TESSLER engenharia / ips	Takeda / Hemobrás
DOC NUMBER: E-569-B07-PRO-400-001	CLIENT NUMBER: PRD-MEC-CLC-001
CLIENT: **TAKEDA/BAXALTA**	
PROJECT **BURITI EPCMV PROJECT**	

PLANT STEAM / CONDENSATE CALCULATION REPORT

0	30JUL2021	ISSUED FOR CONSTRUCTION	MPA	LFF	MSS
D	17JUN2021	90% DD ISSUE	MPA	CCO	MSS
C	16OCT2020	FINAL BD ISSUE	LID	CCO	MSS
B	28AUG2020	90% BD ISSUE	JRM	CCO	MSS
A	09JUL2020	50% BD ISSUE	JRM	CCO	MSS
REV	DATE	DESCRIPTION	EXEC	CHECK	APPROV.

1. REVISION HISTORY

Rev	Reason For Change
A	50% BD ISSUE
B	90% BD ISSUE
C	FINAL BD ISSUE
D	FLOWRATES AND DIAMETERS HAVE BEEN UPDATED. AS WELL AS CALCULATIONS AND EQUIPMENT. ALL DATA WERE UPDATED ACCORDING TO IPS INFORMATION AND INCLUDED EQUIPMENT LIST IN DOCUMENTS REFERENCE.
0	FLOWRATES AND DIAMETERS HAVE BEEN UPDATED. AS WELL AS CALCULATIONS AND EQUIPMENT. ALL DATA WERE UPDATED ACCORDING TO IPS INFORMATION. THE BLOWDOEN AND INDUSTRIAL WATER CALCULATION WERE ADDED.

2. PURPOSE

This document aims to establish the main characteristics for sizing the Plant Steam Distribution System and Condensate Collecting System for Buildings 7A (Final Drug Product – FDP) and 7B (Bulk Drug Substance – BDS), intended to Takeda unit - Buriti Project, located at Hemobrás site in Goiana - Pernambuco state, Brazil.

3. REFERENCE

The following documents were used as reference:

Item	Number	Title
1	ITD19439-BDS_K_Equipment-List	B07B Process Equipment List
2	ITD19439-FDP_K_Equipment-List	B07A Process Equipment List
3	7A-M-0-5-47	PID - DRUG PRODUCT - HEATING HOT WATER SYSTEM (HVAC)
4	7A-Z-0-2-10	PID - DRUG PRODUCT - FORMULATION AREA TEMP CONTROL UNIT, TCU-3903
5	7A-Z-0-2-06	PID - DRUG PRODUCT - AUTOCLAVE, AT-9001
6	7A-Z-0-2-05	PID - DRUG PRODUCT - DECONTAMINATION AUTOCLAVE, AT-9002
7	7A-Z-0-2-25	PID - DRUG PRODUCT - WFI STORAGE, TQ-6401
8	7A-Z-0-2-24	PID - DRUG PRODUCT - WFI STILL, MES-6401
9	7A-Z-0-2-27	PID - DRUG PRODUCT - CLEAN STEAM GENERATOR, CSG-6501
10	7B-M-0-5-46	PID - DRUG SUBSTANCE - HEATING HOT WATER SYSTEM (HVAC) (1/4)
11	7B-Z-0-2-09	PID - DRUG SUBSTANCE - 40L BIOREACTOR, BRE-5401 - GAS MIX RACK & JKT LOOP
12	7B-Z-0-2-11	PID - DRUG SUBSTANCE - 320L BIOREACTOR, BRE-5501 - GAS MIX RACK & JKT LOOP
13	7B-Z-0-2-13	PID - DRUG SUBSTANCE - 2500L BIOREACTOR N°1, BRE-5601,GAS MIX RACK & JKT LOOP
14	7B-Z-0-2-15	PID - DRUG SUBSTANCE - 2500L BIOREACTOR N°2, BRE-5602,GAS MIX RACK & JKT LOOP
15	7B-Z-0-2-17	PID - DRUG SUBSTANCE - 2500L BIOREACTOR N°3, BRE-5603,GAS MIX RACK & JKT LOOP

Item	Number	Title
16	7B-Z-0-2-43	PID - DRUG SUBSTANCE - CIP SYS. N°1 CIP-7701 - MEDIA AND FERM. AREA
17	7B-Z-0-2-46	PID - DRUG SUBSTANCE - CIP SYS. N°2 CIP-7702 - MEDIA AND FERM. AREA
18	7B-Z-0-2-49	PID - DRUG SUBSTANCE - CIP SYS. N°3 CIP-7703 - BUFFER AREA
19	7B-Z-0-2-54	PID - DRUG SUBSTANCE - AUTOCLAVE AT-9001
20	7B-Z-0-2-59	PID - DRUG SUBSTANCE - WFI STILL, MES-6401
21	7B-Z-0-2-63	PID - DRUG SUBSTANCE - CLEAN STEAM GENERATOR, CSG-6501
22	7B-Z-0-2-60	PID - DRUG SUBSTANCE - HOT WFI STORAGE TANK, TQ-6401
23	7B-Z-0-2-53	PID - DRUG SUBSTANCE - PARTS WASHER LV-4601
24	-	FDP-Plant Utility Summary_DD
25	-	BDS-Plant Utility Summary_DD
26	-	2012 ASHRAE HANDBOOK
26	PRD-MEC-LIS-007	Equipment List – Black Utilities

4. BASIC DATA AND PREMISES

The Plant Steam Distribution System is separated in 3 headers for each building: one header is for equipment that use plant steam at least 8 barg, the other header is for equipment that use plant steam at about 4 barg and the last one is for equipment that use plant steam at least 2 barg. The same occurs in the condensate.

The Steam and Condensate System was sized based on the flow rates and diversities indicated below, using the software AFT Arrow version 6 (2018.02.21) and the PID's 7C-M-0-5-41, 7C-M-0-5-61, 7A-M-0-5-61, 7A-M-0-5-62, 7B-M-0-5-61 and 7B-M-0-5-62 for this system were elaborated based on this calculation.

Three boilers were considered in the project, two operating and one in stand-by. Each boiler has a capacity of 4,200 kg/h, thus operating with a maximum capacity of 8,400 kg/h. The maximum flow rate required for building 7A and 7B is 7,094.1 kg/h as show on item 5.1.1 and the excess of flow rate is diverted to a future expansion (tie-in) - 1,305.9 kg/h (8,400 – 7,094.1 = 1,305.9).

