AGH DRILLING, OIL, GAS • Vol. 30 • No. 1 • 2013

http://dx.doi.org/10.7494/drill.2013.30.1.51

Stanisław Dubiel*, Adam Zubrzycki*, Michał Maruta*

DECISION SYSTEM MODEL FOR HC EXPLORATION ON THE BASIS OF DST TEST RESULTS**

Nomenclature

ω – rate of fracture capacity and matrix/fracture system capacity,
λ – contrast capacity parameter between the fracture and whole reservoir,
k – effective permeability of matrix + fracture system,
S – skin-effect,
R_{b2} – radius of the investigation during test,
L – distance between the well and reservoir boundary.

1. INTRODUCTION

Hydrocarbon perspective horizons are selected in the profile of boreholes performed during hydrocarbon exploration program mainly on the basis of previously gathered geological, well-logging and drilling data. These intervals are inspected with DST tests in an open hole section or rarely in a cased hole after earlier borehole casing perforations. DST tests enable one to recognize in more detail the formation permeability (the pore-space structure), reservoir pressure, well productivity, drainage area, information on fluid properties and indications concerning the scale of the accumulation.

DST tests results interpretation is the basis for further technological decisions in a given well. These decisions may lead to radically different effects: hydrocarbons production in the well or the lack of good gas flow and liquidation of a given horizon and even well.

* AGH University of Science and Technology
** Work performed within the statutory research program of the Department of Oil Engineering, Faculty of Drilling, Oil and Gas AGH-UST

The work-flow decision diagram proposed by the authors was elaborated in support of earlier analyses and field experiences concerning the hydrocarbon exploration within the Upper Jurassic carbonate reservoir rock forming the Carpathian Foredeep basement in the Bochnia–Ropczyce area.

2. GEOLOGICAL AND TECHNOLOGICAL SETTINGS OF DST TESTS

The Carpathian Foredeep basement, particularly its Upper Jurassic cover consisting of different facies of carbonate rocks is sealed by a shaley–sandy complex of the Miocene molasses of the Carpathian Foredeep and party by the frontal Flysch Carpathian Thrust (mainly by the Silesian and Skole units). The Bochnia–Ropczyce area is the main target for hydrocarbon exploration. Reservoir rocks are shallow marine carbonates as microbial–sponge or coral biostromes and marly or micrite limestones frequently affected by different diagenetic processes (calcite cementation, dissolution, dolomitization) and by tectonic fracturing. Several oil and gas fields were discovered in the Upper Jurassic carbonate reservoir rocks of this type, e.g. Brzezówka, Korzeniów, Partynia–Podborze and Łapanów.

The description of carbonate rocks in this region and their sedimentological development, sedimentation conditions, facies characterization and diagenetic evolution were published by, e.g. Gutowski J., Urbaniec A. – 2007; Krajewski M., Matyszkiewicz J., Król K. – 2011 and Maksym A., Baszkiewicz A. et al. – 2001.

Three types of pore-space systems can be distinguished on basis of the results of DST analyses performed within various horizons of the Upper Jurassic carbonate rocks on the basis of build up pressure curves vs. time: I – fracture-vuggy porosity system, II – vuggy-fracture porosity system, and III – karst porosity system. A detailed description and explanations concerning relationships between DST results and type pore-space systems for analysed Upper Jurassic carbonate intervals have been presented in papers by Dubiel S., Zubrzycki A., Rybicki C., Maruta M. – 2012, and also by Dubiel S., Zubrzycki A., Maruta M. – 2012. The use of the DST technology for testing Upper Jurassic carbonate profiles in the study area was analyzed in a paper by Dubiel S., Rychlicki S. – 2012.

3. THE WORK-FLOW DECISION DIAGRAM FOR HYDROCARBON EXPLORATION ON THE BASIS OF DST DATA

Gas-bearingness of the Malmian strata has been recognized with the use of data from DST tests performed according to different decision procedures. For the reason of unifying procedures of DST technological decision taking a block diagram (Fig.1) was worked out. It accounts for experiments and results of analyses of 57 tests performed in the Upper Jurassic (Malmian) carbonates in the Bochnia-Ropczyce area. DST tests performed on open or cased and perforated borehole intervals revealed the lack or differentiated inflow of reservoir fluids (frequently gassed drilling mud and reservoir fluids, or gas).

