Congress ABRISCO 2017

PROCEDIMENTOS OPERACIONAIS INTELIGENTES: APLICAÇÃO DE HAZOP HUMANO EM DESENVOLVIMENTO DE PROCEDIMENTO

Dr David Embrey, Managing Director, Human Reliability Associates,

Sara Lucia Zaed, CEO, Zaed Engenharia,

Giuliano Assis, Operation Coordinator, Raízen

ABSTRACT

Lacks have been identified in the standard operating procedures found in the petroleum derivates Terminals. These include poor structuring, and significant differences between the way in which a plant operated in fact, and the information contained in the procedures. These problems arise from a deficiency of a systematic process which gathers information from the end users of the procedures and structures this information in a manner which makes them easy to understand and learn. A new approach is needed in which process hazards arising from potential human errors are explicitly identified and incorporated into the procedures.

This paper describes a process called Intelligent Operating Procedures (IOPTS) design. This enables both procedures design and competence management systems to be linked to a systematic human factors risk analysis process. A case study showing the application of this process to a petrochemical task will be described.

Keywords: Operating procedures, Human factors

INTRODUÇÃO

Standard operating procedures (SOPs) are intended to specify the way in which a plant is to be operated and maintained to ensure safe and efficient production. Procedures should ensure that a hazardous safety critical task is carried out in a standardized way potential failures with serious consequences have been identified and mitigated.

Unfortunately, many SOPs used in high hazard industries fall short of these objectives. Procedures often comprise long lists of task steps which bear little relationship to how the plant is operated. This is because they are often written by personnel who have limited practical operating experience. This creates a number of significant safety and operational problems.

If the procedures are impractical and inaccurate, they may lose credibility with operating staff, leading to untested and possibly unsafe methods being be adopted in order to get the task completed. Reliance on informal operating practices may also lead to inconsistencies between different shifts and to variations between trainers in the information they transmit to trainees. Failure to document the tacit knowledge possessed by operating staff based on operating experience also represents a lost opportunity to capitalize on their experience.

Procedures are frequently poorly structured in terms of identifying the objectives that need to be achieved during the different stages of a process. This makes the procedure difficult to understand and harder to learn. Frequently, no distinctions are made between information intended to tell the user specifically what to do, and supplementary information which would be more appropriate in a training context. In addition, there is rarely any real attempt to link the content of procedures with human factors risk analyses, so that the knowledge of potential failures with significant consequences that emerges from these analyses can be transmitted to the operator in a systematic manner.

In this paper we describe a structured, risk based process called the 'Intelligent Operating Procedures and Training System' (IOPTS). The term 'Intelligent' refers to a process that systematically identifies the risks that the users of the procedure need to be aware of in the operating environment, and delivers this information at the appropriate point in the procedure. Another 'intelligent' aspect of the IOS process aspect of the IOPTS process is the structuring of a task in a hierarchical manner, that identifies the overall task objectives, and the subtasks required to achieve these objectives. The IOPTS process develops plans which describe how these subtasks are executed based on operational conditions. The structure provided by the process makes the resulting procedures easier to understand and much easier to learn.

The core methodology within the IOPTS design process is SHERPA, (Systematic Human Error Reduction and Prediction Approach) was originally developed in nuclear power generation safety analyses [1] Embrey, 1986, and has subsequently been used as a safety analysis tool within many safety critical worldwide industries. A recent review of this methodology illustrating its application in chemical industry safety analyses is available in [2] Embrey, 2013, Currently, it has also been introduced as a tool for the analysis of safety in Brazilian oil derivatives terminals.

The IOPTS process mirrors the Human Factors Critical Task Reviews (HFCTR) carried out as part of COMAH (Control of Major Accident Hazards, HSE, UK) safety reviews [3] (Energy Institute, 2011, Health and Safety Executive, 2012). Thus, very little additional effort is required to utilize the information generated during the HFCTR as the primary input to the IOPTS process. Apart from the saving in the resources by only having to gather this information once, the IOPTS process satisfies the HSE requirement to demonstrate that the results of HFCTR are reflected in the Procedures and the Competency Management systems

In the next section, will describe the stages of the IOPTS process and illustrate how these parallel the application of SHERPA in Human Factors safety reviews at petroleum derivatives terminals. A similar process can also be used to develop Competency Management Systems.

