

DESIGN MANUAL

SPD0043ERN-USA

PROCESS DESIGN MANUAL

STEAM SYSTEM

REV.: 2

DATE: 10 Jun 2011



**SAMSUNG
ENGINEERING**

	DESIGN MANUAL STEAM SYSTEM	SPD0043ERN-USA REV.: 2 Page i of ii
DATE: 10 Jun 2011		

CONTENTS

1. INTRODUCTION	1
2. DESIGN BASIS FOR STEAM SYSTEMS	2
3. STEAM GENERATION - FIRED BOILERS	5
3.1. Design.....	5
3.1.1. General.....	5
3.1.2. Steam Raising Capacity	7
3.2. Installation.....	7
3.3. Instrumentation	8
4. ESTIMATION OF STEAM REQUIREMENTS FOR PROCESS EQUIPMENT.....	9
4.1. Engines and Turbines	9
4.2. Steam Driven Pumps	9
4.3. Steam Stripping.....	11
4.4. Vacuum Producing Systems	11
4.5. Heating Coils for Tanks.....	12
4.6. Miscellaneous	12
4.6.1. Properties of Steam	12
4.6.2. Line Sizing	12
4.6.3. Draining of Steam Mains	13
4.6.4. Flash Steam	14
4.6.5. Steam Condensate	14

	DESIGN MANUAL STEAM SYSTEM	SPD0043ERN-USA REV.: 2 Page ii of ii
DATE: 10 Jun 2011		

5. REFERENCES 15

6. REVISION HISTORY 16

TABLES & FIGURES

Table 1. Requirements for Boiler Feed Water 17

Table 2. Steam Requirements for Vacuum System..... 18

Table 3. Condensate Loads from Steam Mains 19

Table 4. Flash Steam Generation 20

Figure 1. Design Principles for Establishing Water and Steam Balance 21

Figure 2. Condensing Turbine Horsepower Efficiency 22

Figure 3. Turbine Horsepower (Back Pressure) Efficiency 23

	DESIGN MANUAL STEAM SYSTEM	SPD0043ERN-USA REV.: 2 Page 1 of 23
DATE: 10 Jun 2011		

1. INTRODUCTION

This Process Design Manual describes and outlines the basic requirements for, steam systems typically encountered in process plants.

Steam is obtained from the following possible sources:

- a) Fired steam generators or boilers.
- b) Unfired steam generators which are normally located in process units to utilize waste heat in gas turbine exhausts, furnace flue gases, or products.
- c) Steam turbine exhausts and inter-stage extraction.
- d) Pressure reducing valves which throttle higher pressure steam and may be followed with desuperheaters.
- e) Flash drums, where high pressure condensate or boiler blowdowns are flashed to yield saturated, lower pressure steam.

Steam may be used for the following.

- a) Process feed-stock stripping, fuel oil atomization, and heating of tower feed streams.
- b) Process heating in heat exchangers and reboilers, and by live steam injection.
- c) Storage tank heating and pipe line tracing or jacketing.
- d) Offsite and utility plant heating; e.g. fuel oil heating, boiler feed water heating and deaeration, instrument air dryer desiccant regeneration, etc.
- e) Domestic and space heating.
- f) Machine drives for:

Essential services where electricity supply is not entirely dependable.

Large machines where a steam turbine results in lower operating costs than an electric motor.

Any machinery where electric power supply is limited.

	DESIGN MANUAL STEAM SYSTEM	SPD0043ERN-USA REV.: 2 Page 2 of 23
DATE: 10 Jun 2011		

- g) Electric power generation.
- h) Regeneration of certain catalysts, usually in conjunction with air.
- i) Steam and air decoking of furnace tubes.
- j) Snuffing fires at furnaces, relief valve vents, blow-down pits, etc.
- k) Steaming out vessels, pipe lines, and other equipments to displace air, hydrocarbons, or other materials.
- l) Control of smoke emissions at flares.
- m) Producing vacuum, using steam-jet ejectors.
- n) Soot blowing in boilers and process furnaces.

2. **DESIGN BASIS FOR STEAM SYSTEMS**

Initially, establish or identify the layout of the system, in particular the steam pressure levels. Estimate the steam demands and productions of the various equipments at selected pressures and temperatures. Methods of estimating steam requirements for some equipment are given in Section 4. The MP and LP systems will usually operate at or near saturation temperature.

The general principles for establishing the steam and water balance are illustrated in Figure 1. Steps for determining flow rates, pressures, and temperatures follow.

The drivers noted as “Groups A, B, C, and D” in Figure 1 refer to the following:

- a) GROUP A - HP (600 psig +) steam drivers exhausting into the MP (150 psig +) steam system.
- b) GROUP B - MP steam drivers exhausting to the LP (50 psig -) steam system.
- c) GROUP C - HP steam drivers exhausting to the LP steam system.
- d) GROUP D - Fully condensing steam drivers usually supplied from the HP steam system and possibly with an extraction stage feeding to the MP and/or the LP steam systems.

