THERMOFLOW Software

Program Overview

Program: GT PRO & GT MASTER

Program Type: Application-Specific Program (see Pages 2 - 4 for further details)

Power Plant Types: Gas Turbine Simple Cycle, GT & HRSG, GT and Reciprocating Engine Combined Cycle, Cogeneration (CHP) Systems, Integrated Gasification Combined Cycle (IGCC), Desalination Plants (MSF, MED, RO), CO_2 Capture and Sequestration Plants.

Program Features: Automated Design and Off-Design/Simulation. Gas Turbine Database with more than 560 GT and Reciprocating Engine specifications. Cost Estimation and Techno-Economic optimization in conjunction with the PEACE module. Automatic Optimized Cooling System Operation in Off-Design. Multiple Runs to display techno-economical design trends in GT PRO, and produce load profiles in GT MASTER. Bi-Directional Link with MS EXCEL to run plant design and simulation from MS EXCEL. GT PRO and GT MASTER designs can be transferred to the Fully-Flexible Program THERMOFLEX. GT PRO and GT MASTER files can be linked to THERMOFLEX models.

Program: STEAM PRO & STEAM MASTER

Program Type: Application-Specific Program (see Pages 2 - 4 for further details)

Power Plant Types: Conventional Coal/Oil/Gas Fired Plants, Cogeneration Systems (CHP), Biomass Plants, Waste Incineration Plants, Desalination Plants, Solar (CSP Power Block) and Nuclear Cycles, CO_2 Capture and Sequestration Plants.

Program Features: Automated Design and Off-Design/Simulation. Fuel Database with more than 180 pre-defined fuels (coal/gas/biomass/RDF). Cost Estimation and Techno-Economic optimization in conjunction with the PEACE module. Automatic Optimized Cooling System Operation in Off-Design. Multiple Runs to display techno-economical design trends in STEAM PRO, and produce load profiles in STEAM MASTER. Bi-Directional Link with MS EXCEL to run plant design and simulation from MS EXCEL. STEAM PRO designs can be transferred to the Fully-Flexible Program THERMOFLEX. STEAM MASTER files can be linked to THERMOFLEX.

Program: PEACE (Plant Engineering And Construction/Cost Estimator)

Program Type: Optional program for use with GT PRO/MASTER, STEAM PRO/MASTER, and THERMOFLEX

Program Features: provides additional inputs to automate the preliminary engineering and cost estimation, logical cost functions, balance-of-plant & techno-economic optimization, detailed hardware specifications.

Program: THERMOFLEX

Program Type: Fully-Flexible Program (see Pages 2 - 4 for further details)

Power Plant Types: Gas Turbine Simple Cycle, GT & HRSG, GT Combined Cycle, Cogeneration (CHP) Systems, Integrated Gasification Combined Cycle (IGCC), Desalination Plants (MSF, MED, RO), Conventional Coal/Oil/Gas Fired Plants, Biomass Plants, Waste Incineration Plants, Concentrated Solar Thermal Power Plants (CSP), CO_2 Capture Plants, Nuclear Cycles, Kalina Cycles, Organic Rankine Cycles (ORC), and others.

Program Features: Graphical Interface with more than 180 components. Design and Off-Design/Simulation. Gas Turbine Database with more than 560 GTs. Reciprocating Engine database with more than 390 gas and/or liquid fueled engines. Fuel database with more than 180 pre-defined fuels (coal/gas/LNG/biomass/RDF). US NIST fluid property database. Cost Estimation and Techno-Economic optimization in conjunction with the PEACE module. Multiple Runs to display techno-economical design trends and to produce load profiles. Bi-Directional Link with MS EXCEL to run plant design and simulation from MS EXCEL. Loading of GT PRO, GT MASTER, and STEAM PRO files into THERMOFLEX. Able to build composite models by links to GT PRO, GT MASTER, and STEAM MASTER.

Application-Specific or Fully-Flexible Program?

In Application-Specific programs, *the plant model is built from the top down* (see graphic on page 3). Big picture selections are made first, such as plant configuration. The process then continues to lower-level decisions, such as selecting the types of subsystems to be included. Finally, the lowest-level decisions (details) are made. These lowest level decisions are logically and automatically generated by the program. The structured approach automatically considers all interactions between the subsystems. It also allows many decisions to be managed by the program. At any level, however, the user is free to alter any or all of the program´s automatic selections.

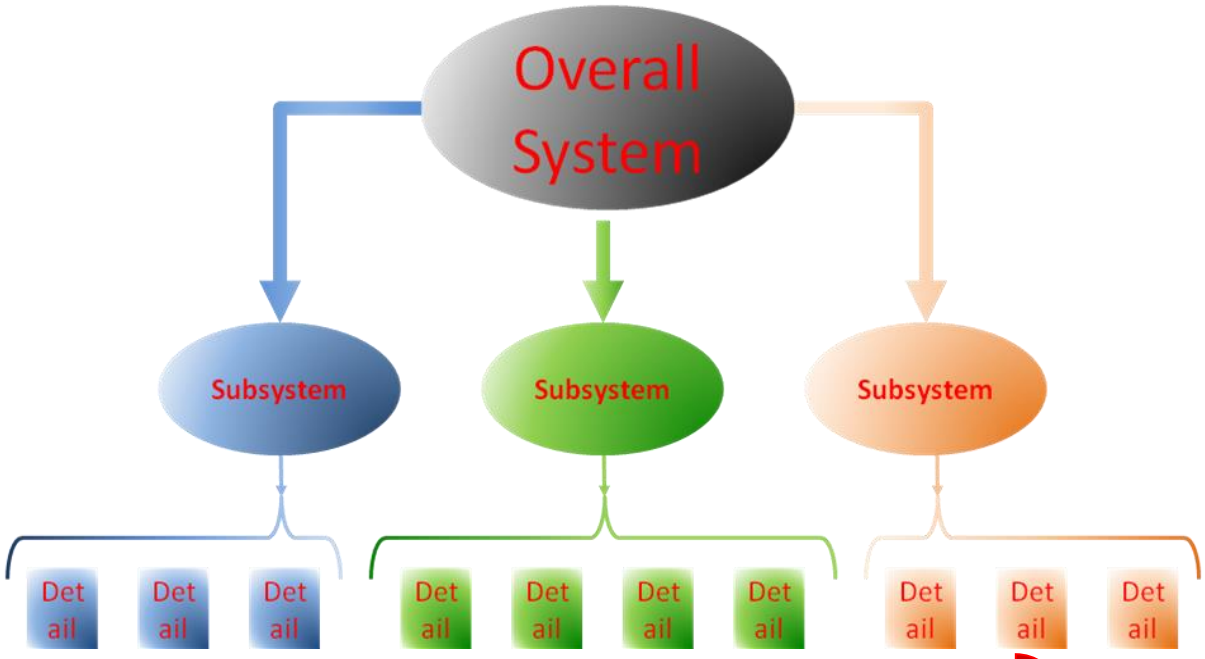
In Fully-Flexible programs, *the plant is built from the bottom up* (see graphic on page 3). The user constructs the subsystems from their basic elements, then the overall scheme emerges from the interconnected subsystems. This method allows great latitude and flexibility, but less structured guidance. The Fully-Flexible approach places a much greater burden of labor and logic on the user.

