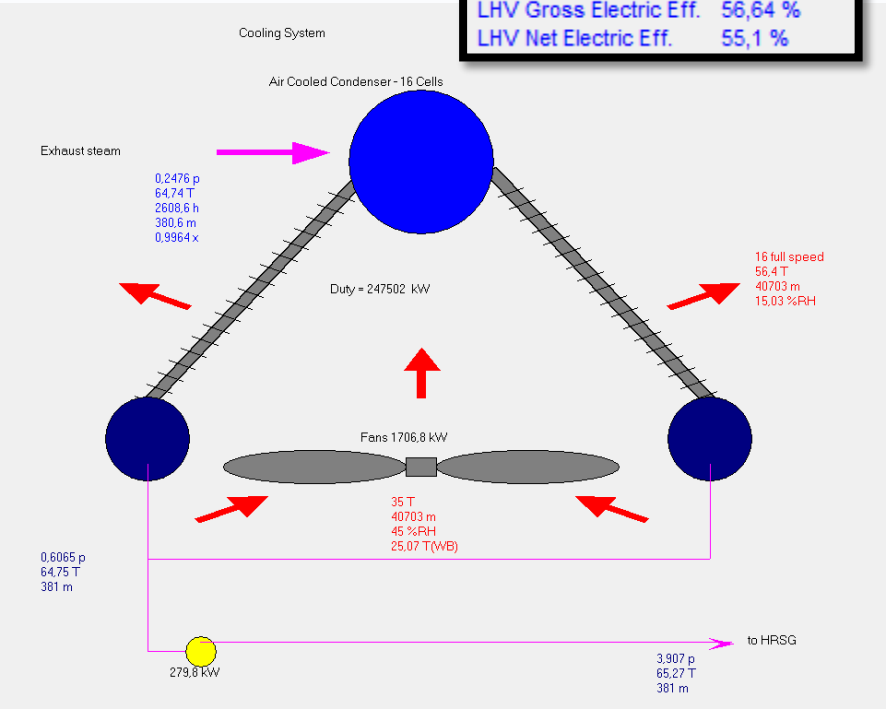
Example 3: GT Master, GT SGT5-4000F, 3PRH, ACC. ***Spray to 100% RH @ 35 C***



Spray Water to ACC to increase output at peak conditions

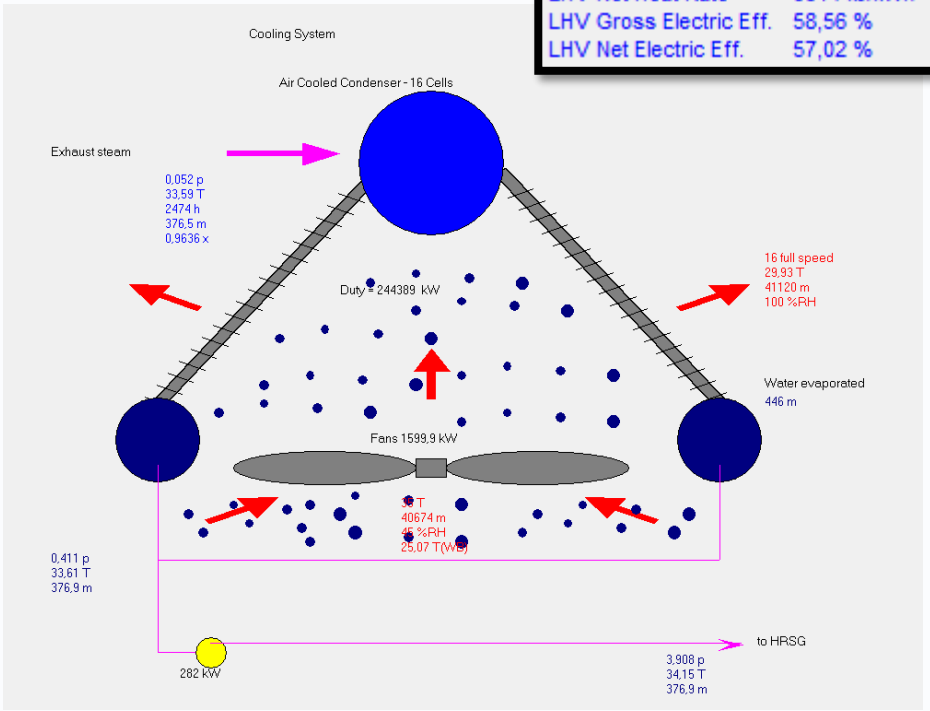
No Spray

Gross Power	401385 kW
Net Power	390445 kW
Aux. & Losses	10940 kW
LHV Gross Heat Rate	6355 kJ/kWh
LHV Net Heat Rate	6533 kJ/kWh
LHV Gross Electric Eff.	56,64 %
LHV Net Electric Eff.	55,1 %