OVERVIEW OF THE IOPTS PROCESS WITHIN TASK REVIEWS

The Figure 1 shows IOPTS development process and its stages:

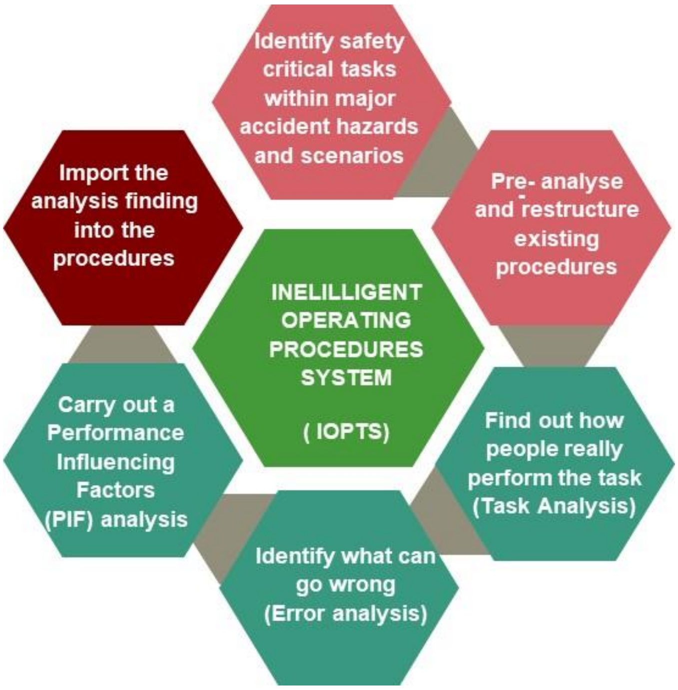

Figure 1: Overview of the IOPTS process.

1. *Identify safety critical tasks within major accident hazard scenarios*

The first step in IOPTS development process is a workshop in which the Major Accident Hazard (MAH) scenarios identified from previous engineering risk analyses such as HAZOPs are reviewed to identify human activities which could:

- Initiate the accident sequence (e.g. an object dropped by a crane operator could rupture a pipeline);
- Affect the ability of engineering safeguards to mitigate the accident scenario (e.g. by failing to correctly maintain gas detectors or high level trips);
- Fail to carry out mitigation activities such as post release emergency plan implementation.

If a previous safety analysis such as a HAZOP is not available, an alternative approach is to first identify Terminals areas where activities with potential MAH risks could exist. These could include areas where flammable or toxic substances are involved, and where tasks are carried out where layers of protection are removed, e.g. during maintenance. A scoring process can then be used (Health and Safety Executive 2000) to risk rank tasks so that analysis resources can be prioritized according to the ranking assigned to each task

2. *Pre-analyze and restructure existing procedures*

The objective of the pre-analysis process is to organize the existing procedure and other relevant documents into a structure which provides a starting point for a later workshop analysis involving operating staff. Carrying out a pre-analysis also identifies operational issues that will need to be explored in the Stage 3 workshop described below. The pre-analysis process also reduces the time required to conduct this later analysis.

The pre-analysis involves the IOPTS facilitator conducting a preliminary task analysis of the existing procedure using a methodology called Hierarchical Task Analysis (HTA). This is described in detail in [4] Kirwan and Ainsworth (1992) and [5] Embrey (1994). The HTA is essentially a graphical representation of the task structure. It breaks complex tasks down into a series of subtasks, governed by a plan that specifies how these are performed to achieve the overall task objective. If necessary, subtasks are broken down to finer levels of detail, and a new plan is developed at each stage of the breakdown.

A detailed example of an HTA will be provided in the Case study in the last section of this paper. The HTA process is re-applied in Stage 3 of IOPTS which is described below.

3. *Develop a Hierarchical Task Analysis using a Consensus Group workshop*

The Consensus Group workshop is intended to reach agreement about how tasks are carried out in practice, based on inputs from experienced operating personnel. The starting point is the preliminary task analysis developed during the pre-analysis. The IOPTS facilitator develops a graphical representation of the task structure using Hierarchical Task Analysis. This can be performed using manual methods such as Post-it notes.