Combining Application-Specific with Fully-Flexible

Thermoflow´s Application-Specific and Fully-Flexible programs are designed to be used on their own, independently of each other. However, their mutual compatibility and connectivity allows the user who has both types to get the best of both modeling approaches. A plant model may be quickly and easily generated in the Application-Specific environment, while one more of its subsystems may be custom built in the Fully-Flexible THERMOFLEX. This “Hybrid Model” then operates seamlessly, as a single system.

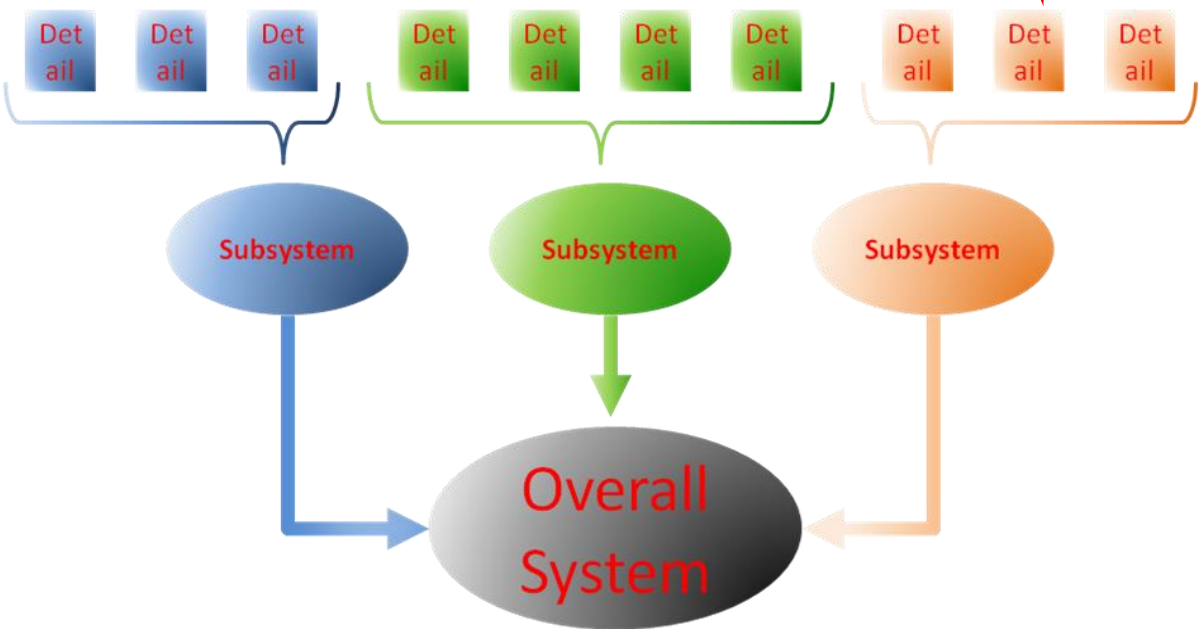
Furthermore, THERMOFLEX can read a plant model built in one of the Application-Specific programs GT PRO, GT MASTER, or STEAM PRO, allowing the user to transition from fast automated design to a Fully-Flexible environment.

Application Specific:



A plant model generated in the Application-Specific environment (GT PRO or STEAM PRO) can be transferred to THERMOFLEX's Fully-Flexible environment.

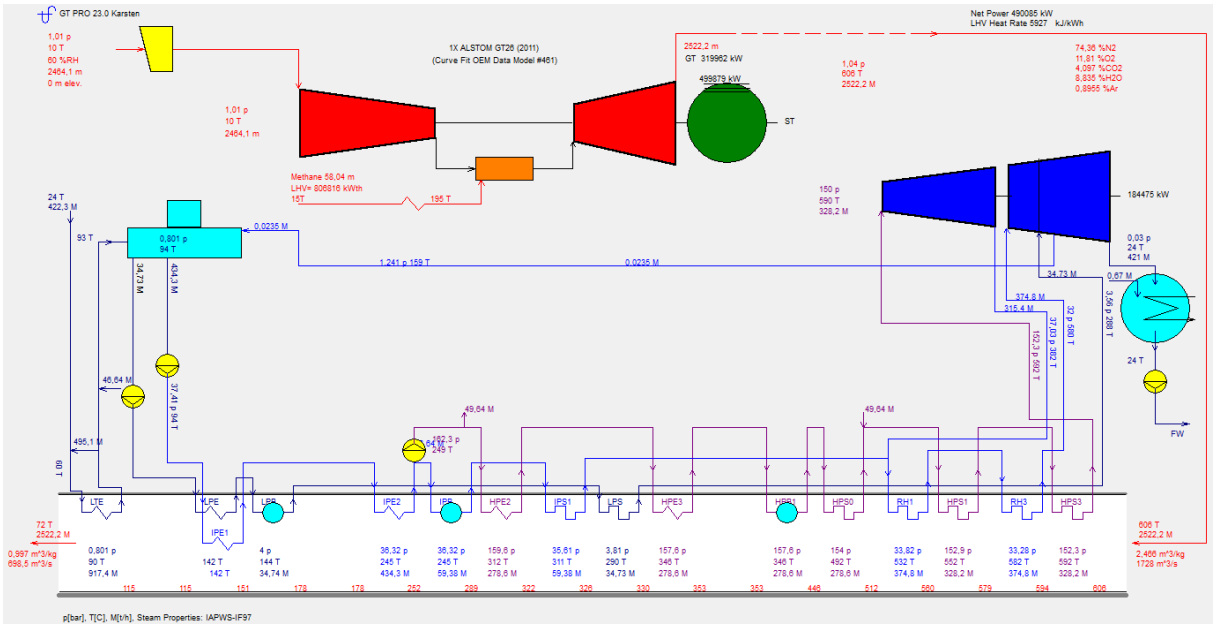
Fully-Flexible:



