Welcome!

Webinar #6: MATCHING STEAM TURBINE PERFORMANCE
19 JULY 2017

Agenda:

* Introduction
* ST basics
* Sample HB's
* The Drill – Performance Matching Procedure
* ST Performance Matching Exercise
* Reference Material- ST LSB's, Pressures & Flow Areas, ST steam sealing
* Q & A Session (pls. send Q's anytime during the presentation to both the presenter & host)

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Support: Meritt Elmasri (U.S. HQ)

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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

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Some Thoughts on ST's

- For a given flow, a fixed flow passing area will generate a corresponding pressure.
- Hence pressure at the HP, IP, LP modules will be dictated by the fixed flow area at the inlet.
- Designing in GTP, STP, TFX (design mode) etc is in reverse to the above ie. Pressures & flows are defined, and flow areas are calculated.
- To accurately match ST performance against a given heat balance need to account for:
  - OEM fixed hardware (nozzles, SV & CV dP, LSB geometries & exhaust loss curves)
  - ST section efficiencies
  - Leakage & sealing flows
  - Generator losses & efficiencies

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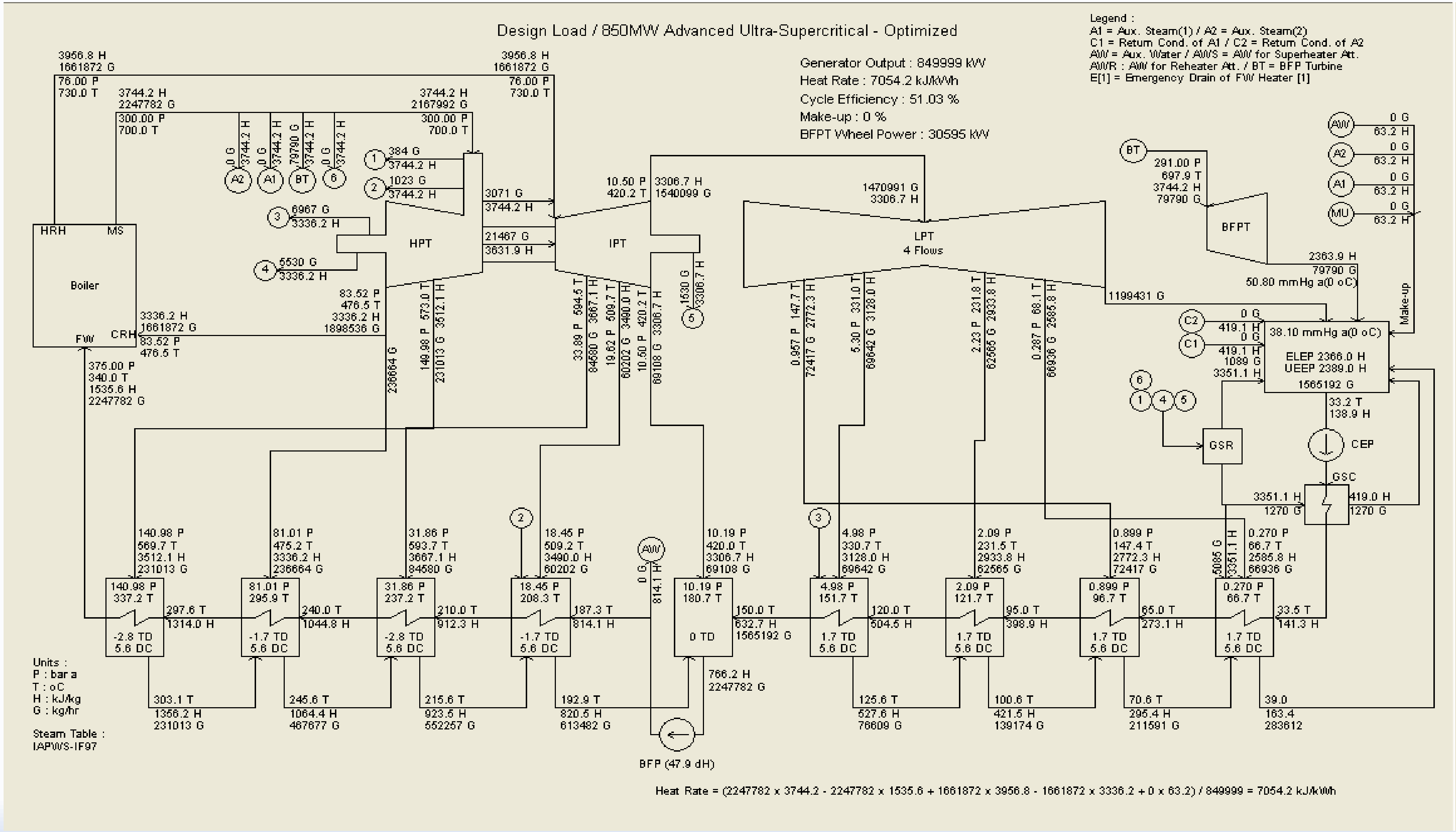
…a typical as received HB ….



Sample Heat Balance

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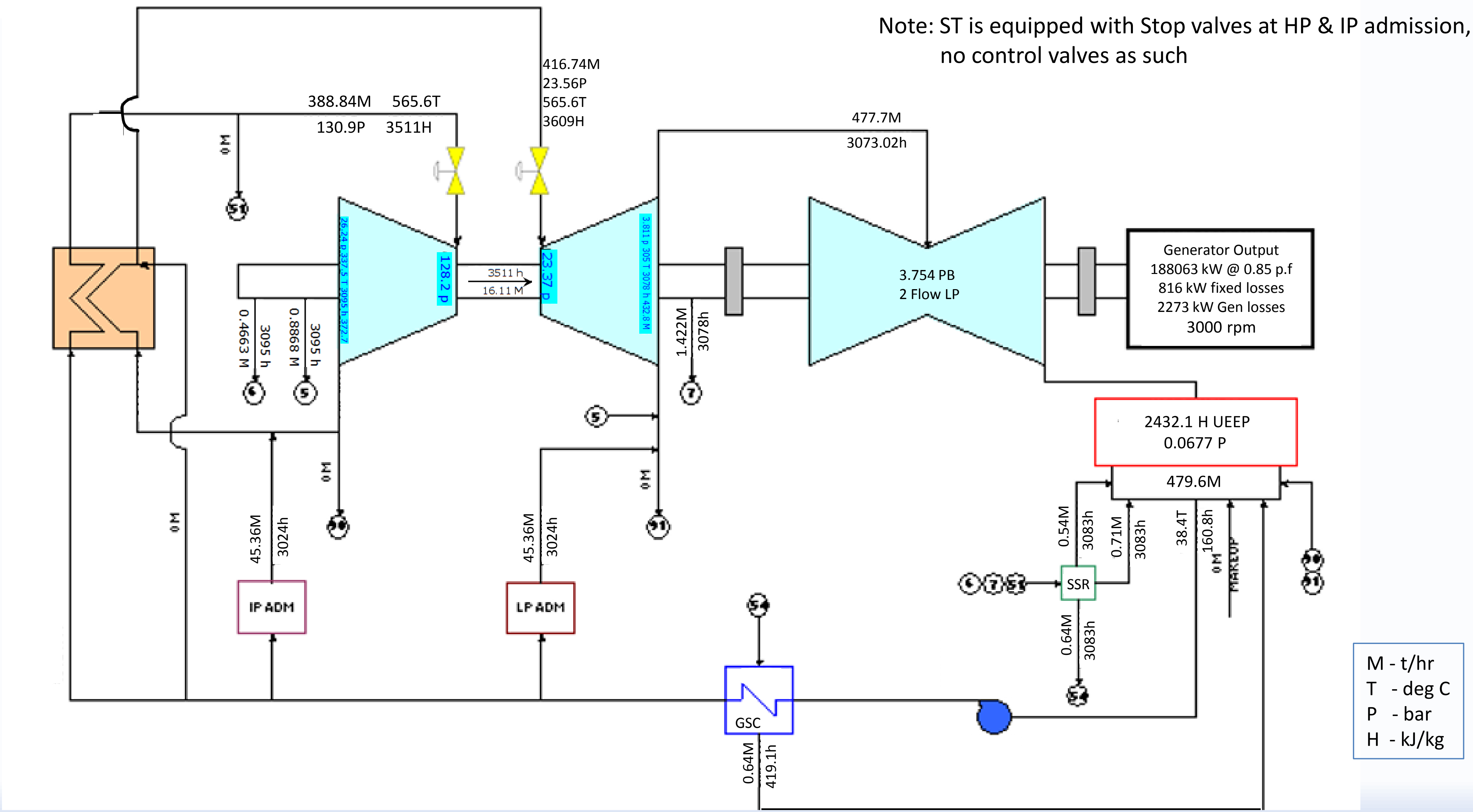
Note: ST is equipped with Stop valves at HP & IP admission, no control valves as such



