AGH DRILLING, OIL, GAS • Vol. 35 • No. 1 • 2018

http://dx.doi.org/10.7494/drill.2018.35.1.309

Petr Bujok*, Martin Klempa*, Jakub Ryba*, Michal Porzer*, Marek Jakubčík **, Lukáš Štastný **, Robert Rado***

SPECIAL SHUT OFF DEVICE FOR LIQUIDATING BLOWOUT FROM THE DRILL STRING****

1. INTRODUCTION

The issue of uncontrolled flux of reservoir fluids to the wellbores and liquidation of open blowout has been widely discussed in specialist literature [5–8, 10–12, 15]. Drilling companies also have their share in developing blowout prevention procedures [4, 9].

Under the notion of pressurized flux of reservoir fluids to a wellbore we understand its uncontrolled penetration. Such a situation takes place when the pressure in the wellbore is out of equilibrium. The pressure balance can be shaken due to sudden escapes of drilling mud or because an interval of anomalously high reservoir pressure was hit. In such cases the equilibrium changes and the hydrostatic pressure in the wellbore is lower than that of the inflowing medium. The pressure equilibrium can be disturbed in the course of various drilling operations, e.g. drilling, tripping in or out of the drill string, boreholes measurements, etc.

The inflow should be considered as a chain reaction. In most of the cases the penetrating reservoir fluid has a lower specific weight then that of drilling mud, and penetrating the wellbore reservoir fluid decreases the specific weight of the mud. This in turn evokes a bigger flux to the wellbore, the total volume of fluids in the well grows up,

* VŠB-Technical University of Ostrava, Faculty of Mining and Geology, Ostrava Poruba, Czech Republic

** HBZS Hodonín, MND S.A., Mikulčice, Czech Republic

*** AGH University of Science and Technology, Faculty of Drilling, Oil and Gas, Krakow, Poland

**** This article was written based on the project Institute of clean technologies for mining and utilization of raw materials for energy use – Sustainability program. Identification code: LO1406. Project is supported by the National Programme for Sustainability I (2013–2020) financed by the state budget of the Czech Republic and BS number 11.11.190.555 realized at FDO&G AGH UST

consequently increasing the difference between reservoir pressure and hydrostatic pressure in the wellbore, on behalf of the former. The speed of the process depends on the properties of the reservoir horizon especially its permeability, porosity, pressure and character of reservoir fluids and the thickness of interval.

2. INTRODUCTION TO THE PROBLEM OF CONTROLLING STRING BLOWOUTS

The outflows and blowouts can be controlled with the use of various procedures, depending on the present condition of the wellbore. The first step to manage the flux or a blowout lies in closing the well and controlled opening with simultaneous injection of properly weighted mud. In this way the pressure equilibrium between hydrostatic pressure and reservoir pressure in the well is under control.

A particularly dangerous case is observed when the inflow or blowout occur while the string is being driven in or out, i.e. when it is open. For closing the open mud pipe, in most cases an Inside Blow Out Preventer (IBOP), Figure 1, also called inside preventer, is used [9]. With the symptoms of flux the string is driven up or tripped down to the shaft floor level and then an Inside BOP is fastened onto the mud pipe or casing.

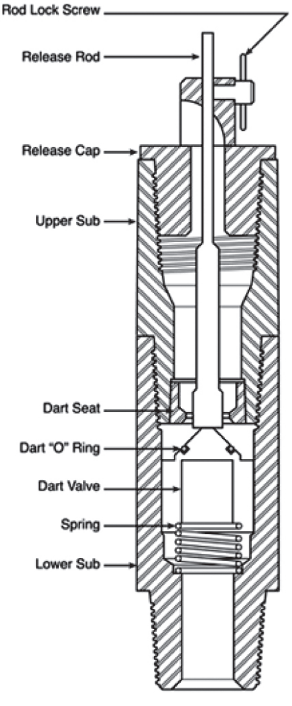

Fig. 1. Inside Blow Out Preventer cross-section

As long as the kelly is present in the string, either the upper- or lower kelly cock can be used [9]. This is *de facto* a specially modified part of sub, which has an inbuilt ball valve. This valve is operated with a key and has two positions: open and closed. The kelly cocks are generally screwed to the kelly permanently. However, sometimes the blowout prevention equipment, e.g. Inside preventer, is either unavailable on the spot in emergency situations or is dissembled from the drill strong (hoisting, tripping in and out of the string are performed without the kelly). When hoisting, the string can be seized in the wellbore and cannot be either driven up or lowered to the level of the shaft floor for the Inside BOP or kelly to be fastened. In other case, the outflow pressure may disable installing classic rescue equipment, the preventer with complete cut-off is broken or the crew has to be evacuated from the well site.

