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FOR AN EFFICIENT MANAGEMENT OF DRILLING RISKS. CASE STUDY: THE BLOWOUT PREVENTER SYSTEM

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Abstract*: One of the most frequent and important hazards in petroleum operations is the risk of a blowout in drilling operations, result of an uncontrolled inflow of gas, oil or other fluids in the well. This occurrence is defined as an intrusion of unwanted fluid from a permeable formation into the drilling area once the bottom hole pressure becomes lower than the pore pressure. Consequently, controlled or uncontrolled wellbore events, when they occur, are not only a waste of time and money but can also lead to human, material and environmental damage, or even to a disaster. Through this study, we are trying to better understand the risks inherent to the use of a blowout preventer, to better control them throughout its life cycle and to reduce their effects without totally eliminating them.*
Key words: blowout, risk management, drilling, petroleum operations, FMECA

1. INTRODUCTION

Identifying the risks associated with any business and managing those risks are important aspects of doing business in today's competitive world [1, 2, 3]. It is even more relevant when talking about oil and gas exploration and production fields where the slightest incident can lead to an explosion or fire [4, 5, 6, 7], or even a catastrophic situation, fig1. Among the most dangerous risks encountered in the drilling works is the kick [8, 9], objective of our study.

Figure 1: The kick's consequences

The term "oil drilling" refers to all the operations that make it possible to reach the porous and permeable rocks of the subsoil, likely to contain liquid or gaseous hydrocarbons. The decision to drill for oil is taken following geological and geophysical studies carried out on a sedimentary basin. These studies give an idea of the constitution of the subsoil and the possibilities of deposits, but they cannot specify the presence of hydrocarbons. Only drilling can confirm the hypotheses made and reveal the nature of the fluids contained in the rocks, or even the uncontrolled inflow of gas, oil or other fluids from the well [10]. In other words, a blowout is an uncontrollable or released eruption of a well to the surface, it is due to the loss of pressure control of the crossed layers, it occurs if the hydrostatic pressure of the mud reaches a level largely lower than that of the zone (layer) in question, the kick will therefore be avoided if the hydrostatic pressure, can counterbalance the pressure of the encountered reservoir (pressure of the layers) [11, 12].

2. RISKS RELATED TO THE DRILLING PROCESS

Drilling is the operation of mechanically breaking up the rock in order to progressively penetrate the subsoil and dig a hole of circular section that will be called "a well". The drilling

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stage constitutes the "core" of a well's life. It includes all the operations carried out with appropriate means (drilling rig and related equipment) which consist in penetrating the subsoil in order to extract the fluid or gas contained in the ground crossed, figure2.

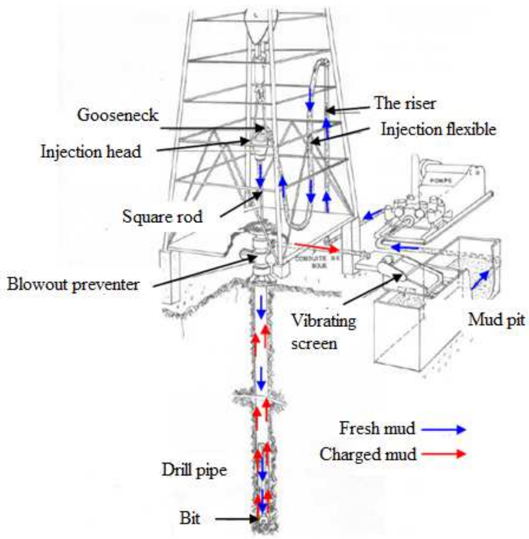


Fig.2. Drilling process

Among the most widespread risks that can become major risks is the risk of the inflow in drilling works [13, 14, 15]. The latter is defined as follows: An inflow is the intrusion of an unwanted fluid from a permeable formation into the well, as soon as the bottom pressure becomes lower than the pore pressure. Thus, the controlled or not, constitute not only a loss of time and money but can also involve if it is not controlled human, material and environmental damage. The most frequent causes of kick are:

- Failure to keep the hole full during packing operations;
- Swabbing during manoeuvres;
- Lost circulation;
- Insufficient drilling fluid density (Mud weight too low);
- Failure of differential fill-up equipment
- Special situations (DST, uncontrolled advancement in a gas containing formation...).