The condensate is collected in 3 headers: one header from high pressure (9.0 barg), the other from medium pressure (4.0 barg) and the last one from low pressure (2.0 barg). These headers collect the two-phase condensate for the condensate pump. This system was considered for each building and the condensate pump is situated at Utilities Room, in Ground Floor. The flash steam produced is separated in the reservoir of the condensate pump ant it is released to the atmosphere through the vent line. The condensate recovered from each building is pumped and interconnected in a single line to the deaerator, by the pumps PC-7A-1 for Building 7A and PC-7B-1 for Building 7B, located at Utilities Room. These pumps are driven with high pressure plant steam.

The BRE-5601-JL, BRE-5602-JL and BRE-5603-JL skids have their own purge pumps, and these lines are interconnected in a single line for the deaerator.

The Condensate Pumping Skid is composed of two mechanically driven pumps, where the driving fluid will be high pressure steam.

The geometric lengths of the system lines are in accordance with the pipeline layout. A clearance of 10% in lengths was considered.

The natural gas system required for the boilers was sized to feed two boilers at the maximum operating condition at the same time, according to recommendations of the Boiler´s supplier. The results can be seen on Item 13.4 and the calculation is on item 10.

Based on the 8,400 kg/h boiler's total capacity, the water softening system has a capacity of 10 m³/h. The calculation can be seen on item 9.

The boiler pumps were sized, and the calculation can be seen on item 11. According to supplier's information, the water at the boiler inlet must be 15 barg. Pump calculations were made based on this parameter and the flow rate and pump head must be re-evaluated by the supplier.

The calculation for the steam and condensate lines were based on 2012 Ashrae Handbook. The economic balance between the speed in the lines and the head loss per meter is considered, as shown in the figures below.

Table 13 Pressure Drops Used for Sizing Steam Pipe[a]

Initial Steam Pressure, kPa[b]	Pressure Drop, Pa/m	Total Pressure Drop in Steam Supply Piping, kPa
Vacuum return	30 to 60	7 to 14
101	7	0.4
108	30	0.4 to 1.7
115	30	3.5
135	60	10
170	115	20
205	225	30
310	450	35 to 70
445	450 to 1100	70 to 105
790	450 to 1100	105 to 170
1140	450 to 2300	170 to 210

[a]Equipment, control valves, and so forth must be selected based on delivered pressures.
[b]Subtract 101 to convert to pressure above atmospheric.

The buildings 7A and 7B have the following consumers with the diversity indicated below.

5. STEAM

The calculations were performed considering the boiler outlet pressure at 9.0 barg. Therefore, the high pressure system will send steam from the boiler to equipment which pressure must be at least 8.0 barg.

It was considered the following Pressure Reducing Valves for Building 7A:

- PV-790201A valve set to 4.1 sized for 1/3 of the maximum flow. This pressure setpoint was requested by IPS even though the pressure in the equipment is less than 4.0 barg;
- PV-790201B valve set to 4.0 sized for 2/3 of the maximum flow. This pressure setpoint was requested by IPS even though the pressure in the equipment is less than 4.0 barg;
- PCV-790101 valve set to 2.1 barg to guarantee steam at a pressure of 2.0 barg at the equipment inlet.

It was considered the following Pressure Reducing Valves for Building 7B:

- PCV-790212A valve set to 4.1 sized for 1/3 of the maximum flow. This pressure setpoint was requested by IPS even though the pressure in the equipment is less than 4.0 barg;
- PCV-790212B valve set to 4.1 sized for 2/3 of the maximum flow. This pressure setpoint was requested by IPS even though the pressure in the equipment is less than 4.0 barg;
- PCV-790104 valve set to 2.1 barg to guarantee steam at a pressure of 2.0 barg at the equipment inlet.

The simulation details and results can be seen on item 13.1.

5.1 FLOW RATE AND DIVERSITY

5.1.1 MAXIMUM DIVERSITY

Building 7A

Equipment	TAG	Steam Flow Rate (Kg/h)	Diversity (Y/N)	Steam Flow Rate (Kg/h)	Required Pressure (barg)	Available Pressure (barg)
Re-Heated Water	HX-7A-1	1,103.5	Y	1,103.5	2	2.0
Deaerator	DA-7C-1	150.0	Y	150.0	0.3	0.3
Formulation Vessel TCU	TCU-3903	23.0	Y	23.0	4	3.8
Autoclave	AT-9001	120.0	Y	120.0	4	3.4
Autoclave	AT-9002	120.0	Y	120.0	4	3.2
WFI - Heat Exchanger	TC-6401	16.5	Y	16.5	4	3.7
CIP - Heat Exchanger	TC-7701	25.0	Y	25.0	4	3.7
WFI Still	MES-6401	345.0	Y	345.0	8	8.3
Clean Steam Generation	CSG-6501	1,010.0	Y	1,010.0	8	8.3
Tie-in	-	1,305.9	N	0.0	8.9	8.9
Condensate Pump	PC-7A-1	18.0	Y	18.0	8.2	8.4
TOTAL		**4,236.9**	**kg/h**	**2,931.0**	**kg/h**	

Building 7B

Equipment	TAG	Steam Flow Rate (Kg/h)	Diversity (Y/N)	Steam Flow Rate (Kg/h)	Pressure (barg)	Available Pressure (barg)
Re-Heated Water	HX-7B-1	1280.1	Y	1280.1	2	2.0
Seed Bioreactor	BRE-5401-JL	5.0	N	0.0	4	3.9
Intermediate Bioreactor (TCU)	BRE-5501-JL	9.0	Y	9.0	4	3.8
Production Bioreactor 1 - Jacket Loop	BRE-5601-JL	23.0	Y	23.0	4	3.8

Equipment	TAG	Steam Flow Rate (Kg/h)	Diversity (Y/N)	Steam Flow Rate (Kg/h)	Pressure (barg)	Available Pressure (barg)
Production Bioreactor 2 - Jacket Loop	BRE-5602-JL	23.0	Y	23.0	4	3.8
Production Bioreactor 3 - Jacket Loop	BRE-5603-JL	23.0	Y	23.0	4	3.8
CIP Skid 1	CIP-7701	250.0	Y	250.0	4	3.8
CIP Skid 2	CIP-7702	250.0	Y	250.0	4	3.8
CIP Skid 3	CIP-7703	250.0	Y	250.0	4	3.8
Autoclave	AT-9001	120.0	Y	120.0	4	3.6
WFI Heaters (TC-6401 and TC-9202)	SK-6401	205.0	Y	205.0	4	3.8
Parts Washer	LV-4601	205.0	N	0.0	4	3.7
WFI Still	MES-6401	345.0	Y	345.0	8	8.3
Clean Steam Generation	CSG-6501	1,360.0	Y	1,360.0	8	8.3
Condensate Pump	PC-7B-1	25.0	Y	25.0	8.2	8.4
TOTAL		**4,373.1**	**kg/h**	**4,163.1**	**kg/h**	

Maximum plant steam flow rate required from the boilers = 2,931 + 4,163.1 = 7,094.1 kg/h.