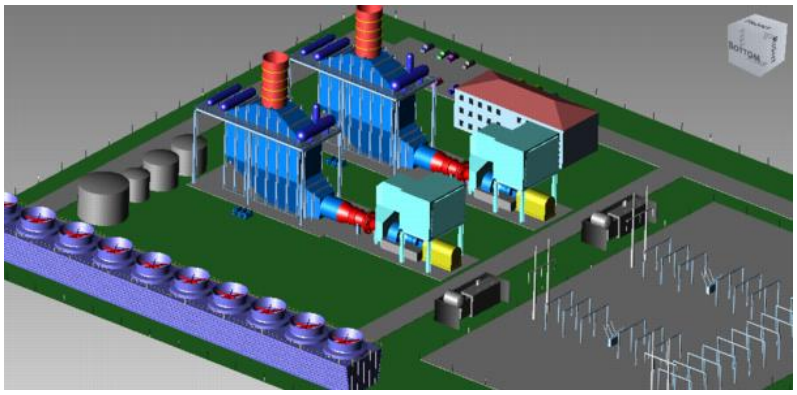
	Application-Specific Program GT PRO/MASTER, STEAM PRO/MASTER	Fully-Flexible Program THERMOFLEX
Advantages	Many system modeling features and details are already in a logical, ordered manner. All the user needs to do is select which features to include and the numerical values of relevant input parameters. Since many complex plant features are already modeled within the software, the user may invoke them by making a few guided selections rather than needing to synthesize their model from elements. Due to the overall logical structure, hundreds of inputs can be automatically created or user-defined, and can be cross-checked and validated to ensure their consistency, preventing errors and crashes.	The program is more general, and can, in principle, model any system that its user wishes to define. The program provides a library of component models, which the user can connect graphically to construct any configuration. This allows greater variety than can possibly be included in an Application-Specific program.
Disadvantages	The pre-built models are, by their nature, finite. The user is limited to features and details that are within the pre-defined scope of the general model. Thus, in order to have a satisfactory Application-Specific program, the pre-engineered model must be large and mature enough to ensure that all reasonable features and details are included. Therefore, it takes many years to develop a comprehensive family of programs of this type, making them more expensive than a Fully-Flexible program that can cover the same scope.	This type of program normally provides component-logic but leaves system-logic up to its user. The burden placed upon the user is thus, by its nature, far greater than for the Application-Specific type. The burden placed upon the program itself is also much greater, because it must be capable of gracefully handling system configurations and component applications that its developers have never intended, conceived of, or tested. Since the program cannot always “know” what its user is trying to do, it cannot cross-check all inputs, increasing the possibility of inconsistencies, problematic calculations, and crashes, relative to a robust, well –organized Application-Specific program.

GT & Recip. Engine Combined Cycle Design, Simulation, and Cost Estimation

GT PRO automates the process of designing a gas-turbine or reciprocating engine based power or cogeneration plant. GT PRO is particularly effective for creating new designs and finding their optimal configuration and design parameters considering technical performance and total plant cost (**techno-economic optimization)**.



Cycle Flow Schematic: GTCC, Single-Shaft, 3p-RH



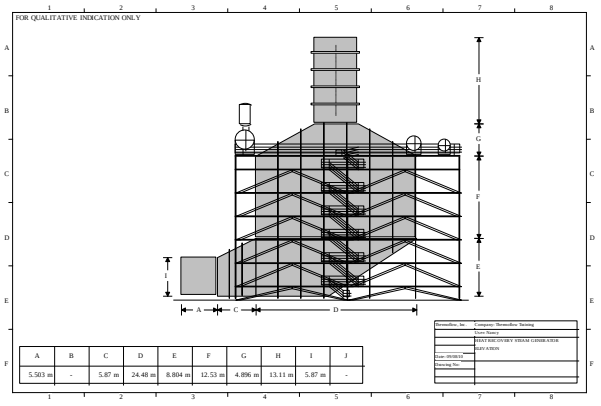
PEACE Output: Site 3D View

The user inputs design criteria and assumptions and the program computes heat and mass balance, system performance, and equipment sizing. The scope and level of detail in GT PRO has been continuously growing since 1988, to the point that the 2015 Version 25 has over 3400 user-adjustable inputs.

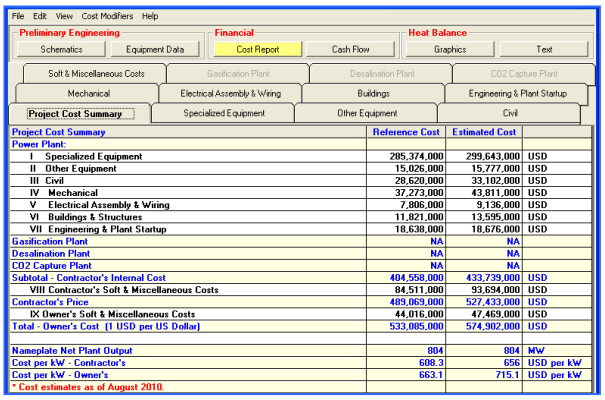
Most key inputs are automatically created by intelligent design procedures that help the user identify the best design with minimal time and effort, while allowing the flexibility to make any changes or user-adjustments.

