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Hazard and Operability Study of Gas Exploration Field Located in Pakistan

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Abstract: Daily huge amount of oil and gas (O&G) is consumed around the world which is mainly transported and distributed through pipelines. The integrity and safety of these pipelines is of primary interest for Oil & Gas companies, consultants, Government agencies, and other stakeholders due to adverse consequences and heavy financial losses in case of operational failure. HAZOP (Hazard and Operability Study) is a widely used technique for the identification of process hazards in the design and operation of a facility. The main objective of this work is to analyze the hazards of existing gas & oil transportation plant located in a rural area of Pakistan. A detailed study was conducted by a team of 4-5 professional Engineers and identified the hazards by using specific guide words afterward, proper safety measure was suggested. The whole study was carried out in 6-9 months.

After detailed HAZOP study in gas processing unit about 14 risks were identified. Out of which only 01 risk is unacceptable and 03 are undesirable that should be mitigated to risk rank 3, the others are acceptable with controls. Based on which about 13 safety measures were recommended and most of them about 53% include regular or periodic checkups and maintenance. This article presents the cause and work stream of HAZOP and gives real case study for the utilization of HAZOP in gas processing fields. This study reveals the deviation occurs in the incoming gas flow pipeline which causes the plant to shut down and increases the downtime in production.

Keywords: HAZOP, Oil and Gas Field, Consequences, Deviation, Design, application and Gas Commingling Line

1. INTRODUCTION

With the passage of time and rise of population life has entered in the era of increasing frequency of environmental hazards. Human's negligence in this regards can cause such hazards that cannot be fully rectified. Safety and Risk management in industries especially in the oil and gas sectors play a crucial role in preventing accidents. The important step relies on risk management at the design phase of any industry. Safety in the design of oil, and gas, petrochemical, and offshore plants depends on the application of various codes of design, which are grounded upon the wide experience and knowledge of the experts and specialists in the industry.

(Selvan, *et al.,* 2015). According to Occupational safety and health administration (OSHA) a hazard is simply a condition or a set of circumstances that present a potential for harm. In order to prevent any Hazard, its identification is the basic and primary step. If the hazard is not identified then risk assessment is not said to be achieved. The unidentified hazard may attack any time resulting in accidents and losses. There are various methods of hazards identification which are applied in different stages and phases whether design or execution phase in a chemical plant. A Hazard and Operability (HAZOP) study is an appropriate, organized, and critical evaluation of the process of new or existing facilities to not only identify the potential for malfunctioning of equipment and property in terms of the resultant impact but also the operability problem of the system (Sikandar, *et al.,* 2016).

HAZOP (Hazard and Operability) studies appeared in a systematic way about 40 years ago where a multidisciplinary group uses keywords on Process variables to find potential hazards and operational problems (Pérez-Marín and Rodríguez-Toral 2013). HAZOP involves a detailed study of the entire process from beginning to end with the help of variations in process conditions in relation to temperature, pressure, material or energy flows in piping and Instrumentation Diagram (P&ID). One important factor to consider in managing HAZOP studies is the time required to execute the entire analysis (Freeman, *et al.,*1992).

The main objective of this work is to analyze the existing gas exploration unit, Gambat Petroleum field (GPF) and conduct detailed HAZOP for main gas distribution lines by a team of professionals. The HAZOP study has been conducted to meet the gas company sales gas specifications.

In this work, HAZOP study was used as a risk management technique on a gas processing field in Pakistan. HAZOP was performed in line using standard

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HAZOP guidewords and deviations applied on identified nodes, identifying credible causes and consequences. This case study attempts to introduce a suitable method for overall safety analysis for oil and gas processing plant located in Pakistan in order for the innocuous functionality of the plant. In 2018 one of the largest oil and gasexploration company of Pakistan discovered about 23.4 million cubic feet per day natural gas from Gambot block , Sind, Pakistan.

2. METHODOLOGY

HAZOP is a rigorous and highly disciplined procedure to identify the gaps in operability and process risks that account for safety. The success lies in the strength of the methodology to follow the system process flow diagram (PFD) / block diagram and piping and instrumentation diagram (P and ID) with clear understanding of gas production unit located in Gambet,Sind. As a first step, the PFD is broken down into different sections with defined boundaries to ensure the analysis of each section in the process (Kashif and Abro 2019). (Gordon. 2014) (Ramzan, *et al.*, 2007). In the first stage raw gas entered into heaters scrubbers and separator to remove oil ,condensate and other impurities e.g. carbon dioxide and hydrogen sulfide. This step is very essential to meet Occupational Safety and Health Administration (OSHA), and National Safety Council and other regulations. After this it must be dehydrated by absorption or adsorption. Nitrogen is an inert gas, non-flammable, and lowers the temperature of natural gas. Natural gas' gross heating value must be between 900-1200 British thermal units (btu) Pure natural gas is almost all methane, which has a heating value of 1010 btu. However the presence of nitrogen in pure natural gas lowers the gross heating value to meet pipeline requirements of gas company. Hence it must be removed by using some nitrogen regection technique.

