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THESIS

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Specialty: Health, Safety and Environment

Risk analysis in a hydrogen production plant

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Acknowledgements

First of all, All praise is for Allah, to whom belongs all that is in the heavens and all that is on the earth; and for Him is all praise in this world and in the Hereafter.

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I would also like to express my gratitude to all the people who contributed in one way or another to this thesis, either workers in the field, professors and to anyone who made the process even a little bit easier.

Dedications

I would to dedicate this thesis to:

My Mom, who without her and the great effort she spent towards raising me, I can say in full confidence I simply wouldn’t be nowhere near where I am today.

My Dad, who sacrificed his health, time and put his family above himself just so he can see them succeed in life.

My Siblings, hoping they all may have great success in their lives.

All my Teachers who were more than teachers thanks to their kindness and great character.

All of those who helped me develop as a person.

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List Of Abbreviations

HAZOP: Hazard and Operability Study

ICI Ltd: Imperial Chemical Industries

IEC: The International Electrotechnical Commission

NO: Number

OMM: Operations and Maintenance Manual

PI: Pressure Indicator

PIAZ: Pressure Indicator Alarm Emergency

PID: Piping and Instrumentation diagram

PSV: Pressure Safety Valve

PT: Pressure Transmitter

PC: Pressure Controller

QRA: Quantitative Risk Assessment

SONELGAZ: National Electricity and Gas Company (Société National d'électricité et gaz)

TI: Temperature indicator

UVCE: Unconfined Vapor Cloud Explosion

Introduction

Context and motivations:

Hydrogen is a fascinating molecule, it's considered the lightest and also the simplest element in the periodic table, and its characteristics make it both very useful and also very dangerous at the same time, useful in the sense that it's used in many different industries such as: energy production since it produces water after burning so it doesn't affect the environment at all ,in cooling due to its capability of absorbing heat, and in petroleum processing and many other industries , and its considered dangerous due to many factors: it has a very low ignition energy which means it ignites very easily ,it leaks easily due to its size and it has a very broad flammability range [1].

In order to get hydrogen we must extract it from other molecules and that is because hydrogen is not found in the universe in its pure form, and extracting it can be done with many different approaches, one of the popular approaches is water electrolysis, where direct electrical current is run through the water to separate the hydrogen and the oxygen, and that way hydrogen can be extracted and used.

Many companies that make use of hydrogen in their process ,make a hydrogen production plant on site because it's cheaper and more efficient that way ,but that comes with the downside of exposing the company to the many risks that come with the different uses of hydrogen causing a threat to the safety of the company.

Workplace safety concerns really started appearing in Europe when workers at the time of the industrial revolution started forming unions and demanded for better working conditions ,years after that and the world started taking occupational safety more seriously after 1970 with the appearance of safety regulations and standards and with that the knowledge on the topic started to expand with the rise of different approaches and the development of new techniques year by year to reach a safe work environment [2] ,one of the essential methods to prevent workplace accidents is risk analysis ,which is a Systematic use of available information to identify hazards and to estimate the risk to individuals, property, and the environment (IEC 60300-3-9, 1995)[3].

On this thesis a risk analysis will be conducted on a hydrogen production plant (based on water electrolysis) that is located on an electricity power plant, the function of the hydrogen plant is to produce hydrogen that is used to cool the generators.

Objectives:

The objective of the analysis is to identify any major potential accident scenarios related to the hydrogen plant.

Thesis outline:

The first chapter gives definitions on: hydrogen and its characteristics, the different methods to get hydrogen, a deep dive into how hydrogen production from water electrolysis works and the different uses of hydrogen.

The second chapter main them is the risk analysis, firstly the company where the analysis will be done is presented ,than after that the focus narrows down to the hydrogen plant ,where the plant will be presented ,its function ,all the equipment in the plant that are related to the production of hydrogen will be listed and defined ,the process of producing hydrogen will be explained from start to finish ,after that general definitions related to risk analysis will be given, its steps, and also the method used in the risk analysis will be defined, and finally the risk analysis will be conducted with its end results given at the end.

CHAPTER 1: General Information About Hydrogen

Introduction:

Hydrogen in today's world is essential in many industries due to its different uses and unique characteristics that make it very different from other molecules, In this chapter the theme would be hydrogen, its proprieties and characteristics, the various processes used to get hydrogen, how they are different, a deep dive into how hydrogen production from electrolysis works, and at the end a list of the different uses of hydrogen.

1-Hydrogen:

Hydrogen is the first element in the periodic table and also the lightest and the simplest, it is a colorless, odorless gas that accounts for 75% of the universe mass. [1]

The properties of hydrogen are:

Property	Value
Name, symbol, number	Hydrogen, H, 1
Category	Nonmetal
Atomic weight	1.008
Electrons, protons, neutrons	1, 1, 0
Color, odor	Colorless, odorless
Toxicity	None, simple asphyxiant
Phase	Gas
Density	Gas: 0.089 g l^{-1}, liquid: 0.07 g cm^3
Ionization energy	13.5989 eV
Liquid to gas expansion ratio	1:848 (atmospheric conditions)
Melting and boiling point	−259.14 °C, −252.87 °C
Lower heat value (LHV)	118.8 MJ kg^{-1}
Adiabatic flame temperature	2107 °C
Flammability range in air	4–75%
Laminar flame velocity	3.06 m s^{-1}
Flash point	−253 °C
Auto ignition temperature	585 °C
Research octane number (RON)	>130

FIGURE 1 : PROPERTIES OF HYDROGEN [4]

Although Hydrogen is the most abundant Element in the universe, it is not found in nature at its purely state, this why in order to obtain it we must extract it from other molecules.

There are different sources from where we get Hydrogen such as fossil fuels, water…etc. , resulting in different methods of extraction each one has its own advantages.

2-Hydrogen production methods:

There are various processes for H_2 production, which can be divided into two broad categories depending on the feedstock used: conventional and renewable technologies. The first category processes fossil fuels and includes hydrocarbon reforming and pyrolysis processes. The hydrocarbon reforming process involves chemical technologies such as steam reforming, partial oxidation, and auto thermal steam reforming. The second category is the production of hydrogen from renewable resources such as biomass and water.[5]

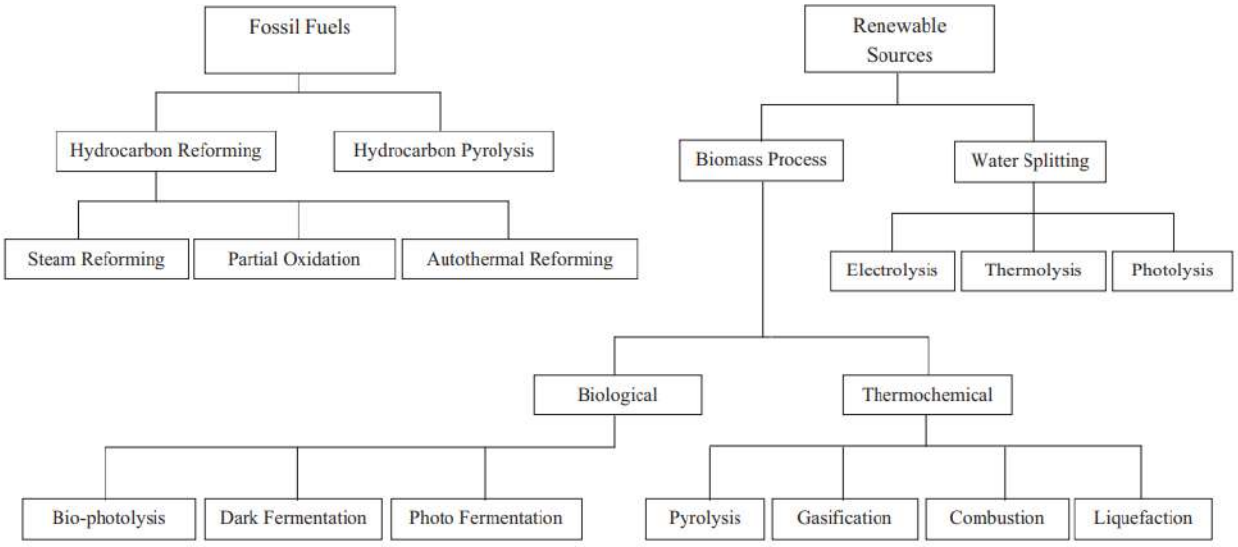


FIGURE 2:HYDROGEN PRODUCTION METHODS [5]

3-Hydrogen production from electrolysis:

Water electrolysis is the process of separating hydrogen and oxygen from water by using a direct current that runs through water thanks to two separated electrodes, those electrodes are separated by a separator or a diaphragm that is responsible for preventing the recombination of the hydrogen and the oxygen. [6]

The reaction taking place is:

$H_2O \rightarrow H_{2\,(g)} + \frac{1}{2}\, O_{2\,(g)}$

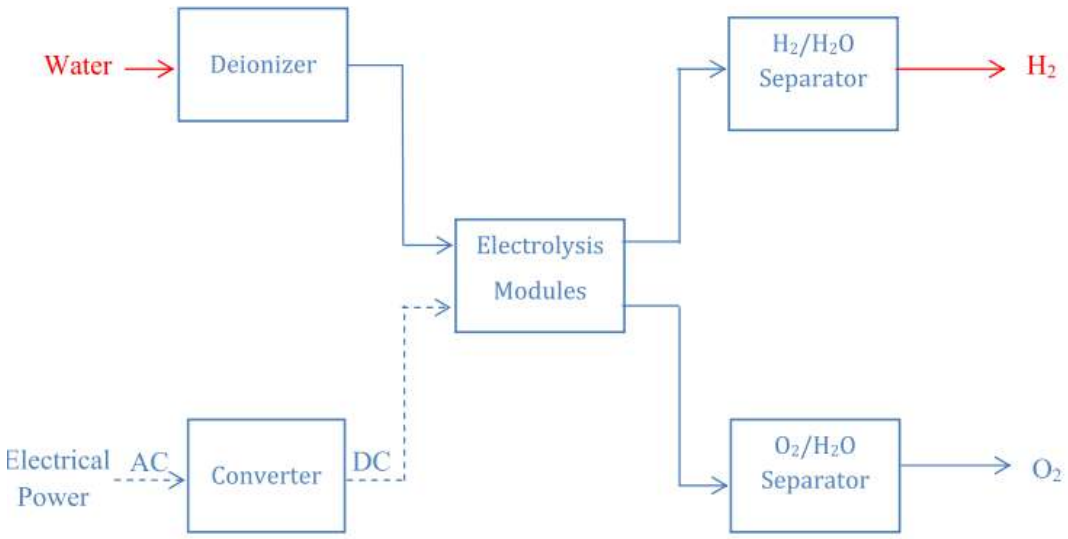


FIGURE 3: THE PROCESS OF WATER ELECTROLYSIS [5]

