STEAM SYSTEM ASSESSMENT TOOL (SSAT): OVERVIEW

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New Steam Tool: Steam System Assessment Tool (SSAT)

Purpose: Software tool to evaluate every aspect of a complicated or simple steam cycle.

A Department of Energy certified steam system heat balance. The result will be a standardized opportunity analyses for each plant surveyed.

SSAT Can Evaluate These Key Steam Improvement Opportunities

Real Cost of Steam

Steam Quality

Boiler Efficiency

Alternative Fuels

Cogeneration Opportunities

Steam Turbines vs PRVs

Boiler Blowdown

Condensate Recovery

Steam Trap Operating Efficiency

Heat Recovery

Flash Steam Recovery

Steam Leaks

Insulation Efficiency

Emissions Calculations

SSAT Can be Used in Two Ways

(1) Information about the existing system is entered into the program and 18 different projects can be exercised to evaluate the impact on the existing plant.

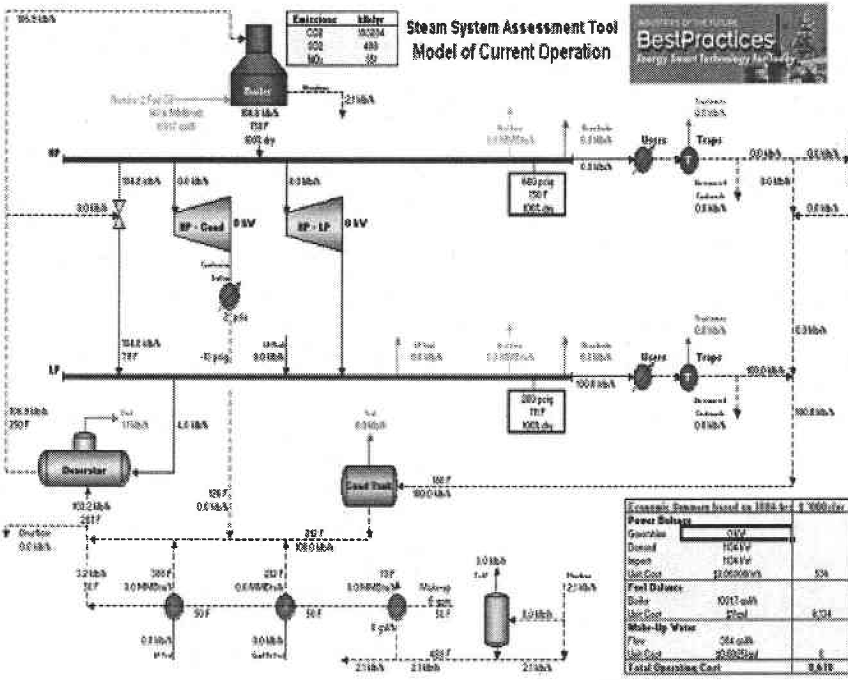
(2) If the desired improvement is not one of the 18 available projects the system can be modeled twice and the results compared.

The 18 Projects in SSAT

Change in steam demand	HP to condensing steam turbine
Use an alternative fuel	Feedwater heat recovery exchanger on condensate vent
Change boiler efficiency	Feedwater heat recovery exchanger on continuous blowdown
Change boiler blowdown rate	Condensate recovery
Blowdown flash to LP header	Condensate flash to MP header
Change steam pressure	Condensate flash to LP header
HP to LP steam turbine	Steam trap losses
HP to MP steam turbine	Steam leaks
MP to LP steam turbine	Improved insulation

Key SSAT Features

- Choice of 1, 2, or 3 header pressure models
- Schematics of model steam system
- Estimates of site environmental emissions
- Major equipment simulated:
  - boiler
  - back pressure turbines
  - condensing turbine
  - deaerator
  - steam traps, leaks, insulation losses
  - pressure reducing valves
  - flash vessels
  - feedwater preheat exchangers



Driving Force

What is the main driving force for improving a steam system?
$$$$

- Energy
- Reliability
- Maintenance
- Productivity
- Quality
- Cost avoidance
- Emissions reductions

Measure

You are not managing what you do not measure.

