



U.S. Department of Energy Steam System Assessment Tool

Version 3



User Guide

Versions 1 and 2 of the Steam System Assessment Tool (SSAT) were developed for the U.S. Department of Energy, under contract with the Oak Ridge National Laboratory, by Linnhoff March, a division of KBC Process Technology Ltd., and Spirax Sarco Inc. with additional support from Dr. Greg Harrell of the University of Tennessee.

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Introduction to SSAT

Versions 1 and 2 of the Steam System Assessment Tool (SSAT) were developed for the U.S. Department of Energy, under contract with the Oak Ridge National Laboratory, by Linnhoff March, a division of KBC Process Technology Ltd., and Spirax Sarco Inc. with additional support from Dr. Greg Harrell of the University of Tennessee.

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SSAT is an integral part of the Industrial Technologies Program BestPractices software tools provided by the U.S. Department of Energy.

For further information or help regarding the ITP Software Tools, please contact the Department of Energy's EERE Information Center at 1-877-EERE-INF (1-877-337-3463) or by sending an e-mail to eereic@ee.doe.gov.

What is SSAT?

SSAT is a structured software-based steam system simulation model. It is designed to allow you to build approximate models of your site steam system and to predict savings achieved from the implementation of key steam system BestPractice measures. The tool is intended for use by all engineers who are involved in the operation and/or improvement of steam systems across the full range of process industries.

What's new in Version 2?

The major change in SSAT Version 3 is the inclusion of a new set of templates that use metric units. The new templates (both metric and US units) also correct all known problems with Version 2. Based on feedback from users of the program, the 'User Calculations' sheet has been further unlocked to allow better access to Excel functionality.

Choice of Units of Measurement

SSAT now offers a choice between two different units of measurement sets, the details of which are given below:

Description	US units	Metric-based units
Pressure	psig	barg
Temperature	°F	°C
Heat energy	MMBtu/h	kW
Electrical power	kW	kW
Mass	klb	t (metric tonne)
Mass specific heat	Btu/lb	kJ/kg
Gas volume	scf	Nm ³
Liquid volume	gallon	m ³
Currency	\$	\$

Key features of SSAT include:

- A choice of 1, 2, or 3 pressure header models
- A choice of two sets of units of measurement
- Rapid simulation convergence time (typically measured in seconds)
- Simulations of major equipment items including:
 - Boiler
 - Back pressure turbines
 - Condensing turbine
 - Deaerator
 - Letdowns
 - Flash vessels
 - Feedwater preheat exchangers
 - Steam traps
- Schematic representations of the site steam system

- Estimates of site environmental emissions
- Calculations of project energy and operating cost savings

Project opportunities which can be evaluated using SSAT include:

- Steam savings
- Use of alternative boiler fuel
- Improved boiler efficiency
- Reduction of boiler blowdown rate
- Installing blowdown flash system to produce low pressure steam
- Change of steam generation conditions
- Installing new back pressure turbine(s)
- Installing new condensing turbine
- Installing new heat recovery exchangers to preheat feedwater
- Increasing condensate recovery
- Installing condensate flash system
- Reducing steam trap losses and steam leaks
- Improving pipework insulation

The essence of SSAT is the performance of automatic mass and energy balancing on steam systems before and after the implementation of projects. The approach used when developing SSAT models has been to provide you with a tool which is easy to use and yet powerful enough to approximate the operation of a wide range of steam systems. The 80/20 rule (obtaining 80% of the benefits for 20% of the work) is key to this approach in that SSAT will give rapid results without the need to construct dedicated system simulation models.

SSAT software runs as an add-in within Microsoft® Excel. SSAT model files are normal Excel files (*.xls) which require SSAT software to be loaded in order to enable them to function correctly.

Limitations of SSAT

SSAT does not offer an exact modeling and simulation solution to match precisely what is happening on your operating site. All steam systems are different and it is likely that there will be specific areas of many systems that cannot be modeled exactly within SSAT. If you are looking for an exact model of your system then specific software tools and/or energy consultants are available to provide this service.

In developing SSAT, we needed to consider which parts of steam systems fell within the 80/20 philosophy and which fell outside it. Here are some of the items that you will **not** find in SSAT:

- Detailed gas turbine + heat recovery steam generator
(An assessment of the economic viability of installing these components is provided)
- Multiple turbines between pressure levels
- Multiple boilers
- Steam generators using process waste heat
- "Over the fence" purchasing of steam
- Detailed combustion efficiency modeling
- Calculation of likely investment costs for project opportunities

The aim of SSAT is to provide guidance to engineers on how to improve their steam systems and to provide approximate estimates of potential savings. It should be stressed that the results obtained from the tool should always be backed up by a detailed evaluation of any project opportunity before proceeding with implementation.

Installing and running SSAT

Installation:

To Install SSAT simply download the file "SSAT_Setup.exe" from the DOE website and follow the onscreen instructions.

Notes

If you use any method to install SSAT other than described above, the program may not function correctly. We cannot provide support in this situation.

Note for user of Windows 2000 or above:

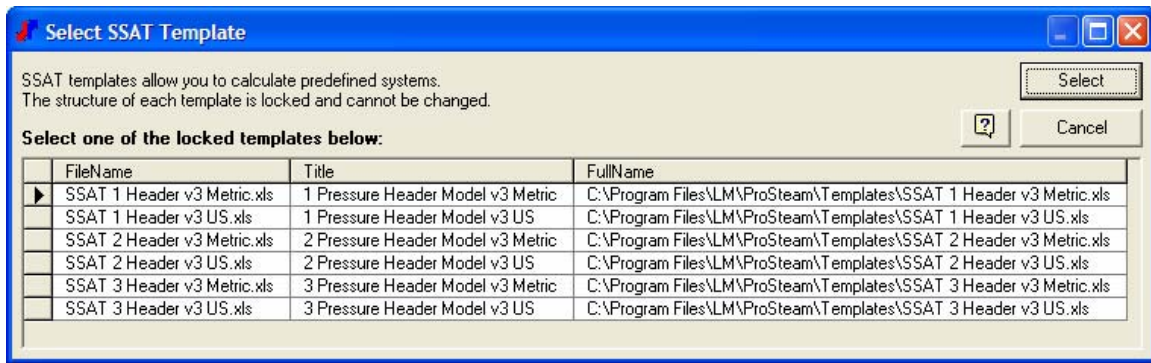
To install SSAT you **must** have **administrator** rights. Once you have run the application for the first time you do not need administrator rights.

Note for users with network installations of Office:

If your copy of Excel is run from a central location on your network, it may not be possible to use SSAT as this tool will need to load a component part to that location.

Loading and saving SSAT models

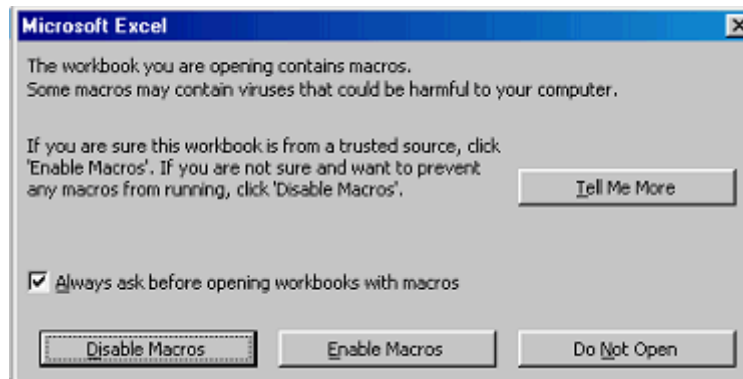
SSAT is supplied with six different template models to allow you to model 1-pressure header, 2-pressure header or 3-pressure header systems in US or Metric units. Upon loading SSAT for the first time, you are presented with the following dialog box from which the appropriate template can be selected:



Please note that when you select a file from this dialogue, it is always opened as “read only”. If you save your own files in the templates directory, they will also be listed in this dialogue and will be opened as “read only”.

If you need to open a file through the standard Excel menu you will find that it will **not** be “read only”.

Each SSAT template file contains macros. Depending on your security settings, you may see the following message when loading a template:



If so, please select “Enable Macros”.

Using SSAT - a quick overview

This section provides a quick overview of how to use SSAT models. More detailed information on all areas of the models is provided in the section “**Using SSAT - detailed description**” and information relating to key modeling assumptions is given in the section “**References and Assumptions**”. The “**Worked Example**” section illustrates the use of the model for a specific 1-header system.

Each SSAT file contains seven worksheets within a single workbook. As with any other Excel workbook, the appropriate worksheet can be accessed using the tabs at the bottom of the Excel window. SSAT files have been locked in order to protect the model calculation structure so that you can only change the input cells. All sheets can be printed out as desired.

Each template is set up to work with a fixed set of units of measurement and it is not possible to change these units from within the template. As discussed earlier however, SSAT now offers a choice between templates based on the US or metric systems.

The following steps should be followed in order to use SSAT to model your steam system:

Step 1 - Input

The **Input** sheet allows you to enter data specific to the operation of any given system. The SSAT template files provided already contain default data but you can overwrite any of this information. You might find it useful to print out a copy of the **Input** sheet prior to carrying out any modeling using SSAT to enable you to gather the required information. It should be noted that collection of all required data may require substantial effort and that the use of default data may result in significant errors.

Cells where your data can be entered into the model are shown shaded yellow. Some inputs require data to be entered directly into the spreadsheet while others require you to select from a set of pre-configured options using a drop-down menu.

Where you are required to make a choice between various options on a drop-down menu, additional information will often be required depending on which choice you make. In such cases, areas where additional information is needed are shaded green and are marked by red arrows “→” and “←”.

As the inputs to the model are changed, SSAT will automatically recalculate the operation of the system. SSAT uses an iterative calculation technique so the model may take several seconds to reach a converged solution. If you wish to make additional changes to the model, SSAT calculations will automatically stop as soon as you begin to enter additional data or click on a model screen using the mouse.

The **Input** sheet is split into two sections – “Quick Start” and “Site Detail”.

The “Quick Start” section is used to define the key operating parameters for the site. After entering this information, you can start to view the results from the model. All other detailed information describing the site operation will use model default settings if the original template has been loaded or the settings from the last time the model was saved if you are working from a configured version.

The “Site Detail” section prompts you to enter detailed information about the specific site configuration (see Using SSAT - detailed description for further information).

Step 2 - Model

The **Model** sheet shows a schematic representation of the current system based on the data contained in the **Input** sheet. This sheet is for viewing only and there are no user inputs. The diagram shown on the schematic is fixed so equipment items are shown even if they are not in use. An example would be a steam turbine with zero flow.

You should refer to this sheet in order to check that the system is being simulated as expected. The **Input** sheet can then be re-visited if any changes are required to the system specifications.

The sheet also displays model status. Once SSAT has completed its calculations, this should display “Model Status :

OK". The results from SSAT are only valid if this message is displayed.

Step 3- Projects Input

Steps 1 and 2 provide an overview of how to set up a model of an existing steam system. An additional key part of SSAT functionality is to evaluate possible BestPractice steam system improvement opportunities.

The Projects Input sheet allows you to select one or more of the pre-defined project options which can be evaluated using SSAT. These project options are selected using drop-down menus and additional information must be provided where indicated.

Step 4 - Projects Model

The *Projects Model* sheet is similar to the *Model* sheet discussed above except that this time the schematic representation shows the updated simulation of the system after the installation of any improvement projects specified in the *Projects Input* sheet.

Step 5 - Results

The *Results* sheet shows the key results from the models of both the current operation and the operation after the implementation of one or more of the chosen BestPractice project opportunities. The savings reported are those resulting from the implementation of all selected projects. Because of the potentially complex project interactions, when more than one project is selected, SSAT does not report the individual benefit for each project. The results are presented in tabular form, allowing you to quickly assess the impact of any changes on your steam system.

Other features of this sheet include the model status, a gross gas turbine assessment and a marginal cost calculation capability.

In order to obtain the marginal steam costs (if no values are currently displayed), you should press the "Calculate Marginal Costs" button. SSAT then carries out the required calculations. It is important that you do not interrupt SSAT while these calculations are being carried out. If the calculations are interrupted (by pressing 'Escape'), please select 'Continue' from the resulting dialog box otherwise the model will fail and you will need to re-load the file. Even if 'Continue' is selected, it is possible that the results displayed will be incorrect.

Further down the sheet, a comment is made on the suitability of the site for the installation of a gas turbine and associated waste heat boiler ("Gas Turbine Assessment") based upon an approximate economic calculation, the details of which are contained in the "**References and Assumptions**" section.

A list of chosen projects (up to a maximum of 10 because of display area limitations) is also displayed along with any warning messages (again up to a maximum of 10) regarding the calculations carried out by SSAT. If you have selected more than 10 projects, all the selected projects will be modeled but not all projects will be listed on the *Results* sheet.