However, for complex tasks, specialist software tools such as the Human Factors Risk Manager (HFRM), developed for HFCTRs by Human Reliability Associates, and other tools such as Task Architect are available, which facilitate the interaction with the workshop participants, and which automatically document the analysis in the form of a Word table or spreadsheet.

The development of the HTA using the Consensus group is one of the most important stages of the IOPTS process as it provides the information to structure the task in a clear and understandable manner. It is also the vehicle identifying the potential risk information such as errors with serious consequences, which needs to be embedded in the final version of the procedures [6,7] Embrey, D. e Zaed, S.L. (2008).

4. *Perform a Predictive Human Error and Consequence Analysis (PHECA)*

This stage of IOPTS uses the graphical task analysis developed during stage 4 to identify potential errors leading to Major Accident Hazard (MAH) consequences. This is achieved by first identifying the Activity types involved in the procedures. Examples of Activity types include Actions, Checking, Monitoring and Communication.

Each activity type has an associated set of failure modes, as showed in Figure 2.

ACTIONS ERROS	CHECKING ERROS	MONITORING ERROS	COMMUNICATION ERROS.
Action omitte.	Check omitted	Monitoring omitted	Information not communicated
Action incomplete.	Check incomplete	Wrong person or process monitored.	Wrong (inappropriate/incorrect) information communicated
Right action on wrong object	Wrong object or action checked.	Monitoring incomplete or interrupted	Incomplete information communicated.
Wrong action on right object	Wrong check	Incorrect values monitored.	Ambiguous /unclear information communicated

Figure 2: Associated set of failure modes.

These failure modes perform a similar function to the Guidewords used in HAZOPs. The failure modes are documented in the human factors report and are also subsequently transferred into the procedure which is developed by the IOPTS process to provide the basis for warnings and comments

5. *Carry out a Performance Influencing Factors (PIF) analysis*

PIFs are the factors which increase or decrease the likelihood that the failures identified during the previous stage will arise. The results of the analysis can provide recommendations to modify the PIFs to reduce the likelihood of errors. Task specific PIFs are error inducing factors that are unique to the task environment being studied. They might include factors such as the quality of the alarm system, organization of the DCS displays, and the labelling of Terminal items such as valves.

In the analysis documentation, PIFs descriptions are preceded by the labels -ve or +ve indicating that the PIFs are likely to have positive or negative effect on the likelihood of error, as showed in Figure 3.

Some of the PIF deficiencies identified at this stage of the process will have implications for procedures development process. The example shown in Figure 3 provides information that could potentially be included in the procedure, e.g. that the low-pressure alarm on 25-PC-005 may indicate a problem with the tank seal.

-ve:	(for low pressure) on 25-PC-005 is a low priority alarm. This provides the first indication of a potential problem with the surge tank seal - this prioritization may affect how quickly this problem is identified by the Control Room Operator (CRO) (i.e. during times of high alarm load)
+ve:	Rate of opening of 24-PC-005 is clearly presented on the DCS (this enables the initial verification of a leak in the tank).
+ve:	Large alarm overview screen is available in the CR (and actively used by most operators)
-ve:	Several CRTs were unaware as to how to access point-of-use alarm response manuals within the DCS.

Figure 3: Example of Task specific PIF analysis.

Generic PIFs are factors influencing error probability associated with each activity type. Example include levels of distractions, fatigue, and time pressure. These types of PIF are important for optimizing operational conditions and hence reducing error likelihood, but are less relevant for procedures development.

6. Import the analysis findings into the procedures

In this final stage, the 'Intelligence' gathered during the preceding stages of the IOPTS process is incorporated into the procedure. Although the exporting of the task analysis information into the procedure is greatly facilitated using software tools, it can be done by hand if only a small number of tasks is being analyzed.

Kinds of imported information are summarized in Table 1.

Table 1:Imported information to the procedures.

