September 26, 2018

Dear Customer,

We are pleased to release Version 28 of our software suite, with the new features and improvements summarised below. Some of the items described here were released as revisions to Version 27, optionally downloaded from our Service Center.

NOVO PRO

Version 28 includes the initial release of NOVO PRO, a new program dedicated to modeling and optimizing renewable energy systems. NOVO PRO allows you to define various combinations of renewable energy sources, energy storage systems, and backup thermal power; then estimates their capital cost, simulates their annual operating cycle, and overall economics.

NOVO PRO may be licensed on its own, and works in conjunction with PDE, GT PRO, GT MASTER, and THERMOFLEX for modeling thermal power plants together with renewables. Customers with keys enabling GT PRO + GT MASTER + THERMOFLEX + PEACE will be granted a free extended trial of NOVO PRO on request. Please contact us for licensing details (info@thermoflow.com / +1 (904) 774-1170).

PDE / GT PRO / GT MASTER / PEACE

(1) Gas Turbine - Multi-Point Model-assisted Tuning – A new Multi-Point GT Tuning feature is available that lets you adjust performance of any library GT model to match updated vendor data. The method allows you to enter desired gas turbine performance data for up to ten compressor inlet conditions for each of five GT loads. For Physical Model gas turbines, the program computes adjustment factors for engine inlet airflow, compressor efficiency, and TIT control temperature to match your data. For Data-Defined and OEM Curve-Fit gas turbine models, the program computes fuel consumption margin, generator power margin, exhaust flow margin, and exhaust temperature adder to match your data.

When using a tuned GT model, the program interpolates on compressor inlet temperature and engine load to compute the adjustment factors or margins applicable at conditions in-between where you've specified vendor data. You may edit the program-computed adjustment factors or margins, if desired, to further tweak the results by clicking the [Model Adjustment Curves] button on the [Gas Turbine Main Inputs] tab.

(2) Annual Model Includes Startup and Shutdown Curves – Detailed plant startup and shutdown curves, previously only available in TIME, are now included for plant models using the Annual Model method to compute plant financial performance. These automatically-initialized, user-editable curves are used to estimate fuel consumption and power production during hot, warm, and cold starts, and plant shutdowns. The curves are initialized based on plant cycle type. Startup definitions are available on the [Annual Model] / [Starts] tab of the [Economics] topic.

(3) Battery Storage System – An option to include a battery storage system to provide fast-response power during startup is available for cases using the Annual Model method to compute plant financial performance. Inclusion of a battery affects estimated plant cost, plant O&M expenditures, and annual plant operating economics.

(4) Other Improvements to PDE / GT PRO / GT MASTER:

1. **Fuel Demand Models** – PDE, GT PRO and GT MASTER include a new feature to create a Fuel Demand Model that encapsulates plant performance and cost into a set of maps used to represent the plant in a NOVO PRO system model. This feature is available under the [Tools] menu on the main menu bar for each of these three programs.
2. **Catalogs** - GT MASTER allows you to store gas turbines in model catalogs, including any user-defined model adjustments or tuning done to adjust the gas turbine model to match data. Cataloging is available under [Tools] on GT MASTER's main menu bar.
3. **PDE** – The Combustor Configuration options list now includes an **Allow reciprocating engines** choice. This enables you to explicitly include, or exclude, reciprocating engines from the engine/cycle list presented on the [Select] topic.
4. **PDE** - SCR effectiveness is now automatically set based on engine type and combustor type, thereby improving cost comparisons between plants using differing engine and/or combustor technologies.

THERMOFLEX / PEACE

(1) Gas Turbine - Multi-Point Model-assisted Tuning – As described above in (1) for GT PRO & GT MASTER, THERMOFLEX includes a new feature to tune gas turbine performance over a range of operating points (up to ten ambient conditions and up to five loads) to reproduce expected data. In THERMOFLEX, this feature is available on the [Main Inputs] tab of the GT input menu for all GT models in the Thermoflow library.

(2) Multi-Point Model-Assisted User-defined Condenser Performance – A new off-design Performance Method was included for all PEACE condensers. This method uses effectiveness correction factors, defined as a function of condenser duty, to adjust the well-proven, built-in, hardware-based Thermoflow performance model. From the input menu, THERMOFLEX includes a tuning feature where you specify desired condenser pressure versus heat input for up to five loads. The program will compute the effectiveness corrections that force the model to reproduce your inputs, if possible. This feature is intended to allow small tweaks to the off-design simulation model for condensers where the hardware definition matches the OEM specification, exactly. For air-cooled condensers, an option exists to establish a fan power correction factor versus condenser duty to adjust computed fan power to match OEM data.