Using SSAT - detailed description

This section provides a detailed description of all aspects of SSAT. Some of the material in this section is repeated from “Using SSAT - a quick overview” in order to produce a full detailed description of the model in a single section of this manual.

Any screen shots provided refer to the 3-header model. The equivalent views in the 1-header and 2-header models will either be identical or they will be simpler because fewer options are available in these systems.

Each SSAT file contains seven worksheets within a single workbook. As with any other Excel workbook, the appropriate worksheet can be accessed using the tabs at the bottom of the Excel window. SSAT files have been locked in order to protect the model calculation structure so you only have access to selected input cells. All sheets can be printed as required.

Each template is set up to work with a fixed set of units of measurement and it is not possible to change these units from within the template. As discussed earlier however, SSAT now offers a choice between templates based on the US or metric systems. All screen shots included in this section of the manual are taken from the US system templates.

A detailed sheet-by-sheet description of the various elements of the model is given below:

The Input Sheet

The **Input** sheet allows you to enter data specific to the operation of any given system. SSAT template files already contain default data but any of this information can be overwritten by you.

Cells where you should enter data into the model are shaded yellow. Some inputs require data to be entered directly into the spreadsheet while others require you to select from a set of pre-configured options using a drop-down menu. You might find it useful to print out a copy of the **Input** sheet prior to carrying out any modeling using SSAT to enable you to gather the required information. It should be noted that collection of all required data may require substantial effort and that the use of default data may result in significant errors.

Where you are required to make a choice between various options on a drop-down menu, additional information will often be required depending on which choice was made. In such cases, areas where additional information is needed are shaded green and are marked by red arrows “→” and “←”.

Should you enter any input values which fall outside the range allowed by SSAT then a warning message will be displayed informing you of the action which will be taken.

As the inputs to the model are changed, SSAT will automatically recalculate the operation of the system. SSAT uses an iterative calculation technique so the model may take several seconds to reach a converged solution. If you wish to make additional changes to the model, SSAT calculations will automatically stop as soon as you begin to enter additional data or click on a model screen using the mouse.

The **Input** sheet is split into two sections – “Quick Start” and “Site Detail”.

“Quick Start” Section

The “Quick Start” section is used to define the key operating parameters for the site. After entering this information, you can start to view the results from the model. All other detailed information describing the site operation will use model default settings if the original template has been loaded or the settings from the last time the model was saved if you are working from a configured version.

A description of the various input parameters in the “Quick Start” section is given below:

Steam System Assessment Tool

3 Header Model

Data Entry Form for Current System

The data entry form is split into two sections. **"Quick Start"** enables you to enter a minimum amount of information about your site and to start modeling your system right away. **"Site Detail"** allows you to provide more detailed information about your site to improve the accuracy of the model.

Yellow shaded cells require user input.

Where different options can be chosen by the user, the required supplementary data input cells are shaded green and are indicated by **red arrows**.

Quick Start

Enter Case Description SSAT Default 3 Header Model

General Site Data	Input Data	Notes/Warnings
Site Power Import (+ for import, - for export)	5000 kW	Power import + site generated power = site electrical demand
Site Power Cost	0.0500 \$/kWh	Typical 2003 value: \$0.05/kWh
Operating hours per year	8000 hrs	
Site Make-Up Water Cost	0.0025 \$/gallon	Typical 2003 value: \$0.0025/gallon
Make-Up Water Temperature	50 F	

Note: Enter average values for the operating period being modeled

Boiler fuel - Choose from this drop-down list	Natural Gas
Site Fuel Cost per 1000 s.cu.ft	5.78 \$
	Typical 2003 value: \$5.78/(1,000 s.cu.ft)

Note: Fuel HHV is 1,000 Btu per s.cu.ft. (23,311 Btu/lb)

For user defined fuels, enter HHV	20000 Btu/lb
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Note: Emissions cannot be calculated for user defined fuels

Steam Distribution	Input Data	Warnings
High Pressure (HP)	600 psig	
Medium Pressure (MP)	150 psig	
Low Pressure (LP)	20 psig	
HP Steam Use by Processes	50 klb/h	
MP Steam Use by Processes	100 klb/h	
LP Steam Use by Processes	200 klb/h	

Note: Enter process steam use at each pressure level. Excludes turbines, letdowns, leaks, trap losses, deaeration steam and vents

Steam Turbines	
Do you have a steam turbine installed between HP and LP?	Yes
Do you have a steam turbine installed between HP and MP?	Yes
Do you have a steam turbine installed between MP and LP?	No
Do you have an HP to condensing turbine installed?	No

For a **Condensing Turbine**, please define how the turbine operates and then provide supplementary information below:

Mode of operation	Not installed
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Option 1 - Fixed power generation	1000 kW
Option 2 - Fixed steam flow	50 klb/h

Steam Traps	Input Data	Warnings
<i>Number of traps at each pressure level</i>		
Traps on HP header	250 traps	
Traps on MP header	300 traps	
Traps on LP header	500 traps	

Select the approximate timing of your last trap testing and maintenance program	3-5 years ago
---	---------------

Enter Case Description

You can enter any text to describe the operating case that is being modeled (e.g. site name, date, time, specific comments on operation). This text is then displayed on the **Model**, **Projects Model** and **Results** sheets.

General Site Data

This section prompts for general operating information for the site.

Site Power Import

You should enter the average power import for the site for the operating period being modeled. This represents the amount of power purchased by the site from its external electricity supplier. If the site is a net exporter of power, the amount of power exported from the site should be entered as a negative number.

Based on this value and a simulation of the power generated in the steam turbines, the model calculates the site power usage as follows:

$$\text{Site power usage (kW)} = \text{On-site turbine power generation (kW)} + \text{Site power import (kW)}$$

This value for site power usage is then fixed during all subsequent project evaluations.

Site Power Cost

For the operating period being modeled, you should enter the average power cost in \$/kWh. For simplicity, SSAT only uses a single cost for power and does not allow the modeling of complex power tariff structures. The power cost should always be entered as a positive number. If the site is a power exporter, the sale price for power should be entered as a positive value.

Operating hours per year

Enter the number of hours per year that the site is operating. This value is used by the model to convert the calculated \$/h operating cost into an annual amount.

Site Make-Up Water Cost

This is cost in \$/gal to supply treated water for use in the site boilers. This should include the cost of raw water and any associated pre-treatment steps such as demineralization.

Make-Up Water Temperature

This is temperature at which the make-up water enters the system. It should be the temperature downstream of any pre-treatment units.

Boiler fuel

SSAT includes a choice of seven different fuels. Alternatively, SSAT allows you to specify a user-defined fuel if none of the standard fuels offers a close enough match to your process. You should choose a fuel from the drop-down menu. It is not possible to specify the use of multiple fuels in a single operating case in SSAT. In these cases, the site marginal fuel should be selected.

The characteristics of the seven fuels built in to SSAT (composition, higher heating value etc.) have been defined using reference information discussed in References and Assumptions. It should however be noted that SSAT cannot carry out emissions calculations for user-defined fuels.

The available choices are as follows:

- Natural Gas
- Number 2 Fuel Oil
- Number 6 Fuel Oil (Low Sulfur)
- Number 6 Fuel Oil (High Sulfur)
- Typical Eastern Coal (Bituminous)
- Typical Western Coal (Subbituminous)
- Typical Green Wood
- User Defined Fuel

Site Fuel Cost

The cost of the fuel should be entered in the units displayed. For natural gas, you are prompted for a cost in \$ per 1000 standard cubic feet. For the oils, a \$/gal value is required and, for the solid fuels, a \$/ton value should be entered.

If you have chosen to specify your own fuel, a cost in \$/MMBtu is required along with the additional input of the fuel higher heating value (HHV) measure in Btu/lb.

Steam Distribution

This section allows you to enter the header pressures in the system and to specify the amount of steam used by the processes on the site.

High Pressure (HP), Medium Pressure (MP) and Low Pressure (LP)

You should enter the operating pressure of the site steam headers. For the 2-header model, only the HP and LP pressures are required. For the 1-header model, only a single pressure is required.

HP/MP/LP Steam Use by Processes

You are asked to specify the amount of steam used by the on-site processes from each header in the system. These values should exclude steam use associated directly with the steam system such as flows through letdowns or turbines, flows to deaerators and vents and any losses associated with steam traps or leaks in the distribution system.

SSAT does not allow you to enter a value for steam generation from the processes (e.g. a heat exchanger using process waste heat to produce steam). In such cases, an approximation can be made by entering the net process steam use (i.e. steam use minus steam generation).

Steam Turbines

You are required to define which steam turbines are operating on the site. For simplicity reasons, SSAT only allows for one turbine to be modeled between each set of pressure levels.

For each option where a turbine is operating, you should select "Yes" from the drop-down menu. For the 3-header system, HP to LP, HP to MP and MP to LP back pressure turbine options are available. For the 2-header system, only an HP to LP back pressure turbine is available. All models provide the option of a condensing turbine taking HP steam as its inlet.

For the back pressure turbines, the model uses data specified later in the "Site Detail" section to model their operation. SSAT models supplied with the software contain default parameters which can be modified by you if required.

Condensing Turbine – Mode of operation

If you have specified that a condensing turbine is installed, further information is required at this stage to define the turbine operation. You can choose between two options as follows:

- Option 1 - Define fixed power generation
- Option 2 - Define fixed steam flow

Depending on which of these options is chosen, you are required to enter either a power produced by the turbine or a steam flow through the turbine in the subsequent data entry cells. The header conditions and the turbine isentropic efficiency are then used by SSAT to calculate the operation of the turbine. Red arrows are used to indicate to you where data is required.

Further discussion of the detailed data required to define the condensing turbine performance can be found in the "Site Detail" section.

Steam Traps

You are prompted to enter the number of steam traps on each pressure level. In the default templates, these values are used to estimate the amount of failed traps on the site.

The values are also used to estimate the amount of steam leaks assuming a direct correlation between the number of traps and the complexity of the steam distribution system and hence the likely number of leaks. You have the option

to override this automatic calculation using options in the “Site Detail” section.

Number of traps at each pressure level

For each header, you should enter the number of steam traps installed, using an approximate value if the exact value is not known.

Select the approximate timing of your last trap testing and maintenance program

Using the drop-down menu, you can select the approximate timing of the last testing and maintenance program aimed at identifying and replacing failed steam traps and identifying and fixing steam leaks. Depending on the value selected here, the model will adjust its automatic estimate of trap failure and leak rates based on operating experience. The longer the period since the last maintenance program, the greater the expected losses. The automatic estimate of trap failures and leak rates is based on correlations derived from extensive field experience.

“Site Detail” Section

The “Site Detail” section allows you to enter detailed information about the specific site configuration. SSAT templates supplied with the software contain default values which enable you to begin to use the tool by modifying the “Quick Start” data only. However, it is likely that almost all users will wish to explore the “Site Detail” section in order to improve the accuracy of their system model.

The example worksheet below shows the initial part of the “Site Detail” entry form:

Site Detail		
Boiler		
Method for specifying boiler efficiency	Option 1 - Model default (85% for Natural Gas) ▼	
<small>Note: Model default efficiencies represent Best Practice values assuming good operation and the installation of an economizer</small>		
Option 2 - Enter efficiency (%)	85 %	
<small>Note: Boiler efficiency is defined as 100% - Stack Loss (%) - Shell Loss (%). The “Stack Loss” sheet gives more information on heat losses Note: Efficiency is based on Higher Heating Value. Economizers are included in the boiler efficiency. Boiler blowdown losses are excluded</small>		
Blowdown Rate (% of feedwater flow)	2 %	
Do you have blowdown flash steam recovery to the LP system?	No ▼	
<small>Please select how you wish to define your HP generation condition and then provide supplementary information below if required:</small>		
Method for specifying HP generation condition	Option 1 - Accept model default conditions ▼	
<small>Note: As a default, the model will use HP steam with 100 F of superheat. At HP pressure (600 psig), this corresponds to a temperature of 589 F</small>		
Option 2 - Enter temperature	600 F	
Option 3 - Enter thermodynamic quality	99 % dry	
<small>Note: Saturation temperature at specified HP pressure (600 psig) is 489 F Note: Steam quality is an expression of the percentage dryness (or vapor fraction) of the steam</small>		
Configure the operation of your HP to LP turbine(s) using the options below:		
HP to LP Steam Turbine(s)	Input Data	Notes/Warnings
→ Isentropic efficiency	65 %	←
<small>Note: If multiple turbines are installed, the operation of the impact turbine (the turbine affected by changes to the system) should be modeled Note: A generator electrical efficiency of 100% is assumed by the model</small>		
→ Select the appropriate turbine operating mode	Option 1 - Balances LP header (Model default option) ▼ ←	
<small>Note: If Option 1 is chosen, the model will preferentially use the HP to LP turbine to balance the LP demand</small>		
Option 2 - How should the fixed turbine operation be defined?	Option 2 not selected ▼	
Option 2 - Fixed steam flow	100 klb/h	
Option 2 - Fixed power generation	2000 kW	
Option 3 - How do you wish to define the operating range?	Option 3 not selected ▼	
Option 3 - Minimum steam flow	50 klb/h	
Option 3 - Maximum steam flow	150 klb/h	
Option 3 - Minimum power generation	1500 kW	
Option 3 - Maximum power generation	2500 kW	

Boiler

You can supply detailed information regarding the operation of the site boiler. For simplicity, SSAT only allows a single boiler to be modeled.

