

## RISK ANALYSIS OF THE SEA DESALINATION PLANT AT THE 5<sup>th</sup> REFINERY OF SOUTH PARS GAS COMPANY USING HAZOP PROCEDURES

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### ABSTRACT

Developments in designs complexity in the last two decades, has underlined the need for a comprehensive and systematic method capable of identifying and evaluating the process hazards. Amongst various methods presented to date, hazard and operability study (HAZOP) has received a considerable attention in the development of chemical and process industries. In this study, hazards in the desalination unit of a gas refinery in Asaluyeh, south of Iran was evaluated, using the PHA-PRO6 software, for which recommendations were made to avoid potential risks involved. Based on 8-years history of the refinery operation, maintenance records, accidents, safety vulnerabilities of the plant were evaluated. Employing the existing techniques and standards as well as installing appropriate flow control devices could ensure maintaining a normal operating pressure, which will in turn reduce pump stoppage and the unit being less out of service due to water flow shortage. Based on the HAZOP study results expressed here, the start-up procedure was also modified and problems associated with design, several mechanical parts and pipe lines installed were identified and adjusted.

**Keywords:** HAZOP; hazard identity; sea water desalination unit; risk; gas refinery.

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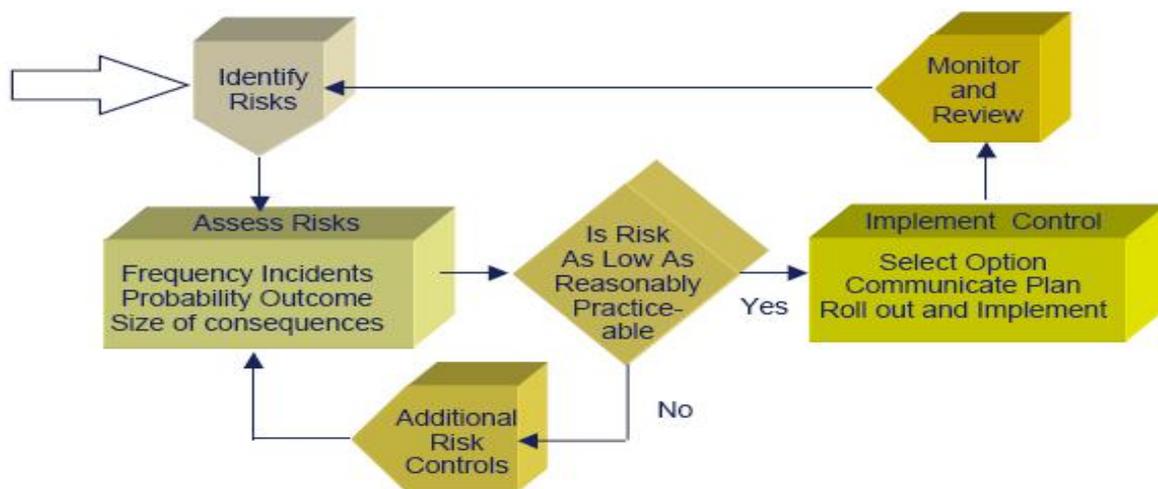
## 1. INTRODUCTION

Living in a safe world has been always the man's ultimate desire, for which he has strived continuously to improve his life style and achieve welfare through industrial efforts. Changes caused by such activities and their seemingly uninterrupted developments, has imposed at times specific hazards in the normal course of natural systems, the extent of which was unthinkable only three decades ago [1]. With development of industrial activities, corresponding risks have evolved. Thus, to achieve a safe environment, developing risk free industries is of great concern for both public and designer experts. The current increase in production capacities and investment necessitate design of safer plants, as in case of any accident, the competing process industries and markets would not tolerate such high costs, and force closure of the affected units. The proximity of industrial sites to cities, and population centers intensifies economic and social impacts of accidents [2]. Industrial accidents continue to occur all over the world despite existence of safety regulations and their implementations and unremitting attempt in developing methods to identify and assess process risks. Iran has had its considerable share of industrialized process accidents. Even the most advanced industrial plants quipped with the latest design specifications and most skilled operators are not protected against accidents, as fire and explosions at a refinery in Texas - USA in 2005 killed 15 people and incurred huge losses [3], or incidents being investigated systematically by the Chemical Safety Boards (CSB) in USA in the last two decades, and being made available to all industries all over the world. To mitigate accident potentiality, risk management methods are employed aiming to identify, evaluate and then eliminate or control risk hubs. The whole procedure is then evaluated and the safety system is reviewed to establish improved standards and operate in a safer mode [4].