GT PRO is truly easy to use, typically requiring only a few minutes to create a new plant design. It computes a heat balance and simultaneously designs the required equipment and site infrastructure.

GT MASTER is the Off-Design Simulation companion to GT PRO. GT MASTER computes (steady-state and **transient**) performance for varying ambient conditions, fuel selection, equipment loading, process steam/water flows, hardware degradation levels, etc. The TIME feature (**T**ime **I**ntegrated **M**odeling **E**conomics) computes the project's NPV considering cold/warm starts and shutdowns, various loads and ambient conditions throughout the year.



PEACE Output: HRSG Elevation 2D View



Project Cost Summary	Reference Cost	Estimated Cost	
Power Plant:			
I Specialized Equipment	285,374,000	299,643,000	USD
II Other Equipment	15,026,000	15,777,000	USD
III Civil	28,620,000	33,102,000	USD
IV Mechanical	37,273,000	43,811,000	USD
V Electrical Assembly & Wiring	7,806,000	9,136,000	USD
VI Buildings & Structures	11,821,000	13,595,000	USD
VII Engineering & Plant Startup	18,638,000	18,676,000	USD
Gasification Plant	NA	NA	
Desalination Plant	NA	NA	
CO2 Capture Plant	NA	NA	
Subtotal - Contractor's Internal Cost	404,558,000	433,739,000	USD
VIII Contractor's Soft & Miscellaneous Costs	84,511,000	93,694,000	USD
Contractor's Price	489,069,000	527,433,000	USD
IX Owner's Soft & Miscellaneous Costs	44,016,000	47,469,000	USD
Total - Owner's Cost (1 USD per US Dollar)	533,085,000	574,902,000	USD
Nameplate Net Plant Output	804	804	MW
Cost per kW - Contractor's	608.3	656	USD per kW
Cost per kW - Owner's	663.1	715.1	USD per kW
* Cost estimates as of August 2010.			

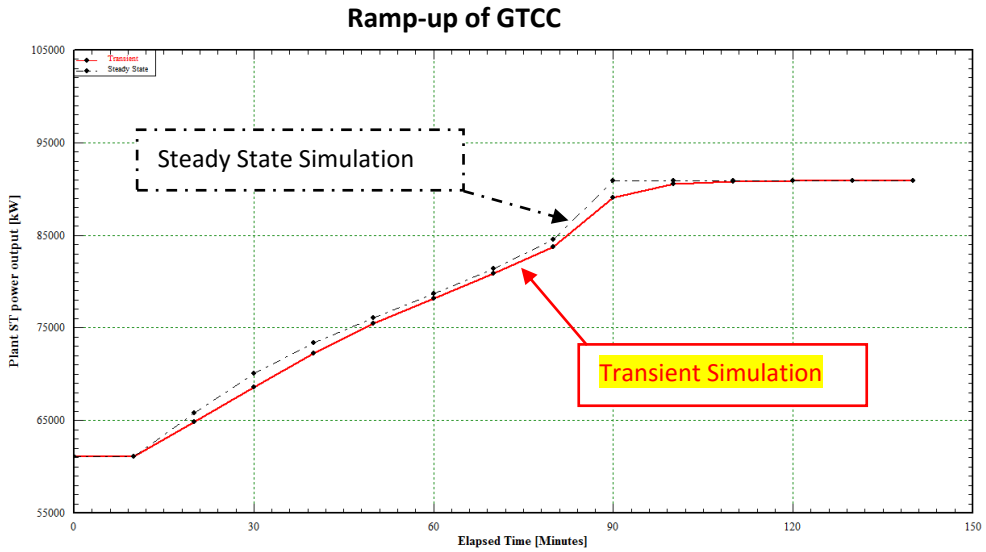
PEACE Output: HRSG Elevation 2D View

When run in conjunction with the optional ***PEACE*** (**P**lant **E**ngineering **A**nd **C**ost **E**stimator) module, the programs provide extensive engineering and **hardware specifications** such as weight and dimensions, plant and equipment **cost estimation**, and site details.

GT PRO and ***GT MASTER*** include a built-in library of **over 560 gas turbine and reciprocating engine specifications**, Integrated Gasification Combined Cycles **(IGCC),** Desalination Plants **(RO, MSF, MED),** and chemical / physical **CO_2 Capture and Sequestration (CCS)** plants.

The 2015 versions include a bi-directional Link to MS-EXCEL (***E-LINK***) which allows running plant models from within MS EXCEL by specifying inputs and receiving outputs in EXCEL cells. E-LINK makes it easy to produce Thermal Heat Rate curves, integrated Annual Simulation results, etc.

A built-in scripting language allows to add own logical blocks to models, or to call an external DLL/EXE, so GT PRO and GT MASTER models can run together with other programs.



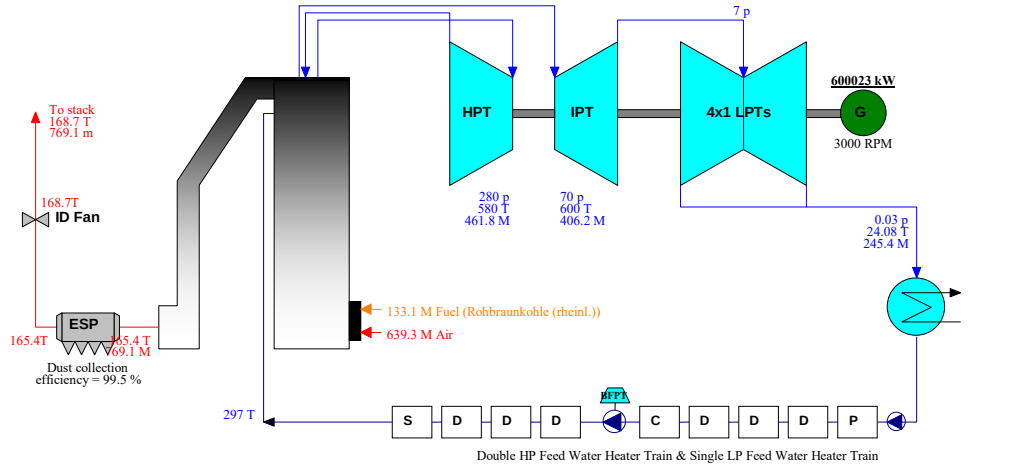
GT MASTER: Transient Simulation of GTCC Ramp-Up and comparison to Steady-State Simulation

