GOSPODARKA SUROWCAMI MINERALNYMI

Tom 24 2008 Zeszyt 2/1

STANISŁAW DUBIEL*, JAN MACUDA**, JAN ZIAJA***

Decision procedures at drilling up hydrocarbon deposits in blow-out hazard

Introduction

Providing safe work conditions for the crew, natural environment and technical equipment is vital when during drilling up hydrocarbon deposits (Dubiel, Bukalski 2007; Dubiel, Macuda, Jamrozik 2003). This task could be principally realized by using a high density drilling mud if not for the protection of original permeability of reservoir rocks and hydrocarbon resources and attempt at acquiring reliable reservoir data at the drilling up stage (Dubiel, Chrząszcz, Rzyczniak 2002).

Selection of a casing scheme and BOP equipment, as well as rheological parameters of drilling muds, and speed of pipes penetration in the well are of great importance for work safety. The reservoir rock permeability in the near-well zone can be protected by proper selection of the drilling mud and its parameters, and also control of downhole changes of hydrostatic pressure of mud column at specific stages of drilling operations. Excessive increase of pressure may result in hydraulic fracturing of reservoir rocks and lost circulations followed by uncontrolled flux of hydrocarbons to the well, and finally the blow out risk (Dubiel 1995; Dubiel, Ziaja 2006).

Information about reservoir parameters is obtained in the course of drilling up operations on the basis of observation of the drilling process, results of measurements made with measuring and control apparatuses, DST results, must frequently realized prior to pipe-cement casing of the reservoir zone (Dubiel 2002; Dubiel, Wiśniowski, Skrzypaszek 2001).

* Prof. dr hab. inż., Faculty of Drilling, Oil and Gas AGH-UST, Kraków; e-mail: dubiel@wnaft.agh.edu.pl
** Dr inż., Faculty of Drilling, Oil and Gas AGH-UST, Kraków; e-mail: macuda@agh.edu.pl
*** Dr inż., Faculty of Drilling, Oil and Gas AGH-UST, Kraków; e-mail: ziaja@agh.edu.pl

On the basis of these data there are determined, e.g. industrial value of a hydrocarbon deposit and degree of blow-out hazard.

1. Characteristic of pressure conditions used for drilling up hydrocarbon deposits

The technological solutions used for drilling up hydrocarbon deposits are mainly based on relations between hydrostatic and hydrodynamic pressure of mud column on the well's bottom and reservoir pressure. On this basis the following drilling up operations can be distinguished:

1) underpressure (depression), the so-called UBD (underbalanced drilling); in this situation the static and dynamic pressures of mud column in the well are lower than the reservoir pressure;
2) balanced dynamic and reservoir pressure (at the verge of preliminary eruption);
3) overpressure (repression) in the well.

In the first case hydrocarbons constantly in-flow to the well, mixing with the drilling mud; then the mixture flows out to the surface, therefore the well's outlet should be hermetized with a rotary wellhead and the hydrocarbons separated from the mud with the use of a separator (Dubiel, Chrząszcz, Rzyczniak 2002). It should be noted that mud saturation with natural gas is an unfavorable phenomenon as gas pillows can form; on the other hand, the oil content in the mud has a positive influence as it increases the lubrication qualities of the mud and lowers the friction forces and hydraulic resistivity of flow. Underbalanced drilling is recommended for oil fields with well recognized reservoir conditions and anomalously low gradient of reservoir pressure ($G_Z < 0.009$ MPa/m). A great advantage of this method is a good protection of reservoir rocks permeability in the near-well zone, and also obtaining considerably higher mechanical drilling rates than in the third case. Higher fire risk is a disadvantage here.

In the case of balanced downhole and reservoir pressures, the drilling process should be entirely controlled with the use of measuring-control apparatuses, and the well's outlet should be hermetized with a rotary wellhead, owing to the high risk of hydrocarbon eruption. Special care should be given to the hoisting operations with the string and during purpo- sefully withheld mud circulation in the well, as the downhole pressure does not compensate for the reservoir pressure. This drilling up option is recommended for partly recognized, relatively low-productive reservoirs. The primary permeability of reservoir rocks can be largely protected against solids from the mud and mud filtrate; the measurement-control indications and DST data are highly reliable (Dubiel, Bukalski 2007). Higher mechanical rates of drilling are obtained for balanced rather than for underbalanced pressures.

Overpressure is commonly applied for oil and natural gas prospecting as it provides considerable work safety, even when applying standard technical solutions, and in the case of anomalously high gradient of reservoir pressure ($G_Z > 0.013$ MPa/m). In this case special attention is paid to the selection of the type of drilling mud and its technological parameters (Dubiel 2002; Falkowicz, Dubiel 2002). Drilling reservoir horizons in such conditions may result in:

— extensive damage done to reservoir rock permeability at a considerable distance from the well's wall owing to the penetration of mud's solids, especially the filtrate,
— low reliability of control-measurement indications and DST data,
— much lower mechanical rate of drilling as compared to the previous cases,
— higher cost of mud technologies,
— high risk of hydraulic fracturing of rocks, mainly during tripping in of the string or casing, and the related very high risk of lost circulations,
— necessity of more complex and more expensive casing scheme as compared to the previous cases (to protect against blow outs).

