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Comparative Assessment of Process Safety Failures in the Macondo and Bhopal Explosion Incidence in Oil and Gas Companies

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ABSTRACT
The study was to compare the assessment of process safety failures in Macondo and Bhopal explosion incidence in oil and gas companies. The survey method involves self-structure questionnaire, the population of the study consist of 4 major oil and gas companies in Port Harcourt, Rivers State. The instrument used for collection of data was structured questionnaire titled "Assessment of Macondo and Bhopal Explosion incidence (using ISC framework)" the instrument has a 43-items questions to obtained primary data. Secondary data was obtained using literature review of Macondo and Bhopal incidence. The Likert scale was used to accommodate all the research questions in the questionnaire. The result of the analysis was organized, summarized and presented using table, SPSS 2.0 was used in the analysis and reliability statistic. Analyses of data were done using mean, standard deviation, frequency and simple percentage. The sampling method used was the purposive sampling. The result obtained after the analysis of data is as follows. Macondo staff response on the series of unsafe acts using the ISC framework, based on the mean and percentage of acceptance shows that lack of communication (4.95 &100) was one of the highest unsafe acts, while Bhopal shows poor maintenance (5.00 &100) as the highest unsafe acts. Macondo staff response on the contributing causes of the incidence was human factors (4.86 & 100%), while in Bhopal was Organizational culture (5.00 & 100%)Major findings was poor safety culture, poor maintenance, lack of communication. Key recommendation was that Oil and gas companies should be 100% conscious of the aspect of process safety management to avoid disaster.

KEYWORDS: comparative assessment of process safety failure in the Macondo and Bhopal explosion incidence in oil and gas companies.

I. INTRODUCTION

Background to the study: Oil and Gas are the heartbeat of recent day society, the economy needs it for growth and expansion, private individuals cannot do without it; but it should not be seen, felt, heard of or toyed with. it's an estimable value to the economy, politics and thus the environment. The Macondo and Bhopal oil and gas explosion has been recorded together as the most industrial disaster in history. Its negative impact has made huge changes within this and future lifetime of the economy. Its disastrous impact has left many in a state of disarray. The incident involves research attention and special attention from the government to clean up the mess. Every company features a process for achieving its objectives through a system which is created from different parts, and if any of the part is inefficient, it ends up in process safety failure. Safety could be a facet of the system that forestall process safety failure by identifying industrial risks before time and tackling them with the correct modalities. The Centre for activity Safety (CCPS) describe process safety as 'a well-organized framework for handling the integrity of hazardous operating systems engineering ethics, and processes by putting on good design and operating application Amin and Khan, (2018). It pacts with the stoppage and control of incidents occurrence that have the ability to release hazardous substance or energy. The explosion and effect of toxic or fire that this accident can cause will eventually result in loss of life, ecological impart, production loss, damage of properties and injury Lees, (2012) Khan and Hashemi (2016)

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opined that process safety may be a disciplined background, attentively on anticipation and control of incidents. Actual, near miss or potential significant can be applied. The release of hazardous energy or material within the definition was important inclusion. Catastrophic consequences can set in when loss of control, containment or energy CCPS (2010) unrestricted LOPC, hit or miss of any hazardous substance including non-flammable and non-toxin was defined as process safety failure (e.g. compressed air steam, hot condensate, compressed CO2 compressed or air nitrogen,) During process, an undesired event or state that, under slightly different circumstances, could have resulted in LOPC Silva (2016) is of the view that API RP applying the broader definition of process safety, limits it attention on loss of primary containment from the CCPS, Energy must also be included . Control effectiveness is a requirement to possess in security system. What this means is that no company or industry can succeed if the safety measures aren't put into consideration. Reason being that its harmful impact is commonly devastating within the current and future, because it regards the economic, political and environmental maladies. A series of devastating accidents during the economic history happened human lives with huge costs in economic. These accidents are the Bhopal fraxinella disaster (1984) Piper Alpha disaster in (1988), BP Deepwater Horizon Oil Spill disaster (2010)., Chernobyl nuclear energy Plant disaster (1986) . Occurrence accidents of in numerous places and time all of them have in common, in line with analyses and official reports of accident investigations, the part played activating the disaster by human error. A crucial element in developing reliability and systematic method to predict risk is analysis of human error and their part in accidents Sharppell and Wiegmam, (2017). Therefore, a correct understanding of human factors within the workplace is a very important aspect within the prevention of accidents. Human Factors Analysis and organisation (HFACS) was used to comparison between (Bhopal and Deepwater Horizon) as two major industrial disasters. Failures and latent failures/conditions a modified version of "Swiss Cheese" model was use to describes the degree of failures in complex operations and supported reports of official investigation Ahmad and Pontiggia,(2015).

All cooperate organisation especially the oil and gas industries are always conscious about the problems of safety, hence, they establish a security department, whose primary duty is to watch the systems, supervise the work environment, service the operation facilities, identify areas of impending risks for correct communication and necessary managerial actions. Perhaps, this can be not the case of the Macondo and Bhopal companies. Macondo otherwise referred to as BP's trouble horizon oil and gas drilling company in Mexico, experienced the world's disastrous oil spillage on April 20, 2010. Although, it's recorded 7 years of operational success without spillage. Yang and Khan (2015) stated that a well-known case that caused disaster is poorly managed operations and mix of inherently unsafe designs. 11 workers died as a result of the explosion, and 5 million barrels of oil were released into the Gulf of Mexico from the Macondo well deep below on the Davy Jones. This flow lasted for 87 days causing treat to human and aquatic life and also the aftermath of off shore industrial practices.

On the opposite hand, the Bhopal chemical explosion incident occurred on December 3, 1984 within the city of Madhya Pradesh State Indian. Reports from Basha and Alajmy (2020), stated that, killing about 15,000 to 20,000 persons children, men and women was the released of harmful methyl isocyanate about 45 tons from an insecticide plant that was owned American firm in India called union carbide cooperation. Men, women and children. Survivors from this explosion are suffering from respiratory diseases, eye problems leading to blindness, cancer, birth deformities, threat in the eco-system, soil and water contamination. This disaster occurred as a result of substandard operating and safety procedures. Its impact is still felt in India today. Similarly, Bhopal explosion occurred as a result of inexperience of the employees that were put in charge of the chemical substance. Macondo, oil and gas companies are attentive to safety and has established a Process safety unit to avert failure of systems during business operations and explorations. Although, within the face of the traditional safety activities, Macondo disaster which resulted deep-water oil spillage that affected the 11 crew members on board and its hazardous impact was mainly felts by the aquatic habitants unlike the Bhopal explosion that basically affected the lifetime of humans, plants and animals. Both disasters occurred as a result of failure within the process system. Chemical Safety Board (CSB) Baybutt, (2016). within the case of Macondo disaster, while Bhopal explosion occurred as a result of a leakage within the safety tank where the chemical was preserved. Despite the safety framework given to both companies, Macondo incident occurred as a result of the negligence of the method safety approaches or framework per

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IChemE Safety Centre (ISC), or because of political and economic reasons. Skogdalen, and Vinnem, (2012) argued that displacement of drilling mud by seawater lead to the flow of hydrocarbons that caused the blowout of the Macondo well during the temporary abandonment process. despite a failure to demonstrate the cement job integrity with negative pressure tests, even after multiple failures, the choice to proceed to displacement of the drilling fluid by seawater was made. The questionable decisions was one in all series, the poor safety-driven decision evidenced had the effect of reducing the margins of safety within the days previous to the blowout. mud suddenly began erupting at around 21:40 hours that night driven by leaked hydrocarbon gas into the well unnoticed , spreading over the drill floor and quickly flow over the derrick. Rapidly increasing as it advanced to the surface. before; the Before crew realized it was too late, the well was uncontrollable. Steps were taken to contain it and divert the erupting gas, all actions failed. The engine room was filled with gas within few minutes and ignited, causing catastrophic explosion. 11 men were killed, spoiled vital hydraulic control lines. This triggered the sinking of the Deepwater Horizon aftermath of the explosion. The blowout preventer (BOP) was incapable to closed by the crew on the seabed or to disengage the rig. The last frantic effort to save it from disaster. Approximately five million drums of oil discharge into Gulf of Mexico in 87 days blowout., BP in 2001 was the biggest U.S. domestic producer of gas and oil. BP was dehumanised. and a public response against the entire oil and gas industry. The two companies were only interested in making profit. It is based on this premise that the researcher wishes to develop a modern process safety model after comparing the process safety failure analysis in Macondo/ Bhopal oil and gas explosion incident.Every process safety procedure is expected to be in line with the internationally based practice. Such standard is to ensure that the operations of the company are secured to its capacity without failures. However, this was not the case of the Macondo and Bhopal companies; they experienced process safety failures as a result of negligence and poor managerial management concerns, leading to loss of cooperate linkages, degradation of environment, soil air and water pollution, loss of human and aquatic lives, loss of finances used in restoring the disaster, and loss of properties. If proper safety procedures were followed Professionally, these problems would have been prevented. Additionally, the Swiss Cheese Model has some flaws which needs to be improved upon. It suffers from interpretation flexibility, simplistic vision of accidents and a high degree of event generalization. The statement of the problem therefore is; to develop a modern process safety model after comparing the process safety failure in Macondo/ Bhopal oil and gas explosion incident.

Statement of the Problem: Every process safety procedure is expected to be in line with the internationally based practice. Such standard is to ensure that the operations of the company are secured to its capacity without failures. However, this was not the case of the Macondo and Bhopal companies; they experienced process safety failures as a result of negligence and poor managerial management concerns, leading to loss of cooperate linkages, degradation of environment, soil air and water pollution, loss of human and aquatic lives, loss of finances used in restoring the disaster, and loss of properties. If proper safety procedures were followed Professionally, these problems would have been prevented. Additionally, the Swiss Cheese Model has some flaws which needs to be improved upon. It suffers from interpretation flexibility, simplistic vision of accidents and a high degree of event generalization. The statement of the problem therefore is; to develop a modern process safety model after comparing the process safety failure in Macondo/ Bhopal oil and gas explosion incident.

1.3 Aim and Objectives of the Study

The aim of this study is to compare the process safety failure in Macondo and Bhopal oil and gas explosion incidence. However, objectives of this study include;

a. Determine the series of unsafe acts (Immediate causes) of the accidents using the ISC framework.
b. Identify the contributing Causes of the Macondo and Bhopal oil and gas explosion using the ISC framework.
c. Evaluate the effectiveness of the immediate or short-term corrective actions in Macondo/ Bhopal oil and gas explosion incidence.
d. Determine the Long term or system improvement action in Macondo/ Bhopal oil and gas explosion incidence.
e. To develop a modern process safety failure model that will be used to determine the Macondo and Bhopal oil and gas explosion, which may prevent future occurrence of oil and gas explosion in companies.

1.4 Research Questions

Five research questions were answered to guide this study;

1. What are the series of unsafe acts (Immediate causes) of the accidents using the ISC framework?
2. What are the contributing Causes of the Macondo and Bhopal oil and gas explosion using the ISC framework?
3. How effective are the immediate or short-term corrective actions in Macondo/ Bhopal oil and gas explosion incident?
4. What process safety procedures should develop to ensure integrity of primary and secondary mechanical barriers are verified by using the best available test procedures?
5. How can a process safety failure procedure be designed so as to investigate the Macondo/Bhopal explosion incidence and to prevent future oil and gas explosion in companies?

1.5 Hypotheses

The following null hypotheses were formulated and tested at .05 level of significance:

H_{01}: There is no significant difference between the mean responses of Macondo
and Bhopal Staff on the series of unsafe acts (Immediate causes) of accidents using the ISC framework.

H_{02}: There is no significant difference between the mean responses of Macondo and Bhopal Staff on contributing Causes of the Macondo and Bhopal oil and gas explosion.

H_{03}: There is no significant difference between the mean responses of Macondo and Bhopal Staff on the effectiveness of the immediate or short-term corrective actions in Macondo/Bhopal oil and gas explosion incident.

H_{04}: There is no significant difference between the mean responses of Macondo and Bhopal Staff on process safety procedures to be developed to ensure integrity of primary and secondary mechanical barriers

H_{05}: There is no significant difference between the mean responses of Macondo and Bhopal Staff on how a process safety failure procedure can be designed so as to investigate the Macondo/Bhopal explosion incidence and to prevent future oil and gas explosion in companies.

1.6 Significance of the study

This research work will serve as a resource base to other scholars and studies interested in carrying out further studies in this field. A better knowledge on the application of process safety procedures to avert oil and gas accident will be gained. An improved process safety procedure management model will be developed which will be used to investigate the future oil and gas explosion, and guide operations and safety personnel to make good decision on industrial analysis. The study will also educate industrial employees on the negative impact of negligence and the importance of safety process managerial supervision, to ensure that all the safety procedures are adhere to. This study will also educate the general public on the dangers of oil and chemical spillages, hence enabling them to report oil vandals to the appropriate authorities.

1.7 Scope of the study

The scope of this study consisted of on dependent variable which is process safety failure and three independent variables which are the factors responsible for the process safety failure in the Macondo/Bhopal oil and gas explosion using the ISC framework, development and testing of a modern process safety management model, drawn out of the Swiss Chess Model of process safety failure approach used in investigating the Macondo and Bhopal oil and gas chemical spillage.

II. LITERATURE REVIEW

2.1 CONCEPTUAL REVIEW

2.1.1 Concept of Process Safety Failures

Process safety is distinct as having a controlled framework focused on averting and control of process safety measures, control needs to be upheld at all stages of a facility lifecycle, and therefore the application in management of process safety starts from introductory concept or exploration phase right through to abandonment or decommissioning Nowamooz and Lemieux (2007). Also, Russ (2019) defined process safety failure as the negligence displayed during an operation that results to future disaster. This negligence could come from the crew members at site, failure in the operating systems or human factor,

2.2 The management of process safety - maintaining control

The ISC considers that process safety is fundamentally built on six functional areas or pillars. These are:

Knowledge and competence (KC), engineering and design (ED), systems and procedures (SP), assurance (AU), human factors (HF), culture (CU) Wiley et al, 2014).

These areas break down aspects of business in an organizational, within each system for leadership, andmanagement action. For

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management of process safety completely, the commitment of leadership is vital to guarantee functional level across all six areas. Knowledge, Competence and Leadership in process safety is fundamental. Saferrobust design andengineering safety systems is underpinned by supporting the upholding and developingcontinually thesystems and procedures for sustaining safer process operations. The best practice and assurance are continuous by process safety in a varying environment taking full accountthecontributions ofexternal influencesandhuman factors behaviours. These collectively elements shape the prevailing culture, society and workplace in order to build a mutual understanding of risk issues and tofurther exploit new ways forrisk reduction,sustainable and cost effectiveness. in the process industries.