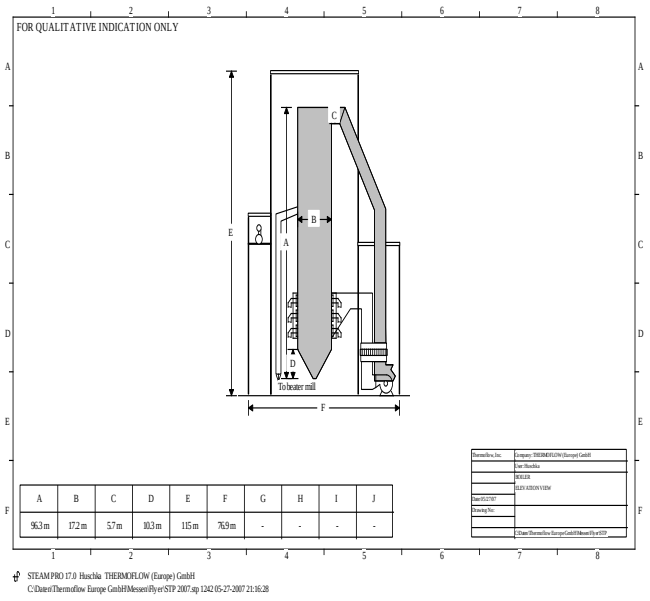
Conventional Cycle Design, Simulation, and Cost Estimation

STEAM PRO automates the process of designing a conventional (Rankine Cycle) steam power plant. It is particularly effective for creating new plant designs and finding their optimal configuration and design parameters considering the plant performance and total plant cost **(techno-economic optimization).**

Plant net power	569992	kW
Number of units	1	
Plant net HR (HHV)	10003	kJ/kWh
Plant net HR (LHV)	8491	kJ/kWh
Plant net eff (HHV)	35.99	%
Plant net eff (LHV)	42.4	%
Aux. & losses	30031	kW
Fuel heat input (HHV)	1583803	kJ/s
Fuel heat input (LHV)	1344344	kJ/s
Fuel flow	11500	t/day