Safe activities, i.e. shut off tap can be used for liquidating blowout when the drill string is available from the level of shaft level. In the first stage of the rescue operation the mud pipe excess should be cut off to a proper height above the shaft floor level. In this case the spark-free cutting methods should be used. According to the Hole Mining Rescue Station MND S.A. Hodonín uses a pipe cutter with hydraulic drive with two opposite rotary blades. The cutter can be used for pipes ∅3 1/2"–∅14" (88.9–355.6 mm). The cutting is performed in water shield protection.

Another option is cutting off pipes with waterjet and abrasive material.

The successive stage of works lies in the preparation of the shut off tap kit.

It consists of a block which is drilled through with two crossing holes. In this way four side holes are made in the block, which are used for connecting pressure fittings. A pipe ended with a cone pin with an elastomer cone-shaped sealing pad is screwed to the lower hole. The device is lowered onto the cut-off mud pipe, and the pin is pushed inside the mud pipe. After installing the device the reservoir fluid flows towards the upper hole to which the shut-off valve is installed. Flange fittings with high-pressure gates and connectors are linked onto the side holes [9].

The blowout is stopped by the closing of the upper shut-off valve; then the drill string can be connected to the mud pumps or cementing aggregate by the side pressure lines for injection and liquidation of the flow.

3. WORKS ON THE CONCEPT AND PROTOTYPE OF DEVICE FOR LIQUIDATING BLOWOUTS THROUGH THE DRILL STRING

Above listed failures can be dealt with by rescue services with specialist equipment. If no such services are available in a given area, as this is the case in the Czech Republic, external services have to be ordered. Unfortunately, this requires agreements and contracts to be signed, which elongates the time of rescue and incurs considerable cost.

For this reason the General Hole Mining Rescue Station MND S.A. Hodonín focused on inventing and implementing a new equipment for controlling the string outflows and blowouts. In this concept the outflows were to be killed by squashing the mud pipes. Their entry below the contraction should be designed in such a way that the sealing media and drilling mud could be injected to liquidate the flux. The following requirements were set before the device as far as its operation and handling are concerned:

- its weight should be minimized to make the handling easy;
- time of installation and rescue operation should be minimized, with minimum number of rescuers involved;
- remote control the system at a safe distance;
- should be compatible with other hole mining rescue devices;
- applicable to all standard materials of pipes used in the Czech Republic, especially MND S.A. (Moravian Petroleum Mines).

Th first device meeting these requirements was worked out at the General Hole Mining Rescue Station MND S.A. Hodonín (HBZS), whereas the prototype was manufactured in MND Drilling & Services S.A. in 2011. The system consisted of three basic working subsystems:

Pipe press

The device is based on the plastic squashing of a mud pipe with a set of rams; one of them is immobile and acts as a matrix, whereas the other one is a mobile stamper. The press elements have the shape of a rounded wedge. In the prototype the hydraulic actuator was activated by a manual pump; in the newest improved version a hydraulic aggregate was used.

Hot tapping device

Hot tapping is a controlled process in which the interior of a mud pipe or casing is made open. The hot tapping device was adjusted to make openings in a steel string or pipe, where the pressure reaches 21 MPa. The drilling is performed with tools 40 mm in diameter, i.e. step reamers or a bit for steel drilling. The drilling tools are powered by a hydraulic aggregate with manual feed.

Pipe sealing system

This system relies on a pump delivering special mass for sealing the clearance in the pipe formed by the press. The components of the sealing mass should have appropriate shape and size so that they can be injected through a 2 inch (50.8 mm) drilled opening. The sealing material should not to let the sealing mass pass through the contracted pipe interior. Besides it should be plastic enough to fill and seal the gap in the pipe. The sealing material should not gravitationally move towards the wellbore bottom and yet the reservoir fluid should be able to move it towards the contraction on the mud pipe. At this stage, rubber, then light duralumin balls were used.

The pipe press prototype was first tested in a Slovakian research area in June 2012. The test area was localized in the Malacky field in Lozorně (Loznica), where a well simulating blowout situations was available. Reservoir fluids were simulated by water and air.

During the test a 5" pipe was pressed. The first attempts did not fully limit the flow through the pipe and the clearance failed to be fully sealed. The outflow was considerably reduced and this sufficed to fully control the blowout, after the remaining procedures were implemented. Despite the fact that the test results were not fully satisfactory, generally the test was considered to be successful.

