

# Injection Process Control of the Well at the Hydrodynamic Research of Coalbed

I G Odnokopylov<sup>1</sup>, O V Galtseva<sup>1</sup>, I Yu Krasnov<sup>1</sup>, A O Smirnov<sup>1</sup>, M S Karpov<sup>3</sup>,  
O A Surzhikova<sup>4</sup>, V V Kuznetsov<sup>5</sup>, and J Li<sup>6</sup>

<sup>1</sup>Associate Professor, National Research Tomsk Polytechnic University, Tomsk, Russia

<sup>2</sup>Senior Lecturer, National Research Tomsk Polytechnic University, Tomsk, Russia

<sup>3</sup>Student, National Research Tomsk Polytechnic University, Tomsk, Russia

<sup>4</sup>Associate Professor, Czech Technical University in Prague, Czech Republic

<sup>5</sup>Associate Professor, Omsk State Technic University, Omsk, Russia

<sup>6</sup>Professor, Tsinghua University, Beijing, China

E-mail: odivan@yandex.ru

**Abstract.** This scientific work is devoted to the study results of water injection process into the well at the hydrodynamic research by using the high pressure unregulated pump. The injection process should be accompanied by the retention of some hydraulic parameters at constant level during some time. Various variants for use of mechatronic nodes for automatization of water injection process are considered. Scheme for reducing the load on the pump and equipment in hydraulic system and also for improving the quality control system with high accuracy is shown. Simulation results of injection process into the well at the pressure and consumption fixation and recommendations for the use of the proposed schemes depending on the technological process are given.

## 1. Introduction

Development of oil and gas fields is based on the modern scientific technologies. They are built on detailed studying of properties of productive layers, gases and fluids and the processes in layers during operation. Research process of fields includes the stages from their opening to full depletion of recoverable gas and oil reserves. This information is used for control, designing and management by field development systems for ensuring the paces and reserve degree of depletion at a minimum cost.

Hydrodynamic (industrial) researches of layers and wells actively are used for obtaining of the necessary information [1]. At the same time the characteristics of the studied layers are specified; the possibility of effective impact on a bottomhole zone of layer is revealed. Hydrodynamic simulation results allow to choose the intensification technology of gas inflow and to carry out the choice of suitable mode of equipment operating of the wells.

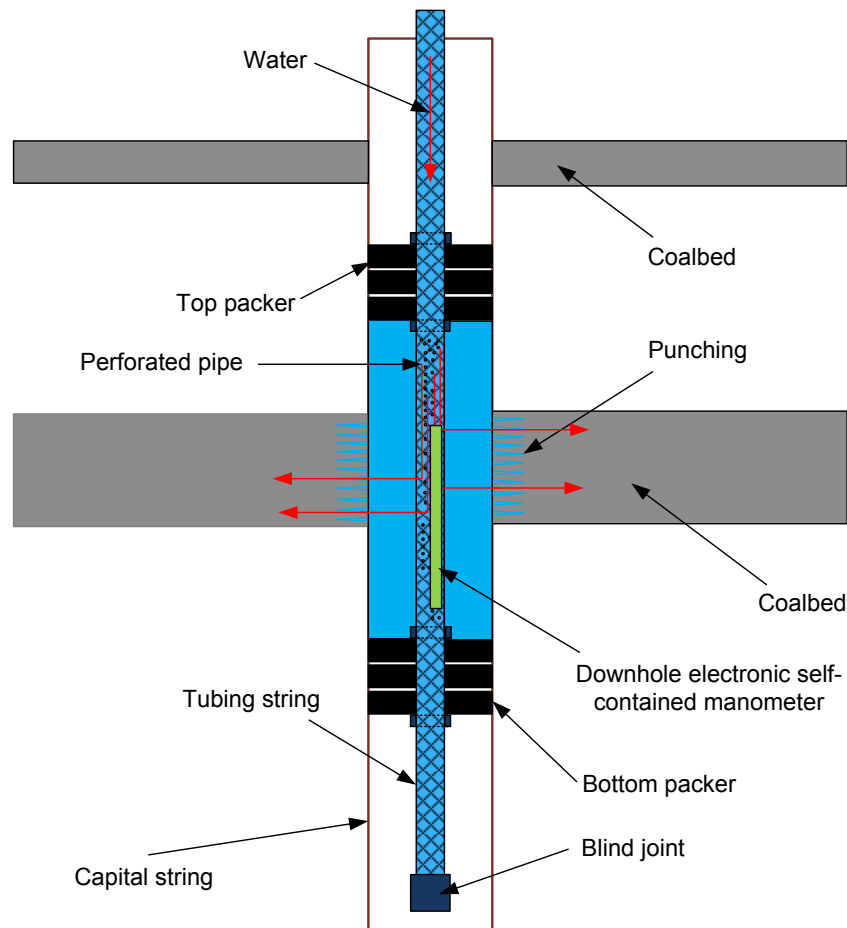
## 2. Hydrodynamic Research of the Wells

