



REDUCTION OF SO₂ EMISSIONS ON SOURCE POINT: DSWS (DOUBLE SOUR WATER STRIPPER) REVAMP

Master thesis presented by Mónica Puig Labrador
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Company Supervisor: Elena Domingo Force
URV Tutor: Mònica Rosell Trillas

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ACADEMIC Year: *2021-2022*

Student: *Mònica Puig Labrador*

ACADEMIC MT SUPERVISOR: *Mònica Rosell Trillas*

Email: *monica.rosell-trillas@technipenergies.com*

Approval Academic Supervisor:

Mr. / Mrs. *Mònica Rosell Trillas*

in his / her capacity as MT supervisor, he / she states that he / she considers that the MT:

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Signature:

 *M. Rosell*

Date: *28/01/2022*

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Signature:

 M. Rosell

Date: 28/01/2022

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NOMENCLATURE LIST

Symbol	Description	Units
A	Darcy's factor parameter	-
A _L	Liquid Area	m ²
A _P	Pressure drop parameter in pipe TEE	-
A _V	Vapor area	m ²
B	Darcy's factor parameter	-
c	Corrosion allowance	mm
C	Lockhart Martinelli's coefficient	-
C _V	Valve sizing coefficient	-
D	Diameter	mm
DT	Design temperature	°C
DP	Design pressure	kg/cm ² g
E	Welding coefficient	-
F _D	Darcy's factor	-
f _f	Friction factor	-
F _i	Cost Factor	-
F _P	Piping geometry factor	-
F _R	Flow regime factor	-
F _Y	Specific heat ratio	-
g	Gravity acceleration	m/s ²
G	Flux velocity	kg/m ² ·s
h	Height elevation	m
h _b	Pump differential height	m
h _f	Equivalent length pressure drop	m
h _P	Pump differential height	m
K	Fitting pressure drop coefficient	-
K _V	Critical velocity coefficient	-
L	Pipe length	m
M	Molecular weight	kg/kmol
MTD	Medium Temperature Differential	°C
n	Number of years	-
ND	Nominal diameter	inch
NPSH	Net Positive Suction Head	m
P _i	Pressure at "i"	kg/cm ² g
P _V	Vapour pressure	kg/cm ² a
Q	Volumetric flowrate	m ³ /h
Q _P	Volumetric flow for press. Drop calc.	m ³ /h
Re	Reynold's number	-
S	Basic allowable stress	bar

Symbol	Description	Units
S_P	Cross section	m^2
t	Thickness	mm
T_i	Operating temperature	$^{\circ}C$
u	Fluid velocity	m/s
U	Overall heat transfer coefficient	$kcal/m^2\text{-}^{\circ}C$
v_C	Newton's critical velocity	m/s
v_{VAP}	Allowable vapour velocity	m/s
W	Mass flowrate	kg/h
x	Liquid mass fraction	-
Y	Joint coefficient	-
Y'	Coefficient	-
Z	Compressibility factor	-
ΔH	Static height difference	m
ΔP	Pressure drop	kg/cm^2
ΔP_{CV}	Control valve pressure drop	kg/cm^2
ΔP_{FT}	Flowmeter pressure drop	kg/cm^2
ΔP_{HE}	Heat exchanger pressure drop	kg/cm^2
ΔP_{PUMP}	Pump differential pressure	kg/cm^2
ε	Effective roughness	mm
θ	Angle of fitting geometry	$^{\circ}$
μ	Fluid viscosity	cP
ρ	Density	kg/m^3
ρ_H	Mixed phase density coefficient	-
ρu^2	Velocity	kg/ms^2
Υ	Specific heat	kcal/kg
χ	Pressure drop ratio	-

ABREVIATURELISTS

Acronym	Name/ Explanation
AFC	Adjusted Cost Factors
BAT	Best Available Technique
B.L.	Battery Limit
BoD	Basis of Design
C	Consequences
DES	Design conditions
DISCH	Pump discharge
DSWS	Double Sour Water Stripper
E	Exposure
F.V.	Full Vacuum
H ₂ S	Sulphide hydrogen
H ₂ SO ₄	Sulphuric acid
HHL	High Liquid Level
HHLA	Very High Liquid Level Alarm
IC	Cost Index
L'	Pipe TEE lateral branch
L	Like hood
LLL	Low Liquid Level
LLLA	Very Low Liquid Level Alarm
MDP	Maximum Discharge Pressure
MMDP	Maximum Motor Differential Pressure
MSP	Maximum Suction Pressure
NaOH	Sodium hydroxide
NH ₃	Ammonia
NI	No Information
OP	Operating conditions
P&ID	Piping and Instrument Diagram
PDS	Process Data Sheet
PFD	Process Flow Diagram
R'	Pipe TEE straight branch
R	Risk gap
Sch	Schedule
SO _x	Sulphur oxides
SW	Sour Water
T.L.	Tangent Line
WWT	Waste-Water Treatment

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EXECUTIVE SUMMARY

Nowadays, the industry trends not only point to higher productions in more efficient processes but also the environmental impact is being reduced. The quick development of the Best Available Techniques (BAT) is leading to the tightening in the legislation referent to the emission limits.

The current project surges as a response to the necessity of a national refinery intending to adapt to these new legal requirements, concretely by reducing the SO_x emissions.

As these oxides proceed from the H_2S burning, the adopted strategy is acting in the source point: The Double Sour Water Stripping unit (DSWS) since it is the main generator of the pollutant.

In the presented project, the basic engineering stage of a unit revamp is carried out to improve the overall treatment efficiency. Thus, a new ammonia water washing column is implemented to complete the abatement of the ammonia and the hydrogen sulphide present in the sour water for decreasing the emissions of the flare.

The performance of the revamp is demonstrated with a plant simulation in *HYSYS V11* using a prediction properties package specifically designed for sour water processes that increases the result accuracy.

Besides, rigorous calculations independent of this software are realized to support to the extracted conclusions, which confirm the technical feasibility of the project.

The design case for all the new equipment and the validation of the existing equipment in the unit guarantee that H_2S concentration in the stream sent to the flare doesn't exceed 13,960 ppm when the workload of the sour water unit reaches 31.9 t/h with feedstock content of H_2S until 20,600 ppm.

The estimation of the capital investment for this new column and its associated equipment is of 1.84 M€. Although no profits are perceived, the revamp is customary to enable future operation as it permits reducing significantly the environmental damages caused by the refinery.

STUDENT'S ROLE IN THE COMPANY

During the internship in Technip Energies company, I have been working in the Process Department carrying out basic engineering tasks for real industry projects. This project diversity offered an overview of petrochemical industry specially at national level.

In advance, a summary of the more relevant projects is presented.

i. Revamp of a sour water unit

My first project in the company was the original revamp presented in this Final Master Thesis, where I participated in the validation of the current configuration and Process Data Sheets deliveries.

First off, I performed rigorous hydraulic calculations for pipeline validation. The obtained pressure profiles were used for instrument, control valve and equipment validation. Thermal assessing of the unit was done with the aid of *HTRI*.

I prepared the different PDS's for instrumentation, control valves and the new equipment, as well as the equipment list.

I revised the Heat and Mass Balance and the line list so that conditions were coherent among the different points of the process.

It should be highlighted the fact that the presented Thesis is not the aforementioned project, but an academic adaptation subjected to confidentiality clauses. All the presented documentation in this report is based on a HMB calculated in *HYSYS* independent of the *T.EN* commercial project.

ii. Green hydrogen

I had the opportunity of participating in a simplified heat and material balance of green hydrogen production from water hydrolysis for different scenarios for centralized and decentralized production.

In addition, I helped to report revision and checking of the commercial project to ensure result consistency in the delivered documentation.

iii. Energy integration of propane/ ethylene columns

This project consisted in the integration of distillation columns to improve propylene and propane purity by taking advantage of the existing equipment.

My participation involved the Process Flow Diagram drawing and HMB tables elaboration for the future operating normal conditions.

I introduced the current unit heat exchangers in *HTRI* to integrate them in *HYSYS V9* to perform rigorous calculations and simulated the column internals to evaluate their adequacy.

iv. Hot oil system

There, the exhaust fume of a turbine was used to thermal oil heating, which was utilized to heat process streams upstream a fired furnace to save energy.

I did a study of legal aspects of the hot oil storage and its thermal expansion tank and proposed a preliminary sizing of the correspondent tanks.

Moreover, I uploaded the PDS's of existing equipment and the new heat exchangers with the new process conditions.

My role in the simulation was the input of heat exchanger geometry in *HTRI* to integrate them in *HYSYS* for rigorous calculations.

Parallely, I drawn the PFD for the presented case study reflecting the changes to be implemented. Finally, I validated the line circuits hydraulically with rigorous methodology.

v. Maintenance aids

I worked in some reduced works of maintenance stops preparing the line list, tie-ins list and assembling/ disassembling diagrams (P&ID markup) for the following projects:

- Metallurgy upgrading of existing lines upstream a reactor for changing its specification since there were corrosion concerns.
- Some metallurgy upgrading of existent columns.
- Isolation of a potable water line for accomplishing legal requirements.

vi. Bio oil tank

In this project, the unit was enabled to operate with bio-oil by adapting the process conditions with traced pipelines, a new storage tank and an alternative pump.

I prepared the instrumentation and safety and control valve PDS's for the new process.

In addition, I performed calculations of estimated length for the new lines based on the lockable sections to accomplish safety requirements.

On the other hand, I revised the line lists providing feedback.

1. INTRODUCTION

The SO_x emissions are expected to tight in the near future because of the recent development of the Best Available Techniques (BATs).

This tendency leads to an increasing need of the industry to enable their processes to respond to the possible legislation changes.

The frame of the current study is a national refinery whose objective is the limitation of the SO_x emissions.

The most effective approach to deal with the challenge is the source point reduction, which implies the modification of the Double Sour Water stripper (DSWS) unit since most of the SO₂ generation is associated to the combustion of the acid gas of the unit in the flare.

1.1. Background

This project is focused on the sour water treating unit, which processes the crude distillation wastewater.

This unit consists in a double stage separation for hydrogen sulphide and ammonia removal. Three streams are obtained from the sour water processing:

- H₂S rich gas from the Water Washing, which is sent to a Sulphur Recovery unit.
- NH₃ rich gas from the second stripper column, send to the HDT unit.
- Treated water that is divided into two parts sent to different destinations (HDT and Wastewater Treatment plant).

These streams are the target of the revamp design specifications. In Figure 1.1 the schematization of the process is presented.

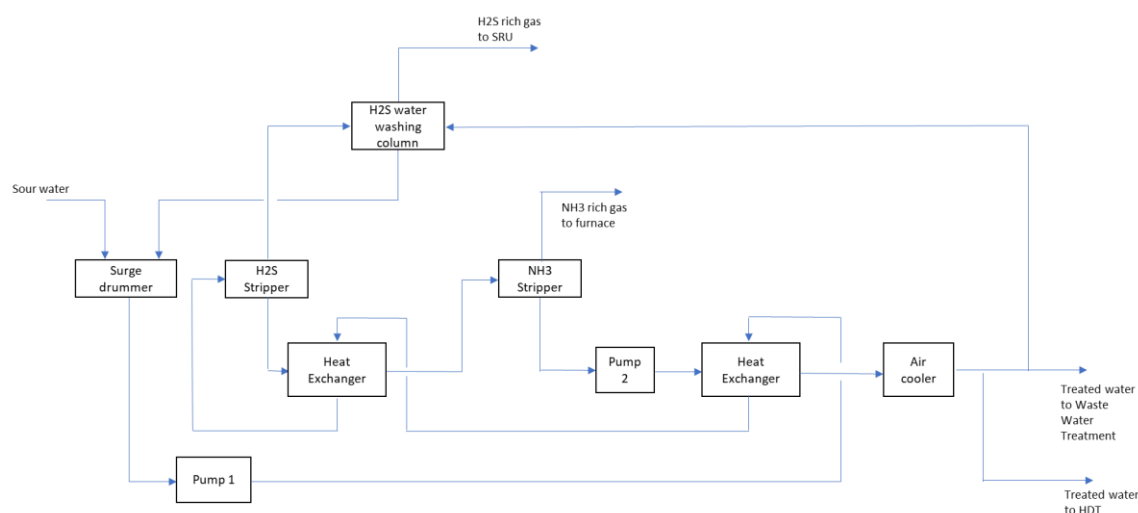


Figure 1.1. Double Sour Water Stripping (DSWS) simplified scheme.

1.2. Current situation of the unit

In the DSWS, the sour water produced in the refinery and hydrotreating units are processed removing ammonia and hydrogen sulphide present in water with the aim of accomplish the refinery current specifications for wastewater.

At the inlet, the input streams are stored in the drum V-101 until their treatment. This feed surge drum also collects the bottom stream proceeding from the H₂S water washing column.

The treatment is carried out in two stages. First, the hydrogen sulphide is the target pollutant to be abated. When the content of this compound has been reduced, the sour water is treated to recover part of the ammonia content since it needs to be limited.

Thus, the sour water is initially routed to the hydrogen sulphide stripper T-101. The overhead of this column is additionally sent to a wet scrubber (the H₂S water washing tower T-103). The double treatment for H₂S recovery has three effluents:

- The H₂S -rich gas stream, obtained by top of the washer, which is further sent to the Sulphur Recovery Unit (SRU).
- The washer bottom stream, which is mixed with the recovered sulphide hydrogen. This stream is recirculated to the feed surge drum V-101 to be processed.
- The stripper bottom stream, which is sent to the second stage of the unit for ammonia content reduction.

After this first treatment, the sour water (T-101 bottoms), is routed to the ammonia stripper T-102, where the following outputs are obtained:

- NH₃-rich gas obtained by the top of the column, which is sent to HDT fired heater for its burning.
- Treated water obtained by bottoms.

Finally, the treated water is divided into two streams. Mostly of treated water is sent to the Wastewater Treatment (WWT) plant, and a small amount is recycled as washing water for the H₂S washing in T-103.

In the original design case, both columns operated with a pump around and a reboiler stage to improve stripping efficiency.

However, only the T-102 (ammonia stripper) pump around is currently in service due to serious corrosion problems suffered by T-101 pump around.

As a result of this problem, operating pressure in T-101 was reduced from 8 kg/cm² g, the normal operating conditions to 4.5 kg/cm² g, and the stripper pump around turned out of service.

2. SCOPE OF THE PROJECT AND SPECIFIC OBJECTIVES

The scope of the current project involves the revamp of the sour water unit to achieve the design specifications presented in the basis of design with the aim of accomplishing future legal limits in SO_x emissions.

At the beginning of the project, the study of alternatives is done for targeting all specifications of the future case, which are tighter than the original, design specifications.

This study of alternatives is developed at qualitative level. Bibliographic based estimations are done for determining the most suitable approach for targeting the new requirements of the sour water unit.

The equipment to implement for the revamp, as well as the already implemented unit, must be validated for the new operating conditions to determine if any equipment, line sections, instruments or control valves needs to be replaced for future operation according to the criteria described in the basis of design chapter.

The study framework is focused on the new part of the unit, which is represented in the Piping and Instrument Diagram.

The overall process, which is described in the corresponding section of the memory, appears in the Process Flow Diagram (PFD).

The new configuration will be analysed with a quantitative HAZOP methodology for improving process safety and reliability of future operation through the recommendations of

the different scenarios. Finally, an economical estimation is presented to determine the capital cost of the project.

3. STUDY OF ALTERNATIVES

The expected emission limits of SO_x in the future will need of an efficiency improvement in the sour water treatment carried out in the refinery. Subsequently, the DSWS unit shall be modified for meeting the new specifications of workload and effluent composition.

In this section, as beginning step of the project, some alternatives will be discussed and compared to select the most indicated for the company.

It should be commented that the study of alternatives was performed at conceptual engineering stage. Hence, the analysis criteria are based on bibliography sources and estimations based on experience rather than in rigorous calculations.

As the main reason of the demanding of emission limits for the near future is the BAT's (Best Available Techniques) development, the state of art of the different treatment processes is extracted from the BREF document for wastewater and gas treatment [1].

Additionally, this information source provides performance data and associated costs based on true plants for the different separation technologies.

These considered alternatives are summarized in the Figure 3.1, where a scheme of the decisions made during the selection process is presented.

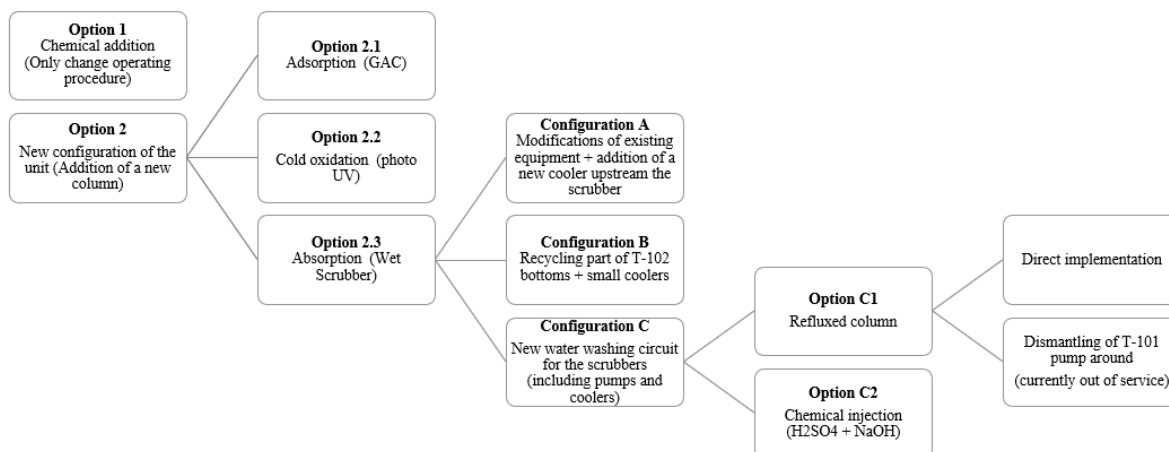


Figure 3.1. Study of alternatives as decision tree.

First off, it is determined whether a revamp is mandatory for the requirement targeting in emission levels. The alternative to the revamp would be maintaining the current configuration of the unit (in case that chemical injection was done to improve the stripping among water, ammonia, and hydrogen sulphide).

As it will be justified in the next sections, the revamp is preferred over the commented alternative.

The study is mainly conditioned by two factors:

- On one hand, the tower should be as reduced as possible because of the current situation of the sour water unit, which was not designed for more equipment than the currently implemented. Consequently, the reported efficiency is a factor for respecting the spare space constraint.

According to BREF's, the ammonia content in the acid gas must be limited to the range of 200 and 1,000 mg/Nm³ for correct operation.

The bottom stream of the first stripper (T-101) is composed of water with and a small amount of H₂S not recovered, and NH₃. This stream is further treated in the ammonia stripper (T-102), which operates at softer pressure and temperature conditions.

In this case, the proposal of caustic soda injection in T-102, would modify the ionic affinity of NH₃ with H₂SO₄ so that ammonia can be stripped, and the sulphuric acid previously added, can be neutralized.

It should be commented that the involved chemical process in this injection-based treatment is very sensitive to the additive concentration since it is required to have stoichiometric amounts.

In fact, caustic soda excess has been reported to cause fouling due to precipitation, which implies higher maintenance costs and pressure drop increments.

Another factor to keep in mind is that in case that soda was below the required amount, it wouldn't neutralize the sulphuric acid, causing corrosion issues to the equipment.

Thus, sour water pH should be in the following ranges to achieve a satisfactory stripping efficiency:

- T-101: pH 2-3 for H₂S stripping from water.
- T-102: pH > 9.5 for NH₃ stripping from water.

3.2. Option 2: New configuration

An alternative to the chemical injection would require from new equipment to meet the design specifications as the existing process doesn't.

Thus, the alternative to chemical injection (option 1) is a revamp of the DSWS unit (option 2).

According to the BAT's, stripping treatment is often complemented with a secondary unit operation to increase the overall efficiency.

The implementation of a new column is considered in option 2 although, the specific treatment working principle is not considered yet at this stage of the alternative study.

3.2.1. Future scenario for option 2

The stripper of H₂S (T-101) maintains its design duty, achieving similar results to the current normal operation since feedstock is similar.

The overhead of T-101 is sent to the H₂S water washing column T-103, set up to achieve ammonia content below 150 ppm vol. in the stream sent to the Sulphur Recovery Unit (SRU), accomplishing one of the new specifications.

The bottom outlet of T-101 has higher quantity of H₂S than in option 1 because there is no chemical injection to enhance the stripping. Consequently, it does not meet the new requirements.

This bottom stream is fed to ammonia stripper T-102, which has a reboiler stage and a pump around.

The current reboiler duty is maintained in this future scenario since it enables to meet the new specifications for stripped water.

On the contrary, the overhead gas of T-102 exceeds specification upper limit, so the addition of a new separation stage downstream T-101/103 is considered for treating the ammonia rich gas. The associated piping circuits, heat exchange equipment, pumps and instrumentation to the new column would be also implemented in option 2.

To be conservative, a recycling of some stripped water in T-103 is considered for the new column operation (as implementing a water washing column is further considered).

3.2.2. Process bottlenecks

The new specifications of the DSWS unit are tighter than the original design ones, so bottlenecks in the unit are expected.

Option 1 (Chemical injection without new equipment) implies to keep the current configuration of the DSWS unit, where the operating conditions of the existing columns are limited by the design conditions.

Separation process is sensitive to temperature and higher values in the top of the H₂S stripper would enable to reduce the chemical injection due to the increasing of the yield.

On the other hand, in option 2 (revamp with a new column), the water recycling for NH₃ washing leads to an increase of feed flowrate to H₂S stripper T-101 and its bottom flowrate. Consequently, thermal, and hydraulic bottlenecks are expected as this workload overcomes the original operating conditions.

3.3. Comparison between option 1 and 2

In the Table 3.1 both options are qualitatively compared.

Table 3.1 . Option 1 vs. Option 2 summary.

	Option 1: Chemical injection	Option 2: New column
CAPEX	Similar	Similar
OPEX	Higher (chemical consumption)	Lower
H ₂ S Rich gas to SRU		
H ₂ S recovery		Similar
Flowrate		Similar
Ammonia content		<150 ppm v.
Ammonia Rich gas to DHT heater		
H ₂ S content [wt. ppm, dry]	Higher	< 9,070
Flowrate	599 kg/h	Higher
Treated Water		
Flowrate		Higher
NH ₃ content [wt. ppm]		< 30
H ₂ S content [wt. ppm]		< 30

Both options meet the new requirements, although OPEX will be significantly higher for option 1 due to expected chemical consumption. Besides, option 1 needs of additional pumps to be implemented for the chemical injection, and the higher steam consumptions since the top temperature of the NH₃ stripper would be increased.

In case of tighter specifications in the future, option 1 would need additional equipment (*i.e.*, a new column), so the investment realized at this beginning stage would make no sense. For these reasons, this alternative is discarded and option 2 is developed.

3.4. Option 2 development

The selected option consisting in the addition of a new water washing system comprises a water washing column and its new pipelines and pumps to enable the recycling of H₂S - containing water to the feed surge drum.

The increasing water flowrates may bottleneck the DSWS unit thermal and hydraulically.

On one hand, the pumps currently installed in the unit might not deliver differential head enough. The higher volumetric flows could cause vibration concerns in the heat exchangers,

which would need equipment modifications, and the existent pipelines pressure drop can exceed allowable values.

3.4.1. Technology selection

According to the Best Available Techniques, the best alternatives for the H_2S and NH_3 separation from water are adsorption, absorption, and cold oxidation.

These technologies have some limitations and restrictions causing that a cold oxidation (photo UV) is not suitable for this scenario as H_2S concentration exceeds 50 ppm (in fact, the content of H_2S in the stream to be processed is near to 420 wt. ppm). The other inconvenient of the technique is that the waste gas flowrate is too high for a satisfactory operation. Consequently, the alternative has been discarded.

Adsorption and absorption are suitable for the separation of H_2S if it is previously cooled (maximum operating temperature is 40 for absorption and from 15 to 80°C for adsorption).

As the reported H_2S recovery is around 95% in both cases, the selection criteria will be based on the OPEX/CAPEX estimation based on the reported information according to the BREFs, which is summarized in the Table 3.2.

Among the possible technologies, packed bed columns are selected for the cost estimation not only for their applicability range of flows and concentrations in the case of the scrubber, but also for their smaller size in comparison to other options.

Table 3.2. Operating/ capital costs in BREFS [1] for adsorption and absorption processes.

	Technique	
	Adsorption	Absorption
OPEX [k€/ yr.]	39.6	20.8
CAPEX [k€]	30	20.7

The selected alternative is the wet scrubber (packed bed absorption), where the waste gas washing is done with washing water, existing the possibility of chemical addition for improving the H_2S removal.

However, the decision about using chemical injection will be taken after evaluating the alternatives for the thermal and hydraulic bottlenecks.

3.4.2. Process debottlenecking

In the frame of the study, the following three configurations have been evaluated considering the bottlenecks of the existent unit, which are analysed in the Table 3.3.

To facilitate the explanations, the different configurations are schematized in Figure 3.3, Figure 3.4, and Figure 3.5.

- Configuration A replaces the feed pumps and modifies the heat exchangers which have vibration concerns. In addition, it adds a cooler upstream the new scrubber (also called NH_3 water washing column in advance).
- Configuration B recycles part of H_2S stripper bottoms to reduce the feed flowrate to the unit. As scrubbers operate at low pressures, it isn't expected the need of a pump to send the water to the new column for the pressure gradient between both columns.
- The recycled water has an initial temperature higher than in previous case, so the cooling is from 170°C to 40°C, which implies the addition of heat exchangers.
- Configuration C consists in a specific water washing circuit for the scrubbers (i.e., the existing H_2S water washing column and the new column) with its respective pumps and coolers.

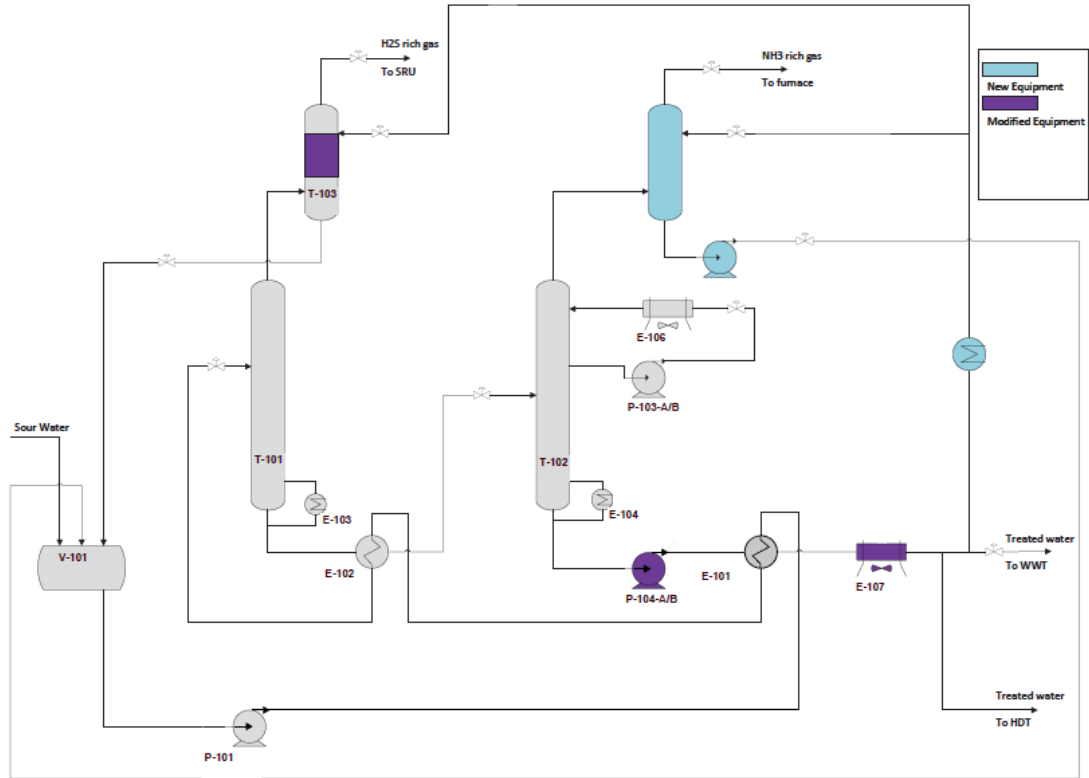


Figure 3.3. Schematic process (Option 2- configuration A).

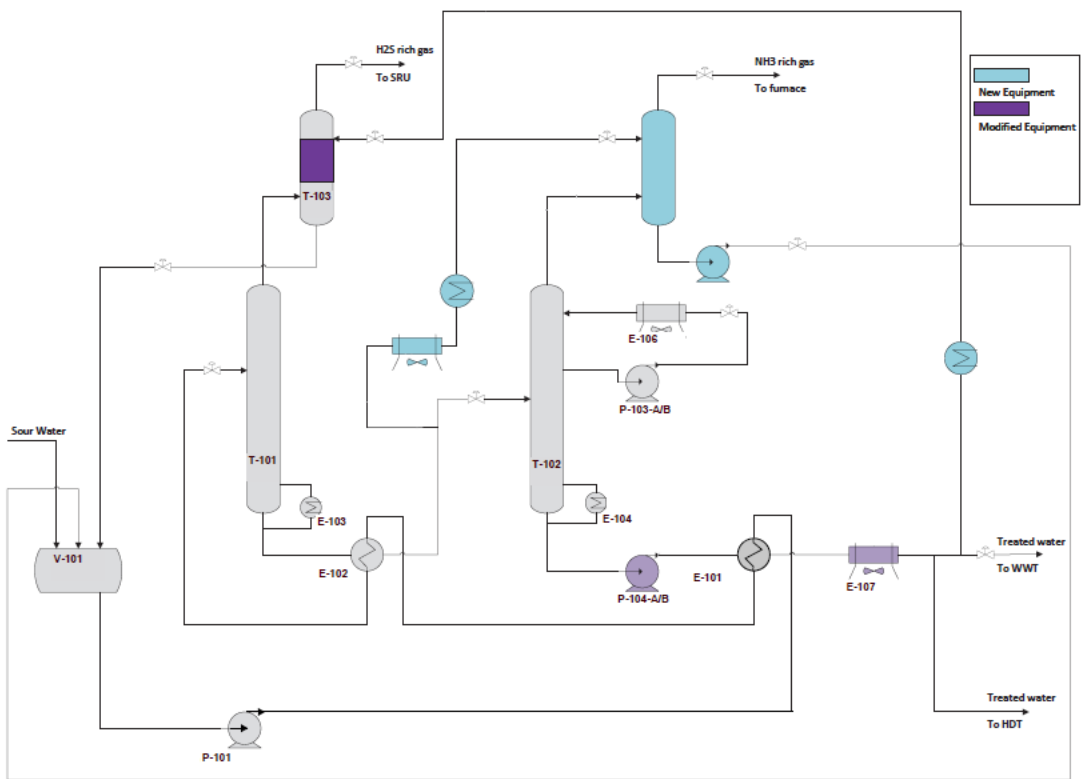


Figure 3.4. Schematic process (Option 2- configuration B).

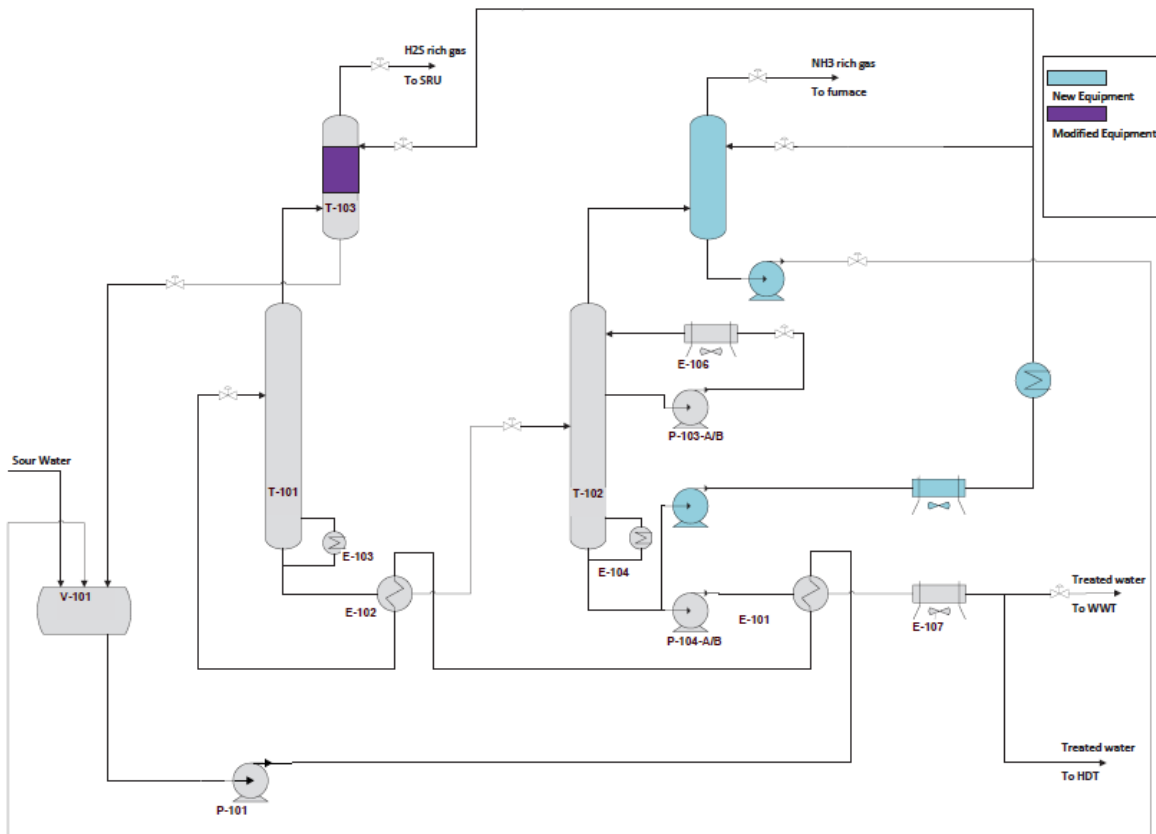


Figure 3.5. Schematic process (Option 2- configuration C).

Table 3.3. Summary of proposed configurations.

	Configuration		
	A	B	C
Advantages	Smaller space occupation.	Small impact on the plot plan (only small coolers). No installation of new equipment or modifications.	No modifications of circuits and existing equipment.
Draws	Higher CAPEX for more potent pumps and heat exchanger/ air cooler modifications.	Problems for treatment control of waste gas for the washing water composition and higher cooling water consumption.	Plot plan impact as more equipment is needed (pumps and water cooler).

Between these three configurations, option “A” is discarded for its required capital investment costs. Same happens to the option “B”, which additionally may affect negatively to the emitted gas quality. Therefore, the selected configuration is “C”.

3.4.3. Option C development

In views of the tightening of the emission legislation, two potential configurations for option “C” are studied with the aim of improving process performance: a reflux system (Option C1) vs. chemical injection (Option C2).

The corresponding schemes are presented in Figure 3.6 and Figure 3.7.

As option C2 implies the usage of sulphuric acid and caustic soda, it will have not only a more complex control for dosage regulation but also higher operating costs.

On the other hand, the spare space limitation of Option 1 could be relaxed if the pump around out of service was dismantled.

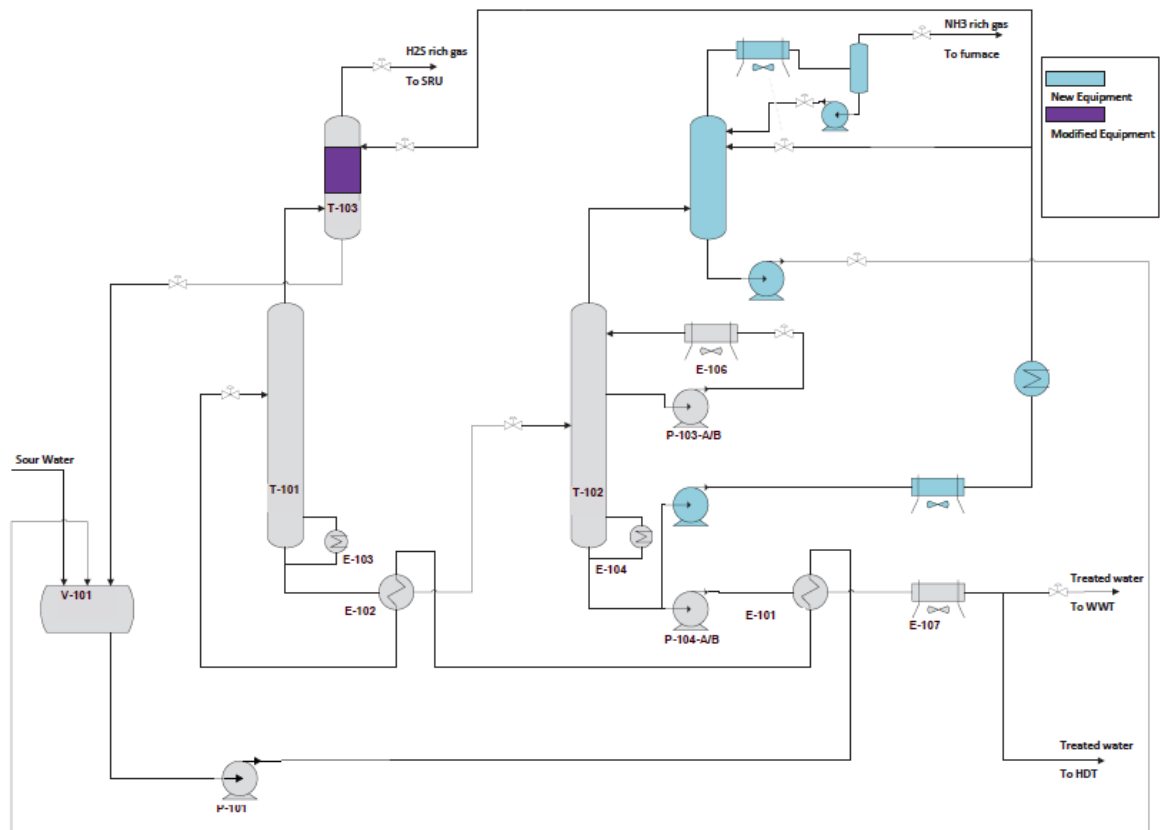


Figure 3.6. Schematic process of revamp with reflux system (Option C- Configuration C1).

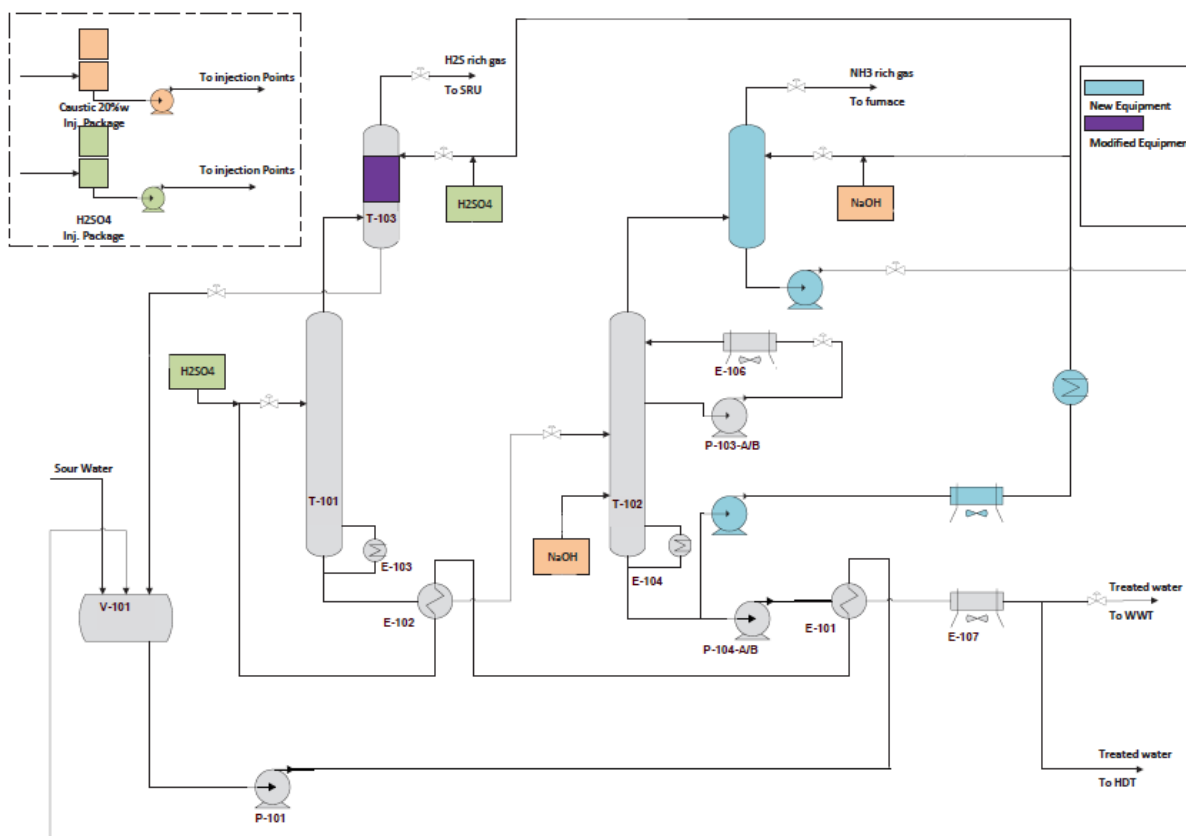


Figure 3.7. Schematic process of revamp with chemical injection (Option C-Configuration C2).

Although both configurations C1 and C2 are considered feasible, they have some advantages and cons to be evaluated, which are summarized in Table 3.4.

Table 3.4. Option C1 vs. Option C2 (qualitative comparison).

	Option C1	Option C2
Pros	Smaller washing water recycled, better NH ₃ removal due to reflux condensation	Less equipment needed and more operating flexibility (better H ₂ S absorption)
Cons	Installation more difficult for lack of space	Chemical consumption makes control more complex

Finally, the option C1 is selected since the absence of additional chemical makes the process control easier and reduces operating issues like hood.

Besides, operating costs are reduced since no chemical substances are required for the separation.

3.5. Conclusion of the study of alternatives

In the previous sections of this chapter, the study of alternatives has been described.

After considering the most suitable alternative for meeting the future case specifications not achieved currently, it is decided to implement a new washer for T-102 gas overhead, specifically, a wet packed bed scrubber.

After the evaluation of different configurations for solving the possible bottlenecks, the new column will have a reboiler and reflux with condenser stages to improve the recovery.

Thus, the new equipment to be installed are:

- NH₃ water washing column (in advance also called T-201).
- Water washing pumps:
 - o For returning the reflux to the column (P-203)
 - o For the column feed (P-202)
 - o For recycling the water (P-201) to H₂S washing.
- Column reflux condenser (air cooler E-203) and heat exchangers for wash water cooling (E-201, E-202).

The revamp implementation includes the dismantling of T-101 pump around, currently out of service for severe corrosion concerns.

4. BASIS OF DESIGN

4.1. Unit capacity and feed quality

The main purpose of the revamp is to improve the processing capacity of SW unit up to 38.8 m³/h (at standard conditions).

This input streams coming from the refinery and hydrotreating (HDT) are stored inside the feed water surge drum V-101 along with the bottoms of the H₂S water washing column (T-103).

The V-101 conditions are:

- 31.2° C and 1.2 kg/cm² (g)
- Low/ High Liquid Level: 0.30/ 2.00 m.

The service factor of the unit must be at least 8,000 h/year and a turnaround capacity of 60% shall be achievable. Therefore, the 60% and 120% of the normal operating conditions are used with the aim of validating the current equipment, lines, and instrumentation.

The expected sour water characterization is summarized in the Table 4.1.

Table 4.1. Feed sour water characterization for the revamp case.

	Revamp Design
Mass flowrate	31,902 kg/h
Volumetric flowrate	33.1 Nm ³ /h
Density	959.3 kg/m ³
H ₂ S content	20,547 wt. ppm
NH ₃ content	11,804 wt. ppm

4.2. Product specifications

The main objective is the H₂S removal from the stream sent to the Wastewater Treatment with the aim of accomplishing the met specifications. Additionally, the composition of the overhead streams of both strippers are being controlled since they are sent to the Sulphur Recovery Unit (SRU) and to the acid flare.

In the case of the ammonia rich gas, the H₂S content is reduce for limiting the SO_x generation in the furnace. On the other hand, the ammonia content in the H₂S rich gas is also being limited.

In the Table 4.2 can be seen the specifications that the effluent streams met after the treatment.

Table 4.2. Design specifications for the effluent streams after the revamp.

Stream	Specification	Original Design	Revamp Design Value
H ₂ S rich gas to SRU	Recovery of H ₂ S [%]	>90	>90
	NH ₃ concentration	<100 wt. ppm	<150 vol. ppm
	Humidity [wt. %]	1.8	Minimum
NH ₃ rich gas to furnace	H ₂ S concentration (dry basis) [wt. ppm]	153,200	≤13,960
	H ₂ O content [vol. %]	36.5	≤59.4
Product water to WWT	H ₂ S concentration [wt. ppm]	<3	<3
	NH ₃ concentration [wt. ppm]	<30	<30

4.3. Battery limit conditions

The battery limits where the feedstock streams come from are the hydrotreating Unit (HDT) and the refinery plant. The treated water stream goes to the Wastewater Treatment Plant and HDT unit the H₂S -rich gas is sent to the Sulphur Recovery Unit (SRU), and the NH₃-rich gas is routed to the HDT furnace.

In the Table 4.3 the temperature and pressure of these limits are presented.

Table 4.3. Battery limit operating conditions.

	Sour water from HDT	Sour water from refinery	SRU	HDT furnace	Water to HDT	WWT plant
Temperature [°C]	30	20	NI	NI	55-65	
Pressure [kg/cm ² g]	1.5	2.5	0.8	0.55	13.8	2.1

4.4. Design of new equipment

4.4.1. General design conditions

The design of the new lines, equipment, control valves and instrumentation consider the following operating margins.

- Design flowrates are 120% of normal flow.
- Fluid conditions and physical properties are extracted from the Heat and Mass Balance (see section 5.1).
- The margins for temperature and pressure over normal operating conditions are presented in Table 4.4.

Table 4.4. Summary of over-design factors.

Equipment type	Over-design margin
Pipelines	- Design temperature equal to the highest design temperature of any upstream equipment of the new line. - Design (internal) pressure equal to the highest value between design pressure of any upstream equipment of the new line and 3.5 kg/cm ² g/ F.V.
Pumps	- Design temperature equal to the highest between design temperature of any upstream equipment of the new line or 80°C.
Control valves	- Pump maximum discharge pressure (shut-off pressure).
Vessels and columns	- Temperature is the maximum between: 120°C and Equation 4.1.
Heat exchangers and air coolers	- Pressure is the maximum value between 3.5 kg/cm ² g, and the results of Expressions 4.2 and 4.3.
Instrumentation	- Same design conditions than the connected line or equipment.

4.4.1.1. Overdesign criteria for pressure and temperature design conditions

$$DT = T_{OP} + 15^{\circ} C \quad (4.1)$$

$$DP = P_{OP} + 1.75 \text{ kg/cm}^2 \quad (4.2)$$

$$DP = P_{OP} + 10\% P_{OP} \quad (4.3)$$

4.4.2. Design of pumps

In the design of the new pumps, the following points are considered:

- Centrifugal pumps are preferred for being more economical and reliable as the current process does not involve high viscosity fluids nor high differential head requirements.
- Hydraulic calculations are based on Bernoulli's Equation (expression 4.4 [2]) for calculating the differential head requirements in the studied pipeline circuit.
- The NPSHa will be always equal or higher than the NPSHr by the pump to avoid cavitation [3].
- In the case of new vessels, the elevation of the equipment is determined for achieving an acceptable Net Positive Suction Height available (NPSHa). This NPSHa is equal or higher to the values of Table 4.5.

$$\frac{P_1}{\rho \cdot g} + \frac{u_1^2}{2 \cdot g} + h_1 + h_p = \frac{P_2}{\rho \cdot g} + \frac{u_2^2}{2 \cdot g} + h_2 + h_f \quad (4.4)$$

Where:

- P_1 and P_2 refer to the pressure in Pa.
- u_1 and u_2 are the fluid velocities in m/s.
- h_1 and h_2 are the studied point height elevations in m.
- h_p is the pump differential head in m.
- h_f are the pressure drops caused by friction and line fittings in m.
- g is the gravity acceleration in m/s².
- ρ is the fluid density in kg/m³.

Table 4.5. NPSHa for centrifugal pumps (3000 rpm and differential head below 200 m).

	NPSHa [m]				
	2.5	3	4	5	6
Flowrate [m ³ /h]	≤ 15	15 to 45	45 to 140	140 to 350	≥350

4.4.2.1. Material selection for the new pumps

The material class for process water and sour water is the following:

- Process water: cast iron/cast iron and cast iron/bronze
- Sour water: DUPLEX/ DUPLEX

This selection based in the API Standard 610 [4] is summarized in the Table 4.6.

Table 4.6. Pump material selection for process water and sour water services.

Part	Service		
	Process water		Sour water
Pressure casing	Cast iron		Duplex
Inner case parts	Cast iron	Bronze	Duplex
Impeller	Cast iron	Bronze	Duplex
Case wear rings	Cast iron	Bronze	Duplex
Impeller wear rings	Cast iron	Bronze	Duplex
Shaft	Carbon steel		Duplex
Shaft sleeves, mechanical seals	Austenitic steel or 12% Chrome hardened		Duplex
Throat brushings	Cast iron	Bronze	Duplex
Interstage Sievers	Cast iron	Bronze	Duplex
Interstage brushings	Cast iron	Bronze	Duplex
Seal gland	316 austenitic steel		Duplex
Case and gland studs	Carbon steel		Duplex
Case gasket	Austenitic steel, spiral wound		Duplex SS spiral wound
Discharge head/ suction	Carbon steel		Duplex
Column/ bowl shaft brushings	Nitrile	Bronze	Filled carbon
Bolts	Carbon steel		Duplex

4.4.3. Design of heat exchangers

The shell and tube heat exchanger is designed according to the client's specifications, which are based in TEMA code [5].

4.4.3.1. General design criteria

- The correction factor for the Medium Temperature Differential is not below 0.8.
- Minimum thickness for shell and headers can't be lower than TEMA standard specification.

- The calculations are performed with *HTRI* [6] in rating mode to consider effective surface area for calculations.
- No vibration concerns at design case.
- Guarantee of a B-fraction percentage equal or greater than 60%.
- Heat exchangers with U tubes in horizontal position.

4.4.3.2. Velocity- ρv^2

In Table 4.7 the criteria of heat exchanger are summarized [7].

Table 4.7. Velocity criteria according to TEMA code.

	Shell side	Tube side
ρv^2	<6,000 kg/ms ² (inlet/outlet nozzle) <2,000 kg/ms ² (shell entrance/ bundle entrance) ρv^2 nozzle > ρv^2 entrance	9,000 kg/m·s ²

4.4.4. Design of vessels and columns

The ammonia water washing column vessel and the reflux drum are designed in accordance with ASME code VIII Division 1 [8].

In addition, the following client's design specifications are considered.

4.4.4.1. Vacuum and jacketing

Vessels subjected to vacuum during normal operation, start-up and regeneration will be designed to full vacuum. Besides, vessels containing water steam will be designed for full vacuum.

4.4.4.2. Required thickness

The minimum vessel thickness (including corrosion over-thickness and excluding cladding over-thickness) will be the highest of the following values:

- 6 mm for carbon steel and 3 mm for stainless steel.
- Equation 4.5 result.

$$t = \frac{D}{650} + 1.8 \text{ mm} \quad (4.5)$$

Where "t" is the thickness and "D" is the diameter in mm.

Nozzle neck thickness, including corrosion over-thickness, must have the least of the following values but never being below design thickness:

- Thickness of the body to which they are welded.
- Thickness defined by diameter, shown in Table 4.8.

Table 4.8. Nozzle thickness according to schedule criteria.

ND [inch]	Nozzle Sch.				
	160	120	80	60	XS
	≤ 3	4 and 6	8 and 10	12	≥ 14

4.4.5. Design of pipelines

4.4.5.1. Sizing criteria

The new pipelines are sized for the maximum flow case (120% of normal flow) and estimating the lengths by taking the equipment distance to the central rack and applying a safety factor of 150%.

The proposed line sizing is valid when accomplishes that:

- The selected pipe diameter inner accomplishes with the validation criteria of Table 4.10 or Table 4.11.
- The line size coincides with one of the standard nominal diameters listed in Table 4.9.
- The selected standard size has an inner and outer diameter equal or higher to the calculated ones although as small as possible [9].

Table 4.9. Standard diameters available for the new line sizing.

ND [inch]	ND [inch]	ND [inch]	ND [inch]
3/4	2	8	6
1	3	10	14
1.5	4	12	16

Table 4.10. Line sizing criteria for liquid streams.

Line type	ΔP [bar/km]		Maximum velocity [m/s]
	Normal	Maximum	
Pump suction (Liquid at bubble point/ with dissolved gases)	0.6	0.9	0.6 for $D \leq 2''$ 0.9 for $3'' \leq D \leq 10''$ 1.2 for $12'' \leq D \leq 18''$ 1.5 for $D \geq 20''$
Centrifugal pump discharge ($\Delta P \leq 50$ bar)	3.5	4.5	1.5
Cooling water	1.5 for the long lines 2.5 to 3.5 for the short lines		1.5 for $D \leq 2''$ 2 for $D = 3''$ 2.5 for $D = 4''$ 3 for $D = 6''$

Table 4.11. Line sizing criteria for gas/ mixed phase streams.