If your site has multiple boilers, the recommended strategy for modeling them depends on which results you require from SSAT. To obtain a good prediction of fuel consumption, total fuel cost and emissions, it is recommended that boiler operations should be combined into a single set of operating data by providing weighted average values for efficiency, blowdown rate etc. However, if there are significant differences in your boilers and you wish to obtain a good estimate of the benefit associated with one of the SSAT project changes, it is recommended that you enter data based on the impact boiler in the system. The term “impact boiler” refers to the boiler which is affected by changes to steam demands in the system.

No gas turbine and associated heat recovery steam generator can be modeled in SSAT.

Method for specifying boiler efficiency

There are two options to define the boiler combustion efficiency as follows:

- Option 1 - Model default (e.g. 85% for Natural Gas)
- Option 2 - Enter user-defined value

Depending on the fuel selected in the “Quick Start” section, SSAT contains default efficiency values which you can apply. The default efficiency value for the selected fuel is displayed in the text in the drop-down menu. These efficiencies represent well operated boilers with economizers installed.

If Option 2 is selected, you are prompted (by red arrows) to enter a user-defined efficiency. SSAT boiler efficiencies are based on the higher heating value for the fuel.

The efficiency required by the model is defined as:

$$SSAT \text{ Boiler efficiency (\%)} = 100\% - \text{Stack Loss (\%)} - \text{Shell Loss (\%)}$$

An additional tool provided in this version of SSAT is the Stack Loss Calculator located in the **Stack Loss** sheet. If you have measurements or estimates of your stack gas temperature and oxygen content, this sheet will estimate the heat lost via the stack. This will help in estimating the boiler efficiency required as an input for Option 2 above. A detailed discussion of the **Stack Loss** sheet is included later in this guide.

Alternatively, the boiler efficiency can be considered as the heat absorbed into water heating and steam generation divided by the amount of heat released from fuel firing.

The heat absorbed into water heating and steam generation is defined as follows (in Btu/h):

$$\text{Steam generation rate (lb/h)} * \text{Steam generation enthalpy (Btu/lb)} + \text{Blowdown rate (lb/h)} * \text{Blowdown enthalpy (Btu/lb)} - \text{Feedwater rate (lb/h)} * \text{Feedwater enthalpy (Btu/lb)}$$

The amount of heat from fuel firing is defined as follows (in Btu/h):

$$\text{Fuel firing rate (lb/h)} * \text{Fuel higher heating value (Btu/lb)}$$

Blowdown Rate (% of feedwater flow)

You should enter the blowdown rate as a percentage. The required value is calculated as follows:

$$\text{Blowdown rate (\%)} = \text{Blowdown flow (lb/h)} / \text{Feedwater flow (lb/h)} * 100$$

Do you have blowdown flash steam recovery to the LP system (2-header and 3-header models only)?

The drop-down menu allows you to specify whether a system is installed to collect boiler blowdown and to flash it in order to produce low pressure steam. The model calculates the flash steam production rate automatically if this option is selected assuming no heat or pressure loss from the blowdown before it reaches the flash vessel.

Do you have blowdown flash steam recovery to the deaerator (1-header model only)?

In the 1-header model, the drop-down menu allows you to specify whether a system is installed to collect boiler blowdown and to flash it into the deaerator. The model calculates the flash steam production rate automatically based on the deaerator pressure assuming no heat or pressure loss from the system.

Method for specifying HP generation condition

You can use the drop-down menu to choose how to specify the steam generation conditions from the boiler. The choices are as follows:

- Option 1 - Accept model default conditions
- Option 2 - User-defined superheated conditions
- Option 3 - User-defined saturated conditions

If Option 1 is chosen, the model assumes that the boiler produces superheated steam with 100°F of superheat (i.e. the steam temperature is equal to the saturation temperature of the steam at the generation pressure plus 100°F). For Options 2 and 3, you are prompted to enter supplementary information.

Option 2 requires you to specify a steam generation temperature.

Option 3 requires you to specify the steam quality. This is the same as the percentage dryness of the steam or the percentage vapor on a mass basis.

HP to LP Turbine(s), HP to MP Turbine(s) and MP to LP Turbine(s)

These sections allow you to specify detailed information about the operation of any back pressure turbines on the site. The “Quick Start” section allowed you to specify which (if any) back pressure turbines are in operation on the site. This does not apply to the 1-header model.

If no turbine was selected in the “Quick Start” section, the following message is displayed at the top of the detailed turbine entry section:

"In the Quick Start section, you specified that no XX to XX turbine(s) were installed - Please move on to the next section"

Note – XX refers to the header names (e.g. HP, LP)

If a turbine was selected, the following message is displayed:

"Configure the operation of your XX to XX turbine(s) using the options below:"

In this case, you can configure the turbine operation using the data inputs discussed below. The data entry options are the same for all back pressure turbines and each option is assigned a separate area in the “Site Detail” section. SSAT only allows one turbine to be modeled between each set of pressure levels. If multiple turbines operate between a given set of pressures, data for the impact turbine should be entered into SSAT. The term “impact turbine” refers to the turbine which is affected by changes to the system. For example, if you have multiple turbines between HP and LP, you should consider which turbine’s operation would change as a result of changes in HP supply or LP demand.

Isentropic efficiency

You should enter the isentropic efficiency of the turbine. SSAT only supports a single fixed efficiency value. It is not possible to enter an equation relating, for example, efficiency to steam throughput. In calculating the power generation from the turbine, the model assumes a 100% generator efficiency.

Isentropic efficiency is defined as:

$$\text{Efficiency (\%)} = (h1 - h2a) / (h1 - h2s) * 100$$

Where:

h1 = enthalpy of turbine inlet (Btu/lb)

h2a = actual enthalpy of turbine exhaust (Btu/lb)

h2s = enthalpy of steam/water at turbine exhaust pressure and turbine inlet entropy (Btu/lb)

Manufacturer’s data is often useful in determining the efficiency. It is also possible to adjust the efficiency on a trial and error basis within SSAT in order to match modeled performance with actual measured data from your site.

Select the appropriate turbine operating mode

You can choose from a drop-down menu to define how the turbine is operating as follows:

- Option 1 - Balances XX header (Model default option)
- Option 2 - Fixed operation
- Option 3 - Operation within min/max limits

Note – XX refers to the exhaust pressure from the turbine (e.g. LP)

Option 1 allows the flow through the turbine to vary depending on the demand on the exhaust header. For example, for a HP to LP turbine, the model will calculate the required LP demand and will send the appropriate amount of steam through the turbine in order to balance the header. Options 2 and 3 require supplementary inputs and you are prompted to provide these.

If Option 2 is selected, you can choose whether to specify a fixed steam flow or a fixed power generation rate for the turbine using another drop-down menu. You are then prompted to enter the appropriate numerical value depending on the option chosen.

For Option 3, you can choose whether to define a range for steam flow or a range for power generation using a drop-down menu. You are then prompted to enter the appropriate minimum and maximum values for the chosen range. Option 3 works in a similar way to Option 1 in that it balances the steam demand on the exhaust header provided that the resulting steam flow or power generation lies within the specified allowable range. If this is not the case, the model will choose to send the minimum flow through the turbine if the demand on the exhaust header is low or the maximum flow if the demand on the exhaust header is high.

Following on from the back pressure turbine data entry sections, the next part of the “Site Detail” section is shown below:

In the Quick Start section, you specified that no condensing turbine(s) were installed - Please move on to the next section

HP to Condensing Steam Turbine(s)	Input Data	Notes/Warnings
Isentropic efficiency	65 %	
Note: If multiple turbines are installed, their data should be combined to allow them to be modeled as a single turbine Note: A generator electrical efficiency of 100% is assumed by the model		
Select the units of measure to specify the condenser pressure		psia ▼
Condenser pressure (psia)	2	

Letdowns / PRVs		
HP to MP - Is desuperheating water used?	No (Model default) ▼	
if yes, enter control temperature	370 F	
Note: Saturation temperature at specified MP pressure (150 psig) is 366 F		
MP to LP - Is desuperheating water used?	No (Model default) ▼	
if yes, enter control temperature	270 F	
Note: Saturation temperature at specified LP pressure (20 psig) is 259 F		

Deaerator	Input Data	Warnings
Vent (as % of boiler feedwater flow)	0.1 %	
Note: Values of around 0.1% are typical		
Select the appropriate deaerator operating mode	Option 3 - Use model default pressure (15 psig) ▼	
Option 2 - Specify pressure	15 psig	
Note: Deaerator uses LP steam. Specified LP pressure is 20 psig		

Feedwater Heat Recovery System		
Heat recovery exchanger on the condensate tank vent?	No ▼	
if yes, enter approach temperature	20 F	
Note: Approach temperature is defined as the minimum allowable temperature difference in the heat exchanger		
Heat recovery exchanger on boiler blowdown?	No ▼	
if yes, enter approach temperature	20 F	

HP to Condensing Steam Turbine(s)

Depending on whether a condensing turbine was selected in the “Quick Start” section, this area of the data entry form can be used to specify further information about the turbine operation. As for each of the back pressure turbines, SSAT only allows a single condensing turbine to be modeled. However, unlike back pressure turbines, if multiple units are installed on the site you should combine their operating data into a single equivalent turbine approximation.

Isentropic efficiency

You should enter the isentropic efficiency of the turbine. SSAT only supports a single fixed efficiency value. It is not possible to enter an equation relating, for example, efficiency to steam throughput. In calculating the power generation from the turbine, the model assumes a 100% generator efficiency.

Select the units of measure to specify the condenser pressure

Different sites use different units to measure the operating pressure of the condenser. You can choose the appropriate units from the following selection using the drop-down menu:

- ins Hg abs
- ins Hg vacuum
- psia
- psig

Condenser pressure

Having selected the appropriate units of measure, you can then specify a numerical value for the condenser pressure. The chosen units of measure are displayed in the text prompt. For information, 0 psig = 14.7 psia.

Letdowns/PRVs

For the multiple header models, letdowns or PRVs (pressure reduction valves) are included between the pressure levels. These can be modeled either with or without desuperheating water depending on the site configuration.

Is desuperheating water used?

For each letdown, you can choose whether desuperheating water is used from a simple drop-down menu.

If yes, enter control temperature

If desuperheating water is used, you should specify a control temperature to which the outlet steam will be desuperheated.

Deaerator

All heat and material balances around the deaerator are carried out automatically by SSAT but you do have some control over the operating parameters.

Vent (as % of boiler feedwater flow)

You can specify how much steam is vented from the deaerator. The vent flow is specified as a percentage of the boiler feedwater flow leaving the deaerator.

Select the appropriate deaerator operating mode

You are presented with various options to define the deaerator operating pressure as follows:

- Option 1 - Assume operation at LP header pressure
- Option 2 - User-defined pressure
- Option 3 - Use model default pressure (15 psig)

Option 1 assumes that the deaerator operates at the same pressure as that specified for the LP header (or for the single header in the 1-header model). Option 3 sets the operating pressure to a typical industrial value of 15 psig (or to the LP header pressure if this is less than 15 psig).

Option 2 requires you to enter a user-defined pressure value and you are prompted to do so using the customary red arrows.

Feedwater Heat Recovery System

SSAT supports the modeling of two heat recovery options to preheat feedwater upstream of the deaerator.

Heat recovery exchanger on the condensate tank vent or boiler blowdown?

For each of the permitted options, you select from a simple drop-down menu whether the particular exchanger is installed.

The exchangers available are to recover heat from the condensate tank vent steam or from the boiler blowdown.

If yes, enter approach temperature

Each exchanger requires you to specify a minimum allowable approach temperature.

For the exchanger using vent steam, this will be the minimum allowable temperature difference between the steam saturation temperature and the feedwater outlet temperature from the exchanger. Depending on the relative flows of steam and water in the exchangers, this approach temperature may not actually be reached.

For the blowdown exchanger, this will be the temperature difference between the blowdown leaving the exchanger and the feedwater entering the exchanger.

For the heat exchanger using vent steam, it should be noted that the condensate from these exchangers is assumed to be saturated liquid at the exchanger inlet pressure. Where the flow of deaerator feed water is limiting, it is possible to reach the specified minimum approach temperature without using all the available steam. In this case, any remaining excess steam is vented.