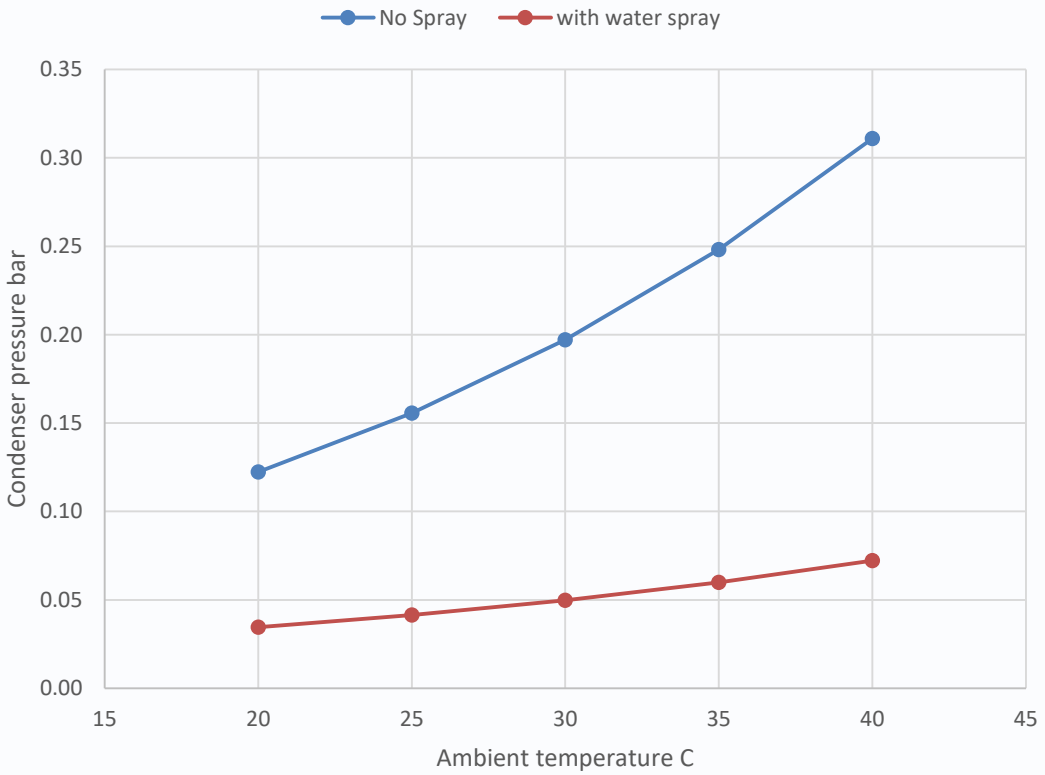
Spray

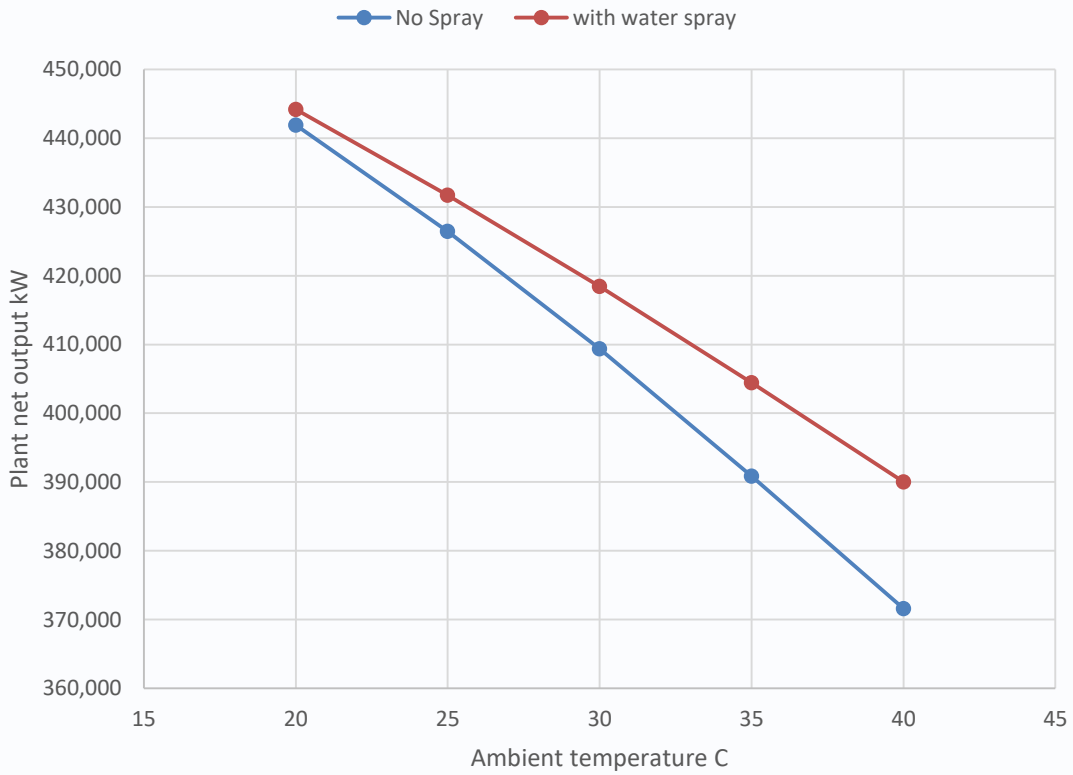
Gross Power	414946 kW
Net Power	404036 kW
Aux. & Losses	10910 kW
LHV Gross Heat Rate	6148 kJ/kWh
LHV Net Heat Rate	6314 kJ/kWh
LHV Gross Electric Eff.	58,56 %
LHV Net Electric Eff.	57,02 %



