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RESULTS OF THE ANALYSIS OF MODERN EQUIPMENT FOR TESTING FORMATIONS IN OIL AND GAS FIELDS OF THE CASPIAN SEA

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ABSTRACT

The article considers in providing barrier between the production fluid and environment. Subsea test tree has 2 ball valves which can prevent blow out in case of abnormal pressure reachs to surface, also isolate well, unlatch and semi subor drill ship can relocate on safe zone. To control the operation of the formation tester, it is necessary to equip it with monometers located in separate sections of the formation tester system. When working with these formation testers, it was necessary to regularly obtain, over a certain period of time, the pressure values (both behind the column and inside) that arise during its operation, which presents certain difficulties, especially when operating this system in offshore conditions. The system has couple of unique features that will tie into the surface well test system and rig. The emergency shut down system is a vital part of the surface welltest equipment. It allows the flow of the well to be stopped in the event of problems occurring at surface and relocate platform into safe zone. Prior to running the equipment, testing should be carried out to allow hardware failures to be tested, including loss of trigger line pressure, loss of subsea electronic module, loss of enhanced data acquisition system surface card and loss of a human machine interface. These tests may be performed by physically disconnecting each device in turn and confirming the expected behavior. It is recommended that the testing should also include a test where the trigger line pressure is raised, triggerlLine rapid vent option enabled, and then the trigger line pressure reduced below the trigger pressure to initiate a triiger line rapid vent – this may be done without the valve mechanism.

Keywords: subsea; shear rams; well; hydraulic; lubricator valves; platform.

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Introduction

Well testing projects in the oil and gas fields of the Caspian Sea (Azeri-Chirag-Guneshli, Shah Deniz, etc.) are always associated with a high degree of risk. Efficiency, reliability and safety are of paramount importance for their successful execution. Currently, various formation tester systems are available that can significantly reduce well testing time. The universal configuration of assemblies is designed taking into account the tasks and conditions at the field by achieving the highest functionality of the system components and cost-effective technical solutions. Thus, it is possible to test several well zones during a single trip.

Wells tied with subsea test wellhead equipment have a good track record of operations in difficult deepwater conditions, at high reservoir pressures. Continuous monitoring and evaluation of the subsea equipment system leads to a decrease in technical risks. Proven technologies work more effectively where their best qualities are expected to manifest themselves.

A wide range of system capabilities in the test program guarantees the reliability of the operations.

Testing of promising horizons in the open hole of drilling wells is one of the most effective methods of obtaining full information about the section passed when searching for oil and gas.

Experience in operating test equipment such as KII2M-146 and KI 2M-95 indicates with increasing well depth, the number of technically unsuccessful operations due to increasing in bottom hole temperatures and pressure drops. For further expansion of using of formation testers, was required significant improvement of existing and development of new testing equipment [1-6].

During testing of formations, as is known, hydraulic multi-fiber formation testers are used. The reservoir filler is a complex hydraulic mechanism consists of various valves, rods, packers, etc.

All these elements operate by hydraulically and according to a certain time schedule in depend on the tasks assigned. By setting a certain pressure of the liquid column poured into the pipes and the reservoir [7, 8].

Is possible to determine the optimal values of the diameters of the hydraulic system of multi-cycle testing equipment

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and the dimensions of its parts, while strictly observing the requirements for the strength of the equipment.

To control the operation of the formation tester, it is necessary to equip it with monometers located in separate sections of the formation tester system. When working with these formation testers, it was necessary to regularly obtain, over a certain period of time, the pressure values (both behind the column and inside) that arise during its operation, which presents certain difficulties, especially when operating this system in offshore conditions.

The relevance of the proposed testing system allows to carry out work, i.e. pressure measurement and determination of the necessary parameters of the formations in real time with the computer system connected to it, which without any lifting and lowering of the formation tests for the operation of the valves included in the formation testers to the at offshore fields relative to a number of deposits (Azeri-Chirag-Guneshli, Shah Deniz,etc.)

The purpose of the work is to use innovative methods for testing formations at offshore fields drilled from floating drilling rigs.

