ON TRANSPORTATION AND STORAGE OF OIL AND GAS

Calculation of modes of work of Bilche-Volytska-Uherska underground gas storage (program complex)

UDK 621.64.029

N. M. Prytula

Candidate of technical sciences

M. H. Prytula

Candidate of physical and mathematical sciences

"Mathematic Centre" LLC

Ya. S. Pidstryhach Centre of Mathematical Modelling IPPMM of National Academy of Ukraine

R. Ya. Shymko

Candidate of technical sciences

S. V. Hladun

"Ukrtransgaz" PJSC

The functionality description of the developed software approved on real date is given in the article. Examples of the solution of specific problems and the analysis of assumption on which development of the modeling software is based are described.

The functionality description of the developed software approved on real date is given in the article. Examples of the solution of specific problems and the analysis of assumption on which development of the modeling software is based are described.

One of the main tool for scientifically grounded taking of decisions concerning rational exploitation of gas storage is modeling. Development of models and modeling complexes is a long-term process. In order to become an effective tool in work of operations control centre, modeling complexes shall comply with certain requirements including simple user interface, automation of the process of actualization of technological scheme and reference data, quick respond of the system to user's requests, visualization of the results of calculation, automation of the process of construction of the model of underground storage of gas (USG) and solution of the tasks etc. the developed modeling program complex "USG Mode" complies with the majority of these requirements.

Analyzing current state of developments on this topic, we see that the majority of monographs and articles in available mass media are dedicated mainly to the issues of extraction of hydrocarbons, gas liquid mixtures with possible phase transits and explorations of mine holes. The problems of modeling of gas storages are considered by insignificant number of researchers, namely [1–11]. Filtration and gas dynamics processes taking place in USG are more dynamic than in gas deposits. Because of this fact they are considerably influenced by homogeneities of penetration anisotropy, and also the existing indeterminations. Research of the above-stated processes requires highly precise models and quick methods of their realization. It is difficult to estimate their comparative characteristics in objective way because of their absence on domestic market. Many approaches to modeling of USG are based on balance model of its layer (layers) or it is declared that layer pressures are determined or can be determined by 3D hydrodynamic model in Eclipse environment. The use of ways of modeling of Schlumberger company (infosis@slb.com) for calculation of modes of work of the production fields as single thermal hydraulic system are often mentioned [12].

Brief characteristic of modeling object

In 1983 pumping of gas to the exhausted XVI horizon of Bilche-Volytskyi deposit started. It became the beginning of the largest in Europe Bilche-Volytske-Uherske USG (BVU USG) which has the most favorable conditions of gas storing – relatively small depth of deposit of collector layer, high filtration and capacity geologic and physical parameters, sufficient sealing, connection with gas transport system and advantageous geographic location.

In compliance with project decisions drilling, arrangement and connection of USG mine holes was completed till 1994. Gas collection stations 1, 2, 3, 4 were built and 291 mine holes were connected to them on Bilche-Volytskyi deposit and over 50 on Uherskyi deposit. Bilche-Volytska compression station of post-contact thrust is equipped with 28 gas delivering devices (ГПА) Ц-16 and ГПА Ц-6,3.

The above-stated USG is connected with the system of gas pipes Ivatsevychi-Dolyna III, Kyiv-West of Ukraine-II, Bilche-Volytsia-Dolyna, which through its continuing pipeline Dolyna-Bohorodchany is connected with main pipelines “Union” and Urenhoy-Pomary-Uzhgorod.

Characteristics of program complex

The developed program complex provides for:

Calculation of thermal and hydraulic parameters for all objects participating in pumping, storage and collection of gas;

Automation of process of formation of model in cases of change of equipment during modernization and reconstruction of separate objects and USG in general;

Adoption of models of technologic objects to variable conditions of their work abd their gas hydrodynamic state;

Simplicity of exploitation, implementation, maintenance and actualization of data;

Timely performance of many-time calculation for search of optimal mode parameters on considerable intervals and in case of necessity comparative analysis of possible variants of reconstruction of USG.

