INSTITUTO FEDERAL DE EDUCAÇÃO, CIÊNCIA E TECNOLOGIA FLUMINENSE

Secretaria de Educação Profissional e Tecnológica

Ministério da Educação

GOVERNO FEDERAL BRASIL PAÍS RICO É PAÍS SEM POBREZA

PROGRAMA DE PÓS-GRADUAÇÃO EM ENGENHARIA AMBIENTAL

MESTRADO EM ENGENHARIA AMBIENTAL

MODALIDADE PROFISSIONAL

DISSERTAÇÃO PARA OBTENÇÃO DO TÍTULO DE MESTRE EM ENGENHARIA AMBIENTAL

SISTEMA DE GESTÃO DE SEGURANÇA DE PROCESSO BASEADO EM RISCOS E PROTEÇÃO AMBIENTAL

FELIPE AUGUSTO GOMIDES PEREIRA GIMENES

MACAÉ/RJ

2015

SISTEMA DE GESTÃO DE SEGURANÇA DE PROCESSO BASEADO EM RISCOS E PROTEÇÃO AMBIENTAL

FELIPE AUGUSTO GOMIDES PEREIRA GIMENES

Dissertação apresentada ao Programa de Pós-Graduação em Engenharia Ambiental do Instituto Federal de Educação, Ciência e Tecnologia Fluminense, na área de atuação Desenvolvimento e Sustentabilidade, como requisito para obtenção do título de Mestre em Engenharia Ambiental.

Orientador: Prof. Romeu e Silva Neto, D.Sc.

Co-Orientador: Prof. Bruno Silvestre, D.Sc.

MACAÉ/RJ

2015

Dados Internacionais de Catalogação na Publicação (CIP)

G491s Gimenes, Felipe Augusto Gomides Pereira.
Sistema de gestão de segurança de processo baseado em riscos e proteção ambiental/ Felipe Augusto Gomides Pereira Gimenes. — Macaé, RJ, 2015.
65 f.: il. color.

Orientador: Romeu e Silva Neto.
Coorientador: Bruno Silvestre.

Dissertação (Mestrado). — Instituto Federal de Educação, Ciência e Tecnologia Fluminense, Programa de Pós-graduação em Engenharia Ambiental, Macaé, RJ, 2015.
Inclui bibliografia.

1. Gerenciamento de risco. 2. Sistemas de segurança. 3. Proteção ambiental. 4. Engenharia de sistemas. I. Silva Neto, Romeu e, orient. II. Silvestre, Bruno, coorient. III. Título.

CDD 363.7 23.ed.

Bibliotecário-Documentalista |Henrique Barreiros Alves | CRB-7/ 6326

Dissertação intitulada SISTEMA DE GESTÃO DE SEGURANÇA DE PROCESSO BASEADO EM RISCOS E PROTEÇÃO AMBIENTAL, elaborada por Felipe Augusto Gomides Pereira Gimenes, e apresentado publicamente perante a Banca Examinadora, como requisito para obtenção do título de Mestre em Engenharia Ambiental pelo Programa de Pós-graduação em Engenharia Ambiental, na área de atuação Desenvolvimento e Sustentabilidade do Instituto Federal de Educação, Ciência e Tecnologia Fluminense - **IFF**.

Aprovada em: 04/08/2015.

Banca Examinadora:

Romeu e Silva Neto

Prof. Romeu e Silva Neto, D.Sc.
Instituto Federal Fluminense – IFF
Orientador

Prof. Bruno Silvestre, D.Sc.
University of Winnipeg – UW
Co-orientador

Prof. Gilson Brito Alves Lima, D.Sc.
Universidade Federal Fluminense - UFF

Prof. Marcos Antonio Cruz Moreira, D.Sc.
Instituto Federal Fluminense – IFF

DEDICATÓRIA

Em especial aos meus familiares e aos meus amigos que se tornaram minha família em Macaé.

AGRADECIMENTOS

A todos que contribuíram para a realização desse trabalho, direta e indiretamente.

Ao professor Romeu e Silva Neto e ao professor Bruno Silvestre que me guiaram ao longo da jornada. Aos demais professores do Instituto Federal Fluminense que se dedicam a desenvolver e iluminar seus alunos.

Aos trabalhadores do IFF, administrativos e de apoio.

Aos colegas da Petrobrás que contribuíram com o desenvolvimento desta dissertação. Não poderia deixar de mencionar alguns que tiveram maior contribuição. À equipe de alto nível do OPM/SPPO, em particular aos especialistas em segurança de processos, levantamento e gerenciamento de riscos: Arijuna Marques Costa, Francimar Vasconcelos, Joabh Luz da Silva, Otávio Adriano de Oliveira, Rodolpho Carlos Cerqueira Junior, Samile Caus Carvalho e Tassiana Bortolini e aos gerentes Ricardo Oliveira, Joaquim Manoel Cassiano Neto, Roberto Campello Moraes e Marcelo Ferreira Batalha que acreditaram no meu trabalho. Também aos profissionais de segurança de processo Alberto Carlos Caldeira Costa Coelho, Antonio José Ramalho, Jorge Luiz Carvalho Ribeiro e Fernando de Carli.

À minha família, Fausto Gimenes, Eliziete Gomides Pereira Gimenes e Monica Smith.

À minha amada, Arijuna Marques Costa, que se privou de momentos de convívio para que eu desenvolvesse este trabalho.

A todos os cidadãos brasileiros, contribuintes que patrocinam a pesquisa e o Instituto Federal Fluminense.

À Petróleo Brasileiro S.A, que me permitiu desenvolver esta pesquisa.

EPÍGRAFE

"Competent people drive performance. And effective management systems drive sustainability"

Sam Mannan

RESUMO

Recentemente, novas dinâmicas de processamento de produtos potencialmente perigosos aumentaram fluxos, pressões, temperaturas e outras variáveis usadas nas indústrias de processo. Com estas novas dinâmicas de processamento, o risco de acidentes maiores em todo o mundo também aumentou. Devido às ocorrências de acidentes maiores, leis e regulamentos foram criados para tentar evitar este tipo de evento, com o objetivo de proteger as pessoas, patrimônio, meio ambiente e imagem das companhias. Sistemas de gestão de segurança de processos são usados para inserir uma série de medidas de bloqueio para impedir o desenvolvimento de acidentes maiores. Para a indústria de petróleo, existem algumas práticas recomendadas por vários institutos e agências governamentais. Essas práticas são Sistemas de Gestão de Segurança de Processos. Com o emprego de estudo descritivo, análise documental e estudo de caso, o presente trabalho tem como objetivo comparar os Sistemas de Gestão de Segurança de Processo existentes com o Sistema de Gestão de Segurança, Meio Ambiente e Saúde de uma grande companhia de energia e principal operadora de petróleo da Bacia de Campos e do Brasil. Operadoras de petróleo, juntamente com os seus sistemas de gestão de segurança de processo, usam técnicas de identificação de perigos e análise de risco, a fim de gerenciar seus riscos operacionais no intuito de prevenir a ocorrência ou mitigar consequências de acidentes maiores. Entre as técnicas, podem ser destacas APR (Análise Preliminar de Riscos), *What-if*? e HAZOP (Hazard and Operability Study). Através de uma pesquisa exploratória e um estudo de caso, o presente trabalho tem como objetivo avaliar como o principal operador de petróleo *offshore* na Bacia de Campos identifica e gerencia seus riscos operacionais, que técnicas são utilizadas e como esta operadora aplica ferramentas de identificação de perigos e avaliação de riscos relativos à segurança de processos. APR e HAZOP são as duas técnicas mais utilizadas na Bacia de Campos e sua aplicação requer um grupo multidisciplinar. A metodologia proposta é a de utilização de ambas as técnicas em conjunto para a identificação e avaliação de riscos de processo nas plataformas *offshore*.

Palavras-chave: Sistema de Gestão de Segurança de Processo; Acidentes Maiores; Prevenção de Perdas; Proteção Ambiental; Segurança de Processos Baseada em Risco.

ABSTRACT

Recently, new processing dynamics of potentially dangerous products has increased flows, pressures, temperatures and other variables used in the process industries. With these new processing dynamics, the risk of major accidents around the world also increased. Due to the occurrence of major accidents, laws and regulations have been created to try to prevent this type of events, aiming to protect people, assets, the environment and corporate image. Process Safety Management Systems (PSMS) are used as a series of blocking barriers to prevent the development of major accidents. For the oil industry, there are some recommended PSMS from multiples institutes and government agencies. By employing a descriptive case study and documental analysis, the present study aims to compare the existing Process Safety Management Systems with the Health, Safety and Environment management system of a world leader energy company which is the main oil operator of Campos Basin and Brazil.. Oil operators, together with its process safety management systems, use hazard identification and risk analysis techniques in order to manage its operational risks aiming to prevent the occurrence or mitigate consequences of major accidents. Among the techniques, we can highlight PreHA (Preliminary Hazard Analysis), What-if? and HAZOP (Hazard and Operability Study). Through an exploratory research and a case study this study also aims to evaluate how the main offshore oil operator in the Campos Basin identifies and manages its operational risks, concerning process accident, which techniques are used and how this operator applies hazard identification and risk assessment tools. PreHA and HAZOP are the two most commonly used in the Campos Basin and their applications require multidisciplinary teams. The proposed methodology is the use of both techniques together for the identification and evaluation of process risks on offshore platforms.

Keywords: Process Safety Management; Major Accidents; Loss Prevention; Environment Protection; Risk Based Process Safety.

LISTA DE ILUSTRAÇÕES

LISTA DE TABELAS

APRESENTAÇÃO

ARTIGO I

ARTIGO II

LISTA DE ABREVIATURAS E SIGLAS

ABNT	Associação Brasileira de Normas Técnicas
AICHE	American Institute of Chemical Engineers
ALARP	As Low As Reasonably Practicable
ANP	Agência Nacional do Petróleo
CCPS	Center for Chemical Process Safety
CETESB	Companhia de Tecnologia de Saneamento Ambiental
CONAMA	Conselho Nacional do Meio Ambiente
E&P	Exploração e Produção
EPA	Environmental Protection Agency
ESD	*Emergency Shutdown* (Parada de Emergência – não programada)
FPSO	*Floating Production Storage and Offloading*
FSO	*Floating Storage and Offloading*
IBP	Instituto Brasileiro do Petróleo
Inea	Instituto Estadual do Ambiente
LOPC	Lost of Primary Containment
OIT	Organização Internacional do Trabalho
OREDA	Offshore Reliability Data
OSHA	Occupational Health and Safety Administration
PETROBRAS	Petróleo Brasileiro S.A.
PSM	Process Safety Management
PSMS	Process Safety Management System
SGSO	Sistema de Gerenciamento da Segurança Operacional
SS	Semi-submersível (Plataforma ou sonda)
TLP	T*ension Leg Platform*
UE	União Européia
UEP	Unidade Estacionária de Produção

SUMÁRIO

1 - INTRODUÇÃO E APRESENTAÇÃO

O surgimento de novas tecnologias somado às novas exigências do mercado, a partir das últimas décadas do século passado, vem gerando grandes alterações nos meios produtivos e industriais. A abertura de novos mercados consumidores, competitividade, evoluções tecnológicas, necessidade de aumento de eficiência produtiva e a busca contínua de se produzir mais com menos recursos disponíveis e em um menor espaço de tempo, faz com que os processos e sistemas produtivos trabalhem com uma nova dinâmica de processamento, processando grandes volumes, pressões, temperaturas e vazões. Ademais, em muitas das vezes, com tempos para manutenções reduzidos. Estes fatores podem levar a um aumento no risco de ocorrência de um incidente de processo, ocasionando crescente probabilidade de perda de contenção, resultando em dano ambiental.

A sociedade contemporânea está fortemente apoiada nas indústrias que fornecem produtos indispensáveis para o atual modelo socioeconômico, baseado nas cidades, e também fornecem emprego e renda (utilizada para comprar seus próprios produtos). As indústrias de base como mineração, siderurgia e petroquímica fornecem os insumos para as outras indústrias como automobilística, manufatura e eletroeletrônica. A indústria transformou óleo, gás e carvão em combustíveis e energia elétrica baratos que ajudaram a construir a moderna civilização (LOVINS, 2012).

O crescimento da economia em escala mundial possibilitou o aumento das dimensões das plantas industriais. Nos anos 60, uma planta industrial para produzir 50 mil toneladas/ano de etileno era considerada de grande porte. A partir dos anos 80, plantas para a produção de etileno ultrapassaram a escala de 1 milhão de toneladas/ano (FREITAS *et al*, 2000).

A história da indústria química e de petróleo é marcada por diversos desastres ambientais causados por incidentes de processo, porém pode-se destacar que após os incidentes de Seveso e Bhopal, houve grandes alterações em leis e normas ambientais em todo o mundo.

O incidente que ocorreu em Seveso, Itália, no ano de 1976 gerou um vazamento de vários quilos de dioxina (2,3,7,8-tetraclorodibenzeno-p-dioxina) na atmosfera, ocasionando a morte de aproximadamente 3.000 animais, além disso, outros 70.000 tiveram de ser

.

sacrificados para que a dioxina não viesse a atingir a cadeia alimentar humana (HAKKINEN, 2005).

Já o incidente de Bhopal, Índia, que ocorreu no ano de 1984, liberou na atmosfera, através de um vazamento, 40 toneladas de metil isocianato, levando a óbito 3.800 pessoas e causando morbidade e morte prematura de outras milhares (BROUGHTON, 2005).

Desde a ocorrência destes incidentes, as indústrias, órgãos de classe, sociedade civil e governos vêm tentando aprender com seus erros e gerar meios para que estes não se repitam, na indústria petrolífera, em especial na *offshore*, isto não é diferente.

Vinnem (2007) descreve que apesar de ter sido um incidente considerado não previsível, como os incidentes geralmente o são, o incidente da plataforma de Piper Alpha, poderia ter sido previsto anteriormente, pois no mesmo ano de 1988, ocorreu incidente similar com a plataforma Brent Alpha, que não resultou em danos mais graves.

Observa-se que neste exemplo acima de Piper Alpha e Brent Alpha, duas plataformas da mesma companhia petrolífera (Occidental Petroleum), um incidente de menor gravidade – Brent Alpha – ocorreu antes do evento de maior gravidade – Piper Alpha – e o primeiro não gerou ações para evitar o segundo. Aprender com o incidente e tomar ações assertivas para evitar sua recorrência poderia ter evitado a explosão de uma plataforma, com ocorrência de 167 óbitos, queima de toneladas de combustível fóssil e contaminação ambiental.

Já o incidente do navio petroleiro Exxon Valdez, ocorrido na costa do Alasca em 1989, foi um dos desastres ambientais mais devastadores mundialmente, levando a óbito aproximadamente 250.000 pássaros, 2.800 lontras, 300 focas, 247 águias carecas, 22 baleias orca e bilhões de salmões e arenques. Isso devido ao derrame de aproximadamente 37.000 toneladas de óleo crú lançados na costa do Alasca. Estima-se que os danos ambientais ocorridos em 1989 repercutam até a atualidade (ZIO, *et* AVEN, 2013).

Apesar de não ter sido o navio que apresentou o maior vazamento, conforme gráfico a seguir, devido ao local onde o acidente ocorreu, se classifica como um dos mais devastadores.

.

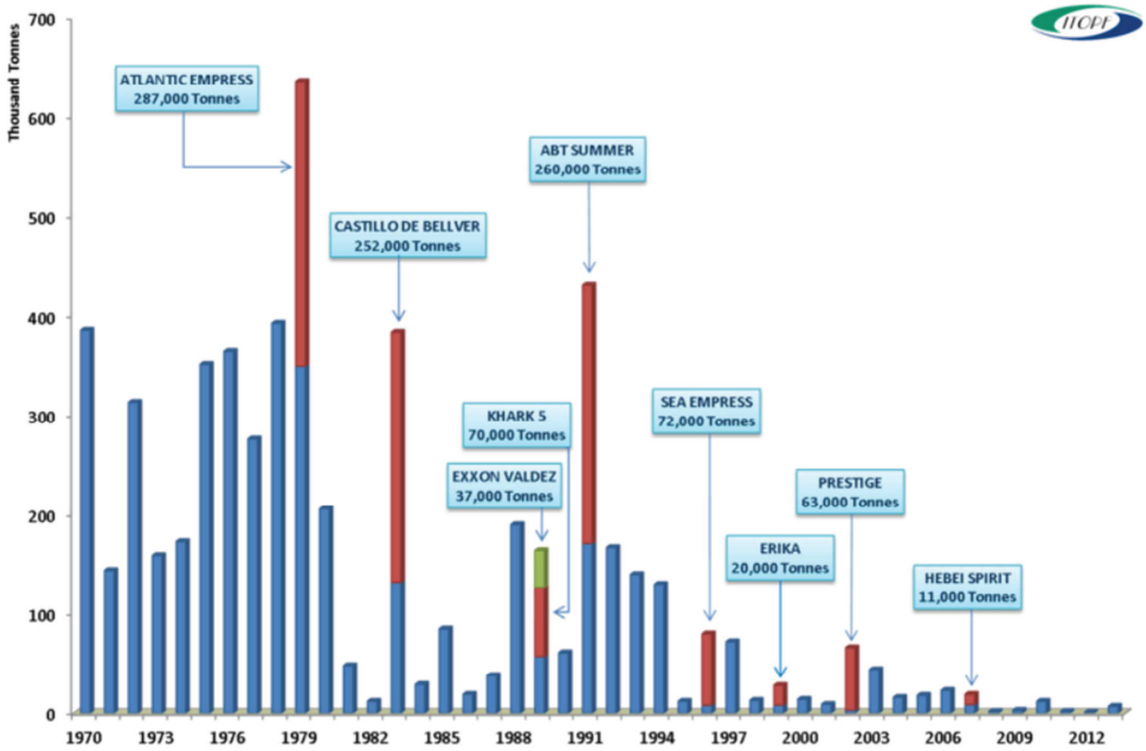

Ilustração 1.1 - Quantidade de óleo vazado por navios petroleiros ao longo do tempo.

