International Journal of Petroleum and Petrochemical Engineering (IJPPE)
Volume 4, Issue 1, 2018, PP 32-44
ISSN 2454-7980 (Online)
DOI: http://dx.doi.org/10.20431/2454-7980.0401005
www.arcjournals.org

A Tool to Identify the Proactive Corrective Actions after the Accidents in Oil and Gas Industry

Walaa Mahmoud Shehata[1,*],**Hamdy Ahmed Faroun**[2]

[1]*Suez University, Faculty of Petroleum & Mining Eng., Chemical & Petroleum Refining Eng. Dept., Egypt*

[2]*Zeit Company, Borg Zahrat Elmaadi, Cornish Elnil Maadi, Egypt*

Corresponding Author:** ***Walaa Mahmoud Shehata, *Suez University, Faculty of Petroleum & Mining Eng., Chemical & Petroleum Refining Eng. Dept., Egypt*

Abstract: *The aim of this paper is to provide a less time-consuming and user friendly tool to find out the most cost-effective and practical corrective actions after the event by improving the data utilization from earlier studies to address the direct and root causes of the incidents. The paper collected frequent incidents contributors for the most common equipment types in oil and gas industry and the typical timing of the error in the lifecycle of the project, and then linked the most frequent accidents' contributors with a direct and root causes. The proposed tool consists of three main steps: 1- Select the equipment type where was the event took place, and identify the most frequent incident contributors of the equipment. 2- Identify the timing of incident errors as per the project lifecycle. 3- Drive out the direct and root causes of the event, and prioritize/ implement the corrective action. The tool is demonstrated and tested using the piper alpha tragedy as a case study. The most distinguished feature of the tool is that it identifies incidents contributors and the timing errors as well as gives ideas on their removal. The tool established a framework to get the best use of the past accidents analysis, in order to obtain a proactive corrective action to prevent incidents recurrence. Additionally, it gives a road map for a better identification of corrective actions that directly address the root causes of the events.*

Keywords: *Accident contributors; direct causes; root causes; corrective actions; accident database; process lifecycle*

1. INTRODUCTION

The history of the oil and gas industry shows unfortunatelymany incidents are repeated after a lapse of few years. Examples of such accidents are the Piper Alpha tragedy which was the North Sea oil production platform. On July 8, 1988, a huge explosion & fire occurred. 226 men on the platform, 62 were night shift. It was not possible to evacuate by helicopter or lifeboats. Accordingly, 61 survived by ascending down marine ropes, hoses or by jumping. 167 persons died, 109 by breath in smoke, 14 while making an effort to escape& a few deaths of burns, 135 bodies were recovered.

The piper alpha was the worst accident which has an offshore installation in the oil and gas industry. The analysis of the event was so difficult and proposed a possible chain of consequences because the platform was totally damaged, and many of those involved died. (Hull et al., 2002). The consequences of accidents vary between fatalities, property damages, environmental impact, time loss, etc. irrespective of the consequences, one thing is clear; oil and gas organizations are in a bad need to best utilize the experience feedback to promote the corrective actions.

The safe operation of oil and gas facilities and the prevention of incidents in this installation remain key concerns for the oil and gas professionals. In this concern, the root cause analysis plays a major role: every processing plant needs to have a system in place to identify and feedback the lesson learned from the operating experience and to implement the effective corrective actions to prevent incidents or near miss from reoccurring to limit the damage and thereby improve safety. The corrective actions are the processes or decisions that reduce or eliminate the potential for the recurrence of an incident or an adverse work practice that is captured and implemented to avoid recurrence. Corrective actions represent the final step where all the efforts to ensure the safety is restored and satisfactory performance is obtained.

In the last years, different analysis and studies have been carried out on the data available in the different databases like Major Accident Reporting System (MARS) managed by EU and Failure Knowledge Database (FKD) managed by Japan & Science Technology (JST) Agency. Previous studies and publications have covered various aspects related to the causes of the accidents. Some of these analyses have been performed at a general level, while others were aimed at obtaining lessons to be learned, focusing on specific issues such as handling of dangerous substances efficiency of emergency systems management issues or chemical reactions (Sales et al., 2007). The analyses so far have been based mainly on the causes directly reported from the Competent Authorities, with little attempt to a deeper analysis of root causes.

There is a lack of studies inthe area of addressing the root causes and little is known about the operational and design reasons of accidents, eg. what are the typical errors made and in which lifecycle of the projectdo the errors take place to be able to select the corrective actions and, prioritize the safety issues for each specific case of the different level of corrective actions: prompt, reactive and proactive corrective actions to prevent occurrence or reoccurrence of incidents.

The aim of this paper is to present a root causes identification tool based on the previous history of accident contributors by identifying the common errors made during the plant design, construction and operations lifecycleand link the common accident contributors with the root causes from accidents reported in FKD and MARS databasesto be able to select the most efficient, reliable corrective actions and go deeper into the root causes of the incident by providing a less time-consuming and user friendly tool. This paper is intended to identify the weakness to be able to make the cost-effective corrective actions. From a practical point of view many of the corrective actions after the event concern only the accidents contributors and the direct causes and ignore the root causes. Some corrective actions will only be effective for a short period of time others for longer. The aim of this work is to create a root causes identification tool based on the frequency of accident contributor by identifying the common errors made during the plant design, construction and operations lifecycle and link the common accident contributor with the root causes, from accidents reported in MARS to be able to select the most efficient, reliable corrective actions. The study goes deeper into the root causes of the incident by providing a less time-consuming tool to compare the extent of corrective actions generated from the tool with those actually reported.

In order to get a conservative decision regarding the most adjacent corrective actions after the event, a reasoned and systematic tool had to be developed and verified by an application on a real accident to compare the results with actual ones. The target of this tool is to be used by oil and gas companies for self-assessment to find opportunities for continuous improvement.