5.2 CONTROL VALVES

Design condition:

Jct	Name	Mass Flow (kg/hr)	P In (barG)	P Out (barG)	dP (bar)
9	7A PV-790201A	102	8.60	4.10	4.46
29	7B PV-790212A	384	8.50	4.10	4.36
30	7B PV-790212B	769	8.40	4.00	4.43
45	7A PV-790201B	203	8.50	4.00	4.52
93	7B PCV-790104	1,280	8.20	2.10	6.16
97	7A PCV-790101	1,104	8.10	2.10	5.99
106	7C PCV-780054	150	8.90	0.31	8.55

5.3 FLOWMETER

Jct	Name	Mass Flow Rate (kg/hr)	P In (barG)	P Out (barG)	dP Total (bar)
50	FIT-790317	1,103.50	8.86	8.56	0.30
51	FIT-790319	4,163.10	8.89	8.59	0.30

Jct	Name	Mass Flow Rate (kg/hr)	P In (barG)	P Out (barG)	dP Total (bar)
52	FIT-790315	304.5	8.95	8.65	0.30
53	FIT-790312	1,373.00	8.90	8.60	0.30

The flowmeters shown below are located in the 7A building.

The FIT-790317 is located in the header that distributes steam to 7A for low pressure equipment.

The FIT-790315 is located in the header that distributes steam to 7A medium pressure equipment.

The FIT-790315 is located in the header that distributes steam to 7A high pressure equipment.

The flowmeter FIT-790319 is located in Building 7B in the header that distributes steam to building 7B.

A vortex-type flow transmitter with pressure drop of 0.3 bar for maximum flow rate was considered. Once the minimum required flow is defined, the pressure drop required for minimum flow will be informed.

The PSV sizing is waiting for pressure regulating valves sizing and selection.

6. CONDENSATE – TWO PHASE

The Condensate Collecting System is separated in 3 headers: one header is for equipment that use plant steam at least 8 barg, the other header is for equipment that use plant steam at around 4 barg and the last one is for equipment that use plant steam at least 2 barg.

The condensate collecting system from the steam traps to condensate pump has two phases, liquid and steam. As 99% of the volume occupied by the piping is the steam flashed phase that represents higher pressure drop in the system, only this phase was considered for sizing the condensate collection system (two-phase).

The sizing of the condensate header was performed considering the equipment in operation as shown below. The same criterion used for Industrial Steam was considered, in which a study of simultaneity of the equipment was carried out.

To size the Flash steam generated, it was considered the pressure before the steam trap and the pressure at the condensate pump. The calculation for Flash Steam is:

$$Q_{flashsteam} = [(E_{po} - E_{atm}) / (E_{va} - E_{atm})] \times Q_{co}$$

Where:

• Enthalpy of the saturated condensate at the pressure of op. = E_{po} (kJ / kg)

• Enthalpy of condensate saturated at 0 bar = E_{atm} (kJ / kg)

• Enthalpy of steam at 0 bar = E_{va} (kJ / kg)

- Condensate flow rate = Q_{co} (kg / h)
- Flash steam flow rate = $Q_{flashsteam}$ (kg / h)

The pressure at the condensate pump is 0 barG and the maximum diversity is shown below:

Building 7A

Equipment	TAG	Condensate Flow Rate (Two phase) (Kg/h)	Diversity (Y/N)	Condensate Flow Rate (Two phase) (Kg/h)	Pressure before the steam trap (barG)	Flash Steam Flow Rate (Kg/h)	Pumped Condensate Flow Rate (Kg/h)
Re-Heated Water	HX-7A-1	1,103.5	Y	1,103.5	1.0	42.3	1,061.2
Tie-in	-	1.371.4	N	0.00	8.6	0.0	0.0
TOTAL		**2,475.0**		**1,103.5**	**-**	**42.3**	**1,061.2**

Equipment	TAG	Condensate Flow Rate (Two phase) (Kg/h)	Diversity (Y/N)	Condensate Flow Rate (Two phase) (Kg/h)	Pressure before the steam trap (barG)	Flash Steam Flow Rate (Kg/h)	Pumped Condensate Flow Rate (Kg/h)
Formulation Vessel TCU	TCU-3903	23.0	Y	23.0	3.0	1.9	21.1
Autoclave	AT-9001	120.0	Y	120.0	3.0	9.9	110.1
Autoclave	AT-9002	120.0	Y	120.0	3.0	9.9	110.1
WFI - Heat Exchanger	TC-6401	16.5	Y	16.5	3.0	1.4	15.1
CIP - Heat Exchanger	TC-7701	25.0	Y	25.0	3.0	2.1	22.9
TOTAL		**304.5**		**304.5**	**-**	**25.1**	**279.4**

Equipment	TAG	Condensate Flow Rate (Two phase) (Kg/h)	Diversity (Y/N)	Condensate Flow Rate (Two phase) (Kg/h)	Pressure before the steam trap (barG)	Flash Steam Flow Rate (Kg/h)	Pumped Condensate Flow Rate (Kg/h)
Clean Steam Generation	CSG-6501	1,010.0	Y	1,010.0	7.0	135.2	874.8
WFI Still	MES-6401	345.0	Y	345.0	7.0	46.2	298.8

Equipment	TAG	Condensate Flow Rate (Two phase) (Kg/h)	Diversity (Y/N)	Condensate Flow Rate (Two phase) (Kg/h)	Pressure before the steam trap (barG)	Flash Steam Flow Rate (Kg/h)	Pumped Condensate Flow Rate (Kg/h)
Deaerator	DA-7C-1	150.0	Y	150.0	7.0	20.1	129.9
TOTAL		**1,505.0**		**1,505.0**	**-**	**201.5**	**1,303.5**

Building 7B

Equipment	TAG	Condensate Flow Rate (Two phase) (Kg/h)	Diversity (Y/N)	Condensate Flow Rate (Two phase) (Kg/h)	Pressure before the steam trap (barG)	Flash Steam Flow Rate (Kg/h)	Pumped Condensate Flow Rate (Kg/h)
Re-Heated Water	HX-7B-1	1,280.1	Y	1,280.1	1.0	49.1	1,231.0
TOTAL		**1,280.1**		**1,280.1**	**-**	**49.1**	**1,231.0**

