Welcome!

Webinar #18: Steam Turbine Tuning

13 December 2017

<u>Agenda</u>:

* Introduction

- Steam Turbine Characterization
- Goals
- Initial Design
- Tuning tools in GT MASTER
- Tuning tools in THERMOFLEX
- Reminders ----

* Q & A Session

Presenter: Norm Decker (U.S. HQ)
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

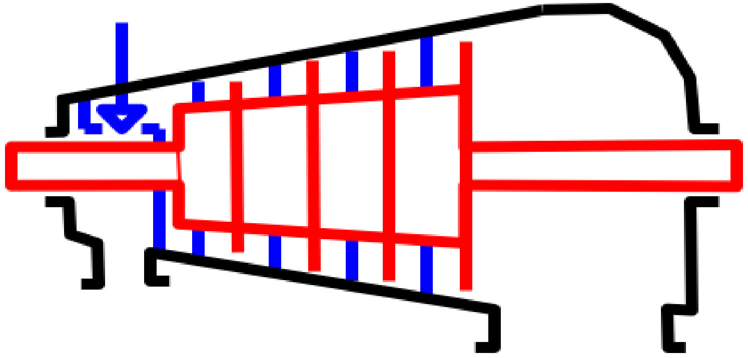
1- Assemblies in TFX
2- Scripts in Thermoflow programs, GTP-GTM-TFX
3- Multi Point Design in GTP-GTM
4- Reciprocating Engines in TFX
5- TIME in GTM
6- Matching ST Performance in STP
7- Modeling Solar Systems in TFX
8- Combining THERMOFLEX & Application-Specific Programs
9- Methods & Methodology in GT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

18- Steam Turbine Tuning

3

Steam Turbine Performance Characterization

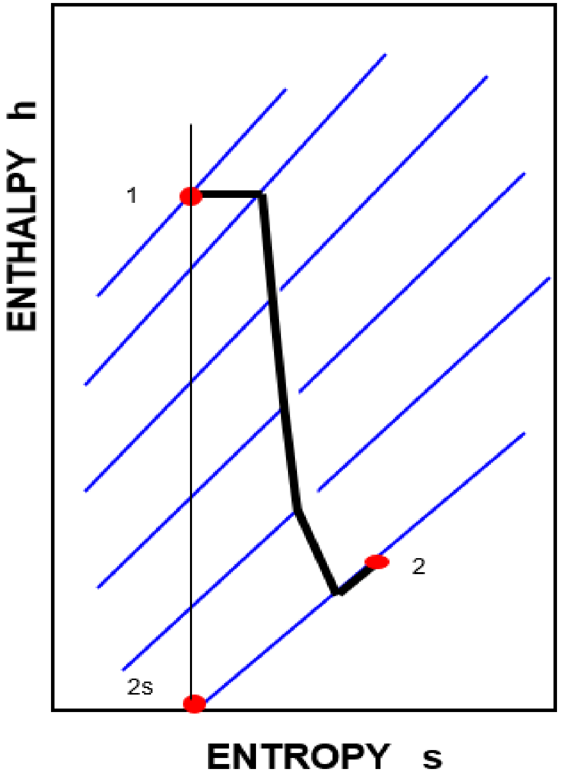
Power = m (h1 – h2)



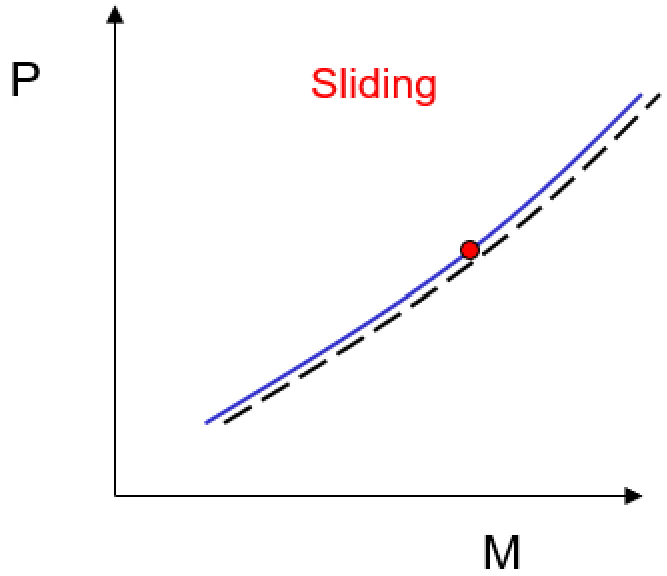
Group overall efficiency

= (h1 – h2)/(h1-h2s)

Spans all blading in group, plus
exhaust loss and control
valve inefficiencies



(h1-h2) = function of {P1, h1, P2, η }



P1 =function of {h1, m, A, P2}

Steam Turbine Performance Characterization

Power = m (h1 – h2)

(h1-h2) = function of {P1, h1, P2, η }

P1 =function of {h1, m, A, P2}

To tune a given model to match measured or proposed performance, you need to control these key values:

Flow (m)

Efficiency (η)

Nozzle area (A)

And… some other details…

5

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Steam Turbine Performance Characterization

The Devil, they say, is in the details, but there really are only a few…

Flow isn't the same through all sections, must sum individual groups:

$\text{Power} = \Sigma\, m_i\, (h_{1i}-h_{2i})$

There may be leakage streams and sealing steam streams

Exhaust loss varies in a separate way with exhaust volume flow rate

Some power is lost

$\text{Power} = \Sigma\, m_i\, (h_{1i}-h_{2i})$ – Bearing loss – Gearbox loss – Generator loss

6

Tuning Goals

Making just one model operating condition match specified performance >>> **Single-point Tuning**

Making a simulation (Off-design) model fit performance specs at several operating conditions >>> **Multi-point Tuning**

In many cases, a carefully tuned Single-point tuning will also well simulate performance at other operating conditions.

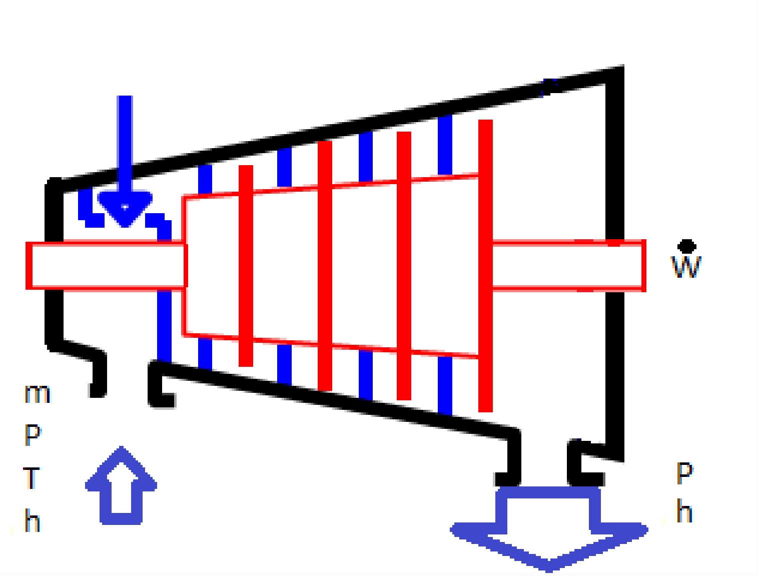
A well-tuned model should predict pressures and enthalpies well in addition to predicting power.