4. LABORATORY ANALYSES OF THE PIPE PRESS

After satisfactory field squashing tests on the pipes in open blowout conditions the Institute of Geological Engineering VŠB-TU Ostrava was asked to undertake works on improving the quality and efficiency of squashing. For this purpose a number of parameters were analyzed, i.e. squashing data, minimum squashing force needed to obtain effective/required contraction of pipes of various diameter and steel grade. The shape of fracture after the pipe was pressed with rams of various shape was also analyzed. The hot tapping device and its design were also assessed [1].

The squashing efficiency tests were performed with a Shrek HL-100T press (Fig. 2), with on-line recording of the results of most important squashing parameters measured during the test.

The tests were focused on the squashing of mud pipes and production pipes of various wall thickness and steel grade to determine the minimum pressure needed to squash the pipe [1]. The press constantly registered the value of pressure and deformation at the stage of pressing down and return of the press. Various shapes of rams were used during the tests.

The design of the FIB-1 prototype was improved on the basis of the obtained test results. The modified FIB-1 press during a 5" mud pipe squashing test is shown in Figure 3.

Fig. 2. Analyses focusing on the design of elastic pipe squashing press. SHREK HL-100T press with hemisphere/flat surface rams during the pipe squashing test

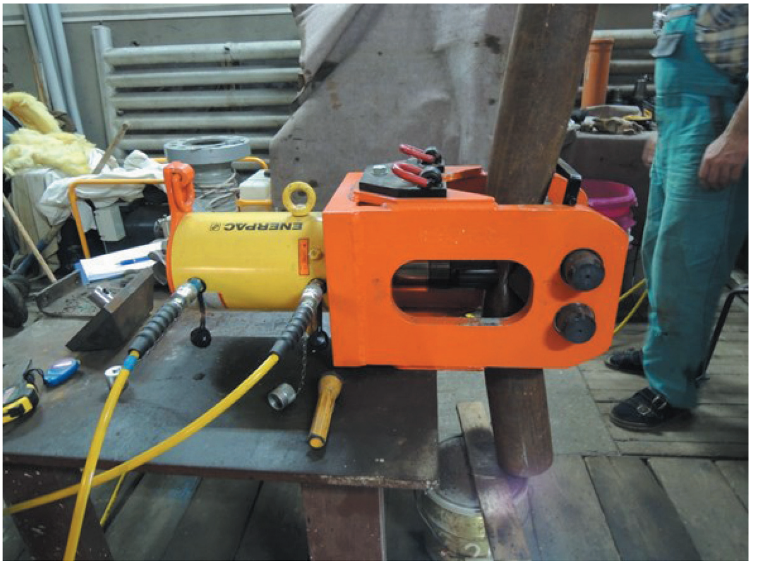

Fig. 3. FIB-1 during a 5" mud pipe squashing test

In the next stage the FIB-1 device was tested and some parameters were established, i.e. optimum shape of the rams and squashing rate at which optimum results would be obtained, i.e. aperture of minimum cross-section. The aim of the tests was also limiting or eliminating lateral breaking of the pipes. The longitudinal cracking of squashed pipe sides (in the place of the biggest bending) was observed in almost all experiments/tests (see Fig. 4).

The third stage lied in finding the most suitable material for sealing the interior of the squashed pipe, as originally used materials failed to give such an effect which would allow for complete elimination of fluid flow through the squashed pipe. As already mentioned, rubber and duralumin balls were used in the first tests.

5. RESULT OF LABORATORY EXPERIMENTS AND MODIFICATION OF THE PRESS DESIGN

As a result of experiments, the size of lateral cracks in the squashed pipes could be finally reduced by using rams of most appropriate shape [2, 3]. After optimizing the shape of rams, the force needed to squash the pipe material considerably decreased. When squashing mud pipes, the best results were obtained for rounded wedge rams with additional elements, whose angle can change while pressing (as in Fig. 4).

Fig. 4. Deformed 5" mud pipe in FIB-1 device while squashing with cone rams with welded additional elements

At the last stage of experiments the emphasis was put on finding out which sealing materials meet the design requirements. The results of laboratory tests and simulation tests imitating the wellbore conditions (Fig. 5) revealed that a sealing mass based on latex and nitrile-soaked fibers is most suitable for further field tests.