2.3 The ISC framework for managing process safety

The ISC framework of six functional areas in managing process safety as shown in Table 2.1. Each significant phase of a facility life cycle is defining, from initial idea or exploration to eventual decommissioning, plotted against the six functional areas. Note should be taken that 'ongoing integrity' 'operation', and 'maintenance' have been gathered together because they are a continuous loop in an operating facility. The lifecycle starts with 'leadership', as this determines every functional area, as well as all decisions and actions within an organization. The main phases of design, construction, operation, maintenance and ongoing integrity and decommissioning or abandonment apply to all manner ofactivities andfacilities, including, but not restricted todrilling of well pipelines and plant.Typical examples of these functional areas have been included to explain in each phase theirapplication. The context in each phase is not complete in this list, but just to aids the context.

Table 2.1 ISC Process Safety Framework

Phases of a facility	knowledge and competence	engineering and design	systems and procedures	assurance	human factors	culture
leadership	demonstratedi mportance of knowledge and competence.	Robust engineering decisions supported,	Robust and practical management systems.	Assurance processes valued in the organisation.	Recognizing that all aspects of HF.	Demonstrated fair and just culture.
design	Design engineers' operations.	location and siting.	design hazard management.	design approvals, safety critical elements.	motivation and empowerment .	operability
construction	construction supervisors.	ensuring as built construct.	fabrication and testing standards.	application of quality assurance.	workforces with multiple nationalities.	worker engagement,

Operation, maintenance and ongoing integrity	operations, drilling maintenance and engineering personnel.	alarm management.	standard operating procedures	lead and lag metrics, system audits.	written procedures operability.	worker engagement,
decommissioning or abandonment	trades engineers, drillers, supervisors	isolation design, flushing.	standard operating procedures.	site inspections quality assurance.	written procedures constructabilityrisk	worker engagement, understanding hazards.

Source -Wiley et al. (2014). Process safety and the ISC Framework.

Document from the functional areas is also used to provide a common platform for Chemical Safety Centre members to communicate, plan and make decisions. This framework focuses on leadership within the organization and how it interacts with day-to-day management. It does not explain the corporate governance of an organisation, though the framework has been mapped to Corporate governance for process safety - guidance for senior leaders in high hazard industries. This simplification of management of process safety is done in an effort to make the concepts accessible to a wide audience. It serves as a road map to show basic concepts and their application. Specific terms used in this framework, including the six functional areas.

There are numerous other frameworks for process safety, namely the Organisation for Economic Co-operation and Development (OECD) andthe CCPS, the Energy Institute (EI) Wiley et al, (2014). Thesystem management principles frameworks focus on high level, and an organization can applied as a management system. To support organization in applying and

e. The organization of the National External Diploma Program (NEDP) form generally

Section 2. Hazards SubstancesInformation

Section 3.ProcessTechnology Information

Section 4. to the EquipmentInformationRelated to the Process (including safe limits)

Section 5.Their Functions and Description of Safety Systems

Section 6.Document Control andManagement Plan

Section 7. CodeEvaluation, Applicability and Compliance NAC 459.95255 "Highly hazardous substance" defined. (NRS 459.3818) "Highly hazardous substance" means a chemical listed in understanding the six areas, thecross referenced of three frameworks have been with the six functional areas. The illustrative of cross referencing is not exhaustive, other explanations are possible. This study seeks not to form another framework to select from, but to offer practical direction in each of the six areas, to support organization to improve the process management safety, if there is a management system in place.

The compiled process safety information is a necessary resource for developing and implementing the remainder of the program requirements. Most notably, the following activities would be impossible without complete Pre-Site Safety Inspection (PSI):

a. The conduct of a thorough Process Hazard Analysis (PHA)
b. The development of standard operating procedures
c. The identification of the need to conduct a management of change, and the ability to evaluate the change
d. The ability to develop a mechanical integrity program.

following the format of the Pre-Site Safety Inspection (PSI) checklist as follows:

subsection 1 of NAC 459.9533, regardless of thequantity oramount of the chemical present.

Data about the substances must be collected to assess the potential hazards posed by its use in the regulated process. Some of this information will be available in the manufacturer's Safety Data Sheets (SDS). information will be accessible in other sources; such as the NIOSH Pocket Guide to Chemical Hazards;Chemical Engineers' Handbook, Genium's Handbook of Safety, Health, and Environmental Data for

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Common Hazardous Substances etc. Recognising the suitable SDS sheetsGenerally is the best way to commence this effort. if the effect of a nonregulated material may need to be considered during the PHA evaluation, the data should be assembled.

2.4Foreseeable Hazardous Effects of Inadvertent Mixing of Different Materials

Foreseeable hazardous effects must beconsideringthe inadvertent mixing of different materials does not end with the listing of incompatibilities for theexplosives or highly hazardous substance. Materials must be considered by the facility what are on-site and if they are mismatched with the highly hazardous substance or explosive and also identify what materials are on-site, for instance:

Chemicals (produced on-site, including intermediates), Chemicals (brought on-site), Utilities (water steam, cooling, compressed air, etc.), Contaminants (foreign objects rust, etc.), Maintenance materials (lubricants solvents, etc.).

The facility should then control which materials are incompatible and facility should construct an incompatibility chart unsuitability, only considers two-component mixtures; the facility may also need to consider whether any relationsbetween the threehazardous materials.

2.5ProcessSafety Performance Indicators for High-hazard Work Environments

Personal safety incidents can have serious consequences for individual workers, and are statistically far more common than major process safety incidents. As such, companies and regulators have taken steps to minimize them with some success. Yet process safety expert and chemical engineer Trevor Kletz (1922-2013) Amin and Khan (2019) noted that relying on good personal safety performance results, such as recordable injury rates, as a barometer for process safety can introduce “a feeling of complacency, a feeling that safety was well managed.

Findings from major chemical and petrochemical accidents in the United States, including the CSB investigated, demonstrate that personal safety statistics are not good indicators for the health of barriers and safety management systems intended to prevent major accidents:

A Phillips chemical plantin 1989, experienced a catastrophic series of fires and explosions that killed 23 workers, Company operated and recorded nolost time incident for several million work hours. Post-incident findings specified that no hazard analysis was applied at the plant to identify process hazards, nenforcementof permit to work system at the plantand critical control equipment for personnel were not separated from process units in agreement with recognised good engineering principles.

According to OSHAcademy Occupational Safety and Health Training, in (2004), the BP Texas City refinery was lauded by the BP Group CEO for the refinery’s “best year ever” in terms of safety performance due to low recordable injury statistics—despite the documented failure to correct major process safety and management system deficiencies identified that same year in audits, mechanical integrity reviews and incident investigations. The following year, OSHA injury data noted the refinery was off to such a good start that its 2005 safety performance record “may be the best ever,” a characterization which was turned on its head when a March 2005 refinery explosion killed 15 workers and injured 180 others. Also, the Valero McKee Refinery in Sunray Texas 2007, 4 workers were seriously burned and the plant was force to shut down due to a process safety incident. despite low-rate injury recordable byOSHA, personal safety record was cited and fine placed. Lack of management of change review, Process hazard analysis were not properly carried to identify hazards posed to nearby equipment and failure to stop high-pressure flammable by using engineering control during post findings of the incident. Bayer Crop Science facility in Institute, West Virginia in 2008, 2 workers were killed and injured 8 others due to process safety incident, OSHA low-rates injuryrecordable Post-incident results indicated that Pre-start-up safety review was not applied and inadequate training of the personnel to function new equipment involved in the accident. Lastly, CITGO’s Corpus Christi refinery in 2010celebrated for safety performance with national industry recognition based on the refinery’s low recordable injury rates in the previous year as reported by OSHA, notwithstanding the major fire outbreak suffered by the company in2009,due to dangerous hydrofluoric acid thatwas released in its alkylation unit.

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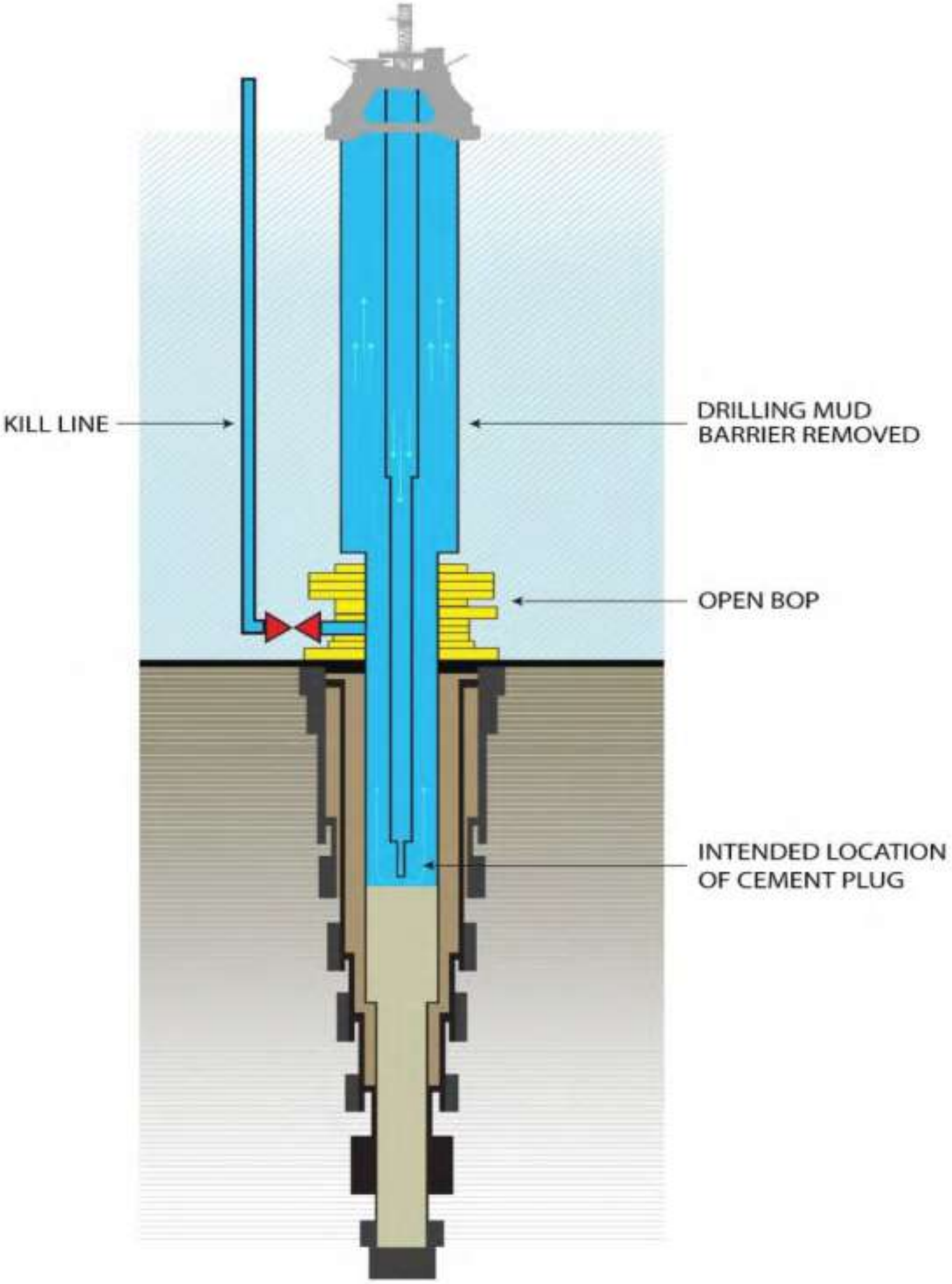

Figure: 2.1 Diagram of a kick control
Source- Deepwater Horizon report, 2010

A mixture of seawater, drilling mud, and hydrocarbons erupted onto the drilling rig,during the process of displacing the riser, Immediately,the crew tried to divert the influx to gas separator (MGS). The fluid overwhelmed MGS within a minute and forced their way to multiple locations.

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Only 9 Minute was left for the crew after the fluid was released onto the deck to determine the best well control responses and implement them before the first explosion. The crew completed action on well control sequence actions.

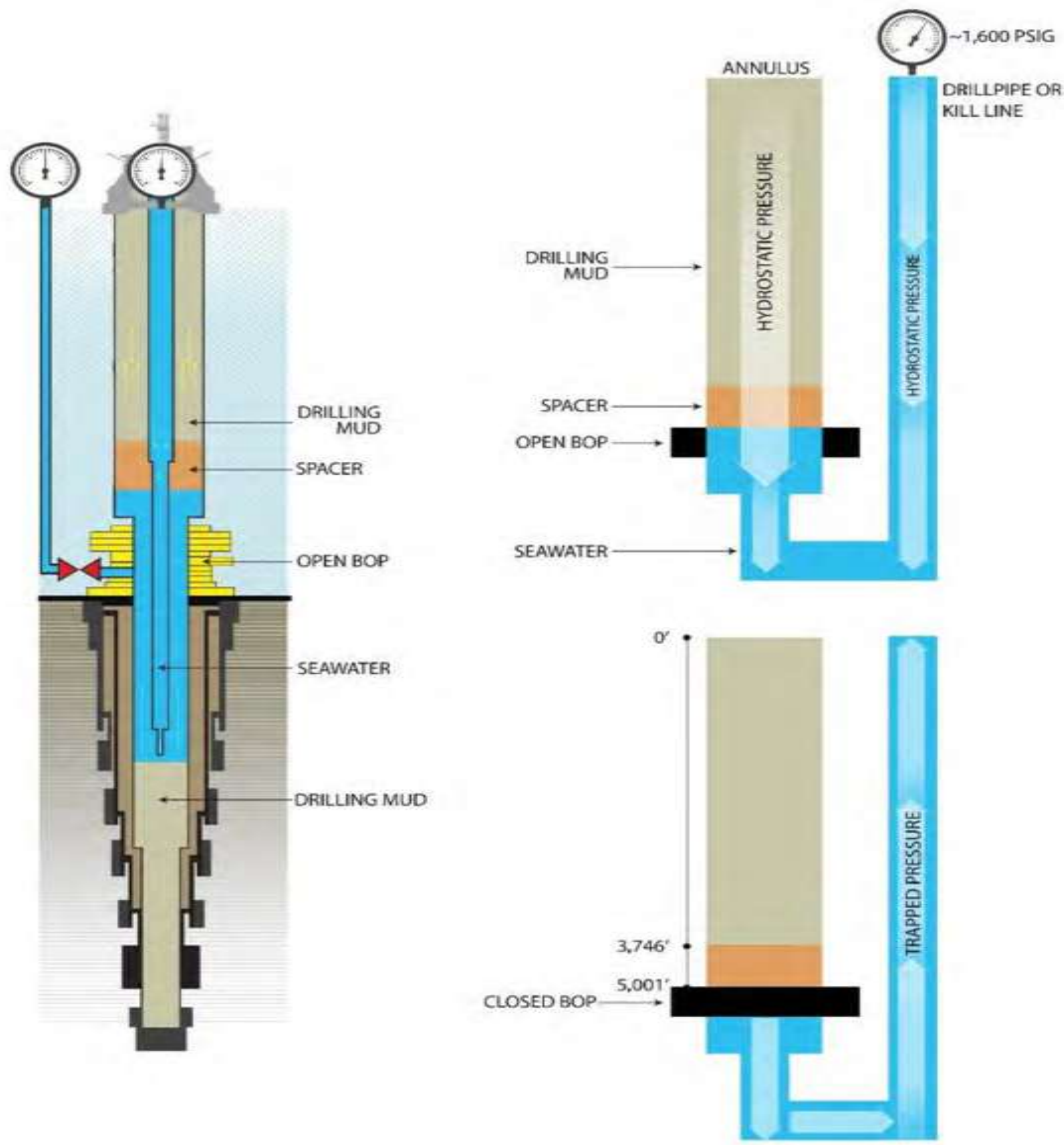

Figure: 2.2: The physical model of fluid flow under gas kick during deep water drilling
Source- Deepwater Horizon report, 2010

As described in the diagram above Figure 2.2, well pressure can be monitor depending on the configuration of a negative test, the kill line or drill pipe can be use to monitored well pressure or in some cases both. After displacing drilling fluid from a well, the crew observed pressure can be seen here using u-tube model to illustrate. The kill line or the drill pipe, containing relatively light seawater only, is display on one side of the u-tube. B on the other side, the annulus containsspacer material, kill drilling mud and some sea water. The heavier mud inannulus pushes down through the u-

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tube and up on the drill pipe seawater, swelling the drill pipe pressure, called u-tube pressure, which can be forecast before fluid conditions in a well variation.
The pressure will remain in a pipe if it is shut in,similar to trapping gas in an inflated balloon, Whenthe BOP was shut by the crew, the u-tube pressure was trapped in the well until the crew released the pressure intentionally from either the kill line or the drill line in preparation for the negative test.