2. LITERATURE SURVEY

A part of the requirements in the Seveso Directive II as a result of catastrophic accidents such as Bhopal and Piper Alpha is reporting of abnormal main events. Several databases have been created for the dissemination of accident information (Meel et al., 2007). Accidents recur due to not taking the effective corrective actions from the earlier accidents. Many efforts have been done to analyze the cause of accidents and to generate corrective actions for effective accident preventions in the oil and gas fields. As a result, many journal papers, books, and accident databases have been produced to support lessons learned from accidents. However, only one-third of the accident cases studied is considered to provide lessons learned on a broader basis (Jacobsson et al., 2010; Jacobsson et al., 2011; Tauseef et al., 2011).

In recent years, more studies based on learning feedbacks experience have been conducted in the oil and gas industry; however, most of them were related to lessons learned from accidents or from near-miss cases (Prem et al., 2010). The current feedback operational experience is not sufficient to prevent unexpected event occurrence due to poor reporting, lack of analysis, and unsatisfactory use of data (Lindberg et al., 2010). Therefore, the main challenge is how to disseminate the accident information effectively and translate the current knowledge into practice (Bell and Healey, 2006).

In order to highlight the translation of the current knowledge into practice, the corrective actions will not be effective unless the events and repeated problems are investigated to their root causes, contributing causes, and direct causes. The root cause can be defined either as ‘‘the combinations of conditions and factors that underlie accidents or incidents or even as the absolute beginning of the causal chain. The contributing factors are not constantly present but turn up occasionally and can make it more difficult to perform a certain task in a correct and safe manner, and thereby contribute to triggering an incident. The direct causes are the first causes of the chain that directly resulted in an event (Hollnagel, 1999).

In this study, the data collected from FKD database (FKD,2011)of the most frequent accident contributors associated with the most common equipment in oil and gas operations were collected and gathered with the timing errors in the lifecycle of the project, then linked with the direct and root causes of reported accident in MARS database in order to make the best use of not usable data format in practice for normal engineering work by providing a user friendly tool, to go beyond the direct causes of incidents.

3. MATERIAL AND METHOD

The databases FKD and MARS were selected for the study in order to make a conservative decision regarding the corrective actions after the accident event by going beyond the direct causes of the most common oil and gas equipment. The selected database covers the most significant accidents worldwide and is supervised by proficient academic circles. Kidam and Hurme (2012, a, b) discussed the aims, basic structure, accident classifications and case expression of the database.

The following procedures shown in Figiure 1 were considered as a structure of the proposed tool. The first step in applying this tool is to select the equipment type, and identify the most frequent accidenent contributors and sub-contributors. The second step is to identify the timing error during the project lifecycle. The third step is to identify the direct and root causes of the incident. The last step is to select the cost effective proposed corrective actions.

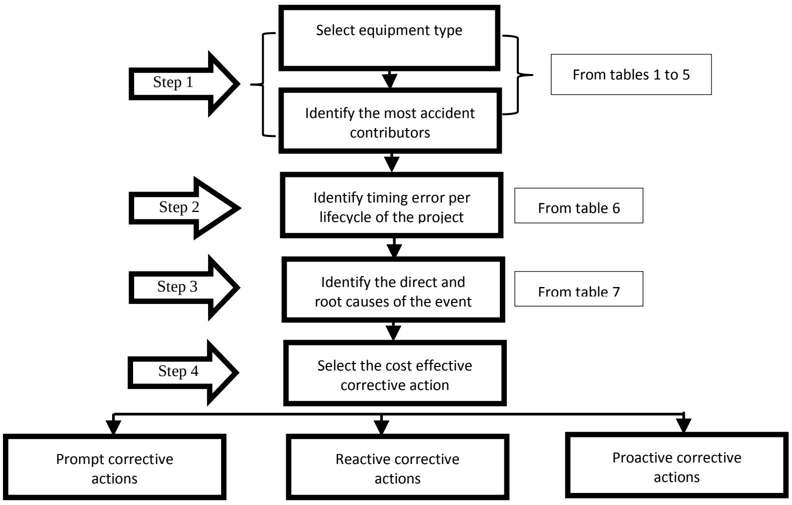

Figure 1. *Body structure of the proposed tool to identify the potential corrective actions*

3.1. Step 1: Select the Equipment Type and Identify the Accident Contributors and Sub-Contributors.

In this step, the study selected the most frequent accident causing equipment in oil and gas industry: piping, storage tanks, heat transfer, separation, and process vessels (Kidam and Hurme, 2012, a). Meantime, transformed the data from FKD database into analytical mapping is presented to identify the relevant accident contributors. The most frequent accident contributors for the most common five equipment in the oil and gas industry were mapped out. The accident contributors were divided into main and sub-contributors as discussed below.

3.1.1. Piping system accident contributors and sub-contributors.

The piping system is the most common risky part in oil and gas industry. The accident main contributors to the piping systems are related to human and organization failure, fabrication and installation, layout, flow related, corrosion, and construction materials as presented in Table 1.

In this table, most of the human and organizational causes are organizational due to lack of inspection testing, poor planning, poor work permit and poor management system. Meantime no double/physical check, misjudgment and not following the procedures are usual sub-contributors under human failure. The layout problem of the piping system is related to incorrect physical arrangement and shape.

Sub-contributors details are the inadequate position, sharing pipes, dead-end, elbows/sharp bends, U-shape, and sizing. Inappropriate construction materials due to chemical and mechanical specifications, unsuitable components, and miss-match martial also contribute to piping failures.

Also, number accident contributors seem to be important contributors to piping failures due to poor fabrication, flow related and corrosion.