Spray Water to ACC to increase output at peak conditions

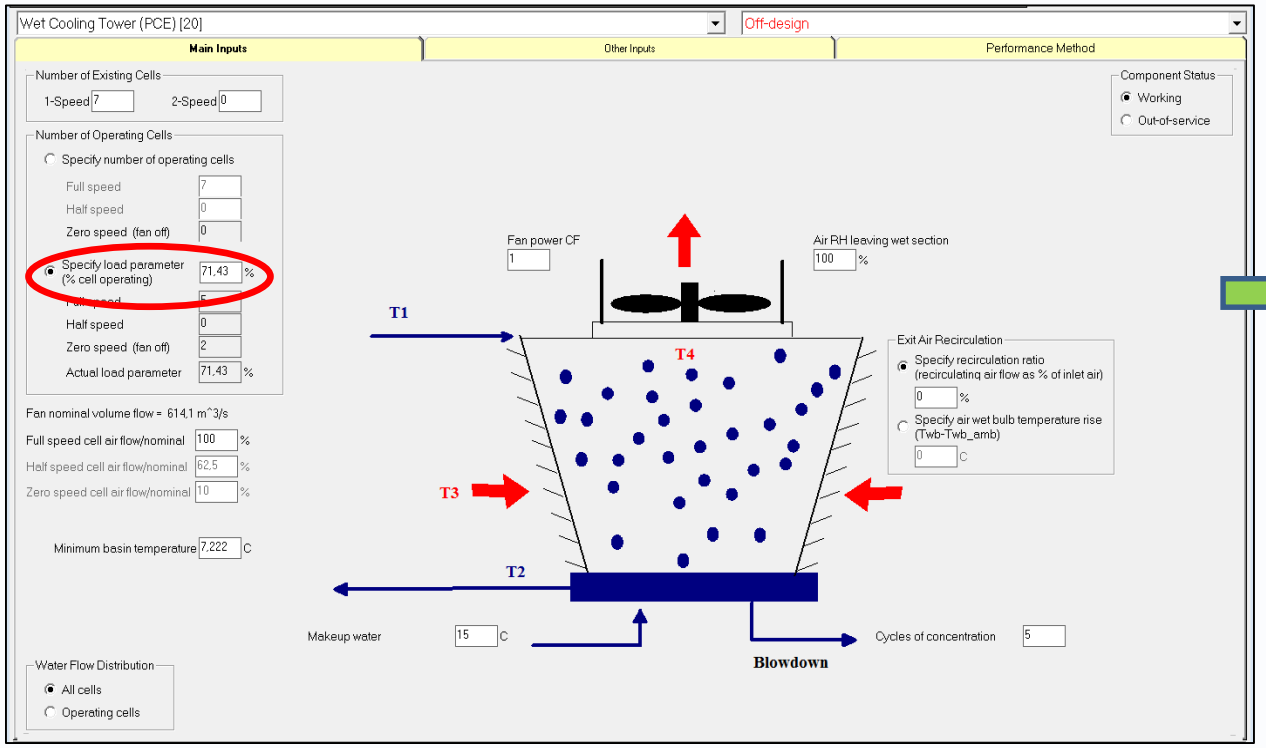
Ambient temperature	C	20	25	30	35	40
Additional Power (net)	MW	2,3	5,3	9,1	13,6	18,4
Water consumption (100% RH at air exit)	t/h	425,2	454,3	480,7	502,9	521,9
Water consumption per adittional Power	(t/h) / MW	183,0	86,1	52,7	37,1	28,3