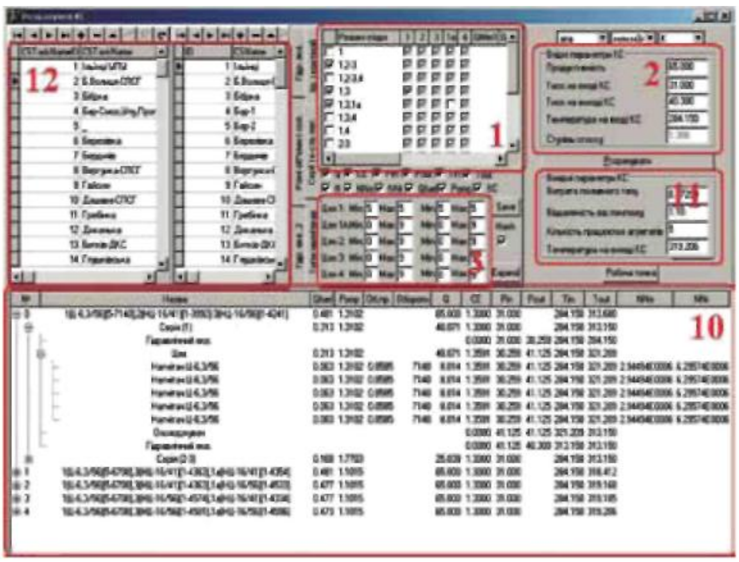

Figure. 1. Main form of the program “Calculation of Bilche-Volytsia DKS”

The main requirements to the method, algorithmic and software are developed.

1. Finding out of parameters of gas streams in complex gas hydrodynamic systems is oriented mainly to provision of fulfillment of the first and second law of Kirchgof (system "apron of mine holes – main pipeline" is presented in terms of theory of graphs) and is not connected with the type of mathematic presentation of models of the objects.

2. Coincidence of the method is provided if we include to the calculation a big number of objects with different mathematical presentation of models of gas streams in objects.

3. Hydraulic calculation of many-workshop compression stations with different-type gas pumping devices gives opportunity to consider the individual characteristics of each of them.

4. Calculation of the initial distribution of pressure in the field of layers-collectors is performed with mentioning of pressures measured in separate mine holes with simultaneous identification of parameters of homogeneous layer subject to performance of balance indices. Distribution of pressure in layer and debits of the mine holes are calculated under condition of non-stationary filtration of gas.

Calculation of modes of DKS work

Let us consider the possible variants of work of Bilche-Volytske-Uherske gas storage. Technological scheme of BVUGS allows its multi-variant work. Combining the streams OF different USG, it is possible to deliver gas to the entrance of USG in one or two streams. These two streams in exit of USG can also be combined or not-combined and directed to different or one of gas pipelines.

Considerable amount of workshops with different-type USG and with set of replacement various flowing parts gives opportunity to realize one and the same mode of DKS work in various ways. Criteria of choosing of the best variant includes summarized spend of fuel gas, remoteness from zone of pompage and the scheme of work of DKS. Criteria of choosing include parameters being competitive ones, so minimum of fuel gas not always provide for reliability (stability) of work characterized by certain remoteness from zone of pompage. In such cases reasonable compromise is necessary.

The tasks being solved by program, complex are stated in window of calculation of DKS (figure 1). The main task is to find according to the parameters of gas in entrance and pressure of gas in exit the parameters of mode of work (10) (schemes of turning-on of the workshops, number of USG on each stage of compression of gas, turnovers and flow parts of centre injectors). Complex provides for opportunity of find out of the third parameter according to two fixed from three possible parameters (2) (pressure in entrance, pressure in exit and apparent resistivity and efficiency). Solving the mode tasks, user of the program have opportunity to set the restriction of minimum and maximum number of USG (3), turnovers at each stage of each workshop, types of USG available in the workshops, values of steps of exhaustive search, criteria of evaluation of optimal mode and way of distribution of gas stream between parallel working USG of the workshop. In the main task it is also necessary to state the variety of modes(1), among which the optimal one will be searched.