Table 1. *The most frequent accident contributors and sub-contributors for the piping system*

Piping system accidents contributors and sub-contributors					
Contributors	**Sub-contributors**		**Contributors**	**Sub-contributors**	
Human & organizational failure	**Organizational failure**	Contractor management	**Fabrication, construction, and installation**	**Poor installation**	Poor installation- bad setting
		Work permitting			Part miss-match
		Poor management system			Bolts tightening-loose
		No procedure-problem reporting			No painting
		Lack of inspection			Part-reused/temporary
		Poor communication			Human–technical related
		Poor planning		**Bolts tightening**	Bolts tightening-loose
		Lack of maintenance			Unbalance bolting
		Lack of supervision			Bolt broken/damage
		Poor safety culture			Positioning
		Improper use of equipment		**Structural/layout/positioning,**	Shape
		Management of change			Stress concentrated
		Misjudgment			Bolts tightening-loose
	Human failure	No procedure-double/physical check			Buried piping
		Misjudgment			Part miss-match
		Not follow procedure			Positioning
		Poor training			Human–technical related
		Poor/wrong instruction		**Support**	Attachment mechanism
		Carelessness			Stress concentrated
		Work permitting			Positioning
		Improper use of equipment			Part miss-match
		Knowledge based/ignorance			Part-reused/temporary
		Poor management system		**Work method**	No double/physical check
Layout	**Physical arrangement**	Positioning			insulation-flammable
		Share line			Welding, Poor heat treatment
		Flow restricted	**Flow related**	**Human–technical related**	Equipment/instrument setting
		U shape-accumulate			Emergency setting
		Positive isolation			By-pass
	Shape	Dead-end			Trap/closed condition
		Flow restricted		**Fluid movement**	Capacity/sizing
		Belt-shaped			Speed/rate/velocity
		Sizing			Shape
		Vertical piping			Turbulent
Corrosion	**Contamination**	Corrosive environment		**Valve leaking**	Object trap
		Sizing			Maintenance/servicing
		Inadequate waterproofing			Single for high pressure system
	Flow	No flow		**Reverse flow**	Check valve malfunction
		Turbulent flow			Pressure difference
		Scale/sludge accumulated		**Blockage**	Valve setting
		Local attack			
		Elbow part			
	Fabrication/installation	Miss match connection	**Construction material**	**Chemical specification**	pH rating
		Unsuitable construction material			Incompatibility study
					unsuitable components
		Thickness		**Mechanical specification**	Wrong wall thickness
					Physical & impact rating
					Pressure rating
					Miss match connection
					Thermal expansion
					Fire rating

3.1.2.Storage Tank Accident Contributors and Sub-Contributors

Compared to other equipment, the tank farms may appear as low interest on maintenance, low staff motivation, and poor safety culture. Proper working procedures, poor training, and contractor control are sub-contributors to human and organizational causes as illustrated in Table 2. This cause is dominated by organizational failures. Other accident contributors are flow related, heat transfer and external factors.

Table 2. *The most frequent accident contributors and sub-contributors for the storage tanks*

Storage tank accidents contributors and sub-contributors						
Contributors	**Sub-contributors**		**Contributors**	**Sub-contributors**		
Human & organizational failure	**Organizational failure**	Poor planning	**Flow related**	**Human design related**	Equipment/instrument setting	
		Lack of analysis			Accessibility	
		No procedure-double/physical check			Valve positioning	
		Improper use of equipment		**Blockage**	No venting/vacuum breaker	
		Work permitting			Trap/closed condition	
		Lack of supervision			Lack of cleaning	
		Lack of inspection		**Over flow**	Human–technical related	
		Lack of maintenance			Valve setting	
		Contractor management		**Fluid movement**	Transfer mechanism-compressed air	
		Management of change			Positioning	
		Poor communication			Object trap	
		Poor safety culture	**Heat Transfer**	**Heat generation/accumulate**	Unwanted reaction	
	Human failure	Misjudgment			Trap/closed condition	
		Not follow procedure			Ambient heat absorbed	
		Knowledge based/ignorance			Structural/layout/positioning-dead end	
		Carelessness			Heat tracing	
		Poor training			Friction/impact	
External factor	**Earthquake**	Vibration – mechanical failure		**Human–technical related**	Heating control	
		Vibration-spark generation			Work sequence	
		Corrosion				
	Freezing	Ice – cannot close valve				
		Design-single valve				
	Heavy rain	Floating tank - water got into two pontoons				
		Drain line blocked by dust				
	Lightning	Lack of protection				

3.1.3. Process Vessel Accident Contributors and Sub-Contributors

In Table 3 the most common contributor for process vessel is contamination. Undesirable chemical reaction in the vessel is caused by accumulation and heat generation. On another hand, the important contributors to be considered in the process vessel are the flow related causes and human & organizational failure.

Table 3. *The most frequent accident contributors and sub-contributors for the process vessels*

Process vessel accidents contributors and sub-contributors				
Contributors	**Sub-contributor**	**Contributors**	**Sub-contributors**	
Contamination	Pressure difference	**Human & organizational failure**	**Organizational failure**	No procedure/system-double/physical check
	valve leak			Lack of analysis
	Insufficient draining/drying/removal			Improper use of equipment
	Insufficient exhaust/venting			Lack of supervision
	Unwanted reaction			Work permitting
	Unsuitable method			Lack of cleaning/maintenance
	Work sequence			Poor communication
Reaction	Contaminations			Poor planning
	Formed an explosive gas–air mixture,		**Human failure**	Not follow procedure
	Repeated adiabatic compression			Poor training
	Heat generated/ accumulate	**Flow related**	Human technical related	
	Human–technical related		Confusing utility connection	
	Abnormal heating		Instrument positioning	
	Unfinished reaction		Difference level	
	Heat generated/accumulate		Speed/rate/velocity	
			Valve leaking	

3.1.4. Heat Transfer Equipment Accident Contributors and Sub-Contributors

As illustrated in Table 4, for process contamination, the main contributing factor is the insufficient purging, removal, drying, and cleaning which causes deterioration of the heat transfer equipment wall.