Fonte: ITOPF - THE INTERNATIONAL TANKER OWNERS POLLUTION FEDERATION LIMITED, 2014.

Após o incidente do navio petroleiro Exxon Valdez, ocorreram inúmeros incrementos nas barreiras de proteção para evitar acidentes semelhantes, dentre eles destaca-se legislação americana, conhecida como Oil Pollution Act, de 1990. Nesta lei americana, entre outros dispositivos, há exigências de casco duplo para os petroleiros construídos a partir de então e um cronograma de retirada de serviço dos navios de casco simples construídos antes de 1990, de acordo com a capacidade do navio e sua idade. Além disso, houve a criação de um fundo para custear a recuperação dos danos não cobertos pelos responsáveis. Esse fundo é constituído pela cobrança de cinco centavos por barril de petróleo. O total disponível para cada acidente foi limitado ao máximo de US$ 1 bilhão. Este fundo incorpora o conceito de poluidor pagador à legislação ambiental.

Seguindo o exemplo da legislação americana, em 1992, importantes emendas foram introduzidas na MARPOL (Convenção Internacional para Prevenção de Poluição por Navios), da qual o Brasil é signatário. As emendas da referida Convenção são especificamente relacionadas à exigência de casco duplo em embarcações petroleiras: as regras 19 e 20 do anexo I.

.

Também gerou alteração de normativa internacional o já citado incidente de Piper Alpha. Após a investigação do incidente, Lorde Cullen elabora o conhecido Cullen Report, relatório que enfatiza a necessidade do Safety Case, um estudo exigido das companhias operadoras de petróleo cujo conteúdo demonstra o nível de risco associado à unidade de produção, ou seja, o risco de ocorrer um grande incidente naquela unidade, gerando impacto ao meio ambiente e à segurança dos trabalhadores.

Segundo ABS (2000), mais recentemente, como forma de proteção ao meio ambiente, alguns países passaram a criar leis acerca da redução dos riscos ambientais, exigindo das corporações o emprego de medidas de redução de risco, e em alguns casos, até a demonstração de que o empreendimento pode ser operado dentro de padrões de riscos aceitáveis/toleráveis. Para isso, tiveram que se mobilizar para definir critérios quantitativos para estabelecer o que vem a ser um risco aceitável.

Em 1982, a primeira diretiva de Seveso recomenda, aos países da comunidade europeia, a elaboração de legislação que obriga as empresas com inventário de produtos perigosos acima de um determinado valor a elaborar relatório de segurança com uma lista de acidentes já ocorridos nas instalações e as medidas que foram adotadas para prevení-los. Nos Estados Unidos foi criada a chamada lei do direito de saber ou Right to Know Act, que determina que as instalações consideradas perigosas devam declarar publicamente sobre os riscos de suas instalações e possíveis acidentes que possam ocorrer, para que seus vizinhos saibam sobre os cenários emergenciais e as ações que devam ser tomadas caso estes cenários ocorram.

É neste contexto e panorama abrangente que se insere a segurança de processos, disciplina que, dentre outros objetivos, busca a prevenção de dano ambiental evitando perdas de contenção de substâncias nocivas para o meio ambiente, ou seja, através de diversas ferramentas, atua para que os fluídos se mantenham dentro dos vasos, sistemas e tubulações de modo a não ocorrerem incidentes, protegendo assim a vida humana, o meio ambiente e as instalações industriais.

Nas últimas décadas, houve um aumento considerável de interesse em plantas químicas inerentemente seguras. Este desenvolvimento foi conduzido pela disciplina científica chamada Segurança de Processos. Esta disciplina foca na prevenção de incêndios, explosões e liberações acidentais de substâncias químicas nas unidades de processamento (CCPS, 1993).

.

1.1 - HISTÓRICO

Internacionalmente, a origem da Segurança de Processos e Prevenção de Perdas ocorreu por volta de 1968, sendo o início dos anos 70 o início da década dourada para esse campo de pesquisa. Segundo Kletz (1999), isso se deu devido ao fato da expansão econômica mundial desde os anos 1950 e uma nova geração de plantas químicas – maiores do que as pré-existentes e operando com novas condições, pressões e temperaturas maiores – apareceram nas décadas de 1950 e 1960, e aumentaram o número de acidentes maiores.

A partir de então, a Segurança de Processo se tornou essencial para lidar com a possibilidade destes acidentes maiores ocorrerem em plantas de processo.

Acidente maior é definido segundo a Diretiva de Seveso como sendo: uma ocorrência de grande emissão, incêndio ou explosão resultante de um descontrole no decorrer do funcionamento de qualquer estabelecimento (DIRECTIVE, 2012).

Para a OGP (2010), acidentes maiores são:
Acidentes que se enquadram em pelo menos um dos critérios abaixo:

- Múltiplas fatalidades;
- Vazamento de pelo menos 1000 barris de óleo e/ou;
- Danos ao patrimônio:
  - Para unidade *onshore*: Aproximadamente US$ 100M em prejuízo devido ao dano ao patrimônio.
  - Para unidades offshore: Perda da unidade ou dano severo (definido a seguir).

Perda da unidade: Perda total da unidade, incluindo perda total do ponto de vista da seguradora, no entanto, a unidade pode ser reparada e colocada em operação novamente.

Dano severo: Danos severos a um ou mais módulos da unidade; danos grandes ou médios a estrutura de suporte de carga; danos maiores a equipamentos essenciais.

Dano significante: Danos que demandem reparação a um ou mais módulos da unidade.

.

Exemplos de acidentes maiores que ocorreram na indústria de processo ao redor do mundo são:

ANO	INSTALAÇÃO	LOCAL	PAÍS	MORTOS	Feridos	LESÕES PESSOAIS E DANOS AMBIENTAIS	DANOS PATRIMONIAIS FORA DA PLANTA
1974	Planta de ciclohexano	Flixbourough	Inglaterra	28	36	ND[1]	1.821 casas e 167 lojas
1976	Planta de dioxina	Seveso	Itália	75.000 animais	156 operários e 37.000 vizinhos	Intoxicação aguda e contaminação do solo	ND[1]
1984	Planta de metil isocianato	Bhopal	Índia	>2500	>20000	Lesões pulmonares permanentes	ND[1]
1986	Cherobyl	Pripyat	Ucrânia	50 diretos 4000 indiretos /câncer	600000	ND[1]	ND[1]
2005	Texas City Refinery	Texas	Estados Unidos	15	100	ND[1]	ND[1]

Ilustração 1.2 - Acidentes maiores.

Fonte: Freitas *et al*, 2000, BROUGHTON, 2005, HAKKINEN, 2005 e ZIO, E. *et* AVEN, T., 2013, adaptado pelo.

[1] ND – Não disponível.

.

Já na indústria de Petróleo o*ffshore*, alguns acidentes de processo são listados no quadro abaixo, classificados do maior para o menor quanto ao número de fatalidades e feridos:

Data	Instalação / Campo	Tipo de unidade	Tipo de operação	Dano	Sequência de eventos	Número de fatalidades	Número de feridos	Área geográfica
6/7/1988	Piper Alpha	Jaqueta	Produção	Perda total	Vazamento - Explosão - Incêndio	167	60	Europa - Mar do Norte
27/03/1980	Alexander L Kielland	Semi submersível	Acomodação	Perda total	Quebra ou fadiga - Adernamento - Emborcamento - Afundamento	123	N.D	Europa - Mar do Norte
3/11/1989	Seacrest	Navio Sonda	Perfuração	Dano severo	Quebra ou fadiga - Emborcamento - Afundamento	91	0	Sul da Ásia
15/02/1982	Ocean Ranger	Semi submersível	Perfuração	Perda total	Quebra ou fadiga - Vazamento no casco - Adernamento - Emborcamento - Afundamento	84	0	América do Norte
25/10/1983	Glomar Java Sea	Navio Sonda	Perfuração	Perda total	Quebra ou fadiga - Vazamento no casco - Adernamento - Emborcamento - Perda de flutuabilidade - Afundamento	81	0	Ásia
25/11/1979	Bohai II	Jaqueta	Transferência de Fluidos	Perda total	Quebra ou fadiga - Vazamento no casco - Adernamento - Emborcamento - Afundamento	72	0	Ásia
16/08/1986	Plataforma Central de Enchova	Jaqueta	Perfuração	Dano significante	*Blowout* - Incêndio - Explosão	42	19	América do Sul - Bacia de Campos
15/10/1995	DLB 269	Balsa	Transferência de Fluidos	Dano severo	Vazamento no casco - Adernamento - Emborcamento -Afundamento	26	0	América do Norte - Golfo do México
15/08/1991	McDermott Lay Barge 29	Lançador de dutos	Construção	Perda total	Vazamento no casco - Adernamento - Emborcamento -Afundamento	22	N.D	Ásia
23/10/2007	Usumacinta	Jaqueta	Perfuração	Dano severo	Colisão - Vazamento - Incêndio	22	N.D	América do Norte - Golfo do México
2/10/1980	Ron Tappmeyer	Jaqueta	Perfuração	Danos leves	Blowout	19	19	Oriente Médio
9/10/1974	Gemini	Jaqueta	Perfuração	Dano severo	Quebra ou fadiga - Emborcamento - Afundamento	18	0	Oriente Médio
8/12/1977	South March, 128A	Jaqueta	Produção	Danos leves	Colisão de Aeronave	17	1	América do Norte - Golfo do México
13/10/1971	Western Offshore 2	Balsa de perfuração	Perfuração	Dano severo	*Blowout* - Explosão - Incêndio	16	0	América do Sul
17/10/1985	Trintoc Atlas	Unidade de Apoio	Construção	Dano severo	Vazamento - Explosão	14	0	América Central
20/03/1983	B.O.S 355	Unidade de Apoio	Construção	Dano severo	Explosão - Incêndio	13	32	África
16/04/1976	Ocean Express	*Jackup*	Mobilização	Perda total	Falha ou ruptura de linha de reboque - Emborcamento - Afundamento	13	0	América do Norte - Golfo do México
27/07/2005	Bombay High North	Jaqueta	Produção	Dano severo	Colisão - Vazamento - Incêndio	12	0	Ásia
3/10/1989	High Island Pipeline	Dutos	Produção	Dano significante	Colisão - Vazamento - Explosão - Incêndio	11	4	América do Norte - Golfo do México
25/03/1993	Lake Maracaibo	N.A	N.A	Dano significante	Explosão - Incêndio	11	N.D	América do Sul
20/04/2010	Deepwater Horizon	Semi submersível	Perfuração	Perda total	*Blowout* - Explosão - Incêndio - Vazamento - Afundamento	11	N.D	América do Norte - Golfo do México
15/03/2001	P-36	Semi submersível	Produção	Perda total	Explosão - Incêndio - Adernamento - Emborcamento - Perda de flutuabilidade - Afundamento	11	N.D	América do Sul - Bacia de Campos
20/05/1985	Tonkawa	Balsa de perfuração	Transferência de Fluidos	Dano severo	Adernamento - Emborcamento - Afundamento	11	0	América do Norte - Golfo do México
18/01/1995	Ubit	Jaqueta	Em manutenção	Dano severo	Explosão - Incêndio	10	23	África
31/07/1989	Avco 5	Unidade de Apoio	Transferência de Fluidos	Perda total	Emborcamento - Afundamento	10	0	América do Norte - Golfo do México
4/11/1985	Concem	Unidade de Apoio	Construção	Perda total	Emborcamento - Afundamento	10	0	Europa - Mar do Norte
11/2/2015	Cidade de São Mateus	FPSO	Produção	Dano significante	Vazamento - Explosão	9	26	América do Sul - Bacia do Espírito Santo

Ilustração 1.3 - Principais acidentes *offshore*.

Fonte: OGP, 2010 e CSB, 2014, adaptado pelo autor.

Na tentativa de se evitar acidentes na indústria de processos fez-se necessário a criação de barreiras preventivas e mitigadoras para a perda de contenção de produtos perigosos. Para isso, foi criada uma série de regulamentações, normas e práticas para diversos tipos de indústrias e equipamentos.

.

O ferramental utilizado para evitar as perdas de contenção ou LOPC (*Lost of Primary Containment*) pode ser agrupado em um Sistema de Gestão de Segurança de Processos – SGSP ou *Process Safety Management System (*PSMS), em inglês.

Segundo EHSO (2010), o objetivo do PSM é prevenir ou minimizar as consequências de uma liberação catastrófica de substâncias inflamáveis, explosivas ou tóxicas de um processo. O PSMS da OSHA, 29 CFR 1910.119, é composto de 14 práticas que as empresas devem implementar.

Uma das primeiras leis escrita, com foco em prevenir e minimizar as consequências de liberações catastróficas, após o acidente de Seveso, foi promulgada pela União Europeia (UE) em 1982 e ficou conhecida como a primeira diretiva de Seveso (DIRECTIVE, 1982). A diretiva tinha o objetivo de atuar na prevenção dos chamados acidentes maiores resultantes de certas atividades industriais. Além de prevenir, esta diretiva também focava na limitação da consequência dos acidentes maiores para o homem e para o meio ambiente.

Portanto, o conceito de salvaguardas preventivas e mitigadoras já está presente na primeira diretiva de Seveso.

O conceito de salvaguarda para evitar que um dano ocorra, pode ser exemplificado pelo diagrama do queijo suiço de Reason, 2007. O conceito proposto por Reason, 2007 é de que cada fatia de queijo suíço é uma salvaguarda e que se o perigo passar pelas fatias de queijo, o dano ocorre. Portanto, para se prevenir os danos/incidentes/perdas, as falhas nas salvaguardas (buracos no queijo) devem ser corrigidas ou então novas salvaguardas (novas fatias de queijo) são colocadas no caminho do perigo para que este não se transforme em dano.

Um sistema de gestão baseado em riscos pode ser implementado para avaliar se as salvaguardas existentes são suficientes e se existe a necessidade de correções e implementações de novas salvaguardas.

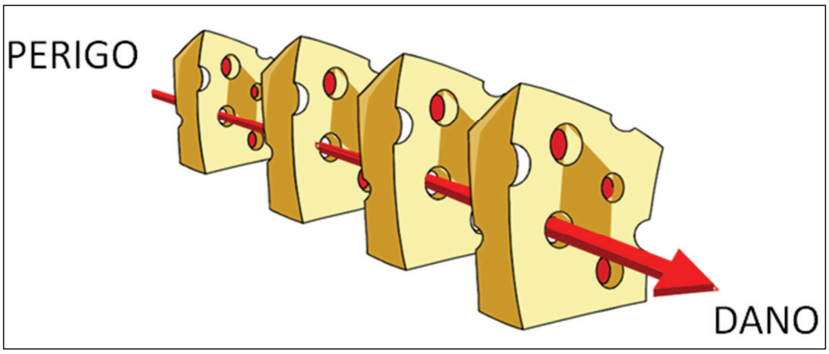

Ilustração 1.4 – Modelo do queijo suíço (Swiss cheese model).

Fonte: REASON, 2007.

.

O API – *American Petroleum Institute* publicou, em 1990, a norma API RP 750. O acrônimo RP significa *Recommended Practice*, ou seja, não tem o caráter mandatório. Esta norma contém um guia com 11 práticas recomendadas para auxiliar as operadoras de petróleo a prevenir a ocorrência ou minimizar as consequências da liberação de substâncias tóxicas, inflamáveis ou explosivas na atmosfera.

Só então, em 24 de fevereiro de 1992, a OSHA veio a publicar seu padrão CFR 1910.119, com força de lei. Este padrão é a base de um PSM para um processo de gerenciamento de risco para substâncias altamente perigosas.

A OIT – Organização Internacional do Trabalho, em junho de 1993, publicou a Convenção 174 da OIT, que tem o objetivo de prevenir a ocorrência dos chamados acidentes maiores, envolvendo substâncias perigosas e também limitando a consequência deste tipo de acidente.

Para o Brasil, esta convenção tem força de lei, pois o país é signatário da OIT.

A EPA – Environmental Protection Agency, publicou a EPA – 40 CFR 68.130, em junho de 1996, as práticas recomendadas de meio ambiente para o plano de gerenciamento de riscos nas industrias, que operam com substâncias tóxicas e inflamáveis (BOBSIN, M.A *et* LIMA, G. B.A, 2005).

Para a indústria de óleo e gás brasileira, em 2007, a ANP - Agência Nacional do Petróleo, Gás Natural e Biocombustíveis, através de sua resolução nº 43, estabelece o Regulamento Técnico do Sistema de Gerenciamento da Segurança Operacional das Instalações Marítimas de Perfuração e Produção de Óleo e Gás Natural, que contém 17 práticas de gestão e que tem o objetivo de estabelecer requisitos e diretrizes para implementação de um Sistema de Gerenciamento da Segurança Operacional (SGSO), visando a segurança operacional das instalações marítimas de perfuração e produção de petróleo e gás natural, com o objetivo de proteger a vida humana e o meio ambiente (ANP, 2007).

1.2 - Objeto da pesquisa

Devido à complexidade das operações de processamento de produtos perigosos e abrangência dos temas intrínsecos à segurança de processo, o trabalho se delimita a verificar como ocorre o gerenciamento da segurança de processos nas operações de produção de óleo e gás *offshore*. Fato este justificado, pois o setor chamado *upstream* fornecer matéria prima (petróleo e gás) para toda a cadeia de petroquímicos (*downstream*).

.

1.3 - Importância para a região e justificativa

A importância da indústria de óleo e gás para a sociedade moderna e para o desenvolvimento material e tecnológico é evidente. Pode-se dizer que a organização em grandes cidades, na escala atual, seria praticamente impossível sem os combustíveis fósseis e a infraestrutura de transporte. Por outro lado, não podemos esquecer os acidentes maiores ocorridos. Como visto anteriormente, nesta indústria, ocorreram diversos incidentes, por isso no caso da indústria do petróleo de Macaé e região, além dos aspectos econômico e social, a componente ambiental ganha também especial atenção devido aos impactos e riscos que as atividades de produção e exploração na Bacia de Campos podem causar ao meio ambiente regional.