	DESIGN MANUAL STEAM SYSTEM	SPD0043ERN-USA REV.: 2 Page 3 of 23
DATE: 10 Jun 2011		

The following outline describes the typical steps taken to develop a facility steam balance and set the design basis for the steam system equipment:

- STEP 1

Determine the LP steam demand at design conditions for the following:

LP stripping steam

Process heaters

Reboilers

Tank heating and steam tracing, jacketing etc.

Domestic and space heating, etc.

- STEP 2

Determine the MP steam demand at design conditions for:

MP process stripping

Process heaters and reboilers

Utilities and offsite heating

Steam jet ejectors

Fuel atomizing

Flare header, etc.

- STEP 3

Determine the quantity of MP steam to be generated in waste heat boilers.

- STEP 4

Tabulate HP steam requirements of major equipment drivers (Groups A and C) which must be steam driven.

- STEP 5

Tabulate MP steam requirements of minor equipment drivers (Group B) which must be steam driven.

	DESIGN MANUAL STEAM SYSTEM	SPD0043ERN-USA REV.: 2 Page 4 of 23
DATE: 10 Jun 2011		

- STEP 6

Tabulate HP steam requirements which shall preferably have condensing/extraction turbines (Group C).

- STEP 7

Tabulate MP steam requirements of minor equipment which may have steam drivers or steam driven spares.

- STEP 8

Estimate LP steam required for the deaerator. assuming an operating pressure of 5-10 psig and vent steam of 1000 lb/hr.

- STEP 9

Balance the total LP steam demand (STEP 1) with the LP steam supply from Groups B and C drives (See STEPS 4 and 5) and any other known sources of LP steam, e.g. from flash drums. Small differences may be balanced by using equipment listed in STEP 7 or by pressure let-down from the MP steam system.

- STEP 10

Determine the total MP steam demand by the sum of the demands in STEP 2 and the quantity determined in STEP 9.

- STEP 11

Balance the MP steam demand (STEP 10) against the total MP steam supply from waste heat boilers (STEP 3), extraction steam (STEP 6), and exhaust steam from HP steam drivers (GROUP A), and any other known sources of MP steam. Small differences may be balanced by changing the extraction steam rate from GROUP D drivers or by pressure let-down from the HP system.

- STEP 12

Remaining HP steam drivers (Group D) should be fully condensing.

	DESIGN MANUAL STEAM SYSTEM	SPD0043ERN-USA REV.: 2 Page 5 of 23
DATE: 10 Jun 2011		

●STEP 13

Determine the demand for HP steam and verify the pressure and temperature assumed. Adjust the balance if necessary by recalculating using a different steam pressure.

●STEP 14

Adjust the complete balance for emergency conditions, eliminating services which would be inoperative, by adding emergency loads and intermittent loads, and by making full use as necessary of the pressure let-down systems to achieve balances during abnormal operations. Steam desuperheaters may be used in conjunction with the let-down stations but have the disadvantage that a source of HP condensate is necessary for their operation.

In a plant having process units which can be operated independently of other units, it is desirable to balance steam requirements at each unit independently of other units, in the interests of thermal economy. Similarly it is preferable to have the Utility plant self-sufficient in relation to exhaust steam requirements.

3. STEAM GENERATION - FIRED BOILERS

3.1. Design

Either package or built-in-place installations are available.

- a) Package installations: Available in various sizes and pressure levels, exceeding 200,000 lb/hr at 600 psig.
- b) Built-in-place installations: Available in a full range of sizes and pressure levels. Boiler fuel may be fuel oil or fuel gas over a wide range of specifications.

3.1.1. General

a) BOILER CAPACITY

Boiler capacity is expressed as net generated steam mass flow rate at product steam conditions. For example: 100,000 lb/h at 600 psia

	DESIGN MANUAL STEAM SYSTEM	SPD0043ERN-USA REV.: 2 Page 6 of 23
DATE: 10 Jun 2011		

and 650°F or 45 UK ton/h at 42.2 Kg/cm² and 910°C superheat. Alternatively, boiler capacity may be expressed as boiler horsepower (HP). 1 HP is equivalent to 5 lb/hr of water evaporated from or at 212°F or 33,475 Btu/h. Conversion to lb/h is referenced in Table 1.

b) FEED WATER PUMP CAPACITY

An overdesign margin of at least 20% of the boiler rated capacity should be applied to boiler feed water pumps to allow for boiler blowdown operation above rated capacity and surges in boiler drum levels.

c) BOILER FEED WATER PUMP PRESSURE

The boiler feed water pump discharge pressure must be above the boiler rated pressure to allow for frictional losses in piping, control valve loss, entrance loss, static head loss, and etc.

Requirements for boiler feed water are given in Table 1.

d) DENSITY OF WATER

Remember that the specific gravity of water leaving a pressure type deaerator operating at 5-10 psig will be approximately 0.95.

e) STEAM REQUIRED FOR OIL BURNERS

Two types of oil burners are commonly used: Inside mix burners, in which steam and fuel oil are mixed in a chamber within the burner then issued from the burner as a single stream, requiring 0.2-0.5 lb of 125 psig; or, outside mix burners requiring up to 1 lb of 125 psig steam per lb of oil.

In general the higher the pressure and temperature of the oil, the lower the steam consumption, but steam pressure should exceed oil pressure by about 25 psi to avoid any possibility of oil flowing down the steam lines.