Type of lines	Max. ρv^2	Maximum velocity [m/s]	ΔP [bar/ km]	
			Normal	Max.
Gas $P \leq 20$ bar g	6,000	15,000	Shall be calculated and consistent with the ΔP allocated to the considered operation.	
Steam (long) lines				
P = 1 bar g	15,000	10	0.12	0.24
P = 10 to 30 bar g		30	0.23	0.92
Mixed flow	10,000	15		

It should be commented that mixed phases flow pattern is considered for the sizing calculations, if necessary, by applying bibliographic charts [10].

These bibliographic charts indicate which apparent gas and liquid velocities corresponds to the different patterns.

- For vertical lines annular or bubble flow are preferred.
- For horizontal lines bubble or dispersed flow.

4.4.6. Design of control valves and instrumentation

4.4.6.1. Control valve selection

The new control valves opening law is selected regarding to the service:

- Iso-percentage characteristic flow and pressure as they are rapid variables.
- Linear characteristic for level and temperature control as they are slow variables.

The model rated valve coefficient selected (C_v) must accomplish the following criteria:

- Required C_v will be the highest value between:
 - o 1.3 times the maximum C_v .
 - o 2 times the normal C_v .
- Opening percentage calculated will be within the following ranges:
 - o Linear characteristic: Between 10 and 75%.
 - o Iso-percentage characteristic: Between 10 and 85%.

4.4.6.2. Flowmeter sizing

The flowmeters will be designed with a pressure drop of 0.25 kg/cm² for the maximum operating flow.

Their pressure drop for normal and minimum flow operation is estimated with the Darcy's law, which is presented below:

$$\Delta P_{op} = \frac{\Delta P_{des}}{\left(\frac{Q_{DES}}{Q_{OP}}\right)^2} \quad (4.6)$$

4.4.6.3. Pressure Safety Valves (PSV's) sizing

The new PSV calculations are based on API RP 521 (fourth edition) [11] applied to the following scenarios to select the most conservative since it will determine the sizing:

- Control valve lockage
- Cooler failure
- Thermal expansion
- Fire

In section 5.5.3 the applied calculation methodology for fire case with liquid filled vessels is described. Calculations are realized under the following assumptions:

- 21% of accumulation is considered.
- The designed PSV's are balanced type as the assumed back pressure is equal or higher than 10% of the set pressure.
- There is no rupture disk upstream the safety valve.
- The stream released is considered in vapour phase.

4.5. Battery limit and utility conditions

The utility conditions that are relevant for the operation of the sour water unit are summarized in the Table 4.12.

Table 4.12. Summary of Battery Limit conditions.

Utility	P [kg/cm ² g]	T [°C]	Density [kg/m ³]	Viscosity (3)
Supply cooling water	7.0	28	996.7	0.858
Return cooling water	6.3 (2)	40 (1)	992.6	0.677
Low pressure steam	4.2	153	2.7	0.0146
Low pressure condensate	1.6 (2)	40 (1)	879.1	0.193
Medium pressure steam	11.0	187	5.9	0.0161
Medium pressure condensate	2.2 (2)	40 (1)	984.5	0.632

Notes:

1.- Maximum temperature of the return stream at B.L.

2.- Pressure at B.L.

3.- cSt (Liquid)/ cP (Vapour).

4.6. Validation of the existing system

At the preliminary study of alternatives, the revamp configuration was selected regarding to the possible process bottlenecks and limitations resulting from the new operating since the new emission requirements are tighter. However, this preliminary analysis does not guarantee that technical limits of the existing system are feasible for the conceptual scenario of the study of alternatives.

For this reason, the equipment being already implemented in the unit before the revamp needs to be validated according to its mechanical design conditions and its performance on operation, which must accomplish with the corresponding performance requirements.

4.6.1. Heat exchanger and air-cooler validation

A heat exchanger or air cooler is valid for future operation when the *HTRI* calculations of the equipment determine that:

- Heat exchanger duty enables to target the required temperatures at both process sides.
- Allowable pressure drop is higher than calculated one
- No vibration concerns appeared (so no warnings about vibration are obtained)

4.6.2. Column validation

The different columns of the sour water unit are considered valid for the revamp operating case when:

- *HYSYS VII* calculations demonstrate that there are no hydraulic problems with the internals.
- Design specifications of the effluents of the unit are met.

4.6.3. Hydraulic validation

The pumps are considered valid for the revamp operating scenario when the following points are accomplished:

- The differential head supplied by the pump is enough for maintaining the design operating pressure of the process at the downstream equipment.
- If it was not possible, an impeller diameter increasement will be studied.
- The NPSHa is higher than vendor's NPSHr.

4.6.4. Control valve and instrument validation

The selected adequacy criteria vary depending on the type of the instrument.

The flowmeters, in addition to the previous requirement, must operate with flowrate conditions below its design flow so that maximum pressure drop is not exceeded.

On the other hand, the control valves must present an opening percentage within the following ranges for the normal, minimum and maximum flow conditions:

- Linear characteristic: 10-75%.
- Iso-percentage characteristic: 10-85%.

5. BASIC ENGINEERING

5.1. Heat and mass balance

The DSWS (Double Stage Sour Water) unit simulation was realized with the aid of Aspen *HYSYS VII* for calculating the heat and mass balance of the process, as well as obtaining the physical properties of the different streams.

The selected model to predict the streams properties is the “Sour Water” fluid package, which combines the “Sour PR” and “Electrolyte NRTL” for liquid and vapor phases, respectively. The criterion for this decision was that flash calculations failed in some points of the simulation when using alternative methods as “Sour PR” or “Sour SRK” since they were more liquid oriented.

However, it should be commented that, although “Sour Water” fluid package was quite better for vapor phase calculations, the liquid physical properties were slightly different from original process properties from the data test, which was based on an electrolyte model in *PROMAX*.

5.1.1. Simulation environment

The process configuration has been input in the simulation environment sequentially in order to facilitate the convergence as the study frame unit involves stream recirculation and several unit operations, that may difficult the simulation convergence.

5.1.1.1. Recirculation of streams

The stream loops may cause instabilities in calculations that are avoided by the implementation of “recycle” manipulator blocks.

This tool was also used for isolating column feeds since it minimized the time spending in iterations as changes in the column inputs were softer.

5.1.1.2. Column simulation

Since that absorption is very sensitive to temperature, T-101 needs a certain inlet temperature at liquid feed to converge. After a sensitivity analysis between the feasible range of operating conditions, it was found that 117°C favoured not only the treatment efficiency but also the convergence time.

Subsequently, the control loop of T-101 inlet temperature was recreated in *HYSYS* with an “adjust” block which manipulated the bypass split ratio. This tool modified the hot shell side flow of the heat exchanger E-102 until the tube outlet temperature was of 117°C. Although the direct manipulation of the shell flowrate was tried, it was rejected due to calculations discrepancies between the heat exchanger and the adjust blocks because the model doesn't have freedom degrees enough for supporting as many user-specified values.

Another measure for simplifying the columns was to use simplified absorbers to reduce the degrees of freedom of the block (to avoid non compatible specifications among them).

Hence, the pump arounds and reflux circuits were simulated outside the column environment after the system convergence and had their own recycle blocks.

The column pressure profiles of *HYSYS* are based on the original Process Data Sheet (PDS) values, which are summarized in the Table 5.1.

Table 5.1. Pressure drops of existing columns.

	H ₂ S stripper	NH ₃ stripper	H ₂ S water washing
ΔP [kg/cm ²]	0.2	0.3	0.1

5.1.1.3. Heat exchanger and air cooler simulation

Although heat exchangers and air coolers are not calculated as “rigorous model” and “rigorous air cooler”, they have been simulated in *HTRI* to determine the overall heat transfer coefficients (*U*) and pressure drops (ΔP). These results are input again in *HYSYS* simulation to obtain the new temperature profiles.

The process is iteratively repeated until the *HYSYS* and *HTRI* results coincide since the similarity with *HTRI* indicates that results are near to the rigorous calculation model.

The conditions of steam and its condensate in reboilers was calculated by connecting the energy streams to coolers where the vapor condensation took place. The heating duties were selected using *HTRI* for steam flow requirement calculation to check the adequacy of existing utility networks.

These duties were tested in *HYSYS* simulation to select the ones favouring equilibrium calculations convergence. The obtained results with this method are better from the revamp design specifications (in addition to need from less computation time resources).

5.1.1.4. Pump simulation

The hydraulic profiles of the unit are calculated by piping section blocks and pumps. The calculation of pipe pressure drops was calculated introducing the main unit circuits according to the isometric diagrams of the plant, and the heat transfer between the pipelines and the environment was estimated with the HTC coefficient calculation assuming an ambient temperature of 25°C. On the other hand, for the existing pumps P-101, P-103 and P-104, differential heights were taken from vendor’s curves; while the new pumps (P-201, P-202 and P-203), were initially calculated by *HYSYS*. Once the pump selection was done, vendor’s curves were input in the simulation to determine the real pressure profiles.

The efficiency curves were also input in the simulation environment with the aim of obtaining the power consumption of the different pumps.

It should be commented that, despite the heat transfer losses calculated in pipes was excessively conservative, only small differences in pressure profiles were detected when comparing with manual calculations.

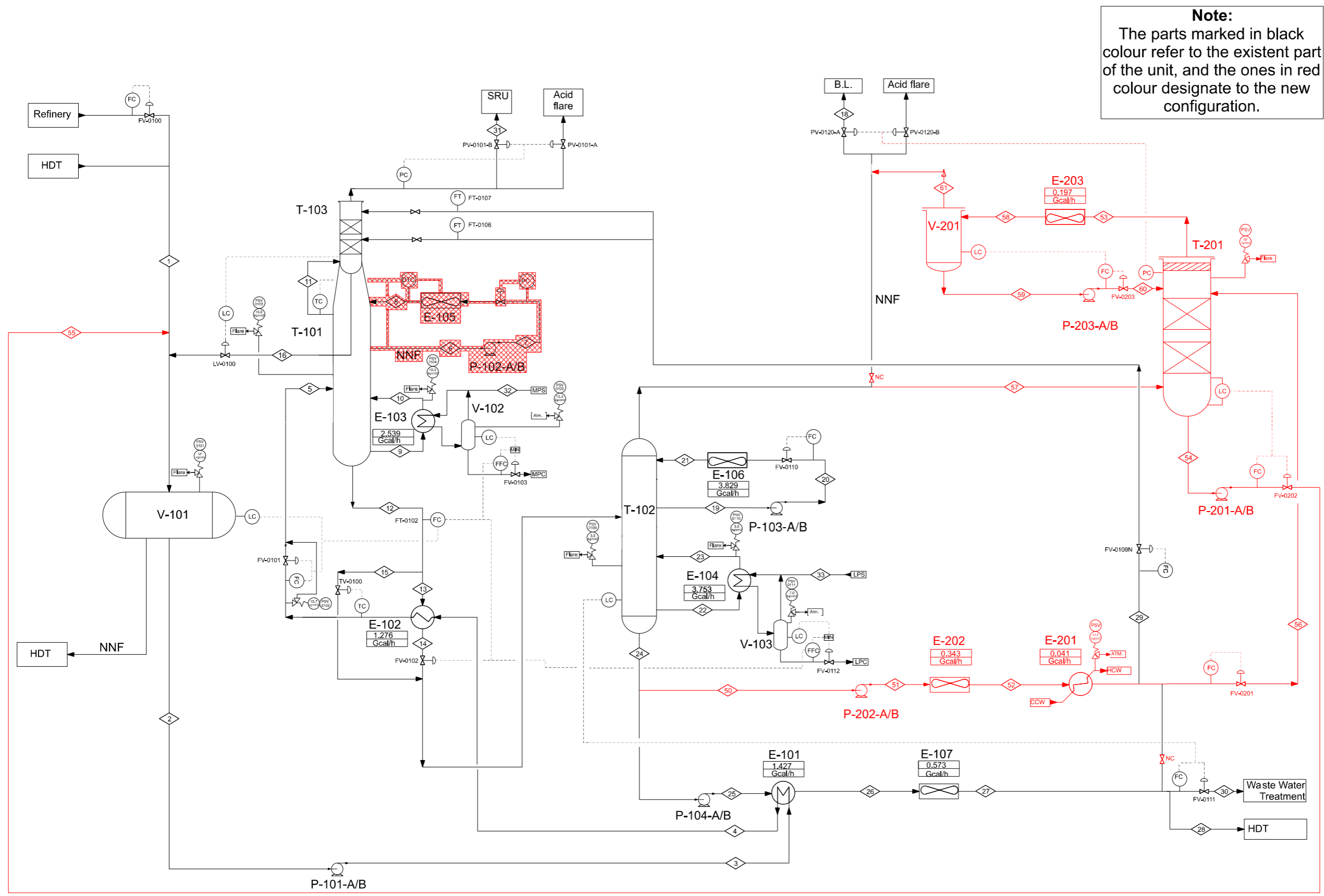
This finding validates the simplification of the model in manual calculations for pressure drops and *HTRI* calculations for heat exchangers. This approach enables to estimate the thermal and hydraulic profiles for the maximum and minimum flow cases on which part of the validity calculations are based.

5.1.2. Process Flow Diagram and Heat and Mass Balance

In this section, the overall process is schematized in the Process Flow Diagram (PFD), were the modifications are marked in colour red.

On the other hand, the existing parts of the DSWS unit are drawn in colour black to be differentiated.

The results obtained with the aid of *HYSYS VII* are summarized in the following tables according with the stream numbering of the PFD.





Note:
The parts marked in black colour refer to the existent part of the unit, and the ones in red colour designate to the new configuration.

	Final Master's Thesis	PREPARED	MEQ
	MEQ URV	CHECKED	EDU
	SCALE:	APPROVED	EDU
	DIN A-3	DATE	REV: 0
PROCESS FLOW DIAGRAM (PFD) SOUR WATER UNIT			
DSWS			

Unit/Stream	1	2	3	4	5	9	10	11	12	13	14	15	16	17	18	19	
Pressure	kg/cm2_g	2.5	1.2	12.7	11.8	10.5	8.2	8.3	8.0	8.3	8.6	8.5	8.6	8.0	1.4	0.3	1.2
Temperature	°C	31.2	43.4	43.8	84.0	117.2	164.3	169.4	133.7	169.4	116.5	169.4	134.0	120.7	42.0	102.8	
Mass Flow	kg/h	3.190E+04	3.728E+04	3.728E+04	3.728E+04	3.728E+04	4880	4880	942.9	3.633E+04	2.138E+04	2.138E+04	1.496E+04	1842	3.634E+04	389.2	1.051E+05
Vap Frac on a Mass Basis	-	-	-	-	-	-	-	-	1.000	-	-	-	-	-	0.039	1.000	-
Mass Flow (Vapour Phase)	kg/h	-	-	-	-	-	-	4.880E+03	942.9	-	-	-	-	-	1.425E+03	389.2	-
Mass Flow (Liquid Phase)	kg/h	3.190E+04	3.728E+04	3.728E+04	3.728E+04	3.728E+04	4.880E+03	-	-	3.633E+04	2.138E+04	2.138E+04	1.496E+04	1.842E+03	3.491E+04	-	1.051E+05
Heat Flow	Gcal/h	-117.6	-136.3	-136.3	-134.9	-133.6	-17.3	-13.41	-0.7632	-130.3	-76.68	-77.96	-53.66	-6.540	-131.6	-0.2800	-367.1
Vapour Phase																	
Actual Gas Flow	ACT_m3/h	-	-	-	-	-	1.04E+03	1.25E+02	-	-	-	-	-	1.07E+03	4.53E+02	-	-
Std Gas Flow	STD_m3/h	-	-	-	-	-	6.41E+03	8.05E+02	-	-	-	-	-	1.88E+03	5.39E+02	-	-
Molecular Weight	-	-	-	-	-	-	17.99	27.70	-	-	-	-	-	17.92	17.06	-	-
Mass Density	kg/m3	-	-	-	-	-	4.681	7.550	-	-	-	-	-	1.327	0.860	-	-
Viscosity	cP	-	-	-	-	-	0.0155	0.0170	-	-	-	-	-	0.0135	0.0108	-	-
Thermal Conductivity	W/m-K	-	-	-	-	-	0.0326	0.0240	-	-	-	-	-	0.0278	0.0268	-	-
Mass Heat Capacity	kJ/kg-C	-	-	-	-	-	2.080	1.333	-	-	-	-	-	1.984	2.129	-	-
Z Factor	-	-	-	-	-	-	0.9513	0.9607	-	-	-	-	-	0.9828	0.9903	-	-
Cp/Cv	-	-	-	-	-	-	1.363	1.353	-	-	-	-	-	1.330	1.311	-	-
Heat Flow	Gcal/h	-	-	-	-	-	-13.41	-0.763	-	-	-	-	-	-3.948	-0.280	-	-
Liquid Phase																	
Phase Actual Liquid Flow	m3/h	33.3	39.1	39.1	40.0	41.2	49.0	-	-	42.1	24.8	23.0	17.3	2.10	39.1	-	117
Vol Flow @Std Cond	m3/h	33.1	38.7	38.7	38.7	38.7	41.7	-	-	36.6	21.5	21.5	15.1	1.93	36.6	-	109
Mass Density	kg/m3	959.3	953.5	953.7	931.7	904.5	840.3	-	-	862.6	862.6	929.8	862.6	877.8	929.5	-	897.3
Mass Density @Std Cond	kg/m3	962.8	962.1	962.1	962.1	962.1	987.6	-	-	993.1	993.1	993.1	993.1	952.7	993.1	-	962.6
Kinematic Viscosity	cSt	0.7101	0.5734	0.5692	0.3190	0.2336	0.2041	-	-	0.1895	0.1895	0.2606	0.1895	0.2052	0.2489	-	0.2955
Thermal Conductivity	W/m-K	0.6117	0.6259	0.6262	0.6352	0.5331	0.6020	-	-	0.6327	0.6327	0.6509	0.6327	0.4019	0.6584	-	0.6021
Mass Heat Capacity	kJ/kg-C	3.761	3.839	3.840	4.157	4.485	4.929	-	-	4.930	4.930	4.511	4.930	4.707	4.536	-	4.386
Heat Flow	Gcal/h	-117.6	-136.3	-136.3	-134.9	-133.6	-17.3	-	-	-130.3	-76.7	-78.0	-53.7	-6.5	-127.7	-	-367.1
Surface Tension	dyne/cm	72.45	70.12	70.05	62.45	56.01	-	-	-	44.39	44.39	55.12	44.39	52.80	54.27	-	58.74
Vapour Pressure	kg/cm2_g	-0.87	-0.88	-0.87	0.01	2.69	8.21	-	-	8.25	8.25	1.23	8.25	8.00	1.55	-	1.24
Mass Composition																	
H2O		0.968	0.961	0.961	0.961	0.961	0.965	0.847	0.221	0.981	0.981	0.981	0.981	0.957	0.981	0.032	0.921
NH3		0.012	0.019	0.019	0.019	0.019	0.033	0.139	0.033	0.018	0.018	0.018	0.018	0.017	0.018	0.968	0.062
H2S		0.021	0.020	0.020	0.020	0.020	0.003	0.014	0.746	0.001	0.001	0.001	0.001	0.026	0.001	0.000	0.017

Unit/Stream	21	22	23	24	25	26	27	28	29	30	31	32	33	50	51	52	
Pressure	kg/cm2_g	1.2	1.5	1.5	1.5	16.5	16.2	14.3	14.3	16.8	2.1	0.8	11.0	4.2	1.5	16.6	
Temperature	°C	69.8	127.3	127.3	127.3	127.7	83.7	65.0	40.0	65.2	31.8	187.3	152.9	127.2	126.8	50.0	
Mass Flow	kg/h	1.051E+05	7168	7168	3.524E+04	3.086E+04	3.086E+04	3.086E+04	1.221E+04	1558	1.865E+04	658.6	5334	7429	4381	4381	
Vap Frac on a Mass Basis	-	0.000	0.000	1.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	1.000	1.000	1.000	0.000	0.000	
Mass Flow (Vapour Phase)	kg/h	-	-	7.168E+03	-	-	-	-	-	-	-	658.6	5.334E+03	7.429E+03	-	-	
Mass Flow (Liquid Phase)	kg/h	1.051E+05	7.168E+03	-	3.524E+04	3.086E+04	3.086E+04	3.086E+04	1.221E+04	1.558E+03	1.865E+04	-	-	-	4.381E+03	4.381E+03	
Heat Flow	Gcal/h	-370.6	-26.4	-22.7	-130.0	-113.8	-115.2	-115.8	-45.8	-5.9	-70.0	-0.1	-16.8	-23.4	-16.2	-16.5	
Vapour Phase																	
Actual Gas Flow	ACT_m3/h	-	-	5.24E+03	-	-	-	-	-	-	-	270	904	2.76E+03	-	-	
Std Gas Flow	STD_m3/h	-	-	9.41E+03	-	-	-	-	-	-	-	4.59E+02	7.00E+03	9.75E+03	-	-	
Molecular Weight	-	-	-	18.015	-	-	-	-	-	-	-	33.916	18.015	18.015	-	-	
Mass Density	kg/m3	-	-	1.369	-	-	-	-	-	-	-	2.438	5.903	2.694	-	-	
Viscosity	cP	-	-	0.0136	-	-	-	-	-	-	-	0.0130	0.0160	0.0146	-	-	
Thermal Conductivity	W/m-K	-	-	0.0269	-	-	-	-	-	-	-	0.0150	0.0327	0.0293	-	-	
Mass Heat Capacity	kJ/kg-C	-	-	1.940	-	-	-	-	-	-	-	1.023	2.065	1.980	-	-	
Z Factor	-	-	-	0.9822	-	-	-	-	-	-	-	0.9866	0.9407	0.9687	-	-	
Cp/Cv	-	-	-	1.339	-	-	-	-	-	-	-	1.335	1.386	1.352	-	-	
Heat Flow	Gcal/h	-	-	-22.7	-	-	-	-	-	-	-	-0.106	-16.765	-23.434	-	-	
Liquid Phase																	
Phase Actual Liquid Flow	m3/h	113	7.7	-	37.6	32.9	31.8	31.5	12.4	1.57	19.0	-	-	-	4.68	4.67	
Vol Flow @Std Cond	m3/h	109	7.2	-	35.3	30.9	30.9	30.9	12.2	1.56	18.7	-	-	-	4.38	4.38	
Mass Density	kg/m3	930.9	936.9	-	936.9	937.3	970.1	981.1	993.0	980.5	-	-	-	-	936.9	938.1	
Mass Density @Std Cond	kg/m3	962.6	999.2	-	999.2	999.2	999.2	999.2	999.2	999.2	-	-	-	-	999.2	999.2	
Kinematic Viscosity	cSt	0.4288	0.2288	-	0.2288	0.2279	0.3494	0.4474	0.4474	0.6758	0.4461	-	-	-	0.2288	0.2294	
Thermal Conductivity	W/m-K	0.6218	0.6849	-	0.6849	0.6849	0.6670	0.6524	0.6524	0.6259	0.6526	-	-	-	0.6849	0.6374	
Mass Heat Capacity	kJ/kg-C	4.094	4.561	-	4.561	4.560	4.234	4.098	4.098	3.922	4.101	-	-	-	4.561	3.991	
Heat Flow	Gcal/h	-370.6	-26.4	-	-130.0	-113.8	-115.2	-115.8	-45.8	-5.9	-70.0	-	-	-	-16.2	-16.5	
Surface Tension	dyne/cm	65.02	-	-	52.91	52.83	61.39	64.96	64.96	69.76	64.92	-	-	-	52.92	53.00	
Vapour Pressure	kg/cm2_g	-0.30	1.50	-	1.50	1.53	-0.47	-0.78	-0.78	-0.96	-0.78	-	-	-	1.50	1.47	
Mass Composition																	
H2O		0.921	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	0.005	1.000	1.000	1.000	1.000	1.000	
NH3		0.062	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	
H2S		0.017	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.995	0.000	0.000	0.000	0.000	0.000	

	Final Master's Thesis	PREPARED	REV.
	MEQ URV	CHECKED	REV.
	SCALE:	APPROVED	REV.
	DIN A3	DATE	REV.
PROCESS FLOW DIAGRAM (PFD) SOUR WATER UNIT			
DSWS		Sheet 22 of 22	REV: 0

	Unit/Stream	54	55	56	57	58	59	60	61
Pressure	kg/cm2_g	1.1	3.3	1.0	1.2	0.8	0.8	1.0	0.8
Temperature	°C	96.0	96.0	40.0	95.2	43.0	42.6	43.0	42.6
Mass Flow	kg/h	3531	3531	2823	1099	731.8	342.7	342.7	389.2
Vap Frac on a Mass Basis	-	0.000	0.000	0.000	1.000	0.533	0.000	0.000	1.000
Mass Flow (Vapour Phase)	kg/h	-	-	-	1.099E+03	389.8	-	-	389.2
Mass Flow (Liquid Phase)	kg/h	3.531E+03	3.531E+03	2.823E+03	-	342.0	342.7	341.2	-
Heat Flow	Gcal/h	-12.24	-12.24	-10.66	-1.66	-1.31	-1.03	-1.02	-0.28
Vapour Phase									
Actual Gas Flow	ACT_m3/h	-	-	-	854	342	-	-	343
Std Gas Flow	STD_m3/h	-	-	-	1.47E+03	5.40E+02	-	-	539
Molecular Weight	-	-	-	-	17.733	17.061	-	-	17.061
Mass Density	kg/m3	-	-	-	1.287	1.141	-	-	1.133
Viscosity	cP	-	-	-	0.0128	0.0108	-	-	0.0108
Thermal Conductivity	W/m-K	-	-	-	0.0298	0.0269	-	-	0.0269
Mass Heat Capacity	kJ/kg-C	-	-	-	2.083	2.137	-	-	2.136
Z Factor	-	-	-	-	0.9852	0.9871	-	-	0.9872
Cp/Cv	-	-	-	-	1.311	1.314	-	-	1.314
Heat Flow	Gcal/h	-	-	-	-1.660	-0.281	-	-	-0.280
Liquid Phase									
Phase Actual Liquid Flow	m3/h	3.91	3.90	2.84	-	0.831	0.389	0.389	-
Vol Flow @Std Cond	m3/h	3.64	3.64	2.83	-	0.964	0.377	0.377	-
Mass Density	kg/m3	903.7	904.5	993.0	-	880.5	880.6	880.1	-
Mass Density @Std Cond	kg/m3	968.9	968.9	999.2	-	759.5	910.0	910.0	-
Kinematic Viscosity	cSt	0.3357	0.3375	0.6758	-	0.8516	0.8571	0.8516	-
Thermal Conductivity	W/m-K	0.5969	0.5975	0.6259	-	0.5512	0.5513	0.5510	-
Mass Heat Capacity	kJ/kg-C	4.380	4.374	3.922	-	4.165	4.161	4.165	-
Heat Flow	Gcal/h	-12.24	-12.24	-10.66	-	-1.027	-1.029	-1.024	-
Surface Tension	dyne/cm	59.82	59.93	69.76	-	69.21	69.28	69.21	-
Vapour Pressure	kg/cm2_g	1.10	1.06	-0.96	-	8.84	0.72	0.74	-
Mass. Composition									
H2O		0.907	0.907	1.000	0.358	0.352	0.714	0.714	0.032
NH3		0.081	0.081	0.000	0.602	0.648	0.286	0.286	0.968
H2S		0.012	0.012	0.000	0.040	0.000	0.000	0.000	0.000

5.2. Process validation

The adequacy of the process is evaluated for the different equipment, lines, instrumentation, and control valves for the new conditions with the aim of ensuring specification meeting within stable, safe, and reliable operating conditions.

Therefore, the scope of this part of the memory is presenting the criteria, methodology and results for adequacy assessment under the exposed assumptions.

5.2.1. Followed approach

The validation is based on the simulation results, which provide information about streams operating conditions and its physical properties.

If any bottlenecks appeared in the process, they would be thermal or hydraulic. They would be due to the already implemented part because the revamp design scenario will be the maximum flow conditions to ensure operation feasibility even in the most demanding scenario. Therefore, two aspects are considered to evaluation of adequacy: pressure profiles and temperatures.

An item will be considered valid only in case of accomplishing with the revamp requirements when operating conditions don't exceed its design conditions.

As the unit has a turnaround of 60%, three scenarios are analysed:

- Normal operating conditions.
- Minimum flow conditions: the unit feed is 60 % of normal flowrate.
- Maximum flow conditions: the unit feed is 120 % of normal flowrate.

The selected criteria used in the evaluation is detailed for the different parts of the system.

5.2.2. Assumptions

- The maximum and minimum flow cases are extrapolated from *HYSYS* results at normal conditions since it is found to be a more conservative approach.
- Pressure at column feeds is regulated by the different control valves, so the pressure differences between the three contemplated scenarios does not affect to columns operation directly.
- In case of affecting to the equipment adequacy results, the limitations would appear upstream pressure changers (pumps, lines, and valves). However, liquid properties are practically the same for the pressure variations among the three scenarios.
- Although the gas properties are more sensitive to pressure changes, the column practically maintain its pressure profiles and line pressure drops for gas phase is almost negligible.
- Neither temperature changes suppose a problem of precision for the analysis because the utility flows are not a constraint. The original design conditions allow some margin in the heat exchanger duties regulating the temperatures in the studied circuits.
- If the calculations are properly adjusted, the possible changes in stream properties does not justify the time and computation resources demanded for the generation of two additional simulations.

5.2.3. Thermal validation results

The validation of heat exchangers has been done with the aid of *HTRI* for the heat exchanger and air cooler calculations, where the actual geometry of the equipment is introduced.

The *HTRI* calculations are done in rating mode so that it is possible to check whether the installed area is over or under designed. The geometry is taken from the mechanical planes and the data sheets for creating an initial file with the heat exchangers at the existing operating

conditions. This enables to check the adequacy of the developed model for calculating the new operating conditions.

The mass flowrates and temperatures are provided from *HYSYS* results at the inlet for both sides, and outlet temperature is only defined for one of them.

The heat exchangers calculated with *HTRI* satisfied the thermal requirements of the process since the new conditions are relatively close to the original process.

No vibration concerns were detected, and pressure drops were inside an allowable range since velocities are not too high.

During E-103 and E-104 reboiler calculations, vibration warnings appeared in the original case conditions, although no vibration problems were commented by the client in the past. As the vibration warnings obtained for the future case are practically the same, the reboilers E-103 and E-104 are considered valid for future operations since required duties are achieved without higher shell critical velocities than in past.

E-101 and E-102 were found valid since the required overall heat transfer coefficient is close to the actual one and fluid temperatures are adequate, although the same runtime message about B-flow fraction than in the original case

HTRI didn't generate any runtime warning for the air-coolers E-106 and E-107, which met thermal specifications.

As happened with the future normal case, the maximum flow temperatures are close to the normal flow ones, and there is absence of vibration issues. Allowable pressure drop is exceeded in a 3.2% the E-106 tube side (0.725 kg/cm^2 were obtained vs. 0.7 kg/cm^2).

Hydraulic calculations carried out manually determined that the existing circuit pump P-103 can supply pressure enough to meet hydraulic requirements, so the slight allowable pressure drop obtained in E-106 maximum flow case is accepted.

In spite of the aforementioned warnings, the heat exchangers are found to be valid for the new configuration of the sour water unit.

5.3. Line sizing and line list

The line size must be adequate for the revamp process conditions since pressure drops of hydraulic circuits may impact significantly in the process pressure profiles.

In this section, the line sizing procedure for the new piping circuits is described.

Besides, the lines currently implemented in the unit are validated for the future operation in accordance with the basis of design for the new lines exposed in section 4.4.5.

5.3.1. New lines sizing

The pipeline sizing has been done according to the overdesign stream flowrates with the basis of design factors.

As it has been previously commented, the considered length for the new lines is estimated with the aid of the Plot Plant of the unit, where distance between equipment and pipe racks are used.

This length is increased in a 150% for being conservative and platform heights are after added to the obtained distance (so that heights are not oversized).

The following calculations are used for the standard diameter and schedule selection.

5.3.1.1. Estimation of internal diameter

First off, the internal diameter is estimated by applying the Equation 5.1.

$$ID = 1000 \cdot \sqrt{\frac{4 \cdot Q}{\pi \cdot u \cdot 3600}} \quad (5.1)$$

Where:

- Q is the volumetric flowrate (m³/h).
- u is the stream velocity (m/s).
- ID is the line internal diameter in mm.

5.3.1.2. Estimation of tube thickness

The minimum required thickness is based on ASME B.31.3 code [12], which is estimated with the following expression:

$$t = \frac{P_{DES} \cdot D}{2 \cdot (S \cdot E + P \cdot Y)} + c \quad (5.2)$$

Where:

- t is the minimum thickness in mm with $(t-c) < D/6$.
- P_{DES} is the design pressure in bar g.
- D is the external diameter in mm.
- S is the basic allowable stress in bar (Selected from ASME B31-3-199).
- E is the welding coefficient (equal to 1).
- Y is the joint coefficient (equal to 0.4).
- C is the corrosion allowance.

The final thickness is calculated by oversizing the “e” value 12.5%, and the minimum thickness values are selected from ASME code values for carbon steel since they are more conservative.

- 3 mm for $D \leq 8''$
- 4 mm for $18'' \geq D \geq 10''$
- 5 mm for $D \geq 20''$

5.3.2. Diameter selection

The diameter estimated is checked with the validation criteria. When these criteria are accomplished, the selected standard diameter is accepted.

Otherwise, a higher standard value is selected, and the results are checked again.

The diameter selection summary (corresponding to normal flow case) is presented in Table 5.2 for the lines with liquid content, and Table 5.3 for mixed and vapour phase.

Table 5.2. Diameter selection for the new lines at normal flow case (liquid phase).

Line number	Q [m ³ /h]	ρ [kg/m ³]	μ [cP]	ND [inch]	u [m/s]	u _{MAX} [m/s]	ΔP [bar/km]	ΔP_{MAX} [bar/km]
CCW-8026-PU	3.75	996.7	0.86	2	0.48	3.00	0.57	1.50
HCW-8027-PU	3.76	992.6	0.67	2	0.48	3.00	0.55	1.50
HCW-8028-PU (2)	3.76	992.6	0.67	1 ½	1.88	-	1.90 (1)	-
HCW-8029-PU (2)	3.76	992.6	0.67	2	0.48	-	0.54	-
W-2001-AP-PP	37.6	936.9	0.73	3	0.27	0.90	0.11	0.90
W-2002-AP-PP	37.6	936.9	0.73	3	0.27	0.90	0.11	0.90
W-2003-P900-PP	4.67	938.1	0.73	2	0.60	-	0.79	4.50
W-2004-P900-PP	4.67	938.1	0.73	2	0.60	-	0.79	4.50
W-2005-P900	4.43	988.8	0.56	2	0.57	-	0.72	4.50
W-2009-P900	2.84	993.0	0.67	2	0.36	-	0.33	4.50
W-2010-AP	2.84	993.0	0.67	2	0.36	-	0.33	4.50
W-2015-ACG-PP	3.91	903.7	0.37	3	0.23	0.90	7.0·10 ⁻²	0.9
W-2016-ACG-PP	3.91	903.7	0.37	3	0.23	0.90	7.0·10 ⁻²	0.9
W-2017-ACG-PP	3.90	904.5	0.31	2	0.83	-	1.74	4.50
W-2018-ACG-PP	3.90	904.5	0.31	2	0.83	-	1.74	4.50
W-2022-AP	0.389	880.6	0.97	2	0.05	0.60	7.00·10 ⁻³	0.90
W-2023-AP	0.389	880.6	0.97	2	0.05	0.60	7.00·10 ⁻³	0.90
W-2024-AP	0.389	880.1	0.97	2	0.05	3.00	7.00·10 ⁻³	4.50
W-2025-AP	0.389	880.1	0.97	2	0.05	3.00	7.00·10 ⁻³	4.50
W-2026-AP	0.389	880.1	0.97	4	0.01	-	~ 0	4.50
W-2027-P900-PP	4.43 (2)	988.8	0.56	2	0.57	-	0.72	4.50
W-2030-P900	1.57	993.0	0.68	2	0.33	-	0.38	4.50
W-2032-P900-I	3.91 (2)	903.7	0.37	2	0.50	-	0.50	0.90
W-2033-AP-I	0.389 (2)	880.6	0.97	2	0.50	-	0.56	-
W-2034-P900-	4.43 (2)	988.8	0.56	1	2.21	-	0.38	-

Notes:

1.- Process Safety Valve (PSV) line.

2.- Normally No Flow (NNF) line.

Table 5.3. Diameter selection for the new lines at normal flow case (gas/mixed phase*).

Line number	Q [m ³ /h@std]	ρ [kg/m ³]	μ [cP]	Cp/Cv	D [inch]	u [m/s]	u _{MAX} [m/s]	ΔP [bar/km]	ΔP_{MAX} [bar/km]
F-2011-AP-S	997 (2)	1.2	0.013	1.31	4	21.4	-	0.48	-
ST-8020-P900-I	25.0 (2)	5.9	0.016	1.39	2	5.43	10.0	0.36	0.92
ST-8021-P900-I	25.0 (2)	5.9	0.016	1.39	2	5.43	10.0	0.36	0.92
WG-2012-AP	997 (2)	1.2	0.013	1.31	3	36.8 (1)	-	1.91	-
WG-2013-AP-PP	631.7	1.2	0.013	1.31	4	21.4	30.0	0.48	-
WG-2019-AP*	341.7 (G) 0.388 (L)	1.1 (G) 880.8 (L)	0.011 (G) 0.97 (L)	1.31	3	19.9	23.0	1.15	-
WG-2021-APS	343.6	1.1	0.011	1.31	3	20.0	-	0.57	-

Notes:

(*) Mixed phase fluid.

1.- Process Safety Valve (PSV) line.

2.- Normally No Flow (NNF) line.

5.3.3. Line specification

The new lines are classified according to the service fluid nature and conditions. The different specifications are defined for the current project are described in the Table 5.4 below.

This classification determines the pipe material selection and the minimum required schedule (which correspond to the most conservative thickness between the sizing calculation results and the specifications).

Table 5.4. Summary of pipe specification for the different services.

Code	Material	Schedule	Rating	Fluids
AP	Seamless steel A-106	1" ≤ ND ≤ 2" : 80 3" to 6" : 40	150	Sour water Acid gas
PU	Seamless steel ASTM A-53	DN < 2" : 80 2" to 6" : 40	150	Cooling water
P900	Seamless steel ASTM A-53	2" to 6" : 40 DN < 2" : 80	300	Slight corrosive water (H ₂ S content < 20 wt. ppm) Medium pressure steam

5.3.3.1. Tracing and insulation types

The following classification is done depending on the insulation finality:

- Heat conservation (I): for maintaining temperature due to process stability requirements.
- Personal protection (PP): for pipes and equipment where no heat conservation is required but the surface exceeds 60°C.
- Steam tracing (S): for pipes where high operating temperatures are required due to the service nature. Implies the addition of heat conservation insulation.

The insulation thickness and material will be selected in accordance with the operating conditions and the previous classification. In the current project, the temperature at normal operating conditions is below 200°C, and the new line nominal diameters are between 1 and 4". Subsequently, no personal protection insulation at normal operating conditions is required in lines nor equipment for the current operating conditions since temperatures are. However, the surfaces classified as "PP" will require the usage of personal guards.

In the Table 5.5, selection criteria is summarized for these three insulation types.

Table 5.5. Summary of equipment and line insulation specifications.

Personal protection (PP)			
No required insulation in lines or equipment, only personal guards when surface temperatures exceeds 60°C.			
Heat conservation (I)			
T [°C]	ND ["]	Insulation thickness [mm]	Material
65-100	1 - 4	30	(1)
	Equipment surfaces	40	(2)
101-150	1 - 2	40	(1)
	3 - 4	50	(1)
	Equipment surfaces	60	(2)
Steam tracing			
Requires from heat conservation insulation			
Notes:			
(1) Glass wool shell / (2) Rock wool blanket a/ASTM C592 type II			

5.3.3.2. Fluid codes

The fluid codes used in the line naming are summarized in the Table 5.6 below.

Table 5.6. Fluid code summary.

Fluid	Code	Fluid	Code
Sour Water	W	Supply cooling water	CCW
Gas to flare	F	Released sour water	OW
Acid gas	WG	Fuel gas	UG
Low pressure steam	SST	Low pressure condensate	CLP
Medium pressure steam	ST	Medium pressure condensate	CMP
Return cooling water	HCW		

5.3.4. Existing pipeline validation

The line is found valid when the criteria presented in the Basis of Design (see section 4.4.5) are accomplished. Besides, the future operating conditions must be below the original design case.

All the DSWS unit lines were studied to determine their adequacy with the described procedures. Geometry information was obtained from the existing isometric diagrams and process information required to pressure drop calculations correspond to the future scenario *HYSYS* simulation. Each of the existing lines was found valid, so no replacement is required.

5.3.5. Line list

As the existing line are valid, the client company information is updated. Subsequently, the line list presented in Table 5.7 contains the new information corresponding to the designed lines.

In fact, it can be noticed in the numbering that the line list lines numbering start by the sequence “02”, which indicates that correspond to the ammonia water washing sub-unit.

The sequence “08” is also utilized to distinguish the utility lines although it also corresponds exclusively to this new sub-unit.

Table 5.7. Line list for the sized pipelines.

ND [inch]	Fluid code	Line number	Piping class spec.	Location		Fluid DESCR.	Density [kg/m ³]	Op. Conditions		Des. Conditions		Wall thickness		Insulation		Test P. [kg/cm ²]
				FROM	TO			PHA (1)	P [kg/cm ²]	T [°C]	P [kg/cm ²]	T [°C]	Sch.	CA [mm]	CODE	
2	CCW	8026	PU	UN (2)	E-201	Cooling water	996.7	7.00	28.0	17.7	80	40	3	-	-	26.6
2	HCW	8027	PU	E-201	UN (2)	Cooling water	992.6	6.3	40.0	17.7	80	40	3	-	-	26.6
1 ½	HCW	8028	PU	HCW-8027-PU	PSV-0202	Cooling water	992.6	17.7 (4)	40.0 (4)	17.7	80	80	3	-	-	26.6
2	HCW	8029	PU	PSV-0202	SINK	Cooling water	992.6	19.5 (4)	40.0 (4)	21.5	80	80	3	-	-	32.3
3	W	2001	AP	T-102	P-202-A	Sour water	936.9	1.50	127	3.5	141	40	3	PP	-	5.3
3	W	2002	AP	W-2001-AP-PP	P-202-B	Sour water	936.9	1.50	127	3.5	141	40	3	PP	-	5.3
2	W	2003	P900	P-202-B	WW-2004- P900-PP	Sour water	938.1	18.6	127	23.0	141	40	3	PP	-	34.5
2	W	2004	P900	P-202-A	E-202	Sour water	938.1	18.6	127	23.0	141	40	3	PP	-	34.5
2	W	2005	P900	E-202	E-201	Sour water	988.8	17.9	50.0	23.0	141	40	3	-	-	34.5
2	W	2009	P900	E-201	FV-0201	Sour water	993.0	16.6	40.0	23.0	141	40	3	-	-	34.5
2	W	2010	AP	FV-0201	T-201	Sour water	993.0	1.00	40.0	3.5	120	40	3	-	-	5.3
3	W	2015	AP	T-201	P-201-A	Sour water	903.7	1.10	96.0	3.5	120	40	3	PP	-	5.3
3	W	2016	AP	W-2015-AP-PP	P-201-B	Sour water	903.7	1.10	96.0	3.5	120	40	3	PP	-	5.3
2	W	2017	AP	P-201-A	FV-0202	Sour water	904.5	3.56	96.0	6.3	120	40	3	PP	-	9.5
2	W	2018	AP	FV-0202	V-101	Sour water	904.5	3.56	96.0	6.3	120	40	3	PP	-	9.5
2	W	2020	AP	P-201-B	2"-W-2017-AP	Sour water	904.5	3.56	96.0	6.3	120	40	3	PP	-	9.5
2	W	2022	AP	V-201	P-203-A	Sour water	880.6	0.8	42.6	3.5	120	80	3	-	-	5.3
2	W	2023	AP	W-2022-AP	P-203-B	Sour water	880.6	0.8	42.6	3.5	120	80	3	-	-	5.3
2	W	2024	AP	P-203-A	W-2025-AP	Sour water	880.1	4.92	43.0	7.8	120	80	3	-	-	11.7
2	W	2025	AP	P-203-B	FV-0203	Sour water	880.1	4.92	43.0	7.8	120	80	3	-	-	11.7
4	W	2026	AP	FV-0203	T-201	Sour water	880.1	1.0	43.0	3.5	120	40	3	-	-	5.3
2	W	2027	P900	2"-W-2004- P900-PP	2"-W-2009- P900	Sour water	938.1	18.6	127	23.0	141	40	3	PP	-	34.5
2	W	2030	P900	W-1009-AP	T-103	Sour water	993.0	16.6	40.0	23.0	141	40	3	-	-	34.5
2	W	2032	AP	T-201	SINK	Sour water	903.7	1.10	96.0	3.5	120	40	3	I	30	5.3
2	W	2033	AP	V-201	SINK	Sour water	880.6	0.8	42.6	3.5	120	80	3	I	30	5.3
1	W	2034	P900	E-202	SINK	Sour water	988.8	17.9	50.0	23.0	120	80	3	-	-	34.5
4	F	2011	AP	PSV-0201	FLARE	Acid gas	1.16	4.2 (4)	150 (4)	6.0	165	40	3	-	-	9.0
2	ST	8020	P900	UN	V-201	Medium pressure steam	5.90	11.0	187	13.4	293	40	3	I	30	20.1
2	ST	8021	P900	UN	T-201	Medium pressure steam	5.90	11.0	187	13.4	293	40	3	I	30	20.1
3	WG	2012	AP	T-201	PSV-0201	Acid gas	1.16	3.5 (4)	150 (4)	5.3	165	40	3	-	-	7.9
4	WG	2013	AP	T-201	E-203	Acid gas	1.16	1.00	91.2	3.5	120	40	3	PP	-	5.3
3	WG	2019	AP	E-203	V-201	Acid gas	(3)	0.8	43.0	3.5	120	40	3	-	-	5.3
4	WG	2021	AP	V-201	WG-1022-AP-S	Acid gas	1.13	0.8	43.0	3.5	120	40	3	S	30	5.3

Notes:

1.- L=Liquid; G= Gas; M=Mixed.

2.- UN: Utility network battery limit.

3.- Density vapour/ liquid phase: 1.1/ 880.8 kg/m³.

4.- According with the Process Safety Valve Design case.

5.3.6. Line pressure drops

As it might have been noticed, one of the checked parameters in the validation process is the line pressure drop.

This pressure drop is caused by friction between the pipe walls and the circulating fluid, and the secondary head losses associated to line fittings. [13]

5.3.6.1. Friction pressure drops for a single-phase fluid

The calculations are done by applying Darcy's equation for a single-phase turbulent flow, which is presented in 5.3.

$$\Delta P = 4 \cdot f_f \cdot \left(\frac{L}{DI}\right) \cdot \left(\frac{G^2}{2 \cdot \rho}\right) = F_D \cdot \left(\frac{L}{D}\right) \cdot \left(\frac{G^2}{2 \cdot \rho}\right) \quad (5.3)$$

Where:

- ΔP is the frictional pressure drop in Pa.
- F_D is the dimensionless Darcy's Factor calculated with the Expression 5.5, where the Churchill's friction factor (f_f) is used.
- L is the pipe length in m.
- DI is the internal diameter in m.
- G is the flux velocity in $\frac{\text{kg}}{\text{m}^2 \cdot \text{s}}$, calculated with the Expression 5.4.
- ρ is the fluid density in kg/m^3 .

$$G = \frac{W}{S_p} \quad (5.4)$$

$$F_D = \left[\left(\frac{8}{12}\right)^{12} + \left(\frac{1}{(A+B)\frac{3}{2}}\right)^{12} \right]^{\frac{1}{12}} \quad (5.5)$$

With the parameters A, B being calculated with Expressions 5.6 and 5.7.

$$A = \left[2.457 \cdot \ln \left(\frac{1}{\left(\frac{7}{Re}\right)^{0.9} + \left(\frac{0.27 \cdot \varepsilon}{D}\right)} \right) \right]^{16} \quad (5.6)$$

$$B = \left(\frac{37530}{Re}\right)^{16} \quad (5.7)$$

In the above expressions:

- W is the mass flowrate in kg/h.
- S_p is the cross section in m^2 .
- Re is the Reynold's number (dimensionless) calculated from Expression 5.8 below.
- ε is the effective roughness in m.

$$Re = \frac{u \cdot D \cdot \rho}{\mu} \quad (5.8)$$

5.3.6.2. Friction pressure drops for a mixed-phase fluid

If there are liquid and gas phases mixed, the friction pressure drop is calculated by applying the Lockhart Martinelli correlation of Equation 5.9.

$$\frac{\Delta P}{\Delta L} = \frac{\Delta P_L}{\Delta L} + C \cdot \sqrt{\frac{\Delta P_L}{\Delta L} \cdot \frac{\Delta P}{\Delta L}} + \frac{\Delta P_v}{\Delta L} \quad (5.9)$$

Where the previous nomenclature maintains, and:

- ΔP_L and ΔP_v are the frictional pressure drop of liquid and vapour phase alone, respectively.
- ΔL is the difference among the start of pipe section and the position where the pressure drop is calculated.
- C is a coefficient depending on vapour and liquid viscosities and densities.

Assuming a boiling regime to be conservative, the C coefficient is expressed as in Equation 5.10.

$$C = 2 \cdot C_0 \quad (5.10)$$

Where C_0 value changes according to the following criteria:

- If $C_1 > C_2$, $C_0 = C_1$
- If $C_1 > C_3$, $C_0 = C_1$
- If $C_1 < C_3$ then,
 - o If $C_3 > C_2$, $C_0 = C_2$
 - o If $C_3 < C_2$, $C_0 = C_3$

With the coefficients C_1 , C_2 and C_3 calculated with Expressions from 5.11, 5.15, and 5.16.

$$C_1 = 2 + \left(\frac{32 \cdot Y}{1 + 0.005664 \cdot C_f^{0.8}} \right) \quad (5.11)$$

Where:

- Y parameter is calculated with Equation 5.12.
- C_f parameter depends on the following criteria:
 - o If $G < 300$, C_f is obtained from Equation 5.13.
 - o Else, C_f is obtained from Equation 5.14.

$$Y = [1 - [0.16 \cdot (2.5 + \log(x))^2]^3 \quad (5.12)$$

$$C_f = 300 + \frac{(300 - G)^2}{40} \quad (5.13)$$

$$C_f = G \quad (5.14)$$

$$C_2 = \sqrt{\frac{\rho_L}{\rho_G}} + \sqrt{\frac{\rho_G}{\rho_L}} \quad (5.15)$$

$$C_3 = \sqrt{\frac{\rho_H}{\rho_v}} \cdot \left(\frac{\rho_L}{\rho_v} \right)^{0.125} \quad (5.16)$$

Where ρ_H is a dimensionless density coefficient of the mixed-phase fluid.

$$\rho_H = \frac{\rho_L \cdot \rho_G}{x \cdot \rho_L + (1-x) \cdot \rho_G} \quad (5.17)$$

5.3.6.3. Line fitting pressure drops

The pressure drop in lines caused by the fittings is calculated with Equation 5.18, and it is summed to the friction pressure drops for obtaining the total pressure losses through the line.

This fitting pressure drop can be calculated with expressions with the form of Equation 5.18.

$$\Delta P = K \cdot \frac{\rho \cdot u^2}{2 \cdot 10^5} \quad (5.18)$$

Where:

- K (dimensionless) factor calculation varies with the type of fitting. Obtained from bibliography sources [13].
- u is the fluid velocity in m/s.

5.4. Equipment design

5.4.1. New pump requirements (P-201, P-202, P-203)

In the current section, the calculations for pump validation are described. In addition, the requirements of differential head to be provided by the new pumps P-201, P-202 and P-203 is presented.

The discharge pressure needs to overcome the circuit pressure drop caused by lines, fittings, equipment, flowmeters, and static height. The excess of pressure is absorbed by the corresponding control valve.

It should be commented that the pressure drop caused by fittings has been only used in existing lines and the geometry information has been extracted from the corresponding isometric diagrams.

In the case of the new lines, the hydraulic calculations consider only the pipe pressure drops of friction since the pipe length is estimated from the Plot Plant distances (applying a security factor of 150%).

5.4.1.1. Calculations at pump suction

The suction pressure at design flow (in kg/cm² g) is calculated with the following data by applying the Equation 5.19:

- Inlet pressure (P_1).
- Height difference (ΔH).between Normal Liquid Level, NNL, and pump center line.
- Line pressures drop estimated from the plot plant distances with security factor of 150% .
- Filter: Equivalent pipe length of 300 ft.

The sum of line and filter equivalent length two pressure drops gives the friction pressure drop h_f .

$$P_{\text{suct}} = (P_1 - \frac{\Delta H}{\rho \cdot g} - (h_f \cdot \rho \cdot g)) \cdot 1.01972 \cdot 10^{-5} \quad (5.19)$$

In the Table 5.8, the suction pressures for the design cases of the three new pumps are summarized.

Table 5.8. Pressure at suction for the new pumps P-201, P-202, and P-203 (@ Q_{DES}).

	Item		
	P-201	P-202	P-203
P _{suction} [kg/cm ² g]	1.61	1.92	1.17

5.4.1.2. NPSH calculation

The Net Pressure Suction Head available (NPSHa) is calculated with the Equation 5.20, where:

- P_{suction} is the absolute pressure at the pump suction in kg/cm² a.
- P_{vap} is the absolute vapour pressure at suction conditions in kg/cm² a.
- ρ is the fluid density at suction conditions of pressure and temperature in kg/m³.
- NPSHa is given in m.

$$NPSH_a = \frac{P_{suction} - P_{vap}}{\rho} \cdot 10^4 \quad (5.20)$$

The detailed values used in calculations are displayed in the corresponding Process Data Sheets of the new pumps. From this information, the Table 5.9 NPSHa are determined by varying the vessel elevation to determine the minimum requirement.

