Performance analysis in accident investigations in the oil and gas industry

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Each operating unit, even belonging to the same company, has cultural factors that are quite different from each other. Some High Reliability Organizations (HRO) need to carry out several event investigations, which is often conflicting with daily demands. The problem identified is that the quality of the investigation is affected due to behavioral factors of engagement of the leaders involved and insufficient data collection, which can interfere with the results of the investigation. The proposed methodology was the creation of a quantitative assessment of the engagement of all those involved and the phases of the investigation, aiming to draw a profile and obtain an assessment of each investigation and, consequently, to draw a pattern of the different operational units of the company. The contribution of this work aims to make a correlation between the investigated events, their recurrences, and how the engagement considered adequate can generate resilience and impact the results of the investigations. This article is the result of a study in one of the largest industries in the oil and gas sector in Brazil, which works in the bottling and distribution of LPG nationwide. This work has more than 100 investigations that took place from north to south in Brazil in a period of 2 years, in a wide geographic and cultural distribution of 16 different Brazilian States.

Keywords: LPG, HRO, analysis, engagement, safety, investigation.

1. Introduction

The process of analyzing and investigating accidents, incidents and critical deviations is part of the routine of most High Reliability Organizations (HROs), which normally have a governance system defined for this purpose, that is, written procedures, forms, matrices that guide the investigation methodology to be used and internal and external communication flow, minimum internal public required for each event and other definitions.

According to Lewis, 2013High Reliability Organizations (HROs) are defined as complex and technologically sophisticated, in which a system failure can result in a catastrophe. Competing Requirements and Constraints, most HROs must learn to deal with Restrictive and

Hazardous Environments, while themselves being required to operate without Errors. They must maintain their high reliability.

It is common for HRO companies to follow well-structured standards covering all phases of the accident analysis process, which can be corporate or references such as NSIA, 2011, which bring a structured model for each phase of an accident analysis, for the modes of transport and defence.

The side effect of major productions is not a new subject, as stated by Rasmussen,1998 "Furthermore, companies today live in a very aggressive and competitive environment which will focus the incentives of decision-makers on short term financial and survival criteria rather

than long term criteria concerning welfare, safety, and environmental impact".

To carry out this dynamic balancing act, a new safety organization will emerge – designed and empowered to be independent, involved, informed, and informative. The safety organization will use the tools of Resilience Engineering to monitor for 'holes' in organizational decision-making and to detect when the organization is moving closer to failure boundaries than it is aware. Together, these processes will create foresight about the changing patterns of risk before failure and harm occur, (HOLLNAGEL, 2007).

In Brazil, the LPG bottling industry is a very important branch of activity, given that cooking food is mostly done using its input, the same being true for industries, homes, hospitals, among others.

The Brazilian refineries are not allowed to sell LPG´s products directly to the final consumers, so it is done through concessions to other companies, which do all the receiving, inventory, filling, loading, distribution and sale for the various clients, residential or industrial.

There are 2 types of LPG filling units: The primary and the secondary. The primary one units that receive LPG directly from the refineries, through the alignment of pipes and from the units do all the processing of the product, from storage, processing, distribution and finally the final sale to consumers. they do all the LPG processing, up to the transport to the distribution centers.

The secondary units are operational bases of the companies that have the concession, but receive the LPG through tanker trucks of their primary filling units and are not directly linked to refineries. From this receipt, the units have the same processes as the primary units, except for the receipt of LPG from the refinery.

Primary or secondary LPG filling units, have mostly of the time a high daily production and some of their operational processes have a large manual intervention, combined with bold production goals, have a greater tendency to have a greater number of occupational or process safety events. On the other hand, characteristic of companies with a high degree of automation, they tend to have few technological failures, but sometimes those who carry out operational interventions at times do not have full technical mastery of these systems, technology and their possible scenarios to happen, and due to rare events, they tend to be sources of technological risks.

The most impactful events in terms of accidents, environmental and material damage in the oil and gas industries are related to process safety events, i.e. rare events that can cause multiple casualties, property and environmental damage due to the loss of unplanned primary containment.

