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Original Article

Modeling the Effects of Accidents on Employees During Blowout Preventer Testing

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Abstract: *The drilling of oil and gas wells also requires ensuring safety in the operation of the well construction systems and the protection of the environment and employees. During the drilling of the wells, eruptive manifestations and/or pressure increases in the well may occur (above the pressure value provided by the weight of the drilling fluid), which may lead to the production of oil fluid eruptions (which also contain rock particles and drilling fluid compounds) and cause fires or accidents human lives, as well as environmental pollution. Also, an uncontrolled eruption can lead to particularly large financial losses for the operator of the oil field, because in addition to the loss (through the eruption) of oil fluids, there is also a drop in the reservoir pressure (which leads to an increase in the costs of equipping and operating the oil structure). This is precisely why the use of equipment necessary to prevent uncontrolled eruptions (blowout preventer) (BOP) is absolutely mandatory. This article analyzed the effects of stress tests on employees in the event of an accident.*

Keywords: *Blowout Preventers, Oil and Gas Wells, Drilling, Accidents.*

I. INTRODUCTION

By definition, an eruption is an uncontrolled release of crude oil and/or natural gas together with dislocated rocks, drilling fluid, and other components thereof (additives, diesel, oil, etc.), and fluid components to increase the extraction capacity or supply the productive layer [1].

Modern wells have devices to prevent uncontrolled eruptions (blowout preventers).

The eruptions were accompanied by fires caused by sparks following the collision of the rocky material with the drilling rig's component metals.

Before 1920 (the date of the first eruption preventer), eruptions were called oil gushers, gushers, or wild wells.

Crude oil blowouts were common in the late 19th and early 20th centuries when rudimentary drilling techniques (percussion or rotary drilling with rock cutters) would penetrate the oil reservoir and cause it to erupt freely (due to the lack of blowout preventers and proper drilling fluids).

Also, during the initial period of extraction, at the exit from the extraction well, a spherical cap (like a spoon) made of wood or cast iron (called lysis) was mounted to separate the gases and volatile fractions from the crude oil.

Later, the crude oil was directed into pits and trenches in the well area, from where it was harvested with pumps and pumped into tanks and pipelines.

Free eruptions, as well as open-mouth extraction of crude oil, decreased the pressure of the crude oil deposit, polluted the environment, and increased employees' insecurity [1].

Usually, the oil spills (uncontrolled eruptions) also cause fires [2].

A fascinating account of an eruption tells us that it was like the roar of a hundred express trains passing through a rolling area, the force of the crude oil causing machinery and equipment to disintegrate and fires breaking out [3].

The development of rotary drilling techniques (in which the density of the drilling fluid was sufficient to overcome the bottom pressure) also led to the penetration of the well into oil formations with high reservoir pressures.

If the fluid density was not adequate or the fluids were lost (penetrated the productive layers), crude oil gushed out in the form of an uncontrolled blowout (there is a significant risk of a good blowout).

In 1924 the first device to prevent eruptions (Blow Out Preventer) was built [4].

Following the advent of this device, uncontrolled free eruptions could be avoided, with 21 accidents followed by fires reported from 1976 to 1981.

Extinguishing oil fires was first practiced (in America and the Caspian Sea) by using explosives, which created an explosion (for rapid oxygen consumption) and no longer provided the necessary fuel.

Myron and Karl Kinley were the first oilmen to use explosives as an oil well firefighting technique (in 1913), establishing the M. M. Kinley Company in 1923.

Later, oilmen with significant experience in firefighting (Asger "Boots" Hansen, Edward Owen "Coots" Matthews, Paul N. "Red" Adair) joined the company.

In 1959, Paul N. "Red" Adair opened Red Adair Co., Inc., a company specializing in firefighting.

Red Adair Co. helped control explosions and fires mainly offshore, including:

- CATCO Fire in the Gulf of Mexico in 1959.
- The Ixtoc I oil spill in Mexico's Gulf of Campeche in 1979.
- The Piper Alpha disaster in the North Sea in 1988.
- Oil fires in Kuwait after the 1991 Gulf War.

In 1994, Adair sold his company to Global Industries.

The company's management created a new company, International Well Control, which was sold to Boots & Coots International Well Control, Inc. in 1997 [5].

In 1922, Harry Cameron and Jim Abercrombie created the first blowout preventers (BOP).

The assembly of valves mounted on protective equipment was installed during drilling to prevent the formation of an explosive atmosphere.

However, the possibility that the high pressure in the well could destroy protective equipment has led to the design and construction of hydraulic, horizontal blowout preventers, which can ensure that the pipes inside the well are cut and, therefore, closed.

The closure system consists of isolation jaws (blind), pipe sealing rings (drill rod) (pipe ram), and well pipe cutting and isolation jaws (shear ram).