Key HB Data

HPT Module

Steam Conditions Prior to HP SV

- 130.9 Bar, 565.6 degC, 388.8 t/hr

Inlet Conditions (Bowl) – after SV

- 128.2 Bar, 564.6 degC, 372.7 t/hr

Exit Conditions

- 26.24 Bar, 3095 kJ/kg, 371.4 t/hr

Leaks

16.11 t/hr from HP inlet to IP inlet

0.8868 t/hr from HP exit to X-O

0.4663 t/hr from HP exit to SSR

IPT Module

Steam Conditions Prior to IP Stop Valve

- 23.56 Bar, 565.6 degC, 416.69 t/hr

Inlet Conditions (Bowl)

- 23.27 Bar, 563.8 degC, 431.4 t/hr (=371.4 + 43.6 + 16.1 t/hr)

Exit Conditions

- 3.811 Bar, 3078 kJ/kg

Leaks

1.422 t/hr from IP exit to SSR

Generator

188063 kWe, 816 kW fixed losses, 2273 kW gen. losses, 0.85 pf, H2 cooled, 60Hz

LPT Module

Inlet Conditions

- 3.754 Bar, 302.5 degC, 477.7 t/hr

Exit Conditions (after LL)

- 0.0677 Bar, 2417.9 kJ/kg

Dual flow exhaust

Steam Seal System

Excess SSR flow -> Condenser

Excess SS Packing Exhaust -> GSC

GSC Pressure – 0.8274 Bar

SSR Pressure – 1.241 Bar

SS Flow to Condenser per LPT Path- 0.3545 t/hr

SS Flow to Packing Exhaust per LPT Path – 0.3175 t/hr

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The Drill – Key Steps

- If possible, determine ST OEM (possibly from internet sources for existing plants)
 Determine the key parameters to be matched ie. type of cycle, line frequency, mass flows, pressures, temperatures, condensing conditions, generator & type, p.f etc
- Set up the cooling system (condenser pressure) per HB info provided
- Set up the model so that mass flows and pressures match the HB
- Set up the ST groups > Group Efficiency on basis of exit enthalpy values provided per the HB
-Set up the ST leakages from HB info provided
-Set up the Steam Sealing System
- Set up the IP and LP admission flows via the “Process > Steam Additions “ tabs
- Run the model & check the results
- Return to Inputs & adjust the HP & IP group SV pressure drops to achieve the required ST bowl pressures.
- Run the model and check results, iterate as required on the pressures, also check the LSB geometry, enter OEM LSB geometry if available
- Run the model, check results. For final trimming to match generator output, adjust “ST Inputs > Design Assumptions > ST mechanical loss as a % of ST expansion power “ (item 17).

Step 1 – Basic Steam Cycle & Flows

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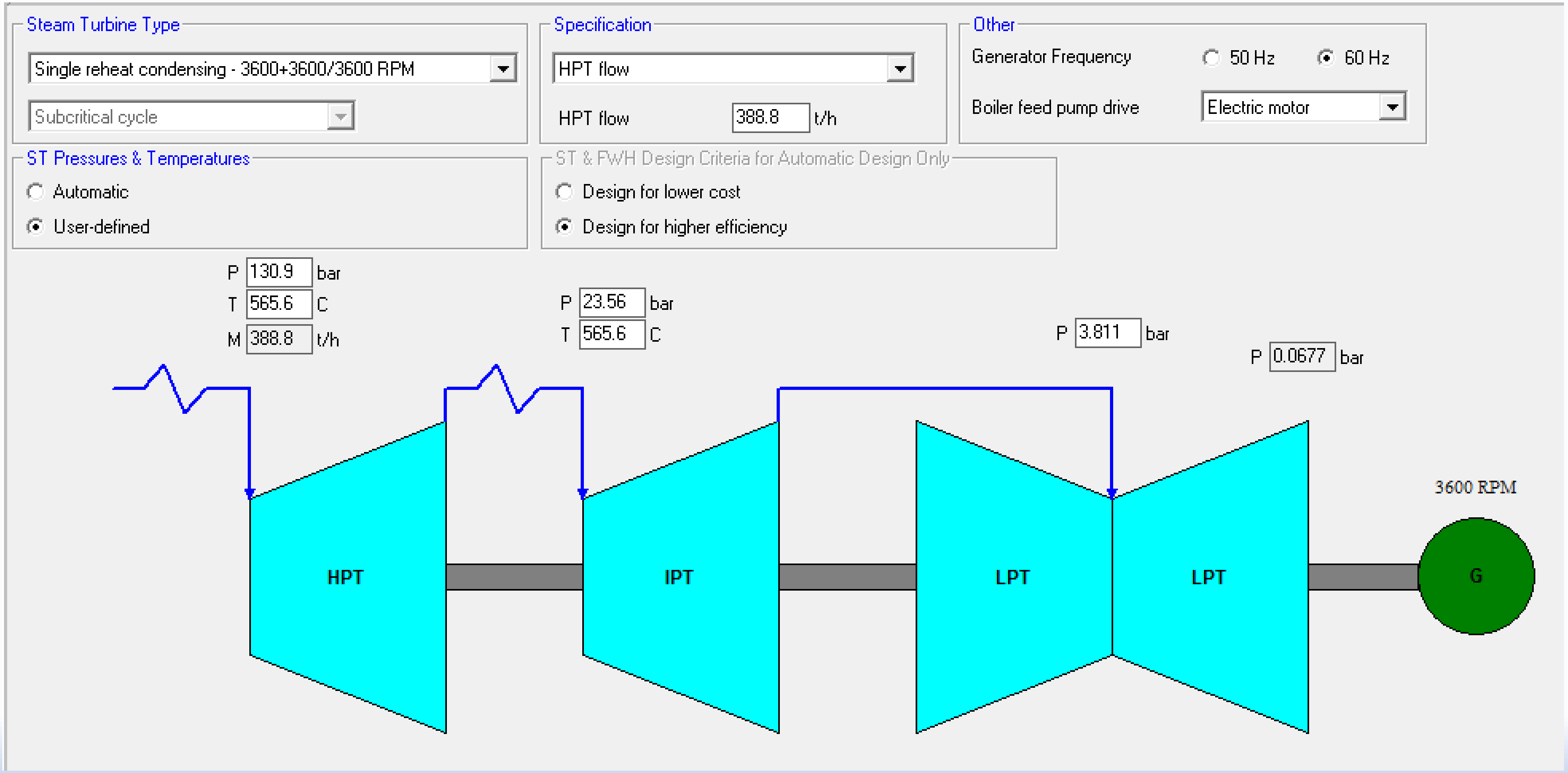
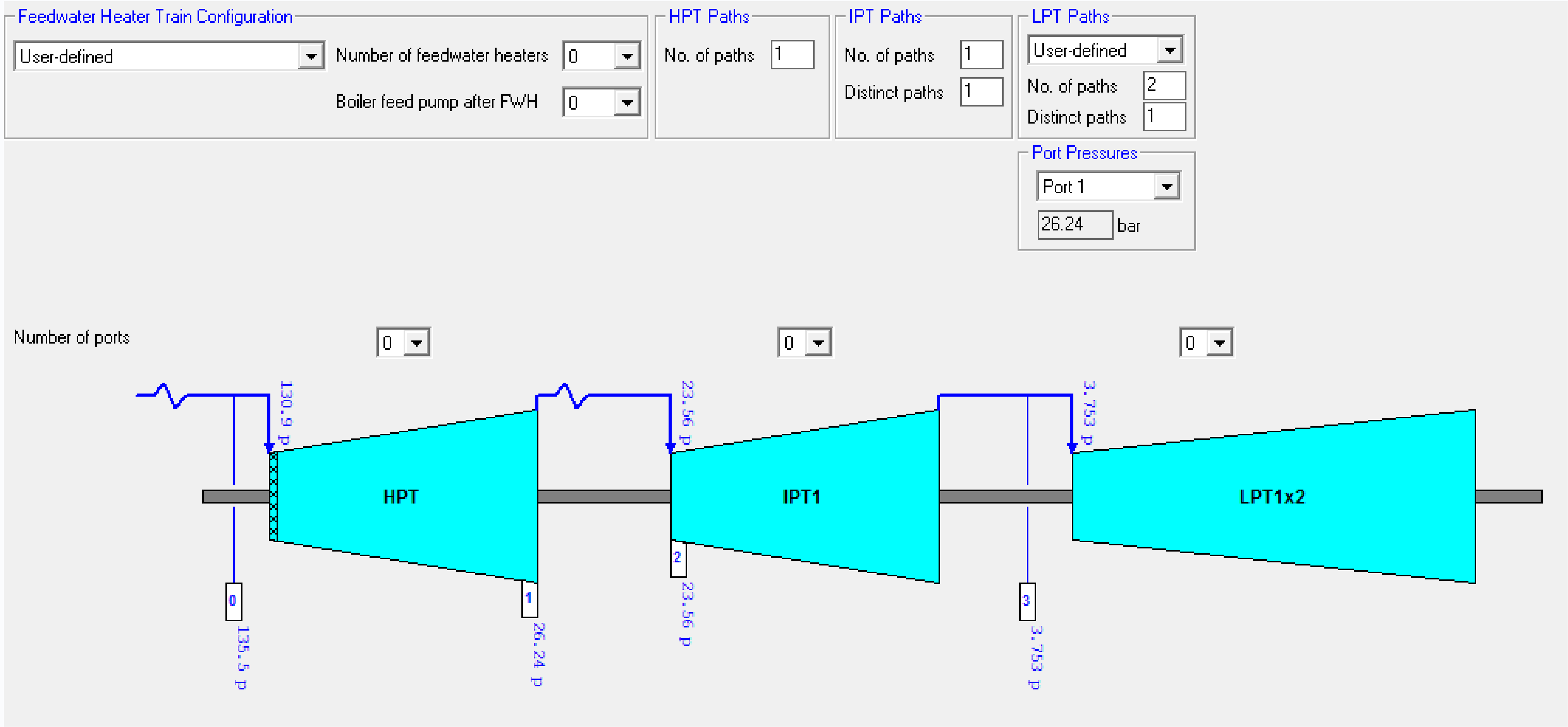
New Session- Black box steam generator, 120 – 200 MW plant output, ST Config = Single Reheat, Condensing
Plant Criteria – take defaults
Cooling System>Main Inputs> Condenser Design Method > User defined Pressure Only> 0.0677 Bar
Steam Cycle – ST P's & T's as shown:



Step 1 Continued…

ST – FWH – Feed Water Heater Train Configuration = User defined, Number of FWH= 0, also define no. of ports for HPT, IPT, LPT groups as zero & LPT Paths = User Defined, No. of Paths = 2, Distinct Paths =1

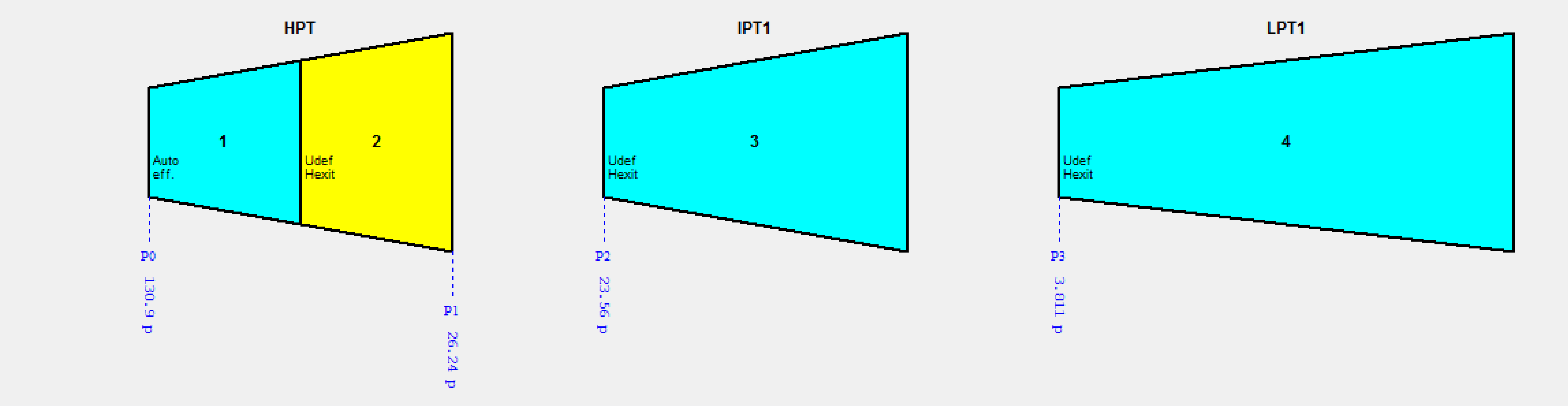
….as shown below.



Step 1 Continued...

ST Inputs– Group Design > As shown below

- Generator > Enter gen. eff. of 98.384% and change PF from 0.9 to 0.85, also define gen. mech. Loss as a % of total loss as 26.42%



Generator Efficiency Inputs

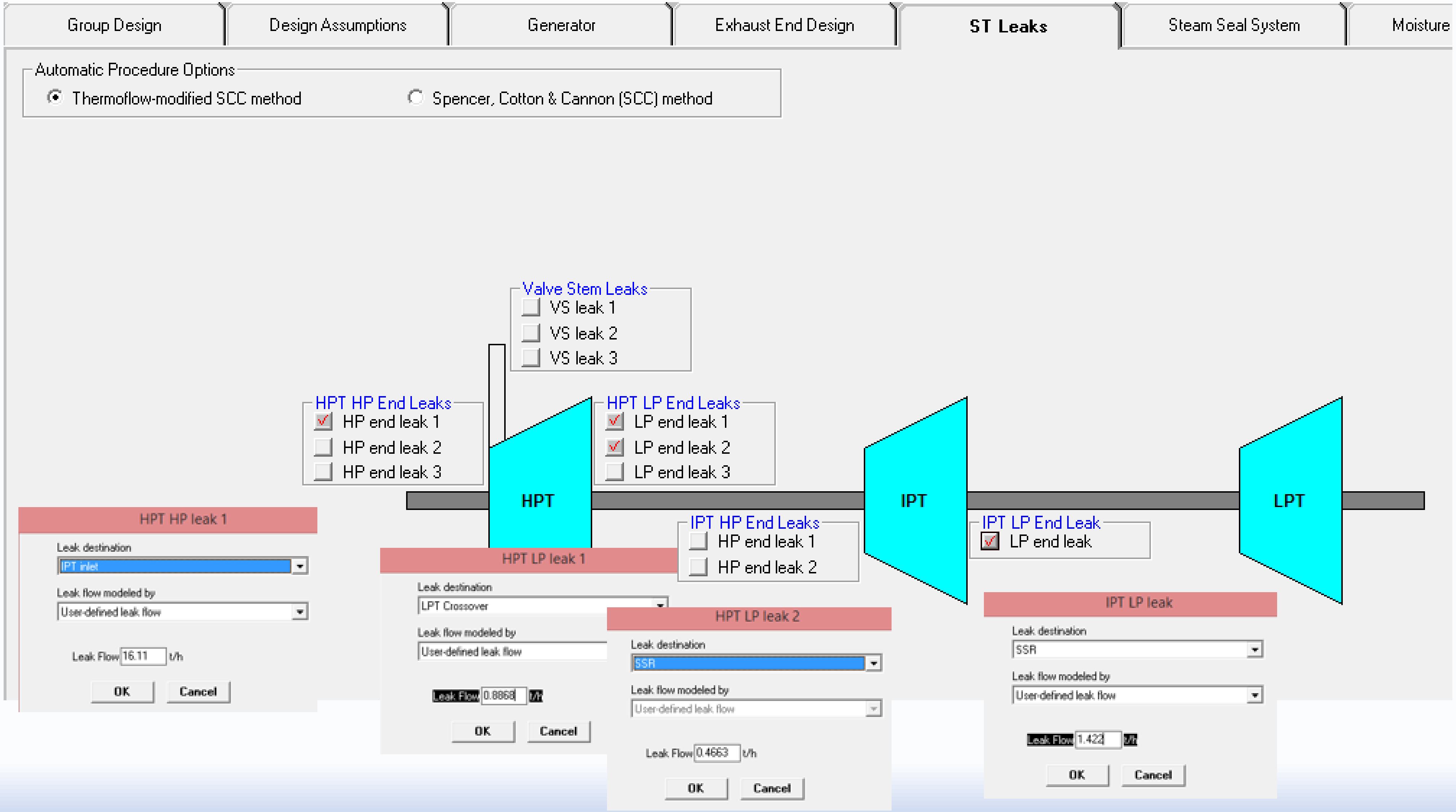
Group Design | Design Assumptions | **Generator**

1. Generator efficiency (0=automatic estimate)	98.38	%
2. C.F. for automatic estimate of generator loss	1	
3. Generator rated power / nominal output	1.05	
4. Generator power factor	0.85	
5. Generator cooling; 0=Open ventilated, 1=H2, 2=TEWAC	1	
6. Oil-cooler heat recovery (ST+Gen mech. losses) to feedwater	0	%
7. Generator coolant heat recovery (elec. & windage losses) to feedwater	0	%
8. Generator mechanical loss as percent of generator total loss @ rating	26.42	%