### 1.1. Risk acceptance criteria

According to the definition of tolerable risk from the England safety and health executive, tolerability doesn't imply accepting the risk, but merely a tendency to live with a certain amount of controlled risk to provide special desired benefits [7]. Risk tolerability doesn't mean ignoring the relevant risks, but it assumes to control and reduce it in a relentless balanced manner, considering the probable benefits gained. Assuming similar risk, the

benefits of a hazardous industry in a developing country is therefore higher than those in a developed country, making it a general justifiable option. Realistically, one may conclude that applying criteria at developed countries may be seen as a hampering approach in realizing their comparative advantage [9]. In chemical industries, risk assessment is an approach for better and more efficient management of the process safety, whereby risk is estimated and considering various factors involved, decisions are made on the appropriate tolerability required. Figure 1 shows the different stages of risk assessment [3].



**Fig.1.** Different stages of risk assessment

Risk assessment involves a process of defining risks, evaluating losses and determining risk properties. The first phase of risk assessment deals with identification of probable risks and accidents in process. Risks identification should be in practice performed at all stages of design, implementation, normal operation, maintenance and on all conditions by which the process might be deviated from its normal performance to mitigate probable risks. Amongst various methods and techniques developed to identify the process risks, HAZOP is one of the most recognized one where risk is assessed qualitatively [5].

## 1.2. Risk Matrix

Risk is a function of probability and severity of an unwanted accident, where both is qualitatively estimated for a certain risk. The accident severity includes human injury, environmental hazards, equipment maintenance costs or brand credibility loss [6]. To estimate the risk quality, a risk matrix as presented in Fig. 2 is provided where probability [7] is plotted

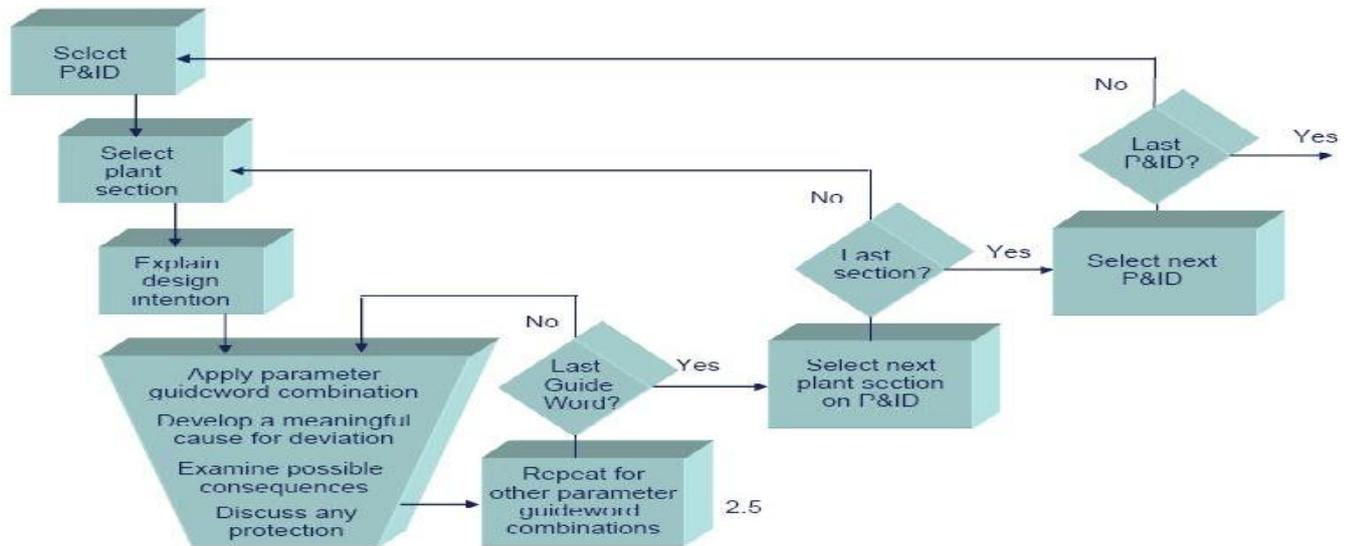
against severity [10]. Parameters or numbers are attributed to these in order to describe their ascending or descending trends. The elements within the matrix are qualitative and correspond to risk value and matrix order depending upon the number of probability and severity descriptions [8].