Table 5.9. Summary of the Net Pressure Suction Height available for the new pumps.

	Item		
	P-201	P-202	P-203
NPSHa [m]	5.56	4.55	5.04
Minimum H (TL to center line) [m]	5.00	*	5.00

(*) The source column T-102 is an existing equipment, so its elevation is "as built".

5.4.1.3. Calculations at pump discharge

The pressure drop profiles in the pipe circuits is based on the next assumptions:

- Distributor pressure drops of 0.3 kg/cm² for design case. Darcy's equation is used to extrapolate pressure drop of flowmeters and distributors for normal and minimum flow cases.
- Static height is converted to pressures with the density at suction conditions since water properties are not sensitive to pressure changes in liquid state.
- Line pressure drops are estimated from plot plant distances by applying a security factor of 150%.
- Heat exchanger pressure drop preliminary set to 0.7 kg/cm² in both sides of the equipment.

Afterwards, it is recalculated with *HTRI*.

- Flowmeter pressure drop 0.25 kg/cm² for design flow. Darcy's equation is used to extrapolate pressure drop of flowmeters and distributors for normal and minimum flow cases.
- Control valve design pressure drop is obtained from the highest value of the following criteria:
 - o 50% of total friction losses excluding the valve.
 - o 1 kg/cm².

- 10% of differential pressure with valve pressure drop equal to the two first criteria.

The required discharge pressure for the design flow is calculated with Equation 5.21.

$$P_{\text{disch}} = P_2 + \Delta P_{\text{distr}} + \frac{\Delta H \cdot \rho}{10^4} + \Delta P_{\text{line}} + \Delta P_{\text{HE}} + \Delta P_{\text{FT}} + \Delta P_{\text{CV}} \quad (5.21)$$

Where:

- P_{disch} is the discharge pressure of the pump in $\text{kg/cm}^2 \text{ g}$.
- P_2 is the operating pressure in the destiny vessel in $\text{kg/cm}^2 \text{ g}$.
- ΔP_{distr} is the distributor channel pressure drop in kg/cm^2 .
- ΔH is the difference of height to overcome between destiny point and the pump discharge in m.
- ρ is the fluid density in kg/m^3 .
- ΔP_{line} is calculated by following the calculations described in 5.3.6, and it is expressed in kg/cm^2 .
- ΔP_{HE} , ΔP_{FT} , and ΔP_{CV} are the pressure drops caused by the heat exchanger, flowmeter, and control valve; being expressed in kg/cm^2 .

In Table 5.10 the different pressure requirements at the discharge are summarized with along the design ΔP_{CV} .

Table 5.10. Discharge pressure requirements for the new pumps (@ Q_{DES}).

	Item		
	P-201	P-202	P-203
$P_{\text{disch}} [\text{kg/cm}^2 \text{ g}]$	3.38	13.6	3.87
$\Delta P_{\text{CV}} [\text{kg/cm}^2]$	1.00	1.06	1.00

5.4.1.4. Maximum suction and maximum discharge pressures

They are calculated with the following expressions:

$$\text{MSP} = P_{\text{vessel}} + H \quad (5.22)$$

$$\text{MDP} = \text{MSP} + \text{MMDP} \quad (5.23)$$

Where:

- MSP stands for Maximum Suction Pressure, " P_{vessel} " is the design pressure of the suction vessel, and H is the pressure obtained from the Equation 5.24.

In the studied cases, P_{vessel} is equal to 3.5 kg/cm^2 since the suction lines don't have a PSV (Pressure Safety Valve). In case there was a PSV installed, the term P_{vessel} would be substituted by the set pressure of the PSV.

- MMDP is the Motor Maximum Differential Pressure, considered equal to the 120% of differential pressure for design flow conditions.

$$H \left[\frac{\text{kg}}{\text{cm}^2} \right] = \frac{\rho \cdot H_{\text{HLL-CL}}}{10000} \quad (5.24)$$

In the expression above, $H_{\text{HLL-CL}}$ is the difference of elevation between the vessel high liquid level and the pump center line, expressed in m.

These maximum pressure values are used as preliminary mechanical design conditions of the designed pumps.

Once the pump curve is selected, this value will be pump differential head at zero flow conditions.

Table 5.11. New pump maximum discharge pressures summary.

	Item		
	P-201	P-202	P-203
Maximum Suction Pressure [kg/cm ² g]	4.15	4.09	4.01
Maximum Discharge Pressure [kg/cm ² g]	6.27	18.1	7.26
Motor Maximum Differential Pressure [kg/cm ² g]	2.12	14.0	3.25

5.4.1.5. Pump selection

The selection process is carried out with the aim of the *KSB Easy Select* tool [14], which enables to compare between different models. This tool permits filtering the results according to parameters such as duty points of flow and pump differential height, operating temperature, etc. The selection has been based on achieving a feasible pressure with a good efficiency for the operating conditions.

The relevant information concerning to the selected models is summarized in the Table 5.12. As it can be appreciated, the discharge pressure requirements are satisfied.

Table 5.12. Pump selection summary.

	Item		
	P-201	P-202	P-203
P_{SUCT} [kg/cm ² g]	1.61	1.92	1.17
P_{DISCH} [kg/cm ² g]	3.52	17.6	4.87
T_{OP} [°C]	96.0	127	42.6
$NPSH_f$ [m] (1)	1.00	1.70	2.00
MDP [kg/cm ² g] (2)	6.27	22.9	8.46
T_{DES} [°C]	120	141	120
Q_{DES} [m ³ /h]	4.69	5.61	0.47

Notes:

1.- Net Positive Suction Head required @ Q_{rated} .

2.- Maximum Discharge Pressure (mechanical design pressure).

As it can be appreciated in the table above, the Net Pressure Suction Head required by the pumps is lower than the available one for preventing flash point as it would cause cavitation.

The vertical configuration is selected for P-201 and P-202, although this is not possible for P-203 since its working flowrate is too low for the static head requirements. The proposed solution by the *KSB* design software is a multipurpose pump with multiple stages.

Since the new pump discharge pressures are different from the hydraulic requirements shown in Table 5.10, the calculations are updated with the new P_{DISCH} values.

In Append B, the new pump Process Data Sheets are presented, where the corresponding curves are attached.

It should be commented that the pump maximum discharge pressures considered in the design of the rest of the equipment corresponds to the selected pump model instead of being estimated for conservative reasons.

5.4.2. Validation of the existing pumps

In this section, the calculations for validating the existing pumps P-101, P-103 and P-104 are presented.

On the other hand, P-102 is being dismantled since the pump around of the H₂S stripper T-101 is no longer in service.

The pump P-102 reutilization was discarded since the revamp operating conditions for the new pumps are much less thig. Subsequently, the pump would suffer from instabilities and low efficiencies at the revamp conditions.

The procedure for validating the pumps P-101, P-103 and P-104 has been quite similar with the hydraulic calculations for the new pumps except for some particularities commented in advance. The summary of the hydraulic results for P-101, P-103, and P-104 is presented in the corresponding Process Data Sheets (PDS) of the three aforementioned pumps.

5.4.2.1. NPSH validation

For each pump, it is checked that the NPSH required is lower than the NPSH available for the maximum flow conditions. The NPSH_r is obtained from the vendor's curves of the equipment, and the NPSH_a is calculated by using the Equation 5.20.

The summary of these NPSH is presented in Table 5.13, where it can be appreciated that the NPSH criteria is satisfied for all the pumps.

Table 5.13. Net Pressure Suction Heads of P-101, P-103, and P-104 (at maximum flow conditions).

	Item		
	P-101	P-103	P-104
NPSH _a [m]	25.7	26.5	4.0
NPSH _r [m]	1.2	3.00	1.5

5.4.2.2. Hydraulic circuit requirements

In the case of equipment already existing, the difference of height between the liquid inside the vessel and the pump suction is as built. The same happens with line geometries, which have been considered in the pressure drop calculations. By applying the Equation 5.19, the different suction pressures have been calculated.

While in the previous section the new pump required the pressure drop calculation for the control valve, the pressure drops of P-101, P-103 and P-104 control valves are obtained by applying the Equation 5.25 (which employs the same nomenclature than the Equation 5.21).

$$\Delta P_{CV} = P_{disch} - (P_2 + \Delta P_{distr} + \frac{\Delta H \cdot \rho}{10^4} + \Delta P_{line} + \Delta P_{HE} + \Delta P_{FT}) \quad (5.25)$$

The discharge pressure is obtained from the Equation 5.26, where:

- ΔP_{Pump} is the pressure obtained from the vendor's curve in kg/cm².
- $P_{suction}$ is the pressure calculated at pump suctions in kg/cm² g.

$$P_{disch} = P_{suction} + \Delta P_{pump} \quad (5.26)$$

As it can be observed in the corresponding Process Data Sheets, the differential head of the pumps is adequate for the revamp operating conditions for all the evaluated items.

The criteria exposed in the basis of design section is totally accomplished, which accounts for the reason why the three existing pumps are feasible for the revamp operating conditions.

5.4.3. Design of the ammonia water washing column (T-201)

The ammonia washer T-201 has been designed from the normal flow conditions and physical properties with an overdesign factor of 110%.

The design procedure has been based on technical guide expressions for column and drums for the vessel sizing; and the internals have been calculated designed with the aid of *Sulcol* [15].

5.4.3.1. Column internals

Since the spare space in the unit is limited, it is convenient that the column diameter is as reduced as possible.

This accounts to the reason why the smallest diameter valid according to *Sulcol* software is selected.

Among the different *Sulzer*'s offers [16], metal random packing is selected for the good performance and economic reasons, concretely *Nutter Ring*™ packings.

The model selection is done according to the absorption constant, and pressure drops of the different alternatives.

The smaller size available, *NR#0.7*, is adequate for the design case scenario for maximum flow conditions according to *Sulcol*.

On the other hand, the *Sulzer* offer has been consulted to determine the size of packing beds.

The number of theoretical stages is estimated with the simulation is determined based on the composition profile. Practically all H₂S content is removed from the treated gas and NH₃ concentration meet the revamp design specifications. Hence, the column is designed assuming 10 theoretical stages. The high equivalent theoretical plates for the selected packing is among 400-560 mm and 10 stages are enough for meeting the specifications. This is possible due to the column reflux, which increases the abatement efficiency of pollutants from the ammonia-rich gas.

Therefore, approximately 6 m of packing bed are required conservatively. For constructability reasons, two packed beds are used to achieve the bed height instead of one single bed.

5.4.3.2. Vessel sizing

T.EN technical design guides establishes that vertical vessel separators usually have hemispherical bottoms and a mesh pad to prevent droplets outlet by the top of the column.

The vapour area (A_v) is determined from Equation 5.32; being the liquid area (A_L) the difference between the total area (calculated with the initial guess of length and diameter), and A_v .

$$A_v = \frac{Q}{v_{\text{vap}}} \quad (5.27)$$

The critical velocity, which is calculated with the Newton's formula shown in Equation 5.33.

$$v_c = 0.048 \cdot \sqrt{\frac{\rho_l - \rho_g}{\rho_g}} \quad (5.28)$$

The allowable vapour velocity (v_{vap}) is expressed as a percentage of the critical velocity, being calculated by applying the Expression 5.34 below:

$$v_{\text{vap}} = K \cdot v_c \quad (5.29)$$

In the previous formula, the subscript “l” stands for the dispersed liquid phase; and “g” refers to the continuous gas phase. K is a coefficient which varies with the service and the presence or absence of a mesh.

In this case, an effluent separator service for a column with mess is selected. Subsequently, the K coefficient is equal to 220%.

The critical velocity calculated with Newton’s formula is 1.34 m/s, which gives an allowable vapor velocity of 2.95 m/s.

The residence time selection, used for heigh sizing, is summarized in Table 5.14.

Table 5.14. Summary of residence times for T-201 sizing.

Description	Bibliographic values	Selected value
Between LLL and LLLA	1-2 min	2 min
Between LLL and HHL	2 min / 5 min for a liquid distillate and 5 min for a gaseous distillate	5 min
Between HHL and HHLA	1 min / 2 min	1 min

The rules for the height calculation and the calculated values for each section lengths are presented in Table 5.15.

Table 5.15. Summary of T-201 sizing results.

Section	Name	Rule	h_i [mm]
From mesh to top T.L.	h_1	For $D < 1200$ mm: 400 mm	400
Mesh	h_2	For non cocking service: $h_2 = 100$ mm	100
From liquid feed inlet to mesh	h_3	For $D < 900$ mm: Equation 5.35.	351
From HHLA to feed liquid inlet	h_4	Biggest value between Equation 5.36 and 5.37.	451
From HHL to HHLA	h_5	When HHLA is present, minimum 200 mm.	253
From LLL to HHL	h_6	300 mm minimum	1,256
From LLLA to LLL	h_7	When LLLA is present, minimum of 200 mm.	506
From bottom T.L to LLL	h_8	300 mm minimum.	300

The meaning of the abbreviations appearing in Table 5.15 is:

- T.L. is the tangent line.
- LLLA is the very low liquid level alarm.
- LLL is the low liquid level.
- HHL is the high liquid level.
- HHLA is the very high liquid level alarm.

In the Expressions 5.35, 5.36, and 5.37, which are referenced in Table 5.15, the heigh and diameter are expressed in mm.

$$h_3 = 300 + \frac{D}{2} \quad (5.30)$$

$$h_4 = 1.5 \cdot D \quad (5.31)$$

$$h_4 = 400 + \frac{D}{2} \quad (5.32)$$

Table 5.16. Ammonia washing column T-201 design summary.

Nozzle service/ Tag	ND [inch]
Reflux return inlet/ I1	4
Washing water inlet/ I2	2
NH ₃ -rich gas inlet/ I3	4
Bottom outlet/ O1	3
Top outlet/ O2	4
Vent/ V	2
Pressure safety valve/ PSV	3
Steam out/ S1	2
Pressure transmitter/ PT1	2
Level transmitter/ LI1	2
Mechanical design conditions	
P _{DES} [kg/cm ² g]	3.5/ F.V.
T _{DES} [°C]	120.0
Parameter	Value
Design flowrate [m ³ /h]	796/ 3.88 · 10 ³ (2)
Density [kg/ m ³] (1)	1.2 (V)/ 903.7 (L)
Residence time [min]	5
Diameter [mm]	600
Length from T.L. to T.L. [mm]	11,184 (3)
Total volume [m ³]	1.08
Notes:	
1.- Biphasic system with liquid-vapour equilibrium. L: Liquid/ V: Vapour.	
2.- Vapour/ liquid feeds volumetric flows (@P,T).	
3.- Vessel length from T.L. to T.L.: 3.63 m. Total packed bed height: 6 m.	

5.4.4. Design of the reflux drum (V-201)

The new column (T-201) has a partial condenser in a fully refluxed circuit, which implies that a liquid and vapor phases are separated in the column reflux drum.

The design case is 110% of normal flow conditions extracted from the heat and material balance, and it is realized following *T. EN* drum design guides.

The drum is for normal service in low pressure conditions, and throughputs are not too high. Therefore, the droplet separation enhancing with a mesh pad is feasible. To be conservative with droplet separation, the taken critical velocity is 220% as it was a compressor suction scenario.

The fluid is biphasic, and a flash separation is assumed, so the expected gas and liquid flowrates are similar since partial condensation of 50% is done.

The liquid level is controlled with very low and high liquid level alarms, which will impact on the height calculations.

The sizing methodology is identical to the one used in the vessel sizing for T-201.

The design case is a reflux drum for a normal service corresponding to a K coefficient of 220% according to theoretical values.

By applying the Equations 5.33 and 5.34, the obtained results are:

- Critical velocity: 1.34 m/s.
- Allowable vapour velocity: 2.94 m/s.

In Table 5.17 and Table 5.18, the summary of the selected residence times and column heights is presented.

Table 5.17. Summary of residence times for V-201 sizing.

Description	Bibliographic values	Selected value
Between LLL and LLLA	1-2 min	2 min
Between LLL and HHL	2 min / 5 min for a liquid distillate and 5 min for a gaseous distillate	5 min
Between HHL and HHLA	1 min / 2 min	2 min

The summary of the most relevant information about the designed vessel is presented in Table 5.18, although the details are presented in the corresponding PDS (available in Appendix B).

Table 5.18. Reflux drum V-201 design summary.

Nozzle service/ Tag	ND [inch]
Reflux inlet/ I1	3
Gas outlet/ O1	4
Liquid outlet/ O2	1
Vent/ V1	2
Level transmitter/ LT1	2
Steam out/ S1	2
Mechanical design conditions	
P_{DES} [kg/cm ² g]	3.5/ F.V.
T_{DES} [°C]	120.0
Parameter	Value
Design flowrate [m ³ /h]	383.8
Density [kg/ m ³] (1)	880.5 (L)/ 1.134 (V)
Residence time [min]	5
Diameter[mm]	570
Length from T.L. to T.L. [mm]	2,276
Total volume[m ³]	0.63
Notes:	
1.- Biphasic system with liquid-vapour equilibrium. L: Liquid/ V: Vapour	

5.4.5. Wash water cooler exchanger (E-201)

The design has been realized with the aim of *HTRI Xchanger Suite 8.2* in rating mode so that the calculations are realized considering the effective surface area.

In accordance with the basis of design, the maximum flowrate is considered (120% of the normal flow), and temperature specifications are input for both inlets and outlets to determine the cooling flowrate requirements.

The fluid is not considered to be clean since its fouling resistance exceeds $0.0002 \text{ h} \cdot \text{m}^2 \cdot ^\circ\text{C}/\text{kcal}$. Consequently, the cooler type selected is shell and tube since it is found to be the most feasible alternative since this configuration, as well as double tube and plate and frame exchangers, provides high heat exchange area in reduced volume. However, the shell and tube heat exchanger result more economical, and its maintenance is easier. Besides, it's the most extended one, which accounts for the reason why does well-defined fabrication techniques and design procedures exist.

5.4.5.1. Fluid allocation

The heat exchanger service is dirty, and without phase changes in any of the streams. The cooling water is preferred to be in the tube side for thermal transfer improvement, while the process stream will be in the shell side despite being a dirty service.

5.4.5.2. TEMA type

The front-end stationary distribution head is type A since it has the advantage of easy maintenance. The main limitations of this type are pressure resistance (which doesn't apply), cost price and tightness.

In the case of equipment cost, the difference in maintenance expenses between A and B makes A more suitable. Besides, the tightness in A head type exchanger is solved by adding two gaskets (one between the channel and head and another in the fixed tube sheet).

The shell type is E (the most common) because the equipment is not a reboiler and there isn't low pressure drop limitations.

Rear end stationary head is S type because tube side thickness is not critical and there is possibility of thermal stress due to thermal expansion of shell.

On the other hand, the tube side may suffer corrosion. Consequently, accessibility to rear head becomes a criterion to be considered. These factors make of S type the most feasible selection.

5.4.5.3. Mechanical and geometrical characteristics

- Tubes:

The exchanger tubes have equal diameter and length. An outside tube diameter of 19.05 mm with BWG 16, and a tube length of 3658 mm are selected. The tube material is carbon steel.

Although the fluid fouling factors exceed $4 \cdot 10^{-4} \text{ m}^2 \cdot ^\circ\text{C} \cdot \text{h}/\text{kcal}$, the layout is 90 degrees rotated (square) because turbulent flow is considered to be more conservative.

- Baffles:

No vibration concerns are expected, so implemented baffles are single segmental with horizontal cut because shell flow is monophasic.

According to TEMA code, floating heads S type must have support baffle located between 100 and 150 mm from internal face of the floating tube-sheet. In this case, 100 mm is considered to be enough.

The selected material is the same as the tubes one according to client's design specifications.

- Nozzles:

The nominal diameter is 2" for all the connections. The program default Schedule for these conditions is 80, although warnings about the nozzle thickness at channel inlet and outlet appears. Hence, a 2" Sch XXS is selected for the shell side, while the tube side maintain the 2" Sch80.

5.4.5.4. E-201 design summary

Although the complete E-201 information is available on its TEMA Data Sheet (see Appendix B), a summary of the most relevant information is presented in the Table 5.19.

Table 5.19. E-201 design summary.

Allocation	Fluid nature	Mass flow [kg/h]	T in/out [°C]	P in [kg/cm ² g]	ΔP allow./ calc. [kg/cm ²]	Duty [Gcal/h]	
Hot side	Shell	H ₂ O	4381	50.0/40.0	16.8	0.2	0.041
Cold side	Tubes	Cooling water	3719	28.0/40.0	7.00	0.7	
Geometry							
TEMA type	Shell ID [mm]	Length [m]	Number of tubes	Tube ND [inch]	Area [m ²]		
AES	400	3.66	124	1	27.1		

5.4.6. Air coolers (E-202, E-203)

The revamp includes two new air coolers used for tempering the NH₃ washing column feed and its reflux partial condenser: E-202 and 203, respectively.

As it can be appreciated in the capital cost estimation, the most important part of primary equipment cost are the air-coolers.

However, they are preferred for cooling at higher temperatures instead of cooling water heat exchangers according to the BAT's since operational costs are reduced.

The usage of air for tempering process streams only requires from fans driven by motors. On the contrary, conventional coolers using cooling water require of a piping circuit connected to a cooling tower from water, the associated pumps, and a water make-up supply. Parallely, the utility network has maintenance costs due to corrosion issues since water is mandatory treated with biocide compounds for legionella prevention.

As the piping damage is unavoidable, carbon steel is often preferred for this purpose due to its (relatively) more economical cost, although it is less resistant to corrosion.

Nevertheless, air coolers don't have these concerns despite being less effective for the achievement of low temperatures. This is the reason why the BAT's recommend a first cooling with air to save cooling water consumption, which is limited to achieve temperatures below air cooler operability range.

Both air coolers are being implemented in an existing platform due to the fact they replace the H₂S pump around air cooler (E-105) which is currently out of service. As a matter of fact, the E-105 is being dismantled for the aforementioned spare space limitations in the DSWS unit.

The main process conditions- calculated with the aim of *HYSYS VII*- are reflected into the correspondents PDS's (Process Data Sheets) presented in Appendix B.

It should be commented that some details, as tube side pressure drop, are determined by vendor according to the PDS emitted in the basic engineering stage.

Consequently, the air cooler E-203 includes the condensation curves valid for a pressure range wider than the *HYSYS* simulation one.

On the other hand, the air cooler PDS of E-202 does not include these curves since the process stream maintains liquid phase during the whole cooling process.

In the *HYSYS* simulation, these unit operations are represented by the “air cooler” blocks, which enable to determine the estimated air flow and electrical power consumption.

The considered pressure drop for hydraulic calculations and heat and material balance realization is the maximum allowed pressure drop for conservative purposes.

5.4.7. Equipment list

The equipment list is presented in the Table 5.20, where the design and operating conditions are compared to validate the mechanical design of the existing items

As it can be seen the new process conditions don't exceed the design case, which makes the mechanical equipment adequate for the future operation.

In the case of the existing equipment, the PDS's contain the pump, and heat exchangers information since their performance is significantly changed by the new process conditions.

On the contrary, the existing vessel and columns are not included in these PDS because the process volumetric flows are close to the current operating conditions, which causes that residence times remain similar without being affected.

Table 5.20. Equipment list with adequacy checking.

Item	Description	Dimensions [m]			P [kg/cm ² g]		T [°C]		Duty [Gcal/h]	Surface [m ²]	Flow [kg/h]	Motor [kW]
		Diam.	L (L.T.)	Width	Op.	Des.	Op.	Des.				
E-101	H ₂ S Stripper feed/ NH ₃ stripper bottom exchanger	0.52	4.88	-	16.5/ 12.7 (1)	18.7 / 15.7	S: 128/ 83.7 T: 43.8/ 84.0	141/ 135	1.43	690	3.09·10 ⁴ / 3.73·10 ⁴ (1)	-
E-102	H ₂ S Stripper bottom/feed exchanger	0.49	4.88	-	8.56/ 11.8 (1)	12.1 / 15.7	S: 169/ 117 T: 84.0/ 117	187/ 145	1.28	720	2.14·10 ⁴ / 3.73·10 ⁴ (1)	-
E-103	H ₂ S Stripper reboiler	1.00	6.10	-	8.38/ 11.0 (1)	10.3 / 13.4	S: 164/ 170 T: 187/ 187	189/ 300	2.54	1.04·10 ³	3.69·10 ⁴ / 7.43·10 ³ (1)	-
E-104	NH ₃ Stripper reboiler	0.88	6.10	-	1.66/ 4.2 (1)	5.4 +F.V./ 7 +F.V. (3)	103/ 69.8	145/ 210	3.53	5.72·10 ³	3.72·10 ⁴ / 5.33·10 ³ (1)	-
E-106	NH ₃ Stripper pump around air cooler	-	8.80	5.11	3.77/ 3.26	5.1	103/ 69.8	118	3.53	5.70·10 ³	1.05·10 ⁵	2 x 30 (5)
E-107	Stripped water air cooler	-	8.80	3.51	16.2	18.6	83.7/ 65.0	126	0.574	673	3.09·10 ⁴	2x 20 (5)
E-201	Wash water cooler (CW)	0.42	3.66	-	16.8/ 7.0 (1)	25.7/ 13.3	S: 50.0/ 40.0 T: 28.0/ 40.0	145/ 80	0.414	27.1	4.38·10 ³ / 3.72·10 ³	-
E-202	Wash water air cooler	-	8.80	3.51 (4)	18.6	25.7	127/ 50.0	145	0.344	645	4.38·10 ³	2x 20 (5)
E-203	NH ₃ Washer air condenser	-	8.80	3.51 (4)	1.0	3.5	91.0/ 43.0	120	0.197	645	732	2x 20 (5)
P-101-A/B	Sour water feed pumps	-	2.35	1.08	12.3 (2)	16.9	42.1	135	-	-	46.9 m ³ /h	56.6
P-103-A/B	NH ₃ stripper pump around pumps	-	2.16	1.07	7.92 (2)	10.3	103	145	-	-	141 m ³ /h	35.0
P-104-A/B	Stripped water pumps	-	0.84	0.75	13.6 (2)	13.6	127	145	-	-	39.5 m ³ /h	40.6
P-201-A/B	NH ₃ washer bottom pumps	-	-	-	3.38 (2)	6.40	96.0	120	-	-	4.69 m ³ /h	0.62
P-202-A/B	Wash water pumps	-	-	-	17.5 (2)	22.8	127	145	-	-	5.61 m ³ /h	4.69
P-203-A/B	NH ₃ washer reflux pump	-	-	-	4.87 (2)	8.46	42.6	120	-	-	0.47 m ³ /h	0.656
T-101	H ₂ S Stripper	1.2	19.7	-	-	10 + F.V. (3)	134/ 169	100/ 187	-	-	-	-
T-102	NH ₃ Stripper	1.9	28.4	-	1.2 / 1.5	3.5 + F.V. (3)	69.8/ 127	141	-	-	-	-
T-103	H ₂ S Washer	0.35	5.80	-	7.9 / 8.0	9.7 + F.V. (3)	42.0/ 169	80/ 126	-	-	-	-
T-201	NH ₃ Washer	0.60	11.2	-	1.0/ 1.1	3.5 + F.V. (3)	91.0/ 96.0	120	-	-	-	-
V-101	Sour water surge drum	3.0	9.00	-	1.2	3.5 + F.V. (3)	42.0	135	-	-	-	-
V-102	E-103 Condensate pot	0.61	2.10	-	11	13.4 + F.V. (3)	187	300/ 192	-	-	-	-
V-103	E-104 Condensate pot	24"	2.65	-	4.2	7 + F.V. (3)	152	210/ 170	-	-	-	-
V-202	T-201 Reflux drum	0.57	2.28	-	0.7	3.5 + F.V. (3)	42.6	120	-	-	-	-

Notes:

1.- Shell side/ tube side.

2.- Pump discharge pressure (@ Q_{rated}).

3.-F.V. : Full vacuum.

4.- Top/ Bottom.

5.- Electrical power consumption extracted for the existing motor Data Sheets.



**VERTICAL VESSELS
V-201**

EQUIPMENT FEATURES

1	Item N°	V-201
2	SERVICE	NH ₃ water washing column reflux drum

OPERATING CONDITIONS

		PRESSURE (kg/cm ² g)		TEMPERATURE (°C)	
		Top	Bottom	Top	Bottom
5	Position (1)	Top	Bottom	Top	Bottom
6	Normal Operating	0.8	0.8	42.6	42.6
7	Mechanical Design	3.5	3.5	120	120
8	Alternative Mechanical Design (regeneration, start-up, etc.)	-	-		
9	Vacuum Mechanical Design	F.V.	F.V.		
10	Minimum Temperature (depressurization, etc)			-	-
11	Steam Out,...		0		187

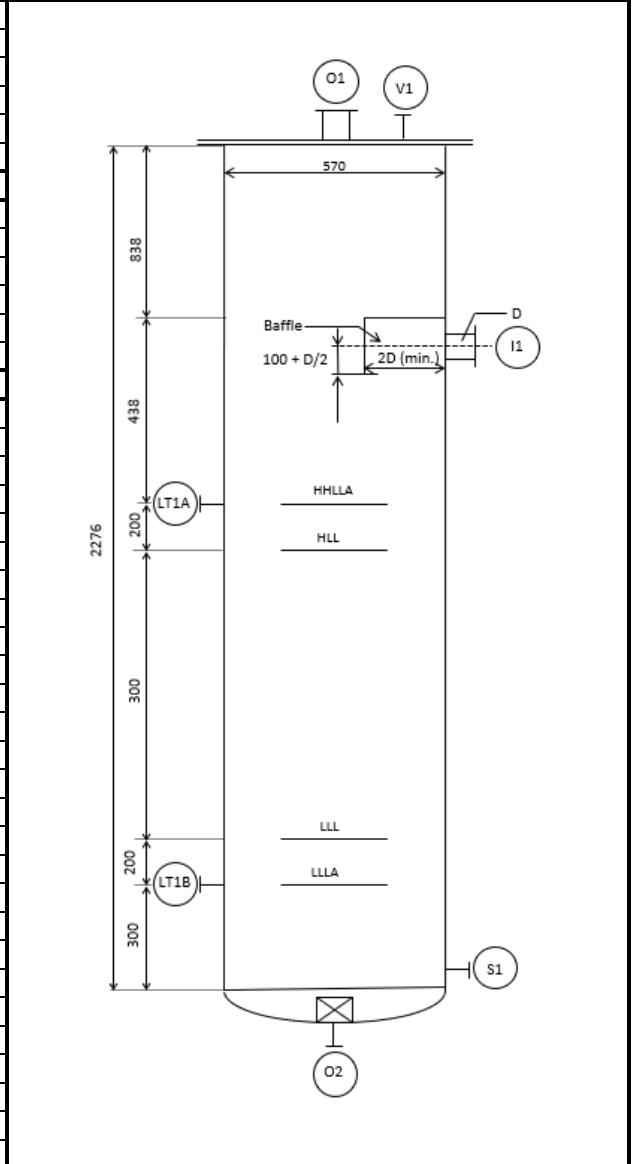
FLUID CHARACTERISTICS **SCHEME**

13	Fluid	H ₂ O+H ₂ S+NH ₃
14	Corrosive Compunds	NH ₃
15	Content (w % / w ppm)	(3)
16	Light Liquid Density @ T (kg/m ³)	(2)
17	Heavy Liquid Density @ T (kg/m ³)	(2)
18	Maximum Liquid Level (mm)	800

MATERIAL				
	Material	Corr.Allow.	PWHT	
20				
21	Shell	KCS	6.0 mm	Yes
22	Heads	KCS	6.0 mm	Yes
23	Internals	SS316L	-	-
24	Trays	-	-	-
25	Insulation			

NOZZLES AND MANWAYS

ID	N°	DIA(")	FLANGE	SERVICE	
28	I1	1	3	#300	Reflux inlet
29	O1	1	4	#300	Gas outlet
30	O2	1	2	#300	Liquid outlet
31	V1	1	2	#300	Vent
32	LT1	2	2	#300	Level transmitter
33	S1	1	2	#300	Steam out
34					
35					
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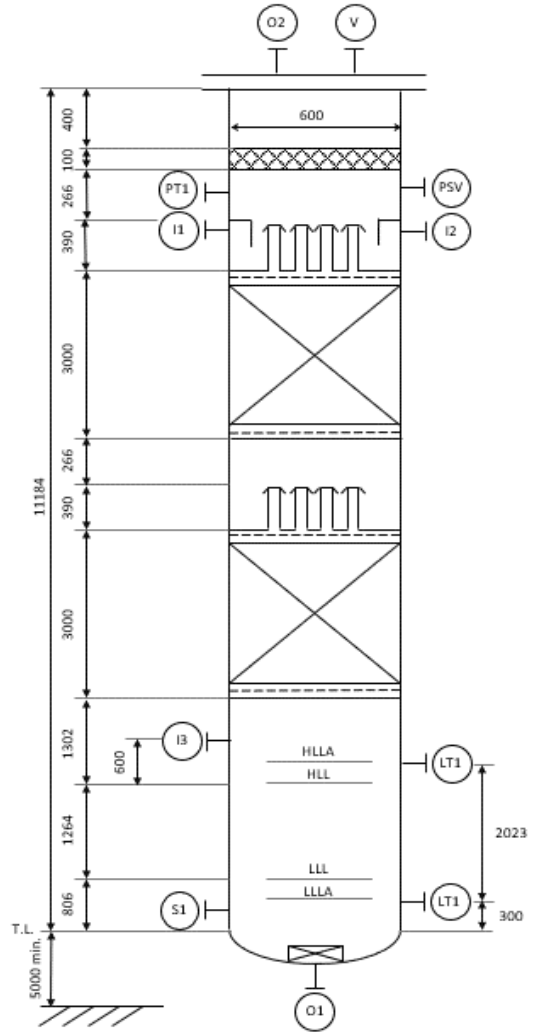


NOTES:

- (1) For columns and for vessels full of liquid indicate normal and mechanical design P, T at the vessel top and bottom.
- (2) Does not apply. The vessel contains a liquid phase and a vapour phase with densities of 880.6 kg/m³ and 1.133 kg/m³, respectively.
- (3) Top: 96.8% wt. / Bottom: 28.6% wt.



Rev	EQUIPMENT FEATURES				
1	Item N°	T-201			
2	SERVICE	NH ₃ water washing column			
3	OPERATING CONDITIONS				
4		PRESSURE (kg/cm ² g)		TEMPERATURE (°C)	
5	Position (1)	Top	Bottom	Top	Bottom
6	Normal Operating	1	1.1	91	96
7	Mechanical Design	3.5	3.5	120	120
8	Alternative Mechanical Design (regeneration, start-up, etc.)	-	-	-	-
9	Vacuum Mechanical Design	FV	FV	-	-
10	Minimum Temperature (depressurization, etc)	-	-	0	0
11	Steam Out,...	0		187	
12	FLUID CHARACTERISTICS			SCHEME	
13	Fluid	H ₂ O+NH ₃			
14	Corrosive Compunds	NH ₃			
15	Content (w % / w ppm)	(2)			
16	Light Liquid Density @ T (kg/m ³)	(3)			
17	Heavy Liquid Density @ T (kg/m ³)	(3)			
18	Maximum Liquid Level (mm)	2070			
19	MATERIAL				
20		Material	Corr.Allow.	PWHT	
21	Shell	KCS	6 mm	Yes	
22	Heads	KCS	6 mm	Yes	
23	Internals	SS316L	-	-	
24	Trays	-	-	-	
25	Insulation	YES (5)			
26	NOZZLES AND MANWAYS				
27	ID	N°	DIA(″)	FLANGE	SERVICE
28	I1	1	4	#150	Liquid reflux inlet
29	I2	1	2	#150	Washing water inlet
30	I3	1	4	#150	NH ₃ -rich gas inlet
31	O1	1	3	#150	Bottom liquid outlet
32	O2	1	4	#150	Gas outlet
33	V	1	2	#150	Vent
34	PSV	1	3	#150	Pressure Safety Valve
35	S1	1	2	#150	Steam feed
36	PT1	1	2	#150	Pressure transmitter
37	LI1	2	2	#150	Level transmitter
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55	NOTES:				
56	(1) For columns and for vessels full of liquid indicate normal and mechanical design P, T at the vessel top and bottom.				
57	(2) Light phase: 64.8% wt. (NH ₃)				
58	Heavy phase: 8.1% wt. (NH ₃), 1.2% wt. (H ₂ S).				
59	(3) Does not apply. The vessel contains a liquid phase and a vapour phase with densities of 903.7 kg/m ³ and 1.159 kg/m ³ , respectively.				
60					
61	(4) Liquid density at bottom outlet conditions.				
62	(5) Rock wool blancket insulation. 60 mm thightness.				
63	(6) Demister designed for maximum droplet diameter of 375 microns (calculated with Newton's formula).				
64	(7) Demister design ΔP: 0.05 kg/cm ² .				
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Rev	EQUIPMENT DATA					
1	Item N°:	T-201				
2	SERVICE:	NH3 water washing column	DESIGN CASE:		Normal flow	
3	FRACTIONATION SECTION					
4	SECTION		Section 1		Section 2	
5	From Real Tray / To Real Tray	From / To	Top	Bottom	Top	Bottom
6	Pressure, P	kg/cm ² g	1	1.04	1.06	1.1
7	Allowable Pressure Drop	kg/cm ²	0.05		0.05	
8	Number of Theoretical Trays	-	5		5	
9	Heat Exchanged in the Section	Gcal/h	-			
10	VAPOUR TO TRAY					
11	Mass Flow	kg/h	723.8	1061.0	1064.4	1082.1
12	Volumetric Flow @ P,T	m ³ /h	637.2	903.3	918.4	908.5
13	Density @ P,T	kg/m ³	1.14	1.2	1.2	1.2
14	Viscosity @ T	cP	0.0127	0.0127	0.0128	0.0128
15	Temperature, T	°C	93.0	95.4	96.1	95.5
16	Operating Flow Range Maximum / Minimum	%	60 / 110			
17	LIQUID FROM TRAY					
18	Mass Flow	kg/h	3483.6	3499.9	3502.9	3524.8
19	Volumetric Flow @ P,T	m ³ /h	4.3	3.8	4.1	4.1
20	Density @ P,T	kg/m ³	813.1	920.4	853.6	849.5
21	Viscosity @ T	cSt	0.4345	0.3532	0.4063	0.0128
22	Surface Tension @ P,T	Dinas/cm	59.6	59.3	59.7	61.4
23	Temperature, T	°C	93.0	95.4	96.1	95.5
24	Operating Flow Range Maximum / Minimum	%	60 / 110			
25	SYSTEM CHARACTERISTICS					
26	System (Foaming) Factor	-	0.85		0.85	
27	Fouling (low / moderate / high)	-	Low		Low	
28	Corrosive Compunds / Content	w % p / w ppm	(1)			
29	CONSTRAINTS IN TRAY / PACKING DESIGN					
30	Jet Flooding, Maximum	%	-		-	
31	Downcomer Backup, Maximum	%	-		-	
32	TRAYS / PACKING DESIGN CHARACTERISTICS					
33	Column Internal Diameter	mm	600		600	
34	Number of Trays	-	-		-	
35	Tray Spacing	mm	-		-	
36	Number of Passes per Tray	-	-		-	
37	Type of Tray (sieve , valves,...)	-	-		-	
38	Packing Height	mm	3000		3000	
39	Type of Packing	-	Nuttering 0.7		Nuttering 0.7	
40	NOTES					
41	(1) Light phase: 64.8% wt. (NH3)					
42	Heavy phase: 8.1% wt. (NH3), 1.2% wt. (H2S).					
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Rev	EQUIPMENT DATA					
1	Item Nº:	T-201				
2	SERVICE:	NH3 Water Washing			DESIGN CASE:	Normal flow
3	COLUMN INLET STREAMS CHARACTERISTICS					
4	SERVICE:	-	Washing Water	Reflux		
5						
6	Nozzle ID	-	I2	I1		
7	Above Tray Number	-	(2)	(2)		
8	Numb. of nozzles/Numb. of Passes per Tray	-	1 / -	1 / -		
9	Nozzle diameter	inch	2	1		
10	Flange	-	#150	#150		
11	Pressure, P	kg/cm2g	1.0	1.0		
12	Temperature, T	°C	40.0	43.0		
13	Operating Flow Range Maximum/Minimum	%	110 / 60	110 / 60		
14	VAPOUR PHASE (1)					
15	Mass Flow	kg/h	-	-		
16	Volumetric Flow @ P,T	m³/h	-	-		
17	Density @ P,T	kg/m³	-	-		
18	Viscosity @ T	cP	-	-		
19	LIQUID PHASE (1)					
20	Mass Flow	kg/h	2822.8	341.2		
21	Volumetric Flow @ P,T	m³/h	2.8	0.4		
22	Density @ P,T	kg/m³	993.0	880.1		
23	Viscosity @ T	cSt	0.6758	0.8516		
24	Surface Tension @ P,T	Dines/cm	69.76	69.21		
25	DISTRIBUTOR CHARACTERISTICS					
26	Service	-	Washing Water	Liquid reflux		
27	Nozzle ID	-	I2	I1		
28	Above Tray Number	-	Above bed 1	(3)		
29	Numb. of nozzles/Numb. of Passes per Tray	-	1	1		
30	Nozzle DN	pulgadas	2	1		
31	Flange	-	#150	#150		
32	Pressure, P	kg/cm2g	1.0	1.0		
33	Temperature, T	°C	40.0	43.0		
34	Operating Flow Range Maximum/Minimum	%	110 / 60	110 / 60		
35	VAPOUR PHASE (1)					
36	Mass Flow	kg/h	-	-		
37	Volumetric Flow @ P,T	m³/h	-	-		
38	Density @ P,T	kg/m³	-	-		
39	Viscosity @ T	cP	-	-		
40	LIQUID PHASE (1)					
41	Mass Flow	kg/h	2822.8	341.2		
42	Volumetric Flow @ P,T	m³/h	2.8	0.4		
43	Density @ P,T	kg/m³	993.0	880.1		
44	Viscosity @ T	cSt	0.7	0.9		
45	Surface Tension @ P,T	Dines/cm	69.8	69.2		
46	NOTES					
47	(1) Flow provided for the total inlet/withdraw nozzles.					
48	(2) I1 / I2 nozzles above bed 1.					
49	(3) I3 nozzle below bed 2.					
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**PUMPS
P-201-A/B**

Rev	EQUIPMENT FEATURES		
1	DESIGN CASE	120% Normal Flow	
2	SERVICE	NH ₃ water washing column bottom pumps	
3	Item N° Operation / Spare	P-201- A/B	
4	Number of Pumps Required for Operation / Spare	1 / 1	
5	Type of Pump (centrifugal / volumetric alternative / volumetric rotative)	Centrifugal	
6	Operation (continuous / discontinuous ; series / parallel)	Continuous	
7	FLUID CHARACTERISTICS		
8	Nature of Fluid	H ₂ O+H ₂ S+NH ₃	
9	Corrosive / Toxic Compounds	% wt. / wt. ppm	8.1% (NH ₃) / 1.2% (H ₂ S)
10	Solids (Quantity / Size)	No	
11	Pour Point	°C	-
12	Self Ignition Point / Flash Point	°C	-
13	Pumping Temperature, T	°C	96.0
14	Density @ T	kg/m ³	903.7
15	Viscosity @ T	cSt	0.34
16	Vapour Pressure @ T	kg/cm ² a	2.13
17	PUMP DESIGN CONDITIONS		
18	Design Flow Q (rated)	m ³ /h	4.69
19	Minimum Process Flow	m ³ /h	1.26
20	Normal Flow	m ³ /h	3.91
21	Discharge Pressure @ Q rated	kg/cm ² g	3.52
22	Suction Pressure @ Q rated	kg/cm ² g	1.61
23	Differential Pressure @ Q rated	kg/cm ²	1.91
24	Differential Head @ Q rated	m	21.10
25	NPSH Available @ Q rated	m	5.65
26	Maximum DP at Zero Flow	kg/cm ²	2.12
27	Maximum Suction Pressure	kg/cm ² g	4.15
28	Maximum Discharge Pressure	kg/cm ² g	6.27
29	Suction / Discharge Piping Size	Inch	3" / 1 1/2"
30	Impeller / Mechanical Seal	-	
31	Tracing / Insulation / Flushing	-	
32	MECHANICAL DESIGN CONDITIONS		
33	Mechanical Design Temperature	°C	120.0
34	Mechanical Design Pressure	kg/cm ² g	6.3
35	DRIVER FEATURES		
36	Type Operating / Spare	-	
37	<u>Estimated</u> Power Demand at Q rated	kWh/h	0.61
38	<u>Estimated</u> Demand at Q rated	Kg/h	-
39	NOTES		
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**PUMPS
P-202-A/B**

Rev	EQUIPMENT FEATURES		
1	DESIGN CASE		120% Normal Flow
2	SERVICE		Wash water pumps
3	Item N° Operation / Spare		P-202-A/B
4	Number of Pumps Required for Operation / Spare		1 / 1
5	Type of Pump (centrifugal / volumetric alternative / volumetric rotative)		Centrifugal
6	Operation (continuous / discontinuous ; series / parallel)		Continuous
7	FLUID CHARACTERISTICS		
8	Nature of Fluid		Water
9	Corrosive / Toxic Compounds	% wt. / wt. ppm	-
10	Solids (Quantity / Size)		No
11	Pour Point	°C	-
12	Self Ignition Point / Flash Point	°C	-
13	Pumping Temperature, T	°C	127.2
14	Density @ T	kg/m ³	936.9
15	Viscosity @ T	cSt	0.23
16	Vapour Pressure @ T	kg/cm ² a	2.53
17	PUMP DESIGN CONDITIONS		
18	Design Flow Q (rated)	m ³ /h	5.61
19	Minimum Process Flow	m ³ /h	2.05
20	Normal Flow	m ³ /h	4.68
21	Discharge Pressure @ Q rated	kg/cm ² g	17.4
22	Suction Pressure @ Q rated	kg/cm ² g	1.9
23	Differential Pressure @ Q rated	kg/cm ²	15.5
24	Differential Head @ Q rated	m	165.0
25	NPSH Available @ Q rated	m	4.53
26	Maximum DP at Zero Flow	kg/cm ²	18.9
27	Maximum Suction Pressure	kg/cm ² g	4.1
28	Maximum Discharge Pressure	kg/cm ² g	23.0
29	Suction / Discharge Piping Size	Inch	1 1/4" / 1 1/4"
30	Impeller / Mechanical Seal		-
31	Tracing / Insulation / Flushing		-
32	MECHANICAL DESIGN CONDITIONS		
33	Mechanical Design Temperature	°C	141.0
34	Mechanical Design Pressure	kg/cm ² g	23.0
35	DRIVER FEATURES		
36	Type Operating / Spare		-
37	Estimated Power Demand at Q rated	kWh/h	4.41
38	Estimated Demand at Q rated	Kg/h	-
39	NOTES		
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**PUMPS
P-203-A/B**

Rev	EQUIPMENT FEATURES		
1	DESIGN CASE	120% Normal Flow	
2	SERVICE	NH ₃ water washing column reflux pump	
3	Item N° Operation / Spare	P-203-A/B	
4	Number of Pumps Required for Operation / Spare	1 / 1	
5	Type of Pump (centrifugal / volumetric alternative / volumetric rotative)	Centrifugal	
6	Operation (continuous / discontinuous ; series / parallel)	Continuous	
7	FLUID CHARACTERISTICS		
8	Nature of Fluid	H ₂ O + H ₂ S+ NH ₃	
9	Corrosive / Toxic Compounds	% wt. / wt. ppm	28.6% (NH ₃)
10	Solids (Quantity / Size)	No	
11	Pour Point	°C	-
12	Self Ignition Point / Flash Point	°C	-
13	Pumping Temperature, T	°C	42.6
14	Density @ T	kg/m ³	880.6
15	Viscosity @ T	cSt	1.11
16	Vapour Pressure @ T	kg/cm ² a	1.69
17	PUMP DESIGN CONDITIONS		
18	Design Flow Q (rated)	m ³ /h	0.47
19	Minimum Process Flow	m ³ /h	-
20	Normal Flow	m ³ /h	0.23 (1)
21	Discharge Pressure @ Q rated	kg/cm ² g	4.87
22	Suction Pressure @ Q rated	kg/cm ² g	1.17
23	Differential Pressure @ Q rated	kg/cm ²	3.71
24	Differential Head @ Q rated	m	42.1
25	NPSH Available @ Q rated	m	5.04
26	Maximum DP at Zero Flow	kg/cm ²	3.79
27	Maximum Suction Pressure	kg/cm ² g	4.01
28	Maximum Discharge Pressure	kg/cm ² g	7.80
29	Suction / Discharge Piping Size	Inch	1"/ 1"
30	Impeller / Mechanical Seal	-	
31	Tracing / Insulation / Flushing	-	
32	MECHANICAL DESIGN CONDITIONS		
33	Mechanical Design Temperature	°C	120.0
34	Mechanical Design Pressure	kg/cm ² g	7.8
35	DRIVER FEATURES		
36	Type Operating / Spare	-	
37	Estimated Power Demand at Q rated	kWh/h	1.18
38	Estimated Demand at Q rated	Kg/h	-
39	NOTES		
40	(1) Pump minimum required flow not available in the vendor's technical information. The shown value		
41	corresponds to the flow when operating at 60% of the normal capacity.		
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Customer				Reference No.			
Address				Proposal No.			
Plant Location				Date		Rev	
Service of Unit		Wash water cooler		Item No.		E-201	
Size		400 x 3657,6 mm		Type		AES Horizontal	
Surf/Unit (Gross/Eff)		27,143 / 25,859 m ²		Shell/Unit		1	
				Connected In		1 Parallel 1 Series	
				Surf/Shell (Gross/Eff)		27,143 / 25,859 m ²	

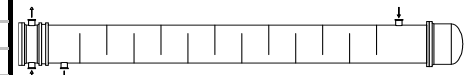
PERFORMANCE OF ONE UNIT

Fluid Allocation		Shell Side		Tube Side	
Fluid Name		H2O (Washing water)		H2O(Cooling water)	
Fluid Quantity, Total		4380.5		3719	
Vapor (In/Out)					
Liquid		4380.5		3719	
Steam					
Water					
Noncondensables					
Temperature (In/Out)		50 / 40		28 / 40	
Specific Gravity		0.9892 / 0.9935		0.9971 / 0.993	
Viscosity		0.5596 / 0.6712		0.8551 / 0.6712	
Molecular Weight					
Molecular Weight, Noncondensables					
Specific Heat		0.9538 / 0.9373		0.9183 / 0.9376	
Thermal Conductivity		0.5482 / 0.5383		0.525 / 0.5383	
Latent Heat		kcal/kg			
Inlet Pressure		16.8		7.00	
Velocity		4.34E-02		0.41	
Pressure Drop, Allow/Calc		0.2 / 0.014		0.7 / 0.061	
Fouling Resistance (min)		0.0004		0.0004	

Heat Exchanged		41416 kcal/hr		MTD (Corrected)		8.7 C	
Transfer Rate, Service		184.4 kcal/m ² -hr-C		Clean		551.14 kcal/m ² -hr-C	
				Actual		370.61 kcal/m ² -hr-C	

CONSTRUCTION OF ONE SHELL

		Shell Side		Tube Side		Sketch (Bundle/Nozzle Orientation)
Design/Test Pressure		23.0 /		17.7 /		
Design Temperature		145		80		
No Passes per Shell		1		8		
Corrosion Allowance		3.175		3.175		
Connections		1 @ 38.176		1 @ 49.251		
Size & Rating		1 @ 38.176		1 @ 49.251		
		@		@		



Tube No.		124		OD		19.05 mm		Thk(Avg)		1.651 mm		Length		3658 mm		Pitch		25.399 mm	
Tube Type		Plain		Material		Carbon steel		Tube pattern		90									
Shell		SA-516 70 PI. K02700		ID		400		OD		419.05 mm		Shell Cover		SA-516 70 PI. K02700		(Remove.)			
Channel or Bonnet		SA-516 70 PI. K02700		Channel Cover		SA-516 70 PI. K02700													
Tubesheet-Stationary		SA-105 Forgings K03504		Tubesheet-Floating		SA-105 Forgings K03504													
Floating Head Cover		SA-105 Forgings K03504		Impingement Plate		None													
Baffles-Cross		Carbon steel		Type		Single-Seg.		%Cut (Diam)		22.22		Spacing(c/c)		250		Inlet		414.55 mm	
Baffles-Long		Seal Type		None															
Supports-Tube		U-Bend		Type		None													
Bypass Seal Arrangement		2 pairs seal strips		Tube-Tubesheet Joint		Expanded (2 grooves)													
Expansion Joint		Type		None															
Rho-V2-Inlet Nozzle		1142.8 kg/m-s ²		Bundle Entrance		1.24		Bundle Exit		2.07		kg/m-s ²							
Gaskets-Shell Side		Mach. Mtl. (Kammprofile\Flex. Face)		Tube Side		Mach. Mtl. (Kammprofile\Flex. Face)													
- Floating Head		Mach. Mtl. (Kammprofile\Flex. Face)																	
Code Requirements		ASME		TEMA Class		R													
Weight/Shell		1389.3 kg		Filled with Water		1883.2 kg		Bundle		555.59 kg									

Remarks:



**AIR COOLERS
E-202**

Rev	EQUIPMENT FEATURES						
1	ITEM Nº	E-202					
2	DESIGN CASE	120% Normal Operation flow					
3	SERVICE	Wash water air cooler					
4	Shared with...	E-107 / E-203 / E-202					
5	Estimated Nº of Bays / Bundles	1 / 3 (2)					
6	Forced / Induced Draft	FORCED					
7	FLUID CHARACTERISTICS AND OPERATING CONDITIONS						
8	SIDE	TUBES			AIR SIDE		
9	Nature	H2O			CONDITIONS		
10	Corrosive Compounds / Content	- / w %	-	-	Atm. Pressure		
11			Inlet	Outlet	1 (4)	kg/cm ² a	
12	TOTAL MASS FLOW	kg/h	4380.5	4380.5	Inlet Temperature		
13	VAPOUR TOTAL MASS FLOW(wet)	kg/h	-	-	28	°C	
14	Non Condensable (N2,...)	kg/h	-	-	Minimum Temperature		
15	Steam	kg/h	-	-	2	°C	
16	Hydrocarbons	kg/h	-	-	Max. Allowable Outlet T		
17	LIQUID TOTAL MASS FLOW	kg/h	4380.5	4380.5	43	°C	
18	Free Water	kg/h	-	-	Relative Humidity @ Tin		
19	Hydrocarbons	kg/h	-	-	80	%	
20	VAPOUR PHASE PROPERTIES(wet)					CONTROL (2)	
21	Molecular Weight	kg/kmol	-	-	Louvers (y / n)		
22	Density @ P,T	kg/m ³	-	-	Existing		
23	Viscosity @ T	cP	-	-	Variable Pitch (y / n)		
24	Thermal Conductivity @ T	kcal/h m °C	-	-	Existing		
25	Specific Heat @ T	kcal/kg °C	-	-	Variable Speed Motor (y / n)		
26	LIQUID PHASE PROPERTIES (dry)					Existing	
27	Density @ P,T	kg/m ³	938.1	988.8	EST. POWER DEMAND		
28	Viscosity @ T	cSt	0.229	0.566	Normal		
29	Thermal Conductivity @ T	kcal/h m °C	0.796	0.741	Existing	kWh/h	
30	Specific Heat @ T	kcal/kg °C	19.05	16.70	Design		
31	Surface Tension @ P,T	dines/cm	53.00	67.84	Existing	kWh/h	
32	Temperature	°C	126.8	50.0	WINTERIZATION		
33	Inlet Pressure	kg/cm ² g	18.6		Process Pour Point		
34	Allowable Pressure Drop	kg/cm ²	(3)		NA	°C	
35	Fouling Factor	m ² h °C / kcal	0.0004		Heating Coil (y / n)		
36	Heat Duty	Gcal/h	0.344		No		
37	Maximum Flows and Heat Duties (8)	%	120		Heating Medium		
38	Allowable Pressure Drop at Max. Flows	kg/cm ²	0.7		No		
39	MECHANICAL DESIGN CONDITIONS				HEATING		
40	CONDITIONS....		Pressure	Temperature	Pressure	Temperature	
41	Mechanical Design	kg/cm ² g ; °C	23.0	145	-	-	
42	Vacuum Mechanical Design	kg/cm ² g ; °C	-	-	-	-	
43		kg/cm ² g ; °C	-	-	-	-	
44	Flushing or Steam Out	kg/cm ² g ; °C	-	-	-	-	
45	CONSTRAINTS FOR THERMAL DESIGN						
46	Maximum Bundle Width (3 m)	(1)		Maximum Bundle Weight (10 t)	X		
47	Tube Outside Diameter (1 inch)	X		Minimum Tube Thickness (BWG)	12		
48	Tube Length (30 ft)	(1)		Split Header (y / n)	Yes (1)		
49	Max./ Min. Allowable Velocity (m/s)	m/s	-				
50	NOTES:						
51	(1) Air cooler bundles to be installed in place of E-105 (to be dismantled) and it must share bay with E-107 (existent) and						
52	new air cooler E-203 / E-202 (see details in page 3).						
53	(2) See details from existent process data sheet in the page 3 (fans and drive data sheet existent).						
54	Existent louvers will be kept and there are two fans one works for E-105 and the other fan works for E-107.						
55	(3) Maximum allowable pressure drop (tube side/ air side), kg/cm ² : 0.0 / 0.7.						
56	(4) 50 meters above sea level.						
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Rev	EQUIPMENT FEATURES						
1	ITEM Nº	E-203					
2	DESIGN CASE	NEW AIR COOLER					
3	SERVICE	NH3 WATER WASHING COLUMN AIR CONDENSER					
4	Shared with...	E-107/ E-202/ E-203					
5	Estimated Nº of Bays / Bundles	1 / 3 (2)					
6	Forced / Induced Draft	FORCED					
7	FLUID CHARACTERISTICS AND OPERATING CONDITIONS						
8	SIDE	TUBES			AIR SIDE		
9	Nature	H2O + H2S + NH3			CONDITIONS		
10	Corrosive Compounds / Content	- / w %	NH3/ 65.2%			Atm. Pressure	
11			Inlet	Outlet	1 (4)	kg/cm ² a	
12	TOTAL MASS FLOW	kg/h	731.8	731.8	Inlet Temperature		
13	VAPOUR TOTAL MASS FLOW(wet)	kg/h	731.8	389.8	27 / 28	°C	
14	Non Condensable (N2,...)	kg/h	-	-	Minimum Temperature		
15	Steam	kg/h	-	-	2	°C	
16	Hydrocarbons	kg/h	-	-	Max. Allowable Outlet T		
17	LIQUID TOTAL MASS FLOW	kg/h	-	342.0	43	°C	
18	Free Water	kg/h	-	-	Relative Humidity @ Tin		
19	Hydrocarbons	kg/h	-	-	80	%	
20	VAPOUR PHASE PROPERTIES(wet)				CONTROL (2)		
21	Molecular Weight	kg/kmol	17.06	17.06	Louvers (y / n)		
22	Density @ P,T	kg/m ³	1.141	1.133	Existing		
23	Viscosity @ T	cP	0.011	0.011	Variable Pitch (y / n)		
24	Thermal Conductivity @ T	kcal/h m °C	0.031	0.031	Existing		
25	Specific Heat @ T	kcal/kg °C	1.796	1.805	Variable Speed Motor (y / n)		
26	LIQUID PHASE PROPERTIES (dry)				Existing		
27	Density @ P,T	kg/m ³	-	880.5	EST. POWER DEMAND		
28	Viscosity @ T	cSt	-	0.852	Normal		
29	Thermal Conductivity @ T	kcal/h m °C	-	0.641	Existing	kWh/h	
30	Specific Heat @ T	kcal/kg °C	-	0.995	Design		
31	Surface Tension @ P,T	dines/cm	-	69.21	Existing	kWh/h	
32	Temperature	°C	91.0	43.0	WINTERIZATION		
33	Inlet Pressure	kg/cm ² g	1.00			Process Pour Point	
34	Allowable Pressure Drop	kg/cm ²	(3)			NA	°C
35	Fouling Factor	m ² h °C / kcal	0.0004			Heating Coil (y / n)	
36	Heat Duty	Gcal/h	0.197			No	
37	Maximum Flows and Heat Duties	%	110			Heating Medium	
38	Allowable Pressure Drop at Max. Flows	kg/cm ²	0.2			No	
39	MECHANICAL DESIGN CONDITIONS				HEATING		
40	CONDITIONS....		Pressure	Temperature	Pressure	Temperature	
41	Mechanical Design	kg/cm ² g ; °C	3.5	120	-	-	
42	Vacuum Mechanical Design	kg/cm ² g ; °C	-	-	-	-	
43		kg/cm ² g ; °C	-	-	-	-	
44	Flushing or Steam Out	kg/cm ² g ; °C	-	-	-	-	
45							
46	CONSTRAINTS FOR THERMAL DESIGN						
47	Maximum Bundle Width (3 m)	(1)		Maximum Bundle Weight (10 t)	X		
48	Tube Outside Diameter (1 inch)	X		Minimum Tube Thickness (BWG)	12		
49	Tube Length (30 ft)	(1)		Split Header (y / n)	Yes (1)		
50	Max./ Min. Allowable Velocity (m/s)	m/s	-				
51	NOTES:						
52	(1) Air cooler bundles to be installed in place of E-105 (to be dismantled) and it must share bay with E-107 (existent) and new						
53	air cooler E-203 / E-202 (see details in page 4).						
54	(2) See details from existent process data sheet in the page 4 (fans and drive data sheet existent).						
55	Existent louvers will be kept and there are two fans one works for E-105 and the other fan works for E-107.						
56	(3) Maximum allowable pressure drop (tube side/ air side), kg/cm ² : 0.0 / 0.2.						
57	(4) 50 meters above sea level.						
58							
59							
60							
61							
62							
63							
64	Condensation curves in attached sheet when applicable. For materials spec., see materials data sheet						

5.5. Instrumentation and control valves

5.5.1. Control valves sizing

Calculations are based on the International Electrotechnical Commission (IEC) and the Instrument Society of America (ISA) international standards [17] [18]. In Europe, the norm EN 60534-2-1 reproduces these standards without modification [19].

This norm establishes reference guidelines for the sizing calculations of valves operating with liquid and compressible fluids, although mixed flows are out of its applicability range.

The valve sizing coefficient, C_v , is calculated according to the following hypothesis:

- There are no adjacent fittings
- Turbulent regime is considered.
- Only one phase is present.

5.5.1.1. Liquid Service

The service is divided into critical and no critical flow according to the pressure drop:

- Non-critical flow when $\Delta P < C_f^2 \cdot \Delta P_s$
- Critical flow when $\Delta P \geq C_f^2 \cdot \Delta P_s$

$$C_v = \frac{w}{27.3 \cdot F_P \cdot F_R \cdot \sqrt{\Delta P \cdot \gamma l}} \quad (5.33)$$

$$C_v = \frac{w}{27.3 \cdot C_f \cdot F_P \cdot F_R \cdot \sqrt{\Delta P_s \cdot \gamma l}} \quad (5.34)$$

Where ΔP_s is calculated with the Expression 5.29 below.

$$\Delta P_s = P_1 - \left(0.96 - 0.28 \cdot \sqrt{\frac{P_v}{P_c}} \right) \cdot P_v \quad (5.35)$$

In Equations 5.33 and 5.34, the terms F_P and F_R referring to the piping geometry and flow regime dimensionless factors (respectively) are equal to 1 due to the calculation hypothesis.

5.5.1.2. Gas service

The pressure drop ratio (" χ ") determines whether flow regime is engorged or non-engorged. Thus, the fluid regime is:

- Non-engorged if $\chi > F\gamma \cdot \chi_T$
- Engorged if $\chi \geq F\gamma \cdot \chi_T$

5.5.1.3. Non-engorged service

The Equation 5.30 is used for C_v calculation,

$$C_v = \frac{w}{94.8 \cdot F_P \cdot P_1 \cdot Y} \cdot \sqrt{\frac{T_1 \cdot Z}{\chi \cdot M}} \quad (5.36)$$

In the expression above:

- W is the mass flowrate.
- P_1 and T_1 are the pressure and temperature upstream the valve, respectively.
- Y is calculated with the Equation 5.37.
- Z and M are the compressibility factor and molecular weight, respectively.

$$Y = 1 - \frac{X}{3 \cdot F_Y \cdot X_T} \quad (5.37)$$

5.5.1.4. Engorged service

The valve coefficient is calculated with the Equation 5.32, where the ratio of specific heats factor, F_Y , is obtained by using Equation 5.33.

$$C_v = \frac{W}{94.8 \cdot F_P \cdot P_1^{0.667}} \cdot \sqrt{\frac{T_1 \cdot Z}{F_Y \cdot X_T \cdot M}} \quad (5.38)$$

$$F_Y = \frac{Y}{1.4} \quad (5.39)$$

5.5.2. Control valves and instrument validation

5.5.2.1. Control valve selection

The existing valves to be replaced and the new valves are selected by following the criteria described in the Basis of Design (see section 4.4.6). The diameter is selected in accordance with the available rated valve coefficient, which must be equal or greater than the estimated requirements while the criteria is accomplished. The selected model among the *Masoneilan* series offer (by *Dresser*) will have equal or lower diameter than the pipeline where it is located [20].

In the Table 5.21, the selected rated C_v and diameters are presented. The complete information about each of the existing and new control valves is presented in the corresponding Process Data Sheets (PDS's) in Append C.

Table 5.21. New valve selection summary.

Control valve tag	Required C_v	Rated C_v	Nominal diameter [inch]
FV-0101N	74.0	110	4
FV-0109N	1.48	1.70	1
FV-0100N	78.4	110	3
FV-0201	1.68	3.80	1
FV-0202	8.28	12.0	1
FV-0203	0.56	0.60	1
LV-0100N	3.38	3.80	1 ½
TV-0100N	41.8	46.0	2

5.5.2.2. Control valve list

The existing control valves are validated for the new operating conditions in accordance with the validation criteria (see section 4.6.4); whereas the new valves are selected considering not only the basis of design criteria (see section 4.4.6) but also the line rating and diameter conditions. These items are substituted by a new control valve maintaining the tag, which is followed by the letter "N". The summary of the valve coefficients and opening percentages is presented in the Table 5.22, where can be noticed that some of the existing valves aren't adequate for the new operating conditions. The complete information for each item is available in the Process Data Sheets (see Append C).

Table 5.22. Summary of valve sizing coefficient and opening percentage calculations.

Item	C_v				Opening law	Opening percentage [%]		
	Min. Flow	Norm. Flow	Max. Flow	Rated		Min. Flow	Norm. Flow	Max. Flow
LV-0100 (1)	1.01	1.69	2.03	1.7	Iso-percentage	86.1	99.8	>100
LV-0100N (2)				3.8		64.68	78.37	83.30
FV-0101 (1)	17.4	37.0	56.9	65.0	Iso-percentage	64.9	85.0	96.4
FV-0101N (2)				110		50.9	70.9	82.4
FV-0102	6.78	11.5	13.9	25.0	Linear	27.1	45.9	55.7
TV-0100 (1)	11.9	20.9	26.1	15.0	Iso-percentage	93.8	>100	>100
TV-0100N (2)				46.0		63.9	78.9	84.8
FV-0111	3.44	6.00	8.25	15.0	Linear	23.0	40.2	55.0
FV-0110	36.4	76.3	110	400	Iso-percentage	36.1	55.8	65.5
FV-0201	0.48	0.84	1.02	3.80	Iso-percentage	45.0	59.6	65.5
FV-0109 (1)	0.38	0.74	0.98	0.60	Linear	63.0	>100	>100
FV-0109N (2)				1.70		22.23	43.35	57.89
FV-0202	2.13	4.14	5.50	12.0	Linear	17.7	34.5	45.8
FV-0203	0.16	0.28	0.34	0.60	Linear	26.2	46.9	56.1
PV-0101-A	2.82	4.70	5.92	13.0	Iso-percentage	59.3	72.9	79.0
PV-0101-B	2.57	4.37	5.32	8.00	Linear	32.2	54.7	66.5
PV-0120-A	18.7	34.3	43.2	65.0	Linear	27.9	52.8	66.5
PV-0120-B	13.2	22.0	26.4	47.0	Linear	28.1	46.8	56.2
PV-0120-C	14.4	24.0	34.5	95.0	Iso-percentage	49.7	63.3	72.9
FV-0103	3.97	6.64	7.98	15.0	Iso-percentage	64.5	78.2	83.2
FV-0112	4.92	8.24	9.99	47.0	Iso-percentage	39.8	53.5	58.7
FV-0100 (1)	8.26	14.0	16.9	26.0	Iso-percentage	84.1	>100	>100
FV-0100N (2)				110		45.6	68.8	84.0

Notes:

1.- Control valve not valid to be substituted.

2.- Substituting control valve.

5.5.2.3. Instrument list

The existing instrument validation is presented in the Table 5.23, Table 5.24, and Table 5.25. It should be commented that the items found to be not valid for the new operating conditions are replaced and renamed by adding a “N” at the beginning numerical sequence of the tag.

Table 5.23. Temperature instrument list (existing items).

Variable	Tag	PFD stream	Design cond.		Op. Cond.		Service	Valid (Y/N)
			P	T	P	T		
T	TI-0102	B.L.	4.1	85.0	2.5	31.2	Sour water from refinery	Y
T	TI-0103	2	3.5	135.0	1.2	43.4	Suction P-104	Y
T	TI-0106	14	12.1	172.0	8.5	116.5	E-102 Shell outlet	Y
T	TT/TE-0100	5	15.7	141.0	10.5	117.2	E-102 Tube outlet	Y
T	TI-0104	5	11.2	141.0	10.5	117.2	H ₂ S stripper inlet	Y
T	TT/TE-0109	32	13.4	300.0	11.0	187.3	E-103 steam inlet	Y
T	TT/TE-0105	11	9.7	86.0	8.0	133.7	H ₂ S stripper overhead	N (1)
T	TT/TE/TI-0115	31	9.7	86.0	0.8	31.8	Acid gas to sulphur plant	Y
T	TI-0112	12	3.5	140.0	8.3	169.4	NH ₃ stripper bottom	N (1)
T	TI-0118	27	18.6	86.0	14.3	65.0	E-107 outlet	Y
T	TT/TE/TI-0110A	19	3.6	118.0	1.2	95.2	NH ₃ strip. pump around	Y
T	TT/TE/TI-0110B	20	5.1	103.0	1.2	102.8	E-106 inlet	Y
T	TE/TI-0113	57	3.6	110.0	1.2	95.2	NH ₃ stripper overhead	Y
T	TI-0116	26	18.6	126.0	16.2	83.7	E-107 inlet	Y
T	TI-0117	33	7.0	210.0	4.2	152.9	NH ₃ Strip. Reb. Steam inlet	Y

Notes:

1.- Op. P and T exceed design conditions.

2.- T: Temperature / TE: Temperature element/ TT: Temperature transmitter/ TI: Temperature indicator

Table 5.24. Pressure instrument list (existing items).

Variable	Tag	PFD stream	Design cond.		Op. Cond.		Service	Valid (Y/N)
			P	T	P	T		
P	PI-0120	21	3.6	141	1.2	69.8	NH ₃ stripper pump around return	Y
P	PT-0121	T-102 (Bottom)	3.5	141	1.5	127.3	NH ₃ stripper	Y
P	PT-0136	30	18.6	86	2.1	65.2	Stripped water B.L.	Y
P	PT-0133	-	7.5	35	3	31.2	Sour water from refinery	Y
P	PI-0100	V-101	3.5	85	1.2	43.4	Sour water feed surge drum	Y
P	PT-0112	T-101 (Bottom)	10	187	8.25	169.4	H ₂ S stripper	Y
P	PT-0107	11	9.7	86	8	133.7	H ₂ S water washing	N
P	PI-0130-A/B/C	31 (1)	9.7	86	7.9	42	Top H ₂ S water washing	Y
P	PT-0101	31 (1)	9.7	86	7.9	42	Top H ₂ S water washing	Y
P	PI-0131-A/B/C	18	3.5	110	0.3	42	NH ₃ rich gas to B.L.	Y
P	PI-0105	5	11.2	141	10.9	117.2	H ₂ S Stripper inlet	N (2)
P	PI-0708	T-103 (Bottom)	12.3	86	8	134.05	H ₂ S water washing column	N
P	PI-0709	T-103 (3)	12.3	86	8	134.05	H ₂ S water washing column	N
P	PI-0735-E	T-103 (4)	9.7	100	8	134.05	H ₂ S water washing tree	N

Notes:

- 1.- Instrument located upstream control valve.
- 2.- Maximum pressure 12.5 kg/cm² g exceeds design pressure.
- 3.- Between packing bed 1 and 2.
- 4.- Above liquid distributor.
5. P: Pressure / PE: Pressure element/ PT: Pressure transmitter/PI: Pressure indicator.
- 6.- Future operating temperature exceeds mechanical design conditions.

Table 5.25. Level instrument list (existing items).

Variable	Tag	PFD stream	Design cond.		Op. Cond.		Service	Valid (Y/N)
			P	T	P	T		
L	LT/LI-0101	V-101	3.5	85	1.2	43.4	Sour water feed surge drum	Y
L	LT/LI-0102	V-101	3.5	135	1.2	43.4	Sour water feed surge drum	Y
L	LT/LI-0100	T-103	9.7	86	11	187.3	H ₂ S water washing	N (1)
L	LT/LI-0104	T-101	10	186	8.2	169.4	H ₂ S stripper	Y
L	LT-0105	V-104	13.4	300	11	187.3	H ₂ S stripper condensate pot	Y
L	LT/LI-0113	T-102	3.5	140	1.5	127.3	NH ₃ Stripper	Y
L	LT/ LI-0117	T-102	3.6	118	1.5	127.3	NH ₃ Stripper	Y
L	LT-0114	V-105	7	210	4.2	152.9	NH ₃ stripper condensate pot	Y
L	LI-0106	V-101	3.5	85	1.2	43.4	Sour water feed surge drum	Y
L	LI-0107	V-101	3.5	135	1.2	43.4	Sour water feed surge drum	Y
L	LI-0109	T-103	9.7	86	11	187.3	H ₂ S water washing	N
L	LI-0110-A	T-101	10	186	8.2	169.4	H ₂ S stripper	Y
L	LI-0110-B	T-101	10	186	8.2	169.4	H ₂ S stripper	Y
L	LI-0119	T-102	3.6	118	1.5	127.3	NH ₃ Stripper	Y
L	LI-0118	T-102	3.5	140	1.5	127.3	NH ₃ Stripper	Y
L	LI-0115-A/B	V-105	7	210	4.2	152.9	NH ₃ stripper condensate pot	Y
L	LI-0111-A/B	V-104	13.4	300	11	187.3	H ₂ S stripper condensate pot	Y

Notes:

1.- Op. P and T exceed design conditions.

2.- L: Level/LT: Level transmitter/LI: Level indicator.

3.- Future operating conditions exceed mechanical design conditions.

5.5.3. Process Safety Valves (PSV's)

In advance, the PSV sizing for the design of the new valves is described. On the other hand, the existing PSV are validated to determine their adequacy for the future operating conditions.

5.5.3.1. PSV design.

After analysing the process with the Hazop methodology, it is concluded that two new safety valves are required:

- PSV-0201 for the column T-201
- PSV-0202 for the cooling water return at E-201 tube side outlet.

The requirements for the different scenarios are studied to select the most conservative case, which corresponds to the fire case for PSV-0201. On the contrary, thermal expansion is considered for PSV-0202 as it is the only applying scenario.

The Pressure Safety Valve calculations are performed with the API 520 (part I) and API 521 formulas. All of the used expressions can be consulted in these documents.

A summary of the designed PSV is presented in the Table 5.26.

Table 5.26. Pressure Safety Valve releasing scenarios.

Item	Protected equipment	Released fluid (1)	Release to	Accum. [%] (2)	Valve size	Req./Selected Area [mm ²]	Relieve conditions			P _{SET} [kg/cm ² g]	
							Scenario	P [kg/cm ² g]	T [°C]		m [kg/h]
PSV-0201	T-201	Sour water (V)	Flare	21	J	612/ 830	Fire	4.2	150	1.73·10 ³	3.5
PSV-0202	HCW-8027	Water (L)	Atmosphere	10	D	-/ 710	Thermal expans.	19.5	40	10.3·10 ³	17.7

Notes:

1.- Considered released fluid phase: L=Liquid; V=Vapour.

2.- Selected depending on design case. 10% for thermal expansion/ 21% for fire case.

The process details are available in the corresponding Process Data Sheet of these PSV's (see Append C).

5.5.3.2. Existing PSV validation

The different released flowrates are calculated to check that the original design value is not exceeded. All the checked PSV's are found valid since the design case is more strict than future operating conditions. This is due to the fact that the current operating conditions are similar to the future normal case.

In Table 5.27 the designed scenarios of the existing PSV's are presented. It should be pointed out that this information is directly extracted from the basic engineering book of the unit and, therefore, part of the information was not available at the moment of the document delivery.

Table 5.27. Existing Process Safety Valves (PSV) summary (Design scenarios).

Item	Location	Causes for relieve										Description	
		General electrical power failure			Fire (1)			Liquid		Other causes			T [°C]
		kg/h	Mw [kg/kmol]	T [°C]	kg/h	Mw [kg/kmol]	T [°C]	kg/h	Density [kg/m ³]	kg/h	Mw [kg/kmol]		
		Set pressure [kg/cm ² g] (4)											
PSV-0101	V-101	3.5			16.2·10 ³	53	162						
PSV-0102	E-102 outlet	15.7						(2)	(2)			(2)	Thermal expansion
PSV-0103	T-101	10.0		168	2.13·10 ³	18	185			928	18	188	Air cooler failure
										5.00·10 ³	18	188	Excess reboiler duty
										1.91·10 ³	18	188	Tube rupture
										218	18	188	Blocked outlet
PSV-0104	E-103	10.3			968	18	186						
PSV-0105	V-102	13.4			(2)	(2)	(3)						
PSV-0109	T-102	3.5		150	1.97·10 ³	18	150			7.94·10 ³	18	150	Air cooler failure
										8.23·10 ³	18	150	Excess reboiler duty
										990	18	150	Tube rupture
										2.30·10 ³	18	172	Inadvert valve opening
										480	18	150	Blocked outlet
PSV-0110	E-104	3.5			977	18	150						
PSV-0111	V-103	7.0			(3)	(3)	(3)						

Notes:

- 1.- Fire zone to be defined during detailed engineering after definitive plot plant.
- 2.- Thermal expansion. By engineering.
- 3.- By engineering.
- 4.- Set pressure of the existing valve.

5.6. Project Drawings

In this section, Piping and Instrument Diagram (P&ID) and Plot Plant are presented.

The P&ID is focused on the new part of the unit since the existing equipment is already represented in the company's diagrams.

The Plot Plant represents the whole unit to provide an overview of the implementation layout, which contributes to the understanding of how the pipeline length was estimated.

Besides, it demonstrates that spare space is enough to the revamp implementation.

5.6.1. Piping and Instrument Diagram (P&ID)

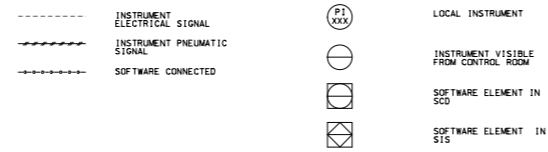
5.6.2. Plot Plan

GENERAL SIMBOLOGY



INSTRUMENT SYMBOLS

GENERAL SYMBOLS



VALVE TYPES



INSTRUMENT DESIGNATION

MEASURED VARIABLE	FUNCTION
A - ANALYSIS	A - ALARM
F - FLOW	C - CONTROL
H - HAND	H - HIGH
L - LEVEL	I - INDICATOR
P - PRESSURE	L - LOW
S - MOTOR SPEED	S - SAFETY
T - TEMPERATURE	T - TRANSMITTER
X - ON/OFF	V - VALVE

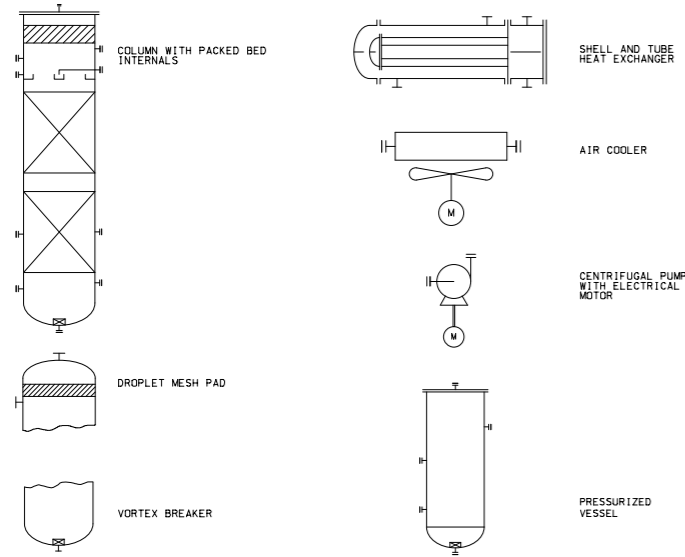
LINE SPECIFICATIONS

SPECIFICATION

MATERIAL

P900	SEAMLESS STEEL A-53 GR.B TYPE S
PU	SEAMLESS STEEL ASTM A-53 GR.B
AP	SEAMLESS STEEL ASTM A-106 GR.B
SS	SEAMLESS STEEL ASTM A-106

EQUIPMENT SIMBOLOGY



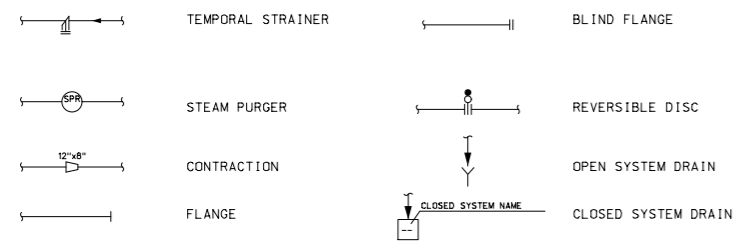
ABREVIATURES

NO	NORMALLY OPEN
NC	NORMALLY CLOSED
FC	FAILURE CLOSE
FO	FAILURE OPEN
CW	COOLING WATER
MPS	MEDIUM PRESSURE STEAM
B.L.	BATTERY LIMIT
NMF	NORMALLY NO FLOW

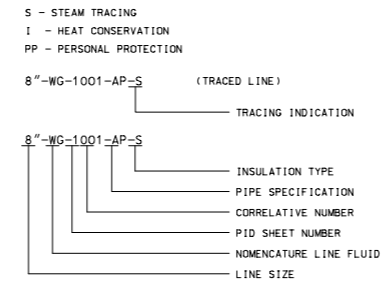
FLUID ABBREVIATIONS

NAME	FLUID NATURE
W	SOUR WATER
F	GAS TO FLARE
WG	ACID GAS
SST	LOW PRESSURE STEAM
ST	MEDIUM PRESSURE STEAM
HCW	RETURN COOLING WATER
CCW	SUPPLY COOLING WATER
OW	RELEASED SOUR WATER
UG	FUEL GAS
CLP	LOW PRESSURE CONDENSATE
CMP	MEDIUM PRESSURE CONDENSATE

LINE FITTINGS

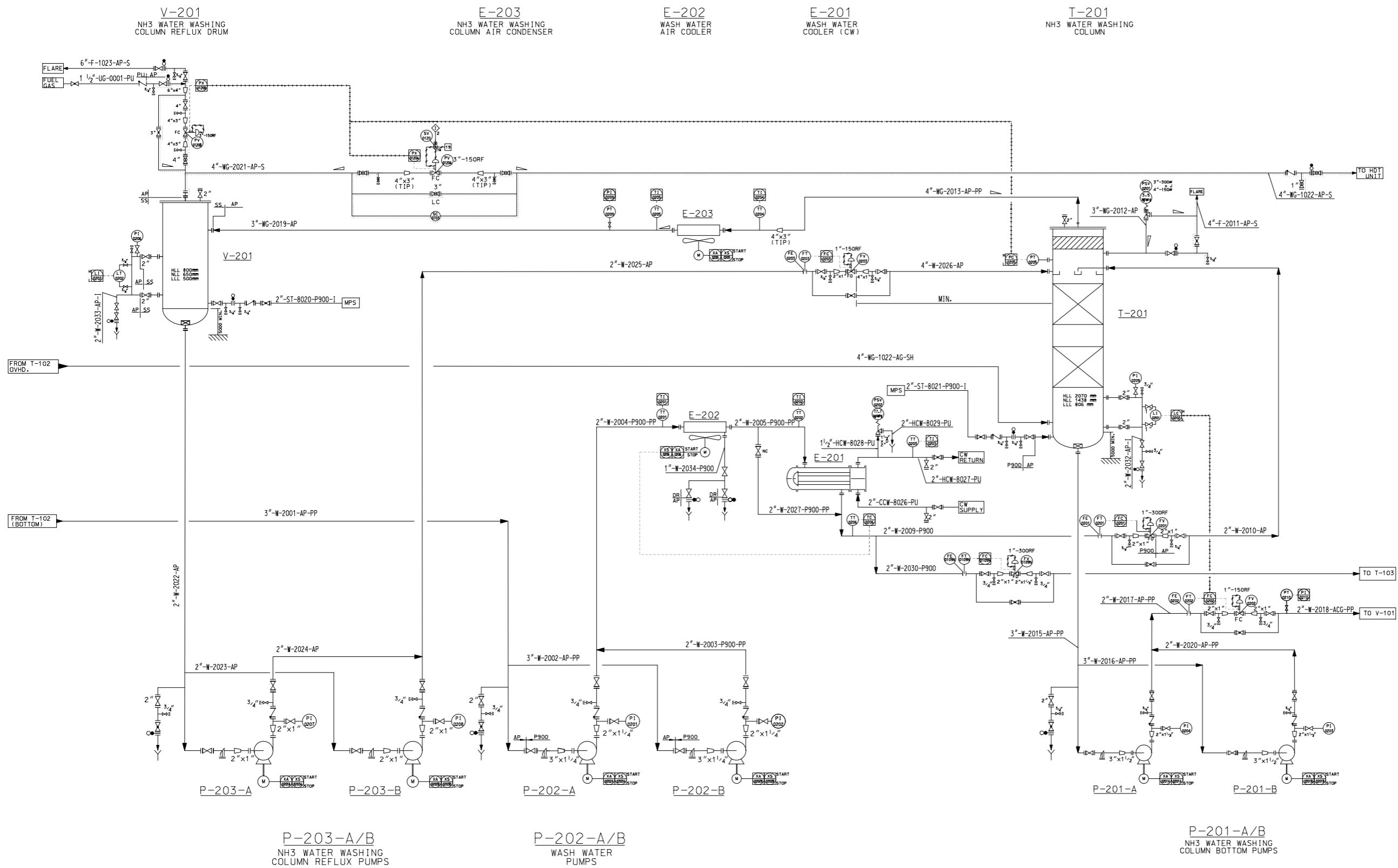


LINE NOMENCLATURE



EQUIPMENT NOMENCLATURE

ABBREVIATURE	EQUIPMENT TYPE
P	PUMP
E	HEAT EXCHANGER/ AIR COOLER
T	STRIPPER COLUMN/ SCRUBBER COLUMN
V	PRESURIZED VESSEL



P-203-A/B
NH3 WATER WASHING
COLUMN REFLUX PUMPS

P-202-A/B
WASH WATER
PUMPS

P-201-A/B
NH3 WATER WASHING
COLUMN BOTTOM PUMPS

N° EQUIPMENT	T-201	V-201	N° EQUIPMENT	E-201	E-202	E-203	N° EQUIPMENT	P-201-A/B	P-202-A/B	P-203-A/B
SERVICE	NH3 WATER WASHING COLUMN	NH3 WATER WASHING COLUMN REFLUX DRUM	SERVICE	WASH WATER COOLER	WASH WATER AIR COOLER	NH3 WATER WASHING COLUMN AIR CONDENSER	SERVICE	NH3 WATER WASHING COLUMN BOTTOM PUMPS	WASH WATER PUMPS	NH3 WATER WASHING COLUMN REFLUX PUMPS
LENGTH LT-LT (mm)	11184	2276	HEAT EXCHANGER AREA (m²)	27.1	645.4	645.4	DENSITY	903.7	936.9	880.6
DIAMETER (mm)	600	570	HEAT TRANSFER (MM.kcal/h)	0.041	0.344	0.20	DESIGN FLOW (m³/h)	4.7	5.6	0.47
VOLUME (m³)	1.08	0.63	DESIGN CONDITIONS				SUCTION PRESSURE (kg/cm²g)	1.6	1.9	1.2
INTERNAL PACKING	PACKING	DEMISTER	TEMPERATURE (°C)	S:23.0/ T:17.7	23.0	3.5	DISCHARGE PRESSURE (kg/cm²g)	3.5	17.4	4.87
DESIGN CONDITIONS			TEMPERATURE (°C)	S:145/ T:80	145	120	POWER (KW/h)	0.61	4.4	1.18
PRESSURE (kg/cm²g)	3.5/ F.V.	3.5/ F.V.	OPERATING CONDITIONS				NPSH REQUIRED (m)	1.00	1.75	2.0
TEMPERATURE (°C)	120	120	PRESSURE (kg/cm²g)	S:16.8/ T:7.0	18.6	1.0	NPSH AVAILABLE (m)	5.65	4.53	5.04
OPERATING CONDITIONS			INLET TEMPERATURE (°C)	S:50.0/ T:28.0	126.8	91.2	TYPE	CENTRIFUGAL	CENTRIFUGAL	CENTRIFUGAL
PRESSURE (kg/cm²g)	TOP 1.0 BOTTOM 1.1	0.8	OUTLET TEMPERATURE (°C)	S:40/ T:40	50.0	43.0	MINIMUM FLOW (m³/h)	1.26	2.05	-
TEMPERATURE (°C)	TOP 91.2 BOTTOM 96.0	42.6	MATERIAL	HEADER: SA-105 TUBES: CS	HEADER: KCS+3mm CA TUBES: KCS	HEADER: DUPLEX TUBES: DUPLEX	DIFFERENTIAL PRESSURE (kg/cm²g)	1.9	15.5	3.7
MATERIAL	KCS (PWHT)+6mm CA	KCS PWHT	INSULATION	-	-	-	MAXIMUM PRESSURE DISCHARGE (kg/cm²g)	6.3	23.0	7.8
ISOLATION	60 mm	NO					MATERIAL	DUPLEX	CAST IRON	CAST IRON
							INSULATION	-	-	-

TEEN TECHNIP ENERGIES

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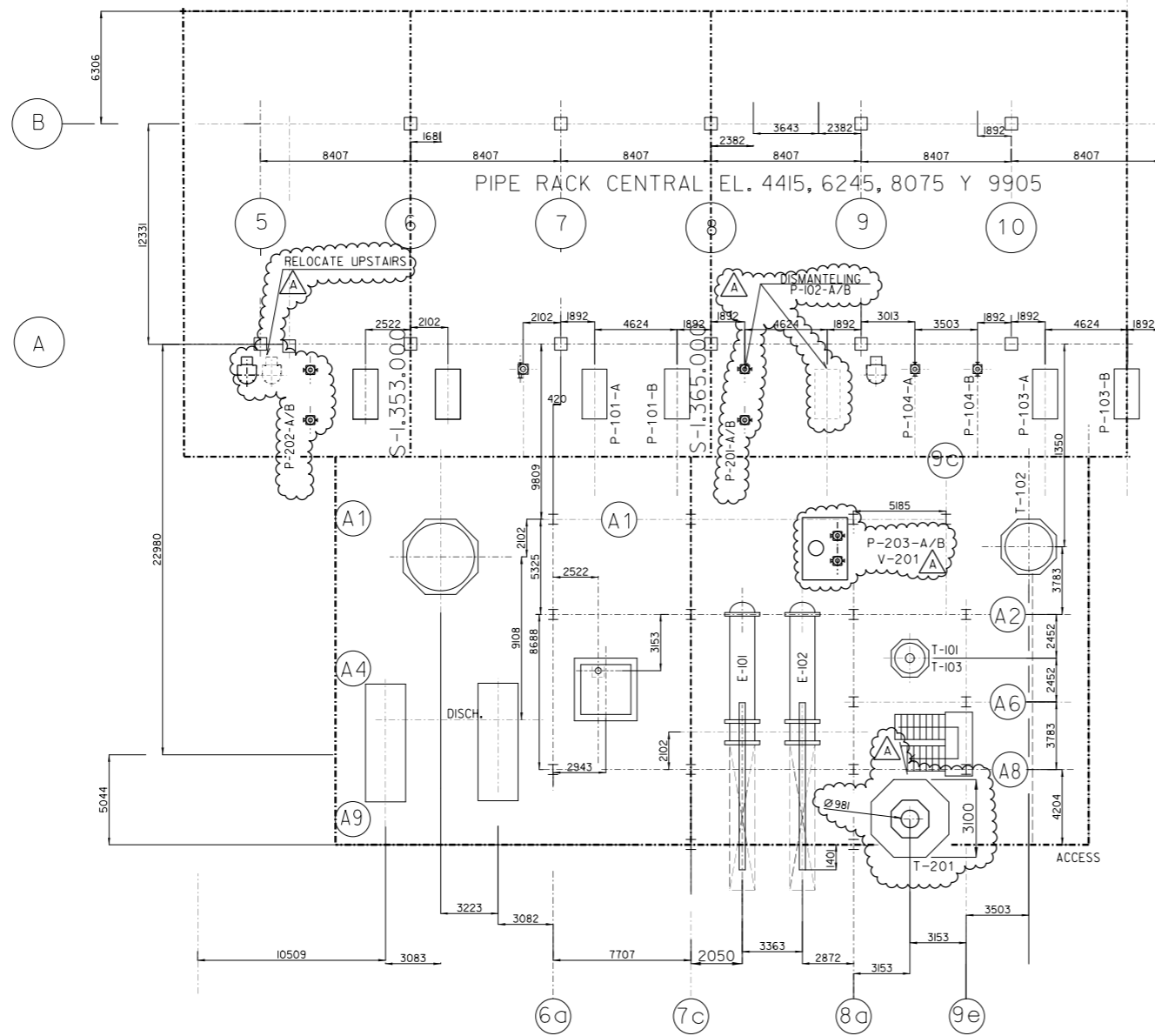
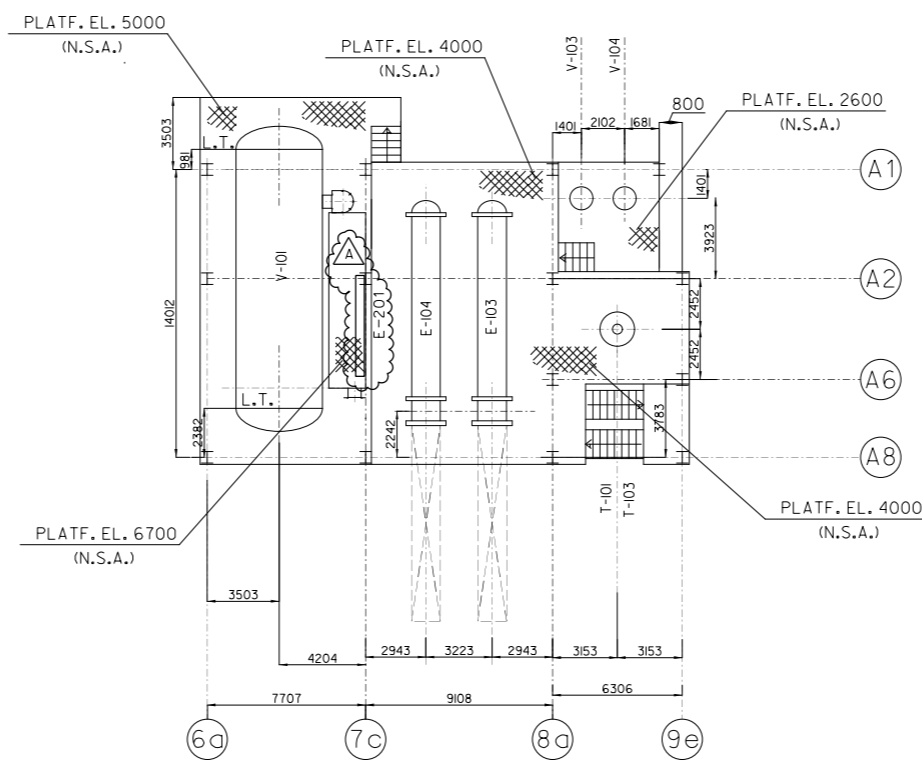
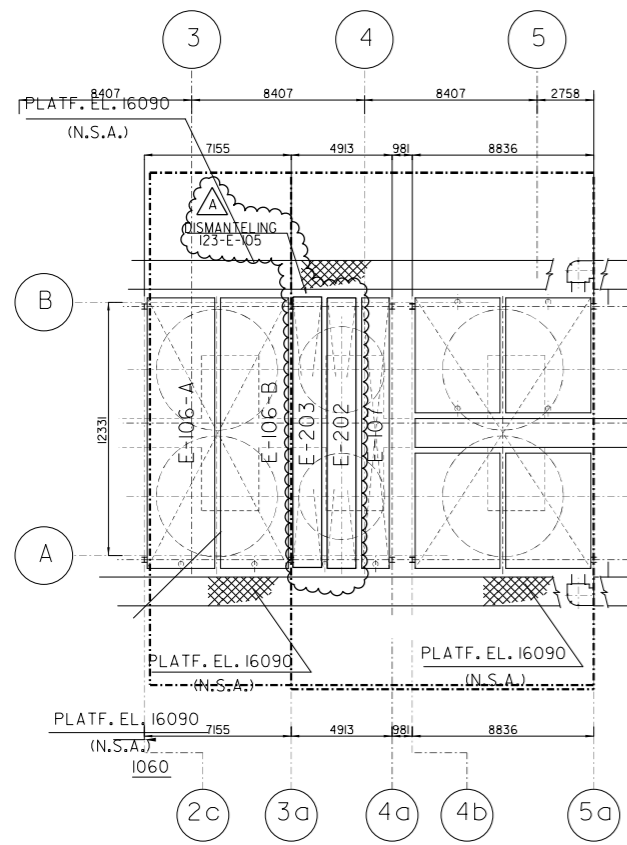
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TITLE: PIPING AND INSTRUMENT DIAGRAM (P&ID) NH3 WASHING COLUMN

SCALE: []
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REV: []

DSWS

Sheet 2 of 2



EQUIPMENT LIST DSWS UNIT

SIGLA	DENOMINACION	ELEV.(*)
T-101	H2S STRIPPER	7000
T-102	NH3 STRIPPER	6000
T-103	H2S WASHING COLUMN	27650
T-201	NH3 WASHING COLUMN	1400
V-101	SOUR WATER FEED SURGE DRUM	7600
V-102	H2S STRIPPER CONDENSATE POT	3850
V-103	NH3 STRIPPER CONDENSATE POT	3300
V-201	T-201 REFLUX DRUM	
E-101	H2S STRIPPER FEED/ NH3 BOTTOM EXCHANGER	1400
E-102	H2S STRIPPER FEED/ BOTTOM EXCHANGER	1400
E-103	H2S STRIPPER REBOILER	4900
E-104	NH3 STRIPPER REBOILER	4900
E-105	H2S STRIPPER PUMPAROUND COOLER	16100
E-106	NH3 STRIPPER PUMPAROUND COOLER	16100
E-107	STRIPPED WATER AIR COOLER	16100
P-101-A/B	SOUR WATER FEED PUMPS	900
P-102-A/B	H2S STRIPPER PUMPAROUND PUMPS	860
P-103-A/B	NH3 STRIPPER PUMPAROUND PUMPS	860
P-104-A/B	STRIPPED WATER PUMPS	513
P-201-A/B	NH3 WASHING COLUMN BOTTOM PUMPS	551
P-202-A/B	NH3 WASH WASHER PUMPS	200
P-203-A/B	NH3 WASHING COLUMN REFLUX PUMPS	200

NEW EQUIPMENT LIST

TAG	DESCRIPTION
T-201	WASH WATER COLUMN
P-201-A/B	WASH WATER COLUMN BOTTOM PUMPS
P-202-A/B	WASH WATER PUMPS
E-201	WASH WATER TRIM COOLER HX
E-202	WASH WATER AIR COOLER
E-203	TOP CONDENSER (AIRCONDENSER)
P-203-A/B	REFLUX PUMPS
V-201	TOP REFLUX DRUM

EQUIPED TO BE DISMANTLED

TAG	DESCRIPTION
E-105	H2S STRIPPER PUMPAROUND COOLER
P-102-A/B	H2S STRIPPER PUMPAROUND PUMPS

PREPARED	REV.:
CHECKED	EQV.
APPROVED	EQV.
DATE	REV.001

SCALE: -
 TAMAÑO: DIN A3
 FILE:

PLOT PLANT SOUR WATER UNIT

4054 - 00001
 DSWS

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5.7. Control narrative

The current project consists in an existing unit revamp, implying that a part of the control philosophy is already defined. However, as the ammonia washing sub-unit is being designed for the future operation, its corresponding control philosophy will be developed during the current project.

It should be commented that the ammonia washing sub-unit described in this section of the report is result of Hazop correcting actions implementation.

5.7.1. Existing process control

5.7.1.1. Process feed

The sour water to be treated is stored in the sour water feed drum (V-101), where the pressure is maintained in 1.2 kg/cm² (g) by a venting discharging to the flare to prevent overpressure. A level controller regulates the flow entering to the ammonia and sulfidic strippers (T-101 and T-102) for preventing overflowing with the FV-0101 and FV-0102.

5.7.1.2. H₂S stripper/ washing column

The inlet temperature of stream 5 in the PFD is limited to 117°C by bypassing part of the shell flow of E-102 to heat the stream 5 until 117°C by varying the control valve TCV-0100 opening percentage.

The overhead of T-101 is sent to T-103 for its water washing, where the liquid level is controlled with the level control valve LV-0100 at bottom outlet. This allows to regulate the liquid flow returning to the feed surge drum V-101. The top pressure is guaranteed by a split range controller connected to PV-0101 A and B which are currently in manual mode to avoid automatically sending gas to the furnace so that emissions are reduced.

The condensate pot V-103 has a level controller that manipulates the output flow according to T-101 feed rate.

5.7.1.3. NH₃ stripper

The pump around draw and return temperatures, as well as top outlet temperature of the column are controlled by a differential temperature controller that manipulates the motor speed of the air condenser E-106.

The condensate pot of the reboiler has a level controller connected to a flow control valve limiting the condensate output.

The liquid level inside T-102 is controlled with a flow control valve (FV-0111) located in the limit of battery to the water treatment plant that relieves the excess of water.

5.7.2. Revamp control

The ammonia washing is the final stage of the sour water treatment. In this sub-section, required for the revamp specification meeting, the absorption of the DSWS remaining H₂S and NH₃ takes place in T-201 wet scrubber (aka. Ammonia water washing column).

The HYSYS simulation results indicate that T-102 bottoms have negligible H₂S and NH₃ concentration, which enables to its recycling for the washing columns T-103 and T-201.

5.7.2.1. Washing water feed

The separation of the target pollutants is enhanced when the solvent- in this case water- is around 40°C.

Thus, the T-102 stripped water stream not sent to the Waste-Water Treatment (WWT) plant, is pumped by P-202-A/B to the air cooler E-202 and the cooler E-201.

Water is cooled at E-202 from 127.2°C to 50°C with the air flow induced by fans and afterwards it is tempered with cooling water until 40°C.

This strategy is based on the Best Available Techniques. The cooling water is used only when target temperatures of the process stream are near or below air temperature (considered 28°C). Otherwise, air cooling is preferred as it does not require of a utility network neither a cooling tower.

The outlet temperature is controlled by TC-0206. TT-0206 measures the controlled temperature. When it is below 40°C, E-202 motor speed decreases for saving energy. On the contrary, when cooling is not enough, motor speed increases.

Subsequently, stripped water is pumped by P-202-A/B to E-202 and E-201 and afterwards split into two streams routed to T-103 and T-201.

The pressure of the water feed to the ammonia washing column T-201 is regulated by the flow control valve FV-0201 to maintain the column operating pressure at 1.1 kg/cm² g (bottom).

This control valve is failure open for ensuring solvent is feed in case of air failure so that operation goes on. Iso-percentage opening characteristic is selected since flow variable needs faster actuation.

5.7.2.2. Ammonia washing column

The other external feed of T-201 is the ammonia stripper T-102 overhead stream, which contains the target pollutants. Revamp specifications are guaranteed by the total reflux, where the ammonia-rich stream partially condensates in the air-cooler E-203 from 91.2 to 40°C.

The air-condenser has a motor start-stop transmitter for checking it is operating when temperature deviations are observed.

The partially condensed stream that outlets from E-203 is sent to the reflux drum V-201, where a flash separation occurs. Vapour phase outside by the top to the flare or HDT unit (depending on the flowrate).

By default, PV-0120-B opens allowing gas goes to the flare. When the valve coefficient requirements exceed control valve rated valve coefficient, P-0120-A opens for reducing the gas flowrate (and sends a part of the flow to the HDT furnace).

On the other hand, V-201 liquid bottom is returned to the T-201 column by P-203-A/B.

In this reflux drum, liquid level is measured by LT-0202 to ensure that liquid level inside the vessel is between the High and Low Liquid Level (800 and 500 mm, respectively).

The residence time is chosen so that an additional level control loop is not considered necessary, although a Very High and Very Low Liquid Alarms are installed (1000 and 300 mm, respectively). This alarm is visible from control room.

Feed flowrate to T-201 is regulated by the control valve FV-0203, which opens when flowrate is low and vice versa.

The designed process has low flowrates at reflux return, expected to not suffer big variations. Therefore, a lineal characteristic valve is selected.

Reflux feeding is ensured by air failure opening in case of instrumental air failure.

On the other hand, T-201 level is controlled by the cascade control loop LC-0202, which measures the column liquid level. T-201 normal liquid level (800 mm) by manipulating the flow control valve FV-0202. In case that the Very High (2320 mm) or Very Low (300 mm) Liquid Level is exceeded, an alarm visible from the control room activates.

T-201 bottoms are pumped by P-201-A/B to this control valve before being recirculated to the feed surge drum V-101 as they contain the recovered pollutants of T-102 gas stream.

5.7.2.3. Designed pumps control

The three designed pumps are equipped with a pressure indicator at discharge for cavitation detection. In case that significant fluctuations of the following values are detected, their mechanical parts should be revised since it may indicate damages to the components:

- P-201-A/B discharge pressure at normal flow conditions: 3.6 kg/cm² g.
- P-202-A/B discharge pressure at normal flow conditions: 18.3 kg/cm² g.
- P-203-A/B discharge pressure at normal flow conditions: 4.9 kg/cm² g.

6. PROCESS SAFETY

The new part of the process is analysed to improve the process safety for workers and environment, as well as increasing the control robustness. With this aim, different scenarios are considered, and their risk is evaluated to determine when the implementation of corrective measures is coherent and necessary.

6.1. Safety study assumptions and followed criteria

The presented project substances are not included in RD 840/2015 (SEVESO Normative transposed in Spain). Subsequently, the safety study does not require a rigorous Quantitative Risk Analysis (QRA).

The selected methodology is a Hazop analysis combined with a quantitative risk estimation based on graphs, enabling to obtain a numerical value indicating whether the severity of the scenario justifies a modification of the original revamp design.

6.1.1. Assumptions

Some assumptions have been made for safety study simplification since expected risk is low and moderate and no ATEX zones are involved.