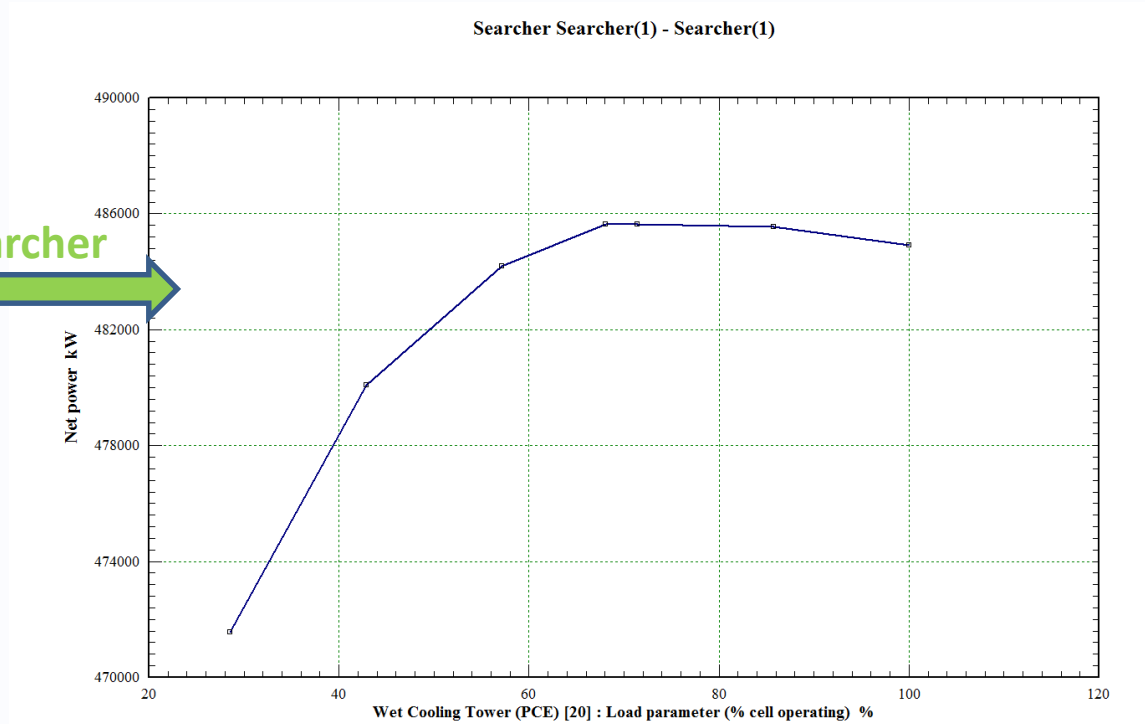


CT n. of cells optimization to maximize Net Power using Searcher

Example 4: Thermoflex, GT SGT5-4000F, 3PRH, WCC+WCT, 2 CWPumps. ***CT Optimization @ 2 C***