S E V E R I T Y	4	8	12	16
	3	6	9	12
	2	4	6	8
	1	2	3	4
LIKELIHOOD				

**Fig.2.** Risk matrix

### 1.3. Hazard and Operability Studies (HAZOP)

The term HAZOP refers literally to the study of hazard and operability. This is a systematic process search and design objectives in order to detect errors or inefficient performance and verify their consequences on the entire unit. The aim of HAZOP studies besides detection of deviations is sequential assessment and presenting suitable resolutions to increase process safety [10]. In this method, the system may only be considered as safe, when all operating parameters including pressures, temperatures, flows, liquid levels, corruptions, pipe leakage and failures are assessed normal. HAZOP studies could be performed throughout the entire life of a plant, however, its implementation at design stage is considered as beneficial and its repetition every 5 years is thought to prevent many accidents in a chemical plant [2]. In this study, first the system was subdivided into smaller subsections or selection of study nodes in order to identify deviations. Figure 3 illustrates the effect of process parameters change in each node [11].



**Fig.3.** The method of HAZOP study

## 2. RESULTS

### 2.1. Risks Assessment of the Seawater Desalination Unit

In this unit seawater is desalinated to provide operating water for different refinery units. The feed input included: seawater from unit 125, LP steam from unit 121 and its product, fresh water supplied to units 132, 130, 103, 127, 128 and saline water to the pond for storage and following operations. This unit consists of three desalination sets, which normally two are working and one is kept at stand-by for emergency failures. Each set could produce up to  $1300 \frac{m^3}{day}$  which is roughly 50% of the total plant capacity. The water in this unit is fed from unit 125 where water is separated from salt using a distillation process with desalinated water being kept in storage tanks and distributed across the plant for its consumption and salt water is returned back to unit 125 and ultimately to the sea. To remove chlorine from water, sodium sulfite is employed. Also, anti foaming and anti-scaling agents are used to limit foam formation and fouling where needed in the system.

Figure 4 is illustrates a schematic of the seawater desalination unit at the South Pars Gas Company. To perform the HAZOP, first, the unit was divided into logical nodes. The group studies revealed 8 operating deviations, where the most important ones with highest associated risk degrees are shown in Tables 1-2.