7

Initializing the Steam Turbine

In GT PRO, STEAM PRO, and THERMOFLEX at design:

Inlet P, T, h, and m are known
Exit P is known



Efficiency is estimated
(or imposed)

Power, Nozzle Area, and Exit h are computed

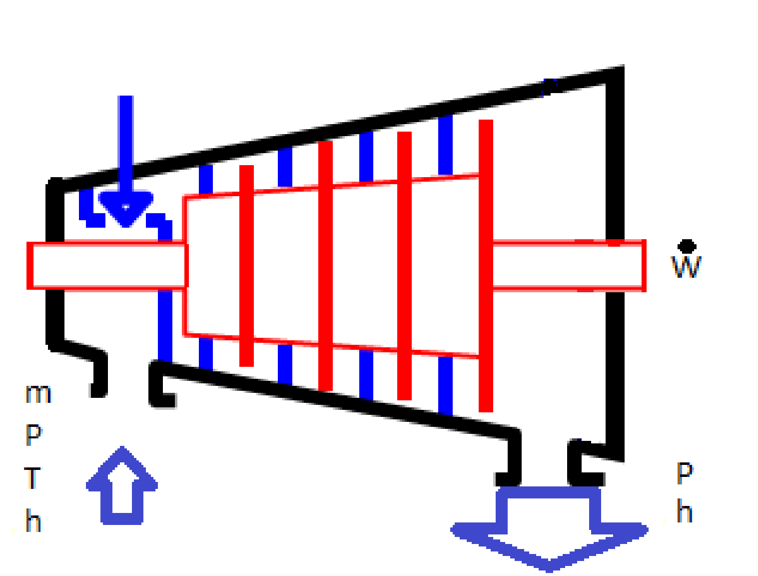
The needed elements here were described with details in Webinar #6: Matching ST Performance in STP

8

Simulating the Steam Turbine

In GT MASTER, STEAM MASTER, and THERMOFLEX at Off-design:

Inlet m and h, are known from upstream, Exit P is known from downstream



Nozzle area is known from design

Efficiency is determined, based on design point efficiency

Power and Exit h are computed

9

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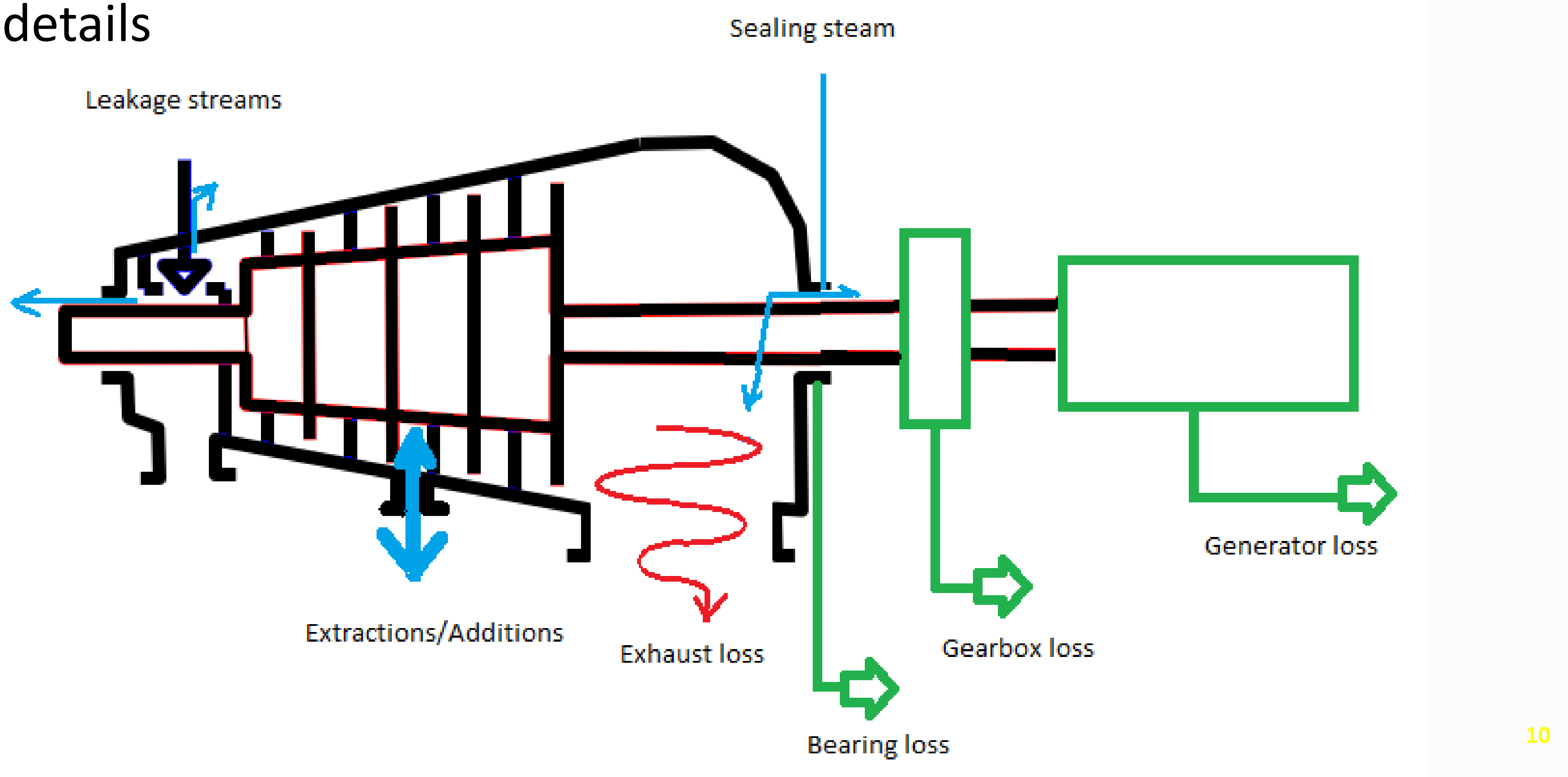
Simulating the Steam Turbine

… and the details



Tuning Methods

Manually…

With careful examination, the simulation programs have long allowed you to iteratively manipulate the entering and exiting flows, adjust nozzle areas to match upstream pressures, and adjust group efficiencies.

With the Automatic Tuning feature…

Much of the performance matching exercise is made easier - specify for each group the upstream and downstream pressure, upstream and downstream enthalpy, and the group flow – the Tuning feature adjusts Areas and Efficiencies.