This study has been conducted by a team of 4 to 6 people with diverse skills and experience of the process, different engineering discipline, management and operational aspect (Kletz, 1992). The HAZOP team comprises of team leader-an independent person who has a sound knowledge and experience of HAZOP techniques. Some understanding of the proposed plant design would also be beneficial for HAZOP team members (Elliott, and Owen. 1998). It is useful for identifying weaknesses in systems (existing or proposed) involving the flow of materials, people or data, or a number of events or activities in a planned sequence. HAZOP may be viewed as an integral part of the overall process of value engineering and risk management (Abro, 2018). Following steps were used during whole HAZOP study conducted as per the requirement of oil and gas processing unit.

To start HAZOP analysis of oil and gas exploration unit first step is to identify a system and subsystem with respect to specific nodes. These nodes decrease the number of consequences with respect to specific line/equipment by adding more safety instruments like alarms/sensors etc. The second step based on question/answers between team members about the deviations possibilities in the process parameter with respect to some specific guide words in **(Table 1).** Then a detailed analysis of causes of deviation, consequences with recommended actions analyzed by the whole team. The hazop steps are summarized in **(Fig 1).**

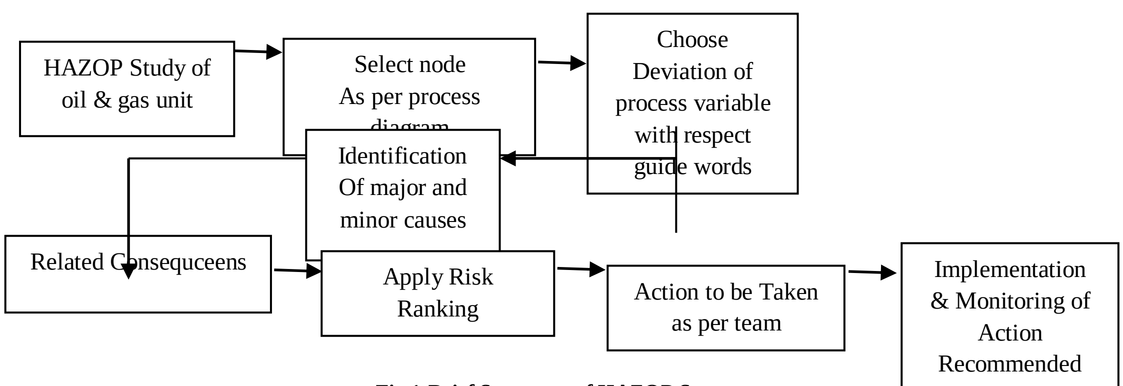

Fig.1:Brief Summary of HAZOP Steps:

To analyze the risk factor involved during the whole process explain as the likelihood combination possibilities and consequences may occur due to the unsafe operation, mathematically define as follows. (Hyne, 2001)

Risk = (Consequence) x (Likelihood) Similarly risk associated with each hazard calculated by risk matrix as mentioned in **(Table 2).**

Table 1. Guide words used to identify risks/operating problems.

GUIDE WORDS	EXPLANATION
NOT/NO	Complete deviation from design.
MORE	The increase of any relevant physical property w.r.t. design.
LESS	The decrease in any relevant physical property.
PART	The composition of the system different from what it should be, e.g. change in the ratio of components, component missing, etc.
AS WELL AS	More components present in the system i.e. qualitative charges.
REVERSE	A parameter occurs in the opposite direction w.r.t design intent.
OTHER THAN	Complete substitution.

Table 2: Standard table for Risk analysis of Oil and Gas Exploration Unit

Risk Categories

Severity of Consequence	Likelihood of Consequence				
	5	4	3	2	1
5	25	20	15	10	5
4	20	16	12	8	4
3	15	12	9	6	3
2	10	8	6	4	2
1	5	4	3	2	1

Risk Decision Criteria

Risk Rank	Recommendation
5	Unacceptable - should be mitigated to risk rank 3 or lower as soon as possible
4	Undesirable - should be mitigated to risk rank 3 or lower within reasonable period
3	Acceptable with controls - verify that procedures, controls, and safeguards are in place
2	Acceptable as is - no action is necessary
1	No Hazard, Not Probable

3. RESULT AND DISCUSSION

The HAZOP technique was found to be one of the effective methods for oil and gas industry. It increased the understanding, safety and environmental compliance of the field and highlights the safety issues. GPF II (Gambet Petroleum Field 2) sales gas is not meeting Local gas company specifications due to high Nitrogen gas content. It has been proposed to comingle GPF I(Gambet Petroleum field 1) gas having low nitrogen content as compared to GPF II gas line. Two options for comingling has been proposed;

1-Comingling of Sales gas line of GPF I and GPF II.
2- Comingling of raw gas at GPF II inlet.