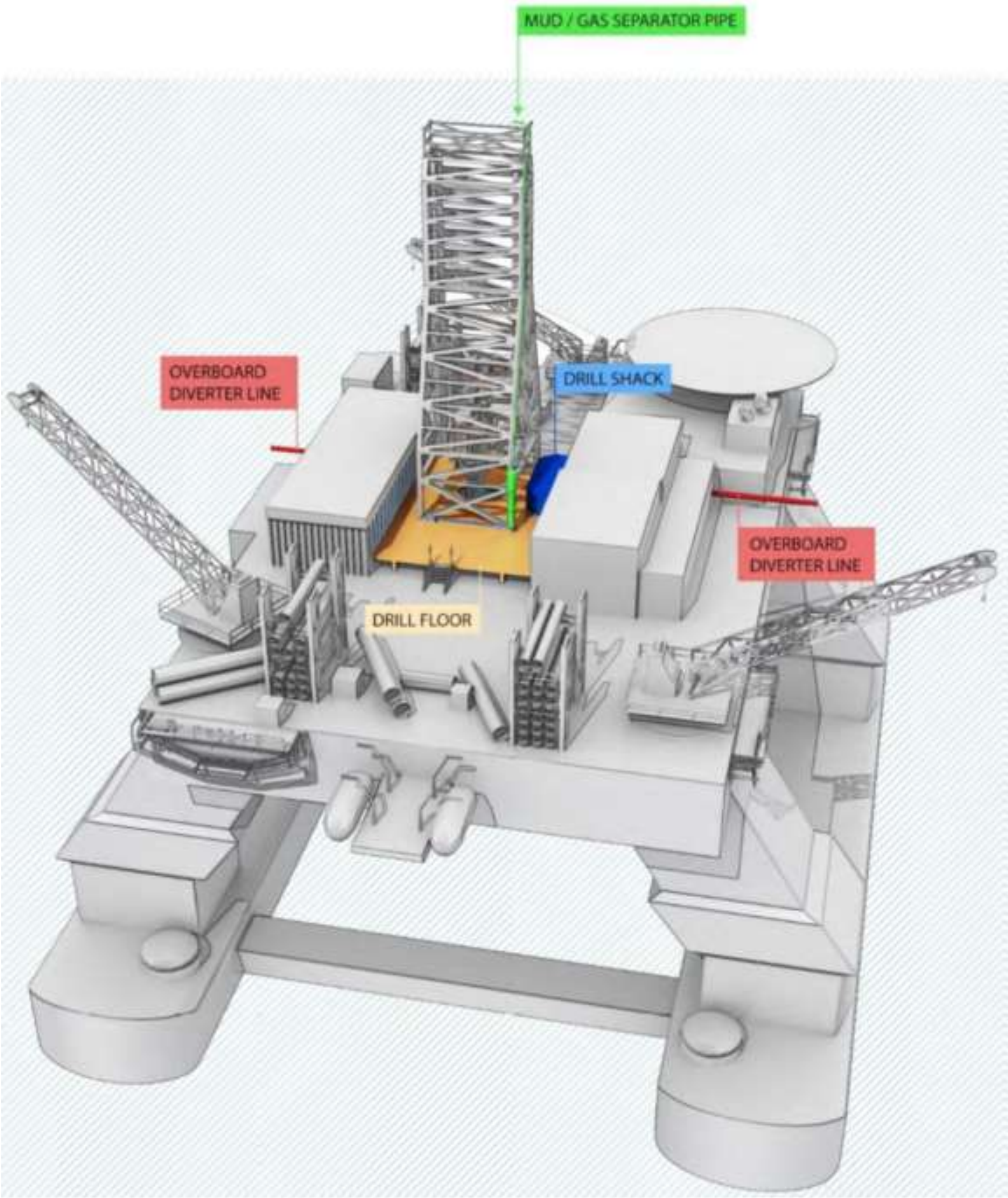

Figure 2.3: The diverter systemshowing lineson a rig where fluids can be routed over board
Source- GeoffFIChemE(2020)

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2.6 Organizational Policy and Practice Influence Human Performance

The criteria for defining the route of diverter during various well operations and well-like route remains neutral. At the time of incident, Transocean's Well Control Handbook (2009) failed to identify criteria. Historically, Deepwater Horizon rig personnel testified that use of the diverter system to send well fluids overboard was seldom, if ever, needed becausepreviossuccessfully handledof well control situationswithMGS, which the mud gas separator route was the quality arrangement on the Deepwater Horizon.Consequences are attached fordiverting mud overboard this includes a number offactorsfor one, on site supplier may not be available and the cost of drilling fluids is very high so use of the MGS allows salvaging the mud. Also, it is illegal to discharging oil-based substance overboard.This is restricted by both theBureau of oceans engineering management (BOEM) and Environmental protection Agency (EPA).Sending material not approved into the ocean is a clear violation of Environmental regulationwhich may attract citation This well-known consequence by the crewmembers avoided. The crew applied pressure on the well in their wisdom to avoid Environmental risk, but the consequences was higher which end up overwhelming the MGS. The design of MGSwas to contained fluids circulated from BOP to vent the trapped gas in when the formation fluids is dictated, the diverter is meant to manage influxes and redirect well fluids overboard.Diverter Could be align base on the rig configuration, which is selected by the company operator for a specific campaign, and Base on risk assessment of the well which the company operator develops.The procedures for well control procedures should predicted and address the flow rates within the well from kick scenarios to avoid MGS overwhelming. 2009 Transocean well control handbook specifies it's "essential to verify that the [MGS] system can handle the volume of gas and fluid in the well in situation of severe kick. The information relevant to the well be drilled, the operator provides and equated to system capacity.

Effective Performance Indicators Selection

Process Safety Performance IndicatorsANSI/API RP 754, for the Petrochemicaland Refining Industries,567 was formed in response torecommendations andfindings thatwas issuedby the CSB's investigation of the BP Texas City disaster. onshore Explicitly, the CSB stated that there were not effective programsfor developing process safety performance indicators inBP—and the oil and chemical industries in general. CSB suggested to API and the United Steelworkers that the two jointly develop a volunteer consensus standard for forminglagging andleading process safety indicators in the petrochemical industries andrefining. Leading indicators were568 for those that record performance before occurrence of the incident, Open item in an audit were monitored and identify.The lagging indicators record theunwanted event and consequences such as a hydrocarbon release. The aimed of recommendationis toprovide guidance and develop a standard that would lead process safety indicators, to drive measurable facility.

API 754 is aPositiveand significant step forward in establishing safety performance indicators, and this wasinternational recommended practice in development of the Process Safety - Recommended Practice on KeyIndicators Performance Report No. 456 (IOGP 456),International Association of Oil & Gas Producers generated 456 (IOGP). Both IOGP456 andAPI 754,process safety indicators is identified by four tiers:

Tier 1: A Loss of Primary Containment (LOPC) that outcome in the release of material with the highestconsequence, such as explosion; a fatality or large fire

Tier 2: LOPC, have lesser consequences than a tier 1 incident (e.g.,property damage less than 2,000$, no casualties, release of process chemical less thanreportable quantities). These events also play a "leading" role in preventing more serious events if the company uses them as a learning opportunity to improve its process safety performance;

Tier 3: whenresults exceeding the defined process limits and a safety system is initiated to restored the system back to an accepted safe state isa challenge to a safety system, (e.g., the shutdown systemactivation or a pressure relief device);

Tier 4: Barriers to performance and management system components, such ascompliance management of change (MOC), timely training schedules. or inspections.

Tiers 1 and 2 tend to be moreinfrequent and lagging, they are more usuallyrelevantin an industry, while 3 and 4 indicators tend to be morefrequent, leading, and company specific. Theguidelines of API and IOGP indicate, process safety monitoring and barrier performance can be intricate, combination of indicators isrequired, so that the tiers help differentiate the timing,frequency, and severity, (leading or lagging) of aprocess or monitored event.

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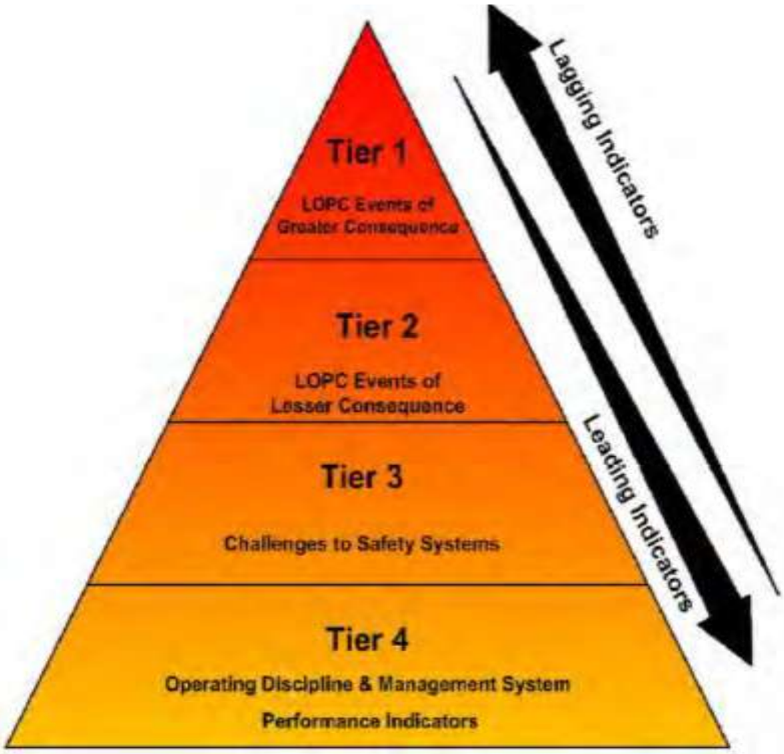

Figure 2.4: Process Safety Indicator Pyramid by theInternational Association of Oil & Gas Producers and the American Petroleum Institute.

Table 2.2: Process Safety Performance Indicators

Indicator Type as per Statoil	**CSB Correlation with Tier Indicator System Developed by API**	**Description**
Lagging measures	Tiers 1 and 2	Statistical accumulations of actual incidents or near-miss events for a facility. Typically, these are slow moving and make sense only over longer time periods (e.g., annual averages).
Leading measures	Tier 4	Measures of PSM management system elements that support environmental, health, and safety (EHS), such as management of change systems, training systems, etc. These are mainly assessed by 2-3 year audits. They are slow moving measures not well suited for day-to-day operational management.
Barrier/Real-Time measures	Tier 3 and 4 (as defined by the WLCPF)	Measures of the status of EHS barriers from fully functional to seriously degraded or non-functioning. Suitable candidate for real-

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		time measure.
Threat measures	No Correlation	Measures of the degree of threat to the facility. These are typically EHS challenges at a rate higher than anticipated in the risk assessment that underlies the safeguarding system. These can be determined by monitoring / predicting weather, nearby ship traffic, work permit activity, contractors on board, etc. This is also a suitable candidate for real-time measure.
Lagging measures	Tiers 1 and 2	Statistical accumulations of actual incidents or near-miss events for a facility. Typically, these are slow moving and make sense only over longer time periods (e.g., annual averages).

Source-CBS process safety (2012)

2.7 Process Safety Information - Safety Data Sheet Summary Form

Theapplicable information and to identify location insafety data summary form will guide the user.The relevant list of SDS sheets start with identifying theavailableinformation note: Example Shown is below:

Facility: Process: Date:

Substance CAS Number Reference Document Revision Date

Required Information (see legend)

TI PEL PD RD CD T&C HEM

Chlorine 7782-50-5 Matheson Tri-Gas SDS - 7/18/2006 Y Y Y Y Y Y Chlorine 7782-50-5 NIOSH Pocket Guide, 2010-149 - 10/2010 Y Y Y Y Chlorine 7782-50-5 The Chlorine Manual 5 1987 Y Y Y Chlorine 7782-50-5 Genium's Handbook - 2000 Y Y Y Y

Notes to Table:

Required Information Legend: TI - Toxicity Information CD - Corrosively Data PEL - Permissible Exposure Limits T&C - Thermal & Chemical Stability Data PD - Physical Data HEM - Foreseeable Hazardous Effects of Inadvertent Mixing of Different Materials RD - Reactivity Data II. Process Safety Information Program Nevada Division of Environmental Protection Chemical Accident Prevention Program Data Form

Revision 3, 2011-03-02

II-Data Form-7

Section 3 – Information Pertaining to the Technology of the Process

TheData is crucial in conducting a process hazard analysis. Without this information, the consequences of many process deviations cannot be adequately defined. Either aprocess flow diagram orblock diagram is allowed by regulation.

To show the major process equipment and interconnecting process flow linesa block flow diagram must be used, Process flow diagramsiscomplex and will display main flow streams, including valves, this will enhance the understanding of the process, points of pressure and temperature control. The major components of loops control and key utilities are shown. AProcess flow diagram would lend itself better to being linked to energybalance andmaterial.

2.8 Human error factor

The term "human factors" was defined by Karwowski, (2006) as the study of the human interactions between machine, this includes: decision making management functions, , learning and communication, resource organisational culture and allocation training, The role of human actions in major disasters, has been widely recognised.The studies conclude that the two types of human error, "active errors" and "latent errors", are accountable for roughly 80 per cent of accidents. The impact of active errors ispractically immediate and are more possible to be caused by frontline operators (production operators control room crews, etc.).The less-visible organizational issuesare described as "latent errors" caused by (fatigue time pressure, understaffing and inadequate equipment) that accumulate over time.