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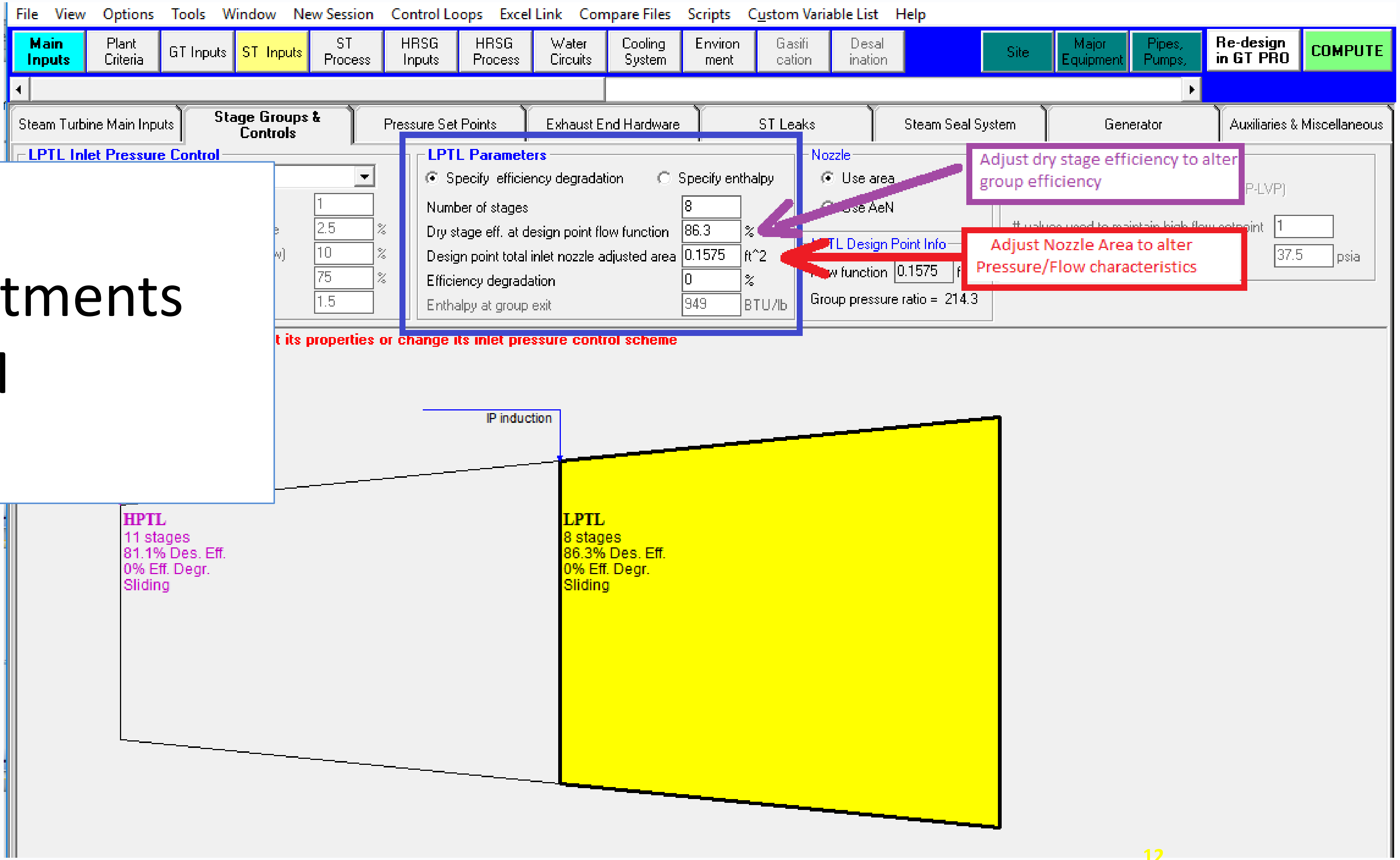
Manual adjustments in GTM



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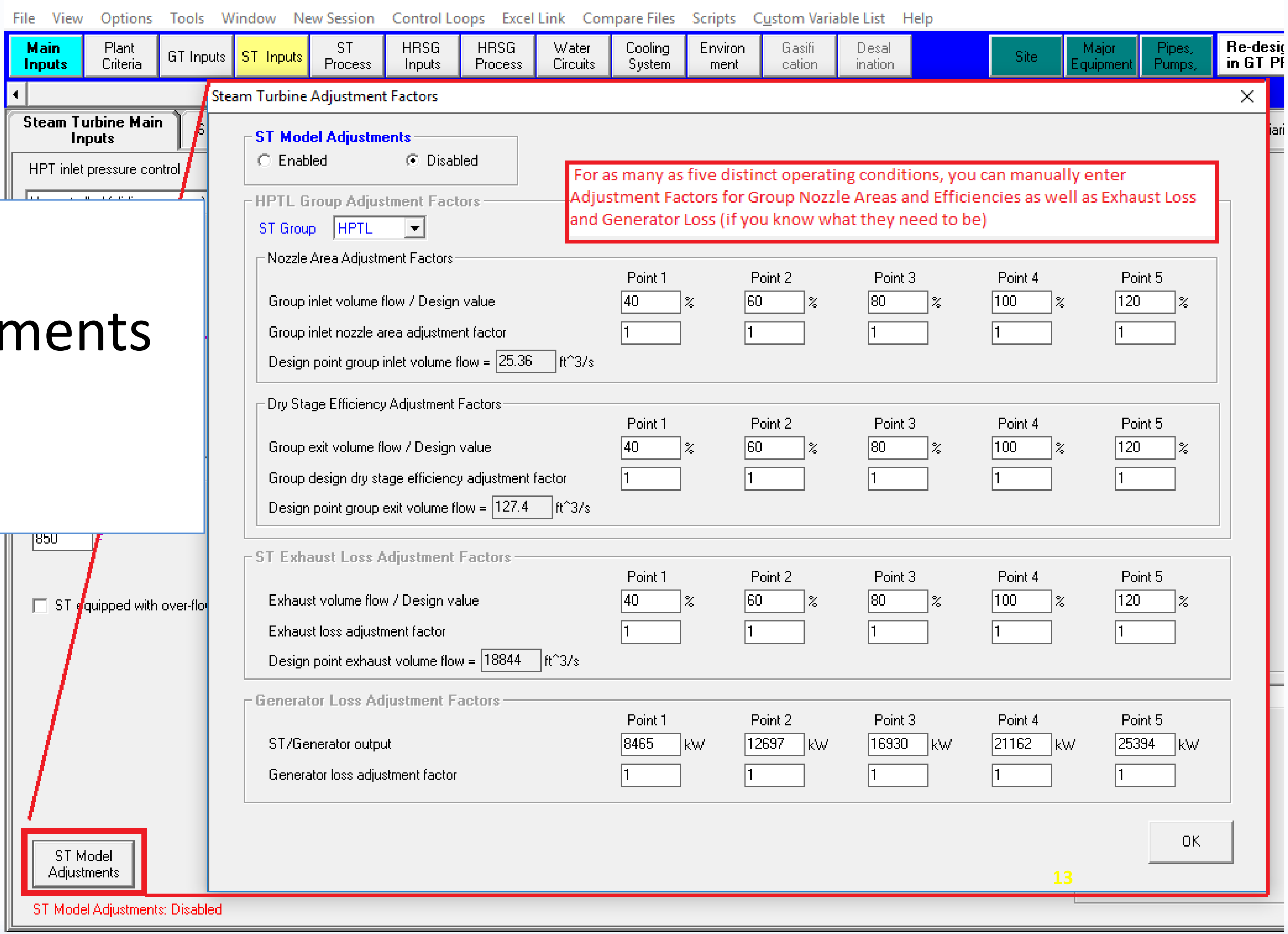
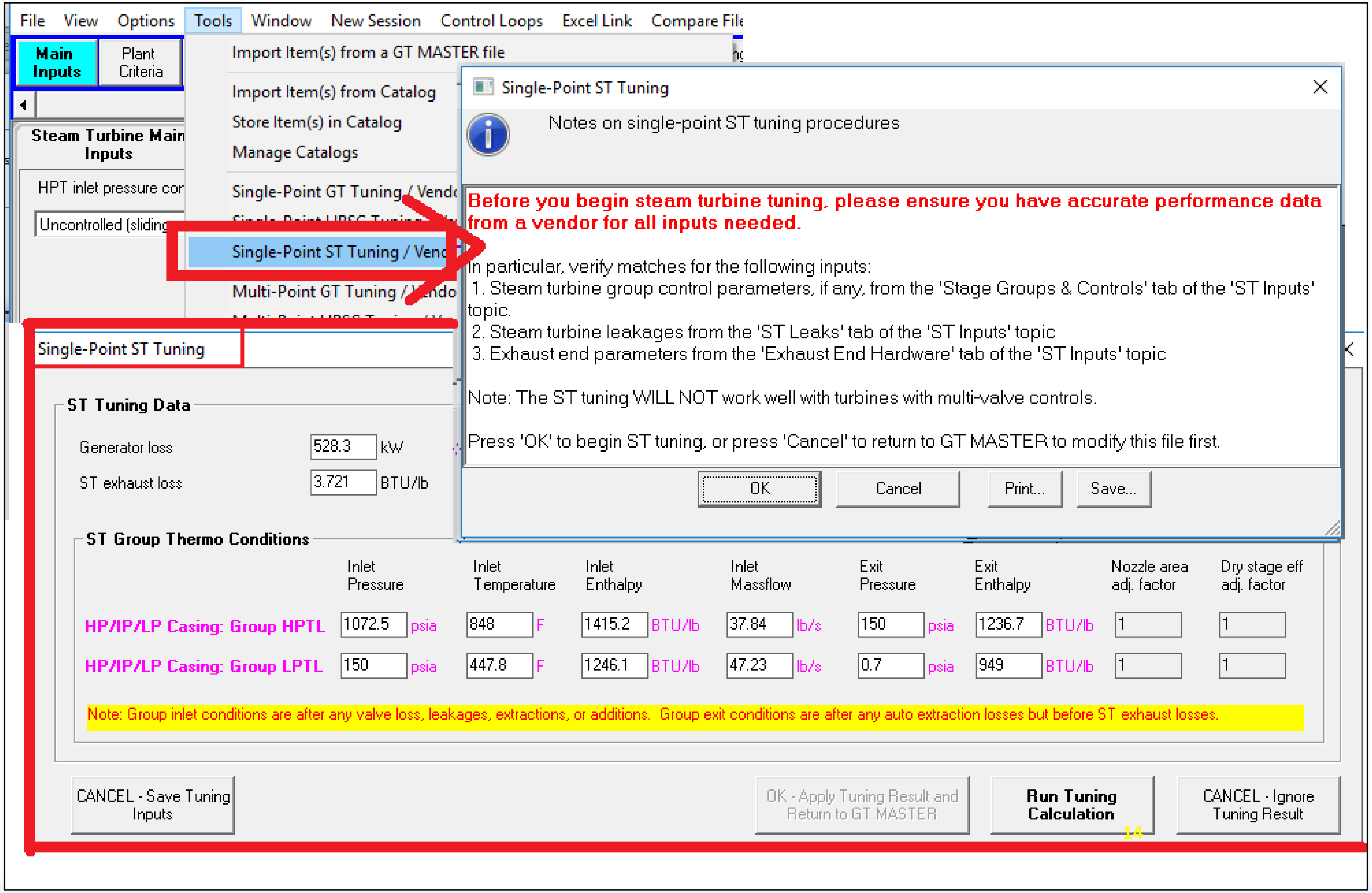
Multi-case adjustments in GTM