Another large technical contributor is heat transfer. Here the main problem is hot spot because of structure, layout, and positioning of internal parts of heat exchangers causing uneven flow.

Table 4. *Map of the most frequent accident contributors and sub-contributors for the heat transfer*

Heat transfer equipment accidents contributors and sub-contributors					
Contributors	**Sub-contributor**		**Contributors**	**Sub-contributors**	
Human & organizational	**Organizational failure**	Lack of inspection/testing	**Contamination**	Lack of detection	
		No procedure-double/physical check		Lack of incompatibility analysis	
		Lack of maintenance		Process residue	
		Poor safety culture			
		Wrong instruction		Process change/ upset	
		Poor planning		Lack of analysis	
		Management of change		Unsuitable method	
		Lack of analysis		Insufficient purging/ removal/ drying/cleaning	
	Human failure	Not follow procedure	**Heat transfer**	**Hot spot**	Structural/layout/positioning
		Misjudgment			Flow reduces
Flow related	Blockage				Friction/impact-moving part
	Scaling				Lack of detection
	Capacity/sizing			**Human–technical related**	Heating empty/wrong tank
	Speed/rate/velocity				Excessive cooling/heating
	Uneven flow			**Thermal expansion**	Support error
	Equipment/instrument setting			**Heat generation/accumulate**	Friction/impact-moving part
	Single valve & share line				

3.1.5. Separation Equipment Accident Contributors and Sub-Contributors

Common accident contributors are the process contamination, heat transfer, human and organizational, reaction, and flow-related aspects. Inadequate discovery andanalysis of contaminants is the key contributing factor in these separation equipment failures. Early detection of hazardous chemicals and adequate removal of residues is necessary tokeep the concentration of hazardous compounds low enough. Waste handling is difficult due to their properties. Typical contaminants are waste oil, sticky process residue in feed or indistillation generated contaminant. Table 5 gives more details of the results.

Table 5. *Map of the most frequent accident contributors and sub-contributors for the separation equipment*

Separation equipment accidents contributors and sub-contributors				
Contributors	**Sub-contributors**	**Contributors**	**Sub-contributors**	
Contamination	Waste oil	**Heat transfer**	**Hot spot**	Dried condition
	Lack of analysis			No flow/reduces
	Lack of detection			Uneven flow-distribution
	Process residue			Hold at high temperature
	Sticky/gummy material		**Human–technical related**	Valve setting
	Insufficient draining/drying/removal			Insufficient detection
	Air purging		**Incorrect cooling/ heating**	Emergency setting
	Valve setting/leaking			Tube blocked
	Unwanted reaction	**Reaction**	Unwanted reactions	
	Sticky/gummy material		Contaminations	
	Unsuitable method		Hold at high temperature/pressure	
	Instrument failure		Hazardous material accumulate/concentrated	
Human & organizational failure	The causes are similar to process vessel		Chemical reactivity	
	The causes are similar to process vessel		Low liquid level	
Flow related	Blockage		High heating rate	
	Lack of cleaning/purging		Hot spot-wall temperature high	
	Sticky/gummy material			
	Trap/closed condition			
	Pressure difference			
	Capacity/sizing			

3.2. Step 2: Identify the Timing Error per Lifecycle of the Project

The lifecycle of the project is classified into six design stages; research and development, basic engineering, preliminary engineering,detailed engineering, construction and start-up,and operations (Kidam and Hurme, 2012,a,b).The most frequent accident contributors for each stage in the lifecycle of the project were mapped out in Table 6. The main findings are that in the preliminary design phase the most important contributors are the process conditions, reactivity/incompatibility, unsuitable equipment for each part, and protectionwhich cause unexpected reactions andcorrosion problems. Therefore it is important to check the actual composition of the feed stream, main product, and by-product.

In basic engineering, the main sub-contributors are mechanical andchemical specifications as well as the physical arrangement of pipingand equipment, sizing, and shared piping. Lack of knowledge of process nature causes a significant amount of sub-contributors in detailed engineering too, suchas flammabilityi.e. inert gas blanketing and static electricity prevention.

In construction and start-up, the quality of fabrication anderection work isimportant, like bolt tightening, preventing stress concentration, and assurance of welding quality. The contributors in the operation phase are reactivity/incompatibility, construction material, automation/ instrumentation, utility set-up, process conditions, layout, and sizing. Hazardous material generated, thermal expansion, high heating sources, and wrong reaction dataare the most sub-contributors'critical faults which causea significant amount of equipment failures. In later modifications, there are various errors especially regarding reactors.

The list of most frequent accident-causing errors mapped out can be compared with the checklists published by CCPS (1998, 2009).

Table 6. *Map of the most frequent accident contributors and sub-contributors per project lifecycle*