	DESIGN MANUAL STEAM SYSTEM	SPD0043ERN-USA REV.: 2 Page 7 of 23
DATE: 10 Jun 2011		

3.1.2. Steam Raising Capacity

- a) Steam should be generated in two or more boilers to provide adequate spare capacity.
- b) The maximum capacity should not be less than 133% of the normal demand and should be at least equal to the emergency steam requirement, assuming that the boilers can be operated at 110% of rated capacity for a short time.
- c) Boilers should be considered as operating at partial loads, while supplying normal requirements.
- d) Shut-down of one boiler:

The remaining boiler(s) should be capable of supplying the plant steam requirement.
- e) The design condition for each boiler and its associated piping and auxiliaries should suit the rated capacity of the boiler.

The emergency design condition for each boiler is 110% of rated capacity, with temperature and pressure assumed to be equal to those at the design condition.
- f) Design pressure should be 10% greater (minimum 25 psi greater) than the maximum operating gauge pressure. The maximum operating pressure is equal to the feed water inlet pressure and exceeds the boiler outlet pressure by the sum of the internal losses.

The outlet pressure of a boiler is expressed as the pressure at the steam drive or superheater outlet, not including valve or piping losses.

3.2. Installation

- a) In warm and temperate climates, boilers can be located completely outside. In cold climates, outside installation should be used, but the front of boilers and the firing aisles should be located inside buildings.

	DESIGN MANUAL STEAM SYSTEM	SPD0043ERN-USA
DATE: 10 Jun 2011		REV.: 2 Page 8 of 23

- b) Boilers can be obtained either "right" or "left-handed."

Use of "opposite hand" boilers may permit common use of one platform for firing, soot blowing etc., and common pipe support structures.

- c) Carbon monoxide boilers should be located close to the catalyst regenerator which produces the carbon monoxide in order to minimize runs of large diameter piping.

The minimum distance of carbon monoxide boilers from process equipment should be 40 feet.

The depressuring chamber should be located approximately 25 feet from the main bypass seal pots.

- d) Accessories:

Boilers are usually supplied with the following accessories:

- Fuel burners, oil and/or gas.
- Forced and/or induced draft fans.
- Flue gas ducts (and stacks, if required).
- Air preheaters.
- Continuous and intermittent blow-down controls.
- Soot blowers, controls and instruments.
- Access platforms, ladders, and walkways.
- Instrumentation for firing and boiler feed water controls.
- Level control, steam pressure and steam temperature controls.

3.3. Instrumentation

Combustion controls provide for adjustment of fuel flow to maintain steam pressure and for adjustment of air flow to maintain the required air-to-fuel ratio.

Controls may be suitable for combination (oil and gas) firing and may include

	DESIGN MANUAL STEAM SYSTEM	SPD0043ERN-USA REV.: 2 Page 9 of 23
DATE: 10 Jun 2011		

the necessary control of atomizing steam. Feed water controls provide for regulation of feed water in proportion to the steam flow and are modified by the level in the steam drum. The feed water control valves should have a minimum pressure drop of 25 psi for low pressure systems rising to 50-75 psi for high pressure boilers. Alarms and fail safe trip systems will normally be a part of vendors' standard supplies.

4. ESTIMATION OF STEAM REQUIREMENTS FOR PROCESS EQUIPMENT

4.1. Engines and Turbines

The theoretical quantity of steam can be calculated from steam tables or Mollier diagram, assuming that condensation occurs at constant entropy.

Calculations related to steam turbines are facilitated by the use of "Theoretical Steam Rate Tables" -by Keenan and Keyes. First Edition, 1938, ASME. Tables are in British units and extend to 3000 psig. Figure 2 gives an indication of expected turbine Rankine cycle efficiency.

4.2. Steam Driven Pumps

The method below applies to regular duplex or power duplex pumps pumping common refinery liquids operating on 125 psig steam exhausting to atmospheric pressure.

Steam quantity can be approximated from the equation:

$$S = (0.07 \cdot C + 1.0) \times (P_d - P_s)$$

Where

S = Steam required (lb/h)

C = Pump capacity (gpm or ft³/hr)

P_d = Discharge pressure (psig)

P_s = Suction pressure (psig)

	DESIGN MANUAL STEAM SYSTEM	SPD0043ERN-USA REV.: 2 Page 10 of 23
DATE: 10 Jun 2011		

If greater accuracy is justified, the following multipliers can be applied.