Producing the Adjustment Factors automatically with the Tuning feature, selected from the [Tools] menu of GT MASTER.

Enter the desired conditions, then click [Run Tuning Calculation]



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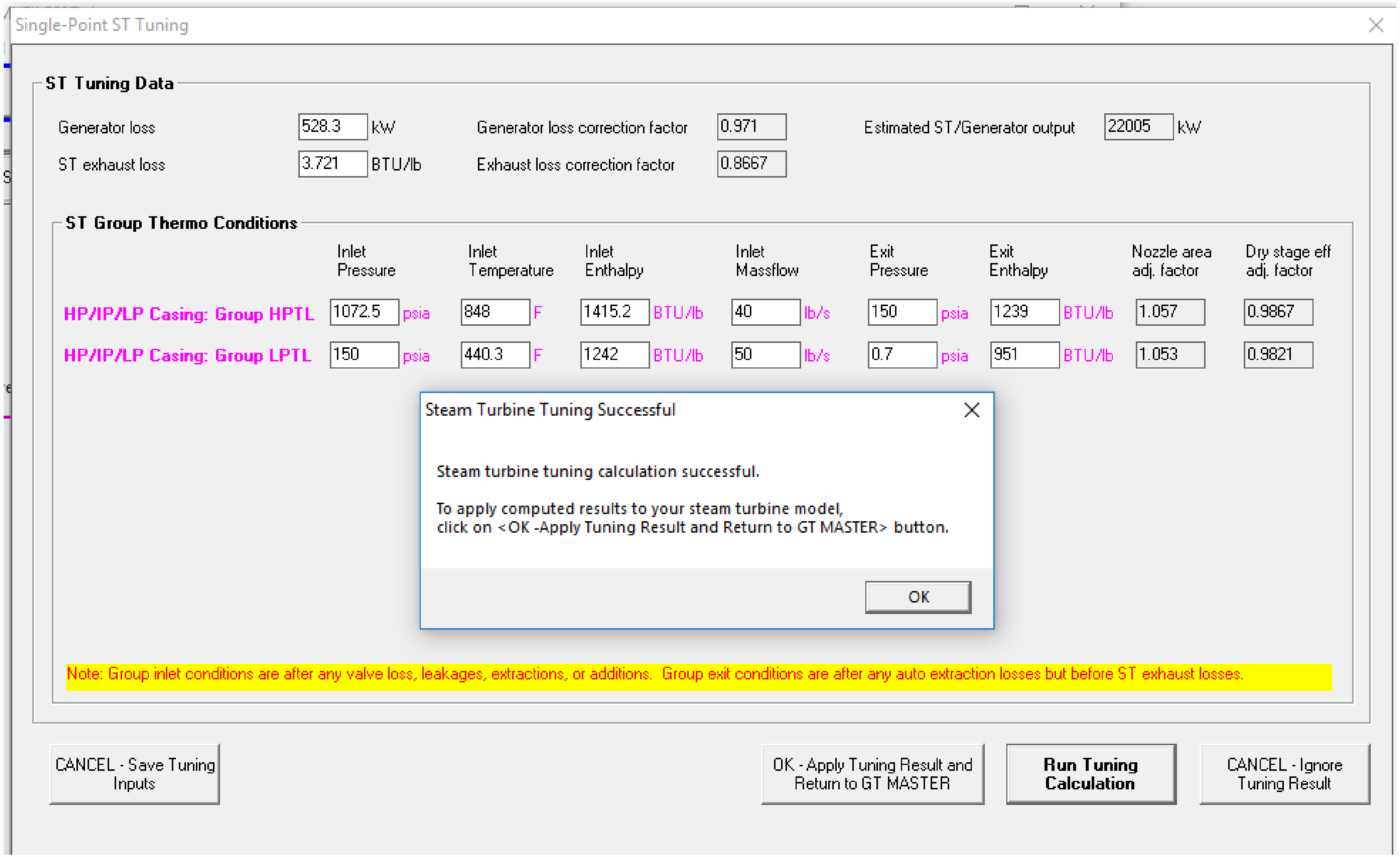
[OK-Apply Result & Return], results will be written to the [Model Adjustments] feature of the [ST Inputs] topic, ready to be employed.