Equipment	TAG	Condensate Flow Rate (Two phase) (Kg/h)	Diversity (Y/N)	Condensate Flow Rate (Two phase) (Kg/h)	Pressure before the steam trap (barG)	Flash Steam Flow Rate (Kg/h)	Pumped Condensate Flow Rate (Kg/h)
Seed Bioreactor	BRE-5401-JL	5.0	N	0.00	3.0	0.0	0.0
Intermediate Bioreactor (TCU)	BRE-5501-JL	9.0	Y	9.0	3.0	0.7	8.3
Production Bioreactor 1 - Jacket Loop	BRE-5601-JL	23.0	Y	23.0	3.0	1.9	21.1
Production Bioreactor 2 - Jacket Loop	BRE-5602-JL	23.0	Y	23.0	3.0	1.9	21.1
Production Bioreactor 3 - Jacket Loop	BRE-5603-JL	23.0	Y	23.0	3.0	1.9	21.1
CIP Skid 1	CIP-7701	250.0	Y	250.0	3.0	20.6	229.4
CIP Skid 2	CIP-7702	250.0	Y	250.0	3.0	20.6	229.4
CIP Skid 3	CIP-7703	250.0	Y	250.0	3.0	20.6	229.4
Autoclave	AT-9001	120.0	Y	120.0	3.0	9.9	110.1
WFI Heaters (TC-6401 and TC-9202)	SK-6401	205.0	Y	205.0	3.0	16.9	188.1
Parts Washer	LV-4601	205.0	N	0.00	3.0	0.0	0.0
TOTAL		**1,363.0**		**1,153.0**	**-**	**95.1**	**1,057.9**

Equipment	TAG	Condensate Flow Rate (Two phase) (Kg/h)	Diversity (Y/N)	Condensate Flow Rate (Two phase) (Kg/h)	Pressure before the steam trap (barG)	Flash Steam Flow Rate (Kg/h)	Pumped Condensate Flow Rate (Kg/h)
WFI Still	MES-6401	345.0	Y	345.0	7.0	46.2	298.8
Clean Steam Generation	CSG-6501	1,360.0	Y	1,360.0	7.0	182.1	1,177.9
TOTAL		**1,705.0**		**1,705.0**	**-**	**228.3**	**1,476.7**

The non pumped rising lines should be kept as short as possible and fitted with a non-return valve to stop condensate falling back down to the trap. For these lines, head losses related to the liquid column of the rising length were considered. It was indicated as general component in the simulation.

The simulation details and the results can be seen on item 13.2.

7. STEAM TRAPS

The steam traps were sized based on the pressure drop between the upstream pressure (steam line) and the downstream pressure (condensate line).

Some of the steam traps are located below the condensate collection line, for this reason a head loss was added in the software. This value is found in the last column of the tables below.

Building 7A

Line TAG	Diameter	Condensate Flow Rate (Kg/h)	Upstream Pressure (barG)	Downstream Pressure (barG)	Pressure Drop (bar)	Flash Steam Flow Rate (Kg/h)	Notes
C4B-930245-CS1-HC	3/4 inch	8.0	3.6	0.51	3.09	0.78	1
C8B-930312-CS2-HC	3/4 inch	15.0	8.4	0.47	7.93	2.28	1
C8B-930309-CS2-HC	1 inch	10.0	8.6	0.48	8.12	1.52	1
C8B-930310-CS2-HC	3/4 inch	50.0	9.0	0.43	8.57	7.59	1
C8B-930308-CS2-HC	3/4 inch	10.0	8.6	0.48	8.12	1.52	1
C8B-930319-CS2-HC	3/4 inch	50.0	8.9	0.07	8.83	7.59	
C8B-930320-CS2-HC	3/4 inch	50.0	8.9	0.07	8.83	7.59	
C8B-930306-CS2-HC	3/4 inch	10.0	8.1	0.06	8.04	1.52	
C8B-930307-CS2-HC	1 inch	10.0	8.1	0.06	8.04	1.52	
C1B-930111-CS1-HC	3/4 inch	13.0	2.1	0.04	2.06	0.82	
C4B-930243-CS1-HC	3/4 inch	8.0	3.4	0.07	3.33	0.78	
C4B-930241-CS1-HC	3/4 inch	8.0	4.0	0.02	3.98	0.78	
C4B-930240-CS1-HC	3/4 inch	8.0	4.0	0.02	3.98	0.78	
C8B-930311-CS2-HC	3/4 inch	50.0	8.9	0.02	8.88	7.59	
C8B-930314-CS2-HC	3/4 inch	10.0	9.0	0.03	8.97	1.52	
C8B-930313-CS2-HC	3/4 inch	10.0	9.0	0.03	8.97	1.52	

Line TAG	Diameter	Condensate Flow Rate (Kg/h)	Upstream Pressure (barG)	Downstream Pressure (barG)	Pressure Drop (bar)	Flash Steam Flow Rate (Kg/h)	Notes
C1B-930110-CS1-HC	3/4 inch	13.0	2.1	0.04	2.06	0.82	
C8B-930323-CS2-HC	3/4 inch	10.0	8.6	0.48	8.12	1.52	1
C4B-930216-CS1-HC	3/4 inch	8.0	4.0	0.02	3.98	0.78	

1- The downstream pressure is higher because of the liquid column, the trap is below the condensate line.

<u>Building 7B</u>

Line TAG	Diameter	Condensate Flow Rate (Kg/h)	Upstream Pressure (barG)	Downstream Pressure (barG)	Pressure Drop (bar)	Flash Steam Flow Rate (Kg/h)	Notes
C8B-930346-CS1-HC	3/4 inch	20.0	8.4	0.49	7.91	3.04	1
C4B-930272-CS1-HC	3/4 inch	8.0	3.9	0.46	3.44	0.78	1
C8B-930341-CS1-HC	3/4 inch	50.0	8.6	0.04	8.56	7.59	
C8B-930345-CS2-HC	3/4 inch	10.0	8.5	0.04	8.46	1.52	
C8B-930344-CS2-HC	1 inch	10.0	8.5	0.04	8.46	1.52	
C4B-930271-CS1-HC	3/4 inch	8.0	3.6	0.02	3.58	0.78	
C8B-930340-CS2-HC	3/4 inch	50.0	8.6	0.05	8.55	7.59	
C8B-930343-CS2-HC	3/4 inch	10.0	8.3	0.05	8.25	1.52	
C1B-930113-CS1-HC	3/4 inch	19.0	2.1	0.02	2.08	1.20	
C4B-930274-CS1-HC	3/4 inch	8.0	3.9	0.91	2.99	0.78	1
C8B-930347-CS1-HC	3/4 inch	20.0	8.4	0.03	8.37	3.04	
C8B-930342-CS2-HC	1 inch	10.0	8.3	0.05	8.25	1.52	
C1B-930112-CS1-HC	3/4 inch	19.0	2.1	0.02	2.08	1.20	
C4B-930273-CS1-HC	3/4 inch	8.0	3.8	0.90	2.90	0.78	1
C8B-930335-CS2-HC	3/4 inch	50.0	8.6	0.06	8.54	7.59	
C8B-930334-CS2-HC	3/4 inch	50.0	8.9	0.06	8.84	7.59	
C8B-930322-CS2-HC	3/4 inch	10.0	8.4	0.04	8.36	1.52	
C4B-930217-CS1-HC	3/4 inch	12.0	4.0	0.02	3.98	1.18	
C4B-930270-CS1-HC	3/4 inch	8.0	4.0	0.02	3.98	0.78	