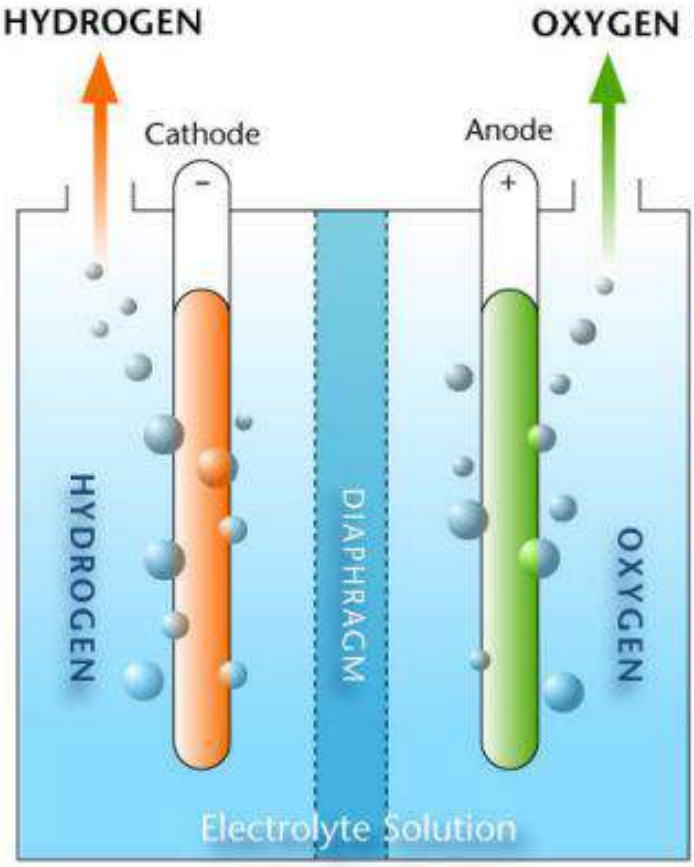


FIGURE 4: DRAWING EXPLAINING HOW WATER ELECTROLYSIS WORKS

4-Hydrogen uses:

The unique properties of Hydrogen has made it very valuable in many industries (used as a reactant, oxygen scavenger ,fuel ,cooling ,and used in petroleum processing [7] and many more industries).

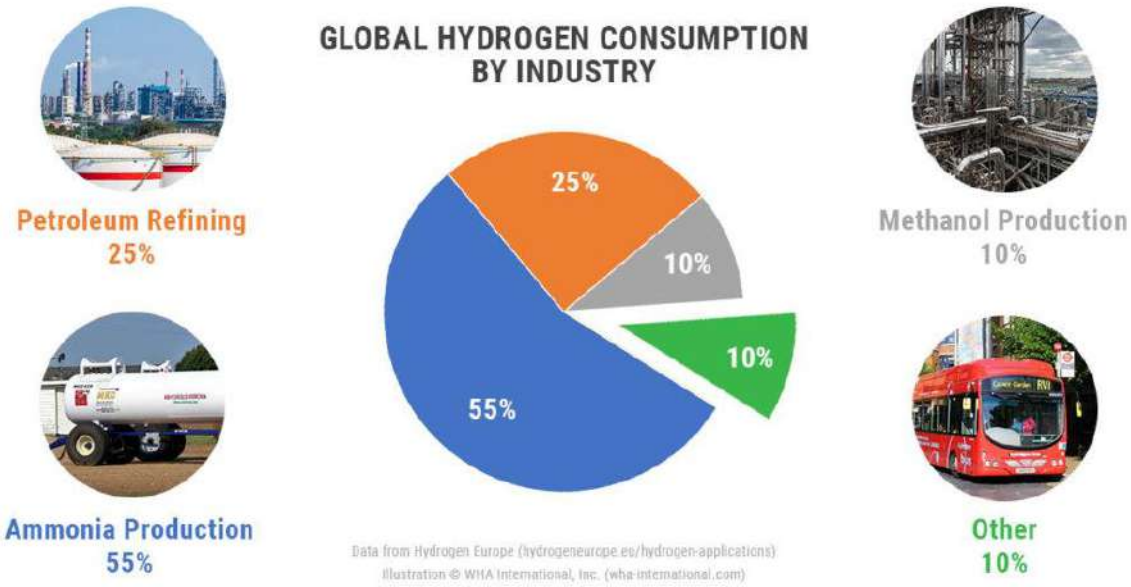


FIGURE 5: HYDROGEN USES[8]

Conclusion:

Different information has been given on hydrogen in this chapter, regarding its characteristics how do we get it, and where do we use it. in this next chapter the main subject is a risk analysis on a hydrogen production plant, firstly there will an introduction into the system that will be studied and also general definitions about risk analysis, and after that the chapter will end off with the analysis and the acquired results by the analysis.

CHAPTER 2: Risk Analysis Of The Hydrogen Production Plant

Introduction

Although hydrogen is considered very valuable in many industries, it still has its downsides, and that is due to the certain characteristics it has, because in addition to it being a flammable gas, hydrogen can be ignited with very low energy increasing the likeliness of a fire or worse an explosion, in addition to that hydrogen has an invisible flame, which can result in workers running into it without them even expecting it , and the list goes on the other dangerous characteristics of hydrogen[9] [4].

In this chapter, a risk analysis on a hydrogen production plant will be done, in the aim of finding critical accident scenarios and putting safety barriers to prevent them, but firstly there will be a presentation of the enterprise, after that basic definitions on risk analysis will be given, and also the method used in the risk analysis will be defined, and at the end of the chapter the risk analysis will be done with the results found through it.

1-Enterprise presentation:

1-1 SPE:

The Algerian Electricity Production Company "SPE" is a subsidiary of the group SONELGAZ, the largest electricity supplier in Algeria.

The Algerian Electricity Production Company (SPE) is responsible for the production of electricity from thermal and hydraulic sources meeting the requirements of reliability, safety and environmental protection.

Aware of the challenges and requirements of meeting future demands and the quality of the desired service, SPE continuously updates its provisional balance sheets and upgrades its production equipment. SPE aims to remain the dominant operator in terms of supply of electrical energy, it is implementing a vast program of rehabilitation and renewal of its production fleet to maintain the current level of production capacity.

1-2 SPE Oumache:

Oumache SPE unit is located 497 km from Algiers and 65 km from Biskra ,close to the national road NO 03 towards the Wilaya of Ouargla.

The unit started production phase in 2017 with a starter capacity of 456 megawatt.

It consists of two main power plants:

1st Power plant:

It contains two gas turbines.

2nd Power plant:

It contains 4 gas turbines and two steam turbines.

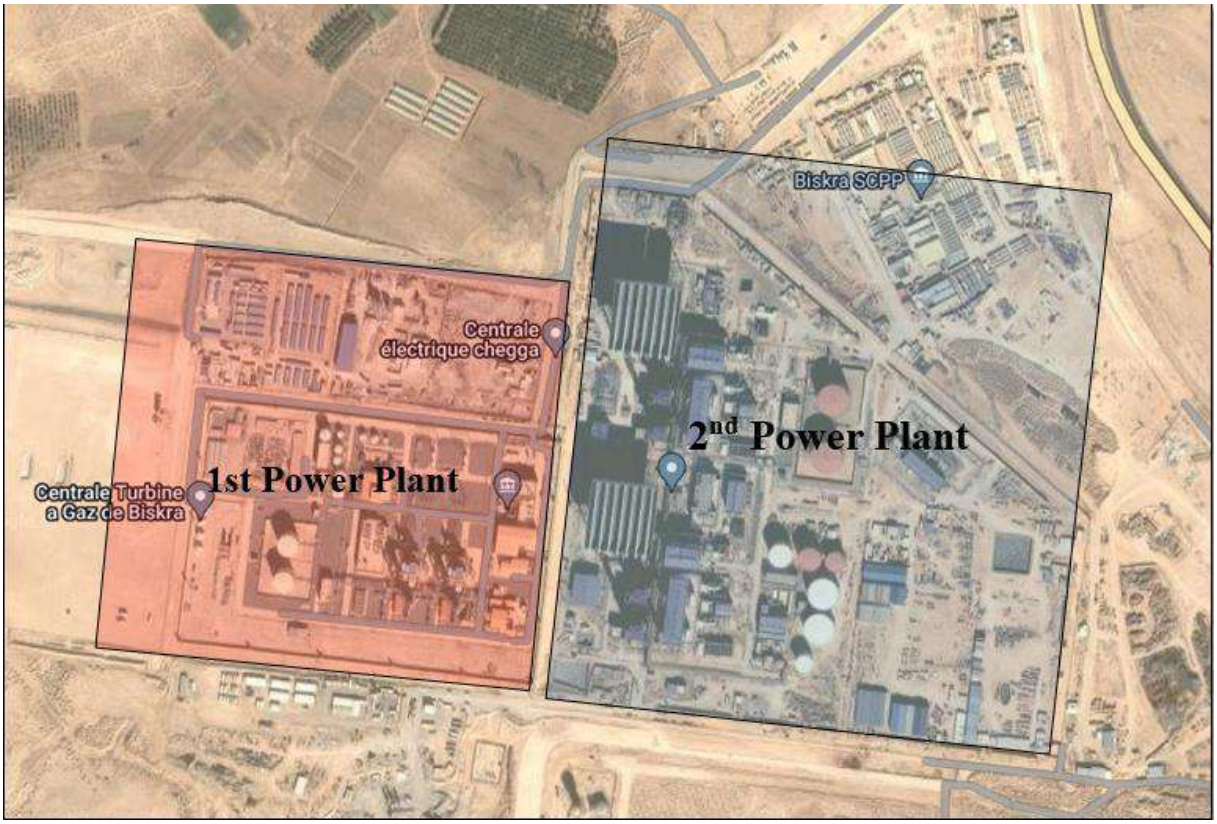


FIGURE 6: MAP OF OUMACHE SPE UNIT

1-3 Oumache 2nd power plant:

-The unit produces its electricity thanks to the 4 gas turbines and the 2 steam turbines.

-In order for the operation to work properly there are other parts to the unit (the control building, hydrogen plant, water treatment building… etc.).

