DOC NUMBER: **569-DB7B-PRO-400-004**	CLIENT NUMBER: **PRD-MEC-CLC-004**
CLIENT: **TAKEDA**	
PROJECT **BURITI EPCMV PROJECT**	

CHILLED GLYCOL AND CHILLED WATER SYSTEM CALCULATION (PROCESS)

0	18AUG2021	ISSUED FOR CONSTRUCTION	JRM	CCO	MSS
C	17MAY2021	90% DD ISSUE	LID	CCO	MSS
B	16OCT2020	FINAL BD ISSUE	JRM	LFF	MSS
A	28AUG2020	90% BD ISSUE	JRM	LFF	MSS
REV	DATE	DESCRIPTION	EXEC	CHECK	APPROV.

1. REVISION HISTORY 4
2. PURPOSE 4
3. REFERENCE 4
4. BASIC DATA AND PREMISES 4
5. CALCULATION 6
5.1 CHILLED water loop 1 (4 °C) – chilled water loop 2 (6 °C) 6
5.1.1 Loop 2 (6 °C) 6
5.1.1.1 Flow rates Required – Loop 2 (6 °C) 6
5.1.1.2 Balancing Valves – Loop 2 (6 °C) 11
5.1.1.3 Process Equipment – Loop 2 (6 °C) 12
5.1.1.4 Pump Capacity – Loop 2 (6 °C) 13
5.1.1.4.1 Design Condition 13
5.1.1.4.2 Maximum Operating Condition 13
5.1.1.4.3 Intermediate Operating Condition 13
5.1.1.4.4 Minimum Operating Condition 13
5.1.2 Loop 1 (4 °C) 14
5.1.2.1 Flow rates Required – Loop 1 (4 °C) 14
5.1.2.2 Balancing Valves – Loop 1 (4 °C) 21
5.1.2.3 Process Equipment (4 °C) 23
5.1.2.4 Pump Capacity – Loop 1 (4 °C) 24
5.1.2.4.1 Design Condition 24
5.1.2.4.2 Maximum Operating Condition 25
5.1.2.4.3 Intermediate Operating Condition 25
5.1.2.4.4 Minimum Operating Condition 25
5.1.2.5 Chiller Capacity 25
5.1.2.6 Buffer Tank 26
5.2 CHILLED Propylene Glycol loop 1 (0 °C) – chilled water loop 2 (4 °C) 27
5.2.1 Loop 2 (4 °C) 27
5.2.1.1 Flow rates Required – Loop 2 (4 °C) 27
5.2.1.2 Balancing Valves – Loop 2 (4 °C) 31
5.2.1.3 Process Equipment – Loop 2 (4 °C) 32
5.2.1.4 Pump Capacity – Loop 2 (4 °C) 33
5.2.1.4.1 Design Condition 33
5.2.1.4.2 Maximum Operating Condition 34
5.2.1.4.3 Intermediate Operating Condition 34
5.2.1.4.4 Minimum Operating Condition 34
5.2.2 Loop 1 (0 °C) 34
5.2.2.1 Flow rates Required – Loop 1 34
5.2.2.2 Balancing Valves – Loop 1 (0 °C) 41
5.2.2.3 Process Equipment (0 °C) 42
5.2.2.4 Pump Capacity – Loop 1 (0 °C) 43
5.2.2.4.1 Design Condition 44
5.2.2.4.2 Maximum Operating Condition 44
5.2.2.4.3 Intermediate Operating Condition 44
5.2.2.4.4 Minimum Operating Condition 44
5.2.2.5 Chiller Capacity 45

5.2.2.6 Buffer Tank 45
5.3 heat exchanger (loop 1-loop 2) 45
6. ATTACHMENTS 46
6.1 Schematics for CHILLED water loop 1 (4 °C) – chilled water loop 2 (6 °C) 46
6.1.1 Design Condition – Loop 1 – CW (4 °C) 46
6.1.2 Design Condition – Loop 2 – CW (6 °C) 46
6.1.3 Maximum Operating Condition 46
6.1.4 Intermediate Operating Condition 47
6.1.5 Minimum Operating Condition 47
6.2 Schematics for CHILLED Propylene Glycol loop 1 (0 °C) – chilled water loop 2 (4 °C) 47
6.2.1 Design Condition – Loop 1 – GLY (0 °C) 47
6.2.2 Design Condition – Loop 2 – CW (4 °C) 47
6.2.3 Maximum Operating Condition 47
6.2.4 Intermediate Operating Condition 47
6.2.5 Minimum Operating Condition 47
6.3 results 47
6.3.1 Loop 1 (Chilled Water – 4 °C) 47
6.3.2 Loop 2 (Chilled Water – 6 °C) 48
6.3.3 Loop 1 (Chilled Propylene Glycol – 0 °C) 49
6.3.4 Loop 2 (Chilled Water – 4 °C) 49
7. PUMPS SELECTED 50
7.1 LOOP 1 51
7.2 LOOP 2 53

1. REVISION HISTORY

Rev	Reason For Change
A	90% BD ISSUE
B	FINAL BD ISSUE
C	FLOW RATES AND DIAMETERS HAVE BEEN UPDATED. AS WELL AS CALCULATIONS AND EQUIPMENT. ALL DATA WERE UPDATED ACCORDING TO IPS INFORMATION
0	ISSUED FOR CONSTRUCTION

2. PURPOSE

This document aims to establish the main characteristics for sizing the Chilled Water/Glycol System for Building 7B (Bulk Drug Substance - BDS), intended to Buriti Project, located at Hemobrás site in Goiana - Pernambuco state, Brazil.

The calculation will be adjusted according to the PID during detailed design.

3. REFERENCE

The following documents were used as reference:

Item	Number	Title
1	-	B07B Process Equipment List
2	7B-M-4-5-40	Drug product - Chilled Water Generation Diagram
3	-	BDS – Clean Utility Diversity Evaluation_BD
4	7B-M-0-5-44	Drug Substance – Chilled Water Generation System Loop 1
5	7B-M-0-5-45	Drug Substance – Chilled Water Distribution System – Loop1 (1/3)
6	7B-M-0-5-52	Drug Substance – Chilled Water Distribution System – Loop1 (2/3)
7	7B-M-0-5-53	Drug Substance – Chilled Water Distribution System – Loop2 (1/2)
8	7B-M-0-5-54	Drug Substance – Chilled Water Distribution System – Loop2 (2/2)
9	7B-M-0-5-51	Drug Substance – Chilled Water Distribution System – Loop1 (3/3)

4. BASIC DATA AND PREMISES

The Chilled Water/Glycol Distribution System for Process Equipment consists of 2 primary pumps (one operating and the other stand-by), 2 process chillers (one operating and the other stand-by), 2 secondary pumps (one operating and the other stand-by) at Loop 1 and 2 secondary pumps (one operating and the other stand-by) and 1 heat exchanger at Loop 2.

The following philosophy distinguishes Chilled Water Loop 1 from Chilled Water Loop 2:

Loop 1: Current design is for chilled water service. There is a possibility for future implementation of a glycol mixture to replace chilled water. To represent this on the P&IDs, the service type for the lines on this loop will be GW0S/GW0R.

Loop 2: Current design for chilled water service. There is no possibility for future implementation of a glycol mixture to replace chilled water. To represent this on the P&IDs, the service type for the lines on this loop will be CW1S/CW1R.

Users allocated to loop 2 include the bioreactor jacket loop skids and clean utility systems.

Users allocated to loop 1 include all process systems (minus the bioreactor jacket loop skids). Rationale for Jacket Loops: The bioreactor jacket loops must drain chilled water in their recirculation loop every batch to be replaced with plant steam. It was determined to be undesirable to implement this practice with a glycol solution due to the cost of replacing discarded glycol. Therefore, all jacket loop skids are serviced by loop 2.

Rationale for Process Users: The current low temperature requirement for process vessels is 5 degrees Celsius. This can be accommodated by chilled water. However, if there is a future design change to meet a lower temperature (i.e., 2 degrees Celsius), then a glycol mixture (lower freezing point) will need to be used. Therefore, the process vessels are serviced by loop 1.

Rationale for Clean Utility Systems: The clean utility systems do not share the potential future requirement to achieve a lower temperature than 5 degrees Celsius. Therefore, the clean utilities are serviced by loop 2. While it would not have been inappropriate to place these systems on loop 1, it was desirable to more evenly distribute the load requirements across the two loops.

Based on that, the chilled water system will have the following conditions:

Loop 1 – chilled water supply = 4°C / chilled water return (glycol) = X°C

Loop 2 – chilled water supply = 6°C / chilled water return = X°C

If this temperature will not sufficient to keep the process working correctly, the installation shall be prepared to operate with Propylene Glycol at the first Loop.

In this case, the chilled water system will have the following conditions:

Loop 1 – chilled water supply (glycol) = 0°C / chilled water return (glycol) = X°C

Loop 2 – chilled water supply = 4°C / chilled water return = X°C

The calculations that considered the system operating with Chilled Water at the two loops, have a temperature of 4 °C at loop 1 and 6 °C at loop 2 and with Propylene Glycol at loop 1 and Chilled Water at loop 2, have temperature of 0 °C and 4 °C, respectively.

For Propylene Glycol calculation, the following properties were considered:

Density = 1.015 kg/m³

Viscosity = 2.68 centipoise

Vapor Pressure = 0,00964 bar

For system sizing, the following conditions were considered:

- DESIGN CONDITION – Sizing Criterion for chillers, lines, valves and pumps to define the Nominal Capacity of each equipment simultaneity of the process equipment and an oversizing of 24 % (Thermal Load), where the excess of flow rate is diverted to a future expansion (tie-in). The oversizing was considered at Loop 1 and at Loop 2 individually.
- MAXIMUM OPERATING CONDITION – The same simultaneity of the Design Condition, without the oversizing.

- INTERMEDIATE OPERATING CONDITION – Equipment out of the diversity in the Maximum Operating Condition.

  MINIMUM OPERATING CONDITION – The process equipment without consumption. The secondary pump operates only for the chilled water recirculation (minimum flow rate).

It was considered the installation of 2 chillers with nominal capacity of 300 TR each one, where 1 chiller is operating and the other as stand-by.

It was estimated an available pressure drop of 1.0 bar for each process equipment and valve control (considering Propylene Glycol mass flow rate).

It was estimated an available pressure drop of 1.0 bar for the chiller for design condition (considering Propylene Glycol mass flow rate).

It was estimated an available pressure drop of 1.0 bar for the Heat Exchanger (HX-7B-2) for design condition (considering Propylene Glycol mass flow rate).

To guarantee a balancing and a good distribution, static balancing valves were considered throughout the system as indicated in the PID´s.

5. CALCULATION

5.1 CHILLED WATER LOOP 1 (4 °C) – CHILLED WATER LOOP 2 (6 °C)

To determinate the thermal load of Loop 1, the thermal load of Loop 2 shall be calculated to determinate the flow rate of the heat exchanger between the 2 loops.

5.1.1 Loop 2 (6 °C)

5.1.1.1 Flow rates Required – Loop 2 (6 °C)

The Chilled Water System has the following consumers in the Loop 2:

- Design Condition

Equipment	TAG	Flow Diversity (Y/N)	Chilled Water Vol. Flow rate (LPM)	Chilled Water Vol. Flow rate (m³/h)	Diversity Chilled Water Mass Flow rate (kg/h)	Load Diversity (Y/N)	Peak Load (Kcal/h)	Peak Load (BTU/h)	Note
40 L Bioreactor (Seed)	*BRE-5401*	N	0.0	0.0	0.0	N	0.0	0.0	
320 L Bioreactor (Intermediate)	*BRE-5501-JL*	Y	15.2	0.9	912	N	0.0	0.0	
2500 L Bioreactor (Chemostat) N° 1	*BRE-5601-JL*	Y	190.0	11.4	11,400	Y	118,069	468,536	
2500 L Bioreactor (Chemostat) N° 2	*BRE-5602-JL*	Y	38.0	2.3	2,280	Y	2,266	8,993	
2500 L Bioreactor	*BRE-5603-JL*	Y	38.0	2.3	2,280	Y	2,266	8,993	

Equipment	TAG	Flow Diversity (Y/N)	Chilled Water Vol. Flow rate (LPM)	Chilled Water Vol. Flow rate (m^3/h)	Diversity Chilled Water Mass Flow rate (kg/h)	Load Diversity (Y/N)	Peak Load (Kcal/h)	Peak Load (BTU/h)	Note
(Chemostat) N° 3									
CPW Maintenance Cooler	*SK-6302 /TC-6302*	Y	11.6	0.7	696	Y	12,574	49,896	
WFI Still	*MES-6401*	Y	240.0	14.4	14,400	Y	86,219	342,144	
WFI Ambient Cooler	*SK-6401 /TC-9201*	Y	890.0	53.4	53,398	Y	319,728	1,268,784	
Clean Steam Generator w/ Sample Cooler	*CSG-6501*	Y	25.0	1.5	1,500	Y	1,210	4,800	
Clean Steam Sample Cooler (Med Prep)	*TC-6501*	N	0.0	0.0	0.0	N	0.0	0.0	
Clean Steam Sample Cooler (Cell Cult)	*TC-6502*	N	0.0	0.0	0.0	N	0.0	0.0	
Clean Steam Sample Cooler (DSP1)	*TC-6503*	N	0.0	0.0	0.0	N	0.0	0.0	
Autoclave	*AT-9001*	Y	60.0	3.6	3,600	Y	21,555	85,536	
TOTAL EQUIPMENT		**-**	**1,507.8**	**90.5**	**90,465**	**-**	**563,886**	**2,237,682**	
Recirculation (BV)		Y	511.7	30.7	30,699	-	-	-	1
Tie-in (Future Expansion)		Y	780.8	46.8	46,845	-	-	-	2
TOTAL		**-**	**2,800.3**	**168.1**	**168,009**	**-**	**563,886**	**2,237,682**	3

Notes:

1. Flow rate through bypasses, it is guaranteed by using of 5 balancing valves.
2. Oversizing of 24 % (See item 4).
3. Total flow rate for Secondary Pump of Loop 2 – Design Condition (Attachment 6.1.2).

- Maximum Operating Condition

Equipment	TAG	Flow Diversity (Y/N)	Chilled Water Vol. Flow rate (LPM)	Chilled Water Vol. Flow rate (m^3/h)	Diversity Chilled Water Mass Flow rate (kg/h)	Load Diversity (Y/N)	Peak Load (Kcal/h)	Peak Load (BTU/h)	Note
40 L Bioreactor (Seed)	*BRE-5401*	N	0.0	0.0	0.0	N	0.0	0.0	
320 L Bioreactor (Intermediate)	*BRE-5501-JL*	Y	15.2	0.9	912	N	0.0	0.0	
2500 L Bioreactor (Chemostat) N° 1	*BRE-5601-JL*	Y	190.0	11.4	11,400	Y	118,069	468,536	
2500 L Bioreactor (Chemostat) N° 2	*BRE-5602-JL*	Y	38.0	2.3	2,280	Y	2,266	8,993	
2500 L Bioreactor (Chemostat) N° 3	*BRE-5603-JL*	Y	38.0	2.3	2,280	Y	2,266	8,993	
CPW Maintenance Cooler	*SK-6302 /TC-6302*	Y	11.6	0.7	696	Y	12,574	49,896	
WFI Still	*MES-6401*	Y	240.0	14.4	14,400	Y	86,219	342,144	
WFI Ambient Cooler	*SK-6401 /TC-9201*	Y	890.0	53.4	53,398	Y	319728	1,268,784	
Clean Steam Generator w/ Sample Cooler	*CSG-6501*	Y	25.0	1.5	1,500	Y	1,210	4,800	
Clean Steam Sample Cooler (Med Prep)	*TC-6501*	N	0.0	0.0	0.0	N	0.0	0.0	
Clean Steam Sample Cooler (Cell Cult)	*TC-6502*	N	0.0	0.0	0.0	N	0.0	0.0	
Clean Steam Sample Cooler (DSP1)	*TC-6503*	N	0.0	0.0	0.0	N	0.0	0.0	
Autoclave	*AT-9001*	Y	60.0	3.6	3,600	Y	21,555	85,536	
TOTAL EQUIPMENT		**-**	**1,507.8**	**90.5**	**90,465**	**-**	**563,886**	**2,237,682**	
Recirculation (BV)		Y	511.8	30.7	30,707	-	-	-	1
Tie-in (Future Expansion)		N	-	-	-	-	-	-	
TOTAL		**-**	**2,019.6**	**121.2**	**121,172**	**-**	**563,886**	**2,237,682**	2

Notes:

1. Flow rate through bypasses, it is guaranteed by using 5 of balancing valves.
2. Total flow rate for Secondary Pump of Loop 2 – Maximum Operating Condition (Attachment 6.1.3).