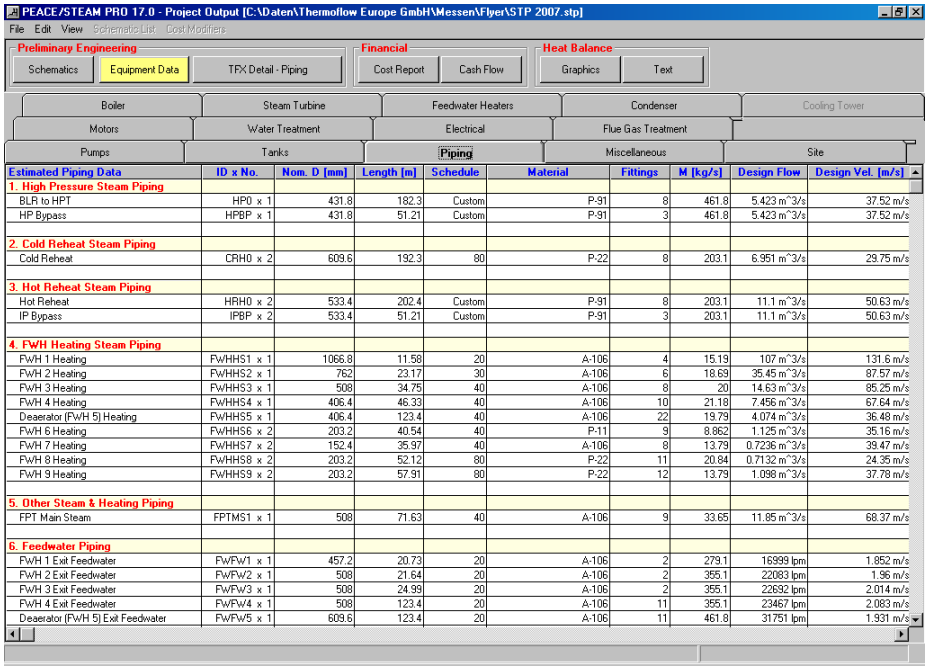
Ambient
1.013 p
15 T
60% RH



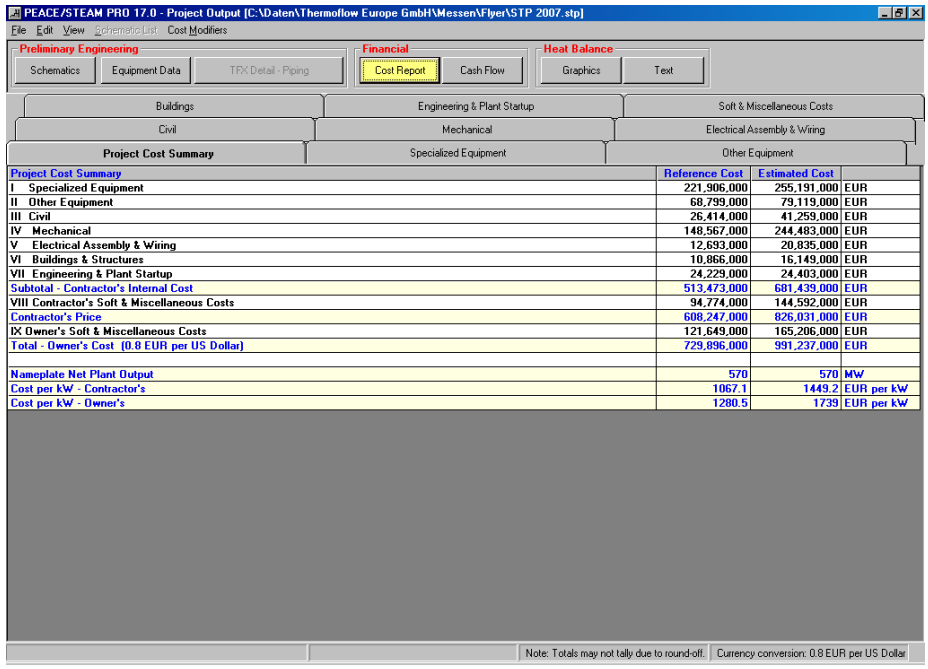


The user inputs design criteria and assumptions and the program computes heat and mass balance, system performance, and component sizing. The scope and level of detail in STEAM PRO has been continuously growing since 1990, to the point that the 2015 Version has over 2100 user-adjustable inputs. Most key inputs are automatically created by intelligent design procedures that help the user identify the best design with minimal time and effort, while preserving the flexibility to make any changes or adjustments.

STEAM PRO is truly easy to use, typically requiring only a few minutes to create a new plant design. It normally computes a heat balance and simultaneously designs the required equipment in under fifteen seconds. When run in conjunction with the optional ***PEACE*** (**P**lant **E**ngineering **A**nd **C**ost **E**stimator) module, the programs provide extensive engineering and cost estimation details.



Estimated Piping Data	ID x No.	Nom. D [mm]	Length [m]	Schedule	Material	Fittings	M [kg/s]	Design Flow	Design Vel. [m/s]
1. High Pressure Steam Piping									
BLR to HPT	HP0 x 1	431.8	182.3	Custom	P-91	8	461.8	5.423 m^3/s	37.52 m/s
HP Bypass	HPBP x 1	431.8	51.21	Custom	P-91	3	461.8	5.423 m^3/s	37.52 m/s
2. Cold Reheat Steam Piping									
Cold Reheat	CRH0 x 2	609.6	192.3	80	P-22	8	203.1	6.951 m^3/s	29.75 m/s
3. Hot Reheat Steam Piping									
Hot Reheat	HRH0 x 2	533.4	202.4	Custom	P-91	8	203.1	11.1 m^3/s	50.63 m/s
IP Bypass	IPBP x 2	533.4	51.21	Custom	P-91	3	203.1	11.1 m^3/s	50.63 m/s
4. FWH Heating Steam Piping									
FWH 1 Heating	FWHHS1 x 1	1066.8	11.58	20	A-106	4	15.19	107 m^3/s	131.6 m/s
FWH 2 Heating	FWHHS2 x 1	762	23.17	30	A-106	6	18.69	35.45 m^3/s	87.57 m/s
FWH 3 Heating	FWHHS3 x 1	508	34.75	40	A-106	8	20	14.63 m^3/s	85.25 m/s
FWH 4 Heating	FWHHS4 x 1	406.4	46.33	40	A-106	10	21.18	7.456 m^3/s	67.64 m/s
Deaerator (FWH 5) Heating	FWHHS5 x 1	406.4	123.4	40	A-106	22	19.79	4.074 m^3/s	36.48 m/s
FWH 6 Heating	FWHHS6 x 2	203.2	40.54	40	P-11	9	8.862	1.125 m^3/s	35.16 m/s
FWH 7 Heating	FWHHS7 x 2	152.4	35.97	40	A-106	8	13.79	0.7236 m^3/s	39.47 m/s
FWH 8 Heating	FWHHS8 x 2	203.2	52.12	80	P-22	11	20.84	0.7132 m^3/s	24.35 m/s
FWH 9 Heating	FWHHS9 x 2	203.2	57.91	80	P-22	12	13.79	1.098 m^3/s	37.78 m/s
5. Other Steam & Heating Piping									
FPT Main Steam	FPTMS1 x 1	508	71.63	40	A-106	9	33.65	11.85 m^3/s	68.37 m/s
6. Feedwater Piping									
FWH 1 Exit Feedwater	FWFW1 x 1	457.2	20.73	20	A-106	2	279.1	16999 lpm	1.852 m/s
FWH 2 Exit Feedwater	FWFW2 x 1	508	21.64	20	A-106	2	355.1	22083 lpm	1.96 m/s
FWH 3 Exit Feedwater	FWFW3 x 1	508	24.99	20	A-106	2	355.1	22692 lpm	2.014 m/s
FWH 4 Exit Feedwater	FWFW4 x 1	508	123.4	20	A-106	11	355.1	23467 lpm	2.083 m/s
Deaerator (FWH 5) Exit Feedwater	FWFW5 x 1	609.6	123.4	20	A-106	11	461.8	31751 lpm	1.931 m/s



Project Cost Summary	Reference Cost	Estimated Cost	
I Specialized Equipment	221,906,000	255,191,000	EUR
II Other Equipment	68,799,000	79,119,000	EUR
III Civil	26,414,000	41,259,000	EUR
IV Mechanical	148,567,000	244,483,000	EUR
V Electrical Assembly & Wiring	12,693,000	20,835,000	EUR
VI Buildings & Structures	10,866,000	16,149,000	EUR
VII Engineering & Plant Startup	24,229,000	24,403,000	EUR
Subtotal - Contractor's Internal Cost	513,473,000	681,439,000	EUR
VIII Contractor's Soft & Miscellaneous Costs	94,774,000	144,592,000	EUR
Contractor's Price	608,247,000	826,031,000	EUR
IX Owner's Soft & Miscellaneous Costs	121,649,000	165,206,000	EUR
Total - Owner's Cost (0.8 EUR per US Dollar)	729,896,000	991,237,000	EUR
Nameplate Net Plant Output	570	570	MW
Cost per kW - Contractor's	1067.1	1449.2	EUR per kW
Cost per kW - Owner's	1280.5	1739	EUR per kW

STEAM PRO allows you to quickly create steam plant design point heat balances, complete with outputs for plant hardware description, preliminary engineering and hardware details, and cost estimate with PEACE.