2.9Human Factors Analysis and Classification System (HFACS)

The Human Factors Analysis and Classification System" (HFACS)is a broad human error framework and it was created to uncover the underlying causal factorswithout blaming the individuals involved that lead to an accident. Four levels of deficiencieswere used in the framework of the analysis which led to accident: 1) Unsafe acts, 2) Unsafe supervision and 3) Pre-conditions for unsafe acts, 4) organizational failures. Each level of HFACS, causal classes were established to identify the active and latent failures that occur.

i. Thelevel of Unsafe Acts represents the unsafe acts of an operator leading to an incident/accident and is divided into two categories –violations and errors.Unintentional behaviours are error, actions of the operator that fail to carry out the desired outcomes, and violations (exceptional violations routine violations,) The rules and regulations are wilful disregard.
ii. The Pre-conditions for Unsafe Acts level and the first latent tier, is divided into three categories: environmental factors, condition of operators and personnel factors. Environmental factors (physical environment, technological environment) refer to the technological andphysical factors that affectconditions, practices and actions of individual that resultinunsafe situationor human error. Operatorscondition (adverse physiological state, adverse mental state, physical/mental limitations) refers to the adverse physiological state, physical/mental limitations andadverse mental state. factors that affectconditions practices, or individuals'actions and result inan unsafe situation orhuman error. Personnel factors refers to personal readiness, crew resource management.
iii. The performance of operators in the frontline depend ondecisions of supervisors and managers therefore unsafe Supervision level deals with performances that can operation and is classify into four classes: inadequate supervision (includestimes when supervision either fails to provideguidance or inappropriate actions,training or oversight), inappropriateplan operation (this involves failure of supervisors to evaluate the risk that is associated with the task, employees will be placed at an unacceptable level of risk; these include violationof the rules/regulations, improper staffing andinadequate opportunity for crew rest), known problemfail to correct (refers to those instances where unacceptable behaviours or conditions of equipment, trainingare identifiedstillconditions or actions remain uncorrected, this shows that supervisors has fail toreport such unsafe situations or initiate corrective actions), supervisory violation (those in positions of leadershipwilfully disregard of the establishedregulations or rules).
iv. The Organizational Influences the level, and the final latent tier, is share into three classes: resource management (includes thedecisions of top management related to the allocation of resources such asmoney, facilities, equipment, and personnel), organizational climate (refers to those variables, such aspolicies the organizational structure and culture), organizational process (refers to the making decisionthat will guide the day-to-day processes of an organization, such asprocedures and oversight operations).

2.10 Two major industrial Disasters.

2.10.1 Bhopal

Short accident description,

Bhopal accident large quantities of methyl isocyanate (MIC) volatile toxic substancewas the spillage to the atmosphere from a pesticide plant. About 5000 people was affectedand they lost their lives. Threefabricatedchrome steel underground tankswere stored with (MIC),the temperature of content that should be kept refrigerated at near 0°C. stop release of MIC within the atmosphere, a vent gas scrubber that could havespraying alkaliand neutralize the MIC, there was a flare tower also to burn the excessgases from the vent gas scrubber. Two months before the incident, plant was due for maintenance because of a series of errors, lack of information andoperators delays in response and poorsupervision.About 40 to 45 heaps of MIC wasreleased, a part of which got decomposed into chemical compound. At 2,30 in the morning, MIC vapours filled thevicinity started toaffect people and homesaround the plant were affected, individuals started running out in numbers. On the morning 3rd December, the local hospital recorded about 12000 persons. Again, more people wereaffected on the night of 3/4 December, from the atmosphere condensed. 4 December 1984, about 55000 people was handle in Hamidia Hospital.

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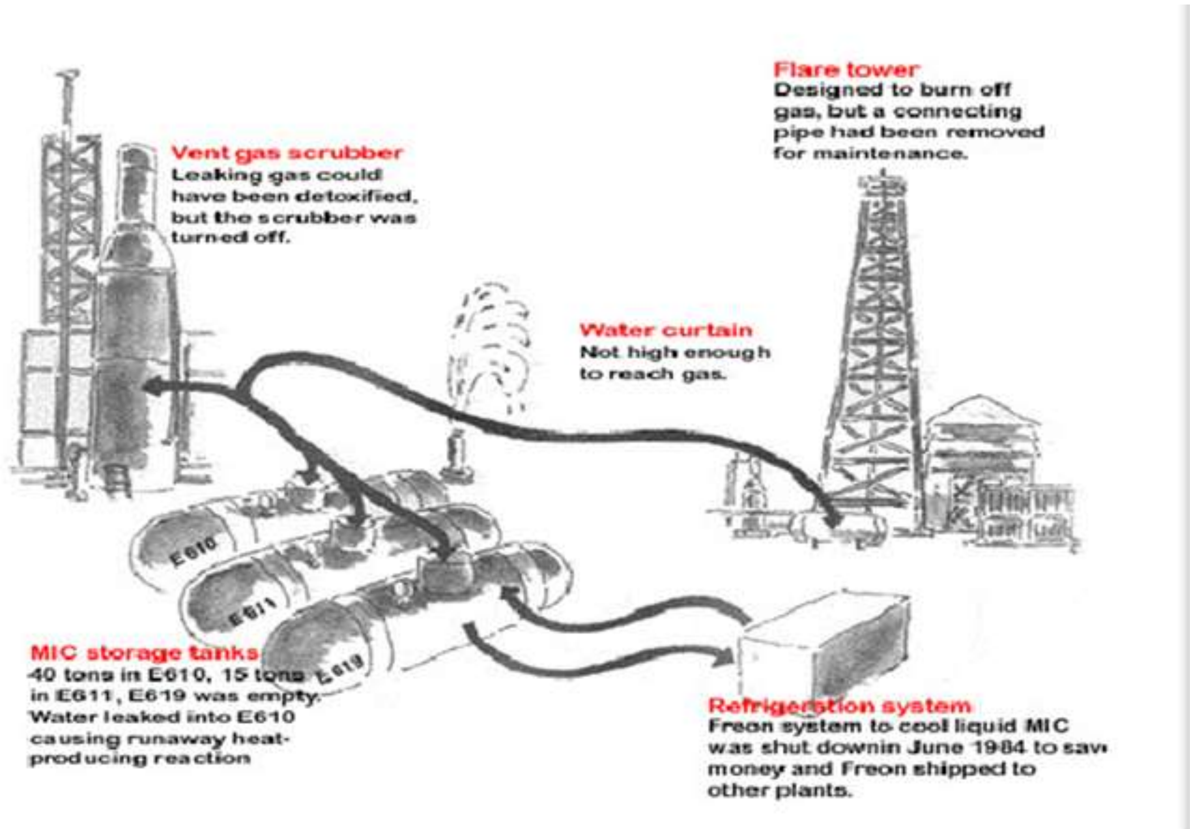

Figure 2.5: Overview of events that led to the Bhopal disaster
Source-Mishra et al, (2014).

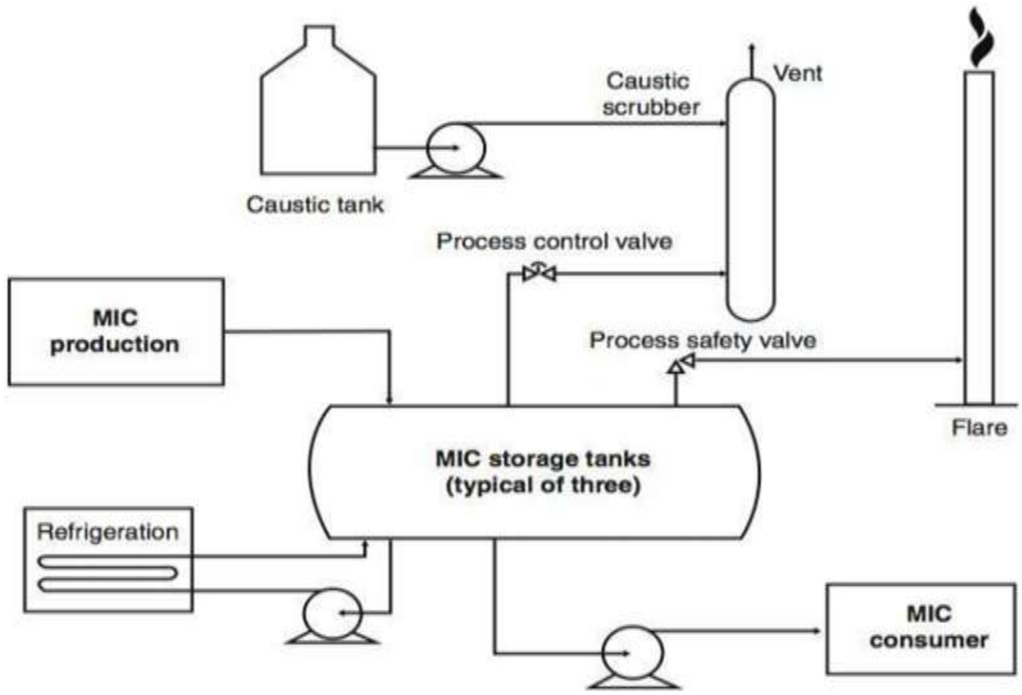

Figure 2.6: The process at the Bhopal plant – Ref adapted from Tierney, (2014).

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2.10.2Factors contributingto accident according to HFACS' levels Organizational Influences is distributed as follows:

1. Plant modifications carry out in hazardous facilities without hazard and operability studies;
2. 5 tons of MIC was daily usage while 55 tons was stored.
3. Safety management wasneglecting at the unit;
4. Action were not taken on earlier accident analysis reports;
5. Depending on inexperienced operators;
6.Wrong decision to reduce workforce in operations, maintenance, control room and plant;

2.10.3 Components of human error analysis

Unsafe Supervision: 1. Superintendent for the plant was not trained; 2. The abnormal pressure was not recognised; 3. TheEmpty MIC tank was not use to release the pressure. Preconditions for Unsafe Acts: 1. Refrigeration plant was shut down; 2.Temperature and pressure indicator not working; 3. flare tower was disconnected; 4. vent gas scrubber was in-active mode; 5. modification of plant; 6. iron pipelines was used for MIC; 7. Control room not having indicator monitory for valves Unsafe Acts: 1. when tankfailed to get pressurized once; it wasDepressurizing ; 2. poorinformation from shift operator to communicate on pressure increase to the next operator; 3. Washing methyl isocyanate tank when it failed to get pressurize; 4. safety precautions was not follow while washing MIC lines; 5. the seriousness of the leak was not recognize; 6. Works Manager was not inform as soon as the leak started.

2.11 Deepwater Horizon

Short accident description

Deepwater Horizon was asemi-submersibledynamically positioned in ultra-deep water, anoffshore oilrig owned by Transocean and hired to British Petroleum. April 20, 2010, at Macondo fieldwhile drilling, 11 crewmen were killed because of an uncontrollable blowout that caused an explosion. ignited a fireball ignited wasvisible 64 km away from the scene, the fire explosion was inextinguishable and, on 22 April, two days later the Horizon sank, while the wellat the seabed still gushing and causingU.S. waters pollution, the biggest oil spill inhistory. Deepwater Horizon's many defences, each one failed, some engaged were too late, some never engaged and did not function as designed. The sequence of events between February and April, at many points, the event that led to the disaster could have been interrupted, but an absence key decision at every step,unclear chain of command, skill and preparation prevented.

2.11.1Factors contributing to accident according to HFACS' levels Organizational Influences is distributed as follows:

1. Wrong decision to continue temporary abandonment of the exploratory well, 2. Prior to critical temporary abandonment,the key personnel in Deepwater Horizon were change abandonment, 3. Time pressure, 4. Poorcommunication among rig crew members who worked for multiple companies and top management,middle andshore superiors 5. Pressuresto complete the operation quickly to serve cost, 6. Insufficient training.

Unsafe Supervision:

1. Instructions oversimplified, 2. Changes of procedures in the last minute,3. Personnel change 4. Insufficient experience personnel.

Preconditions for Unsafe Acts.

1. Technical challenges was presented from the start in Macondo prospect, such as, high formation pressures indeep water and temperatures, and multiple geologic zones needed to drill through. 2., Allowing formation gas to travel up the pipe towards the surface was as the result of valve failure 3. Leak not detected soon enough - the crew at the Rig floor and mud logging unit should be able to detect a flow of gas towards the surfacebyobserving forwell unexpected increases in pressure. 4. Blowout preventer has no batteries 5.The control lines were destroyed by explosion the crew were using to close safety valves in the blowout preventer**.**

Unsafe Acts or Operation:

1.Multiple hydrocarbon and brine zones cementing, encountered different pressure in the deepest part of the well. 2. The cement formulaused was wrong - The cement slurry at the bottom of the hole did not curedand sealed the hole, thereby creating cracks for the formation influx to enter the wellbore. 3. Separatoroverwhelmed-failure of the crew to divert the kick away from the rig, venting it safely through diverter pipes over the side. Instead, the flow was diverted to MGS, designed to separate small amounts of gas from a kick 4.Misinterpretation ofpressure test - Various pressure tests was carried by the crew todetermine the cementing job. However,the results of these tests were misinterpreted, so they assumed the well was under control. 5.Critical indicatorswere not observed and respond.

2.11.2 History of Macondo Well

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11 workers lost theirlives to Macondo well blowout and explosion on April, 2010,about4.9 million barrels of oil spills into the gulf. Sea.$34 million was paid by BP inmarch 2008, to the Minerals Management Service for lease in Mississippi Canyon Block 252to drill about nine square miles.The area inthe Mississippi Canyon that has many productive oil fields The geology of Block 252 was relatively knew little by BP. However, BP was paying out tens of billions of dollars two years later. Azwell et al, (2011) focused his report primarily on its technical causes and blowout, while the containment and response issues was looked at theCommission.

2.11.3 Root Causes/ Failures of Macondo Well Explosion

i.Clearly the root cause of the blowout wasmost significant failureof industry management at Macondo.

ii. Thelate changes to well design and procedures was notadequately identified or address risks byBP‟s management process.

iii.Personnel did not adequatelyconsider the risk indecision making process to savetime and money at Macondo.

iv. Oversights and outright mistakes were thecombinedrisk factors that led to well blew out. The mistakes overwhelm the safeguards meant to prevent such incident from happening.

v. Certainly, the blowout could have beenprevented if ability of individuals involved to identify the risk by BP, Haliburton and Transocean and to properly evaluate,communicate and address them.