TYPE OF PUMP	MULT.	STEAM QUALITY	MULT.
Reciprocating Simplex	0.9	100°C Superheat	0.9
Duplex (Basis)	1.0	40°C Superheat	0.96
Power Plunger	1.02	100 psig Saturated	0.99
In Poor Repair	1.05	200 psig Saturated	1.02
Pressure over 100 psi	1.14	300 psig Saturated	1.04
Viscous Liquid	1.1 to 1.2	98% Quality	1.10

The following equation also gives an estimate of steam requirements for reciprocating pumps for any exhaust pressure.

$$S = C \times \frac{(P_d - P_s)}{(P_1 - P_2)} \times \frac{1}{n} \times \left(\frac{1}{V_1} - \frac{1}{V_2} \right)$$

Where,

S = Steam required (lb/h)

C = Pump capacity (gpm or ft³/hr)

P_d = Discharge pressure (psig)

P_s = Suction pressure (psig)

P_1 = Steam supply pressure (psig)

P_2 = Steam exhaust pressure (psig)

n = Efficiency (for estimating purposes use 0.25)

V_1 = Specific volume of supply steam (ft³/lb)

V_2 = Specific volume of exhaust steam (ft³/lb)

	DESIGN MANUAL STEAM SYSTEM	SPD0043ERN-USA REV.: 2 Page 11 of 23
DATE: 10 Jun 2011		

4.3. Steam Stripping

The following quantities of steam can be used for stripping crude oil distillation unit cuts, as a first approximation:

MATERIAL	(lb of Steam/gallon)
Naphtha	0.2 - 0.5
Kerosene or Diesel Fuel	0.2 - 0.6
Gas Oil	0.1 - 0.5
Neutral Oils	0.4 - 0.9
Topped Crude	0.4 - 1.2
Residual Cylinder Stock	1.0 and up

Further information can be obtained from "Petroleum Refinery Engineering" by W.L. Nelson, Publisher McGraw-Hill: 1958, pp 231-232 Figures 7-3 and 7-4.

4.4. Vacuum Producing Systems

Vacuum is frequently imposed on operating systems by the use of steam jet ejectors. A condenser, equipped with a condensate pump or a barometric drainage leg, is usually located before the first stage ejector to condense process steam and/or vapors.

Several ejector stages may be used, with or without inter-condensers for ejector steam, depending on the vacuum required.

Diagrams of systems used are given in "Petroleum Refinery Engineering" by W.L. Nelson, Publisher McGraw-Hill: 1958, pp 253-254.

Estimates of steam consumption may be obtained from Table 2 or from vendors, or it may be calculated using references given in Section 5.

In specifying ejectors, it is necessary to estimate air leakage into vacuum systems. Refer to SPD0031ERN-USA for additional information on vacuum

	DESIGN MANUAL STEAM SYSTEM	SPD0043ERN-USA REV.: 2 Page 12 of 23
DATE: 10 Jun 2011		

system calculations.

4.5. Heating Coils for Tanks

Nelson (Ref 5_(ix)) gives the approximate quantity of exhaust steam required to heat and maintain temperature in storage tanks.

The amount of exhaust steam heating surface required for tanks containing semi-solids such as heavy fuel oil, residuum, heavy topped crude, and heavy asphaltic crude, but not asphalt or waxes, is indicated in "Nelson's Petroleum Refinery Engineering," pp 582 Figures 17-19.

Vendor's standard tank heaters may frequently be used for storage tanks, when it is necessary to complete only the standard heat exchanger data sheet for the Engineering Department, having calculated the rate of heat loss from the tank.

A rigorous calculation method for sizing free convection heaters (heating coils) for storage tanks is given in "Process Heat Transfer" by D.Q. Kern, Publisher McGraw-Hill: 1950, pp 217.

4.6. Miscellaneous

4.6.1. Properties of Steam

- Properties of steam in English Units may be obtained from "Steam Tables" by Keenan, Keyes, Hill, and Moore, Publisher J Wiley and Sons, Inc: 1938.

Tables extend up to 15,000 psia and 2,400°F

- Alternatively, properties of steam in Metric Units may be obtained from "Steam Tables" (International Edition-Metric Units) by Keenan, Keyes, Hill, and Moore, Publisher J Wiley and Sons, Inc: 1938.

Tables extend up to 1,000 Bar and 13,000°C

4.6.2. Line Sizing

Sizing of steam lines is beyond the scope of this design manual. Please refer to the appropriate design manual for sizing criteria.

	DESIGN MANUAL STEAM SYSTEM	SPD0043ERN-USA REV.: 2 Page 13 of 23
DATE: 10 Jun 2011		

4.6.3. Draining of Steam Mains

- The quantity of condensate formed due to radiation from the surface of insulated mains carrying saturated steam can be estimated from Table 3 and, in practice, will depend on insulation thickness, ambient temperature, and wind velocity for outside pipework.
- Where steam is routed through cold pipework, the condensate production will be heavier. An estimate of the higher load can also be obtained from Table 3.
- Due to the increasing cost effectiveness of additional insulation with increasing energy costs, the efficiency of insulation should be checked if anything other than an order of magnitude estimate of condensate production is required.
- For warm-up operations it may be assumed that steam trap bypasses will be used to handle initial heavy condensate drainage from lines and equipment.
- Drain traps should be provided at all low points or at a maximum spacing in accordance with Piping Standard. Line traps will be located by Piping Department and specified by Process Department.
- Steam systems will normally be specified to operate at least a few degrees above saturation temperature to minimize condensate formation and drainage problems.
- In saturated steam services, horizontal mains should preferably be sloped in the direction of flow by about 1 in 250 (1/2" in 10'). If the main is run without any fall, drain points should be provided more frequently.
- If the main must be sloped against the direction of flow, in saturated steam services, the line should be sized for a modest velocity

 SAMSUNG ENGINEERING	DESIGN MANUAL STEAM SYSTEM	SPD0043ERN-USA REV.: 2 Page 14 of 23
DATE: 10 Jun 2011		

(about 30 feet per second), and a substantial adverse fall should be provided.