Step 1 Continued…

ST Inputs– Exhaust End Design > take the defaults

- ST Leaks > as shown below



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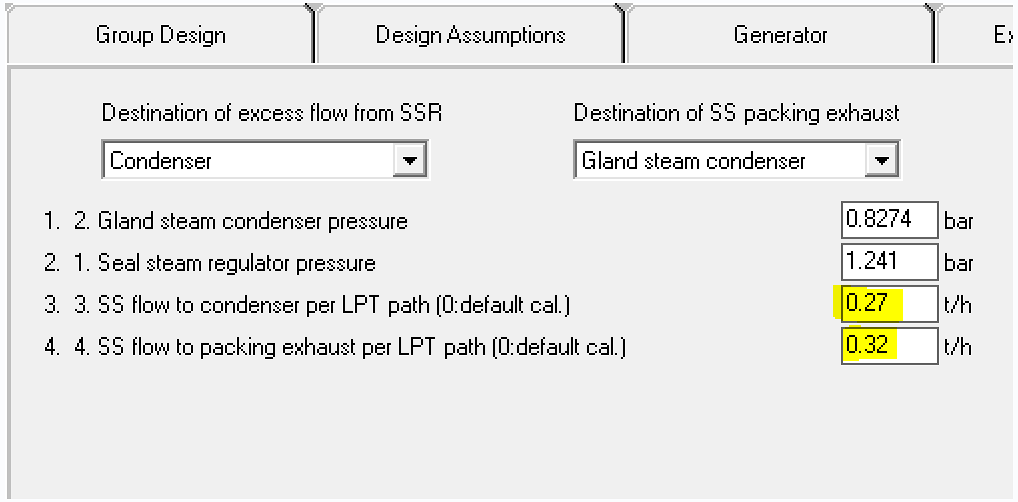
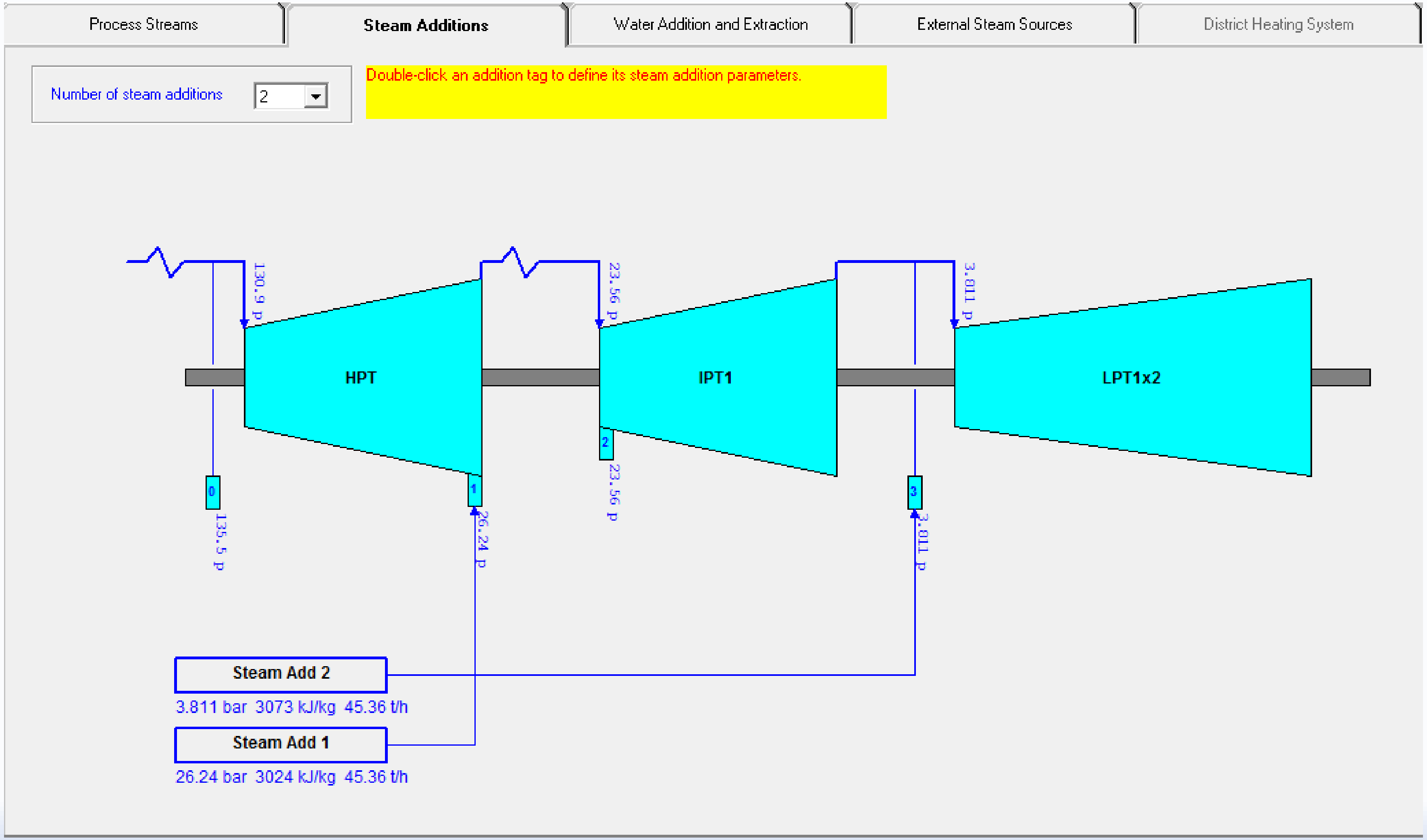
Step 1 Continued

ST Inputs Continued> Steam Seal System> enter the data as shown



Step 1 Continued

Process > Steam Additions > Define the IP and LP Flows (ref. the Heat Balance per Slide 6)



Step 2 – Run the Model & Check Results

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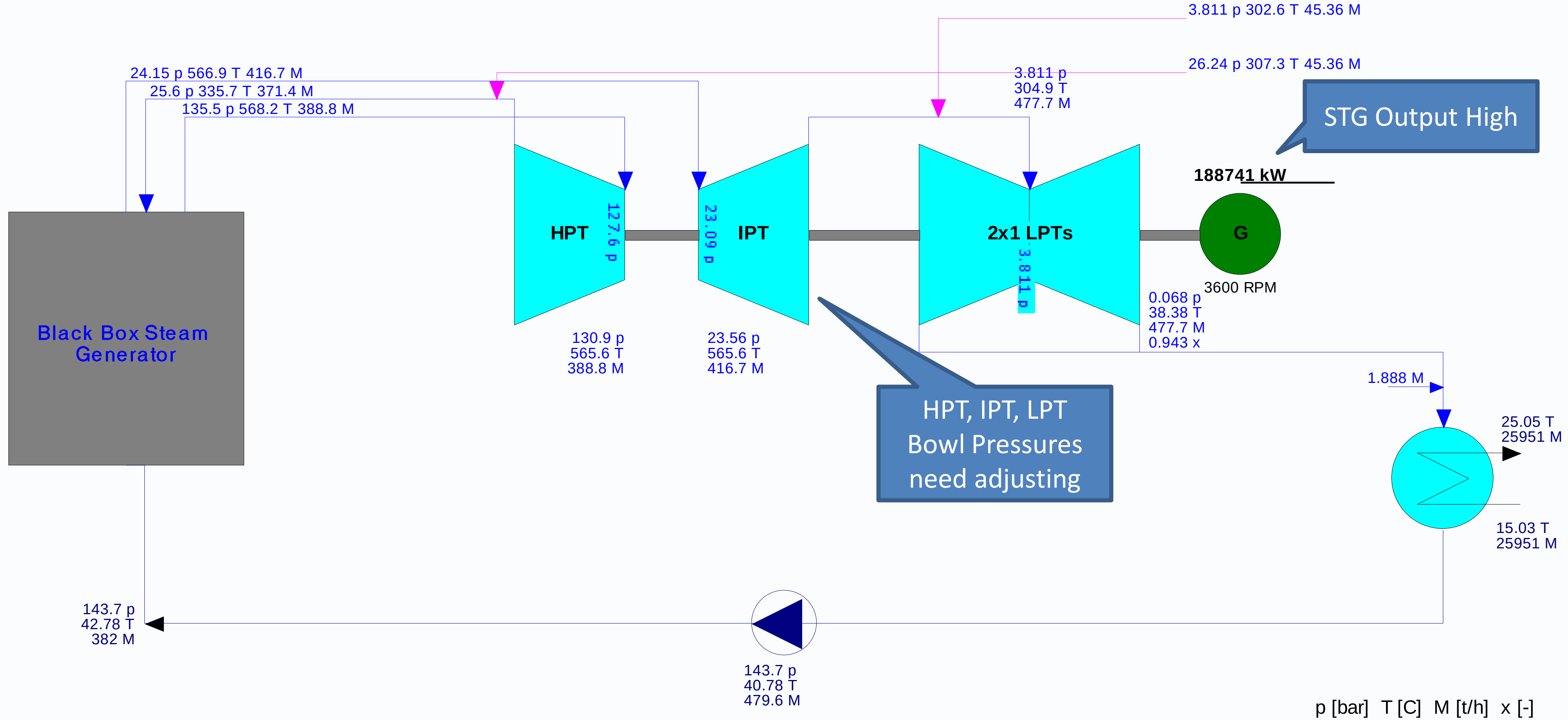
	188741	kW
Plant net power	180475	kW
Aux. & losses	8266	kW
Turbine heat rate	7977	kJ/kWh
Steam cycle heat rate	8016	kJ/kWh
Steam cycle efficiency	44.91	%

Ambient
1.013 p
15 T
60% RH
10.82 T wet bulb



p [bar] T [C] M [t/h] x [-]

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…areas requiring attention….