Errors per project lifecycle stages					
Project Phases	**contributors**	**Sub-contributors**	**Project Phases**	**contributors**	**Sub-contributors**
Research & Development	**Process Condition**	Process contaminations	**Preliminary Engineering**	**Process Conditions**	Process contaminations.
		Uneven flow/dry condition			High temperature.
		High temperature			Secondary reaction.
		More corrosive			More corrosive.
		Hold too long			Hold too long.
		Process contaminations			Uneven flow/dry condition.
		Unbalanced reactant ratio.			Effect of physical condition.
		Wrong reaction data.			Hazardous materials generate.
	Reactivity/incompatibility	Reactions with contaminants			More reactant.
		Incompatible HT medium.			Store at high temperature.
		Unstable at high temperature.			High pressure.
		Heat generated.			Hold too short
		Incompatible raw material.		**Reactivity/incompatibility**	Reactions with contaminants.
		Reactive with cleaning agent.			Heat generated,
		Unstable in dry condition.			Unstable at high temperature.
Basic engineering	**Construction Material**	Chemical resistance spec			Incompatible raw material
		Mechanical spec			Unstable by-product.
		Sizing/Thickness			Unstable in dry condition.
		Friction/impact.			Unstable off-spec product.
		Non-conductive material		**Unsuitable Equipment/Part**	Measurement error
	Layout	Physical arrangement.			Mixing effects.
		Share piping.			Open storage.
		Positive isolation.			Open tank.
		Single valve.		**Protection**	No inhibitor
	Utility Set-up Protection	Over design heat capacity.			React with content
		Incompatible heat medium.	**Detailed engineering**	**Layout**	Dead end.
		Flammable sealing/cleaning agent.			Physical shape error.
					Support arrangement.
		No cooling/natural.			U-shape
		Blockage-gummy material.			Vertical positioning
		Corrosive HT medium.			Flow restriction.
		Incompatible purging medium.			Venting positioning.
		No mixing effects.			Venting shape.
		Normal condition sizing.			Accessibility.
		Sharing cooling source.			Direct connection.
		Single valve.			Positive isolation.
		Single valve.			Similar appearance
		No check valve.			Too closed.
		Friction/impact.			Trap condition.
		No flame arrester.		**Protection**	No nitrogen blanket.
		No gas treatment.			Static electricity.
		No insulation.			Non explosion proof.
		No relief valve.			No coating/painting.
		No vacuum breaker.			Drain without cap.
	Unsuitable Equipment/Part	Mechanical spec.		**Unsuitable Equipment/Part**	Feeding mechanism
		Miss-used.			Spark generation part.
		Small volume.			Non-conductive part.
		Waste handling.			Sampling tools.
		Chemical resistant spec			Shape miss-match.
		Difficult to clean			Part positioning.

Table 6 (continued). *Map of the most frequent accident contributors and sub-contributors per project lifecycle*

Errors per project lifecycle stages					
Project Phases	**contributors**	**Sub-contributors**	**Project Phases**	**contributors**	**Sub-contributors**
Basic engineering	**Unsuitable Equipment/Part**	Heating/cooling error	**Detailed engineering**	**Construction Material**	Non-conductive material.
		Lack of sensor			Thermal expansion.
		Lack of vacuum/exhaust.			Fire rating.
		Wrong absorption system.		**Automation/Instrumentation**	Setting error.
	Process Condition	Inadequate ventilation			Sensor failed.
		Flow velocity			No interlock.
		Sizing		**Utility Set-up**	Difficult to clean
CONSTRUCTION & START-UP	**Fabrication/Construction /Installation**	Stress concentrated.			Positioning.
		Poor fabrication/construction quality.			Power failure - no back-up
		Welding defect.			Direct connection.
		Bolt tightening related.			No vacuum/exhaust.
		Foundation weak		**Operating Manual**	Maintenance/repair.
	Unsuitable Equipment/Part	Poor/under construction			Waste handling
	Utility Set-up	Poor/under construction			Cleaning
					Transfer mechanism
OPERATIONS	**Reactivity/incompatibility**	Hazardous material generated	**Process Conditions**		Process contaminations
		React with contaminants			Effect of by-product.
		Contaminated/reactive waste.			Wrong reaction data
		Secondary reaction			Uneven flow/dry condition
	Construction Material	Mechanical spec	**Layout**		Flow restriction
		React with content			Trap condition
		Thermal expansion	**Sizing**		Smaller after modify
	Automation/ Instrumentation	Setting error			
	Utility Set-up	Incompatible heat transfer medium			
		Flow restriction			
		High heating sources			

3.3. Step 3: Identify the Direct and Root Causes of the Incident

Therefore, after identifying the most frequent accident contributors for each common type of oil and gas equipment and addressing the time of error in the project lifecycle, the next step in the tool is to identify the direct and root causes of the project lifecycle. This step is similar to the approach in the (Rasmussen, 1997) model. A number of typical direct causes and root causes are identified on each lifecycle of the projectbased on the existing causes in MARS database. The major difference is that the direct and root causes in the present work have been modified to reflect the causes of most frequent accidents contributors and sub-contributors of most common equipment in the oil and gas project lifecycle. Whereas the causes givenin the MARS database were collected directly from the companies' accident reports. The tool in the MARS data was validated by an expert group (Jacobsson et al., 2010). In Table7the classification of direct causes and root causes of accidents, split 1 is the direct and root causes related to the design phase (Preliminary study, Basic Eng., and detailed Eng.), split 2 related to theconstruction phase, and split 3 related to operation phase.By applying this step theprobable root causes can be established, and thus one would be able to move forward to the potential corrective actions that could reasonably have beenmade for common equipment in oil and gas.

Table 7. *The direct and root causes based on the project lifecycle*

Split 1		
	Direct causes	**Root causes**
Design phase error	Inadequate systems for designing and installing to good engineering standard	Inadequate or weakness in safety management system
	Poor risk assessment	Inadequate risk assessment procedures
		Inadequate resources/competence
	Loss of process control	Maintenance/inspection program inadequate
Split 2		
Construction phase error	**Direct causes**	**Root causes**
	Inadequate review of systems and safety performance of organization	Inadequate or weakness in safety management system
	Need for training	Inadequate or weakness in safety culture
	Inadequate allocation of responsibility	Poor commitment to safety. Poor leadership
	Poor selection of managers	
	Inadequate risk assessment procedures	Inadequate review and control from senior management
	Purchasing procedures inadequate	Poor resources and competence
Split 3		
Operational phase error	**Direct causes**	**Root causes**
	Incompatible goals and wrong priorities	Sub-standard thing in terms of safety
	Poor communication of priorities related to safety	Poor commitment to safety. Poor leadership
	Inspection inadequate	Inadequate review of systems and safety