Hydrodynamic experiments are implemented by fluid injection into the layer during certain period of time with registration of wellhead and bottomhole pressures. It is known that the relative permeabilities are taken into account by using the technologies of the hydrodynamic studies at the



multiphase filtration flow. Therefore, the filtration flow in the crack system is single-phase for simplification of the data interpretation of such tests [2–7].

The scheme of underground equipment of well is used at conducting of the hydrodynamic studies; its scheme is shown in Figure 1.



**Figure 1.** Scheme of underground equipment of well at hydrodynamic researches.

It is necessary to conduct data interpretation of hydrodynamic tests for evaluating productive and filtration characteristics of the layers and wells (pressure of layer, productivity or filter coefficients, permeability, skin factor, etc.) and features of the borehole and remote zones of layer. The quality of the results interpretation depends on the compliance accuracy of the hydrodynamic research technology [8–11]. It is required to ensure steady monitoring of wellhead and bottomhole pressure and for supporting a constant flow fluid during pumping in the presence of disturbances in the near-well area [12–16].

### 3. Realization of Fluid Injecting into Well

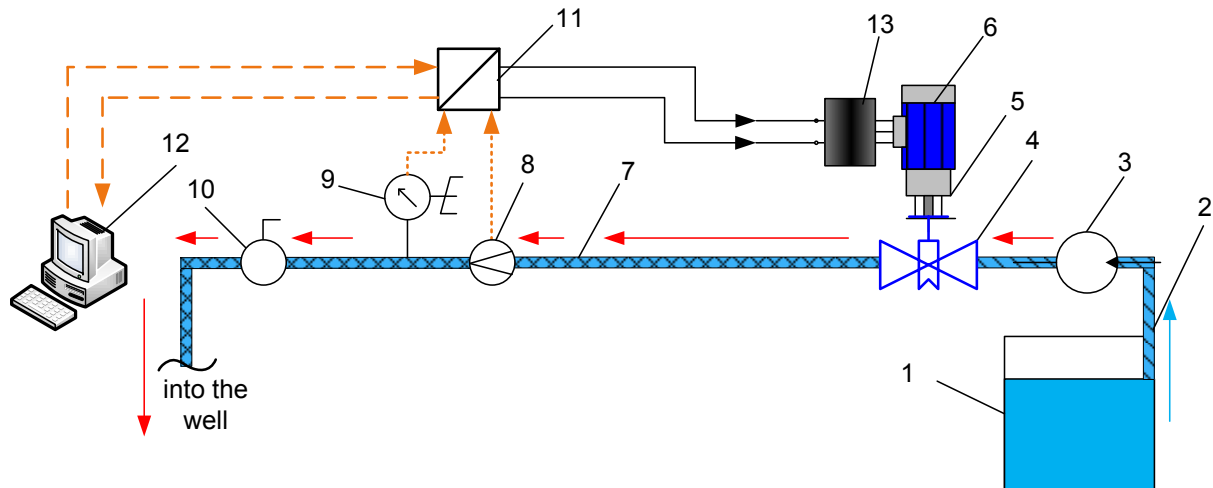
The maintaining of defined consumption of fluid and pressure in the well is done by the operator by using the valve during a long time at the fluid injecting into a well at the hydrodynamic studies.

It was proposed the use of regulating high pressure pump for fluid injecting automation with high precision. The pump outlet is connected via the sensors directly to the well. The main objective of this solution is the creation of deep regulating pump which can hold a small consumption at high pressure with high precision. This decision is not considered in this paper.

The fluid consumption is proposed to be controlled through the regulating throttle.

Figure 2 shows the proposed variant of the process automation scheme for research wells by using the through-type regulating valve.