The final part of the “Site Detail” data entry section is as follows:

Process Condensate	Input Data	Warnings
Condensate return temperature to tank	150 F	
HP condensate recovery	50 %	
MP condensate recovery	50 %	
LP condensate recovery	50 %	

Note: Condensate recovery specified as the percentage of steam supplied to the processes at each level

Do you flash condensate to MP steam?	No	▼
Do you flash condensate to LP steam?	No	▼

Steam Trap Losses and Steam Leaks		
Choose a method for estimating steam losses	Option 1 - Losses automatically estimated by model (Model default) ▼	
Option 2 - Specify number of failed traps at each pressure level	Warnings	
Trap failures on HP header	10 traps	
Trap failures on MP header	10 traps	
Trap failures on LP header	10 traps	
Option 2 - Specify number of steam leaks at each pressure level	Warnings	
Steam leaks on HP header	10 leaks	
Steam leaks on MP header	10 leaks	
Steam leaks on LP header	10 leaks	

Note: Calculated values for current loss and leak rates based on current user inputs are:-
 HP header - Trap failures: 25, Loss per trap 0.134 klb/h - Total trap loss = 3.36 klb/h. Steam leaks: 10, Loss per leak 0.033 klb/h - Total leaks = 0.33 klb/h.
 MP header - Trap failures: 30, Loss per trap 0.038 klb/h - Total trap loss = 1.14 klb/h. Steam leaks: 12, Loss per leak 0.010 klb/h - Total leaks = 0.11 klb/h.
 LP header - Trap failures: 50, Loss per trap 0.003 klb/h - Total trap loss = 0.13 klb/h. Steam leaks: 20, Loss per leak 0.001 klb/h - Total leaks = 0.01 klb/h.

Insulation Heat Losses	Input Data	Notes/Warnings
Choose a method for specifying heat losses	Option 2 - Percentage heat loss on each header (Model default) ▼	
Option 1 - Heat loss on HP header	0.1 MMBtu/h	
Option 1 - Heat loss on MP header	0.1 MMBtu/h	
Option 1 - Heat loss on LP header	0.1 MMBtu/h	
→ Option 2 - % of heat lost on HP header	0.1 %	←
→ Option 2 - % of heat lost on MP header	0.1 %	←
→ Option 2 - % of heat lost on LP header	0.1 %	←

Note: Losses calculated as the percentage of heat flow entering each header
 Note: Current values for heat entering headers are: HP 540 MMBtu/hr, MP 122 MMBtu/hr, LP 301 MMBtu/hr - These may change when the model is updated

Process Condensate

This section of the form allows you to specify how much condensate is recovered from the process units. It also

allows you to take into account the often significant temperature drops which occur in condensate return systems by allowing you to specify a return temperature for the condensate before it enters the condensate tank. The condensate tank is assumed to operate at atmospheric conditions and any flash steam from the tank is calculated automatically.

Condensate return temperature to tank

You should specify the temperature of the condensate as it enters the condensate tank.

HP/MP/LP condensate recovery

You should specify how much condensate is recovered from the process users on each header. The condensate return rate is specified as a percentage of the steam flow to the process users which was defined in the "Quick Start" section.

Do you flash condensate to MP steam?

This option is only available in the 3-header model. You can select, using a simple drop-down menu, whether a system is installed to flash HP condensate to produce MP steam. In carrying out flash calculations, SSAT assumes that condensate leaving the processes is at the header saturation temperature and that no temperature or pressure loss occurs before the condensate enters the flash vessel.

Do you flash condensate to LP steam?

This option is only available in the 2-header and 3-header models. You can select using a simple drop-down menu whether a system is installed to flash HP condensate (or HP and MP condensate in the 3-header model) to produce LP steam. In carrying out flash calculations, SSAT assumes that condensate leaving the processes is at the header saturation temperature and that no temperature or pressure loss occurs before the condensate enters the flash vessel.

Steam Trap Losses and Steam Leaks

Replacing failed steam traps and fixing steam leaks are both key BestPractice opportunity projects. Therefore, SSAT allows you to estimate how much steam is currently being lost from the system. Estimates of the amount of steam being lost per failed trap or per leak are made using correlations provided by the SSAT development partners based on extensive field experience. SSAT assumes that steam from failed traps is being lost to atmosphere.

Choose a method for estimating steam losses

You can choose the calculation basis for failed traps and steam leaks from the following drop-down menu options:

- Option 1 - Losses automatically estimated by model (Model default)
- Option 2 - Losses calculated from user-defined data

For Option 1, the model uses the information entered in the "Quick Start" section relating to the total number of steam traps and the time when the last trap and leak maintenance program was carried out in order to estimate how many failed traps and how many steam leaks there will be on the site. These estimates are based on the results of operating experience across numerous sites in a range of industries.

Option 2 provides you with the chance to override the automatic model estimate by specifying the number of failed traps and the number of steam leaks on each of the headers on the site. With this option, SSAT continues to automatically estimate the steam loss rate per failed trap and per steam leak.

For guidance, the current calculated loss rates are displayed on the data entry form.

Insulation Heat Losses

This final section of the data entry form allows you to take account of heat losses in the steam distribution system. SSAT deals with this issue in a simplified manner by calculating a heat loss on each of the headers. The model determines the total heat entering the header and then subtracts the appropriate heat loss value before re-calculating the enthalpy of the steam on the header. Heat losses in other areas of the steam system are not accounted for.

Should you wish to carry out a more detailed assessment of the likely heat losses through poor insulation in your system, the U.S. Department of Energy software program 3E Plus is available for this purpose.

Choose a method for specifying heat losses

You have two options for specifying heat loss on each header as follows:

- Option 1 - Specify fixed heat loss

- Option 2 - Percentage heat loss on each header (Model default)

Depending on which option is chosen, you are required to provide supplementary information as prompted by the red arrows on the screen.

For Option 1, you should specify a fixed heat loss value for each header.

For Option 2, you specify a percentage heat loss for each header. In this case, SSAT calculates the total heat entering the header and then applies the user-specified percentage in order to determine the heat lost. The current calculated values are displayed on the entry form for guidance.

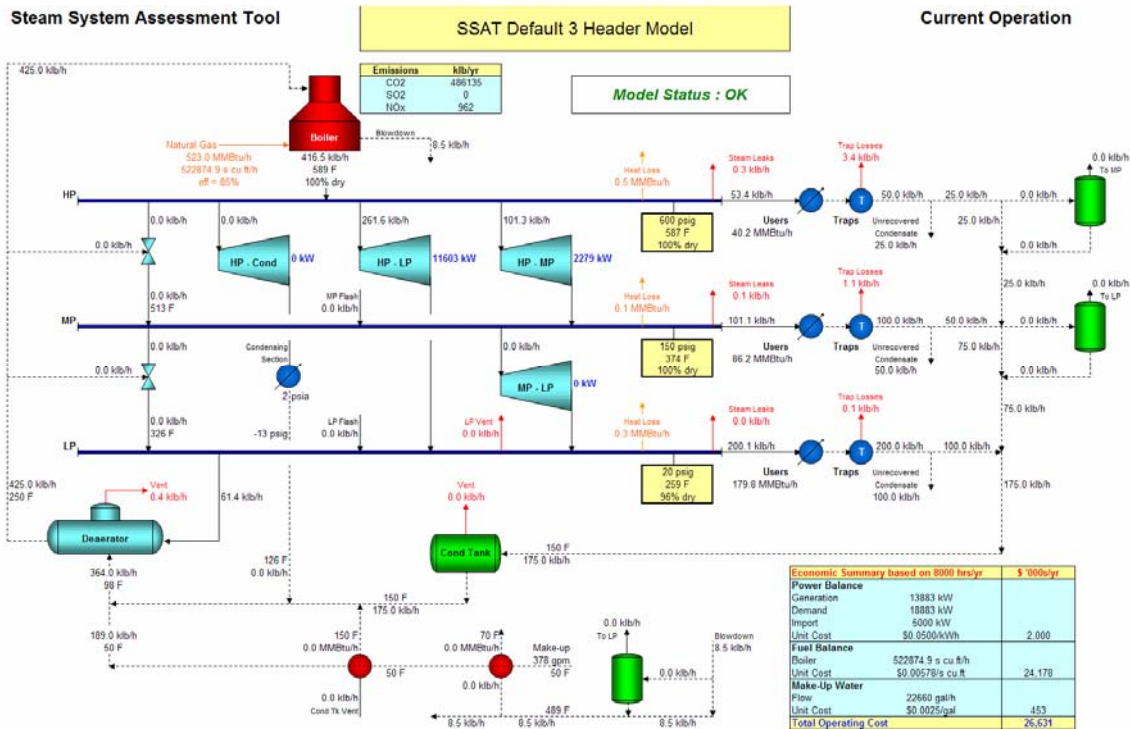
It should be noted that if Option 2 is specified and one or more separate energy improvement projects are selected which result in reduced steam production then the estimated heat loss will automatically reduce as a result. This may lead to a slight overestimate of the potential savings from the selected projects because, in reality, insulation heat losses do not change significantly with respect to steam load.

The Model Sheet

The **Model** sheet displays a schematic representation of the simulation of the current steam system operation as specified on the **Input** sheet. The sheet is for viewing only and contains no user inputs. The diagram shown on the schematic is fixed so equipment items are shown even if they are not in use. An example would be a steam turbine with zero flow.

In general terms, the following color coding is used within the model diagram:

- Orange Fuel duty and thermal losses from the system
- Blue Power generation
- Red Mass losses from the system
- Black All other values



You should refer to this sheet in order to check that the system is being simulated as expected. The **Input** sheet can then be re-visited if any changes are required to the system specifications.

The sheet also displays the current status of the model. The results displayed are only valid if "Model Status: OK" is shown in the box at the top of the schematic diagram.

The Projects Input Sheet

A key part of SSAT functionality is to evaluate possible BestPractice steam system improvement opportunities.

The Projects Input sheet allows you to select one or more of the pre-defined project options which can be evaluated using SSAT. These project options are selected using drop-down menus and additional information should be provided where appropriate. The data inputs are very similar to those in the Input sheet and further information on any of the specific terms can be found in the detailed description of this sheet.

The top section of the **Projects Input** sheet is shown in the following picture. It should be noted that some projects shown for the 3-header model will not be available in the 2-header and 1-header models. Therefore the project numbering will differ from model to model.

Steam System Assessment Tool

3 Header Model

Projects Entry Form

Use this form to specify improvement projects. These projects will then be modeled and compared to the existing operation.

Project 1 - Steam Demand Savings (Changing the process steam requirements)
 Current use - HP: 50 klb/h (40.22 MMBtu/h) MP: 100 klb/h (86.25 MMBtu/h) LP: 200 klb/h (179.82 MMBtu/h)

Do you wish to specify steam demand savings? No

If yes, enter HP steam saving	0 klb/h	
If yes, enter MP steam saving	0 klb/h	
If yes, enter LP steam saving	0 klb/h	

Note: A negative saving can be entered to model an increase in steam demand
 Note: The savings have been converted to heat duties of 0.00 MMBtu/h (HP), 0.00 MMBtu/h (MP) and 0.00 MMBtu/h (LP) based on current header enthalpies
 Note: These heat duties are then used to determine the actual flow change in the Projects Model based on the calculated header enthalpies

Project 2 - Use an Alternative Fuel
 Existing Boiler Fuel : Natural Gas Fuel Cost : \$0.00578/s cu.ft

Do you wish to specify an alternative fuel? No

If yes, choose a new fuel from this drop-down list	Number 2 Fuel Oil	
Site Fuel Cost	0.67 \$/gallon	Typical 2002 value: \$0.67/gallon

Note: HHV for alternative fuel is 139,213 Btu per gal (19,400 Btu/lb)

For user defined fuels, enter HHV	15000 Btu/lb	
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Note: Emissions cannot be calculated for user defined fuels

Project 3 - Change Boiler Efficiency
 Existing Efficiency : 85%

Do you wish to specify a new boiler efficiency? No

Note: An example use of this project option is to model the effect of installing an economizer by increasing the efficiency

If yes, enter new boiler efficiency (%)	90 %	
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Note: Typical Best Practice boiler efficiency for Natural Gas is 85%

Project 4 - Change Boiler Blowdown Rate
 Existing Blowdown Rate : 2%

Do you wish to specify a new boiler blowdown rate? No

If yes, enter new rate (% of feedwater flow)	1 %	
--	-----	--

Project 1 – Steam Demand Savings

You select whether or not to specify steam savings on any of the headers by selecting “Yes” from the first drop-down menu. Then, for each of the headers, you can enter the amount of steam saved. If you wish to model an increase in steam consumption, you should enter a negative number.