The original BOPs, manufactured in the 1920s, were simple and robust manual devices with minimal moving parts and sealing systems that performed well at the time.

The BOP casing (body) had a vertical wellbore and a horizontal wellbore cavity (well guide chamber).

Opposite jacks in the preventer cavity were operated with a screw jack. The torque of the shafts of the vanes with the wrench or handwheel was converted into linear motion, and the vanes on the inner ends of the shafts opened or closed the probes.

Such screw jack operation provided a sufficient mechanical advantage for the jacks to overcome the downhole (productive formation) pressures and seal the good annulus and, therefore, the wellhead (drill string).

BOP hydraulic tanks have been in use since 1940.

Hydraulically actuated blowout preventers had many advantages, namely:

- Pressure could be equalized in opposite hydraulic cylinders, causing the bins to operate unison.
- Relatively fast actuation and remote control were facilitated, and hydraulic tanks were well adapted to high-pressure wells.

In 1930, Regan Type K Annulars blowout preventers were first used to control oil wells.

The role of these devices was to create a system to close the well, even by cutting the drilling or extraction rods, upon the appearance of eruptive manifestations.

In 1946 Granville Sloan Knox introduced the annulus blowout preventers, which sealed the drill string and stopped the flow of wellbore fluid (past the string).

II. MATERIALS AND METHODS

The role of eruption preventers is [5]:

To ensure the tightness of the drilling well in order to prevent uncontrolled free eruptions,

To maintain the integrity of the productive layer, to ensure its productivity, after equipping the well to collect the production of petroleum fluids,

To ensure the rapid closure of wells (drilled wells) in eruptive manifestations.

Blowout preventers are manufactured in vertical or horizontal construction and mounted at the well's mouth.

These BOPs are equipment that ensure the closure of the well and avoid the propagation of free eruptions into the atmosphere (during the drilling of crude oil and gas wells or the preparation of the wells for exploitation).

Vertical blowout preventers, manufactured in Romania, correspond to the BAA temperature class and can work in oil and gas drilling, where the temperature of the fluids handled or pumped (extracted) through it is a maximum of 180˚F (82˚C) (Fig. 1) [6].

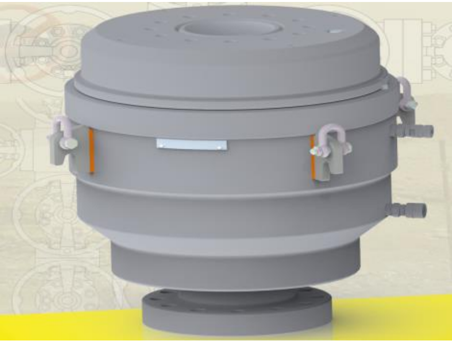


Figure 1: Vertical Blowout Preventer Type AC

The constructive solution of AC type vertical eruption preventers gives them a high degree of sealing efficiency, operational safety and simple maintenance.

Among the factors that contribute to the achievement of these performances can be listed:

- the construction of the preventer ensures the "self-sealing" effect, in the sense that the pressure from the borehole helps to seal the tank;
- the ring buckle is made of elastomer (rubber) vulcanized in the mold, combined with a set of metal inserts;
- the closing pressure acts on the operating piston so that, by its upward movement, the rubber of the annular tank is forced to close on the inside;
- the construction of the tank ensures the reserve of rubber necessary for its repulsion in the direction of the sealing surfaces, until the free interstices are closed.

Technical characteristics of the horizontal preventer analyzed in this article:
Maximum working pressure 210 bar (3000 psi),

- 7 1/16 inch flanged end connections, R45,
- Quick coupler, plug, QHPA54-D7X6-B, 16L for opening/closing port operation,
- Hydraulic oil drive fluid H10,32A,46 A, HPL32.

The horizontal blowout preventers, type ROH2, are closing equipment mounted at the wellhead.

They have the role of ensuring the avoidance of free eruptive manifestations, which may occur during the drilling of crude oil and gas wells.

They are also useful when carrying out operations to prepare crude oil and gas wells in order to exploit the productive layers (fig.2).

The horizontal eruption preventers type ROH2 are equipped on each floor with a set of tanks that ensure the following operations [7]:

- closing the annular space between the column of downspouts on which they are mounted and the outer cylindrical surface of the drill rods, extraction pipes or downspouts that are disturbed, in a dimensional range between 1.66" and

9 5/8";

- the total closing of the well mouth, when the drill rods, the extraction pipes or the tubing pipes are extracted from the well;
- directing the drilling fluid from the well through the side exits to the hubs, in order to reduce the pressure in the well.