1- The downstream pressure is higher because of the liquid column, the trap is below the condensate line.

For the lines indicated above, thermodynamic steam traps with the pressure drops indicated in this same table were considered.

8. PUMPED CONDENSATE

For the Condensate Pump Skid calculation, it was considered a Spirax Sarco equipment (Pivotrol). The recovered condensate will be directed to the deaerator in the Boiler House through the condensate pump that uses plant steam as the driving fluid.

The exhaust steam will be directed to the outside area of the building by a vent and the condensate will be pumped into the condensate collecting system.

The deaerator will be supplied by two headers: one comes from the bioreactors jacket loops (the supplier's package includes a pump trap) and the other comes from the condensate pump skid in buildings 7A and 7B and from the Tie-in.

The pumped condensate lines are sized for speed up to 2.0 m/s. These lines will not have two phases like the low, medium and high-pressure steam condensate lines.

The simulation details and results can be seen on item 13.3.

The maximum diversity is shown in items below:

8.1 BUILDING 7A

Equipment	TAG	Steam Flow Rate (Kg/h)	Flash Steam Flow Rate (Kg/h)	Condensate Total Flow Rate (Kg/h)	Diversity (Y/N)	Condensate Diversity Flow Rate (Kg/h)
Re-Heated Water	HX-7A-1	1,103.5	42.3	1,061.2	Y	1,061.2
Deaerator	DA-7C-1	150.0	20.1	129.9	Y	129.9
Formulation Vessel TCU	TCU-3903	23.0	1.9	21.1	Y	21.1
Autoclave	AT-9001	120.0	9.9	110.1	Y	110.1
Autoclave	AT-9002	120.0	9.9	110.1	Y	110.1
WFI - Heat Exchanger	TC-6401	16.5	1.4	15.1	Y	15.1
CIP - Heat Exchanger	TC-7701	25.0	2.1	22.9	Y	22.9
WFI Still	MES-6401	345.0	46.2	298.8	Y	298.8
Clean Steam Generation	CSG-6501	1,010.0	135.2	874.8	Y	874.8
Tie-in	-	1,305.9	194.3	1,111.6	N	0
TOTAL		**4,218.9**	**463.3**	**3,755.6**		**2,644.1**

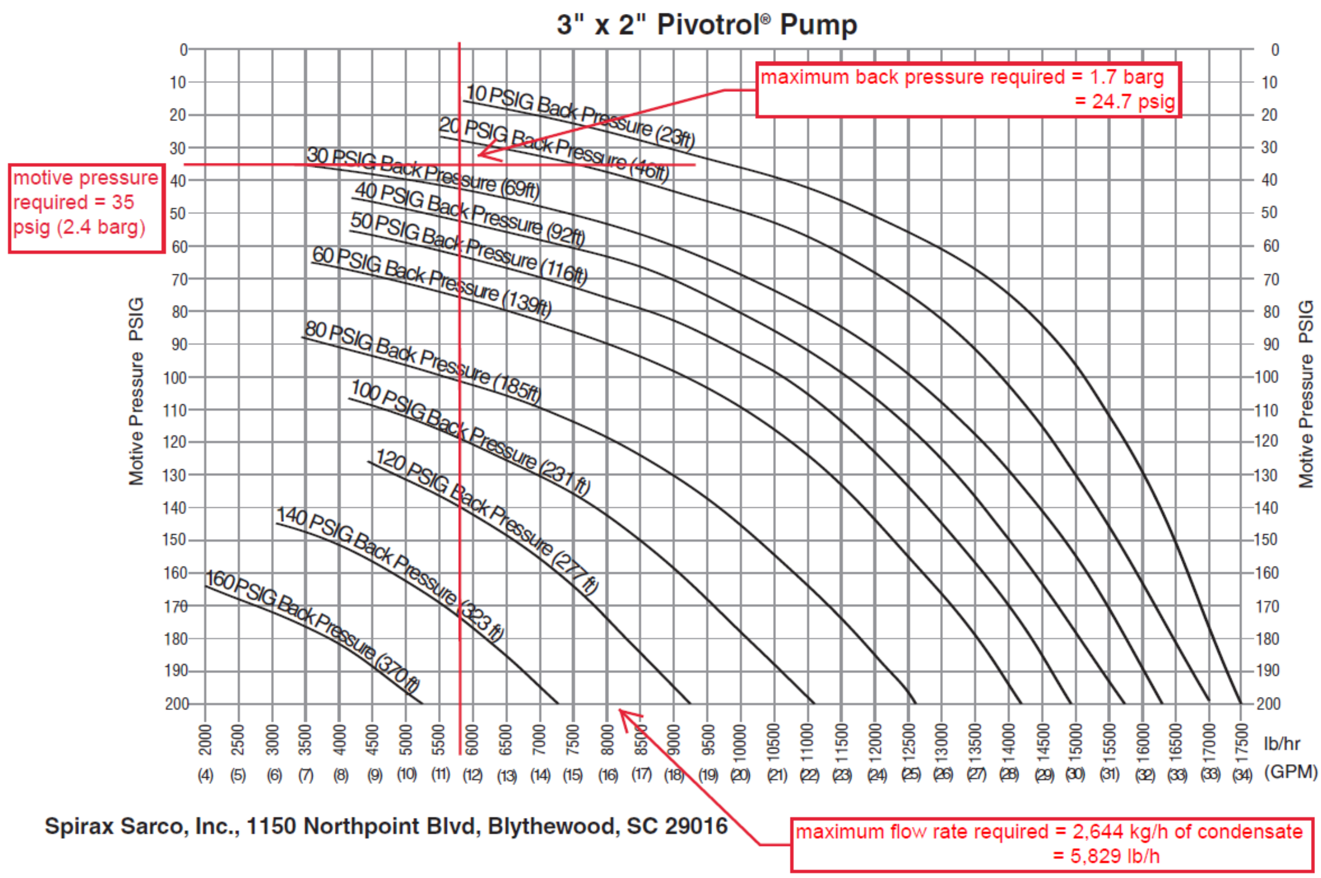
The condensate pump skid for Building 7A was sized to pump the maximum flow rate of 2,644.1 kg/h (5,829 lb/h) of condensate.