2.11.4 Steps System of Safety Processes used by the Company

i. Higher levels of management depend on risk matrix used.
ii. A risk assessment process foreven cost-cutting proposals would go through walking the Walk first - Blackbeard
iii. $200M investment in 2007 Exxon abandonedwalked away from an ultra-deep well 32,000 feet below the sea floor known as Blackbeard, in the gulf shadow water.
iv. Very similar to BP‟s Macondo well, with Exxon's Drillerssuggested a possible blowoutdue to drilling complications, extreme pressures and temperatures, and conditions.
v. The top management took the decision to stop the drilling.
vi. Business Week wanted to find out if the company "a Juggernaut or a dinosaur?" by running a piece.
vii. Similarly, Dittrick, (2010) listed out some possible causes of the BP'S explosion incident as:

a. Endless cost cutting and management changes.
b. Reliance on cheap part at the expensesafety, failure toinvesting in facilities,maintaining mechanical integrity and process safety.
c. Lack of accountability.
d. Culture of intimidation andloss of experienced personnel
e. There were warning signs of a future process safety failure that were ignored; these failures include;

- In March 2004 an ultra-former unit explosion at the Texas City Refinery resulted in 14 OSHA violations and a $63,000 fine
- A worker fell to his death in a tank,2 months later
- A worker burned to death in an accident,few months later
- "We have never seen a site where the notion „I could die today‟ was so real whenBP hired an outside consultant to look at the plant.
- ISOM unit explosion cause 15 deaths and 200 injuries inmarch 2005 due to multiple maintenance failures.
- BP Prudhoe Bay pipeline ruptures inmarch 2006,leaking 4800 barrels a day
- Maintenance was neglected by BP to save money so badly that the fear of rupture lines running of "pigs" through the lines was stop.
- Heavy cost cutting,BP forgo standard maintenance as discovered later by their records

2.11.5 Immediate Causes of the Macondo's Explosion

i. Primary cementing failure possibly due to miscalculation of drill string, well casing even after initial troubleshoot suggested reliability problems
ii. Negative pressure tests,misreading and failure of well "" due to lack ofrisk assessment procedures,poor communication, standard procedures and inadequate training for rig team.
iii. Procedures replacing mud with seawater andpoor temporary abandonment.
iv. Onboard crew misreading of kick detection data.
v. Blow Out Preventerfailure.

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2.11.6 Process Safety Risks at Macondo

i. Industry management failures – ultra deep-water drilling management system.
ii. BP poor communication with service companies, Poor risk assessment, poor management of change and decision-making processes BP
iii. Poor communication between BP, mud logging unit and other contractors (Halliburton, etc.)
iv. Lessons from earlier near-miss was share by drilling contractor (Transocean) to BP and other contractors.
v. Inadequate risk assessments created by money and time saving decisions.

2.11.7 Culture Counts

i. Fatalism- oilfield rig culture of accepting risks as part of the job
ii. Corporate strategy was hinged on bringing online new large fields by BP.
iii. Cost cutting and reliance on outside consultants change BP culture from engineering excellent.

2.12 Risk Assessment using Root Cause Analysis

The design of root causes analysis is a structured process to help an organization to define problems thatunderstand the causes, caused past events and prevent future incidents, most importantly.

When directly integrate within an Enterprise risk management program, root cause analysis program has the most positive impact oneliminating riskor reducing the risk.

2.13 Three Basic Causes Involved in Root Cause Analysis (RCA)

Physical causes – A tangible factual itemfailed in some way. For instance, a car's brakes stopped working. Human causes - People did something wrong or did not do something that was mandatory. Human causes naturally lead to physical causes. For instance, the brake pads were not changed or no one filled the brake fluid when due, which led to the brakes failing.

Organizational causes - A process,policy or system,thatpeople make faulty decisions in doing their work. For instance, responsible for vehicle maintenance, no one was responsible and everyone assumedbrake fluidhad filled by someone else or changed the brake worn out pads

Root causes analysis is often understood as a separate function in risk management program. The Risk assessment process should be key tool instead. It should be used to weigh both the upside and downside consequences of risks and obtainableby the decision makers within an organization. With accurate information on the risks they face, decision makers will make better decisions.

2.14 Nine Steps Approach to Root Cause Analysis

Step 1: Define the problem and verify the incident
Step 2: Timeline of events should be map
Step 3: Critical events identify
Step 4: Critical event's cause and impact should be analysed
Step 5: Root causes identify
Step 6: Each root cause should be supported with evidence
Step 7: Select the best solutions and identify
Step 8: Generate recommendations
Step 9: Implementation of solutions should be track

2.15 Types of Root Cause Analysis

Question Analysis- Ask a sequence of questions on why events occurred, Barrier Analysis –Tracking possible obstacles, Change Analysis- Change inprocesses or procedures, Casual Factor Tree Analysis- used tree assembly to track given significance through logic, Diagram forFish–Bone-Cause and effect diagram looks like a fish, 80% parent Analysis of problems are caused by limited critical causes, Fault Tree Analysis-outcome are lead to causes Failure Mode Effect Analysis-Causes lead to consequences.

Table 2.3 Comparison between Fault Tree Analysis and Failure Mode Effects Analysis

Fault Tree Analysis	Failure Mode Effects Analysis
Take a particular system failure and trace the events leading to the system failure backward in time	An analysis that reverses the direction of reasoning in the fault tree analysis by starting with causes and branching out to consequences
Consequences lead to causes	Consequences lead to causes

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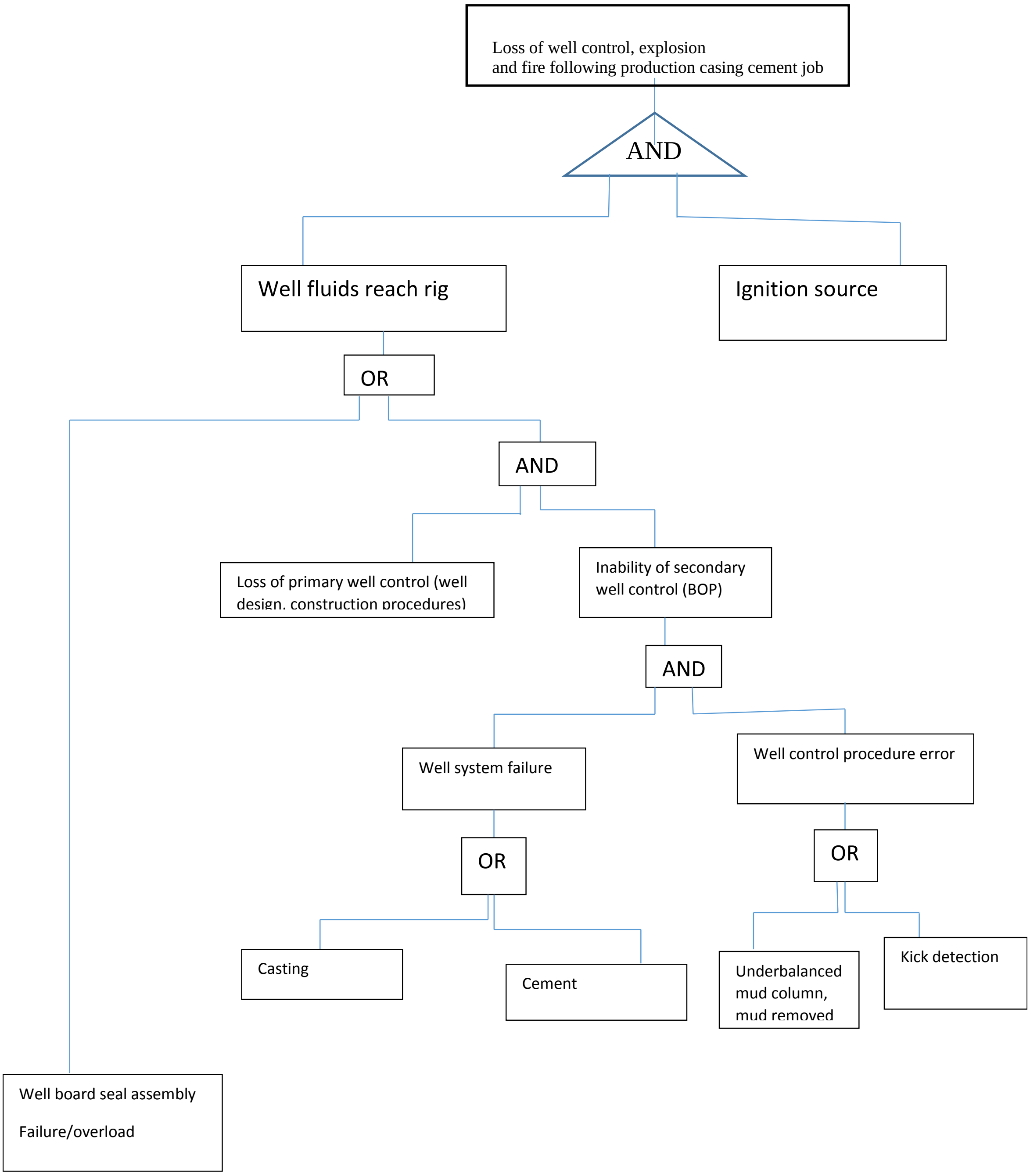

Figure 2.7 Fault Tree Analysis Used in Investigation of Macondo well explosion

2.16 RIMS Risk Maturity Model

Seven Attributes of Risk Maturity Model**,** Adoption of ERM-based approach, ERM process management, Risk appetite management, Root cause discipline, Uncovering risks, Performance management, Business resiliency and sustainability.

Root cause discipline-This attribute focuses on the emphasis placed on searching for root causes of risks, including classifying risks, uncovering risk sources, and focusing on improving internal control responses to risks.

2.17 Root Cause Analysis in Strategic Planning

- To find permanent solutionsbarriers and the causes of problems must be identify

- Logical approach must be developedto solve problem using already exists data in most operations.
- Organizational improvement should identify future and current need
- Step-by-step processes, establish repeatable, in which one process can confirm the results of another.

Modified Swiss cheese model

Swiss cheese model can be usedafter doing a literature review to study the casual factors to an accident in an efficient way. Swiss cheese modelslightly modified a arrangement has been made between the operational errors and the prevention/mitigationerrors during actions. Errors related to all those errors that occur during the normal operations areoperationaland can lead system to an unsought situation, Error that can happen when system is already in an undesired situation is known as prevention/mitigation errors. At this juncture, preventive actions could still be made, if the system still in allowable boundaries and moderation if an accident has already happened. Moreover, the technical/humanclassification is also maintained and automatic/manual correspondinginterventions to operational and barrier layers, correspondingly as detailed in Figure 2.7 The highlighted showing the influence on the active relevant latent errors. An accident can occur whenever, the layers align in a way to provide a pass to existing hazard.

2.18 Modified Swiss cheese model

Operator can interact with the automated safety barrier (e.g., ESD) both during the conventional operating conditions and through the upkeep conditions (e.g., proof test) which are considered within the human operational layer. except automatic safety barriers, manual safety barriers also are considered during this model. If consequences of a failure are extremely local and may be measured by the human barrier, then it's recommended that human barrier should be used. Since, introducing the automated shutdown arrangements also involved steps likedepressurization andisolation which itself can increase the complications. This model assumes thattechnical failure can caused potential and undesired situations (e.g., random rupture) because of human interventionfailure. Moreover, if these scenarios are foreseen during the planning phase of the plant or during the preventive assessment there must be safety barrier to stop the circumstances or at least to alleviate the outcome. An accident can during initial phase as long as the computerised safety barrier doesn't interfere when required. Manual barrier interventions additionally, also can be analyses by looking into supervisions of either providing manual prevention/mitigation measure or byhuman operational interventions during this modelmeteorologicaland organizational latent errors/ performance,factors considered for the equipment, while for the operators'environment, actions organizational, and stress/fatigue are considered. However,other models will be to check an accident thoroughly depending upon the details of an analysis.

2.19 Possible system paths

A preliminary analysis of accidents, shows that an accident can occur by involving different layers. Theinitiating cause of an accident are three predominant accidental situations by involving the different layers. Model "B" involvement of one of the barrier layers represented (either manualor automatic).

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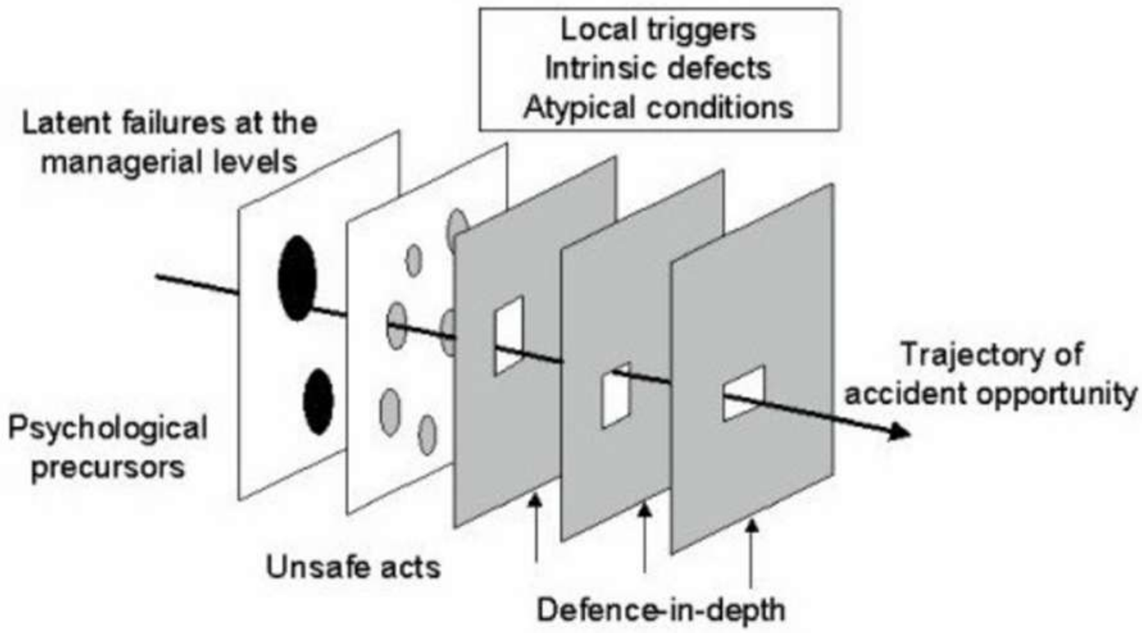

Figure 2.8 This version of Reason's accident causation model (published in Human Error, 1990) explicitly introduced the "Défense in depth" concept as a label.

2.20 EMPERICAL REVIEW

(Darabont et al, 2020) compared four major industrial disasters from the attitude of human error factor.The preliminary findings of a project still current at National Research and Development institute for Environmental (INCDPM) regardingresearch development partnership and Knowledge transfer within theprevention andassessment of occupational risks which may conduct to disaster. After the foremost industrial disasters was studied, it become clear that even with technological development, error inhuman remains the greatest important explanation forincidents and accidents. Human error analysis and their role in accidents is a vital a fragment of developing systematic methods for reliability within the industry andprediction of risk. To investigate incident/ accidents data for predictive analysis is important to spot its causes in terms ofhuman errorsand component failures. Therefore, Human factors need a correctunderstanding within the workplace,it is important aspect within the prevention of accidents, and human factors that should be considered in any program to anticipatethose humanerror.Four major industrial disasters (Bhopal, Deepwater Horizon,Chernobyl, AlphaPiper) wascomparedusing a modified version of "Swiss Cheese" model Human Factors Analysis and classification system (HFACS that describes the total at which latent failures and active failures/conditions may happen within multiple operations.

