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# Improving safety and risk management in high-risk industries: Focus on Safety Instrumented Systems (SIS) in the oil and gas sector

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## ABSTRACT

In the industrial sector, safety is paramount as systems face increasing risks and aging equipment. Recent advances have focused on technological risk management, highlighting the need for safety instrumented systems (SIS), as advocated by standards such as IEC 61508 and IEC 61511. This study highlights the important role of SIS in high-risk industries, particularly in the oil and gas sector, emphasizing the importance of risk analysis and adherence to international guidelines.

## 1. INTRODUCTION

The industrial sector is a multi-faceted ecosystem designed to meet contemporary demands and prepare for future advances. It considers technological, human, and organizational evolution to improve production and marketing efficiency. [1]

Safety is an integral part of the industry, ensuring the protection of systems in the face of growing risks and aging equipment. Recent developments have focused on improving technological risk management, particularly in the chemical and oil industries. System dependability (SdF) encompasses all the parameters and performance characteristics required to control system safety [2]. The performance characteristics of a safety system are not only related to maintenance but also to the risk reduction effectiveness of safety barriers (BS).

Standards such as IEC 61508 and IEC 61511 encourage the use of safety instrumented systems (SIS) to improve system safety. [3][4]

SISs include sensors, logic units and actuators, designed to prevent hazardous events and protect equipment. These systems are particularly effective in the oil and gas sector. However, many high-risk industrial facilities in Algeria lack SISs, posing significant risks.

For example, the gas reheating furnace in the oil and gas processing train is a critical component often lacking an SIS, despite its vital role. This study aims to highlight the importance of SIS in high-risk industries such as oil and gas, using various risk analysis methods while adhering to IEC 61508 and IEC 61511 guidelines [3][4].

## 2. CASE STUDY

Our study was carried out on the production train at the SH-DP Alrar gas processing complex in Illizi. The system studied is the H-182 furnace on a production train, which is the main function of heaters, or furnaces, is to ensure heat exchange between a hot fluid and a cold fluid separated by a surface. Heat exchange in the reboiler is by conduction and convection.

A heater consists of a metal casing, often in the form of a vertical cylinder, and comprises:

a) Radiation zone: where the tubes are directly exposed to the flame.
b) Convection zone: installed at the fume outlet, the tubes receive heat from the temperature of the fumes and are arranged in one or more passes.
c) A brick or concrete lining,
d) Burners: used to mix air and fuel to obtain complete combustion and release the heat contained in the fuel.
e) Tubes: coils through which the fluid to be heated circulates.
f) Chimney
g) Metal casing.

Devices and related:

a. Ignition devices and flame detectors:
Each of the eight (8) burners is equipped with a transformer-generated electric spark ignition device and a flame detector.

b. Control, signaling, and alarm section:
This section contains the actual control elements used for starting and monitoring the H-182 hot oil furnace. Control logic, alarms, and triggers were based on electromagnetic relays and timers, which were subject to more frequent failures due to operation.

## 3. STUDY OBJECTIVES

The study highlights the need for SIS as an essential component in managing and reducing the risks associated with industrial operations. In addition, it seeks to promote the application of various risk analysis methods and compliance with international safety standards (IEC 61508 and IEC 61511) to strengthen safety measures in these industries.

## 4. MATERIALS AND METHODS

To manage the risks associated with the H-182 furnace system, it is imperative to establish a comprehensive and effective risk assessment process by systematically following the following operational safety analysis procedures.

To achieve this objective, our evaluation is divided into two main components: technical-functional analysis and malfunction analysis.

Carrying out such an assessment begins with the initial step of identifying the structure of our vast system and delineating the main functions of the various elements (sub-systems, equipment, and components) that make up the H-182 furnace system. This is the first phase in the risk analysis process.

The comprehensive information obtained from the system decomposition approach enables us to undertake a malfunction analysis using HAZOP (Hazard and Operability) techniques. The various scenarios are summarized using the HAZOP method and presented in tabular form, enabling us to understand potential undesirable events and make the necessary recommendations. [5]

Using the HAZOP method, a summary of the various scenarios is provided in tabular form to determine potential negative consequences. In particular, the HAZOP analysis of the hot oil circuit in the furnace feed is detailed in table 3.