It was observed in this study that the recurrence of some accidental events has as main causes a linear and simplified view of their causes identified in the analysis of accidents, which causes a situation of demotivation and a bias that the causes of the event are already known, which often summarizes the research process, not reaching its real objectives.

Despite these rules of engagement, errors in investigating human error are easily made. All of them actually stem from the hindsight bias in one way or another (DEKKER, 2006).

The reality of occupational safety researchers is different from other areas, as it is composed most of the time of managers and people without adequate training for this activity, according to (MACLEAN, 2022).

According to Rossi, 1985 systemic accidents are not limited to nuclear plants but are also found in chemical plants. Interesting and bizarre examples of the unanticipated interaction of failures appear in chemical plants-a well-run industry with ample riches to spend on safety training and high technology solutions.

Besides that, human errors are symptoms – of a system and should be considered as the starting point of investigations and not the conclusion. (DEKKER, 2006).

The aim of this research is to bring a proposal of a quantitative assessment of the engagement of all those involved and the phases of the investigation, aiming to draw a profile and obtain an assessment of each investigation and, consequently, to draw a pattern of the different operational units of the company.

2. Materials and Methods

This article is the result of an occupational safety, health and process safety research, focused on accident analysis. This work has a monthly workload of 40 hours, distributed in 8 hours per week of analysis within 16 operating units of a LPG company and about 8 hours of data tabulation and general alignment meetings with the client. The technical staff is composed of 2 researchers, with specialization in occupational safety engineering. This work was carried out in one of the largest LPG bottling companies in Brazil, whose initial scope of this work consisted of training the teams of the various operational units in a methodology of analysis of accidents and afterwards monitoring the analysis of accidents through the weekly mentoring on the same subject, through prior scheduling between the corporate safety sector and the researchers.

The weekly mentoring has the objective of broadening the learning about the analysis of events from the external view of the researchers and the interaction with the whole team of research, seeking to understand the complexity of the work environment.

The number of in-person meetings or online meetings was carried out per event to be analyzed, and developed from the evidences presented, actual complexity or potential of the event, and the need for some external technical advice to the analysis´ team of the unit where the event took place. A minimum number of meetings per event was not established, and that could vary from one event to another.

This work has more than 100 investigations that took place from north to south in Brazil in a period of 2 years, in a wide geographic and cultural distribution of 16 different Brazilian States.

This work happened in a hybrid way, that is, both in person and online. The mentoring in accident analysis, aiming to optimize and facilitate the work of the researchers happened exclusively remotely, that is, from a previous schedule, the investigations took place, through the selection of the most significant events made by the company's corporate sector of safety and health headquarters.

After the teams trained in the methodology of accident analysis, they were assigned to units where would be analyzed events. The collection of data information, interviews with witnesses and various evidences, were collected before the online meeting, where the participation of the consultancy consisted of evaluating, contributing and developing the unit´s teams where the unwanted events took place. The company used two accident analysis techniques simultaneously, namely: 5 whys and Fishbone Diagram. After the technical validation meeting of the analysis of the accident or near miss from the minimum corporate model proposed in all its parts, this event is inserted in a ERP software, and the action plan is duly monitored and executed by the respective designated responsible professionals.

The combination of some of these factors and others not mentioned here, can directly influence the engagement of the organization's accident analyses.

From there, a methodology was developed, aiming at the evaluation of the 2 main actors: 1) The manager of the area where the event took place and 2) The analysis team. In addition to evaluating these two main actors, the quality of the Action Plan and also the collection of data from the event was included.

Each of these parameters of analysis has the value from 0 to 10, and if bringing at the Eq. (1), that is, Total Engagement Equation is equal to arithmetic media of the following factors: Manager Engagement (ME), Team Participation (TP) Team Engagement (TE), Action Plan (AP) and Data Collection (DC), according to the eq. (1), as follows:

$$TEE = \frac{(ME+TP+PE+TE+AP+DC)}{6} \quad (1)$$

Eq. (1) Total Engagement Equation (TEE)

Table 1 shows the criteria scores.