- Intermediate Operating Condition

Equipment	TAG	Flow Diversity (Y/N)	Chilled Water Vol. Flow rate (LPM)	Chilled Water Vol. Flow rate (m^3/h)	Diversity Chilled Water Mass Flow rate (kg/h)	Load Diversity (Y/N)	Peak Load (Kcal/h)	Peak Load (BTU/h)	Note
40 L Bioreactor (Seed)	*BRE-5401*	Y	46.0	2.8	2,760	Y	3,757	14,910	
320 L Bioreactor (Intermediate)	*BRE-5501-JL*	Y	76.0	4.6	4,560	Y	13,912	55,208	
2500 L Bioreactor (Chemostat) N° 1	*BRE-5601-JL*	N	0.0	0.0	0.0	N	0.0	0.0	
2500 L Bioreactor (Chemostat) N° 2	*BRE-5602-JL*	Y	190.0	11.4	11,400	Y	2,266	8,993	
2500 L Bioreactor (Chemostat) N° 3	*BRE-5603-JL*	Y	190.0	11.4	11,400	Y	2,266	8,993	
CPW Maintenance Cooler	*SK-6302 /TC-6302*	Y	58.0	3.5	3,480	Y	12,574	49,896	
WFI Still	*MES-6401*	Y	240.0	14.4	14,400	Y	86,219	342,144	
WFI Ambient Cooler	*SK-6401 /TC-9201*	N	0.0	0.0	0.0	N	0.0	0.0	
Clean Steam Generator w/ Sample Cooler	*CSG-6501*	Y	25.0	1.5	1,500	Y	1,210	4,800	
Clean Steam Sample Cooler (Med Prep)	*TC-6501*	Y	7.0	0.4	420	Y	9,475	37,600	
Clean Steam Sample Cooler (Cell Cult)	*TC-6502*	Y	7.0	0.4	420	Y	9,475	37,600	
Clean Steam Sample Cooler (DSP1)	*TC-6503*	Y	7.0	0.4	420	Y	9,475	37,600	
Autoclave	*AT-9001*	N	0.0	0.0	0.0	N	0.0	0.0	
TOTAL EQUIPMENT		**-**	**846.0**	**50.8**	**50,758**	**-**	**150,629**	**597,744**	
Recirculation (BV)		Y	510.9	30.7	30,654	-	-	-	1
Tie-in (Future Expansion)		N	-	-	-	-	-	-	
TOTAL		**-**	**1,356.9**	**81.5**	**81,412**	**-**	**150,629**	**59,7744**	2

Notes:

1. Flow rate through bypasses, it is guaranteed by using 5 of balancing valves.
2. Total flow rate for Secondary Pump of Loop 2 – Intermediate Operating Condition (Attachment 6.1.4).

- Minimum Operating Condition

Equipment	TAG	Flow Diversity (Y/N)	Chilled Water Vol. Flow rate (LPM)	Chilled Water Vol. Flow rate (m³/h)	Diversity Chilled Water Mass Flow rate (kg/h)	Load Diversity (Y/N)	Peak Load (Kcal/h)	Peak Load (BTU/h)	Note
40 L Bioreactor (Seed)	*BRE-5401*	N	0.0	0.0	0.0	N	0.0	0.0	
320 L Bioreactor (Intermediate)	*BRE-5501-JL*	N	0.0	0.0	0.0	N	0.0	0.0	
2500 L Bioreactor (Chemostat) N° 1	*BRE-5601-JL*	N	0.0	0.0	0.0	N	0.0	0.0	
2500 L Bioreactor (Chemostat) N° 2	*BRE-5602-JL*	N	0.0	0.0	0.0	N	0.0	0.0	
2500 L Bioreactor (Chemostat) N° 3	*BRE-5603-JL*	N	0.0	0.0	0.0	N	0.0	0.0	
CPW Maintenance Cooler	*SK-6302 /TC-6302*	N	0.0	0.0	0.0	N	0.0	0.0	
WFI Still	*MES-6401*	N	0.0	0.0	0.0	N	0.0	0.0	
WFI Ambient Cooler	*SK-6401 /TC-9201*	N	0.0	0.0	0.0	N	0.0	0.0	
Clean Steam Generator w/ Sample Cooler	*CSG-6501*	N	0.0	0.0	0.0	N	0.0	0.0	
Clean Steam Sample Cooler (Med Prep)	*TC-6501*	N	0.0	0.0	0.0	N	0.0	0.0	
Clean Steam Sample Cooler (Cell Cult)	*TC-6502*	N	0.0	0.0	0.0	N	0.0	0.0	
Clean Steam Sample Cooler (DSP1)	*TC-6503*	N	0.0	0.0	0.0	N	0.0	0.0	
Autoclave	*AT-9001*	N	0.0	0.0	0.0	N	0.0	0.0	
TOTAL EQUIPMENT		**-**	**0.0**	**0.0**	**0.0**	**-**	**0.0**	**0.0**	
Recirculation (BV)		Y	546.9	32.8	32,812	-	-	-	1
Tie-in (Future Expansion)		N	-	-	-	-	-	-	
TOTAL		**-**	**546.9**	**32.8**	**32,812**	**-**	**0.0**	**0.0**	2

Notes:

1. Flow rate through bypasses, it is guaranteed by using of 5 balancing valves.
2. Total flow rate for Secondary Pump of Loop 2 – Minimum Operating Condition (Attachment 6.1.5).

5.1.1.2 Balancing Valves – Loop 2 (6 °C)

To ensure the correct flow distribution in the installation, the following balancing valves were installed.

a) By-pass at the end of the header distribution

It was considered 30.7 m³/h for chilled water recirculation in the system. This flow rate will be guaranteed by using of 5 static balancing valves in the by-pass as shown below:

ITEM	VALVE	FLOW RATE	PRESSURE LOSS	CV
		(m³/h)	(bar)	(Calculated)
602	BV-070018	6.00	1.74	5.27
603	BV-070040	6.00	1.72	5.29
604	BV-070014	6.00	1.62	5.45
606	BV-070001	6.00	1.69	5.35
607	BV-070033	6.70	1.17	7.16
TOTAL		**30.7**	**-**	**-**

The total flow rate of 30.7 m³/h represents the pump's minimum flow rate, as it can be seen in the pump curve (item 7.2). The pump can operate in the minimum flow rate, where all the process equipment don´t need chilled water and the flow rate required is only for the chilled water recirculation.

b) Balancing valves installed at the beginning of the distribution headers

Throughout the system, 3 static balancing valves in the distribution headers was considered to guarantee the correct water distribution, as shown in the table below:

ITEM	VALVE	FLOW RATE	PRESSURE LOSS	CV
		(m³/h)	(bar)	(Calculated)
581	BV-070039	22.87	0.05	113.30
915	BV-070055	6.00	0.03	37.34
916	BV-070056	21.80	0.44	38.15

c) Balancing valves at the process equipment inlet

Static Balancing valves were considered as shown in the table below:

EQUIPMENT	VALVE	FLOW RATE	PRESSURE LOSS	CV
		(m³/h)	(bar)	(Calculated)
BRE-5401	BV-070045	2.76	0.92	3.32
AT-9001	BV-070020	3.60	0.79	4.68
BRE-5601-JL	BV-070041	11.40	0.72	15.56
BRE-5602-JL	BV-070043	11.40	0.64	16.53
BRE-5501-JL	BV-070047	4.56	0.61	6.75

EQUIPMENT	VALVE	FLOW RATE	PRESSURE LOSS	CV
		(m³/h)	(bar)	(Calculated)
BRE-5603-JL	BV-070049	11.40	0.61	16.95
TC-6501	BV-070016	0.42	0.78	0.55
TC-6502	BV-070012	0.42	0.75	0.56
TC-6503	BV-070008	0.42	0.66	0.60
CSG-6501	BV-070026	1.50	0.70	2.07
MES-6401	BV-070037	14.40	0.21	35.93
SK-6302/TC-6302	BV-070031	3.48	0.11	12.17
SK-6401/TC-9201	BV-070035	53.40	0.67	75.44

5.1.1.3 Process Equipment – Loop 2 (6 °C)

The table below shows the information of the inlet pressures standardized as requested by IPS, the actual inlet pressure in each process equipment and the total DP of 1.0 bar in the equipment and in the temperature control valve.

Equipment	P in Equip. (barG)	Pressure in the PID (barG)	dP Equipment (bar)	dP Temp. Control Valves (bar)	Balancing Valve	dP Balancing Valve (bar)	dP Total (bar)
BRE-5401	2.02	3.0	0.50	0.50	BV-070045	0.92	1.92
AT-9001	2.18	3.0	0.50	0.50	BV-070020	0.79	1.79
BRE-5601-JL	2.87	3.0	0.50	0.50	BV-070041	0.72	1.72
BRE-5602-JL	2.79	3.0	0.50	0.50	BV-070043	0.64	1.64
BRE-5501-JL	2.80	3.0	0.50	0.50	BV-070047	0.61	1.61
BRE-5603-JL	2.80	3.0	0.50	0.50	BV-070049	0.61	1.61
TC-6501	2.36	3.0	0.50	0.50	BV-070016	0.78	1.78
TC-6502	2.38	3.0	0.50	0.50	BV-070012	0.75	1.75
TC-6503	2.42	3.0	0.50	0.50	BV-070008	0.66	1.66
CSG-6501	2.91	3.0	0.50	0.50	BV-070026	0.70	1.70
MES-6401	2.94	3.0	0.50	0.50	BV-070037	0.21	1.21
SK-6302/TC-6302	2.87	3.0	0.50	0.50	BV-070031	0.11	1.11
SK-6401/TC-9201	2.56	3.0	0.50	0.50	BV-070035	0.67	1.67

5.1.1.4 Pump Capacity – Loop 2 (6 °C)

The secondary pumps of the system work with variable speed. Based on the conditions above, the secondary pumps of Loop 2 (P-PCH-7B-5/ P-PCH-7B-6) were sized for the following conditions:

Design Condition – Flow rate = 168.1 m³/h

Maximum Operating Condition = 121.2 m³/h

Intermediate Operating Condition = 81.5 m³/h

Minimum Operating Condition = 32.8 m³/h

There are 2 secondary pumps, where one is operating and the other is in stand-by. They are controlled by the differential pressure transmitter PDIT-070001 maintaining constant the pressure drop of 2.0 bar at the main distribution header.

This instrument is installed at a distance of 2/3 of the main distribution pipe total length, to guarantee a good control.

The pumps selected are indicated in Item 7.2 of this document and the results are shown below.

5.1.1.4.1 Design Condition

Jct	Results Diagram	Name	Vol. Flow (m3/hr)	Mass Flow (kg/hr)	dP (bar)	dH (meters)	Ideal Power (kW)	Overall Efficiency (Percent)	Overall Power (kW)	Speed (Percent)	NPSHA (meters)	P Stag. Suction (barG)	P Stag. Disc. (barG)
810	Show ...	P-PCH-7B-5	168,1	168.012	3,329	33,96	15,53	72,89	21,31	100,0	12,87	0,2119	3,512
X812	Show ...	P-PCH-7B-6	0,0	0	N/A	N/A	N/A	N/A	N/A	0,0	N/A	0,2432	3,480

5.1.1.4.2 Maximum Operating Condition

Jct	Results Diagram	Name	Vol. Flow (m3/hr)	Mass Flow (kg/hr)	dP (bar)	dH (meters)	Ideal Power (kW)	Overall Efficiency (Percent)	Overall Power (kW)	Speed (Percent)	NPSHA (meters)	P Stag. Suction (barG)	P Stag. Disc. (barG)
810	Show ...	P-PCH-7B-5	121,2	121.183	2,779	28,34	9,351	74,31	12,58	86,71	13,06	0,2301	2,980
X812	Show ...	P-PCH-7B-6	0,0	0	N/A	N/A	N/A	N/A	N/A	0,00	N/A	0,2464	2,963

5.1.1.4.3 Intermediate Operating Condition

Jct	Results Diagram	Name	Vol. Flow (m3/hr)	Mass Flow (kg/hr)	dP (bar)	dH (meters)	Ideal Power (kW)	Overall Efficiency (Percent)	Overall Power (kW)	Speed (Percent)	NPSHA (meters)	P Stag. Suction (barG)	P Stag. Disc. (barG)
810	Show ...	P-PCH-7B-5	81,48	81.474	2,310	23,56	5,226	71,58	7,301	75,84	13,19	0,2409	2,522
X812	Show ...	P-PCH-7B-6	0,00	0	N/A	N/A	N/A	N/A	N/A	0,00	N/A	0,2483	2,514

5.1.1.4.4 Minimum Operating Condition

Jct	Results Diagram	Name	Vol. Flow (m3/hr)	Mass Flow (kg/hr)	dP (bar)	dH (meters)	Ideal Power (kW)	Overall Efficiency (Percent)	Overall Power (kW)	Speed (Percent)	NPSHA (meters)	P Stag. Suction (barG)	P Stag. Disc. (barG)
810	Show ...	P-PCH-7B-5	32,82	32.815	1,987	20,26	1,810	54,60	3,315	67,76	13,27	0,2485	2,206
X812	Show ...	P-PCH-7B-6	0,00	0	N/A	N/A	N/A	N/A	N/A	0,00	N/A	0,2497	2,205

5.1.2 Loop 1 (4 °C)

5.1.2.1 Flow rates Required – Loop 1 (4 °C)

The Chilled Water System has the following consumers in the Loop 1:

- Design Condition

Equipment	TAG	Flow Diversity (Y/N)	Chilled Water Vol. Flow rate (LPM)	Chilled Water Vol. Flow rate (m³/h)	Diversity Chilled Water Mass Flow rate (kg/h)	Load Diversity (Y/N)	Peak Load (Kcal/h)	Peak Load (BTU/h)	Note
250 L Media Prep Tank	TQ-5101	N	0.0	0.0	0	N	0	0	
4500 L Media Prep Tank	TQ-5102	Y	192.9	11.6	11,571	N	0	0	
3800 L Media Hold Tank N°1	TQ-5201	Y	192.9	11.6	11,571	N	0	0	
3800 L Media Hold Tank N°2	TQ-5202	Y	192.9	11.6	11,571	N	0	0	
3800 L Media Hold Tank N°3	TQ-5203	Y	192.9	11.6	11,571	N	0	0	
3400 L Collection Vessel N°1	TQ-5701	Y	192.9	11.6	11,571	Y	36,320	144,130	
3400 L Collection Vessel N°2	TQ-5702	N	0.0	0.0	0	N	0	0	
4200 L Harvest Vessel N°1	TQ-5901	Y	192.9	11.6	11,571	Y	35,721	141,754	
4200 L Harvest Vessel N°2	TQ-5902	N	0.0	0.0	0	N	0	0	
500 L Buffer Prep Tank N°1	TQ-3701	N	0.0	0.0	0	N	0	0	
3000 L Buffer Prep Tank N°2	TQ-3702	Y	192.9	11.6	11,571	Y	45,363	180,013	
3000 L Buffer Prep Tank N°3	TQ-3703	N	0.0	0.0	0	N	0	0	
320 L Bioreactor (Intermediate)	BRE-5501	Y	8.1	0.5	487	Y	479	1,901	
2500 L Bioreactor (Chemostat) N° 1	BRE-5601	Y	16.2	1.0	974	Y	958	3,802	
2500 L Bioreactor (Chemostat) N° 2	BRE-5602	Y	16.2	1.0	974	Y	958	3,802	
2500 L Bioreactor	BRE-5603	Y	16.2	1.0	974	Y	958	3,802	

Equipment	TAG	Flow Diversity (Y/N)	Chilled Water Vol. Flow rate (LPM)	Chilled Water Vol. Flow rate (m³/h)	Diversity Chilled Water Mass Flow rate (kg/h)	Load Diversity (Y/N)	Peak Load (Kcal/h)	Peak Load (BTU/h)	Note
(Chemostat) N° 3									
320 L Bioreactor Utility Panel	UP-5500	Y	38.6	2.3	2,314	Y	2,275	9,029	
3800 L Media Hold Tank N°1 Utility Panel	UP-5201	Y	38.6	2.3	2,314	Y	2,275	9,029	
3800 L Media Hold Tank N°2 Utility Panel	UP-5202	N	0.0	0.0	0	N	0	0	
3800 L Media Hold Tank N°3 Utility Panel	UP-5203	N	0.0	0.0	0	N	0	0	
Heat Exchanger Chilled Water	TC HX-7B-2	Y	1,342.6	80.6	80,555	Y	563,886	2,237,682	1,2
TOTAL EQUIPMENT		**-**	**2,826.6**	**169.6**	**169,591**	**-**	**689,194**	**2,734,944**	
Recirculation (BV)		Y	756.7	45.4	45,400	-	-	-	3
Tie-in (Future Expansion)		Y	1,133.4	68.0	68,006	-	218,006	865,116	4
TOTAL		**-**	**4,716.3**	**283.0**	**282,997**	**-**	**907,200**	**3,600,060**	5

Notes:

1. The flow rate was calculated based on the peak load required by the process for Loop 2 (item 5.1.1.1 Design Condition). For this case, the differential temperature is 7.0 °C (Attachment 6.1.1).
2. The heat exchanger HX-7B-2 is used to produce chilled water at 6.0 °C for Loop 2.
3. Flow rate through bypasses, guaranteed by using of 8 balancing valves.
4. Oversizing of 24 % (See item 4).
5. Total flow rate for Primary and Secondary Pump of Loop 1 – Design Condition (Attachment 6.1.1).