Our study for the Alrar site uses a risk assessment matrix, as defined by SONATRACH DP, to assign risk ratings. This matrix is constructed based on an assessment of the probability of occurrence and the severity of consequences associated with the identified risks. The specific criteria for categorizing severity and probability are detailed in Table 1.

The barrier types and their RRFs are shown in Table 2.

**Table 1:** Risk matrix defined by SONATRACH DP

| Fr | Frequency | Occ/year | 1. Moderate | 2. Serious | 3. Important | 4. Catastrophic | 5. Disastrous |
|---|---|---|---|---|---|---|---|
| 1 | A. Certain | $1 \leq F$ | 4 | 4 | 4 | 4 | 4 |
| 0 | B. Almost certain | $10^{-1} \leq F < 1$ | 3 | 4 | 4 | 4 | 4 |
| -1 | C. Probable | $10^{-2} \leq F < 10^{-1}$ | 2 | 3 | 4 | 4 | 4 |
| -2 | D. Possible | $10^{-3} \leq F < 10^{-2}$ | 1 | 2 | 3 | 4 | 4 |
| -3 | E. Rare | $10^{-4} \leq F < 10^{-3}$ | 1 | 1 | 2 | 3 | 4 |
| -4 | F. Very rare | $10^{-5} \leq F < 10^{-4}$ | 1 | 1 | 1 | 2 | 3 |
| -5 | G. Improbable | $10^{-6} \leq F < 10^{-5}$ | 1 | 1 | 1 | 1 | 2 |
| -6 | H. Very improbable | $10^{-7} \leq F < 10^{-6}$ | 1 | 1 | 1 | 1 | 1 |
| -7 | I. Extremely improbable | $10^{-8} \leq F < 10^{-7}$ | 1 | 1 | 1 | 1 | 1 |
| -8 | J. Impossible | $F < 10^{-9}$ | 1 | 1 | 1 | 1 | 1 |

**Table 2:** Code, barrier type, and associated RRFs

| Barrier Type Code and Associated RRFs | | |
|---|---|---|
| **Code** | **Description** | **RRF** |
| Alm | Control Room Alarm | 10 |
| Ctrl | Control function made by the control system | 10 |
| Proc | Procedure | 10 |
| Red | Redundancy | Depending on the architecture |
| SIS | Safety Instrumented System | * 10 to 100 for a SIL1<br>* 100 to 1000 for a SIL2<br>* 1,000 to 10,000 for a SIL3 |
| BSL | Interrupter (Safety switch) | 10 |
| HZI | Manual Position Indicator | 10 |

## 5. RESULTS

The results of the analysis are summarized in the HAZOP presented in Table 3.

- Our HAZOP study focused on 4 critical deviations: - very low hot oil flow rate, very high outlet temperature, low H182 pilot gas pressure, and high gas burner fuel gas pressure.
- The results show that the safety system of the H-182 furnace with the existing safety barriers is fragile and needs reinforcement.
- The SIL required is SIL max (SIL 2) for safety reasons (pessimistic thinking).
- A safety instrumented system has been proposed, including sensors, indicators, and alarms.

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We proposed a safety instrumented system with more redundant sensors, indicators, and alarms, and a new, more efficient digital logic unit with a SIL2 safety integrity level.

The new safety function has a real SIL2 that can meet safety requirements and bring the risk down to an acceptable level.