Table 7 (continued). *The direct and root causes based on the project lifecycle*

Split 3		
	Direct causes	**Root causes**
Operational phase error	Supervision/review/control of systems inadequate	Risk awareness not adequate
	Operation procedure not adequate	Poor resources and competence
	Inadequate training and competence	Inadequate commitment from senior management
	Manager doesn't care or do not show they actually care	Inadequate awareness of the need of maintenance program or deliberate negligence
	Maintenance/inspection program not adequate	Inadequate review of system and safety performance
	Other priorities higher than safety	Need for training /competence
	Maintenance procedure not adequate	Procedures inadequate
	Attitude of personnel not adequate	Inadequate training
	Operation outside design condition	Inadequate supervision and control
	Procedures not followed.	
	Direct operator error	
	Shortcoming of personnel	

3.4. Step 4: Identify the Proposed Corrective Actions

When selecting the corrective actions, priority is given to the process safety to prevent occurrence or recurrence of safety significant events. As the study proposed from the operating experience in the oil and gas industry there are three levels of corrective actions: prompt corrective actions, reactive corrective actions, and proactive corrective actions.

Prompt corrective actions are actions taken to promptly restore the normal operating conditions. For example, theonly repair of failed equipment/ plain acceptance of human error, procedures are written, and discussion within a shift, etc.

Reactive corrective actions are short-term actions to reduce the risk of recurrence while awaiting long-term corrective actions. Reactive corrective actions deal with the contributing factors. For example, an operating procedure to prevent oil holding tank overfilling while awaiting design change of shutdown instrumentation philosophy of the tank.

Proactive corrective actions are to prevent recurrence. This level prevents the problem from ever happing again. The selection of proactive corrective actions that directly address the root causes of the event is important for the process safety, asset integrity, and performance of the process to prevent further interruptions.

4. TOOL VERIFICATION AND TEST

The tool is tested using the piper alpha tragedy. The Piper Alpha tragedy was the worst oil and gas accident killing 165 persons in 1988 in the North Sea.

On 6th July 1988 an explosion occurred in the gas compression module of the Piper Alpha oil production platform in the North Sea. A large pool fire took hold in the adjacent oil separation module, and a massive plume of black smoke enveloped the platform at and above the production deck, including the accommodation. The pool fire extended to the deck below, where after 20 minutes it burned through a gas riser from the pipeline connection between the Piper and tartan platforms. The gas from the riser burned as a huge jet flame. Most of those on board were trapped in the accommodation. The life boats were inaccessible due to the smoke. An investigation of the disaster was immediately carried out by the department of energy (DoEn).

The proposed tool was applied to the piper alpha tragedy to compare the actual corrective actions after the incident and the potential corrective actions proposed by the tool. DoEn issued two reports (Petrie, 1988a, b) put forward the scenario of the hydrocarbon leaks leads to the explosion. Table 8 summarizes the accident scenario, consequences of the explosions, findings, and recommendation after the event.

Table 8. *Summary of (Petrie,1988a, b) piper alpha report*

Aspects	NO	Steps
Scenario	1	A condensate pump was taken out of service for maintenance by day shift
	2	Leaking pressure safety valve (PSV) of the pump was taken out of service and blind was installed loosely (bolts not tight)
	3	Firewater system was on manual for diving operations
	4	21:45 two condensate pumps tripped, re-started by night shift without knowing the PSV was removed and blind improperly installed. Leaking occurred after the pump was re-started. A large amount of condensate was released which created an explosive vapor cloud.
consequences	1	22:00 first explosion occurred resulting in oil leaking from separation module and main oil line to shore.
	2	22:20-second major explosion due to rupture of one of the incoming pipeline risers
	3	On 22:50&23:20 the third and fourth explosion occurred as a result of the failure of the other two pipeline risers.
	4	A few hours later, only a few pieces of steel structure above the sea surface were the only remains of the piper alpha platform
	5	165 lives were lost
Finding	1	Failure of permit to work system
	2	No formal hand-over from day shift to night shift
	3	Non-compliance with company procedures
	4	Company management was easily satisfied with the safety system (lack of control

Table 8 (continued). *Summary of (Petrie, 1988 a, b) piper alpha report*

Aspects	NO	Steps
Finding	5	No proper training)
	6	Safety policy and procedures were in place but not practiced
	7	Emergency induction was not provided or inconsistently given
	8	No drills or exercises were conducted to test emergency preparedness
	9	No emergency response training was provided
	10	Inadequate guidance or means to assess the effectiveness of safety management system
	11	Poor management system
Recommendations	1	Organization, to submit a formal safety assessment of hazard in design and operation
	2	Auditing of the organization's management of safety
	3	Independent assessment &survey of installations
	4	Permit to work system to be a part of the organization's management system
	5	Review the incident reporting system
	6	Review the control of process
	7	Review the hydrocarbon inventory, riser, and pipeline
	8	Review fire detection and emergency shutdown
	9	Review accommodation, Temporary safe refuge (TSR), escape routes and embarkation points
	10	Review the emergency system

The tool for root causes identification of oil and gas accidents is illustrated in Figure 2. In step 1(A), equipment type is selected. Then in step 1 (B), the relevant accident contributors and sub- contributors are identified. This is based on the most frequent accident contributors of the equipment identified previously illustrated in Tables 1, 2, 3, 4, and 5. In step 2, the most common accident contributors and sub-contributors are linked to the project lifecycle by identifying their time of occurrence as previously illustrated in Table 6. Next, in step 3 the possible design, construction, and operation direct and root cause are identified by using the map in Table 7.