- Maximum Operating Condition

Equipment	TAG	Flow Diversity (Y/N)	Chilled Water Vol. Flow rate (LPM)	Chilled Water Vol. Flow rate (m³/h)	Diversity Chilled Water Mass Flow rate (kg/h)	Load Diversity (Y/N)	Peak Load (Kcal/h)	Peak Load (BTU/h)	Note
250 L Media Prep Tank	TQ-5101	N	0.0	0.0	0	N	0	0	
4500 L Media Prep Tank	TQ-5102	Y	192.9	11.6	11,571	N	0	0	
3800 L Media Hold Tank N°1	TQ-5201	Y	192.9	11.6	11,571	N	0	0	
3800 L Media Hold Tank N°2	TQ-5202	Y	192.9	11.6	11,571	N	0	0	
3800 L Media Hold Tank N°3	TQ-5203	Y	192.9	11.6	11,571	N	0	0	
3400 L Collection Vessel N°1	TQ-5701	Y	192.9	11.6	11,571	Y	36,320	144,130	
3400 L Collection Vessel N°2	TQ-5702	N	0.0	0.0	0	N	0	0	
4200 L Harvest Vessel N°1	TQ-5901	Y	192.9	11.6	11,571	Y	35,721	141,754	
4200 L Harvest Vessel N°2	TQ-5902	N	0.0	0.0	0	N	0	0	
500 L Buffer Prep Tank N°1	TQ-3701	N	0.0	0.0	0	N	0	0	
3000 L Buffer Prep Tank N°2	TQ-3702	Y	192.9	11.6	11,571	Y	45,363	180,013	
3000 L Buffer Prep Tank N°3	TQ-3703	N	0.0	0.0	0	N	0	0	
320 L Bioreactor (Intermediate)	BRE-5501	Y	8.1	0.5	487	Y	479	1,901	
2500 L Bioreactor (Chemostat) N° 1	BRE-5601	Y	16.2	1.0	974	Y	958	3,802	
2500 L Bioreactor (Chemostat) N° 2	BRE-5602	Y	16.2	1.0	974	Y	958	3,802	
2500 L Bioreactor (Chemostat) N° 3	BRE-5603	Y	16.2	1.0	974	Y	958	3,802	
320 L Bioreactor Utility Panel	UP-5500	Y	38.6	2.3	2,314	Y	2,275	9,029	

Equipment	TAG	Flow Diversity (Y/N)	Chilled Water Vol. Flow rate (LPM)	Chilled Water Vol. Flow rate (m³/h)	Diversity Chilled Water Mass Flow rate (kg/h)	Load Diversity (Y/N)	Peak Load (Kcal/h)	Peak Load (BTU/h)	Note
3800 L Media Hold Tank N°1 Utility Panel	UP-5201	Y	38.6	2.3	2,314	Y	2,275	9,029	
3800 L Media Hold Tank N°2 Utility Panel	UP-5202	N	0.0	0.0	0	N	0	0	
3800 L Media Hold Tank N°3 Utility Panel	UP-5203	N	0.0	0.0	0	N	0	0	
Heat Exchanger Chilled Water	TC HX-7B-2	Y	1,342.6	80.6	80,555	Y	563,886	2,237,682	1,2
TOTAL EQUIPMENT		**-**	**2,826.6**	**169.6**	**169,591**	**-**	**689,194**	**2,734,944**	
Recirculation (BV)		Y	756.7	45.4	45,400	-	-	-	3
Tie-in (Future Expansion)		N	-	-	-	-	-	-	
TOTAL		**-**	**3,583.3**	**215**	**214,991**	**-**	**689,194**	**2,734,944**	4

Notes:

1. The flow rate was calculated based on the peak load required by the process for Loop 2 (item 5.1.1.1 – Maximum Operating Condition). For this case, the differential temperature is 7.0 °C (Attachment 6.1.3).
2. The heat exchanger HX-7B-2 is used to produce chilled water at 6.0 °C.
3. Flow rate through bypasses, guaranteed by using of 8 balancing valves.
4. Total flow rate for Primary and Secondary Pump of Loop 1 – Maximum Operating Condition (Attachment 6.1.3).

- Intermediate Operating Condition

Equipment	TAG	Flow Diversity (Y/N)	Chilled Water Vol. Flow rate (LPM)	Chilled Water Vol. Flow rate (m³/h)	Diversity Chilled Water Mass Flow rate (kg/h)	Load Diversity (Y/N)	Peak Load (Kcal/h)	Peak Load (BTU/h)	Note
250 L Media Prep Tank	TQ-5101	Y	38.6	2.3	2,314	Y	9,192	36,476	
4500 L Media Prep Tank	TQ-5102	N	0.0	0.0	0.0	N	0.0	0.0	
3800 L Media Hold Tank N°1	TQ-5201	N	0.0	0.0	0.0	N	0.0	0.0	
3800 L Media Hold Tank N°2	TQ-5202	N	0.0	0.0	0.0	N	0.0	0.0	
3800 L Media Hold Tank N°3	TQ-5203	N	0.0	0.0	0.0	N	0.0	0.0	
3400 L Collection Vessel N°1	TQ-5701	N	0.0	0.0	0.0	N	0.0	0.0	
3400 L Collection Vessel N°2	TQ-5702	Y	192.9	11.6	11,571	Y	36,320	144,130	
4200 L Harvest Vessel N°1	TQ-5901	N	0.0	0.0	0.0	N	0.0	0.0	
4200 L Harvest Vessel N°2	TQ-5902	Y	192.9	11.6	11,571	Y	35,721	141,754	
500 L Buffer Prep Tank N°1	TQ-3701	Y	77.1	4.6	4,628	Y	12,852	51,002	
3000 L Buffer Prep Tank N°2	TQ-3702	N	0.0	0.0	0.0	N	0.0	0.0	
3000 L Buffer Prep Tank N°3	TQ-3703	Y	192.9	11.6	11,571	Y	45,363	180,013	
320 L Bioreactor (Intermediate)	BRE-5501	N	0.0	0.0	0.0	N	0.0	0.0	
2500 L Bioreactor (Chemostat) N° 1	BRE-5601	N	0.0	0.0	0.0	N	0.0	0.0	
2500 L Bioreactor (Chemostat) N° 2	BRE-5602	N	0.0	0.0	0.0	N	0.0	0.0	
2500 L Bioreactor (Chemostat) N° 3	BRE-5603	N	0.0	0.0	0.0	N	0.0	0.0	

Equipment	TAG	Flow Diversity (Y/N)	Chilled Water Vol. Flow rate (LPM)	Chilled Water Vol. Flow rate (m³/h)	Diversity Chilled Water Mass Flow rate (kg/h)	Load Diversity (Y/N)	Peak Load (Kcal/h)	Peak Load (BTU/h)	Note
320 L Bioreactor Utility Panel	UP-5500	N	0.0	0.0	0.0	N	0.0	0.0	
3800 L Media Hold Tank N°1 Utility Panel	UP-5201	N	0.0	0.0	0.0	N	0.0	0.0	
3800 L Media Hold Tank N°2 Utility Panel	UP-5202	Y	38.6	2.3	2,314	Y	2,275	9,029	
3800 L Media Hold Tank N°3 Utility Panel	UP-5203	Y	38.6	2.3	2,314	Y	2,275	9,029	
Heat Exchanger Chilled Water	TC HX-7B-2	Y	358.7	21.5	21,519	Y	150,629	597,744	1,2
TOTAL EQUIPMENT		**-**	**1,130.1**	**67.8**	**67,803**	**-**	**294,628**	**1,169,177**	
Recirculation (BV)		Y	792.6	47.6	47556	-	-	-	3
Tie-in (Future Expansion)		N	-	-	-	-	-	-	
TOTAL		**-**	**1,922.7**	**115.4**	**115,359**	**-**	**294,628**	**1,169,177**	4

Notes:

1. The flow rate was calculated based on the intermediate load required by the process for Loop 2 (item 5.1.1.1 Intermediate Operating Condition). For this case, the differential temperature is 7.0 °C (Attachment 6.1.4).
2. The heat exchanger HX-7B-2 is used to produce chilled water at 6.0 °C.
3. Flow rate through bypasses, guaranteed by using of 8 balancing valves.
4. Total flow rate for Primary and Secondary Pump of Loop 1 – Intermediate Operating Condition (Attachment 6.1.4).

- Minimum Operating Condition

Equipment	TAG	Flow Diversity (Y/N)	Chilled Water Vol. Flow rate (LPM)	Chilled Water Vol. Flow rate (m³/h)	Diversity Chilled Water Mass Flow rate (kg/h)	Load Diversity (Y/N)	Peak Load (Kcal/h)	Peak Load (BTU/h)	Note
250 L Media Prep Tank	TQ-5101	N	0.0	0.0	0.0	N	0.0	0.0	
4500 L Media Prep Tank	TQ-5102	N	0.0	0.0	0.0	N	0.0	0.0	
3800 L Media Hold Tank N°1	TQ-5201	N	0.0	0.0	0.0	N	0.0	0.0	
3800 L Media Hold Tank N°2	TQ-5202	N	0.0	0.0	0.0	N	0.0	0.0	
3800 L Media Hold Tank N°3	TQ-5203	N	0.0	0.0	0.0	N	0.0	0.0	
3400 L Collection Vessel N°1	TQ-5701	N	0.0	0.0	0.0	N	0.0	0.0	
3400 L Collection Vessel N°2	TQ-5702	N	0.0	0.0	0.0	N	0.0	0.0	
4200 L Harvest Vessel N°1	TQ-5901	N	0.0	0.0	0.0	N	0.0	0.0	
4200 L Harvest Vessel N°2	TQ-5902	N	0.0	0.0	0.0	N	0.0	0.0	
500 L Buffer Prep Tank N°1	TQ-3701	N	0.0	0.0	0.0	N	0.0	0.0	
3000 L Buffer Prep Tank N°2	TQ-3702	N	0.0	0.0	0.0	N	0.0	0.0	
3000 L Buffer Prep Tank N°3	TQ-3703	N	0.0	0.0	0.0	N	0.0	0.0	
320 L Bioreactor (Intermediate)	BRE-5501	N	0.0	0.0	0.0	N	0.0	0.0	
2500 L Bioreactor (Chemostat) N° 1	BRE-5601	N	0.0	0.0	0.0	N	0.0	0.0	
2500 L Bioreactor (Chemostat) N° 2	BRE-5602	N	0.0	0.0	0.0	N	0.0	0.0	
2500 L Bioreactor	BRE-5603	N	0.0	0.0	0.0	N	0.0	0.0	

Equipment	TAG	Flow Diversity (Y/N)	Chilled Water Vol. Flow rate (LPM)	Chilled Water Vol. Flow rate (m³/h)	Diversity Chilled Water Mass Flow rate (kg/h)	Load Diversity (Y/N)	Peak Load (Kcal/h)	Peak Load (BTU/h)	Note
(Chemostat) N° 3									
320 L Bioreactor Utility Panel	UP-5500	N	0.0	0.0	0.0	N	0.0	0.0	
3800 L Media Hold Tank N°1 Utility Panel	UP-5201	N	0.0	0.0	0.0	N	0.0	0.0	
3800 L Media Hold Tank N°2 Utility Panel	UP-5202	N	0.0	0.0	0.0	N	0.0	0.0	
3800 L Media Hold Tank N°3 Utility Panel	UP-5203	N	0.0	0.0	0.0	N	0.0	0.0	
Heat Exchanger Chilled Water	TC HX-7B-2	N	0.0	0.0	0.0	N	0.0	0.0	
TOTAL EQUIPMENT		**-**	**0.0**	**0.0**	**0.0**	**-**	**0.0**	**0.0**	
Recirculation (BV)		Y	798.0	47.9	47,880	-	-	-	1
Tie-in (Future Expansion)		N	-	-	-	-	-	-	
TOTAL		**-**	**798.0**	**47.9**	**47,880**	**-**	**0.0**	**0.0**	2

Notes:

1. Flow rate through bypasses, guaranteed by using of 8 balancing valves.
2. Total flow rate for Primary and Secondary Pump of Loop 1 – Minimum Operating Condition (Attachment 6.1.5).

The Simultaneous Peak Load is 689,194 kcal/h (Design Condition) and it is equivalent to 228 TR. Therefore, it will be considered the installation of 2 chillers with a nominal capacity of 300 TR each one of them. So, the chillers have an oversizing of 24 % (72 TR).

5.1.2.2 Balancing Valves – Loop 1 (4 °C)

To ensure the correct flow distribution in the installation, the following balancing valves were installed.

a) By-pass at the end of the header distribution

It was considered 45.4 m³/h for chilled water recirculation in the system. This flow rate will be guaranteed by using of 8 static balancing valves in the by-pass as shown below:

ITEM	VALVE	FLOW RATE (m³/h)	PRESSURE LOSS (bar)	CV (Calculated)
501	BV-9800210	6.90	1.07	7.73
505	BV-9800123	5.50	1.24	5.71
506	BV-9800124	5.50	1.18	5.87
507	BV-9800133	5.50	1.19	5.83
508	BV-9800134	5.50	1.18	5.85

ITEM	VALVE	FLOW RATE	PRESSURE LOSS	CV
		(m³/h)	(bar)	(Calculated)
509	BV-9800141	5.50	1.22	5.75
510	BV-9800142	5.50	1.19	5.83
514	BV-980010	5.50	1.37	5.44
TOTAL		**45.40**	**-**	**-**

The total flow rate of 45.4m³/h in these valves represents the pump's minimum flow rate, as it can be seen in the pump curve (item 7.1). The pump can operate in the minimum flow rate, where all the process equipment don´t need chilled water and the flow rate required is only for the chilled water recirculation.

b) Balancing valves installed at the beginning of the distribution headers

Throughout the system, 4 static balancing valves in the distribution headers were considered to guarantee the correct water distribution, as shown in the table below:

ITEM	VALVE	FLOW RATE	PRESSURE LOSS	CV
		(m³/h)	(bar)	(Calculated)
713	BV-9800203	23.62	0.09	93.07
714	BV-9800213	48.03	0.08	202.32
715	BV-9800201	34.14	0.09	130.64
916	BV-9800100	80.55	0.04	485.56

c) Balancing valves at the process equipment inlet

Static Balancing valves were considered as shown in the table below:

EQUIPMENT	VALVE	FLOW RATE	PRESSURE LOSS	CV
		(m³/h)	(bar)	(Calculated)
TQ-5902	BV-9800117	11.57	0.35	22.59
TQ-5702	BV-9800121	11.57	0.33	23.47
TQ-5901	BV-9800104	11.57	0.36	22.30
TQ-5701	BV-9800107	11.57	0.33	23.44
BRE-5602	BV-9800129	0.97	0.21	2.46
BRE-5501	BV-9800127	0.49	0.16	1.40
UP-5500	BV-9800200	2.31	0.21	5.82
BRE-5603	BV-9800131	0.97	0.15	2.92
UP-5201	BV-980094	2.31	0.29	5.00
BRE-5601	BV-9800126	0.97	0.22	2.43
TQ-5201	BV-9800135	11.57	0.18	31.42
TQ-5202	BV-9800137	11.57	0.22	28.26
UP-5202	BV-980096	2.31	0.44	4.02

EQUIPMENT	VALVE	FLOW RATE	PRESSURE LOSS	CV
		(m³/h)	(bar)	(Calculated)
UP-5203	BV-980098	2.31	0.43	4.06
TQ-5203	BV-9800139	11.57	0.17	32.06
TQ-3702	BV-9800147	11.57	0.21	28.95
TQ-3701	BV-9800143	4.63	0.42	8.30
TQ-5102	BV-9800145	11.57	0.18	31.29
TQ-3703	BV-9800151	11.57	0.31	23.99
TQ-5101	BV-9800155	2.31	0.40	4.21

d) Balancing valves at the chillers´s outlet

Static balancing valves were considered after the chiller, as shown in the table below:

ITEM	VALVE	FLOW RATE	PRESSURE LOSS	CV
		(m³/h)	(bar)	(Calculated)
748	BV-980001	283.0	0.06	1369.98
749	BV-980002	283.0	0.06	1369.98

5.1.2.3 Process Equipment (4 °C)

The table below shows the information of the inlet pressures standardized as requested by IPS, the actual inlet pressure in each process equipment and the total DP of 1.0 bar (equipment + temperature control valve).