Objective of the work

Improving the efficiency and quality of well construction at the stage of opening up a productive formation, developing oil fields by using modern technologies for studying formations during drilling and the information content and reliability of well testing during drilling by improving technologies and designs of well equipment.

Materials and methods

The problem of successful testing is especially acute when studying a section in exploratory wells. Exploratory wells are laid in areas with the purpose of discovering new oil and gas fields, and are also drilled in previously discovered fields to search for new deposits located below or above previously identified productive horizons. Thus, based on the results of testing an exploratory well, it is necessary to establish the oil and gas content of the section and study the hydrodynamic characteristics of the productive formations. The information obtained following the construction of the well serves as the basis for making a decision on the development of the project. In an optimistic scenario, the exploratory well will discover a field or a new deposit, otherwise it will confirm the futility of the region [1, 2, 7, 8].

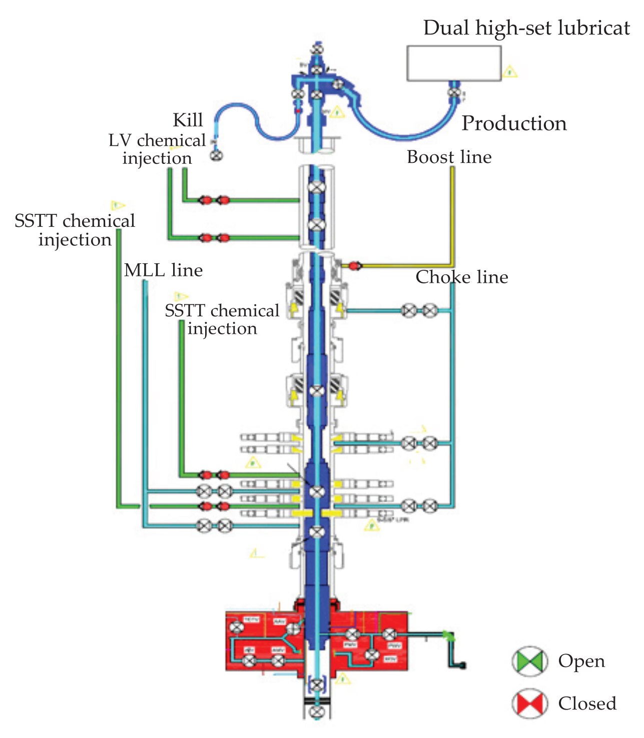

Fig. 1. Main schematic of subsea equipment into blow out preventer

That is why, in order to make the right decision on the development of the project, it is very important to obtain correct data following the construction of exploratory wells that most accurately reflect the real picture of the geological structure and oil and gas content of the region. Formation testing is a technological complex of works in a well, associated with lowering and lifting operations of the tool, creation of a deep depression in the formation, multi-cycle induction of formation fluid inflow and collection of deep samples with registration of pressure and temperature change diagrams at the bottomhole and in pipes using autonomous pressure gauges [9, 10].

The purpose of testing exploratory wells is to obtain inflow curves and pressure build-up curves. Formation testing at a qualitative level allows: - to confirm the fluid saturation of reservoir rocks; - to study the patterns of change in reservoir properties of the formation in the near-wellbore and remote zones; - to determine the boundaries of intervals with different fluid saturation in the exposed stratigraphic section. Formation testing at a quantitative level makes it possible to: - determine formation pressures and hydrodynamic parameters of the formation; - estimate the initial flow rates of oil, gas, formation water; - estimate the reserves and potential capabilities of the studied horizons. Hydrodynamic studies of wells are reflected in the works of P. Ya. Polubarinova-Kochina, V. N. Shchelkacheva, M. Masketa, I. A. Charny, G. I. Barenblatt, Yu. P. Borisova, E. B. Chekalyuka, S. N. Buzinov and I. D. Umrikhina, B. S. Chernova, M. N. Bazlova, A. I. Zhukova, S. G. Kamenetsky, L. G. Kulpina and Yu. A. Myasnikova, R. G. Shagieva, R. S. Khisamova et al., V. D. Lysenko, Miller, Dyess and Hutchinson, Horner, Hirst, Van Everdingen, R. S. Khisamov, V. S. Mikhailov and many other researchers. Based on their scientific works, the theoretical foundations of hydrodynamic methods for studying oil and gas wells were created.

