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UNITED STATES DEPARTMENT OF ENERGY
BESTPRACTICES STEAM PROGRAM
STEAM TOOLS SPECIALIST QUALIFICATION TRAINING
PREREQUISITE STUDY GUIDE

(1/12/2004)

Table of Contents

1) Introduction

The United States Department of Energy (USDOE) BestPractices Steam Tools Specialist Qualification Training is designed to equip participants to be fluent in the use of the USDOE BestPractices Steam Program Tools Suite. This suite of tools consists of a text and three software packages.

- *Steam System Survey Guide*
  - Primary reference text
- *Steam System Scoping Tool (SSST)*
  - Software package designed to
    - Develop awareness of potential areas of investigation importance
    - Link users to technical resources and identifies "next steps"
- *Steam System Assessment Tool (SSAT)*
  - Software package designed to model steam systems
    - Completes a mass, energy, and economic balance on a complex steam system
    - Provides analysis of proposed projects
- *3E Plus*
  - Software package designed to evaluate thermal insulation projects

Steam systems are complex with many components, which interact and influence the operation of the entire system. Specialist Qualification Training will emphasize a global investigation approach to analyzing steam systems for potential energy saving opportunities. This global approach investigates individual components and evaluates the impact of these components on the global system. The software tools associated with this training allow the system to be incorporated into the individual component analysis.

The primary goal and objective of Specialist Qualification Training is to equip a participant to be fluent in the use of the USDOE Steam Tools software packages—SSST, SSAT and 3E Plus. Becoming fluent in the tools includes software utilization and data acquisition. A Qualified Specialist is expected to understand:

- The principles described in the *Steam System Survey Guide*
- The methods required to obtain the data utilized in the software tools
- The implications of the results of SSST
- The projects identified in SSAT
- The implications of the results of SSAT analysis
- The common evaluations required in insulation investigations

It should be noted that this Specialist Qualification Training will not cover all of the aspects of the 3E Plus insulation software. The National Insulation Association (NIA) provides comprehensive training and certification in the use and application of the 3E Plus software and related topics. The reason 3E Plus is included in this Specialist Qualification Training is because insulation issues are an integral part of the management of steam systems.

The Specialist Qualification Training is extensive and the amount of time available for the training is limited. As a result, participants are required to enter the course with at least a minimum level of knowledge and equipment. This Prerequisite Study Guide is designed to allow the participants to determine their readiness to proceed through Specialist Qualification Training.

Participants are expected to be familiar with the Steam Tools Suite prior to attending the course. Because the principal tools are software based each participant must be equipped with a computer. Participants must bring a laptop computer with a functioning CD drive to the training session. Information will be exchanged during the training sessions requiring the CD format. The computer must be equipped with the USDOE Steam Tools. The training course will not devote any time to software startup or initiation. The course will involve many computations; therefore, participants must bring computational instruments they would use for field evaluations—calculator, computer, or other device. Any additional field instrumentation will be provided by the instructor. Again, each participant must bring a laptop computer to the course and have a functioning Steam Tools Suite available on the computer.

It is the purpose of the Specialist Qualification Training to provide SSST, SSAT, and 3E Plus training. However, each participant must enter the training with significant familiarity of these tools. In general, participants should understand the general application of each tool and should know how to navigate through the various sections of each software package. Furthermore, participants must know how to input basic data, complete evaluations, and interpret analysis results. These activities are a focal point of this guide.

Participants should be familiar with the format of the reference tables presented in the *Steam System Survey Guide—Stack Loss Tables* and *Steam Property Tables*. Variations of these tables will be used for in-class and examination computations. It is understood that there are other representations of the same data and participants may be more familiar and comfortable with the use of the other representations. However, to ensure uniformity in the course presentation and in testing, participants are required to utilize data presented with the course exercises. In general the data will be presented in form similar to the reference tables.