2- Hydrogen plant:

Because of the high temperatures the generator in the gas turbine reaches, hydrogen is used to cool the generator.

Due the physical properties of hydrogen it is considered a great medium to cool the generator and this why a hydrogen plant exists on site because it’s more efficient and cheaper that way.

2-1 plant P&ID:

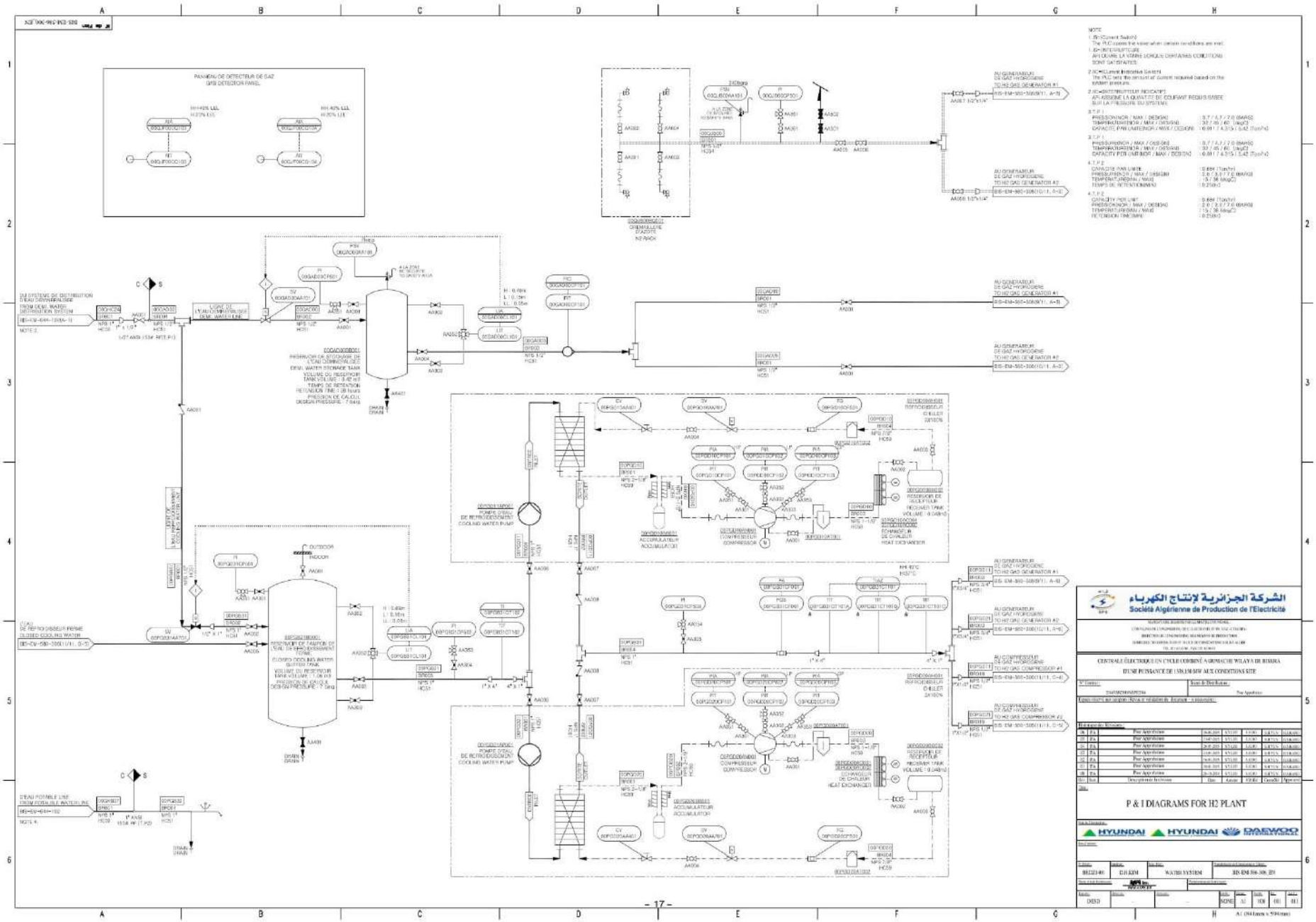


Figure 7: P&ID of the plant (part 1 / 3)

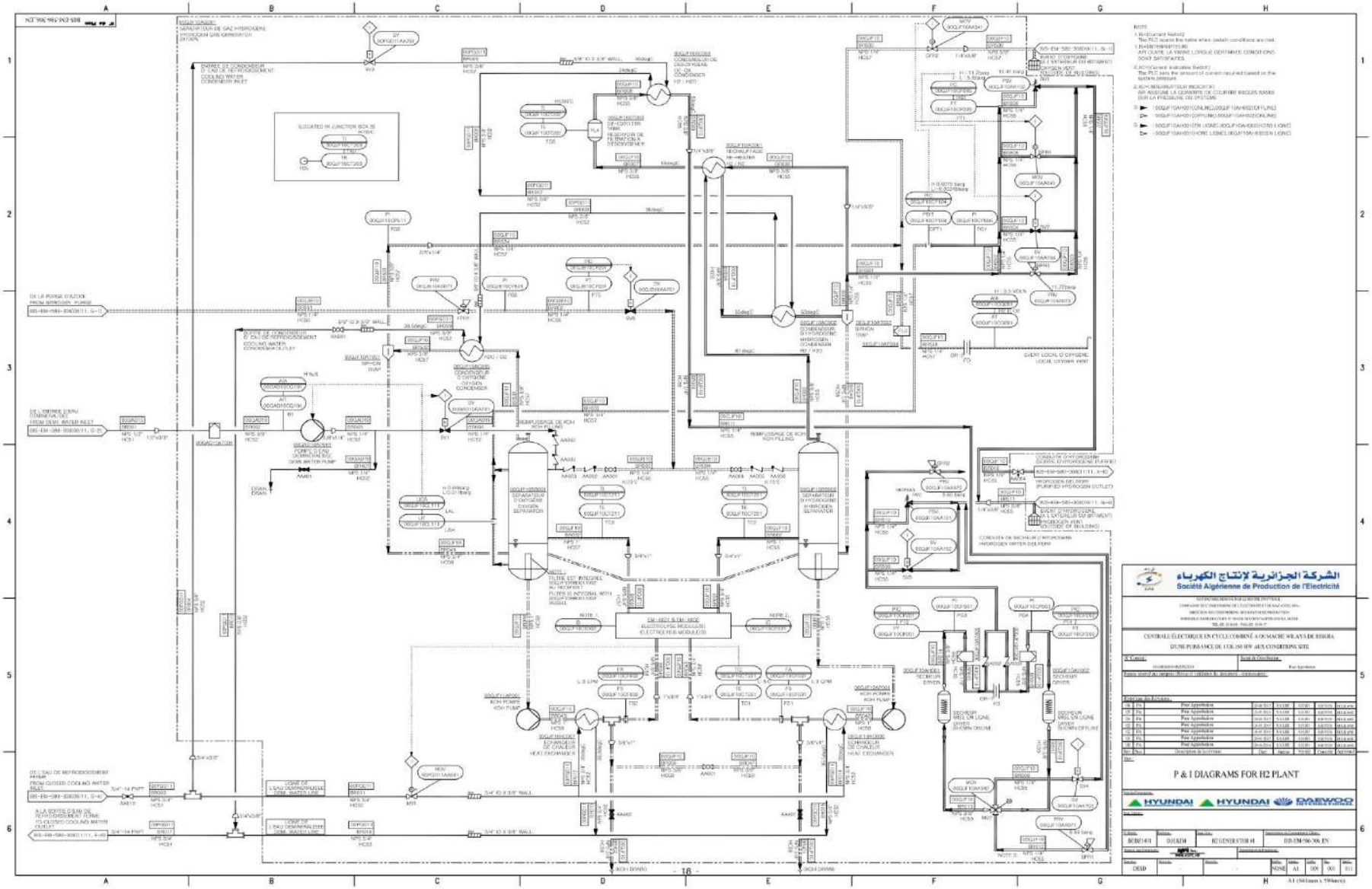


Figure 8 : P&ID of the plant (part 2 / 3)