- steam flow, total steam generated
- fuel used, cost of fuel
- electricity used, electricity cost
- flue gas oxygen (excess combustion air)
- makeup water used

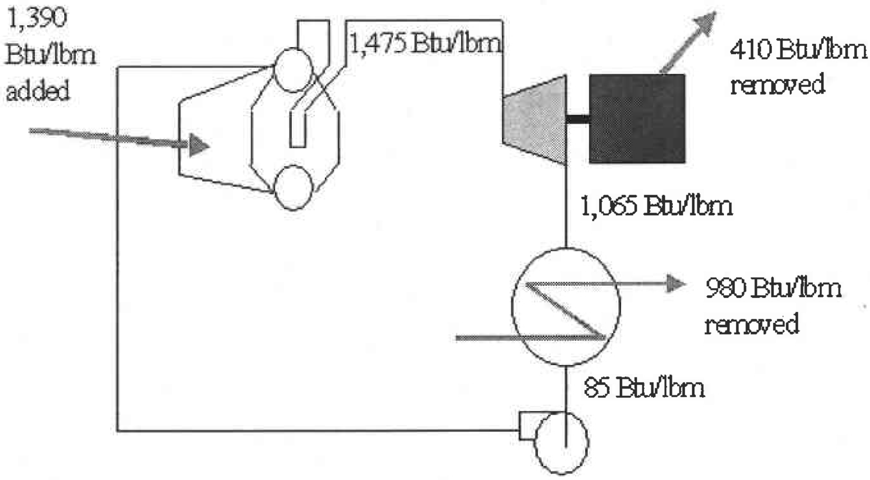
New Dry Kiln Systems

- For a new system, an evaluation should be made of generating steam at high pressure with superheat, reducing the steam pressure to the dry kilns through a steam turbine generator, and using the exhaust steam to dry lumber.

- This cycle would provide the facility with all of its electricity requirements and all of its steam for drying lumber.

- The above system will provide the faculty with the lowest possible energy costs.

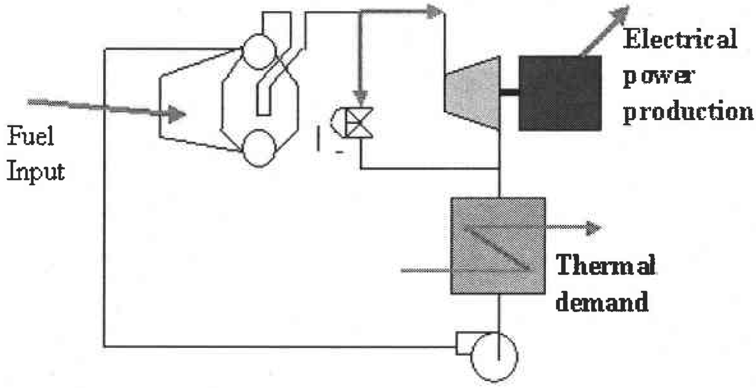
Utility Power Cycle



$$\eta = \frac{\dot{W}_{electrical}}{\dot{E}_{fuel}} = \frac{410\frac{Btu}{lbm}}{1{,}390\frac{Btu}{lbm}} = 30\%$$

Industrial Power Cycle

Steam generated at high pressure and temperature.
Steam pressure reduced through turbine generator.
Exhaust steam used to dry lumber.