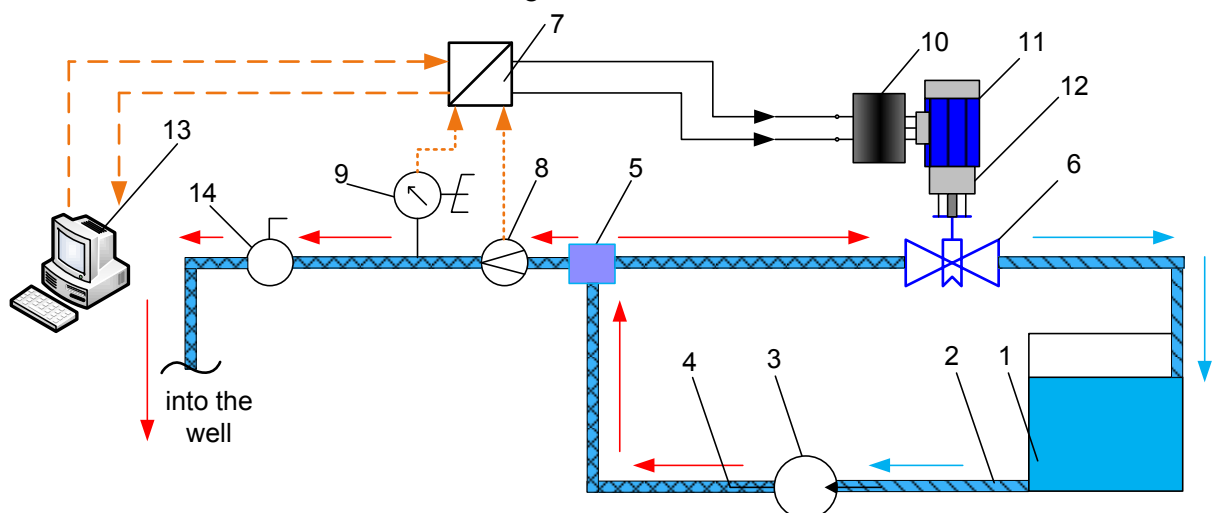
The work of the present scheme is described below. The fluid from tank (1) is supplied to the unregulated high-pressure pump (3) of low pressure pipeline (2); further, on the high-pressure pipeline fluid is supplied via the regulating valve (4), which regulates the amount of fluid coming into the well. The regulating valve is driven by asynchronous motor (6) through gear (5).



**Figure 2.** Functional automation scheme by using the through-type regulating valve.

After that the fluid moves through the flowmeter (8) into the well through the high-pressure pipeline (7). Data from the flowmeter (8) and pressure sensor (9) is processed by programmable logic controller (11); the formed task is transmitted to frequency converter (13). Personal computer (12) is used for visually displaying the information in real time and recording the data in defined format. The pressure pipeline is closing by using a ball valve (10) after reaching the needed pressure in the well. The injection process is complete.

Figure 3 shows a functional scheme of the hydrodynamic studies by using the through-type regulating valve in the dumping letdown. The work of the present scheme is described below. The working fluid is in the tank (1); it goes into the unregulated high-pressure pump (3) on the low-pressure pipeline (2). In the pipeline (4) under a high pressure fluid is supplied to the T-bend (5), which divides the fluid flow into the working and waste flow.



**Figure 3.** Functional scheme of the hydrodynamic studies by using the through-type regulating valve in the dumping letdown.

After the T-bend a working flow passes through the flowmeter (8) and goes in the well. The selected pump productivity is more than the required consumption of working fluid injection into the

well, so some part of the working fluid goes on the return pipeline through the regulating valve (6) into the container (1). Consumption of working fluid injection into the well on defined level can be maintained by changing the amount of fluid which is discharged back into the tank.

Control of the working fluid injecting consumption into the well provides by the programmed logic controller (7). This controller receives data from the flowmeter and pressure sensor (9); after processing data it forms the task for frequency converter (10) which feeds the induction motor (11). Next through a reducing gear (12) the engine drives the stem of the regulating valve (6), which varies the quantity of passing fluid. The personal computer (13) is required for visual display of information in real time and for recording the data into the nonvolatile memory. Electronic manometer (9) is needed to control the pressure in the well. It is necessary to close the injection pipeline by using the ball valve (14) once the well pressure will reached a defined level.