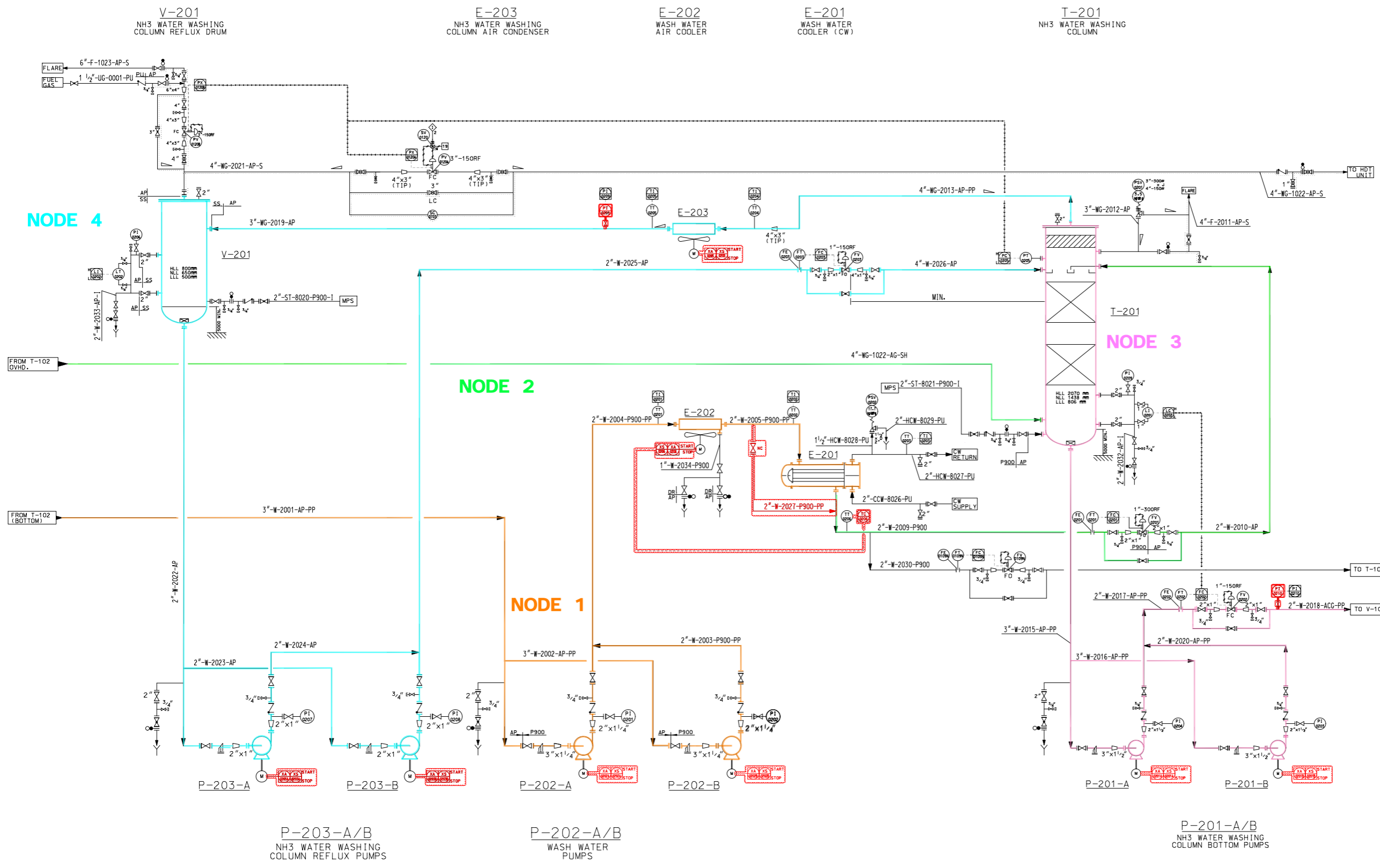
Thus, the following hypothesis are considered:

- Exposure, as well as consequence, exposition, probability, and risk level factors provided by the client's company.
- Scenarios without safety consequences are not included in the report as they are not relevant for the study.
- The implementation of corrective measures recommended in the first Hazop analysis when convenient is considered enough to solve the safety problems detected. Consequently, a second analysis has not been performed for resources saving.
- Conservative values are taken for the factors and considered scenarios are coherent with company criteria for credible scenarios (detailed in advance).
- The analysed nodes only belong to the new part of the unit and its effects in the existing part safety are not considered.

6.1.2. Considered nodes

The part of the process to be studied is divided into nodes to simplify the safety analysis. In this case, as it can be seen in the P&ID markup shown below, four specific nodes are distinguished:

- Node 1: Washing water tempering section, marked in colour red in P&ID.
- Node 2: Column feeds (marked in green colour).
- Node 3: Washing column (pink colour circuit in P&ID markup).
- Node 4: Reflux circuit (marked in blue colour on P&ID).



P-203-A/B
NH3 WATER WASHING
COLUMN REFLUX PUMPS

P-202-A/B
WASH WATER
PUMPS

P-201-A/B
NH3 WATER WASHING
COLUMN BOTTOM PUMPS

N# EQUIPMENT	T-201	V-201	N# EQUIPMENT	E-201	E-202	E-203	N# EQUIPMENT	P-201-A/B	P-202-A/B	P-203-A/B
SERVICE	NH3 WATER WASHING COLUMN	NH3 WATER WASHING COLUMN REFLUX DRUM	SERVICE	WASH WATER COOLER	WASH WATER AIR COOLER	NH3 WATER WASHING COLUMN AIR CONDENSER	SERVICE	NH3 WATER WASHING COLUMN BOTTOM PUMPS	WASH WATER PUMPS	NH3 WATER WASHING COLUMN REFLUX PUMPS
LENGTH LT-LT (mm)	11184	2276	HEAT EXCHANGER AREA (m²)	27.1	645.4	645.4	DENSITY	903.7	936.9	880.6
DIAMETER (mm)	600	570	HEAT TRANSFER (MM.kcal/h)	0.041	0.344	0.20	DESIGN FLOW (m³/h)	4.7	5.6	0.47
VOLUME (m³)	1.08	0.63	DESIGN CONDITIONS				SUCTION PRESSURE (kg/cm²g)	1.6	1.9	1.2
INTERNALS	PACKING	DEMISTER	TEMPERATURE (°C)	S:23.0/ T:17.7	23.0	3.5	DISCHARGE PRESSURE (kg/cm²g)	3.5	17.4	4.87
DESIGN CONDITIONS			OPERATING CONDITIONS	S:145/ T:80	145	120	POWER (KW/hp)	0.61	4.4	1.18
PRESSURE (kg/cm²g)	3.5/ F.V.	3.5/ F.V.	TEMPERATURE (°C)	S:16.8/ T:7.0	18.6	1.0	NPSH REQUIRED (m)	1.00	1.75	2.0
OPERATING CONDITIONS			INLET TEMPERATURE (°C)	S:50.0/ T:28.0	126.8	91.2	NPSH AVAILABLE (m)	5.65	4.53	5.04
PRESSURE (kg/cm²g)	TOP 1.0 BOTTOM 1.1	0.8	OUTLET TEMPERATURE (°C)	S:40/ T:40	50.0	43.0	TYPE	CENTRIFUGAL	CENTRIFUGAL	CENTRIFUGAL
TEMPERATURE (°C)	TOP 91.2 BOTTOM 96.0	42.6	MATERIAL	HEADER: SA-105 TUBES: CS	HEADER: KCS+3mm CA TUBES: KCS	HEADER: DUPLEX TUBES: DUPLEX	MINIMUM FLOW (m³/h)	1.26	2.05	-
MATERIAL	KCS (PWHT) 6mm CA	KCS PWHT	INSULATION	-	-	-	DIFFERENTIAL PRESSURE (kg/cm²g)	1.9	15.5	3.7
ISOLATION	60 mm	NO					MAXIMUM PRESSURE DISCHARGE (kg/cm²g)	6.3	23.0	7.8
							MATERIAL	DUPLEX	CAST IRON	CAST IRON
							INSULATION	-	-	-

SCALE:	TANK NO.:	APPROVED:	DATE:
-	DN A-3	DSW	0

FILE: PIPING AND INSTRUMENT DIAGRAM (P&ID) NH3 WASHING COLUMN

DSWS

6.1.3. Causes and consequences definition

The deviations resulting from parameter and guide words combination is directly applied to the specific equipment and pipelines in the analysed node.

The causes summarized in

Table 6.1 are considered to be the most probable in the current case framework.

On the other hand, causes due to multiple factors are analysed independently to determine its credibility.

In this case, causes considered non credible are:

- Two consecutive concurrent human errors.
- Simultaneous failure of two or more independent equipment parts.
- Equipment simple failure/ human error with external event.
- Simultaneous occurrence of two or more external events.

Table 6.1. Summary of analysed causes for deviations.

Deviation	Causes to consider
More level	Level control failure, lockage of valve completely closed (bottom), flow hindered downstream.
Less level	Control level failure, lockage of valve (bottom) completely open, drain valve opened.
No flow	Valve closure, wrong pathway (fluid circulating through a different pipe of analysed conduct), hinting, blind flange not removed, tube or vessel rupture, pump failure, flow control failure.
Less flow	Partial lockage, obstructed strain, pump efficiency loss, flow control failure.
More flow	Control valve locked completely opened, flow controller failure, more than one pump working, tube rupture in a heat exchanger.
Inverse flow	High downstream pressure or low upstream pressure, wrong pathway, no random pipe rupture, vessel rupture, valve failure, emergency vent, pump failure, anti-return valve failure.
More pressure	Pressure release device failure, high pressure connection leakage, solar radiation in a locked pipe/section, pressure control failure, level control failure.
Less pressure	Pressure control failure, regulation valve with seat failure, outlet pump flow exceeds vent capacity of the vessel, vent hinging during emptying, pump suction hinging.
More temperature	Control temperature failure, solar radiation, high ambient temperature, cooling pipes dirty/ hinged, cooling water failure, air cooler failure, heat exchanger rupture.
Less temperature	Lower ambient temperature than the expected, temperature control failure.
Other composition	Contamination, undesired utility entrance.
Other phase	Biphasic mixture by pressure sudden releasement, precipitation or solidification, fire.
Without services	Instrumental air failure, electricity failure, cooling water failure, steam failure.
No contention	Uncontrolled purges/ drains/ vents in process nodes. Equipment/ piping sensitive elements rupture.

6.1.4. Calculation of risk

The risk is quantified with the following expression:

$$R = E \cdot L \cdot C \quad (6.1)$$

Where “R” represents the risk level, “E” the exposition, “L” the like hood, and “C” the consequence.

In

Table 6.2, the different levels of risk are presented along with the needed action.

Table 6.2. Actions to perform according to risk level.

Type of risk	Risk level	Needed actions
Minor	$R \leq 14$	Evaluation of corrective measures with the aim of continuous improvement. Low investment measures are implemented.
Moderate	$14 < R \leq 35$	All measures whose benefit overcomes its cost must be implemented.
High	$35 < R \leq 82$	Implementation of necessary measures to reduce the risk, at less, to moderate level.
Urgent	$82 < R \leq 350$	
Extreme	$R > 350$	Evaluation of emergency stop.

The values of consequences, exposure and probability for the risk calculation are obtained from the following matrixes.

In Table 6.3, the consequence matrix is presented. The applying consequences of each column are selected and the highest value is assigned.

Table 6.3. Matrix of consequences.

	Consequences (C)			
	Damage to people	Property damage. Economic losses, Environmental remediation costs	Environment	
Minor	Incident without leave	5 k to 100 k €	Irrelevant environmental incidence or no contingent zone inside property limits.	1.7
Moderated	Until 30 days of leave. < 1% like hood of one death	100 k to 1 M€	Relevant environmental damage exceeding environmental quality reference levels or able to generate a sanction. No permanent effects.	3
Serious	More than 30 days of leave. <10% of like hood of 1 death.	1 M€ to 10 M€	Grave environmental damage that may affect to property surroundings. Environmental quality reference levels exceeded in wide zones. May affect to third parties.	7

Table 6.3. Matrix of consequences. (Cont.)

		Consequences (C)			
		Damage to people	Property damage. Economic losses, Environmental remediation costs	Environment	
Very serious	May cause a death or permanent injuries.		10 M€ to 100 M€	Very grave environmental damage. Corrected measures and/or important indemnifications required. Exceeding in wide zones environmental quality reference levels. High probability of permanent damage.	16
		Damage to people	Property damage. Economic losses, Environmental remediation costs	Environment	
Disastrous	May cause between 2 and 9 deaths		100 M€ to 1000 M€	Catastrophic environmental damage. Environmental resources and services losses. Permanent damage.	40
Catastrophic	May cause 10 or more deaths		Above 1000 M€	Environmental damage catastrophic of high extension. Extensive environmental resources and services losses.	100

The exposure matrix is presented in Table 6.4. This matrix determines the frequency with which an initiator event may occur.

Table 6.4. Matrix of exposure.

		Exposure (E)	
Very rare	Frequency: 10^{-3} /year	Not expected to happen	0.3
Rare	Frequency: 10^{-2} /year	Possible to happen	0.6
Little usual	Frequency: 10^{-1} /year	Expected to happen at least once	1.2
Occasional	Frequency: 10^0 /year	Frequently happens yearly	2.5
Frequent	Frequency: 10^1 /year	Happens sometimes yearly	5
Very frequent	Frequency: 10^2 /year	More than once per month	10

The like hood matrix is presented in Table 6.5. This matrix expresses the probability that a determinate consequence happens once the initiator event develops.

Table 6.5. Matrix of like hood.

		Like hood (L)	
Practically impossible		10^{-5}	0.3
Highly improbable		10^{-4}	0.6
Remotely possible		10^{-3}	1.2
Little usual		10^{-2}	2.5
Possible		10^{-1}	5
Almost sure		10^0	10

6.2. HAZOP Analysis

A summary of the Hazop resultant recommendations is presented in Table 6.6. As these recommendations are an output from moderate risk scenarios, they are being implemented in the P&ID.

Table 6.6. Summary of Hazop recommendations.

Node	Recommendation
#1. Washing water cooling	Add a start/ stop indicator at P-202-A/B motor. Add a start/ stop indicator at E-202 motor. Add a start/ stop indicator at P-202-A/B motor. Add a bypass to E-201 for its maintenance. Add a temperature control loop to vary E-202 motor speed.
#3. NH ₃ washing column	Add a pressure indicator visible from control room downstream FV-0202.
#4. Column reflux circuit	Minimum distance between T-201 and FV-0203. Add a pressure indicator between E-203 and V-201 to discard upstream causes.

6.2.1. Node 1 (Washing water tempering).

Table 6.7. Hazop analysis summary (node 1).

Parameter	Guide word	Deviation	Causes	Scenario	Consequences	Risk graphs				Safeguards	Recommendations
						C	E	P	R		
Flow	No	No flow to E-201/202.	Suction line W-2001/2002 lockage.	P-202-A/B doesn't pump water to the coolers E-201/202, so water is not feed downstream (pollutant emissions increasing).	P-202-A/B motor damage. Environmental damage (potential economical sanction).	3	1.2	0.6	2.2	Prevention: No pressure lecture at PI-0201/0202	
			Suction line W-2001/2002 rupture.	Same as previous.							
			P-202-A/B mechanical failure.	Same as previous.						Add a start/ stop indicator at P-202-A/B motor.	
			No flow at E-202 air side (motor mechanical failure).	Water is not tempered for E-202 motor failure. Thermal expansion of process stream/ cooling water at E-201. Feed water temperature downstream decreases separation efficiency.	Same as previous.					Prevention: TI-0202/0206 indicate higher temperature. Process Safety Valve (PSV-0202) designed for thermal expansion case. Prevention: PI-0201/0202 indicates pressure oscillations.	Add a start/ stop indicator at E-202 motor.
	Less	Less water flow to E-201/ E-202.	P-202-A/B cavitation (flash at suction).	Water flash separation at suction of P-202-A/B causes efficiency loss and reduces water feed flowrate.	Potential damage to P-202-A/B. Mild environmental damage.	3	1.2	0.6	2.2		
	More	More water flow to E-201/ E-202.	P-202-A and B working simultaneously.	E-201/202 cooling duty insufficient for tempering feed water. Downstream separation affected.	Undesired operating conditions (OPEX increasing).	1.7	1.2	10	20.4	Prevention: PI-0101 and 0202 indicate discharge pressure.	Add a start/ stop indicator at P-202-A/B motor.
Pressure	Less	Less pressure at E-201/ E-202.	Same as "P-202-A/B cavitation" Same as "P-202-A/B mechanical failure".								
Temperature	More	More temperature at E-201 shell side/ E-202 tube side outlet.	Same as "No flow at E-202 air side".								
			E-201 duty decreasing (fouling).		Undesired operating conditions.					Prevention: TI-0203/0206 indicate higher values than usual.	Add a bypass to E-201 for its maintenance.
Services	Without	Without cooling water	Cooling water pump failure	E-201 doesn't cool process stream.	Environmental damage (potential economical sanction).	3	1.2	0.6	2.2	E-202 enables cooling until safe operating temperature.	Add a temperature control loop to vary E-202 motor speed.

6.2.2. Node 2 (Column feeds)

Table 6.8. Hazop analysis summary (node 2).

Parameter	Guide word	Deviation	Causes	Scenario	Consequences	Risk graphs				Safeguards	Recommendations
						C	E	P	R		
Flow	No	No water flowrate fed to T-201.	Upstream conditions.	Ammonia-rich gas not washed in T-201. Overhead stream out of specifications.	Environmental impact (emissions exceed legal limits).	1.7	0.3	10	5.1		
			Flow control valve FV-0201 failure (blocked at closed position).	Pressure drop difficult water reaches T-201 inlet nozzle (T-201 doesn't wash NH ₃ -rich gas). All W-2009 content circulates through W-2030 overloading the recirculation circuit to V-101.	Potential damage to pipelines. Environmental impact (emissions exceed legal limits).	3	0.3	10	9		
	Less	Less water flowrate fed to T-201.	FV-0201 partially locked. FC-0201 failure.	Undesired operating conditions in T-201 (potential spraying). Lecture higher than real value causes FV-0201 closes.							
Pressure	More	More pressure at T-201 water feed.	Flow control valve failure (locked in open position).								
	Less	Less pressure at T-201 water feed.	Flow control valve FV-0201 failure (blocked at closed position).								
Temperature	More	More temperature at T-201 feeds.	Upstream conditions.	T-201 operating temperature exceeds the normal profile causing separation efficiency decreases. Potential thermal expansion.						Prevention: Process Safety Valve (PSV-0201) design covers thermal expansion case.	

6.2.3. Node 3 (Ammonia washing column).

Table 6.9. Hazop analysis summary (node 3).

Parameter	Guide word	Deviation	Causes	Scenario	Consequences	Risk graphs				Safeguards	Recommendations
						C	E	P	R		
Level	More	More liquid level in T-201.	LIC-0202 failure (read lower than actual level). Flow control valve FV-0202 locked in completely closed position. P-201-A/B motor failure.	FV-0202 open percentage decreases. Potential hydraulic problems in T-201 leading to NH ₃ -rich gas efficiency treatment decreasing. Pressure downstream FV-0202 increases. Same as "LIC-0202 failure". Water is not suctioned by P-201-A/B. Liquid level increasing may cause overpressure. T-201 hydraulic problems reduce NH ₃ -rich gas efficiency treatment.	Mild environmental impact. Undesirable operating conditions (potential hydraulic problems at T-201).	1.7	1.2	10	20.4	Prevention: FV-0202 opening percentage and flow visible from control room. PI-0209 confirms LI-0201 liquid level lecture.	Add a pressure indicator visible from control room downstream FV-0202.
	Less	Less liquid level in T-201.	LIC-0202 failure (read higher than actual level). Flow control valve FV-0202 locked in opened position.	FV-0202 open percentage increases. Potential hydraulic problems in T-201 leading to NH ₃ -rich gas efficiency treatment decreasing. FV-0202 opening increases bottoms flowrate (not exceeding feed flowrate). Potential hydraulic problems in T-201 leading to NH ₃ -rich gas efficiency treatment decreasing. Liquid level inside T-201 isn't enough for P-201-A /B operation, which causes cavitation. Impossibility of treating NH ₃ -rich gas.	Same as "More liquid level in T-201". Same as "More liquid level in T-201".					Prevention: Process Safety Valve (PSV-0201) design case covers FV-0202 lockage. PI-0203/ 0204 (downstream P-201-A/B) indicate no discharge pressure.	
Flow	No	No bottom flow at T-201	No washing water feed to T-201 (upstream deviation).	T-201 liquid level above 2070 mm may cause hydraulic problems, decreasing treatment efficiency.	Environmental impact (legal limits exceeded, possibility of economical sanction). Potential damage to P-201-A/ B.	3	1.2	0.6	2.2	Prevention: FT-0202 indicate no bottom stream flowrate. LI-0201 very low-level liquid alarm indicates abnormal conditions (level below 300 mm).	
	Less	Less flow at T-201 bottoms.	Less water fed to T-201 (upstream deviation).								
	More	More T-201 bottom flowrate.	More washing water feed flowrate (upstream deviation).		Same as "More liquid level in T-201".						

Table 6.9. Hazop analysis summary (node 3). (Cont.)

Parameter	Guide word	Deviation	Causes	Scenario	Consequences	Risk graphs				Safeguards	Recommendations
						C	E	P	R		
Pressure	More	More pressure in T-201.	Water feed at high temperature.	Water feed not previously cooled causes causing thermal expansion of column contents as operating temperature increases. NH ₃ -rich gas treatment efficiency decreases.	Potential emissions out of specification (high humidity content) may cause downstream operating problems in HDT burners. Potential damage to P-201-A/B.	3	0.3	0.3	0.3	Prevention: PI-0209 indicates pressure (above 1.1 kg/cm ² g). Process Safety Valve (PSV-0201) design covers thermal expansion case.	
			More liquid level in T-201.	Same as "More liquid level in T-201".							
	Less	Less pressure at P-201-A/B suction.	Medium pressure steam leakage.	Steam connexion not properly isolated after steam out causes pressure increasement in T-201 and may increase NH ₃ -rich gas humidity content.	Potential emissions out of specification (high humidity content) may cause downstream operating problems in HDT burners. Potential damage to T-201, P-201-A/B and pump suction lines (W-2015/ 2016).	3	0.3	0.3	0.3	Prevention: Process Safety Valve (PSV-0201) releases vapour phase.	
			Less liquid level in T-201.	Same as "Less liquid level in T-201".							
Temperature	More	More temperature in T-201.	Water feed at high temperature.	Same as "More pressure in T-201. (Water feed at high temperature)".							
Composition	Other	Other composition in T-201 overhead stream.	Medium pressure steam leakage.	Same as "More pressure in T-201 (Medium pressure steam leakage)".	Same as previous scenarios.						
			Separation efficiency decreasing.	Same as "More pressure in T-201 (Medium pressure steam leakage)".							
			Medium pressure steam leakage.	Same as "More pressure in T-201 (Medium pressure steam leakage)".							

6.2.4. Node 4 (T-201 reflux circuit)

Table 6.10. Hazop analysis summary (node 4).

Parameter	Guide word	Deviation	Causes	Scenario	Consequences	Risk graphs				Safeguards	Recommendations
						C	E	P	R		
Level	Less	Less level in V-201.	E-203 motor failure.	Mechanical failure in E-203 motor prevents from T-201 top stream condensation (or reduces condensation rate). Top stream with high humidity content may be out of specification, causing downstream operating problems in HDT unit and corrosion issues in pipes when condensing. P-203-A/B may cavitate.	Downstream operating problems in HDT furnace burners. Environmental damages (potential economic sanction for legal emission limits exceeded).	3	1.2	0.3	1.1	Prevention: TI-0205 indicates temperature above 43°C at E-203 outlet.	
Flow	No/Less	No/less reflux return flowrate to T-201.	FV-0203 failure/ FC-0203 failure.	Flow control valve FV-0203 closes, increasing its pressure drop. Reflux return stream cannot reach T-201. Locked line section (W-2025) with potential content thermal expansion.	Potential damage to line W-2025. Undesirable operating conditions.	3	1.2	0.3	1.1	Prevention: FIC-0203 indicates abnormal opening percentage of control valve FV-0203.	Minimum distance between T-201 and FV-0203.
			P-203-A/B failure	P-203-A/B motor fails. Reflux stream is not pumped to T-201, increasing T-201 liquid level.	Undesirable operating conditions may cause NH ₃ -rich gas is out of specifications.	1.7	1.2	0.3	0.6	Prevention: LI-0202 indicates very high liquid level in V-201. PI-0207/ 0208 indicates abnormal pressure profiles.	
Pressure	More	More pressure at V-201.	Medium pressure steam leakage.	Steam connexion not properly isolated after steam out causes pressure increase in V-201 and may increase NH ₃ -rich gas humidity content.	Potential emissions out of specification (high humidity content) may cause downstream operating problems in HDT burners. Potential damage to V-201, P-203-A/B, and lines (W-2021/ 2022/ 2023).	3	0.3	0.3	0.3	Prevention: Downstream Safety Valves P-0120-A/B indicate higher pressure than usual and release the vapour phase. PI-0206 indicates higher pressure than usual (~0.7 kg/cm ² g).	Add a pressure indicator between E-203 and V-201 to discard upstream causes.
	Less	Less pressure at V-201.	See "E-203 motor failure".								
	More	Less pressure downstream P-203-A/B. More temperature in V-201.	P-203-A/B failure. See "E-203 motor failure".	P-203-A/B doesn't operate for motor failure.	See "No/less reflux return flowrate to T-201 (P-203-A/B failure)".						

7. ECONOMIC ESTIMATION

7.1. Purpose of the revamp project

The investment for this project is done with no lucrative purpose but with the aim of achieving a safer and environmentally friendly plant respectful to emission limits, even in case of legislation tightening.

As the whole revamp is carried out inside an existent unit taking advantage of spare space, no additional visual impact is generated (apart from the existing one).

Neither acoustic nor light pollution are increased since changes are practically not perceptible from surrounding units. On the other hand, emission levels of not only ammonia and sulphur oxides are reduced but also waste water routed to maritime emissary has better quality.

Besides, this type of projects can contribute to the public awareness of keeping in mind the importance of environmental impact reduction. The opportunity of such projects can offer academic support to students, whose competences development will be critical in future to achieve the transition to a greener industry.

7.2. Equipment cost estimation

The considered purchase costs listed in Table 7.1 are based on Matches' Process Equipment Cost Estimates [21], which gives the estimated price depending on the equipment main characteristics.

On the contrary, the air cooler purchase costs correspond to a real vendor's offer because the cost breakdown is required as some E-105 components are being reutilized.

The new air coolers are being implemented in the E-105 bundle location (currently out of service), which is possible due to it is dismantling.

This permit taking advantage not only from the spare space but also from the existing louvers, fans, and motors for capital saving.

The mechanical parts to be reused are properly reflected in the corresponding Process Data Sheets of E-202 and E-203 (see Append B).

The purchase costs of all the equipment were compared with *Aspen Capitals Cost Estimator VII* results. However, the bibliographic values were used in calculations due to the fact that they are more conservative.

7.2.1. Purchase costs considered for the estimation

As it can be appreciated, the amount of purchased units varies depending on the equipment type.

In the case of the new air coolers, as it has been explained, there is assumed to be a single unit to be consistent with offer data (which is a total amount comprising both E-202 and E-203). There are 2 pumps for the same service (A/B) for enabling operation in case of mechanical failure. For instance, there were purchased two pumps for covering P-201 requirements: P-201-A and P-201-B.

In the case of vessels there is a single equipment of each type.

Table 7.1. Equipment mechanical costs comparison.

Tag	Number of items	Reported prices in 2014 [21]	Cost Aspen estimator [€]
P-201	2	20,200	7,780
P-202	2	23,000	11,600
P-203	2	15,400	14,800
T-201	1	303,300	49,300
V-201	1	184,000	9,500
E-201	1	54,200	11,800
E-202/E-203	2	94,250 (actual offer)	80,200

7.3. Installation cost calculations

The calculations described in advance are based on a calculation sheet property of *T.EN* (developed by A.Rolán feb03 / C. Valdes jan09) which estimates the installation costs by applying theoretical factors.

7.3.1. Calculation basis.

The estimation is carried out within an accuracy range of $\pm 10\%$. A probable value is determined between the upper and lower limits.

First off, the equipment estimated costs shown in Table 7.1 are converted in the probable cost with Equation 7.1.

$$\text{Probable cost} = \text{Equipment estimated cost} \cdot \text{IC} \quad (7.1)$$

Where the equipment estimated cost is 701,854€ and IC is obtained with the following expression:

$$\text{IC} = (100\% + i)^n \quad (7.2)$$

Where:

- IC is the Index Cost
- i is the inflation rate (considered 3%).
- n is the number of years from the data base prices to the present (approx. 7 years).

This probable value is multiplied by the accuracy percentage (in this case assumed to be 15% to guarantee that actual CAPEX is within the assumed range).

These upper, lower, and probable values are oversized to include the effect of no listed equipment to the capital cost.

The security oversizing is higher when the project cost estimated is preliminary since the probability of adding new equipment in the future is higher. In these cases, taken value is between 2 and 10%. On the contrary, for very elaborated projects, the probability of future costs associated with no current listed equipment is more reduced, and the range is from 10 to 20%.

The revamp of DSWS unit is considered to cover the basic engineering stage, so it would be in this last elaboration level. However, for conservative reasons the 10% value of FPC (Future Cost Probability) is selected.

Finally, the Base Equipment Cost (BEC) for probable, lower and upper costs are calculated with the Equation 7.3.

$$\text{BEC} = \text{no listed equipment price} + \text{main equipment estimated price} \quad (7.3)$$

7.3.2. Calculation factors

The factor selection, summarized in the Table 7.2, has been done within bibliography ranges, and differ depending on the following parameters:

- The cost breakdown type.
- The equipment average price
- The considered scenario for the different breakdown types
- The accuracy of estimation.

Table 7.2. Estimation factors used for CAPEX breakdown (probable case).

Capital cost breakdown	Factor	Scenario description
Basic equipment assembling	10	Basic
Structure and foundation	0.2	Low-Equipment on the floor
Piping	12	High- Petrochemical racks
Piping and equipment isolation	7.0	Low
Electricity and light	7.2	Liquid
Instrumentation	10	Medium
Other (no accounted)	1.0	Simple process

7.3.3. Criteria for factor selection

The project development level determines the deviation from actual investment due to underestimated equipment number. For preliminary projects, the PFC (Probability of Future Costs) is between 10-20%, while in elaborated projects is 2-10%.

Although in current project, the basic engineering stage is finished and, therefore, no additional equipment is expected to be listed; a factor of 10% is selected since it is the intermediate case.

7.3.3.1. Basic equipment assembly

Basic equipment assembly is considered since there is few equipment to be installed.

The percentage range is from 9.2 to 14% , so 10% factor is selected for the probable case.

7.3.3.2. Structure and foundations

This factor estimates the cost of construction and civil engineering depending on the elevation where the new equipment is located.

Although most of new equipment is implemented in platforms, the capital cost of structure is not affected as spare space is used.

Consequently, selected scenario is “equipment on the floor”, which covers the range between 0.1 and 2% . The estimation is done with 0.2% factor for this reason.

7.3.3.3. Piping and racks without isolation/ equipment and piping isolation

The higher factors correspond to piping and racks since these costs can take values practically as high as the principal equipment costs.

However, in the DSWS revamp pipe sections length is moderate and existing racks are used. This existing infrastructure saves an important percentage of capital.

Thus, low impact in costs associated to hydraulic circuits is expected.

The selected scenario is a standard liquid and/or solid plant, which normally have not long pipelines. The factor range for this type of projects represent from 5.5 to 12% of the base equipment cost. A factor of 12.0% is selected for the probable cost.

On the other hand, insulation is considered low since operating temperatures aren't excessive.

The range percentages compared to basic equipment costs for this scenario is from 5.4 to 12%.

An important part of the new pipe circuits transport liquid cooled by E-201, E-202 and E-203 exchangers, so piping insulation is not required for these services. In this case 11 equipment items, appearing in the Process Flow Diagram, are implemented and some of them operate at higher temperatures than 60°C, so insulation may be required for risk prevention.

Subsequently, a percentage of 7.0% is selected for probable case.

7.3.3.4. Electricity and light

Electric power installation is already available, although non important modifications may be required for the new equipment operation. Therefore, a reduced impact in capital costs is considered by assuming a liquid process installation, corresponding to costs from 5.4 to 9% of base equipment costs. An intermediate value of 7.0% is selected for calculations.

7.3.3.5. Instrumentation

The process of sour water treating does not require of a sophisticated control strategy with several instrumentation and control valves. Nevertheless, there are some indicators visible from control room and its wiring will need to be routed from instrument to control room.

For this reason, the assumed scenario is a solid process, the simplest one, which has an historical magnitude of instrumentation cost from 3.5 to 10% of principal equipment cost.

A factor of 10% has been selected.

7.3.3.6. Not considered costs

According to the complexity of process, some costs not considered may appear, although in this case, the process is simple and only a 0.6% is assumed for probable case.

7.3.4. Adjustment of factors

In Table 7.2 can be seen the summary of factor selection. The sum of all these factors gives the subtotal factors (SF in the expression below).

$$SF = \sum_{i=1}^n F_i \quad (7.4)$$

The probable subtotal factor is adjusted considering 5% of error. The lower and upper limits are the adjusted factor costs (AFC in the following expressions).

$$AFC_{\text{lower}} = SF_{\text{probable}} \cdot 105\% \quad (7.5)$$

$$AFC_{\text{upper}} = SF_{\text{probable}} \cdot 95\% \quad (7.6)$$

These resulting ACF upper and lower are applied to the base equipment cost to obtain the different installation capital estimation.

The total amount of base equipment and installation costs constitutes the direct cost.

7.3.5. Total capital investment estimation

From the direct costs, the indirect costs are estimated assuming they are around 29% of direct costs.

Finally, contingencies are calculated from the subtotal of direct and indirect costs. It is assumed that a 14% of subtotal will correspond to unforeseen.

Both subtotal and unforeseen are the final total cost of installation, which is presented within an upper and lower limit calculated with commented procedure.

7.4. Economic estimate results

In Table 7.3 the estimation cost results are summarized.

Table 7.3. Cost estimation summary.

	Low	Probable	High
Main equipment cost [k€]	710.9	789.9	868.9
No listed equipment cost [k€]	71.10	78.99	86.89
Base equipment cost [k€]	353.4	415.5	485.8
Adjusted factors cost [k€]	457.1	509.2	558.7
Direct costs of plant limits [M€]	1.135	1.284	1.442
Indirect Costs [k€]	329.3	372.5	418.1
Subtotal [M€]	1.465	1.657	1.860
Contingencies [k€]	159.0	179.8	201.8
Total Cost [M€]		1.837M€ ± 12%	

8. CONCLUSIONS

The revamp design presented in the current project is one of the several approaches to satisfy the client's requirements of adapting to the future legislation. The wide range of existing alternatives makes of the necessity and open and complex problem since there isn't a single "correct" answer. In this type of problems there isn't a "best" solution to solve the problematic since only the experience can determine the goodness. However, in spite of the absence of guidelines to determine the best solution, the presented revamp design is found adequate to deal with the environmental problematic since each decision made during the development of the project has been based on the experience and bibliographic reports, which demonstrates the technical feasibility of the selected proposal in the study of alternatives.

The simulation carried out with the aid of *HYSYS VII* confirm that the designed sub-unit will be able to meet the new requirements of the refinery when the new column and its corresponding equipment will be implemented. Although the Heat and Mass Balance represents the results of an ideal operation, the manual calculations permit the adjustment of the model for ensuring a good performance considering the turndown of the unit.

Besides, the process safety has been improved with a Hazop analysis to reinforce the control philosophy proposed preliminary at the beginning of the project.

As a result of these previous factors, the following conclusions have been extracted:

- The proposed revamp design is feasible for accomplishing the requirements since it meets the requirements and all the made decisions have been coherent with the design specifications and experience knowledge reported in bibliography.
- The emissions are more effectively controlled when the taken actions are applied on the source point.
- The simulation tools, in this particular case, *HYSYS VII*, enable to predict the behaviour of the system although the results must be carefully interpreted since they are based on predictions.
- The accuracy of a model of the plant does not necessarily require a complex simulation for obtaining a good prediction. In fact, overspecification of the unit tends to cause convergence instabilities leading to wrong results. This illustrates the importance of evaluating the simulation outputs and adjusting iteratively the model for ensuring the calculation reliability.
- The capital costs often are not associated with a direct profit, although it doesn't mean a lack of benefits. In this project, the revamp supposes not only a reduction of environmental damage but also a guarantee of the possibility of operating in the future without legacy problems.
- In the design stage of a project, it is crucial consider the future requirements since the social, legal and economic environment is permanently changing. Sometimes it is preferable the implementation of a flexible process that enables to adapt to these new requirements in spite of designing a more economical alternative that limits the operation.

In any case, it should be kept in mind the following:

- First off, the current project is presented with academic purpose, and it is at the basic engineering level, so changes during the detail engineering stage are expected.
- Prior to implementation, a carefully analysis of the design should be made for guarantee the system response in operation and the accuracy of cost estimation, although the calculations carried out permit demonstrating that the thesis project objectives have been accomplished.

9. REFERENCES

- [1] Brinkmann T; Giner Santonja G; Yukseler H; Roudier S; Delgado Sancho L. Best Available Techniques (BAT) Reference Document for Common Waste Water and Waste Gas Treatment/Management Systems in the Chemical Sector. Industrial Emissions Directive 2010/75/EU (Integrated Pollution Prevention and Control). EUR 28112 EN. Luxembourg (Luxembourg): Publications Office of the European Union; 2016. JRC103096
- [2] Mott RL, Untener JA. Mecánica de fluidos. Séptima edición. Estado de México: Pearson Educación de México; 2015.
- [3] Centrifugal Pumps and system hydraulics. Igor Karassik. Chem Eng. Oct, 4 1982. Pag 84 a 106. (47.8.33)
- [4] American Petroleum Institute, API. (1995). Centrifugal Pumps for Petroleum, Heavy Duty Chemical, and Gas Industry Services (API 610). <https://www.api.org/>
- [5] Tubular Exchanger Manufacturers Association, TEMA. (2007). <http://kbcdo.tema.org/>
- [6] HTRI. Design Manual. Volume B: Exchanger Performance Prediction Methods. Issued (April 2018).
- [7] INGENIERÍA QUÍMICA JOURNAL. Diseño Térmico de intercambiadores de calor. Abril, 1971.
- [8] ASME code VIII Division 1.
- [9] ANSI/ASME B36.10M-1985 & 19M-1985
- [10] G.A. Gregory & M. Fogaric K.A212. Course notes for the design of pipelines for gas, liquid mixtures. Chapters 5,6,7- University of Calgary ALBERTA 1977.
- [11] American Petroleum Institute, API RP 521 (fourth edition). Pressure-Relieving and Depressurizing Systems.
- [12] ASME code B.31.3
- [13] Mataix C. Mecánica de fluidos y máquinas hidráulicas / Claudio Mataix. 2nd ed. Madrid: Ediciones del Castillo,S.A; 1982. 203-226,236-247 p.
- [14] KSB EasySelect. (2022). Retrieved 25 November 2021, from <https://www.ksb.com/es-es/herramientas-y-know-how-de-ksb/herramientas-de-diseno/ksb-easyselect>
- [15] Sulzer Chemtech. (2015). *Sulcol* (Version v3.2.15) [Windows].
- [16] Sulzer. (2022). Random packing – from competitive products to advanced solutions. Winterthur, Switzerland. Retrieved from <https://www.sulzer.com/>

[/media/files/products/separation-technology/distillation-and-absorption/brochures/random_packing.pdf?la=en](#)

[17] International Electrotechnical Commission, IEC. (2005). Industrial-process control valves (60534-1). <https://webstore.iec.ch/publication/2460#additionalinfo>

[18] Instrument Society of America, ISA. (2012). Industrial-Process Control Valves (ANSI/ISA-75.01.01). <https://www.isa.org/products/ansi-isa-75-01-01-2012-60534-2-1-mod-industrial-pr>

[19] Asociación Española de Normalización, AENOR. (1996) Válvulas de regulación de procesos industriales (EN 60534-2-1). <https://tienda.aenor.com/norma-une-en-60534-2-1-1992-n0014793>

[20] Dresser, Inc., Flow Technologies. (2022). *21000 Series Control Valves* [Ebook]. Houston, Texas. Retrieved from <https://fluid-control.bg/wp-content/uploads/2014/05/Catalog-21000-full.pdf>

[21] Index of Process Equipment Costs. (2022). Retrieved 10 December 2021, from <http://www.matche.com/equipcost/EquipmentIndex.html>

Confidential manuals and guidelines from T.EN have been used in the elaboration of the project.

APPEND A:
EXISTING EQUIPMENT PDS



Customer						Reference No.					
Address						Proposal No.					
Plant Location						Date					
Service of Unit	H2S Stripper feed / NH3 Stripper bottom exchanger					Item No.	E-101				
Size	520 x 4877 mm		Type	AES Horizontal		Connected In	1	Parallel	1	Series	
Surf/Unit (Gross/Eff)	64,796 / 61,873 m ²		Shell/Unit	1		Surf/Shell (Gross/Eff)	64,796 / 61,873 m ²				

PERFORMANCE OF ONE UNIT

Fluid Allocation		Shell Side		Tube Side	
Fluid Name		H2O		H2O+H2S+NH3	
Fluid Quantity, Total kg/hr		30860		37275	
Vapor (In/Out)					
Liquid		30860	30860	37275	37275
Steam					
Water				37275	37275
Noncondensables					
Temperature (In/Out) C		127.67	83.68	43.83	83.95
Specific Gravity		0.9377	0.9705	0.9542	0.9321
Viscosity cP		0.2136	0.339	0.5428	0.2973
Molecular Weight				17.47	17.47
Molecular Weight, Noncondensables					
Specific Heat kcal/kg-C		1.0898	1.0119	0.9179	0.9934
Thermal Conductivity kcal/hr-m-C		0.5891	0.5737	0.5386	0.5463
Latent Heat kcal/kg					
Inlet Pressure kgf/cm ² G		16.491		12.672	
Velocity m/s		0.3		1.02	
Pressure Drop, Allow/Calc kgf/cm ²		0.5	0.175	0.6	0.231
Fouling Resistance (min) m ² -hr-C/kcal		0.0004		0.0004	

Heat Exchanged	1426953 kcal/hr	MTD (Corrected)	33.1 C
Transfer Rate, Service	696.45 kcal/m ² -hr-C	Clean	1776.5 kcal/m ² -hr-C
		Actual	691.19 kcal/m ² -hr-C

CONSTRUCTION OF ONE SHELL

		Shell Side		Tube Side		Sketch (Bundle/Nozzle Orientation)
Design/Test Pressure kgf/cm ² G		18.661	/	15.704	/	
Design Temperature C		145		135		
No Passes per Shell		1		4		
Corrosion Allowance mm		6		3		
Connections	In mm	1 @	87.325	1 @	87.325	
Size & Rating	Out mm	1 @	87.325	1 @	87.325	
	Intermediate	@		@		

Tube No.	222	OD	19.05 mm	Thk(Avg)	1.651 mm	Length	4877 mm	Pitch	25.4 mm
Tube Type	Plain		Material		SA-789 Tube (S) S31803		Tube pattern 90		
Shell	SA-516 70 Pl. K02700		ID	520	OD	542 mm	Shell Cover	SA-516 70 Pl. K02700 (Remove.)	
Channel or Bonnet	SA-516 70 Pl. K02700		Channel Cover		SA-516 70 Pl. K02700				
Tubesheet-Stationary	SA-182 F51 Forgings S31803		Tubesheet-Floating		SA-182 F51 Forgings S31803				
Floating Head Cover	SA-182 F51 Forgings S31803		Impingement Plate		Rectangular plate				
Baffles-Cross	Carbon steel	Type	Single-Seg.	%Cut (Diam)	13.38	Spacing(c/c)	104	Inlet	510 mm
Baffles-Long	Seal Type		None						
Supports-Tube	U-Bend		Type		None				
Bypass Seal Arrangement	2	pairs seal strips	Tube-Tubesheet Joint		Expanded (2 grooves)				
Expansion Joint	Type		None						
Rho-V2-Inlet Nozzle	2185.5	kg/m-s ²	Bundle Entrance		55.59	Bundle Exit	57.11	kg/m-s ²	
Gaskets-Shell Side	Mach. Mtl. (Kammprofile\Flex. Face)		Tube Side		Mach. Mtl. (Kammprofile\Flex. Face)				
- Floating Head	Mach. Mtl. (Kammprofile\Flex. Face)								
Code Requirements	TEMA Class		R						
Weight/Shell	2780.7	kg	Filled with Water		3861.5	kg	Bundle	1251.5 kg	

Remarks:



Customer						Reference No.					
Address						Proposal No.					
Plant Location						Date					
Service of Unit	NH3 Stripper feed/ Bottom exchanger					Item No.	E-102				
Size	490 x 4877 mm		Type	AES Horizontal		Connected In	1	Parallel	1	Series	
Surf/Unit (Gross/Eff)	56.04 / 53.581 m ²		Shell/Unit	1		Surf/Shell (Gross/Eff)	56.04 / 53.581 m ²				

PERFORMANCE OF ONE UNIT

Fluid Allocation	Shell Side				Tube Side			
Fluid Name	H2O+H2S+NH3				H2O+H2S+NH3			
Fluid Quantity, Total	21378				37275			
Vapor (In/Out)								
Liquid	21378		21378		37275		37275	
Steam								
Water	21378		21378		37275		37275	
Noncondensables								
Temperature (In/Out)	C		169.4 / 116.5		83.95		117.14	
Specific Gravity	0.863		0.9302		0.9321		0.9053	
Viscosity	cP		0.1635 / 0.2423		0.2972		0.2117	
Molecular Weight	17.66		17.66		17.47		17.47	
Molecular Weight, Noncondensables								
Specific Heat	kcal/kg-C		1.1784 / 1.0782		0.9934		1.0719	
Thermal Conductivity	kcal/hr-m-C		0.5442 / 0.5598		0.5463		0.4584	
Latent Heat	kcal/kg							
Inlet Pressure	kgf/cm ² G		8.561		11.769			
Velocity	m/s		0.25		1.21			
Pressure Drop, Allow/Calc	kgf/cm ²		0.5 / 0.113		0.7		0.286	
Fouling Resistance (min)	m ² -hr-C/kcal		0.0004		0.0004			

Heat Exchanged	1275772 kcal/hr			MTD (Corrected)	33	C
Transfer Rate, Service	721.89 kcal/m ² -hr-C			Clean	1980.4	kcal/m ² -hr-C
				Actual	720.03	kcal/m ² -hr-C

CONSTRUCTION OF ONE SHELL

		Shell Side		Tube Side		Sketch (Bundle/Nozzle Orientation)
Design/Test Pressure	kgf/cm ² G	12.1 /		15.7 /		
Design Temperature	C	187		141		
No Passes per Shell		1		4		
Corrosion Allowance	mm	6		3		
Connections	In mm	1 @	87.325	1 @	87.325	
Size & Rating	Out mm	1 @	87.325	1 @	87.325	
	Intermediate	@		@		

Tube No.	192	OD	19.05 mm	Thk(Avg)	1.651 mm	Length	4877 mm	Pitch	25.4 mm		
Tube Type	Plain		Material SA-789 Tube (S) S31803			Tube pattern 90					
Shell	347 Stainless steel		ID	490	OD	510 mm	Shell Cover	SA-240 347 Pl. S34700 (Remove.)			
Channel or Bonnet	SA-240 347 Pl. S34700						Channel Cover	347 Stainless steel			
Tubesheet-Stationary	347 Stainless steel						Tubesheet-Floating	317 Stainless steel			
Floating Head Cover	SA-182 F347 Forgings S34700						Impingement Plate	Rectangular plate			
Baffles-Cross	347 Stainless steel		Type	Single-Seg.		%Cut (Diam)	14	Spacing(c/c)	98	Inlet	424 mm
Baffles-Long			Seal Type	None							
Supports-Tube			U-Bend	Type None							
Bypass Seal Arrangement	3 pairs seal strips		Tube-Tubesheet Joint	Expanded (2 grooves)							
Expansion Joint			Type	None							
Rho-V2-Inlet Nozzle	1139.7	kg/m-s ²	Bundle Entrance	46.64	Bundle Exit	36.85	kg/m-s ²				
Gaskets-Shell Side	Mach. Mtl. (Kammprofile\Flex. Face)					Tube Side	Mach. Mtl. (Kammprofile\Flex. Face)				
- Floating Head	Mach. Mtl. (Kammprofile\Flex. Face)										
Code Requirements							TEMA Class	R			
Weight/Shell	2511.1 kg	Filled with Water	3477.8 kg	Bundle	1149.6 kg						

Remarks:



Customer						Reference No.			
Address						Proposal No.			
Plant Location						Date			
Service of Unit	H2S stripper reboiler					Item No.	E-103		
Size	1000	x	6096	mm	Type	AES	Horizontal	Connected In	1 Parallel 1 Series
Surf/Unit (Gross/Eff)	375.04	/	358.4	m ²	Shell/Unit	1		Surf/Shell (Gross/Eff)	375.04 / 358.4 m ²

PERFORMANCE OF ONE UNIT

Fluid Allocation	Shell Side				Tube Side				
Fluid Name	H2O+H2S+NH3				H2O (MP Steam)				
Fluid Quantity, Total	36933				5334,0				
Vapor (In/Out)	4.6562		4917.6		5334		5334		
Liquid	36929		32016				5334		
Steam	4.6562		4917.6						
Water	36929		32016						
Noncondensables									
Temperature (In/Out)	C		164.26		187.3		187.26		
Specific Gravity	0.8407		0.8648				0.8795		
Viscosity	cP	0.0154	V/L 0.1715	0.0155	V/L 0.1631	0.016	0.1429		
Molecular Weight	13.36		V/L 17.37		15.37		V/L 17.68		
Molecular Weight, Noncondensables									
Specific Heat	kcal/kg-C	0.5024	V/L 1.1779	0.4963	V/L 1.1779	0.4936	1.1976		
Thermal Conductivity	kcal/hr-m-C	0.0285	V/L 0.5178	0.028	V/L 0.5464	0.0281	0.5791		
Latent Heat	kcal/kg	459.34		479.04		475.93	475.97		
Inlet Pressure	kgf/cm2G	8.38				11			
Velocity	m/s	0.53				1.31			
Pressure Drop, Allow/Calc	kgf/cm2			0.049		0.1		0.01	
Fouling Resistance (min)	m2-hr-C/kcal	0.0004				0.0001			

Heat Exchanged	2539211 kcal/hr	MTD (Corrected)	19.8	C	
Transfer Rate, Service	357.98 kcal/m2-hr-C	Clean	2254.3 kcal/m2-hr-C	Actual	1036.7 kcal/m2-hr-C

CONSTRUCTION OF ONE SHELL

		Shell Side		Tube Side		Sketch (Bundle/Nozzle Orientation)
Design/Test Pressure	kgf/cm2G	10.3	/	13.4	/	
Design Temperature	C	189		300		
No Passes per Shell		1		2		
Corrosion Allowance	mm	3		3		
Connections	In mm	1 @	154.05	1 @	154.05	
Size & Rating	Out mm	1 @	254.6	1 @	52.502	
	Intermediate	@		@		

Tube No.	1028	OD	19.05 mm	Thk(Avg)	1.651 mm	Length	6096 mm	Pitch	25.4 mm		
Tube Type	Plain		Material SA-789 Tube (S) S31803			Tube pattern 90					
Shell	SA-516 70 Pl. K02700		ID	1000	OD	1030 mm	Shell Cover	SA-516 70 Pl. K02700 (Remove.)			
Channel or Bonnet	SA-516 70 Pl. K02700						Channel Cover SA-516 70 Pl. K02700				
Tubesheet-Stationary	SA-182 F51 Forgings S31803						Tubesheet-Floating SA-182 F51 Forgings S31803				
Floating Head Cover	Alloy 2205 (S31803)						Impingement Plate Rectangular plate				
Baffles-Cross	Alloy 2205 (S31803)		Type	Double-Seg.		%Cut (Diam)	19.96	Spacing(c/c)	580	Inlet	468.17 mm
Baffles-Long			Seal Type	None							
Supports-Tube			U-Bend	Type None							
Bypass Seal Arrangement	2	pairs seal strips		Tube-Tubesheet Joint	Expanded (2 grooves)						
Expansion Joint	Type None										
Rho-V2-Inlet Nozzle	368.57	kg/m-s2		Bundle Entrance	47.42	Bundle Exit	323.1	kg/m-s2			
Gaskets-Shell Side	Mach. Mtl. (Kammprofile\Flex. Face)					Tube Side	Mach. Mtl. (Kammprofile\Flex. Face)				
- Floating Head	Mach. Mtl. (Kammprofile\Flex. Face)										
Code Requirements							TEMA Class	R			
Weight/Shell	10350	kg	Filled with Water		15578	kg	Bundle	5699 kg			

Remarks:



Customer				Reference No.			
Address				Proposal No.			
Plant Location				Date			
Service of Unit	Stripper Reboiler NH3			Item No.	E-104		
Size	882 x 6096	mm	Type	BJ12U	Horizontal	Connected In	1 Parallel 1 Series
Surf/Unit (Gross/Eff)	287.49 / 283.69	m ²	Shell/Unit	1	Surf/Shell (Gross/Eff)	287.49 / 283.69 m ²	