Through this study we try to highlight the different risks that arise from a blowout, or even an uncontrolled inflow of gas, oil or other fluids from the well. This last one if not controlled can become a major risk, objective of our study.

3. WORK METHODOLOGY

Risks in a project are more or less probable events that can cause damage and harm the smooth running of the project [16], or even jeopardize the sustainability of the company [17]. These events can have negative consequences on the achievement of objectives and the respect of deadlines. Consequently, risk management plays an important role in the realization of any project and risk mapping is a means of managing the sensitive points inherent in it. The latter consists in eliminating or reducing the level of risks by implementing adequate prevention measures leading to a healthy and safe workplace. We aim through this study to make a contribution to the analysis of our drilling system in order to understand it and to evaluate and judge its performance with regard to the risks identified during the drilling operation. In this way, we will be able to better understand the risks inherent to the use of the blowout preventer, to better control them throughout its life cycle and to reduce their effects without totally eliminating them. The methods of risk analysis, whether qualitative, semi-qualitative or quantitative, are numerous and their use differs according to the fields of activity, the systems (simple or complex), the work environment, etc. To carry out our study, we have used the complementarity of three methods of risk analysis which are respectively (FMECA, AdD and AdE) whose main objective is to find the causes and consequences that can cause adverse effects on workers, property and the environment during drilling operations. Thus, the FMECA allows us to identify the different causes of failure of the blowout preventer system, their consequences and their criticality. The fault tree (AdD) allows us to visualize all the combinations of elementary events leading to a failure, that is to say that it allows us to have a global and logical vision of the functioning and the dysfunctions of the system, even the blowout preventer system. Finally, the work is completed by the use of the event tree (AdE) that allows us to determine the sequence of events as well as the final result:

success or failure [18]. Like the fault tree analysis on which it is based, the Event Tree allows us to estimate the probabilities of occurrence of accidental sequences [19, 20]. It allows us to highlight the different scenarios of blowout preventer (BOP) closure in a state of success or failure of the safety barrier function.

4. CASE STUDIES

In this study we are interested in the blowout preventer control system. This is the most important piece of equipment used for well blocking: blowout preventer control (BOP), figure 2.

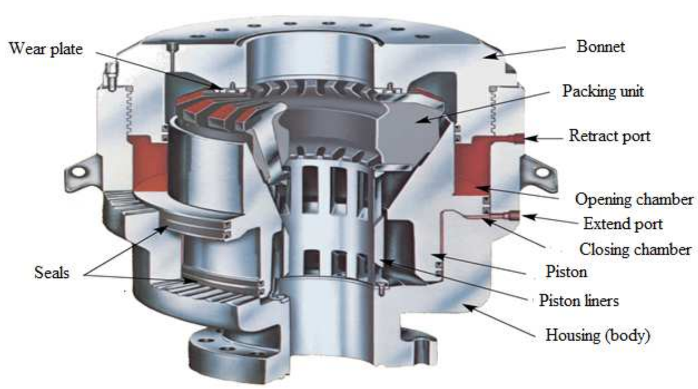
It is represented by a set of valves placed on the head of a wellbore. It is the safety instrument that allows the well to be closed in the event of extreme pressures emanating from the reservoir, to prevent hydrocarbon leaks. Two types of blowout preventers are used, the annular blowout preventer (annulus BOP) and the rams BOP, figure 3.

Fig.2. Blowout preventer at ENAFOR

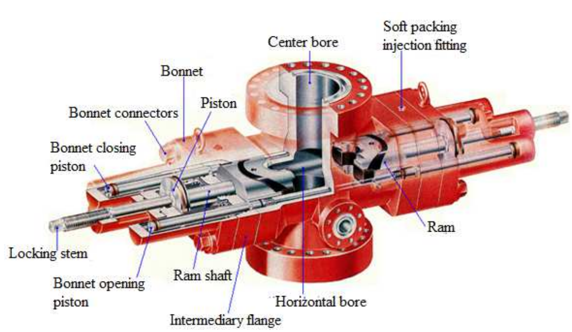
4.1. Determination of the different causes of failure of blowout preventer system.