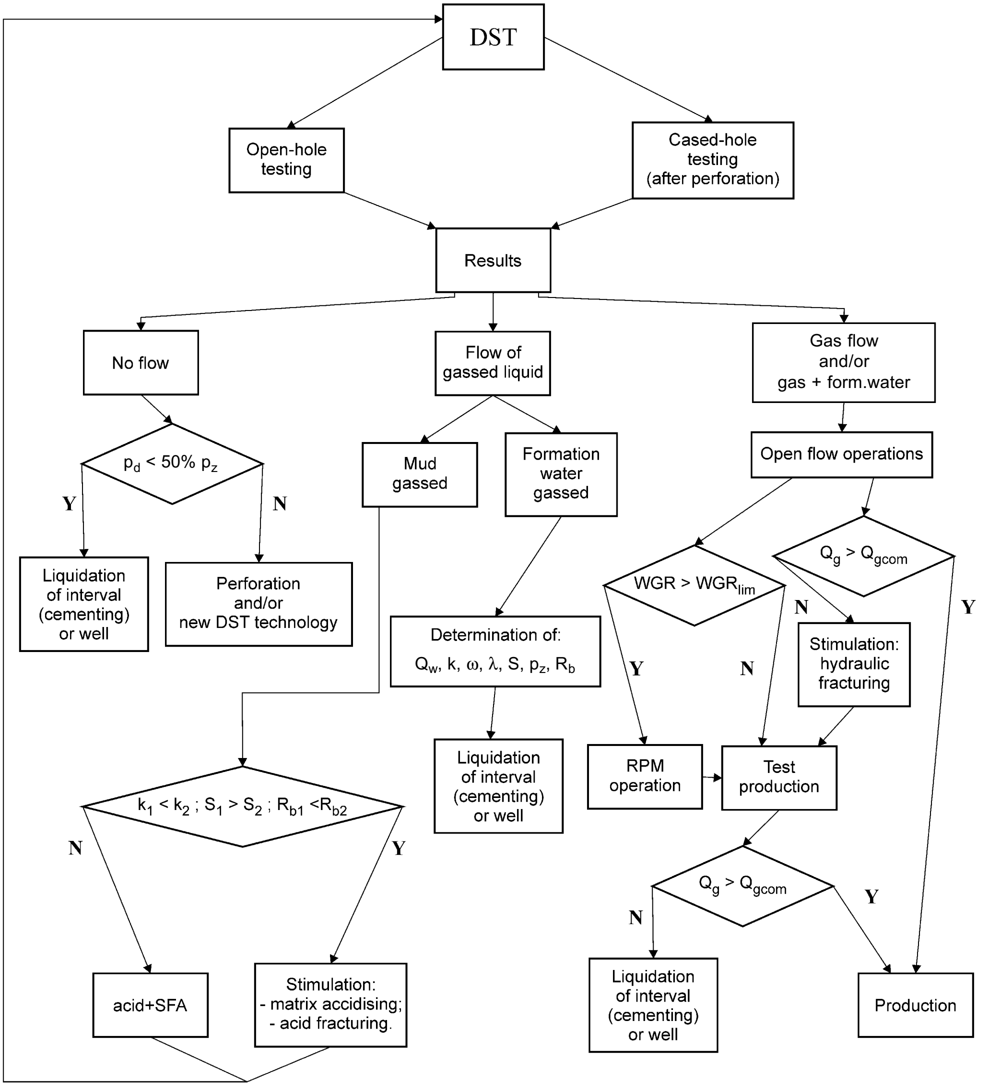

Fig. 1. Block diagram of technological decisions based on DST data

The flow test is the first stage of the DST technology. Its results give information about the flow (or its lack) (fig.1), the type of the flowing medium (gassed fluid or gas), and also degree of saturation of fluid with natural gas (gas traces or low or high saturation).

The lack of reservoir fluid flow from the analyzed interval (despite positive reservoir parameters confirmed with well-logs) substantiates a decision about liquidating the interval or well. The correctness of this decision is confirmed by the build-up test results: if the final build-up pressure decreases to a value lover than 50% of the predicted reservoir pressure then a hydraulic contact (during DST) with reservoir rocks is not observed. If this value is lower, the DST test should be repeated in this perforated interval, using different technological parameters [Dubiel S., Chrzaszcz W., Rzyczniak M. – 2003].

In the case of gassed drilling mud or reservoir water (brine) flows, different decision procedures have to be applied. The flow of gassed drilling mud shows to the damaged reservoir rock permeability in the near-well zone. Flow enhancement operations are recommended, e.g. washing the near-borehole zone with hydrochloric acid solution premixed with surfactants. Then the test should be repeated. The correctness of the decision is proved by the build-up tests: in the case of one build-up test, when the skin-effect S is bigger than zero (S>0), and in the case of two build-up tests, when the permeability calculated from the first build-up test is lower than that in the second test, and the skin-effect from the first test is higher than that in the second test, and the radius of the study area in the first test is smaller than in the second test, i.e. ($k_1<k_2$; $S_1>S_2$ i $R_{b1}<R_{b2}$) [Dubiel S. – 1987; Dubiel, Rychlicki – 2012]. When the stimulated natural gas flow (observed during the DST tests) is smaller than the minimum commercial yield ($Q_g < Q_{g\ kom.}$), then a decision about liquidating the analyzed interval or well can be taken. Otherwise the well is designed for production purposes.

In the case of an inflow of reservoir water saturated to a varying degree with gas, a decision about liquidating the analyzed interval or well can be taken after performing complete DST test, i.e. usually the double-cycle technology. The results of these tests are used for determining basic reservoir parameters (rate of reservoir water inflow – Q_w; reservoir pressure – p_z, rock permeability – k, skin-effect – S, radius of the investigation test – R_b, and other). These parameters can be used for evaluating reservoir conditions in the water bearing part of the recognized geological structure (and which can be gas-bearing in the other part) [Dubiel S. Rzyczniak M., et al. – 1993–1998].