Mode of work of USG

Mode of work of USG is calculated for known initial distribution of layer pressures, temperatures and composition of layer gas on the considered forecasted period of time according to the set distribution of spending (collection or injection) and gas pressure in main gas pipeline. Losses of pressure in apron zone and work mine hole are described in compliance with [12]. Such model of work in the mine hole requires availability of known filtration rates, rates of hydraulic opposition to movement of gas in a mine hole, and also in binding of a mine hole. During calculation of mode of mine hole work the opportunity of consideration of restrictions for maximum debits and depressions of pressure for layer in the field of apron zones.

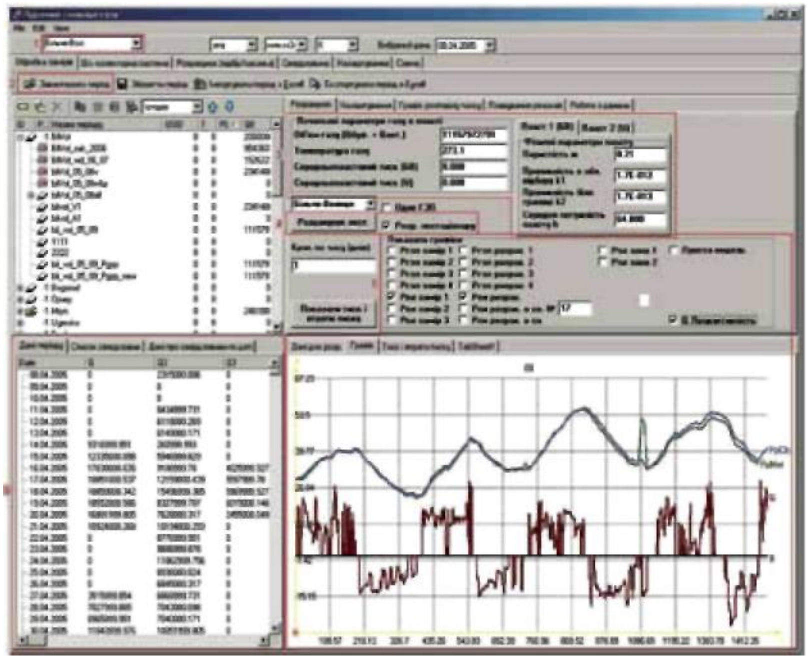

Figure 2. Main form of the program and marker "Processing of measurements". Two graphics in the top represents calculated and measured layer pressures in the field of collection of gas, and in the bottom there is injection (over the axis) and collection (under the axis) of gas.

Hydraulic losses in shelf collection system and in apron zones, mine hole and binding of mine hole acre calculated with the help of one and the same program complex used for calculation of distribution networks of high pressure.

There is a set of direct and inverse mode tasks, which shall be solved. Direct tasks include the tasks, where the process of calculation is performed in direction from layer to entrance of DKS or to the entrance to main gas pipeline. If reference data are the pressure or spending on the entrance of DKS (in gas pipeline), and it is necessary to calculate layer pressure on contour of field of feeding of mine holes, in such case the task is called inverse one. All sets of tasks are given for isothermal case. The issue of thermal and hydraulic calculation is considered at the end of paragraph. In all tasks we consider the graph scheme ШКС-ВС to be nominal one, its geometric parameters (internal diameters and lengths) and functions of losses of pressure on binding of craters depending on spending of gas and buffered pressure for all available types of bindings.

Task 1

Given: rates of filtration oppositions of apron zones of mine holes, hydraulic oppositions of miner holes and areas of shelf and collection system; one of the values is the average layer pressure for each mine hole, summary debit of mine holes, debit of each mine hole; one of the values for USG – pressure of spending.

To find: debit of each mine hole, spending or pressure of gas in USG (not given).