Because some of the other project options within SSAT can result in changes to the header enthalpies, it is possible that you will observe unexpected results from this project option. To explain this, the calculation method used within SSAT is as follows:

1. Determine the heat duty per unit steam consumption for each header based on the data specified in the Input sheet. This is calculated as follows:

$$\text{Specific Enthalpy for current operation (Btu/lb)} = \text{Header Enthalpy for current operation (Btu/lb)} - \text{Condensate Enthalpy (Btu/lb)}$$

Condensate enthalpy is calculated assuming saturated water at the header pressure.

2. The change in duty associated with the steam saving is then calculated as follows:

$$\text{Change in duty (MMBtu/h)} = \text{Steam saving (klb/h)} * \text{Specific Enthalpy for current operation (Btu/lb)} / 1000$$

SSAT calculates a revised header enthalpy for the operation after projects and then calculates the revised steam demand as follows:

$$\text{Current heat duty (MMBtu/h)} = \text{Current steam use (klb/h)} * \text{Specific enthalpy for current operation (Btu/lb)} / 1000$$

$$\text{Heat duty after projects (MMBtu/h)} = \text{Current heat duty (MMBtu/h)} - \text{Change in duty (MMBtu/h)}$$

$$\text{Steam use after projects (klb/h)} = \text{Heat duty after projects (MMBtu/h)} / \text{Specific Enthalpy after projects (Btu/lb)} * 1000$$

An example calculation is given below:

$$\text{Specific Enthalpy for current operation} = 800 \text{ Btu/lb}$$

$$\text{Current steam use} = 50 \text{ klb/h}$$

$$\text{Steam saving} = 5 \text{ klb/h}$$

Assuming that other implemented projects cause the Specific Enthalpy after projects to increase to 802 klb/h, the following calculation results:

$$\text{Current heat duty} = 50 * 800 / 1000 = 40 \text{ MMBtu/h}$$

$$\text{Change in duty} = 5 * 800 / 1000 = 4 \text{ MMBtu/h}$$

$$\text{Heat duty after projects} = 40 - 4 = 36 \text{ MMBtu/h}$$

$$\text{Steam use after projects} = 36 / 802 * 1000 = 44.9 \text{ klb/h}$$

Therefore, although a steam saving of 5 klb/h was specified, the actual observed saving in SSAT is 5.1 klb/h.

This calculation method has been chosen because it is felt to be the most consistent with the data specified. If SSAT were to fix the steam saving to the exact value specified, the results obtained could be misinterpreted, especially if large changes in header enthalpies occur. When you specify a steam saving, it should be thought of in terms of how much of the current steam use could be saved and this is normally the case when evaluating project opportunities.

Project 2 - Use an Alternative Fuel

You select whether or not to specify a new fuel for use in the boiler by selecting “Yes” from the drop-down menu. You are then prompted to choose a new fuel from the pre-defined choices within SSAT and to enter a new fuel cost. If you choose to specify your own fuel, you will also be prompted to enter the fuel higher heating value (HHV).

Changing the fuel is also likely to result in a change in boiler efficiency (see Project 3 below).

Project 3- Change Boiler Efficiency

You select whether to specify a new efficiency for the boiler from the drop-down menu and then enter the new value when prompted.

Project 4 - Change Boiler Blowdown Rate

You select whether to specify a new boiler blowdown rate from the drop-down menu and then enter the new value when prompted.

The next part of the **Projects Input** sheet is as follows:

Project 5 - Blowdown Flash to LP Not currently installed		
Do you wish to modify the blowdown flash system?	Option 2 - No change	
Project 6 - Change Steam Generation Conditions Existing Conditions : 600 psig Superheated steam at 589 F		
Do you wish to change the HP steam generation conditions?	Option 3 - No change	
Option 1 - Enter temperature	600 F	
Note: Saturation temperature at specified HP pressure (600 psig) is 489 F		
Option 2 - Enter thermodynamic quality	99.9 % dry	
Project 7 - HP to LP Steam Turbine(s) Efficiency : 65% Operation : Balances LP Header		
Do you wish to modify the HP to LP turbine operation?	No	
If yes, select the appropriate turbine operating mode	Option 1 - Balances LP header	
Note: If Option 1 is chosen, the model will preferentially use the HP to LP turbine to balance the LP demand		
Specify a new isentropic efficiency (%)	70 %	
Note: A generator electrical efficiency of 100% is assumed by the model Note: Isentropic efficiency of existing turbine is 65%		
Option 2 - How do wish to define the fixed turbine operation?	Option 2 not selected	
Option 2 - Fixed steam flow	100 klb/h	
Option 2 - Fixed power generation	2000 kW	
Option 3 - How do wish to define the operating range?	Option 3 not selected	
Option 3 - Minimum steam flow	50 klb/h	
Option 3 - Maximum steam flow	150 klb/h	
Option 3 - Minimum power generation	1500 kW	
Option 3 - Maximum power generation	2500 kW	

Project 5 - Blowdown Flash to LP (or to Deaerator in 1-header model)

You select whether to modify the blowdown flash system using the drop-down menu. If a blowdown flash is not installed (as specified on the **Input** sheet), you are given the option of installing one. If one is already in place, you are given the option to remove it. All calculations relating to this project are handled automatically by SSAT and no supplementary user inputs are needed.

Project 6 - Change Steam Generation Conditions

You can choose to change the boiler steam generation conditions. Three options are available from the drop-down menu as follows:

- Option 1 - New superheated steam condition
- Option 2 - New saturated steam condition
- Option 3 - No change

Options 1 and 2 require you to enter supplementary information to specify the new steam conditions.

Projects 7, 8, 9 - HP to LP/HP to MP/MP to LP Steam Turbine(s)

These sections allow you to add, modify or remove back pressure steam turbines.

If a turbine is installed between a given set of pressure levels (as specified on the **Input** sheet), then you are given the option of modifying its operation in the first drop-down menu. If no turbine is installed, you are given the option of adding one.

You can then choose one of four options from the second drop-down menu to define how the turbine should operate:

- Option 1 - Balances XX header
- Option 2 - Fixed operation
- Option 3 - Operation within min/max limits
- Option 4 - Turbine not operating

Note – XX refers to the exhaust pressure from the turbine (e.g. LP)

Options 1, 2 and 3 are the same as those provided on the **Input** sheet and Options 2 and 3 require supplementary information where prompted. Option 4 is provided to enable you to disable an existing turbine.

The project entries for the back pressure turbines are followed by those for the condensing turbine:

Project 10 - HP to Condensing Steam Turbine(s) Not installed		
Do you wish to add an HP to condensing turbine?		No
if yes, enter a new isentropic efficiency (%)	70 %	
Note: A generator electrical efficiency of 100% is assumed by the model		
if yes, select the units to specify the condenser pressure		psia
New condenser pressure (psia)	2	
if yes, select the new mode of operation		Not installed
Option 1 - Fixed power generation	1000 kW	
Option 2 - Fixed steam flow	50 klb/h	

Project 10 - HP to Condensing Steam Turbine(s)

If no condensing turbine was specified on the **Input** sheet, you are given the opportunity to add one using the first drop-down menu.

If you specified that a condensing turbine was installed on the **Input** sheet then you are asked “Do you wish to modify the HP to condensing turbine operation?” and are presented with three options as follows:

- Yes, modify operation of existing turbine
- No, maintain current operation
- Yes, switch off existing turbine

If a new turbine is to be added or the operation of an existing turbine is to be modified, you are required to enter supplementary information where prompted.

The next set of project opportunities are:

Project 11 - Feedwater Heat Recovery Exchanger using Condensate Tank Vent
Not currently installed

Modify the condensate tank vent heat recovery system?

Note: An approach temperature of 20 F will be assumed for a new exchanger

Project 12 - Feedwater Heat Recovery Exchanger using Boiler Blowdown
Not currently installed

Modify the boiler blowdown heat recovery system?

Note: An approach temperature of 20 F will be assumed for a new exchanger

Project 11 - Feedwater Heat Recovery Exchanger using Condensate Tank Vent

This project option deals with a heat exchanger which recovers heat into deaerator feed water from the condensate tank vent. If you specified on the **Input** sheet that no such exchanger was installed then the option is given to add one. Conversely, if an exchanger was specified in the **Input** sheet then the option is given to remove it.

No supplementary information is required when adding a new exchanger. A minimum allowable approach temperature of 20°F is assumed by SSAT. This refers to the minimum temperature difference between the vent steam entering the exchanger and the deaerator feed water leaving the exchanger.

Project 12 - Feedwater Heat Recovery Exchanger using Boiler Blowdown

This project option deals with a heat exchanger which recovers heat into deaerator feed water from the boiler blowdown. If you specified on the **Input** sheet that no such exchanger was installed then the option is given to add one. Conversely, if an exchanger was specified in the **Input** sheet then the option is given to remove it.

No supplementary information is required when adding a new heat exchanger. A minimum allowable approach temperature of 20°F is assumed by SSAT. This is the minimum temperature difference between the blowdown leaving the exchanger and the deaerator feedwater entering the exchanger.

The sheet then deals with condensate opportunities as follows:

Project 13 - Condensate Recovery
Currently recover 50% of HP, 50% of MP and 50% of LP at 150 F

Do you wish to specify new condensate recovery rates?

if yes, enter new HP condensate recovery	75 %	
if yes, enter new MP condensate recovery	75 %	
if yes, enter new LP condensate recovery	75 %	

Note: Condensate return temperature will be assumed to be 150 F as for the current operation

Project 14 - Condensate Flash to MP
Not currently installed

Do you wish to modify the MP condensate flash system?

Project 15 - Condensate Flash to LP
Not currently installed

Do you wish to modify the LP condensate flash system?

Project 13 - Condensate Recovery

You are given the opportunity of specifying new condensate recovery rates for each header. If “Yes” is chosen from the drop-down menu, you are prompted to enter new percentage condensate return values. Condensate return is

defined as a percentage of the steam supplied to the processes at each pressure level.

Project 14 - Condensate Flash to MP

You can choose whether to modify the system to flash HP condensate to produce MP steam. You can add a flash system if no such system was specified in the **Input** sheet, or can remove it if the **Input** sheet specified that one was in place.

Project 15 - Condensate Flash to LP

You can choose whether to modify the system to flash HP/MP condensate to produce LP steam. You can add a flash system if no such system was specified in the **Input** sheet, or can remove it if the **Input** sheet specified that one was in place.

The final section of the **Projects Input** sheet is as follows:

Project 16 - Steam Trap Losses		
Losses estimated automatically by model - Last maintenance program 3-5 years ago		
Do you wish to model the impact of a maintenance program?	No	
Note: For Option 1, the model estimates a new trap failure rate. The rate reported is for 6 months after the maintenance program is carried out		
Option 2 - Trap failures on HP header	5	
Option 2 - Trap failures on MP header	5	
Option 2 - Trap failures on LP header	5	
Note: Calculated values based on current user inputs are:- HP header - Trap failures: 25, Loss per trap 0.134 klb/h - Total trap loss = 3.36 klb/h. MP header - Trap failures: 30, Loss per trap 0.038 klb/h - Total trap loss = 1.14 klb/h. LP header - Trap failures: 50, Loss per trap 0.003 klb/h - Total trap loss = 0.13 klb/h.		

Project 17 - Steam Leaks		
Losses estimated automatically by model - Last maintenance program 3-5 years ago		
Do you wish to model the impact of a maintenance program?	No	
Note: For Option 1, the model estimates a new steam leakage rate. The rate reported is for 6 months after the maintenance program is carried out		
Option 2 - Steam leaks on HP header	5	
Option 2 - Steam leaks on MP header	5	
Option 2 - Steam leaks on LP header	5	
Note: Calculated values based on current user inputs are:- HP header - Steam leaks: 10, Loss per leak 0.033 klb/h - Total leaks = 0.33 klb/h. MP header - Steam leaks: 12, Loss per leak 0.010 klb/h - Total leaks = 0.11 klb/h. LP header - Steam leaks: 20, Loss per leak 0.001 klb/h - Total leaks = 0.01 klb/h.		

Project 18 - Improved Insulation		
Currently modeled based on percentage heat loss on each header		
Do you wish to model the impact of improved insulation?	No	
Note: Model will assume that heat losses are reduced to 10% of the current value by improving insulation		

Project 16 - Steam Trap Losses

You are asked whether they would like to model the impact of carrying out a steam trap maintenance program on the site. The drop-down menu has three options in answer to this question :

- Option 1 - Yes, model to estimate new loss values
- Option 2 - Yes, enter new number of failed traps
- No

Option 1 uses experience values to estimate the total number of trap failures that there will be following the maintenance program. SSAT chooses an arbitrary time period of six months since the maintenance program and displays the estimated trap failures at this point. In reality, the number of trap failures will increase with time following the last maintenance program so this point is chosen in order to give an indication of the savings achievable in the short term.

Option 2 prompts you to enter the number of traps that are expected to remain failed following the maintenance program. You could enter zeroes at this point in order to estimate the maximum savings from correcting all trap failures.