This pump was sized, calculating the discharge pressure required for the pump with the maximum flow rate required.

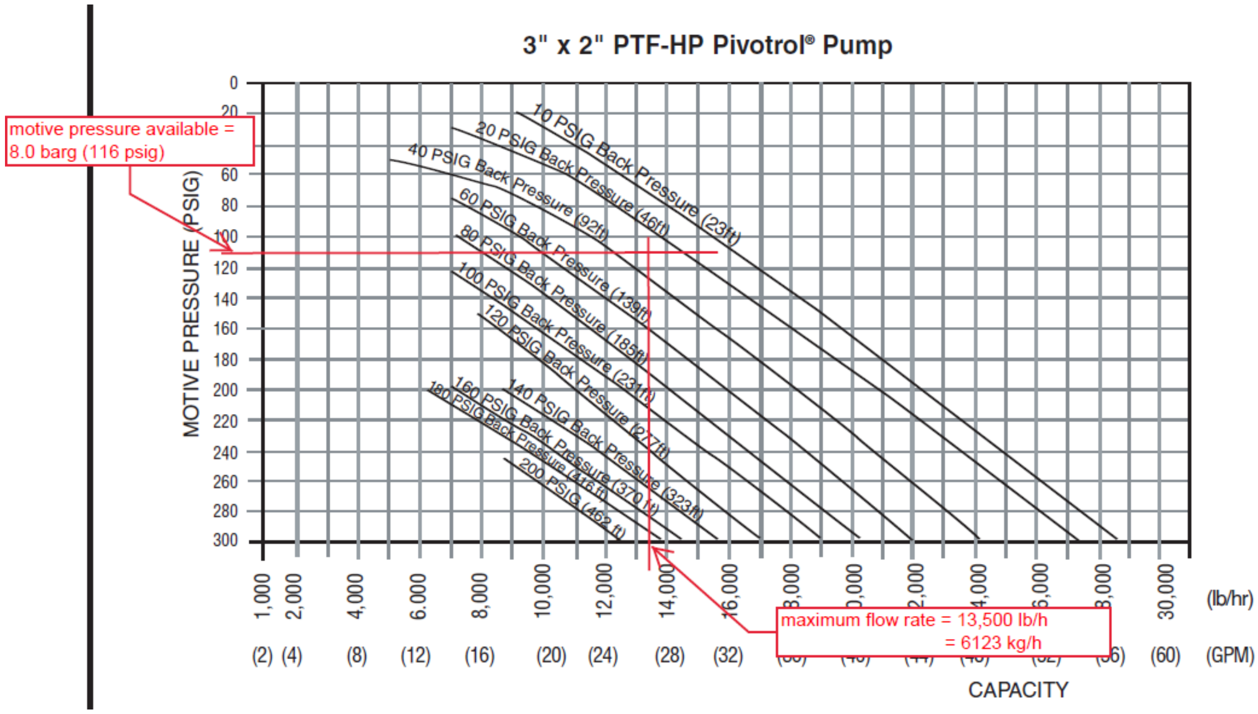
According to Item 13.3, the discharge pressure required is 1.7 barg (24.7 psig).

As shown in the graph below, the minimum pressure required for the motive fluid is 35 psig (2.4 barg).

TESSLER engenharia / ips	Takeda / Hemobrás	
DOC NR: **PRD-MEC-CLC-001**	CLIENT NR: -	
TITLE: PLANT STEAM / CONDENSATE CALCULATION		SHEET 14 of 21
		REV.: **0**



It is considered a line of high pressure steam (at least 8.0 barg) as motive fluid for this pump that results in a maximum capacity to be pumped of 6,123 kg/h (13,500 lb/h) of condensate (see graph below).



It was selected the pump 3”x2” PIVOTROL with 2 pumps installed.

8.2 BUILDING 7B – BIOREACTORS JACKET LOOP

It was considered a pump trap to be supplied in each equipment below. Each pump trap needs the capacity indicated in the column Condensate Flow Rate Pumped.

Equipment	TAG	Steam Flow Rate (Kg/h)	Flash Steam Flow Rate (Kg/h)	Condensate Total Flow Rate (Kg/h)	Diversity (Y/N)	Condensate Flow Rate Pumped (Kg/h)
Seed Bioreactor	BRE-5401-JL	5.0	0.4	4.6	N	0
Intermediate Bioreactor (TCU)	BRE-5501-JL	9.0	0.7	8.3	Y	8.3
Production Bioreactor 1 - Jacket Loop	BRE-5601-JL	23.0	1.9	21.1	Y	21.1
Production Bioreactor 2 - Jacket Loop	BRE-5602-JL	23.0	1.9	21.1	Y	21.1
Production Bioreactor 3 - Jacket Loop	BRE-5603-JL	23.0	1.9	21.1	Y	21.1
TOTAL		**83.0**	**6.8**	**76.2**		**71.6**

As these skids are near each other, it was considered only one collecting header to recovery the condensate to deaerator, that was sized with a diameter of 1" and the back pressure required for each pump was calculated as shown in Item 13.3. The table below shows the back pressure and flow rate required for these skids.