One of the primary prerequisites of the training is to be knowledgeable in many areas of steam systems. A definitive method to determine readiness to participate in the training is to successfully complete this Prerequisite Study Guide. The Prerequisite Study Guide is designed as an examination. The primary purpose of the guide is to aid the potential participant in determining if skills required to progress successfully through the Specialist Qualification Training are resident. This study guide consists of several problems associated with steam system management. The study guide has problems that require the use of the USDOE Steam Tools for their solution. Also, some general energy related problems are provided. The information covered in the guide is considered the minimum knowledge required to enter the course.

Each Specialist Qualification Training participant should have a good comprehension of the course objectives of BestPractices Steam End User Training. The End User Training course objectives are provided below.

- Utilize tools developed by the United States Department of Energy to assess steam systems
- Identify the measurements required to manage steam systems
- Measure boiler efficiency
- Estimate the magnitude of specific boiler losses
- Identify and prioritize areas of potential boiler efficiency improvement
- Recognize the impacts of fuel selection
- Characterize the operational impact of backpressure steam turbines
- Characterize the operational impact of condensing steam turbines
- Recognize the requirements of an appropriate steam trap management program
- Evaluate the effectiveness of system insulation
- Evaluate the primary economic impact of condensate recovery
- Recognize the economic impact of all aspects of steam system operation

Even if a Specialist Qualification participant has attended End User training, it is strongly recommended for the participant to complete the Prerequisite Study Guide.

2) Prerequisite Study Guide Problems

The following Prerequisite Study Guide is designed in examination form so that the participant can complete a self-evaluation of resident skills. Solutions to the problems will be provided in a web-based training session that will be scheduled prior the next Specialist Qualification Training class. If aid is needed in any of the areas, references are provided to support the solutions. There are four primary areas of technical prerequisites

- SSST general familiarity
- General understanding of steam system technology
- SSAT general familiarity
- 3E Plus general familiarity

It should be noted that all of the prerequisite material is covered in the BestPractices Steam End User Training. End User Training is offered as a one-day introductory course on steam systems.

The Prerequisite Study Guide should be used as an indicator of readiness to participate in the Specialist Qualification Training. Participants should be confident in the solution method of each problem.