Project 17 - Steam Leaks

You are asked whether they would like to model the impact of carrying out a steam leak maintenance program on the site. The drop-down menu has three options in answer to this question:

- Option 1 - Yes, model to estimate new leak values
- Option 2 - Yes, enter new number of leaks
- No

Option 1 uses experience values to estimate the total number of steam leaks that there will be following the maintenance program. These experience values are based on extensive field data gathered by the SSAT developers. SSAT chooses an arbitrary time period of six months since the maintenance program and displays the number of leaks at this point. In reality, the number of leaks will increase with time following the last maintenance program so this point is chosen in order to give an indication of for the savings achievable in the short term.

Option 2 prompts you to enter the number of leaks that are expected to remain following the maintenance program. You could enter zeros at this point in order to estimate the maximum savings from correcting all leaks.

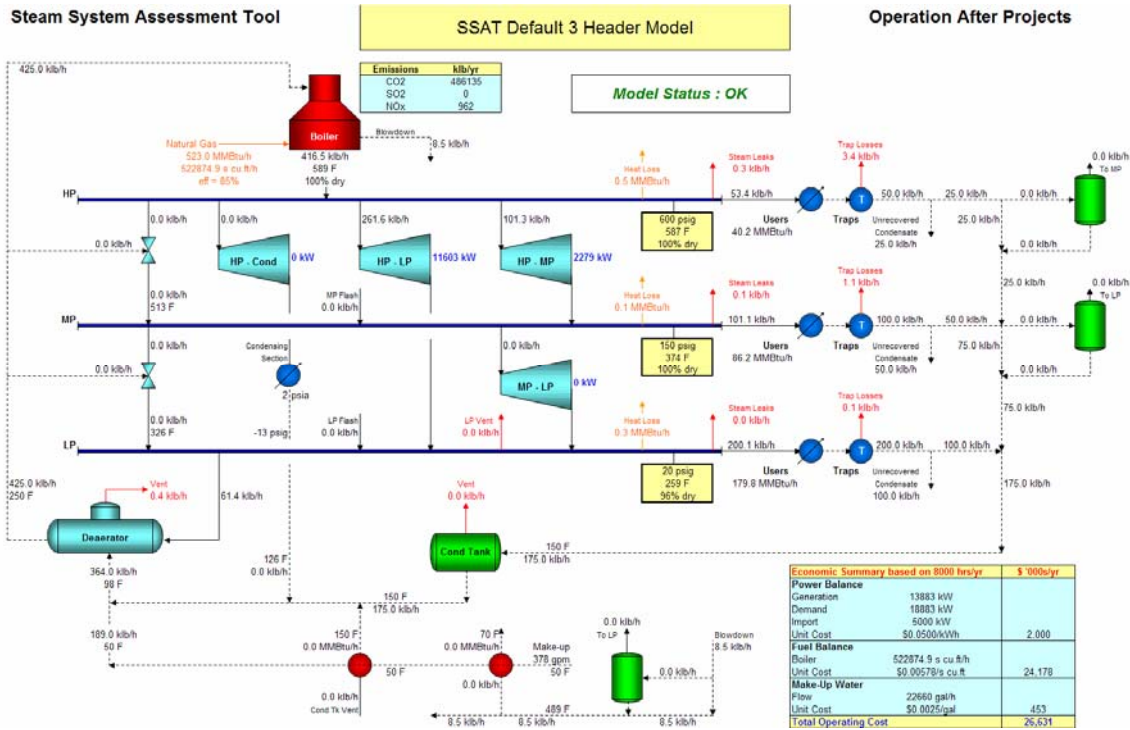
Project 18 - Improved Insulation

You choose from the simple drop-down menu whether to investigate the impact of improving insulation on the steam distribution system. SSAT calculates the new heat loss values on the headers as being 10% of the values defined for the current operation. This is an approximate calculation but gives an indication of the likely energy savings.

The Projects Model Sheet

The **Projects Model** sheet is similar to the **Model** sheet discussed above except that this time the schematic representation shows the updated simulation of the system after the installation of any improvement projects specified in the **Projects Input** sheet.

The sheet also displays the current status of the model. The results displayed are only valid if "Model Status: OK" is shown in the box at the top of the schematic diagram.



The Results Sheet

The **Results** sheet shows the key results from the models of the both the current operation and the operation after the implementation of the chosen BestPractice project opportunities. The savings reported are those resulting from the implementation of all selected projects. Because of the potentially complex project interactions, when more than one project is selected, SSAT does not report the individual benefit for each project. The results are presented in tabular form, allowing you to quickly assess the impact of any changes.

Other features of this sheet include a model status report, a gas turbine assessment and a marginal cost calculation facility.

Starting at the top of the sheet, the model displays the case description entered on the **Input** sheet. Just below this, the model status is displayed. Once SSAT has completed its calculations, this should display "Model Status : OK". The results from SSAT are only valid if this message is displayed.

The first of the main tables in the sheet summarizes the operational cost for the current and after projects cases. Any changes in operating costs resulting from the implementation of BestPractice project ideas can be easily identified.

The second table reports the on-site emissions for the two cases along with the emissions reduction resulting from the projects. These calculations are only possible using the pre-defined fuels within SSAT. If a user-defined fuel was specified then "N/A" is shown to indicate that emissions calculations cannot be displayed.

When assessing the true environmental impact of projects which affect the amount of power that the site imports or exports, it is necessary to take into account what happens to the external power station emissions. For example, installing a good back pressure turbine on the site is likely to lead to an increase in site fuel demand and hence emissions. The true environmental benefit can only be realized by taking into account the fact that an external power station no longer needs to produce power equivalent to that produced in the new on-site back pressure turbine. The power station emissions reduce accordingly and the overall environmental impact is a positive one.

The next table in the sheet looks at this and displays the reduction in external power station emissions after the implementation of the chosen projects. The "Total Reduction" table then adds the reductions in the on-site and power station emissions to determine the overall environmental impact.

The "Utility Balance" table summarizes key operating parameters from the simulations and the "Turbine Performance" table displays the steam rates for the chosen turbines.

The next table on this sheet shows the marginal steam costs for the system. In order to calculate these values (if they are not already displayed), you should press the "Calculate Marginal Costs" button. SSAT then carries out the required calculations. It is important that you do not interrupt SSAT while these calculations are being carried out. If the calculations are interrupted (by pressing 'Escape'), please select 'Continue' from the resulting dialog box otherwise the model will fail and you will need to re-load the file. Even if 'Continue' is selected, it is possible that the results displayed will be incorrect. Marginal cost values will only be displayed if no changes have been made to the **Input** sheet since the last time they were calculated. If you make any **Input** changes, you will need to re-calculate the marginal costs again.

The marginal costs are calculated based on the system configuration as defined on the **Input** sheet and shown in schematic form on the **Model** sheet and are defined as the cost of supplying an additional 1 klb of steam at the given pressure level.

The "Projects List" displays the projects chosen by you (up to a maximum of 10 because of display area limitations). If you have selected more than 10 projects, all the selected projects will be modeled but not all projects will be listed on the **Results** sheet.

Below this, a comment is made on the suitability of the site for the installation of a gas turbine and associated waste heat boiler ("Gas Turbine Assessment") based upon an approximate economic calculation.

The final part of the **Results** sheet displays any warning messages which SSAT feels should be drawn to your attention. These warnings relate to specific operating conditions which were encountered by SSAT in carrying out its calculations (e.g. "Inlet steam to HP to LP turbine is wet"). Up to 10 warnings can be displayed for each of the current and after projects cases. You should review each warning to determine whether it has a significant impact on the validity of the results obtained from SSAT.

Steam System Assessment Tool

3 Header Model

Results Summary

SSAT Default 3 Header Model

Model Status : OK

Cost Summary (\$ '000s/yr)	Current Operation	After Projects	Reduction	
Power Cost	2,000	2,000	0	0.0%
Fuel Cost	24,178	24,178	0	0.0%
Make-Up Water Cost	453	453	0	0.0%
Total Cost (in \$ '000s/yr)	26,631	26,631	0	0.0%

On-Site Emissions	Current Operation	After Projects	Reduction	
CO2 Emissions	486135 klb/yr	486135 klb/yr	0 klb/yr	0.0%
SOx Emissions	0 klb/yr	0 klb/yr	0 klb/yr	N/A
NOx Emissions	962 klb/yr	962 klb/yr	0 klb/yr	0.0%

Power Station Emissions	Reduction After Projects		Total Reduction	
CO2 Emissions	0 klb/yr		0 klb/yr	-
SOx Emissions	0 klb/yr		0 klb/yr	-
NOx Emissions	0 klb/yr		0 klb/yr	-

Note - Calculates the impact of the change in site power import on emissions from an external power station. Total reduction values are for site + power station

Utility Balance	Current Operation	After Projects	Reduction	
Power Generation	13883 kW	13883 kW	-	-
Power Import	5000 kW	5000 kW	0 kW	0.0%
Total Site Electrical Demand	18883 kW	18883 kW	-	-
Boiler Duty	523.0 MMBtu/h	523.0 MMBtu/h	0.0 MMBtu/h	0.0%
Fuel Type	Natural Gas	Natural Gas	-	-
Fuel Consumption	522874.9 s cu.ft/h	522874.9 s cu.ft/h	-	-
Boiler Steam Flow	416.5 klb/h	416.5 klb/h	0.0 klb/h	0.0%
Fuel Cost (in \$/MMBtu)	5.78	5.78	-	-
Power Cost (as \$/MMBtu)	14.65	14.65	-	-
Make-Up Water Flow	22660 gal/h	22660 gal/h	0 gal/h	0.0%

Turbine Performance	Current Operation	After Projects	Marginal Steam Costs	
HP to LP steam rate	44 kWh/klb	44 kWh/klb	(based on current operation)	
HP to MP steam rate	23 kWh/klb	23 kWh/klb	HP (\$/klb)	8.28
MP to LP steam rate	Not in use	Not in use	MP (\$/klb)	7.16
HP to Condensing steam rate	Not in use	Not in use	LP (\$/klb)	6.06

List of Selected Projects

Gas Turbine Assessment
Your site is an above average candidate for the installation of a gas turbine + waste heat boiler

Warnings - Any warnings listed below may impact on the validity of the simulation	
Current Operation	After Projects

The Stack Loss Sheet

This sheet contains the Stack Loss Calculator tool. The purpose of this tool is to enable calculations of the amount of heat lost in the boiler stack gas to be made.

The sheet reports stack losses as a percentage of the fired duty of the fuel based on HHV. In SSAT, the stack losses are related to boiler efficiency as follows:

$$\text{SSAT Boiler efficiency (\%)} = 100\% - \text{Stack Loss (\%)} - \text{Shell Loss (\%)}$$

Shell losses refer to the radiant heat loss from the boiler. These are boiler specific and cannot be estimated by SSAT. Values of less than 1% are typical at full load, increasing to 1-2% at reduced loads.

The "Input Data" for the sheet are the stack gas temperature (°F), the ambient temperature (°F) and the oxygen content of the stack gas (%). The key temperature parameter in determining the stack loss is the difference between the stack temperature and ambient and this is why both values are requested. The oxygen content of the stack is expressed as a percentage based on either molar or volumetric measurements.

The "Results" section displays the stack loss based on the supplied temperature and oxygen values for each of the standard fuels in SSAT.

As with all other data entry sheets, warnings will be displayed if the values supplied by the user are outside the permitted ranges. Correlations have been fitted to determine stack losses within the following ranges:

$$230^{\circ}\text{F} \leq \text{Stack temperature} - \text{Ambient temperature} \leq 510^{\circ}\text{F}$$

$$1\% \leq \text{Stack oxygen} \leq 11\%$$

For data outside of these ranges, the results may be highly inaccurate.

The sheet is intended to assist in calculating the efficiency of site boilers, one of the key data inputs in SSAT. An example calculation is as follows:

Stack temperature = 400°F

Ambient temperature = 70°F

Stack oxygen = 5%

Fuel = Number 2 Fuel Oil

From the "Results" table, the stack loss is calculated by SSAT to be 14.1%. An approximate boiler efficiency would then be:

$$\begin{aligned} \text{Boiler efficiency (\%)} &= 100\% - \text{Stack Loss (\%)} - \text{Shell Loss (\%)} \\ &= 100\% - 14.1\% - 1.5\% \text{ (assumed value)} \\ &= 84.4\% \end{aligned}$$

Graphs showing the stack loss for the various SSAT default fuels are given below the "Results" table.

Steam System Assessment Tool

Stack Loss Calculator

Based on user inputs of Stack Temperature, Ambient Temperature and Stack Oxygen Content, an estimate will be provided of the heat loss from the boiler stack. Losses are expressed as a percentage of the heat fired.

Stack losses are related to SSAT Boiler Efficiency as follows:

$$\text{SSAT Boiler Efficiency} = 100\% - \text{Stack Loss (\%)} - \text{Shell Loss (\%)}$$

Shell Loss refers to the radiant heat loss from the boiler. Typically <1% at full load, 1-2% at reduced load.