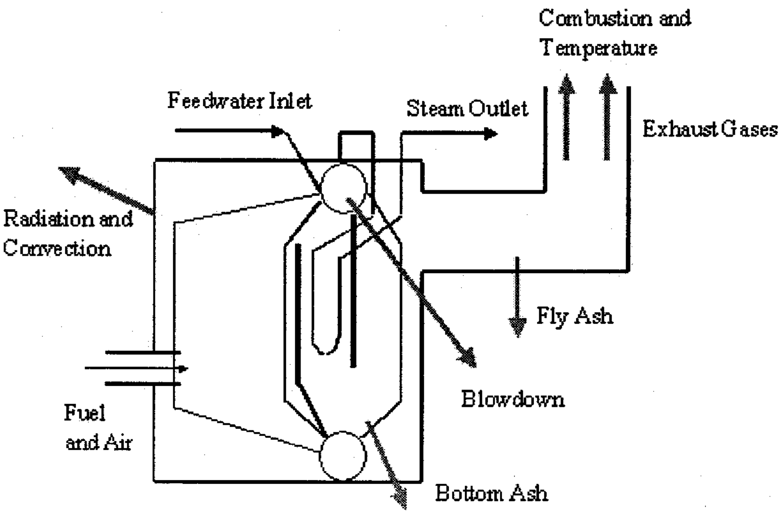
Improving Existing Dry Kiln Systems

Reduce stack losses
- reduce excess combustion air
- economizers, air heaters

Reduce blowdown losses
- reduce makeup water
- improve makeup water quality
- install blowdown heat recovery

Recover Energy in Distribution System
- recover more condensate
- recover sensible heat in the condensate
- improve steam trap maintenance
- improve insulation

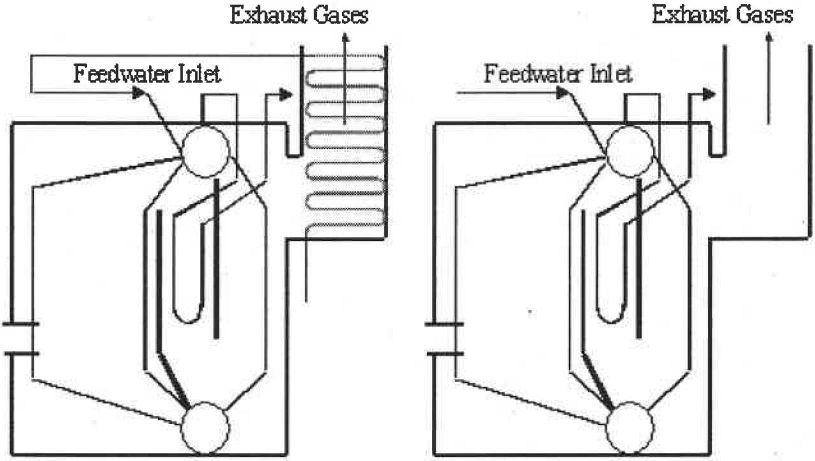
Identify Boiler Losses



Typical Green Wood Stack Loss [%]

Flue Gas O_2 Content [%]	Flue Gas Temperature - Combustion Air Temperature [°F]														
	230	**250**	**270**	**290**	**310**	**330**	**350**	**370**	**390**	**410**	**430**	**450**	**470**	**490**	**510**
1.0	21.5	21.9	22.3	22.7	23.1	23.5	23.9	24.3	24.7	25.1	25.5	25.9	26.3	26.7	27.2
2.0	21.7	22.1	22.5	22.9	23.4	23.8	24.2	24.6	25.1	25.5	25.9	26.3	26.8	27.2	27.6
3.0	21.9	22.4	22.8	23.2	23.7	24.1	24.6	25.0	25.5	25.9	26.4	26.8	27.3	27.7	28.2
4.0	22.2	22.6	23.1	23.6	24.0	24.5	25.0	25.4	25.9	26.4	26.8	27.3	27.8	28.3	28.7
5.0	22.5	23.0	23.4	23.9	24.4	24.9	25.4	25.9	26.4	26.9	27.4	27.9	28.4	28.9	29.4
6.0	22.8	23.3	23.8	24.4	24.9	25.4	25.9	26.4	27.0	27.5	28.0	28.6	29.1	29.6	30.2
7.0	23.2	23.7	24.3	24.8	25.4	25.9	26.5	27.1	27.6	28.2	28.7	29.3	29.9	30.4	31.0
8.0	23.6	24.2	24.8	25.4	26.0	26.6	27.2	27.8	28.4	29.0	29.6	30.2	30.8	31.4	32.0
9.0	24.1	24.8	25.4	26.0	26.7	27.3	27.9	28.6	29.2	29.9	30.5	31.2	31.8	32.5	33.1
10.0	24.7	25.4	26.1	26.8	27.5	28.2	28.9	29.6	30.3	31.0	31.7	32.4	33.1	33.8	34.5
11.0	25.4	26.2	26.9	27.7	28.5	29.2	30.0	30.7	31.5	32.3	33.0	33.8	34.6	35.4	36.1
Flue Gas T [°F]	**300**	**320**	**340**	**360**	**380**	**400**	**420**	**440**	**460**	**480**	**500**	**520**	**540**	**560**	**580**
Ambient T [°F]	70	70	70	70	70	70	70	70	70	70	70	70	70	70	70