4.6.4. Flash Steam

Flash steam is produced when condensate (or boiler blowdown, etc) under pressure is released to a lower pressure. The amount of flash steam produced can be estimated from Table 4 or calculated by heat balance.

4.6.5. Steam Condensate

Condensate handling facilities are described in the Water Systems Design Manual, SPD0041ERN-USA.

	DESIGN MANUAL STEAM SYSTEM	SPD0043ERN-USA REV.: 2 Page 15 of 23
DATE: 10 Jun 2011		

5. REFERENCES

- i. "Fundamentals of Engineering Offsites and Utilities for the HPI." George C Patterson Petro-Chem Engineering, August 1967- Also in Petroleum Processing [handbook W Bland and R Dividson Publ- McGraw-Hill.
- ii. "Steam in the Oil and Chemical industries." Spirax Sarco Bulletins (Also other related Spirax Catalogues).
- iii. "Process Plant Utilities." L Monroe CE, 14 Dec. 1970.
- iv. "Flash Steam: Make it an Asset." T MacMillan Chemical Engineering, 20 June 1966.
- v. Steam Tables Keenan, Keyes, Hill and Moore Publ. Wile,Y, 1938.
- vi. "Process Heat Transfer." D. Q. Kern Publ. McGraw-Hill, 1950.
- vii. The Efficient Use of Fuel Publ. H. M. Stationery Office.
- viii. The Efficient Use of Steam Lyle publ. H. M. Stationery Office.
- ix. "Petroleum Refinery Engineering." W. C. Nelson publ. McGraw Hill, 1958.
- x. Heating Coils for Tanks W L Nelson Oil and Gas Journal, 7 Oct 1944.
- xi. "Steam Jet Ejectors." (Box File, Engineering 18) R Frumerman. Chemical Engineering, June 1956, pp 196-201.
- xii. "Nomograph Finds Steam Required for Two-Stage Ejectors." (Box File, Engineering 18) J. F. Kuong Hydrocarbon Processing, February 1967, p.140.

	DESIGN MANUAL STEAM SYSTEM	SPD0043ERN-USA REV.: 2 Page 16 of 23
DATE: 10 Jun 2011		

6. REVISION HISTORY

SEA issue of SPD0043ERN-USA

REV NO.	DATE	SCOPE	DESCRIPTION
2	10 Jun 2011	Revised for new Doc. Numbering System	-Team: Process Engineering -Prepared by: K. Elliott -Checked by: S. Wenger -Approved by: M. Czaikowski

Previously issued as SEM-9454E-USA

REV NO.	DATE	SCOPE	DESCRIPTION
1	1 Dec 2010	ALL PAGES	First Edition - SEA -Team: Process Engineering -Prepared by: K.M. Elliott -Checked by: M. Czaikowski -Approved by: H. M. Feintuch

 DATE: 10 Jun 2011	DESIGN MANUAL STEAM SYSTEM	SPD0043ERN-USA REV.: 2 Page 17 of 23
--	---	--

Table 1. Requirements for Boiler Feed Water

TYPE PF TURBINE	SINGLE STAGE	MULTI - STAGE	
	BACK PRESSURE	BACK PRESSURE	CONDENSING
CORRECTION METHOD	ADD TO OR SUBTRACT FROM R.C.E.	MULTIPLY BY	MULTIPLY BY
SUPERHEAT °F			
0	ADD 0.6	0.963	0.977
100	-	1.000	1.000
200	SUBTRACT 0.6	1.012	1.018
300	SUBTRACT 1.2	1.015	1.034

BACK PRESSURE (PSIG)

	BACK PRESSURE				CONDENSING			
R.P.M.	3,000	5,000	7,500	10,000	3,600	5,000	7,500	10,000
500 BHP	1.000	1.030	1.0360	1.0180	1.000	1.000	1.000	1.000
1000 BHP	1.000	1.013	1.0060	0.9820	1.000	1.000	1.000	1.000
2000 BHP	1.000	1.001	0.9800	0.9400	1.000	1.000	1.000	0.957
3000 BHP	1.000	0.997	0.9680	0.9200	1.000	1.000	0.984	0.929
5000 BHP	1.000	0.994	0.9590	0.9020	1.000	1.000	0.955	0.895

BOILER HP	lb/h	BOILER HP	lb/h	BOILER HP	lb/h
50	1,725	900	31,050	15,000	517,500
75	2,587	1,000	34,500	20,000	690,000
100	3,450	2,500	86,250	25,000	862,500
200	6,900	3,000	103,500	35,000	1,207,500
300	10,350	3,500	120,750	40,000	1,380,000
400	13,800	4,000	138,000	45,000	1,552,500
500	17,250	4,500	155,250	50,000	1,725,000
600	20,700	5,000	172,500	60,000	2,070,000
700	24,150	7,500	258,750	80,000	2,760,000
800	27,600	10,000	345,000	100,000	3,450,000