	P	Preq
	bar	bar
HPT GROUP IN	127.591	128.2
IPT GROUP IN	23.09	23.27
LPT GROUP IN	3.811	3.753

Pressure discrepancy at HP Inlet – fix by adjusting the stop valve pressure losses (2%)

Pressure discrepancy at IP Inlet – fix by adjusting the stop valve pressure losses (0.8%)

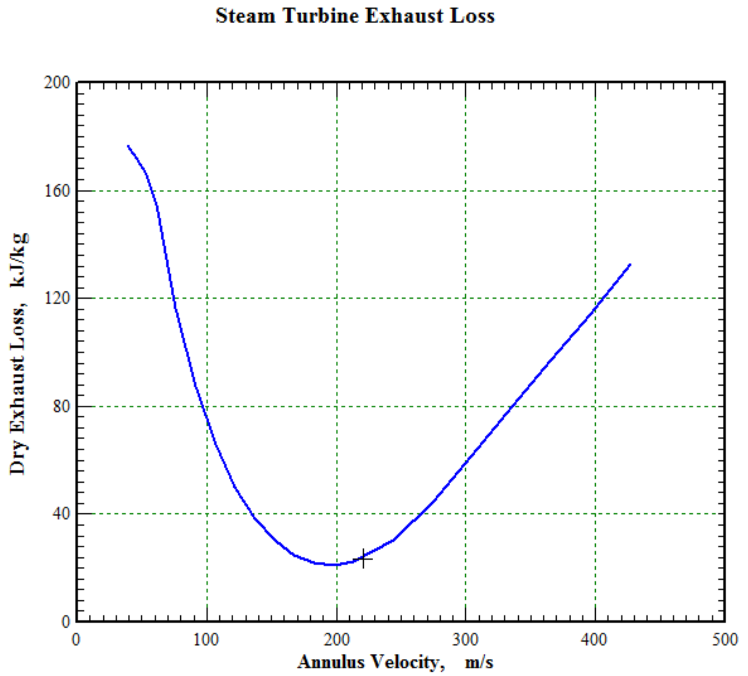
Pressure discrepancy at LP Inlet – fix by adjusting the LP Intercept Valve dP

Blading Exit		
Pressure	0.0677	bar
Temperature	38.38	C
Enthalpy	2413.9	kJ/kg
Volume flow (per path)	1313.8	m^3/s
Annulus area (per path)	5.963	m^2
Annulus velocity	220.3	m/s
Pitch Diameter	2320.3	mm
Bucket Length	818	mm
Pitch Speed	437.4	m/s
Tip Speed	591.6	m/s

LSB Detail – change to OEM LSB if available

Annulus velocity	220.3	m/s
Dry exhaust loss	23.41	kJ/kg
Corrected exhaust loss	18.24	kJ/kg

Exhaust Loss Curve



Make the required changes & re-run the model

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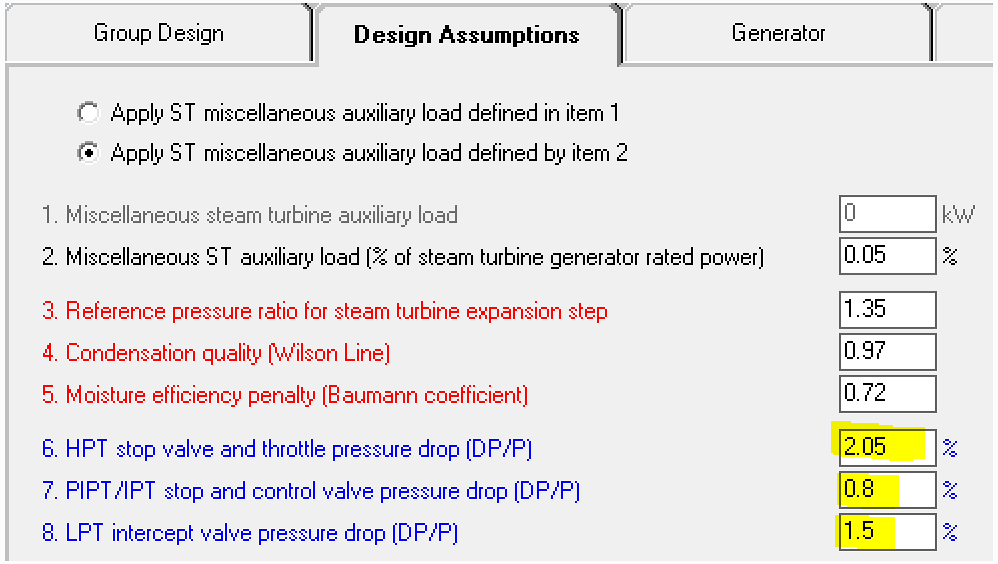
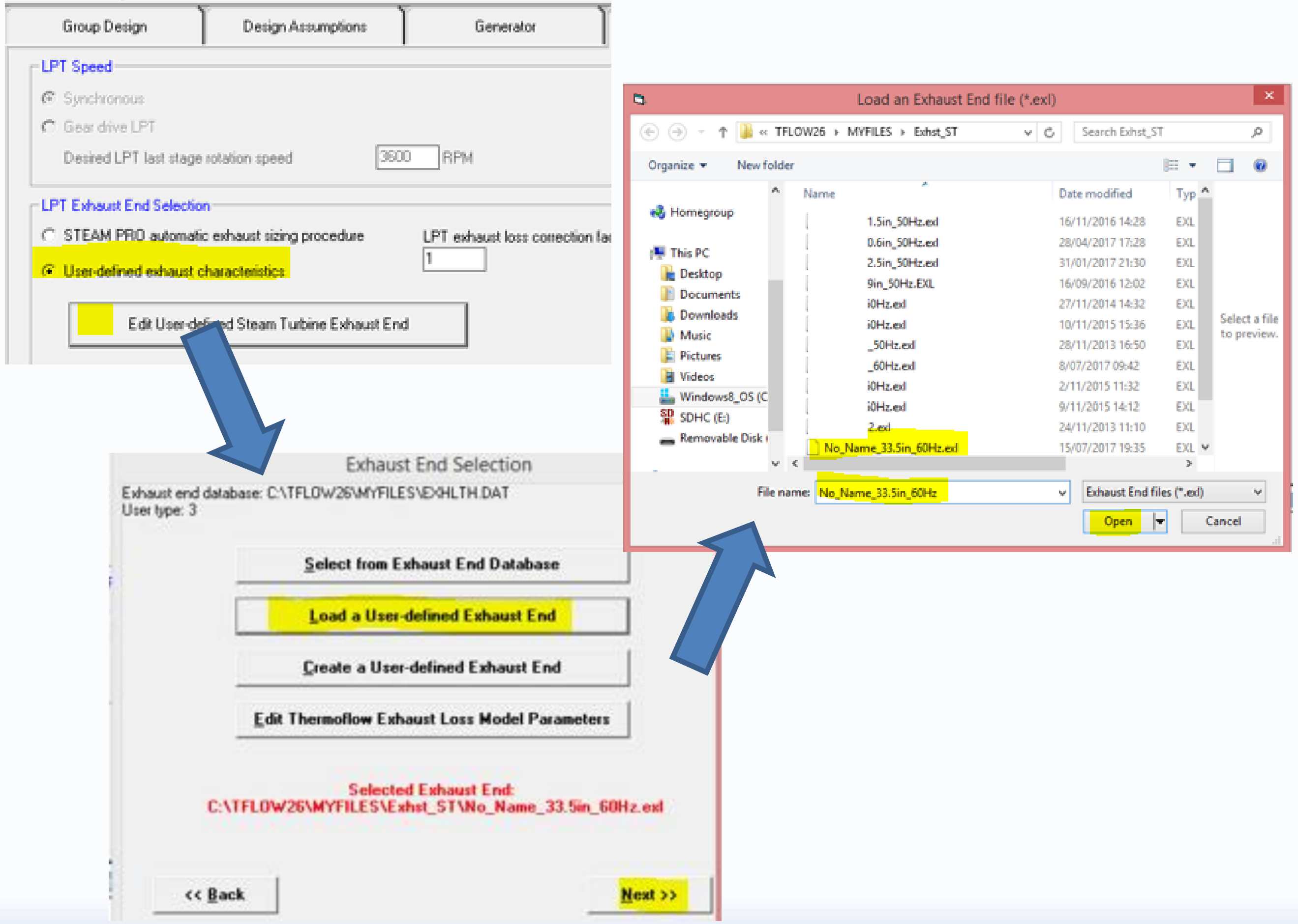
Changes Made to Correct HP, IP, LP inlet Pressures,