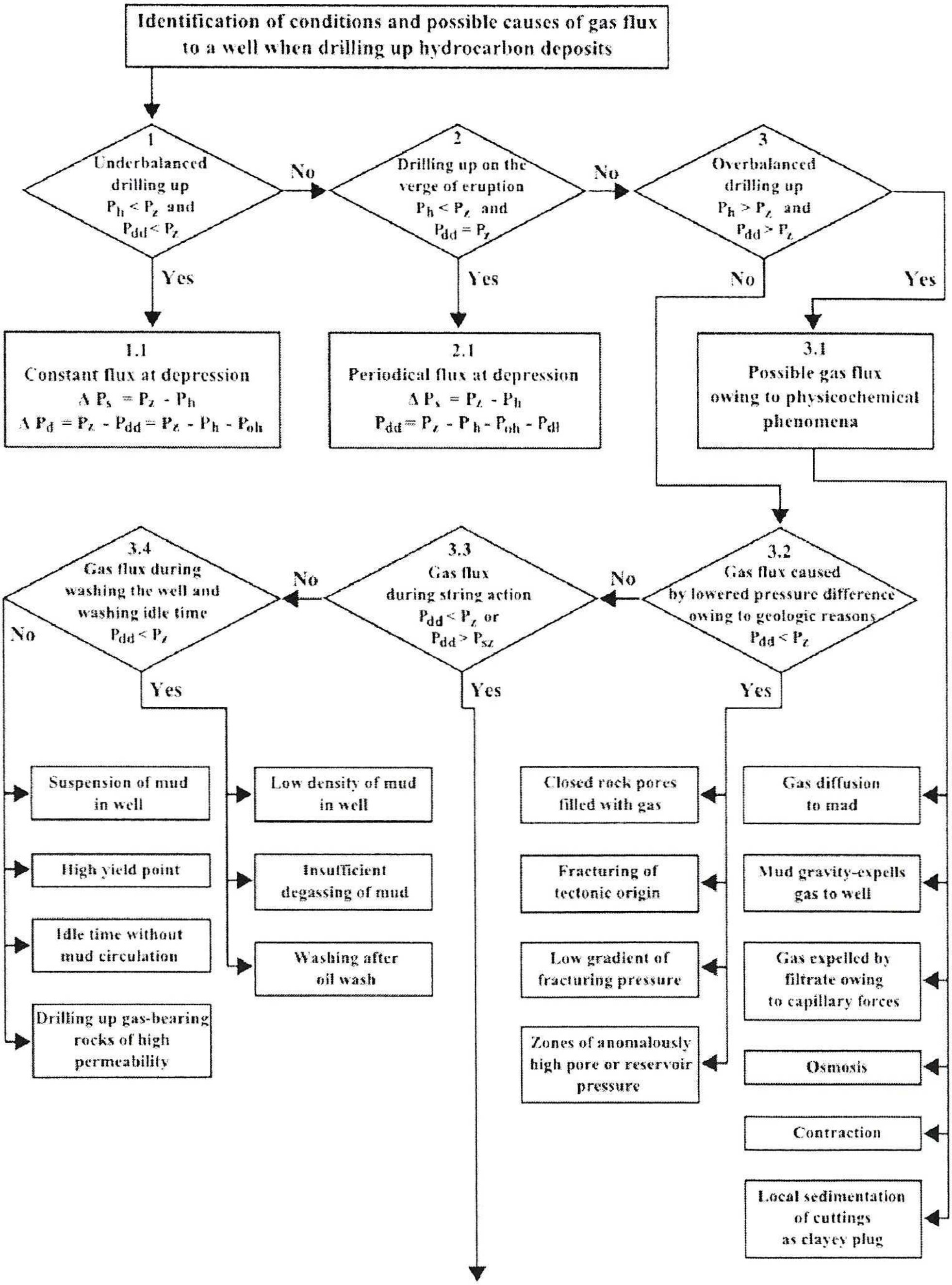
2. Identification of conditions and causes of natural gas flux to the well

Hydrocarbon flux to a drilling well causes a change of mud parameters (density, viscosity, structural strength, yield point), and also pushing the mud out of the well. If not managed in time, the uncontrolled flux of hydrocarbons to the well (natural gas in particular) may result in throwing out of the mud from the well, and consequently, an uncontrolled eruption (Dubiel 1997; Dubiel, Ziaja 2007).

A block diagram representing identification of conditions and possible causes of hydrocarbon flux to the well accompanying drilling of oil- and natural gas-bearing strata is presented in Fig. 1 (Dubiel, Ziaja 2007). In the scheme (Fig. 1) three already discussed technological solutions are presented (1, 2 and 3); however, the detailed identification of pressure conditions and causes of natural gas flux to the well should be done only for the third solution. Basic technological operations: tripping out and tripping in of the string, as well as washing of the well have been accounted for.

Physicochemical phenomena taking place within the well's bottom (presented in Fig. 1, item 3.1), may result in a gas flux to the well also in the conditions of strong counterpressure exerted during drilling up operations. Such causes of gas flux are not hazardous as far as eruptions are concerned; however, giving strong gaseous manifestations they may be a cause of erroneous technological decisions, e.g. increasing the mud density.

Geologic causes (Fig. 1, item 3.2) are usually difficult to identify. Not being pushed out by mud filtrate from the near-well zone, natural gas (filling up the closed rock pores) is liberated by the cutting tools in the course of mechanical destruction of the rock structure. It saturates the mud with gas, lowers its density, thus decreasing the pressure exerted by mud in the well. The tectonically disturbed gas-bearing zones are intensely fractured. This may cause mud escapes, followed by a flux of hydrocarbons to the well. In the case of gas-bearing rocks having a low gradient of hydraulic fracturing pressure ($G_{SZ} < 0.014$ MPa/m), mechanical splitting of these rocks may take place even for a small increase of mud pressure.