 DATE: 10 Jun 2011	DESIGN MANUAL STEAM SYSTEM	SPD0043ERN-USA REV.: 2 Page 18 of 23
--	---	--

Table 2. Steam Requirements for Vacuum System

<u>SYSTEM PRESSURE</u> <u>MM Hg Abs.</u>	<u>EJECTOR SYSTEM</u> <u>NUMBER OF STAGES</u>	<u>lb. STEAM PER lb. of</u> <u>TOTAL MIXTURE (1)</u>
200	2	4.3(2.5 - 11)
100	2	6.0(3 - 17)
70	2	7.0(4 - 23)
50	2	8.2(4.5 - 27)
40	2	9.0(5 - 30)
30	2	10.2(6 - 35)
20	3	12.3(4 - 40)
10	3	16.8(10 - 50)
7	3	20.0(12 - 58)
5	3	23.0(14 - 64)
4	3	25.5(16 - 70)

PRESSURE (mm Hg abs.) PRODUCED BY EJECTOR SYSTEM	760	200	100	60	50	40	35	30	25
TEMPERATURE (°F) AT VAPORIZER IF NO PROCESS STEAM IS USED	950	830	780	750	735	725	715	708	700
PROCESS STEAM FOR VAPORIZER AT 720 °F(1) (lb/h)	10,300	2,490	1,070	460	325	190	122	54	-
AT 680 °F(1) (lb/h)	24,000	6,220	3,020	1,800	1,340	1,040	885	733	580
JET STEAM FOR EJECTOR AT 80 °F COOLING WATER (lb/h)	-	150	232	378	492	830	1,600	-	-
70 °F COOLING WATER (lb/h)	-	146	222	311	368	480	600	857	2,010
TOTAL STEAM REQUIRED (lb/h)									
680 °F VAPR 70 °F WATER	24,000	6,370	3,252	2,178	1,832	1,870	2,485	-	-
680 °F VAPR 70 °F WATER	24,000	6,366	3,242	2,111	1,708	1,520	1,485	1,590	1,590
720 °F VAPR 80 °F WATER	10,300	2,640	1,302	838	817	1,020	1,722	-	-
720 °F VAPR 70 °F WATER	10,300	2,636	1,292	711	683	670	722	911	2,010

DESIGN MANUAL STEAM SYSTEM

Table 3. Condensate Loads from Steam Mains

STEAM PRESSURE (PSIG)	STEAM MAIN SIZE												0 °F AMBIENT CORRECTION FACTOR
	2"	3"	4"	6"	8"	10"	12"	14"	16"	18"	20"	24"	
10	6	9	11	16	20	24	29	32	36	39	44	53	1.58
30	8	11	14	20	26	32	38	42	48	51	57	68	1.50
60	10	14	18	27	33	41	49	54	62	67	74	89	1.45
100	12	18	22	33	41	51	61	67	77	83	93	111	1.41
125	13	20	24	36	45	56	66	73	84	90	101	121	1.39
175	16	23	26	38	53	66	78	86	98	107	119	142	1.38
250	18	27	34	50	62	77	92	101	116	126	140	168	1.36
300	20	30	37	54	68	85	101	111	126	138	154	184	1.35
400	23	34	43	63	80	99	118	130	148	162	180	216	1.33
500	27	39	49	73	91	114	135	148	170	185	206	246	1.32
600	30	44	55	82	103	128	152	167	191	208	232	277	1.31

STEAM PRESSURE (PSIG)	STEAM MAIN SIZE												0 °F AMBIENT CORRECTION FACTOR
	2"	3"	4"	6"	8"	10"	12"	14"	16"	18"	20"	24"	
0	6.2	12.8	18.2	32	43	68	90	107	140	176	207	208	1.5
5	6.9	14.4	20.4	36	48	77	101	120	157	193	233	324	1.44
10	7.5	15.5	22.0	39	58	83	109	130	169	213	251	350	1.41
20	8.4	17.5	24.9	44	66	93	124	146	191	241	284	396	1.37
40	9.9	20.6	29.3	52	78	110	145	172	225	284	334	465	1.32
60	11.0	22.9	32.6	57	86	122	162	192	250	316	372	518	1.29
80	12.0	24.9	35.3	62	93	132	175	208	271	342	403	561	1.27
100	12.8	16.6	37.8	67	100	142	188	222	290	366	431	600	1.26
125	13.7	28.4	40.4	71	107	152	200	238	310	391	461	642	1.25
150	14.5	30.0	42.8	75	113	160	212	251	328	414	487	679	1.24
175	15.3	31.7	45.1	79	119	169	224	265	347	437	514	716	1.23
200	16.0	33.1	47.1	83	125	177	234	277	362	456	537	748	1.22
250	17.2	35.8	50.8	89	134	191	252	299	390	492	579	807	1.21
300	25.0	51.3	74.8	143	217	322	443	531	682	854	1045	1182	1.2
400	27.8	57.1	83.2	159	241	358	493	590	759	971	1163	1650	1.18
500	30.2	62.1	90.5	173	262	389	535	642	825	1033	1263	1793	1.17
600	32.7	67.1	97.9	187	284	421	579	694	893	1118	1367	1939	1.16