Equipment	P in Equip. (barG)	Pressure in the PID (barG)	dP Equipment (bar)	dP Temp. Control Valves (bar)	Balancing Valve	dP Balancing Valve (bar)	dP Total (bar)
TQ-5901	2.22	2.5	0.50	0.50	BV-9800104	0.36	1.36
TQ-5701	2.23	2.5	0.50	0.50	BV-9800107	0.33	1.33
TQ-5902	2.18	2.5	0.50	0.50	BV-9800117	0.35	1.35
TQ-5702	2.19	2.5	0.50	0.50	BV-9800121	0.33	1.33
BRE-5601	2.21	2.5	0.50	0.50	BV-9800126	0.22	1.22
BRE-5501	2.24	2.5	0.50	0.50	BV-9800127	0.16	1.16
BRE-5602	2.25	2.5	0.50	0.50	BV-9800129	0.21	1.21
BRE-5603	2.28	2.5	0.50	0.50	BV-9800131	0.15	1.15
TQ-5201	2.27	2.5	0.50	0.50	BV-9800135	0.18	1.18
TQ-5202	2.25	2.5	0.50	0.50	BV-9800137	0.22	1.22
TQ-5203	2.28	2.5	0.50	0.50	BV-9800139	0.17	1.17
TQ-3702	2.26	2.5	0.50	0.50	BV-9800147	0.21	1.21
TQ-3701	2.14	2.5	0.50	0.50	BV-9800143	0.42	1.42
TQ-5102	2.27	2.5	0.50	0.50	BV-9800145	0.18	1.18
TQ-3703	2.20	2.5	0.50	0.50	BV-9800151	0.31	1.31
TQ-5101	2.16	2.5	0.50	0.50	BV-9800155	0.40	1.40
UP-5500	2.22	2.5	0.50	0.50	BV-9800200	0.21	1.21

Equipment	P in Equip. (barG)	Pressure in the PID (barG)	dP Equipment (bar)	dP Temp. Control Valves (bar)	Balancing Valve	dP Balancing Valve (bar)	dP Total (bar)
UP-5201	2.20	2.5	0.50	0.50	BV-980094	0.29	1.29
UP-5202	2.10	2.5	0.50	0.50	BV-980096	0.44	1.44
UP-5203	2.11	2.5	0.50	0.50	BV-980098	0.43	1.43

5.1.2.4 Pump Capacity – Loop 1 (4 °C)

- Primary Pump

The primary pumps of the system work with fixed speed. Based on the conditions above, the primary pumps for Loop 1 (P-PCH-7B-1/ P-PCH-7B-2) were sized for the following condition:

Design Condition – Flow rate = 283.0 m³/h

Maximum Operating Condition = 215.0 m³/h

The excess of flow rate for the other conditions of the system will be directed to supply the Chiller through the Buffer Tank where the overflow occur from the cold side to the hot side of the tank.

The results of the pumps calculated are indicated in Item 7.1 of this document.

- Secondary Pump

The secondary pumps of the system work with variable speed. Based on the conditions above, the secondary pumps of Loop 1 (P-PCH-7B-3/ P-PCH-7B-4) were sized for the following conditions:

Design Condition – Flow rate = 283.0 m³/h

Maximum Operating Condition = 215.0 m³/h

Intermediate Operating Condition = 115.4 m³/h

Minimum Operating Condition = 47.9 m³/h

There are 2 secondary pumps, where one is operating and the other is in stand-by. They are controlled by the differential pressure transmitter PDIT-980010 maintaining constant the pressure drop of 1.5 bar at the main distribution header.

This instrument is installed at a distance of 2/3 of the main distribution pipe total length, to guarantee a good control.

The pumps selected are indicated in Item 7.1 of this document and the results are shown below.

5.1.2.4.1 Design Condition

Jct	Results Diagram	Name	Vol. Flow (m3/hr)	Mass Flow (kg/hr)	dP (bar)	dH (meters)	Ideal Power (kW)	Overall Efficiency (Percent)	Overall Power (kW)	Speed (Percent)	NPSHA (meters)	P Stag. Suction (barG)	P Stag. Disc. (barG)
10	Show ...	P-PCH-7B-3	283,0	282.997	1,949	19,88	15,31	81,19	18,86	100,00	11,43	0,1162	2,036
X11	Show ...	P-PCH-7B-4	0,0	0	N/A	N/A	N/A	N/A	N/A	0,00	N/A	N/A	N/A
128	Show ...	P-PCH-7B-1	283,0	282.983	1,332	13,58	10,46	80,97	12,92	96,47	13,55	0,3256	1,628
X129	Show ...	P-PCH-7B-2	0,0	0	N/A	N/A	N/A	N/A	N/A	0,00	N/A	N/A	N/A

5.1.2.4.2 Maximum Operating Condition

Jct	Results Diagram	Name	Vol. Flow (m3/hr)	Mass Flow (kg/hr)	dP (bar)	dH (meters)	Ideal Power (kW)	Overall Efficiency (Percent)	Overall Power (kW)	Speed (Percent)	NPSHA (meters)	P Stag. Suction (barG)	P Stag. Disc. (barG)
10	Show ...	P-PCH-7B-3	215,0	214.998	1,8923	19,296	11,294	80,02	14,113	92,85	11,63	0,1358	1,999
X11	Show ...	P-PCH-7B-4	0,0	0	N/A	N/A	N/A	N/A	N/A	0,00	N/A	N/A	N/A
128	Show ...	P-PCH-7B-1	215,0	214.987	0,7778	7,931	4,642	80,98	5,732	73,60	13,91	0,3602	1,109
X129	Show ...	P-PCH-7B-2	0,0	0	N/A	N/A	N/A	N/A	N/A	0,00	N/A	N/A	N/A

5.1.2.4.3 Intermediate Operating Condition

Jct	Results Diagram	Name	Vol. Flow (m3/hr)	Mass Flow (kg/hr)	dP (bar)	dH (meters)	Ideal Power (kW)	Overall Efficiency (Percent)	Overall Power (kW)	Speed (Percent)	NPSHA (meters)	P Stag. Suction (barG)	P Stag. Disc. (barG)
10	Show ...	P-PCH-7B-3	115,4	115.385	1,8028	18,383	5,774	64,94	8,892	85,02	11,83	0,1550	1,928
X11	Show ...	P-PCH-7B-4	0,0	0	N/A	N/A	N/A	N/A	N/A	0,00	N/A	N/A	N/A
128	Show ...	P-PCH-7B-1	215,0	214.992	0,7778	7,932	4,642	80,98	5,733	73,60	13,91	0,3602	1,109
X129	Show ...	P-PCH-7B-2	0,0	0	N/A	N/A	N/A	N/A	N/A	0,00	N/A	N/A	N/A

5.1.2.4.4 Minimum Operating Condition

Jct	Results Diagram	Name	Vol. Flow (m3/hr)	Mass Flow (kg/hr)	dP (bar)	dH (meters)	Ideal Power (kW)	Overall Efficiency (Percent)	Overall Power (kW)	Speed (Percent)	NPSHA (meters)	P Stag. Suction (barG)	P Stag. Disc. (barG)
10	Show ...	P-PCH-7B-3	47,89	47.893	1,7671	18,020	2,349	40,34	5,823	82,68	11,90	0,1614	1,899
X11	Show ...	P-PCH-7B-4	0,00	0	N/A	N/A	N/A	N/A	N/A	0,00	N/A	N/A	N/A
128	Show ...	P-PCH-7B-1	215,00	215.002	0,7780	7,933	4,643	80,98	5,734	73,61	13,92	0,3602	1,109
X129	Show ...	P-PCH-7B-2	0,00	0	N/A	N/A	N/A	N/A	N/A	0,00	N/A	N/A	N/A

5.1.2.5 Chiller Capacity

According to item 5.1.1.1, the Simultaneous Peak Load is 689,194 kcal/h and it is equivalent to 228 TR. This is the maximum operating condition for the chillers.

Therefore, it will be considered the installation of 2 chillers with a Nominal Capacity of 300 TR each one of them. So, the chillers have an oversizing of 24 % (72 TR).

At the Design and Maximum Operating Conditions, the inlet temperature for the process equipment's is 4.0 ºC and the outlet temperature (return to Chiller) is 7.2 ºC (see attachments 6.1.1 and 6.1.3).

At the Intermediate Operating Condition, the inlet temperature for the process equipment's is 4.0 ºC and the outlet temperature (return to Chiller) is 6.6 ºC (see attachment 6.1.4).

At the Minimum Operating Condition, the inlet temperature for the process equipment's and the outlet temperature (return to Chiller) is 4.0 ºC, because at this condition, all equipment's are closed, and the recirculation has no thermal load (see attachment 6.1.5).

According to recommendation of Chiller´s supplier, the minimum stabilization time is 2 minutes. For that reason, it was adopted the residence time of 3 minutes, guaranteeing the thermal load when the chiller shuts down.

5.1.2.6 Buffer Tank

For the selection of the tank, the design condition was considered.

The Buffer tank is divided in 2 sides (cold side and hot side) and it was sized based on the residence time of 3 minutes for each side (minimum time required to stabilize the chiller in the event of a temporary shortages of electric energy supply).

Buffer Tank (BT-7B-1)			
Flow rate	283.0	m^3/h	
	4716.7	L/min	
Autonomy	3	min	
Tank Vol.	14150	L	by camara
	28300	L	total
Tank Vol.	**15**	**m^3**	***by camara***
	30	**m^3**	***Total***

5.2 CHILLED PROPYLENE GLYCOL LOOP 1 (0 °C) – CHILLED WATER LOOP 2 (4 °C)

5.2.1 Loop 2 (4 °C)

5.2.1.1 Flow rates Required – Loop 2 (4 °C)

The Chilled Water System has the following consumers in the Loop 2:

- Design Condition

Equipment	TAG	Flow Diversity (Y/N)	Chilled Water Vol. Flow rate (LPM)	Chilled Water Vol. Flow rate (m^3/h)	Diversity Chilled Water Mass Flow rate (kg/h)	Load Diversity (Y/N)	Peak Load (Kcal/h)	Peak Load (BTU/h)	Note
40 L Bioreactor (Seed)	*BRE-5401*	N	0.0	0.0	0.0	N	0.0	0.0	
320 L Bioreactor (Intermediate)	*BRE-5501-JL*	Y	15.2	0.9	912	N	0.0	0.0	
2500 L Bioreactor (Chemostat) N° 1	*BRE-5601-JL*	Y	190.0	11.4	11,400	Y	118,069	468,536	
2500 L Bioreactor (Chemostat) N° 2	*BRE-5602-JL*	Y	38.0	2.3	2,280	Y	2,266	8,993	
2500 L Bioreactor (Chemostat) N° 3	*BRE-5603-JL*	Y	38.0	2.3	2,280	Y	2,266	8,993	
CPW Maintenance Cooler	*SK-6302 /TC-6302*	Y	11.6	0.7	696	Y	12,574	49,896	
WFI Still	*MES-6401*	Y	240.0	14.4	14,400	Y	86,219	342,144	
WFI Ambient Cooler	*SK-6401 /TC-9201*	Y	890.0	53.4	53,398	Y	319,728	1,268,784	
Clean Steam Generator w/ Sample Cooler	*CSG-6501*	Y	25.0	1.5	1,500	Y	1,210	4,800	
Clean Steam Sample Cooler (Med Prep)	*TC-6501*	N	0.0	0.0	0.0	N	0.0	0.0	
Clean Steam Sample Cooler (Cell Cult)	*TC-6502*	N	0.0	0.0	0.0	N	0.0	0.0	
Clean Steam Sample Cooler (DSP1)	*TC-6503*	N	0.0	0.0	0.0	N	0.0	0.0	
Autoclave	*AT-9001*	Y	60.0	3.6	3,600	Y	21,555	85,536	
TOTAL EQUIPMENT		**-**	**1,507.8**	**90.5**	**90,465**	**-**	**563,886**	**2,237,682**	

Equipment	TAG	Flow Diversity (Y/N)	Chilled Water Vol. Flow rate (LPM)	Chilled Water Vol. Flow rate (m³/h)	Diversity Chilled Water Mass Flow rate (kg/h)	Load Diversity (Y/N)	Peak Load (Kcal/h)	Peak Load (BTU/h)	Note
Recirculation (BV)		Y	511.7	30.7	30,699	-	-	-	1
Tie-in (Future Expansion)		Y	780.7	46.8	46,844	-	-	-	2
TOTAL		**-**	**2,800.2**	**168.0**	**168,008**	**-**	**563,886**	**2,237,682**	3

Notes:

1. Flow rate through bypasses, it is guaranteed by using of 5 balancing valves.
2. Oversizing of 24 % (See item 4).
3. Total flow rate for Secondary Pump of Loop 2 – Design Condition (Attachment 6.2.2).

- Maximum Operating Condition

Equipment	TAG	Flow Diversity (Y/N)	Chilled Water Vol. Flow rate (LPM)	Chilled Water Vol. Flow rate (m³/h)	Diversity Chilled Water Mass Flow rate (kg/h)	Load Diversity (Y/N)	Peak Load (Kcal/h)	Peak Load (BTU/h)	Note
40 L Bioreactor (Seed)	*BRE-5401*	N	0.0	0.0	0.0	N	0.0	0.0	
320 L Bioreactor (Intermediate)	*BRE-5501-JL*	Y	15.2	0.9	912	N	0.0	0.0	
2500 L Bioreactor (Chemostat) N° 1	*BRE-5601-JL*	Y	190.0	11.4	11,400	Y	118,069	468,536	
2500 L Bioreactor (Chemostat) N° 2	*BRE-5602-JL*	Y	38.0	2.3	2,280	Y	2,266	8,993	
2500 L Bioreactor (Chemostat) N° 3	*BRE-5603-JL*	Y	38.0	2.3	2,280	Y	2,266	8,993	
CPW Maintenance Cooler	*SK-6302 /TC-6302*	Y	11.6	0.7	696	Y	12,574	49,896	
WFI Still	*MES-6401*	Y	240.0	14.4	14,400	Y	86,219	342,144	
WFI Ambient Cooler	*SK-6401 /TC-9201*	Y	890.0	53.4	53,398	Y	319,728	1,268,784	
Clean Steam Generator w/ Sample Cooler	*CSG-6501*	Y	25.0	1.5	1,500	Y	1,210	4,800	
Clean Steam Sample Cooler (Med Prep)	*TC-6501*	N	0.0	0.0	0.0	N	0.0	0.0	
Clean Steam Sample Cooler (Cell Cult)	*TC-6502*	N	0.0	0.0	0.0	N	0.0	0.0	

Equipment	TAG	Flow Diversity (Y/N)	Chilled Water Vol. Flow rate (LPM)	Chilled Water Vol. Flow rate (m³/h)	Diversity Chilled Water Mass Flow rate (kg/h)	Load Diversity (Y/N)	Peak Load (Kcal/h)	Peak Load (BTU/h)	Note
Clean Steam Sample Cooler (DSP1)	*TC-6503*	N	0.0	0.0	0.0	N	0.0	0.0	
Autoclave	*AT-9001*	Y	60.0	3.6	3,600	Y	21,555	85,536	
TOTAL EQUIPMENT		**-**	**1,507.8**	**90.5**	**90,465**	**-**	**563,886**	**2,237,682**	
Recirculation (BV)		Y	511.6	30.7	30694	-	-	-	1
Tie-in (Future Expansion)		N	-	-	-	-	-	-	
TOTAL		**-**	**2,019.4**	**121.2**	**121,159**	**-**	**563,886**	**2,237,682**	2

Notes:

1. Flow rate through bypasses, it is guaranteed by using of 5 balancing valves.
2. Total flow rate for Secondary Pump of Loop 2 – Maximum Operating Condition (Attachment 6.2.3).