(OEM ".exl " also loaded)



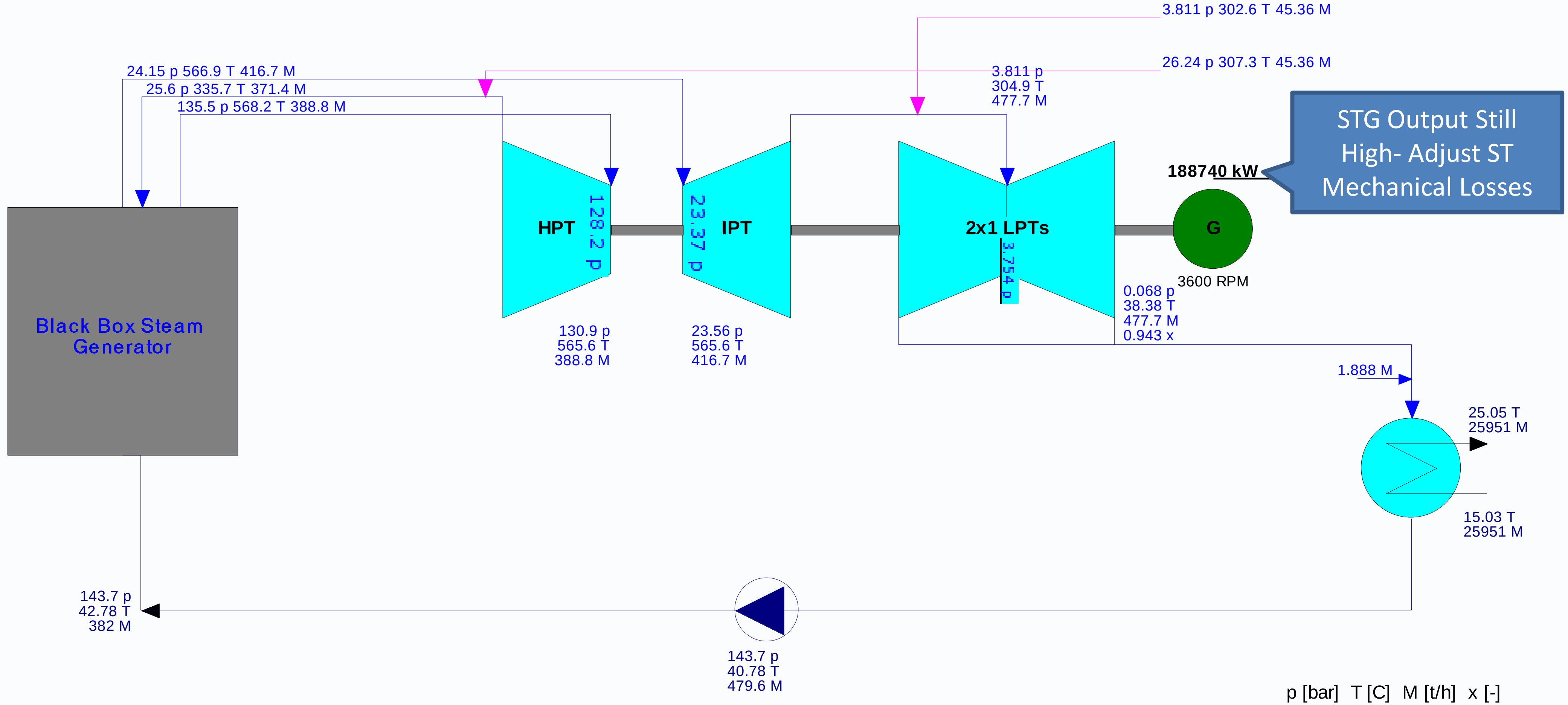
Required to correctly simulate the LP bowl pressure



	188740	kW
	180475	kW
Aux. & losses	8266	kW
Turbine heat rate	7977	kJ/kWh
Steam cycle heat rate	8016	kJ/kWh
Steam cycle efficiency	44.91	%

Corrected Run Results

Ambient
1.013 p
15 T
60% RH
10.82 T wet bulb



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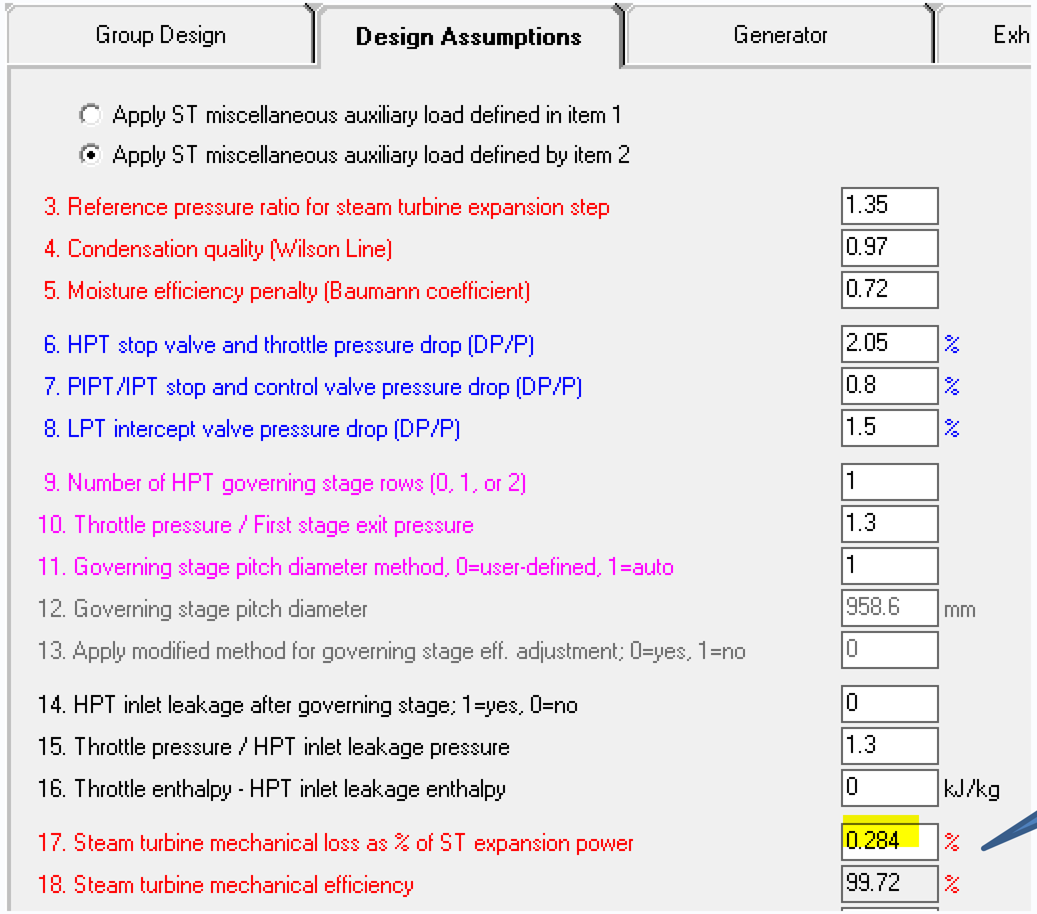
Final Adjustment