Identification of conditions and possible causes of gas flux to a well when drilling up hydrocarbon deposits
1 Underbalanced drilling up $P_h < P_z$ and $P_{dd} < P_z$
No
2 Drilling up on the verge of eruption $P_h < P_z$ and $P_{dd} = P_z$
No
3 Overbalanced drilling up $P_h > P_z$ and $P_{dd} > P_z$
Yes
Yes
No
Yes
1.1 Constant flux at depression $\Delta P_s = P_z - P_h$ $\Delta P_d = P_z - P_{dd} = P_z - P_h - P_{oh}$
2.1 Periodical flux at depression $\Delta P_s = P_z - P_h$ $P_{dd} = P_z - P_h - P_{oh} - P_{dl}$
3.1 Possible gas flux owing to physicochemical phenomena
3.4 Gas flux during washing the well and washing idle time $P_{dd} < P_z$
No
3.3 Gas flux during string action $P_{dd} < P_z$ or $P_{dd} > P_{sz}$
No
3.2 Gas flux caused by lowered pressure difference owing to geologic reasons $P_{dd} < P_z$
No
Yes
Yes
Yes
Suspension of mud in well
High yield point
Idle time without mud circulation
Drilling up gas-bearing rocks of high permeability
Low density of mud in well
Insufficient degassing of mud
Washing after oil wash
Closed rock pores filled with gas
Fracturing of tectonic origin
Low gradient of fracturing pressure
Zones of anomalously high pore or reservoir pressure
Gas diffusion to mud
Mud gravity-expells gas to well
Gas expelled by filtrate owing to capillary forces
Osmosis
Contraction
Local sedimentation of cuttings as clayey plug

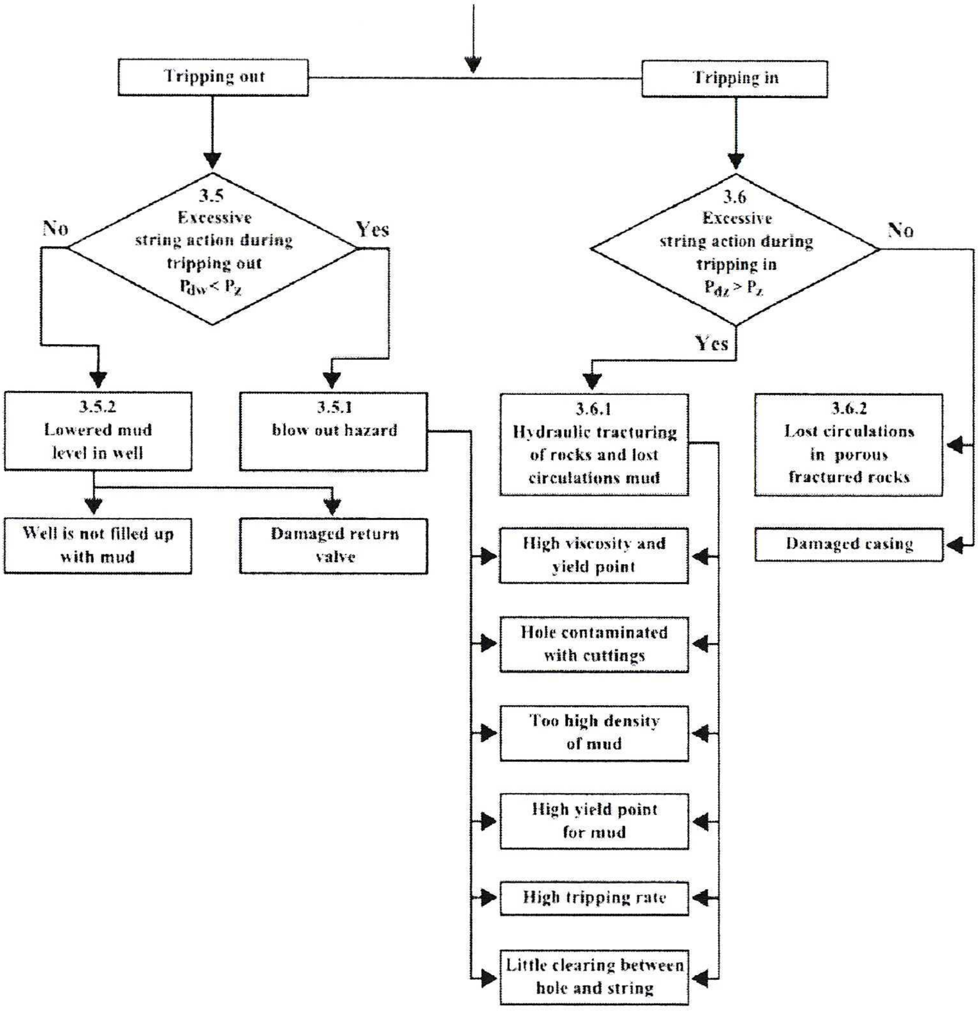
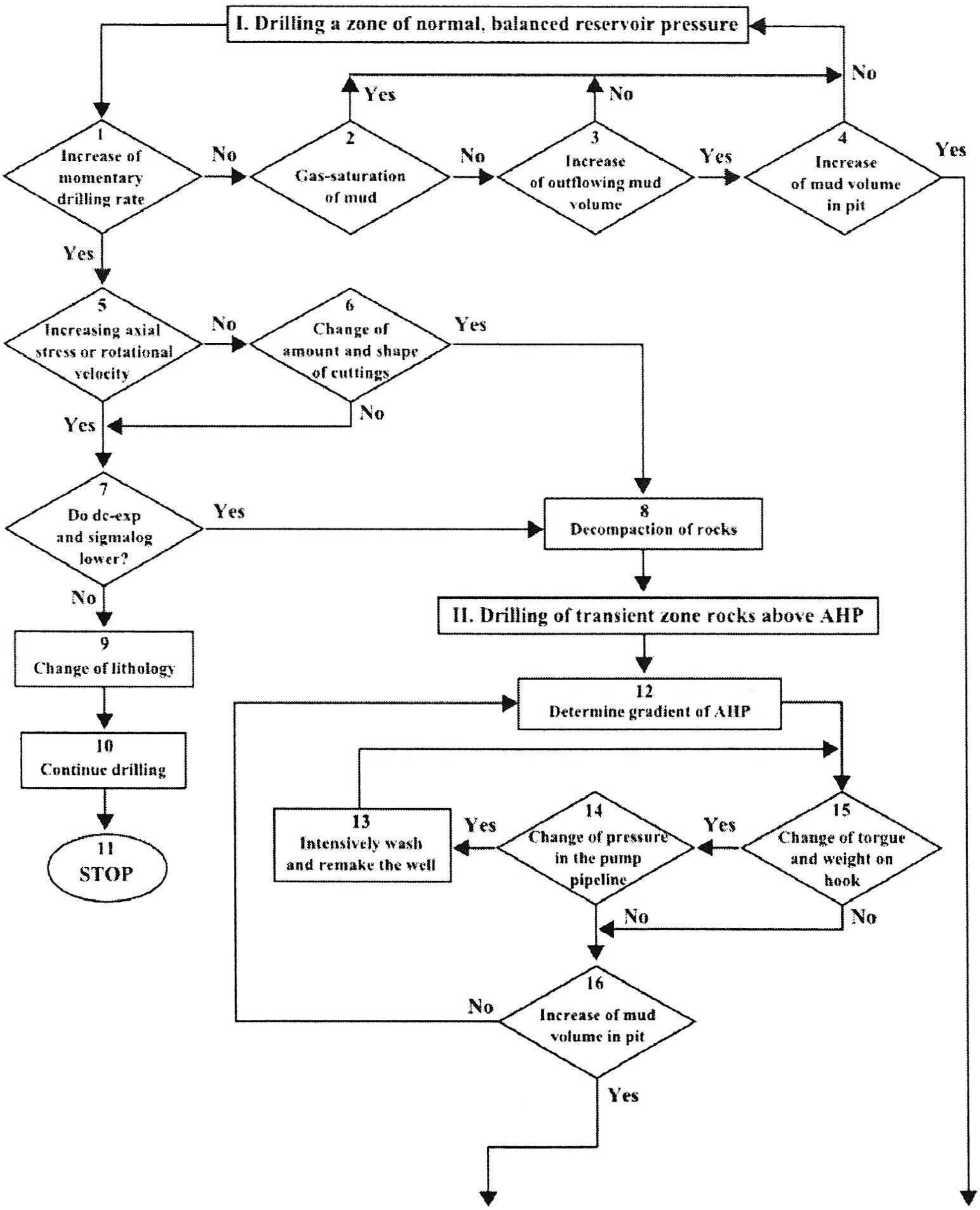