The variety of steam plant configurations is virtually endless. From back pressure units with gas fired boilers feeding desalination plants, to oil-fired boilers feeding straight condensing turbines with a small number of heaters, to coal fired PC boilers, or CFBs feeding single reheat turbines with seven or eight heaters, to supercritical double-reheat plants of the largest variety, or even biomass plants and waste incineration plants using grate fired boilers or BFB, each with any sort of cooling system, are all easily accommodated in STEAM PRO.

STEAM PRO includes a fuel database with more than 180 pre-defined coals, biomass, waste materials, and other fuels. STEAM PRO, in conjunction with PEACE, has an option to automatically include/exclude FGD, ESP or baghouse filter, and SCR using current fuel characteristics and plant size for guidance. It also allows inclusion of a chemical/physical **CO_2 Capture Plant**.

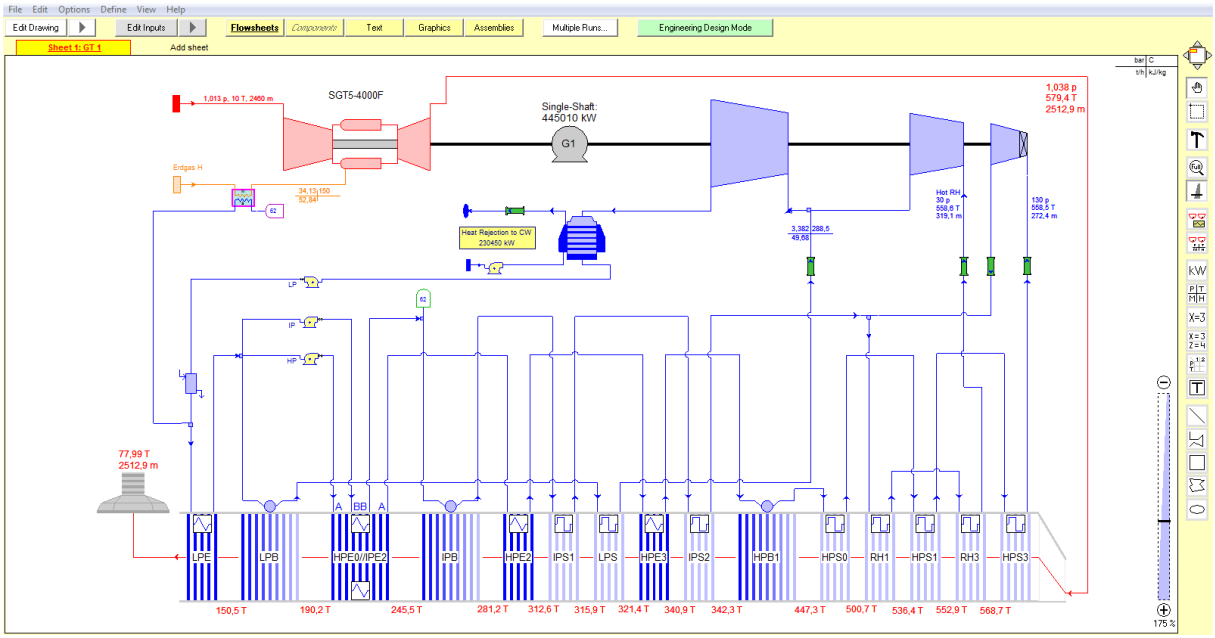
STEAM MASTER is the companion to STEAM PRO and is used for Off-Design simulation. STEAM MASTER computes plant performance for varying ambient conditions, fuel characteristics and fuel blends, equipment loading, process steam/water flows, hardware degradation levels, etc.

Fully-Flexible Plant Design, Simulation, and Cost Estimation

THERMOFLEX is a modular heat balance program with a graphical interface that allows you to assemble models using icons representing **over 180 components**. The program covers both design and off-design modeling. It can model all types of power and heat plants including GT or Reciprocating Engine Combined Cycles, Conventional Coal/Oil/Gas/Biomass/Waste fired Rankine Steam Cycles, Concentrated Solar Thermal Power Plants (CSP), Gasification and CCS Systems, Seawater Desalination Plants, Organic Rankine Cycles (ORC), Kalina Cycles, Repowering, etc.

In conjunction with the optional ***PEACE*** (***P***lant ***E***ngineering ***A***nd ***C***ost ***E***stimator) module, the program includes engineering hardware models that provide detailed hardware specifications and cost estimates.

Flowsheet: GTCC, Single-Shaft, 3p-RH

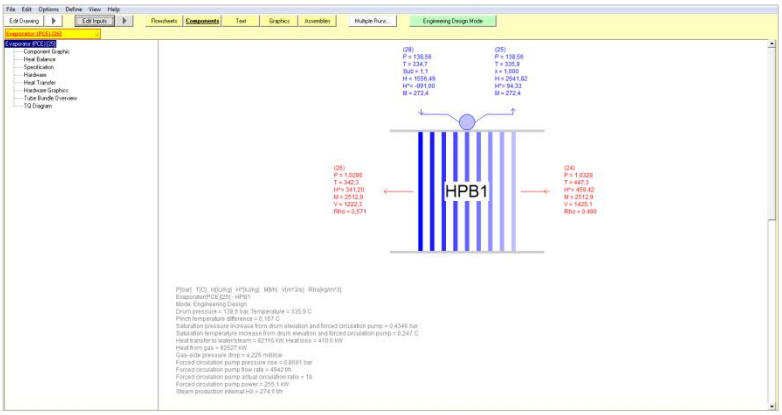


THERMOFLEX provides the ***GT PRO*** gas turbine library and a reciprocating gas and diesel engine library which in the 2015 version include more than **560 gas turbine and 380 gas/diesel engine specifications**. The **Steam Turbine Assembly** feature provides automatic estimation of efficiencies, leakage flows and information about the entire steam turbine such as dimensions, weight and costs.