This systematic and proactive analysis is to detect major failures in complex processes [21]. It is a tool for operational safety and quality management. This analysis phase consists in evaluating the criticality of the failures of each element by using the rating criteria defined by the FMECA analysis cited in Tables 1, 2 and 3, based on:

- Group members' knowledge of malfunctions;
- Reliability databases.



a. Annular Preventer (BOP annular)



b- Ram preventer (BOP rams)

Fig.3.The preventers used (a, b)

The criticality C is determined as a function of ($C=F \times N \times G$, therefore varies from 1 to 80). The failures can then be classified into two categories by comparison with a predefined admissible criticality threshold Clim= 16 in this case.

- Critical failures for which $C \geq Clim$;
- Non-critical failures for which $C < Clim$

Table 1

Gravity index

Values of G	Severity of the failure
1	Minor failure: no important material damage
2	Moderate failure requiring short term repair
3	Major failure requiring a long-term intervention
4	Very critical catastrophic failure requiring major intervention

Table 2

Frequency index

F : Frequency Level		Definition of the levels
very low frequency	1	Rare failure: Less than one failure per year
low frequency	2	Possible failure: Less than one failure per quarter
Average frequency	3	Frequent failure: Less than one failure per week
High frequency	4	Very frequent failure: several failures per week

Table 3

Non-detection index

Value of N	Non-detection of the failure
1	The measures taken ensure total detection of the initial cause or mode of failure, thus avoiding the most serious effect caused by the failure during production.
2	The detection is exploitable : There is a warning sign of the failure but there is a risk that this sign will not be perceived by the operator;
3	The detection is weak: The cause and/or mode of failure are difficult to detect or the detection elements are not very usable.
4	This is the case without detection: There is no way to detect the failure before the effect occurs:

The calculation results are summarized in table 4 and the most critical failures identified by the FMECA method are colored in red. From these results, we can see that the failures identified are generally related to the service and maintenance operations. Therefore, we recommend an action plan that meets the specificities of the system with adequate training of personnel.

4.2. Determining the causes of the blowout:

The fault tree analysis makes it possible to go back from cause to cause until the basic event likely to be at the origin of the feared event. This analysis focuses on a particular event described as undesirable or feared that we do not want to see it materialize. The results of the analysis are presented in Figure 4. In this tree, we have defined all the causes that can cause a blowout in the drilling system. However, special attention is given to the causes of inflow without forgetting the role of the human operator on the work site (Fig. 4.).

4.3. Highlighting the different scenarios of blowout preventer (BOP) closure in a state of success or failure of the safety barrier function.

It can be seen that the closure of the SHEAR RAMS is necessary to have a control of inflow. The failure of the detection barrier and the human operator, inevitably leads to the eruption. Therefore, the human operator must have a good understanding of the warning signs of the inflow (Fig. 5).

5. CONCLUSION

The role of the petroleum sector in the development of the national economy is unavoidable. However, it can present serious risks for people, installations and various environmental impacts. In drilling, the major risk is Blowout.

The well control equipment is of paramount importance during the drilling operation, because without the blowout preventers the continuity of the required function cannot be ensured. It has been found that there are hazards related to the blowout and the inflow phenomena that can destroy the probe endanger the safety of the operators and the premature disposal of the installation, or even the sustainability of the wells.

From the results of the FMECA analysis it can be deduced that the failures identified are generally related to maintenance services and operations.

Therefore, we recommend an action plan that meets the specificities of the system with adequate training of personnel and daily checks are necessary for a functional assurance of the device.

From a qualitative point of view, the ADD analysis allowed us to highlight the importance of the S RAMS which ensures the control of the inflow.

And that the failure of the detection barrier and the human operator (OH), inevitably leads to the blowout. Therefore, the human operator must acquire a good knowledge of the warning signs of a kick.

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Table 4.