- Intermediate Operating Condition

Equipment	TAG	Flow Diversity (Y/N)	Chilled Water Vol. Flow rate (LPM)	Chilled Water Vol. Flow rate (m³/h)	Diversity Chilled Water Mass Flow rate (kg/h)	Load Diversity (Y/N)	Peak Load (Kcal/h)	Peak Load (BTU/h)	Note
40 L Bioreactor (Seed)	*BRE-5401*	Y	46.0	2.8	2,760	Y	3,757	14,910	
320 L Bioreactor (Intermediate)	*BRE-5501-JL*	Y	76.0	4.6	4,560	Y	13,912	55,208	
2500 L Bioreactor (Chemostat) N° 1	*BRE-5601-JL*	N	0.0	0.0	0.0	N	0.0	0.0	
2500 L Bioreactor (Chemostat) N° 2	*BRE-5602-JL*	Y	190.0	11.4	11,400	Y	2,266	8,993	
2500 L Bioreactor (Chemostat) N° 3	*BRE-5603-JL*	Y	190.0	11.4	11,400	Y	2,266	8,993	
CPW Maintenance Cooler	*SK-6302 /TC-6302*	Y	58.0	3.5	3,480	Y	12,574	49,896	
WFI Still	*MES-6401*	Y	240.0	14.4	14,400	Y	86,219	342,144	
WFI Ambient Cooler	*SK-6401 /TC-9201*	N	0.0	0.0	0.0	N	0.0	0.0	
Clean Steam Generator w/ Sample Cooler	*CSG-6501*	Y	25.0	1.5	1,500	Y	1,210	4,800	

Equipment	TAG	Flow Diversity (Y/N)	Chilled Water Vol. Flow rate (LPM)	Chilled Water Vol. Flow rate (m³/h)	Diversity Chilled Water Mass Flow rate (kg/h)	Load Diversity (Y/N)	Peak Load (Kcal/h)	Peak Load (BTU/h)	Note
Clean Steam Sample Cooler (Med Prep)	*TC-6501*	Y	7.0	0.4	420	Y	9,475	37,600	
Clean Steam Sample Cooler (Cell Cult)	*TC-6502*	Y	7.0	0.4	420	Y	9,475	37,600	
Clean Steam Sample Cooler (DSP1)	*TC-6503*	Y	7.0	0.4	420	Y	9,475	37,600	
Autoclave	*AT-9001*	N	0.0	0.0	0.0	N	0.0	0.0	
TOTAL EQUIPMENT		**-**	**846.0**	**50.8**	**50,758**	**-**	**150,629**	**597,744**	
Recirculation (BV)		Y	510.7	30.6	30643	-	-	-	1
Tie-in (Future Expansion)		N	-	-	-	-	-	-	
TOTAL		**-**	**1,356.7**	**81.5**	**81,401**	**-**	**150,629**	**597,744**	2

Notes:

1. Flow rate through bypasses, it is guaranteed by using of 5 balancing valves.
2. Total flow rate for Secondary Pump of Loop 2 – Intermediate Operating Condition (Attachment 6.2.4).

- Minimum Operating Condition

Equipment	TAG	Flow Diversity (Y/N)	Chilled Water Vol. Flow rate (LPM)	Chilled Water Vol. Flow rate (m³/h)	Diversity Chilled Water Mass Flow rate (kg/h)	Load Diversity (Y/N)	Peak Load (Kcal/h)	Peak Load (BTU/h)	Note
40 L Bioreactor (Seed)	*BRE-5401*	N	0.0	0.0	0.0	N	0.0	0.0	
320 L Bioreactor (Intermediate)	*BRE-5501-JL*	N	0.0	0.0	0.0	N	0.0	0.0	
2500 L Bioreactor (Chemostat) N° 1	*BRE-5601-JL*	N	0.0	0.0	0.0	N	0.0	0.0	
2500 L Bioreactor (Chemostat) N° 2	*BRE-5602-JL*	N	0.0	0.0	0.0	N	0.0	0.0	
2500 L Bioreactor (Chemostat) N° 3	*BRE-5603-JL*	N	0.0	0.0	0.0	N	0.0	0.0	
CPW Maintenance Cooler	*SK-6302 /TC-6302*	N	0.0	0.0	0.0	N	0.0	0.0	
WFI Still	*MES-6401*	N	0.0	0.0	0.0	N	0.0	0.0	

Equipment	TAG	Flow Diversity (Y/N)	Chilled Water Vol. Flow rate (LPM)	Chilled Water Vol. Flow rate (m³/h)	Diversity Chilled Water Mass Flow rate (kg/h)	Load Diversity (Y/N)	Peak Load (Kcal/h)	Peak Load (BTU/h)	Note
WFI Ambient Cooler	*SK-6401 /TC-9201*	N	0.0	0.0	0.0	N	0.0	0.0	
Clean Steam Generator w/ Sample Cooler	*CSG-6501*	N	0.0	0.0	0.0	N	0.0	0.0	
Clean Steam Sample Cooler (Med Prep)	*TC-6501*	N	0.0	0.0	0.0	N	0.0	0.0	
Clean Steam Sample Cooler (Cell Cult)	*TC-6502*	N	0.0	0.0	0.0	N	0.0	0.0	
Clean Steam Sample Cooler (DSP1)	*TC-6503*	N	0.0	0.0	0.0	N	0.0	0.0	
Autoclave	*AT-9001*	N	0.0	0.0	0.0	N	0.0	0.0	
TOTAL EQUIPMENT		**-**	**0.0.**	**0.0**	**0.0**	**-**	**0.0**	**0.0**	
Recirculation (BV)		Y	546.7	32.8	32,804	-	-	-	1
Tie-in (Future Expansion)		N	-	-	-	-	-	-	
TOTAL		**-**	**546.7**	**32.8**	**32,804**	**-**	**0.0**	**0.0**	2

Notes:

1. Flow rate through bypasses, it is guaranteed by using of 5 balancing valves.
2. Total flow rate for Secondary Pump of Loop 2 – Minimum Operating Condition (Attachment 6.2.5).

5.2.1.2 Balancing Valves – Loop 2 (4 °C)

To ensure the correct flow distribution in the installation, the following balancing valves were installed.

a) By-pass at the end of the header distribution

It was considered 30.7 m³/h for chilled water recirculation in the system. This flow rate will be guaranteed by using 5 static balancing valves in the by-pass as shown below:

ITEM	VALVE	FLOW RATE (m³/h)	PRESSURE LOSS (bar)	CV (Calculated)
602	BV-070018	6.00	1.73	5.27
603	BV-070040	6.00	1.72	5.29
604	BV-070014	6.00	1.62	5.46
606	BV-070001	6.00	1.68	5.35
607	BV-070033	6.70	1.17	7.16
TOTAL		**30.7**	**-**	**-**

The total flow rate of 30.7 m³/h in these valves represents the pump's minimum flow rate, as it can be seen in the pump curve (item 7.2). The pump can operate in the minimum flow rate, where all the process equipment don´t need chilled water and the flow rate required is only for the chilled water recirculation.

b) Balancing valves installed at the beginning of the distribution headers

Throughout the system, 1 static balancing valve in the distribution headers were considered to guarantee the correct water distribution, as shown in the table below:

ITEM	VALVE	FLOW RATE	PRESSURE LOSS	CV
		(m³/h)	(bar)	(Calculated)
581	BV-070039	22.87	0.05	113.30
915	BV-070055	6.00	0.03	37.34
916	BV-070056	21.80	0.44	38.15

c) Balancing valves at the process equipment inlet

Static Balancing valves were considered as shown in the table below:

EQUIPMENT	VALVE	FLOW RATE	PRESSURE LOSS	CV
		(m³/h)	(bar)	(Calculated)
BRE-5401	BV-070045	2.76	0.92	3.32
AT-9001	BV-070020	3.60	0.79	4.68
BRE-5601-JL	BV-070041	11.40	0.72	15.57
BRE-5602-JL	BV-070043	11.40	0.63	16.55
BRE-5501-JL	BV-070047	4.56	0.61	6.76
BRE-5603-JL	BV-070049	11.40	0.60	16.97
TC-6501	BV-070016	0.42	0.78	0.55
TC-6502	BV-070012	0.42	0.75	0.56
TC-6503	BV-070008	0.42	0.66	0.60
CSG-6501	BV-070026	1.50	0.70	2.07
MES-6401	BV-070037	14.40	0.21	36.04
SK-6302/TC-6302	BV-070031	3.48	0.11	12.27
SK-6401/TC-9201	BV-070035	53.40	0.67	75.50

5.2.1.3 Process Equipment – Loop 2 (4 °C)

The table below shows the information of the inlet pressures standardized as requested by IPS, the actual inlet pressure in each process equipment and the total DP of 1.0 bar (equipment + temperature control valve).

Equipment	P in Equip. (barG)	Pressure in the PID (barG)	dP Equipment (bar)	dP Temp. Control Valves (bar)	Balancing Valve	dP Balancing Valve (bar)	dP Total (bar)
BRE-5401	2.02	3.0	0.50	0.50	BV-070045	0.92	1.92
AT-9001	2.18	3.0	0.50	0.50	BV-070020	0.79	1.79

Equipment	P in Equip. (barG)	Pressure in the PID (barG)	dP Equipment (bar)	dP Temp. Control Valves (bar)	Balancing Valve	dP Balancing Valve (bar)	dP Total (bar)
BRE-5601-JL	2.87	3.0	0.50	0.50	BV-070041	0.72	1.72
BRE-5602-JL	2.79	3.0	0.50	0.50	BV-070043	0.63	1.63
BRE-5501-JL	2.80	3.0	0.50	0.50	BV-070047	0.61	1.61
BRE-5603-JL	2.81	3.0	0.50	0.50	BV-070049	0.60	1.60
TC-6501	2.37	3.0	0.50	0.50	BV-070016	0.78	1.78
TC-6502	2.38	3.0	0.50	0.50	BV-070012	0.75	1.75
TC-6503	2.42	3.0	0.50	0.50	BV-070008	0.66	1.66
CSG-6501	2.91	3.0	0.50	0.50	BV-070026	0.70	1.70
MES-6401	2.94	3.0	0.50	0.50	BV-070037	0.21	1.21
SK-6302/TC-6302	2.87	3.0	0.50	0.50	BV-070031	0.11	1.11
SK-6401/TC-9201	2.56	3.0	0.50	0.50	BV-070035	0.67	1.67

5.2.1.4 Pump Capacity – Loop 2 (4 °C)

The secondary pumps of the system operated with variable speed. Based on the conditions above, the secondary pumps of Loop 2 (P-PCH-7B-5/ P-PCH-7B-6) were sized for the following conditions:

Design Condition – Flow rate = 168.0 m³/h

Maximum Operating Condition = 121.2 m³/h

Intermediate Operating Condition = 81.5 m³/h

Minimum Operating Condition = 32.8 m³/h

There are 2 secondary pumps, where one is operating and the other is in stand-by. They are controlled by the differential pressure transmitter PDIT-070001 maintaining constant the pressure drop of 2.0 bar at the main distribution header.

This instrument is installed at a distance of 2/3 of the main distribution pipe total length, to guarantee a good control.

The results of the pumps calculated are indicated in Item 7.2 of this document.

5.2.1.4.1 Design Condition

Jct	Results Diagram	Name	Vol. Flow (m3/hr)	Mass Flow (kg/hr)	dP (bar)	dH (meters)	Ideal Power (kW)	Overall Efficiency (Percent)	Overall Power (kW)	Speed (Percent)	NPSHA (meters)	P Stag. Suction (barG)	P Stag. Disc. (barG)
810	Show ...	P-PCH-7B-5	168,0	168.012	3,330	33,96	15,53	72,90	21,31	100,0	12,89	0,2119	3,513
X812	Show ...	P-PCH-7B-6	0,0	0	N/A	N/A	N/A	N/A	N/A	0,0	N/A	0,2432	3,481

5.2.1.4.2 Maximum Operating Condition

Jct	Results Diagram	Name	Vol. Flow (m3/hr)	Mass Flow (kg/hr)	dP (bar)	dH (meters)	Ideal Power (kW)	Overall Efficiency (Percent)	Overall Power (kW)	Speed (Percent)	NPSHA (meters)	P Stag. Suction (barG)	P Stag. Disc. (barG)
810	Show ...	P-PCH-7B-5	121,2	121.169	2,780	28,35	9,351	74,31	12,58	86,71	13,07	0,2301	2,980
X812	Show ...	P-PCH-7B-6	0,0	0	N/A	N/A	N/A	N/A	N/A	0,00	N/A	0,2464	2,964

5.2.1.4.3 Intermediate Operating Condition

Jct	Results Diagram	Name	Vol. Flow (m3/hr)	Mass Flow (kg/hr)	dP (bar)	dH (meters)	Ideal Power (kW)	Overall Efficiency (Percent)	Overall Power (kW)	Speed (Percent)	NPSHA (meters)	P Stag. Suction (barG)	P Stag. Disc. (barG)
810	Show ...	P-PCH-7B-5	81,46	81.463	2,311	23,56	5,226	71,58	7,301	75,84	13,20	0,2409	2,522
X812	Show ...	P-PCH-7B-6	0,00	0	N/A	N/A	N/A	N/A	N/A	0,00	N/A	0,2483	2,515

5.2.1.4.4 Minimum Operating Condition

Jct	Results Diagram	Name	Vol. Flow (m3/hr)	Mass Flow (kg/hr)	dP (bar)	dH (meters)	Ideal Power (kW)	Overall Efficiency (Percent)	Overall Power (kW)	Speed (Percent)	NPSHA (meters)	P Stag. Suction (barG)	P Stag. Disc. (barG)
810	Show ...	P-PCH-7B-5	32,81	32.809	1,987	20,26	1,810	54,60	3,315	67,76	13,28	0,2485	2,206
X812	Show ...	P-PCH-7B-6	0,00	0	N/A	N/A	N/A	N/A	N/A	0,00	N/A	0,2497	2,205

5.2.2 Loop 1 (0 °C)

5.2.2.1 Flow rates Required – Loop 1

The Chilled Water System has the following consumers in the Loop 1:

- Design Condition

Equipment	TAG	Flow Diversity (Y/N)	Chilled Water Vol. Flow rate (LPM)	Chilled Water Vol. Flow rate (m³/h)	Diversity Chilled Water Mass Flow rate (kg/h)	Load Diversity (Y/N)	Peak Load (Kcal/h)	Peak Load (BTU/h)	Note
250 L Media Prep Tank	TQ-5101	N	0.0	0.0	0.0	N	0.0	0.0	
4500 L Media Prep Tank	TQ-5102	Y	190.0	11.4	11,571	N	0.0	0.0	
3800 L Media Hold Tank N°1	TQ-5201	Y	190.0	11.4	11,571	N	0.0	0.0	
3800 L Media Hold Tank N°2	TQ-5202	Y	190.0	11.4	11,571	N	0.0	0.0	
3800 L Media Hold Tank N°3	TQ-5203	Y	190.0	11.4	11,571	N	0.0	0.0	
3400 L Collection Vessel N°1	TQ-5701	Y	190.0	11.4	11,571	Y	36,320	144,130	