Participations	The percentage of participations will be an integer from 0 to 10	
Engagement	Terrible (0)	Participated in less than 30% of the research or did not participate
	Poor (4)	Not actively participated in the investigation, is reluctant about the ideas proposed, has culpable thinking about employees, production in the first place, unjustified absences of the manager
	Medium (7)	had satisfactory participation in the investigations, accepts the proposed ideas but still with some reluctance, believes that accidents are half the fault, is in doubt between production and safety
Good (10)		Good participation in investigations, accepts proposed ideas and seeks to cooperate with all, seeks to know the reasons, seeks to understand the new visions, focus on solving problems

2.1 Participation of the manager

The evaluation of the participation of the manager or responsible for the unit is very important, both from the point of view of information, support, example for the participants, direction of the plan of action and formation of a culture of safety.

Table 2. Continuation the criteria scores

Participations	The percentage of participations will be an integer from 0 to 10 (considering a total of those directly involved)	
Engajament	Poor (4)	Has not actively participated in the investigation, is reluctant about the ideas proposed, has culpable thinking about the employees, production in the first place, unjustified lack of the team, lack of commitment to the meetings

	Medium (7)	Had satisfactory participation in the investigations, accepts the proposed ideas but still with some reluctance, believes that accidents are half the fault, is in doubt between production and safety, little commitment to meetings		Medium (7)	They can propose more comprehensive solutions, have a vision of employee control and processes, seek to review the Tool Box Talking and training for continuous improvement
	Good (10)	Good participation in investigations, accepts proposed ideas and seeks to cooperate with all, seeks to know the reasons, seeks to understand the new visions, focus on solving problems, there is commitment to meetings		Good (10)	Proposals aimed at the whole process, seek to solve the flawed procedures, do not control the employee, sought solutions in the new visions of safety
Action plan	Poor (4)	Focused on Tool Box Talking and training, they cannot propose macro solutions, focus on controlling the employee	**Collection of information**	Poor (4)	They were not able to collect enough information for the beginning of the investigations, they did not provide photos of the events, interviews with the injured did not occur or were not efficient

	Medium (7)	Some information still needed to be collected for better understanding, available photographs still generate doubts for the understanding of the facts, information collected from the injured still need to be checked
	Good (10)	Information collected is arranged in an effective and well-understood way, good photographic record of events, interviews with injured people were efficient

STATE	VALUE 2022
Espírito Santo	8,0
Pernambuco	8,0
Rio Grande do Norte	7,5
Rio de Janeiro	7,3
São Paulo	7,3
Ceara	7,2
Minas Gerais	7,2
Piaui	7,2
Santa Catarina	6,8
Bahia	6,5
Goias	6,5
Maranhão	6,3
Paraná	6,2
Alagoas	6,0
Rio Grande do Sul	5,9
Para	

Fig. (1) shows an overview of the geographical distribution for the year 2022.

The year 2021 was the beginning of the research project and even with the teams having been trained in the technique of accident analysis, the daily practice requires a high rigor in the investigation process from beginning to end.

The data obtained in the year 2022, according to Fig. (1), show us a variation in the results, within the range of 0 to 10, with a minimum value of 3.7, in the state of Rio Grande do Sul, maximum of 8.0 for the states of Espírito Santo and Pernambuco. We evaluated 15 states in 2022 and the average value obtained was 6.9.

Despite being the same company, the practices between the units is quite heterogeneous, due to the professionals having distinct professional experiences and cultural and regional factors present, among other factors.