Fig. 1. Block diagram of identification of conditions and causes of natural gas flux to a drilling well
pz – reservoir pressure, Pa; pd – bottom pressure,Pa; ph – hydrostatic pressure of drilling mud column in a well, Pa; pdd – hydrostatic pressure of drilling mud column (mud circulation, string motion), for tripping in the string is equal to: pdd = pdz, and for tripping out: pdd = pdw, Pa; poh – pressure needed for compensating for mud hydraulic resistivities in annular space during its right circulation, Pa; pdł – choking pressure of mud outflow at the well's outlet, Pa; Gz – gradient of reservoir pressure, MPa/m; Gsz – gradient of hydraulic rock fracturing, MPa/m; psz – hydraulic pressure of rock fracturing, Pa

Rys. 1. Schemat blokowy identyfikacji warunków i przyczyn dopływu gazu ziemnego do otworu wiertniczego


I. Drilling a zone of normal, balanced reservoir pressure
No
Yes
No
1
Increase of momentary drilling rate
No
2
Gas-saturation of mud
No
3
Increase of outflowing mud volume
Yes
4
Increase of mud volume in pit
Yes
Yes
5
Increasing axial stress or rotational velocity
No
6
Change of amount and shape of cuttings
Yes
Yes
No
7
Do dc-exp and sigmalog lower?
Yes
8
Decompaction of rocks
No
II. Drilling of transient zone rocks above AHP
9
Change of lithology
12
Determine gradient of AHP
10
Continue drilling
13
Intensively wash and remake the well
Yes
14
Change of pressure in the pump pipeline
Yes
15
Change of torgue and weight on hook
11
STOP
No
No
16
Increase of mud volume in pit
No
Yes

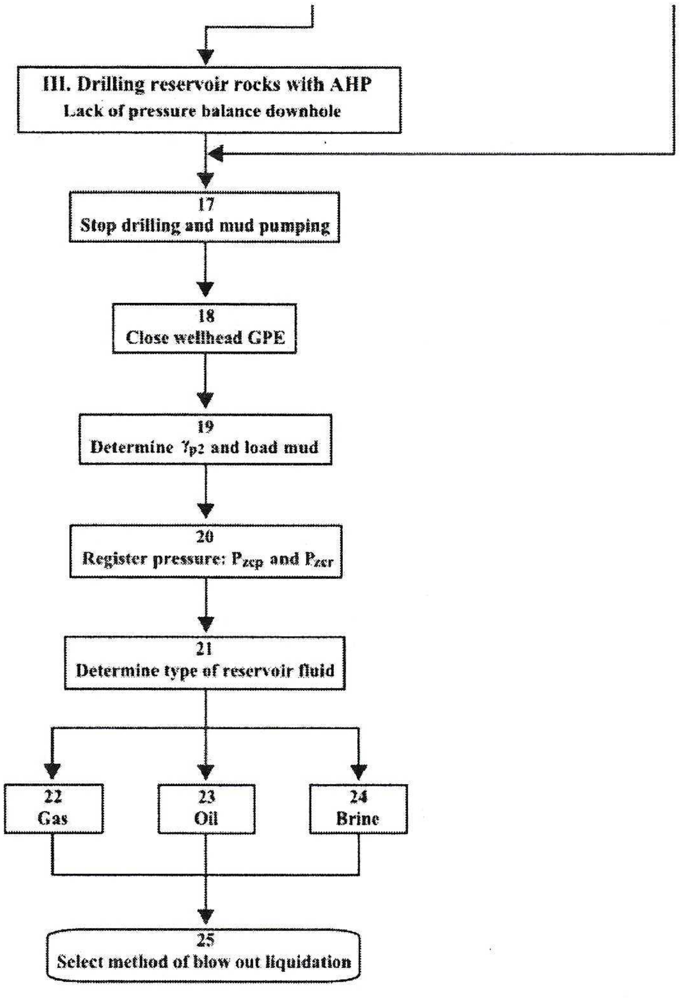


Fig. 2. Block diagram of conditions of drilling up hydrocarbon deposits in view of blow-out hazard detection