O tema interessa também à sociedade e ao meio ambiente, que se beneficia, com a redução da frequência e/ou da consequência de perdas de contenção de matéria e/ou energia de plantas de processamento.

1.4 - Estrutura e organização do trabalho

Esta dissertação por agregação de artigos é composta de 4 capítulos, o primeiro apresenta a introdução ao tema segurança de processo, histórico do surgimento da disciplina segurança de processo, os principais acidentes maiores *offshore,* principais *guidelines* que tratam de gestão de segurança de processo e a importância para a região e justificativa da pesquisa. O segundo capítulo apresenta artigo científico que utilizando de pesquisa exploratória, pesquisa documental e estudo de caso avalia os princpais *guidelines* e propostas de sistemas de gestão de segurança de processos existentes, comparando-os entre si e com o sistema de gestão de segurança, meio ambiente e saúde de Petrobrás. O terceiro capítulo apresenta artigo que utilizando de pesquisa exploratória e estudo de caso avalia como é feito o levantamento de perigos e análise de riscos das operações de produção de petróleo e gás *offshore* na Bacia de Campos, através de metodologia estruturada que utiliza duas técnicas em sequência para o levantamento e análise dos riscos, que respectivamente são: APR - Análise Preliminar de Riscos e HAZOP - *Hazard e Operability Study*. Ambos os artigos, em conjunto, suportam o que se denomina de Segurança de Processos Baseada em Riscos Já no quarto capítulo são apresentadas as conclusões sobre o gerenciamento da segurança de processos nas operações de produção de óleo e gás *offshore* no Brasil, especificamente na Bacia de Campos.

.

2 - ARTIGO CIENTÍFICO I

Sustainable Operations and Process Safety Management Systems: Implications for the offshore oil industry and Petrobras

GIMENES, F. [a*], SILVA NETO, R. [b], SILVESTRE, B. S.[c]
a. Instituto Federal Fluminense, Rio de Janeiro, Brazil
b. Instituto Federal Fluminense, Campos dos Goytacazes, Brazil
c. Faculty of Business and Economics, The University of Winnipeg, Winnipeg, Canada

**Corresponding author, felipefelll@gmail.com*

Abstract

Recently, new processing dynamics of potentially dangerous products has increased flows, pressures, temperatures and other variables used in the process industries. With these new processing dynamics, the risk of major accidents around the world also increased. Due to the occurrence of major accidents, laws and regulations have been created to try to prevent this type of events, aiming to protect people, assets, the environment and corporate image. Management systems for process safety are used as a series of blocking barriers to prevent the development of major accidents. For the oil industry, there are some recommended practices from multiples institutes and government agencies. By employing a descriptive case study and documental analysis, the present study aims to compare the existing Process Safety Management Systems with the Health, Safety and Environment management system of a world leader energy company. More specifically, this research maps, compares and verifies which elements of these established management systems have been incorporated to the organization's HSE management system and provides a series of recommendations for practice and policy as well as contributions to the literature.

Keywords: Process Safety Management; Major Accidents; Loss Prevention, Environment Protection.

2.1 – Introdução / Introduction

The emergence of new technologies combined with new market requirements has generated major changes in the means of production in any industry. The opening of new consumer markets, globalization, stiffer competition, technological changes and the need to increase production efficiency make the management of productive systems a challenging task. In the oil and gas industry it is not different (Silvestre and Dalcol, 2009; Matos and Silvestre, 2013) and these factors combined with the need to produce large volumes under more hostile conditions (i.e., higher pressure, temperature and flow rates, with reduced time for maintenance) generate a scenario where companies remain exposed to higher risks of accidents, which can cause irreparable environmental and/or social losses (Hall et al, 2012; Silvestre, 2014).

The history of the oil and gas supply is marked by several accidents with severe environmental and social impacts. For example, the Piper Alpha and Exxon Valdez accidents were milestones for the oil and gas industry (Vinnem, 2007; Zio, E. et Aven, T., 2013). More recently, the 2010 Deepwater Horizon accident "revealed a series of management and technical gaps in the field of offshore drilling process. The loss of 11

.

lives and the short-term and long-term environmental impacts have brought the world a big lesson" (Mannan, 2012, p.10).

After these accidents, which usually become learning opportunities for the oil and gas industry, the society may observe the discussion and sometimes the implementation of new and stricter regulations, normative changes, new measures for risk reduction and additional protective barriers to prevent similar accidents (Gupta et al, 2005; Decola, 2009; ABS, 2010, NASA, 2013; Mendes et at., 2014). These new directives are usually proposed by a number of organizations and governmental agencies, but there are few mechanisms to ensure companies comply with all required guidelines to operate. This is because the globalization and the fact that supply chains are often spread across multiple countries, make the control and enforcement especially complex to be executed.

This study aims to help to address this gap and assess the main proposals of process safety management systems (PSMS) guidelines and compare them with each other and with the Petrobras' Health, Safety and Environment (HSE) management system. More specifically, this research aims to verify if the Petrobras' HSE management system meets all requirements of the main PSMS guidelines and contribute to the improvement of the Petrobras' HSE management system by providing key recommendations for policy, practice and research.

The paper continues as follows: in the Section 2, we examine how accidents work as triggers for changes in safety regulations and procedures while in the Section 3, we discuss issues related to the Process Safety Management Systems. In the Section 4, we discuss the methods used in this research, followed by the case of Petrobras' HSE management system in Section 5, and the results and discussion of this article in the Section 6

2.2 – Discussões recentes de acidentes e mudanças regulamentares / Recent discussion of accidents and regulation changes

The Seveso disaster, which occurred in a small chemical manufacturing in 1976 in Italy generated an important discussion across industries. Although, it occurred in the chemical industry, the Seveso accident gave rise to numerous standardized industrial safety regulations, affecting also the oil and gas industry. For example, in 1982, the first Seveso directive urged countries of the European Community to create legislation requiring companies with inventory of hazardous materials above a certain amount to prepare the safety report with a list of accidents that have occurred on the premises and measures to be taken to prevent these incidents to occur. In the United States the law called Right to Know Act, which requires that the facilities considered dangerous should declare publicly about the risks of its facilities and possible accidents that might occur was created, so the neighbors know about emergency scenarios and the actions that should be taken if these scenarios occur (Gupta et al, 2005).

Although regulations and safety investments for the oil and gas industry have been on the core of the industry discussions, historically severe accidents within the industry have also worked as triggers for change, especially related to offshore production facilities. For example, the accident with the oil tanker Exxon Valdez, which occurred on the coast of Alaska in 1989, was one of the most devastating environmental disasters worldwide, leading to death approximately 250,000 birds, 2,800 sea otters, 300 seals, 247 bald eagles, 22 killer whales and billions of salmon and herrings. This is due to the spill of approximately 37,000 ton of crude oil released in the Alaskan coast (ZIO, et AVEN, 2013). After the Exxon Valdez accident, the number of protective barriers to prevent similar accidents increased such as the Oil Pollution Act of 1990. This US law, among

.

other directives, requires for double hull on tankers built since then and a timeline for phasing out of single hull vessels built before 1990, according to the capability of the ship and its age (Decola, 2009).

The Piper Alpha accident also generated changes in regulations. After the investigation of the accident, Lord Cullen elaborated the Cullen Report emphasizing the need for the Safety Case, which is a study required from the oil and gas companies whose content specifies the environmental and human risk level, associated with the production unit (NASA, 2013). More recently, the Deepwater Horizon accident has prompted governments and industry to move forward and adopt new safety measures and procedures to reduce the risk to have accidents of such proportions.

2.3 – Sistemas de gestão de segurança de processos / Process Safety Management Systems

Process Safety Management Systems (PSMS) help ensure long-term sustainability of effective safety, health and environmental performance. The literature recognizes that effective PSMS drive sustainability performance (Mannan, 2012). The main idea is that if a hazard passes through an existing barrier (or multiple layers of barriers), then the incident/loss will occur. To prevent incidents and losses to occur, a PSMS needs to be broader and more comprehensive by implementing as many barriers or safeguards as possible to reduce the likelihood of the accidents to occur (Reason, 2007).

Process Safety Management Systems (PSMS) have usually two main drivers, which cover a full range of the incident spectrum: a) Occupational health and safety (OH&S) management, and b) engineering and process safety (EPS) management. The OH&S management at the workplace addresses the low severity-high frequency end of the incident spectrum .These essentially cover work related injuries (e.g. slips, trips, falls, injury sustained during manual handling, man-machine interfaces, exposure to high noise levels etc.). The main characteristics of the OH&S management system are injury prevention and rehabilitation. The EPS management involves the identification and management of hazards and risks involved in industrial facilities. And it consists of policies, in a process that involves establishment of procedures, standards and allocation of resources that will be strategic used to ensure safety. The implementation of a PSMS helps the company to manage the risk of the installation throughout its life cycle. (CCPS, 1993, CCPS, 1994, CCPS, 2008, Mannan, 2012).

Therefore, PSMS is a program or activity involving the application of management principles and analytical techniques to ensure the safety of industrial processes (CCPS, 1992, apud, Barbosa, 2009). The importance of effective PSMS has been stressed in a number of reports on safety in the oil and gas industry (Cullen,1990; Mannan, 2012).

The likelihood of major accidents is generally very low. However, the absence of very unlikely events is not, in itself, a sufficient indication of good safety management (EPSC, 1996, apud Mannan, 2012). PSMS involves the application of management principles and analytical techniques to ensure the safety of industrial processes. According to Mannan, (2012) PSMS components are: 1. Safety Policy development and communication; 2. Organizational development; 3. Development and implementation of SMS; and 4. Development of a system to measure SMS performance through an auditing process.

In this context that the PSMS, which among other objectives seeks to prevent environmental damage without loss of containment of hazardous substances to the environment, in other words, through various tools, works to fluids remain within the vessels, piping and systems so incidents not occur, thus protecting the environment, human life and industrial facilities. These tools can be grouped into a Process Safety Management (PSM) (Mannan, 2012; Souza et Lima, 2013).

.

2.3.1. Seveso III

The first international experience for the prevention of major accidents occurred in June 1982, with the publication in the European Community (now European Union) of Directive 82/501/ECC, better known as "Seveso Directive" (PUIATTI, 2000). The Seveso accident contributed dramatically to the growth of public concern about the risks associated with the industrial production (De Marchi et al., 2000).

The Seveso directives have been updated through several versions. More recently, Seveso III (2003) proposes an inherent three-level provisioning of proportional controls, which in practice means that where the quantities are greater control is also greater. Companies working with hazardous substances in excess of the amounts set by the directive need to establish a Safety Report, a Safety Management System and Emergency Plan. The new Directive also includes detailed rules to ensure proper public consultation on individual projects and introduces stricter rules for inspections.

2.3.2. International Labour Organization (ILO) Convention 174

The International Labour Organization - ILO, in June 1993, issued the Convention 174, which aims at the prevention of major accidents involving dangerous substances and limit the consequences of such accidents (ILO, 2002). According to Rocha et al. (2006), after the Bhopal disaster in India in 1984, the ILO initiated a series of activities in the field of chemical safety, as the ILO Convention 170 on the safe use of chemicals in the workplace, approved in 1990, and its recommendations, which provide basis for a system of chemical safety. Special attention should be given to the ILO Convention 174 on the prevention of major industrial accidents, approved in 1993, accompanied by Recommendation 181 by a code of practice and a manual for the prevention of major industrial accidents. Its main objective is to prevent major accidents involving dangerous substances and limit their consequences (Machado, 2004)

According to the classification of Soares (2001), this international agreement composes the group of multilateral treaties and conventions on the environment, entitled "Protection of Workers, Regulating Toxic Materials, in several aspects, the Regulations of Certain Industrial Activities "and refers more specifically to the field of chemical safety. The Convention has its basis in the "Seveso Directive" and has the scope and application only in facilities exposed to major accidents, as the chemical, petrochemical, oil and gas, explosives, storage of dangerous products, terminals, etc.

2.3.3. SGSO – ANP

The National Petroleum Agency (ANP) is the regulator of the activities of the oil and gas industry and the biofuels industry in Brazil. After the accident of the P-36, ANP conducted a benchmarking study with the regulatory agencies in other countries, especially the United States, Norway and the UK to set its model of Operational Safety Management in 2007 (ANP,2007).

Through Resolution Nº.43/2007, ANP established the Operational Safety Management System (SGSO), whose scope is offshore exploration and production, i.e., drilling, completion, well intervention, production of oil and natural gas, primary oil processing, storage, oil transferring and compression and transferring of natural gas (ANP, 2007; Mendes et al, 2014). The SGSO aims to establish the requirements and guidelines for implementation and operation of PSMS based on the adoption of 17 Management Practices (MP) divided into three categories: a) leadership, staff and management (1: Safety Culture, Commitment and Managerial Responsibility; 2: Workforce commitment; 3: Qualification, Training and Personal Performance; 4: Working Environment and Human Factors; 5: Selection, Control and Management of Contractors; 6: Monitoring and Continuous Performance Improvement; 7: Auditing; 8: Information Management and

.

Documentation; and 9: Incident Investigation), b) installation and technology (10: Design, Construction, Installation and Decommissioning; 11: Critical Elements of Operational Safety; 12: Risk Identification and Risk Analysis; 13: Mechanical integrity; and 14: Planning and Management of Major Emergencies), and c) operational practices (15: Operational Procedures; 16: Management of Change; and 17: Safe Work Practice and Control Procedures in Special Activities).

2.3.4. API RP 750

API Recommended Practice 750 was developed by the American Petroleum Institute, directed to the oil and gas industry (API, 1990). API model has 11 elements. Management commitment, responsibility and accountability, and employee participation/communication have not been included as separate elements. Its 11 elements are: Process safety information; Process hazard analysis; Management of change; Operating procedures; Safe work practices; Training; Assuring the quality and mechanical integrity of critical equipment; Pre-start-up safety review; Emergency response and control; Investigation of process-related incidents; Audit of process hazards management systems (API, 1990).

2.3.5. Center for Chemical Process Safety - CCPS

The CCPS was created by the American Institute of Chemical Engineers (AIChE) in 1985, after the accident at Bhopal, India, in order to contribute to the evolution of process safety in the chemical, pharmaceutical and oil industries. The CCPS brings together companies in the industry, government agencies, consultants and academics.

The PSMS proposed by the CCPS consists of 20 elements, structured around four blocks: Block 1 – Commitment to process safety (1.1 Process safety culture; 1.2 Standards, Codes, Regulations and Laws; 1.3 Process safety competency; 1.4 Workforce involvement; and 1.5 Stakeholders outreach); Block 2 – Understand Hazards and Evaluate Risk (2.1 Process Knowledge Management; and 2.2 Hazard Identification and Risk Analysis), Block 3 – Risk Management (3.1 Operating Procedures; 3.2 Safe Work Practices; 3.3Asset Integrity and Reliability; 3.4 Contractor Management; 3.5 Training and Performance Assurance; 3.6 Management of Change; 3.7 Operational Readiness; 3.8 Conduct of Operations; 3.9 Emergency Management), and Block 4 – Learn from Experience (4.1 Incident Investigation; 4.2 Measurement and Metrics; 4.3 Auditing; and 4.4 Management Review and Continuous Improvement) (CCPS, 1993, CCPS, 1994, Frank, 2007, CCPS, 2008).

2.4 – Método / Material and Method

Research consists of a formal procedure, with method of reflective thinking that takes a scientific approach, through which we can know the reality or discover partial truths, with the objective of finding answers to questions formulated by the researcher. The method used in the research should be related to the problem to be analyzed, depending on the observed phenomenon, objective and other issues involving the process of scientific research (Marconi and Lakatos, 2008).

According to Gil (2011), there are three research groups according to the proposed goals, classified as: exploratory, descriptive and explicative.

In this study, was chose initially an exploratory research. The exploratory research are those whose primary purpose is to develop clarify and modify concepts and ideas, in order to formulate more precise hypotheses or searchable problems for further studies (Gil, 2011).

.

This research was done through a search in the Engineering Village database and through a bibliographic and documentary review of bibliographic material published since 2009 and documents such (legislations, standards and guidelines). This exploratory research aims to present the evolution of the theme, through the main guidelines, regulations and management systems for process safety around the world and, subsequently, their influence and implementation (when applicable) in offshore production activities of oil and natural gas in Brazil.

Engineering Village (Elsevier) was chosen as search database because it has access to major journals that deal with the research's subject. Then, the work has a more descriptive characteristics. Descriptive studies are defined as those whose primary objective is description of the characteristics of a given population or phenomenon, or even the establishment of relationships between variables (Gil, 2011).

This study aims to present and compare the functions of the Management Systems of the main guidelines for the management of process safety around the world. It was chosen on this study, to analyze the following standards, national laws and international laws: Process Safety Management System of CCPS (Center for Chemical and Process Safety), ILO (International Labour Organization) Convention 174, Seveso Directive III these last two used mainly in North America and Europe, respectively. For the oil and gas industry there is recommended practices (RP) of API (American Petroleum Institute) 750 and the management practices of the Brazilian ANP's Operational Safety Management System.

This descriptive part of the research and the exploratory part of the research were done by search in Engineering Village databank and search of guidelines and legislations on the World Wide Web. This study also sought to evaluate how a large energy company in Brazil, object of case study, incorporated the functions of these guidelines for managing process safety in the company's health, safety and environment management system. Therefore, it also develops a case study that aimed to describe its management system based on the guidelines of process safety management.

According to Yin (2005), the case study is an empirical study that investigates a current phenomenon of real life, generally considering that the boundaries between the phenomenon and the context in which it operates are not clearly defined. It is actually a kind of history of the phenomenon, extracted from multiple sources of evidence where any relevance to the chain of events that describe the phenomenon actually is particular potential for the case study.