3. Results

The monitoring of the engagement of the manager and the investigation team in the analysis of accidents brings an important panorama of the evolution of the cultural aspects of occupational safety and that can reflect in the index of occurrences of events. According to the researcher team, the monitoring of these parameters are considered fundamental, not only in the analysis meeting of the event, but also later, in the management of the information obtained and sequencing of the same. Table 3 shows the distribution of values by state.
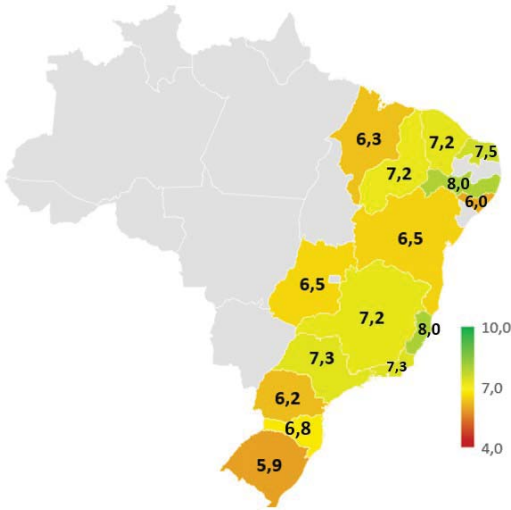
Table 3. Distribution of value by State in 2022

Fig. 1. Engagement map by state year 2022

The results we present are based on a partial sample of the data, and do not reflect all the events that occurred in the organization, only those that were directed to this research team and new information is still awaited, aiming at a broader comparison and cross-referencing of data.

Lack of engagement in the analysis of industrial accidents can lead to serious consequences, which include, but are not limited to:

(i)   Early conclusions of the causes of accidents without investigation or copying investigation of similar accidents that were not carried out with the minimum of technical rigor.

(ii)   Absence of active participation of leadership in investigations. Fictitious, theatrical or concurrent participations with the demands of operation.

(iii)   Transfer of responsibility in the analysis of accidents, where the occupational safety professional has the individual responsibility to do all the work and a division of responsibility between what is production and what is safety.

(iv)   Action plans disconnected from the reality of the facts, with superficial actions or from poor or incomplete collection of information and evidence.

(v)   Absence of a correct analysis of scope, especially in multi-site organizations and with different business units.

(vi)   Absence of investments aimed at eliminating risks.

(vii)   Culture of employee blaming and approach to accident prevention focused solely on worker behavior.

(viii)   Engagement dependent on some members of the board of directors, or on situations that may publicly expose the company's reputation.

(ix)   Absence of an internal investigation procedure and process instituted by the organization that defines the minimum team and which methodologies should be used.

The improvement in the engagement in the analysis of accidents can generate long-term benefits in the operational units, making the frequency of events increasingly greater between one event and another.

One of the ways to enhance learning from accident analysis is through the monitoring and effectiveness of the proposed change actions, CIEHF, 2020, that is, not only observing the date of implementation, but also the effectiveness of each action. Another learning measure is to propose appropriate control barriers in action plans. The Mcleod & Randle, 2017 informs that the generally accepted criteria for controlling control barriers must bring necessary robustness actions to their processes.

4. Discussion

One of the limitations of this study is that as the units improve their engagement and make the proper management of the action plans, the number of events that occur decreases, not generating a proportionally equal amount of events for data comparison.

Another factor that can influence the results of this study is a change in team and management components, which can positively or negatively impact the level of engagement. , especially regarding the posture and positioning of the manager

The next steps of this work will be to collect data for the year 2023 and after that, make a comparative analysis of the results, regarding the evolution and other conclusions that can be made from it. One of the limitations is that the interpretation of the criteria presented here may vary, according to the criteria of each professional and it is recommended that an investigation be evaluated by a professional who actively participated in all analysis meetings.

Another point of limitation of this study is its use with the aim of dispute between units.The scope of the study occurred in 16 different states and with very different cultural aspects, which may influence the investigation teams.

5. Conclusions

The data collected in the year 2022, demonstrated that there are different levels of engagement between the States and their respective operational units. We identified that units and regions that obtained the best results, naturally need less consulting monitoring, and this work can be directed to other units that need more continuous follow-up work. We attribute these results to a work of training, monitoring and increasing the maturity of the participants in the research process.

To improve the conditions of the working environment, adequate investment in the elimination of sources of danger is also necessary.

Another aspect that can be considered in later studies would be the inclusion of adherence to compliance with action plans as an item to be evaluated, which is an important aspect, ranging from the beginning of the process, that is, from the analysis of the event to the conclusion or not of the action plans to avoid recurrences.

Although the company's internal accident analysis procedure is corporate, different patterns of application were identified among the units.

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