To perform HAZOP study on above process 02 nodes were selected by the HAZOP team on the basis of Change in design intent, change in state (e.g. from liquid to vapor) and major pieces of equipment. Guidewords were selected and applied in turn to each parameter (Hyne, 2001). HAZOP summary report of whole plant is shown in Table 2 in which action required with respect to existing Safty measures also discussed.

In the **(Table 3),** we used the guide word like more, less, reverse, others like isolation, rupture, relief etc. Some deviations can be easily controlled by taking a minor control action. (HIPAP 8: 2011) (British Standard BS: IEC61882: 2002) (Ali *et al.*, 2017) (Rossing, *et al.*, 2010). (Chandio, *et al.*, 2018) (Abro 2019) All potential causes were established for each deviation from intention considered. All potential practical consequences for each cause must be identified, especially the potential for harm to people and the environment. Then safeguards are applied to prevent or mitigate the hazard. Finally, if the safeguards are insufficient to solve the problem, offering recommendations must be considered (Jordi *et al.*, 2010). (Shagufta *et al.*, 2017), In this step, the team identified the Engineered system (as defined in the PandIDs and other engineering information) and administrative controls (such as operator response to alarms) that can prevent or mitigate the hazard. The team should also consider whether operability is damaged if any deviations occur or whether the design could be improved to give the operator better information or facilities to prevent/control/mitigate the hazard as mention in **(Table 3).**

After the implementation of HAZOP team recommendations hazards will be controlled in time before they turn into a disaster. This case study belongs to one of the largest oil exploration unit of Pakistan HAZOP . Based on the detail shown in the block flow diagram provided by process engineer about 2 nodes were recognized. The team members primarily focused on the operational problems and more attention was focused on the deviations with a negative influence on the operation of the system resulting in financial losses and personal injuries. After detailed work about 11 deviations and 14 possible causes were identified. However about 5 were related to Node 1 and about 9 were related to Node 2. After Risk calculation, 14 risks were identified **(Table 2).** Out of which only 01 risk is unacceptable and 03 are undesirable that should be mitigated to risk rank 3, the others are acceptable with controls.

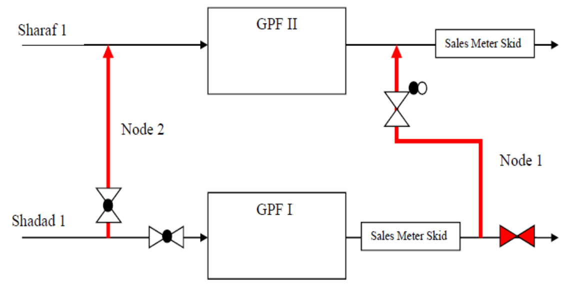

Fig. 1: Block Flow diagram of Comingling of gas Supply Lines from GPF1 and GPF 11 showing 02 nodes.

Table 3: Summerize HAZOP Sheet to analyze the existing Safeguards on node 1 and 2 of Gass Processing Plant

The deviation with a rep to guide words	Causes	Consequences	Safeguards	Recommendation	Risk= consequences* likelihood
More flow	Due to Failure of Pressure control valve PCV-114-001.	1) Pressure in sales header drops leading to more flow from the centrifugal compressor at GPF II causing process upset. Centrifugal compressor may stall leading stone wall effect, no impact at GPF I. 2) Gas loss into a flare as GPF I and II gas will be diverted to flare.	1- Compressor shutdown	Develop Standard operating procedure SOP for communication b/w GPF I and GPF II control room in case of an emergency.	5*2=10
Less/ No flow	The manual valve on GPF I line and GPF II closed inadvertently	1) GPF I plant tripping causing GPF II gas getting off spec, revenue loss.	The close manual valve on GPF I sale gas line towards	Regular inspection and monitoring are required.	4*2=8
Isolation	1- Single isolation on comingling line b/w GPF IandII 2- line depressurization arrangement not available on comingling line in case GPF II is operational	1) Failure to isolate GPF I, when required e.g. for rotation of spectacle blind or for intrusive maintenance activity on ESDV 500, in case of single valve passing requiring both plant shutdown and depressurization leading to plant downtime and production loss. 2) ESDV-500 cannot be removed for any maintenance activity		Evaluate and document requirement of Double Block and Bleed arrangement on comingling line b/w GPF Iand II considering the requirement for positive isolation for any intrusive maintenance at either side. 4-Evaluate and document provision of line blow down facility d/s ESDV-500.	5*3=15
Rupture/leak	Leakage or rupture in piping due to corrosion, mechanical impact, dropped object etc. Unavailability of ESD valve on commingling line at GPF-ii battery limit may lead to escalation of event due to longer blowdown time of piping section isolated from GPF i	1)loss of containment leading to fire upon ignition potential for serious injuries or fatalities and asset damage, potential for escalation into a major fire in case of longer blowdown time needed to depressurize notable section of piping causing 2)failure of adjacent piping and equipment exposed to fire	FandG detectors available at GPF II cause GPF I and II shut down.	1-Evaluate and document the requirement of ESDV on comingling line at GPF II battery limits for isolation and blowdown of contents of comingling lines of ESV as per existing isolation and blowdown. 2- Evaluate and document requirement for integration of ESD logics of GPFF iand ii upon detection of low pressure at either unit.	5*4=20