Equipment	TAG	Flow Diversity (Y/N)	Chilled Water Vol. Flow rate (LPM)	Chilled Water Vol. Flow rate (m³/h)	Diversity Chilled Water Mass Flow rate (kg/h)	Load Diversity (Y/N)	Peak Load (Kcal/h)	Peak Load (BTU/h)	Note
3400 L Collection Vessel N°2	TQ-5702	N	0.0	0.0	0.0	N	0.0	0.0	
4200 L Harvest Vessel N°1	TQ-5901	Y	190.0	11.4	11,571	Y	35,721	141,754	
4200 L Harvest Vessel N°2	TQ-5902	N	0.0	0.0	0.0	N	0.0	0.0	
500 L Buffer Prep Tank N°1	TQ-3701	N	0.0	0.0	0.0	N	0.0	0.0	
3000 L Buffer Prep Tank N°2	TQ-3702	Y	190.0	11.4	11,571	Y	45,363	180,013	
3000 L Buffer Prep Tank N°3	TQ-3703	N	0.0	0.0	0.0	N	0.0	0.0	
320 L Bioreactor (Intermediate)	BRE-5501	Y	8.0	0.5	487	Y	479	1,901	
2500 L Bioreactor (Chemostat) N° 1	BRE-5601	Y	16.0	1.0	974	Y	958	3,802	
2500 L Bioreactor (Chemostat) N° 2	BRE-5602	Y	16.0	1.0	974	Y	958	3,802	
2500 L Bioreactor (Chemostat) N° 3	BRE-5603	Y	16.0	1.0	974	Y	958	3,802	
320 L Bioreactor Utility Panel	UP-5500	Y	38.0	2.3	2,314	Y	2,275	9,029	
3800 L Media Hold Tank N°1 Utility Panel	UP-5201	Y	38.0	2.3	2,314	Y	2,275	9,029	
3800 L Media Hold Tank N°2 Utility Panel	UP-5202	N	0.0	0.0	0.0	N	0.0	0.0	
3800 L Media Hold Tank N°3 Utility Panel	UP-5203	N	0.0	0.0	0.0	N	0.0	0.0	
Heat Exchanger Chilled Water	TC HX-7B-2	Y	1,382.0	82.9	84,162	Y	563,886	223,7682	1,2
TOTAL EQUIPMENT		**-**	**2,844.0**	**170.6**	**173,198**	**-**	**689,194**	**2,734,944**	
Recirculation (BV)		Y	745.5	44.7	45400	-	-	-	3
Tie-in (Future Expansion)		Y	1135.4	68.1	69147	-	218,006	865,116	4

Equipment	TAG	Flow Diversity (Y/N)	Chilled Water Vol. Flow rate (LPM)	Chilled Water Vol. Flow rate (m³/h)	Diversity Chilled Water Mass Flow rate (kg/h)	Load Diversity (Y/N)	Peak Load (Kcal/h)	Peak Load (BTU/h)	Note
TOTAL		**-**	**4,724.9**	**283,5**	**287,745**	**-**	**907,200**	**3,600,060**	5

Notes:

1. The flow rate was calculated based on the peak load required by the process for Loop 2 (item 5.2.1.1 Design Condition). For this case, the differential temperature is 6.7 °C (Attachment 6.2.1).
2. The heat exchanger HX-7B-2 is used to produce chilled water at 4.0 °C for Loop 2.
3. Flow rate through bypasses, guaranteed by using of 8 balancing valves.
4. Oversizing of 24 % (See item 4).
5. Total flow rate for Primary and Secondary Pump of Loop 1 – Design Condition (Attachment 6.2.1).

- Maximum Operating Condition

Equipment	TAG	Flow Diversity (Y/N)	Chilled Water Vol. Flow rate (LPM)	Chilled Water Vol. Flow rate (m³/h)	Diversity Chilled Water Mass Flow rate (kg/h)	Load Diversity (Y/N)	Peak Load (Kcal/h)	Peak Load (BTU/h)	Note
250 L Media Prep Tank	TQ-5101	N	0.0	0.0	0.0	N	0.0	0.0	
4500 L Media Prep Tank	TQ-5102	Y	190.0	11.4	11,571	N	0.0	0.0	
3800 L Media Hold Tank N°1	TQ-5201	Y	190.0	11.4	11,571	N	0.0	0.0	
3800 L Media Hold Tank N°2	TQ-5202	Y	190.0	11.4	11,571	N	0.0	0.0	
3800 L Media Hold Tank N°3	TQ-5203	Y	190.0	11.4	11,571	N	0.0	0.0	
3400 L Collection Vessel N°1	TQ-5701	Y	190.0	11.4	11,571	Y	36,320	144,130	
3400 L Collection Vessel N°2	TQ-5702	N	0.0	0.0	0.0	N	0.0	0.0	
4200 L Harvest Vessel N°1	TQ-5901	Y	190.0	11.4	11,571	Y	35,721	141,754	
4200 L Harvest Vessel N°2	TQ-5902	N	0.0	0.0	0.0	N	0.0	0.0	
500 L Buffer Prep Tank N°1	TQ-3701	N	0.0	0.0	0.0	N	0.0	0.0	
3000 L Buffer Prep Tank N°2	TQ-3702	Y	190.0	11.4	11,571	Y	45,363	180,013	
3000 L Buffer Prep Tank N°3	TQ-3703	N	0.0	0.0	0.0	N	0.0	0.0	

Equipment	TAG	Flow Diversity (Y/N)	Chilled Water Vol. Flow rate (LPM)	Chilled Water Vol. Flow rate (m³/h)	Diversity Chilled Water Mass Flow rate (kg/h)	Load Diversity (Y/N)	Peak Load (Kcal/h)	Peak Load (BTU/h)	Note
320 L Bioreactor (Intermediate)	BRE-5501	Y	8.0	0.5	487	Y	479	1,901	
2500 L Bioreactor (Chemostat) N° 1	BRE-5601	Y	16.0	1.0	974	Y	958	3,802	
2500 L Bioreactor (Chemostat) N° 2	BRE-5602	Y	16.0	1.0	974	Y	958	3,802	
2500 L Bioreactor (Chemostat) N° 3	BRE-5603	Y	16.0	1.0	974	Y	958	3,802	
320 L Bioreactor Utility Panel	UP-5500	Y	38.0	2.3	2,314	Y	2,275	9,029	
3800 L Media Hold Tank N°1 Utility Panel	UP-5201	Y	38.0	2.3	2,314	Y	2,275	9,029	
3800 L Media Hold Tank N°2 Utility Panel	UP-5202	N	0.0	0.0	0.0	N	0.0	0.0	
3800 L Media Hold Tank N°3 Utility Panel	UP-5203	N	0.0	0.0	0.0	N	0.0	0.0	
Heat Exchanger Chilled Water	TC HX-7B-2	Y	1,382.0	82.9	84,162	Y	563,886	2,237,682	1,2
TOTAL EQUIPMENT		**-**	**2,844.0**	**170.6**	**173,198**	**-**	**689,194**	**2,734,944**	
Recirculation (BV)		Y	748.9	44.9	45,610	-	-	-	3
Tie-in (Future Expansion)		N	-	-	-	-	-	-	
TOTAL		**-**	**3592.9**	**215.6**	**218,808**	**-**	**689,194**	**2,734,944**	4

Notes:

1. The flow rate was calculated based on the peak load required by the process for Loop 2 (item 5.2.1.1 Design Condition). For this case, the differential temperature is 6.7 °C (Attachment 6.2.3).
2. The heat exchanger HX-7B-2 is used to produce chilled water at 4.0 °C for Loop 2.
3. Flow rate through bypasses, guaranteed by using of 8 balancing valves.
4. Total flow rate for Primary and Secondary Pump of Loop 1 – Maximum Operating Condition (Attachment 6.2.3).

- Intermediate Operating Condition

Equipment	TAG	Flow Diversity (Y/N)	Chilled Water Vol. Flow rate (LPM)	Chilled Water Vol. Flow rate (m³/h)	Diversity Chilled Water Mass Flow rate (kg/h)	Load Diversity (Y/N)	Peak Load (Kcal/h)	Peak Load (BTU/h)	Note
250 L Media Prep Tank	TQ-5101	Y	38.0	2.3	2,314	Y	9,192	36,476	
4500 L Media Prep Tank	TQ-5102	N	0.0	0.0	0.0	N	0.0	0.0	
3800 L Media Hold Tank N°1	TQ-5201	N	0.0	0.0	0.0	N	0.0	0.0	
3800 L Media Hold Tank N°2	TQ-5202	N	0.0	0.0	0.0	N	0.0	0.0	
3800 L Media Hold Tank N°3	TQ-5203	N	0.0	0.0	0.0	N	0.0	0.0	
3400 L Collection Vessel N°1	TQ-5701	N	0.0	0.0	0.0	N	0.0	0.0	
3400 L Collection Vessel N°2	TQ-5702	Y	190.0	11.4	11,571	Y	36,320	144,130	
4200 L Harvest Vessel N°1	TQ-5901	N	0.0	0.0	0.0	N	0.0	0.0	
4200 L Harvest Vessel N°2	TQ-5902	Y	190.0	11.4	11,571	Y	35,721	141,754	
500 L Buffer Prep Tank N°1	TQ-3701	Y	76.0	4.6	4,628	Y	12,852	51,002	
3000 L Buffer Prep Tank N°2	TQ-3702	N	0.0	0.0	0.0	N	0.0	0.0	
3000 L Buffer Prep Tank N°3	TQ-3703	Y	190.0	11.4	11,571	Y	45,363	180,013	
320 L Bioreactor (Intermediate)	BRE-5501	N	0.0	0.0	0.0	N	0.0	0.0	
2500 L Bioreactor (Chemostat) N° 1	BRE-5601	N	0.0	0.0	0.0	N	0.0	0.0	
2500 L Bioreactor (Chemostat) N° 2	BRE-5602	N	0.0	0.0	0.0	N	0.0	0.0	
2500 L Bioreactor (Chemostat) N° 3	BRE-5603	N	0.0	0.0	0.0	N	0.0	0.0	

Equipment	TAG	Flow Diversity (Y/N)	Chilled Water Vol. Flow rate (LPM)	Chilled Water Vol. Flow rate (m³/h)	Diversity Chilled Water Mass Flow rate (kg/h)	Load Diversity (Y/N)	Peak Load (Kcal/h)	Peak Load (BTU/h)	Note
320 L Bioreactor Utility Panel	UP-5500	N	0.0	0.0	0.0	N	0.0	0.0	
3800 L Media Hold Tank N°1 Utility Panel	UP-5201	N	0.0	0.0	0.0	N	0.0	0.0	
3800 L Media Hold Tank N°2 Utility Panel	UP-5202	Y	38.0	2.3	2,314	Y	2,275	9,029	
3800 L Media Hold Tank N°3 Utility Panel	UP-5203	Y	38.0	2.3	2,314	Y	2,275	9,029	
Heat Exchanger Chilled Water	TC HX-7B-2	Y	369.2	22.1	22,482	Y	150,629	597,744	1,2
TOTAL EQUIPMENT		**-**	**1,129.2**	**67.7**	**68,766**	**-**	**294,628**	**1,169,177**	
Recirculation (BV)		Y	784.9	47.1	47,798	-	-	-	3
Tie-in (Future Expansion)		N	-	-	-	-	-	-	
TOTAL		**-**	**1,914.1**	**114.9**	**116,564**	**-**	**294,628**	**1,169,177**	4

Notes:

1. The flow rate was calculated based on the intermediate load required by the process for Loop 2 (item 5.2.1.1 Intermediate Operating Condition). For this case, the differential temperature is 6.7 °C (Attachment 6.2.4).
2. The heat exchanger HX-7B-2 is used to produce chilled water at 4.0 °C for Loop 2.
3. Flow rate through bypasses, guaranteed by using of 8 balancing valves.
4. Total flow rate for Primary and Secondary Pump of Loop 1 – Intermediate Operating Condition (Attachment 6.2.4).

- Minimum Operating Condition

Equipment	TAG	Flow Diversity (Y/N)	Chilled Water Vol. Flow rate (LPM)	Chilled Water Vol. Flow rate (m³/h)	Diversity Chilled Water Mass Flow rate (kg/h)	Load Diversity (Y/N)	Peak Load (Kcal/h)	Peak Load (BTU/h)	Note
250 L Media Prep Tank	TQ-5101	N	0.0	0.0	0.0	N	0.0	0.0	
4500 L Media Prep Tank	TQ-5102	N	0.0	0.0	0.0	N	0.0	0.0	
3800 L Media Hold Tank N°1	TQ-5201	N	0.0	0.0	0.0	N	0.0	0.0	
3800 L Media Hold Tank N°2	TQ-5202	N	0.0	0.0	0.0	N	0.0	0.0	
3800 L Media Hold Tank N°3	TQ-5203	N	0.0	0.0	0.0	N	0.0	0.0	
3400 L Collection Vessel N°1	TQ-5701	N	0.0	0.0	0.0	N	0.0	0.0	

Equipment	TAG	Flow Diversity (Y/N)	Chilled Water Vol. Flow rate (LPM)	Chilled Water Vol. Flow rate (m³/h)	Diversity Chilled Water Mass Flow rate (kg/h)	Load Diversity (Y/N)	Peak Load (Kcal/h)	Peak Load (BTU/h)	Note
3400 L Collection Vessel N°2	TQ-5702	N	0.0	0.0	0.0	N	0.0	0.0	
4200 L Harvest Vessel N°1	TQ-5901	N	0.0	0.0	0.0	N	0.0	0.0	
4200 L Harvest Vessel N°2	TQ-5902	N	0.0	0.0	0.0	N	0.0	0.0	
500 L Buffer Prep Tank N°1	TQ-3701	N	0.0	0.0	0.0	N	0.0	0.0	
3000 L Buffer Prep Tank N°2	TQ-3702	N	0.0	0.0	0.0	N	0.0	0.0	
3000 L Buffer Prep Tank N°3	TQ-3703	N	0.0	0.0	0.0	N	0.0	0.0	
320 L Bioreactor (Intermediate)	BRE-5501	N	0.0	0.0	0.0	N	0.0	0.0	
2500 L Bioreactor (Chemostat) N° 1	BRE-5601	N	0.0	0.0	0.0	N	0.0	0.0	
2500 L Bioreactor (Chemostat) N° 2	BRE-5602	N	0.0	0.0	0.0	N	0.0	0.0	
2500 L Bioreactor (Chemostat) N° 3	BRE-5603	N	0.0	0.0	0.0	N	0.0	0.0	
320 L Bioreactor Utility Panel	UP-5500	N	0.0	0.0	0.0	N	0.0	0.0	
3800 L Media Hold Tank N°1 Utility Panel	UP-5201	N	0.0	0.0	0.0	N	0.0	0.0	
3800 L Media Hold Tank N°2 Utility Panel	UP-5202	N	0.0	0.0	0.0	N	0.0	0.0	
3800 L Media Hold Tank N°3 Utility Panel	UP-5203	N	0.0	0.0	0.0	N	0.0	0.0	
Heat Exchanger Chilled Water	TC HX-7B-2	N	0.0	0.0	0.0	N	0.0	0.0	
TOTAL EQUIPMENT		**-**	**0.0**	**0.0**	**0.0**	**-**	**0.0**	**0.0**	
Recirculation (BV)		Y	790.3	47.4	48,129	-	-	-	1
Tie-in (Future Expansion)		N	-	-	-	-	-	-	
TOTAL		**-**	**790.3**	**47.4**	**48,129**	**-**	**0.0**	**0.0**	2

Notes:

1. Flow rate through bypasses, guaranteed by using of 8 balancing valves.
2. Total flow rate for Primary and Secondary Pump of Loop 1 – Minimum Operating Condition (Attachment 6.2.5).

The Simultaneous Peak Load is 689,194 kcal/h and it is equivalent to 228 TR. Therefore, it will be considered the installation of 2 chillers with a nominal capacity of 300 TR each one of them. So, the chillers have an oversizing of 24 % (72 TR).