DESIGN MANUAL STEAM SYSTEM

Table 4. Flash Steam Generation

INITIAL STEAM PRESSURE PSIG.	STEAM TEMPERATURE °F	FLASH TANK PRESSURE PSIG.											
		0	5	10	20	30	40	50	75	100	125	150	
25	267	5.7	4.1	3	1	-	-	-	-	-	-	-	
50	298	9	7.4	6.2	4.3	2.6	1	-	-	-	-	-	
75	320	11.3	10.8	8.6	6.7	5	3.7	2.5	-	-	-	-	
100	338	13.3	11.7	10.6	8.7	7	5.7	4.6	2.2	-	-	-	
125	353	14.8	13.4	12.2	10.3	8.7	7.4	6.3	3.8	1.7	-	-	
150	366	16.8	14.8	13.7	11.8	10.2	8.8	7.8	5.4	2.3	1.6	-	
175	377	17.4	16	15	13	11.6	10	9	6.7	4.6	3	1.5	
200	388	18.7	17.5	16.2	14.4	12.8	11.5	10.4	8	6	4.4	2.8	
225	397	19.7	18.2	17	15.4	13.8	12.4	11.4	9	7	5.4	3.8	
250	406	20.7	19.2	18.2	16.4	15	13.6	12.5	10	8.2	6.6	5	
300	422	22.4	21	20	18.2	16.7	15.5	14.4	11	10	8.5	7	
350	436	24	22.7	21.6	20	18.4	17	16	13.8	12	10.4	8.9	
400	448	25.5	24.2	23	21.5	20	18.7	17.7	15.6	13.5	12	10.5	
450	459	26.8	25.3	24.4	22.7	21.2	20	19	16.8	15	13.4	12	
500	470	28.2	26.7	25.7	24	22.6	21.4	20.4	18.2	16.4	14.6	13.4	
550	480	29.2	27.8	27	25.3	23.7	22.5	21.6	19.5	17.5	16	14.7	
600	488	30.2	28.8	28	26.4	25	23.6	22.7	20.5	18.7	17.3	16	
TOTAL HEAT OF FLASH STEAM BTU/lb		1150	1156	1160	1167	1172	1176	1179	1185	1189	1193	1195	
LATENT HEAT OF EVAPORATION BTU/lb		970	960	952	939	929	919	912	895	881	868	857	
HEAT OF LIQUID BTU/lb		180	196	208	227	243	257	267	290	308	324	338	
SATURATED WATER TEMPERATURE °F		212	228	240	259	274	287	298	320	338	353	366	
SPECIFIC VOLUME PF FLASH STEAM FT3/lb		26.8	20.0	16.3	11.9	9.4	7.8	6.6	4.9	3.9	3.2	2.7	