Deviation	Cause	Consequence	Safeguards	Recommendation	Risk= Consequences* Likelihood
More flow	1- Spurious Trip - ESDV-110 fails in closed position 2- Control failure - PCV-110 at GPF-I fails in closed position 3- manual valve V-110 closed inadvertently	well total flow diverted to GPF II exceeding GPF II plant capacity leading to off-spec gas and revenue loss	**1)**- FI at GPF I and II will alert operators in both control room to intervene and take corrective action **2)**- Process upset at GPF I will alert operators to intervene and take corrective actions	Regular inspection and monitoring are required.. Operator training	4*2=8
Less flow	More flow diverted to GPF I and less towards GPF II (Manual flow distribution)	Nitrogen/HCV off spec at GPF II metering skid	FI at GPF I and II will alert operators in both control room to intervene and take corrective action	Regular inspection and monitoring are required. Training of technical persons	3*2=6
Reverse flow	The manual valve at GPF II inadvertently closed	1- GPF II flow towards GPF I, exceeding GPF I plant capacity causing off-spec gas at GPF -II. The 2- pressure at GPF I may exceed design pressure may lead to line rupture fire upon ignition potential for serious injuries/ fatalities and asset damage	1-flow line overpressure protection available at the wellhead. 2- PSV-101-001 set at 1320 psi design for block flow 3-PCVdiverts flow towards flare 4- NRV at upstream of ESDV-002	Periodical checkup. Technical training	5*3=15
Misdirected flow	Control failure PCV-002 open fully	Flow diverted towards flare, production loss.		Regular inspection and monitoring are required.	4*2=8
High pressure	Pressure buildup in the good flow line when GPF II trips, SSV at wellhead takes a long time to close, due to short pipe length pressure in good headline builds up.	The pressure at GPF I may exceed design pressure may lead to line rupture fire upon ignition potential for serious injuries/ fatalities and asset damage	1-PCV-101-002 diverts flow towards flare 2- PSV-101-001 set at the high-pressure design for block flow	Regular inspection and monitoring are required. .	5*3=15
High temperature	The high flowing gas temperature increase	Personal injury upon contact with the high-temperature piping surface.	Personal protection insulation on piping in place	Periodical checkup.	4*2=8
Relief	Additional PCV added to the flare system	Total blow down rate at GPF-II may exceed flare header capacity, leading to flare header vibration and ultimately damage		Confirm adequacy of relief system in case IA failure i.e. maximum blow down the case.	3*2=6

Key Note: Petroleum field (PF), Standard operating procedure (SOP), Pressure switch low for pressure below PSL (PSLL), Emergency Shutdown Valve (ESDV), Pressure control valve (PCV), Pressure safety valve (PSV), Flow Indicator (FI), Non return valve (NRV), Soft seat valve (SSV), Flame and gas detector (FandG detectors).

4. CONCLUSION

The HAZOP analysis is one of the best tools for the identification and control of hazard existing in the industry during design and operational phase. However, in Pakistan, Hazop exists only on paper and is not properly implemented.

Whereas there are only some large organizations like oil and gas exploration, oil refinery and Fertilizer plant etc. have a complete implementation of Hazop. This study concludes that Hazop measures are not incorporated in a gas field with respect to 02 identified node, the chances of catastrophic accidents onsite would be increased. However the HAZOP team concluded that both options for the commingling of Gas from 02 different gas streams,to improve the quality of consumer gas have no serious safety concerns and either or both can be implemeneted subject to commericial and other technical aspects such as ease of implementation

It is therefore recommended by the HAZOP team to provide onsite easy to use safety equipment for machines and personnel to minimize all type of losses during operational hours of the plant.

The recommendation includes a standard operating procedure for communication between gas processing facilities in case of an emergency. The Evaluation must be done on comingling line and relief system in case of failure. The results of this procedure present a wide multidimensional view of the Petroleum and gas industry safety.

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