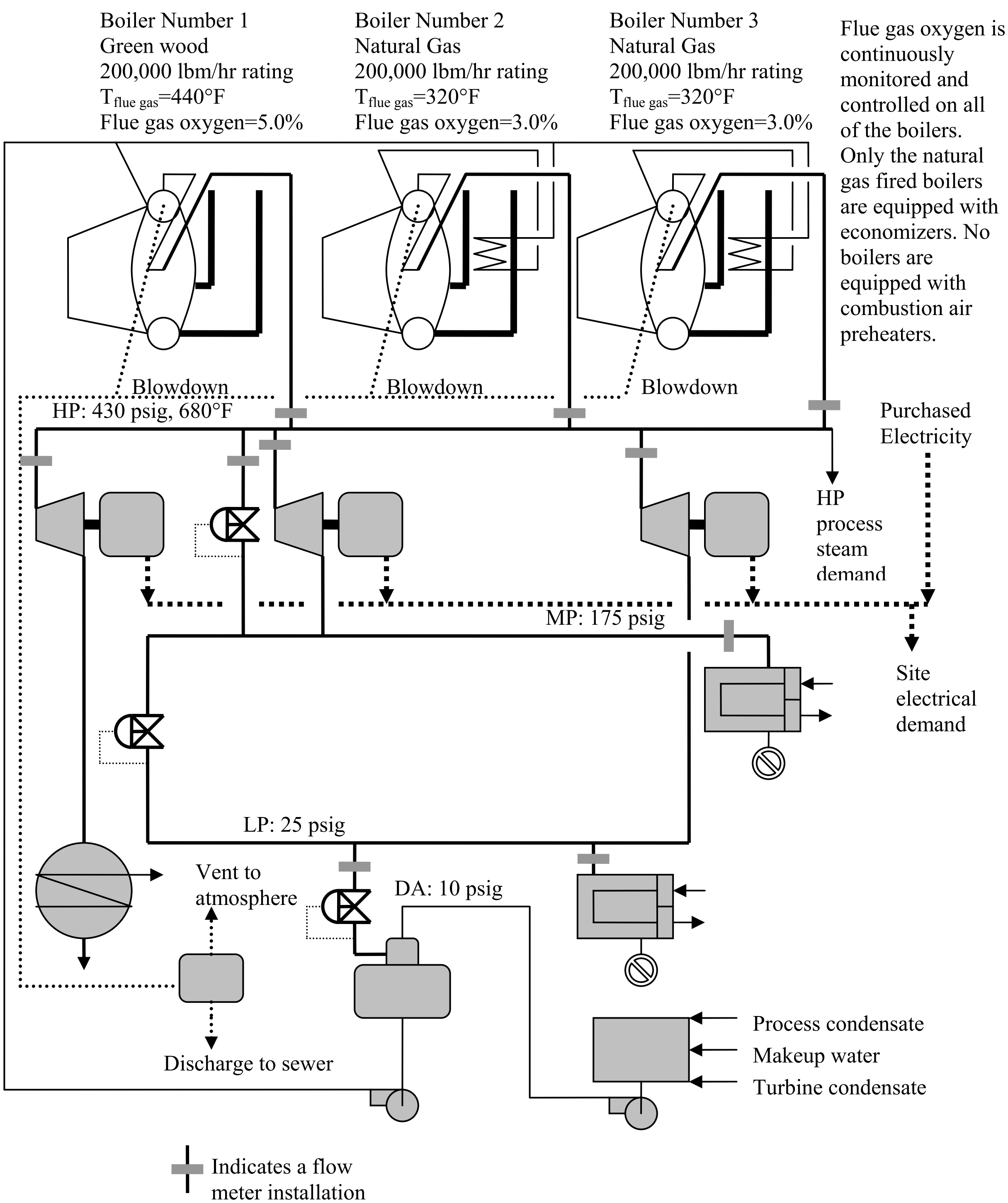
2.1 Solution Nomenclature

The following is a list of symbols used throughout this text.

A	flow area
$\dot{E}$	energy flow rate
HHV	fuel higher heating value
h	enthalpy
$\dot{K}$	operating cost
$\dot{m}$	mass flow rate
P	pressure
$\dot{Q}$	heat transfer rate
τ	operating period
$\dot{V}$	volume flow rate
$\dot{W}$	power
x	thermodynamic quality (mass basis)
η	efficiency
κ	energy unit cost
ρ	density
σ	savings
$\dot{\Lambda}$	loss rate
λ	loss
ϕ	factor or ratio

2.2 Prerequisite Study Guide System

The evaluations required to complete the Prerequisite Study Guide are associated with an example steam system. The following schematic is a simplified representation of the system in question.


Boiler Number 1
Green wood
200,000 lbm/hr rating
T flue gas=440°F
Flue gas oxygen=5.0%
Boiler Number 2
Natural Gas
200,000 lbm/hr rating
T flue gas=320°F
Flue gas oxygen=3.0%
Boiler Number 3
Natural Gas
200,000 lbm/hr rating
T flue gas=320°F
Flue gas oxygen=3.0%
Flue gas oxygen is continuously monitored and controlled on all of the boilers. Only the natural gas fired boilers are equipped with economizers. No boilers are equipped with combustion air preheaters.
Blowdown
Blowdown
Blowdown
HP: 430 psig, 680°F
Purchased Electricity
HP process steam demand
MP: 175 psig
Site electrical demand
LP: 25 psig
Vent to atmosphere
DA: 10 psig
Discharge to sewer
Process condensate
Makeup water
Turbine condensate
Indicates a flow meter installation

2.2.1 System Operating Information

The following descriptions provide operational data for the system. The evaluations to be completed for this guide are considered estimates of continuous operation—24 hours/day, 365 days/yr.