The proposed equipment allows you to monitor pressure changes by connecting many test elements to a computer system. This, firstly, facilitates the work of employees monitoring the operation of the system and reduces the time for transmitting information [5, 8, 9, 11].

A landing string provides the primary means of well control during operations on board Istiglal platform. Subsea safety system (landing string) functionality are next: isolate the well bore below the shear rams (dual barrier); cut coil tubing/wireline located across the subsea test tree upper valve; disconnect the landing string from the isolated well bore; provision of a shearable member across the blow out preventer shear rams (shear sub); facilitate well kill with the valves in the failed closed position; provide well control & disconnect through a secondary means of control; to contain riser inventory; to provide dual barrier between the production fluids and the environment (dual seal) (fig. 1).

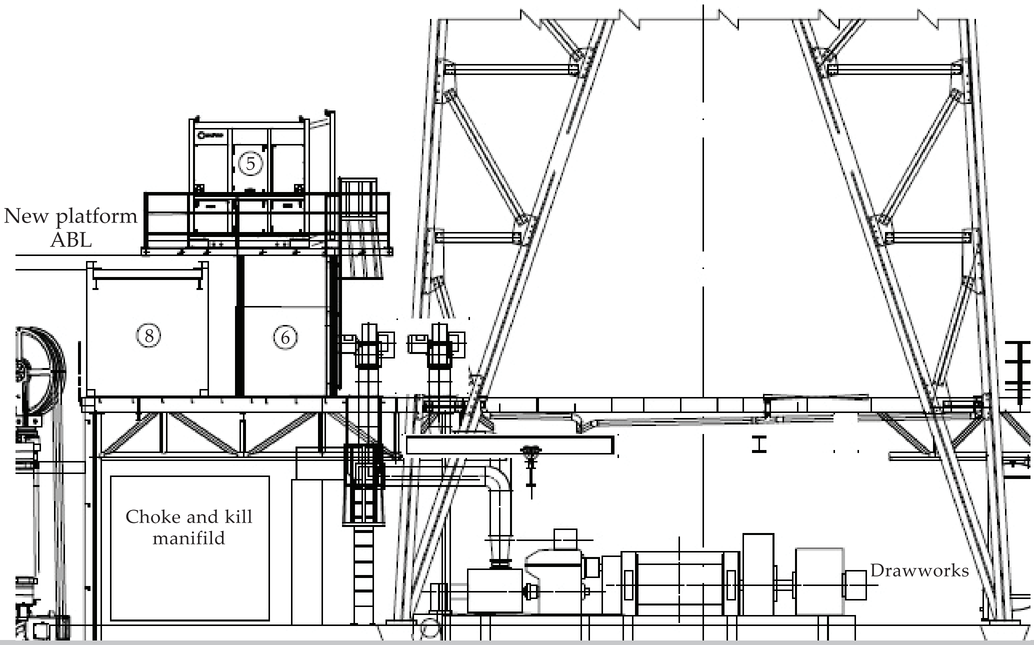

Fig. 2. Location of surface equipment on rig

The lower landing string assembly is operated by 2× umbilical's and (identical) reeler units. *1* is electro hydraulic and the other is solely hydraulic (although this could be added). The units are fitted with remote operating panels to add greater visibility to RIH/POOH operations (20 m range) [12-14]. They have 12×15 kpsi lines with «live feed» hydraulic slip rings which enable hydraulic control to be maintained during the reeler's operation. There are 4× electrical lines terminated on one of the umbilical's (the other has them blanked). These are located on the high deck of the platform (fig. 2).