It is necessary to remember that distribution of layer pressure is considerably influenced by parameters of the layer (porosity, penetration, effective thickness, geologic, geometric etc), known mainly rather approximately. Because of this very often reference parameters satisfy the respective mathematic equations also approximately.

Task 2

Given (during the season of collection/injection): one of the values is an average layer pressure in the field of collection; layer pressure for each mine hole, summary debit of mine holes, debit of each mine hole; one of values at USG is the pressure, spending, spending and pressure.

To find: rates of filtration oppositions of apron zones of mine holes, hydraulic oppositions of mine holes and shelf collection systems.

Rates of hydraulic oppositions of SK areas for each USG differs not considerably, so we consider them equal. Allowability of such admission is proved by performed numeric experiments.

Table 1 Collection of gas

Day	Q_1 (mln m^3/day	Q_{1p} (mln m^3/	Q_2 (mln m^3/day	Q_{2p} (mln m^3/	%
10	124,6	0 ,12	–	–	–
20	127, 8	0,23	12 2	0,32	145
30	128 ,9	0,33	12 2	0,44	139
40	12 7, 7	0,43	12 2	0,8	19 4
50	128, 5	0,57	12 2	1,04	191
60	123, 8	0,73	10 0	0,8	136
70	113 , 2	0,78	10 0	0,91	131
80	101,6	0,78	95	0,95	131
90	95,1	0,78	89	0,97	132
100	81,5	0,73	81	0,95	131
110	70,9	0,63	66	0,76	130
120	66,9	0,63	61,5	0,72	12 5
130	5 7, 3	0,63	–	–	–
140	4 7,8	0,52	–	–	–
150	43	0,47	–	–	–
160	38,2	0,42	–	–	–
165	38,2	0,42	–	–	–

Table я 2 Injection of gas

Day	Q_1 (mln m^3/day	Q_{1p} (mln m^3/	Q_2 (mln m^3/day	Q_{2p} (mln m^3/	%
10	–	–	–	–	–
20	102,2	0,14	–	–	–
30	106,8	0,18	100	0,27	164
40	106,7	0, 21	100	0,29	144
50	106,5	0,26	100	0,34	140
60	106,4	0,29	100	0,38	138
70	106,3	0,32	100	0,46	154
80	106,2	0,35	100	0,63	193
90	102,8	0,36	100	0,66	186
100	108,6	0,42	100	0,68	17 7
11 0	101	0,42	100	0,71	17 2
12 0	10 7,1	0,47	100	0,74	169
130	10 0,8	0,47	100	0,77	165
140	106, 3	0,52	100	0,83	169
150	102,4	0,62	100	0,85	139