2.2.1.1 General Utilities

Electricity is generated onsite and purchased from a local utility supplier. Purchased electrical costs can be considered to be $0.0505/kWh. Purchased electricity is typically 12 MW. The site is supplied two fuels, natural gas and green wood. Natural gas is purchased under contract with a price of $\$5.50/10^6$Btu. Projections indicate wood purchase prices will be approximately $\$1.05/10^6$Btu for the near term—the fuel properties contained in SSAT are appropriate to describe the fuels. Makeup water is supplied to the facility with a cost of $\$2.0/10^3$gallon and a temperature of 65°F. The production activities of this facility are in continuous operation. Ambient air temperature is approximately 70°F. Atmospheric pressure is 14.7 psia.

2.2.1.2 Boiler Information

The site is supplied steam from three operating boilers. One of the boilers is fired with green wood. The other operating boilers are natural gas fired. The wood fired boiler load is consistently 90% of design. The natural gas fired boilers operate responding to the load with nominal steam flows of 50% of design and variations of ±30%. A fourth, natural gas fired boiler is in reserve as a cold standby boiler. The boilers are field erected, water-tube type boilers. The wood fired boiler was the original boiler for the site—a second wood fired boiler has been taken out of service. The natural gas fired boilers have been installed in the recent past. Steam exported from the boilers is significantly superheated.

Boiler water treatment data indicates all three boilers operate with similar water conditions. The boilers operate continuously with a boiler water conductivity of approximately 2,500 µmho/cm. Feedwater conductivity is approximately 125 µmho/cm. Chlorides measurements of the boiler water typically indicates 280 ppm, and the feedwater indicates 14 ppm.

The steam system manager for the site has provided the following information. In addition, you have toured the steam system and made personal observations. Data obtained from these events included the following:

- The boiler is safety inspected annually by a boiler consultant who also verifies the operation of the combustion control equipment.
- There was no mention by the steam utilities manager of any problems related to wet steam (corrosion, water hammer), the ability to maintain normal boiler water levels or the ability to maintain steam pressure to within 20 psig of the set-point value.
- Automatic boiler blowdown systems are installed but have not operated properly recently so blowdown has been adjusted manually based on once-a-day measurement of boiler water conductivity.

2.2.1.3 Steam Consumption

High pressure steam is supplied to only one process unit. This process unit utilizes steam in a direct contact process application. This process steam demand is not equipped with a flow meter but the steam supply to this process is relatively constant. Each of the boilers is equipped with a flow meter indicating steam production. All of the turbines receiving high-pressure steam are equipped with flow meters. The extraction turbine is equipped with a flow meter on the exhaust stream. The pressure reducing station receiving high-pressure steam is also equipped with a flow meter. The deaerator is equipped with a flow meter on the steam supply to the unit. All of these flow meters, and additional flow meters supporting the system, are indicated on the system schematic.

The following flow rate values were observed during a period when some of the process units were out of service but the process unit requiring high-pressure steam was operating under normal conditions. In other words, the flow rate data contained in the following list can be used to determine the high-pressure steam demand using a mass balance on the high-pressure steam header. It should be noted that the information provided immediately below is not indicative of normal system operation for the remainder of the system.

- Combined boiler steam production—370,000 lbm/hr
- Combined backpressure turbine high-pressure steam consumption—277,000 lbm/hr
    - HP-LP main generator turbine
    - HP-MP main generator turbine
- Condensing turbine steam consumption—25,000 lbm/hr
- High-pressure to medium-pressure pressure reducing station—60,000 lbm/hr
- Deaerator steam flow—30,000 lbm/hr

Steam flow meters are in place on the medium-pressure and low-pressure steam headers. These flow meters record the total steam flow to the process steam demands. During normal operation steam supply to the medium-pressure users is approximately 75,000 lbm/hr. Low-pressure process steam demand is approximately 220,000 lbm/hr—during normal operation. It has been estimated that one half of the medium and low-pressure steam users are connected to the condensate collection system.