The upper landing string assembly lubricator valves have their own dedicated umbilical and reeler unit. It has 6× «live feed» hydraulic slip rings which enable hydraulic control to be maintained during the reeler's operation. 4 off hydraulic and 2 off chemical. It has 1× electrical line for connection to the pressure monitoring sub (fig. 3).

There is a hydraulic power unit (HPU) to operate the subsea equipment below the upper landing string assembly. This has 26 high pressure hydraulic lines. This has 4×50 L piston accumulators. Electrical link between HPU and SECP. Houses UPS as backup. This is located on the deck of Istiglal platform (fig. 4).

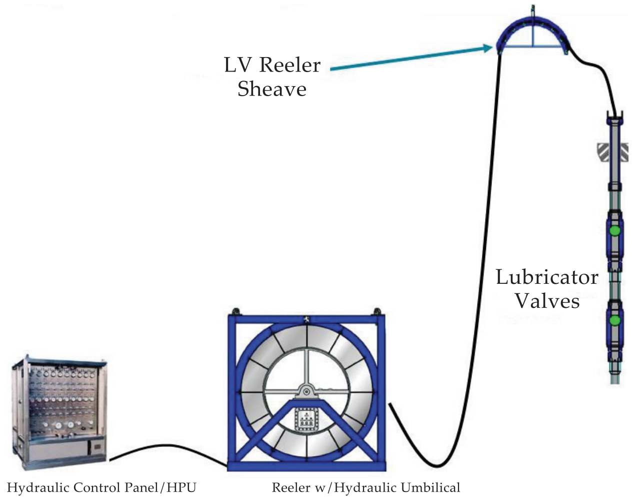

Fig. 3. Operation of lubricator valves and monitoring sub

Fig. 4. Main 26-way hydraulic power unit

Results and discussion

The electrical interface between the 26 station hydraulic power unit / reeelers and the subsea equipment. The interface between operator and electrical-hydraulic (EH) controlled functions by use of human machine interface (HMI). Shows status of EH (electrical-hydraulic) controlled functions subsea as well as surface flow and tree lubricator valve (SFT & LV) valve positions. Houses emergency shutdown button and functionality. The surface test tree flow is the uppermost component on the landing string. It diverts the produced fluids/gases to the surface well test equipment. It enables the reservoir to be isolated and allows fluids to be pumped down the landing string. Intervention equipment (wireline / coiled tubing) is connected to the top of it. See below picture:

The system has couple of unique features that will tie into the surface Well Test system & Rig:

- Low pilot overrides: there is the potential that during a subsea emergency shutdown (ESD) (closure of the subsea test tree valves that the resulting drop in pressure will activate the well test low pressure pilot (closing the flow wing valve).
- To avoid this, when we initiate an ESD, a signal is sent to their system overriding (creating an open circuit) the low pressure pilot and thus the flow wing valve remains open.
- A subsea ESD can be initiated from our control panel and from remote buttons in the Dog House and Tool pusher office [14-16].

The pressure & temperature readings taken by our subsea controls system is also being transmitted to the Well test lab. cabin (via a fibre optic cable) to enable them to also monitor the readings. The upper landing string assembly is located above the EH string and is comprised of 10 ft pup joint (c/w coupling) with 7⅝″ TSH Wedge 563 connections. Upper high set lubricator valve adapter between the pup and the lubricator valve c/w offset umbilical clamp (7⅝″ TSH Wedge 563 pin x 10″ SA pin). A lubricator valve (LV) to provide additional reservoir isolation & enable testing of the surface equipment. This will have chemical injection ability (10″ SA box × 10″ SA box). A pressure monitoring sub (10″ SA Pin × 10″ SA Pin). A lower lubricator valve (LV) to provide a tested reservoir barrier during the installation of surface equipment (10″ SA box × 10″ SA Box). Lower HSLV adapter between the pup and the lubricator valve c/w offset umbilical clamp (10″ SA pin × 7⅝″ TSH Wedge 563 pin). 10 ft pup joint with 7⅝″ TSH Wedge 563 connections. Lubricator valve provides a means of isolating surface equipment from reservior. Full 15 ksi test capability above and below closed ball valve. Allows safe passage of an 85 mm diameter umbilical along its length via offset umbilical clamps. Hydraulically operated from surface. «Fail as is» design concept. Metal to metal sealing ball valve technology. Facilitates the introduction of through tubing (i.e. coil & wireline) into production string. Full «well kill» capability in the event of hydraulic failure. Facilitates the injection of chemicals via a separate conduit to the production bore. 4 × 6.045″ lubricator valves are being supplied for these operations (2× primary & 2 back up).