The use of two ROH2 type blowout preventers mounted in series ensures the total closure of the well mouth, as well as the closure of at least two diameters of drill rods, extraction pipes or casing pipes, additionally allowing the following operations to be performed:

- doubling the closing of the rod bins, achieving an increased operational safety coefficient;
- tight closing of the well mouth in the case of using a drill rod with different diameters;
- tight closing of the well mouth in the event of stopping a connection for assembling the rods next to a bar of the preventer;
- alternative use of two manifolds with adjustable nozzles, one mounted between the tanksof the preventer and another under the lower bar;
- extraction operations, under pressure, of drill rods together with other used equipment

Type ROH2 horizontal blowout preventers are designed for temperature class BAA and can be used for fluids up to 180˚F (82˚C).

ROH type blowout preventers can be: single (ROH), double (ROH2) or triple (ROH3), i.e. the preventer body is provided with: one, two or three sets of closing devices (bars).

As a rule, the upper closing device is equipped with bars for total closing, the horizontal preventers being provided at the top and bottom with connection flanges, with bolts embedded in the body and with 2 side exits each.

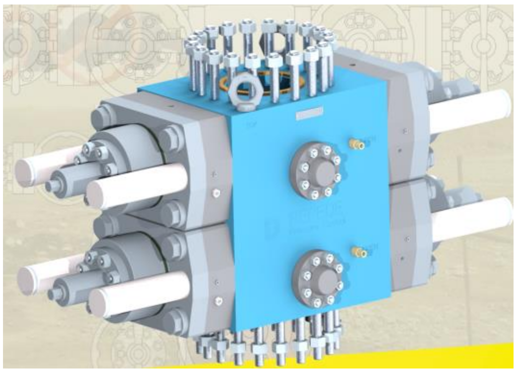


Figure 2: The Horizontal Eruption Preventers Type ROH2

III. MODELING THE EFFECTS OF ACCIDENTS ON EMPLOYEES DURING BLOWOUT PREVENTER TESTING

A. Eruption Preventers are Tested According to:

The API 16 A standard, which consists of performing the hydrostatic, closure test, the mandrel test for horizontal blowout preventers and the tests for the hydraulic actuation system (as an integral part of the preventer or delivered separately), [7,8].

a) The Hydrostatic (Strength) Test of the Actuator Body Consisted of Three Stages [60,61,62]:

- Hold the pressure for 3 minutes,
- Reducing the pressure to zero,
- Increase the pressure and maintain the pressure for 15 minutes.

The maximum value of the test pressure is a function of the operating pressure, namely:

- Working pressure 140 bar, test pressure 210 bar,
- Working pressure 210 bar, test pressure 310 bar.

Acceptance criterion: no fluid leaks during each period of maintaining pressure. As long as no fluid leakage is visible, a pressure drop of 1% of the test pressure is accepted during the holding period under pressure

b) The Requirements of the Closure Tests of Horizontal Preventer Tanks

In order to carry out the closing tests of the tanks of the horizontal preventers, the following general requirements must be met:

- each horizontal eruption preventer will be tested upon closing after performing the hydrostatic tests of the preventer body and the body of the hydraulic actuation system;
- the closing test will be performed on each floor of the preventer separately; on each floor, a set of bins will be mounted, different in size from each other (the dimensions of the bins will be those with which the horizontal preventer will be delivered);
- the pressure value of the tank actuation fluid will be 103-114 bar at an operating value of 140 bar;

c) *The Minimum Pressure Preventer Closure Test*, Equipped with a Fixed Hole Bucket

- close the barrel with the fixed hole on the test mandrel corresponding to the size of the tested barrel;
- a pressure of 200 to 300 psi (14 bar to 21 bar) is applied in the body of the horizontal preventer (under the tank);
- the pressure in the preventer's body is maintained for at least 10 minutes, after stabilization.

Acceptance criterion: no fluid leaks during the period of keeping under pressure.

As long as no fluid leakage is visible, a pressure drop of 1% of the test pressure is acceptable during the hold-in period.

d) *The Minimum Pressure Preventer Closure Test*, Equipped with a Variable Bore Bucket

- the tank is closed with the variable hole on the test mandrel corresponding to the minimum sealing size of the tested tank;
- a pressure of 200 to 300 psi (14 bar to 21 bar) is applied in the body of the horizontal preventer (under the tank);
- the pressure in the preventer's body is maintained for at least 10 minutes, after stabilization;
- the pressure in the preventer's body is brought to zero;
- the test mandrel corresponding to the minimum tank sealing size is replaced with the test mandrel corresponding to the maximum tank sealing size;
- the tank is closed with the variable hole on the test mandrel corresponding to the maximum sealing size of the tested tank;
- a pressure of 200 to 300 psi (14 bar to 21 bar) is applied in the body of the horizontal preventer (under the tank);
- the pressure in the preventer's body is maintained for at least 10 minutes, after stabilization;

Acceptance criterion: no fluid leaks during the period of keeping under pressure. As long as no fluid leakage is visible, a pressure drop of 1% of the test pressure is accepted during the holding period.

e) *The Minimum Pressure Preventer Closure Test*, Equipped With a Total Tank

- close the total tank (without mandrel);
- a pressure of 200 to 300 psi (14 bar to 21 bar) is applied in the body of the horizontal preventer (under the tank);
- the pressure in the preventer's body is maintained for at least 10 minutes, after stabilization.