Rys. 2. Schemat blokowy analizy warunków dowiercania złóż węglowodorów pod kątem wykrywania zagrożenia erupcyjnego

In such cases the mud escapes to the formed fractures cause a blow out risk. When the geological-reservoir conditions are insufficiently recognized in the drilling area and the standard overpressure technology is applied, the downhole pressure may turn out defficient as compared to the reservoir pressure and cause flux of hydrocarbons to the well in the zones with anomalously high reservoir or porous pressure (Dubiel, Ziaja 2007).

Natural gas flux to a drilling well during technological string operations (Fig. 1, item 3.3) may be caused by lowering of drilling mud pressure in the well below the reservoir pressure owing to the string action. The string action effect is proportionate to the speed of string motion; density, viscosity and yield point of the mud as well as contamination of the well with cuttings; it is reversely proportional to the clearing between the well's wall and the string (Fig. 1, item 3.5.1 and 3.6.1). The mud pressure is frequently lowered owing to the mud escapes or a lack of systematic addition of the mud during tripping out operations. Technical and technological causes of mud escapes are sometimes due to damaged casing or bad cementing. However, the most frequent causes are hydraulic fracturing of rocks in an uncased section of the well, caused by wrong start-up of the pumps or renewed circulation of mud having a high yield point and structural strength, or more frequently too high rates of tripping the string. In definite downhole conditions the axial movement of the string in the mud environment will create blow out hazard during the tripping operation (Fig. 1, item 3.5.1), and hydraulic fracturing of rocks and mud losses during tripping of the string (Fig. 1, item 3.6.1), followed by a flux of hydrocarbons to the well. Dangerous changes of downhole pressure may also be generated either in the case of covering the drill bit with cuttings and choking of its mud channels, or when the string column is equipped with stabilizers, oversized collars and rubber protection rings.

Natural gas flux during washing of the well and the washing idle time (Fig. 1, item 3.4). As a result of the forming mud gel structure of high viscosity, yield point and structural strength, the mud's hydrostatic pressure exerted on the gas-bearing bed caused by mud suspension in the well may be lowered. The static friction forces acting on the contact of the mud and the string's outer wall partially supports the mud column's weight (the so-called mud suspension in the annular space), in the course of which the hydrostatic pressure of the mud's column lowers.

Drilling up highly permeable gas-bearing rocks may lead to an intense flux of natural gas to the well during washing of the well, and also during washing idle time, therefore can be a cause of a considerable blow out risk. In such situation gas pillows are usually forming in the annular space of the well.

3. Analysis of hydrocarbon deposits drilling up conditions in view of blow out hazard prediction

Predicting blow out hazard in oil prospecting areas, especially predicting the depth of zones of abnormal high pressure (AHP) is important for predicting reservoir fluid eruptions and planning methods of preliminary eruption liquidation (Dubiel 2002; Dubiel, Macuda, Jamrozik 2003).

Methods of predicting blow out risk in the oil prospecting areas can be divided into methods based on:

1) analysis of changes of mechanical drilling rate, rock drillability (exponential index d in Bingham's equation) or rock strength (index „sigmalog") in a function of depth of drilling,
2) information from the mud outflowing from the well (increase of volume of outflowing stream and gas content in the mud, change of density, volume and shape of cuttings and mud temperature),

3) observations of changes of the torque on drilling table, weight on the hook, number of string rotations and pressure of mud pumping (Dubiel 1995).

The first group of methods lies in comparing the state of incomplete compaction of clayey rocks with the state of normal compaction, which requires determining a normal clayey rocks compaction trend straight line for the controlled intensification index of AHP zones. The normal clayey rocks compaction trend straight line is established locally, i.e. for a given geologic area, on the basis of collected industrial data. The determined straight line frequently has to be made more precise, i.e. they have to be shifted in the coordinates system to fit data to those obtained from a specific well in the analyzed area.

When drilling geologic prospecting wells for hydrocarbons it is recommended to trace the changes of, e.g. changes in gas content in the mud; number, density and shape of the cuttings; change of the torque of the drilling table; change of weight on the hook, number of string rotations and changes of mud pumping, etc. (Dubiel 2002). Such an observation of the drilling process, especially when performed in a continuous manner with the use of measuring-control apparatuses, may provide information about the conditions of pressure balance downhole and constitutes a basis for separating an AHP zone.

Changes of the mentioned indices and manifestations may take place in the case of drilled transient zones made of impermeable rocks over the AHP zones, and also when drilling deposition zones.

4. Selecting methods of gas pillow removal from the vertical well

The highest blow out hazard is created by the flux of natural gas to the well, especially when its volume (equal to the increase of mud in the working pit ΔV_{zb}) is higher than 5 m^3 (Dubiel, Ziaja 2006). Gas siezed in the well in the form of a gas pillow is moving towards the outlet, regardless the density of the mud and magnitude of the pressure under the wellhead. If the closed well is entirely tight, the free gas will be moving without changing its volume and pressure. It will maintain the same volume and pressure as in the initial conditions, i.e. after the pressures are stabilized and the wells outlet is closed.

The complication of works related to the liquidation of eruptions is frequently caused by too late detection of manifestations. A greater amount of gas running to the well lowers the hydrostatic pressure exerted by fluid in the annular space, and this in turn, causes that pressure registered in the annular space after closing of the well is higher. The higher is the initial volume, the higher is the pressure in the annular space, when the gas gets under the wellhead during its pumping out with drilling mud.