THERMOFLEX also includes a fuel database with more than **180 pre-defined fuels** such as coal, biomass, RDF, LNG, and other fuels. The US NIST (REFPROP) fluid database is included besides a Heat Transfer Fluids/Molten Salts/Thermal Oils database to provide properties for over 120 refrigerants, heat transfer fluids, hydrocarbons, and other pure substances such as CO2. These fluids are used in modeling Concentrated Solar Power (CSP), closed cooling and heating systems, desalination systems, Organic Rankine and Kalina Cycles, closed CO2 cycles, CO2 capture and sequestration (CCS) plants, etc. Water properties based on IFC-67 and IAPWS-IF97 are available covering the subcooled liquid, wet steam, superheated steam, and supercritical states. Properties of gaseous mixtures are included covering a wide range of conditions including compressibility effects.

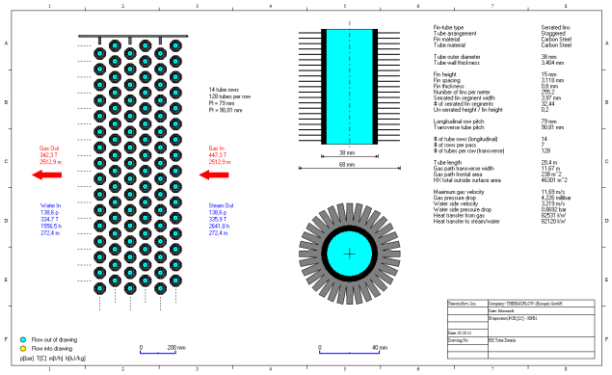
THERMOFLEX includes a bi-directional Link to MS-EXCEL (***E-LINK***) which allows running plant models from within MS EXCEL by specifying inputs and receiving outputs in EXCEL cells. E-LINK makes it easy to produce Thermal Heat Rate curves, integrated Annual Simulation results, Maximum Capacity Curves, etc. A built-in **scripting language** allows to add own logical blocks, or to call an external DLL/EXE, so THERMOFLEX models can run together with external programs.

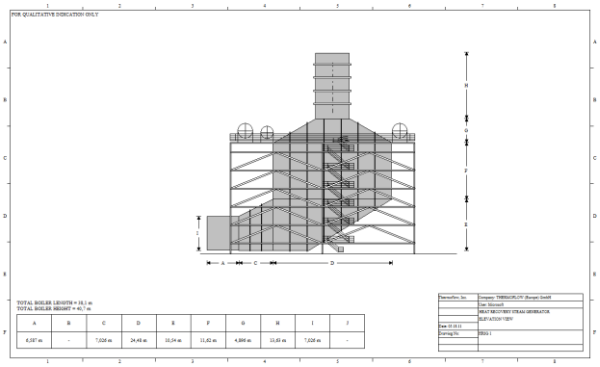
THERMOFLEX Outputs



In addition to being a comprehensive standalone tool, THERMOFLEX becomes more powerful when used together with Thermoflow's Application–Specific Programs ***GT PRO*** and ***STEAM PRO.***

GT PRO, GT MASTER, and STEAM PRO models can be directly loaded into THERMOFLEX, where they can be modified in the fully flexible environment, and/or run in off-design mode. Composite models, built partly in GT PRO, GT MASTER, STEAM MASTER and THERMOFLEX, can be created to take advantage of the best features of the Application-Specific and Fully-Flexible approaches to plant modeling.





File Edit Options Define View Help

Edit Drawing | Edit Inputs | Flowsheets | Components | Text | Graphics | Assemblies | Multiple Runs... | Engineering Design Mode

Reports
- System Summary
- Heat/Mass Balances

Messages
- Warnings
- Remarks

PEACE
- Cost Summary
- Cost Breakdown
- Financial Summary
- Cash Flow

Tables
- Plant Summary
- Generator & Motor Power
- Stream Table
- Emissions
- Flow Solver Matrix
- Pressure Solver Matrix
- Water Accounting
- Macro Table

Streams
- Gas/Air
- Water/Steam
- Fuel

Components

Custom Table

Cost Breakdown	Unit Cost	Cost Adj. Factor	Ref. Cost	Est. Cost	
Sum of Costs of PEACE Components & Linked Files			138.891.200	148.028.500	EUR
HRSG 1		1	37.567.040	40.806.270	EUR
Duct[19]					
Economiser[PCE][27] - HPE3					
Economiser[PCE][30] - HPE2					
Economiser[PCE][34] - LPE					
Evaporator[PCE][25] - HPB1					
Evaporator[PCE][31] - IPB					
Evaporator[PCE][33] - LPB					
Parallel Economisers[PCE][32] - HPE0//IPE2					
Stack[36]					
Superheater[PCE][20] - HPS3					
Superheater[PCE][21] - RH3					
Superheater[PCE][22] - HPS1					
Superheater[PCE][23] - RH1					
Superheater[PCE][24] - HPS0					
Superheater[PCE][26] - IPS2					
Superheater[PCE][28] - LPS					
Superheater[PCE][29] - IPS1					
ST 1		1	38.007.140	40.281.770	EUR
Steam Turbine[6]					
Steam Turbine[7]					
Steam Turbine[8]					
Gas Turbine(GT PRO)			54.358.200	57.076.110	EUR
Gas Turbine(GT PRO)[2]	54.358.200	1			
Pump(PCE)			2.183.097	2.350.020	EUR
Pump(PCE)[15]	514.438	1			
Pump(PCE)[18]	208.424	1			
Pump(PCE)[37]	1.114.116	1			
Pump(PCE)[38]	346.118	1			
Water-cooled Condenser(PCE)			1.889.394	2.056.192	EUR
Water-cooled Condenser[PCE][13]	1.889.394	1			
Pipe(PCE)			4.886.303	5.458.193	EUR
Pipe[PCE][5]	573.204	1			
Pipe[PCE][9]	168.982	1			
Pipe[PCE][10]	549.549	1			
Pipe[PCE][12]	223.806	1			
Pipe[PCE][14]	3.370.763	1			
Makeup/Blowdown					
Makeup/Blowdown[41]	not included				

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