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ANALYSIS OF SELECTED PROBLEMS ENCOUNTERED WHILE TESTING NATURAL GAS-CONDENSATE FIELDS IN THE WESTERN CARPATHIANS**

1. INTRODUCTION

The paleozoic basement of the flysch Carpathians, mainly the fractured-cavern limestones and dolomites of the Middle and Upper Devonian, contains gaseous and gas-condensate accumulations [1, 7]. In the 1990s two horizontal geological-prospecting wellbores were drilled on the Stryszawa field (S-1K and S-2K). The S-2K well gave, among other things, general (approximated) data about the chemical composition of reservoir fluid in the Devonian strata. The DST no. 8/97 of the Devonian strata was performed in an open interval, therefore no suitable Ful-Flo sampler could be used, e.g. SG-15 controlled by pressure exerted by the annular space. Reservoir fluid samples were collected for laboratory tests from the DST column in various periods of the test (in surface conditions). An analysis of the results of DST tests revealed that depending on the applied technology, significant changes might take place in the gas composition in the DST column and in the near-wellbore zone due to the condensation of heavier gas fractions when the downhole pressure changed. The confirmed presence of gasoline in rocks of the near-wellbore zone would significantly limit the inflow of reservoir fluid to the tester, and in the case of large colmatation of collector rocks by drilling mud in this zone would result in the no flow of reservoir fluid [6].

The DST tests of gas-bearing Devonian strata in the Western Carpathians were aimed at [1, 4, 7]:

- finding the degree and type of saturation of the Devonian strata with hydrocarbons (natural gas, gasoline, oil),
- determining basic reservoir parameters (reservoir pressure, efficient rock permeability for natural gas, deposit productivity index),

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– evaluating changes of permeability of Devonian rocks in near-wellbore zone on the basis of the skin-effect index,
– determining the occurrence and type of deposit boundaries (fault, wedging-out, fracture zones) on the basis of the interpretation of the data obtained with DST by log-log [5].

The potential change of natural gas composition in the near-wellbore zone creates a big problem with the selection of appropriate initial value of counterpressure exerted by the displacement fluid on reservoir during the test, and also with the interpretation of the reservoir and production test results. An analysis of the industrial data revealed that the effect of condensate production in the near-wellbore zone could take place while using too high counterpressure during DST tests, as a consequence of using a relatively high column of water displacement fluid in the DST column, i.e. about 2500 m [4]. This thesis can be confirmed after a further detailed theoretical analysis of the occurring thermodynamic conditions.

2. ANALYSIS OF DST RESULTS FOR GAS-BEARING DEVONIAN STRATA IN S-2K WELLBORE

The double-cycle DST test no. 8/97 of the Devonian strata in the uncased interval of the S-2K wellbore (3255–3265 m) in the Stryszawa gas field was performed with a Halliburton drill stem tester Ful-Flo 5". The DST was driven on a string to the wellbore filled with a column of water to about 1390 m. The packer of the tester was fixed at 2984 m of depth (in vertical). The pressure changes were measured with Kuster downhole manometers AK1. The plot of the downhole pressure changes during the test is presented in Figure 1.

A – hydrostatic pressure of mud column in wellbore, A–B – fixing of packer and the 1st opening of the main valve (Hydrospring Ful-Flo), B–C – the 1st flow test, D – closing of the main valve, D–E – the 1st build-up test, E–F – the 2nd opening of the main valve, F–G – the 2nd flow test, H – closing of the main valve, H–M – the 2nd build-up test, p_z – reservoir pressure, dashed line – reservoir pressure extrapolated from the 2nd build-up test with Horner method

After the packer was fixed and the main vale opened for the first time (Hydrospring Ful-Flo), a rapid drop of pressure from about 35 MPa to 13.92 MPa was observed due to the presence of the column of water displacement fluid 1390 m high plus possible choking on the manifold. After opening the main valve of the tester there was initially observed air outflowing from the string as a consequence of the operation of displacement fluid (water) in the column by the inflowing reservoir fluid. This stage lasted about 9 minutes, as in Figure 1. After the first stage of flow, the main valve was closed to perform the first build-up test. The analysis of the course of the pressure curve shows that initially the increase was rapid to gently stabilize with time. The pressure build-up lasted about 62 minutes. Ultimately, the build-up pressure equaled to 28.24 MPa. The first build-up period was followed by a re-opening of the main valve. As a result a rapid drop of pressure to 14.42 MPa was observed. At that stage after ten or so minutes an intense gas outflow from the DST column was recorded. It was a consequence of its passing through the column of the displacement fluid, which lasted about 6 minutes, followed by an outflow of intensely gassed displacement water about 1 m^3

for about 8 minutes. The outflow of the displacement fluid with gas resulted in a slight but noticeable drop of pressure in the plot of the 2nd flow (Fig. 1). The closing of the displacement fluid outflow on the manifold caused a pressure build-up to 17.86 MPa and after about 25 minutes an increase of wellhead pressure to 5.5 MPa was observed on the surface.