Economizer



Steam Distribution Losses

Steam leaks
Heat transfer loss through insulation
Condensate loss
Overall system

Steam Leaks

Orifice Diameter [inch]	Leak Rate [lbm/hr]						
	Steam Temperature is 500°F						
	Steam Supply Pressure [psig]						
	50	100	150	200	250	300	350
1/16	6	10	15	19	24	30	34
1/8	23	41	59	77	96	119	134
3/16	51	92	132	173	215	269	302
1/4	91	163	235	308	382	478	536
5/16	143	254	367	481	597	747	838
3/8	206	366	529	693	860	1,075	1,207
7/16	280	499	720	944	1,170	1,464	1,642
1/2	366	651	940	1,232	1,528	1,912	2,145
	20	47	74	100	125	151	176
	Discharge Pressure [psig]						
Discharge coefficient	0.6 dimensionless						

Data based on isentropic compressible flow evaluation

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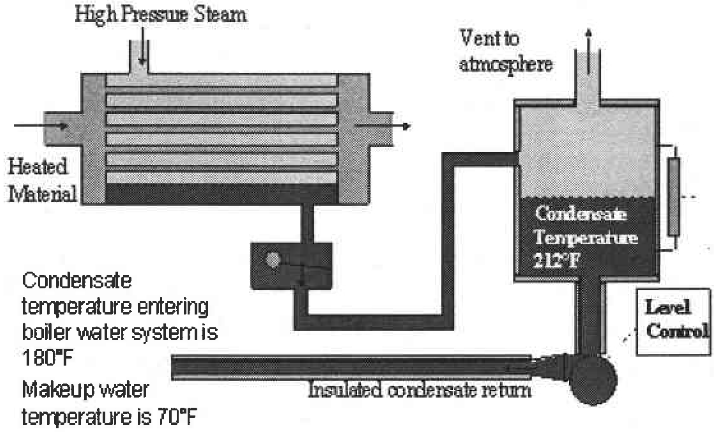
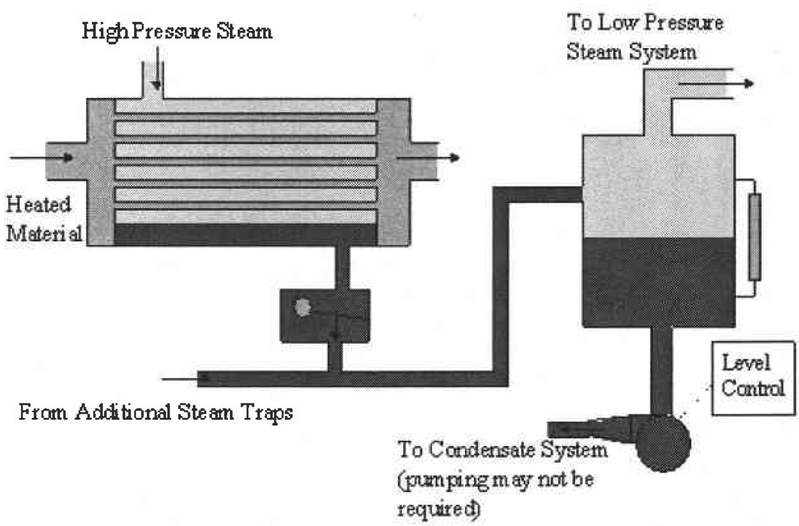
Condensate Return Example



Cascade Condensate Systems



Demonstrating the Usefulness of SSAT

Three-header system example
- 200, 100, 25 psig
- Wood waste boiler
- 30,000 lbs/hr steam load
- 2,000 kW site electrical load

Evaluating steam improvements
- Boiler efficiency change
- Boiler blowdown improvements
- Condensate flash to LP
- Reduce steam leaks