FORMATTING CONVENTIONS	Most organizations have a standard procedures format which includes standard headings, logos and quality control information. In addition, there may be standard information about the hazards in the substances being used in the task, the PPE required and global risk management information. All this information can be incorporated into a software template, and automatically added to the content derived from the task analysis to produce a fully customized procedure.
STRUCTURAL INFORMATION	The structure of subtasks, plans and task steps developed during the task analysis are directly translated into the structure of the procedure. This ensures that the procedure is easy to read, understand and learn. The translation process uses a to map the task structure developed in the Consensus Group HTA to the procedures preconditions, objectives, and the subtasks and steps required to achieve these objectives. The template also determines the relationship between the information in the task analysis and its location in the final procedure
WARNINGS AND COMMENTS	The PHECA risk analysis carried out in step 4 of the IOPTS process allows the identification of task steps where potential failures that could impact on safety or production might occur. This information is captured in a spreadsheet-like data grid during the analysis and used to place warnings at appropriate points in the procedure. Comments, for example, background information about why a step is required are also translated from the spreadsheet into the procedure in an equivalent manner.
ROLES AND RESPONSIBILITIES	During the task analysis process in Step 4, the roles and responsibilities of personnel to carry out the tasks and subtasks are defined. This information is recorded in the analysis report generated by the IOPTS process and can then be exported into the procedure and located in a manner determined by the template

CASE STUDY

In this section, is presented a case study to illustrate the stages of the IOPTS process. It is assumed that the task under consideration has already been identified as being safety critical during Stage 1 of the IOPTS process [7,8] Assis G., Zaed S. L.

Task Analysis (Stages 2 and 3)

The top level for the HTA task analysis shown in Figure 4 is developed during Stages 2 and 3.

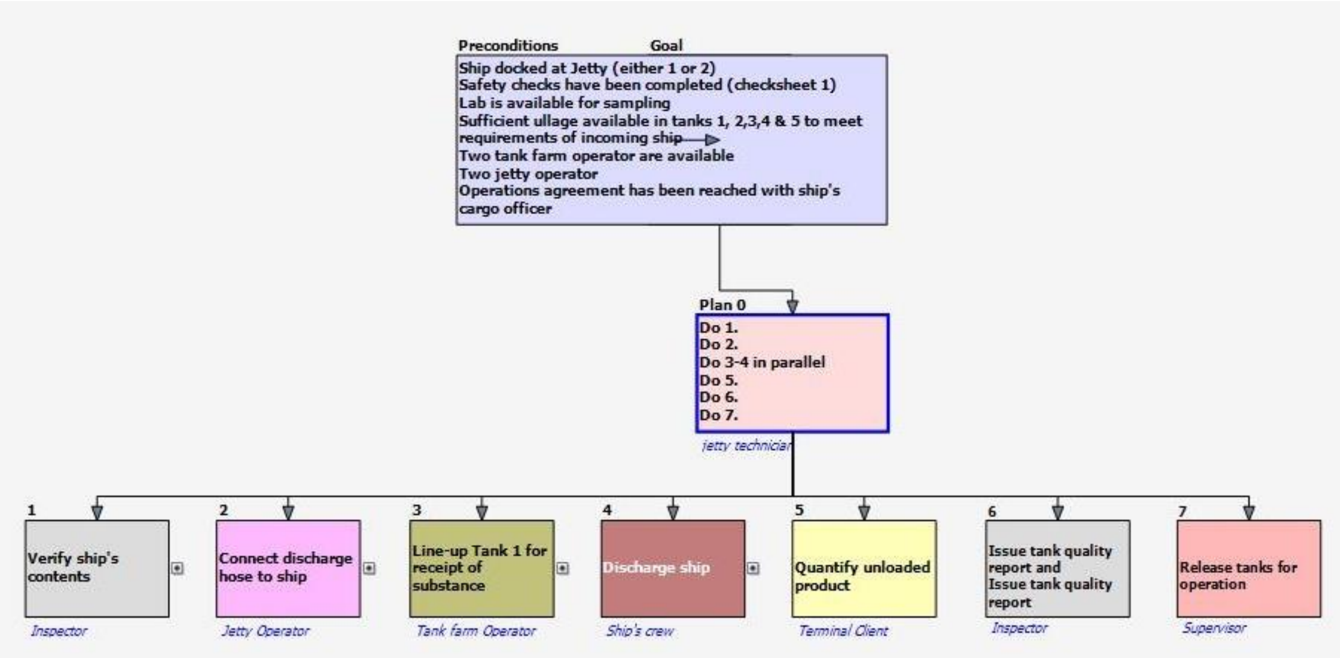

Figure 4: **Top level of HTA for drain HP column task, showing subtasks.**

The Figure 5 shows how subtask 2 is broken down into further detail, together with the associated plans which specify the conditions determining the order of execution for the lower level subtasks and their individual steps.