In 1990, Reason developed the swiss cheese model. The origin model was in 1987-8 during the writing of Human Error. The intention for the book was to produce an essentially cognitive psychological explanation of the character first, varieties, and mental sources of human error thereafter. The fundamentalquery was: What can the presence of comparatively non-random error approaches tell us about the mostly hidden processes that rule our actions and thoughts? J. Reason’s peers: academic cognitive psychologists were primary aim of the book. No plan from the outset to include the chapter onsystems disasters and latent errors during which theversion Mark 1 of the model released. Two thingspromptedits inclusion: first, thespate of disasters occurring within the late 1970s/1980sand abandonment of a extensive chapter on the history of error studies was influence bythese included Challenger Flixborough, Three Mile Island,the Herald of economyChernobyl, Bhopal and also the King’s Cross Underground fire. !990 James Reason inUniversity of Manchester was then a professor, madea crucial input to the concretization of this concept by suggesting a “model” of how accidents might be seen because the fallouts of interrelations between real time “unsafe acts” by

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latent conditions and front operators. This model curved to be highly pedagogical, and massive number of safety analysts andseveral industries round the world quickly began to use it.Within the early 90's,Flight Safety working party and the ICAO Human Factors adopted it as a conceptual framework. Many folks – including the author himself – tried their own refinements and variants of the initial model. for instance, (Shappell et al, 2000) adapted the explanation model to develop the Human Factors Analysis & classification system (HFACS), an accident/incident analysis methodology of which the Office of aeromedicine of the US Federal Aviation Administration sponsored. swiss Cheese Model (SCM) was adopted by the accident investigation community quickly, the aviation domain was not left out, the enthusiastic use sometimes relied on explanations of the model's semantics that went pretty far beyond what was originally intended. The aim of this report is therefore to debate thelimitations and relevance of using the SCM, accident investigation perspective,particularly from an ATM. Managing the risks of organisational accidents, published in 1997,TheAttempts to trace down possible errors and accidentpendulum may have swung too far in our present contributions that are widely separated in bothplace and time from the events themselves, Reason warned.The modelemployment continued to grow despite this caution, (Shorrock et al, 2005) andLarouzee (2020) "ironically, remarked that it seems that the sole person to query the employment of Reason's cheese model is Reason himself" The core subject of the document is that the Swiss cheese Model (SCM). The aim is to supply the reader with some resources to understand entirely the choice of the SCM, still suitability on assesses – or otherwise – of the criticisms that are imply. Additionally,the aim is to discussion how the SMC has been employed by practitioners, so as to help these practitioners in understanding the SCM limitations capabilities, hopefully avertexcessivelyin flexibleapplications. Key accidents all listed above had happened inmultiple productive systems.How humans contribute to the breakdown of those systems if we must know, first, we have to spot the mandatory and 'healthy' elements of production so as to describe how and why they might fail.J. Reason and John Wreathall portrayed these as order of five 'planes' lying one behind the other: Decision makers at top level, line management,productive activities preconditions, and defences. One of those levels, anyfailures can arise Note that there's unknown Swiss-cheese-like in anything but the top plane where there's one hole.The then Director of the Bureau of Air Safety Investigation (BASI) in Canberra.Rob Lee,originate the 'Swiss cheese' label not. J. Reason.

McAndrews (2011) investigated the implications of Macondo: AProposed Summary of Recently and Ratified Changes to U.S. Offshore Safety and Environmental Drilling Regulation. Changes are enacted post-Macondo and additional changes are possible.Deepwater drillingnew prescriptive rules will have a big impact on drillingoperations, engineering, and costs. Performance-based regulations that needimplementation by all operators a security and Environmental Management System within the Outer ocean bottom to became law. This study summarizes the Macondo blowout, State agencies and BP. U.S. Government changes in regulations are summarized, including aprescriptive discussion versusbased-performanceregulation. it's resolved that the proposed and enacted changes to offshore drilling safety and environmental regulations required good thing to be deliverby reducing the likelihood of future blowouts in Deepwater.

Hoffman (2011) studied the Organizational,Safety System and FactorsHuman, of the Macondo Blowout.Offshore oil and gas industry experienced its deadliest accident in 1988 whenPiper Alpha drilling platform took the lives of 167 individuals in an explosion aboard.ASignificant incident investigation aftermath,exposed variety of majormanagement issues concerning accident/risk offshore. 1., The Piper Alpha disastertwenty-five years later was described as "the lens which offshore industryview their safety efforts. 2. The main target of the lens was Macondo incident, because the blowout illuminates thecomplexity of increasing offshore operations,drilling environments,and technologies. The investigation of the Macondo incident byCSB revisits a number of Piper Alpha's lessons, and new ones associated with human performance was introduces, organizational learning, risk management coordination,safety performance indicators and culture of the company that promote safety. Incident-free waspromote dueto the chance management policies of both BP and Transocean in workplace. Operating Management System (OMS) of BP's 2008 major corporate Safetyframework states, "Our goals are simply stated: no harm to people no accidents, and no damage to the environment." 2009 Health and SafetyTransocean Policy statement, the commitment ofcorporate is to operate in an "incident-free workplace—all the time, everywhere."ShellExxonMobil, Global, Total, Chevron and ConocoPhillips, have equally stated "zero incident" risk management goals, but

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zero incidents for on a daily basis, month, or maybe years don't preclude an organization from tomorrow's occasion. A shift focussed from past successes to current risk reduction activities isrequires toprevent incidents Ultimately, continual risk reduction efforts must be account for inevitably changing circumstances (e.g.,knowledge, the drilling environment, workforce and technology). While Under the direction of Transocean and BP,the Macondo blowout occurred it affected the worldwide, offshore industry signifying that risk management formajoraccidentevents prevention, continues to be challenge to offshore industry notwithstanding the various lessons from the Piper Alpha incident. for example,after five years the Macondo blowout, audit findings from, Bureau of Safety and EnvironmentalEnforcement (BSEE), one among offshores US regulators state that safety and environmental management system (SEMS) programssome companies use to document regulatorycompliance instead of managing riskstruly. In fact, Transocean and BP risk management policies, post-incident CSB analyses at the time of the blowout reveal that several of the policies would have fulfilled current SEMS requirements. Policies to manage the keybusinesses of accident risks was not effectively implement in the Macondo well, and also the regulatordid not hold companies accountable to confirm that they safety was managed as their company policies stipulated. Beyond Transocean and BP, the CSB discover Volume 3, an absence peoples offshore industry regulations and guidance for human factors, process safety indicators, and company governance of the CSB.The insufficient target of managing major hazard risk throughout the lifecycle, Macondo investigation report addresses of the Macondo well, beginning with the well's initial design, through implementation of the project, including several alterations, and finally during momentary abandonment planning. Altabbakh (2013) argued thateverydaychallenges within the safety field face more with the expanding modern socio-technical systems. Safety analysis like hazard analysis,risk assessmentand accident causation analysis are being revisited to beat the inadequacy of the standard safety analysis. With progressively complex human system interface in today's modern systems, new safety encounters are being confronted that and addressed.Engineersand managers face the challenge to settle on from the vast number of techniques accessible and utilize the appropriate one. Indeed,improved or newrisk assessment tools that may address these complexities are needed.Assessing risk is first to categorize itis one of needed to be evaluated important steps.Product component failure,there are risks related to it, human error, environmental disasters,operational failure etc. however, there has been little conversation about how do managers select from the existing risk assessments tools, which this measuredas primary step in risk analysis. during this study, risk assessment tools are analysed, categorized,investigated,and applied to situation studies in many industries.The difficulties in choosing risk assessment tools,a pathway for researchers has been paved to beat the challenge.

The review of literature during this study comprises of conceptual and empirical findings. The conceptual review of literature described that process safety failure could be a important issue in occupational health and safety. It refers to the disaster caused as a results of latent and active failures conditions within a complex operation. The empirical studiesreview showed that the majority of the works by scholars wereoutside tired locations this area of study with collection different mode ofknowledge. Therefore, it's important that this study should compare process safety failure in Macondo/ Bhopal oil and gas explosion incident.

III. METHODOLOGY

3.0 Research Design

The case study research design is an in-depth comprehensive study of a person, an episode, a social group,a situation, a process, a program, a institution and community or any other social unit, for the purpose of understanding the life cycle of the unit under study of the interactions between factors that explains the present status or the development over a period of time. It may be conducted as an independent study or a supplementary investigation to a survey (Ibeaja, 2017).

3.1 Population of the Study

The target population of the study was the collective responses from employees in 4 oil and gas industries who are aware of the Macondo and Bhopal oil and gas explosion. As at the time of the study, a total number of 100 respondents were used, out of which 88 responded.

3.2 Sample and Sampling Techniques

The sample size of the study was 88 oil and gas company workers who are aware of the Macondo and Bhopal oil and gas explosion. The simple random sampling technique was used to select 4 major oil and gas companies in Port

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Harcourt, Rivers State, Nigeria. (Exxon-Mobil, Total exploration, Shell Petroleum and Chevron.). Thereafter, the purposive sampling technique was used to get the required respondents for the study on line. In using purposive sampling technique, the instrument alongside the online videos showing the Macondo and Bhopal explosion were placed online for worker who had knowledge about the incident to answer within the stipulated time and submit it.

3.3 Instruments for Data Collection

A self-structured questionnaireinstrumentwasuse to elicit personal information from the respondents and indicating the aspects that led to the incidents based on individual opinions in line with the ISC organisational framework and the Swiss Chess Model used to develop a study-based model (five pillar model) for investigating the possible failures in line with the ISC framework. Whileonline video showing a detailed record of the Macondo and Bhopal oil and gas explosion and literature review will use in secondary data collection.

3.4. Validity/Reliability of the Instruments

The validity of the instruments was determined through expert judgment. Some copies of the preliminary versions of the instruments were given to Project supervisorin University of Port Harcourt for proper scrutiny and approval.

The questionnaire was able to ascertain the level of awareness among oil workers in Macondo and Bhopal disaster, evaluate their knowledge in process safety failure, human error and management system failure.

3.5 Method of Data Collection

100 copies of a self-structure questionnaire administered to the respondents through online direct delivery method, 88 responded.The specific members of the population who were in the best position to provide the needed information were selected, which in this case were the heads of departments and supervisors in the various major oil and gas company in Nigeria.

3.6 Nature and source of data

The primary data was be collected using a open and closed ended questionnaire for qualitative statistic. The questionnaire was adapted from a questionnaire used for similar study in Macondo and Bhopal gas explosion.

3.7 Methods of Data Analyses

Analyses of data were done on the research questions and were answered using mean, standard deviation, frequency and simple percentage. SPSS 2.0 was used for data analysis and reliability statistic.

IV. PRESENTATION OF RESULT AND DISCUSSION

4.1Analysis of Data and Results

The targeted sample size for the study was 95, According to Kreuter et al, (2010) increased effort to collect survey data reduces nonresponse bias, I issued 100 questionnaire which is about 100% of calculated sample size as a measure to reduce non-response bias. I had 88respondents;the 88 responses were valid. Cunningham et al, (2015). stated that average response rate of 30% to 40% is reasonable for deliver and collect survey method.

The first objective of this studies was to determine the level of respondent's awareness of unsafe acts (Immediate causes) of the accidents in Macondo and Bhopal. The result obtained after the analysis of data is presented in this chapter was analysed in line with the research questions developed and hypotheses formulated for the study. The results and interpretations to the research questions are presented simultaneously in the same table.

Research Question 1

What are the series of unsafe acts (Immediate causes) of the accidents using the ISC framework?

Table 4.1.1: Mean Responses of Macondo Staff on Unsafe Acts (Immediate Causes) of the Accidents Using the ISC Framework

	Macondo Staff (n_1=44)									
Unsafe Act	**SA**	**A**	**D**	**SD**	**U**	**M**	**SD**	**% of A**	**Decision**	**Rank**
Poor safety culture	26	18				4.59	.50	100	Agree	8th
Poor maintenance	40	4				4.91	.29	100	Agree	2nd
Lack of communication	42	2				4.95	.21	100	Agree	1st

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Depressurizing the tank when it failed to get pressurized	16	6	8	14	3.54	1.28	50.0	Agree	18th
Failure of shift operator to communicate information	20	18	4	2	4.27	.81	86.4	Agree	12th
Issuing orders for washing when methyl isocyanate tank failed	32	8	4		4.64	.65	90.9	Agree	5th
Not following the safety precautions while washing MIC	20	10	6	8	3.95	1.16	68.2	Agree	17th
Failure to recognize the leak	42		2		4.91	.42	95.5	Agree	2nd
Failure to inform Works Manager	18	24		2	4.31	.71	95.4	Agree	11th
Failure of the primary cementing	32	10		2	4.64	.72	95.4	Agree	5th
Misreading and failure of well	20	16	4	4	4.18	.95	81.9	Agree	15th
lack of standard procedures risk	34	8	2		4.73	.54	95.5	Agree	4th
Inadequate training for rig team	18	20	6		4.27	.69	86.4	Agree	12th
Poor temporary abandonment	18	16	6	4	4.09	.96	77.3	Agree	16th
Displacing mud with seawater	32	8		4	4.55	.90	90.9	Agree	10th
Failure and misreading of kick	16	24	2	2	4.23	.74	90.9	Agree	14th
Failure of Diverter	34	4	4	2	4.59	.84	86.4	Agree	9th
Failure of Blow Out Preventer	28	16			4.64	.49	100	Agree	5th
Mean					**4.44**	**.71**			

Source: Field Survey, 2020

Table 4.1.1 shows Macondo staff response on the series of unsafe acts (Immediate causes) of accidents using the ISC framework. Based on the mean and percentage of acceptance, respectively of Macondo staff, poor safety culture (4.59 & 100%), poor maintenance (4.91 & 100%), lack of communication (4.95 & 100%), depressurizing the tank when it failed to get pressurized once (3.54 & 50.0%), failure to shift operator to communicate information on pressure increase to the next operator (4.27& 86.4%), issuing orders for washing when methyl isocyanate tank failed to get pressurize (4.64& 90.9%), not following the safety precautions while washing MIC lines (3.95& 68.2%), failure to recognize the seriousness of the leak (4.91& 95.5%), failure to inform Works Manager as soon as the leak started (4.31 % 95.4%), failure of the primary cementing (4.64& 95.4%), misreading and failure of well negative pressure tests (4.18& 81.9%), lack of standard procedures, risk assessment procedures (4.73& 95.5%), inadequate training for rig team and poor communication (4.27& 86.4%), poor temporary abandonment procedure (4.09& 77.3%), displacing mud with seawater (4.55 & 90.9%), failure and misreading of kick detection data by onboard crew (4.22& 90.9%), failure of Diverter (4.59& 90.9%) and failure of blow out preventer (4.64 & 100%) are series of unsafe acts (Immediate causes) of accidents using the ISC framework.