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:

SSAT Boiler Efficiency = 100% - Stack Loss (%) - 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)	550 °F	Stack Temperature - Ambient Temperature = 480°F
Ambient Temperature (°F)	70 °F	

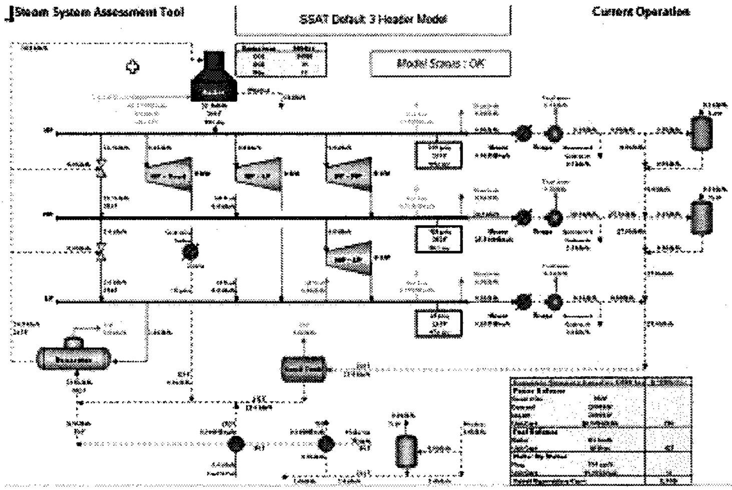
Stack Gas Oxygen Content (%)	10 %	

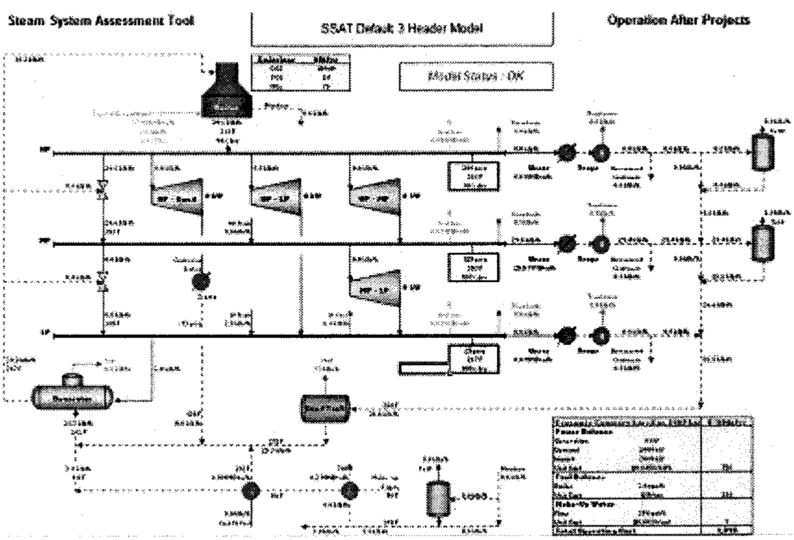
Note: Stack gas oxygen content is expressed on a molar or volumetric basis

Results

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

Natural Gas	**28.2 %**
Number 2 Fuel Oil	**23.5 %**
Number 6 Fuel Oil (Low Sulfur)	**23.1 %**
Number 6 Fuel Oil (High Sulfur)	**23.3 %**
Typical Eastern Coal (Bituminous)	**21.7 %**
Typical Western Coal (Subbituminous)	**23.2 %**
Typical Green Wood	**33.5 %**


Steam System Assessment Tool
SSAT Default 3 Header Model
Current Operation
Model Status : OK


Steam System Assessment Tool
SSAT Default 3 Header Model
Operation After Projects
Model Status : OK

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	756	756	0	0.0%
Fuel Cost	421	334	88	20.8%
Make-Up Water Cost	18	9	9	49.6%
Total Cost (in $ '000s/yr)	**1,195**	**1,099**	**96**	**8.1%**

On-Site Emissions	Current Operation	After Projects	Reduction	
CO2 Emissions	50551 klb/yr	40049 klb/yr	10503 klb/yr	20.8%
SOx Emissions	31 klb/yr	24 klb/yr	6 klb/yr	20.8%
NOx Emissions	88 klb/yr	70 klb/yr	18 klb/yr	20.8%