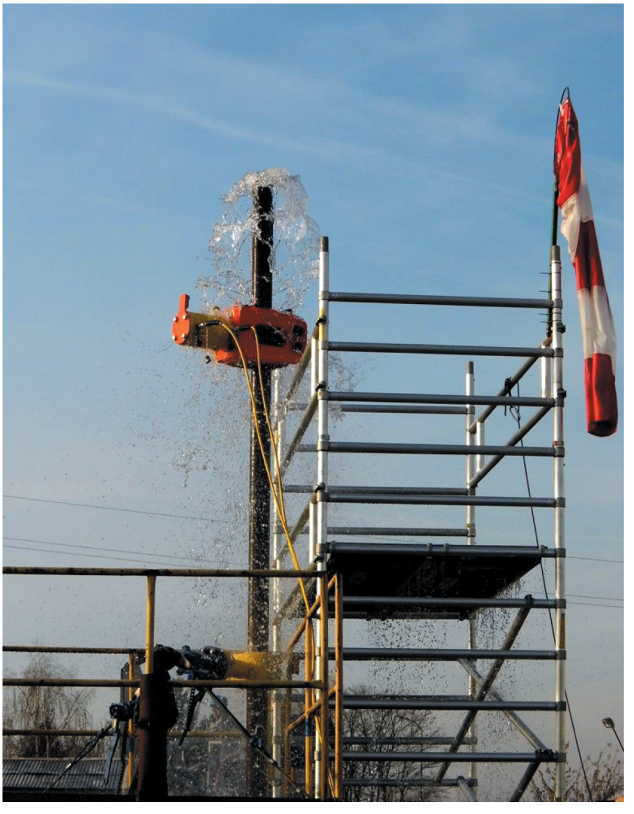

Fig. 5. FIB-1 press for squashing pipes installed in a mud pipe.
Simulated liquidation of open blowout
(test performed in HBZS Lužice, 4 Dec., 2013)

New sealing material consisted of cylindrical elements which were formed of latex and nitrile-soaked fibers and filled with beech cuttings and polystyrene balls. The composition of the sealing mass should provide appropriate specific weight of the seal, thanks to which it would not drop down in the mud pipe column. Beech balls should give the cylinders appropriate mechanical strength to rolling, feeding, pushing through the aperture of the squashed pipe. The polystyrene balls with cuttings would provide the required plasticity while pumping the sealing mass, transporting it through the pressure supply device and sealing up the gap formed on the pipe after squashing [3].

The last version of FIB-1 device bearing the name of Drilling Pipe Rescue Press I (DPRP I) was tested in an experimental area of EXALO Drilling S.A. in Tarnawa Dolna near Sanok, Poland, where the hole mining rescue teams had their competition. The newest variant of the device presented during that event is shown in Figure 6. Unfortunately, due to the time and technical limitations, the team was not able to test various sealing masses in the inner contraction on the mud pipe.

Fig. 6. Test of DPRP I device for reducing pipe blowout in an experimental zone of EXALO Drilling S.A. in Tarnawa Dolna, n. Sanok

6. MODERNIZATION OF HOT TAPPING DEVICE

Presently the pipes in HBZS MND Hodonin S.A. in Lužicích are opened with a DN 40 PN 350 hot tapping device, presented in Figure 7.

A new variant of the hot tapping device was designed on the basis of the results of the tests and experiments as well as technical requirements specified by the General Hole Mining Rescue Station MND S.A. Hodonín (HBZS). The technical requirements set before the modernized version of the device were based on the experiences gathered during exploitation of the prototype and opinions of the crew working with it.

Fig. 7. DN 40 PN 350 hot tapping device

The requirements were as follows:

Technical requirements:

- mud pipes or casing of well thickness up to 20 mm can be drilled with a reamer or drill bit;
- safe drilling in mud pipes or casing, where the inner pressure evoked by reservoir fluid reaches up to 21 MPa;
- drilling diameter should be up to ∅ 40 mm;
- hole drilling with remote control of a hydraulically powered device from the control panel.

Handling requirements:

- the size of the device should facilitate its transportation to the well site and mounting on the mud pipes or casing;
- the device should be light enough to be handled by maximum two crew workers;
- the connection sites for the injection pipeline (leading to the cementing aggregate) and remotely controlled connection to the sealing material supply should be prepared in such a way that the hot tapping can be performed without dismembering the device.

After working out the preliminary design and introducing corrections and improvements suggested by practitioners and scientists, the final version of the device was prepared. The schematic of the device with the assembly method with a system of accesses for the pipeline from the cementing aggregate and sealing mass is presented in Figure 8. Hydraulic motor driving the drill was placed in the housing of the device. The device was equipped with a connection for injecting fluid (in that sealing mass).