PERFORMANCE OF ONE UNIT

Fluid Allocation		Shell Side				Tube Side	
Fluid Name		C-02 reboiler				H2O (Steam)	
Fluid Quantity, Total		37177				7429,1	
kg/hr							
Vapor (In/Out)				7167,6		7429,1	
Liquid		37177		30010			7429.1
Steam				7167.6			
Water		37177		30010			
Noncondensables							
Temperature (In/Out)	C	127.27		127.27		152.9	152.58
Specific Gravity		0.9373		0.9373			0.9148
Viscosity	cP	0.2144		0.0136 V/L 0.2144		0.0146	0.1763
Molecular Weight		18.02		18.02 V/L 18.02			
Molecular Weight, Noncondensables							
Specific Heat	kcal/kg-C	1.0901		0.4636 V/L 1.0901		0.4733	1.135
Thermal Conductivity	kcal/hr-m-C	0.589		0.0231 V/L 0.589		0.0252	0.5891
Latent Heat	kcal/kg	523.57		523.57		504.78	505.03
Inlet Pressure	kgf/cm2G			1.661		4.2	
Velocity	m/s			2.19		7.27	
Pressure Drop, Allow/Calc	kgf/cm2			0.035		0.1	0.044
Fouling Resistance (min)	m2-hr-C/kcal			0.0004		0.0001	

Heat Exchanged	3753281 kcal/hr	MTD (Corrected)	25,4	C
Transfer Rate, Service	521.5 kcal/m2-hr-C	Clean	2367	kcal/m2-hr-C Actual 1037.9 kcal/m2-hr-C

CONSTRUCTION OF ONE SHELL

		Shell Side		Tube Side		Sketch (Bundle/Nozzle Orientation)
Design/Test Pressure	kgf/cm2G	5.4	/	7	/	
Design Temperature	C	141		210		
No Passes per Shell		1		2		
Corrosion Allowance	mm	6		6		
Connections	In mm	1 @	154.05	1 @	254.51	
Size & Rating	Out mm	2 @	390.55	1 @	77.927	
	Intermediate	@		@		

Tube No.	394U	OD	19.05	mm	Thk(Avg)	2.77	mm	Length	6096	mm	Pitch	25.4	mm
Tube Type	Plain		Material SA-179 Tube (S) K01200				Tube pattern		90				
Shell	SA-516 70 Pl. K02700		ID	882	OD	908	mm	Shell Cover	SA-516 70 Pl. K02700 (Integ.)				
Channel or Bonnet	SA-516 70 Pl. K02700							Channel Cover					
Tubesheet-Stationary	SA-105 Forgings K03504							Tubesheet-Floating					
Floating Head Cover								Impingement Plate Rectangular plate					
Baffles-Cross	Carbon steel	Type	Single-Seg.	%Cut (Diam)	45	Spacing(c/c)	750	Inlet	1119.9 mm				
Baffles-Long				Seal Type	None								
Supports-Tube				U-Bend	Type Full support								
Bypass Seal Arrangement	1	pairs seal strips	Tube-Tubesheet Joint	Expanded (2 grooves)									
Expansion Joint				Type	None								
Rho-V2-Inlet Nozzle	327.67	kg/m-s2	Bundle Entrance	1.39	Bundle Exit	159.46	kg/m-s2						
Gaskets-Shell Side	Mach. Mtl. (Kammprofile\Flex. Face)				Tube Side	Mach. Mtl. (Kammprofile\Flex. Face)							
- Floating Head													
Code Requirements								TEMA Class	R				
Weight/Shell	8945.2	kg	Filled with Water	13117	kg	Bundle	6353.2 kg						



Remarks:



Process Conditions		Outside		Tubeside		
Fluid name	Air			H2O+H2S+NH3		
Fluid condition			Sens. Gas		Sens. Liquid	
Total flow rate	(kg/hr)		690000		105064	
Weight fraction vapor, In/Out		1	1	0	0	
Temperature, In/Out	(Deg C)	28	49.28	102.91	69.8	
Skin temperature, Min/Max	(Deg C)	39.54	60.49	67.25	99.2	
Pressure, Inlet/Outlet	(kgf/cm2G)	-6.10E-03	-7.9E-03	3.772	3.26	
Pressure drop, Total/Allow	(kgf/cm2)	1.82E-03	0	0.514	0.7	
Midpoint velocity	(m/s)		7.96		1.33	
- In/Out	(m/s)			1.36	1.31	
Heat transfer safety factor	(-)		1		1	
Fouling	(m2-hr-C/kcal)		0		0	
Exchanger Performance						
Outside film coef	(kcal/m2-hr-C)	60.85		Actual U	(kcal/m2-hr-C) 14.8	
Tubeside film coef	(kcal/m2-hr-C)	6475.6		Required U	(kcal/m2-hr-C) 13	
Clean coef	(kcal/m2-hr-C)	17.697		Area	(m2) 5717	
Hot regime			Sens. Liquid	Overdesign	(%) 13.6	
Cold regime			Sens. Gas	Tube Geometry		
EMTD	(Deg C)	47.5		Tube type	Low-finned	
Duty	(kcal/hr)	3530958.1		Tube OD	(mm) 25.4	
Unit Geometry			Tube ID	(mm) 21.2		
Bays in parallel per unit		1	Length	(mm) 9144		
Bundles parallel per bay		2	Area ratio(out/in)	(--)	28.1	
Extended area	(m2)	5716.9	Layout		Staggered	
Bare area	(m2)	243.95	Trans pitch	(mm) 66.7		
Bundle width	(mm)	2310	Long pitch	(mm) 59.5		
Nozzle	Inlet	Outlet	Number of passes	(--)	5	
Number	(--)	1	Number of rows	(--)	5	
Diameter	(mm)	146.33	Tube count	(--)	170	
Velocity	(m/s)	0.97	Tube count Odd/Even	(--)	34 / 34	
R-V-SQ	(kg/m-s2)	839.07	Material		Alloy 2205 (S31803)	
Pressure drop	(kgf/cm2)	4.7E-03	2.89E-03	Fin Geometry		
Fan Geometry			Type		Round	
No/bay	(--)		2	Fins/length	(fin/meter) 433	
Fan ring type			30 deg	Fin root	(mm) 26.2	
Diameter	(mm)		3353	Height	(mm) 15.9	
Ratio, Fan/bundle face area	(--)		0.418	Avg. thickness	(mm) 0.41	
Driver (design/min. ambient)	(kW)	28,50	/	Over fin	(mm) 57.9	
Tip clearance	(mm)		16.765	Efficiency	(%) 32.2	
Efficiency	(%)		65	Area ratio (fin/bare)	(--)	23.4
Fans turned-off	(--)		All Fans On	Material		Alloy 2205 (S31803)
Airsides Velocities			Thermal Resistance; %			
Face	(m/s)	Actual	Standard	Air		24.3
Maximum	(m/s)	3.89	3.78	Tube		6.41
Flow	(100 m3/min)	7.71	7.48	Fouling		16.6
Velocity pressure	(kgf/cm2)	9.9E+01	95.722	Metal		52.7
Bundle pressure drop	(kgf/cm2)	5.2E-04		Bond		0
Bundle flow fraction	(--)	1.8E-03				
		1				
Bundle	98,30	Airsides Pressure Drop; %			Louvers	0
Ground clearance	0,00	Fan guard		0	Hail screen	0
Fan ring	1,70	Fan area blockage		0	Steam coil	0



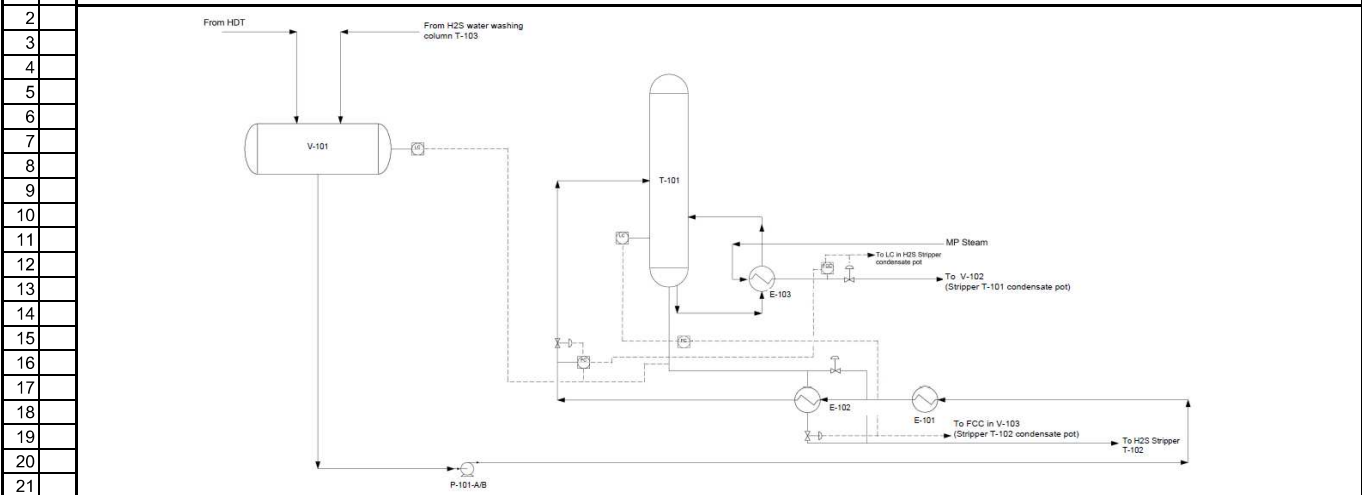
Process Conditions		Outside		Tubeside		
Fluid name	Air			H2O		
Fluid condition			Sens. Gas		Sens. Liquid	
Total flow rate	(kg/hr)		151000		30859.5	
Weight fraction vapor, In/Out		1	1	0	0	
Temperature, In/Out	(Deg C)	28	43.82	83.68	65	
Skin temperature, Min/Max	(Deg C)	42.89	57.06	61.72	79.6	
Pressure, Inlet/Outlet	(kgf/cm2G)	-0.0061	-0.0074	16.172	15.9	
Pressure drop, Total/Allow	(kgf/cm2) (kgf/cm2)	1.33E-03	0	0.304	0.7	
Midpoint velocity	(m/s)		8.94		1.47	
- In/Out	(m/s)			1.49	1.47	
Heat transfer safety factor	(-)		1		1	
Fouling	(m2-hr-C/kcal)		0		0	
Exchanger Performance						
Outside film coef	(kcal/m2-hr-C)	59.63		Actual U	(kcal/m2-hr-C) 21.7	
Tubeside film coef	(kcal/m2-hr-C)	7286.8		Required U	(kcal/m2-hr-C) 22.4	
Clean coef	(kcal/m2-hr-C)	29.467		Area	(m2) 673	
Hot regime		Sens. Liquid		Overdesign	(%) -3.31	
Cold regime		Sens. Gas		Tube Geometry		
EMTD	(Deg C)	38.1		Tube type	Low-finned	
Duty	(kcal/hr)	574243.2		Tube OD	(mm) 25.4	
Unit Geometry			Tube ID	(mm) 19.5		
Bays in parallel per unit		1	Length	(mm) 9144		
Bundles parallel per bay		1	Area ratio(out/in)	(--)	30.6	
Extended area	(m2)	673.05	Layout		Staggered	
Bare area	(m2)	28.72	Trans pitch	(mm) 66.7		
Bundle width	(mm)	933	Long pitch	(mm) 59.5		
Nozzle	Inlet	Outlet	Number of passes	(--)	2	
Number	(--)	1	Number of rows	(--)	3	
Diameter	(mm)	87.325	Tube count	(--)	40	
Velocity	(m/s)	1.48	Tube count Odd/Even	(--)	13 / 14	
R-V-SQ	(kg/m-s2)	2111.7	Material		Carbon steel	
Pressure drop	(kgf/cm2)	0.012	7.45E-03	Fin Geometry		
Fan Geometry			Type		Round	
No/bay	(-)		2	Fins/length	(fin/meter) 433	
Fan ring type			30 deg	Fin root	(mm) 25.8	
Diameter	(mm)		2743	Height	(mm) 15.9	
Ratio, Fan/bundle face area	(-)		1.3853	Avg. thickness	(mm) 0.41	
Driver (design/min. ambient)	(kW)	4	/	Over fin	(mm) 57.6	
Tip clearance	(mm)		12.7	Efficiency	(%) 58.3	
Efficiency	(%)		65	Area ratio (fin/bare)	(--)	23.4
Fans turned-off	(-)		All Fans On	Material		Carbon steel
Airsides Velocities		Actual	Standard	Thermal Resistance; %		
Face	(m/s)	4.22	4.09	Air	36.3	
Maximum	(m/s)	8.72	8.46	Tube	9.1	
Flow	(100 m3/min)	21.596	20.948	Fouling	26.5	
Velocity pressure	(kgf/cm2)	5.5E-05		Metal	28.1	
Bundle pressure drop	(kgf/cm2)	1.3E-03		Bond	0	
Bundle flow fraction	(-)	1				
Bundle	99.75	Airsides Pressure Drop; %		Louvers	0	
Ground clearance	0	Fan guard	0	Hail screen	0	
Fan ring	0.25	Fan area blockage	0	Steam coil	0	

  UNIVERSITAT ROVIRA i VIRGILI	PUMPS P-101-A/B		
Rev	EQUIPMENT FEATURES		
1	DESIGN CASE	Validation for normal/ design cases	
2	SERVICE	Sour water feed	
3	Item N° Operation / Spare	P-101-A/B	
4	Number of Pumps Required for Operation / Spare	1 / 1	
5	Type of Pump (centrifugal / volumetric alternative / volumetric rotative)	Centrifugal	
6	Operation (continuous / discontinuous ; series / parallel)	Continuous	
7	FLUID CHARACTERISTICS		
8	Nature of Fluid	H2O + H2S+ NH3	
9	Corrosive / Toxic Compounds	% wt. / wt. ppm	2.0% (H2S) / 1.9% (NH3)
10	Solids (Quantity / Size)	No	
11	Pour Point	°C	-
12	Self Ignition Point / Flash Point	°C	-
13	Pumping Temperature, T	°C	43.4
14	Density @ T	kg/m ³	953.5
15	Viscosity @ T	cSt	0.57
16	Vapour Pressure @ T	kg/cm ² a	0.25
17	PUMP DESIGN CONDITIONS		
18	Design Flow Q (rated)	m ³ /h	46.90
19	Minimum Process Flow	m ³ /h	12.0
20	Normal Flow	m ³ /h	39.10
21	Discharge Pressure @ Q rated	kg/cm ² g	12.3
22	Suction Pressure @ Q rated	kg/cm ² g	1.7
23	Differential Pressure @ Q rated	kg/cm ²	10.6
24	Differential Head @ Q rated	m	111.0
25	NPSH Available @ Q rated	m	25.7
26	Maximum DP at Zero Flow	kg/cm ²	12.7
27	Maximum Suction Pressure	kg/cm ² g	4.1
28	Maximum Discharge Pressure	kg/cm ² g	16.9
29	Suction / Discharge Piping Size	Inch	3" / 2"
30	Impeller / Mechanical Seal		-
31	Tracing / Insulation / Flushing		-
32	MECHANICAL DESIGN CONDITIONS		
33	Mechanical Design Temperature	°C	135
34	Mechanical Design Pressure	kg/cm ² g	16.9
35	DRIVER FEATURES		
36	Type Operating / Spare		-
37	Estimated Power Demand at Q rated	kWh/h	57
38	Estimated Demand at Q rated	Kg/h	-
39	NOTES		
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PUMP CALCULATION SHEET
P-101-A/B

Rev SERVICE / CASE: Sour water feed / Validation



Fluid Nature				
Pumping T	°C			
Viscosity @ T	cSt			
Density @ T	kg/m ³		953.5	
Capacity		Q Nor.	Q Des.	
Mass Flow	kg/h	37275.4	44730.0	
Volumetric Flow	m ³ /h	39.10	46.90	
Suction Pressure		Q Nor.	Q Des.	
Vessel Operating P	kg/cm ² g	1.20	1.20	
H (TL to center line)	kg/cm ²	-0.50	-0.50	
DP Line	kg/cm ²	0.01	0.01	
DP Strainer	kg/cm ²	0.02	0.03	
DP Other	kg/cm ²			
Suction Pressure	kg/cm ² g	1.67	1.66	
NPSH Available		Q Des.		
Suction Pressure	kg/cm ² a	2.70		
Vapour Pressure @ T	kg/cm ² a	0.25		
Difference	kg/cm ²	2.46		
NPSHA	m	25.75		
Estimated Power Consumption		Q Nor.	Q Des.	
HHP	CV	32.0	35.0	
Pump Efficiency	%	46%	50%	
BHP	CV	69.57	70.00	
Motor				
Motor Efficiency	%	91%	91%	
Power	kWh/h	56.23	56.58	

Discharge P	Q Nor.			Q Des.
	Circ.1	Circ.2	Circ.3	
	kg/cm ² g ó kg/cm ² (DP)			
Destination P	8.1			8.1
DP Distributor	0.21			0.30
Static Height	1.79			1.79
DP Line	0.27			0.39
DP Strainer				
DP E-101 (T)	0.23			0.33
DP E-102 (T)	0.29			0.40
DP				
DP				
DP Flowmeter	0.17			0.25
DP Control Val.	1.54			0.94
Discharge P	12.60			12.3

Differential P @ Q des		Q Des.
Discharge P	kg/cm ² g	12.25
Suction P	kg/cm ² g	1.66
Differential P	kg/cm ²	10.59
Differential Head	m	111.02

Maximum Suction P		Q Des.
Vessel P	kg/cm ² g	3.50
H (HHL-Center Line)	kg/cm ²	0.64
Maximum Suction P	kg/cm ² g	4.14

Maximum Discharge P		Q Des.
Max. Differ. P motor	kg/cm ²	12.71
Max. Differ. P turbine	kg/cm ²	-
Max. Discharge P	kg/cm ² g	16.85

NOTES

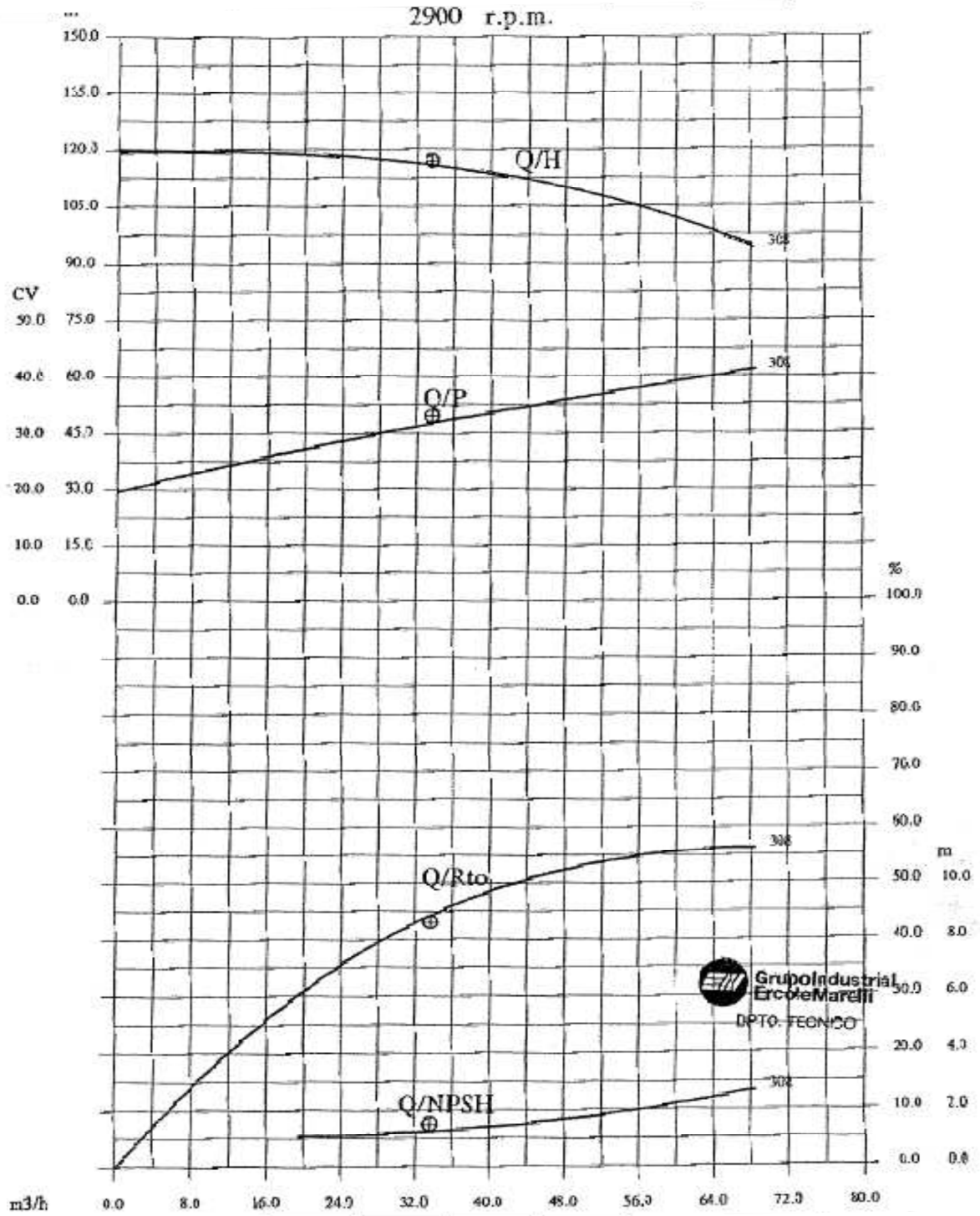


PUMP CALCULATION SHEET
P-101-A/B

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NOTES

PUMP CURVE SUPPLIED BY VENDOR

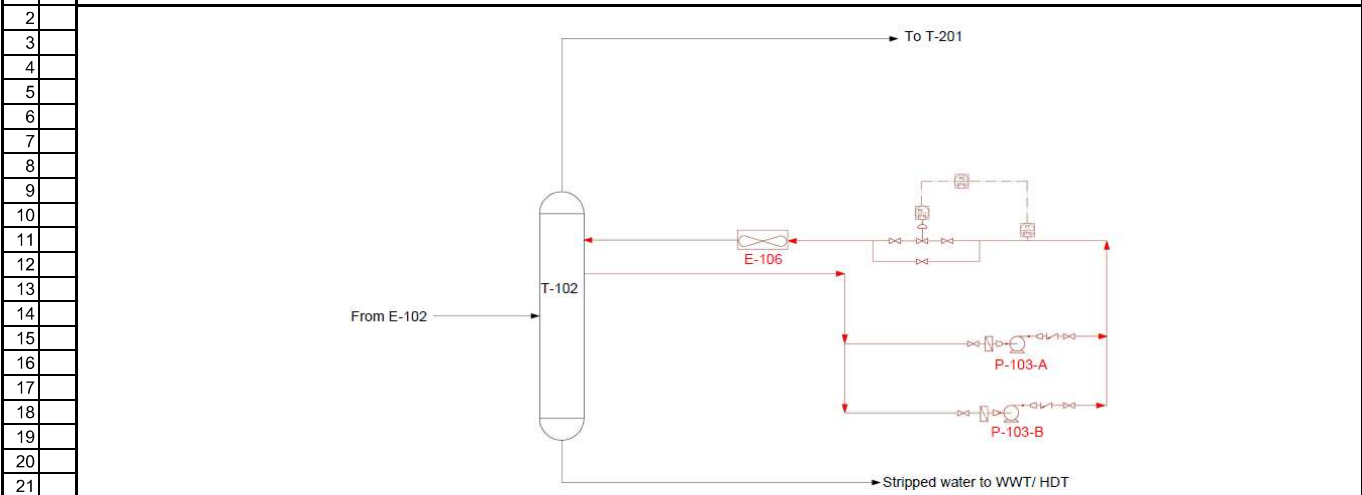


TEN	UNIVERSITAT ROVIRA i VIRGILI	PUMPS P-103-A/B	
Rev	EQUIPMENT FEATURES		
1	DESIGN CASE	Validation for normal/ design cases	
2	SERVICE	T-102 Pump around	
3	Item N° Operation / Spare	P-103-A/B	
4	Number of Pumps Required for Operation / Spare	1 / 1	
5	Type of Pump (centrifugal / volumetric alternative / volumetric rotative)	Centrifugal	
6	Operation (continuous / discontinuous ; series / parallel)	Continuous	
7	FLUID CHARACTERISTICS		
8	Nature of Fluid	H2O + H2S+ NH3	
9	Corrosive / Toxic Compounds	% wt. / wt. ppm	1.7% (H2S) / 6.2% (NH3)
10	Solids (Quantity / Size)	No	
11	Pour Point	°C	-
12	Self Ignition Point / Flash Point	°C	-
13	Pumping Temperature, T	°C	102.8
14	Density @ T	kg/m ³	897.3
15	Viscosity @ T	cSt	0.296
16	Vapour Pressure @ T	kg/cm ² a	2.28
17	PUMP DESIGN CONDITIONS		
18	Design Flow Q (rated)	m ³ /h	140.5
19	Minimum Process Flow	m ³ /h	42.0
20	Normal Flow	m ³ /h	117.1
21	Discharge Pressure @ Q rated	kg/cm ² g	7.92
22	Suction Pressure @ Q rated	kg/cm ² g	3.62
23	Differential Pressure @ Q rated	kg/cm ²	4.30
24	Differential Head @ Q rated	m	47.89
25	NPSH Available @ Q rated	m	26.48
26	Maximum DP at Zero Flow	kg/cm ²	6.19
27	Maximum Suction Pressure	kg/cm ² g	4.06
28	Maximum Discharge Pressure	kg/cm ² g	10.25
29	Suction / Discharge Piping Size	Inch	4" / 6"
30	Impeller / Mechanical Seal		-
31	Tracing / Insulation / Flushing		-
32	MECHANICAL DESIGN CONDITIONS		
33	Mechanical Design Temperature	°C	145.0
34	Mechanical Design Pressure	kg/cm ² g	10.25
35	DRIVER FEATURES		
36	Type Operating / Spare		-
37	Estimated Power Demand at Q rated	kWh/h	35.0
38	Estimated Demand at Q rated	Kg/h	-
39	NOTES		
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PUMP CALCULATION SHEET
P-103-A/B

Rev SERVICE / CASE: T-102 Pump around / Validation



Fluid Nature				
23	Pumping T	°C		
24	Viscosity @ T	cSt		
25	Density @ T	kg/m ³	897.3	
Capacity				
27	Mass Flow	kg/h	105064.0	126077.0
28	Volumetric Flow	m ³ /h	117.08	140.50
Suction Pressure				
31	Vessel Operating P	kg/cm ² g	1.20	1.20
32	H (TL to center line)	kg/cm ²	-2.45	-2.45
33	DP Line	kg/cm ²	0.01	0.02
34	DP Strainer	kg/cm ²	0.01	0.01
35	DP Other	kg/cm ²		
36	Suction Pressure	kg/cm ² g	3.63	3.62
NPSH Available				
39	Suction Pressure	kg/cm ² a		4.65
40	Vapour Pressure @ T	kg/cm ² a		2.28
41	Difference	kg/cm ²		2.38
42	NPSHA	m		26.48
Estimated Power Consumption				
44	HHP	CV	25.0	30.0
45	Pump Efficiency	%	67%	70%
46	BHP	CV	37.31	42.86
Motor				
47	Motor Efficiency	%	90%	90%
48	Power	kWh/h	30.49	35.02

Discharge P	Q Nor.			Q Des.
	Circ.1	Circ.2	Circ.3	
Destination P	1.2			1.2
DP Distributor	0.21			0.30
Static Height	2.89			2.89
DP Line	0.37			0.53
DP Strainer				
DP E-106	0.52			0.73
DP				
DP				
DP				
DP Flowmeter	0.17			0.25
DP Control Val.	3.03			2.02
Discharge P	8.48			7.92

Differential P @ Q des		Q Des.
Discharge P	kg/cm ² g	7.92
Suction P	kg/cm ² g	3.62
Differential P	kg/cm ²	4.30
Differential Head	m	47.89

Maximum Suction P		Q Des.
Vessel P	kg/cm ² g	3.50
H (HHL-Center Line)	kg/cm ²	0.56
Maximum Suction P	kg/cm ² g	4.06

Maximum Discharge P		Q Des.
Max. Differ. P motor	kg/cm ²	6.19
Max. Differ. P turbine	kg/cm ²	-
Max. Discharge P	kg/cm ² g	10.25

NOTES

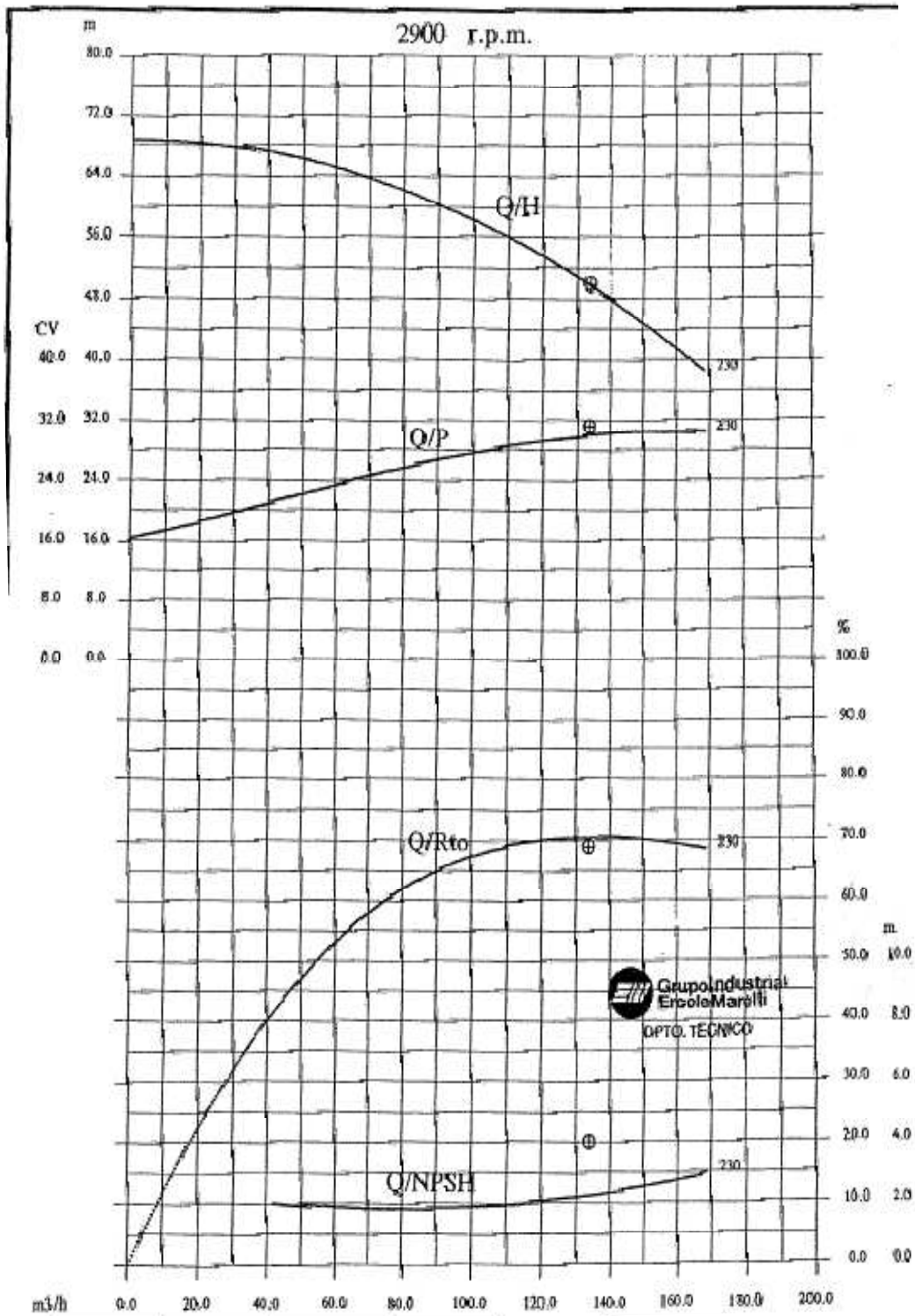


PUMP CALCULATION SHEET
P-103-A/B

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PUMP CURVE SUPPLIED BY VENDOR



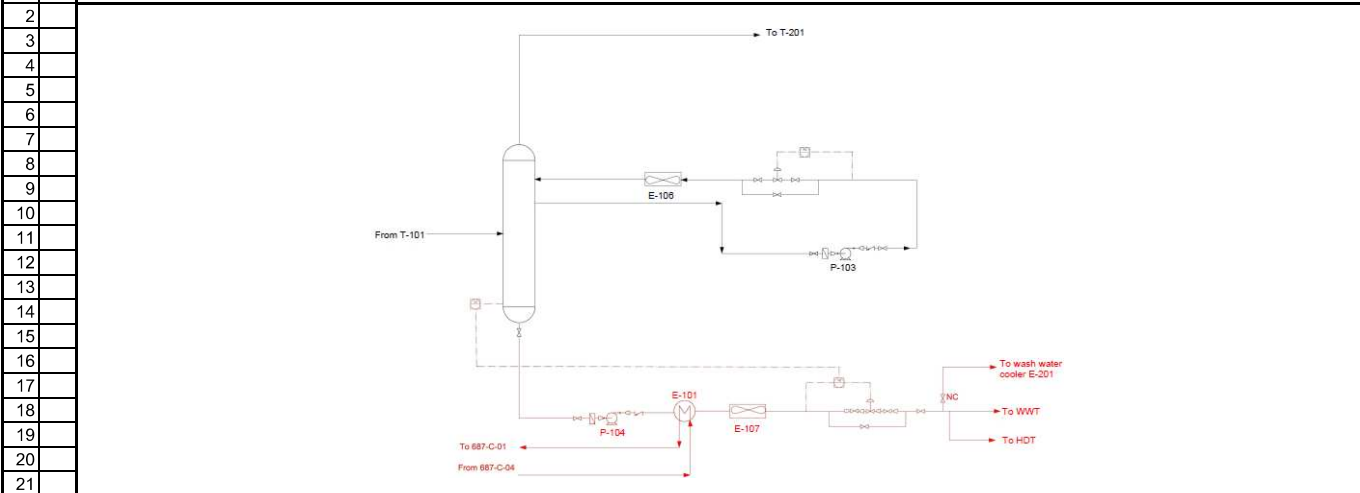
TEN	UNIVERSITAT ROVIRA I VIRGILI	PUMPS P-104-A/B	
Rev	EQUIPMENT FEATURES		
1	DESIGN CASE	Validation	
2	SERVICE	Stripped water to B.L	
3	Item N° Operation / Spare		
4	Number of Pumps Required for Operation / Spare	1 / 1	
5	Type of Pump (centrifugal / volumetric alternative / volumetric rotative)	Centrifugal	
6	Operation (continuous / discontinuous ; series / parallel)	Continuous	
7	FLUID CHARACTERISTICS		
8	Nature of Fluid	H2O	
9	Corrosive / Toxic Compounds	% wt. / wt. ppm	-
10	Solids (Quantity / Size)	No	
11	Pour Point	°C	-
12	Self Ignition Point / Flash Point	°C	-
13	Pumping Temperature, T	°C	127.7
14	Density @ T	kg/m ³	937.3
15	Viscosity @ T	cSt	0.23
16	Vapour Pressure @ T	kg/cm ² a	2.56
17	PUMP DESIGN CONDITIONS		
18	Design Flow Q (rated)	m ³ /h	39.51
19	Minimum Process Flow	m ³ /h	16.30
20	Normal Flow	m ³ /h	32.92
21	Discharge Pressure @ Q rated	kg/cm ² g	13.6
22	Suction Pressure @ Q rated	kg/cm ² g	1.9
23	Differential Pressure @ Q rated	kg/cm ²	11.7
24	Differential Head @ Q rated	m	124.9
25	NPSH Available @ Q rated	m	4.0
26	Maximum DP at Zero Flow	kg/cm ²	14.1
27	Maximum Suction Pressure	kg/cm ² g	4.11
28	Maximum Discharge Pressure	kg/cm ² g	18.2
29	Suction / Discharge Piping Size	Inch	3" / 2"
30	Impeller / Mechanical Seal	-	
31	Tracing / Insulation / Flushing	-	
32	MECHANICAL DESIGN CONDITIONS		
33	Mechanical Design Temperature	°C	145
34	Mechanical Design Pressure	kg/cm ² g	18.17
35	DRIVER FEATURES		
36	Type Operating / Spare	-	
37	Estimated Power Demand at Q rated	kWh/h	1
38	Estimated Demand at Q rated	Kg/h	-
39	NOTES		
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PUMP CALCULATION SHEET
P-104-A/B

Rev SERVICE / CASE: Stripped water to B.L/ Validation

FLOW SCHEME



Fluid Nature			
Pumping T	°C	127.7	
Viscosity @ T	cSt	0.2	
Density @ T	kg/m ³	937.3	

Capacity		Q Nor.	Q Des.	Discharge P	Q Nor.			Q Des.
					Circ.1	Circ.2	Circ.3	
Mass Flow	kg/h	30858.0	37029.6		kg/cm ² g ó kg/cm ² (DP)			
Volumetric Flow	m ³ /h	32.92	39.51					
Suction Pressure								
Vessel Operating P	kg/cm ² g	1.50	1.50	Destination P	2.1	2.1		2.1
H (TL to center line)	kg/cm ²	-0.45	-0.45	DP Distributor				
DP Line	kg/cm ²	0.02	0.03	Static Height	0.53	0.04		0.04
DP Strainer	kg/cm ²	0.01	0.02	DP Line	0.14	0.17		
DP Other	kg/cm ²			DP Strainer				
Suction Pressure	kg/cm ² g	1.92	1.91	DP E-107	0.30	0.30		0.43
NPSH Available								
Suction Pressure	kg/cm ² a		2.94	DP E-101 (S)	0.18	0.18		0.25
Vapour Pressure @ T	kg/cm ² a		2.56	DP				
Difference	kg/cm ²		0.38	DP				
NPSHA	m		4.04	DP				
Estimated Power Consumption								
HHP	CV	18.39	20.59	DP Flowmeter		0.14		0.21
Pump Efficiency	%	51%	41%	DP Control Val.		13.52		10.34
BHP	CV	36.05	50.23	Discharge P	16.45	16.45		13.62
Motor				Differential P @ Q des				Q Des.
Motor Efficiency	%	91%	91%	Discharge P		kg/cm ² g		13.62
Power	kWh/h	29.30	40.60	Suction P		kg/cm ² g		1.91
				Differential P		kg/cm ²		11.71
				Differential Head		m		124.90
				Maximum Suction P				Q Des.
				Vessel P		kg/cm ² g		3.50
				H (HHL-Center Line)		kg/cm ²		0.61
				Maximum Suction P		kg/cm ² g		4.11
				Maximum Discharge P				Q Des.
				Max. Differ. P motor		kg/cm ²		14.05
				Max. Differ. P turbine		kg/cm ²		-
				Max. Discharge P		kg/cm ² g		18.17

NPSH Available			
Suction Pressure	kg/cm ² a		2.94
Vapour Pressure @ T	kg/cm ² a		2.56
Difference	kg/cm ²		0.38
NPSHA	m		4.04

Estimated Power Consumption			
HHP	CV	18.39	20.59
Pump Efficiency	%	51%	41%
BHP	CV	36.05	50.23

Motor			
Motor Efficiency	%	91%	91%
Power	kWh/h	29.30	40.60

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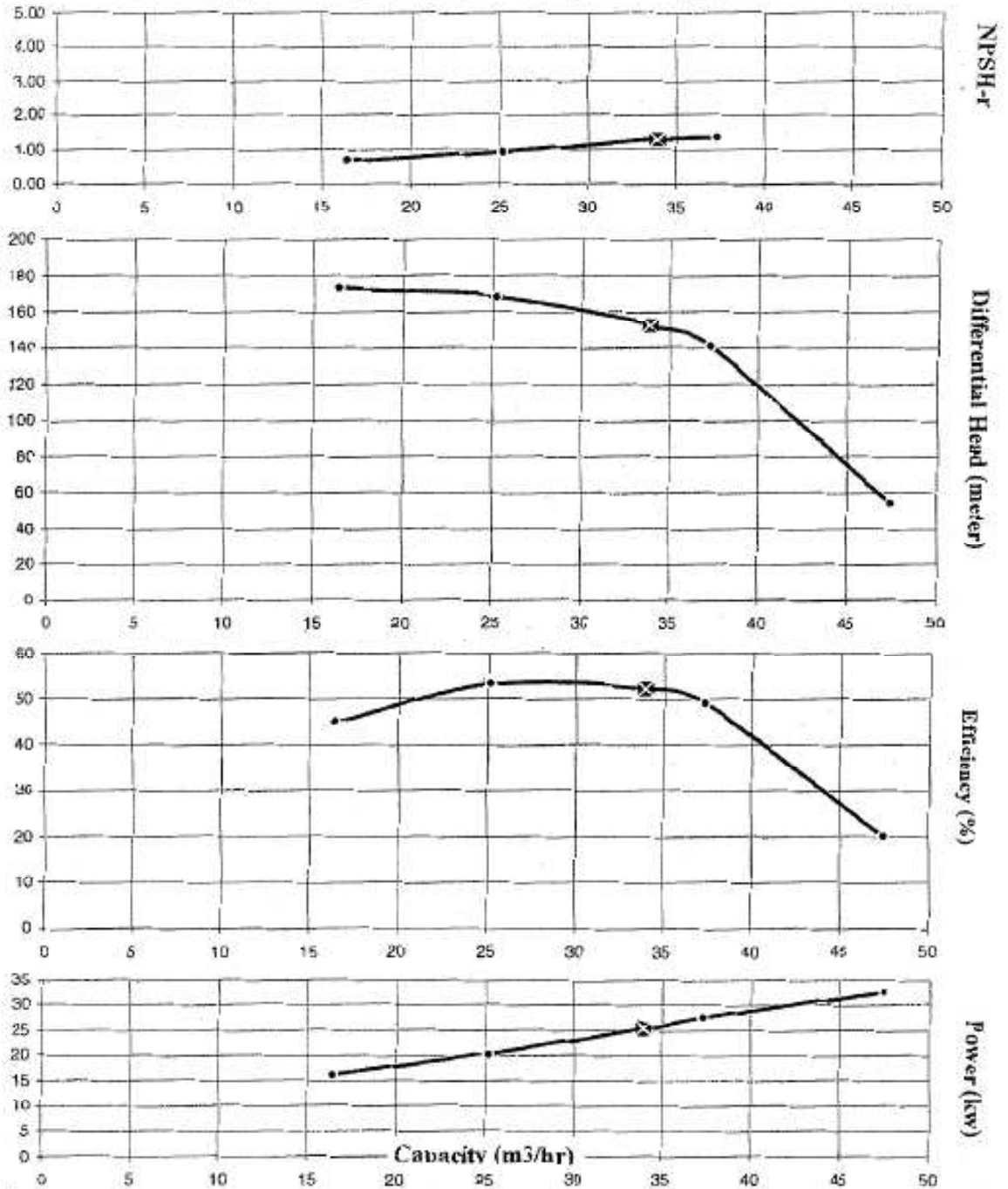


PUMP CALCULATION SHEET
P-104-A/B

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PUMP CURVE SUPPLIED BY VENDOR



APPEND B:

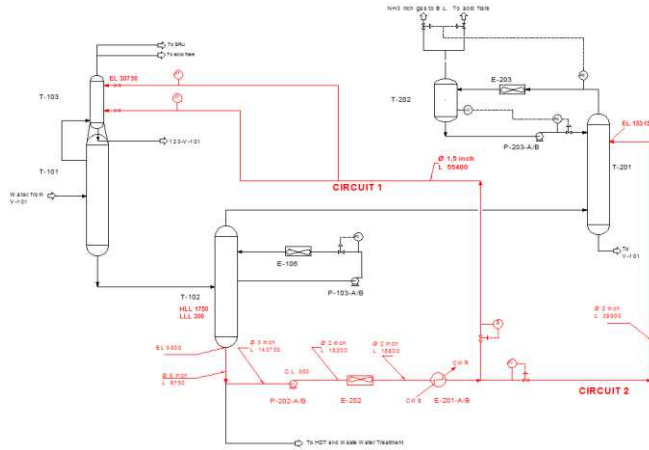
NEW EQUIPMENT PDS



PUMP CALCULATION SHEET
P-202-A/B

Rev SERVICE / CASE: Wash water pumps / Design case (120% normal flow)

FLOW SCHEME



Fluid Nature			
Pumping T	°C	127.2	
Viscosity @ T	cSt	0.23	
Density @ T	kg/m ³	936.9	
Capacity		Q Nor.	Q Des.
Mass Flow	kg/h	4381	5257
Volumetric Flow	m ³ /h	4.68	5.61
Suction Pressure		Q Nor.	Q Des.
Vessel Operating P	kg/cm ² g	1.50	1.50
H (TL to center line)	kg/cm ²	-0.47	-0.45
DP Line	kg/cm ²	0.02	0.03
DP Strainer	kg/cm ²	(1)	(1)
DP Other	kg/cm ²		
Suction Pressure	kg/cm ² g	1.93	1.92
NPSH Available		Q Des.	
Suction Pressure	kg/cm ² a	2.96	
Vapour Pressure @ T	kg/cm ² a	2.53	
Difference	kg/cm ²	0.42	
NPSHA	m	4.53	
Estimated Power Consumption		Q Nor.	Q Des.
HHP	CV	2.68	3.21
Pump Efficiency	%	63%	67%
BHP	CV	4.25	4.79
Motor			
Motor Efficiency	%	80%	80%
Power (4)	kWh/h	3.91	4.41

Discharge P	Q Nor.			Q Des.
	Circ.1	Circ.2	Circ.3	
Destination P	7.90	1.00		7.90
DP Distr. (2)	0.21	0.21		0.30
Static Height	2.84	0.93		2.84
DP Line	0.47	0.45		0.67
DP Strainer				
DP E-202 (3)	0.70	0.70		0.70
DP E-201 (3)	0.20	0.20		0.20
DP FT-0201(2)				
DP FT-0106(2)	0.17			0.25
DP FT-0107(2)	0.17			0.25
DP FT-0109(2)	0.17	0.17		0.25
DP Control Val.	5.49	14.84		4.03
Discharge P	18.33	18.33		17.38

Differential P @ Q des		Q Des.
Discharge P	kg/cm ² g	17.38
Suction P	kg/cm ² g	1.92
Differential P	kg/cm ²	15.46
Differential Head	m	165.0

Maximum Suction P		Q Des.
Vessel P	kg/cm ² g	3.50
H (HHL-Center Line)	kg/cm ²	0.59
Maximum Suction P	kg/cm ² g	4.09

Maximum Discharge P		Q Des.
Max. Differ. P motor	kg/cm ²	18.9
Max. Differ. P turbine	kg/cm ²	-
Max. Discharge P	kg/cm ² g	23.0

NOTES

- (1) Strainer pressure drop included in line pressure drop as an equivalent straight pipe length of 300 ft.
- (2) DP estimated with Darcy's equation from design pressure drop .
- (3) Maximum allowable pressure drop (provided by vendor).
- (4) Estimated power consumption from theoretical expressions since it is more conservative than the pump curve one.

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PUMP CALCULATION SHEET
P-202-A/B

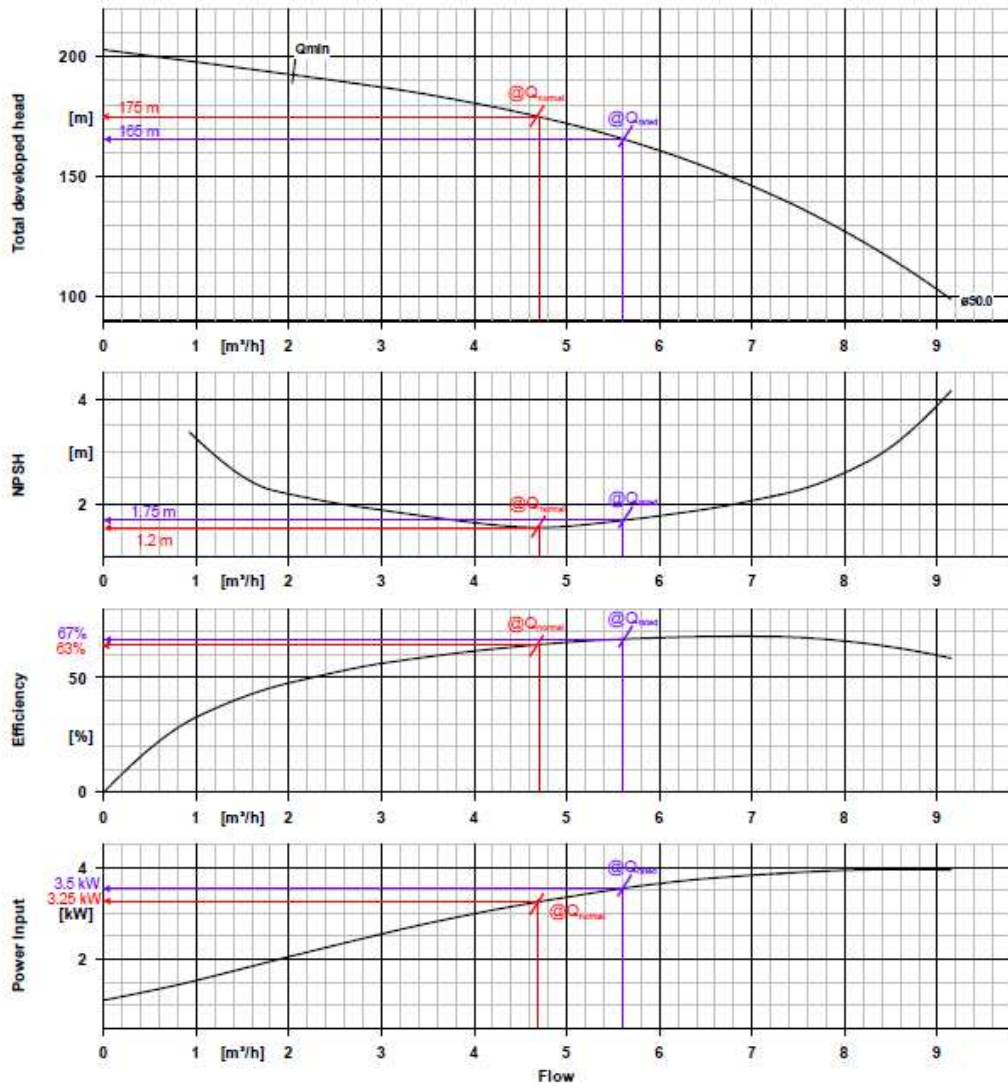
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PUMP CURVES SUPPLIED BY VENDOR

MovitecV F006/20-B1D20CS132D5VW
High pressure Inline Pump

Version no.:

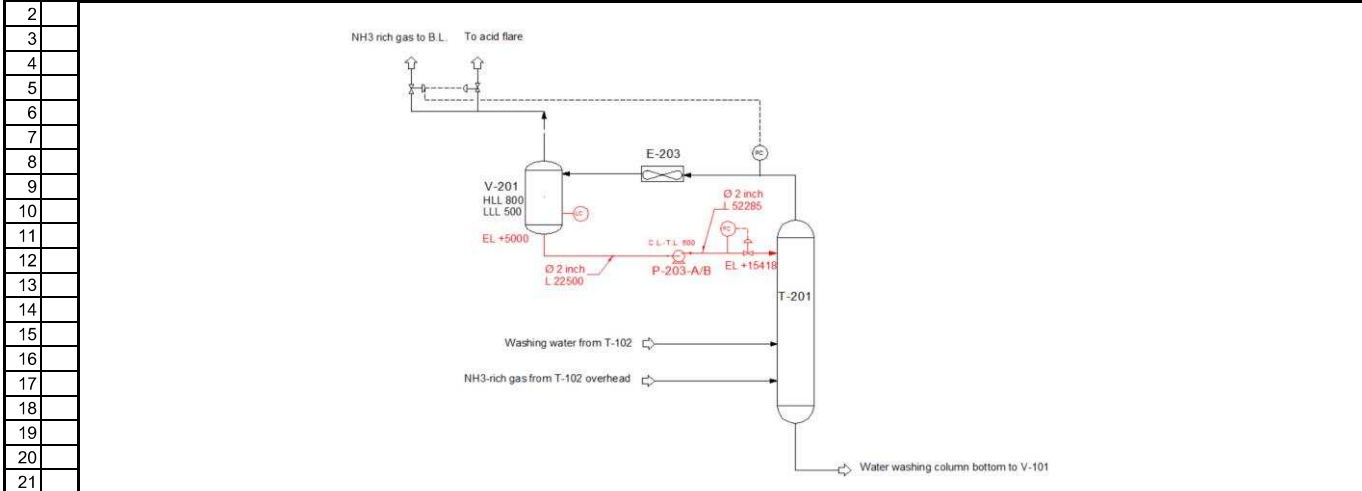




PUMP CALCULATION SHEET
P-203-A/B

Rev SERVICE / CASE: NH3 water washing column reflux pump / Design case (120% normal flow)

1 FLOW SCHEME



Fluid Nature				Discharge P	Q Nor.			Q Des.
Pumping T	°C	42.6	Circ.1		Circ.2	Circ.3		
Viscosity @ T	cSt	0.86	kg/cm ² g ó kg/cm ² (DP)					
Density @ T	kg/m ³	880.6						

Capacity		Q Nor.	Q Des.	Destination P	1.0		1.0
Mass Flow	kg/h	343	411	DP Distributor	0.21		0.30
Volumetric Flow	m ³ /h	0.389	0.467	Static Height	1.31		1.31
				DP Line	0.01		0.02

Suction Pressure		Q Nor.	Q Des.	DP Strainer			
Vessel Operating P	kg/cm ² g	0.72	0.72	DP			
H (TL to center line)	kg/cm ²	-0.48	-0.48	DP			
DP Line	kg/cm ²	0.03	0.04	DP			
DP Strainer	kg/cm ²	(1)	(1)	DP Flowmeter	0.17 (2)		0.25
DP Other	kg/cm ²			DP Control Val.	2.21		1.99
Suction Pressure	kg/cm ² g	1.18	1.17	Discharge P	4.92		4.87

NPSH Available		Q Des.	Differential P @ Q des		Q Des.
Suction Pressure	kg/cm ² a	2.20	Discharge P	kg/cm ² g	4.87
Vapour Pressure @ T	kg/cm ² a	1.76	Suction P	kg/cm ² g	1.17
Difference	kg/cm ²	0.44	Differential P	kg/cm ²	3.71
NPSHA	m	5.04	Differential Head	m	42.1

Estimated Power Consumption		Q Nor.	Q Des.	Maximum Suction P		Q Des.
HHP	CV	0.07	0.08	Vessel P	kg/cm ² g	3.50
Pump Efficiency	%	8%	8%	H (HHL-Center Line)	kg/cm ²	0.51
BHP	CV	0.95	1.12	Maximum Suction P	kg/cm ² g	4.01

Maximum Discharge P		Q Des.
Max. Differ. P motor	kg/cm ²	3.79
Max. Differ. P turbine	kg/cm ²	-
Max. Discharge P	kg/cm ² g	7.80

NOTES

- (1) Strainer pressure drop included in line pressure drop as an equivalent straight pipe length of 300 ft.
- (2) DP Flowmeter FT-0203 estimated with Darcy's equation from design pressure drop .