Table 3 Mode of work of Bilche-Volytsia USG

Day	Mode of work of compression station
30	[1]1:Ц-6,3/41[6318], [2]9,10,12:НЦ-16/56[4124]
40	[1]1 :Ц-6,3/41 [6108], [2]9,10,12:НЦ-16/56[4395]
50	[1]1:Ц-6,3/41[6035], [2]9,10,12:НЦ-16/56[4936]
60	[1]1 :Ц-6,3/41 [6879], [2]9,10,12:НЦ-16/56[5067]
70	[2]9,10,12,13:НЦ-16/56[5087], [4]24:Ц-6,3В/29[6448]
80	[2]9:НЦ-16/56[4765],11:НЦ-16/41[4671] - [2]12,13:НЦ-16/56[4119], [4]24,25:Ц-6,3В/29[6204] - [4]27,28:Ц-6,3В/41[6300]
90	[2]9:НЦ-16/56[4765],11:НЦ-16/41[4671] - [2]12,13:НЦ-16/56[4349], [4]24,25:Ц-6,3В/29[6204] - [4]27,28:Ц-6,3В/41[6642]
100	[2]9:НЦ-16/56[4924],11:НЦ-16/41[4674] - [2]12,13:НЦ-16/56[4685], [4]24,25:Ц-6,3В/29[6006] - [4]27,28:Ц-6,3В/41[6092]
11 0	[2]9:НЦ-16/56[4924],11:НЦ-16/41 [4674] - [2]12,13:НЦ-16/56[4872], [4]24,25:Ц-6,3В/29[6006] - [4]27,28:Ц-6,3В/41[6468]
12 0	[2]9,10:НЦ-16/56[5150] - [2]12,13:НЦ-16/56[4410], [4]24,25,26:Ц-6,3В/29[6045] - [4]27,28:Ц-6,3В/41[6478]
130	[2]9,10:НЦ-16/56[4860],11:НЦ-16/41[5030] - [2]12,13:НЦ-16/56[4484], [4]24,25:Ц-6,3В/29[6325] - [4]27,28:Ц-6,3В/41[6254]
140	[2]9,10:НЦ-16/56[4692],11:НЦ-16/41[4872] – [2]12,13:НЦ-16/56[4562],14:НЦ-16/76[4564], [4]24,25:Ц-6,3В/29[6086] – [4]27, 2 8 : Ц - 6 , 3 В /41[6511]
150	[1a]22:Ц-16/29-1.6[5506],23:НЦ-16/41[3985] - [2]9,10,12:НЦ-16/56[4279] - [3]15,16,17,18,19:НЦ-16/100[4506]

Table 4 Calculation summary day collections under different layer pressures in work zones and set pressures in entrances of USG and MG

Average pressure in work field (MPa)		Daily volume of collection from (mln m^3/day)		Pressure in entrance (in MPa)		Summary daily collection (mln m^3/day)
Bilche-Volytska	Uherska	Bilche-Volytska	Uherska	First USG	In MG	
5,50	**3,60**	12 3, 8	20,9	1,80	4,00	14 4,6
5,20	**3,50**	115, 0	19,9	1,80	4,00	13 4,9
4,90	**3,40**	106,2	18,9	1,80	4,00	12 5 ,1
4,60	**3,30**	97, 3	17, 9	1,83	4,00	115, 2
4,30	**3,20**	88,2	16,8	1,83	4,00	105,1
4,00	**3,10**	78,9	15, 8	1,83	4,00	94,7
3,70	**3,00**	69,3	14,7	1,83	4,00	84,0
3,40	**2,90**	59,3	13, 6	1,83	4,00	**72,9**
3,05	**2,80**	46,9	12, 4	1,85	4,00	**59,3**
2,75	**2,70**	35,1	11, 2	1,85	4,00	**46,3**
2,45	**2,60**	21,1	9,9	1,85	4,00	**30,9**
2 ,10	**2,45**	7,1	7, 6 4	1,85	4,00	**14,7**

Numeric experiments

For Bilche-Volytske-Uherske gas storage gas regime of collection and injection of gas is realized. Within the limits of the existing exactnesses of measured data and change of layer pressures water drive mode of work is not manifested.

Complex “ISG Mode” helps to perform adaption of models of technologic objects in considerable time intervals. For this the opportunity of visualization of calculated and measured data was realized, which allows quick estimation of influence of one or another parameter on change of layer pressure. Program complex “USG Mode” is realized in DELPHI environment and has the convenient user interface complying with the main requirements to graphic interfaces.

The main menu of the complex consists of the name of period, initial data (summary volume of gas in gas storage, temperature of gas in the layer, average layer pressures in Bilche-Volytska and Uherska layers); means of the main parameters of the layer (porosity, penetration to work fields and to the fields bordering the layer, average power of the layer); graphic window with opportunity of choice of set of data for graphic representation.

Calculation of layer pressure of Bilche-Volytska USG during four period of collection/injection of gas is showed on figure 2.

Example 1

Numeric experiments were performed at program complex for estimation of efficiency of use of devices of WARTSILA firm according to fuel gas in comparison with available devices under given pressures in entrance and exit of USG. In exit of USG 5.5 MPa were accepted.