When THERMOFLEX computes the condenser as part of a plant model, it interpolates to compute condenser effectiveness adjustment (and fan power correction if used) for other, intermediate, operating conditions. The adjustment factors may be edited directly, if desired. The choice to use this new feature is available on the [Performance Method] tab for PEACE condensers in off-design mode.

(3) Multi-Point Model-Assisted User-defined Cooling Tower Performance – A new off-design Performance Method was included for PEACE cooling towers. This method uses an effectiveness correction factor, defined as a function of inlet air wet bulb temperature, to adjust the behavior of Thermoflow's built-in, longstanding, physically-derived cooling tower performance model. From the input menu, THERMOFLEX includes a tuning feature where you specify desired cold water exit temperatures as a function of inlet wet bulb temperatures for a given hot water flowrates and ranges. The program computes the effectiveness corrections that force the model to reproduce your data, if possible. This feature is intended to allow small tweaks to the off-design simulation model for cooling towers where the tower definition matches the OEM specification. An option exists to establish a fan power correction factor versus inlet wet bulb temperature to adjust computed fan power to match OEM data.

When THERMOFLEX computes the tower as part of a plant model, it interpolates to compute the tower effectiveness adjustment factor (and fan power correction if used) for other, intermediate, operating conditions. The adjustment factors are available for direct user input if needed. The choice to use this

new feature is available on the [Performance Method] tab for PEACE cooling towers in off-design mode.

(4) Multi-Point Model-assisted User-defined Performance for PEACE HRSG/Boiler Heat Exchangers – A new off-design Performance Method was included for the PEACE Economizer, Evaporator, Superheater, Integral DA, OTB element, Parallel Economizer, and Parallel Superheater. This method uses correction factors applied to the well-proven, built-in, hardware-based Thermoflow simulation model to force it to match user-specified data, if possible. Factors are available to modify the model's calculation of heat exchanger effectiveness, water-side pressure drop, and gas-side pressure drop. This feature is intended to be used to introduce small tweaks to the off-design simulation model for heat exchangers where the physical definition (geometry, materials, and flow configuration) match the OEM's specification, exactly.

On the input menus for these components, THERMOFLEX provides ability to edit the effectiveness correction as a function of heat transfer rate, and the pressure drop correction factors as a function of dynamic head ($\rho V^2/2$). In addition, THERMOFLEX provides a tuning feature that automatically computes the correction factors to reproduce user-specified thermal-hydraulic performance data for the heat exchanger.

(5) Energy Storage Icons – New energy storage icons used to model Batteries, Pumped Hydro plants, and User-Defined storage systems were added for THERMOFLEX/PEACE licensees. These icons, available on the [General] tab of the icon selection bar, can store excess power produced by the plant, thereby reducing power delivered to the grid. Likewise, they can augment output to the grid to make-up for a shortfall in production by the THERMOFLEX system model. The Battery and Pumped Hydro models include design and off-design modes along with an overall all-in owner's cost model. These icons will be most useful for modeling plant operation over time in ELINK, where power shifting can be accomplished by charging and discharging the storage systems throughout the day.

(6) Other Improvements to THERMOFLEX:

1. **Solar PV Panel Library** – The built-in panel library was expanded. It now includes size and performance data for over 130 panels from ten manufacturers.
2. **Hot Water 'Boiler'** - A new PEACE Hot Water package boiler icon was added. This model, available from the [Boilers/HRSGs] tab, is akin to the Steam Package boiler that's been in THERMOFLEX for many years. However, this 'boiler' produces hot water. It may be configured as a fired unit operating in standalone mode, or it may be used in heat recovery applications with or without additional firing. Model output includes boiler dimensions, weight, and estimated cost.
3. **Fuel Demand Models** – A new feature allowing you to create a Fuel Demand Model that encapsulates plant performance and cost into a set of maps used to represent the plant in a NOVO PRO system model. This feature is available under [Define] on the main menu bar.
4. **Fin Fan Cooler** model was improved to allow condensing steam and refrigerants.
5. **Steam Turbine Wizard** was improved to include a comprehensive input menu to edit assembly inputs and those for steam turbine groups it contains. The assembly output report was enhanced to include outputs for all groups in the steam turbine assembly.