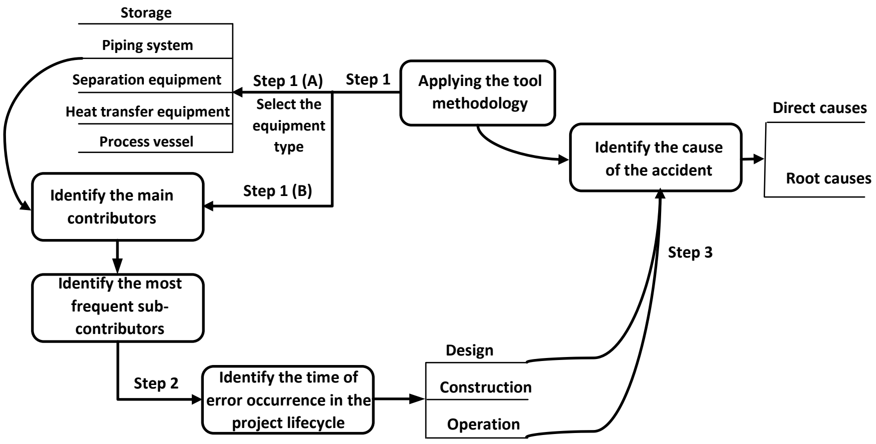

Figure2.*Map of the direct and root cause identification methodology*

The tool applied to the following: 1- leaking pressure safety valve PSV that triggered the incident. 2- The ruptured pipeline risers. Therefore, the equipment type selected to represent the PSV and the pipeline risers were a piping system to be analyzed.The result of the tool for thepiping system is summarized in table 1. The study predicted human and organizational failure,layout, corrosion, flow related, and fabrication /installation and construction material with high frequency in the piping system. Meantime predicted the errors occurred in the design and operations phases of the project lifecycle and go beyond the direct causes to stand on the root causes of the incident.

The Petrie investigation report stressed the following findings: 1-the PSV was off and was not communicated in the handovers of the lead maintenance hand, the phase 1 operator and the lead production operator did not learn of it through the Permit to work (PTW) system. 2-The crew was unable to put the PSV back that evening, the scoring supervisor came up to the control room to suspend the permit. He was on his first tour as a supervisor and had no training in the PTW system in use on the platform. 3- The score supervisor did not make a final inspection of the job site before going off work and evidently, the lead production operator did not inspect the job site either. 4- The leak would not have occurred if there had been a positive isolation of the pump by means such as the use of a slip plate. 5- The leak occurred from PSV is due to the blind flange was not leak-tight,the report proposed many pieces of evidencewere led to the effect that an experienced and competent fitter would not make up a blind flange which was not leaked tight. This finding is clearly predicted in the proposed tool as human and organizational failure, installation related contributors and represented in the tool by work permit, no procedure-problem reporting, poor communication, poor training, bolt tightening, unbalanced bolting and lack of supervision.

Physical arrangement sub-contributor was predicted in the tool under layout contributors which was mentioned in the report as the size of oil pool fire indicated that the supply of oil to the fire probably exceeded the oil inventory of the of the separators and there was a leak from main oil line due to the wrong allocation of the main emergency shut down valve ESD. Also, corrosion was predicted by the tool with contamination as sub-contributors which is clearly mentioned in the report as the blockage caused by corrosion products in the firewater deluge system affect the reliability of firefighting operations.See Table 1: the map of most frequent accident contributors and sub-contributors for piping system.

On the other hand the following consequences was concluded from the report, the initial event: gas explosion which is operational control failure and this was clearly addressed in the tool in Table 6 under operation and modification phase due to work permit, not follow procedures, no problem reporting…etc., and then followed by four escalation explosion damage due to design related error like oil pool fire, pipeline rupture, and accommodation failure which deficiencies in hazards identification, assessment, and management explosion and fire mitigation, fire protection emergency command and control.In Table 6: the mapping of the accident contributors in the lifecycle of the project identified the next three explosions is a design error (preliminary, basic, and detailed engineering) and also in the operation modification phase.

The tool also predicted the direct and root causes as shown in Table 7 and by considering the predicted direct/root causes to extract the corrective actions, it is clearly and completely matched with the recommendations of DoEn reports part 2 of piper alpha tragedy (Petrie, J.R., 1988b) as shown in Tables 8 and 9.

Table 9. *Results of piper alpha tragedy analysis as a piping system*

	parameters	**Findings**					
Step 1							
a	Equipment type	Piping system					
b	Accident main contributors	Human and organization failure	Layout	Corrosion	Fabrication installation	Flow related	Construction material
	Accident sub-contributors	1- Organization failure 2- Human failure Continue table 1	1- Physical arrangement 2- Shape Continue table 1	1- Contamination 2- Flow 3- Fabrication/ installation Continue table 1	1- Poor installation 2- Bolt tightening 3- Structure/ layout positioning 4- Support 5- Work method Continue table 1	1- Human-technical related 2- Fluid movement 3- Valve leaking 4- Reverse flow 5- Blockage Continue table 1	1- Chemical specification 2- Mechanical specification Continue table 1
Step 2	Time of error during lifecycle	Design phase		Operation phase			
Step 3	Accident causes	**Direct causes in Design Phase**		**Direct causes in Operation Phase**			
		1. Inadequate systems for designing and installing to good engineering standard 2. Poor risk assessment 3. Loss of process control		1. Incompatible goals and wrong priorities 2. Poor communication of priorities related to safety 3. Inspection inadequate 4. Supervision/review/control of systems inadequate 5. Operation procedure not adequate 6. Inadequate training and competence 7. Manager doesn't care or do not show they actually care 8. Maintenance/inspection program not adequate 9. Other priorities higher than safety 10. Maintenance procedure not adequate 11. Attitude of personnel not adequate 12. Operation outside design condition 13. Procedures not followed. 14. Direct operator error 15. Shortcoming of personnel			
		Root causes in design Phase		**Root causes in Operation Phase**			
		1. Inadequate or weakness in safety management system 2. Inadequate risk assessment procedures 3. Inadequate resources/competence 4. Maintenance/inspection program inadequate		1. Sub-standard thing in terms of safety 2. Poor commitment to safety. Poor leadership 3. Inadequate review of systems and safety 4. Risk awareness not adequate 5. Poor resources and competence 6. Inadequate commitment from senior management 7. Need for training /competence 8. Inadequate awareness of the need for maintenance program or deliberate negligence 9. Inadequate review of system and safety performance 10. Procedures inadequate 11. Inadequate training 12. Inadequate supervision and control			