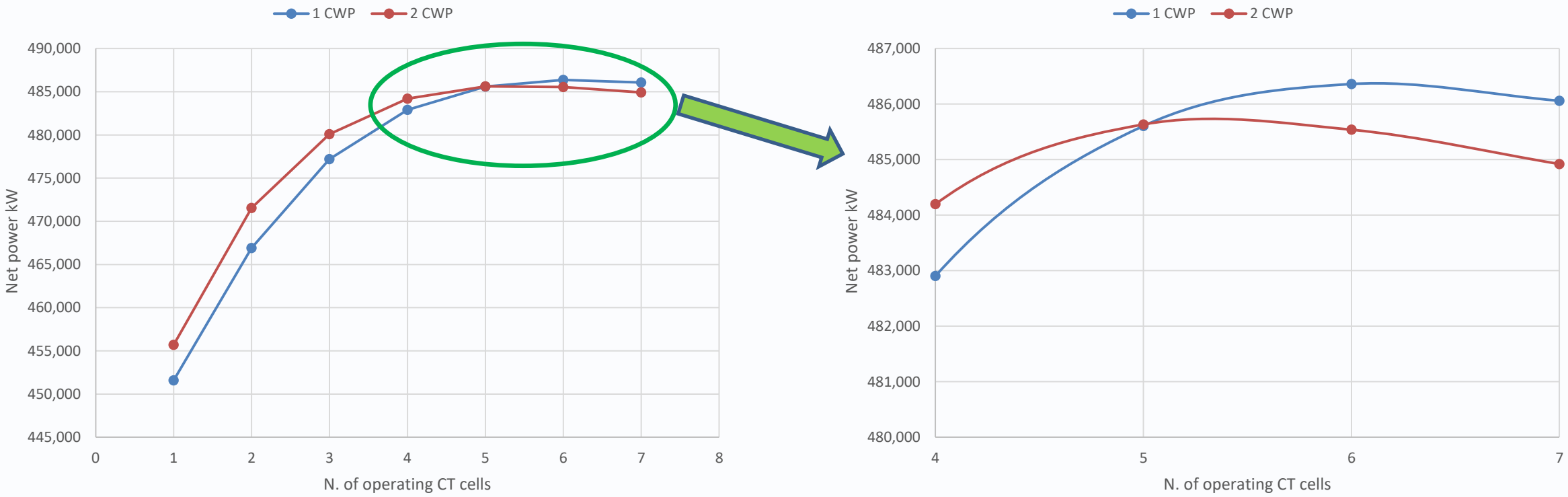


Searcher



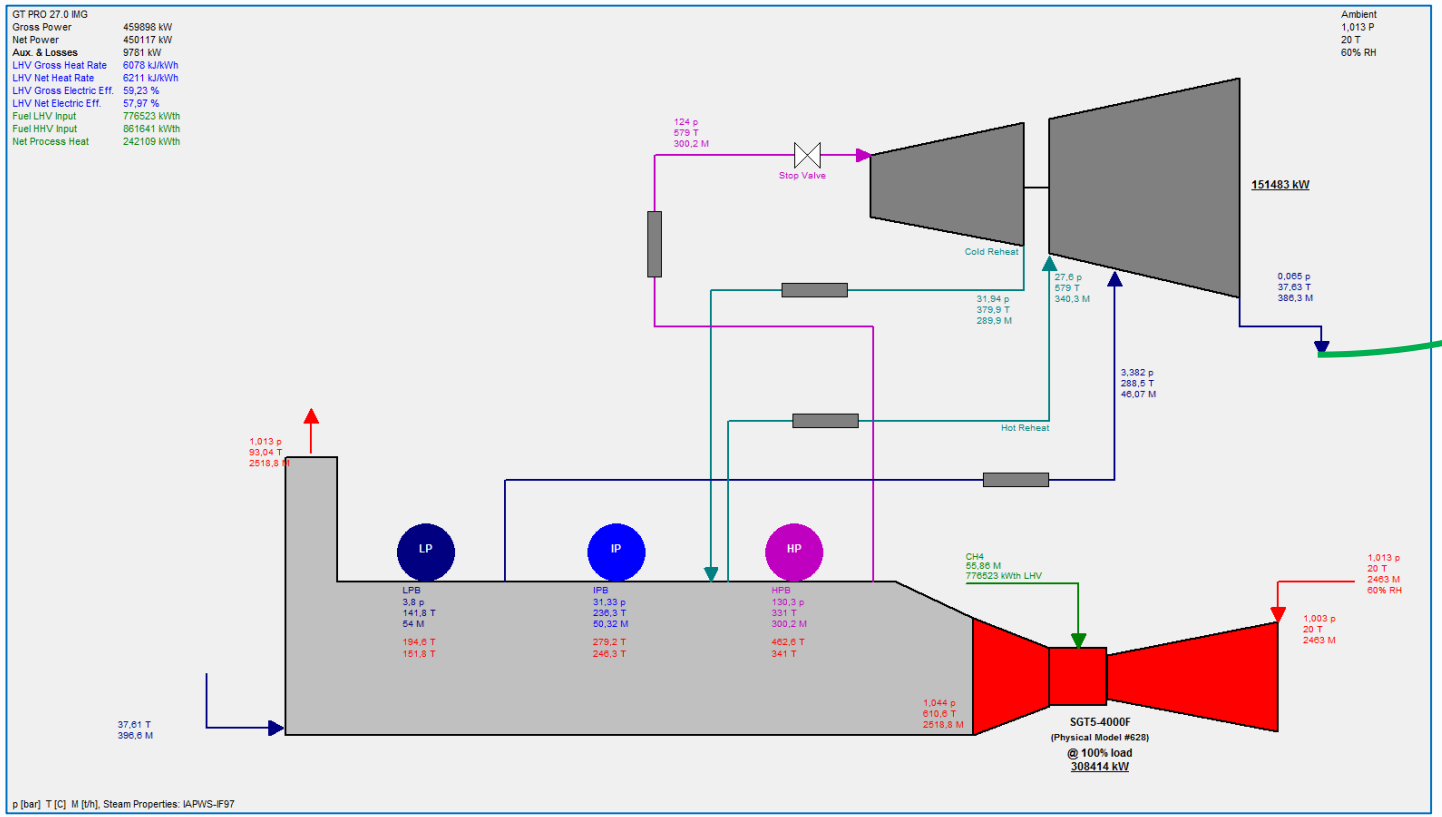
CT n. of cells optimization to maximize Net Power using Searcher