The company, object of the case study, is the largest company in the energy sector in Brazil and was chosen for having enormous challenges for the management of process safety, due to its operations complexity in the sector. The case study, that intended to evaluate the process safety management system of the company based on main guidelines, was done from an extensive documentary research and review on the health, safety and environment management system company's guidelines.

2.5 – O caso do Sistema de segurança, meio ambiente e saúde da Petrobrás / The Case of Petrobras' Health, Safety and Environment Management System

According to Souza et Lima (2013), in 2001/2002, the company started the Safety Process Management Program helped by a consulting company. In that moment, despite of the program be called of a Process Safety Program, the main practices consolidated were regarded to occupational safety, i.e., practices to prevent accidents/incidents when a task is performed. The main idea of the 15 guidelines are placed above.

.

Guideline 1 – LEADERSHIP AND ACCOUNTABILITY: To specify the necessary conditions to conform to Health, Safety and Environment (HSE) Corporate Guideline. By integrating health, safety and environment into corporate strategy, the company confirms the commitment of all employees and contractors to excellence in these areas. The main focus on this guideline is "leadership by example" - The commitment with HSE performance of persons with positions such as president, director, manager, coordinator, supervisor, contract manager and contract inspector within the Company System is clear: the leadership shall be performed by example to seek the commitment of the workforce with HSE performance.

Guideline 2 – REGULATORY COMPLIANCE: The company's activities shall comply with current health, safety and environmental legislation. On this guideline, the company make a statement that the company's activities shall comply with current health, safety and environmental legislation, and all the employees and contractors must do the same.

Guideline 3 – RISK EVALUATION AND MANAGEMENT: To specify the necessary conditions to conform to Health, Safety and Environment (HSE) Corporate Guideline. The risks inherent to the company's activities shall be identified, evaluated and managed to prevent accidents and/or ensure the minimization of their effects.

Guideline 4 – NEW PROJECTS: To establish the general requirements to the HSE Management, aiming the excellence of HSE and Energetic Efficiency along of the project life cycle. The new project shall be in accordance with the legislation and incorporate the best, safety and environment practices during their entire life cycle.

Guideline 5 – OPERATION AND MAINTENANCE: To specify the necessary conditions to conform to Health, Safety and Environment (HSE) Corporate Guideline. The company's operations shall be carried out according to established procedures, and using adequate facilities and equipment, inspected and fit to meet health, safety and environment requirements.

Guideline 6 – MANAGEMENT OF CHANGE: To specify the necessary conditions to conform to Health, Safety and Environment Corporate Guideline. Temporary or permanent changes shall be evaluated in order to eliminate and/or minimize implementation risks.

Guideline 7 - ACQUISITION OF GOODS AND SERVICES: To specify the necessary conditions to conform to Health, Safety and Environment (HSE) Corporate Guideline. Contractors', suppliers' and partners' health, safety, and environmental performance shall be consistent with the company's system.

Guideline 8 – TRAINING, EDUCATION AND AWARENESS: To specify the necessary conditions to conform to Health, Safety and Environment (HSE) Corporate Guideline. Training, education and awareness shall be continuously promoted in order to reinforce the work force's commitment to health, safety and environmental performance.

Guideline 9 – INFORMATION MANAGEMENT: To specify the necessary conditions to conform to Health, Safety and Environment (HSE) Corporate Guideline. Information and knowledge regarding health, safety and environment shall be accurate, updated and documented in order to facilitate its consultation and use.

Guideline 10 – COMMUNICATION: To specify the necessary conditions to conform to Health, Safety and Environment (HSE) Corporate Guideline. Information concerning health, safety and environment shall be reported clearly, objectively and promptly to produce expected effects.

.

Guideline 11 – CONTINGENCY: To specify the requirements to conform to Health, Safety and Environment Corporate Guideline. Emergency situations should be quickly and effectively anticipated and confronted in order to reduce the effects of such situations.

Guideline 12 – COMMUNITY RELATIONS: To specify the necessary conditions to conform to Health, Safety and Environment Corporate Guideline. Care for the safety of the communities where it operates, by keeping the communities informed of impacts and/or risks eventually caused by its activities.

Guideline 13 – ACCIDENTS AND INCIDENTS ANALYSIS: To specify the necessary conditions to conform to Health, Safety and Environment (HSE) Corporate Guideline. Accidents and incidents caused by the company´s activities shall be reviewed, investigated and documented to prevent their recurrence and/or to ensure the minimization of their effects.

Guideline 14 - PRODUCT STEWARDSHIP: To specify the necessary conditions to conform to Health, Safety and Environment (HSE) Corporate Guideline. The company shall take care of all health, safety and environmental aspects of its products from their origin to final destination, as well as be committed to continuously reduce potential impacts its products may cause.

Guideline 15 - ASSESSMENT AND CONTINUOUS IMPROVEMENT: To specify the necessary conditions to conform Health, Safety and Environment (HSE) Corporate Guideline – Assessment and Continuous Improvement. Assurance of health, safety and environmental performance shall be promoted at all levels of the company, in order to ensure improvements in these areas.

2.6 – Resultados e conclusões / Results and Conclusions

All comparisons in this section where done arranging the Process Safety Systems according to the 4 blocks proposed by CCPS Management System (Commitment to Process Safety, Understand Hazards and Evaluate Risk, Manage Risk and Learn from Experience). After the assessment of the various proposals of systems to the management of process safety was possible to compare them to the Petrobras' HSE management system. The Table 1 shows a detailed comparison between the different systems.

A greater importance is given to those items presented in the Block "Understand and Evaluate Hazards Risk", which emphasizes Knowledge of the Process, Hazard Identification and Risk Analysis, because these items are essential to identify what can go wrong and what can be done to prevent major accidents.

The block "Manage Risk" implements the safeguards themselves. Both preventive (Procedures, Safe Work Practices, Asset Integrity and Reliability, Contractor Management, Training and Performance Assurance, Management of Change, Operational Readiness Conduct of Operations) and mitigatory (Emergency Management). Safe Work Practices is not a guideline on Petrobras' HSE management system due to the fact that it is an operational process covered by the Permit to Work procedure that is mandatory to every task involving risk. Management of Change and Safe Work Practice items are not in ILO 174 and Contractor Management item is not included in Seveso III or API RP 750. Training and performance assurance is not an issue present on the Seveso III safety system proposal.

The item Operational Readiness is not explicit in any system unless the on CCPS proposal. As a term used in the reliability of safety systems, when transported to an operator it is inherent to safe operating practices in any condition. However, Conduct of

.

Operations is present only on Petrobras' HSE management system due to the fact that as an operator all employees must follow which was determined by the employer and the employer has to ensure that.

Learning from experience gives great importance on incident investigation and is present in all management systems evaluated. Measurement and metrics are present only on CCPS, ANP, Petrobras' HSE and Seveso III, also on these Management Review and Continuous Improvement is an item of great importance to improve the safety systems and the safety conditions. On the other hand, Auditing is present on ILO, API RP 750, ANP, Petrobras and Seveso III and its results also improve the safety systems and the safety conditions.

Policy is present only in Seveso III and Petrobras' HSE management system (Table 2). On the latter, each organizational unit has its own HSE policies, which always comply with the company's HSE guidelines. Other items that were not classified by the frame of CCPS system were: ANP Management Practice nº4: Working Environment and Human Factors; ANP Management Practice nº 10 – Design, Construction, Installation and Decommissioning; Petrobras Guideline 4 – New Projects; and Petrobras Guideline 14 – Product Stewardship.

.

Tabela 2.1– Guidelines de segurança de processo comparados com o PSMS proposto pelo CCPS (Table 1- Safety Management guidelines compared with CCPS Management System).

MANAGEMENT FUNCTION	CCPS	ILO	API RP 750	ANP	PETROBRAS	SEVESO III
COMMITMENT TO PROCESS SAFETY	PROCESS SAFETY CULTURE	-	-	MP Nº 1: SAFETY CULTURE, COMMITMENT & MANAGERIAL RESPONSIBILITY	GUIDELINE 1 – LEADERSHIP & ACCOUNTABILITY	-
	STANDARDS, CODES, REGULATIONS & LAWS	-	-	-	GUIDELINE 2 – REGULATORY COMPLIANCE	-
	PROCESS SAFETY COMPETENCY	-	-	-	GUIDELINE 8 – TRAINING, EDUCATION & AWARENESS	-
	WORKFORCE INVOLVMENT	-	-	MP Nº 2: WORKFORCE COMMITMENT	GUIDELINE 1 – LEADERSHIP & ACCOUNTABILITY	ORGANISATION & PERSONNEL - ANNEX III (I)
	STAKEHOLDERS OUTREACH	ART. 16	-	-	GUIDELINE 10 – COMMUNICATION & GUIDELINE 12 – COMMUNITY RELATIONS	NOTIFICATION - ARTICLE 7
UNDERSTAND HAZARDS AND EVALUATE RISK	PROCESS KNOWLEDGE MANAGEMENT	ART. 8	PROCESS SAFETY INFORMATION	MP Nº 8: INFORMATION MANAGEMENT & DOCUMENTATION	GUIDELINE 9 – INFORMATION MANAGEMENT	SAFETY REPORT - ARTICLE 10
	HAZARD IDENTIFICATION & RISK ANALYSIS	ART. 7 & 9	PROCESS HAZARD ANALYSIS	MP Nº 12: RISK IDENTIFICATION & RISK ANALYSIS;	GUIDELINE 3 – RISK EVALUATION & MANAGEMENT	IDENTIFICATION & EVALUATION OF MAJOR HAZARDS - ARTICLE 9, 10 & ANNEX III (II)
MANAGE RISK	OPERATING PROCEDURES	ART. 21	OPERATING PROCEDURES & PRE-START-UP SAFETY REVIEW	MP Nº 15 OPERATIONAL PROCEDURES	GUIDELINE 5 – OPERATION & MAINTENANCE:	OPERATIONAL CONTROL - ANNEX III (III)
	SAFE WORK PRACTICES	-	SAFE WORK PRACTICES	MP Nº 17: SAFE WORK PRACTICE & CONTROL PROCEDURES IN SPECIAL ACTIV.	-	OPERATIONAL CONTROL - ANNEX III (III)
	ASSET INTEGRITY & RELIABILITY	ART. 9(C)	ASSURING QUALITY & MECHANICAL INTEGRITY OF CRITICAL EQUIPMENT	MP Nº 11: CRITICAL ELEMENTS OF OPERATIONAL SAFETY & MP Nº 13: MECHANICAL INTEGRITY	GUIDELINE 5 – OPERATION & MAINTENANCE	INSPECTIONS (INCLUDING MECHANICAL INTEGRITY) - ARTICLE 20
	CONTRACTOR MANAGEMENT	ART. 9(C)	-	MP Nº 5: SELECTION, CONTROL & MANAGEMENT OF CONTRACTORS	GUIDELINE 7 - ACQUISITION OF GOODS & SERVICES	-
	TRAINING & PERFORMANCE ASSURANCE	ART. 9(C)	TRAINNING	MP Nº 3: QUALIFICATION, TRAINING & PERSONAL PERFORMANCE	GUIDELINE 8 – TRAINING, EDUCATION & AWARENESS	-
	MANAGEMENT OF CHANGE	-	MANAGEMENT OF CHANGE	MP Nº 16: MANAGEMENT OF CHANGE	GUIDELINE 6 – MANAGEMENT OF CHANGE	MANAGEMENT OF CHANGE - ARTICLE 11 & ANNEX III (IV)
	OPERATIONAL READINESS	-	-	-	-	-
	CONDUCT OF OPERATIONS	-	-	-	GUIDELINE 5 – OPERATION & MAINTENANCE	-
	EMERGENCY MANAGEMENT	ART. 9(D/E)	EMERGENCY RESPONSE & CONTROL	MP Nº 14: PLANNING & MANAGEMENT OF MAJOR EMERGENCIES	GUIDELINE 11 – CONTINGENCY	PLANNING FOR EMERGENCIES - ANNEX III (V)
LEARN FROM EXPERIENCE	INCIDENT INVESTIGATION	ART. 9(G), 13 & 14	INVESTIGATION OF PROCESS-RELATED INCIDENTS	MP Nº 9: INCIDENT INVESTIGATION	GUIDELINE 13 – ACCIDENTS & INCIDENTS ANALYSIS	MONITORING PERFORMANCE - ANNEX III(VI)
	MEASUREMENT & METRICS		-	MP Nº 6: MONITORING & CONTINUOUS PERFORMANCE IMPROVEMENT	GUIDELINE 15 - ASSESSMENT & CONTINUOUS IMPROVEMENT	MONITORING PERFORMANCE - ANNEX III(VI)
	AUDITING	ART. 18	AUDIT OF PROCESS HAZARDS MANAGEMENT SYSTEMS	MP Nº 7: AUDITING	GUIDELINE 15 - ASSESSMENT & CONTINUOUS IMPROVEMENT	AUDIT & REVIEW - ANNEX III (VII)
	MANAGEMENT REVIEW & CONTINUOUS IMPROVEMENT		-	MP Nº 6: MONITORING & CONTINUOUS PERFORMANCE IMPROVEMENT	GUIDELINE 15 - ASSESSMENT & CONTINUOUS IMPROVEMENT	MONITORING PERFORMANCE - ANNEX III (VI)

.

Tabela 2.2–*Itens identificados nos guidelines e Sistema de gestão de SMS da Petrobrás, que não estão contidos no PSMS proposto pelo CCPS (*Table 1 – Items not included in CCPS Management System).

ITEM	CCPS	OIT	API RP 750	ANP	PETROBRAS	SEVESO III
POLICY / STATEMENTS	-	-	-	-	HSE POLICY OF EACH ORGANIZATIONAL UNIT	MAJOR ACCIDENT PREVENTION POLICY (MAPP) - ARTICLE 8
OTHERS	-	-	-	MP Nº 4: WORKING ENVIRONMENT & HUMAN FACTORS & MP Nº 10: DESIGN, CONSTRUCTION, INSTALLATION & DECOMMISSIONING	GUIDELINE 4 – NEW PROJECTS & GUIDELINE 14 - PRODUCT STEWARDSHIP	-

2.7 – Referências / References

API – American Petroleum Institute. Management of Process Hazards Recommended Practice 750. 1990.

BARBOSA, D. P.; HARGUENAUER, D. F. A influência do fator humano nos cenários acidentais de uma refinaria de petróleo. In: V Congresso Nacional de Excelência em Gestão. Niterói, 2009.

CCPS - Center for chemical process safety. Guidelines for engineering design for process safety. 2. ed. New York: American Institute of Chemical Engineers, 1993.

CCPS - CENTER FOR CHEMICAL PROCESS SAFETY. Guidelines for Hazard Evaluation Procedures. 3. ed. New York: AICHE, 2008.

CCPS - CENTER FOR CHEMICAL PROCESS SAFETY. Guidelines for preventing human error in process safety. New York: AICHE, 1994.

CULLEN, W. D. Report of the Official Inquiry into the Piper Alpha Disaster. 1990.

DE MARCHI, B.; FUNTOWICZ. S.; RAVETZ, J. O. Acidente industrial de Seveso: paradigma e paradoxo. In: FREITAS, C. M; PORTO, M. F .S.; MACHADO, J. M. H. (Orgs.). Acidentes industriais ampliados: desafios e perspectivas para o controle e a prevenção. Rio de Janeiro: Editora Fiocruz, 2000. p. 129-148.

DECOLA, E. A Review of Double Hull Tanker Oil Spill Prevention Considerations. Nuka Research & Planning Group, LLC. 2009.

DIRECTIVE 82/501/CEE of the council of 24 June 1982 on the major-accident hazards of certain industrial activities. Official Journal of the European Communities, L 230/1, 1982.

EPSC - European Process Safety Centre. Safety Management Systems. Institution of Chemical Engineers, Rugby, 1994.

FRANK, W. L. Process safety culture in the CCPS risk based process safety model. Process safety progress. 2007. v. 26, n. 3, p. 203-208.

GUPTA, J. P.; NETO, A. D. C.; MERRITT, C. W.; HUNGERBUHLER, K .; MANNAN, M. S.; Tamaura, M. Announcement / Journal of Loss Prevention in the Process Industries 18, 2005.

HALL, J., MATOS, S., & SILVESTRE, B. (2012). Understanding why firms should invest in sustainable supply chains: a complexity approach. International journal of production research, 50(5), 1332-1348.

ILO (2001). INTERNATIONAL LABOUR ORGANIZATION. Guidelines on occupational safety and health management systems. ILO-OSH 2001. Geneva: International Labour Office, 2001.

.

ILO (2002). International Labor Organization. Convention ILO 174, Recommendation 181: Prevenção de acidentes industriais maiores. Tradução de Abiquim/Fundacentro. São Paulo: Fundação Jorge Duprat Figueiredo de Segurança e Medicina do Trabalho, 2002.

SOUZA, R. G., LIMA, G.B.A. IMPORTÂNCIA DOS ELEMENTOS ESTRUTURANTES DE UM PROGRAMA DE GESTÃO DE SEGURANÇA DE PROCESSO: ESTUDO DE CASO EM UMA EMPRESA DE ENERGIA. ISSN 1984-9354, Jun, 2013.

MANNAN, S. (Ed.). Lees' Loss prevention in the process industries: Hazard identification, assessment and control. Butterworth-Heinemann, 2012. ISBN: 978-0-7506-7555-0

MATOS, S., & SILVESTRE, B. S. (2013). Managing stakeholder relations when developing sustainable business models: the case of the Brazilian energy sector. Journal of Cleaner Production, 45, 61-73.

MENDES, P. A., HALL, J., MATOS, S., & SILVESTRE, B. (2014). Reforming Brazil' s offshore oil and gas safety regulatory framework: Lessons from Norway, the United Kingdom and the United States. Energy Policy, 74, 443-453.

NASA - National Aeronautics and Space Administration. The Case for Safety - The North Sea Piper Alpha Disaster, May 2013 Volume 7 Issue 4.