These are a variation on the High Debris type, a tried and tested design used for many years. They are a relatively simple design with only 2 control lines and a chemical injection. These valves are not designed to be opened with differential pressure and so equalisation of any pressure below or above a closed ball must be performed prior to reopening (fig. 5).

Fig. 5. Lubricator valve

The EH landing string assembly is situated above the lower landing string assembly and sits above the blow out preventer in the riser, it is connected to the lower landing string assembly by means of a pup joint (stress joint). The EH landing string is made up of two main assemblies. an accumulator module. A riser control module (RCM) [1-5, 17]. Accumulators are pre-charged to varying pressure at surface according to the pressure-temperature chart. See picture below subsea test tree provides a primary safety system to control tubing pressure with dual barrier isolation. Provides a safe mechanism for disconnection & reconnection of the landing string, with full hydraulic / electric communication, whilst within the blow out preventer (BOP) stack. Facilitated chemical injection directly into the well stream, using injection outlets located at the latch & between the upper & lower subsea test tree (SSTT) valves. Facilitates closure of appropriately sized pipe rams to allow isolation of BOP annular pressure when rams are sealed. Provides cutting capability for coiled tubing & slickline. Provides independent inherent primary & secondary methods for disconnecting. «Fail safe close» valves, each able to isolate & contain maximum well bore pressure from below the valve. For upper valve, deadman system is activated during shearing of sub. An above valve test is enabled to test latch interface after reconnection.

Materials and methods of research

The HMIs will receive subsea trigger line pressure and temperature data from the enhanced data acquisition system electronics as normal. When the operator wants to enable the triiger line rapid vent option, the operator will select the new triiger line rapid vent option on the human machine interface. In triiger line rapid vent option, the system will evaluate the trigger line pressure and initiate a trigger line rapid vent when the required conditions are met (as defined in the cause and effects). Alarms shall be described in ER-1991, but it is assumed that both the surface and subsea trigger line pressures will have associated low level alarms, such that if the low level set point is reached, the surface electrical control panel sounder and beacon shall be activated. The subsea marine riser transducer pressure may also have alarms associated with it, as the marine riser pressure is used to calculate the gauge pressure on the trigger line [6, 17, 18].

Figure 6 shows how data will flow from the trigger line subsea transducer to the PLC. It also shows how each section of the data transmission is checked for errors. These error checks will be used to confirm data integrity at the PLC (programmable logic controller) and prevent accidental trigger line rapid vent (TLRV) initiation (fig.6). Failure of one surface enhanced data acquisition system (EDAS) card will result in loss of the rolling count at one of the HMIs/PLCs – the remaining surface card will still read data from the subsea electronics and trigger line subsea transducer – trigger line rapid vent is not activated automatically but will still be enabled.

Failure of both enhanced data acquisition system surface cards results in loss of the rolling count at both HMIs/PLCs – this results in an alarm at the human machine interface (HMI). Trigger line rapid vent will not be activated but also will no longer be functional.

Thus, substantiation of the reservoir production characteristics for attributing gas reserves in new areas requires solving the following problem – ensuring the necessary and sufficient volumes of research using various formation tester assemblies in order to obtain reliable values of hydrodynamic parameters.

The modular formation dynamics tester device measures the reservoir gas pressure using both a clamp probe and a two-packer assembly. Quartz and piezo metric pressure gauges are used simultaneously to measure pressure, which ensures quality control and increases the reliability of the device.

The high accuracy of pressure sensors and the short duration of measurement at one point allow for a significant number of pressure measurements during one tripping operation and, thus, for profiling the reservoir pressure along the section [8-10, 19-21].