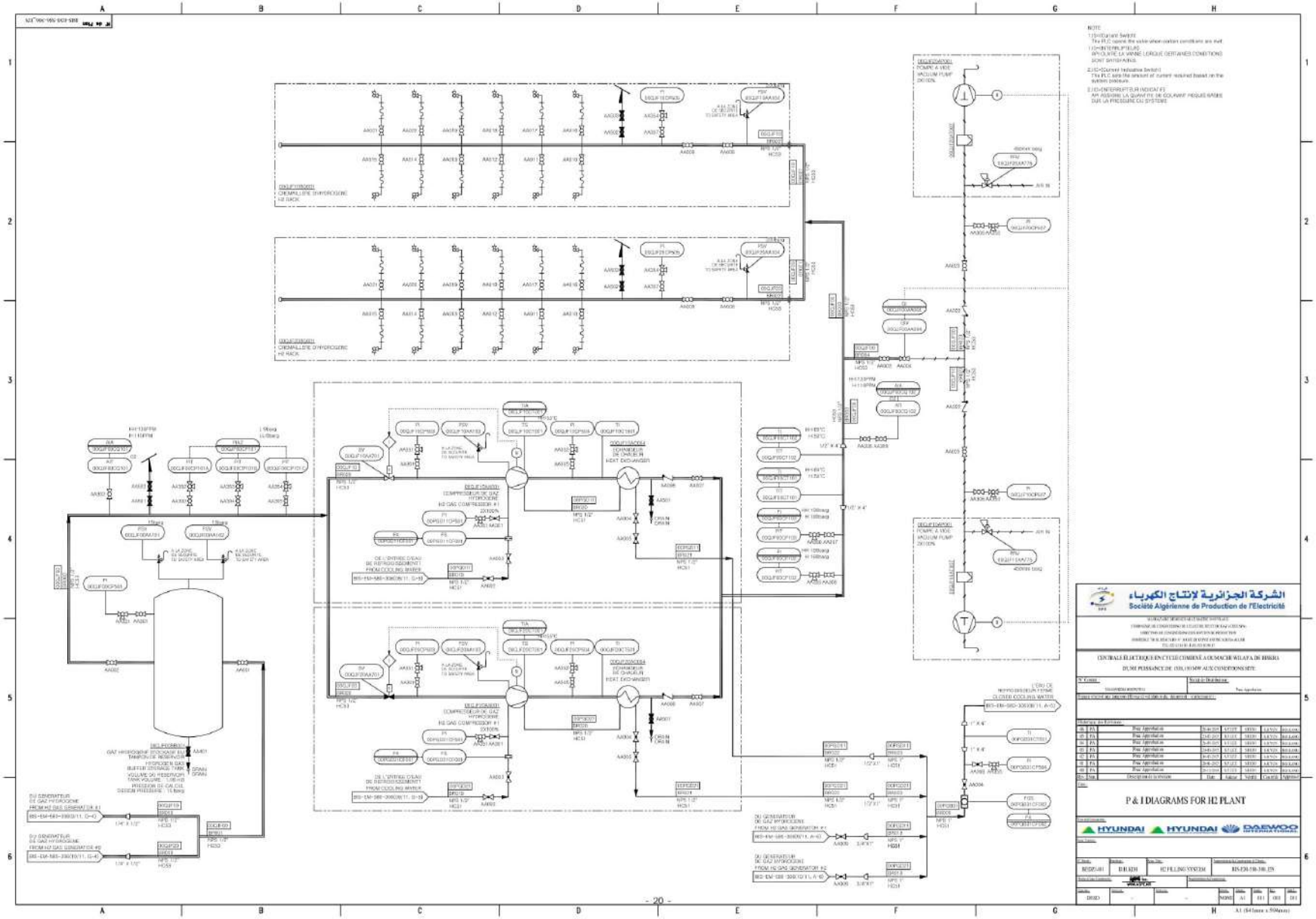


FIGURE 9: P&ID OF THE PLANT (PART 3/3)

2-2 P&ID GUIDE:

A list of P&ID symbols and their meaning:

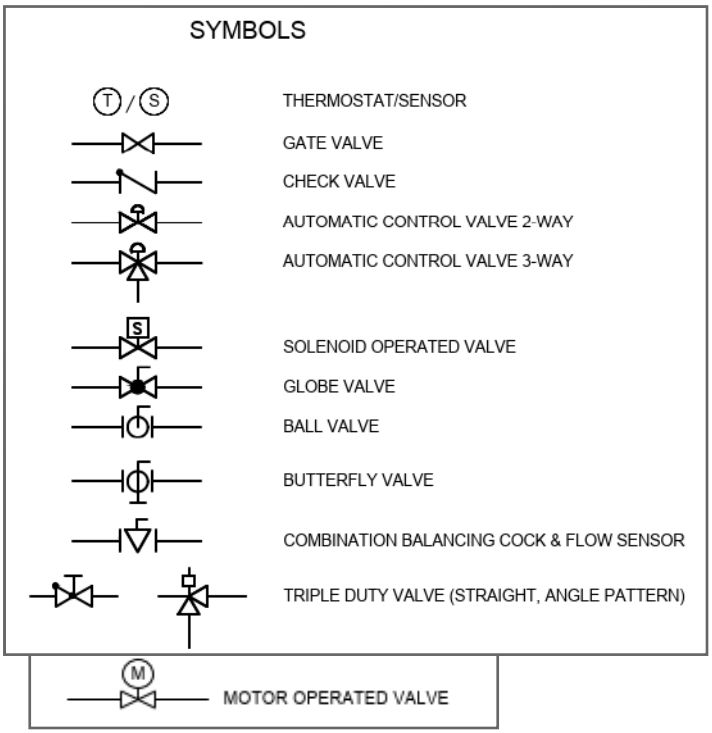


FIGURE 10 P&ID SYMBOLS AND THEIR MEANING

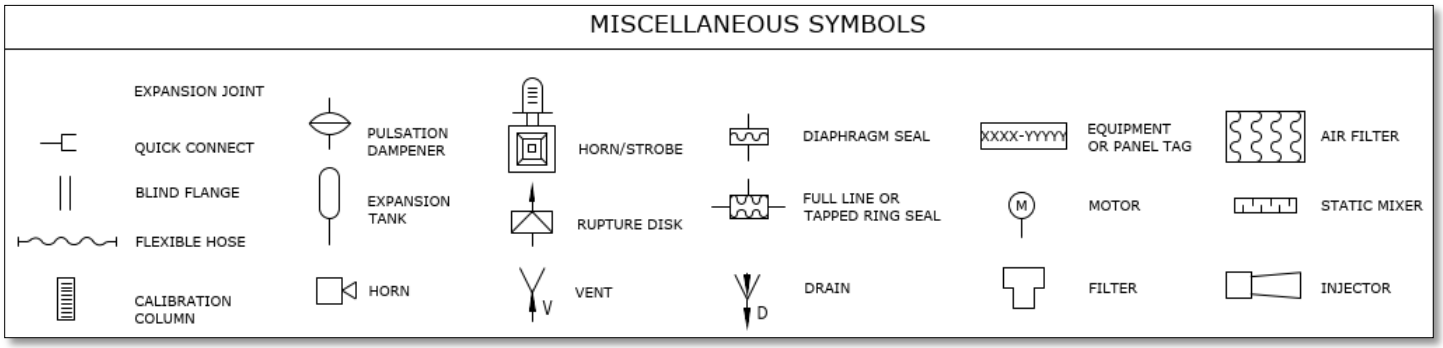


Figure 11 P&ID miscellaneous symbols and their meaning

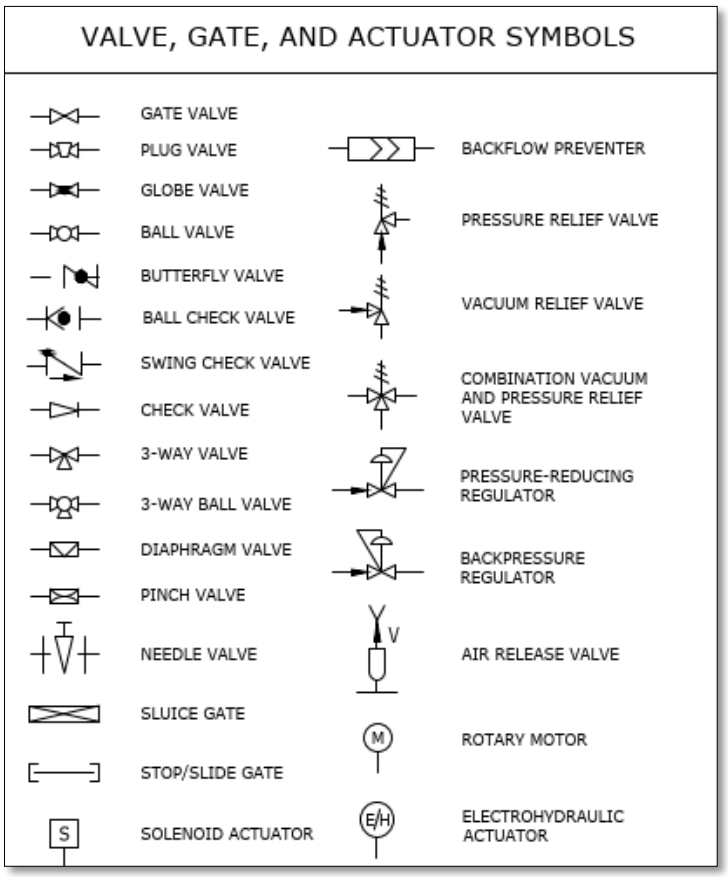


FIGURE 12 : P&ID VALVE, GATE, AND ACTUATOR SYMBOLS AND THEIR MEANINGS

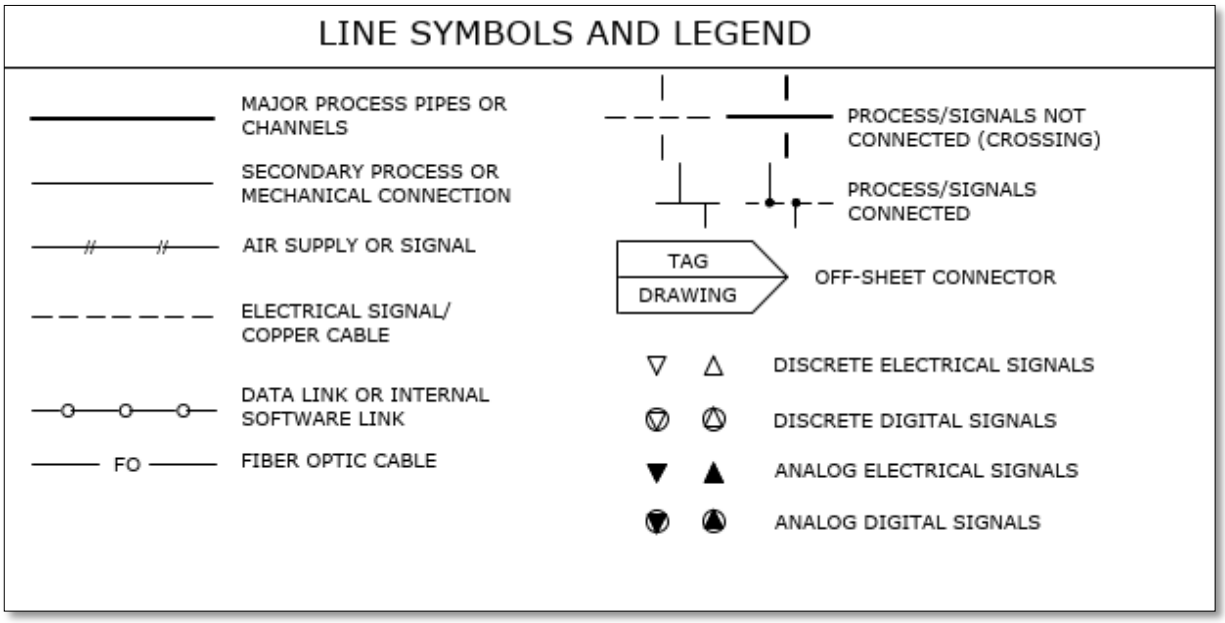


FIGURE 13 P&ID LINE SYMBOLS AND LEGEND AND THEIR MEANING

IDENTIFICATION LETTERS

	FIRST LETTERS		SUCCEEDING LETTERS		
	MEASURED OR INITIATING VARIABLE	VARIABLE MODIFIER	READOUT/ PASSIVE FUNCTION	OUTPUT/ ACTIVE FUNCTION	FUNCTION MODIFIER
A	ANALYSIS		ALARM		
B	BURNER, COMBUSTION		USER'S CHOICE	USER'S CHOICE	USER'S CHOICE
C	CONDUCTIVITY			CONTROL	CLOSE
D	DENSITY (MASS) OR SPECIFIC	DIFFERENCE, DIFFERENTIAL			DEVIATION
E	GRAVITY VOLTAGE (EMF)		SENSOR, PRIMARY ELEMENT		
F	FLOW, FLOW RATE	RATIO			
G	USER'S CHOICE		GLASS, GAUGE, VIEWING DEVICE		
H	HAND				HIGH
I	CURRENT		INDICATE		
J	POWER		SCAN		
K	TIME, SCHEDULE	TIME RATE OF CHANGE		CONTROL STATION	
L	LEVEL		LIGHT		LOW
M	MOISTURE OR HUMIDITY	MOMENTARY			MIDDLE, INTERMEDIATE
N	TORQUE		USER'S CHOICE	USER'S CHOICE	USER'S CHOICE
O	USER'S CHOICE		ORIFICE, RESTRICTION		OPEN
P	PRESSURE		POINT (TEST CONNECTION)		
Q	QUANTITY	INTEGRATE, TOTALIZE	INTEGRATE, TOTALIZE		
R	RADIATION		RECORD		RUN
S	SPEED, FREQUENCY	SAFETY		SWITCH	STOP
T	TEMPERATURE			TRANSMIT	
U	MULTIVARIABLE		MULTIFUNCTION	MULTIFUNCTION	
V	VIBRATION, MECHANICAL ANALYSIS			VALVE, DAMPER, LOUVER	
W	WEIGHT, FORCE		WELL PROBE		
X	UNCLASSIFIED	X-AXIS	ACCESSORY DEVICES, UNCLASSIFIED	UNCLASSIFIED	UNCLASSIFIED
Y	EVENT, STATE, PRESENCE	Y-AXIS		AUXILIARY DEVICES	
Z	POSITION, DIMENSION	Z-AXIS, SAFETY INSTRUMENTED SYSTEM		DRIVER, ACTUATOR, UNCLASSIFIED FINAL CONTROL ELEMENT	

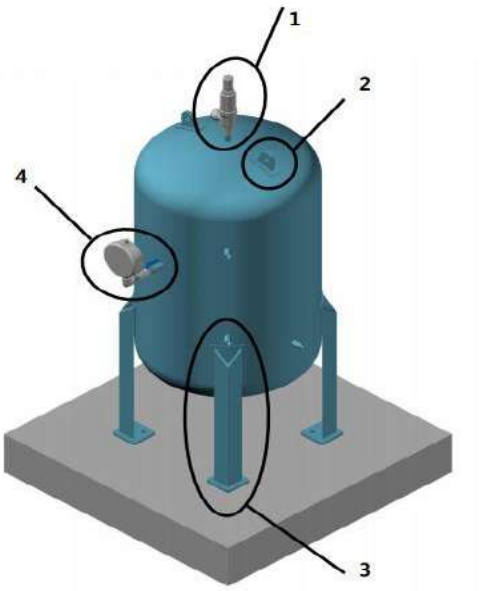
FIGURE 14 P&ID IDENTIFICATION LETTERS

2-3 Equipment in the hydrogen plant:

2-3-1 Two demineralized water storage tanks:

Both of them are used to store demineralized water that is used for:

- Production of hydrogen and oxygen (00GAD00BB001).
- Cooling the equipment (compressors, generators) (00PGB31BB001).



1: PSV

2: Lifting eye

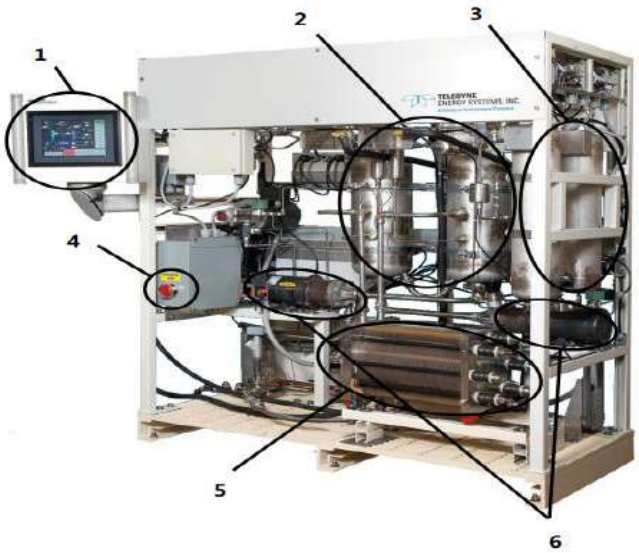
3: Support leg

4: manometer

FIGURE 15: WATER STORAGE TANK

2-3-2 Hydrogen Generator 2×100% (00QJF10AG001):

The equipment responsible for extracting the hydrogen and the oxygen from water.



1: Screen

2: Gas/liquid separator

3: dryer

4: Emergency stop

5: Electrolysis module

FIGURE 16:-HYDROGEN GENERATOR

2-3-3 Hydrogen storage tank (00QJF00BB001):

Used to store the hydrogen temporarily before it getting compressed into the cylinders rack.

FIGURE 17: HYDROGEN STORAGE TANK

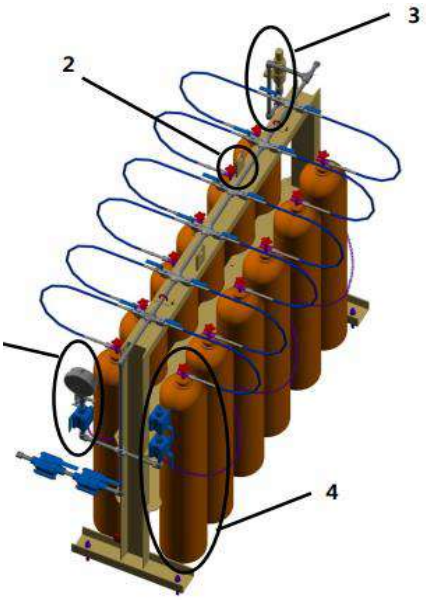
2-3-4 Hydrogen compressor 2×100% (00QJF10AN001):

Its function is to compress the hydrogen into the gas cylinders.

FIGURE 18: HYDROGEN COMPRESSOR

2-3-5 Hydrogen cylinders:

Its function is to store the produced hydrogen.



1: Manometer

2: Lifting eye

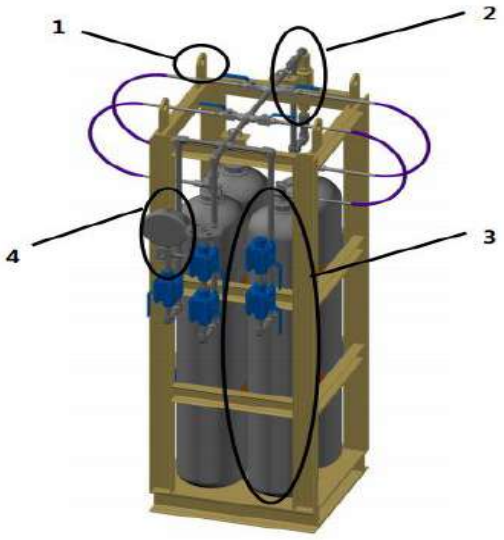
3: Security valve

4: Cylinder

FIGURE 19: HYDROGEN CYLINDER RACK

2-3-6 N_2 cylinders:

N_2 is used before starting the process, by pumping into the pipes it empties the pipes and the equipment from leftover gas.



1: Lifting eye

2: Security valve

3: Cylinder

4: Manometer

FIGURE 20: N_2 CYLINDRES

2-3-7 Suction pumps 2×100% (00QJF20AP001):

It’s used to empty the cylinder rack of any leftover gas.

FIGURE 21: HYDROGEN SUCTION PUMPS

2-3-8 Chillers pumps 2×100% (00PGD10AH001):

Its function is to cool the water used for cooling the equipment.

FIGURE 22: CHILLERS

2-3-9 Safety equipment:

Anti-fire wall, gas detectors.

2-4 Process explained:

2-4-1 Pre startup:

- Azote is injected into the pipes to remove any leftover gas.
- Vacuum pumps empty out the cylinders until they are empty.

2-4-2 Normal operation:

1-Demineralized water comes from the water treatment building then it gets stored in the demineralized Water storage tank.

2-The generator fueled by its inputs (KOH, Water, and Electricity) produces Hydrogen and Oxygen.

3-The produced O_2 is vented out in the atmosphere, and the H_2 is stored temporarily in the hydrogen gas buffer storage tank.

4- H_2 stored in the hydrogen gas buffer storage tank is then compressed into the cylinder rack until they are full at the pressure of 160 bar.

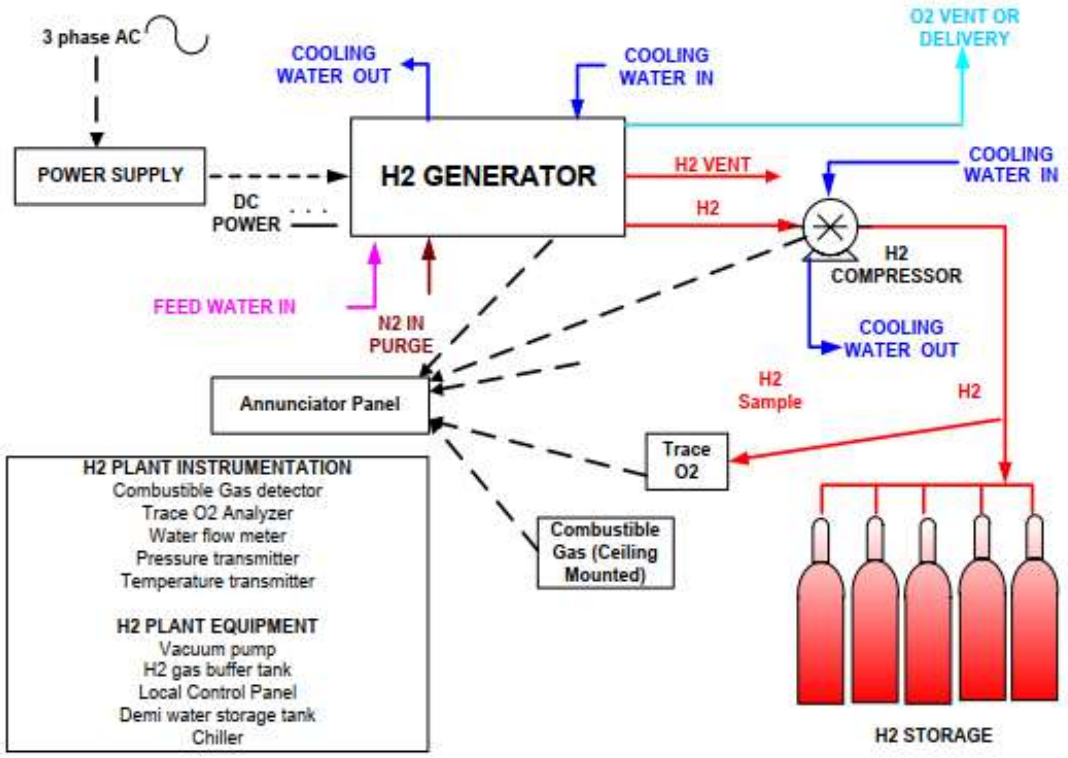


FIGURE 23: HYDROGEN PRODUCTION PLANT PROCESS

3- Terms and definitions in Risk analysis:

3-1 Risk analysis definitions:

A Risk analysis is a Systematic use of available information to identify hazards and to estimate the risk to individuals, property, and the environment (IEC 60300-3-9, 1995).[3]

3-1-1 Terms in risk analysis:

Risk: Combination of the frequency, or probability, of occurrence and the consequences of a specified hazardous event (IEC 60300-3-9, 1995). [3]

Hazard: source of danger that may cause harm to an asset. [3]

3-1-2 Qualitative vs. Quantitative Analysis:

The risk analysis may be qualitative or quantitative, depending on the objective of the analysis:

Qualitative risk analysis: A risk analysis where probabilities and consequences are determined purely qualitatively.

Quantitative risk analysis (QRA): A risk analysis that provides numerical estimates for probabilities and/or consequences-sometimes along with associated uncertainties.

[3]

3-1-3 Steps of a risk analysis :

I. Planning and preparing for the risk analysis.

2. Define the system, and determine the scope of the study.

3. Identify hazards and potential hazardous events.

4. Determine the causes.

5. Identify the accident scenarios.

6. Select relevant accident scenarios.

7. Determine the consequences.

8. Summarize the risk picture.

[3]

Step 1: Plan and Prepare the Risk Analysis:

To get quality results and actual helpful data, we must ensure a quality approach, one of the essential first steps of a quality risk analysis is the planning and the preparation of the analysis, this step contains usually:

Objectives and boundaries:

- Why are we doing the risk analysis?
- What do we do after we get the results (where do we use them)?
- What type of data do you must have after the analysis (type and format)?
- Who are the ones that give opinion in the analysis?
- Do you have a risk acceptance criteria?

1.2 Establish study team, ensure quality and involvement

- Is using local personnel enough or should there be external consultants?
- What different expertise are required?
- How to ensure quality communication between the study team?
- How to involve the personnel?

1.3 Select analytical approach

- What is the appropriate approach (method) to use in this system to meet your goals?
- Can we do the approach with available data and with underlined objectives?

1.4 Provide background information

- Is there any complaints, accidents that happened before in the system?

- Is there events, accidents that happened in similar systems?
- What is generally the acceptance criteria for this type of system?

[3]

Step 2: Define and delimit the system and the scope of the analysis.

To do the risk analysis it's essential that we understand how the system operates, and also define which parts of the system we are going to study.

2.1 System function

- Different operations done by the system?
- What are the Inputs in the system?
- Which part should be studied?
- Which operational phases will be studied (normal operation, startup)?

2.2 Assets and consequences

- What assets might be affected by an accident related to the system?
- What are the consequences that should be taken seriously?

2.3 Safety harriers and emergency provisions:

- Which safety barriers exist in the system (alarms, fireproof wall…)?

2.4 Details of the analysis:

- Is it a detailed or a general analysis?
- What events or accidents might be disregarded?

2.5 Data dossier:

- What are the elements in the system that need data?
- Where to find the needed data?
- Can we trust the source of the data?

[3]

Step 3: Identify hazards and potential hazardous events.

Step 4: Determine causes of each hazardous event.

Step 5: Identify accident scenarios (i.e., event sequences) that may be initiated by each Hazardous event.

Step 6: Select relevant and typical accident scenarios.

Step 7: Determine the consequences of each accident scenario.

Step 8: Establish and describe the risk picture.

A presentation of the relevant accidents and their consequences.

[3]

3-2 The risk analysis method defined:

3-2-1 HAZOP definition:

HAZOP (Hazard and Operability) study is a systematic hazard identification process to explore how a system or plant deviates from its design intent, resulting in hazards and operability problems .The approach was developed for the chemical industry in 1963 by ICI Ltd. (Kletz, 1999). [3]

3-2-2 Objectives:

- Identify all deviations, causes, and all the operability problems related to it.
- Share the found operability problems with the operators.
- Avoid potential accidents.

[3]

3-2-3 Different approaches:

There are several HAZOP approaches:

Process HAZOP:

This is the original HAZOP approach that was developed to assess process plants and systems.

Human HAZOP:

It focuses more on human errors rather than on technical failures.

Procedure HAZOP:

This HAZOP approach is used to review procedures or operational sequences.

Software HAZOP:

Identify possible errors in software.

[3]

3-2-4 Method Description:

The system or facility is divided into several study nodes, which are examined one by one. At each study node, the design objectives and normal conditions are defined. Then, in a brainstorming session, guide words and process parameters are used to suggest possible deviations in the system.

Guidewords:

Words that describe the current state of a parameter.

Examples: No flow, High temperature, Low pressure... Etc.

Process Parameters:

Some examples are:

- Flow.

- Pressure.

- Temperature.

- Level.

- Composition.

Deviation:

A combination of the guide word and the parameter.

Examples are:

No flow, high pressure, high temperature…etc.

[3]

3-2-5 Advantages and Limitations:

Advantages:

- Used worldwide which means we have more data on it.
- Takes advantage of personnel experience in the study.
- Organized and systematic.
- Able to identify all deviations in the system.
- Takes into account current safety measures.
- Works great with teams with different disciplines.

[3]

Limitations:

- Depends on the knowledge of the team.
- Sometimes there isn’t the required documents to launch the study.
- Sometime the study becomes lengthy.
- May miss problems that can occur between two different study nodes.

[3]

4- Risk analysis of the hydrogen plant:

4-1 Planning and preparing the risk analysis:

4-1-1 Motives behind doing the risk analysis:

Doing a risk analysis on the hydrogen plant is crucial and that is due to the nature of hydrogen, because hydrogen is the lightest and the simplest element in the periodic table it has a very unique set of characteristics that make it very dangerous:

- Hydrogen is a gas with a very low ignition energy, which means it ignites very easily.
- The flame of hydrogen is invincible.
- Hydrogen leaks easily due to its size.
- Hydrogen has a very broad flammability range.

[1, 4, 9]

And there is many examples of accidents that happened in the industry because of hydrogen:

FIGURE 24 :FATAL HYDROGEN EXPLOSION AT A POWER PLANT IN MUSKINGUM, OHIO ,USA[10]

4-1-2 The method used in the risk analysis:

The method used in the risk analysis is HAZOP, a method that works very well specially in systems that are composed of fluid circulation, and also because all majors accidents that could happen in the plant are related to fluids, specifically high pressure fluids.

4-1-3 Data sources:

The data needed to initiate the method is the P&ID of the system and data regarding alarm thresholds, details on the equipment in the plant...Etc. which are found in the OMM (Operation and Maintenance Manual).

4-1-4 The risk analysis team:

The team of the analysis is composed of:

- The one responsible for the risk analysis.
- Hydrogen plant operators to consult about the plant.
- HSE engineers to help in the analysis.

4-1-5 Desired results:

After the analysis is done, there should be a list of accident scenarios where the most critical ones will be extracted paired with appropriate safety measures to prevent them.

4-2 Defining the system and the scope of the study:

4-2-1 The studied system:

The hydrogen production plant (explained in chapter 2,2nd title.).

4-2-2 The scope of the study:

-The system will be studied in the operational phases (normal operation/startup).

-The system that will be studied is:

From the water buffer tank to the hydrogen gas cylinders.

-The parts that will be excluded are:

- All the inputs will be presumed to be in the expected characteristics (KOH, Electricity, and Water).
- The generator will be expected to be working without component failure.

4-2-3 Notes about the system:

The system started operation less than two years (the study was done on 2023), therefore all the equipment in the system is presumed to be on a good state.

4-3 Applying HAZOP:

Node 1

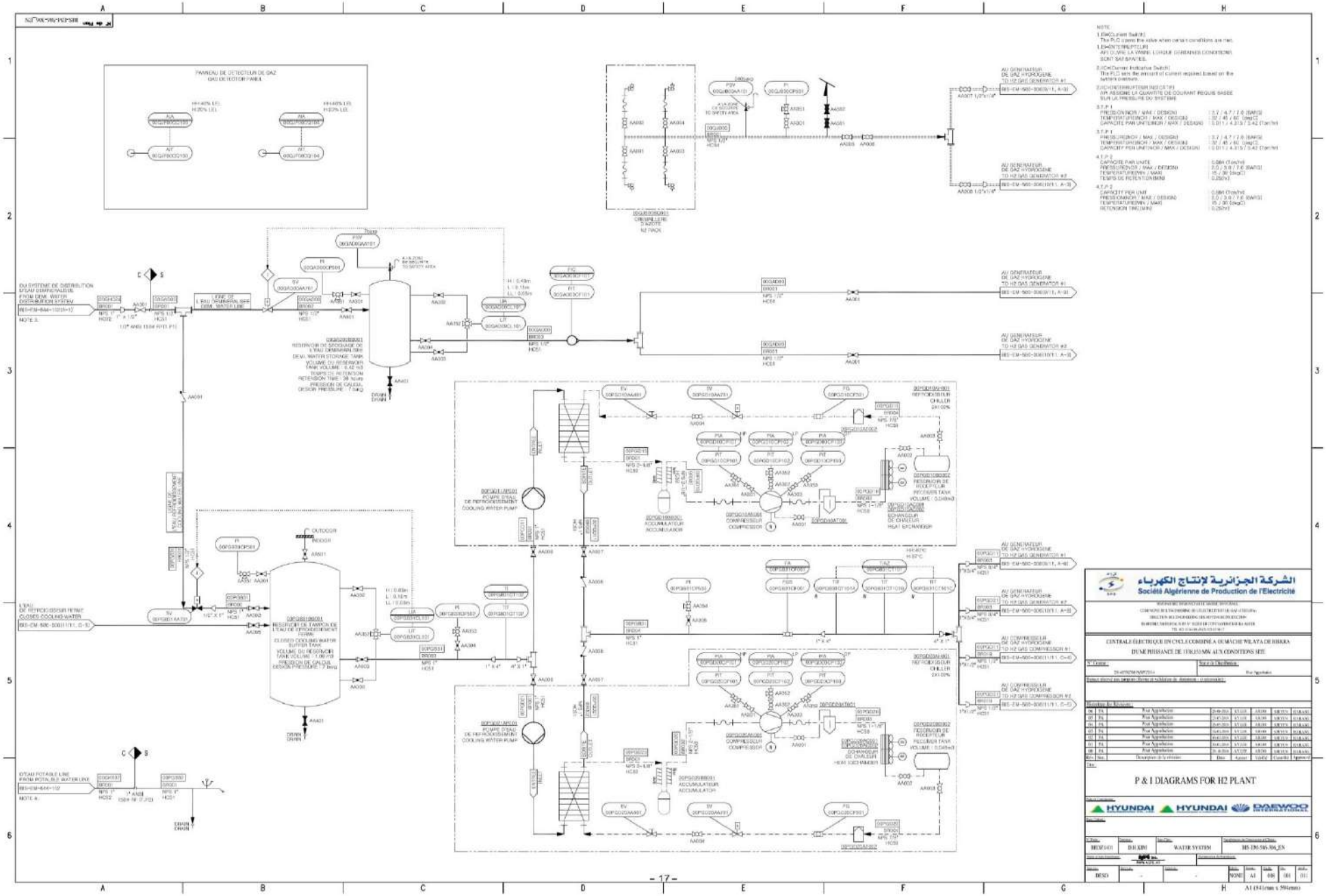


FIGURE 25 : P&ID OF THE FIRST NODE

WATER TANK TO GENERATOR

Demi water storage tank to generator					
No	Parameter	Deviation	Causes	Consequences	Protections
1	Flow	No flow	-Either or both: Ball valve AA004 forgotten closed. Ball valve AA001 forgotten closed. -Level control system dysfunction.	-No water flow to the generator -No hydrogen production	None

TABLE 1: HAZOP TABLE (1ST NODE)

Node 2

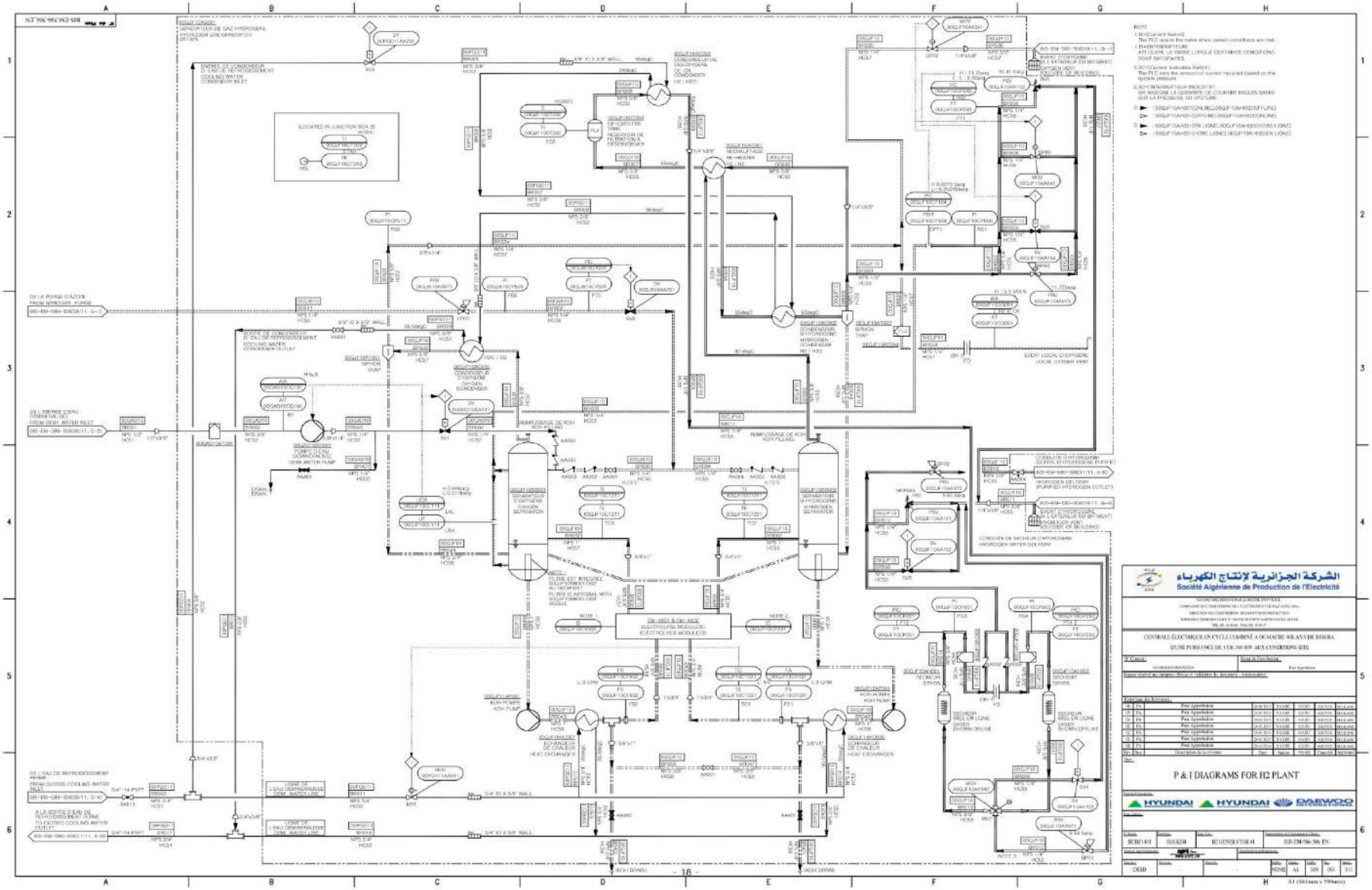


FIGURE 26: P&ID OF THE SECOND NODE (PART 1/2)

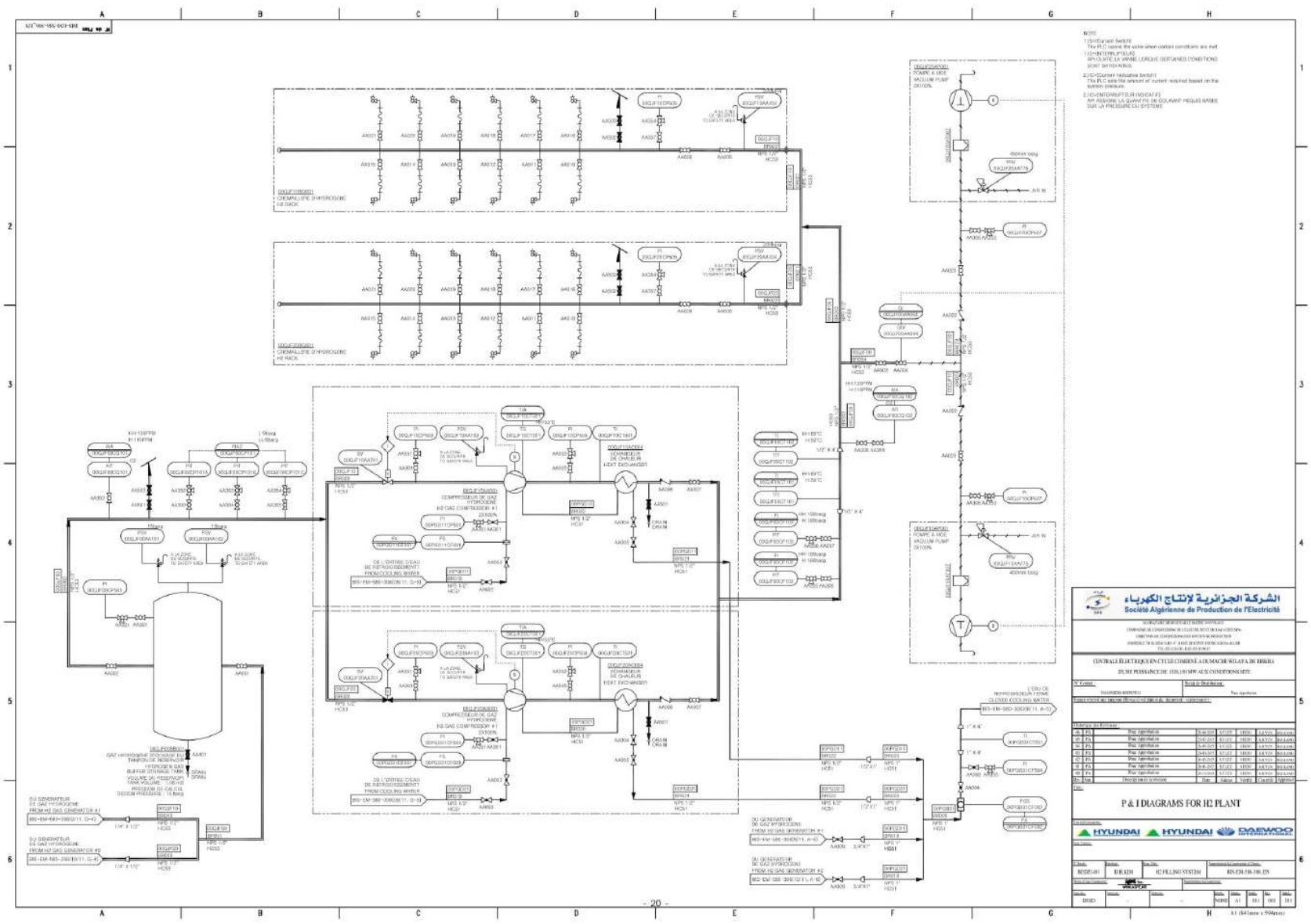


FIGURE 27: P&ID OF THE SECOND NODE (PART 2/2)