2.2.1.4 Steam Turbines and Pressure Reducing Valves

The site is equipped with three steam turbines as noted on the system schematic. The general operation of all of the turbines is described in this text. The primary steam turbine is a backpressure unit operating between the high-pressure and low-pressure steam systems. This unit is connected to an electrical generator and is rated to produce 20 MW of electric power. This unit manages the steam supply into the low-pressure header. This turbine receives high pressure steam—boiler outlet conditions are assumed—and discharges steam with a temperature of 321°F and a pressure of 25 psig. This turbine typically operates with a load between 50% and 60% of full load.

Another backpressure turbine-generator unit is in operation. The turbine receives high-pressure steam and exhausts medium-pressure steam. This unit is rated to produce approximately 0.5 MW of electrical power. This turbine has a maximum high-pressure throttle flow of 25,000 lbm/hr and a minimum required steam flow of 5,000 lbm/hr. A recent turbine performance evaluation indicates the turbine operates with an isentropic efficiency of 63%—under "normal" conditions. This turbine typically operates discharging the maximum amount of steam.

The site is equipped with a condensing steam turbine connected to an electrical generator. This component was installed with the original plant construction when two wood fired boilers served the site. The output of the generator is typically 2.0 MW of electrical power. Steam supply to the turbine is 25,000 lbm/hr of high pressure steam—to produce 2.0 MW of electrical output. The condensing turbine operates with a condensing pressure of 1.5 psia. The manufacturer of the generator indicates the component operates with an efficiency of 95%. It should be noted that *generator efficiency* is in reference to the electrical generator only and is defined as the ratio of turbine shaft power input to electrical power output. Generator efficiency is not turbine isentropic efficiency.

The steam system is equipped with two pressure reducing stations. One operates between the high-pressure and the medium-pressure systems and the other operates between the medium-pressure and the low-pressure systems. These pressure reducing stations are not equipped with desuperheating stations.

2.2.1.5 Distribution System

The condensate recovery system is extensive. Recovered condensate is collected in many individual area condensate receivers. All of the receivers are vented to the atmosphere. A thorough steam trap survey was completed recently—within six months. There had not been a steam trap evaluation for a significant period of time prior to this. Maintenance activities have not been initiated in response to the steam trap survey at this point. The last significant maintenance activity associated with steam traps was four years ago.

Steam Trap Survey

		Trap Condition		
System Pressure	**Traps Surveyed [Number of traps]**	**Good [# of traps]**	**Blocked or Low Temp [# of traps]**	**Leaking or Blowing [Number of traps]**
High-pressure	17	13	3	1
Medium-pressure	265	207	26	32
Low-pressure	1,971	1,726	108	137
Total	2,253	1,946	137	170

The main condensate receiver for the facility is vented to the atmosphere. The vent piping presents a minor (negligible) amount of steam but this indicates the condensate entering the receiver is saturated liquid. Steam leaks appear to be well managed with only very minor (negligible) leaks observed.