Example of calculation of percent in the sixths column (see data from table 1): 145 %=100 % * (0,32/122)/(0,23/127,8).

Table 5 Calculated summary daily collections under various layer pressures in work zones and given pressures in entrances of USG and MG

Average pressure in work field (MPa)		Daily volume of collection from (mln m^3/day)		Pressure in entrance (in MPa)		Summary daily collection (mln m^3/day)
Bilche-Volytska	Uherska	Bilche-Volytska	Uherska	First USG	In MG	
5,50	**3,60**	116 , 6	17, 3	2,30	4,00	133,9
5,20	**3,50**	1 0 7,4	15, 8	2,30	4,00	123, 2
4,90	**3,40**	9 7, 9	14,6	2,30	4,00	112 ,6
4,60	**3,30**	88,3	13, 3	2,33	4,00	101,6
4,30	**3,20**	78,3	11 ,9	2,33	4,00	**90,2**
4,00	**3,10**	67, 8	10,4	2,33	4,00	**78,3**
3,70	**3,00**	56,7	8,8	2,33	4,00	**65,5**
3,40	**2,90**	44,5	6,9	2,33	4,00	**51,4**
3,05	**2,80**	27, 6	4,5	2,35	4,00	**32 ,1**
2,75	**2,70**	5,4	0 ,1	2,35	4,00	5,4

Table 6 Calculated summary daily collections under different layer pressures in work zones and given pressures in entrances of DKS and MG

Average pressure in work field (MPa)		Daily volume of collection from (mln m^3/day)		Pressure in entrance (in MPa)		Summary daily collection (mln m^3/day)
Uherska	Bilche-Volytska	Uherska	First USG	In MG		
5,50	**3,60**	107, 3	10,8	2,80	3,60	**118 ,1**
5,20	**3,50**	97, 3	8,9	2,80	3,60	**106,2**
4,90	**3,40**	86,9	6,7	2,80	3,60	**93,6**
4,60	**3,30**	76,0	3,6	2,83	4,00	**79,6**
4,30	**3,20**	64,4	2,6	2,83	4,00	**67, 0**
4,00	**3,10**	51,6	–	2,83	4,00	**51,6**
3,70	**3,00**	36,9	–	2,83	4,00	**36,9**
3,40	**2,90**	17, 3	–	2,83	4,00	**17, 3**

Table 7 Calculated summary daily collections under different layer pressures in work zones and given pressures in entrances of DKS and MG

Average pressure in work field (MPa)		Daily volume of collection from (mln m^3/day)		Pressure in entrance (in MPa)		Summary daily collection (mln m^3/day)
Uherska	Bilche-Volytska	Uherska	First USG	In MG		
5,50	**3,60**	95,3	7, 4	3,50	4,00	**102,7**
5,20	**3,50**	84,0	–	3,50	4,00	**84,0**
4,90	**3,40**	72,0	–	3,50	4,00	**72,0**

Gas pumping devices of USG Bilche-Volytsia use 45% of fuel gas per unit of gas volume more than USG of WARTSILA firm. In tables 1 and 2: second column represents daily volumes (mln m^3) of pumping of USG of WARTSILA firm; the third column represents daily volumes (mln m^3) of pumping of USG to Bilche-Volytsia DSK; 130–165 days – available USG at Bilche-Volytsia DKS are not able to provide for planned modes on gas collection.

In table 3 the results of calculation of FKS modes according to the table 2 is presented

Structure of line modes [2]9,10:НЦ-16/56[4692], 11:НЦ-16/41[4872] – [2]12,13:НЦ-16/56[4562],14:НЦ-16/76[4564], [4]24,25:Ц-6,3В/29[6086] – [4]27,28:Ц-6,3В/41[6511] is the following: [№ workshop] № ГПА1, № ГПА2 [turnovers] – [№ workshop] № ГПА1, № Г П А 2 [turnovers], [№ of workshop] № Г П А1, № Г П А 2 [turnovers] – [№ of workshop] № ГПА1, № ГПА2 [turnovers], де «–» – disconnect stages, а «,» – work in parallel.