Equipment	TAG	Flow Rate Required (Kg/h)	Diversity (Y/N)	Maximum Flow Rate Required (Kg/h)	Back Pressure Required (barg)
Seed Bioreactor	BRE-5401-JL	4.6	N	0	1.2
Intermediate Bioreactor (TCU)	BRE-5501-JL	8.3	Y	8.3	1.2
Production Bioreactor 1 - Jacket Loop	BRE-5601-JL	21.1	Y	21.1	1.2
Production Bioreactor 2 - Jacket Loop	BRE-5602-JL	21.1	Y	21.1	1.2
Production Bioreactor 3 - Jacket Loop	BRE-5603-JL	21.1	Y	21.1	1.2
	TOTAL	**76.2**	**-**	**71.6**	-

8.3 BUILDING 7B

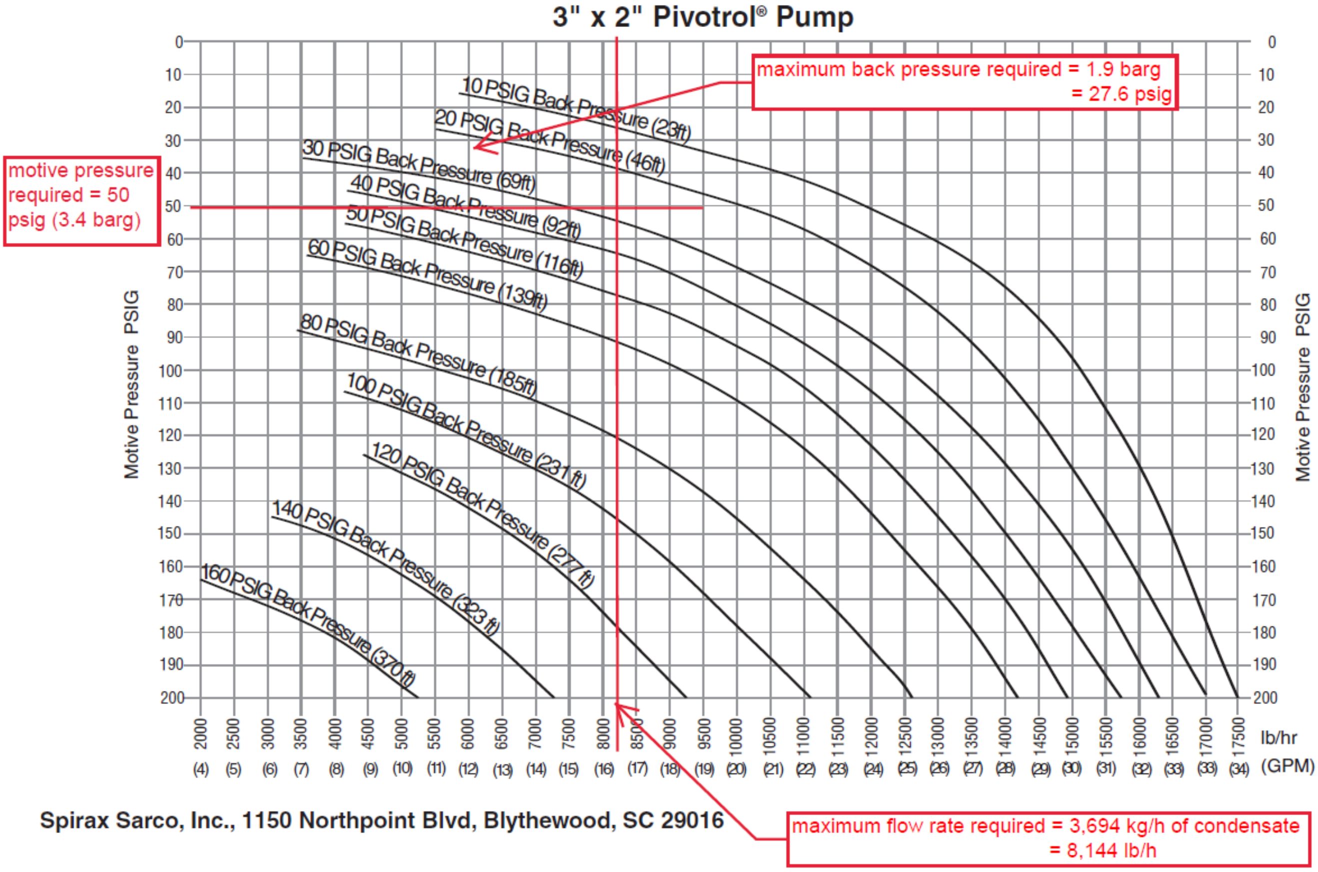
Equipment	TAG	Steam Flow Rate (Kg/h)	Flash Steam Flow Rate (Kg/h)	Condensate Total Flow Rate (Kg/h)	Diversity (Y/N)	Condensate Diversity Flow Rate (Kg/h)
Re-Heated Water	HX-7B-1	1,280.1	49.1	1231.0	Y	1231.0
CIP Skid 1	CIP-7701	250.0	20.6	229.4	Y	229.4
CIP Skid 2	CIP-7702	250.0	20.6	229.4	Y	229.4
CIP Skid 3	CIP-7703	250.0	20.6	229.4	Y	229.4
Autoclave	AT-9001	120.0	9.9	110.1	Y	110.1
WFI Still	MES-6401	345.0	46.2	298.8	Y	298.8
Clean Steam Generation	CSG-6501	1,360.0	182.1	1177.9	Y	1177.9
WFI Heaters (TC-6401 and TC-9202)	SK-6401	205.0	16.9	188.1	Y	188.1
Parts Washer	LV-4601	205.0	16.9	188.1	N	0
TOTAL		**4,265.1**	**383.0**	**3,882.1**		**3,694.0**

The condensate pump skid for Building 7B was sized to pump the maximum flow rate of 3,694 kg/h (8,144 lb/h) of condensate.