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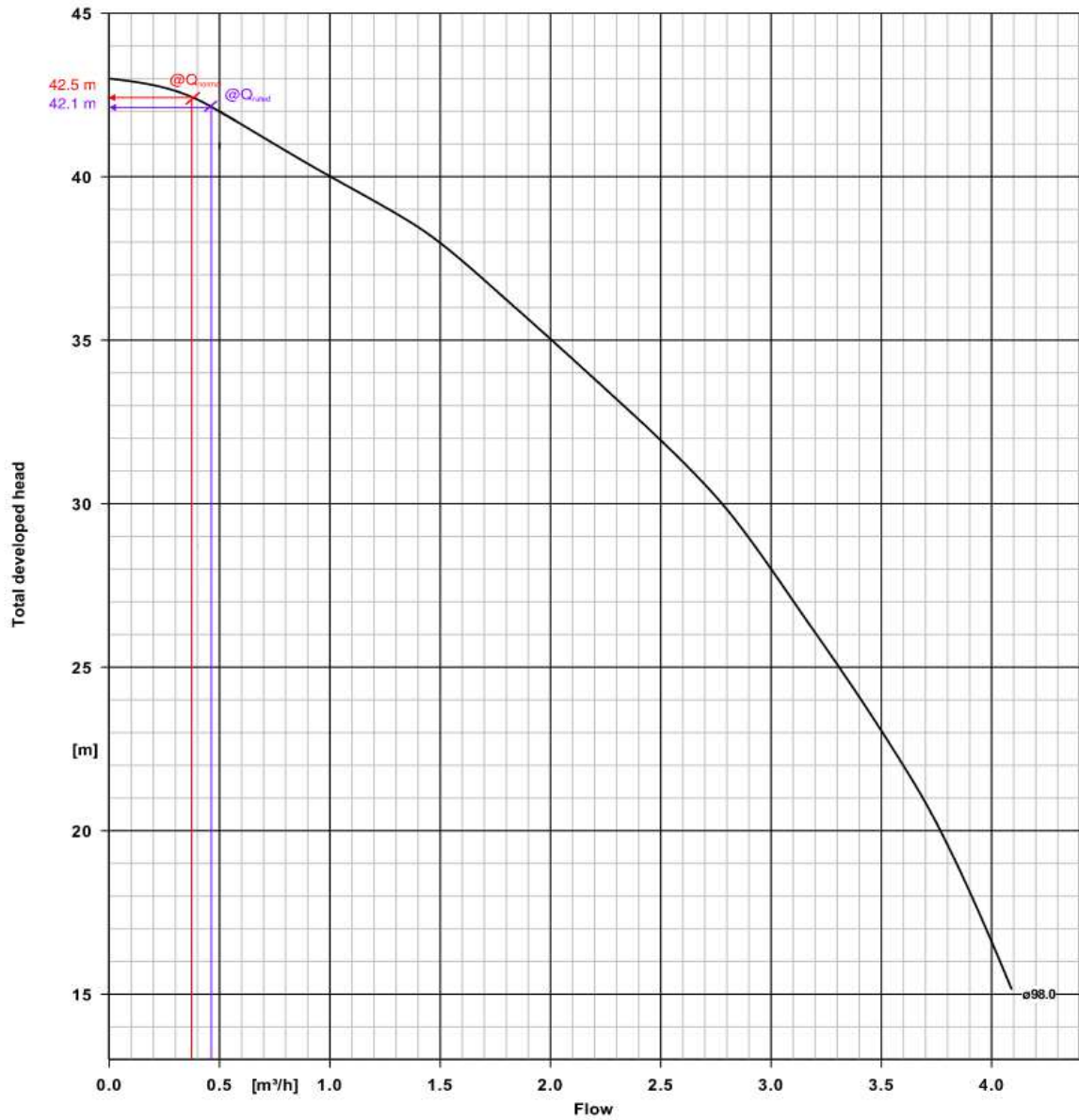


PUMP CALCULATION SHEET
P-203-A/B

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PUMP CURVE SUPPLIED BY VENDOR



TEN		UNIVERSITAT ROVIRA I VIRGILI		AIR COOLERS E-203									
Rev	CONDENSATION CURVES												
1	SIDE	TUBES	1	2	3	4	5	6	7	8	9	10	NOTES
2	Position		Outlet									Inlet	
3	Temperature, T	°C	43.0	48.4	53.7	59.1	64.4	69.8	75.1	80.5	85.8	91.2	
4	Pressure, P	kg/cm ² g	0.8	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80	
5	Vapour flow (wet)	kg/h	389.8	408.7	432.2	457.6	486.2	519.9	561.4	614.6	686.4	758.1	
6	Liquid Flow (dry)	kg/h	342.0	323.1	299.6	274.3	245.7	211.9	170.5	117.2	45.5	-	
7	Free water flow	kg/h	-	-	-	-	-	-	-	-	-	-	
8	Latent heat	kcal/kg	-1787	-1771	-1752	-1731	-1708	-1680	-1647	-1605	-1550	-1494	
9	Heat exchanged	Gcal/h	-1.31	-1.30	-1.28	-1.27	-1.25	-1.23	-1.21	-1.17	-1.13	-1.09	
10	Vapor phase (wet)												
11	Mol. Weight	kg/kmol	17.06	17.07	17.09	17.11	17.14	17.17	17.21	17.27	17.33	17.39	
12	Density @P,T	kg/m ³	1.14	1.14	1.14	1.13	1.11	1.10	1.08	1.07	1.06	1.05	
13	Viscosity @T	cP	0.011	0.011	0.011	0.011	0.012	0.012	0.012	0.012	0.012	0.013	
14	Thermal conduct. @T	kcal/h m °C	0.0240	0.024	0.024	0.024	0.025	0.025	0.025	0.025	0.025	0.025	
15	Specific heat @T	kcal/kg°C	0.510	0.512	0.513	0.514	0.514	0.514	0.513	0.511	0.508	0.505	
16	Liquid Phase (dry)												
17	Density @T	kg/m ³	880.5	885.0	891.5	897.5	903.0	908.1	912.8	917.1	921.1	-	
18	Viscosity @T	cSt	0.852	0.777	0.000	0.643	0.585	0.532	0.484	0.441	0.403	-	
19	Thermal conduct. @T	kcal/h m °C	0.4739	0.4756	0.4790	0.4829	0.4875	0.4926	0.4984	0.5049	0.5123	-	
20	Specific heat @T	kcal/kg°C	0.9948	1.01	1.016	1.024	1.031	1.037	1.042	1.047	1.052	-	
21	Surface tension @P,T	dines/cm	69.20	68.2	67.1	66.1	65.1	64.1	63.1	62.0	61.0	-	
22	NOTES:												
23													
24													
25													
26	CONDENSATION CURVES												
27	SIDE	TUBES	1	2	3	4	5	6	7	8	9	10	NOTES
28	Position		Outlet									Inlet	
29	Temperature, T	°C	43.0	48.4	53.7	59.1	64.4	69.8	75.1	80.5	85.8	91.2	
30	Pressure, P	kg/cm ² g	0.9	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	
31	Vapour flow (wet)	kg/h	379.6	402.9	426.1	451.0	478.6	510.9	550.1	599.7	665.5	731.4	
32	Liquid Flow (dry)	kg/h	352.3	329.0	305.7	280.9	253.2	221.0	181.8	132.1	66.3	-	
33	Free water flow	kg/h	-	-	-	-	-	-	-	-	-	-	
34	Latent heat	kcal/kg	-1792.850	-1774	-1756	-1735	-1713	-1687	-1655	-1616	-1565	-1514	
35	Heat exchanged	Gcal/h	-1.312	-1.30	-1.28	-1.27	-1.25	-1.23	-1.21	-1.18	-1.15	-1.11	
36	Vapor phase (wet)												
37	Mol. Weight	kg/kmol	17.05377	17.07	17.08	17.10	17.13	17.16	17.20	17.25	17.31	17.37	
38	Density @P,T	kg/m ³	1.247	1.23	1.21	1.19	1.17	1.16	1.14	1.13	1.11	1.10	
39	Viscosity @T	cP	0.011	0.011	0.011	0.011	0.012	0.012	0.012	0.012	0.012	0.013	
40	Thermal conduct. @T	kcal/h m °C	0.0232	0.024	0.024	0.024	0.025	0.025	0.025	0.025	0.026	0.026	
41	Specific heat @T	kcal/kg°C	0.5114	0.513	0.514	0.514	0.515	0.515	0.514	0.512	0.510	0.507	
42	Liquid Phase (dry)												
43	Density @T	kg/m ³	874.5	881.1	887.7	893.9	899.5	904.6	909.4	913.8	917.9	-	
44	Viscosity @T	cSt	0.8041	0.777	0.709	0.646	0.588	0.535	0.488	0.445	0.407	-	
45	Thermal conduct. @T	kcal/h m °C	0.4658	0.4737	0.4769	0.4806	0.4849	0.4898	0.4954	0.5017	0.5088	-	
46	Specific heat @T	kcal/kg°C	1.007	1.008	1.017	1.026	1.033	1.039	1.045	1.050	1.054	-	
47	Surface tension @P,T	dines/cm	69.20	68.2	67.1	66.1	65.1	64.1	63.1	62.0	61.0	-	
48	NOTES:												
49													
50													
51													
52	CONDENSATION CURVES												
53	SIDE	TUBES	1	2	3	4	5	6	7	8	9	10	NOTES
54	Position		Outlet									Inlet	
55	Temperature, T	°C	43.0	48.4	53.7	59.1	64.4	69.8	75.1	80.5	85.8	91.2	
56	Pressure, P	kg/cm ² g	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	
57	Vapour flow (wet)	kg/h	374.1	397.2	420.3	444.7	471.7	502.7	539.9	586.5	647.4	731.8	
58	Liquid Flow (dry)	kg/h	357.8	334.6	311.5	287.1	260.2	229.2	192.0	145.4	84.5	-	
59	Free water flow	kg/h	-	-	-	-	-	-	-	-	-	-	
60	Latent heat	kcal/kg	-1796	-1778	-1759	-1740	-1718	-1693	-1663	-1626	-1579	-1515	
61	Heat exchanged	Gcal/h	-1.31	-1.30	-1.29	-1.27	-1.26	-1.24	-1.22	-1.19	-1.16	-1.11	
62	Vapor phase (wet)												
63	Mol. Weight	kg/kmol	17.05	17.07	17.08	17.10	17.12	17.15	17.19	17.24	17.30	17.36	
64	Density @P,T	kg/m ³	1.31	1.29	1.27	1.25	1.23	1.22	1.20	1.18	1.17	1.16	
65	Viscosity @T	cP	0.011	0.011	0.011	0.011	0.012	0.012	0.012	0.012	0.012	0.013	
66	Thermal conduct. @T	kcal/h m °C	0.0232	0.024	0.024	0.025	0.025	0.025	0.025	0.026	0.026	0.026	
67	Specific heat @T	kcal/kg°C	0.5119	0.513	0.514	0.515	0.515	0.515	0.515	0.513	0.511	0.508	
68	Liquid Phase (dry)												
69	Density @T	kg/m ³	870.7	877.4	884.1	890.3	896.0	901.3	906.1	910.6	914.8	-	
70	Viscosity @T	cSt	0.805	0.776	0.710	0.648	0.591	0.538	0.491	0.448	0.410	-	
71	Thermal conduct. @T	kcal/h m °C	0.464	0.472	0.475	0.478	0.483	0.487	0.493	0.499	0.505	-	
72	Specific heat @T	kcal/kg°C	1.008	1.010	1.019	1.028	1.035	1.041	1.047	1.052	1.056	-	
73	Surface tension @P,T	dines/cm	69.2	68.2	67.1	66.1	65.1	64.1	63.1	62.0	61.0	-	
74	NOTES:												
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NOTES:

FANS AND DRIVE FROM EXISTENT PROCESS DATA SHEET

FANS				DRIVE			
Manufacturer				Driver data sheet	20 Kw		
Model	ENM/ENF			Driver type	Eexe, clase I, Z2, IIC T3		
Nº per bay	2			Drive type	V- belts		
Driver BHP/Duty	15.7 Kw			For Vee belt drive:			
Diameter	9	ft.RPM	348	400 V	50 Hz	1450 rpm	
Blades: Nº	4	angle	19,4	Fan shaft bearing			
Blade matl:	POLIESTER			manufacturer			
Fan adjustment:				Bearing typ. (s)			
	manual	50%	auto	50%			
Louvre adjustment:				For gearbox drive:			
	manual		auto	100%			
				Manufacturer			
				Type			
				Ratio			
				AGMA rating			
				Bearings			
				Coupling mfg.			
				Coupling type.			

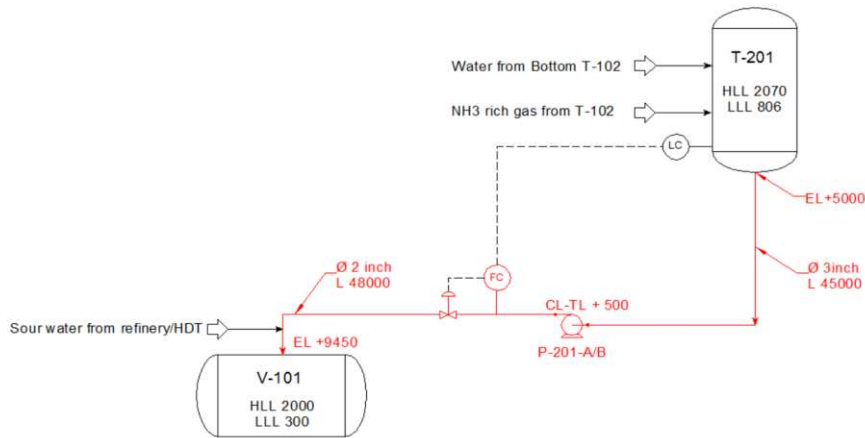


PUMP CALCULATION SHEET
P-201-A/B

SERVICE / CASE: NH3 water washing column bottom / Design (120% normal flow)

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FLOW SCHEME



Fluid Nature			
Pumping T	°C	96.0	
Viscosity @ T	cSt	0.34	
Density @ T	kg/m ³	903.7	
Capacity		Q Nor.	Q Des.
Mass Flow	kg/h	3531	4237
Volumetric Flow	m ³ /h	3.91	4.69
Suction Pressure		Q Nor.	Q Des.
Vessel Operating P	kg/cm ² g	1.10	1.10
H (TL to center line)	kg/cm ²	-0.52	-0.52
DP Line	kg/cm ²	0.010	0.014
DP Strainer	kg/cm ²	(1)	(1)
DP Other	kg/cm ²		
Suction Pressure	kg/cm ² g	1.61	1.61
NPSH Available		Q Des.	
Suction Pressure	kg/cm ² a	2.64	
Vapour Pressure @ T	kg/cm ² a	2.13	
Difference	kg/cm ²	0.51	
NPSHA	m	5.65	
Estimated Power Consumption		Q Nor.	Q Des.
HHP	CV	0.28	0.33
Pump Efficiency	%	51%	55%
BHP	CV	0.54	0.60
Motor			
Motor Efficiency	%	70%	73%
Power (3)	kWh/h	0.57	0.61

Discharge P	Q Nor.			Q Des.
	Circ.1	Circ.2	Circ.3	
Destination P	1.20			1.20
DP Distributor				
Static Height	0.81			0.81
DP Line	0.09			0.12
DP Strainer				
DP				
DP				
DP				
DP				
DP Flowmeter	0.17 (2)			0.25
DP Control Val.	1.29			1.14
Discharge P	3.56			3.52

Differential P @ Q des		Q Des.
Discharge P	kg/cm ² g	3.52
Suction P	kg/cm ² g	1.61
Differential P	kg/cm ²	1.91
Differential Head	m	21.1

Maximum Suction P		Q Des.
Vessel P	kg/cm ² g	3.50
H (HLL-Center Line)	kg/cm ²	0.65
Maximum Suction P	kg/cm ² g	4.15

Maximum Discharge P		Q Des.
Max. Differ. P motor	kg/cm ²	2.12
Max. Differ. P turbine	kg/cm ²	-
Max. Discharge P	kg/cm ² g	6.27

NOTES

- (1) Strainer pressure drop included in line pressure drop as an equivalent straight pipe length of 300 ft.
- (2) DP Flowmeter FT-0202 estimated with Darcy's equation from design pressure drop .
- (3) Estimated power consumption from theoretical expressions since it is more conservative than the pump curve one.



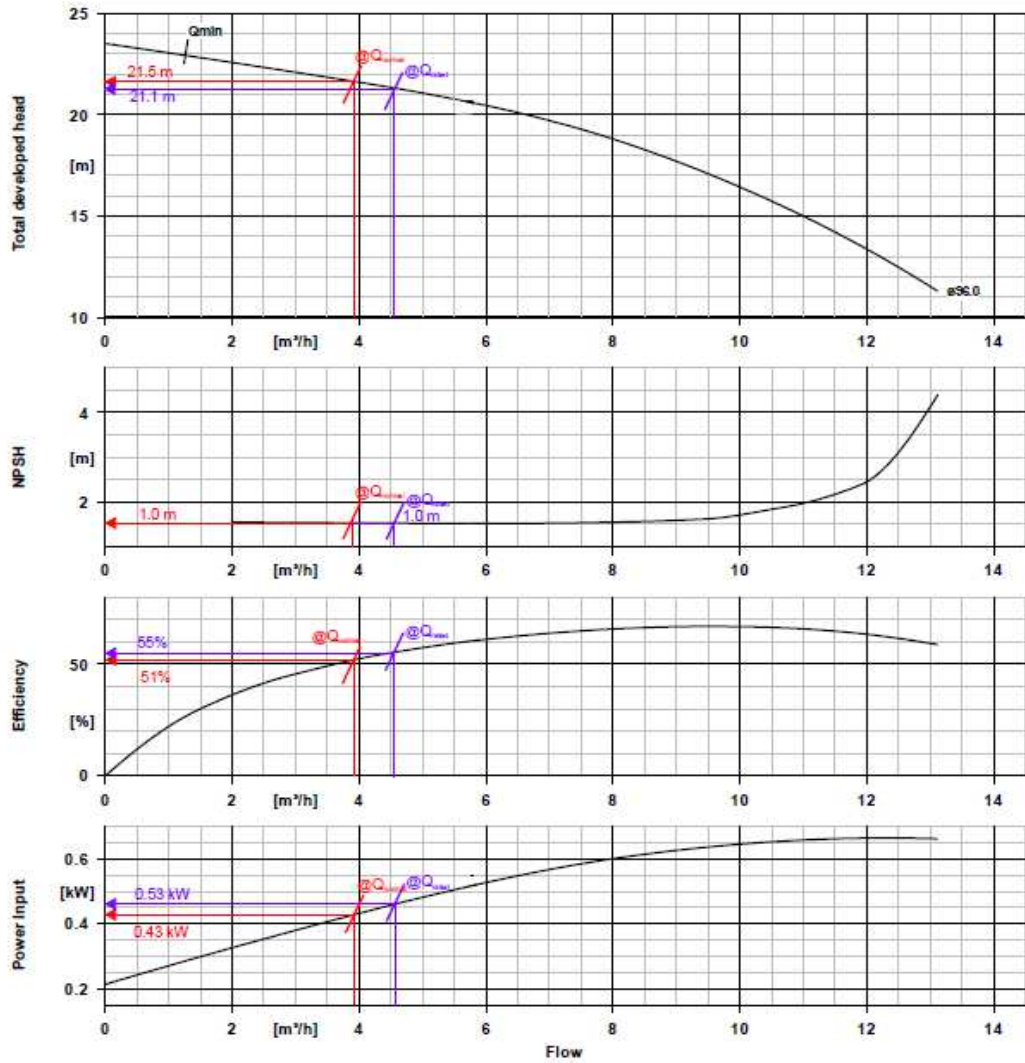
PUMP CALCULATION SHEET
P-201-A/B

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NOTES

PUMP CURVES SUPPLIED BY VENDOR

MovitecV 010/02-B4F13ES080B5UW
High pressure Inline Pump



APPEND C: INSTRUMENT PDS



FLOW INSTRUMENTS

Rev						
1	GENERAL DATA					
2	ITEM N°		FT/FE-0100 (5)	FT/FE-0101 (6)	FT/FE-0102	FT/FE-0103 (5)
3						
4	Service/Purpose (control, H&MB info,...)		Sour water from refinery	H ₂ S stripper inlet	E-102 shell inlet	E-103 condensate
5						
6	Design Case		Validation-Normal op.	Validation-Normal op.	Validation-Normal op.	Validation-Normal op.
7						
8	OPERATING CONDITIONS AND FLUID PROPERTIES					
9	Fluid Nature		H ₂ O+H ₂ S+NH ₃	H ₂ O+H ₂ S+NH ₃	H ₂ O+H ₂ S+NH ₃	MP condensate
10	Corrosive / Toxic Compounds (1)	wt % / wt ppm	2.1% (H ₂ S) / 1.2% (NH ₃)	2.0% (H ₂ S) / 1.9% (NH ₃)	0.12% (H ₂ S) / 1.8% (NH ₃)	-
11	Phase (2)		L	L	L	L
12	NORMAL FLOW : Liquid @ 15,4 °C	m ³ /h	13.72	38.74	36.6	5.34
13	Gas @ 0°C y 1 atm.	Nm ³ /h	-	-	-	-
14	Steam	kg/h	-	-	-	-
15	Minimum / Maximum Flow	%	60% / 120%	60% / 120%	60% / 120%	60% / 120%
16	Inlet Temperature (Q min / norm / max)	°C	31.2	117.2	169.4	187.3
17	Inlet Pressure (Q min / norm / max)	kg/cm ² g	2.6/2.6/2.5	12.8/11.9/11.2	8.5/ 8.5/ 8.5	10.7/10.6/10.3
18	Gas Molecular Weight		-	-	-	-
19	Liquid Density @ 15,4 °C	Sp.Gr	0.99	0.96	0.99	1.00
20	Liquid Pour Point	°C	-	-	-	-
21	Liquid vapour pressure	kg/cm ² a	0.16	3.7	9.3	12.0
22	Density @ P,T	kg/m ³	959.3	904.5	862.6	879.1
23	Viscosity @ T	cP (G) / cSt (L)	0.710	0.234	0.190	0.163
24	INSTRUMENT CHARACTERISTICS					
25	Type of Measuring Device (orifice,...)		Orifice	Orifice	Orifice	Orifice
26	Location (3)		P	L	L	-
27	Maximum Allowable DP at End of Scale (4)	mm wc	-	-	2416	1500
28	Alarm and Trips Settings(Normal Flow:100%)		-	-	-	
29	Alarm High (H) / Very High (HH)	%				
30	Alarm Low (L) / Very Low (LL)	%				
31	Trip High (H) / Low (L)	%				
32	Tracing,Diaphragm,Flushing Requirements		-	-	-	
33	Located in : "Line Size / Number"		3" / W-0501	4" / W-0106	4" / W-0107	2" / CMP-0526
34	Desing Conditions (P - T)	kg/cm ² g - °C	7.5 - 35.0	15.7 - 125.8	12.1 - 171	13.4 - 185.8
35	NOTES:					
36	(1) To be indicated particles, gums and any other component causing fouling.					
37	(2) Specify gas (G), liquid (L), or steam (V).					
38	(3) Specify local (L), control room (P) or local panel (PL).					
39	(4) Indicate when max. pressure drop is limited to values below the normal 2500 mm wc.					
40	(5) Not valid for normal flow conditions.					
41	(6) Not valid for maximum flow conditions.					
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FLOW INSTRUMENTS

Rev						
1	GENERAL DATA					
2	ITEM N°		FT-0106 (5)	FT/FE-0107 (5)	FT-0109 (5)	123-FT-0110 (6)
3						
4	Service/Purpose (control, H&MB info,...)		Washing water to T-103	Washing water to T-103	Washing water to T-103	E-106 inlet
5						
6	Design Case		Validation-Normal op.	Validation-Normal op.	Validation-Normal op.	Validation-Normal op.
7						
8	OPERATING CONDITIONS AND FLUID PROPERTIES					
9	Fluid Nature		H ₂ O	H ₂ O	H ₂ O	H ₂ O+H ₂ S+NH ₃
10	Corrosive / Toxic Compounds (1)	wt % / wt ppm	-	-	-	1.7% (H ₂ S)/ 6.2% (NH ₃)
11	Phase (2)		L	L	L	L
12	NORMAL FLOW : Liquid @ 15,4 °C	m ³ /h	0.78	0.78	1.6	109.10
13	Gas @ 0°C y 1 atm.	Nm ³ /h	-	-	-	-
14	Steam	kg/h	-	-	-	-
15	Minimum / Maximum Flow	%	60% / 120%	60% / 120%	60% / 120%	60% / 120%
16	Inlet Temperature (Q min / norm / max)	°C	40.0	40.0	40.0	102.9
17	Inlet Pressure (Q min / norm / max)	kg/cm ² g	8.0/8.1/8.2	8.0/8.1/8.2	19.4/ 18.0/ 16.9	9.3/8.4/7.8
18	Gas Molecular Weight		-	-	-	-
19	Liquid Density @ 15,4 °C	Sp.Gr	1.00	1.00	1.00	0.96
20	Liquid Pour Point	°C	-	-	-	-
21	Liquid vapour pressure	kg/cm ² a	0.08	0.1	0.1	2,3
22	Density @ P,T	kg/m ³	993.0	993.0	993.0	897.3
23	Viscosity @ T	cP (G) / cSt (L)	0.677	0.677	0.677	0.297
24						
25	Type of Measuring Device (orifice,...)		Orifice	Orifice	Orifice	Orifice
26	Location (3)		P	P	L	L
27	Maximum Allowable DP at End of Scale (4)	mm wc	-	-	-	-
28	Alarm and Trips Settings(Normal Flow:100%)		-	-	-	-
29	Alarm High (H) / Very High (HH)	%				
30	Alarm Low (L) / Very Low (LL)	%				
31	Trip High (H) / Low (L)	%				
32	Tracing,Diaphragm,Flushing Requirements		-	-	-	-
33	Located in : "Line Size / Number"		1 1/2" / W-1009	1 1/2"/ W-0119	1 1/2"/ W-1009	6" / W-1012
34	Desing Conditions (P - T)	kg/cm ² g - °C	18.6 - 65	18.6 - 65	13.8 - 65	11.1 - 118
35	NOTES:					
36	(1) To be indicated particles, gums and any other component causing fouling.					
37	(2) Specify gas (G), liquid (L), or steam (V).					
38	(3) Specify local (L), control room (P) or local panel (PL).					
39	(4) Indicate when max. pressure drop is limited to values below the normal 2500 mm wc.					
40	(5) FT-0106/0707/0709 not valid for normal flow. Design pressure of existing flowmeters is below P-202-A/B closed valve pressure.					
41	(6) FT-0110 not valid for maximum flow (120%).					
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FLOW INSTRUMENTS

Rev						
1	GENERAL DATA					
2	ITEM N°		FT-0111	FT-0112	FT-0116	FT-0201
3						
4	Service/Purpose (control, H&MB info,...)		Stripped water B.L.	E-104 condensate	Acid gas to sulphur plant	Washing water to T-201
5						
6	Design Case		Validation-Normal op.	Validation-Normal op.	Validation-Normal op.	120% Normal Flow
7						
8	OPERATING CONDITIONS AND FLUID PROPERTIES					
9	Fluid Nature		H ₂ O	LP condensate	H ₂ O+H ₂ S	H ₂ O
10	Corrosive / Toxic Compounds (1)	wt % / wt ppm	-	-	99.9% (H ₂ S)	-
11	Phase (2)		L	L	G	L
12	NORMAL FLOW : Liquid @ 15,4 °C	m ³ /h	18.67	7.43	-	2.83
13	Gas @ 0°C y 1 atm.	Nm ³ /h	-	-	459.15	-
14	Steam	kg/h	-	-	-	-
15	Minimum / Maximum Flow	%	60% / 120%	60% / 120%	60% / 120%	60% / 120%
16	Inlet Temperature (Q min / norm / max)	°C	65.2	152.6	31.8	40.0
17	Inlet Pressure (Q min / norm / max)	kg/cm ² g	15.3/13.7/10.3	4.2/4.2/4.1	7.9/7.8/7.8	19.1/ 18.0/ 16.9
18	Gas Molecular Weight		-	-	33.92	-
19	Liquid Density @ 15,4 °C	Sp.Gr	1.00	1.00	-	1.00
20	Liquid Pour Point	°C	-	-	-	-
21	Liquid vapour pressure	kg/cm ² a	0.26	5.2	-	0.1
22	Density @ P,T	kg/m ³	980.5	914.4	2.4	933.0
23	Viscosity @ T	cP (G) / cSt (L)	0.446	0.193	0.014	0.676
24	INSTRUMENT CHARACTERISTICS					
25	Type of Measuring Device (orifice,...)		Orifice	Orifice	Orifice	Orifice
26	Location (3)		P	-	-	-
27	Maximum Allowable DP at End of Scale (4)	mm wc	-	1500	-	-
28	Alarm and Trips Settings(Normal Flow:100%)		-	-	-	-
29	Alarm High (H) / Very High (HH)	%				
30	Alarm Low (L) / Very Low (LL)	%				
31	Trip High (H) / Low (L)	%				
32	Tracing,Diaphragm,Flushing Requirements		-	-	-	-
33	Located in : "Line Size / Number"		4" / W-1007	3" / CLP-1024	2" / WG-0520	2" / W-2009
34	Desing Conditions (P - T)	kg/cm ² g - °C	18.6 - 86	7.0 - 147.4	4.5 - 110	19.0-145
35	NOTES:					
36	(1) To be indicated particles, gums and any other component causing fouling.					
37	(2) Specify gas (G), liquid (L), or steam (V).					
38	(3) Specify local (L), control room (P) or local panel (PL).					
39	(4) Indicate when max. pressure drop is limited to values below the normal 2500 mm wc.					
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FLOW INSTRUMENTS

Rev					
1	GENERAL DATA				
2	ITEM N°		FT-0202	FT-0203	
3					
4	Service/Purpose (control, H&MB info,...)		T-201 bottom	Liquid from V-201	
5					
6	Design Case		120% Normal Flow	120% Normal Flow	
7					
8	OPERATING CONDITIONS AND FLUID PROPERTIES				
9	Fluid Nature		H ₂ O+H ₂ S+NH ₃	H ₂ O+H ₂ S+NH ₃	
10	Corrosive / Toxic Compounds (1)	wt % / wt ppm	1.2% (H ₂ S) / 8.1% (NH ₃)	28.6% (NH ₃)	
11	Phase (2)		L	L	
12	NORMAL FLOW : Liquid @ 15,4 °C	m ³ /h	3.64	0.38	
13	Gas @ 0°C y 1 atm.	Nm ³ /h	-	-	
14	Steam	kg/h	-	-	
15	Minimum / Maximum Flow	%	60% / 120%	60% / 120%	
16	Inlet Temperature (Q min / norm / max)	°C	96.0	42.6	
17	Inlet Pressure (Q min / norm / max)	kg/cm ² g	3.6/3.6/3.5	5.0/4.8/4.9	
18	Gas Molecular Weight		-	-	
19	Liquid Density @ 15,4 °C	Sp.Gr	0.97	0.91	
20	Liquid Pour Point	°C	-	-	
21	Liquid vapour pressure	kg/cm ² a	2.13	1.8	
22	Density @ P,T	kg/m ³	903.7	880.6	
23	Viscosity @ T	cP (G) / cSt (L)	0.336	0.857	
24	INSTRUMENT CHARACTERISTICS				
25	Type of Measuring Device (orifice,...)		Orifice	Orifice	
26	Location (3)		-	-	
27	Maximum Allowable DP at End of Scale (4)	mm wc	-	-	
28	Alarm and Trips Settings(Normal Flow:100%)		-	-	
29	Alarm High (H) / Very High (HH)	%			
30	Alarm Low (L) / Very Low (LL)	%			
31	Trip High (H) / Low (L)	%			
32	Tracing,Diaphragm,Flushing Requirements		-	-	
33	Located in : "Line Size / Number"		2" / W-2018	4" / WG-1022	
34	Desing Conditions (P - T)	kg/cm ² g - °C	6.2 - 120	7.7 - 120	
35	NOTES:				
36	(1) To be indicated particles, gums and any other component causing fouling.				
37	(2) Specify gas (G), liquid (L), or steam (V).				
38	(3) Specify local (L), control room (P) or local panel (PL).				
39	(4) Indicate when max. pressure drop is limited to values below the normal 2500 mm wc.				
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TEMPERATURE INSTRUMENTS

Rev							
1	GENERAL DATA						
2	ITEM N°		TI/TT-0201	TI/TT-0202	TI/TT-0203	TI/TT-0204	
3							
4	Service/Purpose (control, H&MB info,...)		E-202 inlet	E-202 outlet	E-201 outlet (tubes)	E-203 inlet	
5							
6	Design Case		Normal	Normal	Normal	Normal	
7							
8	OPERATING CONDITIONS AND FLUID PROPERTIES						
9	Fluid Nature		Treated water	Treated water	CWR	H ₂ O+NH ₃	
10	Corrosive / Toxic Compounds (1)		wt % / wt ppm	-	-	64.8% (NH ₃)	
11	Phase (2)		L	L	L	G	
12	Pressure		kg/cm ² g	18.6	16.8	6.3	
13	Temperature		Min. °C	-	-	-	
14			Norm. °C	126.8	50.0	40	91.2
15			Max. °C	141 (5)	141 (5)	80 (6)	120 (7)
16	INSTRUMENT CHARACTERISTICS						
17	Situation			P	P	P	
18	Settings		Alarms	TAL °C	-	-	-
19				TALL °C	-	-	-
20				TAH °C	-	-	-
21				TAHH °C	-	-	-
22			Trip	TSL °C	-	-	-
23				TSH °C	-	-	-
24	Tracing (4)		(y/n)	n	n	n	
25	Located in Line / Vessel			W-2004	W-2005	CCW-8027	
26	Design Conditions		Pressure	kg/cm ² g	23.0 (5)	23.0 (5)	
27			Temperature	°C	145 (5)	145 (5)	80 (6)
28	NOTES:						
29	(1) Specify gas (G), liquid (L), steam (V) or mixed (M).						
30	(2) Specify operating conditions. For mech. design conditions refer to associated line or equipment .						
31	(3) Specify local (L), control room (P) or local panel (PL).						
32	(4) Indicate Tracing / Diaphragm / Flushing.						
33	(5) P-202 mechanical design conditions.						
34	(6) E-201 tube side mechanical design conditions.						
35	(7) T-201 mechanical design conditions.						
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CONTROL VALVES

Rev	GENERAL FEATURES					
1	ITEM N°		FV-0100		FV-0100N	
2	SERVICE		Sour water from refinery		Sour water from refinery	
3						
4	Design Case		Validation		Maximum flow	
5	OPERATING CONDITIONS					
6			INLET		OUTLET	
7	Fluid Nature		H ₂ O+H ₂ S+NH ₃		H ₂ O+H ₂ S+NH ₃	
8	Corrosive / Toxic Compounds (1)	wt % / wt ppm	2.1% (H ₂ S)/ 1.2% (NH ₃)		2.1% (H ₂ S)/ 1.2% (NH ₃)	
9	Liquid Normal Flow	kg/h	1.321E+04	1.321E+04	1.321E+04	1.321E+04
10	Gas Normal Flow	kg/h	-	-	-	-
11	Steam Normal Flow	kg/h	-	-	-	-
12	Minimum / Maximum Flow	%	60/ 120%		60/ 120%	
13	Temperature	°C	31.2		31.2	
14	Liquid Density @ P, T	kg/m ³	959.30		959.30	
15	Liquid Viscosity @ P, T	cSt	0.71		0.71	
16	Vapour Pressure @ T	kg/cm ² a	0.16		0.16	
17	Critical Pressure	kg/cm ² a	280.4		280.4	
18	Gas Molecular Weight	-	-		-	
19	Gas Density @ P, T	kg/m ³	-		-	
20	Gas Compressibility, Z @ P,T	-	-		-	
21	Cp / Cv	-	-		-	
22	Pressure at Normal Flow	kg/cm ² g	3.0	1.8	3.0	1.8
23	Pressure at Maximum Flow	kg/cm ² g	2.8	1.8	2.8	1.8
24	Pressure at Minimum Flow	kg/cm ² g	3.1	1.7	3.1	1.7
25	Pressure at Closed Valve	kg/cm ² g	-		-	
26	CARACTERÍSTICAS DE LA VÁLVULA					
27	Valve Tightness (2)	y / n	n		n	
28	Min/Max Valve Opening (Limit Stop)(3)	%	n		n	
29	Maximum Allowable CV (4)	-	-		-	
30	Air Failure Action (5)	-	FC		FC	
31	On / Off Action	y / n	n		n	
32	Valve Size Equal to Line Size	y / -	n		n	
33	DESIGN CONDITIONS					
34	Design Pressure	kg/cm ² g	7.0		7.0	
35	Design Temperature	°C	200.0		200.0	
36	EXISTING VALVES VALIDATION					
37	Located in Line	-	3"-W-0101		3"-W-0101	
38	Valve Model and Maker	-	88-21124/78/SVI - Dresser			
39	Valve Curve (6)	-	Isopercentage		Isopercentage	
40	Installed CV in Existing Valve	-	26.0		46.0	
41	Estimated CV for New Conditions (8)	-	8.26/ 14.0/ 16.9		8.26/ 14.0/ 16.9	
42	Validity (7)	-	NOT VALID (9)		(10)	
43	NOTES:					
44	(1) To be indicated particles, gums and any other component causing fouling.					
45	(2) Tight valve means ANSI class V or VI. Indicate TSO for requirements above class V or VI.					
46	(3) Indicate if valve opening shall be limited because of process or safety reasons.					
47	(4) Indicate max allowable CV (downstream PSV sizing,...).					
48	(5) Safety valve position for air failure: FA (Fail open), FC (Fail close) o FP (Fail keeps position).					
49	(6) Indicate Lineal, Isopercentage or Quick opening.					
50	(7) Indicate VALID or NOT VALID. NOT VALID might mean changes or new valve.					
51	(8) Cv calculated for minimum/ normal/ maximum flow.					
52	(9) FV-0100 not valid for maximum flow conditions (Valve opening exceeds 85%). Replaced by FV-0100N.					
53	(10) New valve substituting to FV-0100.					
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CONTROL VALVES

Rev	GENERAL FEATURES					
1	ITEM N°		FV-0101		FV-0101N	
2	SERVICE		H2S stripper inlet		H2S stripper inlet	
3						
4	Design Case		Validation		Maximum flow	
5	OPERATING CONDITIONS					
6			INLET	OUTLET	INLET	OUTLET
7	Fluid Nature		H ₂ O+H ₂ S+NH ₃		H ₂ O+H ₂ S+NH ₃	
8	Corrosive / Toxic Compounds (1)	wt % / wt ppm	2.0% (H ₂ S)/ 1.9% (NH ₃)		2.0% (H ₂ S)/ 1.9% (NH ₃)	
9	Liquid Normal Flow	kg/h	3.728E+04	3.728E+04	3.728E+04	3.728E+04
10	Gas Normal Flow	kg/h	-	-	-	-
11	Steam Normal Flow	kg/h	-	-	-	-
12	Minimum / Maximum Flow	%	60/ 120%		60%	120%
13	Temperature	°C	117.2		117.2	117.2
14	Liquid Density @ P, T	kg/m ³	904.50		904.50	904.40
15	Liquid Viscosity @ P, T	cSt	0.23		0.23	0.23
16	Vapour Pressure @ T	kg/cm ² a	3.7		3.7	3.7
17	Critical Pressure	kg/cm ² a	221.4		221.4	221.4
18	Gas Molecular Weight	-	-		-	-
19	Gas Density @ P, T	kg/m ³	-		-	-
20	Gas Compresibility, Z @ P,T	-	-		-	-
21	Cp / Cv	-	-		-	-
22	Pressure at Normal Flow	kg/cm ² g	12.4	10.9	12.4	10.9
23	Pressure at Maximum Flow	kg/cm ² g	12.0	11.0	12.0	11.0
24	Pressure at Minimum Flow	kg/cm ² g	12.9	10.4	12.9	10.4
25	Pressure at Closed Valve	kg/cm ² g	19.9		19.9	
26	CARACTERÍSTICAS DE LA VÁLVULA					
27	Valve Tightness (2)	y / n	n		n	
28	Min/Max Valve Opening (Limit Stop)(3)	%	n		n	
29	Maximum Allowable CV (4)	-	-		-	
30	Air Failure Action (5)	-	FC		FC	
31	On / Off Action	y / n	n		n	
32	Valve Size Equal to Line Size	y / -	n		n	
33	DESIGN CONDITIONS					
34	Design Pressure	kg/cm ² g	15.7		15.7	
35	Design Temperature	°C	141.0		141.0	
36	EXISTING VALVES VALIDATION					
37	Located in Line	-	4"-W-0506		4"-W-0506	
38	Valve Model and Maker	-	88-21124/78/SVI - Dresser			
39	Valve Curve (6)	-	Isopercentage		Isopercentage	
40	Installed CV in Existing Valve	-	65.0		110	
41	Estimated CV for New Conditions (8)	-	17.4/ 37.0/ 56.9		17.4/ 37.0/ 56.9	
42	Validity (7)	-	NOT VALID (9)		(10)	
43	NOTES:					
44	(1) To be indicated particles, gums and any other component causing fouling.					
45	(2) Tight valve means ANSI class V or VI. Indicate TSO for requirements above class V or VI.					
46	(3) Indicate if valve opening shall be limited because of process or safety reasons.					
47	(4) Indicate max allowable CV (downstream PSV sizing,...).					
48	(5) Safety valve position for air failure: FA (Fail open), FC (Fail close) o FP (Fail keeps position).					
49	(6) Indicate Lineal, Isopercentage or Quick opening.					
50	(7) Indicate VALID or NOT VALID. NOT VALID might mean changes or new valve.					
51	(8) Cv calculated for minimum/ normal/ maximum flow.					
52	(9) FV-0101 not valid for normal/ maximum flow operation (required opening percentage greater than 85%).					
53	Replaced by FV-0101N.					
54	(10) Replaces to FV-0101.					
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CONTROL VALVES

Rev	GENERAL FEATURES					
1	ITEM N°		FV-0102		FV-0103	
2	SERVICE		E-102 Shell outlet		MP condensate	
3						
4	Design Case		Validation		Validation	
5	OPERATING CONDITIONS					
6			INLET	OUTLET	INLET	OUTLET
7	Fluid Nature		H ₂ O+H ₂ S+NH ₃		H ₂ O	
8	Corrosive / Toxic Compounds (1)	wt % / wt ppm	0.12% (H ₂ S)/ 1.8% (NH ₃)		-	
9	Liquid Normal Flow	kg/h	2.138E+04	2.138E+04	5334	5334
10	Gas Normal Flow	kg/h	-	-	-	-
11	Steam Normal Flow	kg/h	-	-	-	676.1
12	Minimum / Maximum Flow	%	60/ 120%		60%	120%
13	Temperature	°C	116.5		187.3	135.2
14	Liquid Density @ P, T	kg/m ³	929.80		880.70	930.1
15	Liquid Viscosity @ P, T	cSt	0.26		0.16	0.22
16	Vapour Pressure @ T	kg/cm ² a	2.27		11.62	3.19
17	Critical Pressure	kg/cm ² a	229.8		229.8	229.8
18	Gas Molecular Weight	-	-		-	18.02
19	Gas Density @ P, T	kg/m ³	-		-	1.703
20	Gas Compresibility, Z @ P,T	-	-		-	0.9786
21	Cp / Cv	-	-		-	1.342
22	Pressure at Normal Flow	kg/cm ² g	8.6	3.5	11.0	2.2
23	Pressure at Maximum Flow	kg/cm ² g	8.5	3.5	11.0	2.2
24	Pressure at Minimum Flow	kg/cm ² g	8.8	3.5	11.0	2.2
25	Pressure at Closed Valve	kg/cm ² g	-		-	
26	CARACTERÍSTICAS DE LA VÁLVULA					
27	Valve Tightness (2)	y / n	n		n	
28	Min/Max Valve Opening (Limit Stop)(3)	%	n		n	
29	Maximum Allowable CV (4)	-	-		-	
30	Air Failure Action (5)	-	FC		FC	
31	On / Off Action	y / n	n		n	
32	Valve Size Equal to Line Size	y / -	n		y	
33	DESIGN CONDITIONS					
34	Design Pressure	kg/cm ² g	12.1		13.4	
35	Design Temperature	°C	172.0		300.0	
36	EXISTING VALVES VALIDATION					
37	Located in Line	-	4"-W-0508		2"-CMP-0526	
38	Valve Model and Maker	-	88-21714/78/SVI - Dresser		88-21124/78/SVI - Dresser	
39	Valve Curve (6)	-	Linear		Isopercentage	
40	Installed CV in Existing Valve	-	25.0		15.0	
41	Estimated CV for New Conditions (8)	-	6.78/ 11.5/ 13.9		3.97/ 6.64/ 7.98	
42	Validity (7)	-	VALID		VALID	
43	NOTES:					
44	(1) To be indicated particles, gums and any other component causing fouling.					
45	(2) Tight valve means ANSI class V or VI. Indicate TSO for requirements above class V or VI.					
46	(3) Indicate if valve opening shall be limited because of process or safety reasons.					
47	(4) Indicate max allowable CV (downstream PSV sizing,...).					
48	(5) Safety valve position for air failure: FA (Fail open), FC (Fail close) o FP (Fail keeps position).					
49	(6) Indicate Lineal, Isopercentage or Quick opening.					
50	(7) Indicate VALID or NOT VALID. NOT VALID might mean changes or new valve.					
51	(8) Cv calculated for minimum/ normal/ maximum flow.					
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CONTROL VALVES

Rev	GENERAL FEATURES					
1	ITEM N°		FV-0109		FV-0109N	
2	SERVICE		Washing water to T-103		Washing water to T-103	
3						
4	Design Case		Validation		Maximum flow	
5	OPERATING CONDITIONS					
6			INLET	OUTLET	INLET	OUTLET
7	Fluid Nature		-		-	
8	Corrosive / Toxic Compounds (1)	wt % / wt ppm	-		-	
9	Liquid Normal Flow	kg/h	1558	1558	1558	1558
10	Gas Normal Flow	kg/h	-	-	-	-
11	Steam Normal Flow	kg/h	-	-	-	-
12	Minimum / Maximum Flow	%	60/ 120%		60/ 120%	
13	Temperature	°C	40.0		40.0	
14	Liquid Density @ P, T	kg/m ³	993.0		993.0	
15	Liquid Viscosity @ P, T	cSt	0.68		0.68	
16	Vapour Pressure @ T	kg/cm ² a	0.08		0.08	
17	Critical Pressure	kg/cm ² a	229.8		229.8	
18	Gas Molecular Weight	-	-		-	
19	Gas Density @ P, T	kg/m ³	-		-	
20	Gas Compressibility, Z @ P,T	-	-		-	
21	Cp / Cv	-	-		-	
22	Pressure at Normal Flow	kg/cm ² g	17.8	12.3	17.8	12.3
23	Pressure at Maximum Flow	kg/cm ² g	16.6	12.5	16.6	12.5
24	Pressure at Minimum Flow	kg/cm ² g	19.3	10.9	19.3	10.9
25	Pressure at Closed Valve	kg/cm ² g	23.0		23.0	
26	CARACTERÍSTICAS DE LA VÁLVULA					
27	Valve Tightness (2)	y / n	n		n	
28	Min/Max Valve Opening (Limit Stop)(3)	%	n		n	
29	Maximum Allowable CV (4)	-	-		-	
30	Air Failure Action (5)	-	FC		FC	
31	On / Off Action	y / n	n		n	
32	Valve Size Equal to Line Size	y / -	n		n	
33	DESIGN CONDITIONS					
34	Design Pressure	kg/cm ² g	18.6		23.0	
35	Design Temperature	°C	86.0		145.0	
36	EXISTING VALVES VALIDATION					
37	Located in Line	-	1 1/2"-W-1009		1 1/2"-W-1009	
38	Valve Model and Maker	-	88-21114/78/SVI - Dresser			
39	Valve Curve (6)	-	Linear		Linear	
40	Installed CV in Existing Valve	-	0.60		1.70	
41	Estimated CV for New Conditions (8)	-	0.38/ 0.78/ 1.09		0.38/ 0.78/ 1.09	
42	Validity (7)	-	NOT VALID (9) (10)			
43	NOTES:					
44	(1) To be indicated particles, gums and any other component causing fouling.					
45	(2) Tight valve means ANSI class V or VI. Indicate TSO for requirements above class V or VI.					
46	(3) Indicate if valve opening shall be limited because of process or safety reasons.					
47	(4) Indicate max allowable CV (downstream PSV sizing,...).					
48	(5) Safety valve position for air failure: FA (Fail open), FC (Fail close) o FP (Fail keeps position).					
49	(6) Indicate Lineal, Isopercentage or Quick opening.					
50	(7) Indicate VALID or NOT VALID. NOT VALID might mean changes or new valve.					
51	(8) Cv calculated for minimum/ normal/ maximum flow.					
52	(9) FV-0109 not valid for normal/maximum flow operating conditions (opening percentage required exceeds 100%).					
53	Operating pressure exceeds mechanical design conditions.					
54	(10) Replaced by FV-0109N.					
55	(11) Replaces to FV-0109.					
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CONTROL VALVES

Rev	GENERAL FEATURES					
1	ITEM N°		FV-0110		FV-0111	
2	SERVICE		E-106 inlet		Stripped water B.L.	
3						
4	Design Case		Validation		Validation	
5	OPERATING CONDITIONS					
6			INLET	OUTLET	INLET	OUTLET
7	Fluid Nature		H ₂ O+H ₂ S+NH ₃		H ₂ O	
8	Corrosive / Toxic Compounds (1)	wt % / wt ppm	1.7 wt% (H ₂ S)/ 6.2% (NH ₃)		-	
9	Liquid Normal Flow	kg/h	1.050E+05	1.050E+05	1.865E+04	1.865E+04
10	Gas Normal Flow	kg/h	-	-	-	-
11	Steam Normal Flow	kg/h	-	-	-	-
12	Minimum / Maximum Flow	%	60/ 120%		60/ 120%	
13	Temperature	°C	102.9		65.0	
14	Liquid Density @ P, T	kg/m ³	897.5		980.50	
15	Liquid Viscosity @ P, T	cSt	0.30		0.45	
16	Vapour Pressure @ T	kg/cm ² a	2.28		0.25	
17	Critical Pressure	kg/cm ² a	233.1		229.8	
18	Gas Molecular Weight	-	-		-	
19	Gas Density @ P, T	kg/m ³	-		-	
20	Gas Compresibility, Z @ P,T	-	-		-	
21	Cp / Cv	-	-		-	
22	Pressure at Normal Flow	kg/cm ² g	8.2	5.3	15.7	2.2
23	Pressure at Maximum Flow	kg/cm ² g	7.6	5.6	12.5	2.2
24	Pressure at Minimum Flow	kg/cm ² g	9.6	5.1	17.4	2.2
25	Pressure at Closed Valve	kg/cm ² g	9.9		21.53	
26	CARACTERÍSTICAS DE LA VÁLVULA					
27	Valve Tightness (2)	y / n	n		n	
28	Min/Max Valve Opening (Limit Stop)(3)	%	n		n	
29	Maximum Allowable CV (4)	-	-		-	
30	Air Failure Action (5)	-	FA		FC	
31	On / Off Action	y / n	n		n	
32	Valve Size Equal to Line Size	y / -	y		n	
33	DESIGN CONDITIONS					
34	Design Pressure	kg/cm ² g	11.1		18.6	
35	Design Temperature	°C	135.0		86.0	
36	EXISTING VALVES VALIDATION					
37	Located in Line	-	6"-W-1012		4"-W-1007	
38	Valve Model and Maker	-	87-21124/78/SVI - Dresser		88-21714/78/SVI	
39	Valve Curve (6)	-	Isopercentage		Linear	
40	Installed CV in Existing Valve	-	400		15.0	
41	Estimated CV for New Conditions (8)	-	36.4/ 76.3/ 110		3.44/ 6.00/ 8.25	
42	Validity (7)	-	VALID		VALID	
43	NOTES:					
44	(1) To be indicated particles, gums and any other component causing fouling.					
45	(2) Tight valve means ANSI class V or VI. Indicate TSO for requirements above class V or VI.					
46	(3) Indicate if valve opening shall be limited because of process or safety reasons.					
47	(4) Indicate max allowable CV (downstream PSV sizing,...).					
48	(5) Safety valve position for air failure: FA (Fail open), FC (Fail close) o FP (Fail keeps position).					
49	(6) Indicate Lineal, Isopercentage or Quick opening.					
50	(7) Indicate VALID or NOT VALID. NOT VALID might mean changes or new valve.					
51	(8) Cv calculated for minimum/ normal/ maximum flow.					
52	(9) Valve opening exceeds 100% at normal/maximum flow conditions.					
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CONTROL VALVES