Research Question 1 continues
What are the series of unsafe acts (Immediate causes) of the accidents using the ISC framework?

Table 4.1.2: Mean Responses of Bhopal Staff on Unsafe Acts (Immediate Causes) of the Accidents Using the ISC Framework

	Bhopal Staff (n_2=44)									
Unsafe Act	**SA**	**A**	**D**	**SD**	**U**	**M**	**SD**	**% of A**	**Decision**	**Rank**
Poor safety culture	22	22				4.50	.51	100	Agree	5th
Poor maintenance	44					5.00	.00	100	Agree	1st
Lack of communication	42	2				4.95	.21	100	Agree	2nd
Depressurizing the tank when it failed	10	16	12	6		3.68	.98	59.1	Agree	18th
Failure of shift operator to communicate	24	14	6			4.41	.73	86.3	Agree	7th
Issuing orders for washing	20	20	2	2		4.32	.77	91.0	Agree	12th
Not following the safety precautions	24	2	4	10		4.09	1.16	68.1	Agree	17th
Failure to recognize the seriousness of the leak	32	10	2			4.68	.56	95.4	Agree	3rd
Failure to inform Works Manager	22	20		2		4.36	.72	95.5	Agree	10th
Failure of the primary cementing	26	16	2			4.55	.59	95.5	Agree	4th
Misreading and failure of well negative pressure tests	20	18	4	2		4.27	.82	86.4	Agree	13th
lack of standard procedures risk	20	20	4			4.36	.65	91.0	Agree	10th
Inadequate training for rig team	22	22				4.50	.51	100	Agree	5th

Poor temporary abandonment	18	22	2	2		4.27	.76	90.9	Agree	13th
Displacing mud with seawater	22	16	4	2		4.23	.80	86.4	Agree	15th
Failure and misreading of kick detection	20	22	2			4.41	.58	95.5	Agree	7th
Failure of Diverter	18	22	2	2		4.23	.86	90.9	Agree	15th
Failure of Blow Out Preventer	22	20		2		4.41	.73	95.5	Agree	7th
Mean						**4.40**	**.67**			

Source: Field Survey, 2020

Table 4.1.2 shows Bhopal staff response on the series of unsafe acts (Immediate causes) of accidents using the ISC framework. Based on the mean and percentage of acceptance, respectively of Bhopal staff shows that poor safety culture (4.50 & 100%), poor maintenance (5.00 & 100%), lack of communication (4.95 & 100%), depressurizing the tank when it failed to get pressurized once (3.68& 59.1%), failure to sift operator to communicate information on pressure increase to the next operator (4.41& 86.3%), issuing orders for washing when methyl isocyanate tank failed to get pressurize (4.32& 91.0%), not following the safety precautions while washing MIC lines (4.09& 68.1%), failure to recognize the seriousness of the leak (4.68& 95.4%), failure to inform Works Manager as soon as the leak started (4.36 % 95.5%), failure of the primary cementing (4.55& 95.5%), misreading and failure of well negative pressure tests (4.27& 86.4%), lack of standard procedures, risk assessment procedures (4.36& 91.0%), inadequate training for rig team and poor communication (4.50 & 100%), poor temporary abandonment procedure (4.27& 90.9%), displacing mud with seawater (4.23& 86.4%), failure and misreading of kick detection data by onboard crew (4.41& 95.5%), failure of Diverter (4.23& 90.0%), failure of blow out preventer (4.41& 95.5%) are series of unsafe acts (Immediate causes) of accidents using the ISC framework

Research Question 2

What are the contributing Causes of the Macondo and Bhopal oil and gas explosion?

Table 4.2.1: Mean Responses of Macondo Staff on Contributing Causes of the Macondo and Bhopal Oil and Gas Explosion

Macondo Staff (n_1=44)										
Contributing Causes	**SA**	**A**	**D**	**SD**	**U**	**M**	**SD**	**% of A**	**Decision**	**Rank**
Knowledge and Competence	18	18			8	3.86	1.44	81.8	Agree	4th
Engineering and Design	8	14	18		4	3.50	1.09	50.0	Agree	6th
Systems and Procedures	4	40				4.09	.29	100	Agree	3rd
Quality Assurance	2	30	12			3.77	.52	72.7	Agree	5th
Human Factors	38	6				4.86	.35	100	Agree	1st
Organisational Culture	40		4			4.81	.58	90.9	Agree	2nd
Mean						**4.15**	**.71**			

Table 4.2.1 shows Macondo staff response on the contributing causes of the Macondo oil and gas explosion. Based on the mean and percentage of acceptance respectively of Macondo staff, knowledge and competence (3.86 & 81.8%), engineering and design (3.50 & 50.0%), systems and procedures (4.09 & 100%), quality assurance (3.77 & 72. 7%), human factors (4.86& 100%) and organizational culture (4.81 & 90.9%) are the contributing causes of the Macondo oil and gas explosion.

Research Question 2
What are the contributing causes of the Macondo and Bhopal oil and gas explosion?

Table 4.2.2: Mean Responses of Bhopal Staff on Contributing Causes of the Macondo and Bhopal Oil and Gas Explosion

	Bhopal Staff (n_2=22) DF = 42									
Contributing Causes	**SA**	**A**	**D**	**SD**	**U**	**M**	**SD**	**% of A**	**Decision**	**Rank**
Knowledge and Competence	18	22		4		4.22	.86	95.3	Agree	4th
Engineering and Design	8	22	14			3.86	.70	71.4	Agree	6th
Systems and Procedures		44				5.00	.00	100	Agree	3rd
Quality Assurance		44				5.00	.00	100	Agree	4th
Human Factors	26	18				4.59	.50	100	Agree	2nd
Organisational Culture	44					5.00	.00	100	Agree	1st
Mean						**4.61**	**.34**			

Table 4.2.2 shows Bhopal staff response on contributing causes of the Bhopal oil and gas explosion. Based on the mean and percentage of acceptance, respectively of Bhopal Staff shows that knowledge and competence (4.22& 95.3%), engineering and design (3.86& 71.4%), systems and procedures (5.00 & 100%), quality assurance (5.00 & .00%), human factors (4.59& 100%) and organizational culture (5.00 & 100%) are the contributing causes of the Bhopal oil and gas explosion.

Research Question 3
How effective were the immediate or short-term corrective actions in Macondo/Bhopal oil and gas explosion incident?

Table 4.3.1: Mean Responses for Macondo Staff on the Effectivenessof immediate or Short-Term Corrective Actions in Macondo/Bhopal Oil and Gas Explosion Incident

	Macondo Staff (n_1=44)						
Effectiveness of Short-Term Corrective Action	**E**	**NE**	**N**	**M**	**SD**	**% of A**	**Decision**
Pre-Site Safety Inspection	9		13	2.27	.98	63.6	E
The conduct of a thorough Process Hazard Analysis	20	1	1	2.91	.29	90.9	E
Development of standard operating procedures	19	1	2	2.77	.61	86.4	E

Identification of the need to conduct a management of change, and the ability to evaluate the change	20	1	1	2.91	.43	95.5	E
Developing a mechanical integrity program	12	7	3	2.41	.73	54.5	E
Safe operation procedure	21	1		2.95	.21	95.5	E
Routine inspections and maintenance	19	3		2.86	.35	86.4	E
Emergency evacuation plan	19	3		2.86	.35	86.4	E
Gas detector system	21	1		2.95	.21	95.5	E
Blowout preventer	17	4	1	2.72	.55	77.3	E
Mean				**2.76**	**.47**		

Table 4.3.1 shows Macondo staff response on the effectiveness of the immediate or short-term corrective actions in Macondo oil and gas explosion incident. Based on the mean and percentage of acceptance, respectively of Macondo staff, pre-site safety inspection (2.27 & 63.6%), the conduct of a thorough Process Hazard Analysis (2.91 & 90.9%), development of standard operating procedures (2.77 & 86.4%), identification of the need to conduct a management of change, and the ability to evaluate the change (2.91 & 95.5%), developing a mechanical integrity program (2.41 & 54.5%), safe operation procedure (2.95 & 95.5%), routine inspections and maintenance (2.86 & 86.4%), emergency evacuation plan (2.86 & 86.4%), gas detector system (2.95 & 95.5%) and blowout preventer (2.72 & 77.3%) as correction actions are effective..

Table 4.3.2: Mean Responses for Bhopal Staff on the Effectivenessof immediate or Short-Term Corrective Actions in Macondo/Bhopal Oil and Gas Explosion Incident

	Bhopal Staff (n_2=44)							
Effectiveness of Short-Term Corrective Action	**E**	**NE**	**N**	**M**	**SD**	**% of A**	**Decision**	**Rank**
Pre-Site Safety Inspection	10	7	6	2.22	.81	45.5	E	10th
The conduct of a thorough Process Hazard Analysis	21	1		2.95	.21	95.5	E	1st
Development of standard operating procedures	19	1	2	2.77	.61	86.4	E	6th
Identification of the need to conduct a management of change, and the ability to evaluate the change	20	1	1	2.86	.46	90.9	E	3rd
Developing a mechanical integrity program	17	3	2	2.68	.64	77.3	E	8th
Safe operation	14	7	1	2.59	.59	63.6	E	9th

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procedure								
Routine inspections and maintenance	20	1	1	2.86	.46	90.9	E	3rd
Emergency evacuation plan	21	1		2.95	.21	95.5	E	1st
Gas detector system	20	1	1	2.86	.46	90.9	E	3rd
Blowout preventer	19		3	2.72	.70	86.4	E	7th
Mean				**2.75**	**.52**			

Table 4.3.2 shows Bhopal staff response on the effectiveness of the immediate or short-term corrective actions in Bhopal oil and gas explosion incident. Based on the mean and percentage of acceptance, respectively of Bhopal staff, pre-site safety inspection (2.22 & 45.5%), the conduct of a thorough Process Hazard Analysis (2.95 & 95.5%), development of standard operating procedures (2.77 & 86.4%), identification of the need to conduct a management of change, and the ability to evaluate the change (2.86 & 90/9%), developing a mechanical integrity program (2.68 & 77.3%), safe operation procedure (2.59 & 63.6%), routine inspections and maintenance (2.86 & 90.0%), emergency evacuation plan (2.95& 95.5%), gas detector system (2.86 & 90/9%) and blowout preventer (2.72 & 86.4%) as correction actions are effective.

Research Question 4

What process safety procedures to be developed to ensure integrity of primary and secondary mechanical barriers?

Table 4.4.1: Mean Responses for Macondo Staff on Process Safety Procedures to be developed to Ensure Integrity of primary and Secondary Mechanical Barriers

Macondo Staff (n_1=44)										
Process Safety Procedures	**SA**	**A**	**D**	**SD**	**U**	**M**	**SD**	**% of A**	**Decision**	**Rank**
Evaluation of process safety MS	2	40	2			4.00	.31	95.4	Agree	1st
Effectiveness and reliability of barriers		44				4.00	.00	100	Agree	1st
Process safety performance metrics		40	4			3.91	.29	90.9	Agree	3rd
Audits of asset integrity against engineering standards	2	32	10			3.81	.50	77.2	Agree	4th
Mean						**3.93**	**.28**			

Table 4.4.1 shows Macondo staff response on the process safety procedures to be developed to ensure integrity of primary and secondary mechanical barriers. Based on the mean and percentage of acceptance of Macondo staff, evaluation of process safety MS (4.00& 95.4%), effectiveness and reliability of barriers (4.00 & 100%), process safety performance metrics (3.91& 90.9%) and audits of asset integrity against engineering standards (3.81& 77.2%) are process safety procedures to be developed to ensure integrity of primary and secondary mechanical barriers

Table 4.4.2: Mean Responses for Bhopal Staff on Process Safety Procedures to be developed to Ensure Integrity of primary and Secondary Mechanical Barriers

	Bhopal Staff (n_2=44)								
Process Safety Procedures	**SA**	**A**	**D**	**SD**	**U**	**M**	**SD**	**% of A**	**Decision**	**Rank**
Evaluation of process safety MS	42		2			4.91	.42	95.5	Agree	1st
Effectiveness and reliability of barriers		42			2	3.86	.63	95.5	Agree	2nd
Process safety performance metrics		32	10		2	3.68	.56	72.7	Agree	4th
Audits of asset integrity against engineering standards		34	10			3.77	.42	77.3	Agree	3rd
Mean						**4.06**	**.51**			

Table 4.4.2 shows BhopalStaff response on the process safety procedures to be developed to ensure integrity of primary and secondary mechanical barriers. Based on the mean and percentage of acceptance of Bhopal staffevaluation of process safety MS (4.91& 95.5%), effectiveness and reliability of barriers (3.86& 95.5%), process safety performance metrics (3.68& 72.7%) and audits of asset integrity against engineering standards (3.77& 77.3%) are process safety procedures to be developed to ensure integrity of primary and secondary mechanical barrier.

Research Question 5

How can a process safety failure procedure be designed so as to investigate the Macondo/Bhopal explosion incidence and to prevent future oil and gas explosion in companies?

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Table 4.5.1: Mean Responses of Macondo Staff on how a Process Safety failure Procedure can be designed so as to Investigate the Macondo/Bhopal Explosion Incidence and to Prevent Future Oil and Gas Explosion in Companies

Macondo Staff (n_1=44)										
Process Safety Failure Procedures	**SA**	**A**	**D**	**SD**	**U**	**M**	**SD**	**% of A**	**Decision**	**Rank**
Ongoing integrity and reliability	32	12				4.73	.46	100	Agree	4th
Reporting of process deviations		44				5.00	.00	100	Agree	1st
Communication of process safety critical information		44				5.00	.00	100	Agree	1st
Audits of asset integrity against engineering standards		44				5.00	.00	100	Agree	1st
Mean						**4.93**	**.12**			

Table 4.5.1 shows Macondo staff response on how a process safety failure procedure can be designed so as to investigate the Macondo/Bhopal explosion incidence and to prevent future oil and gas explosion in companies. Based on the mean responses and percentage of acceptance respectively of Macondo staff, ongoing integrity and reliability (4.73 & 100%), reporting of previous deviations (5.00 & 100%), communication of process safety critical information (5.00 & 100%) and audit of a asset integrity against engineering standards (5.00 & 100%) are processes safety failure procedure can be designed so as to investigate the Macondo/Bhopal explosion incidence and to prevent future oil and gas explosion in companies.