PUIATTI, R. A prevenção e os trabalhadores – aspectos comparativos da legislação dos EUA, da Grã-Bretanha e da Holanda. In: FREITAS, C. M; PORTO, M. F .S.; MACHADO, J. M. H. (Orgs.). Acidentes industriais ampliados: desafios e perspectivas para o controle e a prevenção. Rio de Janeiro: Editora Fiocruz, 2000.

REASON, J. Human error. New York: Cambridge University Press, 2003.

ROCHA JR, Edson; CAROLINA MAGGIOTTI COSTA, Maria; DOROTÉA GODINI, Maria. Acidentes ampliados à luz da "Diretiva Seveso" e da convenção Nº 174 da International Labor Organization - ILO. InterfacEHS-Revista de Saúde, Meio Ambiente e Sustentabilidade, v. 1, n. 2, 2013.

SEVESO III, Directive. Council Directive 2003/105/EC of the European Parliament amending Council Directive 96/82/EC on the control of major-accident hazards involving dangerous substances. Official Journal of the European Union No. L, v. 345, 2003.

SILVESTRE, B. S. (2014). A hard nut to crack! Implementing supply chain sustainability in an emerging economy. Journal of Cleaner Production.

SILVESTRE, B., & DALCOL, P. R. T. (2009). Geographical proximity and innovation: Evidences from the Campos Basin oil & gas industrial agglomeration—Brazil. Technovation, 29(8), 546-561.

SOARES,G. F. S. Direito Internacional do Meio ambiente: emergência, obrigações e responsabilidades. São Paulo: Atlas, 2001. TAVARES, R. N. As Organizações Não-Governamentais nas Nações Unidas. Brasília: Instituto Rio Branco; Fundação Alexandre Gusmão; Centro de Estudos Estratégicos, 1999.

VINNEM, Jan Erik. Offshore Risk Assessment: Principles, Modelling and Applications of QRA Studies. 2nd edition, London: Springer-Verlag London Limited, 2007.

ZIO, E., AVEN, T.; Industrial disasters: Extreme events, extremely rare. Some reflections on the treatment of uncertainties in the assessment of the associated risks. Process Safety and Environmental Protection 91, 2013.

.

3 - ARTIGO CIENTÍFICO II

Offshore oil production and process safety risk assessment in Brazil
Produção de petróleo *offshore* e avaliação de riscos de processo no Brasil

FELIPE A. G. P. GIMENES[2], ROMEU E SILVA NETO[3]

Resumo

A perspectiva de expansão da produção de petróleo e gás nas bacias exploratórias do mar territorial brasileiro, hoje, significa que há uma maior dinâmica de processamento de hidrocarbonetos nas plataformas de produção offshore. Com a instalação de novas unidades de produção e aumento dos volumes processados, o risco de acidentes de processo também aumenta. A fim de prevenir a ocorrência ou mitigar consequências desses eventos, operadoras de petróleo, juntamente com os seus sistemas de gestão de segurança de processos, utilizam técnicas de identificação de perigos e análise de riscos. Entre elas podemos destacar APR (Análise Preliminar de Riscos), *What-if?* e HAZOP (*Hazard and Operability Study*). Este trabalho tem como objetivo avaliar como a principal operadora de petróleo *offshore* da Bacia de Campos identifica e gerencia seus riscos operacionais, relativos a acidentes de processo, quais técnicas são utilizadas e como estas técnicas são aplicadas. APR e HAZOP são as duas técnicas mais comumente utilizadas na Bacia de Campos e suas aplicações exigem equipes multidisciplinares. Estas técnicas se mostraram complementares para a indústria *offshore* e se concentram em identificar e evitar consequências indesejadas para as pessoas, meio ambiente, patrimônio e imagem da empresa. As técnicas podem exigir, posteriormente, estudos adicionais.

Palavras-chave: Sistema de Gestão de Segurança de Processo; Acidentes Maiores; Prevenção de Perdas; Proteção Ambiental; Segurança de Processos Baseada em Risco.

[2] Safety Engineer at Petróleo Brasileiro S/A and Master Student at Instituto Federal Fluminense (IFF), this paper is part of a Master Dissertation to be presented to IFF.
[3] PHD in Production Engineering and Professor at Instituto Federal Fluminense.
.

Abstract

The perspective of expansion of oil and gas production in the exploratory basins of the Brazilian territorial sea, today, means that there is a greater dynamic of hydrocarbon processing on offshore production platforms. With the installation of new production units and the increasing of the processed volumes, the risk of process accidents also increases. In order to prevent the occurrence or mitigate consequences of these events, oil operators, together with its process safety management systems, use hazard identification and risk analysis techniques. Among them, we can highlight PreHA (Preliminary Hazard Analysis), What-if? and HAZOP (Hazard and Operability Study). This paper aims to evaluate how the main offshore oil operator in the Campos Basin identifies and manages its operational risks, concerning process accident, which techniques are used by this operator and how this operator applies hazard identification and risk assessment tools. PreHA and HAZOP are the two most commonly techniques used in Campos Basin and their applications require multidisciplinary teams. These techniques are complementary for the offshore industry. Both of them focus to identify and avoid unintended consequences for personal safety, environmental damage, property damage and damage to the company's image. The techniques may require subsequently additional safety studies.

Keywords: Process Safety Management; Major Accidents; Loss Prevention, Environment Protection.

3.1 – Introdução / Introduction

The oil industry in Brazil, through the platforms and onshore fields was responsible for the production of 2.03 million barrels of oil per day in 2013, as seen in chart 1, and has been increasing its production every year. Brazil´s main operator is expecting to produce in 2018 approximately 2.5 million barrels of oil per day and 2.8 million barrels of oil per day in Brazil in 2020 (ANP, 2014; PETROBRAS, 2015). The charts below show the period from 2004 up to 2013 of oil and gas production, stratified by type of production onshore/offshore and oil and gas production by concessionary.

According to Petrobras (2013), 2014-2018 the company will receive another 35 oil and gas production platforms to meet the expected production curve for 2020.

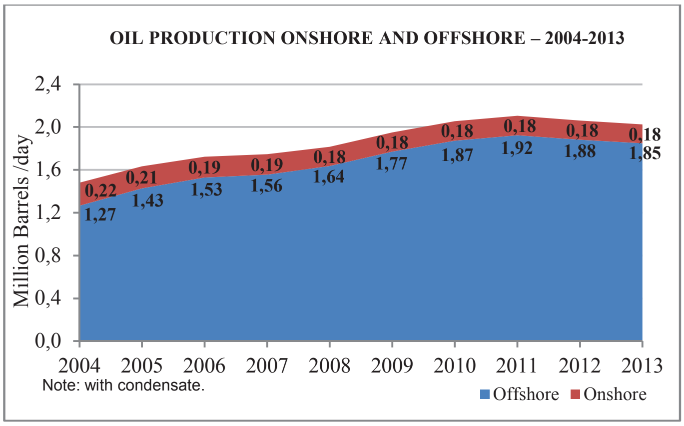

Ilustração 3.5 – Produção de óleo no Brasil de 2004 a 2013 (Chart 1 – Brazil´s oil production 2004-2013).

Source: ANP, 2014.

.

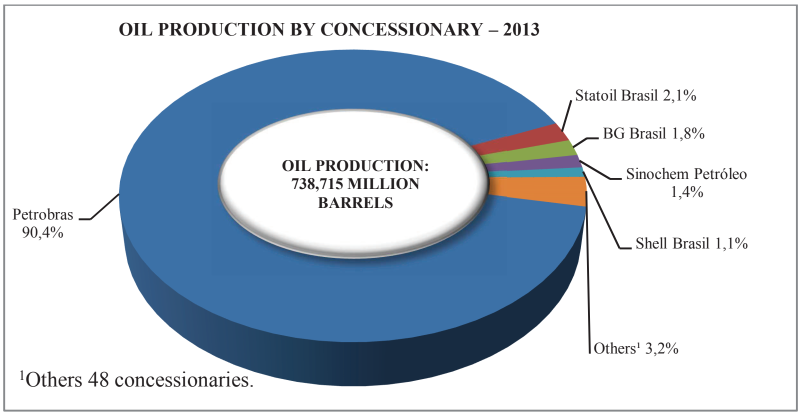

Ilustração 3.6 – Produção de óleo por concessionária (Chart 2 – Oil production by concessionary).

Source: ANP, 2014.

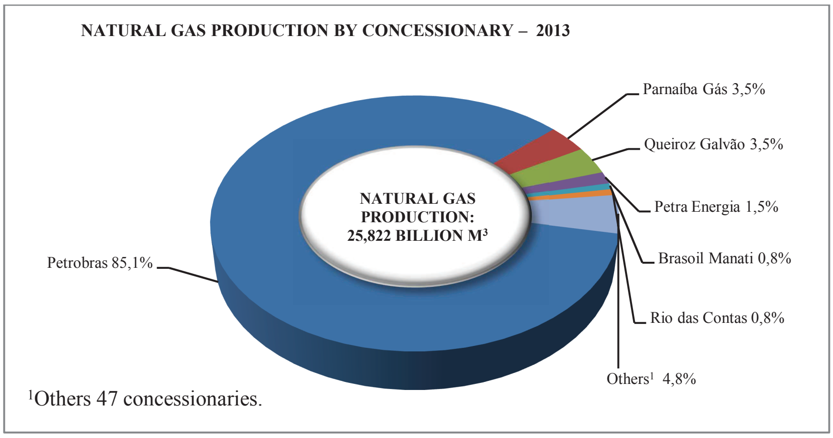

Ilustração 3.7 - Produção de gás por concessionária (Chart 3 – Gas production by concessionary).

Source: ANP, 2014.

As the biggest concessionary, processing expressive amount of oil and gas, as seen above, the concern with process safety should be presents in Petrobras operations as in any other concessionary and process industry. Therefore, those operations maintain their level of reliability and integrity, avoiding losses of containment and accidents. To avoid losses of containment, risk-based process safety management can be applied through the use of hazards identification and risk evaluation tools.

3.2 – Identificação de perigos e avaliação de riscos / Hazard identification and risk evaluation

According to Seveso III Directive, a Major Accident is an occurrence such as a major emission, fire, or explosion resulting from uncontrolled developments in the course of the operation of any establishment (covered by this Directive), and leading to serious danger to human health or the environment, immediate or delayed, inside or outside the establishment, and involving one or more dangerous substances. The denomination itself of these types of accidents varies from country to country. They are often called Major Accidents, this definition comes from Sevesso III Directive and is how this paper will name this type off accident. However, it is also called accidents majeurs in France, acidentes industriais graves in Portugal and Störfall in Germany, the last one means something like a Perturbation Accident. In Brazil, sometimes it´s called Major Accident (acidentes maiores) and sometimes acidentes industriais ampliados (DIRECTIVE, 2012; FREITAS *et al*, 1995).

.

According to ANP, 2007, API, 1990, CCPS, 2008, ILO, 2000, OSHA, 1992, Directive, 2012 and Mannan, 2012, hazard identification and risk analysis when inside a Process Safety Management (PSM) System are very important when we want to prevent the occurrence of major accidents.

The table below shows the relationship in all those standards and guidelines regarding to understanding hazards and evaluating risks.

Tabela 3.3– Itens relacionados ao bloco entendimento de perigos e avaliação de riscos (*Table 1 – Items related to Understand Hazards and Evaluate Risk created by the author).*

MANAGEMENT FUNCTION - ACCORDING TO CCPS	**CCPS**	**ILO**	**API RP 750**	**OSHA**	**ANP**	**SEVESO III**
UNDERSTAND HAZARDS AND EVALUATE RISK	PROCESS KNOWLEDGE MANAGEMENT	ARTICLE 8	PROCESS SAFETY INFORMATION	D. PROCESS SAFETY INFORMATION	MANAGEMENT PRACTICE Nº 8: INFORMATION MANAGEMENT AND DOCUMENTATION	SAFETY REPORT - ARTICLE 10
	HAZARD IDENTIFICATION AND RISK ANALYSIS	ARTICLE 7 ARTICLE 9	PROCESS HAZARD ANALYSIS	E. PROCESS HAZARD ANALYSIS	MANAGEMENT PRACTICE Nº 12: RISK IDENTIFICATION AND RISK ANALYSIS	IDENTIFICATION AND EVALUATION OF MAJOR HAZARDS - ARTICLE 9, 10 AND ANNEX III (II)

Process hazard identification and risks reviews are not intended to identify the minor “slips, trips, or falls”; these are the responsibility of the company’s general safety management system requirements and can be analyzed with other tools that are well established (e.g., Job Safety Analysis (JSA), Work Permit Procedure, etc.) (NOLAN, DENNIS P., 2011, p2).

It is qualitatively estimated that up to 80% of a company’s hazard identification and process safety analyses may consist of PreHA, What-If, and HAZOP reviews, with the remaining 20% comprising checklists, fault tree analysis, event tree analysis, failure mode and effects analysis, etc (NOLAN, DENNIS P., 2011, p3).

Conventional methods or techniques to analyze safety hazards can be categorized in two categories: qualitative and quantitative analyses. Qualitative methods normally require less information on technical details. These qualitative methods are based on brainstorming techniques or set of questions relevant to the process. These techniques are simple yet easy to understand. What-if, Checklist, Preliminary Hazard Analysis (PreHA) and Hazard and Operability Studies (HAZOP) are some examples of conventional qualitative methods used to review and identify hazards, both at early design and operating stage (RUSLI, 2010).

PreHA, What-If, and HAZOP reviews are, basically, a communication exercise, performed by a team. Information is presented, discussed, analyzed, and recorded. Specifically, the safety aspects are identified, to determine if adequate design measures have been taken to prevent major incidents/accidents as perceived by the review team (NOLAN, DENNIS P, 2014 p.9).

The primary objective of PreHA, What-If, and HAZOP reviews is to assure that major accidents will be avoided during the lifetime of the facility that the processes are under review. The objectives of these reviews should be thorough, impartial, and adequate (NOLAN, DENNIS P, 2014 p.10).

Generally, in the upstream (E&P) sector, 60%–80% of the safety reviews will be PreHA or What-If reviews, while in the downstream sector, 60%–80% will be HAZOP reviews (NOLAN, DENNIS P, 2014, p.33).

It has been found that the PreHA or What-If style of analysis is generally a convenient method to use for a “simple” facility when conducting a process hazard review. For simple facilities, the detailed

.

HAZOP approach has been found to be tedious and just as productive as a PreHA or What-If method (NOLAN, DENNIS P, 2014, p-33).

The PreHA and What-If approach stimulates generation of new ideas and discussion to cover issues associated with items under review as well as addressing generic issues. The specific HAZOP review is not necessary when the process is simple and well understood by the reviewing team. The team can readily review the major items of concern by asking What-If questions, such as what happens when a pump fails, without relying on itemized and detailed variations of a process condition as required by the HAZOP method, such as high level, low pressure or less flow.

Tabela 3.4– Técnicas qualitativas, semiquantitativa e quantitativas (Table 2 – Quantitative, semi quantitative and qualitative methods).

Qualitative Methods	**Semi Quantitative Methods**	**Quantitative Methods**
Checklists	Layers of Protective Analysis (LOPA)	Event Trees
Preliminary Hazard Analysis (PreHA)/Preliminary Risk Analysis (PRA)	-	Fault Trees
What-If Reviews	-	Failure Modes and Effects Analysis
Hazard and Operability Study (HAZOP)	-	Safety Integrity Level (SIL) Analysis
Bow-Tie Analysis (BTA)	-	-
Fishbone/Ishikawa diagram	-	-

Source: NOLAN, DENNIS P, 2014 adapted by the author.

HAZOP reviews have been stated as arising from the chemical industry in U.K. during the 1960s. Imperial Chemical Industries, Ltd. (ICI), developed a standardized method of analyzing processing hazards based on the basic operation conditions and then changed individual parameters one at a time to see the subsequent consequences. The technique evolved into a standard practice within their company and soon found its way into the general chemical industry, even though it was not universally or consistently applied (CCPS, 1992, NOLAN, DENNIS P., 2011, p7-8).

Simultaneously, most petroleum and chemical companies had also brainstormed a safety review which asks “What-If” questions of the process. This was common practice in the industry and during the design phases of a facility but was usually verbal and less formal in its application. Therefore, not as much historical documentation is available on it as compared to the HAZOP method (NOLAN, DENNIS P., 2011, p9).

In 1977 the U.S Military Standard System Safety Program Requirements was created and in 1984 it was updated to the MIL-STD-882B, a standard that had the purpose to identify the hazards of a system and to impose design requirements and management controls to prevent events that results in death, injury, occupational illness or damage to equipment. At that time the PreHA also had a hazard risk matrix (UNITED STATES, 1984).

The qualitative techniques used to assess risks in Campos Basin, the major offshore oil regions of Brazil, are mostly Hazard and Operability Study (HAZOP) and Preliminary Hazard Analysis (PreHA).

.

3.2.1. Techniques Advantages

According to Nolan, D. P (2014) and Nolan, D. P (2011) these are the PreHA, What-If and HAZOP advantages:

3.2.1.1 Preliminary Hazard Analysis

1. It is generally economical. The time/man-hours needed to perform the review will not be extensive;
2. It can identify concerns early in the project. Since a PreHA is usually conducted early in a project's life cycle, it can identify concerns early in the project's conceptual stage and avoid costly changes later but it can also be done in operational phase.

3.2.1.2 What-If Reviews

1. It can be accomplished with a relatively low skill level, Typically is a basic brainstorming session;
2. It is fast to implement compared to other qualitative techniques. Since What-If review is a direct question method, possibly from a standardized checklist, the questions can be easily and usually rapidly addressed;
3. It can analyze a combination of failures. The option of addressing continuing sequential failures can be investigated to the final outcome;
4. It is flexible. It is readily adaptable to any type of process flow or facility. Questions can focus on specific potential failures.