2.2.1.6 *Steam and Water Properties*

Properties								
Location	**Temperature [°F]**	**Pressure [psia]**	**Specific Volume [ft³/lbm]**	**Internal Energy [Btu/lbm]**	**Enthalpy [Btu/lbm]**	**Entropy [Btu/lbm°R]**	**Quality [%]**	**Pressure [psig]**
	498	667.0	0.68964	1,118.12	1,203.25	1.42094	100.0	652.3
	498	667.0	0.02038	482.63	485.14	0.68583	0.0	652.3
Feed-pump exit	242	667.0	0.01692	208.53	210.62	0.35643	****	652.3
Boiler outlet	680	444.7	1.44581	1,230.10	1,349.08	1.61682	****	430.0
	455	444.7	1.04448	1,118.80	1,204.75	1.46189	100.0	430.0
	455	444.7	0.01951	434.27	435.87	0.63408	0.0	430.0
	651	189.7	3.40359	1,229.60	1,349.08	1.70727	****	175.0
	608	189.7	3.25840	1,212.60	1,326.98	1.68697	****	175.0
	539	189.7	3.02057	1,184.95	1,290.98	1.65212	****	175.0
	476	189.7	2.79461	1,158.76	1,256.86	1.61682	****	175.0
	377	189.7	2.40741	1,113.11	1,197.62	1.55181	100.0	175.0
	377	189.7	0.01833	350.00	350.64	0.53786	0.0	175.0
	307	74.7	5.83767	1,101.15	1,181.84	1.62830	100.0	60.0
	307	74.7	0.01753	276.89	277.14	0.44682	0.0	60.0
	150	74.7	0.01634	117.65	117.88	0.21481	****	60.0
	120	74.7	0.01620	87.69	87.92	0.16448	****	60.0
	633	39.7	16.30819	1,229.28	1,349.08	1.87753	****	25.0
	490	39.7	14.12262	1,176.27	1,280.01	1.80979	****	25.0
	364	39.7	12.15149	1,129.48	1,218.74	1.74054	****	25.0
	321	39.7	11.47172	1,113.39	1,197.66	1.71425	****	25.0
	267	39.7	10.57308	1,091.91	1,169.58	1.67623	100.0	25.0
	267	39.7	10.08505	1,052.32	1,126.40	1.61682	95.4	25.0
	267	39.7	10.37502	1,075.84	1,152.06	1.65212	98.1	25.0
	267	39.7	0.01714	235.44	235.57	0.39132	0.0	25.0
	631	24.7	26.22014	1,229.24	1,349.08	1.92962	****	10.0
	239	24.7	16.48986	1,084.95	1,160.32	1.71313	100.0	10.0
	239	24.7	0.01692	207.67	207.74	0.35233	0.0	10.0
	212	14.7	26.79675	1,077.52	1,150.41	1.75443	100.0	0.0
	212	14.7	0.01671	180.04	180.08	0.31197	0.0	0.0
	180	14.7	0.01650	147.87	147.91	0.26289	****	0.0
	65	14.7	0.01602	33.02	33.06	0.06510	****	0.0
	628	1.5	432.48987	1,229.19	1,349.08	2.23820	****	-13.2
	116	1.5	227.98819	1,048.63	1,111.83	1.94826	100.0	-13.2
	116	1.5	216.86651	1,001.55	1,061.67	1.86087	95.1	-13.2
	116	1.5	185.80702	870.07	921.57	1.61682	81.5	-13.2
	116	1.5	0.01619	83.57	83.58	0.15697	0.0	-13.2

2.2.1.7 <u>Boiler Stack Losses</u>

Stack Loss in % based on fuel HHV for:	Typical Natural Gas														
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	14.7	15.1	15.5	16.0	16.4	16.9	17.3	17.7	18.2	18.6	19.1	19.5	20.0	20.4	20.9
2.0	14.9	15.4	15.8	16.3	16.7	17.2	17.7	18.1	18.6	19.1	19.5	20.0	20.5	20.9	21.4
3.0	15.2	15.7	16.1	16.6	17.1	17.6	18.1	18.6	19.1	19.5	20.0	20.5	21.0	21.5	22.0
4.0	15.5	16.0	16.5	17.0	17.5	18.0	18.5	19.1	19.6	20.1	20.6	21.1	21.6	22.2	22.7
5.0	15.8	16.3	16.9	17.4	18.0	18.5	19.1	19.6	20.1	20.7	21.2	21.8	22.3	22.9	23.4
6.0	16.2	16.8	17.3	17.9	18.5	19.1	19.6	20.2	20.8	21.4	22.0	22.5	23.1	23.7	24.3
7.0	16.6	17.2	17.8	18.5	19.1	19.7	20.3	20.9	21.5	22.2	22.8	23.4	24.0	24.6	25.3
8.0	17.1	17.8	18.4	19.1	19.7	20.4	21.1	21.7	22.4	23.1	23.7	24.4	25.1	25.7	26.4
9.0	17.7	18.4	19.1	19.8	20.5	21.2	22.0	22.7	23.4	24.1	24.8	25.6	26.3	27.0	27.7
10.0	18.4	19.2	19.9	20.7	21.5	22.2	23.0	23.8	24.6	25.4	26.1	26.9	27.7	28.5	29.3
11.0	19.2	20.1	20.9	21.7	22.6	23.4	24.3	25.1	26.0	26.9	27.7	28.6	29.4	30.3	31.2
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