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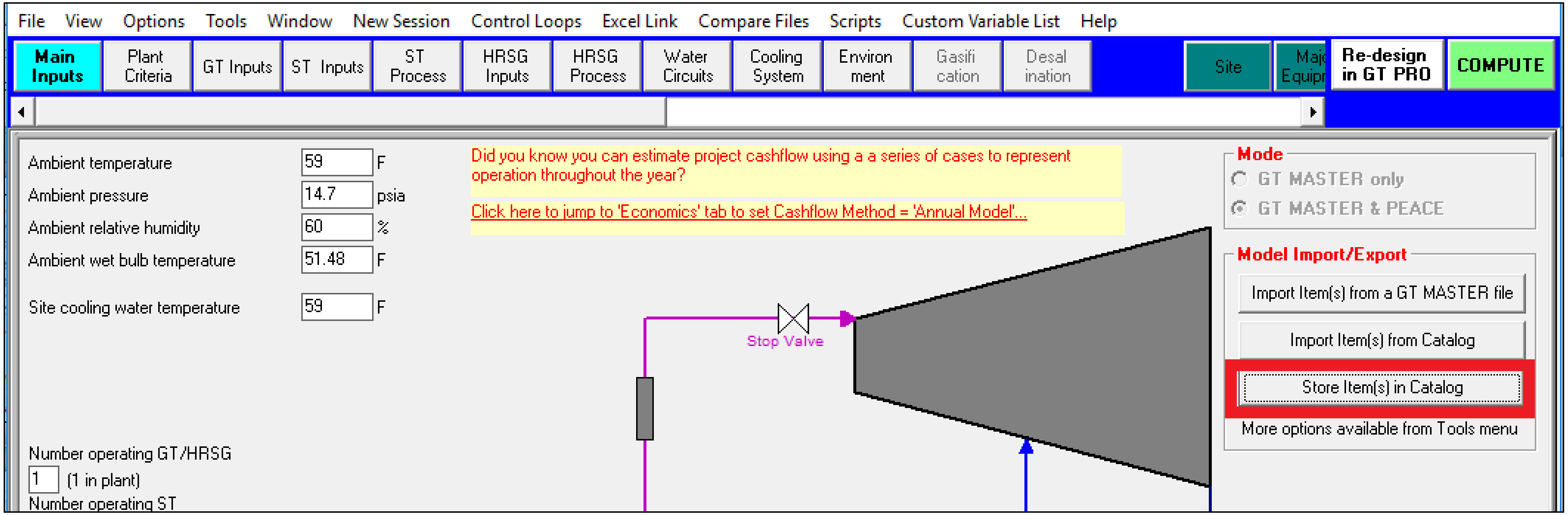
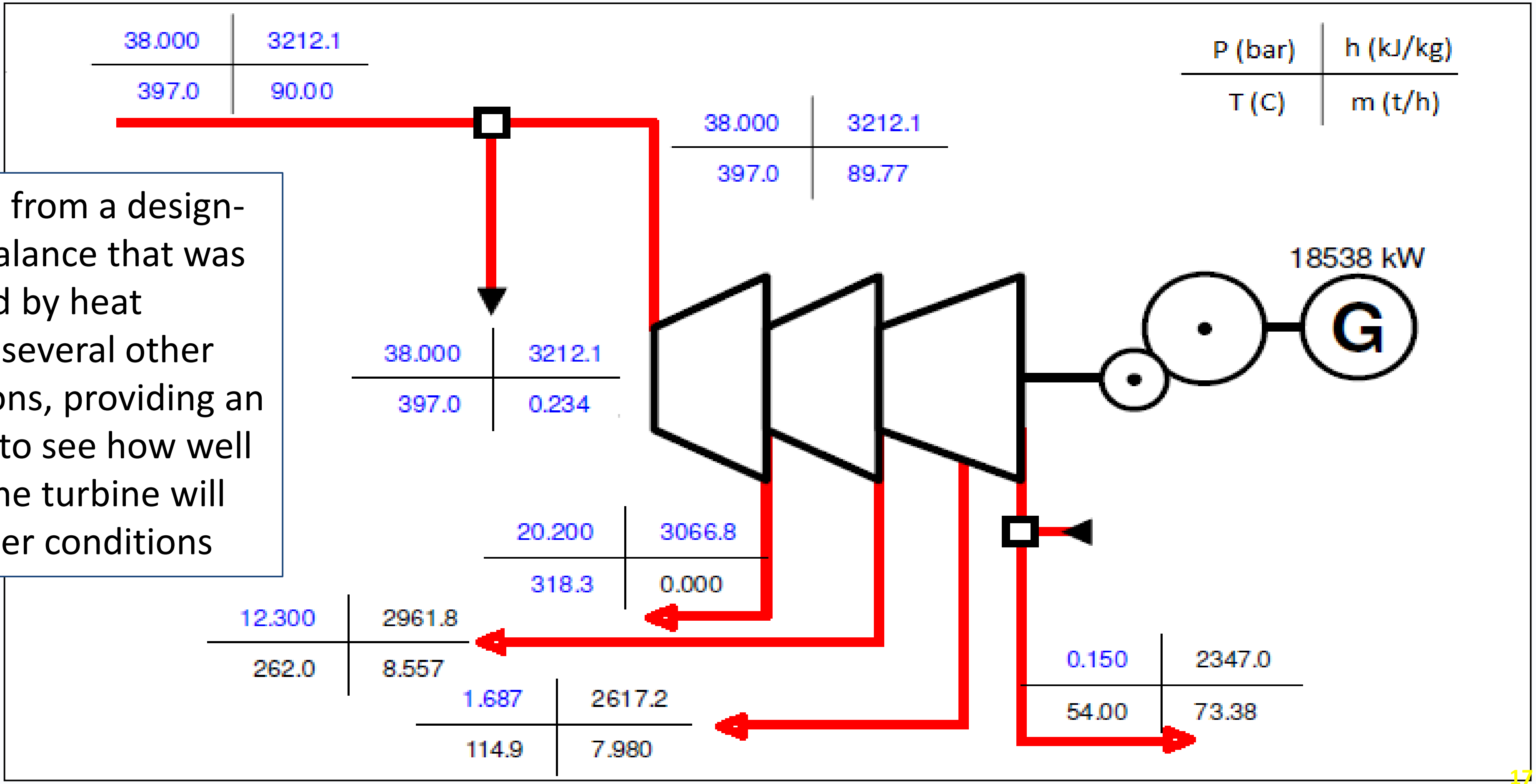
The Tuned Steam Turbine can be stored in the 'Catalog' to be available for being directly loaded into a different GT MASTER file



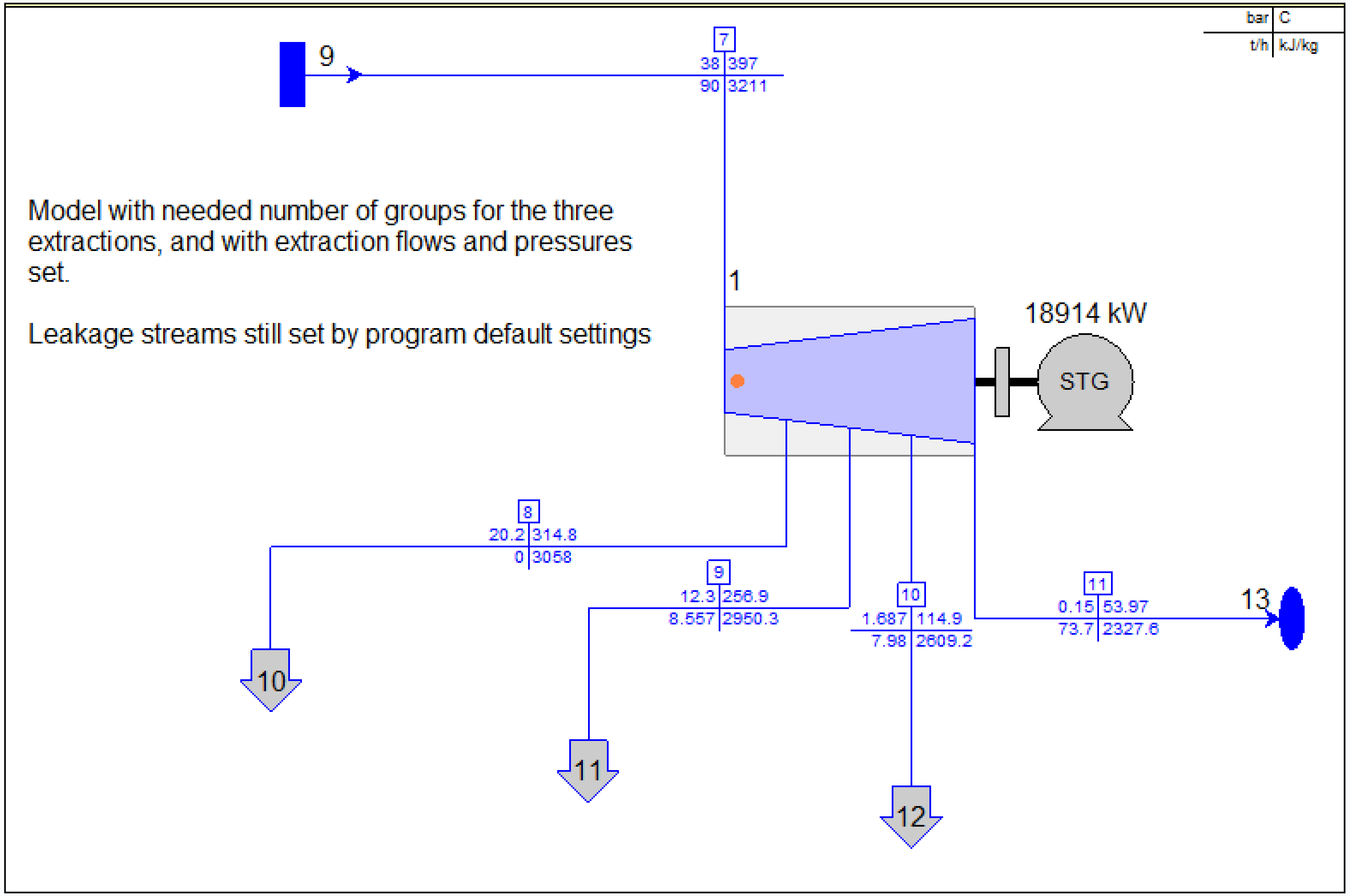
ST Tuning in THERMOFLEX

This image is from a design-point heat balance that was accompanied by heat balances for several other load conditions, providing an opportunity to see how well a model of the turbine will ‘track’ at other conditions