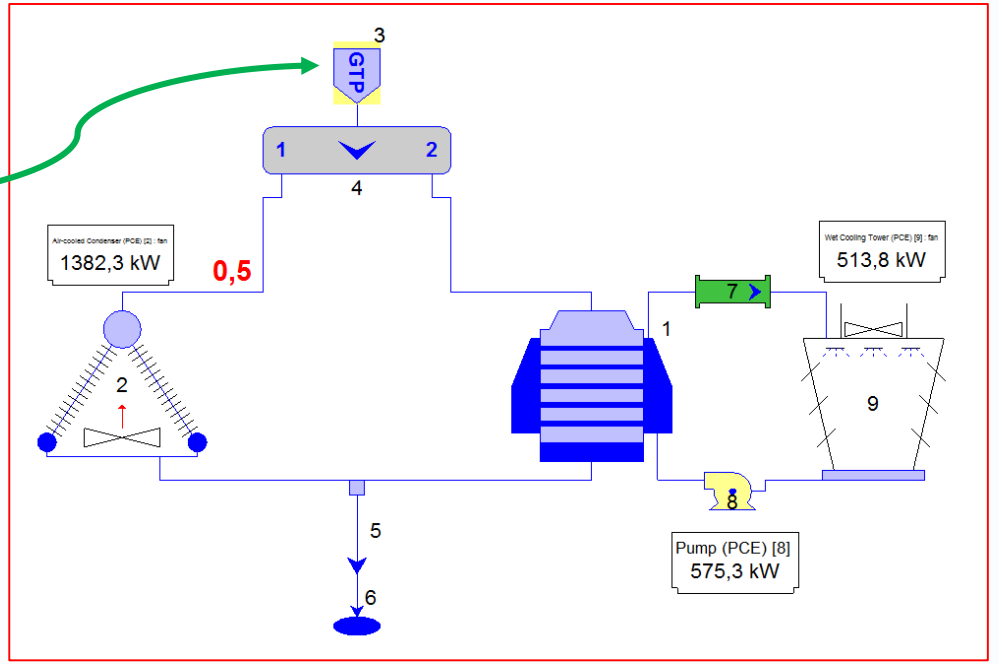
CT n. of cells Optimization with 1 or 2 CW pumps running (ELink)