Stack Loss in % based on fuel HHV for:	Wet Wood														
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

2.2.1.8 <u>Potentially Useful Data</u>

3,413 Btu = 1.0 kWh
7.48 gallons = 1.0 ft^3
8,760 hours = 1.0 years

2.3 Steam System Scoping Tool (SSST) Software Function Problem

Install the SSST software onto your computer; this software is provided in the Qualified Specialist Training Pre-Course Package. Ensure the software functions properly. This problem is designed to ensure the computer you will be using during the training is properly equipped and that you have a general level of familiarity with the software tool.

Follow the installation instructions provided with the package. If difficulty is experienced contact Tony Wright, Group Leader-Engineering Science and Technology Division, Oak Ridge National Laboratory—by telephone at (865) 574-6878 or by email wrightal@ornl.gov.

2.4 Steam System Scoping Tool (SSST) System Evaluation Problem

Complete the SSST Section 3: Boiler Plant Operating Practices based on the information provided above. Also, indicate how you would proceed to obtain any additional information you would need beyond that provided in information above. Finally, based on this completion of SSST Section 3 list the specific areas on which you would focus your attention to achieve boiler-related energy savings in the example plant.

2.5 Wood-Fired Boiler Operation

This section of the evaluation focuses on the operation of the wood-fired boiler. For this boiler determine the following. The calculations for this problem should **not** be completed by SSAT.

1. Estimate the fuel related operating cost of the wood fired boiler
   a. Only the largest boiler loss should be used in the calculation
2. Determine the *impact* of the installation of a feedwater economizer on site operations
   a. The economizer will reduce the flue gas exhaust temperature to 320°F for the general boiler load
3. Determine an estimate of the loss associated with boiler blowdown [1, Section 4.2.4 equation 29]
   a. Determine the loss as a fraction of fuel energy input to the boiler
   b. Determine the loss on an energy loss basis (Btu/hr)
4. Determine an estimate of the boiler shell loss as a fraction of fuel energy input and in terms of energy transfer ("Btu/hr") [1, Section 4.2]
5. Determine the classic boiler efficiency (direct efficiency) [1, Section 4.2 equation 10]
   a. Assume a field evaluation has been completed and the fuel flow rate is 54,000 lbm/hr
   b. The fuel higher heating value is 10,502,984 Btu/ton
6. Determine the indirect boiler efficiency [1, Section 4.2 equation 13]

2.6 HP-LP Turbine Performance

Determine the isentropic efficiency of the main steam turbine operating between the high-pressure and low-pressure systems.

2.7 Condensing Turbine Efficiency

Determine the isentropic efficiency of the condensing turbine.

2.8 Steam System Assessment Tool (SSAT) Software Function Problem

Install the SSAT software onto your computer; this software is provided in the Specialist Qualification Training Pre-Course Package. Open the one, two, and three header templates;

ensure that the models converge and the software functions properly. This problem is designed to ensure the computer you will be using during the training is properly equipped and that you have a general level of familiarity with the software tool.

Follow the installation instructions provided with the package. If difficulty is experienced contact Tony Wright, Group Leader-Engineering Science and Technology Division, Oak Ridge National Laboratory—by telephone at (865) 574-6878 or by email wrightal@ornl.gov.

2.9 Steam System Assessment Tool (SSAT) System Evaluation Problem

Develop the SSAT model that best represents the general characteristics of the example facility for an evaluation that will provide representative marginal steam costs. This model should also provide a good description of the steam mass balance through the system. In other words the boiler information input should be that of one of the natural gas fired boilers and the fuel should be natural gas. The analyses required for this exercise should be considered preliminary; as a result individual boiler shell losses should be considered as negligible. Outputs for this exercise are the marginal steam costs for the system and the steam flows through the pressure reducing valves.