5. CONCLUSION

The paper exploited the earlier studies that carried out to analyzethe frequency of earlier accident contributors and sub-contributors of the most common equipment in oil and gas industry and addressed time of error in the lifecycle of the project to predict the direct and root causes of the event. The proposed tool has several advantages that could overcome some of the limitation of the current design/operation hazard identification tools. The most important feature of the tool is to predict accidents contributors, sub-contributor, and direct/root causes as well as give the incident investigator ideas on the potential accident contributors throughout the lifecycle of the project. Also the tool can be used by the operations personnel to review the facilities to discover the hidden hazard. Meantime the designer can use it to remove the process engineering related faults before the time to be late and changes will be expensive

The study isto enhance the experience feedback after the event by increasing the general usability of the accident information. This is done by creating a general tool to be used after the event for enhancement of safety in oil and gas industry and discover the potential corrective actions. As there is no clear tool for predicting learning from previous experience and derive the potential corrective actions that will support the oil and gas operation, The study provided aframework to drive out cost-effectivecorrective actions after the event bygoing deeper into the root causes for supporting the operational activities.

The proposed tool has been verified and tested using the piper alpha tragedy casestudy. The method successfully predicted the accident contributors, pointed out common design, construction, and operating errors if the type of equipmentis selected correctly.

REFERENCES

[1] Bell, J., Healey, N. (2006). The Causes of Major Hazard Incidents and How to Improve Risk Control and Health and Safety Management: A Review of the Existing Literature. Health and Safety Laboratory.

[2] CCPS. (1998). Guidelines for design solutions for process equipment failures. Center for chemical process safety/AIChE. New York: John Wiley & Sons, Inc.

[3] CCPS. (2009). Inherently safer chemical processes: A lifecycle approach, 2nd ed., New York,AIChE

[4] FKD. (2011). Failure knowledge database. http://www.sozogaku.com/fkd/en/ available online 29.05.11

[5] Hollnagel, E. (1999). Barriers and accident prevention. Routledge.

[6] Hull, A. M., Alexander, D. A., Klein, S. (2002). Survivors of the Piper Alpha oil platform disaster: long-term follow-up study. The British Journal of Psychiatry, 181(5), 433-438.

[7] Jacobsson, A., Ek, Å.Akselsson, R. (2011). Method for evaluating learning from incidents using the idea of “level of learning”. Journal of loss prevention in the process industries, 24(4), 333-343.

[8] Jacobsson, A., Sales, J., Mushtaq, F. (2010). Underlying causes and level of learning from accidents reported to the MARS database. Journal of Loss Prevention in the Process Industries, 23 (1), 39-45.

[9] Kidam, K, Hurme M., (2012,a) Origin of equipment design and operation errors, Journal of Loss Prevention in the Process Industries, 25, 937-949

[10] Kidam, K, Hurme M., (2012,b) Design as a contributor to chemical process accidents. Journal of Loss Prevention in the Process Industries, 25, 655-666

[11] Lindberg, A. K., Hansson, S. O.,Rollenhagen, C. (2010). Learning from accidents–what more do we need to know? Safety Science, 48(6), 714-721.

[12] Meel, A., O’neill, L. M., Levin, J. H., Seider, W. D., Oktem, U., & Keren, N. (2007). Operational risk assessment of chemical industries by exploiting accident databases. Journal of Loss Prevention in the Process Industries, 20(2), 113-127.

[13] Petrie, J.R., (1988,a), "Piper Alpha Technical Investigation. Interim Report", London, Department of Energy, paras. 4.7.6, 10.1.8.

[14] Petrie, J.R., (1988,b), "Piper Alpha Technical Investigation. Further Report", London, Department of Energy, para. 4.2.1.

[15] Prem, K. P., Ng, D.,Mannan, M. S. (2010). Harnessing database resources for understanding the profile of chemical process industry incidents. Journal of Loss Prevention in the Process Industries, 23(4), 549-560.

[16] Rasmussen, J. (1997). Risk management in a dynamic society: a modeling problem. Safety Science, 27(2), 183-213.

[17] Sales, J.,Mushtaq, F., Christou, M. D., Nomen, R. (2007). Analysis of Major Accidents Reported to the MARS Database During the Period 1994-2004.

[18] Tauseef, S. M., Abbasi, T.,Abbasi, S. A. (2011). Development of a new chemical processindustry accident database to assist in past accident analysis. Journal of loss prevention in the process industries, 24(4), 426-431.

AUTHORS' BIOGRAPHY

Dr. Walaa Mahmoud Shehata, is an assistant lecturer in the department of chemical and refinery engineering, Suez university, Egypt. She has many international publications with interest in hydrogen and water networks design, natural gas processing, refinery processes, bio-refinery

Dr. HamdyAhmed Faroun, is the production operations manager at East Zeit petroleum company with responsibility for production operations activities: offshore &onshore oil and gas production, terminal and tanker shipping.His professional interests focus on scientific research, and his current projects include many scientific published studies about flared gas recovery and process safety management. He shared his practical and academic experience at international summits and lead international workshops worldwide.

Citation: *Walaa Mahmoud Shehata & Hamdy Ahmed Faroun, (2018). A Tool to Identify the Proactive Corrective Actions after the Accidents in Oil and Gas Industry, International Journal of Petroleum and Petrochemical Engineering (IJPPE), 4(1), pp.32-44, DOI: http://dx.doi.org/10.20431/2454-7980.0401005*