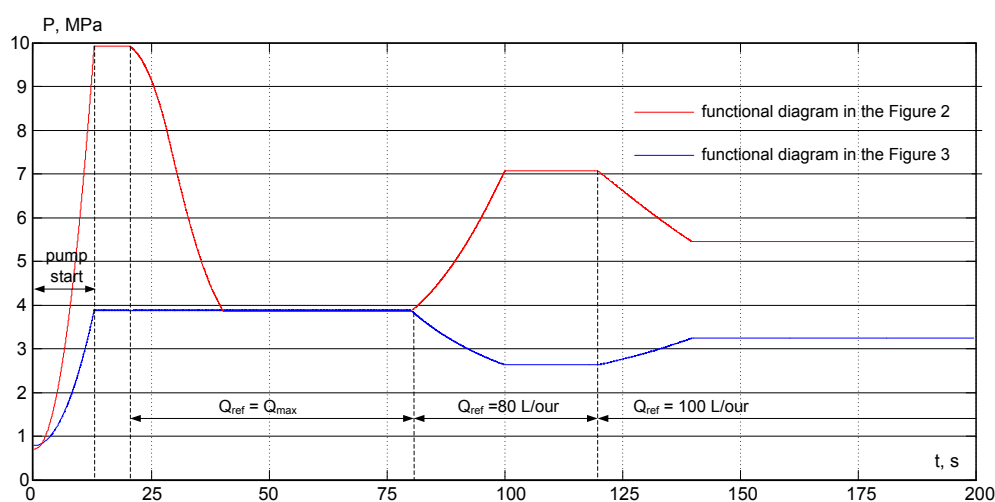
According to analysis of the both variants the scheme (Figure 4) has many disadvantages such as the high cost and low efficiency of the system. This is because most of the fluid which supplied by the pump (3) is discharged back into the tank (1). However, the scheme allows making the injection process with high accuracy; electrical and hydraulic equipment for realization is accessible.

#### 4. Simulation of the of Injection Fluid Process into the Well

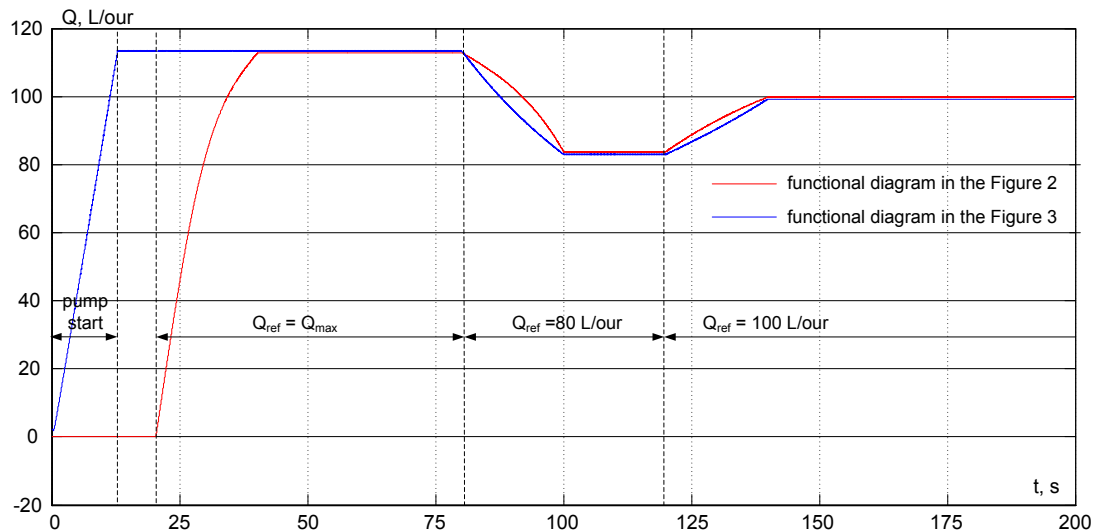
Simulation model of the injection fluid into the well has been developed in the Matlab software. For simulation in statics and dynamics the SimPowerSystems library (for modeling of adjustable speed drives) [10] and the SimHydraulics library (for modeling of hydraulic systems) are used. The model scheme includes a hydraulic tank (for storage of working fluid), a pump (for injecting the working fluid in the system); regulating valve (throttle); fluid conductors (for connection of hydraulic elements to each other). Appropriate sensors in the fluid conductor are used to measure pressure and consumption. Water is used as working fluid; losses in the fluid conductors were not taken into account. Figures 4, 5 show the simulation results of the hydrodynamic studies with the use of through-type regulating valve in supply pipeline and the dumping letdown.