5.2.2.2 Balancing Valves – Loop 1 (0 °C)

To ensure the correct flow distribution in the installation, the following balancing valves were installed.

a) By-pass at the end of the header distribution

It was considered 44.7 m³/h for chilled water recirculation in the system. This flow rate will be guaranteed by using 8 static balancing valves in the by-pass as shown below:

ITEM	VALVE	FLOW RATE	PRESSURE LOSS	CV
		(m³/h)	(bar)	(Calculated)
501	BV-9800210	6.8	1.06	7.69
505	BV-9800123	5.4	1.24	5.67
506	BV-9800124	5.4	1.17	5.84
507	BV-9800133	5.4	1.19	5.80
508	BV-9800134	5.4	1.18	5.81
509	BV-9800141	5.4	1.22	5.72
510	BV-9800142	5.4	1.19	5.80
514	BV-980010	5.4	1.36	5.41
TOTAL		**47.7**	**-**	**-**

The total flow rate of 47.7 m³/h in these valves represents the pump's minimum flow rate, as it can be seen in the pump curve (item 7.1). The pump can operate in the minimum flow rate, where all the process equipment don´t need chilled water and the flow rate required is only for the chilled water recirculation.

b) Balancing valves installed at the beginning of the distribution headers

Throughout the system, 4 static balancing valves in the distribution headers were considered to guarantee the correct water distribution, as shown in the table below:

ITEM	VALVE	FLOW RATE	PRESSURE LOSS	CV
		(m³/h)	(bar)	(Calculated)
713	BV-9800203	23.28	0.08	93.07
714	BV-9800213	47.32	0.07	202.32
715	BV-9800201	33.64	0.09	130.64
916	BV-9800100	82.92	0.04	485.56

c) Balancing valves at the process equipment inlet

Static Balancing valves were considered as shown in the table below:

EQUIPMENT	VALVE	FLOW RATE	PRESSURE LOSS	CV
		(m³/h)	(bar)	(Calculated)
TQ-5902	BV-9800117	11.40	0.35	22.50
TQ-5702	BV-9800121	11.40	0.32	23.46
TQ-5901	BV-9800104	11.40	0.36	22.19
TQ-5701	BV-9800107	11.40	0.32	23.42
BRE-5602	BV-9800129	0.96	0.20	2.48
BRE-5501	BV-9800127	0.48	0.16	1.41
UP-5500	BV-9800200	2.28	0.21	5.83
BRE-5603	BV-9800131	0.96	0.14	3.00
UP-5201	BV-980094	2.28	0.29	4.97
BRE-5601	BV-9800126	0.96	0.21	2.44
TQ-5201	BV-9800135	11.40	0.18	31.39
TQ-5202	BV-9800137	11.40	0.22	28.14
UP-5202	BV-980096	2.28	0.44	4.00
UP-5203	BV-980098	2.28	0.43	4.04
TQ-5203	BV-9800139	11.40	0.17	32.02
TQ-3702	BV-9800147	11.40	0.21	28.99
TQ-3701	BV-9800143	4.56	0.41	8.25
TQ-5102	BV-9800145	11.40	0.18	31.42
TQ-3703	BV-9800151	11.40	0.31	24.04
TQ-5101	BV-9800155	2.28	0.40	4.20

d) Balancing valves at the chillers´s outlet

Static balancing valves were considered after the chiller, as shown in the table below:

ITEM	VALVE	FLOW RATE	PRESSURE LOSS	CV
		(m³/h)	(bar)	(Calculated)
748	BV-980001	283.50	0.06	1369.98
749	BV-980002	283.50	0.06	1369.98

5.2.2.3 Process Equipment (0 °C)

The table below shows the information of the inlet pressures standardized as requested by IPS, the actual inlet pressure in each process equipment and the total DP of 1.0 bar (equipment + temperature control valve).

Equipment	P in Equip. (barG)	Pressure in the PID (barG)	dP Equipment (bar)	dP Temp. Control Valves (bar)	Balancing Valve	dP Balancing Valve (bar)	dP Total (bar)
TQ-5901	2.24	2.5	0.50	0.50	BV-9800104	0.36	1.36
TQ-5701	2.25	2.5	0.50	0.50	BV-9800107	0.32	1.32
TQ-5902	2.20	2.5	0.50	0.50	BV-9800117	0.35	1.35
TQ-5702	2.21	2.5	0.50	0.50	BV-9800121	0.32	1.32

Equipment	P in Equip. (barG)	Pressure in the PID (barG)	dP Equipment (bar)	dP Temp. Control Valves (bar)	Balancing Valve	dP Balancing Valve (bar)	dP Total (bar)
BRE-5601	2.24	2.5	0.50	0.50	BV-9800126	0.21	1.21
BRE-5501	2.27	2.5	0.50	0.50	BV-9800127	0.16	1.16
BRE-5602	2.27	2.5	0.50	0.50	BV-9800129	0.20	1.20
BRE-5603	2.31	2.5	0.50	0.50	BV-9800131	0.14	1.14
TQ-5201	2.30	2.5	0.50	0.50	BV-9800135	0.18	1.18
TQ-5202	2.27	2.5	0.50	0.50	BV-9800137	0.22	1.22
TQ-5203	2.30	2.5	0.50	0.50	BV-9800139	0.17	1.17
TQ-3702	2.28	2.5	0.50	0.50	BV-9800147	0.21	1.21
TQ-3701	2.16	2.5	0.50	0.50	BV-9800143	0.41	1.41
TQ-5102	2.29	2.5	0.50	0.50	BV-9800145	0.18	1.18
TQ-3703	2.22	2.5	0.50	0.50	BV-9800151	0.31	1.31
TQ-5101	2.18	2.5	0.50	0.50	BV-9800155	0.40	1.40
UP-5500	2.24	2.5	0.50	0.50	BV-9800200	0.21	1.21
UP-5201	2.22	2.5	0.50	0.50	BV-980094	0.29	1.29
UP-5202	2.12	2.5	0.50	0.50	BV-980096	0.44	1.44
UP-5203	2.12	2.5	0.50	0.50	BV-980098	0.43	1.43

5.2.2.4 Pump Capacity – Loop 1 (0 °C)

- Primary Pump

The primary pumps of the system work with fixed speed. Based on the conditions above, the primary pumps for Loop 1 (P-PCH-7B-1/ P-PCH-7B-2) were sized for the following condition:

Design Condition – Flow rate = 283.5 m³/h

Maximum Operating Condition = 215.4 m³/h

The excess of flow rate for the other conditions of the system will be directed to supply the Chiller through the Buffer Tank where the overflow occur from the cold side to the hot side of the tank.

The results of the pumps calculated are indicated in Item 7.1 of this document.

- Secondary Pump

The secondary pumps of the system work with variable speed. Based on the conditions above, the secondary pumps of Loop 1 (P-PCH-7B-3/ P-PCH-7B-4) were sized for the following conditions:

Design Condition – Flow rate = 283.5 m³/h

Maximum Operating Condition = 215.6 m³/h

Intermediate Operating Condition = 114.9 m³/h

Minimum Operating Condition = 47.4 m³/h

There are 2 secondary pumps, where one is operating and the other is in stand-by. They are controlled by the differential pressure transmitter PDIT-980010 maintaining constant the pressure drop of 1.5 bar at the main distribution header.

This instrument is installed at a distance of 2/3 of the main distribution pipe total length, to guarantee a good control.

The results of the pumps calculated are indicated in Item 7.1 of this document.

5.2.2.4.1 Design Condition

Jct	Results Diagram	Name	Vol. Flow (m3/hr)	Mass Flow (kg/hr)	dP (bar)	dH (meters)	Ideal Power (kW)	Overall Efficiency (Percent)	Overall Power (kW)	Speed (Percent)	NPSHA (meters)	P Stag. Suction (barG)	P Stag. Disc. (barG)
10	Show ...	P-PCH-7B-3	283,5	287.745	1,961	19,70	15,43	81,16	19,02	99,73	N/A	0,1175	2,049
X11	Show ...	P-PCH-7B-4	0,0	0	N/A	N/A	N/A	N/A	N/A	0,00	N/A	N/A	N/A
128	Show ...	P-PCH-7B-1	283,5	287.753	1,374	13,81	10,81	80,98	13,36	97,09	N/A	0,3294	1,674
X129	Show ...	P-PCH-7B-2	0,0	0	N/A	N/A	N/A	N/A	N/A	0,00	N/A	N/A	N/A

5.2.2.4.2 Maximum Operating Condition

Jct	Results Diagram	Name	Vol. Flow (m3/hr)	Mass Flow (kg/hr)	dP (bar)	dH (meters)	Ideal Power (kW)	Overall Efficiency (Percent)	Overall Power (kW)	Speed (Percent)	NPSHA (meters)	P Stag. Suction (barG)	P Stag. Disc. (barG)
10	Show ...	P-PCH-7B-3	215,6	218.812	1,9022	19,111	11,384	80,12	14,208	92,53	N/A	0,1376	2,010
X11	Show ...	P-PCH-7B-4	0,0	0	N/A	N/A	N/A	N/A	N/A	0,00	N/A	N/A	N/A
128	Show ...	P-PCH-7B-1	215,4	218.631	0,8026	8,063	4,799	80,98	5,926	74,08	N/A	0,3650	1,138
X129	Show ...	P-PCH-7B-2	0,0	0	N/A	N/A	N/A	N/A	N/A	0,00	N/A	N/A	N/A

5.2.2.4.3 Intermediate Operating Condition

Jct	Results Diagram	Name	Vol. Flow (m3/hr)	Mass Flow (kg/hr)	dP (bar)	dH (meters)	Ideal Power (kW)	Overall Efficiency (Percent)	Overall Power (kW)	Speed (Percent)	NPSHA (meters)	P Stag. Suction (barG)	P Stag. Disc. (barG)
10	Show ...	P-PCH-7B-3	114,9	116.585	1,8094	18,178	5,769	64,97	8,880	84,55	N/A	0,1573	1,937
X11	Show ...	P-PCH-7B-4	0,0	0	N/A	N/A	N/A	N/A	N/A	0,00	N/A	N/A	N/A
128	Show ...	P-PCH-7B-1	215,4	218.631	0,8026	8,063	4,799	80,98	5,926	74,08	N/A	0,3650	1,138
X129	Show ...	P-PCH-7B-2	0,0	0	N/A	N/A	N/A	N/A	N/A	0,00	N/A	N/A	N/A

5.2.2.4.4 Minimum Operating Condition

Jct	Results Diagram	Name	Vol. Flow (m3/hr)	Mass Flow (kg/hr)	dP (bar)	dH (meters)	Ideal Power (kW)	Overall Efficiency (Percent)	Overall Power (kW)	Speed (Percent)	NPSHA (meters)	P Stag. Suction (barG)	P Stag. Disc. (barG)
10	Show ...	P-PCH-7B-3	47,43	48.144	1,7725	17,807	2,334	40,26	5,797	82,19	N/A	0,1639	1,906
X11	Show ...	P-PCH-7B-4	0,00	0	N/A	N/A	N/A	N/A	N/A	0,00	N/A	N/A	N/A
128	Show ...	P-PCH-7B-1	215,40	218.631	0,8026	8,063	4,799	80,98	5,926	74,08	N/A	0,3650	1,138
X129	Show ...	P-PCH-7B-2	0,00	0	N/A	N/A	N/A	N/A	N/A	0,00	N/A	N/A	N/A

5.2.2.5 Chiller Capacity

According to item 5.2.1.1, the Simultaneous Peak Load is 689,194 kcal/h and it is equivalent to 228 TR. This is the maximum operating condition for the chillers.

Therefore, it will be considered the installation of 2 chillers with a Nominal Capacity of 300 TR each one of them. So, the chillers have an oversizing of 24 % (72 TR).

At the Design and Maximum Operating Conditions, the inlet temperature for the process equipment's is 0.0 ºC and the outlet temperature (return to Chiller) is 3.2 ºC (see attachment 6.2.1 and 6.2.3).

At the Intermediate Operating Condition, the inlet temperature for the process equipment's is 0.0 ºC and the outlet temperature (return to Chiller) is 2.6 ºC (see attachment 6.2.4).

At the Minimum Operating Condition, the inlet temperature for the process equipment's and the outlet temperature (return to Chiller) is 0.0 ºC, because at this condition, all equipment's are closed, and the recirculation has no thermal load (see attachment 6.2.5).

According to recommendation of Chiller´s supplier, the minimum stabilization time is 2 minutes. For that reason, it was adopted the residence time of 3 minutes, guaranteeing the thermal load when the chiller shuts down.

5.2.2.6 Buffer Tank

For the selection of the tank, the design condition was considered.

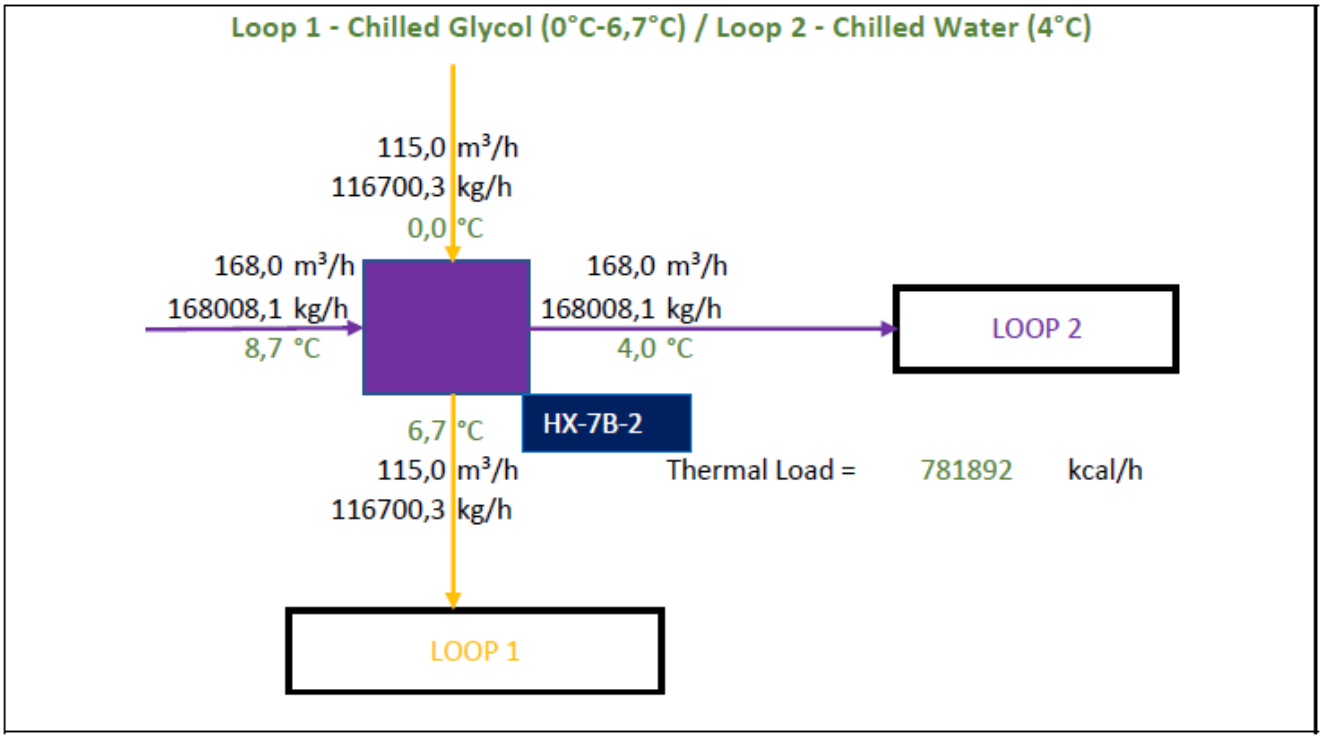
The Buffer tank is divided in 2 sides (cold side and hot side) and it was sized based on the residence time of 3 minutes for each side (minimum time required to stabilize the chiller in the event of a temporary shortages of electric energy supply).

Buffer Tank (BT-7B-1)			
Flow rate	283.5	m³/h	
	4724.9	L/min	
Autonomy	3	min	
Tank Vol.	14175	L	by camara
	28349	L	total
Tank Vol.	**15**	**m³**	***by camara***
	30	**m³**	***Total***

5.3 HEAT EXCHANGER (LOOP 1-LOOP 2)

The loops 1 and 2 are separated by a heat exchanger. The loop 1 operates with the temperature from de chiller and the loop 2 operates with the temperature from the heat exchanger.

Analyzing all scenarios calculated for this system, the sizing scenario for the heat exchanger is the design condition of Loop 2, when it is chilled by propylene glycol at 0 °C:



According to the calculation, the thermal load of the heat exchanger is 781,892 kcal/h (3,102,799 Btu/h).

The complete scenario can be seen at attachment 6.2.2.