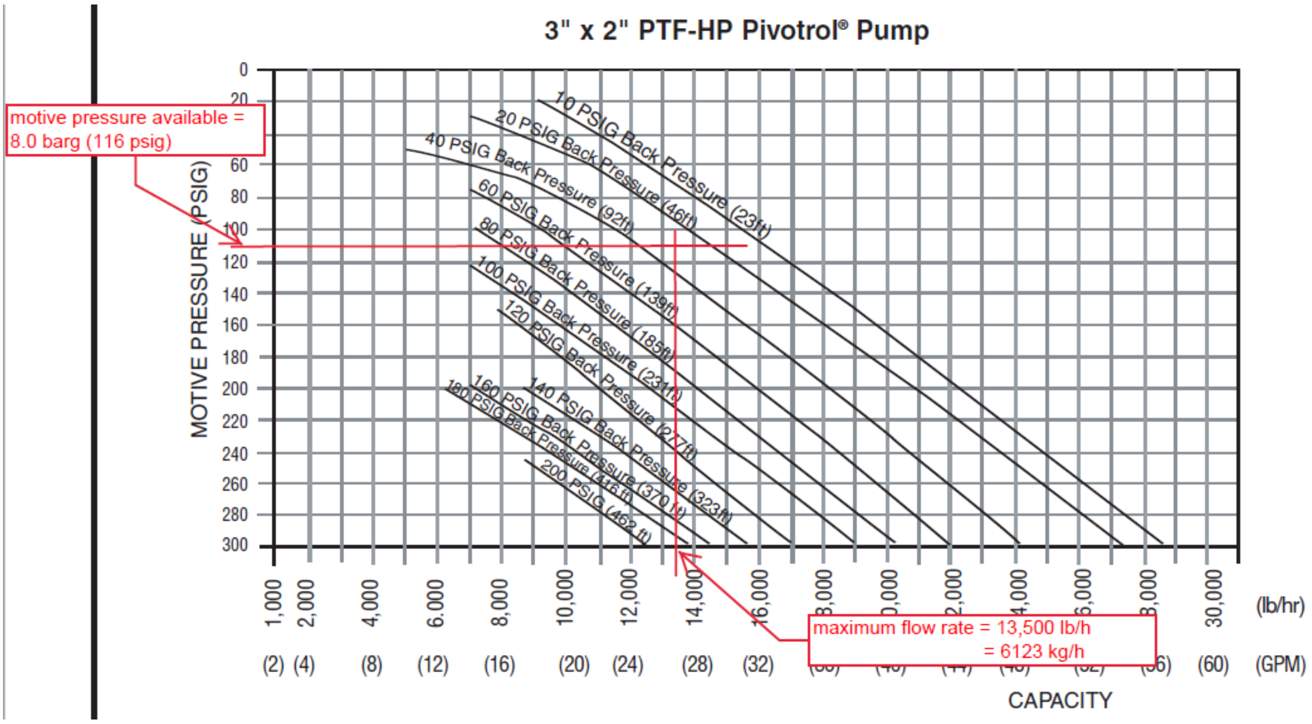
This pump was sized, calculating the discharge pressure required for the pump with the maximum flow rate required.

According to item 12.3, the discharge pressure required is 1.9 barg (27.6 psig).

As shown in the graph below, the minimum pressure required for the motive fluid is 50 psig (3.4 barg).



It is considered a line of high pressure steam (at least 8.0 barg) as motive fluid for this pump that results in a maximum capacity to be pumped of 6,123 kg/h (13,500 lb/h) of condensate (see graph below).



9. SOFTENED WATER (MAKE-UP)

The water softening system has a capacity of 10 m³/h (166.7 LPM) according to supplier information. This full capacity will be utilized during the Boiler´s start-up.

Considering the maximum flow rate of the boilers of 8,400 kg/h and the water softened at 25°C and density 997.08 kg/m³, we have:

$$\frac{8{,}400}{997.08} = 8.42\ m^3/h$$

Thus, the equipment meets the required flow for the Boiler's start-up.

For the maximum operating condition, in which the make-up water is replaced according to the system's flashed steam, there are:

Building	Flash Steam Flow Rate (Kg/h)
7A	268,97
7B	372,53
TOTAL	**641,50**

Considering the water softened at 25°C and density 997.08 kg/m³, we have:

$$\frac{641.5}{997.08} = 0.6434\frac{m^3}{h} = 10.7\ LPM$$

10. NATURAL GAS CALCULATION FOR THE BOILERS

The fuel used for the boilers is natural gas. Each boiler requires the following consumption:

- Flow rate required = 290 Nm³/h (informed by supplier)
- Pressure required at boiler inlet = 300 mbarg (informed by supplier)
- Pressure required at tie-in = 1,0 barg
- Two boilers operating at the same time

Based on the information above, the lines to feed the boilers were calculated and the results are shown in item 13.4.

Considering the distance between the Main Entrance and the Tie-in of natural gas around of 612 meters, the pressure required for the natural gas is 1.35 barg, with a maximum flow rate of 580 Nm³/h.

11. BOILER WATER CALCULATION

The boilers are fed by the pumps P-7C-1; P-7C-2 and P-7C-3.

According to supplier´s information, these pumps requires the following conditions:

- Flow rate = 12.1 m³/h (informed by supplier)
- Pressure required at boiler inlet = 15 barg (informed by supplier)
- Pressure required at deaerator = 0.3 barg (informed by supplier)

Based on these information, the pump calculation is shown in item 12.5.

The pumps will be supplied with the boilers, and they need to have the following characteristics:

Flow rate required = 12.1 m³/h

Head = 152 mlc

12. BLOWDOWN CALCULATION

According to the vendor, the blowdown flow rate is equivalent to 20% of the total boilers capacity.

$$4{,}200 \times 20\% = 840\frac{kg}{h}$$

Thus, a 2.1/2" line was considered going from each boiler to the blowdown tank.

Also, the industrial water for the blowdown tank was calculated.

For 3 boilers, the blowdown flow rate is:

$$840 \times 3 = 2520\frac{kg}{h}$$

Using the calculation for Flash Steam on item 6, the condensate flow rate from the boilers is 2,136.15 kg/h at 100ºC and it requires cooling to 45ºC with industrial water at 25ºC.

2,136.15	kg/h	-	100	ºC
X	kg/h	-	25	ºC
2,136.15+X	kg/h	-	45	ºC

So the calculation is:

$$2{,}136.15 \times 100 + X \times 25 = (2{,}136.15 + X) \times 45$$

$$X = 5{,}874.4\frac{kg}{h} @ 25ºC$$

$$Density = 997.1\ kg/m^3$$

Thus, the industrial water required for the blowdown tank is 6.0 m³/h.

13. RESULTS

13.1 STEAM CALCULATION

13.1.1 SIMULATION 1

In this scenario, the maximum simultaneous flow rate was calculated.

1 VR MAX SIMULTANEITY.pdf   1 OUTPUT MAX SIMULTANEITY.pdf

13.1.2 SIMULATION 2

In this scenario, the equipment that were not operating on scenario 1 were opened and calculated.

2 OUTPUT STEAM.pdf   2 VR STEAM.pdf

13.1.3 SIMULATION 3

In this scenario, the tie-in was opened and the boilers were calculated within its maximum flow rate of 8,400.0 kg/h.

3 OUTPUT BOILER 8400 KG-H.pdf   3 VR BOILER 8400 KG-H.pdf

13.2 CONDENSATE (TWO PHASE) CALCULATION

VR CONDENSATE.pdf   OUTPUT CONDENSATE.pdf

13.3 PUMPED CONDENSATE CALCULATION

OUTPUT PUMP COND.pdf   VR PUMP COND.pdf

13.4 NATURAL GAS CALCULATION

OUTPUT NATURAL GAS.pdf   VISUAL REPORT NATURAL GAS.pdf

13.5 BOILER WATER CALCULATION

VISUAL REPORT BOILER WATER.pdf

OUTPUT BOILER WATER.pdf