Failure mode and effects Analysis (FMECA)

BOP Annular Component											
N	**component**	**Function**	**Failure Mode**	**Cause of failure**	**Effect of failure**	**Detection**	**Criticality**				**Corrective action**
							F	**N**	**G**	**C**	
1	Bonnet	-Ensure a compression surface for elastic packing (packing unit) -Cover interior components	External leak (at threads)	Wear, corrosion of threads	Fluid loss and annular pressure decrease (long term)	Visual (manometer)	2	1	4	8	- Replacement part: Bonnet
				Manufacturing defect	Fluid loss and annular pressure decrease (long term)	Visual (manometer)	1	1	4	4	
2	The elastic lining the packing unit	Ensure closure, opening on the rods of variable diameters with possibility of closing on vacuum	Incomplete closure and opening.	-Wear corrosion	Insufficient sealing	- during the maintenance	**3**	**3**	**4**	**36**	- Periodic test - Replacement part: elastic packing -Miscellaneous: operator training
				Mechanical fatigue		-BOP testing	**3**	**4**	**4**	**48**	
				Use not recommended (vacuum closure)	Disturbance of annular inflow control	- BOP testing - during the maintenance	**1**	**3**	**4**	**12**	
3	Liners piston	-Provide support for elastic packing -ensure translation piston	Vibration of the Liner	-Wear, corrosion of fixing screws	-Vibration of the elastic packing	Visual (Maintenance examination)	**2**	**2**	**4**	**16**	-Miscellaneous: operator training -Replacement part: liners bolts
4	Wear plate	Protect and keep the elastic packing from friction	bad protection	Wear and tear (excessive function)	Destruction of the contact surface of the elastic packing	Visual (Maintenance examination)	**3**	**3**	**4**	**36**	- Replacement part: Plate, chamber seals -Periodic BOP testing
5	Opening chamber	Contain a pressurised oil	Internal oil leakage	Wear of chamber seals		-Visual (manometer)	**2**	**2**	**4**	**16**	-Replacement part: chamber seals

6	Closing chamber				Fluid losses and annulus pressure decrease (long term)						-Periodic test of the BOP
7	Piston	Apply pressure to the elastic packing	Seizing or partial jamming	Presence of impurities	Wear and tear and overheating	Visual (maintenance exam)	**2**	**3**	**3**	**18**	Cleaning
				Corrosion caused by drilling fluids	Decrease in the longevity of pressure	Visual (maintenance exam)	**3**	**3**	**3**	**27**	-Replacement part: Piston
8	The opening and closing port	Allow oil to flow in and out under pressure	Partial/full clogging	Unfiltered oil	Possibility to damage the opening	Visual (manometer, maintenance)	**2**	**2**	**3**	**12**	-Miscellaneous: the right choice of operating fluid - Provide a grid on tank filler cap
			Leakage at the hose connection	Incorrect tightening of hoses -Wear of the thread	Fluid loss and annulus pressure decrease (long term)	-Visual (manometer)	**2**	**2**	**4**	**16**	-Miscellaneous: operator training -Replacement part: threading
9	Body	-Contain and protect elements of the BOP (ring finger) -to ensure the balance -ensure the translation of the piston by its internal wall	Partial loss of balance	-Choc	Decreased resistance to high pressures	Visual (manometer)	**1**	**2**	**3**	**6**	Operator training
				- Tightening defect	Leakage of drilling fluids	Visual	**2**	**1**	**3**	**6**	-Replacement part: Compliant screw -Miscellaneous: Operator training
			Hinders the piston	Corrosion and wear, scratching of the contact surface	- loss of oil -disrupting the operation of the BOP (annular)	Visual (manometer) maintenance)	**2**	**3**	**4**	**24**	Operator training
10	Seals Chambers	-Ensure the watertightness of the chambers	Leakage	- Wear (aging of the rubber)	- loss of oil -disrupting the operation of the BOP (annular)	visual (maintenance manometer)	**2**	**3**	**4**	**24**	Systematic replacement of the seal

BOP Rams component								
N	**Component**	**Function**	**Failure Mode**	**Cause of failure**	**Effect of failure**	**Detection**	**Criticality**	**Corrective action**