6. ATTACHMENTS

6.1 SCHEMATICS FOR CHILLED WATER LOOP 1 (4 °C) – CHILLED WATER LOOP 2 (6 °C)

6.1.1 Design Condition – Loop 1 – CW (4 °C)

Schematic_Design_Loop 1_CW_4°C.pdf

6.1.2 Design Condition – Loop 2 – CW (6 °C)

Schematic_Design_Loop 2_CW_6°C.pdf

6.1.3 Maximum Operating Condition

Schematic_Max._Loop 1-4°C and 2-6°C_

6.1.4 Intermediate Operating Condition

Schematic_Inter._Loop 1-4°C and 2-6°C_

6.1.5 Minimum Operating Condition

Schematic_Min._Loop 1-4°C and 2-6°C_

6.2 SCHEMATICS FOR CHILLED PROPYLENE GLYCOL LOOP 1 (0 °C) – CHILLED WATER LOOP 2 (4 °C)

6.2.1 Design Condition – Loop 1 – GLY (0 °C)

Schematic_Design_Loop 1_GLY_0°C.pdf

6.2.2 Design Condition – Loop 2 – CW (4 °C)

Schematic_Design_Loop 2_CW_4°C.pdf

6.2.3 Maximum Operating Condition

Schematic_Max._Loop 1-0°C and 2-4°C_

6.2.4 Intermediate Operating Condition

Schematic_Inter._Loop 1-0°C and 2-4°C_

6.2.5 Minimum Operating Condition

Schematic_Min._Loop 1-0°C and 2-4°C_

6.3 RESULTS

6.3.1 Loop 1 (Chilled Water – 4 °C)

- Design Condition

Design_Loop 1_CW_4°C_Visual Re1_CW_4°C_Output.p

Design_Loop 1_CW_4°C_Visual Re1_CW_4°C_Output1.1_CW_4°C_Visual Re1_CW_4°C_Output.p

Design inter_Loop

Design inter_Loop

- Maximum Operating Condition

Max. Op._Loop 1_CW_4°C_Visual Re1_CW_4°C_Output.p

- Intermediate Operating Condition

Inter. Op._Loop 1_CW_4°C_Visual Re1_CW_4°C_Output.p

- Minimum Operating Condition

Min. Op._Loop 1_CW_4°C_Visual Re1_CW_4°C_Output.p

6.3.2 Loop 2 (Chilled Water – 6 °C)

- Design Condition

Design_Loop 2_CW_6°C_Visual Re2_CW_6°C_Output.p

Design inter_Loop 2_CW_6°C_Visual Re2_CW_6°C_Output1.2_CW_6°C_Visual Re2_CW_6°C_Output.p

Design_Loop

Design inter_Loop

- Maximum Operating Condition

Max. Op._Loop 2_CW_6°C_Visual Re2_CW_6°C_Output.p

- Intermediate Operating Condition

Inter. Op._Loop 2_CW_6°C_Visual Re2_CW_6°C_Output.p

- Minimum Operating Condition

Min. Op._Loop 2_CW_6°C_Visual Re
Min. Op._Loop 2_CW_6°C_Output.p

6.3.3 Loop 1 (Chilled Propylene Glycol – 0 °C)

- Design Condition

Design_Loop 1_GLY_0°C_Visual Re
Design_Loop 1_GLY_0°C_Output.p

Design inter_Loop 1_GLY_0°C_Visual Re
Design_Loop 1_GLY_0°C_Output
Design_Loop 1.1_GLY_0°C_Visual Re
Design inter_Loop 1_GLY_0°C_Output.p

- Maximum Operating Condition

Max. Op._Loop 1_GLY_0°C_Visual Re
Max. Op._Loop 1_GLY_0°C_Output.p

- Intermediate Operating Condition

Inter. Op._Loop 1_GLY_0°C_Visual Re
Inter. Op._Loop 1_GLY_0°C_Output.p

- Minimum Operating Condition

Min. Op._Loop 1_GLY_0°C_Visual Re
Min. Op._Loop 1_GLY_0°C_Output.p

6.3.4 Loop 2 (Chilled Water – 4 °C)

- Design Condition

Design_Loop 2_CW_4°C_Output.p
Design_Loop 2_CW_4°C_Visual Re

Design_Loop 2_CW_4°C_Output
Design inter_Loop 1.2_CW_4°C_Visual Re
Design inter_Loop 2_CW_4°C_Output.p
Design_Loop 2_CW_4°C_Visual Re

- Maximum Operating Condition

Max. Op._Loop 2_CW_4°C_Output.p

Max. Op._Loop 2_CW_4°C_Visual Re

- Intermediate Operating Condition

Inter. Op._Loop 2_CW_4°C_Output.p

Inter. Op._Loop 2_CW_4°C_Visual Re

- Minimum Operating Condition

Min. Op._Loop 2_CW_4°C_Output.p

Min. Op._Loop 2_CW_4°C_Visual Re

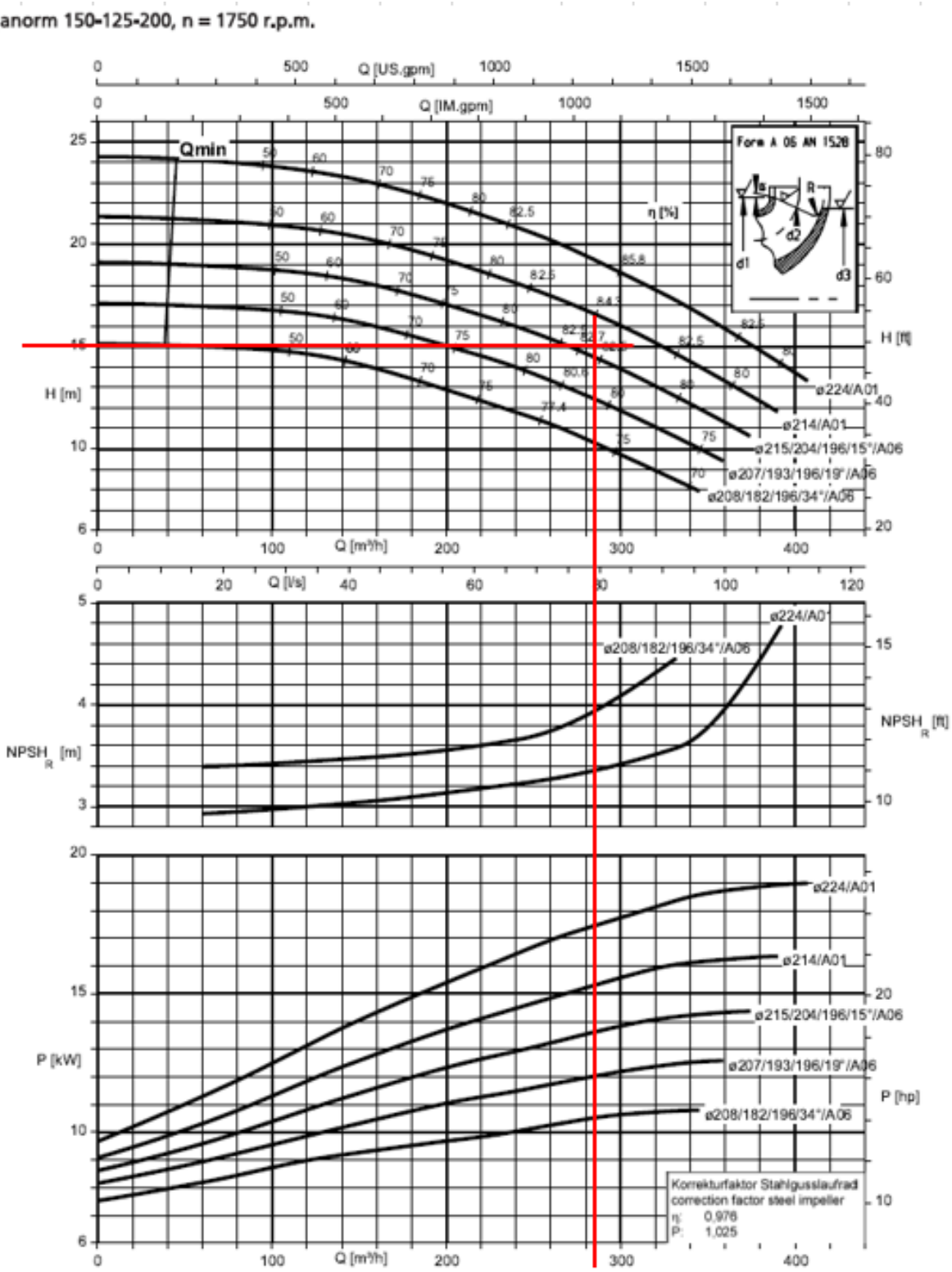
7. PUMPS SELECTED

The Chilled Water/Glycol System has 2 primary centrifugal pumps, one operating (P-PCH-7B-1) and the other stand-by (P-PCH-7B-2) and 4 secondary centrifugal pumps: 2 for Loop 1 (P-PCH-7B-3 and P-PCH-7B-4, one operating and the other stand-by) and 2 for Loop 2 (P-PCH-7B-5 and P-PCH-7B-6, one operating and the other stand-by).

7.1 LOOP 1

Primary pump – P-PCH-7B-1 / P-PCH-7B-2

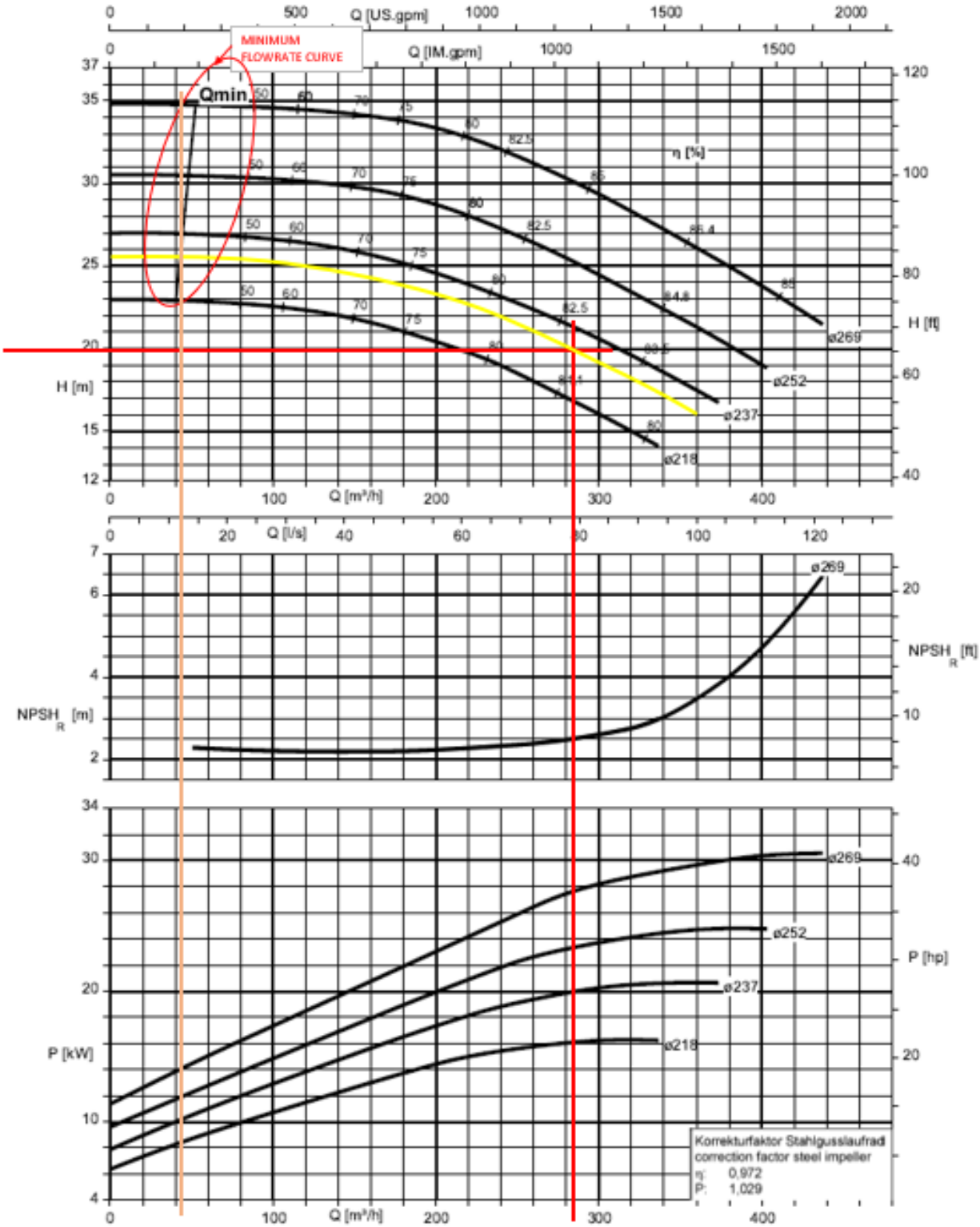
Model selected – Meganorm 1750 rpm – 150-125-200



Secondary pump - P-PCH-7B-3 / P-PCH-7B-4

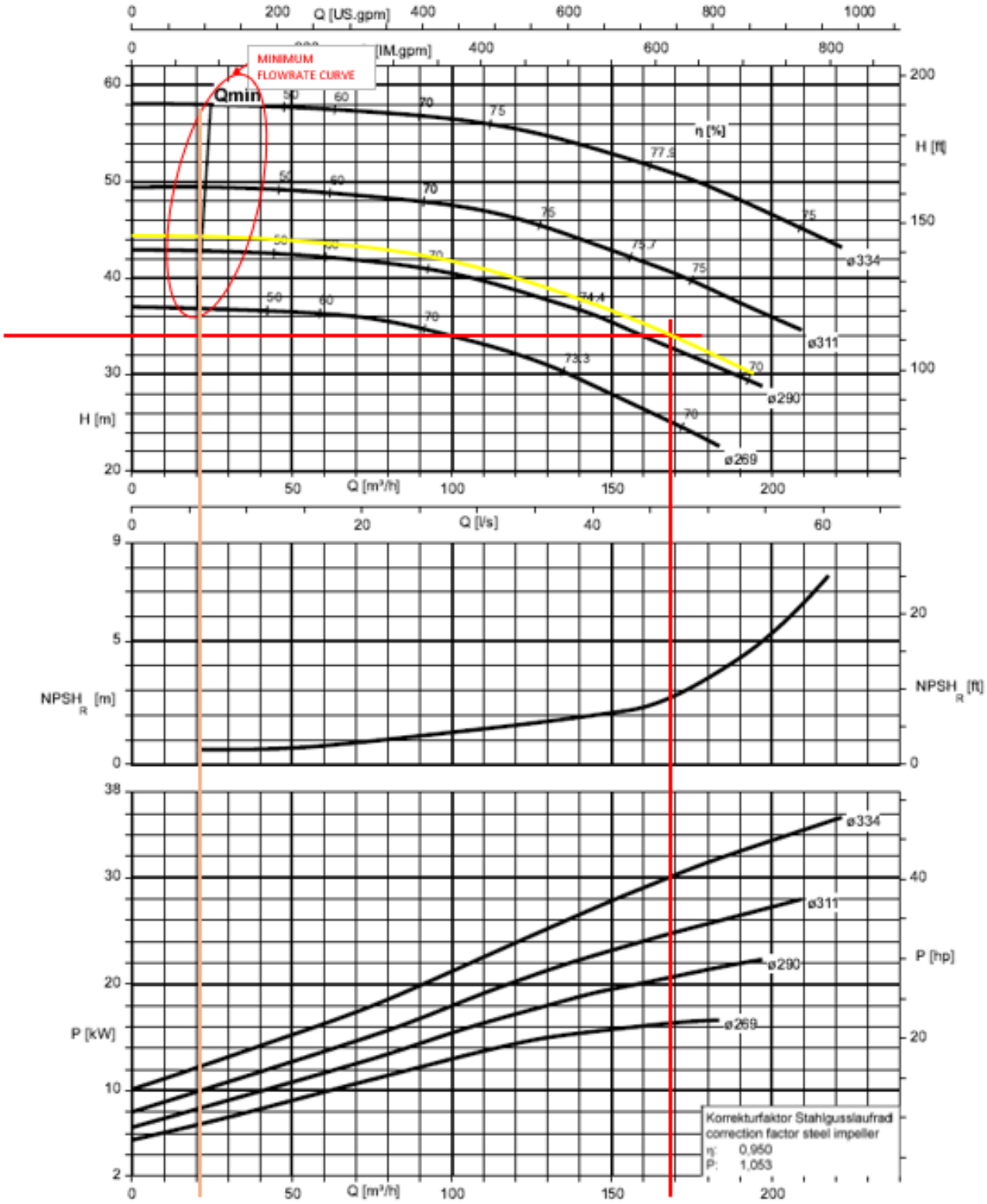
Model selected – Meganorm 1750 rpm – 150-125-250

Meganorm 150-125-250, n = 1750 r.p.m.



7.2 LOOP 2

Secondary pump - P-PCH-7B-5/ P-PCH-7B-6

Model selected – Meganorm 1750 rpm – 125-080-315

Meganorm 125-080-315, n = 1.750 rpm