Example 2

The numeric experiments concerning the subject of peak collections for given conditions o layer pressures in work zones Bilche-Volytska and Uherska layers and pressures in main gas pipeline. Different pressures in entrance of the first level of DKS were set. Maximum possible collections from each layer separately were calculated. After this the calculation of DKS was performed. In the last column the daily collections that can be provided (available mode of work) by DKS (see tables 4-7). At the result the main factor of restriction of the peakness of USG is DKS of USG.

Explanations to accepted admissions

1. Filtration processes in layers-collectors are permanently non-stationary.

2. Filtration rates of apron zones of mine holes don't give opportunity to calculate expressly debit of mine hole and depression of the layer in the field of apron of mine hole.

Value of filtration rates of specific mine holes depends significantly on parameters of formed fields of their feeding. These fields (feeding of mine holes) are variable in time and are formed depending on many factors effecting distribution of layer pressure and debit of mine holes. Filtration rates are stable in considerable time intervals for systems of gas extraction, because filtration processes in gas deposits are close to stationary ones and their fields of feeding set during considerable time period are rather stable ones.

It is necessary to expect that the value of filtration parameters will be mostly influenced by close zone of apron of mine holes. Setting of average means of filtration rates of mine holes and their dispersions requires processing of data in considerable time intervals.

3. For management of the modes of USG work knowledge of filtration rates of each mine hole is not always necessary. In many cases it is enough to know their average meaning, which in considerable time intervals is rather stable. Average layer pressure in the field of collection/injection of gas is also calculated in stable way. For this it is necessary to find the average penetration value of separate parts of layer-collector according to the measurements of layer pressures in available work and observation mine holes during 3-5 last years.

4. Performed numeric experiments proved that considerable accidental perturbation of layer pressure with zero average in broad diapason does not cause change of calculated parameters of gas in entrance of DKS. It grounds separate conclusions formulated above.

5. Distribution of layer pressure in the whole field of layer-collector is formed during the considerable time interval. For its reproduction modeling of work of USG during certain time (three-five years) is necessary. Distribution of layer pressure is influenced by mode of collection and injection of gas and distributed parameters (porosity, penetration) and geometric parameters of layer-collector. The majority of the above-stated parameters are known approximately. Setting of distribution of layer pressure is performed simultaneously with identification of distributed parameters of the layer. In such way we can obtain the coincidence of calculated and measured average layer pressures in the field of collection and injection of gas. The question of univocacy of reproduction of parameters of the layer (one equation of filtration and many parameters to be identified).

Main results

The model of USG offered in work and developed iteration procedures provided for sufficient exactness of calculation of distributed parameters (pressures, debits etc) and provides with necessary exactness for the parameters of material balance in layers of USG. It is necessary to note that today 2D model of gas filtration in porous homogeneous layers satisfies operation centre calculation tasks completely within the terms of exactness and timeliness.

References

1. **Бузинов С.Н.** Расчет технологической цепочки пласт–скважина–шлейф–КС–соединительный газопровод при циклической эксплуатации ПХГ / С.Н. Бузинов, Г.Ф. Толкушин // Транспорт и хранение газа. – 1980. – № 7. – С. 13–20.

2. **Тетерев И.Г.** Управление процессами добычи газа / И.Г. Тетерев, Н.Л. Шешуков, Е.М. Нанивский. - М.: Недра, 1981. - 248 с.

3. **Ковалев А.Л.** Опыт создания и использования программных комплексов для расчета технологических показателей ПХГ/ А.Л. Ковалев, Г.С. Крапивина // Международная конференция «Подземное хранение газа: надежность и эффективность». -М.: ООО«ВНИИГАЗ», 2007. - Т.1. - С. 144-151.

4. **Коротаев ю.П.** Добыча, подготовка, транспорт природного газа и конденсата. Справочное руководство в 2-х т. / Ю.П. Коротаев, Р.Д. Маргулов. - М.: Недра, 1984. - 360 с.