Acceptance criteria: lack of fluid leaks during the period of maintaining under pressure. As long as no fluid leakage is visible, a pressure drop of 1% of the test pressure is accepted during the holding period.

f) The Cutting and Sealing Test of the Total Cutting Tank of the Horizontal Preventer

Each horizontal preventer equipped with a total cutting tray shall be subjected to the cutting and sealing test.

After the drill rod has been cut and before the cutting buckets are withdrawn, a pressure at least equal to the maximum working pressure of the tested horizontal preventer shall be applied to the body of the horizontal preventer (under the bucket);

The test must be performed without the drill rod being subjected to any tension (ex.: stretching, torsion) and it is performed without pressure in the body of the preventer.

Cutting and sealing of the drill rod must be done with a single operation of the cutting bucket

The pressure in the preventer's body is maintained for at least 10 minutes, after stabilization.

Acceptance criterion: no fluid leaks during the period of keeping under pressure. As long as no fluid leakage is visible, a pressure drop of 1% of the test pressure is acceptable during the hold-in period.

g) The Fixed-Hole Tank Mechanical Lock Test Having Minimal Pressure in the Preventer Body

- close the barrel with the fixed hole on the test mandrel corresponding to the size of the tested barrel;
- the locking system is activated and the tank actuation fluid pressure is reduced to 0 (zero);

- a pressure of 200 to 300 psi (14 bar to 21 bar) is applied in the body of the horizontal preventer (under the tank);
- the pressure in the preventer's body is maintained for at least 10 minutes, after stabilization.

Acceptance criterion: no fluid leaks during the period of keeping under pressure. As long as no fluid leakage is visible, a pressure drop of 1% of the test pressure is accepted during the holding period.

h) The Mechanical Lock Test of the Tank with a Variable Hole Having Minimum Pressure in the Body of the Preventer

- close the tank with the variable hole on the test mandrel corresponding to the minimum sealing size of the tested tank;
- the locking system is activated and the tank actuation fluid pressure is reduced to 0 (zero);
- a pressure of 200 to 300 psi (14 bar to 21 bar) is applied in the body of the horizontal preventer (under the tank);
- the pressure in the preventer's body is maintained for at least 10 minutes, after stabilization.
- the pressure in the preventer's body is brought to zero;
- the test mandrel corresponding to the minimum sealing size of the tank is replaced with the test mandrel corresponding to the maximum sealing size of the tank;
- close the tank with the variable hole on the test mandrel corresponding to the maximum sealing size of the tested tank;
- the locking system is activated and the tank actuation fluid pressure is reduced to 0 (zero);
- a pressure of 200 to 300 psi is applied in the body of the horizontal preventer (under the tank).
- (14 bar to 21 bar);
- the pressure in the preventer's body is maintained for at least 10 minutes, after stabilization.

Acceptance criterion: lack of fluid leaks during the period of keeping under pressure. As long as no fluid leakage is visible, a pressure drop of 1% of the test pressure is accepted during the period of holding under pressure.

i) The Mechanical Lock Test of the Tank with Variable Hole Having Maximum Pressure in The Body of the Preventer

- the tank is closed with the variable hole on the test mandrel corresponding to the minimum sealing size of the tested tank;
- the locking system is activated and the tank actuation fluid pressure is reduced to 0 (zero);
- a pressure equal, at least, to the maximum working pressure of the tested horizontal preventer is applied in the body of the horizontal preventer (under the tank);
- the pressure in the preventer's body is maintained for at least 10 minutes, after stabilization.
- the pressure in the preventer's body is brought to zero;
- the test mandrel corresponding to the minimum tank sealing size is replaced with the test mandrel corresponding to the maximum tank sealing size;
- the tank is closed with the variable hole on the test mandrel corresponding to the maximum sealing size of the tested tank;
- the locking system is activated and the tank actuation fluid pressure is reduced to 0 (zero);
- a pressure equal, at least, to the maximum working pressure of the tested horizontal preventer is applied in the body of the horizontal preventer (under the tank);
- the pressure in the preventer's body is maintained for at least 10 minutes, after stabilization.