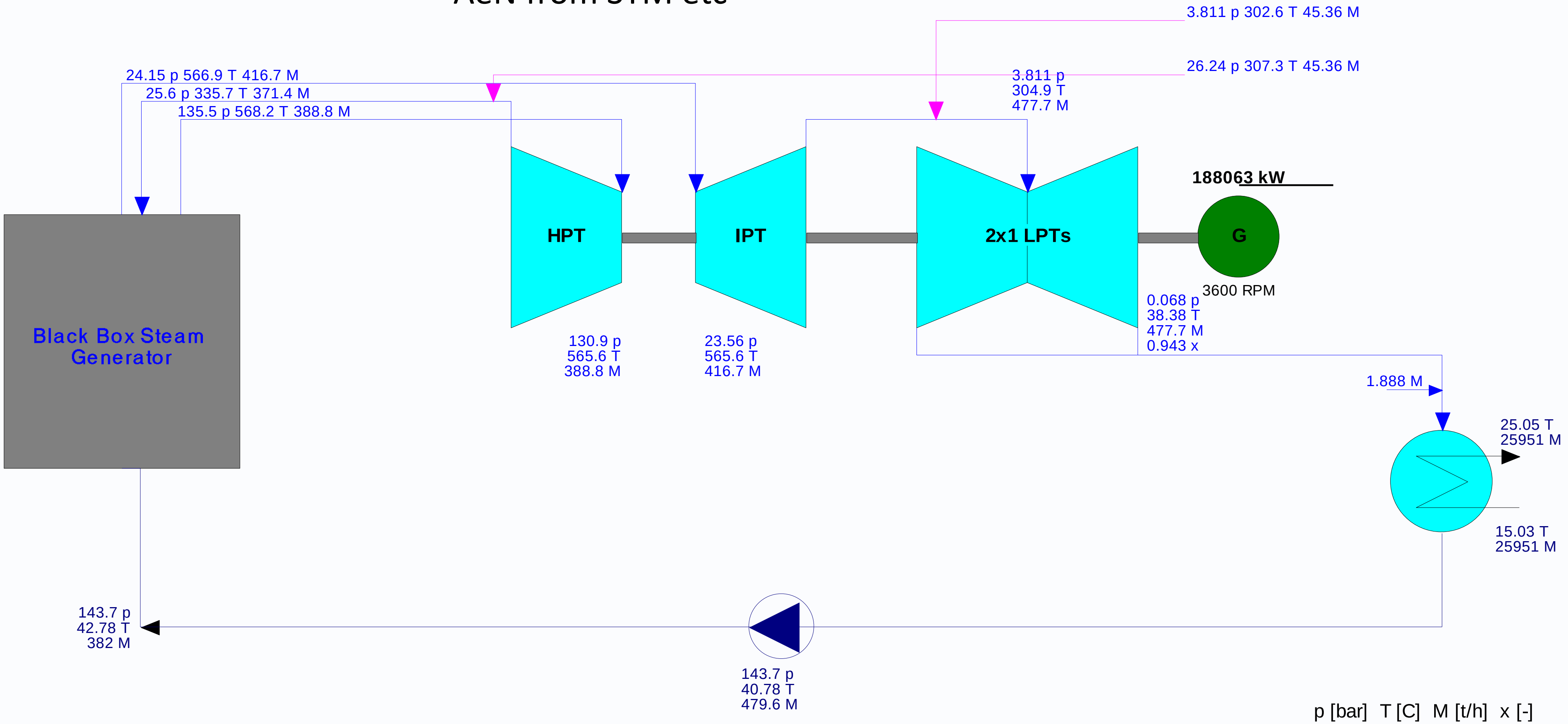
Adjust to give 188063kW at generator

Final Result….

	188063	kW
	179801	kW
Aux. & losses	8262	kW
Turbine heat rate	8006	kJ/kWh
Steam cycle heat rate	8045	kJ/kWh
Steam cycle efficiency	44.75	%

Ambient
1.013 p
15 T
60% RH
10.82 T wet bulb

Generator Output @ 188063 kW as required
Check through other parameters to verify results,
AeN from STM etc



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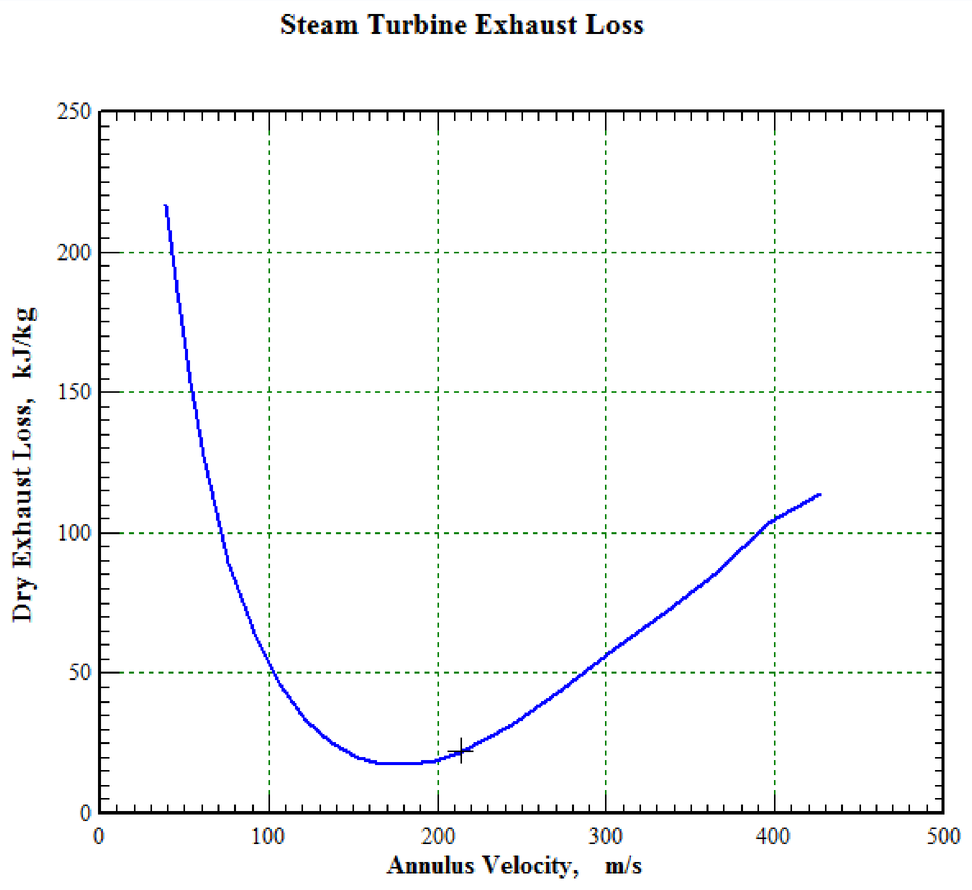
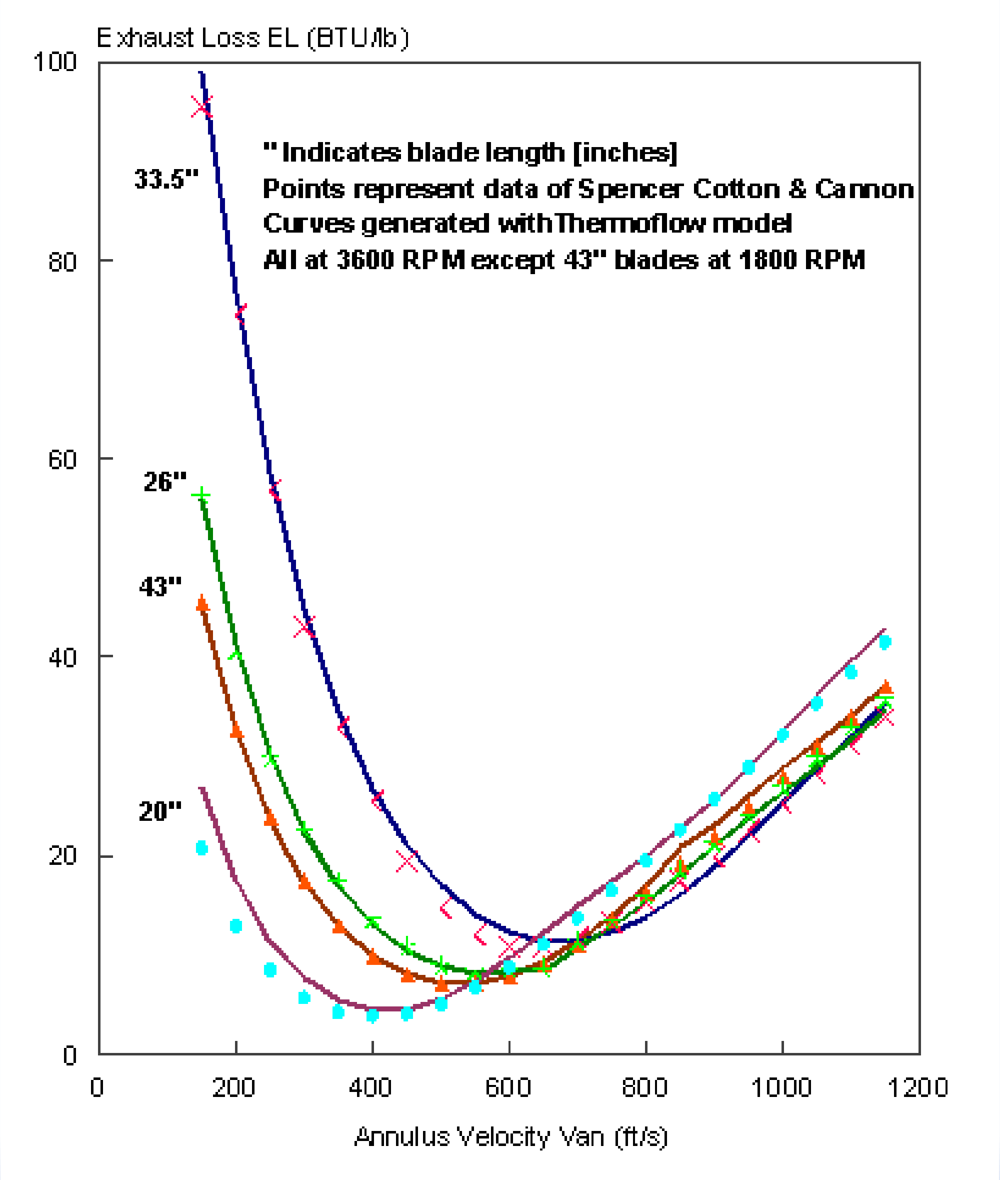
OEM Exhaust End – Losses Data