**Table 3:** HAZOP of old and new systems with and without the proposed SIS

| Nº | Parameter | Key-word | Deviation | Possible causes | Consequences | G | F | R | type | Existing Protection | G | F | R | Added Protection | RFF | E/A | G | F | R |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | Flow | F- Oil | Low Oil Flow HotH182 | - Anomaly in the regulation of the flow of hot oil by FIC158 recirculation. - Unintentional closing of the furnace inlet valve XV139 -FIC158 loop failure. -failure of the FIC 156 loop. | -Excessive temperature rise of the oil that vaporizes. Overheating tubes that are no longer cooled by oil. Deconfinement and internal furnace fire. - Tube melting. -Temperature increase. -Risk of fire on the furnace | 3 | -1 | 4 | Alm | - Low flow alarm by FI158 (in partial common mode with the control sensor) | 3 | -3 | 2 | / | 3 | E | 3 | -4 | 1 |
| | | | | | | | | | Proc | -Heater Inspection Procedure | 3 | -3 | | / | 10 | E | | | |
| | | | | | | | | | SIS | / | | | | -SIF0181-3: PSLL H182 Oil: On detection of low flow of H182 oil by FI158x monitored by FI158, retreat of the H182 furnace by gas shutdown. -SIF0181-4: H182 XV139 inlet oil valve not open: On detection of non-opening of the XV139 valve by the limit switches (to be replaced), folding of the H182 furnace by gas stop. | 300 | A | | | |
| 2 | Temperature | T+ fume | - High Smoke Temp Outlet H182 | Anomaly in the temperature control of hot oil by the TIC135/FIC157 control or anomaly in the management of the burners | -Excessive temperature rise of the oil that vaporizes. -Overheating of tubes that are no longer cooled by oil. Deconfinement and internal furnace fire. Degradation of refractories. Normal operating temperature 405°C. | 3 | -1 | 4 | Alm | High-temperature alarm by TI185 at 430°C | 3 | -2 | 3 | / | 10 | E | 3 | -4 | 1 |
| | | | | | | | | | SIS | / | | | | SIF0181-6*: TSHH fumes H182: Over detection of high temperature smoke by TAHH185x at 440°C monitored by TI185, retreat of furnace H182 by gas shutdown | 100 | A | | | |
| 3 | Pressure | P- Pilot gas | Low Pressure Gaspilot H182 | Failure to regulate pressure by PCV173 pilot fuel oil regulator on H182 gas valve | Loss of flame, build-up of gas, which can lead to an explosion in the furnace with missile effects out of the furnace | 3 | -1 | 4 | Proc | - Observation window. | 3 | -3 | 2 | / | 10 | E | 3 | -5 | 1 |
| | | | | | | | | | Ctrl | - Flame detectors (BE101 each driver). | 3 | -3 | | / | 10 | E | | | |
| | | | | | | | | | SIS | / | | | | SIF0181-8: PSLL pilot gas H182: On low gas pressure detection controlled by PALL173x, retreat of the 8 H182 furnace drivers (and complete shutdown of the furnace) | 30 | A | | | |
| | | | | | | | | | SIS | / | | | | SIF0181-9: BSL H182 pilots: On detection of burner flame loss by BSL101-i (i = 1 to 8), retreat of the associated pilot by the gas valves of the H182 furnace pilot | 300 | A | | | |
| 4 | Pressure | P+ Gas Burners | High Pressure Fuel Oil Burner Gases | Failure to regulate pressure by gas regulator PCV172 on the gas panoply | Flame blowing, accumulation of gas that can lead to an explosion in the furnace with missile effects out of the furnace | 3 | -1 | 4 | Proc | - Observation window. | 3 | -3 | 2 | / | 10 | E | 3 | -4 | 1 |

## 6. CONCLUSION

The use of risk analysis techniques is strongly recommended as part of a hazard study, as these methods facilitate a more complete identification of risks and, consequently, improve the management of significant hazards. It is important to note that there is no single risk analysis tool, as each has its advantages and disadvantages. Consequently, the suitability of a specific tool generally depends on the unique characteristics of the facility being studied and the specific objectives being pursued.

## REFERENCES


[1] J. Wolff, "How Is Technology Changing the World, and How Should the World Change Technology?" Global Perspectives, vol. 2, no. 1, Aug. 2021, doi: 10.1525/gp.2021.27353.

[2] Tarej Aven, "Introduction to risk management and risk assessments. Challenges," in Quantitative Risk Assessment, Cambridge University Press, 2011, pp. 1–15. doi: 10.1017/CBO9780511974120.002.

[3] IEC 61508, "IEC 61508 :2010: Functional safety of electrical/electronic/programmable electronic safety-related systems," 2010.

[4] IEC 61511, Functional safety - Safety instrumented systems for the process industry sector - Part 1: Framework, definitions, system, hardware and application programming requirements, 1st ed., vol. 1. IEC, 2016.

[5] IEC, "IEC 61882:2016: Hazard and operability studies (HAZOP studies) - Application guide," Mar. 2016.