Table 4.5.2: Mean Responses of Bhopal Staff on how a Process Safety failure Procedure can be designed so as to Investigate the Macondo/Bhopal Explosion Incidence and to Prevent Future Oil and Gas Explosion in Companies

Bhopal Staff (n_2=44) DF = 42										
Process Safety Failure Procedures	**SA**	**A**	**D**	**SD**	**U**	**M**	**SD**	**% of A**	**Decision**	**Rank**
Ongoing integrity and reliability	6	36	2			4.09	.42	95.4	Agree	1st
Reporting of process deviations		40	2	2		3.86	.46	90.9	Agree	4th
Communication of process safety critical information	2	38	4			3.95	.37	90.9	Agree	3rd
Audits of asset integrity against engineering standards		42	2			3.95	.21	95.5	Agree	2nd
Mean						**3.96**	**.37**			

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Table 4.5.2 shows Bhopal staff response on how a process safety failure procedure can be designed so as to investigate the Macondo/Bhopal explosion incidence and to prevent future oil and gas explosion in companies. The mean responses of Bhopal staff shows that ongoing integrity and reliability (4.09& 95.4%), reporting of previous deviations (3.86& 90.9%), communication of process safety critical information (3.95& 90.9%) and audit of a asset integrity against engineering standards (3.95& 95.9%) are processes safety failure procedure can be designed so as to investigate the Macondo/Bhopal explosion incidence and to prevent future oil and gas explosion in companies.

Hypothesis 1
There is no significant difference between the mean responses of Macondo and Bhopal Staff on the series of unsafe acts (Immediate causes) of the accidents using the ISC framework.

Table 4.6: z-Test for Responses on the Series of Unsafe Acts (Immediate Causes) of the Accidents using the ISC Framework

Categories	n	$\bar{X}$	SD	DF	z-cal	z-crit	Decision
Macondo Staff	44	4.44	.71				
				86	.27	1.96	Not Significant
Bhopal Staff	44	4.40	.67				

Table 4.6 shows that Macondo staff had Mean and standard deviation score of 4.44 and .71 respectively, while Bhopal staff had Mean and standard deviation scores of 4.40 and .67 respectively. The z-cal value was .27, while the z-crit was 1.96 at a 0.05 level of significance for two tailed test. This result shows that z-cal was less than z-crit, which means that the null hypothesis was accepted. Thus, there was no significant difference between the mean responses of Macondo and Bhopal Staff on the series of unsafe acts (Immediate causes) of the accidents using the ISC framework.

Hypothesis 2
There is no significant difference between the mean responses of Macondo and Bhopal Staff on contributing Causes of the Macondo and Bhopal oil and gas explosion

Table 4.7: z-Test for Responses on the Contributing Causes of the Macondo and Bhopal Oil and Gas Explosion

Categories	n	$\bar{X}$	SD	DF	z-cal	zcrit	Decision
Macondo Staff	44	4.15	.71				
				86	3.88	1.96	Significant
Bhopal Staff	44	4.61	.34				

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Table 4.7 shows that Macondo staff had Mean and standard deviation score of 4.18 and .68 respectively, while Bhopal staff had Mean and standard deviation scores of 4.59 and .42 respectively. The z-cal value was 2.41, while the z-crit was 1.96 at a 0.05 level of significance for two tailed test. This result shows that z-cal was greater than z-crit, which means that the null hypothesis was rejected. Thus, there was a significant difference between the mean responses of Macondo and Bhopal Staff on the contributing causes of the Macondo and Bhopal oil and gas explosion.

Hypothesis 3
There is no significant difference between the mean responses of Macondo and Bhopal Staff on the effectiveness of the immediate or short-term corrective actions in Macondo/Bhopal oil and gas explosion incident.

Table 4.8: z-Test for Responses on How Effective were the immediate or Short-Term Corrective Actions in Macondo/Bhopal Oil and Gas Explosion Incident

Categories	n	$\bar{X}$	SD	DF	z-cal	z-crit	Decision
Macondo Staff	44	2.76	.47	86	.07	1.96	Not Significant
Bhopal Staff	44	2.75	.52				

Table 4.8 shows that Macondo staff had Mean and standard deviation score of 2.76 and .47 respectively, while Bhopal staff had Mean and standard deviation scores of 2.75 and .52 respectively. The z-cal value was .07, while the z-crit was 1.96 at a 0.05 level of significance for two tailed test. This result shows that z-cal was less than z-crit, which means that the null hypothesis was accepted. Thus, there was no significant difference between the mean responses of Macondo and Bhopal Staff on the effectiveness of the immediate or short-term corrective actions in Macondo/Bhopal oil and gas explosion incidents.

Hypothesis 4
There is no significant difference between the mean responses of Macondo and Bhopal Staff on process safety procedures to be developed to ensure integrity of primary and secondary mechanical barriers.

Table 4.9: z-Test for Responses on Process Safety Procedures to be developed to Ensure Integrity of Primary and Secondary Mechanical Barriers

Categories	n	$\bar{X}$	SD	DF	z-cal	z-crit	Decision
Macondo Staff	44	3.93	.28	86	1.48	1.96	Not Significant
Bhopal Staff	44	4.06	.51				

Table 4.9 shows that Macondo staff had Mean and standard deviation score of 3.93 and .28 respectively, while Bhopal staff had Mean and standard deviation scores of 4.06 and .51 respectively. The z-cal value was 1.48, while the z-crit was 1.96 at a 0.05 level of significance for two tailed test. This result shows that z-cal was less than z-crit, which means that the null hypothesis was accepted. Thus, there was no significant difference between the mean responses of Macondo and Bhopal Staff on process safety procedures to be developed to ensure integrity of primary and secondary mechanical barriers**.**

Hypothesis 5
There is no significant difference between the mean responses of Macondo and Bhopal Staff on how a process safety failure procedure can be designed so as to investigate the Macondo/Bhopal explosion incidence and to prevent future oil and gas explosion in companies**.**

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Table 4.10: z-Test for Responses on How a Process Safety Failure Procedure can be designed so as to investigate the Macondo/Bhopal Explosion Incidence and to Prevent Future Oil and Gas Explosion in Companies

Categories	n	$\bar{x}$	SD	DF	z-cal	z-crit	Decision
Macondo Staff	44	4.93	.12				
				86	16.54	1.96	Significant
Bhopal Staff	44	3.96	.37				

Table 4.10 shows that Macondo staff had Mean and standard deviation score of 4.93 and .12 respectively, while Bhopal staff had Mean and standard deviation scores of 3.96 and .37 respectively. The z-cal value was 16.54, while the z-crit was 1.96 at a 0.05 level of significance for two tailed test. This result shows that z-cal was greater than z-crit, which means that the null hypothesis was rejected. Thus, there was a significant difference between the mean responses of Macondo and Bhopal Staff how a process safety failure procedure can be designed so as to investigate the Macondo/Bhopal explosion incidence and to prevent future oil and gas explosion in companies

4.2 Summary of Major Findings

The findings of this study are presented as follows:

1. That poor safety culture, poor maintenance, lack of communication, depressurizing the tank when it failed to get pressurized once, failure to sift operator to communicate information on pressure increase to the next operator, issuing orders for washing when methyl isocyanate tank failed to get pressurize, not following the safety precautions while washing MIC lines, failure to recognize the seriousness of the leak, failure to inform Works Manager as soon as the leak started, failure of the primary cementing, misreading and failure of well negative pressure tests, lack of standard procedures, risk assessment procedures, inadequate training for rig team and poor communication, poor temporary abandonment procedure, displacing mud with seawater, failure and misreading of kick detection data by onboard crew, failure of Diverter and failure of blow out preventer are series of unsafe acts (Immediate causes) of accidents using the ISC framework.
2. Knowledge and competence, engineering and design, systems and procedures, quality assurance, human factors and organizational culture are the contributing causes of the Macondo and Bhopal oil and gas explosion.
3. Pre-site safety inspection, the conduct of a thorough process hazard analysis, development of standard operating procedures, identification of the need to conduct a management of change, and the ability to evaluate the change, developing a mechanical integrity program, safe operation procedure, routine inspections and maintenance, emergency evacuation plan, gas detector system and blowout preventer as correction actions are not effective.
4. That evaluation of process safety MS, effectiveness and reliability of barriers, process safety performance metrics and audits of asset integrity against engineering standards are process safety procedures to be developed to ensure integrity of primary and secondary mechanical barriers.
5. That ongoing integrity and reliability, reporting of previous deviations, communication of process safety critical information and audit of asset integrity against engineering standards are processes safety failure procedure can be designed so as to investigate the Macondo/Bhopal explosion

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incidence and to prevent future oil and gas explosion in companies.

4.3 Discussion of Findings

Findings of this study were discussed under the following heading:

Series of Unsafe Acts (Immediate Causes) of the Accidents Using the ISC Framework

The result in Table 4.1 on the series of unsafe act (immediate causes) of accidents using the ISC framework shows that poor safety culture, poor maintenance, lack of communication, depressurizing the tank when it failed to get pressurized once, failure to sift operator to communicate information on pressure increase to the next operator, issuing orders for washing when methyl isocyanate tank failed to get pressurize, not following the safety precautions while washing MIC lines, failure to recognize the seriousness of the leak, failure to inform Works Manager as soon as the leak started, failure of the primary cementing, misreading and failure of well negative pressure tests, lack of standard procedures, risk assessment procedures, inadequate training for rig team and poor communication, poor temporary abandonment procedure, displacing mud with seawater, failure and misreading of kick detection data by onboard crew, failure of Diverter and failure of blow out preventer are series of unsafe acts (Immediate causes) of accidents using the ISC framework. Also, there was no significant difference between the mean responses of Macondo and Bhopal Staff on the series of unsafe acts (Immediate causes) of the accidents using the ISC framework. This is in line with Abadie et al, (2010) that listed out some possible causes of the BP'S explosion incident as: endless cost cutting and management changes, focusing on the "cheap part" of safety at the expense of investing in and maintaining facilities, mechanical integrity and process safety, lack of accountability and loss of experienced personnel and a culture of intimidation.

Contributing causes of the Macondo and Bhopal Oil and Gas Explosion

The result in Table 4.2 on the contributing causes of the Macondo and Bhopal Oil and Gas Explosion shows that knowledge and competence, engineering and design, systems and procedures, quality assurance, human factors and organizational culture are the contributing causes of the Macondo and Bhopal oil and gas explosion. Also, there was a significant difference between the mean responses of Macondo and Bhopal Staff on the contributing Causes of the Macondo and Bhopal oil and gas explosion.Wiley (2014) that stated that process safety is fundamentally built on six functional areas or pillars, such as knowledge and competence (KC), engineering and design (ED), systems and procedures (SP), assurance (AU), human factors (HF) and culture (CU).

Effectiveness of Immediate or Short-Term Corrective Actions in Macondo/Bhopal Oil and Gas Explosion Incident

The result in Table 4.3 on the effectiveness of immediate or short-term corrective actions in Macondo/Bhopal oil and gas explosion incident shows that pre-site safety inspection, the conduct of a thorough Process Hazard Analysis, development of standard operating procedures, identification of the need to conduct a management of change, and the ability to evaluate the change, developing a mechanical integrity program, safe operation procedure, routine inspections and maintenance, emergency evacuation plan, gas detector system and blowout preventer as correction actions are not effective. Also, there was no significant difference between the mean responses of Macondo and Bhopal Staff on the effectiveness of the immediate or short-term corrective actions in Macondo/Bhopal oil and gas explosion incident.

Process Safety Procedures to be developed to Ensure Integrity of Primary and Secondary Mechanical Barriers

The result in Table 4.4 on the process safety procedures to be developed to ensure integrity of primary and secondary mechanical barriers shows that evaluation of process safety MS, effectiveness and reliability of barriers, process safety performance metrics and audits of asset integrity against engineering standards are process safety procedures to be developed to ensure integrity of primary and secondary mechanical barriers. Also, there was no significant difference between the mean responses of Macondo and Bhopal Staff on process safety procedures should be developed to ensure integrity of primary and secondary mechanical barriers**.**This is in conformity with Wiley (2014) that opined that there are several other frameworks or models for process safety, namely the CCPS, the Energy Institute (EI) and the Organisation for Economic Co-operation and Development (OECD).

How a Process Safety Failure Procedure can be designed so as to investigate the Macondo/Bhopal Explosion Incidence and to Prevent Future Oil and Gas Explosion in Companies

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The result in Table 4.5 on how a process safety failure procedure can be designed so as to investigate the Macondo/Bhopal explosion incidence and to prevent future oil and gas explosion in companies shows that ongoing integrity and reliability, reporting of previous deviations, communication of process safety critical information and audit of asset integrity against engineering standards are processes safety failure procedure can be designed so as to investigate the Macondo/Bhopal explosion incidence and to prevent future oil and gas explosion in companies. Also, there was a significant difference between the mean responses of Macondo and Bhopal Staff how a process safety failure procedure can be designed so as to investigate the Macondo/Bhopal explosion incidence and to prevent future oil and gas explosion in companies.

V. SUMMARY, CONCLUSIONSAND RECOMMENDATIONS

5.1 Summary

The aim of this study was to compare the process safety failure in Macondo/ Bhopal oil and gas explosion incident. The study wascarried out to assess the level of process safety failures awareness among oil workersin Port Harcourt that lead to Macondo and Bhopal explosion.The incident was attributed to the process safety failure in the human error analysis, without putting into consideration the aspect of knowledge and competence, engineering and design, systems and procedures, assurance and safety culture. The study was guided by five research questions. The relevance of the study to other stakeholders including oil and gas companies, Chemical industries, administrators, engineers and the society at large were clearly stated. The areas of the study Port Harcourt, Rivers States of Nigeria.

Chapter two reviewed the conceptual, empirical literature relevant to the variables under study. These variables include the dependent variable (process safety failure), independent variables (comparison done between Macondo and Bhopal). The theories relating to oil and gas were reviewed.

Chapter three described the research design and the population of the study (100), sample size (88) and sampling techniquesused for the study.Instrument usedwas a self-structure questionnaire, online videos of the two incidence, literature review were used in secondary data collation. Research questions were answered using mean, frequency and simple percentage.

5.2 CONCLUSIONS

From the study carried out, it was shown that human factor error has the highest cause of process safety failure in Macondo and Bhopal oil and gas explosion. Lastly, the five-pillar model shows that all the process safety components must be in place for accident not to occur. The reverse was the case of the Macondo and Bhopal oil and gas explosion. The result was further discussed in the light of the existing literature.

5.3 Recommendations

On the basis of the result obtained, the following recommendations were made

• Oil and gas companies should be 100% conscious of the aspect of process safety management.

• The government/non-governmental organizations have a major role to play in this issue of maintenance of facilities, by not only trying to reduce cost, but also to service, replace and remove faulty equipment.

• Oil and gas employees should erase the issue of negligence and nonchalant attitude and imbibe in good work behaviour so as to avoid disasters that will endanger their lives and the lives of every member of the society.

5.4 Limitations of the Study

Despite the success of the present study, some factors limited the generalization of this result based on the findings were:

• Primary Data was collated online through self-reports documents from those who are aware of the Macondo and Bhopal oil and gas explosion incidence which affected the target sample.

• Respondents were feeling reluctant to respond to the online questionnaire due to malware in email, hence they delayed and reduced the number of responses.

5.5 Contributions to Knowledge

The findings from this study will contribute to the knowledge by determining the direct effect of human error in the process safety failure in Macondo and Bhopal oil and gas explosion and provide improve information on the effectivemanagement of process safetyin oil and gas companies.

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