Bearing this in mind, a block diagram was worked out (Fig. 3). It facilitates selection of methods of gas pillow removal from the annular space of the well. Those three methods of preliminary eruption presented in Fig. 3 have two things in common: necessity of constant pumping rate during mud injection and constant pressure in the string. The remaining properties differ (Dubiel, Ziaja 2006).

The pressure balance is shortly provided by the single circulation method: downhole pressure P_d and reservoir pressure P_z (i.e., after one circulation) on the condition that there are provided loaded mud reserves of specific gravity $\gamma_{p.ob.}$ close to the required γ_{p2} and volume $V_{p.ob,}$ being ca. 1.5 of the well's volume $V_{otw.}$. Otherwise, there is no possibility of using it because of a long time needed for loaded mud preparation. In this method, the maximum value of head pressure $P_{g.\ max.}$ is lower than the admissible value P_{dop}.

The double circulation method is least complicated, but most dangerous. The first hazardous situation occurs when the expelled mud (so far specific gravity γ_{pl}) the gas pillow is at a depth where the shoe of the last casing column has been set H_r (Fig. 3).

Then the pressure at the depth P_o can assume a higher value than the hydraulic pressure of rock fracturing P_{sz} at the uncased section. Another risky situation occurs when the gas pillow is under the BOP wellhead. The admissible pressure value can be exceeded in the annular space ($P_{g.\ max} > P_{dop}$). To provide a downhole pressure balance at the end of the first circulation, when the gas pillow is released to the atmosphere ($P_{d1} = P_z$), considerable choking pressure $P_{dł1}$ should be applied. In the first circulation the downhole pressure P_{d1} is

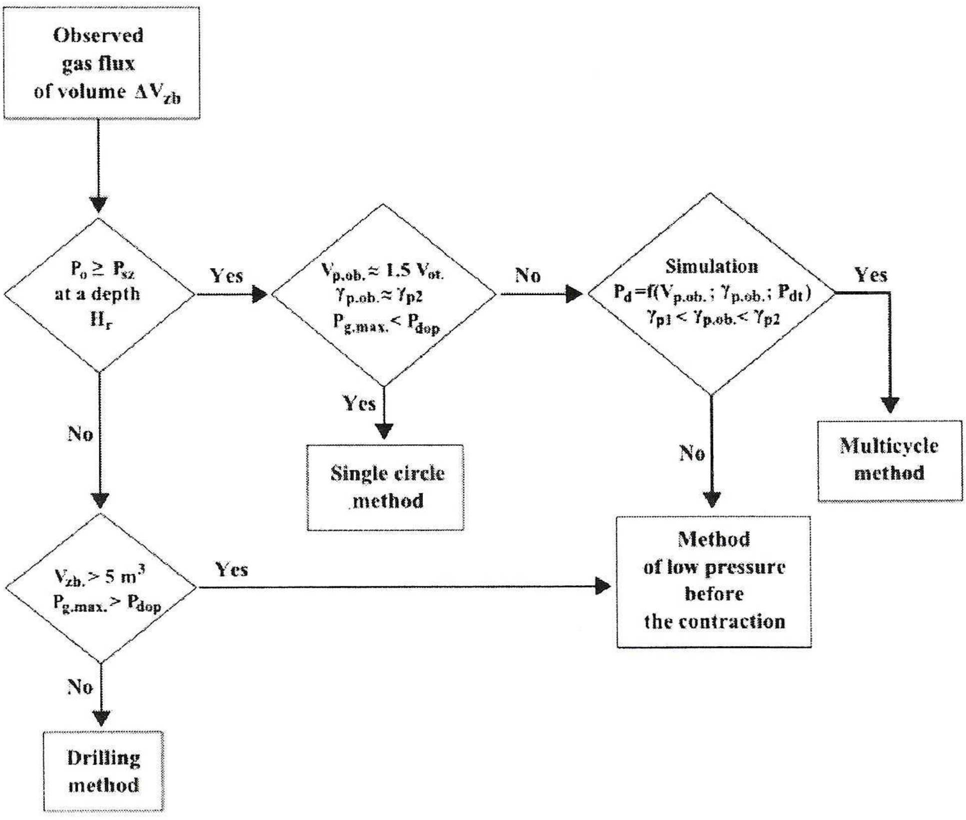


Fig. 3. Block diagram of selection of a method for removing gaseous pillow from the annular space

Rys. 3. Schemat blokowy doboru metody usuwania poduszki gazowej z przestrzeni pierścieniowej otworu a function of low specific gravity γ_{p1} and high choking pressure $P_{dł1}$. Only in the second circulation, when the loaded mud (γ_{p2}) and lower choking pressure ($P_{dł2}$) have been used, the appropriately high downhole pressure ($P_{d2} \geq P_z$) is obtained.

The multicycle method lies in the current loading and partial injecting of drilling mud of specific gravity ($\gamma_{p1} < \gamma_{p.ob.} < \gamma_{p2}$), and this may be too complicated and too little controllable for the crew. It is advisable to use a specific simulator. In this case the downhole pressure depends on the volume of a given part of loaded mud ($V_{p.ob.}$) ($\gamma_{p.ob.}$), forming (in a given capacity of the string or annular space) a column of specific height. In this method the pressure in the annular space is lower than in the multicycle method, and higher than in the single circle method.

The method of maintaining a low pressure before the choker ($P_g = P_{dł} < P_{dop}$) admits a procedure of momentary lowering of downhole pressure ($P_d < P_z$), and so a considerable volume of gas flow to the well V_g, to maintain the condition that wellhead pressure cannot exceed the admissible pressure ($P_g < P_{dop}$). Therefore, the removal of the first gas pillow is accompanied by the formation of another one but of smaller volume ($V_{g1} > V_{g2} > ... > V_{gn}$) as the removal of the successive gas pillows takes place at higher and higher values of downhole pressure ($P_{d1} < P_{d2} < ... < P_{dn}$), until the following condition holds true: $P_{dn} \geq P_{z.}$

The basic question to be faced during blow out liquidation in a directional well is the fact that the vertical depth of the well is used for calculating the specific gravity of drilling mud (γ_{p2}) needed for obtaining pressure balance downhole, and the length of the well – for calculating the volume of the mud ($V_{p.ob.}$).