Figure 4 shows the transient curves of P pressure during the starting up the pump and the regulating the valve in supply pipeline (red curve in Figures 2, 3) and in the dumping letdown (blue curve in Figures 2, 3).

Figure 5 shows the transient curves of Q consumption during the starting up the pump and the regulating the valve in supply pipeline (red curve in Figures 2, 3) and in the dumping letdown (blue curve in Figures 2, 3).



**Figure 4.** Transient curves of P pressure during the starting up the pump and the regulating the valve.



**Figure 5.** Transient curves of  $Q$  consumption during the starting up the pump and the regulating the valve.

Transient curves of consumption for both variants are almost identical except the stage of the pump starting up. If through-type regulating valve is installed in the delivery pipe, the beginning of fluid injection into the well is determined by the position of the valve; in this case the injection into the borehole starts at 20 seconds. If through-type regulating valve is installed in the dumping letdown, the beginning of fluid injection is determined by the moment of the pump starting up.

Analyzing Figure 4, it is possible to say that the fluid consumption regulation is characterized by elevated pressure in the dumping letdown at the implementation of the first variant of placement of the through-type regulating valve. It creates a strain on the pump and elements of the hydraulic system that will reduce the equipment life.

## 5. Conclusion

Method of injection fluid into the coalbed for permeability determination is well established in low-permeability fractured-porous reservoirs of the CBM fields. It allows determining the filtration parameters of the coalbeds more reliably for a short time at a low cost.

Based on the data interpretation experience of the hydrodynamic studies, the most successful tests are at the constant fluid consumption during the pumping period throughout the all test. Interpreted data analysis of the hydrodynamic studies shows that the fluid consumption stabilization on the defined level throughout the all test is a mandatory condition for obtaining of the acceptable data.

Conducted research of various automated schemes of the hydrodynamic tests show that the using the through-type regulating valve is a most simple and effective way of the accurate maintenance of the working fluid consumption.

Practice shows that the fluid consumption control is performed more precisely at the low pressures; the variant with through-type regulating valve in the dumping letdown is more preferred.

## References

- [1] Saulsberry J L *et al* 1996 *Gas Research Institute Report GRI-94/0397* (Chicago: Gas Research Institute)
- [2] Hopkins C W *et al* 1998 *Proc. of the SPE Gas Technology Symposium '98* 9–24
- [3] Negrov D A *et al* 2017 *IOP Conf. Ser.: Mater. Sci. Eng.* **168**(1) 012061 DOI: 10.1088/1757-899X/168/1/012018
- [4] Yakimov E *et al* 2017 *J. of Physics: Conf. Ser.* **783** 012061 DOI: 10.1088/1742-6596/783/1/012061
- [5] Surzhikova O A 2015 *IOP Conf. Ser.: Mater. Sci. Eng.* **81**(1) 012098 DOI: 10.1088/1757-899X/81/1/012098
- [6] Skutin E D *et al* 2016 *Procedia Engineering* **152** 493–496 DOI: 10.1016/j.proeng.2016.07.633
- [7] Langraf S *et al* 2017 *MATEC Web of Conferences* **102** 01026 DOI: 10.1051/mateconf/201710201026

- [8] Vlasov V A *et al* 2015 *IOP Conf. Ser.: Mater. Sci. Eng.* **71** 012029 DOI: 10.1088/1757-899X/71/1/012029
- [9] Taco G *et al* 2010 *SPE Asia Pacific Oil and Gas Conference and Exhibition* **2** 1240–1245
- [10] Galtseva O V *et al* 2016 *IOP Conf. Ser.: Mater. Sci. Eng.* **110** 012094 DOI: 10.1088/1757-899X/110/1/012094
- [11] Krasnov I *et al* 2015 *IOP Conf. Ser.: Mater. Sci. Eng.* **93** 012061 DOI: 10.1088/1757-899X/93/1/012061
- [12] Odnokopylov I G *et al* 2015 *Proc. of Int. Conf. SIBCON'15* DOI: 10.1109/SIBCON.2015.7147249
- [13] Frantsina E V *et al* 2016 *AIP Conference Proceedings* **1772** 060017 DOI: 10.1063/1.4964597
- [14] Mustafina R M *et al* 2016 *J. of Physics: Conf. Ser.* **671** DOI: 10.1088/1742-6596/671/1/012046
- [15] Iuriev I Y *et al* 2015 *IOP Conf. Ser.: Mater. Sci. Eng.* **71** 012022 DOI: 10.1088/1757-899X/71/1/012022