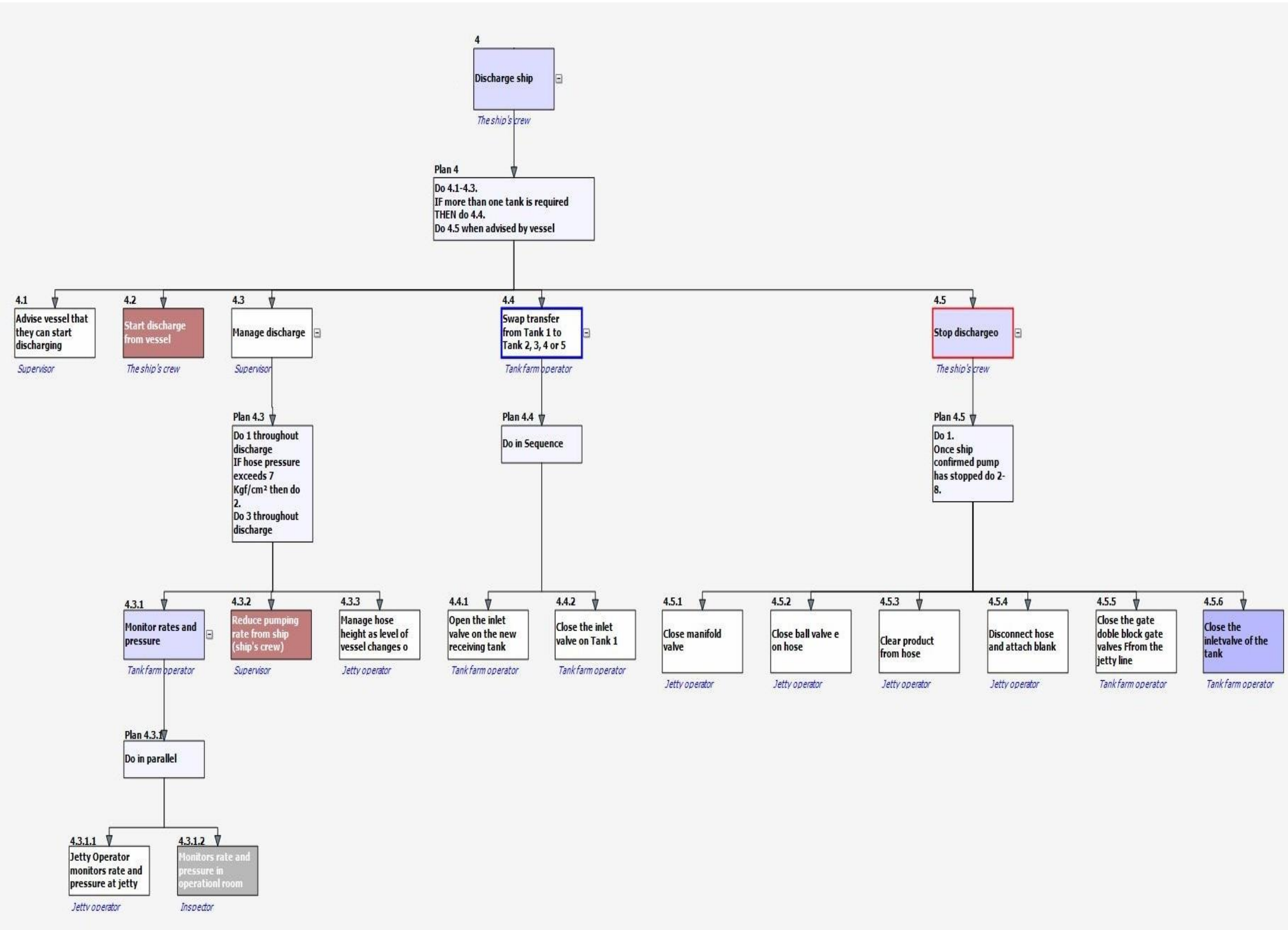

Figure 5: Further breakdown of subtask 2 showing plans and task steps.