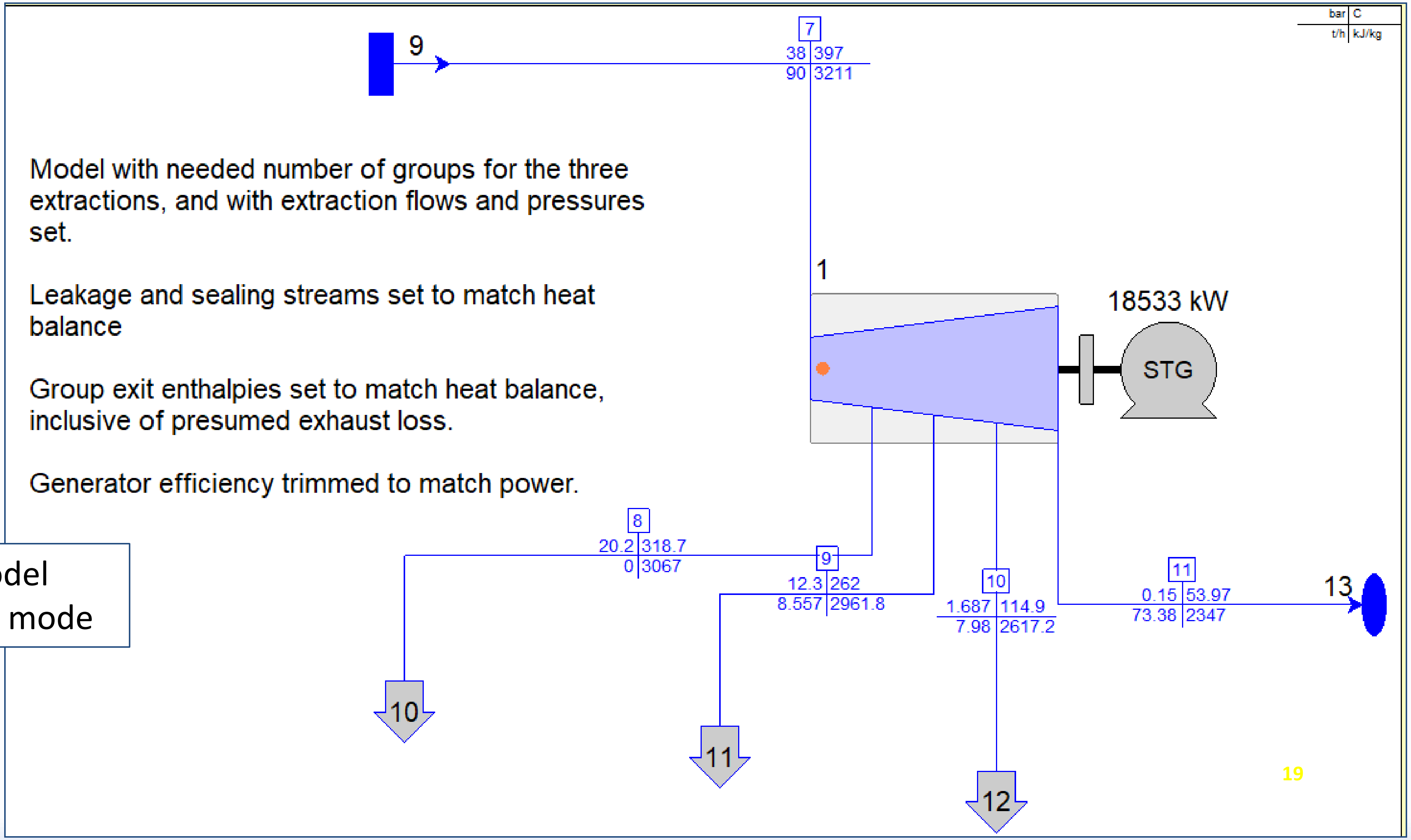
ST Tuning in THERMOFLEX

Initial TFX model



18

ST Tuning in THERMOFLEX



Trimmed TFX model adjusted in Design mode

ST Tuning in THERMOFLEX

Data from related heat balance cases

	Case 1	Case 2	Case 3	Case 4
Pin	38	38	38	38
Tin	397	397	374	357
Hin	3212.1	3212.1	3157.9	3116.9
min	89.77	80.77	62.77	53.77
Group flow	89.77	80.77	62.77	53.77
Pe1	20.2	19.02	14.4	12.098
hex1	3066.8	3073.3	3023.5	2966
mex1	0	0	0	0
Group flow	89.77	80.77	62.77	53.77
Pe2	12.3	10.88	8.158	6.821
hex2	2961.8	2964.8	2917.4	2882.5
mex2	8.557	8.1	7.181	6.598
Group flow	81.213	72.67	55.589	47.172
Pe3	1.687	1.509	1.142	0.964
hex3	2617.2	2621.4	2589.4	2566.3
mex3	7.98	7.053	5.335	4.439
Group flow	73.233	65.617	50.254	42.733
Pexh	0.15	0.13	0.09	0.075
hexh after seal addition	2347	2349.7	2322.3	2303.6
mexh	73.38	65.76	50.4	42.88
Mseal	0.234	0.234	0.234	0.234
Mmu	0.087	0.087	0.087	0.087
diff	0.147	0.147	0.147	0.147
Generator Power	18,538	16,520	12,194	10,025
h before seal addition	2345.263492	2347.625	2319.81	2300.802