3.2.1.3 HAZOP Reviews

1. It uses a systematic and logical approach. It has a specific guideword listing and the process under review is subdivided into smaller sections for analysis;
2. It can analyze a combination of failures. The option of addressing continuing sequential failures can be investigated to the final outcome;
3. It provides an insight into operability features. Operation control methods are fully investigated for potential varying conditions in the entire process flow. From this review, an operator can readily deduct what hazards may be present at the facility.

3.2.2 Techniques Limitations or Disadvantages

According to Nolan, D. P (2014) and Nolan, D. P (2011) these are the techniques limitations:

3.2.2.1 Preliminary Hazard Analysis

1. It is based on experience. Usually, these reviews cannot be relied upon for identifying unrecognized hazards. A review team may fail to delve deep enough into the process or the process control with which they have become superficially familiar. Unless the right questions are asked by the review team, hazards may go unidentified;
2. It is not systematic. These reviews are typically considered a brainstorming session. Personnel familiar with the facility discuss aspects in a random fashion (i.e., whatever comes to mind). Therefore, most PreHA or What-If reviews refer to a checklist to overcome this handicap;
3. It is usually applied when limited information is available or may change. A PreHA is usually conducted early in a project's life cycle, usually in the initial conceptual stages or early design phase. Some information about the project may not be fully defined for an adequate review or the project scope or conceptual design may change significantly during this period.

.

3.2.2.2 *What-If Reviews*

1. It is based on experience. Usually, these reviews cannot be relied upon for identifying unrecognized hazards. A review team may fail to delve deep enough into the process or the process control with which they have become superficially familiar. This may be true for older team members where new technological control systems have made the application of 25–30 years of experience in older process control methods less relevant (e.g., PLCs versus relays, analog versus digital) However, experience and insight together will allow the identification of hazard scenarios that are not readily apparent. Unless the right questions are asked by the review team, hazards may go unidentified;
2. It is not systematic. These reviews are typically considered a brainstorming session. Personnel familiar with the facility discuss aspects in a random fashion (i.e., whatever comes to mind). Therefore, most PreHA or What-If reviews refer to a checklist to overcome this handicap.

3.2.2.3 HAZOP Reviews

1. It needs a moderate level of skill to implement. The review is a thorough and systematic process that has to be conducted in a proper fashion and accurately recorded. In order to perform a HAZOP review, a specialized team leader is assigned to guide the review team during the process. The team leader is usually someone who has had specialized training and experience in the conduction of HAZOP reviews;
2. It may be slower to implement than other methods. In order to perform a HAZOP review, a specialized team leader is assigned to guide the review team throughout the process. The team leader follows a standard format with special guidewords and deviations that need to be addressed. Because a standardized listing is used for all systems, some unnecessary and unimportant issues may be addressed in some portions of the system under review.

Tabela 3.5–*Comparativo entre as técnicas (*Table 3 – Techniques comparisons).

	PreHA/PRA	**What-If**	**HAZOP**
Experienced based	Yes	Yes	No
Systematic	Partially	Partially	Yes
Skill	Low	Moderate-Low	Moderate
Speed	Fast	Fast-moderate	Slow
Level of detail	General	Medium specific	Very specific
Relative cost	Moderate-low	Moderate-low	High-moderate
Flexible	Yes	Yes	Yes

Source: NOLAN, DENNIS, 2014.

.

3.3 – Método / Material and Method

According to Gil (2011), there are three research groups according to the proposed goals, classified as exploratory, descriptive and explicative.

In this study, was chose initially an exploratory research. The exploratory research are those whose primary purpose is to develop, clarify and modify concepts and ideas, in order to formulate more precise hypotheses or searchable problems for further studies (GIL, 2011).

According to Theodorson *et* Theodorson (1970), Exploratory study is a preliminary study that the major purpose of which is to become familiar with a phenomenon that is to investigate, so that the major study to follow may be designed with greater understanding and precision. The exploratory study (which may use any of a variety of techniques) permits the investigator to define his research problem and formulate his hypothesis more accurately. It also enables him to choose the most suitable techniques for his research and to decide on the questions most in need of emphasis and detailed investigation, and it may alert him to potential difficulties, sensitivities, and areas of resistance.

Exploratory studies are most typically done for three purposes: (1) simply to satisfy the researcher's curiosity and desire for better understanding, (2) to test the feasibility of undertaking a more careful study, and (3) to develop the methods to be employed in a more careful study (BABBIE, 1986).

First to carry out this work, an extensive literature review of risk assessment and risk management was done.

After the exploratory study, the research problem became clearer: Risk evaluations of offshore oil platforms, in Brazil, through PreHA and HAZOP techniques are sufficient to prevent major accidents?

Then, a case study to evaluate the research problem was performed.

According to Yin (2005), the case study is an empirical study that investigates a current phenomenon of real life, generally considering that the boundaries between the phenomenon and the context in which it operates are not clearly defined. It is actually a kind of history of the phenomenon, extracted from multiple sources of evidence.

The company, object of the case study, is the largest company in the energy sector in Brazil and was chosen for having enormous challenges for the management of process safety, due to its operations complexity in the sector.

Three PreHA and Hazop studies were followed. These studies were carried out on three types of platforms: Semi-submersible Platform (SS), Fixed Platforms and a Floating Production, Storage and Offloading (FPSO). These studies were complete reviews of offshore oil and gas production plants on operational phase in Campos Basin. During these risk assessments it was observed as these are carried out and its peculiarities. The techniques applications are more detailed on the next section.

3.4 – Técnicas aplicadas na Bacia de Campos / Campos Basin Techniques Application

Through the guideline 3, which is part of its Health, Safety and Environment (HSE) management system, risk management is part of company's operations. The way of preventively anticipate its risks and hazards is the application of techniques for hazard identification and risk analysis. These techniques must comply with a company standard, NI-2782. With the use of these techniques a

.

better risk management can be done into company´s operations, including the offshore oil and gas production (PETROBRAS, 2014a).

The technique to apply depends on the facility life cycle. Offshore platforms in Campos Basin are in operation lifecycle, so based on the chart below all techniques can be applied. To perform safety reviews on Campos Basin two risk assessment techniques are performed. The two techniques performed are Preliminary Risk Analysis and Hazard and Operability Study.

Applicable techniques for Operational Life Cycle of a Project
Checklist
What-If?
Preliminary Risk Analysis (PRA) Preliminary Hazard Analysis (PreHA)
Layers of Protection Analysis (LOPA)
Consequence Analysis
Quantitative Risk Analysis (QRA)

Ilustração 3.8 – Técnicas aplicáveis na fase operacional do ciclo de vida de um empreendimento (Chart 4 – Techniques and facility life cycle).

Both techniques are performed by teams and all studies are conducted by a Safety Study Leader that is familiar with the study method. The multidisciplinary team recommended is formed by professionals of process, operation, instrumentation/automation, industrial safety and maintenance areas. In most of the cases, a Scribe participates to fill the worksheets and help the Study Leader to conduct the study. HAZOP and PRA of an offshore platform are divided into four stages: (1) planning and documentation survey, (2) visit of the study leader to the platform, (3) multidisciplinary team meetings and (4) report preparation.

(1) planning and documentation survey:

The Safety Study Leader and the Plant Manager should plan and prepare a timetable for the study. This plan includes:

- Definition of the multidisciplinary team;
- Dates, location and resources for the meetings;
- Providing and verification of documentation.

Some examples of documentation to be considered are:

- Engineering and Process Flowcharts;
- P&ID - Piping and instrumentation diagram;
- Fire and Safety Plan;
- Area classification;
- MSDS - *Material Safety Data Sheet;*
- Equipment data sheets.

(2) visit of the study leader to the platform:

This visit has the objective to learn more about the unit, check its condition, the implemented recommendations of the last(s) risk assessment(s), changes made and ongoing projects.

.

(3) multidisciplinary team meetings

This step is the risk assessment and analysis using one or more structured techniques, with the participation of the multidisciplinary team. The techniques are going to be addressed in Sections 4.1 and 4.2 below.

(4) report preparation

After performing the analysis itself, the report that is the final product of the analysis should contain the team findings and recommendations, it also should contain:

- List of participants and the discipline in which they represented at the meeting (process, operation, instrumentation/control, industrial safety or maintenance);
- Study premises - the considerations which the study was based;
- Description of the risk assessment methodology;
- Study worksheets;
- Recommendations and observations;
- Annexes (if any);
- Conclusions.

The application of the methodology of HAZOP and PRA within the multidisciplinary team is described below.

The average time to conduct a HAZOP review of an offshore unit is 3 to 6 weeks and to conduct a PreHA review is 4 to 5 weeks, it depends on how complex is the unit process plant. All meetings are onshore and are during business hours from Monday to Friday.

3.4.1 APR Análise Preliminar de Riscos / PRA - Preliminary Risk Analysis reviews

PreHA is derived from the U.S Military Standard System Safety Program Requirements, MIL-STD-882B, nowadays this standard is MIL-STD-882E. PreHA focuses in a general way on the hazardous materials and major process areas of a plant. In a PreHA, the team lists the basic elements of the system and hazards of interest. As each hazardous situation is identified, the potential causes, effects and possible corrective and/or preventive measures are listed. Then, Hazard analysts assess the significance of process hazards and assign a criticality ranking to each particular situation. This criticality ranking is used to prioritize any recommendations for improving safety (UNITED STATES, 1984).

According to Oliveira et Qualharini (2009), Esteves (2004), Cardella (1999) and Kavianian et al (1992), Preliminary Hazard Analysis is a qualitative technique of hazard identification and risk analysis that fundamentally consists of identifying hazardous events, causes and consequences, and establishes control measures, thus analyzing global risks of a Process Plant. The causes of hazards can be due to human errors or equipment failures. When the technique is performed by a team, provides a considerable reflection on the design and operation of the facility, even for the most experienced operator, PreHA can also serve as an effective training tool. It analyses global risks by identifying potential causes and consequences of loss of containment of substance and/or energy. It includes protection devices, detections, equipment, instrumentation, utilities, human actions and external factors that may affect the process. It is called “preliminary” because it is refined through additional studies and is used as a first approach to assess safety on the object of study. In many cases it is sufficient to establish risk control measures. The object of a PreHA study can be an area, a system, a procedure, a project or an activity. The main focus of a PreHA is all dangerous or undesirable events affecting personal safety, environment, installation and company image. The PreHA is also known as Preliminary Risk Analysis PRA. Below is an example of a PreHA worksheet.

.

PRELIMINARY HAZARD ANALYSIS TITLE			
PROCESS HAZARD TECHNIC	Preliminary Hazard Analysis	STUDY NUMBER	
STUDY TITLE	PHA - XYZ	INSTALATION	
SPREADSHEET ID	18909	LEADER	
PROCESS NAME		SUBPROCESS NAME	
ANALYSIS FRAGMENT			

					SEVERITY				RISK				OBSERVATIONS AND RECOMMENDATIONS	SCENARIO
HAZARD	CAUSE	EFFECT	DETECTION AND SAFEGUARD	F	S	H	E	I	S	H	E	I		

Note: S - Personal safety E - Environment F - Frequency
H- Heritage (Assets) I - Image

Ilustração 3.9 – Planilha de registro de análise preliminar de perigos - (Chart 5 – PreHA worksheet created by the author).

The results of a PreHA study can also be summarized in form of table (above) or a logic diagram (below).

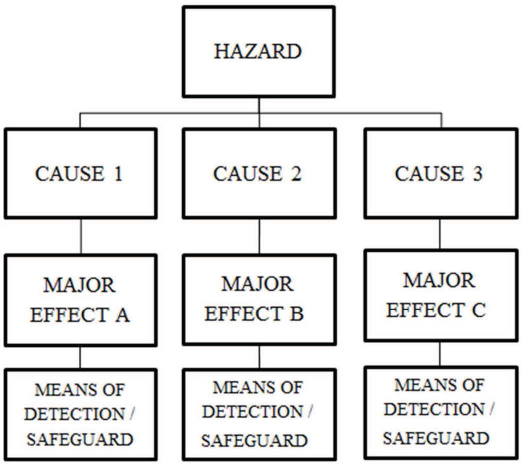

Ilustração 3.10 –Diagrama lógico de uma análise preliminar de perigos, adaptado pelo autor (Chart 6 – PreHA logic diagram adapted from Nolan, D. P (2014) by the author).

A preliminary hazard analysis or preliminary risk analysis is structured in a similar manner to a HAZOP study. However it is usually possible to partition the plant into fewer sections (WELLS et al, 1993).

Differently from HAZOP, all PRA in Campos Basin are performed with risks categorization according the risk matrix of NI-2782. This categorization is in compliance with item 12.3 (f) of ANP, 2007.

During meetings, all registration is done in a worksheet similar to the one in chart 8, in a software based on the web that can be accessed from any company’s computer. The phases of PRA analysis are expressed in chart 9 below.

Below is presented a flow chart with the phases of the method applied during the PRA meetings.

.

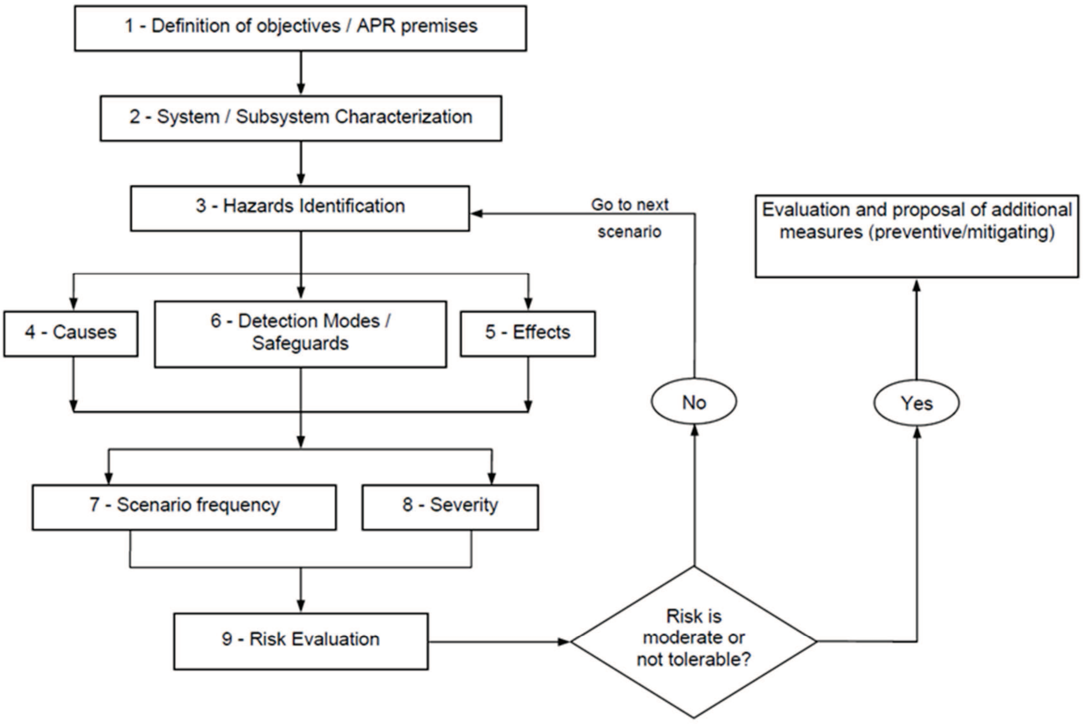

Ilustração 3.11 – Fluxograma de aplicação da APR (Chart 7 – PRA flow chart.)

Source: Petrobras, 2014b.

After the definition of the scope and objectives of the PRA, all the plant has to be divided into smaller portions of analysis, called systems or subsystems. All hazards are identified and all causes, detection modes, safeguards and possible effects are registered, the team assess the scenario frequency and the severity of the possible effect, after that the risk is evaluated using the risk matrix and recommendations, are made if necessary. Then the process is repeated until the evaluation of the last scenario of the system or subsystem and then repeated until the evaluation of the last system or subsystem of the plant.

	PRELIMINARY RISK ANALYSIS (APR)		Protection Level
			Document Issuer
Unit:		System:	Date:
Subsystem:	Description:		Drawings and revision:

Hazard	Causes	Consequences	Detection Modes / Safeguards	Freq.	People		Asset		Environ.		Image		Recommendation / Observations	Scenario
					S	R	S	R	S	R	S	R		
	-	-	-											
	-	-	-											

*Ilustração 3.12 - Planilha de análise preliminar de riscos (APR) (*Chart 4 **–** PRA worksheet).

Source: Petrobras, 2014b.

.

The team members, using their experience and knowledge of the platform and the process, evaluate possible effects of the scenario to the workforce (people), company asset, environment and company image and categorize its severity using the matrix in chart 10. If the possible effect is an oil spill, then, the severity to the environment is based on the possible volume and ºAPI[4] of the oil released and follows the criteria on chart 12 below. The frequency category of the scenario is divided into five categories (A) Extremely remote, (B) Remote, (C) Not likely, (D) Possible and (E) Frequent and the team choose which one better fits the scenario based on the team knowledge and history of similar incidents.

							Frequency categories				
			Description / Characteristics				A Extremely remote	B Remote	C Not likely	D Possible	E Frequent
			People	Asset / operational continuity	Environment	Image	Conceptually possible, but with no references in the industry	Not expected to occur, although there are references in similar facilities in the industry	Not likely of occurring during the life time of a group of similar facilities	Possible of occurring once during the facility life time	Possible of occurring many times during the facility life time
Consequences Severity Categories	V	Catastrophic	Multiple fatalities on-site or off-site fatality	Catastrophic damages which can lead to the loss of the industrial facility	Severe damages in sensitive areas or extending to other places	International impact	M	M	NT	NT	NT
	IV	Critical	Onsite fatality or severe injuries off-site	Severe damage to systems (slow repair)	Severe damages with localized effects	National impact	T	M	M	NT	NT
	III	Medium	Severe on-site injuries or light off-site injuries	Moderate damage to systems	Moderate damages	Regional impact	T	T	M	M	NT
	II	Marginal	Light injuries	Light damages to systems / equipment	Light damages	Local impact	T	T	T	M	M
	I	Negligible	First aid cases or no injuries	Light damages to equipment without compromising the operational continuity	Insignificant damages	Insignificant impact	T	T	T	T	M

Ilustração 3.13 –Matriz de risco da NI-2782 (Chart 9 **–** Risk matrix).