							F	N	G	C	
1	Body	- Protect the rams and allow them to move the passage of tools and tubular material	Distortion	Choc	Damage	Visual	**1**	**1**	**3**	**3**	- Replacement part: body -Repair -Miscellaneous: operator training
2	Rams	-Ensure closure on a given diameter (pipe rams) -To ensure the total closure (blind rams) -To ensure the total closure with shear rams (blind shear rams)	Insufficient sealing	-Packer wear and corrosion	- Leakage of fluids (sludge or formation fluids)	- During maintenance -BOP test	**3**	**4**	**3**	**36**	- Replacement part: Packer
			- Bad shear	- Wear and corrosion of shear blade	- Disruption of the inflow control	- During maintenance -BOP test	**2**	**3**	**4**	**24**	- Replacement part: Shear blade
3	Piston	Ensure the closing and opening of the rams	- Seizure or partial jamming	Presence of impurities	- Incomplete closing and opening -Decreased piston life	Visual	**2**	**1**	**2**	**4**	Cleaning
						Visual	**3**	**1**	**4**	**12**	- Replacement part: Piston

Pressure accumulator unit (kommey)											
N	**component**	**Function**	**Failure Mode**	**Cause of failure**	**Effect of failure**	**Detection**	**Criticality**				**Corrective action**
							F	**N**	**G**	**C**	
1	4-way control valve	Check the opening and closing pressure of the preventers and the hydraulically operated valves	Leakage	- Wear (excessive function)	Loss of oil	-Visual	**2**	**2**	**4**	**16**	-Replacement part: Valve
			Seizure	- Lack of lubrication	- Disrupting the procedure Valve malfunction	- Manually	**2**	**2**	**4**	**16**	-Periodic lubrication
				-aggressive environment (sandy wind)		Manually	**2**	**2**	**4**	**16**	-Replacement part: contact surface -Cleaning valve
2	Pressure gauges	Indicates service oil	Wrong indication	Choc	- false intervention reaction -waste of time	Visual	**2**	**4**	**3**	**24**	- Miscellaneous: operator training - Periodic verification

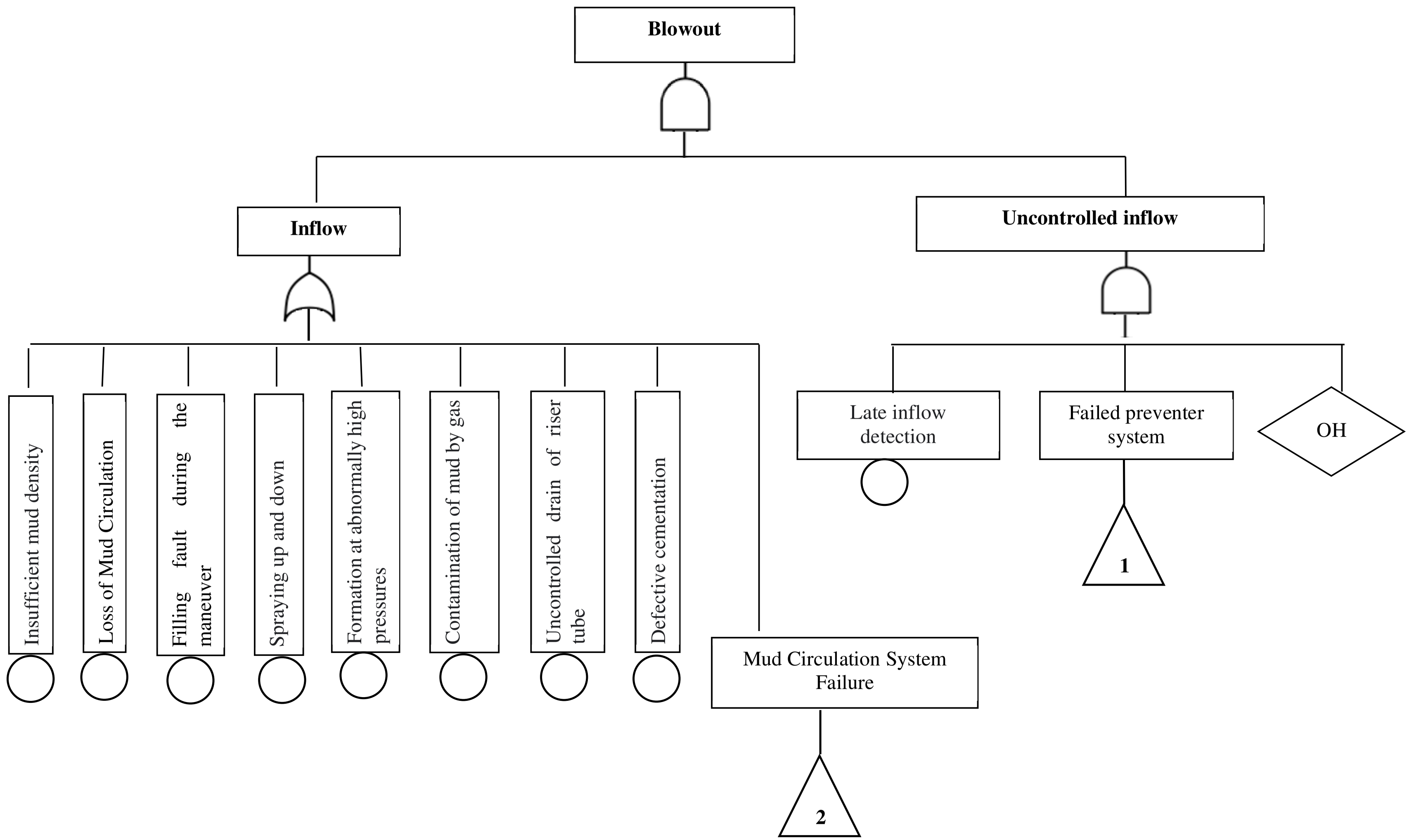
3	Pressurized service oil hose (annular, rams)	Ensure the passage of service oil to the BOP	Leakage	Wear corrosion	Fatal damage to humans -loss of closing pressure	Visual	**2**	**2**	**4**	**16**	- Replacement part: Flexible - Control - Miscellaneous: Operator training