20

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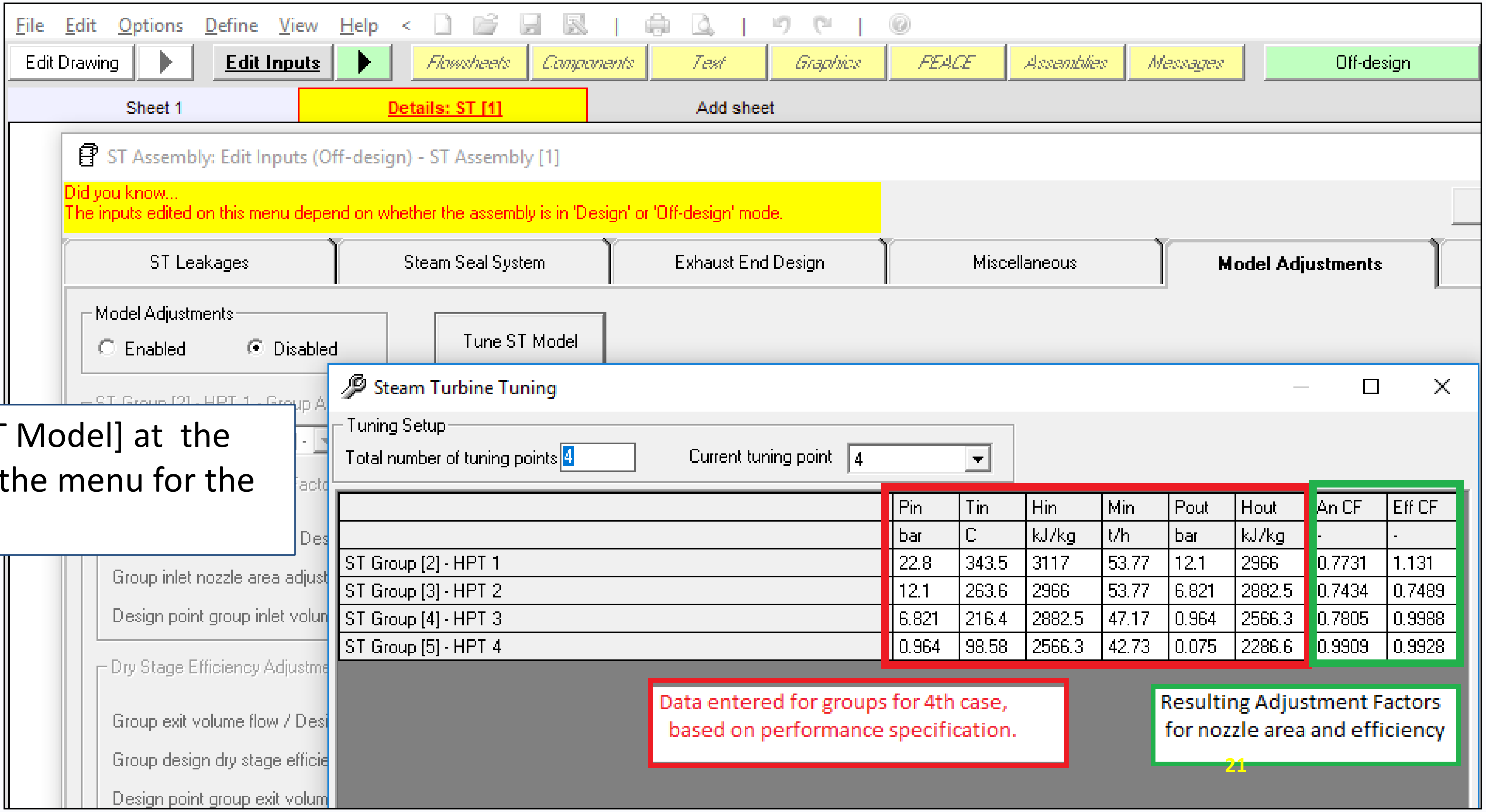
ST Tuning in THERMOFLEX



	Pin	Tin	Hin	Min	Pout	Hout	An CF	Eff CF
	bar	C	kJ/kg	t/h	bar	kJ/kg	-	-
ST Group [2] - HPT 1	22.8	343.5	3117	53.77	12.1	2966	0.7731	1.131
ST Group [3] - HPT 2	12.1	263.6	2966	53.77	6.821	2882.5	0.7434	0.7489
ST Group [4] - HPT 3	6.821	216.4	2882.5	47.17	0.964	2566.3	0.7805	0.9988
ST Group [5] - HPT 4	0.964	98.58	2566.3	42.73	0.075	2286.6	0.9909	0.9928

Data entered via [Tune ST Model] at the Model Adjustments tab of the menu for the ST Assembly

Data entered for groups for 4th case, based on performance specification.

Resulting Adjustment Factors for nozzle area and efficiency

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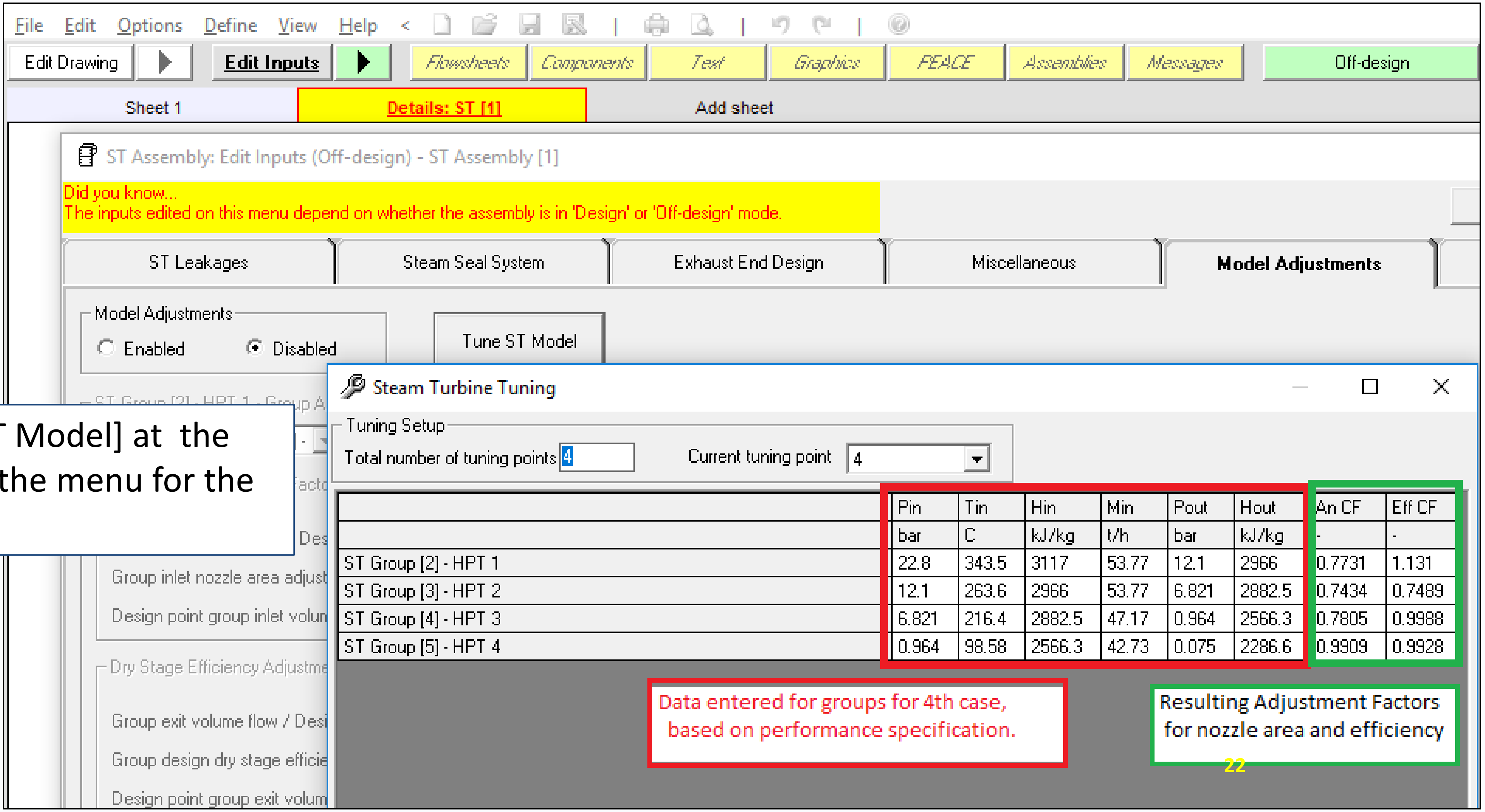
ST Tuning in THERMOFLEX

Data entered via [Tune ST Model] at the Model Adjustments tab of the menu for the ST Assembly