Hybrid Condenser in TFX, link to GTP/GTM

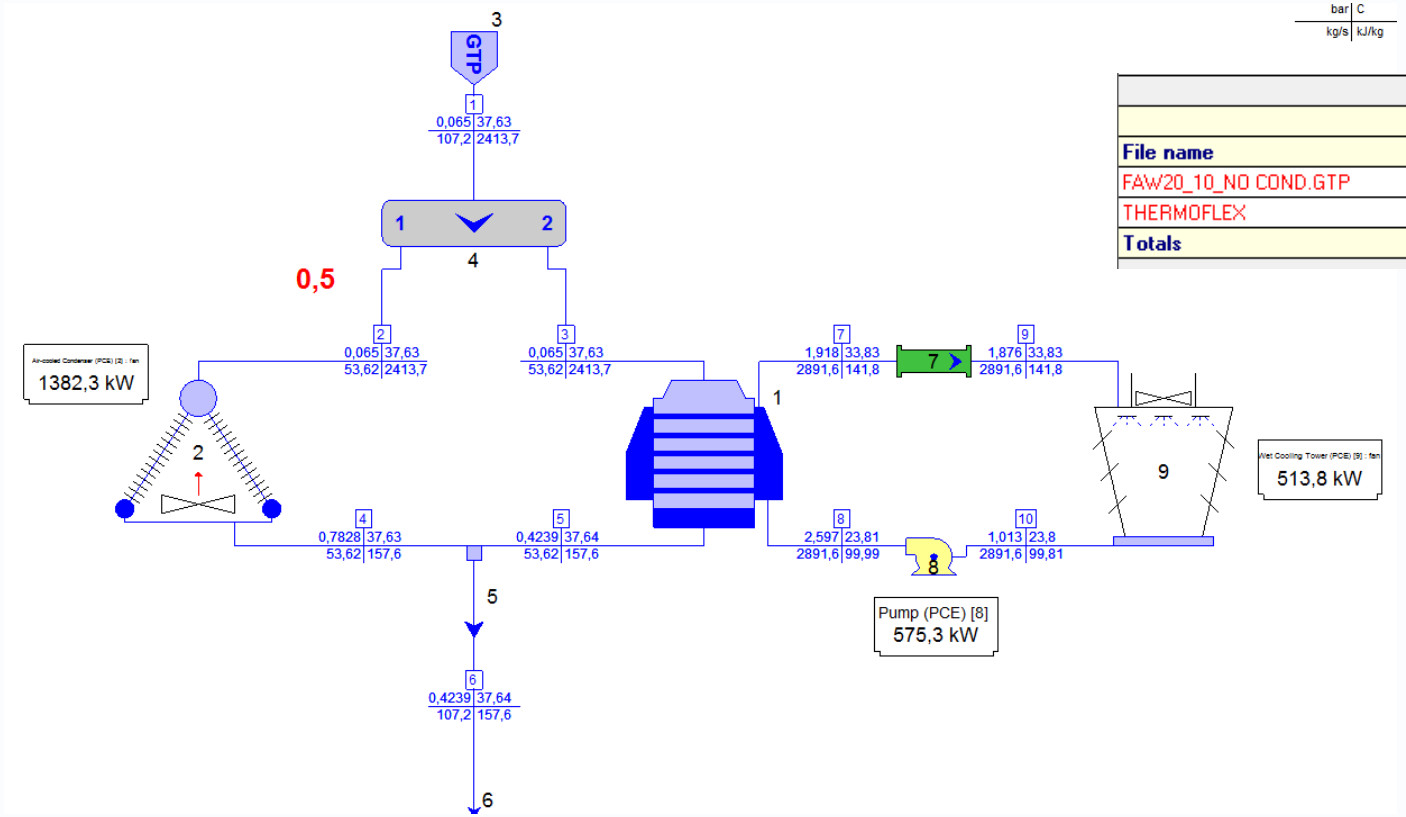
Example 5: Thermoflex & GTPM, GT SGT5-4000F, 3PRH, Hybrid Condenser, 50-50 at 20 C





Hybrid Condenser in TFX, link to GTP/GTM

Design → TFX (ED) & GTP, T=20 C, 50%-50% Split, sizing the condensers



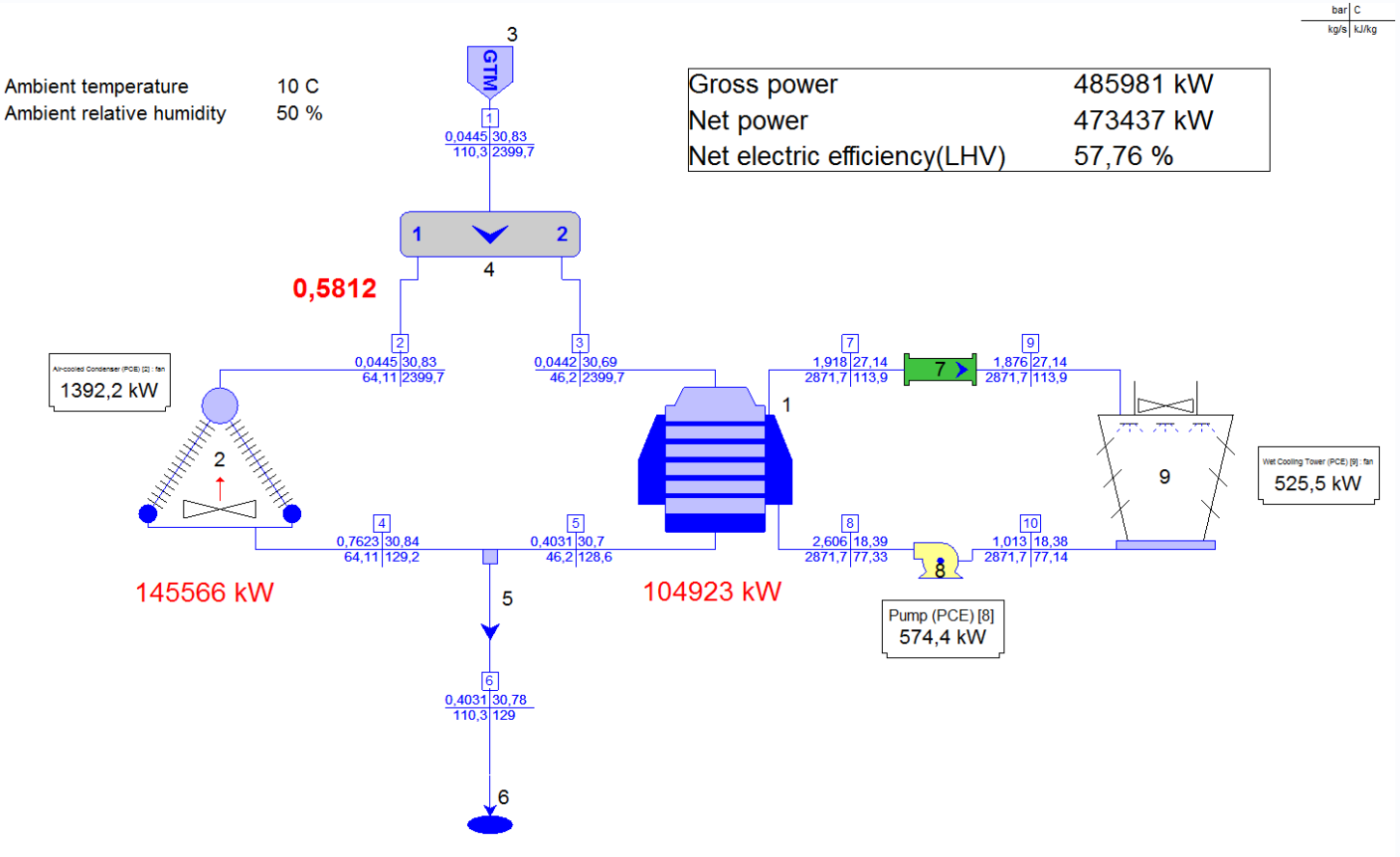
Results from both programs combined in TFX