Input Data

Stack Gas Temperature (°F)	400 °F	Stack Temperature - Ambient Temperature = 330°F
Ambient Temperature (°F)	70 °F	

Stack Gas Oxygen Content (%)	5 %
------------------------------	-----

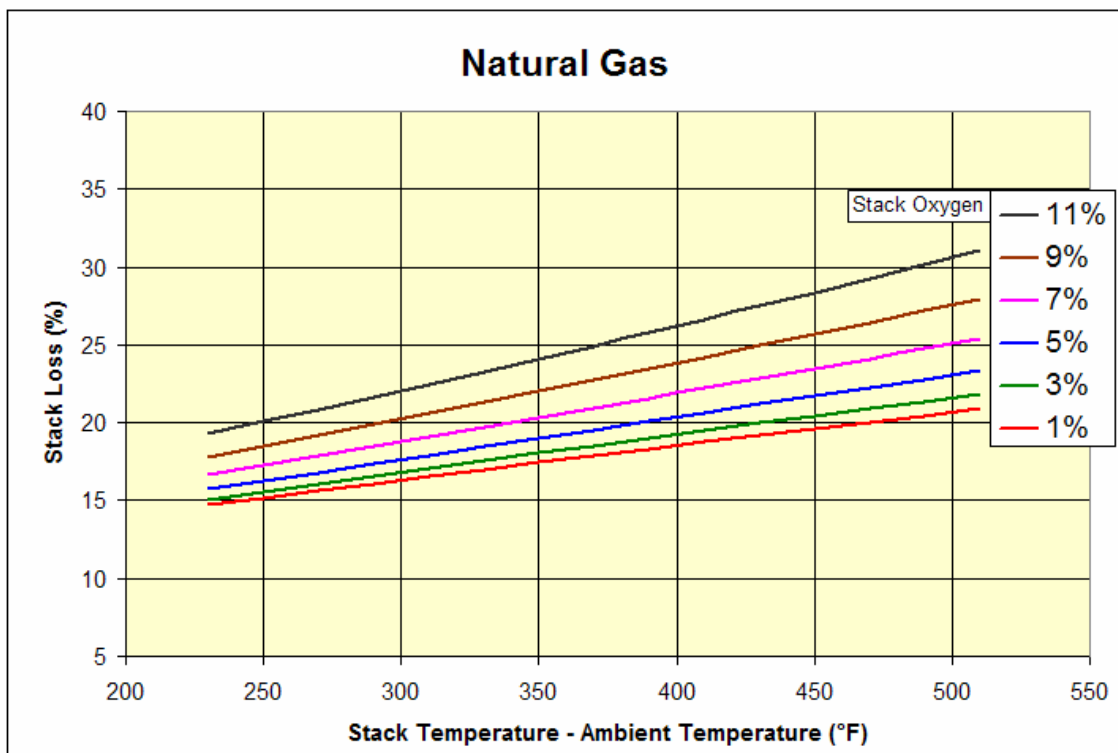
Note: Stack gas oxygen content is expressed on a molar or volumetric basis

Results

Estimated Stack Losses for each of the default fuels are as follows:

Natural Gas	18.5 %
Number 2 Fuel Oil	14.1 %
Number 6 Fuel Oil (Low Sulfur)	13.7 %
Number 6 Fuel Oil (High Sulfur)	13.9 %
Typical Eastern Coal (Bituminous)	12.2 %
Typical Western Coal (Subbituminous)	13.8 %
Typical Green Wood	24.9 %

For further information, scroll down for graphs of stack loss as a function of stack oxygen and temperature



The User Calculations Sheet

This sheet provides an unlocked area for you to carry out side calculations or to make notes when using SSAT.

Worked Simulation Example

This section illustrates the use of the 1-header template model. Specific operating information for the site is as follows:

“Quick Start” information –

Site Power Import	4000 kW
Site Power Cost	\$0.08 per kWh
Operating hours per year	8500
Site Make-Up Water Cost	\$0.003 per gallon
Make-Up Water Temperature	45°F
Boiler Fuel	Number 2 Fuel Oil
Fuel Cost	\$0.70 per gallon
Steam Header Pressure	180 psig
Steam used by Processes	100 klb/h
Condensing Turbine Installed?	No
Number of Steam Traps	400
Timing of last Maintenance Program	1-2 years ago

This information is entered into the *Input* sheet as shown below:

Steam System Assessment Tool

1 Header Model

Data Entry Form for Current System

The data entry form is split into two sections. **"Quick Start"** enables you to enter a minimum amount of information about your site and to start modeling your system right away. **"Site Detail"** allows you to provide more detailed information about your site to improve the accuracy of the model.

Yellow shaded cells require user input.

→ Where different options can be chosen by the user, the required supplementary data input cells are shaded green and are indicated by **red arrows**. ←

Quick Start

Enter Case Description SSAT Default 1 Header Model

General Site Data	Input Data	Notes/Warnings
Site Power Import (+ for import, - for export)	4000 kW	Power import + site generated power = site electrical demand
Site Power Cost	0.0800 \$/kWh	Typical 2003 value: \$0.05/kWh
Operating hours per year	8500 hrs	
Site Make-Up Water Cost	0.0030 \$/gallon	Typical 2003 value: \$0.0025/gallon
Make-Up Water Temperature	45 F	

Note: Enter average values for the operating period being modeled.

Boiler fuel - Choose from this drop-down list	Number 2 Fuel Oil	
Site Fuel Cost	0.70 \$/gallon	Typical 2003 value: \$1.00/gallon

Note: Fuel HHV is 139,213 Btu per gal (19,400 Btu/lbm)

For user defined fuels, enter HHV	20000 Btu/lb	
-----------------------------------	--------------	--

Note: Emissions cannot be calculated for user defined fuels

Steam Distribution	Input Data	Warnings
Header Pressure	180 psig	
Steam Use by Processes	100 klb/h	

Note: Enter process steam use excluding turbines, leaks, trap losses, deaeration steam and vents

Steam Turbines	
Do you have a condensing turbine installed?	No

If **yes**, please define how the turbine operates and then provide supplementary information below:

Mode of operation	Not installed
-------------------	---------------

Option 1 - Fixed power generation	1000 kW
Option 2 - Fixed steam flow	50 klb/h

Steam Traps	Input Data	Warnings
Enter total number of steam traps	400 traps	

Select the approximate timing of your last trap testing and maintenance program	1-2 years ago
---	---------------

“Site Detail” information –

Additional detailed information relating to the site operation is as follows:

Boiler Efficiency	80%
Blowdown Rate	3%
Blowdown Flash to Deaerator?	No
Steam Generation Temperature	480°F
Deaerator Vent Rate	0.5%
Deaerator Pressure	15 psig
Feedwater Heat Recovery Exchangers?	None
Condensate Return Temperature	175°F
Condensate Return Rate	60%
Steam Trap Losses and Leaks	Unknown so allow model to estimate
Insulation Heat Losses	Uncertain so fix to 0.05% of heat entering header

This additional information is entered into the **Input** sheet as shown below:

Site Detail

Boiler

Method for specifying boiler efficiency	Option 2 - Enter user-defined value
--	-------------------------------------

Note: Model default efficiencies represent Best Practice values assuming good operation and the installation of an economizer

→ Option 2 - Enter efficiency (%)	80 %		←
--	------	--	---

Note: Boiler efficiency is defined as 100% - Stack Loss (%) - Shell Loss (%). The "Stack Loss" sheet gives more information on heat losses
Note: Efficiency is based on Higher Heating Value. Economizers are included in the boiler efficiency. Boiler blowdown losses are excluded

Blowdown Rate (% of feedwater flow)	3 %	
Do you have blowdown flash steam recovery to the deaerator?	No	

Please select how you wish to define your steam generation condition and then provide supplementary information below if required:

Method for specifying steam generation condition	Option 2 - User-defined superheated conditions
---	--

Note: As a default, the model will use steam with 100 F of superheat. At the given pressure (180 psig), this corresponds to a temperature of 480 F

→ Option 2 - Enter temperature	480 F		←
Option 3 - Enter thermodynamic quality	99 % dry		

Note: Saturation temperature at specified pressure (180 psig) is 380 F
Note: Steam quality is an expression of the percentage dryness (or vapor fraction) of the steam

In the Quick Start section, you specified that no condensing turbine(s) were installed - Please move on to the next section

HP to Condensing Steam Turbine(s)	Input Data	Notes/Warnings
Isentropic efficiency	65 %	

Note: If multiple turbines are installed, their data should be combined to allow them to be modeled as a single turbine
Note: A generator electrical efficiency of 100% is assumed by the model

Select the units of measure to specify the condenser pressure	psia
Condenser pressure (psia)	2

Deaerator	Input Data	Warnings
Vent (as % of boiler feedwater flow)	0.5 %	

Note: Values of around 0.1% are typical

Select the appropriate deaerator operating mode	Option 3 - Use model default pressure (15 psig)
--	---

Note: Specified header pressure is 180 psig

Feedwater Heat Recovery System

Heat recovery exchanger on the condensate tank vent?	No
--	----

if yes, enter approach temperature: 20 F
Note: Approach temperature is defined as the minimum allowable temperature difference in the heat exchanger

Heat recovery exchanger on boiler blowdown?	No
---	----

if yes, enter approach temperature: 20 F

Process Condensate	Input Data	Warnings
Condensate return temperature to tank	175 F	
Condensate recovery	60 %	

Note: Condensate recovery specified as the percentage of the steam supplied to the processes

Steam Trap Losses and Steam Leaks

Choose a method for estimating steam losses	Option 1 - Losses automatically estimated by model (Model default)
--	--

Option 2 - Specify number of failed traps	
Trap failures	10 traps

Option 2 - Specify number of steam leaks	
Steam leaks	10 leaks

Note: Calculated values for current loss and leak rates based on current user inputs are:-
Trap failures: 20, Loss per trap 0.042 kJ/h - Total trap loss = 0.85 kJ/h. Steam leaks: 8, Loss per leak 0.011 kJ/h - Total leaks = 0.08 kJ/h.

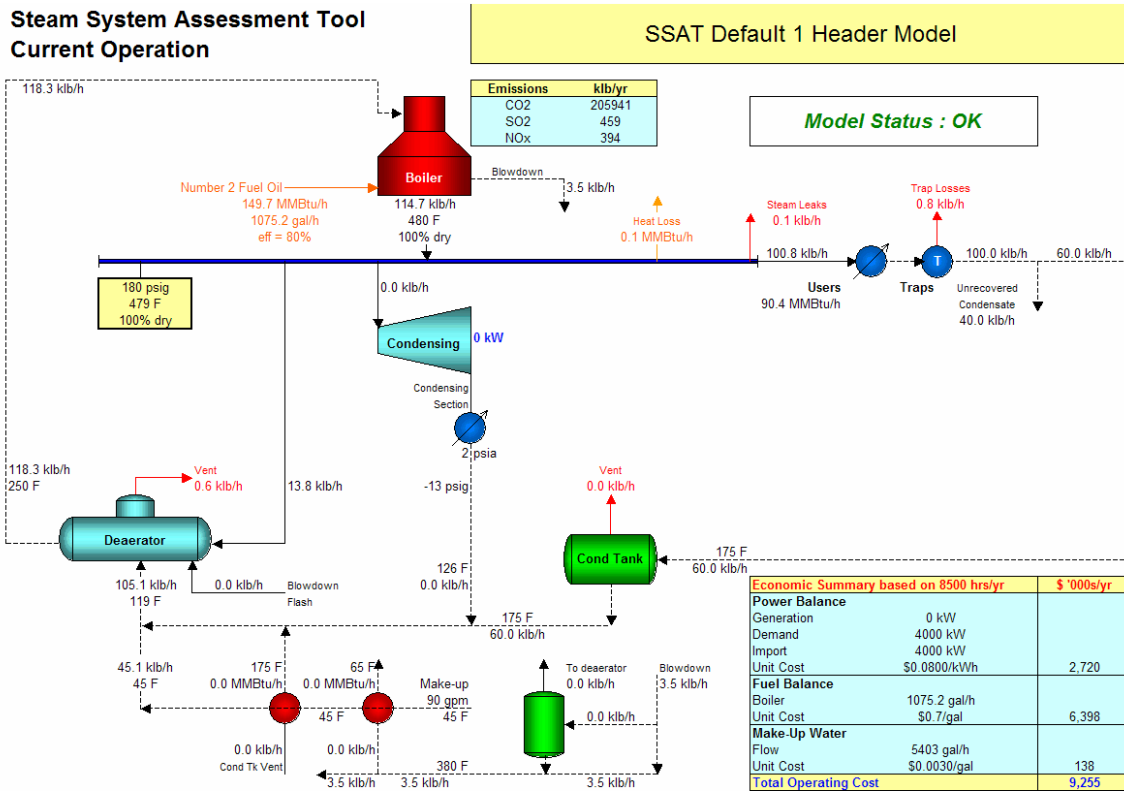
Insulation Heat Losses	Input Data	Notes/Warnings
Choose a method for specifying heat losses	Option 2 - Percentage heat loss on header (Model default)	