Two special drilling tools can be used for drilling holes below the pipe crush site. The first of them is a classic drill for metal or more precisely, a step reamer for making holes. The other one is a magnetic bit, which cuts the annular groove; the magnetic bit was used not to let the core drop inside the pipe. Both tools are presented in Figure 9.

Fig. 8. Working position of the new version of the hot tapping device

Fig. 9. Hot tapping device. Left: step reamer, right: magnetic bit

The drilling tools were tested with a Hilti drill. The average time of drilling of a pipe ∅51/2" (139.7) and wall 8.2 mm thick with a bit drilling at 2500 rpm was about 35 s. The view of the modified drill bit with a pilot drill and the pipe is presented in Figure 10.

Fig. 10. View of modified bit with pilot drill. A hole in the casing in the background

7. FINAL REMARKS

Drilling failures accompanying drilling jobs are the case now and will happen in the future. Despite applied rigorous safety procedures they will always take place. Nature is unpredictable and not all anomalies in the rock mass, hardware failures, or human errors can be foreseen. Drilling procedures based on practice and observations do not enumerate all possible hazards which may occur.

Reservoir fluid blowouts through the string are not frequent but they happen therefore large drilling companies and Wellbore Rescue Stations should be equipped with specialist tools for controlling such blowouts. Therefore the works on improving the equipment presented in this paper will continue, especially that some elements are unique and introduced to drilling practice for the first time. Field experiments will be continued to train the rescue teams how to use it and check its operation in untypical rescue conditions. The collected experience will be used for making further improvements and increasing the efficiency of operation.

REFERENCES

[1] Bujok P., Gondek H., Frydrýšek K., Kalus D., Zegzulka J., Klempa M., Porzer M., Pavluš J., Kostrhun J., Selzer L., Weiper M.: *Řešení dílčích problémů zmáhání otevřené erupce vrtním nářadím*. Závěrečná zpráva k HS 511 301, Ostrava 2013.

[2] Bujok P., Fibinger J., Klempa M., Porzer M., Kalus D., Rado R.: *The problem of liquidation of the open eruption by drilling tools*. AGH Drilling, Oil, Gas, vol. 31, no. 2, 2014, pp. 199–205.

[3] Bujok P., Klempa M., Porzer M., Ryba J., Weiper M., Selzer L.: *Řešení dílčích problémů zmáhání otevřené erupce vrtným nářadím.* Závěrečná zpráva k HS 511 17 03. VŠB-TU, Ostrava 2017.

[4] Catalog of the Nonstardardized Equipment GAZOBEZOPASNOST firmy VEYA Investments ltd. Moskva, 2009.

[5] Geare J. de, Haughton D., McGurk M.: *The Guide to Oilwell Fishing Operations – Tools, Techniques, and Rules of Thumb*. Gulf Professional Publishing, 2003.

[6] Fanguy D.: *Coiled Tubing Conveyed Hydromechanical Pipe Cutting: A Safe, Effective Alternative to Chemical and Explosive Severing Methods*. Presented at SPE ICoTA 2001 Coiled Tubing Roundtable and Exhibition.

[7] Gonet A., Knez D. (Ed.), Macuda J., Stryczek S.: *Selected Issues of Wellbore Hydraulics and Cementing.* Wydawnictwa AGH, Krakow 2017.

[8] Hinojosa R., Ryan J., Wyman R., Barton W.: *Whipstock Performance Review in Gulf Coast Region Yields Operational*. IADC/SPE paper #39402, March 1998.

[9] Catalogs Wild Well Control. USA.

[10] Pinka J., Sidorová M., Dudla A.N.: *Vrtné súpravy a ich diagnostikovanie*. Fakulta BERG, TU Košice, Slovensko, 2009.

[11] Caenn R., Darley H.C.H., Gray G.R.: *Composition and Properties of Drilling and Completion Fluids. Gulf Professional Publishing*. 6th ed., USA, 2011.

[12] Speight J.G.: *Handbook of Hydraulic Fracturing*. John Wiley & Sons, New Jersey 2016.

[13] Stryczek S.: *Materialy dydaktyczne z przedmiotów „Technologia cementowania“ oraz „Technologia zaczynów uszczelniajacych“.* AGH, Wydzial Wiertnictwa, Nafty i Gazu, Krakow 2013.

[14] Šťastný L.: *Současný stav a perspektivy metod likvidací erupcí na vrtech.* Bakalářská práce, VŠB-TU, Ostrava 2016.

[15] Watson D., Brittenham T., Moore P.L.: *Advanced Well Control. Society of Petroleum Engineers Inc*. SPE Textbook series, Texas, 2003.