Plotting the dependences of the calculated reservoir gas pressure at each measurement point on the depth allows, using the least squares method, to confirm the depths of the contacts of reservoir gases, the nature of the saturation of the reservoir by the density of gases in reservoir conditions with clarification of the gradients of the reservoir pressure (fig. 7).

Various analytical and numerical models of the gas reservoir are used to estimate the vertical and horizontal permeability. With a sufficiently long depression, the pressure change curve recorded by the vertical probe is inversely proportional to the horizontal permeability (1/kh), and the pressure interference recorded by the horizontal probe is inversely proportional to the square root of the product of the vertical and horizontal permeability's.

It should be noted that for the calculation method presented here, it is necessary to have accurate information on the gas extraction rate. The best way to achieve a constant gas extraction rate is to use an additional gas flow control module.

The system will perform data integrity checks at various nodes between the trigger line subsea transducer and the programmable logic controller. The system will alert the operator and prevent accidental trigger line rapid vent initiation should one or more devices in the system fail.

Thus, by reconstructing the actual pressure measurement data in the specified coordinates, it is possible to determine the productivity factor.

It should be noted that the productivity factor calculated by the identification method reflects the state of the remote formation zone (the «natural» state).

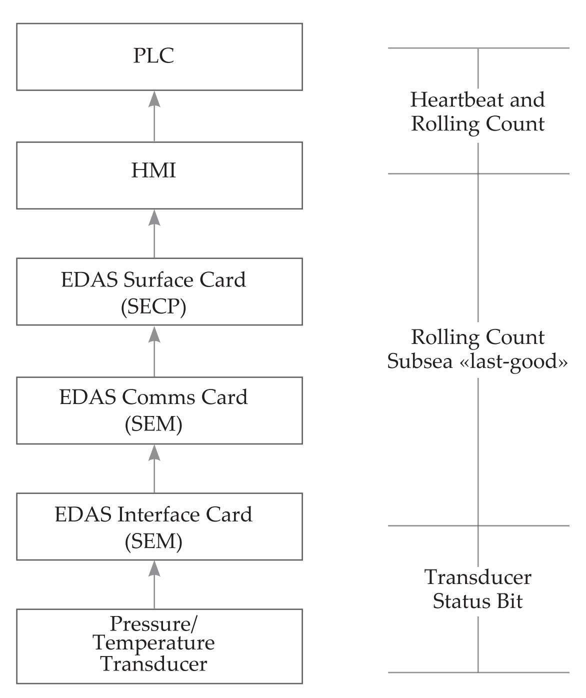

Fig. 6. Enhanced Data Acquisition System Data Flow

Based on the assessment of the productivity of individual intervals of the well section, it becomes possible to predict the operational characteristics of the entire studied deposit [10, 14, 20, 22-24].

Analysis of the factors influencing productivity shows that the calculated productivity based on the results of processing the MDT measurements by the identification method is determined mainly by the mobility of the gas saturating the studied interval at the time of its testing (fig. 8).

The identification method is selected to assess the productive capabilities of the reservoir formation. The essence of the identification method is to construct a reservoir model and determine its parameters based on the input and output «influence». For a formation that is considered as an identification object, the «input influence» is the flow rate of a