5. Blow out hazard during directional drilling

The advancement in contemporary drilling technology enabled the development of directional drilling with its specific variant – horizontal wells. Regardless all technological difficulties related to drilling directional wells with a long horizontal section, attention should be paid to difficulties related to the recognition of preliminary eruption (flux of reservoir fluid to the well). This is related with the behavior of gas in the horizontal section of the well. It should be remembered that in the case of directional drilling, horizontal wells in particular, two parameters should be distinguished: measured length of the well, i.e. actual number of meters of the string tripped into the well, and actual vertical depth of the well, which is smaller from the measured length.

It is important to differentiate between these two parameters as there is a close relation between the vertical depth and the hydrostatic pressure of the mud in the well, which depends on the column of fluid. The length of the horizontal section, on which mostly depends the length measured in horizontal wells, does not have an influence on the increase of hydrostatic pressure. If we make a relation between mud's hydrostatic pressure and downhole pressure then the introduction of these two parameters becomes clear. In the case of vertical wells the flux of reservoir fluid can be precisely referred to the depth at which it had taken place;

otherwise in the case of horizontal wells it is not possible to precisely define the place and magnitude of the flux. The gas found in the horizontal section will not migrate if the angle of well's inclination is ca. 90°. After stopping the drilling, the gas will flow from the deposit without showing any expansion tendencies. Accumulating in the topmost parts of the horizontal section of the well or in washed out caverns and vertical fractures, the gas hinders quick recognition of the blow out hazard. It may happen that the crew can see symptoms of eruption only when the gas gets to the vertical section of the well. Owing to a great gas accumulation in the horizontal section performed in the deposit, the registered pressured in the annular space may suddenly increase after closing the outlet of the well to such an extent that the first stage of rescue activities can be significantly hindered. The expected value of flux of reservoir fluid with hydrogen sulfide in the horizontal sections (within the reservoir), made it necessary to, e.g. qualify of the well Grotów 8H (horizontal) in the field Lubiatów-Międzychód-Grotów (Polish Lowland) the highest, i.e. I category of hydrogen sulfide hazard (Dubiel, Bukalski 2007). It also necessitated the use of highly efficient BOP measures, thanks to which the well's outlet can be closed in a relatively short time, and start liquidation of the preliminary blow out.

After closing of the outlet of a directional well with a horizontal section, attention should be paid to the oscillating pressure in the annular space and the string. Idle mud circulations are possible in horizontal wells right after closing the wellhead, which may result in underground blow out and seizure of the string in the horizontal section. If the horizontal section is drilled with underpressure, a rotary head is used. A rotary head acts as a contraction, evoking counterpressure on the well's bottom, which in turn, can be a cause of idle mud circulations in the well. In the case of a flux of reservoir fluid to the well, the pressure evoked after closing the well's outlet may result in hydraulic fracturing of weakest rocks with reservoir fluid in the uncased part of the well. If the mud pump is out, the pressure losses in the annular space and the pressure on the bottom evoked by choking on the rotary head do not occur. It is possible that the reservoir fluid injected to the weakly compact rocks shall return to the well.

To avoid another flux of reservoir fluid during liquidation of the blow out, a constant downhole pressure should be maintained at a depth of flux, slightly higher than the reservoir pressure and yet smaller than the fracturing pressure of the weakest rocks in the uncased section of the well. The overpressure value depends of the conditions and state of the well; however, generally 0.5 to 1.0 MPa are applied for 1000 m of depth. The excessive downhole pressure over the reservoir pressure in the course of tripping out operations should stay within the limits of 1.0 to 1.5 MPa (Uliasz, Dudek, Herman 1984).

6. Final remarks and conclusions

1) Safety of drilling up hydrocarbon deposits with downhole mud overpressure requires constant analysis of conditions and causes of natural gas in-flow to the well and

undertaking decisions about a change of technological parameters of the applied drilling mud.

2) Protection against complications and drilling failures during drilling up hydrocarbon deposits is possible thanks to registering, processing and interpretation of indications and manifestations of drilling process to currently identify hole and reservoir conditions.
4) Hydrocarbon blow out hazards that have not been liquidated at their initial stage can be disastrous for the crew, hydrocarbon deposit and natural environment, therefore observing signs of it, and selection of appropriate liquidation method are related with strict obeying of decision procedures.
5) The presented scheme diagrams and meant to help to make a correct decision as far as identification and liquidation of blow out risk is concerned during drilling up of hydrocarbon deposits.

LITERATURA

Dubiel S., 1995 – Analiza warunków wiercenia otworu pod kątem ujawnienia zagrożenia erupcyjnego. Kwartalnik AGH, Górnictwo, z. 2, s. 131–145.

Dubiel S., 1997 – Decyzje technologiczne w zakresie identyfikacji i likwidacji zagrożenia erupcyjnego w procesie dowiercania do złóż gazu ziemnego. Rocznik AGH, Wiertnictwo, Nafta Gaz, t. 14, s. 27–39.

Dubiel S., 2002 – Analiza zmian naturalnej przepuszczalności skał zbiornikowych miocenu w strefie przyodwiertowej na podstawie wyników badań próbnikami złoża. Rocznik AGH, Wiertnictwo, Nafta, Gaz, t. 19, z. 1, s. 53–58.

Dubiel S., Bukalski P., 2007 – Bezpieczeństwo dowiercania złóż węglowodorów w regulacjach prawnych. Bezpieczeństwo Pracy i Ochrona Środowiska w Górnictwie. Miesięcznik Wyższego Urzędu Górniczego nr 10, s. 12–20 .