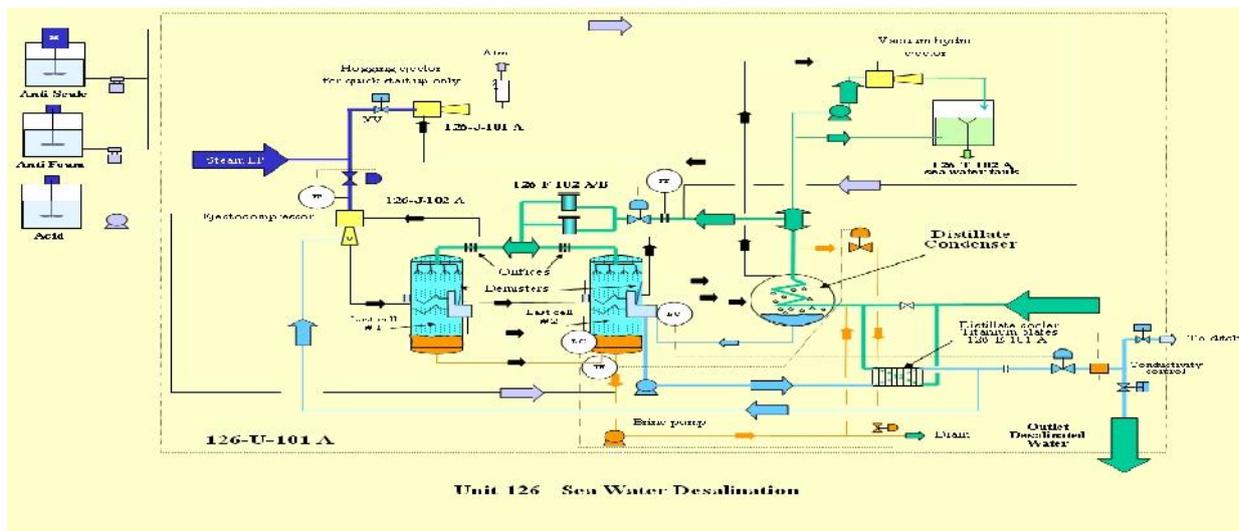


Fig.4. A view of sea water desalination unit

### 3. DISCUSSION

This project offered valuable results in terms of safety; process and environmental points of view, as indeed the recommendations yielded are expected to lead directly/indirectly to improved safety, productivity, reduced costs, plant availability, plant efficiency and capacity. The HAZOP group evaluated 8 operating deviations, 23 causes and 40 consequences. Results suggested that 30% of the deviations were of high risk category. Deviations were classified into two groups: those associated with start-up operations, those leading to the unit being out of service. Following a detailed examination of the operating nodes in the seawater desalination unit, several recommendations were made to improve plant safety and operation, as presented in Tables 1-2 output from the PHA-PRO6 software. These proposed recommendations could be divided into three general categories including: hardware, instructional and research proposals.

- 1- Pressure increase at cooling water could be due to malfunction at PCV0001 for which a PG should be employed and installed on the D101.
- 2- Pressure reduction in the pump which could be due to malfunction of PCV0001, for which a PG should be installed along the path, with a measurement device installed on D101 equipped with a pressure reducer alarm.

- 3- Water shortage in D101 due to valve closure for which one LG should be installed. To mitigate this installation of a level measurement device is recommended along the path.
- 4- Level increase at D101, due to valve opening, for which a high LG and LI alarm should be installed.
- 5- Fault in the PCV0001 due to pump stoppage and it being out of service, for which a pressure gauges to be installed along D101 is recommended. It was proposed to consider installing a PG keeping in mind the possibility of negative pressure characteristics.
- 6- PIC installation on the valve measuring pressure to alarm water shortage in unit 103 for being out of service.
- 7- FI-LL installation to alarm reduced flow, where conditions arise where no water is discharged at the unit 103.
- 8- In case of flow increase, to avoid probable consequence which could include water shortage at unit 103, one could install a PIC alarm on the T0046 valve.
- 9- Simultaneous running of two pumps would lead to increased pressure, for which installation of at the same time can lead to pressure increase and by installing a high pressure alarm (PIC-0046), this trend is avoided.
- 10- After P-102 became out of service, the materials are returned from unit 103 unit, for which installation of electrical valves operating as check Valve, would prevent return of the returned materials.
- 11- FIC installation is recommended to alarm for low surface level at tank 101 which should be installed compulsory.
- 12- It is recommended to install a FIC next to the valve, to alarm for reduced flow in case of pressure reduction.
- 13- FI-L needs to be installed at the drinking water inlet to the T101 storage tank for flow reduction alarm, thereby preventing water distribution.
- 14- FA-LL needs to be installed at the drinking water package to the T101 storage tank for flow reduction alarm, thereby preventing water distribution.

15- LA-LL should be installed to alarm level increase in Tank 101 which could lead to spilling.

16- If flow enters the tank, it would lead to level increase, for which installation of a LI is recommended as a guiding tool.

17- In case of a flow increase, the valve is opened, in order to avoid water level increase inside the drum, installation of a LI and a LG is required along the inflow path to the drum.