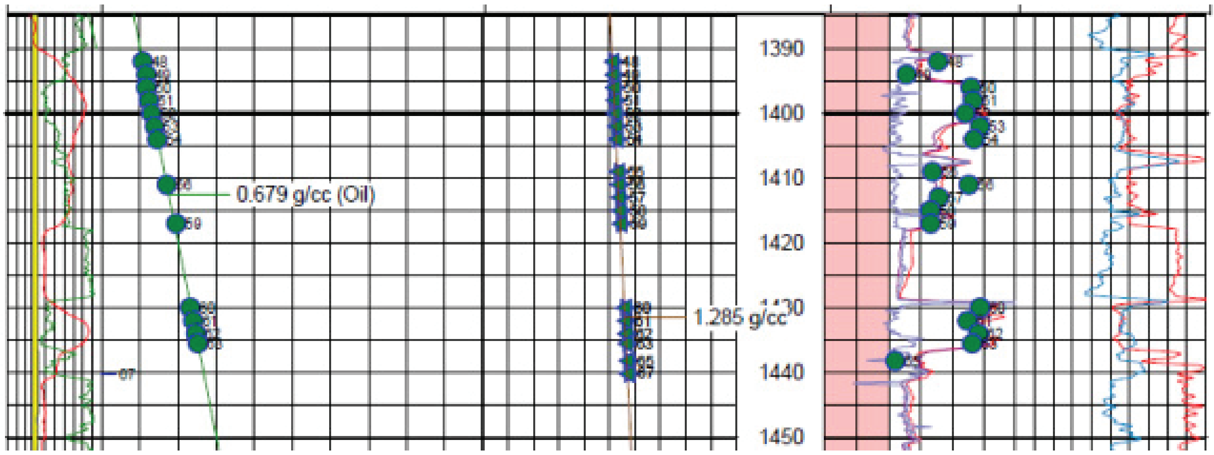

Fig. 7. Pressure profile and gradient from MDT results in well SDF2 Shah Deniz

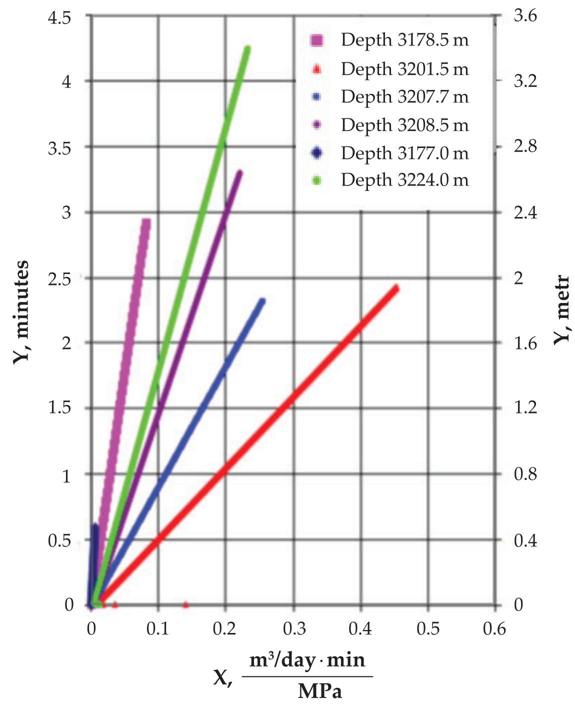

Fig. 8. Determination of productivity coefficients by the identification method in the well SDF2 Shah Deniz

specific well $Q(t)$ or gas inflow in the well, and at the output $P(t)$ is the change in bottom hole pressure [25-29].

The recovery of pressure at the bottom hole of the well is considered as a dynamic process, described in the simplest case by the following differential equation:

$$T\cdot\frac{d\Delta P(t)}{dt}+\Delta P(t)=C\cdot Q(t) \tag{1}$$

where $c^{-1}=\eta$ – productivity coefficient, m³/day· MPa; T – transition process time, h.

From equation (1) we obtain an integral formula for processing the pressure recovery curve:

$$\frac{\Delta V(t)}{\Delta P(t)}=\frac{1}{C}\cdot\frac{\Delta I(t)}{\Delta P(t)}+\frac{T}{C} \tag{2}$$

where

$$\Delta V(t)=\int_0^t\left[Q_0-Q(t)\right]\cdot d\tau;$$

$$\Delta I(t)=\int_0^t\left[P(t)-P_0\right]\cdot d\tau$$

Q_0, P_0 – respectively, the initial gas flow rate and the established bottom hole pressure.