Option 1 - Specified heat loss	0.1 MMBtu/h
---------------------------------------	-------------

→ Option 2 - % of heat lost on header	0.05 %		←
--	--------	--	---

Note: Losses calculated as the percentage of heat flow entering the header.
Note: Current value for heat entering the header is 144 MMBtu/hr - This value may change when the model is updated

The **Model** sheet shows the simulation of the existing system based on the provided data:



You can now use the **Projects Input** sheet to model the impact of any of the BestPractice project opportunities included in the SSAT. In this example, we will investigate the impact of the following:

- Reducing boiler blowdown rate from 3% to 1%
- Installing a new heat exchanger to recover heat from boiler blowdown

These projects are selected as follows from the **Projects Input** sheet:

Project 4 - Change Boiler Blowdown Rate
Existing Blowdown Rate : 3%

Do you wish to specify a new boiler blowdown rate? Yes

If yes, enter new rate (% of feedwater flow) 1 %

Project 9 - Feedwater Heat Recovery Exchanger using Boiler Blowdown
Not currently installed

Modify the boiler blowdown heat recovery system? Yes, install a new heat exchanger

Note: An approach temperature of 20 F will be assumed for a new exchanger

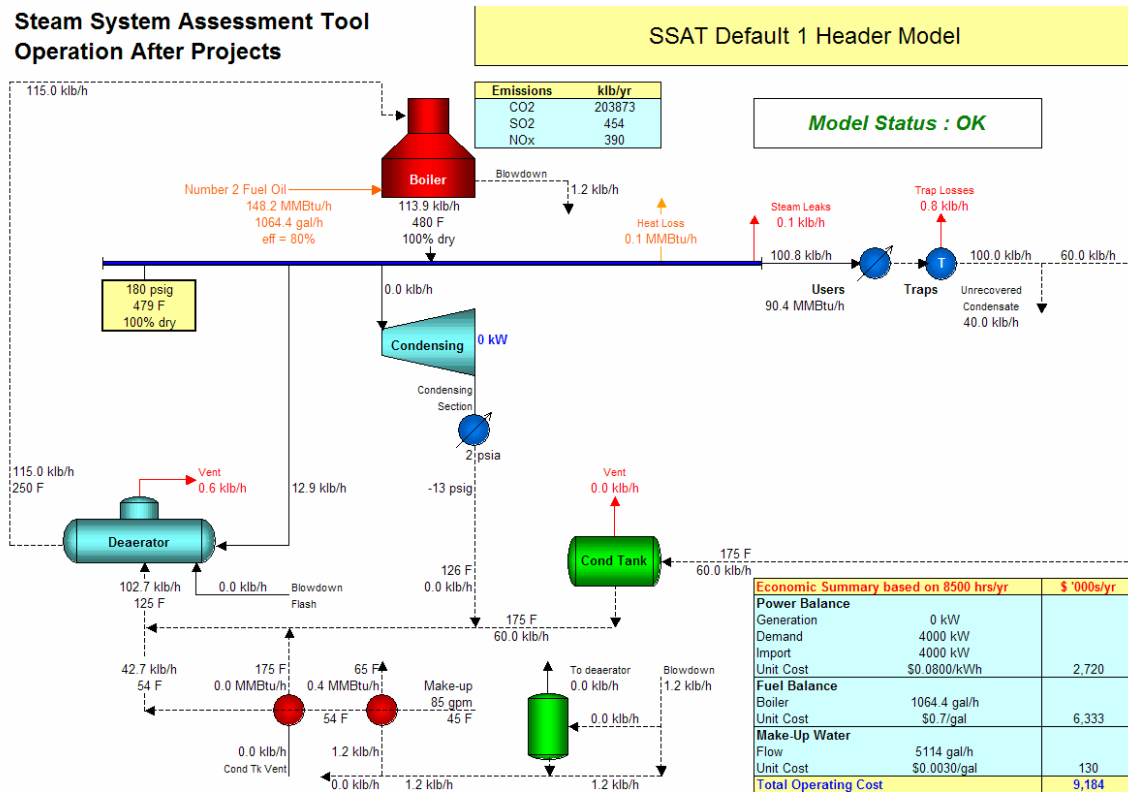
The impact of these projects can be seen on the **Projects Model** schematic and on the **Results** sheet.

The savings achieved from making these changes are summarized below:

Reducing boiler blowdown rate	\$52,000 per year
Installing new heat exchanger to recover heat from boiler blowdown	\$61,000 per year
Implementing both projects	\$72,000 per year

These results demonstrate one of the key uses of the SSAT in that it allows the interactions in the system to be fully investigated. The combined saving from implementing both projects is significantly less than the sum of the two individual project savings. In this case, it is relatively easy to see why this happens because reducing the amount of boiler blowdown reduces the amount of heat available for recovery in a new heat exchanger.

The **Projects Model** sheet showing the situation after implementing both projects is shown below:



The **Results** sheet following the implementation of both projects is shown below:

Steam System Assessment Tool

1 Header Model

Results Summary

SSAT Default 1 Header Model

Model Status : OK

Cost Summary (\$ '000s/yr)	Current Operation	After Projects	Reduction	
Power Cost	2,720	2,720	0	0.0%
Fuel Cost	6,398	6,333	64	1.0%
Make-Up Water Cost	138	130	7	5.4%
Total Cost (in \$ '000s/yr)	9,255	9,184	72	0.8%

On-Site Emissions	Current Operation	After Projects	Reduction	
CO2 Emissions	205941 klb/yr	203873 klb/yr	2067 klb/yr	1.0%
SOx Emissions	459 klb/yr	454 klb/yr	5 klb/yr	1.0%
NOx Emissions	394 klb/yr	390 klb/yr	4 klb/yr	1.0%

Power Station Emissions	Reduction After Projects	Total Reduction
CO2 Emissions	0 klb/yr	2067 klb/yr -
SOx Emissions	0 klb/yr	5 klb/yr -
NOx Emissions	0 klb/yr	4 klb/yr -

Note - Calculates the impact of the change in site power import on emissions from an external power station. Total reduction values are for site + power station

Utility Balance	Current Operation	After Projects	Reduction	
Power Generation	0 kW	0 kW	-	-
Power Import	4000 kW	4000 kW	0 kW	0.0%
Total Site Electrical Demand	4000 kW	4000 kW	-	-
Boiler Duty	149.7 MMBtu/h	148.2 MMBtu/h	1.5 MMBtu/h	1.0%
Fuel Type	Number 2 Fuel Oil	Number 2 Fuel Oil	-	-
Fuel Consumption	1075.2 gal/h	1064.4 gal/h	-	-
Boiler Steam Flow	114.7 klb/h	113.9 klb/h	0.8 klb/h	0.7%
Fuel Cost (in \$/MMBtu)	5.03	5.03	-	-
Power Cost (as \$/MMBtu)	23.45	23.45	-	-
Make-Up Water Flow	5403 gal/h	5114 gal/h	289 gal/h	5.4%

Turbine Performance	Current Operation	After Projects	Marginal Steam Cost
HP to Condensing steam rate	Not in use	Not in use	(based on current operation) \$/klb 7.61

List of Selected Projects
Decrease boiler blowdown rate Install blowdown heat exchanger

Gas Turbine Assessment

Your site is a very good candidate for the installation of a gas turbine + waste heat boiler

Warnings - Any warnings listed below may impact on the validity of the simulation

Current Operation	After Projects

References and Assumptions

The following sections explain what assumptions were made in constructing these models, and the sources of the data embedded in the model.

Simulation Assumptions

Several assumptions have been made in setting up the simulation models in SSAT. The key modeling assumptions are listed below:

1. Users on each header are assumed to be supplied by steam at the header condition, even if the steam quality is not 100%
2. The enthalpy of steam in a given header is calculated based on the combined enthalpy of the various streams entering the header minus the defined heat loss on the header
3. No rigorous heat balance is carried out on the condensate return line. You specify the temperature of the condensate entering the condensate tank
4. Apart from the header heat losses and the heat loss in the condensate return line, no other heat losses are included in the steam/condensate system
5. Condensate recovered from processes for flashing is assumed to be saturated at the header pressure as it enters the flash drum
6. The boiler blowdown is assumed to be saturated water at the steam generation pressure as it enters the flash drum (or heat recovery exchanger if no flash drum is installed)
7. A heat duty for each group of process users is calculated for the current operation based on the steam flow and the difference between the header enthalpy and the enthalpy of saturated water at the header pressure (the assumed condensate condition). This heat duty is fixed in the "After Projects" case so the actual steam flow can vary as the header enthalpy changes
8. The condensate tank operates at atmospheric pressure
9. The LP vent and condensate tank vent heat exchangers recover latent heat only
10. Condensate is recovered from the LP vent and condensate tank vent exchangers
11. Condensate from the HP to Condensing turbine is recovered
12. In calculating marginal costs, condensate recovery is assumed at the percentage specified for the given pressure level in the simulation of the current case
13. Steam losses from steam traps are assumed to be to atmosphere
14. Generator efficiency is assumed to be 100%

Fuels

Fuel compositions and higher heating values were obtained from the following sources:

1. *Steam: Its Generation and Use, Fortieth Edition*
Author: S. C. Stultz, Editor: J. B. Kitto, Publisher: Babcock and Wilcox Co
2. *Perry's Chemical Engineers' Handbook, Sixth Edition*
Author R. H. Perry, Publisher McGraw-Hill Companies Inc.

Default fuel prices in the model are based on observed market values for third quarter 2002.

On-Site Emissions

CO₂ emissions are calculated assuming full combustion of all carbon present in the fuel to produce CO₂.

SO_x emissions are calculated assuming full combustion of all sulfur present in the fuel to produce SO₂.

NO_x emissions are calculated using factors relating NO_x produced to fuel fired. These factors are taken from the following source:

United States Department of Energy Office of Energy Efficiency and Renewable Energy, GPRA Data Call 2003, USDOE, 2001

Calculated emissions values are approximate, particularly for NO_x, where several factors beyond the scope of SSAT come into play, relating in particular to the combustion zone characteristics of the particular burner and fuel combination.

Power Station Emissions

Correlations are used to relate the change in power generation from an external power station to changes in airborne emissions from the power station. These correlations were obtained from the following sources:

1. *United States Environmental Protection Agency, Office of Air Quality Planning and Standards, Technology Transfer Network, Clearinghouse for Inventories and Emissions Factors, AP-42, Fifth Edition, Volume 1, EPA, 1998*
2. *United States Department of Energy Office of Energy Efficiency and Renewable Energy, GPRA Data Call 2003, USDOE, 2001*

The correlations used reflect a representative mix of coal, natural gas and oil used for power generation in the United States and, as such, are approximate.

Stack Loss Calculations

The correlations relating stack loss to stack temperature and oxygen content were derived from combustion models developed by Greg Harrell, Ph.D., P.E. and based on the fuel properties identified for SSAT.

Gas Turbine Assessment

The **Results** sheet provides a qualitative message regarding the suitability of the site for the installation of a gas turbine (GT) plus accompanying heat recovery steam generator (HRSG). There are several assumptions made in providing this assessment as follows:

1. The system size is set to either match the site power import or to match the total site steam generation (whichever is limiting)
2. An efficiency of 30% is assumed for the GT (fuel to power)
3. An efficiency of 70% is assumed for the HRSG (heat absorbed/heat available) based on higher heating value
4. No supplementary firing is assumed in the HRSG
5. The GT is assumed to be supplied by 100% natural gas.
6. If you have specified that the site currently uses natural gas in the **Input** sheet, your specified cost for the natural gas will be used in the economic calculations for the GT.
7. If you have specified that the site currently uses a fuel different to natural gas, the natural gas cost used in the calculations is calculated as follows:

*Natural gas cost = Model default natural gas cost * User-specified cost for chosen fuel / Model default cost for chosen fuel*

8. A capital cost for the GT+HRSG is calculated using a factor of \$750/kWe, allowing an overall payback to be estimated and a message displayed on the **Results** sheet.

Because of the approximate nature of this calculation, no detailed payback results are reported. This assessment is intended as a guide only and a detailed evaluation will always be required to investigate the true cost and benefit implications for the site.

Traps/Leaks

Equations to calculate the rates of steam loss from failed steam traps and from steam leaks were provided by Spirax Sarco Inc. based on an orifice size of 1/8" for traps and 1/16" for leaks. Estimates of the percentage of failed steam traps and the amount of steam leaks on operating sites in relation to the timing of the last maintenance program were also provided by Spirax Sarco Inc. based on its extensive field experience. This information is proprietary and cannot be reproduced here.