GENERATOR TO COMPRESSOR

NOTE: Normal operating pressure in this node is 10 barg					
No.	Parameter	Deviation	Causes	Consequences	Protections
1	**Pressure**	Higher than 10 barg	-Ball valve(AA001) Forgotten Closed	-High pressure in the system -Potential damage to the equipment -Process shutdown/release of the hydrogen to the atmosphere - Hydrogen Explosion	-2 PSV's in the generator (00QJF20AA101/ 00QJF20AA102) -PC (00QJF10CP205)
2			-Ball valve forgotten closed (AA002) -Solenoid valve closed(regulator error or valve error)	-High pressure in the system -Potential damage to the equipment -Process shutdown/release of the hydrogen to the atmosphere - Hydrogen Explosion	-Two PSV's in the H_2 gas buffer storage tank (00QJF00AA101/ 00QJF00AA102) -2 PSV's in the generator (00QJF20AA101/ 00QJF20AA102) -PC (00QJF10CP205)
6	**Pressure**	Less than 10 barg	Either or both: -Drain ball valve forgotten open (AA401). -Vent valves(AA501,AA502) forgotten open.	-Loss of hydrogen in the atmosphere -technical problems in the compressor	-PIAZ (00QJF00CP101)

TABLE 2: HAZOP TABLE (2ND NODE)

NODE 3

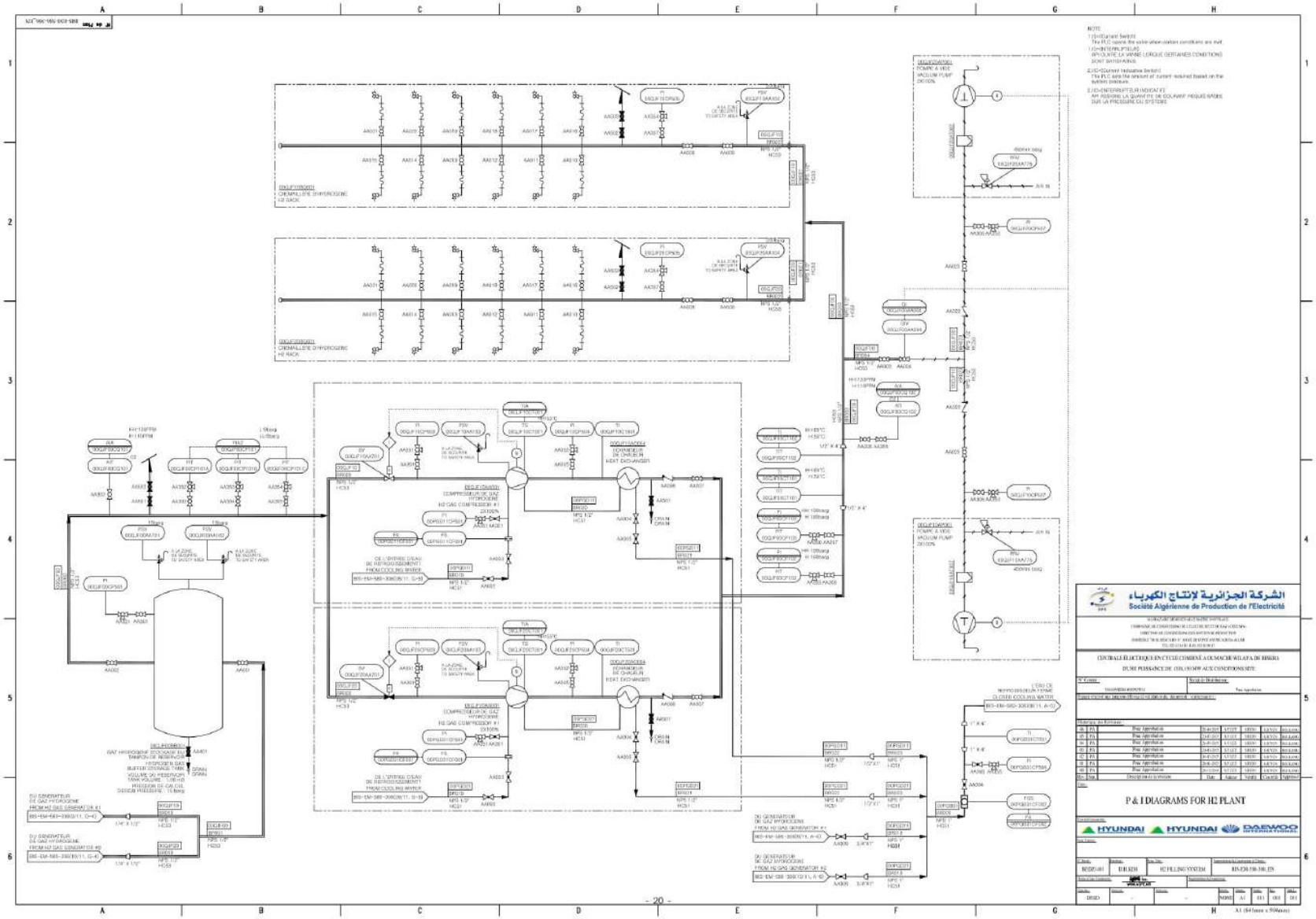


FIGURE 28: P&ID OF THE THIRD NODE

Compressor to cylinder rack:

Note: Normal operating pressure in this Node is (10-160 Barg)					
NO	Parameter	Deviation	Causes	Consequences	Protections
1	**Pressure**	Higher than 160 Barg	-Ball valve forgotten closed (AA007) -Check valve stuck closed(AA006)	-High pressure in the system -Potential damage to the equipment -Hydrogen Explosion	-PSV in the compressor (00QJF10AA103)
2			-Ball valves forgotten closed(AA008,AA009) (one or the two)	-High pressure in the system -Potential damage to the equipment -Hydrogen Explosion	-PSV in the rack (00QJF20AA104) -Two PI's (00QJF00CP102) (00QJF00CP103) , Two TI's (00QJF00CT101) (00QJF00CT102) -PSV in the compressor (00QJF10AA103)
3			-Compressor didn't stop	-High pressure in the system -Potential damage to the equipment -Hydrogen Explosion	-PSV in the rack (00QJF20AA104) -Two PI's (00QJF00CP102) (00QJF00CP103) , Two TI's (00QJF00CT101) (00QJF00CT102) -PSV in the compressor (00QJF10AA103)
4		Less than 10 barg	Either or both: -Drain valve (AA501) forgotten open. -Vent valves forgotten opened (AA502 and AA503).	-Loss of hydrogen in the atmosphere	-None

5		Slow increase or no increase in pressure	-Leak in the rack.	-Formation of explosive cloud, possibility of UVCE -Loss of hydrogen in the atmosphere	-Two gas detectors

TABLE 3: HAZOP TABLE (3RD NODE)

Relevant accident scenarios:

The relevant results of the HAZOP study are:

Scenario number	Relevant accident scenario	Recommendation
1st NODE (NO 1)	No water flow to the generator due to either: 1-A dysfunction in the level control system. 2-Either or both: -Ball valve AA004 forgotten closed. -Ball valve AA001 forgotten closed.	1-Add a secondary water line to the generator that starts working in case of no water flow to the generator.
3rd NODE (NO 1)	Hydrogen compressor (00QJF10AN001) explosion due to: 1-Outlet blockage caused either by the ball valve forgotten closed (AA007) or the check valve stuck closed (AA006). 2-And the fail of the PSV in the compressor to operate on demand.	1-Add a PSV in the line between the compressor (00QJF10AN001) and the check valve (AA006). 2-Schedule regular preventive inspection and maintenance sessions for the PSV's in plant.
3rd NODE (NO 4)	Hydrogen loss in the atmosphere due to : 1-Either or both: drain valve (AA501) forgotten open /Vent valves forgotten opened (AA502 and AA503). 2-And the missing of close by detectors to notice it.	1-Add a PIAZ system before the cylinder rack (L=9 barg , LL=8 barg).
3rd NODE (NO 5)	Hydrogen leak from the connections of the hydrogen gas cylinders with the production pipes due to not connecting the cylinders fully.	1-Schedule a training session on how to connect gas cylinders properly in the hydrogen production pipe.

Conclusion:

In this chapter the hydrogen production plant that is intended to be studied is presented after the main enterprise, its components and an explanation on how it works, after that basic terms and definitions were given about risk analysis, its steps and how to do them, next to that the method used in risk analysis was presented with general information about it, and at the end the risk analysis on the hydrogen production plant was done with its results given at the end of the chapter.

Global conclusion

The study conducted in this thesis was about doing a risk analysis on a hydrogen production plant, specifically through using HAZOP, which is the method that fits this kind of systems that are mainly composed of circulating of fluids.

The results of the study has shown that there are some flaws in the system, some of them may lead to very major accidents, and others may cause some problems to the production process:

- The potential of a compressor responsible for compressing hydrogen causing an explosion due to the lack of proper safety barriers.
- The potential of a hydrogen loss in the atmosphere without noticing it due to the missing of detection systems in certain places in the system.
- The potential of a UVCE caused by human error due to poor training of the workers.
- The potential of the production stopping due to the missing of a secondary water line to the generator.

We concluded after this study that indeed HAZOP is a very good tool to identify potential safety problems in fluid systems, and also realized the importance of constant risk analysis of systems to identify unidentified potential problems.

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Abstract

Hydrogen is considered very crucial in many different industries, in the ammonia production industry, as a mean of cooling for machinery, plus many more applications, but although hydrogen is a very useful molecule, we should be aware of its inherent hazards, because due to certain properties of hydrogen, the molecule is capable of causing major fires and fatal explosions.

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In this thesis a risk analysis is done on a hydrogen production plant, the plant is located in SONELGAZ SPE electricity power plant (OUMACHE Unit) and its function is to produce hydrogen that is used to cool the generators in the power plant, the risk analysis is done using HAZOP (Hazard and Operability) study, and all the relevant hazards and operability problems found by the risk analysis were given their proper safety barriers.

يعتبر الهيدروجين عنصر اساسيا في العديد من الميادين الصناعية،في مجال صناعة الامونيا ,كوسيلة لتبريد الالات , بالاضافة الى استعملات اخرى عديدة, لكن رغم كل هذه الاستعمالات المفيدة لهذه الجزيئة, يجب علينا الحظر من بعض خصائصها الخطيرة, فالهيدروجين قادر على احداث حرائق و انفجارات المميتة.

في هذه الاطروحة سيتم تحليل المخاطر الموجودة في محطة لانتاج الهيدروجين,تقع المحطة في شركة انتاج الكهرباء سونلغاز فرع اوماش و تستعمل لانتاج الهيدروجين المستعمل في تبريد مولدات الكهرباء, تم تطبيق تحليل الخاطر باستعمال طريقة HAZOP ,و تم اقتراح تدابير السلامة المناسبة لكل النتائج ذات الصلة المتحصل عليها.