Source: Petrobras, 2014b.

The risk categorization is a function of Severity and Frequency of the scenario. Its tolerability and necessity to put in place more safeguards or detections is shown on chart 10 below.

Note that if the risk is T or tolerable, there is no need to implement any other safeguards or detection. If the risk is M or moderate, the team to obtain risk reduction assesses the application of additional controls, those additional controls considered practicable must be implemented. If the risk is NT or not tolerable, the existing controls are insufficient and controls have to be implemented to bring the risk to M or to T.

[4] ºAPI = (141,5 ÷ (specific gravity of the liquid in relation to water)) - 131,5

Specific gravity of the liquid in relation to water, both at 15,55°C or 60°F.

.

Risk category	Description of the necessary control level
Tolerable (T)	There is no need for additional measures. Monitoring is necessary to ensure that the controls are kept.
Moderate (M)	Additional controls must be assessed with the purpose of obtaining a risk reduction and implementing those considered practicable (ALARP region – "As Low As Reasonably Practicable").
Not Tolerable (NT)	The existing controls are insufficient. Alternative methods shall be considered to reduce the probability of occurrence or the severity of consequences, so as to bring the risks to regions of lower magnitude of risks (ALARP or tolerable regions).

Ilustração 3.14 – Categorização de riscos e critério ALARP para a geração de recomendação (Chart 5- Risk category and ALARP criteria to generate a recommendation).

Source: Petrobras, 2014b.

Type of environment (water)	Severity Category	Volume leaked (V) in m^3, according to the API degree			
		API ≥ 45	35 ≤ API < 45	17,5 ≤ API < 35	API < 17,5
1 Oceanic regions	V Catastrophic	≥ 1 000	≥ 700	≥ 400	≥ 200
	IV Critical	100 ≤ V < 1 000	80 ≤ V < 700	40 ≤ V < 400	20 ≤ V < 200
	III Medium	5 ≤ V < 100	4 ≤ V < 80	2 ≤ V < 40	1 ≤ V < 20
	II Marginal	0,5 ≤ V < 5	0,4 ≤ V < 4	0,2 ≤ V < 2	0,1 ≤ V < 1
	I Negligible	V < 0,5	V < 0,4	V < 0,2	V < 0,1
2 Coastal regions	V Catastrophic	≥ 500	≥ 350	≥ 200	≥ 100
	IV Critical	50 ≤ V < 500	35 ≤ V < 350	20 ≤ V < 200	10 ≤ V < 100
	III Medium	4 ≤ V < 50	2 ≤ V < 35	1 ≤ V < 20	0,5 ≤ V < 10
	II Marginal	0,4 ≤ V < 4	0,2 ≤ V < 2	0,1 ≤ V < 1	0,05 ≤ V < 0,5
	I Negligible	V < 0,4	V < 0,2	V < 0,1	V < 0,05

Ilustração 3.15 – Categorização de severidade de uma perda de contenção de hidrocarboneto em região oceânica (Chart 6- Severity categorization of an oil release on oceanic regions and coastal regions).

Source: Petrobras, 2014b.

3.4.2 Estudo de perigo e operabilidade / HAZOP - Hazards and Operability Study reviews

HAZOP studies appeared in systematic way in 1974 (LAWLEY, 1974), a HAZOP study is a highly disciplined procedure meant to identify how a process may deviate from its design intent. A multidisciplinary team uses keywords on process variables to find potential hazards and operability troubles (MANNAN, 2012). It is defined as the application of a formal, systematic critical examination of the process and the engineering intentions of a new or an existing facility. It is used to assess the potential for malfunctioning of individual pieces of equipment, and the consequential effects on the facility as a whole (DUNJÓ, JORDI et al, 2010). The basic principle is to have a full process description of a part of the plant (node) and to ask in each node what deviations to the design purpose can occur, what causes can produce these deviations, and what consequences it can generates. This is done systematically by applying the guide words: Not, More than, Less than, etc(PÉREZ-MARÍN, 2013).

.

According to Cardella (1999), HAZOP is a hazard and operability identification technique and consists of detecting deviations of process variables (deviations from values established as normal). The object of a HAZOP study is a systems and it focus on its system process deviations. HAZOP uses guidewords that stimulate creativity to detect deviations.

According to IEC (2001) HAZOP is a structured and systematic technique for examining a defined system, with the objective of identifying potential hazards in the system. The hazards involved may include those essentially relevant only to the immediate area of the system and those with a much wider sphere of influence, e.g. some environmental hazards. Additionally the objective is identifying potential operability problems of the system and, in particular, identifying causes of operational disturbances and production deviations likely to lead to nonconforming products. An example of a HAZOP worksheet, extracted from IEC (2001) standard is shown below.

STUDY TITLE: OIL VAPORIZER									
Drawing No. :					**REVISION No.:**			**DATE:**	
TEAM COMPOSITION: MG, NE, DH, EK, LB								**MEETING DATE:**	
PART CONSIDERED: Vaporizer coil from oil inlet (before flow measurement), to vapour exit to process (after temperature control)					**DESIGN INTENT:** **Inputs:** Oil flow from the feed line, heat from the furnace **Activities:** Vaporize, superheat and transfer oil vapour to the process				
No.	**Guide word**	**Element**	**Deviation**	**Possible causes**	**Consequences**	**Safeguards**	**Comments**	**Actions required**	**Action by**
1	No	Oil flow	No oil flow	– Supply failure – Flow control valve PCV closed	Vaporizer coil overheats and may fail	Low flow alarm FAL High temperature trip TSH	Safeguard depends on quick operator response	Consider low flow element FE to close main burner valve TCV	LB
				– Plugging of coil – Blockage down-stream of vaporizer	Oil in vaporizer will boil: Possible overheating and coking of heating coil	Low flow alarm FAL High temperature trip TSH		Check whether these safeguards are adequate and the ease with which the coil could be cleaned	NE
2	No	Heat	No heat	Flame out in the furnace	Unvaporized liquid oil fed to the process	None		– Investigate effect of liquid oil on the process – Consider interlocking the furnace flame out signal with closure of FCV – Consider providing a low oil outlet temperature alarm	DH

Ilustração 3.16 - Exemplo de uma planilha de HAZOP (Chart 12 –Example of a HAZOP worksheet*)*.

Source: BS IEC 61882:2001.

An example of a HAZOP worksheet used is shown above in chart 12. As preconized in IEC (2001) and CCPS (1992) most of the Campos Basin Hazops are not categorized due to the fact that the categorization only is used to prioritize recommendations (PÉREZ-MARÍN, M. et RODRÍGUEZ-TORAL, M. A, 2013). When a recommendation is generated without categorization, it has to be implemented or properly denied.

.

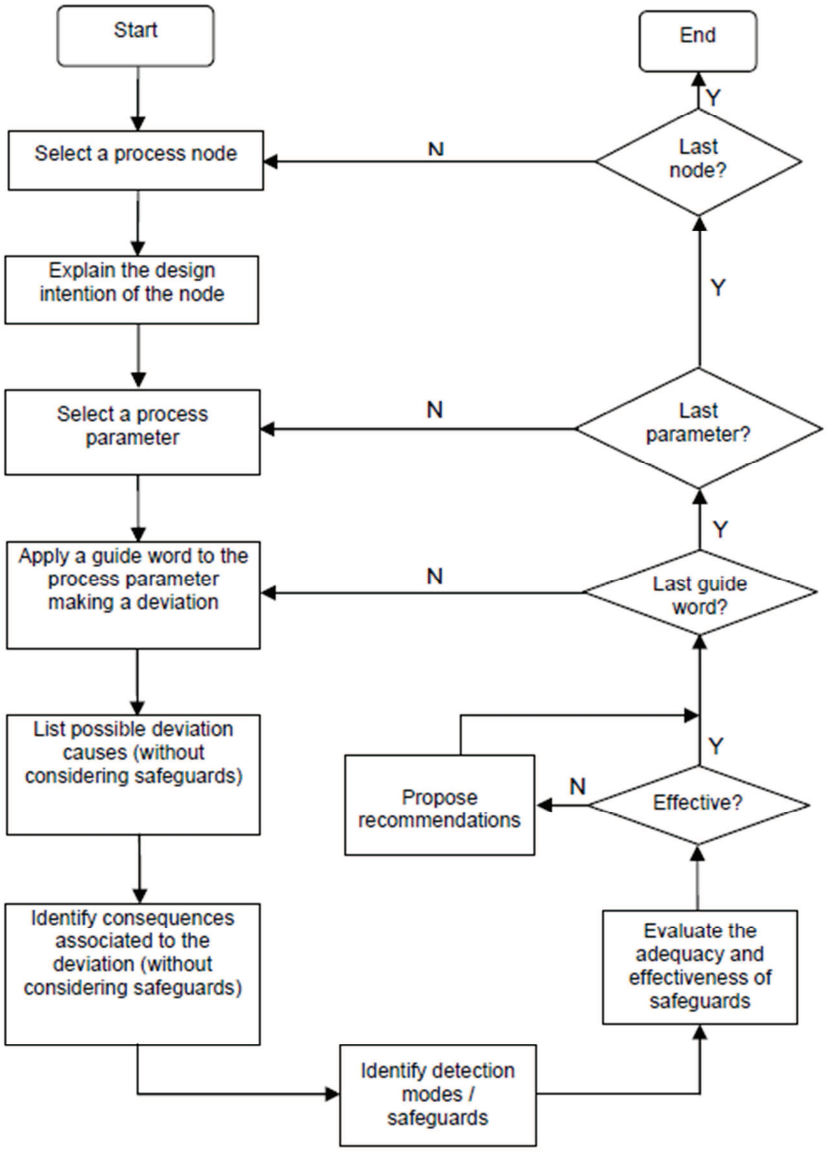

Ilustração 3.17 – Fluxograma para a execução da técnica HAZOP (Chart 13 – HAZOP flow chart).

Source: Petrobras, 2014b.

.

	HAZOP – (Hazard and Operability Study)				Protection Level Document Issuer	
Unit:			System:		Date:	
Subsystem:					Drawings and revision:	
Node 1:						
Deviation	**Possible Causes**	**Possible Effects**	**Detection Modes**	**Safeguards**	**Recommendation / Observations**	**No.**
	-	-	-	-		
	-	-	-	-		
	-	-	-	-		
	-	-	-	-		
	-	-	-	-		
	-	-	-	-		
	-	-	-	-		
	-	-	-	-		
	-	-	-	-		
	-	-	-	-		
	-	-	-	-		

*Ilustração 3.18 – Planilha de HAZOP recomendada (*Chart 14 – HAZOP worksheet recommended*).*

Source: Petrobras, 2014B.

There are several ways to register a Hazop study, (1) consequence by consequence, (2) cause by cause, (3) deviation by deviation and (4) registration by exception. The last one includes only the deviations that the team identifies as probable. Although reducing the time of the meetings, registration by exception form of registration cannot be audited and it is strongly not recommended to use.

Deviation	Possible Cause	Possible Consequence	Means of detection /safeguard	Recomendations /observations	Scenario Number
Deviation A	Cause 1	Conseq. A	Safeguard. A	Action Z	1
	Cause 2		Safeguard B	Action W	
Deviation B	Cause 1	Conseq. B	Safeguard. A	Action Z	2
	Cause 3		Safeguard C		

Ilustração 3.19 – Tipo de registro de HAZOP consequência por consequência, exemplo criado pelo autor (Chart 15 – Consequence by consequence HAZOP registration, created by the author).

.

Deviation	Possible Cause	Possible Consequence	Means of detection /safeguard	Recomendations /observations	Scenario Number
Deviation A	Cause 1	Conseq. A	Safeguard. A	Action K	1
	Cause 2	Conseq. B	Safeguard B		
			Detection A	Action Q	
	Cause 3	Conseq. C	Safeguard C		
Deviation B	Cause 1	Conseq. A	Safeguard. A	Action Q	2
	Cause 2	Conseq. B	Detection C	Action O	
	Cause 4	Conseq. D	Safeguard. B	Action L	
	Cause 5	Conseq. F	Safeguard C		

Ilustração 3.20 – Tipo de registro de HAZOP desvio por desvio, exemplo criado pelo autor (Chart 16 – Deviation by deviation HAZOP registration example, created by the author*)*.

The recommended form of HAZOP registration is the Cause by Cause registration, because each consequences, safeguards and actions are associated with each particular deviation cause (PÉREZ-MARÍN, M. *et* RODRÍGUEZ-TORAL, M. A, 2013).

Deviation	Possible Cause	Possible Consequence	Means of detection /safeguard	Recomendations /observations	Scenario Number
Deviation A	Cause A	Conseq. A	Safeguard A	Action X	1
			Detection A		
		Conseq. C	Safeguard B		
	Cause B	Conseq. A	Safeguard A	Action Z	2
Deviation B	Cause C	Conseq. A	Safeguard A	Action Y	3
			Detection A		

Ilustração 3.21 - Tipo de registro de HAZOP causa por causa, exemplo criado pelo autor (Chart 17 – Cause by cause HAZOP registration example, created by the author).

Below is presented a flow chart with the phases of the method applied during the HAZOP meetings.

All process plant has to be divided into smaller portions of analysis, called nodes. After that a parameter (i.e., pressure, flowrate, temperature, etc) is evaluated with the use of guide-words (i.e., none, lower, higher, reverse, etc), after that a deviation to analyze is made and it´s cause,

.

consequences detection modes and safeguards are analyzed. The method continue by the last deviation and node of the plant.

In both techniques, after verification and approval of the report, its recommendations are treated and addressed. Management performs this treatment and it is controlled by an information system (software) that ensures the traceability of any recommendation. Using the ALARP criteria management can deny, approve and delegate or suggest an alternative solution to recommendation.

3.5 - Conclusões / Conclusions

HAZOP (Hazard and Operability Study) and PreHA (Preliminary Hazard Analysis) or PRA (Preliminary Risk Analysis) studies are not ordinary and fast forward procedure application that assures safety to Process Industries on its own. To improve safety to process industries, these studies must be part of a PSMS. HAZOP and PRA within a PSMS are utilized first of all to prevent the occurrence of major accidents and second of all to mitigate it´s effect, by evaluating scenarios and proposing recommendations that after they are put in place they became safety barriers. Both techniques are qualitative and have advantages and disadvantages that are inherent of each one.

PRA and HAZOP are being used on Campos Basin operations to perform hazard identification and risk assessment and these techniques, as proposed by this paper, are the base of the Process Safety Management System and besides of its disadvantages these techniques are complementary for each other and useful for the offshore industry. Because PRA study what can go wrong in several areas of an offshore production platform and HAZOP verify in the process which parameters can generate deviation(s) that can lead to undesired consequences. When necessary, more in-depth safety studies must be done to achieve the main objective of the techniques, prevent and/or mitigate risks.

When auditing these qualitative processes safety studies auditors need to understand the techniques limitations, as well as a study leader. In Campos Basin operations, the HAZOP studies do not rank risk like PRA because the only gain on doing so is to prioritize recommendations, they also complement each other in this sense.

3.6 Referências / References

API – American Petroleum Institute. Management of Process Hazards Recommended Practice 750. 1990.

ANP – Agência Nacional do Petróleo, Anuário Estatístico Brasileiro do Petróleo. Gás Natural e Biocombustíveis, 2014.

ANP – Agência Nacional do Petróleo. Resolução ANP Nº 43, 2007.

BABBIE, E. The practice of social research. 4th ed. Belmont, Wadsworth Publ., 1986.

CARDELLA, Benedito. Segurança no trabalho e prevenção de acidentes: uma abordagem holística: segurança integrada à missão organizacional com produtividade, qualidade, preservação ambiental e desenvolvimento de pessoas. São Paulo: Atlas, v. 1, 1999.

.

CCPS – CENTER FOR CHEMICAL PROCESS SAFETY. Guidelines for Hazard Evaluation Procedures. 3. ed. New York: AICHE, 2008.

DE FREITAS, Carlos M.; PORTE, Marcelo F. de S.; GOMEZ, Carlos M. Acidentes químicos ampliados: um desafio para a saúde pública. Revista de Saúde Pública, v. 29, n. 6, p. 503-514, 1995.

DIRECTIVE 82/501/CEE of the council of 24 June 1982 on the major-accident hazards of certain industrial activities. Official Journal of the European Communities, L 230/1, 1982.

DIRECTIVE 96/82/EC. Control of Major Accident Hazards Involving Dangerous Substances, Council of the European Union, 1996.

DIRECTIVE 2012/18/EU. European parliament and the council of 4th of July 2012 on the control of major-accident hazards involving dangerous substances, amending and subsequently repealing directive 96/82/EC. Official Journal of the European Union, L 197/1, 2012.

DUNJÓ, Jordi et al. Hazard and operability (HAZOP) analysis. A literature review. Journal of hazardous materials, v. 173, n. 1, p. 19-32, 2010.

FREITAS, C. M.; PORTO, M.F.S.; MACHADO, J.M.H. Acidentes industriais ampliados: Desafios e Perspectivas para o Controle e a Prevenção. Rio de Janeiro: Editora Fiocruz, 2000.

ILO - INTERNATIONAL LABOUR ORGANIZATION. Guidelines on occupational safety and health management systems. ILO-OSH 2001. Geneva: International Labour Office, 2001.

KAVIANIAN, Hamid. R; RAO, J. K; BROWN, G. V. Application of Hazard Evaluation Techniques to the Design of Potentially Hazardous Industrial Chemical Processes, U.S. Department of Health and Human Services, Public Health Service, Centers for Disease Control, National Institute for Occupatonal Safety and Health, Division of Training and Manpower Development, 1992

LAWLEY, H. G. Operability studies and hazard analysis. Chemical Engineering Progress, 70(4), p. 45 - 56, 1974

MANNAN, S. Lee’s loss prevention in the process industries. Hazard identification, assessment and control, Vol. 1, 3rd ed., Elsevier, (pp. 8 - 31), 2012.