Predictive Human Error and Consequence Analysis (Stage 4)

The Table 2 shows how the results of the PHECA analyses are documented.

This table describes the results of the possible failure modes and their consequences, based on the activity types associated with the task steps. In some cases, the consequences of an error are also recorded in the Warnings column, to indicate that this information needs to be transmitted to the procedure, to raise the awareness of the operator prior to carrying out this step.

Table2: Example of documentation of the PHECA analysis.

ID	Description	Role	Warnings	Comments	Activity Type	Failure Mode	Error Description	Consequences
4.1	Advise vessel that they can start discharging	Supervisor	Check alignment of tanking at the tank farm (double check)	Always Check the ship discharge plan and the spaces available.	Information Communication	COM3 Incomplete information communicated	Receive on unauthorized tank	Lack of possibility of quantification due to receiving tank while aligns expedition.
4.2	Start discharge from vessel	Ship's crew	Check the pump pressure. Risk of high speed line	Advise the immediate ship to connect the ship's pumps 5 minutes before	Actions	ACT5 Action too fast/slow	High speed on empty row	Risk of internal explosion in line with product leak in fragile points.
4.3	Manage discharge	Supervisor	Check alignment of tanking at the tank farm (double check)	Evaluate hourly the flow rate, the pressure and the level of the tanks.	Monitoring	MON1 Monitoring omitted	Neglect to monitor levels of products in tanks	Tank overfill and possibility of explosion not confined

Performance Influencing Factor analysis (Stage 5)

This stage of the analysis records the PIFs that might affect the probability of the errors identified in Stage 4. As can be seen from Table 3, some of the PIF information such as 'Possibility that system could drain more quickly than expected' could be transmitted to the operator in the form of a warning in the procedure.

Table3: Example PIF analysis documentation generated during IOPTS Stage 5.

ID	Description	Assigned Role	Activity Type	Failure Mode	Error Description	Consequences	Performance Influencing Factors
4.4.1	Open the inlet valve on the new receiving tank	Tank farm operator	Actions	SEL2 Selection incorrect	Incorrect selection of tank with receiving less than the tank space of the string.	Open inlet valve in tank wrong- potential overflow Possible MAH	-ve: Competing tasks - possible distraction. +ve: Expectations: Tank3 fills up faster than Tank 2. If Tank 3 is selected, in case of human error the management from the operation room of the Terminal may not react more quickly to sound the alarms. -ve: Possibility that system could response more quickly than expected.
4.4.2	Close the inlet valve on Tank 1	Tank farm operator	Checking	CH2 check incomplete	Incomplete closing of the inlet valve	Ability to overfill the receiver tank. Possible MAH	-ve: Competing tasks - possible distraction. +ve: Tank1 fills up more quickly, in the case of human error management from the operation room of the Terminal may not react more quickly to sound the alarms.

Import the IOPTS analysis data into the procedure (Stage 6)

In his stage of the IOPTS process, relevant information from stages 1-5 is imported into the procedure, based upon the designated template which maps it into the appropriate position. This is done automatically if the HFRM software has been used for the previous stages, but can also be carried out manually if required. Table 4 gives an example of the format of the procedure that results by importing the data described earlier into the procedures template.

It should be noted that Table 4 omits the boilerplate and other formatting information that would normally be added by the template. Both warnings and comments that were specified in the earlier stages of the analysis have been imported into the generated procedure

Table4: Example of section of procedure generated by the IOPTS process (header, footer and other information omitted).