Power Station Emissions	Reduction After Projects	Total Reduction	
CO2 Emissions	0 klb/yr	10503 klb/yr	-
SOx Emissions	0 klb/yr	6 klb/yr	-
NOx Emissions	0 klb/yr	18 klb/yr	-

Note - Calculates the impact of the change in site power import on emissions from a conventional 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	2000 kW	2000 kW	0 kW	0.0%
Total Site Electrical Demand	2000 kW	2000 kW	-	-
Boiler Duty	47.9 MMBtu/h	37.9 MMBtu/h	5.3 MMBtu/h	20.8%
Fuel Type	Typical Green Wood	Typical Green Wood	-	-
Fuel Consumption	4.6 ton/h	3.6 ton/h	-	-
Boiler Steam Flow	33.1 klb/h	29.6 klb/h	3.5 klb/h	10.5%
Fuel Cost (in $/MMBtu)	1.05	1.05	-	-
Power Cost (as $/MMBtu)	13.19	13.19	-	-
Make-Up Water Flow	704 gal/h	354 gal/h	349 gal/h	49.6%

Turbine Performance	Current Operation	After Projects
HP to LP steam rate	Not in use	Not in use
HP to MP steam rate	Not in use	Not in use
MP to LP steam rate	Not in use	Not in use
HP to Condensing steam rate	Not in use	Not in use

Marginal Steam Costs	
(based on current operation)	
HP ($/klb)	1.67
MP ($/klb)	1.69
LP ($/klb)	1.58

Press this button if marginal costs are not shown

Calculate Marginal Costs

List of Selected Projects
Increase boiler efficiency
Decrease boiler blowdown rate
Install blowdown heat exchanger
Increase MP condensate recovery
Install condensate flash to LP
Improve pipework insulation

Fuel Savings or Steam Capacity Increase

- Boiler efficiency is equal to the energy output in the steam divided by the energy input in the fuel.
- If we improve the efficiency of the boiler and hold the steam use constant, as shown in the SSAT model, we can save fuel and reduce our operating expense.
- If we improve the efficiency of the boiler and hold the fuel firing rate constant we can generate more steam. In our example, we could increase steam production 8,000 lbs/hr, improving the capacity of the system by 26 percent.

Using SSAT

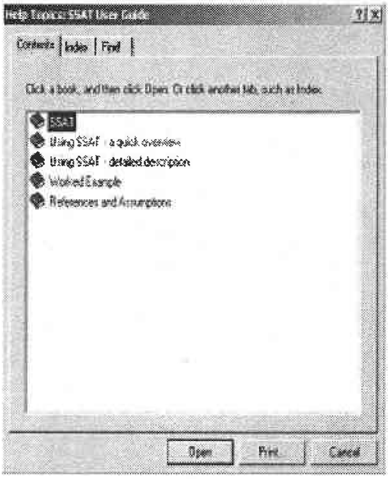
The software is free and available at the Office of Industrial Technology web site.

Originally we thought that facilities would be able to download the tool and use it to evaluate their system.

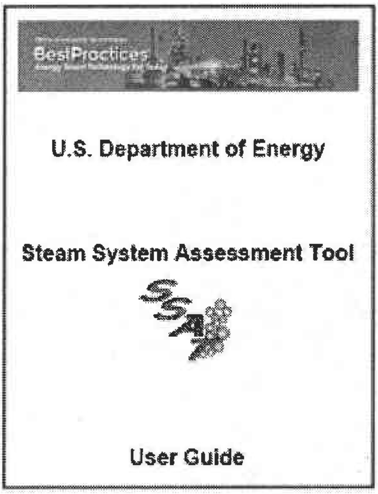
We have found that it takes a good steam system background to be able to use the tool effectively and the Department of Energy provides one day end user courses and they provide a list of Certified Steam System Specialists. These are people that have attended intensive training on the use of the software tools and have then been tested on their knowledge.

Two Types of SSAT "Help"

On-line Version



Text Version



For Further Information

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