Rev	GENERAL FEATURES					
1	ITEM N°		FV-0112		FV-0201	
2	SERVICE		LP condensate		Washing water to T-201	
3						
4	Design Case		Validation		Maximum flow	
5	OPERATING CONDITIONS					
6			INLET	OUTLET	INLET	OUTLET
7	Fluid Nature		H ₂ O		H ₂ O	
8	Corrosive / Toxic Compounds (1)	wt % / wt ppm	-		-	
9	Liquid Normal Flow	kg/h	7398	7037	2823	2823
10	Gas Normal Flow	kg/h	-	361.0	-	-
11	Steam Normal Flow	kg/h	-	-	-	-
12	Minimum / Maximum Flow	%	60%	120%	60/ 120%	
13	Temperature	°C	150.7	128.5	40.0	
14	Liquid Density @ P, T	kg/m ³	916.1	935.8	993.0	
15	Liquid Viscosity @ P, T	cSt	0.20	0.2267	0.68	
16	Vapour Pressure @ T	kg/cm ² a	5.23	2.62	0.08	
17	Critical Pressure	kg/cm ² a	229.8	229.8	229.8	
18	Gas Molecular Weight	-	-	-	-	
19	Gas Density @ P, T	kg/m ³	-	-	-	
20	Gas Compressibility, Z @ P,T	-	-	-	-	
21	Cp / Cv	-	-	-	-	
22	Pressure at Normal Flow	kg/cm ² g	4.2	1.6	17.8	2.8
23	Pressure at Maximum Flow	kg/cm ² g	4.1	1.6	16.7	3.0
24	Pressure at Minimum Flow	kg/cm ² g	4.2	1.6	19.0	2.1
25	Pressure at Closed Valve	kg/cm ² g	-		23.0	
26	CARACTERÍSTICAS DE LA VÁLVULA					
27	Valve Tightness (2)	y / n	n		n	
28	Min/Max Valve Opening (Limit Stop)(3)	%	n		n	
29	Maximum Allowable CV (4)	-	-		-	
30	Air Failure Action (5)	-	FC		FA	
31	On / Off Action	y / n	n		n	
32	Valve Size Equal to Line Size	y / -	y		n	
33	DESIGN CONDITIONS					
34	Design Pressure	kg/cm ² g	7.0		23.0	
35	Design Temperature	°C	210.0		145.0	
36	EXISTING VALVES VALIDATION					
37	Located in Line	-	3"-CLP-1024		2"-W-2009	
38	Valve Model and Maker	-	88/21124/78/SVI			
39	Valve Curve (6)	-	Isopercentage		Isopercentage	
40	Installed CV in Existing Valve	-	47.0		3.80	
41	Estimated CV for New Conditions (8)	-	4.92/ 8.24/ 9.99		0.50/ 0.86/ 1.07	
42	Validity (7)	-	VALID		-	
43	NOTES:					
44	(1) To be indicated particles, gums and any other component causing fouling.					
45	(2) Tight valve means ANSI class V or VI. Indicate TSO for requirements above class V or VI.					
46	(3) Indicate if valve opening shall be limited because of process or safety reasons.					
47	(4) Indicate max allowable CV (downstream PSV sizing,...).					
48	(5) Safety valve position for air failure: FA (Fail open), FC (Fail close) o FP (Fail keeps position).					
49	(6) Indicate Lineal, Isopercentage or Quick opening.					
50	(7) Indicate VALID or NOT VALID. NOT VALID might mean changes or new valve.					
51	(8) Cv calculated for minimum/ normal/ maximum flow.					
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CONTROL VALVES

Rev	GENERAL FEATURES					
1	ITEM N°		FV-0202		FV-0203	
2	SERVICE		NH ₃ water washing column bottom		T-201 Reflux	
3						
4	Design Case		Maximum flow		Maximum flow	
5	OPERATING CONDITIONS					
6			INLET	OUTLET	INLET	OUTLET
7	Fluid Nature		H ₂ O+H ₂ S+NH ₃		H ₂ O+H ₂ S+NH ₃	
8	Corrosive / Toxic Compounds (1)	wt % / wt ppm	1.2% (H ₂ S)/ 8.1% (NH ₃)		28.6% (NH ₃)	
9	Liquid Normal Flow	kg/h	3531	3531	341.2	341.2
10	Gas Normal Flow	kg/h	-	-	-	-
11	Steam Normal Flow	kg/h	-	-	-	-
12	Minimum / Maximum Flow	%	60/ 120%		60/ 120%	
13	Temperature	°C	95.4		43.0	
14	Liquid Density @ P, T	kg/m ³	904.5		880.1	
15	Liquid Viscosity @ P, T	cSt	0.34		0.85	
16	Vapour Pressure @ T	kg/cm ² a	2.10		1.83	
17	Critical Pressure	kg/cm ² a	231.8		228.8	
18	Gas Molecular Weight	-	-		-	
19	Gas Density @ P, T	kg/m ³	-		-	
20	Gas Compressibility, Z @ P,T	-	-		-	
21	Cp / Cv	-	-		-	
22	Pressure at Normal Flow	kg/cm ² g	3.4	2.3	4.7	2.5
23	Pressure at Maximum Flow	kg/cm ² g	3.3	2.4	4.6	2.6
24	Pressure at Minimum Flow	kg/cm ² g	3.6	2.1	4.9	2.4
25	Pressure at Closed Valve	kg/cm ² g	6.3		7.8	
26	CARACTERÍSTICAS DE LA VÁLVULA					
27	Valve Tightness (2)	y / n	n		n	
28	Min/Max Valve Opening (Limit Stop)(3)	%	n		n	
29	Maximum Allowable CV (4)	-	-		-	
30	Air Failure Action (5)	-	FA		FA	
31	On / Off Action	y / n	n		n	
32	Valve Size Equal to Line Size	y / -	n		n	
33	DESIGN CONDITIONS					
34	Design Pressure	kg/cm ² g	6.3		7.8	
35	Design Temperature	°C	120.0		120.0	
36	EXISTING VALVES VALIDATION					
37	Located in Line	-	2"-W-2017-AP		4"-W-2026-AP	
38	Valve Model and Maker	-				
39	Valve Curve (6)	-	Linear		Linear	
40	Installed CV in Existing Valve	-	12.0		0.60	
41	Estimated CV for New Conditions (8)	-	2.13/ 4.14/ 5.50		0.16/ 0.28/ 0.34	
42	Validity (7)	-	-		-	
43	NOTES:					
44	(1) To be indicated particles, gums and any other component causing fouling.					
45	(2) Tight valve means ANSI class V or VI. Indicate TSO for requirements above class V or VI.					
46	(3) Indicate if valve opening shall be limited because of process or safety reasons.					
47	(4) Indicate max allowable CV (downstream PSV sizing,...).					
48	(5) Safety valve position for air failure: FA (Fail open), FC (Fail close) o FP (Fail keeps position).					
49	(6) Indicate Lineal, Isopercentage or Quick opening.					
50	(7) Indicate VALID or NOT VALID. NOT VALID might mean changes or new valve.					
51	(8) Cv calculated for minimum/ normal/ maximum flow.					
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CONTROL VALVES

Rev	GENERAL FEATURES					
1	ITEM N°		LV-0100		LV-0100N	
2	SERVICE		H ₂ S water washing bottom		H ₂ S water washing bottom	
3						
4	Design Case		Validation		Maximum flow	
5	OPERATING CONDITIONS					
6			INLET	OUTLET	INLET	OUTLET
7	Fluid Nature		H ₂ O+H ₂ S+NH ₃		H ₂ O+H ₂ S+NH ₃	
8	Corrosive / Toxic Compounds (1)	wt % / wt ppm	2.6 % (H ₂ S)/ 1.7% (NH ₃)		2.6 % (H ₂ S)/ 1.7% (NH ₃)	
9	Liquid Normal Flow	kg/h	1842	1842	1842	1842
10	Gas Normal Flow	kg/h	-	-	-	-
11	Steam Normal Flow	kg/h	-	-	-	-
12	Minimum / Maximum Flow	%	60/ 120%		60/ 120%	
13	Temperature	°C	134.0		134.0	
14	Liquid Density @ P, T	kg/m ³	877.8		877.8	
15	Liquid Viscosity @ P, T	cSt	0.21		0.21	
16	Vapour Pressure @ T	kg/cm ² a	9.03		9.03	
17	Critical Pressure	kg/cm ² a	234.0		234.0	
18	Gas Molecular Weight	-	-		-	
19	Gas Density @ P, T	kg/m ³	-		-	
20	Gas Compressibility, Z @ P,T	-	-		-	
21	Cp / Cv	-	-		-	
22	Pressure at Normal Flow	kg/cm ² g	9.4	1.2	9.4	1.2
23	Pressure at Maximum Flow	kg/cm ² g	9.4	1.3	9.4	1.3
24	Pressure at Minimum Flow	kg/cm ² g	9.4	1.2	9.4	1.2
25	Pressure at Closed Valve	kg/cm ² g	-		-	
26	CARACTERÍSTICAS DE LA VÁLVULA					
27	Valve Tightness (2)	y / n	n		n	
28	Min/Max Valve Opening (Limit Stop)(3)	%	n		n	
29	Maximum Allowable CV (4)	-	-		-	
30	Air Failure Action (5)	-	FC		FC	
31	On / Off Action	y / n	n		n	
32	Valve Size Equal to Line Size	y / -	y		y	
33	DESIGN CONDITIONS					
34	Design Pressure	kg/cm ² g	12.1		12.1	
35	Design Temperature	°C	172.0		172.0	
36	EXISTING VALVES VALIDATION					
37	Located in Line	-	1 1/2"-W-0165		1 1/2"-W-0165	
38	Valve Model and Maker	-	88-21124/78/SVI - Dresser			
39	Valve Curve (6)	-	Isopercentage		Isopercentage	
40	Installed CV in Existing Valve	-	1.70		3.80	
41	Estimated CV for New Conditions (8)	-	1.01/ 1.69/ 2.03		1.01/ 1.69/ 2.03	
42	Validity (7)	-	NOT VALID (9)		(10)	
43	NOTES:					
44	(1) To be indicated particles, gums and any other component causing fouling.					
45	(2) Tight valve means ANSI class V or VI. Indicate TSO for requirements above class V or VI.					
46	(3) Indicate if valve opening shall be limited because of process or safety reasons.					
47	(4) Indicate max allowable CV (downstream PSV sizing,...).					
48	(5) Safety valve position for air failure: FA (Fail open), FC (Fail close) o FP (Fail keeps position).					
49	(6) Indicate Lineal, Isopercentage or Quick opening.					
50	(7) Indicate VALID or NOT VALID. NOT VALID might mean changes or new valve.					
51	(8) Cv calculated for minimum/ normal/ maximum flow.					
52	(9) LV-0100 not valid for the new operating conditions. Required opening percentage at minimum/ normal/ maximum flow conditions exceeds 85%. Replaced by LV-0100N.					
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CONTROL VALVES

Rev	GENERAL FEATURES					
1	ITEM N°		TV-0100		TV-0100	
2	SERVICE		E-102 Shell bypass		E-102 Shell bypass	
3						
4	Design Case		Validation		Maximum flow	
5	OPERATING CONDITIONS					
6			INLET	OUTLET	INLET	OUTLET
7	Fluid Nature		H ₂ O+H ₂ S+NH ₃		H ₂ O+H ₂ S+NH ₃	
8	Corrosive / Toxic Compounds (1)	wt % / wt ppm	0.12% (H ₂ S)/ 1.82% (NH ₃)		0.12% (H ₂ S)/ 1.82% (NH ₃)	
9	Liquid Normal Flow	kg/h	1.496E+04	1.496E+04	1.496E+04	1.496E+04
10	Gas Normal Flow	kg/h	-	-	-	-
11	Steam Normal Flow	kg/h	-	-	-	-
12	Minimum / Maximum Flow	%	60/ 120%		60/ 120%	
13	Temperature	°C	169.4		169.4	
14	Liquid Density @ P, T	kg/m ³	862.60		862.60	
15	Liquid Viscosity @ P, T	cSt	0.19		0.19	
16	Vapour Pressure @ T	kg/cm ² a	9.29		9.29	
17	Critical Pressure	kg/cm ² a	234.0		234.0	
18	Gas Molecular Weight	-	-		-	
19	Gas Density @ P, T	kg/m ³	-		-	
20	Gas Compressibility, Z @ P,T	-	-		-	
21	Cp / Cv	-	-		-	
22	Pressure at Normal Flow	kg/cm ² g	8.4	3.5	8.4	3.5
23	Pressure at Maximum Flow	kg/cm ² g	8.3	3.5	8.3	3.5
24	Pressure at Minimum Flow	kg/cm ² g	8.5	3.5	8.5	3.5
25	Pressure at Closed Valve	kg/cm ² g	-		-	
26	CARACTERÍSTICAS DE LA VÁLVULA					
27	Valve Tightness (2)	y / n	n		n	
28	Min/Max Valve Opening (Limit Stop)(3)	%	n		n	
29	Maximum Allowable CV (4)	-	-		-	
30	Air Failure Action (5)	-	FC		FC	
31	On / Off Action	y / n	n		n	
32	Valve Size Equal to Line Size	y / -	n		n	
33	DESIGN CONDITIONS					
34	Design Pressure	kg/cm ² g	12.1		12.1	
35	Design Temperature	°C	187.0		187.0	
36	EXISTING VALVES VALIDATION					
37	Located in Line	-	2"-W-0109		2"-W-0109	
38	Valve Model and Maker	-	88-21124/78/SVI - Dresser		88-21124/78/SVI - Dresser	
39	Valve Curve (6)	-	Isopercentage		Isopercentage	
40	Installed CV in Existing Valve	-	15.0		46.0	
41	Estimated CV for New Conditions (8)	-	11.9/ 20.9/ 26.1		11.9/ 20.9/ 26.1	
42	Validity (7)	-	NOT VALID (9)		(10)	
43	NOTES:					
44	(1) To be indicated particles, gums and any other component causing fouling.					
45	(2) Tight valve means ANSI class V or VI. Indicate TSO for requirements above class V or VI.					
46	(3) Indicate if valve opening shall be limited because of process or safety reasons.					
47	(4) Indicate max allowable CV (downstream PSV sizing,...).					
48	(5) Safety valve position for air failure: FA (Fail open), FC (Fail close) o FP (Fail keeps position).					
49	(6) Indicate Lineal, Isopercentage or Quick opening.					
50	(7) Indicate VALID or NOT VALID. NOT VALID might mean changes or new valve.					
51	(8) Cv calculated for minimum/ normal/ maximum flow.					
52	(9) TV-0100 not valid for the new operating condition. Required opening percentage exceeds 85% at minimum/ normal/ maximum flow conditions. Replaced by TV-0100N.					
53	(10) Replaces to TV-0100.					
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CONTROL VALVES

Rev	GENERAL FEATURES					
1	ITEM N°		PV-0101A		PV-0101B	
2	SERVICE		Acid gas to SRU		Acid gas to SRU	
3						
4	Design Case		Validation		Validation	
5	OPERATING CONDITIONS					
6			INLET	OUTLET	INLET	OUTLET
7	Fluid Nature		H ₂ O+H ₂ S+NH ₃		H ₂ O+H ₂ S+NH ₃	
8	Corrosive / Toxic Compounds (1)	wt % / wt ppm	99.5 % (H ₂ S)		99.5 % (H ₂ S)	
9	Liquid Normal Flow	kg/h	-	-	-	-
10	Gas Normal Flow	kg/h	658.6	658.6	658.6	658.6
11	Steam Normal Flow	kg/h	-	-	-	-
12	Minimum / Maximum Flow	%	60%	120%	60%	120%
13	Temperature	°C	41.9	31.8	41.9	31.8
14	Liquid Density @ P, T	kg/m ³	-	-	-	-
15	Liquid Viscosity @ P, T	cSt	-	-	-	-
16	Vapour Pressure @ T	kg/cm ² a	-	-	-	-
17	Critical Pressure	kg/cm ² a	-	-	-	-
18	Gas Molecular Weight	-	33.92	33.92	33.92	33.92
19	Gas Density @ P, T	kg/m ³	12.09	2.438	12.09	2.438
20	Gas Compressibility, Z @ P,T	-	0.938	0.987	0.94	0.9866
21	Cp / Cv	-	1.39	1.329	1.39	1.329
22	Pressure at Normal Flow	kg/cm ² g	7.0	0.8	7.6	0.8
23	Pressure at Maximum Flow	kg/cm ² g	6.6	0.8	7.5	0.8
24	Pressure at Minimum Flow	kg/cm ² g	7.0	0.8	7.8	0.8
25	Pressure at Closed Valve	kg/cm ² g	-	-	-	-
26	CARACTERÍSTICAS DE LA VÁLVULA					
27	Valve Tightness (2)	y / n	y		y	
28	Min/Max Valve Opening (Limit Stop)(3)	%	n		n	
29	Maximum Allowable CV (4)	-	-		-	
30	Air Failure Action (5)	-	FC		FC	
31	On / Off Action	y / n	n		y	
32	Valve Size Equal to Line Size	y / -	n		n	
33	DESIGN CONDITIONS					
34	Design Pressure	kg/cm ² g	9.7		9.7	
35	Design Temperature	°C	86.0		86.0	
36	EXISTING VALVES VALIDATION					
37	Located in Line	-	4"-WG-0120		2"-F-0121	
38	Valve Model and Maker	-	88-21624/78/SVI - Dresser		88-21714/78/SVI - Dresser	
39	Valve Curve (6)	-	Isopercentage		Lineal	
40	Installed CV in Existing Valve	-	13.0		8.00	
41	Estimated CV for New Conditions (8)	-	2.82/ 4.70/ 5.92		2.57/ 4.37/ 5.32	
42	Validity (7)	-	VALID		VALID	
43	NOTES:					
44	(1) To be indicated particles, gums and any other component causing fouling.					
45	(2) Tight valve means ANSI class V or VI. Indicate TSO for requirements above class V or VI.					
46	(3) Indicate if valve opening shall be limited because of process or safety reasons.					
47	(4) Indicate max allowable CV (downstream PSV sizing,...).					
48	(5) Safety valve position for air failure: FA (Fail open), FC (Fail close) o FP (Fail keeps position).					
49	(6) Indicate Lineal, Isopercentage or Quick opening.					
50	(7) Indicate VALID or NOT VALID. NOT VALID might mean changes or new valve.					
51	(8) Cv calculated for minimum/ normal/ maximum flow.					
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CONTROL VALVES

Rev	GENERAL FEATURES					
1	ITEM N°		PV-0120A		PV-0120B	
2	SERVICE		NH3 Rich gas to B.L.		NH3 Rich gas to B.L.	
3						
4	Design Case		Validation		Validation	
5	OPERATING CONDITIONS					
6			INLET	OUTLET	INLET	OUTLET
7	Fluid Nature		H ₂ O+H ₂ S+NH ₃		H ₂ O+H ₂ S+NH ₃	
8	Corrosive / Toxic Compounds (1)	wt % / wt ppm	96.8% (NH ₃)		96.8% (NH ₃)	
9	Liquid Normal Flow	kg/h	-	-	-	-
10	Gas Normal Flow	kg/h	389.3	389.3	389.3	389.3
11	Steam Normal Flow	kg/h	-	-	-	-
12	Minimum / Maximum Flow	%	60%	120%	60%	120%
13	Temperature	°C	42.6	42.0	42.6	42.0
14	Liquid Density @ P, T	kg/m ³	-	-	-	-
15	Liquid Viscosity @ P, T	cSt	-	-	-	-
16	Vapour Pressure @ T	kg/cm ² a	-	-	-	-
17	Critical Pressure	kg/cm ² a	132.6	132.6	132.6	132.62
18	Gas Molecular Weight	-	17.06	17.06	17.06	17.06
19	Gas Density @ P, T	kg/m ³	1.13	0.86	1.13	0.86
20	Gas Compressibility, Z @ P,T	-	0.99	0.99	0.99	0.99
21	Cp / Cv	-	1.31	1.31	1.31	1.31
22	Pressure at Normal Flow	kg/cm ² g	0.7	0.6	7.0	0.8
23	Pressure at Maximum Flow	kg/cm ² g	0.7	0.6	6.6	0.8
24	Pressure at Minimum Flow	kg/cm ² g	0.8	0.6	7.0	0.8
25	Pressure at Closed Valve	kg/cm ² g	-		-	
26	CARACTERÍSTICAS DE LA VÁLVULA					
27	Valve Tightness (2)	y / n	y		y	
28	Min/Max Valve Opening (Limit Stop)(3)	%	n		n	
29	Maximum Allowable CV (4)	-	-		-	
30	Air Failure Action (5)	-	FC		FC	
31	On / Off Action	y / n	y		y	
32	Valve Size Equal to Line Size	y / -	n		y	
33	DESIGN CONDITIONS					
34	Design Pressure	kg/cm ² g	3.5		3.5	
35	Design Temperature	°C	110.0		110.0	
36	EXISTING VALVES VALIDATION					
37	Located in Line	-	4"-WG-1022		4"-WG-1022	
38	Valve Model and Maker	-	88-21614/78/SVI - Dresser		88-21614/78/SVI - Dresser	
39	Valve Curve (6)	-	Linear		Linear	
40	Installed CV in Existing Valve	-	65.0		47.0	
41	Estimated CV for New Conditions (8)	-	18.7/ 34.3/ 43.2		13.2/ 22.0/ 26.4	
42	Validity (7)	-	VALID		VALID	
43	NOTES:					
44	(1) To be indicated particles, gums and any other component causing fouling.					
45	(2) Tight valve means ANSI class V or VI. Indicate TSO for requirements above class V or VI.					
46	(3) Indicate if valve opening shall be limited because of process or safety reasons.					
47	(4) Indicate max allowable CV (downstream PSV sizing,...).					
48	(5) Safety valve position for air failure: FA (Fail open), FC (Fail close) o FP (Fail keeps position).					
49	(6) Indicate Lineal, Isopercentage or Quick opening.					
50	(7) Indicate VALID or NOT VALID. NOT VALID might mean changes or new valve.					
51	(8) Cv calculated for minimum/ normal/ maximum flow.					
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CONTROL VALVES

Rev	GENERAL FEATURES					
1	ITEM N°			PV-0120B		
2	SERVICE			NH3 Rich gas to B.L.		
3						
4	Design case			Validation		
5	OPERATING CONDITIONS					
6			INLET	OUTLET	INLET	OUTLET
7	Fluid Nature			H ₂ O+H ₂ S+NH ₃		
8	Corrosive / Toxic Compounds (1)	wt % / wt ppm	96.8% (NH ₃)			
9	Liquid Normal Flow	kg/h	-	-		
10	Gas Normal Flow	kg/h	389.3	389.3		
11	Steam Normal Flow	kg/h	-	-		
12	Minimum / Maximum Flow	%	60%	120%		
13	Temperature	°C	42.6	42.0		
14	Liquid Density @ P, T	kg/m ³	-	-		
15	Liquid Viscosity @ P, T	cSt	-	-		
16	Vapour Pressure @ T	kg/cm ² a	-	-		
17	Critical Pressure	kg/cm ² a	132.6	132.62		
18	Gas Molecular Weight	-	17.06	17.06		
19	Gas Density @ P, T	kg/m ³	1.13	0.86		
20	Gas Compressibility, Z @ P,T	-	0.99	0.99		
21	Cp / Cv	-	1.31	1.31		
22	Pressure at Normal Flow	kg/cm ² g	7.0	0.8		
23	Pressure at Maximum Flow	kg/cm ² g	6.6	0.8		
24	Pressure at Minimum Flow	kg/cm ² g	7.0	0.8		
25	Pressure at Closed Valve	kg/cm ² g	-			
26	CARACTERÍSTICAS DE LA VÁLVULA					
27	Valve Tightness (2)	y / n	n			
28	Min/Max Valve Opening (Limit Stop)(3)	%	n			
29	Maximum Allowable CV (4)	-	-			
30	Air Failure Action (5)	-	FC			
31	On / Off Action	y / n	n			
32	Valve Size Equal to Line Size	y / -	n			
33	DESIGN CONDITIONS					
34	Design Pressure	kg/cm ² g	3.5			
35	Design Temperature	°C	110.0			
36	EXISTING VALVES VALIDATION					
37	Located in Line	-	4"-WG-1067			
38	Valve Model and Maker	-	3241-SAMSON			
39	Valve Curve (6)	-	Isopercentage			
40	Installed CV in Existing Valve	-	95.0			
41	Estimated CV for New Conditions (8)	-	22.0			
42	Validity (7)	-	VALID			
43	NOTES:					
44	(1) To be indicated particles, gums and any other component causing fouling.					
45	(2) Tight valve means ANSI class V or VI. Indicate TSO for requirements above class V or VI.					
46	(3) Indicate if valve opening shall be limited because of process or safety reasons.					
47	(4) Indicate max allowable CV (downstream PSV sizing,...).					
48	(5) Safety valve position for air failure: FA (Fail open), FC (Fail close) o FP (Fail keeps position).					
49	(6) Indicate Lineal, Isopercentage or Quick opening.					
50	(7) Indicate VALID or NOT VALID. NOT VALID might mean changes or new valve.					
51	(8) Cv calculated for minimum/ normal/ maximum flow.					
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PRESSURE INSTRUMENTS

Rev

GENERAL DATA						
1						
2	ITEM N°		PI-0107	PI-0108	PI-0109	PI-0135-E
3						
4	Service/Purpose (control, H&MB info,...)		H2S Stripper ovhd.	H2S water washing column	T-201 level measurement	H2S water washing tree
5						
6	Design Case		Validation-Normal op.	Validation-Normal op.	Validation-Normal op.	Validation-Normal op.
7						
8	OPERATING CONDITIONS AND FLUID PROPERTIES					
9	Fluid Nature		H ₂ O+H ₂ S+NH ₃	H ₂ O+H ₂ S	H ₂ O+H ₂ S	H ₂ O+H ₂ S+NH ₃
10	Corrosive / Toxic Compounds (1)	wt % / wt ppm	74.6% (H2S) / 3.3% (NH3)	99.5% (H2S)	99.5% (H2S)	2.6% (H2S) / 1.7% (NH3)
11	Phase (2)		G	G	G	L
12	Temperature		°C	133.7	134.0	134.0
13	Pressure:	Min.	kg/cm ² g	-	-	-
14		Norm.	kg/cm ² g	8	7.9	7.9
15		Max.	kg/cm ² g	-	-	-
16	INSTRUMENT CHARACTERISTICS					
17	Location (3)		P	L	L	L
18	Settings	Alarms	PAL	kg/cm ² g	-	-
19			PALL	kg/cm ² g	-	-
20			PAH	kg/cm ² g	-	-
21			PAHH	kg/cm ² g	-	-
22		Trip	PSL	kg/cm ² g	-	-
23			PSH	kg/cm ² g	-	-
24	Tracing (4)		(y/n)	n	n	n
25	Located in Line / Vessel		(5)	T-103	T-103	T-103 (7)
26	Design Conditions	Pressure	kg/cm ² g	9.7	12.3	12.3
27		Temperature	°C	86 (6)	86 (6)	86 (6)
28	NOTES:					
29	(1) Specify gas (G), liquid (L), steam (V) or mixed (M).					
30	(2) Specify operating conditions. For mech. design conditions refer to associated line or equipment .					
31	(3) Specify local (L), control room (P) or local panel (PL).					
32	(4) Indicate Tracing / Diaphragm / Flushing.					
33	(5) Instrument located in line between T-101 top and T-103 gas inlet. Corresponds to stream 11 in PFD.					
34	(6) PI-0106/0107/0108/0109					
35	(7) Instrument connected to T-103 level measurement lines.					
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PRESSURE INSTRUMENTS

Rev							
1	GENERAL DATA						
2	ITEM N°		PI-0201	PI-0202	PI-0203	PI-0204	
3							
4	Service/Purpose (control, H&MB info,...)		P-202-A discharge	P-202-B discharge	P-201-A discharge	P-201-B discharge	
5							
6	Design Case		120% Normal Flow	120% Normal Flow	120% Normal Flow	120% Normal Flow	
7							
8	OPERATING CONDITIONS AND FLUID PROPERTIES						
9	Fluid Nature		Treated water	Treated water	H ₂ O+H ₂ S+NH ₃	H ₂ O+H ₂ S+NH ₃	
10	Corrosive / Toxic Compounds (1)		wt % / wt ppm	-	-	1.2% (H ₂ S)/ 8.1% (NH ₃)	
11	Phase (2)		L	L	L	L	
12	Temperature		°C	126.8	126.8	96	
13	Pressure:		Min.	kg/cm ² g	17.6	17.6	
14			Norm.	kg/cm ² g	18.6	18.6	3.6
15			Max.	kg/cm ² g	23.0 (5)	23.0 (5)	6.3 (7)
16	INSTRUMENT CHARACTERISTICS						
17	Location (3)		L	L	L	L	
18	Settings	Alarms	PAL	kg/cm ² g	-	-	
19			PALL	kg/cm ² g	-	-	
20			PAH	kg/cm ² g	-	-	
21			PAHH	kg/cm ² g	-	-	
22		Trip	PSL	kg/cm ² g	-	-	
23			PSH	kg/cm ² g	-	-	
24	Tracing (4)		(y/n)	n	n	n	
25	Located in Line / Vessel			2"-W-2004-P900	2"-W-2024-P900	2"-W-2018-RW	
26	Design Conditions		Pressure	kg/cm ² g	23.0 (5)	23.0 (5)	
27			Temperature	°C	141 (6)	141 (6)	120 (8)
28	NOTES:						
29	(1) Specify gas (G), liquid (L), steam (V) or mixed (M).						
30	(2) Specify operating conditions. For mech. design conditions refer to associated line or equipment .						
31	(3) Specify local (L), control room (P) or local panel (PL).						
32	(4) Indicate Tracing / Diaphragm / Flushing.						
33	(5) P-202-A/B mechanical design pressure.						
34	(6) T-102 mechanical design temperature.						
35	(7) P-201-A/B mechanical design conditions.						
36	(8) T-201 mechanical design conditions.						
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PRESSURE INSTRUMENTS

Rev

GENERAL DATA							
1							
2	ITEM N°			PT-0205	PI-0206	PI-0207	PI-0208
3							
4	Service/Purpose (control, H&MB info,...)			T-201 top pressure	V-201 level measurement	P203-A discharge	P-203-B discharge
5							
6	Design Case			120% Normal flow	120% Normal Flow	120% Normal Flow	120% Normal Flow
7							
8	OPERATING CONDITIONS AND FLUID PROPERTIES						
9	Fluid Nature			H ₂ O+NH ₃	H ₂ O+NH ₃	H ₂ O+NH ₃	H ₂ O+NH ₃
10	Corrosive / Toxic Compounds (1)		wt % / wt ppm	64.8% (NH ₃)	96.8% (NH ₃)	28.6% (NH ₃)	28.6% (NH ₃)
11	Phase (2)			G	G	L	L
12	Temperature		°C	91.2	42.6	42.6	42.6
13	Pressure:	Min.	kg/cm ² g	-	-	4.8	4.8
14		Norm.	kg/cm ² g	1.0	0.7	4.9	4.9
15		Max.	kg/cm ² g	3,5 (6)	3,5 (7)	7.8 (5)	7.8 (5)
16	INSTRUMENT CHARACTERISTICS						
17	Location (3)			P	P	L	L
18	Settings	Alarms	PAL	kg/cm ² g	-	-	-
19			PALL	kg/cm ² g	-	-	-
20			PAH	kg/cm ² g	-	-	-
21			PAHH	kg/cm ² g	-	-	-
22		Trip	PSL	kg/cm ² g	-	-	-
23			PSH	kg/cm ² g	-	-	-
24	Tracing (4)			(y/n)	n	n	n
25	Located in Line / Vessel			T-201 (top)	V-201 (top)	2"-W-2024-H2S	2"-W-2024-H2S
26	Design Conditions	Pressure	kg/cm ² g	3.5 (6)	3.5 (7)	7.8 (5)	7.8 (5)
27		Temperature	°C	120 (5)	120 (7)	120 (5)	120 (5)
28	NOTES:						
29	(1) Specify gas (G), liquid (L), steam (V) or mixed (M).						
30	(2) Specify operating conditions. For mech. design conditions refer to associated line or equipment .						
31	(3) Specify local (L), control room (P) or local panel (PL).						
32	(4) Indicate Tracing / Diaphragm / Flushing.						
33	(5) P-203-A/B mechanical design conditions.						
34	(6) T-201 mechanical design conditions.						
35	(7) V-201 mechanical design conditions.						
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PRESSURE INSTRUMENTS

Rev						
1	GENERAL DATA					
2	ITEM N°		PI/PT-0209	PT/PI-0210		
3						
4	Service/Purpose (control, H&MB info,...)		V-201 inlet pressure	Recirculated water to V-101		
5						
6	Design Case		120% Normal flow	120% Normal Flow		
7						
8	OPERATING CONDITIONS AND FLUID PROPERTIES					
9	Fluid Nature		H ₂ O+NH ₃	H ₂ O+H ₂ S+NH ₃		
10	Corrosive / Toxic Compounds (1)		wt % / wt ppm	64.8% (NH ₃)	1.2% (H ₂ S)/ 8.1% (NH ₃)	
11	Phase (2)		M	L		
12	Temperature		°C	43.0	95.4	
13	Pressure:		Min.	kg/cm ² g	-	
14			Norm.	kg/cm ² g	0.8	3.6
15			Max.	kg/cm ² g	3.5	23.0 (6)
16	INSTRUMENT CHARACTERISTICS					
17	Location (3)			P	P	
18	Settings	Alarms	PAL	kg/cm ² g	-	
19			PALL	kg/cm ² g	-	
20			PAH	kg/cm ² g	-	
21			PAHH	kg/cm ² g	-	
22		Trip	PSL	kg/cm ² g	-	
23			PSH	kg/cm ² g	-	
24	Tracing (4)		(y/n)	n	n	
25	Located in Line / Vessel			3"-WG-2021-AP-S	2"-W-2018-ACG-PP	
26	Design Conditions		Pressure	kg/cm ² g	3.5	
27			Temperature	°C	120.0	120.0
28	NOTES:					
29	(1) Specify gas (G), liquid (L), steam (V) or mixed (M).					
30	(2) AAAAA					
31	(3) Specify local (L), control room (P) or local panel (PL).					
32	(4) Indicate Tracing / Diaphragm / Flushing.					
33	(5) P-203-A/B mechanical design conditions.					
34	(6) P-201-A/B mechanical design conditions.					
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LEVEL INSTRUMENTS

Rev						
1	GENERAL DATA					
2	ITEM N°		LT-0100	LI-0109	LT/LI-0201	LI-0202
3						
4	Service		H ₂ S Water Washing	H ₂ S Water Washing	NH ₃ Water Washing col.	Reflux Drum V-201
5						
6	Design Case		Validation-Normal op.	Validation-Normal op.	Design case (120%)	Design case (120%)
7						
8	OPERATING CONDITIONS					
9	Upper / Lower Fluid Nature		H ₂ O+H ₂ S+NH ₃	H ₂ O+H ₂ S+NH ₃	H ₂ O+H ₂ S+NH ₃	H ₂ O+NH ₃
10	Corrosive / Toxic Compounds (1)	wt % / wt ppm	(6)	(6)	(8)	(9)
11	Compounds with tendency to bring into (2)		-	-	-	-
12	Type of Interphase (3)		L-V	L-V	L-V	L-V
13	Temperature	°C	134.0	134.0	96.0	42.6
14	Pressure	kg/cm ² g	8.0	8.0	1.1	0.8
15	FLUID PROPERTIES					
16	Upper Phase Density @ P, T	kg/m ³	2.44	2.44	1.16	1.13
17	Upper Phase Viscosity @ P, T	cP (G) / cSt (L)	0.013	0.013	0.013	0.011
18	Lower Phase Density @ P, T	kg/m ³	877.8	877.8	903.7	880.6
19	Lower Phase Viscosity @ P, T	cP (G) / cSt (L)	0.205	0.205	0.336	0.857
20	INSTRUMENT CHARACTERISTICS					
21	Type of Measuring Device		Pressure differential	Magnetic	Pressure differential	Pressure differential
22	Location (4)		P	L	P	P
23	Alarm and Trips Settings. Normal level :(5)		-	-	1438	650
24	Alarm High (H) / Very High (HH)	mm / %	-	-	2323	800
25	Alarm Low (L) / Very Low (LL)	mm / %	-	-	300	300
26	Trip High (H) / Low (L)	mm / %	-	-	-	-
27	Tracing, Diaphragm, Flushing Requirements		n	n	n	n
28	Located in Vessel		T-103	T-103	T-201	V-201
29	Design Conditions (P - T)	kg/cm ² g - °C	9.7-86.0 (7)	9.7-86.0 (7)	3.5-120	3.5-120
30	NOTES:					
31	(1)	To be indicated particles, gums and any other component causing fouling				
32	(2)	To be indicated any tendency of compounds to produce foaming, emulsions, sticky polymers, solids precipitation, other.				
33	(3)	Specify liquid - liquid (L-L) or liquid - vapor (L-V).				
34	(4)	Specify local (L), control room (P) or local panel (PL).				
35	(5)	Specify normal level as mm over TL or % of instrument span and alarm / trip settings in the same units.				
36	(6)	% wt. Composition upper phase: 99.5% (H ₂ S).				
37	(6)	% wt. Composition lower phase: 2.6% (H ₂ S) / 1.7% (NH ₃).				
38	(7)	LT-0100/LI-0109 not valid for normal operation (temperature exceeds design conditions).				
39	(8)	% wt. Composition upper phase: 64.8% (NH ₃).				
40	(8)	% wt. Composition lower phase: 1.2% (H ₂ S) / 8.1% (NH ₃).				
41	(9)	% wt. Composition upper phase: 96.8% (NH ₃).				
42	(9)	% wt. Composition lower phase: 28.6% (NH ₃).				
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 		SAFETY VALVES						
Rev	GENERAL FEATURES							
1	ITEM N°	PSV-0201						
2	N° Required (Operating / Spare)	1			0			
3	PROTECTED EQUIPMENT(S)	T-201 / V-201						
4	Normal Operating Pressure / Temperature	1	kg/cm ² g		91.2		°C	
5	Mechanical Design Pressure / Temperature	3.5	kg/cm ² g		120		°C	
6	Fluid Nature	H ₂ O+H ₂ S+NH ₃						
7	Corrosive / Toxic Compounds (w % / w ppm)	H ₂ O/ NH ₃ (1)						
8	VALVE DESIGN CASE (2)	Fire case	Blocked valve PV-0120A	Blocked valve FV-0201	Electrical Failure	Blocked valve FV-0202 (3)	Air Cooler Failure E-203	
9	RELIEVING CONDITIONS AT VALVE INLET							
10	Set Pressure	kg/cm ² g	3.5	3.5	3.5	3.5	-	3.5
11	Maximum Accumulation	%	21	10	10	10	-	10
12	Relieving Pressure (Set + Accumulation)	kg/cm ² g	4.24	3.85	3.85	3.85	-	3.85
13	Discharge Temperature	°C	150.4	42.6	95.2	91.2	-	83
14	GAS OR STEAM RELIEVING FLOW @ P,T	kg/h	1728	389.0	367.4	731.8	-	202
15	Molecular Weight	kg/kmol	17.06	17.06	17.73	17.36	-	17.06
16	Cp / Cv	-	1.31	1.31	1.31	1.31	-	1.3
17	Compressibility Factor	-	0.99	0.99	0.99	0.986	-	0.99
18	LIQUID RELIEVING FLOW @ P,T	m ³ /h	-	-	-	-	-	-
19	Liquid Density @ P, T	kg/m ³	-	-	-	-	-	-
20	Liquid Viscosity @ P, T	cSt	-	-	-	-	-	-
21	RELIEVING CONDITIONS AT VALVE OUTLET							
22	Temperature	°C	150.4	58	95.2	91.2	-	58
23	GAS OR STEAM RELIEVING FLOW @ P,T	kg/h	1973	389.0	367.4	1099	-	202
24	Molecular Weight	kg/kmol	18.01	17.06	17.06	17.36	-	17.06
25	Compressibility Factor	-	0.986	0.987	0.987	0.986	-	0.96
26	LIQUID RELIEVING FLOW @ P,T	m ³ /h	-	-	-	-	-	-
27	Liquid Density @ P, T	kg/m ³	-	-	-	-	-	-
28	Valve Relieving to Atm / Flare,...	-	Flare	Flare	Flare	Flare	-	Flare
29	VALVE CHARACTERISTICS							
30	Set Pressure (1st Valve)	kg/cm ² g	3.5	3.5	3.5	3.5	-	3.5
31	Set Pressure (Others)	kg/cm ² g	-	-	-	-	-	-
32	Conventional / Balanced / Pilot Operated	-	-	-	-	-	-	-
33	SPECIFICATION FOR NEW VALVES							
34	Total Maximum Backpressure	kg/cm ² g	1.1	1.1	1.1	1.1	-	1.1
35	Superimposed Backpressure @ BL	kg/cm ² g	0.3	0.3	0.3	0.3	-	0.3
36	Superimp. + Built Up Backpressure @ BL	kg/cm ² g	0.4	0.4	0.4	0.4	-	0.4
37	Available Pressure Drop ISBL	kg/cm ²	0.7	0.7	0.7	0.7	-	0.7
38	Estimated / Selected Area	mm ²	612 / 830	143 / 198	141 / 198	418 / 506	-	73/ 126
39	Selected Orifice as per API	-	3"J 4"	1 1/2" F 2"	1 1/2" F 2"	1 1/2" H 3"	-	1" E 2"
40	EXISTING VALVES CHECK							
41	Valve Model and Maker	-	-	-	-	-	-	-
42	Superimposed Backpressure @ BL	kg/cm ² g	-	-	-	-	-	-
43	Superimp. + Built Up Backpressure @ BL	kg/cm ² g	-	-	-	-	-	-
44	Calculated Pressure Drop ISBL	kg/cm ²	-	-	-	-	-	-
45	Total Maximum Backpressure	kg/cm ² g	-	-	-	-	-	-
46	Estimated / Installed API Orifice	-	-	-	-	-	-	-
47	Valve Validity	-	-	-	-	-	-	-
48	NOTES							
49	(1) H ₂ S content: 1.2% wt. (Liquid phase)/ ~ 0 wt. ppm (Vapour phase).							
50	NH ₃ content: 8.1% wt. (Liquid phase)/ 64.8% wt. (Vapour phase).							
51	(2) Fire case selected for design case, although all the studied cases are presented.							
52	(3) Blocked valve of outlet liquid (at the bottom of column C-N1) has been studied, but the liquid volume discharge with pumps during a residence time set up, it will be less than maximum volume in the column (HLL) thus complying with API521, so the discharge is not expected.							
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SAFETY VALVES

Rev	GENERAL FEATURES								
1	ITEM N°							PSV-0202	
2	N° Required (Operating / Spare)	1						0	
3	PROTECTED EQUIPMENT(S)							E-201	
4	Normal Operating Pressure / Temperature	6.3		kg/cm ² g					
5	Mechanical Design Pressure / Temperature	17.7		kg/cm ² g					
6	Fluid Nature							Cooling water	
7	Corrosive / Toxic Compounds (w % / w ppm)							-	
8	VALVE DESIGN CASE (2)	Thermal expansion							
9	RELIEVING CONDITIONS AT VALVE INLET								
10	Set Pressure	kg/cm ² g	17.7						
11	Maximum Accumulation	%	10						
12	Relieving Pressure (Set + Accumulation)	kg/cm ² g	19.5						
13	Discharge Temperature	°C	40						
14	GAS OR STEAM RELIEVING FLOW @ P,T	kg/h	-						
15	Molecular Weight	kg/kmol	-						
16	Cp / Cv	-	-						
17	Compressibility Factor	-	-						
18	LIQUID RELIEVING FLOW @ P,T	m ³ /h	(1)						
19	Liquid Density @ P, T	kg/m ³	992.4						
20	Liquid Viscosity @ P, T	cSt	0.66						
21	RELIEVING CONDITIONS AT VALVE OUTLET								
22	Temperature	°C	40						
23	GAS OR STEAM RELIEVING FLOW @ P,T	kg/h	-						
24	Molecular Weight	kg/kmol	-						
25	Compressibility Factor	-	-						
26	LIQUID RELIEVING FLOW @ P,T	m ³ /h	(1)						
27	Liquid Density @ P, T	kg/m ³	992.4						
28	Valve Relieving to Atm / Flare,...	-	Atmosphere						
29	VALVE CHARACTERISTICS								
30	Set Pressure (1st Valve)	kg/cm ² g	17.7						
31	Set Pressure (Others)	kg/cm ² g	-						
32	Conventional / Balanced / Pilot Operated	-	-						
33	SPECIFICATION FOR NEW VALVES								
34	Total Maximum Backpressure	kg/cm ² g	19.5						
35	Superimposed Backpressure @ BL	kg/cm ² g	0						
36	Superimp. + Built Up Backpressure @ BL	kg/cm ² g	0						
37	Available Pressure Drop ISBL	kg/cm ²	4.4						
38	Estimated / Selected Area	mm ²	-						
39	Selected Orifice as per API	-	1 1/2" D 2"						
40	EXISTING VALVES CHECK								
41	Valve Model and Maker	-	-	-	-	-	-	-	-
42	Superimposed Backpressure @ BL	kg/cm ² g	-	-	-	-	-	-	-
43	Superimp. + Built Up Backpressure @ BL	kg/cm ² g	-	-	-	-	-	-	-
44	Calculated Pressure Drop ISBL	kg/cm ²	-	-	-	-	-	-	-
45	Total Maximum Backpressure	kg/cm ² g	-	-	-	-	-	-	-
46	Estimated / Installed API Orifice	-	-	-	-	-	-	-	-
47	Valve Validity	-	-	-	-	-	-	-	-
48	NOTES								
49	(1) No discharge flow for the design conditions is expected, so the minimum available orifice is selected for the new PSV.								
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SAFETY VALVES SUMMARY

Rev	VALVE	Service	Size	Type (1)	Set Pressure kg/cm ² g	RELIEVING CASES														
						FIRE			CW FAILURE			POWER FAILURE			OTHER					
						kg/h	MW (4)	°C	kg/h	MW	°C	kg/h	MW (4)	°C	VAPOUR		LIQUID		°C (2)	CASE
															kg/h	MW	m ³ /h	ρ(kg/m ³)		
4	PSV-0201	V-201/ T-201	J	B	3.5	1973	17.06	150.4				1099	17.36	91.2	389	17.06			58	Blocked valve PV-0120A
5															367.4	17.06			58	Blocked valve FV-0201
6															202	17.06			58	Air Cooler Failure E-203
7																				
8																				
9	PSV-0202	E-201	D	C	17.7										-	-	(5)	992	40	Blocked valve FV-0202 (3) Thermal Expansion
10																				
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25	TOTAL																			

NOTES

- (1) B: Balanced/ C: Conventional.
- (2) Calculated temperature at relieving conditions (@PSET).
- (3) Discharge is not expected because the liquid volume discharge with pumps will be less than maximum volume in the column HLL thus complying with API521.
- (4) Molecular weight [kg/kmol].
- (5) No discharge flow for the design conditions is expected, so the minimum available orifice is selected for the new PSV.

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**APPEND E: SELF-EVALUATION
QUESTIONNAIRE**

a) Evaluate the acquired **competences** according to the **tasks** you have carried out.

Degree Competences		Task in which you have observed the competence	Self evaluation [Rank 1 to 10]	Aspects to be improved
SPECIFIC COMPETENCES				
A1.1	Effectively apply knowledge of basic, scientific and technological materials pertaining to engineering.	Calculation related tasks for equipment sizing, design and validation.	10	
A1.2	Design, execute and analyze experiments related to engineering	Conceptual/ Basic engineering design	9.5	
A1.3	Be able to analyze and synthesize the continuous progress of products, processes, systems and services, whilst applying criteria of safety, economic viability, quality and environmental management. (G6)	Cost estimation based on <i>Aspen</i> software and safety analysis (HAZOP, LOPA).	9	
A1.4	Know how to establish and develop mathematical models by using the appropriate software in order to provide the scientific and technological basis for the design of new products, processes, systems and services and for the optimization of existing ones. (G5)	Implementation in <i>HYSYS</i> environment of <i>HTRI</i> heat exchanger models for rigorous calculations. Usage of commercial software for column internal selection.	9.5	
A2.1	Be able to apply the scientific method and the principles of engineering and economics to formulate and solve complex problems that arise in processes, equipment, installations and services, in which the material undergoes changes to its composition, state or energy content, these changes being characteristic of industrial chemistry and other related sectors such as pharmacology, biotechnology, materials sciences, energy, food and the environment. (G1)	Development of projects for the company at conceptual/ basic engineering stages.	9.5	

A2.2	Conceive, project, calculate and design processes, equipment, industrial installations and services in the field of chemical engineering and related industrial sectors in terms of quality, safety, economics, the rational and efficient use of natural resources and the conservation of the environment. (G2)	Development of projects for the company at conceptual/ basic engineering stages.	9.5	
A2.3	Lead and technically and economically manage projects, installations, plants, companies and technological centres in the ambit of chemical engineering and related industrial sectors. (G3)	Final Master's Thesis development.	9.5	

A3.1	Apply knowledge of mathematics, physics, chemistry, biology and other natural sciences by means of study, experience, practice and critical reasoning in order to establish economically viable solutions for technical problems (I1).	Development of projects for the company at conceptual/ basic engineering stages.	9.5	
A3.2	Design and optimize products, processes, systems and services for the chemical industry on the basis of various areas of chemical engineering, including processes, transport, separation operations, and chemical, nuclear, electrochemical and biochemical reactions engineering (I2).	Unit revamps at basic engineering stage to adapt the plant for accomplishing with client's requirements	9	
A3.3	Conceptualize engineering models and apply innovative problems solving methods and appropriate IT applications to the design, simulation, optimization and control of processes and systems (I3).	Usage of simulation software (<i>HYSYS</i> , <i>Aspen Plus</i> , and <i>HTRI</i>), and in house tools.	9	
A3.4	Be able to solve unfamiliar and ill-defined problems by taking into account all possible solutions and selecting the most innovative. (I4)	Development of projects at conceptual/ basic engineering stages.	9	
A3.5	Lead and supervise all types of installation, process, system and service in the different industrial areas related to chemical engineering (I5).	Validation of existing units to adequacy checking. Usage of simulators.	9.5	
A3.6	Design, construct and implement methods, processes and installations for the integrated management of waste, solids, liquids and gases, whilst also taking into	Development of projects associated to waste streams treatment for reducing environmental impact.	9.5	

	account the impacts and risks of these products (I6).			
A4.1	Lead and organize companies and production and service systems by applying knowledge and abilities regarding industrial organization, commercial strategy, planning and logistics, mercantile and labour legislation, and financial and costs accounting (P1).	Study of alternatives. Cost estimation, legislation research previous to design of equipment.	9	
A4.2	Lead and manage the organization of work and human resources by applying criteria regarding industrial safety, quality management, occupation risk prevention, sustainability and environmental management (P2).	HAZOP analysis.	9	
A4.3	Manage research, development and technological innovation whilst ensuring the transfer of technology and taking into account property and patent rights (P3).	Development of projects at conceptual/ basic engineering stages.	9.5	
A4.4	Adapt to structural changes in society caused by economic, energy or natural factors so as to be able to solve any	Development of projects for the company at conceptual/	9.5	

	resulting problems and to contribute technological solutions with a high commitment to sustainability (P4).	basic engineering stages.		
A4.5	Lead and monitor the control of installations, processes, products, certification, auditing, verification, testing and reports (P5).	Final Master's Thesis development	10	
A5.1	Carry out, present and defend (once all the curriculum credits have been obtained) an original individually produced piece of work before a university panel. The work will consist of a professional integrated Chemical Engineering project that synthesizes (TFM1)	Final Master's Thesis development	9	
TRANSVERSAL COMPETENCES				
B1.1	Communicate and discuss proposals and conclusions in a clear and unambiguous manner in specialized and non-specialized multilingual forums (G9).	Final Master's Thesis development	9	
B1.2	Adapt to changes and be able to apply new and advanced technologies and other important developments with initiative and entrepreneurial spirit. (G10)	Final Master's Thesis development/ Company's projects	9.5	
B2.1	Lead and define multidisciplinary teams that are able to make technical changes and address management needs in national and international contexts. (G8)	Project/ Internship	9	
B3.1	Work in a team with responsibilities shared among multidisciplinary, multilingual and multicultural teams	Internship	9.4	

B4.1	Be able to learn autonomously in order to maintain and improve the competences pertaining to chemical engineering that enable continuous professional development. (G11)	Internship/ project	10	
B5.1	Carry out and lead the appropriate research, design and development of engineering solutions in new or little understood areas, whilst applying criteria of creativity, originality, innovation and technology transfer. (G4)	Internship/ project	10	
B5.2	Bring together knowledge, make judgements and take decisions on the basis of incomplete or limited knowledge whilst taking into account the social and ethical responsibilities of professional practice. (G7)	Internship/ project	9.5	
NUCLEAR COMPETENCES				
C1.1	Have an intermediate mastery of a foreign language, preferably English	Internship/ project (English)	9	
C1.2	Be advanced users of the information and communication technologies	Internship/ project	9	
C1.3	Be able to manage information and knowledge	Usage of T.EN's technical guides	9	
C1.4	Be able to express themselves correctly both orally and in writing in one of the two	Internship/ project	9	

	official languages of the URV			
C2.1	Be committed to ethics and social responsibility as citizens and professionals	Internship/ project	10	
C2.2	Be able to define and develop their academic and professional project	Internship/ project	9	

b) **Evaluate** the final master project and suggest improvements.

Key steps	Evaluation [Mark 1 to 10]	Improvement proposed
Selection/assignment of the project (dissemination, communication, assignment requirements...)	10	N.A.
Stay (welcome, length, relationship, follow-up made by the company...)	10	N.A.
Follow-up made by URV tutor	10	N.A.
Other aspects to be considered (which ones...)	-	N.A.