NOLAN, Dennis P. Safety and Security Review for the Process Industries: Application of HAZOP, PHA, What-IF and SVA Reviews. William Andrew, 2011.

NOLAN, Dennis P. Safety and Security Review for the Process Industries: Application of HAZOP, PHA, What-IF and SVA Reviews. Elsevier, 2014.

.

OLIVEIRA, M. de P; QUALHARINI, E. GESTÃO DE RISCOS NA OPERAÇÃO DE PLATAFORMAS DE PETRÓLEO, Congresso Nacional de Excelência em Gestão, 2009.

OSHA- OCCUPATIONAL SAFETY AND HEALTH ADMINISTRATION. PSM, CFR 1910.119. Process Safety Management of Highly Hazardous Chemicals, 29, 1992.

PÉREZ-MARÍN, M.; RODRÍGUEZ-TORAL, M. A. HAZOP–Local approach in the Mexican oil & gas industry. Journal of Loss Prevention in the Process Industries, v. 26, n. 5, p. 936-940, 2013.

PETROBRAS-PETRÓLEO BRASILEIRO, S. A. Plano de Negócios e Gestão 2014-2018 para a área de E&P, 2013.

PETROBRAS-PETRÓLEO BRASILEIRO, S. A. Guideline to Risk Evaluation and Management, 2014a.

PETROBRAS - PETRÓLEO BRASILEIRO, S. A. NI-2782 - Applicable techniques to Industrial Risk Analysis, 2014b.

PETROBRAS-PETRÓLEO BRASILEIRO, S. A. Plano de Negócios e Gestão 2015-2019 para a área de E&P, 2015.

PÉREZ-MARÍN, M.; RODRÍGUEZ-TORAL, M. A. HAZOP– Local approach in the Mexican oil & gas industry. Journal of Loss Prevention in the Process Industries, v. 26, n. 5, p. 936-940, 2013.

RUSLI, Risza; SHARIFF, Azmi Mohd. Qualitative Assessment for Inherently Safer Design (QAISD) at preliminary design stage. Journal of Loss Prevention in the Process Industries, v. 23, n. 1, p. 157-165, 2010

THEODORSON, G. A. & THEODORSON, A. G. A modern dictionary of sociology. London, Methuen, 1970.

UNITED STATES, Military Standard System Safety Program Requirements, MIL-STD-882B, Department of Defense, 1984.

WELLS, Geoff; WARDMAN, Mike; WHETTON, Cris. Preliminary safety analysis. Journal of loss prevention in the process industries, v. 6, n. 1, p. 47-60, 1993.

ZIO, E., AVEN, T.; Industrial disasters: Extreme events, extremely rare. Some reflections on the treatment of uncertainties in the assessment of the associated risks. Process Safety and Environmental Protection 91, 2013.

.

4 - CONCLUSÕES

Com os resultados obtidos em ambos os artigos científicos acima, foi possível verificar como ocorre o gerenciamento da segurança de processo nas operações de produção de óleo e gás *offshore*. No primeiro artigo foi verificado que o sistema de gestão de segurança, meio ambiente e saúde da principal operadora de petróleo no Brasil apresenta itens em conformidade com diversos *guidelines* mundiais e nacionais acerca da segurança de processos. Todos estes guidelines possuem itens específicos que ressaltam a importância do entendimento de perigos e avaliação de riscos. Tema este do segundo artigo que verifica a metodologia utilizada por esta operadora para o levantamento destes perigos e análise dos riscos de processo.

O método empregado para este levantamento de perigos e avaliação de riscos utiliza duas técnicas com a participação de equipe multidisciplinar. Primeiramente aplica-se a APR e em seguida aplica-se o HAZOP. As técnicas se mostraram complementares para o levantamento de perigos e avaliação de riscos para o setor de produção de óleo e gás *offshore*. Visto que a APR de forma mais abrangente verifica o que pode dar errados nas operações ocasionando prioritariamente perdas de contenção primária de produtos perigosos ou energia. Resultando em consequências indesejadas nas plataformas como, por exemplo, possíveis vazamentos, possíveis incêndios, possíveis explosões e/ou possíveis adernamentos. E ainda, que medidas de controle existem para prevenir e/ou mitigar estas perdas de contenção.

Já a técnica HAZOP verifica no processo produtivo que desvios das intenções de projeto podem ocorrer levanto o processo para situação anormal e/ou emergencial de operação, verificando as medidas de controle existentes para manter o processo dentro das condições normais de operação. Para ambas as técnicas as recomendações geradas nos estudos devem ser tratadas.

Além dos estudos APR e HAZOP, quando necessário, estudos adicionais são executados para melhorar o entendimento dos perigos e avaliação dos riscos. Para pesquisas futuras sugere-se aprofundamento nos chamados estudos de consequência, comparando-os com as APR que servem de base para estes tipos de estudos. Verificando para quais tipos de cenário são empregados quais tipos de estudos de consequência.

.

REFERÊNCIAS BIBLIOGRÁFICAS

ABCM - Association of British Chemical Manufacturers. **Safety and Management**. London, 1964.

ABS - AMERICAN BUREAU OF SHIPPING. **Guidance Notes on Risk Assessment Applications for the Marine and Offshore Oil and Gas Industries**. 2000.

API – American Petroleum Institute. **Management of Process Hazards Recommended Practice 750**. 1990.

BARBOSA, D. P.; HARGUENAUER, D. F. **A influência do fator humano nos cenários acidentais de uma refinaria de petróleo**. In: V Congresso Nacional de Excelência em Gestão. Niterói, 2009.

BCISC - British Chemical Industry Safety Council. **Safe and Sound. Summary for Managements**. London, 1969.

BCISC - British Chemical Industry Safety Council. **Safety Audits. Summary for Managements**. London, 1973.

BELLAMY, L. J.; GEYER, T. A; WILKINSON, J. Development of a functional model which integrates human factors, safety management systems and wider organisational issues. **Safety science**. 2008. v. 46, n. 3, p. 461-492.

BENTES, S. R.; CRUZ, M. The Seveso Directives and Their Application to Enterprise Risk Management. **International Journal of Latest Trends in Finance and Economic Sciences**. 2014. v. 3, n. 3, p. 9.

BHOPAL. **20 Anos e o pesadelo continua.** Informativo DIESAT. 15 de janeiro de 2005, p. 1-2. Disponível em: <http://www.diesat.org.br/Informativos/janeiro_2005.pdf>. Acesso em: 12 jul. 2013.

BOBSIN, Marco Aurélio; LIMA, Gilson Brito Alves. Gestão de segurança, meio ambiente e saúde: proposta de estrutura de sistema e metodologia de avaliação de desempenho. **Dissertação de Mestrado**, , 2005

BRASIL. CONGRESSO NACIONAL. **Decreto no 4.085**. Diário Oficial. Brasília, 16 jan. 2002.

BROUGHTON, E. The Bhopal disaster and its aftermath: a review. **Environmental Health: A Global Access.** Science Source. 2005. In: < http://www.ehjournal.net/content/4/1/6> Acesso em: Jun. 2013.

BURK, A. F.; SMITH, W. L. Process safety management within DuPont. **Plant/Operations Progress**. 1990. v. 9, n. 4, p. 269-271.

CCPS - CENTER FOR CHEMICAL PROCESS SAFETY. **Guidelines for engineering design for process safety**. 2. ed. New York: American Institute of Chemical Engineers, 1993.

.

CCPS - CENTER FOR CHEMICAL PROCESS SAFETY. **Guidelines for Hazard Evaluation Procedures**. 3. ed. New York: AICHE, 2008.

CCPS - CENTER FOR CHEMICAL PROCESS SAFETY. **Guidelines for preventing human error in process safety**. New York: AICHE, 1994.

CLINI, Francesco; DARBRA, R. M.; CASAL, J. **Historical analysis of accidents involving domino effect**. Chemical Engineering, v. 19, p. 335-340, 2010.

COMISSÃO EUROPÉIA. RELATÓRIO DA COMISSÃO. **Relatório sobre a aplicação, nos Estados-Membros, da Diretiva 96/82/CE, relativa ao controlo dos perigos associados a acidentes graves que envolvem substâncias perigosas, para o período 2009-2011**. Bruxelas, 2013.

CRESWELL, John W. **Projeto de Pesquisa:** métodos qualitativo, quantitativo e misto. Tradução Luciana de Oliveira Rocha. 2. ed. Porto Alegre: Artmed, 2007.

CSB – US CHEMICAL SAFETY AND HAZARD INVESTIGATION BOARD. **Macondo Investigation**. Report. Jun 2014.

CULLEN, W. D. **Report of the Official Inquiry into the Piper Alpha Disaster**. 1990.

DECOLA, E. **A Review of Double Hull Tanker Oil Spill Prevention Considerations**. Nuka Research & Planning Group, LLC. 2009.

DELVOSALLE, C. **Domino Effects Phenomena: Definition, Overview and Classification**. Leuven, 1996.

DHARA, V. R.; DHARA, R. The Union Carbide disaster in Bhopal: a review of health effects. **Archives of Environmental Health: An International Journal**. 2002. v. 57, n. 5, p. 391-404.

DIRECTIVE 2012/18/EU. European parliament and the council of 4th of July 2012 on the control of major-accident hazards involving dangerous substances, amending and subsequently repealing directive 96/82/EC**. Official Journal of the European Union, L 197/1**, 2012.

DIRECTIVE 82/501/CEE of the council of 24 June 1982 on the major-accident hazards of certain industrial activities. **Official Journal of the European Communities, L 230/1**, 1982.

DIRECTIVE 96/82/EC. C**ontrol of Major Accident Hazards Involving Dangerous Substances, Council of the European Union**, 1996.

EHSO. **PSM: OSHA Process Safety Guidance and Information**. Georgia, USA, 2010. Disponível em http://www.ehso.com/ProcessSafety.htm. Accessed in Apr:2014.

EPSC - European Process Safety Centre. **Safety Management Systems**. Institution of Chemical Engineers, Rugby, 1994.

.

EUROPEAN COMMISSION. **Report on the Application in the Member States of Directive 96/82/EC on the control of major-accident hazards involving dangerous substances for the period 2009-2011**, Brussels, 2013.

FRANK, W. L. Process safety culture in the CCPS risk based process safety model. **Process safety progress. 2007.** v. 26, n. 3, p. 203-208.

FREITAS, C. M; PORTO, M. F .S.; GOMEZ, C. M. **Acidentes químicos ampliados: um desafio para a saúde pública**. Revista de Saúde Pública. 1995. v. 29, n. 6, p. 503-514.

FREITAS, C. M; PORTO, M. F .S.; MACHADO, J. M. H. (Orgs.). **Acidentes industriais ampliados: desafios e perspectivas para o controle e a prevenção.** Rio de Janeiro: Editora Fiocruz, 2000.

GIL, Antonio Carlos. **Métodos e Técnicas de Pesquisa Social**. 6. ed. São Paulo: Atlas, 2011.

GUPTA, J. P.; NETO, A. D. C.; MERRITT, C. W.; HUNGERBUHLER, K .; MANNAN, M. S.; Tamaura, M. Announcement / **Journal of Loss Prevention in the Process Industries 18**, 2005.

HAKKINEN, Pertti J. **Seveso Disaster, and the Seveso and Seveso II Directives**, Elsevier 2005.

HARVEY, B. H. **Second Report of the Advisory Committee on Major Hazards**. HM Stationery Office. London, 1976.

HARVEY, B. H. **Second Report of the Advisory Committee on Major Hazards**. HM Stationery Office. London, 1979.

HARVEY, B. H. **Third Report of the Advisory Committee on Major Hazards**. HM Stationery Office. London, 1984.

HARVEY, B.H. **Flixborough – five years later**. Chem. Eng.London 349, 697, 1979.

HEALTH AND SAFETY COMMISSION et al. **Advisory Committee on Major Hazards: First Report**, ISBN 0, v. 11, n. 880884, p. 2, 1976.

HOLDSWORTH, R. **Practical applications approach to design, development and implementation of an integrated management system.** Journal of Hazardous Materials, 2003. v. 104, n. 1, p. 193-205.

HOPKINS, Andrew. **Lessons from Longford: the Esso gas plant explosion**. CCH Australia limited, 2000

IAN CAMERON, R. Raman. **Process Systems Engineering, Volume 6**, Process Systems Risk Management Pages 1-615, May 2005 , ISBN 13: 978-0-12-156932-7

.

ILO - INTERNATIONAL LABOUR ORGANIZATION. **Guidelines on occupational safety and health management systems.** ILO-OSH 2001. Geneva: International Labour Office, 2001.

ITOPF - **THE INTERNATIONAL TANKER OWNERS POLLUTION FEDERATION LIMITED,** 2014 In: <http://www.itopf.com/> Accecced in Jul: 2014.

KAPP, Robert. TCDD (2,3,7,8-Tetrachlorodibenzo-p-Dioxin), Encyclopedia of Toxicology, Elsevier, 2005 page 35.

KLETZ, Trevor A. **O que houve de errado?: casos de desastres em indústrias químicas, petroquímicas e refinarias**. Pearson Makron Books, 2005.

SOUZA, R. G., LIMA, Gilson Brito Alves. I**MPORTÂNCIA DOS ELEMENTOS ESTRUTURANTES DE UM PROGRAMA DE GESTÃO DE SEGURANÇA DE PROCESSO: ESTUDO DE CASO EM UMA EMPRESA DE ENERGIA**. ISSN 1984-9354, Jun, 2013.

LOVINS, A. B., 2012. **A Farewell to Fossil Fuels Answering the Energy Challenge**. Revista Foreign Affairs. Volume 91 No. 2.

MACHADO, P. A. L. **Direito Ambiental Brasileiro**. 11. ed. São Paulo: Malheiros Editores, 2003.

MANNAN, Sam (Ed.). **Lees' Loss prevention in the process industries: Hazard identification, assessment and control**. Butterworth-Heinemann, 2012. ISBN: 978-0-7506-7555-0

MARCONI, Marina de Andrade; LAKATOS, Eva Maria **Técnicas de Pesquisa**. 7. ed. São Paulo: Atlas, 2008.

NASA - National Aeronautics and Space Administration. **The Case for Safety - The North Sea Piper Alpha Disaster**, May 2013 Volume 7 Issue 4.

OGP - International Association of Oil & Gas Producers**. Managing major incident risks**, Workshop report – 406, 2008.

OSHA - OCCUPATIONAL SAFETY AND HEALTH ADMINISTRATION – OSHA 3132. **Process Safety Management.** Washington: U.S. Department of Labour, 1993.

OIT - ORGANIZAÇÃO INTERNACIONAL DO TRABALHO. **Convenção OIT 174**, Recomendação 181: Prevenção de acidentes industriais maiores. Tradução de Abiquim/Fundacentro. São Paulo: Fundação Jorge Duprat Figueiredo de Segurança e Medicina do Trabalho, 2002.

OSHA- OCCUPATIONAL SAFETY AND HEALTH ADMINISTRATION. PSM, CFR 1910.119. **Process Safety Management of Highly Hazardous Chemicals**, 29, 1992.

.

PUIATTI, R. **A prevenção e os trabalhadores – aspectos comparativos da legislação dos EUA, da Grã-Bretanha e da Holanda**. In: FREITAS, C. M; PORTO, M. F .S.; MACHADO, J. M. H. (Orgs.). Acidentes industriais ampliados: desafios e perspectivas para o controle e a prevenção. Rio de Janeiro: Editora Fiocruz, 2000.

OLIVEIRA, M. de P; QUALHARINI, E. **GESTÃO DE RISCOS NA OPERAÇÃO DE PLATAFORMAS DE PETRÓLEO**, Congresso Nacional de Excelência em Gestão, 2009.

REASON, J. **Human error**. New York: Cambridge University Press, 2003.

ROCHA JR, Edson; CAROLINA MAGGIOTTI COSTA, Maria; DOROTÉA GODINI, Maria. **Acidentes ampliados à luz da "Diretiva Seveso" e da convenção Nº 174 da Organização Internacional do Trabalho–OIT.** InterfacEHS-Revista de Saúde, Meio Ambiente e Sustentabilidade, v. 1, n. 2, 2013.

SARAIVA, Renato **CLT-Consolidação das Leis do Trabalho**, Ed.Método, 2010.

SEVESO III, Directive. Council Directive 2003/105/EC of the European Parliament amending Council **Directive 96/82/EC on the control of major-accident hazards involving dangerous substances**. Official Journal of the European Union No. L, v. 345, 2003.

SOARES,G. F. S. **Direito Internacional do Meio ambiente: emergência, obrigações e responsabilidades**. São Paulo: Atlas, 2001. TAVARES, R. N. As Organizações Não-Governamentais nas Nações Unidas. Brasília: Instituto Rio Branco; Fundação Alexandre Gusmão; Centro de Estudos Estratégicos, 1999.

UNECE - UNITED NATIONS ECONOMIC COMMISSION FOR EUROPE. **Chemical Accident Prevention, Preparedness and Response: The Seveso II Directive**. Janeiro de 2005. Disponível em: http://europa.eu.int/comm/environment/seveso/index.htm. Acesso em: 03 de nov. de 2005.

VINNEM, Jan Erik. **Offshore Risk Assessment: Principles, Modelling and Applications of QRA Studies**. 2nd edition, London: Springer-Verlag London Limited, 2007.

YIN, Robert K.. **Estudo de Caso como Ferramenta Metodológica Estudo de caso: planejamento de métodos**. 4. ed. Porto Alegre: Bookman, 2010

ZIO, E., AVEN, T.; **Industrial disasters: Extreme events, extremely rare. Some reflections on the treatment of uncertainties in the assessment of the associated risks**. Process Safety and Environmental Protection 91, 2013.

.