**Table 1.** Risk assessment of sea water desalination at the 5th refinery of South Pars Gas Company

Type: Pumps; Line; Storage Tank

Deviation: 1. No/Low Flow - Low and High Pressure and Temperature

Causes	Consequences	Risk Matrix			Safeguards	Recommendations
		S	L	RR		
1. Less water in than out.	1. Tank level failing.	4	3	12	1. Low level alarm LI0042 and low low level LA0041 and pump trip.	7. Review functionality of LI0042.
1. Less water in than out.	1. Tank level failing.	4	3	12	1. Low level alarm LI0042 and low low level LA0041 and pump trip.	8. Query the low level interlocks.

Causes	Consequences	Risk Matrix			Safeguards	Recommendations
		S	L	R R		
1. Unit103 shutdown.	1. No water to unit103	2	1	2	1. High pressure alarm for PIC0046.	2. Safeguards considered adequate.
2. Pump stops.	1. No water to unit103	3	3	9	1. Low pressure alarm on PIC0046	2. Safeguards considered adequate.
3. Butterfly valves failure on T101 Block strainer.	1. No water to unit103	3	3	9	1. Low low flow alarm FI0046	2. Safeguards considered adequate.
4. P102 suction starved when two P101s on line .	1. Pump damage.	4	2	8	1. Low low flow FI0046	6. Review hydraulics to prevent P102 suction starvation when both P101 pumps on line, or consider additional safeguards.
5. PV0046 closed	1. High pressure	4	4	16	1. High pressure alarm PIC0046	6. Review hydraulics to prevent P102 suction starvation when both P101 pumps on line, or consider additional safeguards.
6. suction strainer blocked on P102	1. Pump damage.	3	4	8	1. High pressure alarm PIC0046	6. Review hydraulics to prevent P102 suction starvation when both P101 pumps on line, or consider additional safeguards.

**Table 2-**Risk assessment of the water desalination unit at the 5th refinery of South Pars Gas Company

Type: Dosing Package; Biocide

Deviation: 1. No/Low Flow - Low and High Pressure and Temperature

Causes	Consequences	Risk Matrix			Safeguards	Recommendations
		S	L	RR		
1. Addition quill blocked.	1. No biocide addition	2	2	4	1. sampling procedure and analysis in unit 130	10. Vendor package to include diagnostics including remote trouble alarm on DCS.
2. No material from package	1. No biocide additions	2	3	6	1. Sampling procedure and analysis.	18. Ensure procedures in place.
4. FT0051 reads low	1. Reduced biocide in firewater tank	3	4	12	1. sampling procedure and analysis in unit 130	14. Vendor package to include diagnostics

#### 4. CONCLUSION

The most important problem in the seawater desalination plant was the impact of pressure increase on unit which would render the unit being out of service and pipes being burst, where there is lack of necessary standard instrumentations. At the time of delivering the system, pipelines were made of glass fiber G.R.P which offer high resistance to water and corrosion, but are weak in terms of stress and mechanical resistance and could easily be broken in case of increased pressure. Since the start of the plant in (2008), 3km pipelines were replaced twice. Other risks involved in this unit concerned the material with which distilled water pipes were made. They should be made from Titanium based according to the standard designs. However, due to shortages caused by the recent economic sanctions in Iran, they were made of aluminum with three layers of U.P.V.C., hence, the pipes were worn out rapidly over this operating time causing leakage in the unit. Some of the leakage occurred where saline and desalinated waters were running adjacent to each other, causing excessive

reduced quality of desalinated water product. As regards implementing hardware recommendations, economic evaluations could determine the value and importance of each recommendation which helps enormously the decision making process about priority in implementation. As regards death and injuries experienced in this unit, one could refer to two deaths caused primarily by not observing the exiting safety and HSE instructions. However, these instructions were reviewed and improved to avoid repetition of such accidents. The most important feature of the HAZOP study was its comprehensive approach, in which all existing deviations were considered separately on their own merits, by an experienced HAZOP team. The most significant weakness of the HAZOP study is that only issues are being investigated for which process charts and operating data exist. Another drawback about HAZOP study is its slow and time-consuming nature of it. However, it is worth noting that performing a HAZOP study constitute, only the first step in the risk assessment and it is highly recommended to implement methods where sequential analysis and evaluation of risks severity in the unit are taken into consideration.

## 5. ACKNOWLEDGEMENTS

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