Dubiel S., Macuda J., Jamrozik A., 2003 – Ocena wpływu technologii stosowanych w wiertnictwie naftowym na środowisko gruntowo-wodne. Rocznik AGH, Wiertnictwo, Nafta, Gaz. t. 20, z. 2, s. 331–342.

Dubiel S., Wiśniowski R., Skrzypaszek K., 2001 – Identyfikacja zagrożenia erupcyjnego na podstawie procedury diagnostycznej. Rocznik AGH, Wiertnictwo, Nafta, Gaz, t. 18, z. 1, s. 65–74.

Dubiel S., Ziaja J., 2006 – Schematy blokowe analizy warunków otworowych podczas dowiercania złóż węglowodorów oraz wyboru metody likwidacji erupcji wstępnej. Rocznik AGH, Wiertnictwo, Nafta, Gaz, t. 23, z. 1, s. 155–161.

Dubiel S., Ziaja J., 2007 – Identyfikacja przyczyn dopływu gazu ziemnego do otworu w zależności od warunków ciśnieniowych dowiercania złóż węglowodorów. Półrocznik AGH, Wiertnictwo, Nafta, Gaz, t. 24, z. 1, s. 153–159.

Falkowicz S., Dubiel S., 2002 – Badanie wpływu płuczek wiertniczych na przepuszczalność skał miocenu autochtonicznego Przedgórza Karpat. Rocznik AGH, Wiertnictwo, Nafta, Gaz, t. 19, z. 2, s. 49–355.

Uliasz J., Dudek L., Herman Z., 1984 – Poradnik zapobiegania i likwidacji erupcji. Warszawa, Wydawnictwa Geologiczne. s. 192.

PROCEDURY DECYZYJNE PRZY DOWIERCANIU ZŁÓŻ WĘGLOWODORÓW W WARUNKACH ZAGROŻENIA ERUPCYJNEGO

Słowa kluczowe

Złoża węglowodorów, dowiercanie, erupcja, zagrożenie erupcyjne, profilaktyka przeciwerupcyjna, procedury, schematy blokowe

Streszczenie

Brak przewidywalności zjawisk przyrody oraz możliwość popełnienia błędu przez człowieka sprawiają, że przy prowadzeniu prac poszukiwawczych za złożami węglowodorów należy się liczyć z możliwością wystąpienia stanów awaryjnych w postaci erupcji ropy naftowej lub gazu ziemnego. Dochodzi do nich zwykle w wyniku niespodziewanego nawiercenia struktur zbiornikowych zawierających gaz, ropę lub solankę pod wysokim ciśnieniem, którego nie jest w stanie zrównoważyć ciśnienie słupa płuczki wiertniczej.

Erupcja gazu lub gazu i ropy prowadzi najczęściej do pożaru natomiast gwałtowny wypływ gorącej solanki do znacznego zanieczyszczenia gleb, gruntów i wód w rejonie wiertni. Zagrożenie dla załogi oraz dla środowiska uzależnione jest od wielu czynników jednak do najważniejszych należy zaliczyć: rodzaj płynu wypływającego w niekontrolowany sposób, występujące w nim toksyczne zanieczyszczenia, czas trwania erupcji, szybkości podjęcia działań ratunkowych oraz trafność ich doboru.

Prawdopodobieństwo wystąpienia erupcji w trakcie wiercenia otworu można zminimalizować dzięki prowadzonym na bieżąco pomiarom podstawowych parametrów technologicznych i kontrolnych oraz posiadaniu efektywnych procedur i nowoczesnych systemów przeciwerupcyjnych.

W artykule dokonano identyfikacji geologicznych, technicznych i technologicznych przyczyn występowania erupcji węglowodorów w trakcie prowadzenia prac wiertniczych, zwłaszcza w warunkach występowania anomalnie wysokich ciśnień złożowych. Na tej podstawie autorzy opracowali efektywne metody prognozowania zagrożenia erupcyjnego przy prowadzeniu prac poszukiwawczych za złożami węglowodorów oraz metody likwidacji erupcji. W tym celu opracowano również algorytmy postępowania, które umożliwiają szybkie i prawidłowe podejmowanie decyzji oraz prowadzenie działań ratunkowych,

Sformułowano także zalecenia technologiczne, które pozwalają łatwo i efektywnie prowadzić profilaktykę przeciwerupcyjną.

DECISION-MAKING PROCEDURES FOR DRILLING UP HYDROCARBON FIELDS IN BLOW-OUT HAZARD CONDITIONS

Key words

Hydrocarbon fields, drilling up, eruption, blow-out hazard, blow-out prophylaxy, procedures, block diagrams

Abstract

The unpredictability of natural phenomena and erroneousness of human decisions cause that exploration works for hydrocarbon deposits may be accompanied by failure situations, e.g. oil or natural gas eruptions. They usually take place when reservoirs containing high pressure natural gas, oil or brine are drilled, and the pressure of the drilling mud column cannot compensate for it.

Natural gas or oil eruption frequently leads to fires, and the outflow of hot brine considerably destroys the soil, ground and water in the vicinity of the rig. Depending on such factors as, e.g. type of the spontaneously outflowing fluid, toxic contaminations, eruption duration, time at which the rescue measures were undertaken and methods selected – the risk for he crew and the environment may differ.

The probability of eruption during drilling operations can be minimized thanks to the on-going measurements of basic technological and control parameters, as well as the possessed efficient procedures and modern blow-out prevention systems.

The geologic, technical and technological causes of hydrocarbon eruptions accompanying drilling operations, especially at anomalously high formation pressures, have been analyzed in the paper. On this basis, the authors worked out efficient methods of predicting eruption hazard at exploration for hydrocarbons as well as methods of liquidating eruptions. Algorithms for quick and correct making decisions and carrying rescue procedures were created.

Technological recommendations for easy and effective blow-out prophylaxy follow.