With a sufficiently long pressure recovery coefficient and a constant initial gas flow rate during the inflow process, equation (2) can be simplified:

$$T+\frac{\Delta I(t)}{\Delta P(t)}=C\cdot\frac{Q_0t}{\Delta P(t)} \tag{3}$$

Formula (3) is the equation of a straight line in coordinates

$$\left[\frac{Q_0t}{\Delta P(t)}\cdot\frac{\Delta I(t)}{\Delta P(t)}\right]$$

Individual elements and their work on the slides to describe the operation of these devices. Data from the formation tester goes to the operator's monitor, where they are decrypted and, if necessary, the lower element of the formation tester. Subsequently, this data is deciphered and decisions for further work [1-7, 9, 11, 17, 30].

As mentioned above, the composition of reservoir tests includes valves that open and close under a certain pressure.

The condition under which premature opening of the equalizer valve is experienced is determined from the equation [31-34]:

$$A_{P_{column}}+B_{P_{pipe}}\geq C_{P_{form}} \tag{4}$$

where, A, B, C – constant; P_{column}, P_{pipe}, P_{form} – respectively, the pressure of the liquid column in the annulus, the pressure of the liquid column pouring into pipes, and formation pressure.

These datas make it possible to determine the optimal values of the diameters of the hydraulic system, taking into account its rationally designed series

The condition under which premature opening of the equalizing valve is excluded is determined from the equation [18- 21, 38]:

$$B\frac{P_{pipe}}{P_{form\,T}}>C\frac{P_{form}}{P_{pipe}}$$

Then

$$\frac{P_{pipe}}{P_{column}}\geq\frac{C}{B}\frac{P_{form}}{P_{pipe}}-\frac{A}{B}$$

$$\frac{P_{form}}{P_{pipe}}=\frac{1}{k}\quad\text{have}$$

$$\frac{P_{pipe}}{P_{column}}\geq\frac{C}{B_k}-\frac{A}{B}\quad\text{or}\quad\frac{P_{pipe}}{P_{column}}\geq\frac{1}{B}\frac{P_{form}}{P_{column}}\left(\frac{C}{k}-A\right)$$

where, κ – coefficient characterizing the excess of hydrostatic pressure over reservoir pressure.Its value, depending on the geological conditions of the areas being drilled, can vary widely from 1.10 to 1.24 and higher.

For different test circuits, the values of A, B, C can be taken from the literature [18, 35-40].

We can determine the value of the ratio, specifying different values of the coefficient k obtained using the above formulas. Knowing the values of this ratio, it is possible to determine the minimum pressure value of the liquid column at which the possibility of opening the equalizing valve is excluded [12-16, 41-43]:

$$\left(\frac{P_{pipe}}{P_{column}}\right)=k \tag{5}$$

We recommend that these calculations be made by companies operating in this field.

Conclusions

1. The described technical and methodological approach to conducting geophysical studies and testing formations in the wellbore using KII complexes allows, at the early stages of construction of exploratory wells in Shah Deniz, to evaluate formation gas in real time and select representative deep samples for all research objects, thereby obtaining the necessary physical and chemical parameters to clarify the petrophysical model, and therefore, to correctly estimate the geological reserves of gas.
2. Modern testers allow creating an instantaneous depression to cause gas inflow and perform several cycles of opening and closing the valve at the well bottom, which allows assessing the productive characteristics of the well and calculating the filtration and capacity parameters of the formation. The results of our studies allow us to increase the importance of testing methods for solving the problems of searching for and exploring promising objects of the Caspian Sea shelf fields.
3. The system has couple of unique features that will tie into the surface well test system and rig. The emergency shut down system is a vital part of the surface welltest equipment. It allows the flow of the well to be stopped in the event of problems occurring at surface and relocate platform into safe zone.
4. Prior to running the equipment, testing should be carried out to allow hardware failures to be tested, including loss of trigger line pressure, loss of subsea electronic module, loss of enhanced data acquisition system surface card and loss of human machine interface. These tests may be performed by physically disconnecting each device in turn and confirming the expected behavior.

It is recommended that the testing should also include a test where the trigger line pressure is raised, trigger line rapid vent option enabled, and then the trigger line pressure reduced below the trigger pressure to initiate a trigger line rapid vent – this may be done without the valve mechanism.

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