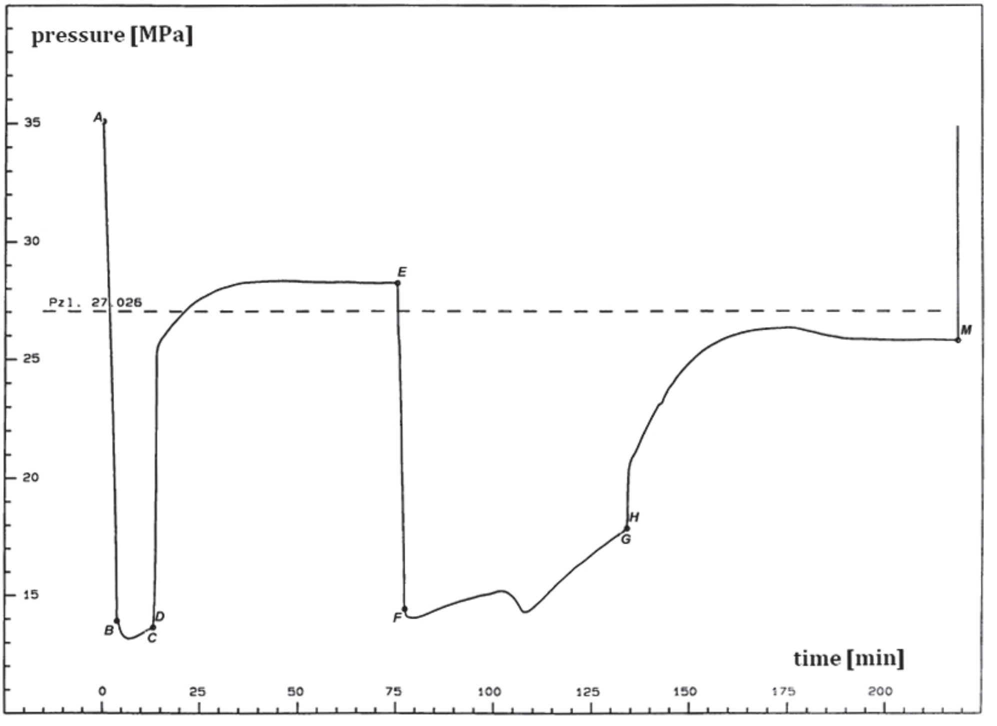

Fig. 1. Pressures registered by downhole pressure manometer during a DST test no. 8/97 (Devonian, 3255–3265 m) in S-2K well

According to the authors the temporary penetration of gas through the column of displacement fluid significantly changed the composition of gas under the displacement fluid and probably in the zone close to the wellbore. Most probably the lightest fractions of gas were liberated. The remaining gas (with changed composition) was subjected to the second pressure build-up from 17.86 MPa to about 25.79 MPa after about 40 minutes. Later at this stage the pressure dropped down to about 25 MPa, which value was maintained on the stable level. Prior to the test the tightness tests were performed for the whole DST setup. The authors suggest that this drop of pressure might be caused by a condensation of part of the hydrocarbons [8].

The difficulty with explaining the change of pressure value at the build-up stage lies in the fact that no temperature variations were measured during the test. Despite this deficiency, the authors try to explain the character of the effect as visualized in Figure 2.