CHOKE LINE component

N	Component	Function	Failure Mode	Cause of failure	Effect of failure	Detection	Criticality				Corrective action
							F	N	G	C	
1	Manual valve	Ensures the passage of the mud and the flow to the Nozzle manifold.	Blocking	Rust	Pressure leakage (mud, inflow)	Manual	**2**	**2**	**4**	**16**	- Replacement part: Valve
			Deformation.	Shock	Dysfonctionnement de la vanne	Visual	**2**	**3**	**3**	**18**	- Replacement part: Valve
2	hydraulic Valve	Ensures the passage of the mud and the flow to the Duse manifold.	Blocking	Rust	Disruption of the inflow control	Manual remote control	**1**	**3**	**4**	**12**	- Replacement part: The manual valve

KILL LINE component

N	Component	Function	Failure Mode	Cause of failure	Effect of failure	Detection	Criticality				Corrective action
							F	N	G	C	
1	Manual valve	Ensures the passage of mud to the well.	Blocking	Rust	Pressure leakage (mud, Flow)	Manual	**1**	**4**	**4**	**16**	- Replacement part: Valve
			Deformation	Shock	Loss of control inflow	Manual	**2**	**4**	**4**	**32**	- Replacement part:Valve
2	Flexible connection	Ensure BOP-manifold communication	Leakage	Shock	Disruption of inflow control	Visual	**4**	**3**	**2**	**24**	- Replacement part: Flexible


Blowout
Inflow
Uncontrolled inflow
Insufficient mud density
Loss of Mud Circulation
Filling fault during the maneuver
Spraying up and down
Formation at abnormally high pressures
Contamination of mud by gas
Uncontrolled drain of riser tube
Defective cementation
Mud Circulation System Failure
2
Late inflow detection
Failed preventer system
1
OH