5. **Лейбензон Л.С.** Движение природных жидкостей и газов в пористой среде / Л.С. Лейбензон. - М: Изд-во технико-теоретической литературы, 1947. - 245 с.

6. **Бузинов С.Н.** Программный комплекс «GAHRAN» расчета технологических режимов отбора и закачки газа на ПХГ / С.Н. Бузинов, А.Л. Ковалев, Г.С. Крапивина, Г.С. Трегуб // Сборник научных трудов «Подземное хранение газа. Проблемы и перспективы». -М.: ВНИИГАЗ, 2003. - С. 257-263.

7. **Вечерік Р.Л.** Математичне моделювання процесу руху газу в системі пласт підземного сховища газу-магістральний газопровід / Р.Л. Вечерік, Я.Д. П'янило, М.Г. Притула, Ю.Б. Хаєцький // Нефть и газ. - 2004. - № 6. - С. 83-89.

8. **Вечерік Р.Л.** Математичний аналіз акумулюючої здатності газоносних пластів ПСГ / Р.Л. Вечерік, Я.Д. П'янило, М.Г. Притула, Ю.Б. Хаєцький // Нафт. і газова пром-сть. - 2005. - № 6. - С 55-59.

9. **П'янило Я.Д.** Неусталений рух газу в трубопроводах і пористих середовищах / Я.Д. П'янило, М.Г. Притула, Н.М. Притула //Фізико-математичне моделювання і інформаційні технології. - 2006. - Вип. 4. - С 72-80.

10. **Лопух Н.Б.** Розрахунок початково- граничних умов в задачах фільтрації газу в пористих середовищах / Н.Б. Лопух, Я.Д. П'янило, М.Г. Притула, Н.М. Притула // Вісник Національного університету «Львівська політехніка». Комп'ютерні науки та інформаційні технології. - 2009. - № 638. - С 239-243.

11. **Притула Н.** Математична модель Більче-Волицького сховища газу / Н.Притула, М.Притула, Р.Боровий, О.Химко // Вісник Національного університету «Львівська політехніка». Комп'ютерні науки та інформаційні технології. - 2010. - № 686. - С 192-198.

12. **Ротов А.А.** Моделирование режимов работы газового промысла как единой термогидравлической системы

13. А.А. Ротов, А.В. Трифонов, В.А. Сулейманов, В.А. Истомин // Газовая промышленность. - 2010. - № 10. - С. 46-50.

Authors of the article

Nazar Myroslavovych Prytula

Candudate of technical sciences, doctoral candidate of IPPMM of National Academy of Ukraine, leading engineer of sector of algorithmization and mathematical modeling of department of administration of systems of management of production of IT Department and "Uktransgaz" PJSC. The main direction of scientific researches is development of methods of solution of direct and reverse tasks of mathematical physics; optimization of difficult non-linear systems with distributed parameters; optimal administration of gas streams.

Myroslav Hryhorovych Prytula

Candidate of physical and mathematical sciences, director of "Mathematical Centre" LLC, chief research officer of Centre of Mathematical Modeling of IPPMM of National Academy of Ukraine, head of sector of algorithmization and mathematical modeling of IT Department and "Uktransgaz" PJSC. The main direction of scientific researches is analysis, synthesis, modeling and optimization of discrete and constant processes of different physical nature.

Roman Yaroslavovych Shymko

Candidate of technical sciences, director of department of underground storage of gas of "Ukrtransgaz" PJSC. His specialty is engineer-mechanic, the main direction of activity is optimal exploitation of gas storages; filtration of gas in multi-binding homogeneous porous environments.

Serhii Valentynovych Hladun

Deputy head of operation centre of "Uktransgaz" PJSC. His education is engineer-mechanic. The main direction of activity is optimization of modes of gas transport system; optimal planning and optimal exploitation of underground gas storages in gas transport system.