STEAM PRO / STEAM MASTER / PEACE

(1) STEAM PRO - Improved New Session Wizard – STEAM PRO now provides guidance to select a boiler type appropriate for the fuel you plan to burn. It will also, by default, restrict the type of steam turbine and the turbine power range to be compatible with the selected boiler type. Users with intimate knowledge of steam plant design can elect to relax these restrictions, but will be warned that PEACE results may not provide reasonable cost estimates. When defining fuels on the Plant Criteria topic, STEAM PRO will enforce restrictions on fuel class consistent with the current boiler type.

(2) STEAM MASTER - Multi-Point Model-Assisted User-defined Condenser Performance – A new off-design Performance Method was included for all condenser types. This feature is identical to that included in THERMOFLEX and described in Item (2) above for THERMOFLEX.

(3) STEAM MASTER - Multi-Point Model-Assisted User-defined Cooling Tower Performance – A new off-design Performance Method was included for cooling towers. This feature is identical to that included in THERMOFLEX and described in Item (3) above for THERMOFLEX.

GT TEMPLATE

(1) Calculation Speed Improved – time required to compute GTT models was significantly reduced leading to speedier overall plant calculations.

(2) Define GTT Files using Excel – a new method was added to create a GTT model using performance data stored in an Excel file. This can dramatically reduce data entry effort and facilitates automatic transfer of data from an OEM cycle deck (or output file) into a workbook that can be read by GT TEMPLATE. An Excel template file and set of instructions are provided in the GTDU folder under the main installation folder. The files are '`GTPerformanceDataForGTTmodel.xltx`' and '`Instructions - Creating GTT from Excel.pdf`'.

(3) Added/Revised Correction Factors – Correction factors to model compressor air discharge and compressor spray intercooling were added. The method to specify up to two heat rejection streams was improved. The ability to specify inlet and exhaust pressure losses using a method similar to that used by some OEMs was added to facilitate using engine data from their programs.

PEACE

Gas turbine prices for particular engines were revised based on informal feedback from some OEMs. Other major equipment prices were left unchanged from last year to reflect ongoing pricing pressure in the fossil-fired power equipment market. Labor rates, commodity costs, and prices for the 'Other Equipment' category were revised to reflect inflation over the past several years. Relative to Version 27, owner's costs for GTCC plant will rise between 2 to 5% for cases where the GT cost is unchanged.

Gas Turbine Database

The gas turbine database was updated as shown below. Some of these engine models were included in revisions to TFLOW27 available from the Service Center.

Engines added to the database

672 SIE SGT5-9000HL	677 GE 9HA.02	694 ANS AE 64.3A
673 SIE SGT6-9000HL	678 GE 9HA.01	692 ANS AE 94.3A
674 SIE SGT-800-57	679 GE 9F.05	693 ANS AE 94.2
675 SIE SGT-400	680 GE 9F.04	696 ANS AE GT36-S5
676 SIE SGT-4000F	681 GE 7AH.02	697 ANS AE GT36-S6
686 SIE SGT-800-57	682 GE 7HA.01	698 ANS AE GT26E
687 SIE SGT-800-56	683 GE 7F.05	
688 SIE SGT-800-53	684 GE 6F.03	669 SOL Titan 130 22401S Axial
689 SIE SGT-750-40	685 GE 6F.01	670 SOL Titan 130 22401S Axial
690 SIE SGT 700-33	699 GE 13E2	671 SOL Titan 250 30000S Phase 4
691 SIE SGT700-33	700 GE 13E2	
701 SIE SGT-600		695 KHI GPB 50D
702 SIE SGT-700-33	703 MHPS 501JAC	

Existing engines with modified performance

66 SIE SGT-600	628 SIE SGT 5-4000F	665 SIE SGT-800-53

Reciprocating Engine Database

The reciprocating engine database, used by NOVO PRO, THERMOFLEX, and RECIPRO, was updated by the addition of the following engine specs.

432 RR B36:45V12 AG (50Hz, Gas)	438 RR B33:45V12 A (50Hz, Oil)
433 RR B36:45V16 AG (50Hz, Gas)	439 RR B33:45V16 A (50Hz, Oil)
434 RR B36:45V20 AG (50Hz, Gas)	440 RR B33:45V20 A (50Hz, Oil)
435 RR B36:45V12 AG (60Hz, Gas)	441 RR B33:45V12 A (60Hz, Oil)
436 RR B36:45V16 AG (60Hz, Gas)	442 RR B33:45V16 A (60Hz, Oil)
437 RR B36:45V20 AG (60Hz, Gas)	443 RR B33:45V20 A (60Hz, Oil)