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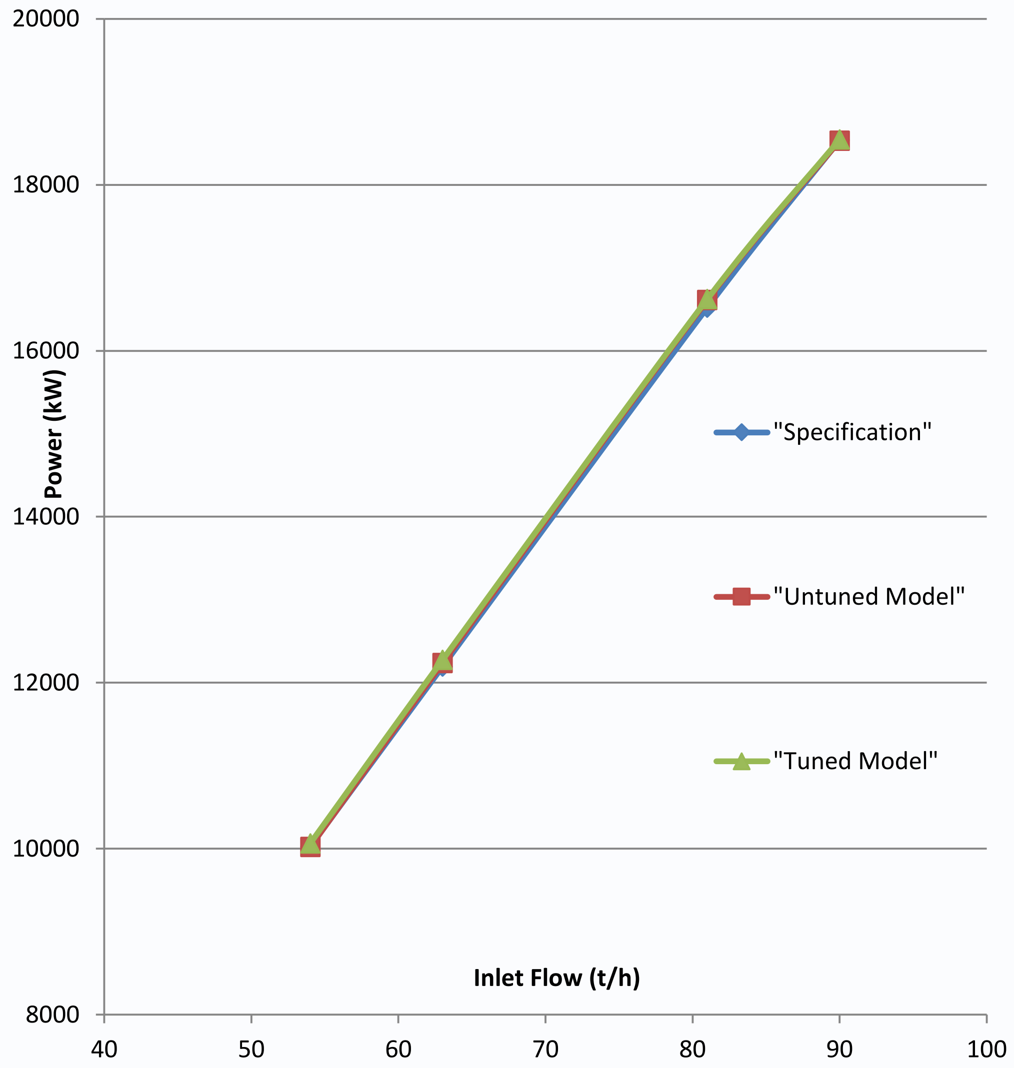
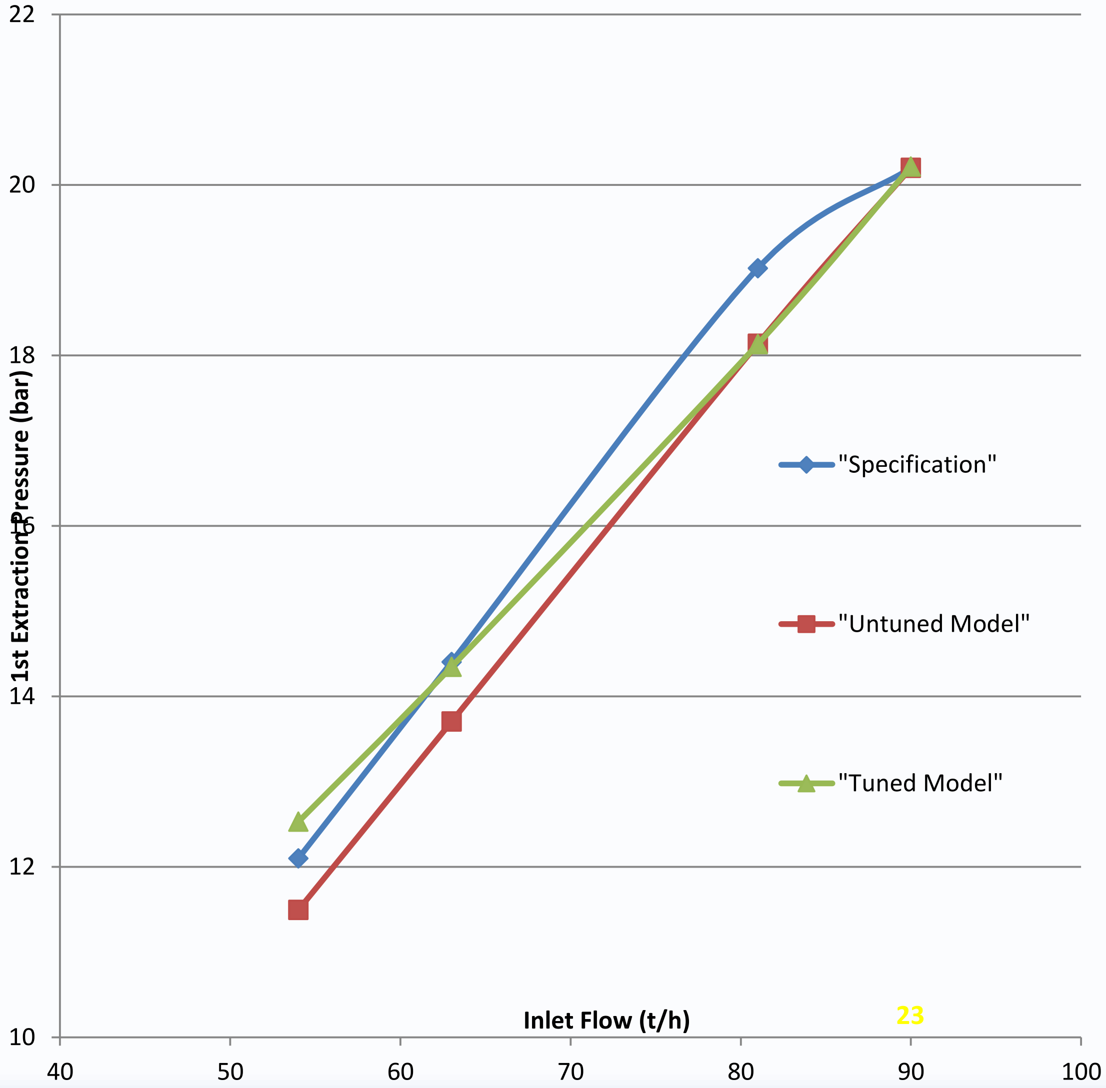
ST Tuning in THERMOFLEX - Results





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ST Tuning – Reminder…

ST Tuning

Notes on ST tuning procedures

Before you begin steam turbine tuning, please ensure you have accurate performance data from a vendor for all inputs needed.

In particular, verify you have setup your model to match the following inputs:

1. Steam turbine group control parameters as defined on individual input menus for groups in this turbine
2. Steam turbine leakages defined on the [ST Leakages] tab of this ST Assembly input menu
3. Exhaust end parameters defined on the [Exhaust End Design] tab of this ST Assembly input menu

Note: The ST tuning WILL NOT work well with turbine with multi-valve controls.

Press 'OK' to begin ST tuning, or press 'Cancel' to return so you can modify this model first.

OK | Cancel | Print... | Save...

24

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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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