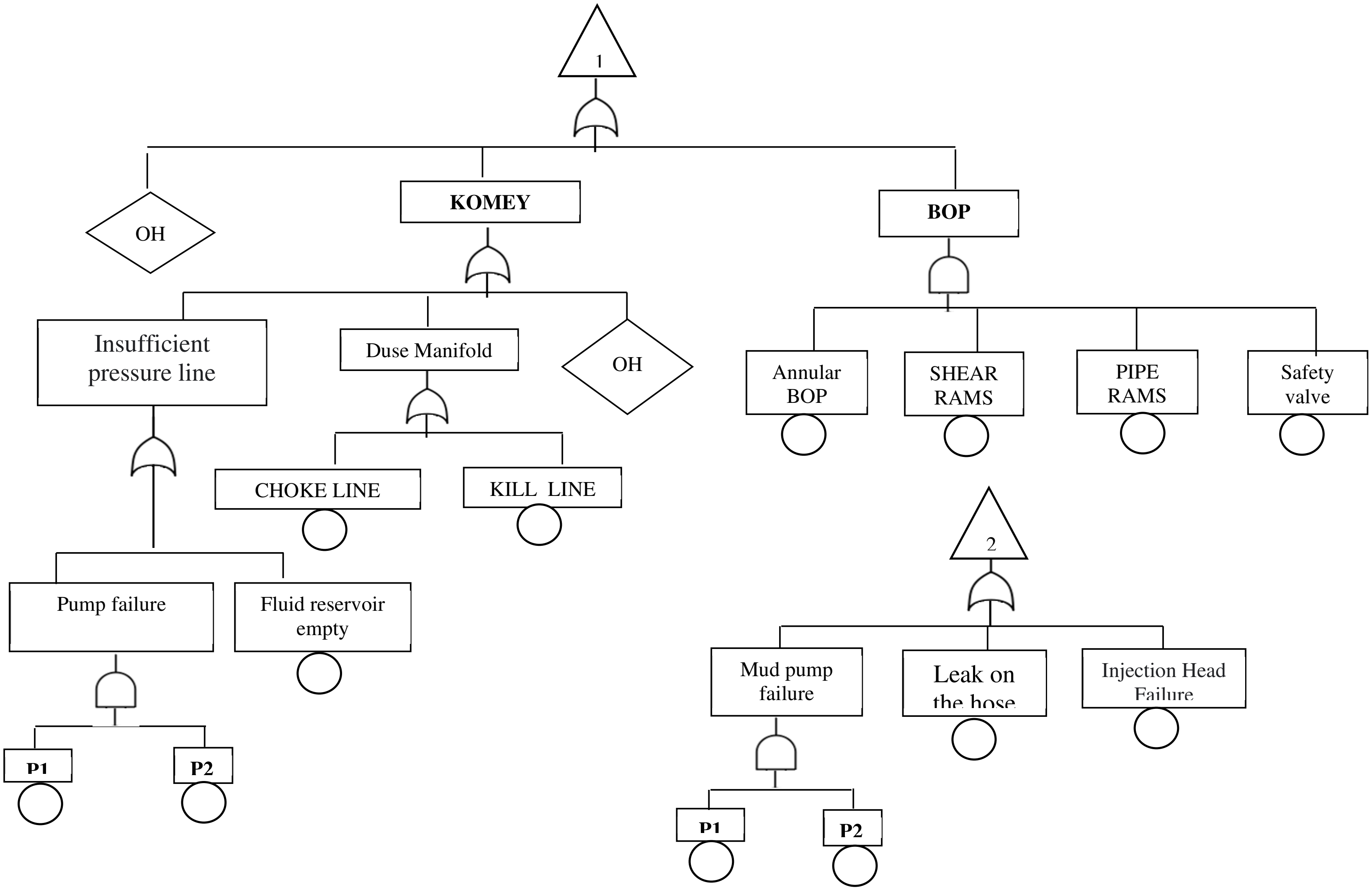
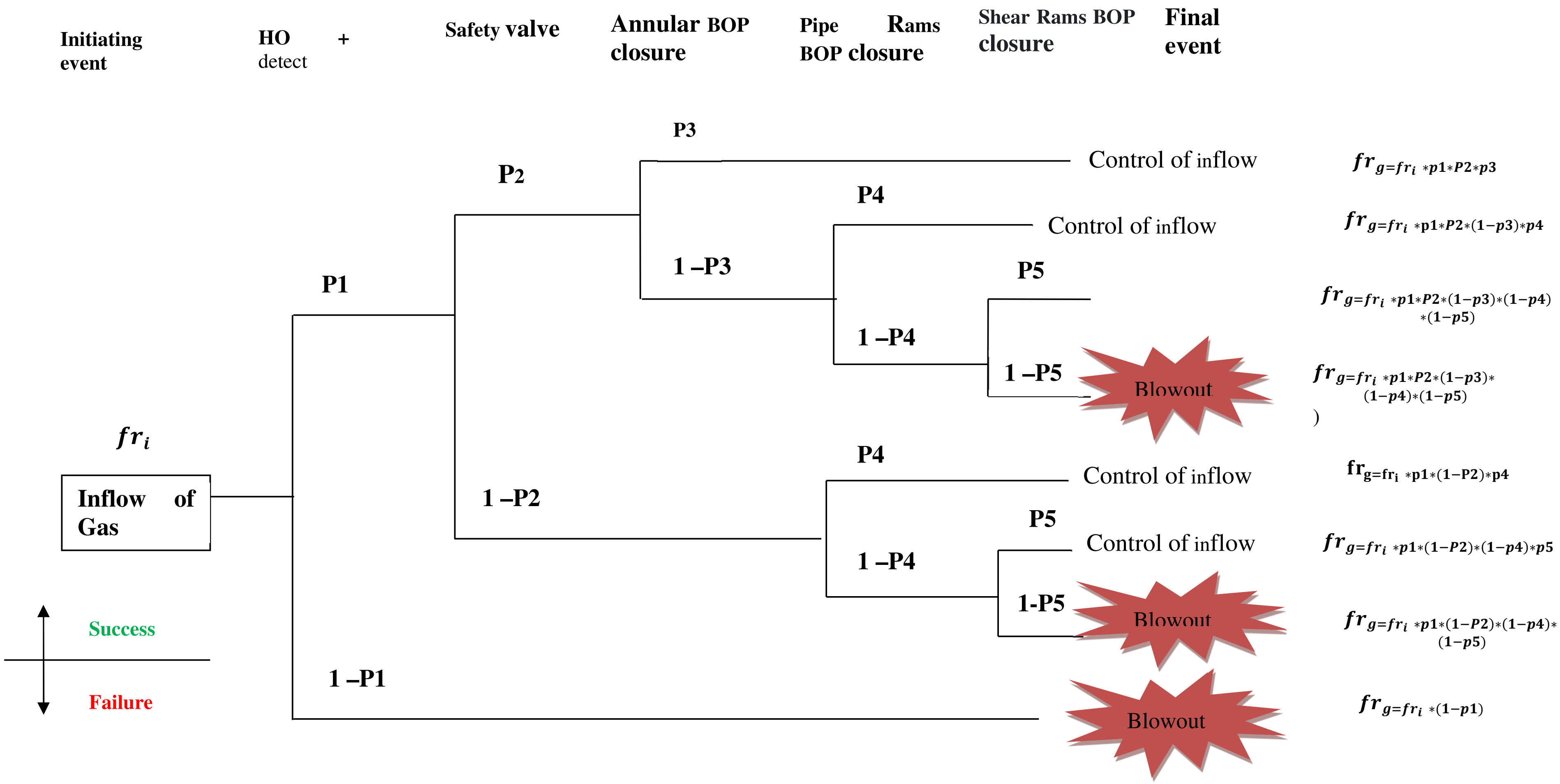


Fig.4. Fault tree analysis of Blowout preventer control

Fig.5. Presentations of: BOP



PENTRU UN MANAGEMENT EFICIENT AL RISCURILOR LA FORARE. STUDIU DE CAZ : SISTEMUL DE STINGERE PRIN SUFLARE

Rezumat: Unul dintre cele mai frecvente și importante pericole în operațiunile petroliere este riscul unei explozii în operațiunile de foraj, rezultat al unui aflux necontrolat de gaz, petrol sau alte fluide în puț. Acest fenomen este definit drept o intruziune a fluidului nedorit dintr-o formațiune permeabilă în zona de forare, odată ce presiunea găurii inferioare devine mai mică decât presiunea porilor. În consecință, evenimentele controlate sau necontrolate, atunci când au loc, nu sunt doar o pierdere de timp și bani, ci pot duce și la daune umane, materiale și de mediu, sau chiar la un dezastru. Prin acest studiu, încercăm să înțelegem mai bine riscurile inerente utilizării unui dispozitiv de prevenire a exploziei, să le controlăm mai bine pe tot parcursul ciclului de viață și să le reducem efectele, fără a le elimina însă complet.

Cuvinte cheie: explozie, managementul riscului, foraj, operațiuni petroliere, AMDEC

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