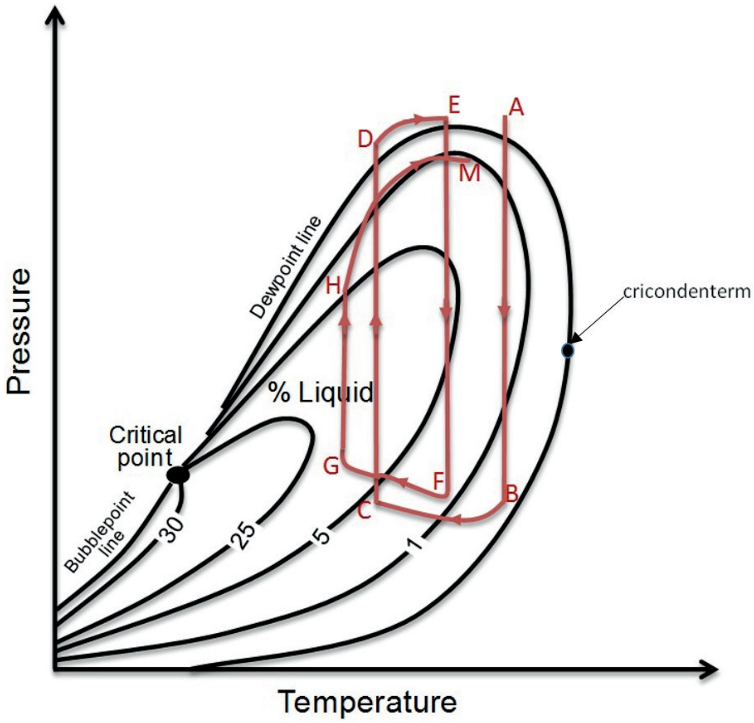

Fig. 2. Feasible course of pressure and temperature during the DST test

Figure 2 illustrates a phase diagram typical of a gas-condensate field. Such a character of the gas field was assumed on the basis of information about the characteristic of reservoir fluids coming from the Devonian strata. The phase diagram for a gas-condensate field has typically a large temperature range between the critical and cricondenterm temperatures. It was also assumed that in the initial conditions of the deposit (Fig. 2 – point A,) the fluid is in gaseous phase (high reservoir pressure).

The analysis of Figure 1 reveals that the pressure rapidly drops after the packer has been fixed, therefore the temperature was assumed not to change much in this time (vertical line from point A to point B). After opening of the main valve the fluid flows into point B enabling the fluid to cool down as a result of the Joule-Thomson effect with a concurrent slight increase of pressure (curve B–C). Because of the drop of pressure both points B and C stay in a two-phase area. The closing of the valve in point C might cause a strong thrust of the liquid (condensate) through the thrust of the reservoir fluid. After a certain time of pressure build-up the two-phase zone is left behind (point D) and the fluid flowing from the reservoir heats up the fluid in the wellbore. Then point E follows. According to the schedule of the test the valve is re-opened at this stage and a rapid drop of pressure is observed to point F. At point F the second fluid flow begins. The fluid is chilled in the wellbore with an increase of pressure, higher than at the first period. As a consequence of cooling we pass to point G, where heavy fractions were condensed. The pressure values indicate that more liquid (condensate) is present in the reservoir fluid. According to the authors this caused higher filtration resistance in the wellbore zone. After closing the main valve at point G the pressure builds-up without leaving the two-phase area. As a result of heating with the fluid flowing from the reservoir the temperature increases. Passing to the right, part of the initial gaseous phase (close to the dew point) is re-condensed. This process results in the lowering of the fluid volume and so a drop of pressure which is maintained on a constant level. The authors stress that this analysis is only qualitative, not quantitative. It is absolutely necessary to know the original composition of reservoir fluid and temperature variations during the DST tests.

The authors suggest that in this case the primary (original) chemical composition of gas might be analyzed with a Halliburton Ful-Flo sampler, e.g. SG-15 with which gas samples can be collected at any time of the flow test and build-up test. The Ful-Flo sampler is operated in the annular space of a cased wellbore by exerting a pressure difference, which causes a disc rupture and a shift of the tube due to the mud pressure in the space. Consequently, a reservoir fluid sample is captured in the sampler chamber (1200 cm^3 capacity). The pressure with which the sampler is controled is 7 MPa (1000 psi) lower than the pressure which operates the circulating valve (SG-15 RD). The samples can be taken from the sampler either directly or in a workshop.

The production of condensate in the near-wellbore zone during the flow test or in the tester string during the build-up test has a negative impact on the clearness of the obtained reservoir test results, which are interpreted with the Horner method [8] or log-log method [6].

3. CONCLUSIONS

1. The use of new types of drill stem testers and appropriate interpretation methods, which would account for a detailed analysis of technological and reservoir conditions allows for more efficient oil prospecting and deciding about enhancement methods in hydrocarbon production.
2. The analysis of thermodynamic conditions on the bottom of the wellbore allows for selecting proper counterpressure values in view of the condensation of heavier gas fractions in the near wellbore rocks.
3. The analysis of conditions in which heavier gas fractions undergo condensation is approximate and general because the gas samples were collected at the outlet of the DST string (in surface conditions), without a Ful-Flo sampler and without temperature measurements.
4. The exemplary analysis of DST results for the presence of natural gas condensate in the Devonian strata in S-2K wellbore in the Stryszawa field reveals that:
   – values of counterpressure on deposit during DST tests should be selected very thoroughly,
   – industrial applications impose certain limitations on the use of DST and the log-log method,
   – samples should be collected with a Ful-Flo sampler.
5. Condensation in the wellbore zone during the flow test or in the DST string during the build-up pressure has a negative impact on the clearness of the obtained DST results interpreted with the Horner method [8] or with the log-log method [6].

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