Annulus velocity	214.1	m/s
Dry exhaust loss	22.04	kJ/kg
Corrected exhaust loss	17.18	kJ/kg



Reference Material – Last Stage Blade Lengths

(Condensing ST)



From TF Help Menu, GTPro, Ch. 12.5.1

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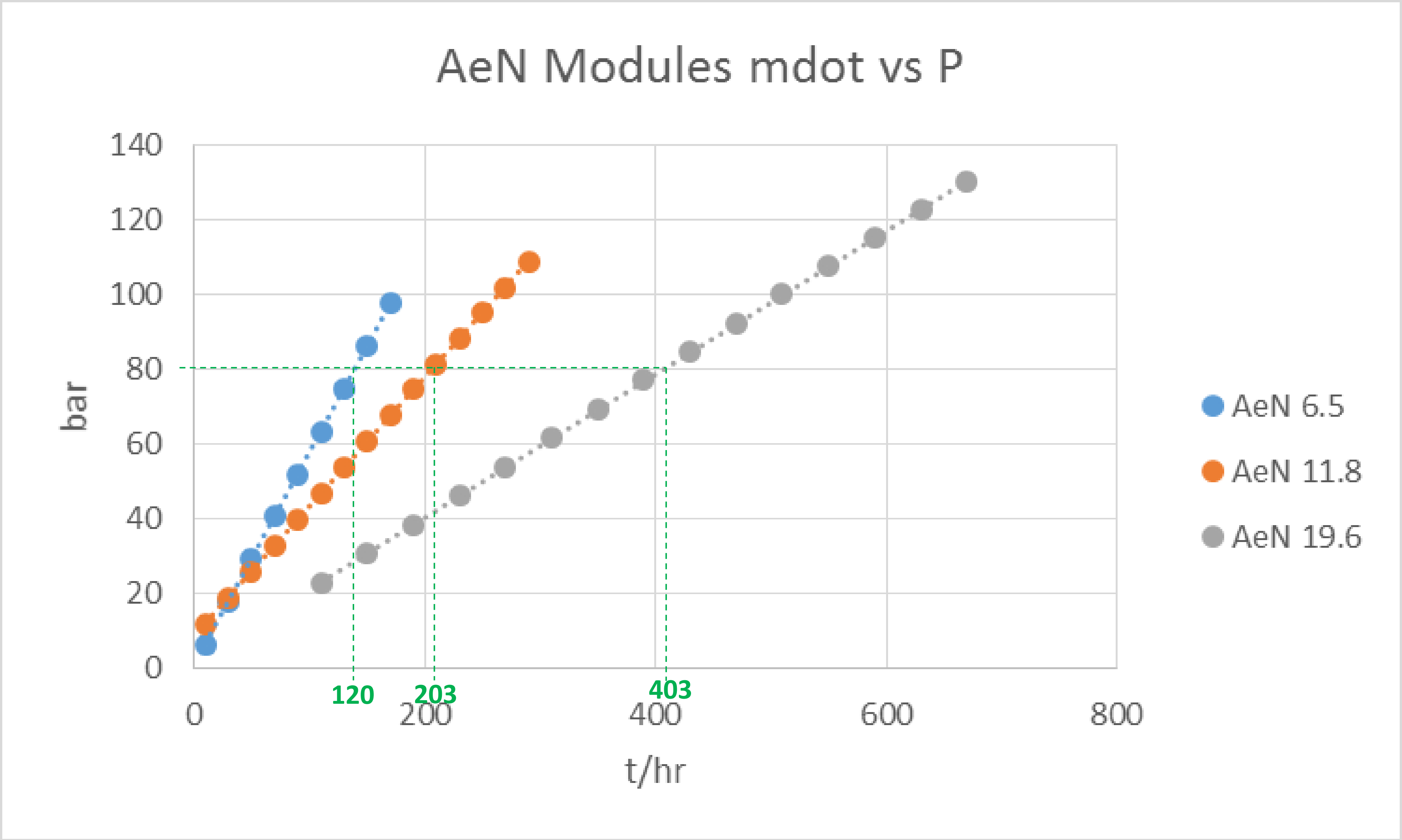
Reference Material – Pressures & Flow Areas



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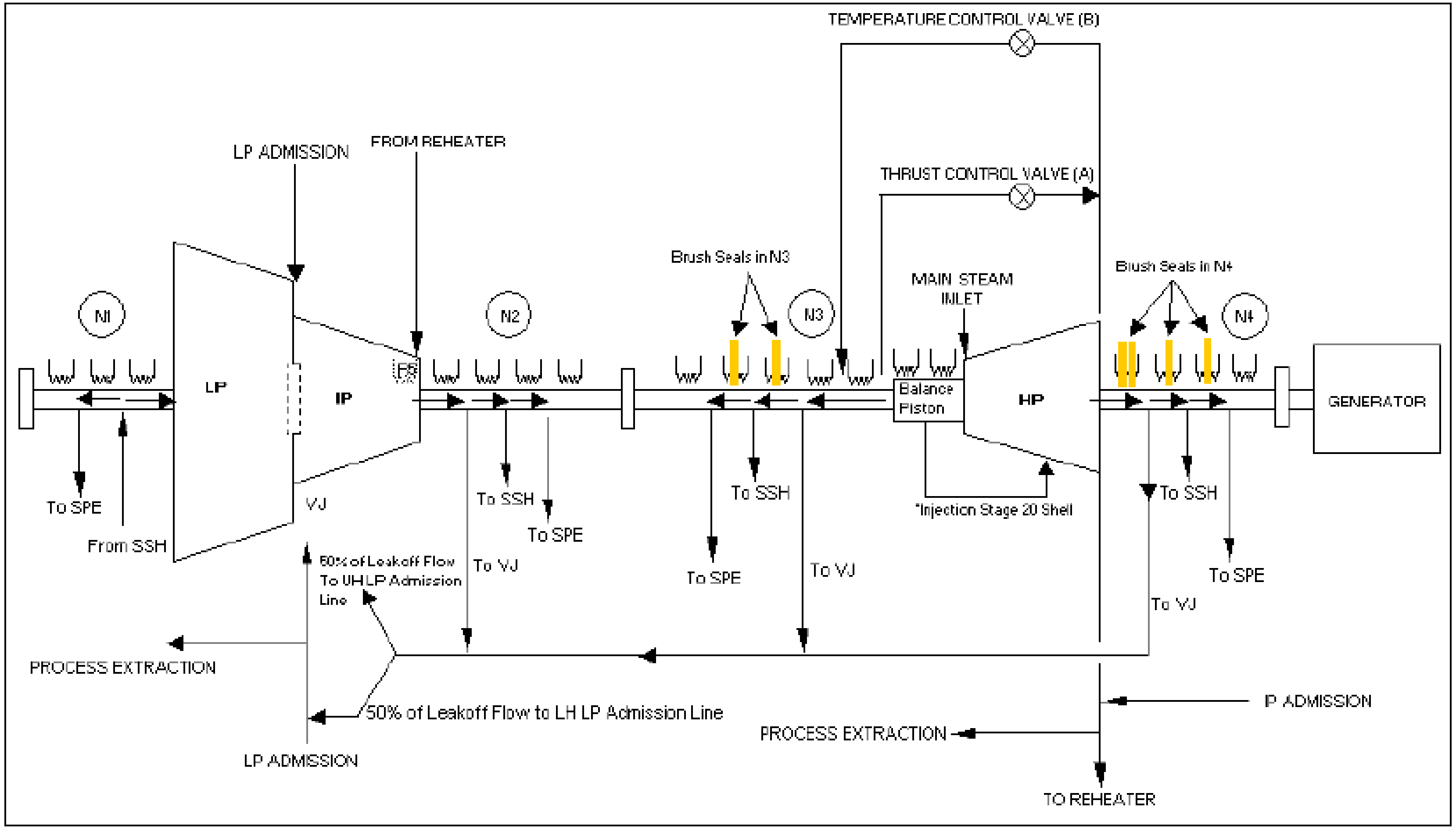
Reference Material - Typical Sealing System for ST Configuration Being Considered



Q & A Time….