Step	Description	Role	Comments	Initial
4	Discharge ship	Ship's crew	Do not start the transfer before all the pre-condition is satisfied.	
Plan4	Do 4.1-4.3. IF more than one tank is required THEN do 4.4. Do 4.5 when advised by vessel			
4.1	Advise vessel that they can start discharging	Supervisor	Always Check the ship discharge plan and the spaces available.	
	***WARNING*: Check alignment of tanking at the tank farm (double check).**			
4.2	Start discharge from vessel	Ship's crew	Advise the immediate ship to connect the ship's pumps 5 minutes before.	
	***WARNING:* Check the pump pressure. Risk of high speed line.**			
4.3	Manage discharge	Supervisor	Evaluate hourly the flow rate, the pressure and the level of the tanks.	
Plan 4.3	Do 1 throughout discharge IF hose pressure exceeds 7 Kg/cm² then do 2. Do 3 throughout discharge			
4.3.1	Monitor rates and pressure	Tank farm operator		
Plan 4.3.1	Do in parallel			
4.3.1.1	Jetty Operator monitors rate and pressure at jetty	Jetty operator		
4.3.1.2	Monitors rate and pressure in operation room	Inspector	Check status of the group to ensure that they will be vigilant and able to perform checks	
4.3.2	Reduce pumping rate from ship (ship's crew)	Supervisor		
	***WARNING:* Notify the crew at least 5 minutes in advance.**			

CONCLUSIONS

The IOPTS process described in this paper has been applied extensively in safety critical terminal and industries such as the oil and gas sector. It provides a systematic and logical approach to ensuring that procedures development utilizes all the intelligence that is available from safety analyses

It has advantages in ensuring that procedures and competency management systems are risk based, and hence are closely integrated in the risk management process

With the development of intelligent procedures (through the IOPTS methodology), the objectives related to the review of human factors in client tasks are also achieved. It is very import mention that, in some countries of the world, such as the United Kingdom, this control already exists through public agencies such as COMAH-HSE.

Operational discipline, one of the risk management elements, can also result in considerable savings, by combining the resources of analysis necessary for these activities is fully auditable. Showing that the insights of risk analyses are fully used for control during terminal operations and industries

A final major IOPTS process, is that it actively involves the workforce in safety and risk management efforts, and thus has the potential to contribute towards a positive and participatory safety culture.

Feedback from participants in the process has been very positive, as shown by the following comments:

"Those involved have a greater understanding of how other shifts operate (and) improved continuity between shifts when doing tasks"

"Improved my own knowledge of the task being assessed. Good cross shift communication of methods employed to identify issues of concern across the site"

"Methodical by nature, in depth with genuine open discussion concerning the real issues associated with the task (i.e. safety, real world practices)"

"Very good, a lot easier to understand as (the task steps) are broken down"

"Has been informative and made people think more about the tasks they are doing"

"I feel more involved in the development of procedures"

"People have a greater understanding of why the task is done in a particular way"

"People have a greater understanding of the risks associated with the task we have looked at"

Finally, the implementation of smart procedures IOPTS is an ideal framework for organizations wishing to address a wide range of human factors issues such as safety reviews, procedures development and competency management across their sites in a systematic and integrated manner. We also believe that the process makes a major contribution to developing a participative and risk aware safety culture in the organization.

REFERENCES

[1] Embrey, D.E., 1986, SHERPA: A systematic human error reduction and prediction approach. Proceedings of the International Topical Meeting on Advances in Human Factors in Nuclear Power Systems, Knoxville, Tennessee American Nuclear Society La Grange Park, Illinois 60525 USA.

[2] Embrey, D.E., 2013, SHERPA: A Systematic Human Error Reduction and Prediction Approach to Modelling and Assessing Human Reliability in Complex Tasks Proceedings of the European Safety and Reliability Conference (ESREL) Amsterdam

[3]

[4] Kirwan, B. and Ainsworth L. A., 1992, A Guide to Task Analysis CRC Press

[5] Embrey D.E., 1994 Guidelines for Reducing Human Error in Process Safety. Center for Chemical Process Safety New York

[6,7] Embrey, D.E., Zaed S.L, 2008, Ferramentas para avaliação dos fatores humanos em Tarefas Críticas e desenvolvimento de Procedimentos Operacionais e de manutenção baseado em análise hierárquica de tarefas e HAZOP humano, AES, Uruguaiana.

[8,9] Zaed, S.L, Assis G, 2017, Avaliação de Fatores Humanos em Tarefas Críticas envolvendo Operações Portuárias, São Luiz MA