2.10 Steam Turbine versus Electric Motor

Determine the economic impact of replacing a 100 kW process drive electric motor with a steam turbine. Assume the process turbine will operate continuously between the high-pressure and medium-pressure systems. The turbine will have an isentropic efficiency of 35%.

SSAT should be used to evaluate this exercise. The solution should follow the plan of replacing the high-pressure to medium-pressure steam turbine with the 100 kW turbine noted in this problem. The replacement should take place on the *Input* page. The economic impact is determined by exercising the appropriate project to turn the turbine off.

2.11 Condensate Flash Steam Recovery

Using the SSAT model developed for the general steam system determine the economic impact of recovering flash steam produced from the existing condensate recovery system. Present the individual areas of economic impact contributing to the results.

2.12 Blowdown Energy Recovery

Using the SSAT model developed for the general steam system determine the economic impact of recovering thermal energy from boiler blowdown. Present the individual areas of economic impact contributing to the results.

2.13 Steam Demand

A process evaluation was completed, which identified the fact that process water was being unnecessarily heated from 120°F to 150°F with low-pressure steam. The steam trap serving the heat exchanger is functioning properly and is discharging saturated liquid at steam pressure. Steam entering the heat exchanger can be assumed to be at the pressure of the low-pressure system and saturated vapor conditions—heat transfer losses in this branch line account for the energy loss from the superheated supply condition. The process water is approximately 60 psig and has a continuous flow rate of 100 gal/min. Determine the steam system operational cost impact of eliminating this steam demand. Utilize SSAT developed marginal steam costs for the economic evaluation.

2.14 <u>3E Plus Software Function Problem</u>

Install the 3E Plus software onto your computer; this software is provided in the Specialist Qualification Training Pre-Course Package. Ensure that the software functions properly. This problem is designed to ensure <u>the computer you will be using during the training</u> is properly equipped and that you have a general level of familiarity with the software tool.

Follow the installation instructions provided with the package. If difficulty is experienced contact Tony Wright, Group Leader-Engineering Science and Technology Division, Oak Ridge National Laboratory—by telephone at (865) 574-6878 or by email wrightal@ornl.gov.

2.15 <u>3E Plus Piping Insulation Problem</u>

One of the process units is supplied medium-pressure steam through a 10 inch nominal diameter header. A 20 foot long section of the header was observed to be un-insulated—the result of a past maintenance activity. The majority of the piping system is covered with a 2.0 inch thick covering of calcium silicate insulation and aluminum jacket. Determine the energy loss reduction associated with replacing the missing insulation. Ambient conditions are typical for an industrial facility. The piping is located outside on a pipe bridge.

2.16 <u>Steam Leak</u>

Determine an order of magnitude estimate of the steam loss through a failed steam trap. The steam trap is equipped with a ⅛ inch diameter orifice. The steam supplied to the application is medium pressure steam. The condensate collection system is equipped with relatively large piping. Reference [1, 6-2] provides the approximate flow of steam through a sharp-edged orifice.

3) References

1. *Steam System Survey Guide*, Greg Harrell, United States Department of Energy BestPractices Steam Program, 2002.
2. Fundamentals of Engineering Thermodynamics, Second Edition, Michael J. Moran and Howard N. Shapiro, John Wiley and Sons, 1992.
3. Steam Tables, Thermodynamic Properties of Water Including Vapor, Liquid, and Solid Phases, Joseph Keenan, Frederick Keyes, Philip Hill, Joan Moore, John Wiles and Sons, 1969.
4. Thermodynamic Properties, Version 2.0 (software) To Accompany Thermodynamics, Second Edition, Software by: James Hartley, George Woodruff, Text by: William Black, James Hartley, Harper Collins Publishers, 1990.
5. NIST/ASME Steam Properties Database: Version 2.2 (software), National Institute for Standards and Testing.
6. Mark's Standard Handbook for Mechanical Engineers, Eugene Avallone and Theodore Baumeister, McGraw-Hill Book Company, 1999.