Summary of TFX & Linked Files			
	Gross power	Net power	Net HR
File name	[kW]	[kW]	[kJ/kWh]
FAW20_10_NO COND.GTP	459737	449961	6210
THERMOFLEX		-2471,3	
Totals	459737	447490	6244

Cost Breakdown	Unit Cost	Cost Adj. Factor	Ref. Cost	Est. Cost	
Sum of Costs for Equipment and PEACE Components & Linked Files			287.904.500	311.971.900	USD
FAW20_10_NO COND.GTP			265.667.900	287.810.600	USD
Pump (PCE)			375.389	397.558	USD
Pump (PCE) [8]	375.389	1			
Water-cooled Condenser (PCE)			2.176.807	2.357.284	USD
Water-cooled Condenser (PCE) [1]	2.176.807	1			
Wet Cooling Tower (PCE)			1.988.332	2.159.866	USD
Wet Cooling Tower (PCE) [9]	1.988.332	1			
Pipe (PCE)			335.355	366.962	USD
Pipe (PCE) [7]	335.355	1			
Air-cooled Condenser (PCE)			17.360.790	18.879.600	USD
Air-cooled Condenser (PCE) [2]	17.360.790	1			

Hybrid Condenser in TFX, link to GTP/GTM

Simulation: TFX (OD) & GTM



Macros at different Amb T

Parameter	Units	Case 1	Case 2	Case 3	Case 4	Case 5
Ambient temperature	C	7,459852E-06	10	20	30	40
Ambient relative humidity	%	50	50	50	50	50
Ambient temperature	C	7,459852E-06	10	20	30	40
Ambient RH	%	50	50	50	50	50
Gross power	kW	491948	485981	459646	427920	391337
Net power	kW	479326	473437	447400	415990	379768
Net electric efficiency(LHV)	%	57,438	57,7557	57,6409	56,8112	55,3949
Generator, Motor, and Aux Loads: Air-cooled Condenser (PCE) [2] : fan	kW	1401,51	1392,25	1381,31	1370,3	1357,72
Generator, Motor, and Aux Loads: Pump (PCE) [8]	kW	572,952	574,405	575,272	575,725	575,865
Generator, Motor, and Aux Loads: Wet Cooling Tower (PCE) [9] : fan	kW	538,117	525,493	513,943	502,127	489,862
Air-cooled Condenser (PCE) [2] : Condenser pressure	bar	0,0284208	0,0445321	0,0651077	0,094589	0,135892
Air-cooled Condenser (PCE) [2] : Condenser heat rejection	kW	163737	145566	122035	100627	80699,9
Water-cooled Condenser (PCE) [1] : Condenser heat rejection (per unit)	kW	89721,4	104923	120075	137864	155790
Balancing Splitter [4] : Actual flow fraction of 1st outlet		0,645936	0,581191	0,504114	0,421982	0,341276

Q & A Session

- Please forward your questions to 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!

IGNACIO MARTIN
Málaga – SPAIN
martin@thermoflow.com