Acceptance criterion: no fluid leaks during the period of keeping under pressure. As long as no fluid leakage is visible, a pressure drop of 1% of the test pressure is accepted during the holding period.

j) Mandrel Test Requirements

- All horizontal eruption preventers must pass the mandrel test.
- The mandrel test is carried out on the horizontal eruption preventers, after all the pressure tests have been carried out beforehand.
- The mandrel test is performed with the preventer's jaws in the fully open position.

1. The standard API Spec. 16A, point 7.5., which consists in meeting the requirements of the hydrostatic, closure test, the mandrel test for vertical blowout preventers and the hydrostatic tests for the hydraulic actuation system,

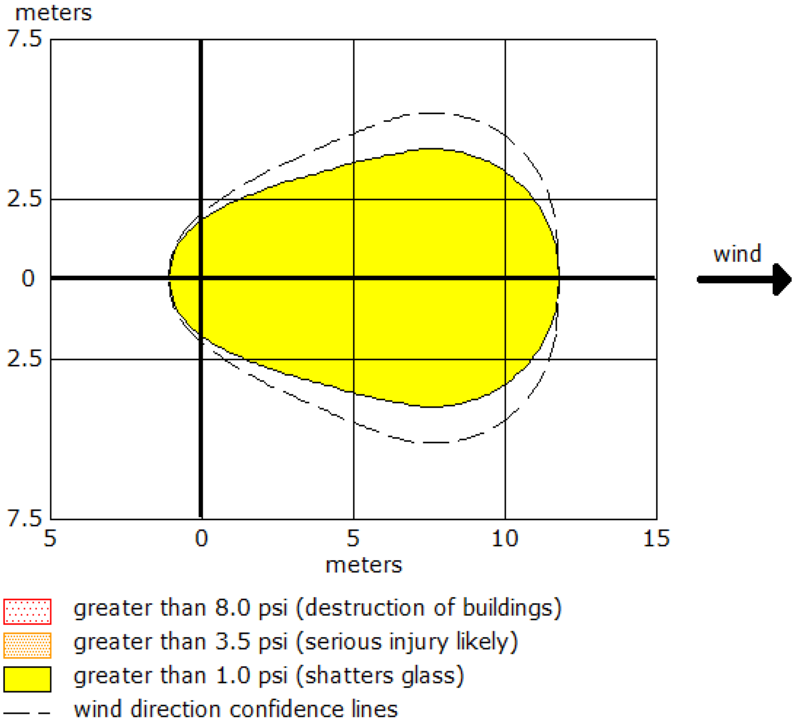
2. Fulfilling the requirements of the tests for the operational characteristics of the horizontal blowout preventers, as well as the validation extension criteria, in accordance with API 16A, point 4.7,

3. Fulfilling the requirements of the tests for the operational characteristics of the vertical blowout preventers, as well as the validation extension criteria, in accordance with API 16A, point. 4.7,

In the following, we conducted a study on the effects of pressure tests on employees.

We analyzed the effects of the test pressure on the environment in case of rupture or leakage of the test equipment (blowout preventer).

For testing I took water with oil (fuming sulfuric acid) $ySO_3{\cdot}H_2O$ with a concentration of 1%.



Figur3 : Effects of a breakdown on the environment at 100 atm pressure (BOP test)

Table 1: The effects of blowout preventer damage in the event of accidents occurring during their testing

Test pressure, atm	Damage diameter, cm	Gas flow rate in the atmosphere, kg/min	Area of building destruction, m	Area with human accidents, m	Area where glass breaks and small detachments of material may occur, m
50	1	5,48	1	3	9
100	1	12,2	5	7	12
150	1	19	7	9	15
200	1	24,7	9	11	18
250	1	29,1	11	13	19
50	2	5,48	2	4	10
100	2	12,24	6	8	12
150	2	19,08	12	14	15
200	2	25,08	14	16	18
250	2	29,52	15	17	20