Natural gas flow with or without water requires open flow operations to clean up the well from the drilling mud and reservoir water residues, followed by build-up tests to determine the basic reservoir and borehole parameters (reservoir pressure, permeability, skin-effect, radius of the study area, distance between the well and the reservoir boundary). In the case of natural gas flow with water it is important to determine the water-to-gas ratio (WGR) and determine whether its value is lower than the admissible WGR_{lim}. The admissible WGR_{lim} corresponds to the profitability limits with economically justifiable amount of reservoir water. Mainly the cost of utilization of reservoir water exploited with natural gas is accounted for. If $WGR < WGR_{lim}$, then the production test can be performed, otherwise the Relative Permeability Modification (RPM) has to be involved [Dubiel, Uliasz-Misiak – 2013]. The production test should follow such an operation. When the natural gas flow (without reservoir water) is bigger than the minimum commercial yield ($Q_g < Q_{g\ com.}$), then a decision about gas production or enhancement of natural gas production (e.g. hydraulic fracturing) can be taken.

4. FINAL CONCLUSIONS

1. The work-flow decision diagram illustrating technological operations during DST was elaborated on the basis of the analysis of 57 DST results performed in the selected Upper Jurassic carbonate horizons (intervals) within the Carpathian Foredeep basement in the Bochnia–Ropczyce area in the years 1993 to 1998.
2. The presented work-flow diagram may be useful for designing the process of DST operations in new wells exploring carbonate reservoir rocks, particularly within the Upper Jurassic profiles of the Carpathian Foredeep basement.
3. This flow-work diagram may be also useful in the process of the hydrocarbon reservoir and production management.

REFERENCES

[1] Dubiel S.: *Metodyka interpretacji wyników dwucyklowego opróbowania gazo- i roponośnego poziomu perspektywicznego rurowym próbnikiem złoża*. Kwartalnik „Górnictwo",z. 1, 1987, 17.

[2] Dubiel S., Chrząszcz W., Rzyczniak M.: *Problemy opróbowania warstw perspektywicznych rurowymi próbnikami złoża*. Uczelniane Wydawnictwo Naukowo-Dydaktyczne AGH, Kraków 2003.

[3] Dubiel S., Rzyczniak M., *et al.*: *Analiza i interpretacja wyników badań rurowymi próbnikami złoża warstw perspektywicznych w rejonie Przedgórza Karpat, w celu oceny właściwości zbiornikowych skał i parametrów złożowych poszczególnych poziomów*. Praca naukowo-badawcza, WWNiG, AGH, Kraków 1993–1998.

[4] Dubiel S., Zubrzycki A., Rybicki C., Maruta M.: *Application of DST interpretation results by log – log method in the pore-space type estimation for the Upper Jurassic carbonate reservoir rocks of the Carpathian Foredeep basement*, Archives of Mining Sc. Polish Academy of Sc., vol. 57, nr 2, Kraków 2012, 413–424.

[5] Dubiel S., Zubrzycki A., Maruta M.: *Analysis of carbonate rock properties on the basis of DST and well logging (the Upper Jurassic basement of the Carpathian Foredeep).* AGH Drilling Oil and Gas, vol. 29, nr 1, Kraków 2012, 127–134.

[6] Dubiel S., Rychlicki S.: *The results of double – cycle DSTests of the Malm carbonate rocks of the Carpathian Foredeep.* AGH Drilling Oil and Gas, vol. 30, nr 2, Kraków 2012.

[7] Dubiel, Uliasz-Misiak: *Typowanie odwiertów wydobywczych do zabiegów ograniczania dopływu wody przy eksploatacji złóż węglowodorów.* Selection of production wells to shutoff water treatment during hydrocarbons exploitation. Przegląd Górniczy 2013 (w druku).

[8] Gutowski J., Urbaniec A. *et al.*: *Stratygrafia górnej jury i dolnej kredy środkowej części przedpola polskich Karpat*. Biul. IG 426, Warszawa 2007, 1–26.

[9] Krajewski M., Matyszkiewicz J., Król K.: *Facies of the Upper Jurassic – Lower Cretaceous deposits from the southern part of the Carpathian Foredeep basement in the Kraków-Rzeszów area (southern Poland)*. Annales Soc. Geol. Pol., vol. 81, nr 3, 2011, 269–290.

[10] Maksym A., Baszkiewicz A. *et all.*: *Środowiska sedymentacji i właściwości zbiornikowe utworów najwyższej jury i kredy dolnej rejonu Brzezówka-Zagorzyce na tle budowy geologicznej S części zapadliska przedkarpackiego*. Przegląd Geol., vol. 49, nr 5, 2001.

[11] Schlumberger: *Well Test Interpretation Seminar*. Polish Oil & Gas, Warszawa 1993.