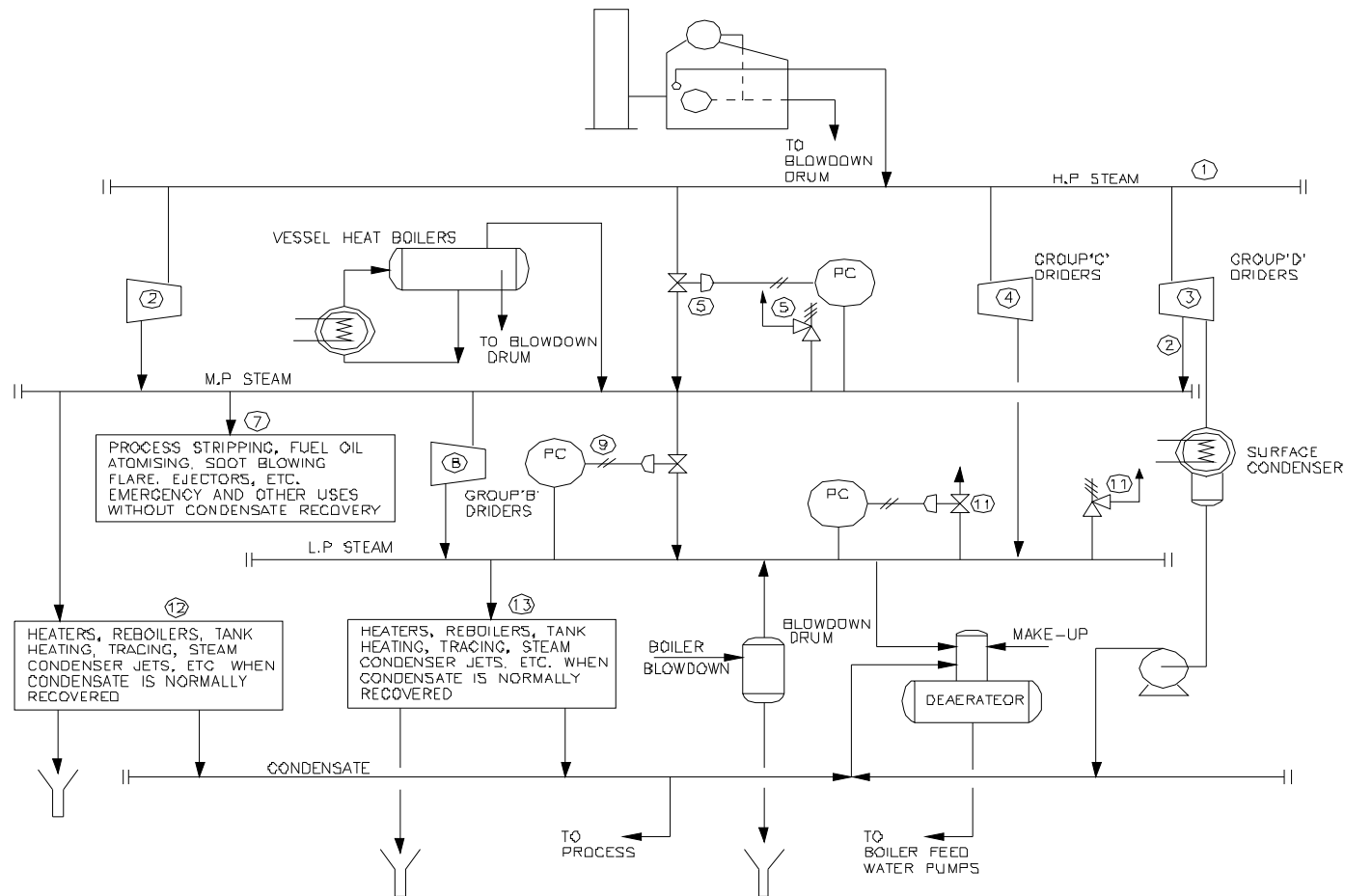


Figure 1. Design Principles for Establishing Water and Steam Balance

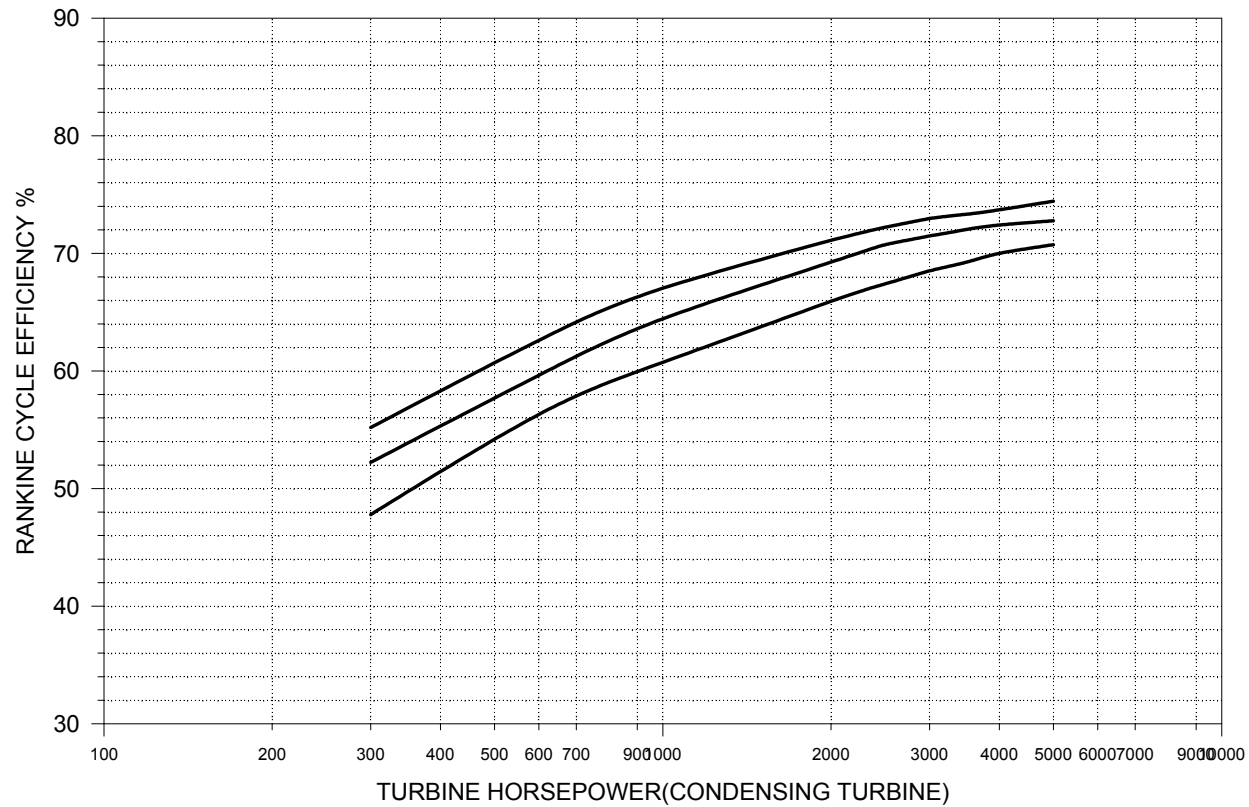


Figure 2. Condensing Turbine Horsepower Efficiency

 SAMSUNG ENGINEERING	DESIGN MANUAL STEAM SYSTEM	SPD0043ERN-USA REV.: 2
DATE: 10 Jun 2011		Page 23 of 23

Figure 3. Turbine Horsepower (Back Pressure) Efficiency