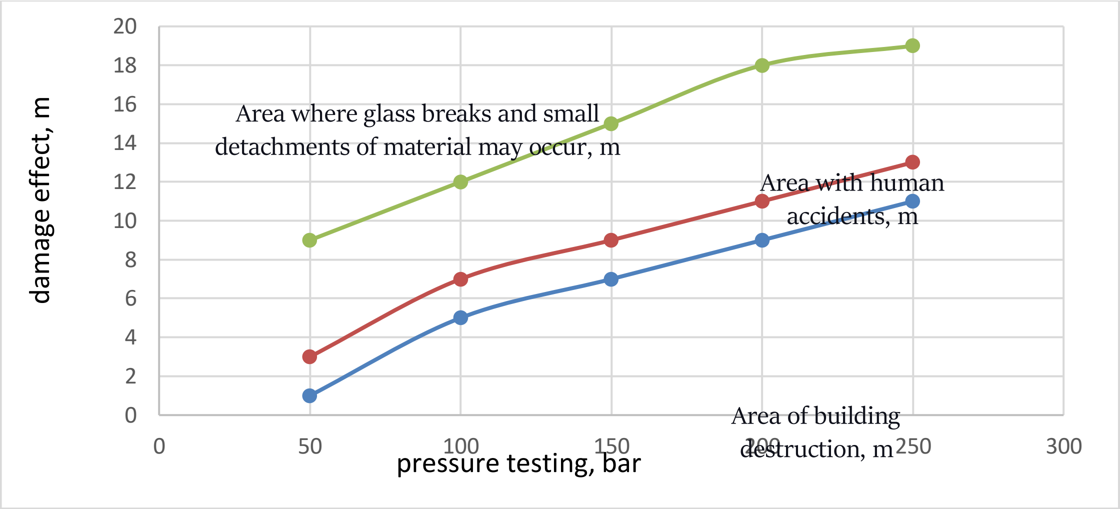


Figure 4: Effects of a damage on the environment at 1 cm diameter (BOP test)

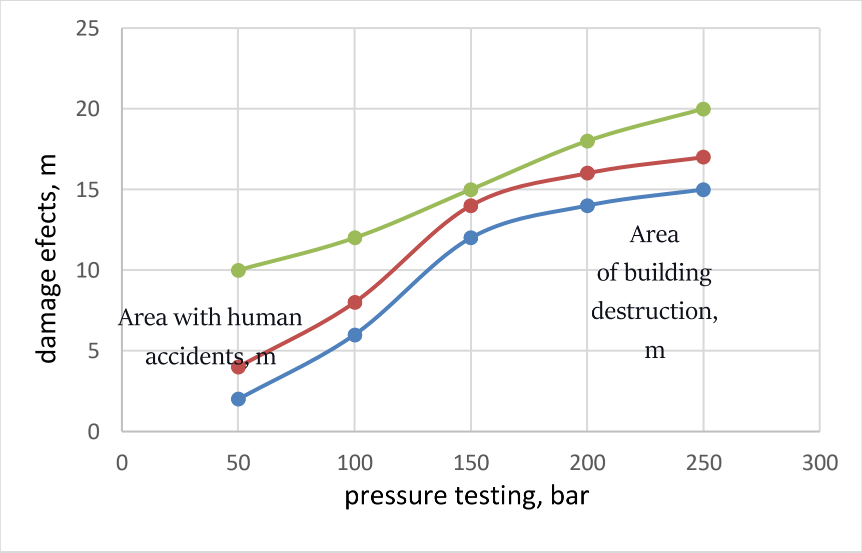


Figure 5: Effects of a Damage on the Environment at 2 CM Diameter (BOP Test)

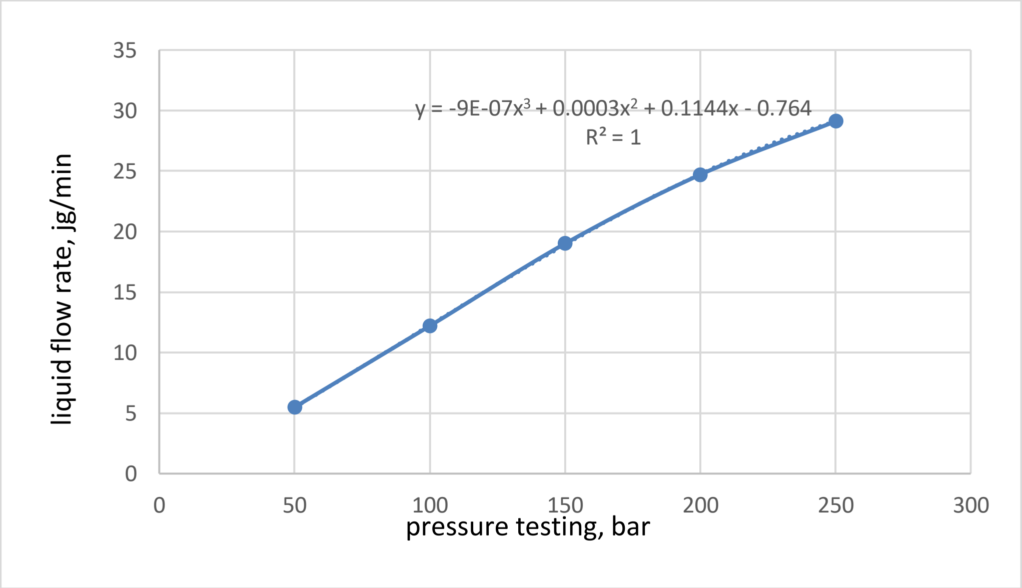


Figure 7: Effects of a Failure on the Leakage of Liquids from the BOP at a Diameter of 1 Cm (BOP Test)

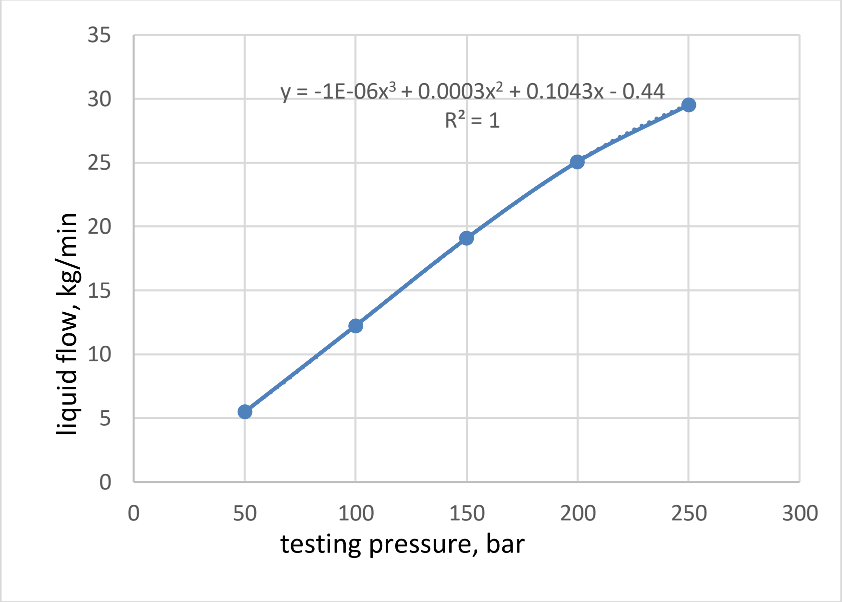


Figure 8: Effects of a Failure on the Leakage of Liquids from the BOP at a Diameter of 2 Cm (BOP Test)

In this case, the variation equations of the amount of liquid leaked into the atmosphere depending on the pressure and diameter are:

$y = -1\ E\text{-}06\ x^3 + 0.0003\ x^2 + 0.1043\ x - 0.44$ at a damage diameter of 2 cm, (y is the amount of liquid drained kg/min),

$y = -9\ E\text{-}07\ x^3 + 0.0003\ x^2 + 0.1144x - 0.764$ at a damage diameter of 1 cm, (y is the amount of liquid drained kg/min),

It is very important to numerically determine the areas affected by the damage as a function of the pressure and the diameter of the damage.

Equation of the diameter of the building destruction zone (Y), m (ie the diameter of the damage zone) as a function of the test pressure (bar) (X1) and the diameter of the damage (cm) (X2).

$Y=-5{,}3+0{,}058\ X1+ 3{,}2\ X2$

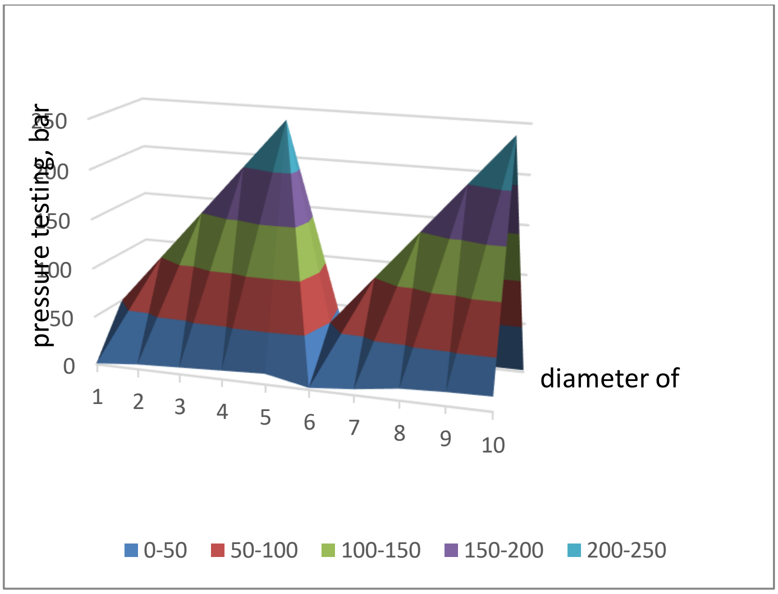


Figure 9: Damage effects on buildings (total destruction) as a function of blowout preventer test pressure and damage diameter

Equation of the diameter of the human accident zone (Y), m (ie the diameter of the damage zone) as a function of the test pressure (bar) (X1) and the diameter of the damage (cm) (X2).

$Y=-3{,}3+0{,}058\ X1+ 3{,}2\ X2$

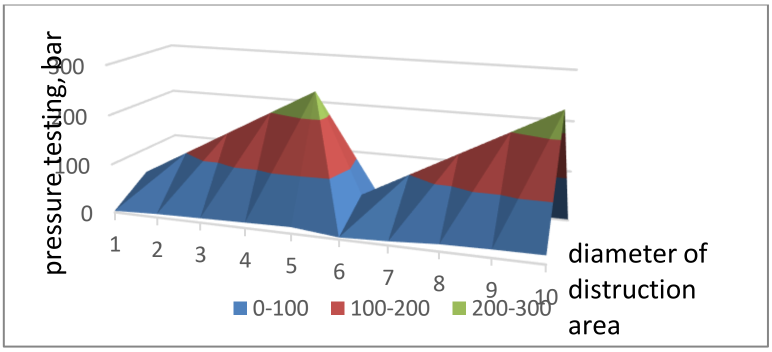


Figure 10: Effects of a failure on the human casualty area as a function of the blowout preventer's test pressure and the diameter of the failure

Equation of the diameter of the Zone where glass breaks and small material detachments can occur, m (Y), m (ie the diameter of the damage zone) as a function of the test pressure (bar) (X1) and the diameter of the damage (cm) (X2).

$Y=6{,}4+0{,}052\ X1+\ 0{,}4\ X2$

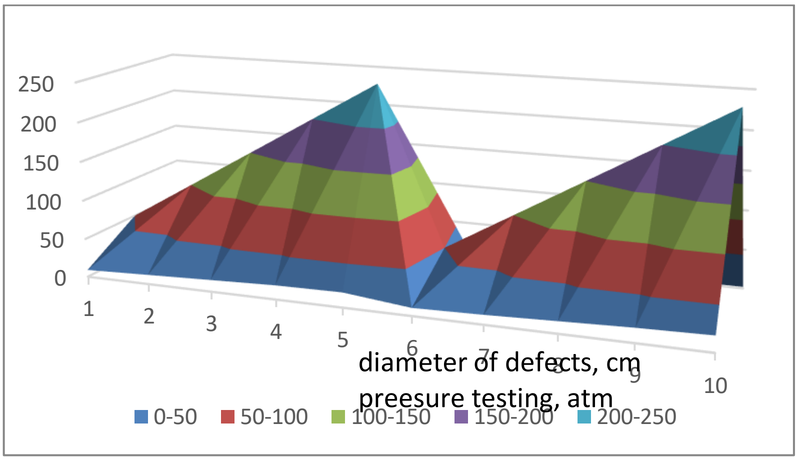


Figure 11: Effects of a failure on the area where small building destruction may occur, as a function of the blowout preventer test pressure and the diameter of the failure

IV. CONCLUSION

I have also described in paper the test requirements for putting the eruption preventers into operation as well as the acceptance criteria.

Next, we carried out a study on the effects of pressure tests on employees.

We analyzed the effects of the test pressure on the environment in case of rupture or leakage of the test equipment (blowout preventer).

For testing I took water with oil (fuming sulfuric acid) $ySO3{\cdot}H2O$ with a concentration of 1%.

The equations for the variation of the amount of liquid leaked into the atmosphere according to pressure and diameter are:

$y = -1E\text{-}06x^3 + 0{,}0003x^2 + 0{,}1043x - 0{,}44$ at a damage diameter of 2 cm, (y is the amount of liquid drained kg/min),

$y = -9E\text{-}07x^3 + 0{,}0003x^2 + 0{,}1144x - 0{,}764$ at a damage diameter of 1 cm, (y is the amount of liquid drained kg/min).

It is very important to numerically determine the areas affected by the damage as a function of the pressure and the diameter of the damage.

Equation of the diameter of the building destruction zone (Y), m (ie the diameter of the damage zone) as a function of the test pressure (bar) (X1) and the diameter of the damage (cm) (X2).

$Y=-5{,}3+0{,}058\ X1+\ 3{,}2\ X2$

Equation of the diameter of the human accident zone (Y), m (ie the diameter of the damage zone) as a function of the test pressure (bar) (X_1) and the diameter of the damage (cm) (X_2).

$$Y=-3,3+0,058\,X_1+3,2\,X_2$$

Equation of the diameter of the Zone where glass breaks and small material detachments can occur, m (Y), m (ie the diameter of the damage zone) as a function of the test pressure (bar) (X_1) and the diameter of the damage (cm) (X_2).

$$Y=6,4+0,052\,X_1+0,4\,X_2$$

We also determined:

- The effects of a damage on the environment at a diameter of 1 cm (BOP test)
- The effects of a damage on the environment at a diameter of 2 cm (BOP test)
- The effects of a breakdown on the leakage of liquids from the BOP at a diameter of 1 cm (BOP test),
- The effects of a breakdown on the leakage of liquids from the BOP at a diameter of 2 cm (BOP test).

Interest Conflicts

"The author(s) declare(s) that there is no conflict of interest concerning the publishing of this paper,"

V. REFERENCES

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