BULETINUL Universităţii Petrol – Gaze din Ploieşti	Vol. LXII No. 3B/2010	73 - 80	Seria Tehnică

Why Horizontal Wells for Underground Gas Storage?

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Abstract

Starting from the idea that in the near future the current peaks of demand of natural gas will increase more and more, it is necessary that the exploatation of underground gas storage to be made at a bigger frequency. So, it must to find the ways to increase the fill – discharge flow rate at least ten times. At this level of technical and technological development, only the horizontal wells, and especially performant horizontal wells can answer to this challenges.

Key words: *performant horizontal well, underground gas storage, depleted reservoir, effective radius of the well.*

Introduction

The use of horizontal drilling technology in oil and gas exploration, development, and production operations has grown rapidly over the past 30 years. This method became an invaluable technology in the petroleum industry. The horizontal wells can provide more area for gas injection/withdrawal, as well as reducing the risk of high water cut and conning problem during underground natural gas storage. The use of horizontal wells, generally, is superior to vertical wells and also in this case.

Underground natural gas storage is an important activity which allows to efficiently resolving demand seasonality problems. It can say that the underground natural gas storage is the storage in reservoirs of porous medium (depleted hydrocarbon reservoirs), aquifers and salt caverns at different depths of large quantities of natural gas in order to sustain the natural gas demand in industrial, commercial, domestic areas, or space heating which is the most critical case and reason for underground storage especially in cold winter months. In table 1 is presented repartition of storage in different type of storage and in table 2, the number of type of storage in the world.

Storage facilities in porous and permeable media, oil and gas depleted reservoirs and aquifers account for more than 90 % (Table 1) of the working gas volume capacity world-wide. The strong tendency to increasing the number of underground natural gas storage facilities, which is currently seen in the countries with some important weather differences between winter and summer, is related to the fact that this operating tool is the most adequate, economical, safe and environment-friendly technological means that the industry has to store large volumes of natural gas ready to be marketed.

Table 1. Storage in type of storage [2007, IEA]

Country	Type of storage		
	Depleted Reservoirs	Salt Caverns	Aquifers
	%	%	%
USA	87	4	9
UK	89	11	0
Germany	58	33	9
Italy	100	0	0
France	0	8	92
Romania	100	0	0

Table 2. Number of UGS Facilities, Jan. 2007 [9]

	Type of Facilities					Working Gas Volume	Deliverability
Area	Gas &Oil Depleted Reservoirs	Aquifers	Salt Caverns	Other	Total	10^9 m^3	10^6 m^3/d
Europe	68	23	29	3	123	79	1560
Russia	36	13	1	0	50	109	980
USA	318	45	26	1	390	108	2560
Canada	45	0	9	0	54	20	315
South America	2	0	0	0	2	0.2	2
Asia	5	0	0	0	5	1.6	11
Australia	4	0	0	0	4	1	10
Total	478	81	65	4	628	318.8	5438

Horizontal drilling appeared in the 1950's in some areas of oil production, with commercial success (In fact the patent for this technology appertain to Robert Lee - 1891). This technique is now generally used all over the world in oil and gas fields. The application of this technique to underground natural gas storage is starting slowly with only a few successful horizontal gas storage wells. In 2000, the published data show that, out of some 10000 storage wells in the 600 underground gas storage facilities in the world, only less than 100 were horizontal wells. At the same time, at least more than 100 new horizontal wells were planned, emphasizing the fast growth in the use of this technique to increase maximum deliverability [6,8].

The international experts in costs showed that the horizontal wells became a favor method for oil and gas recovery from horizontal or nearly horizontal reservoirs, because they offer a larger contact area with productive formation than in case of vertical wells. So, the cost factor for an horizontal well can be two or three times more than for vertical well, and the production factor can be improved from 15 until 20 times.

To have un idea about the efficiency of horizontal well, it can see in American published data that it determine the increasing of reserves with 2% regardless of the initial reserves. The same data show that the rapport of productivity index for horizontal and vertical wells is 3,2:1, and the rapport of their costs is only 2:1 [6,8].

Beside these financial and economical advantages, the horizontal drilling could be used in many situations where the conventional drilling is impossible or the cost is huge. So, the horizontal drilling is necessary to reach and extract oil and gas from productive formations that are not accessible with vertical drilling and this has made it an invaluable technology. Also, the horizontal drilling allows an increase in the recoverable oil and gas in a given formation, and even increases the production in fields previously thought of as marginal or mature. The horizontal drilling allows more economical drilling, and less impact on environmentally sensitive areas. In fact, in some areas in which drilling is not allowed for environmental reasons,

it is possible to drill horizontal wells to the targeted deposit without harming the environment above (Figure 1).
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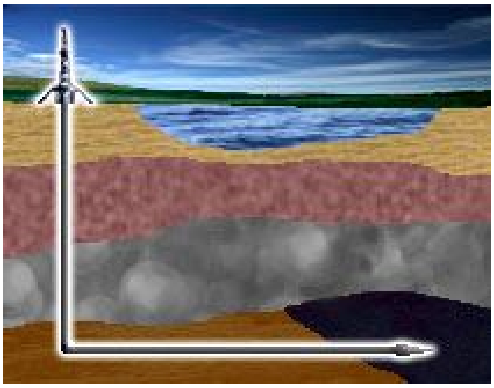

Fig. 1. Horizontal well under water [8].

Depleted Reservoir Storage

Depleted reservoir storage utilizes a depleted underground reservoir that originally contained oil and/or gas. Gas is injected back into the depleted reservoir in order to re-fill the reservoir.

The withdrawal process for the gas, in storage normally replicates the process originally used to produce gas from the reservoir. In the past, the conversion of a depleted gas reservoir for storage use traditionally involved drilling many new wells that would enable a more rapid withdrawal of gas than was originally used to deplete the reservoir. The injection and withdrawal flow rates are proportional to the surface area of the wellbore that is exposed to the pay zone in the depleted reservoir.
Until the early 1990's the development of storage facilities in depleted reservoirs involved the use of vertical wells (Figure 2). This meant that for a reservoir to be a candidate for development into a storage reservoir, the formation had to be fairly thick and the reservoir characteristics had to be very conducive to storage requirements.

Several of the advantages and disadvantages of using depleted reservoirs for storage through the old traditional use of vertical wells are listed on going.

Advantages

- Reservoir history is known;
- Minimal distruction to environment beyond that caused by original drilling operations;
- No routine service interruptions for periodic inspections;
- Multiple access points to reservoir eliminating service interruptions due to well problems.

Disadvantages

- Reservoir characteristics (e.g., low porosity and permeability) can limit injection and withdrawal flow rates;
- Reservoir formation must be fairly thick;
- Except for a few superior reservoir storage facilities, most existing reservoir storage is limited to seasonal service;
- On average traditional reservoir storage requires 50 - 60 % of total storage capacity to be used for base gas;

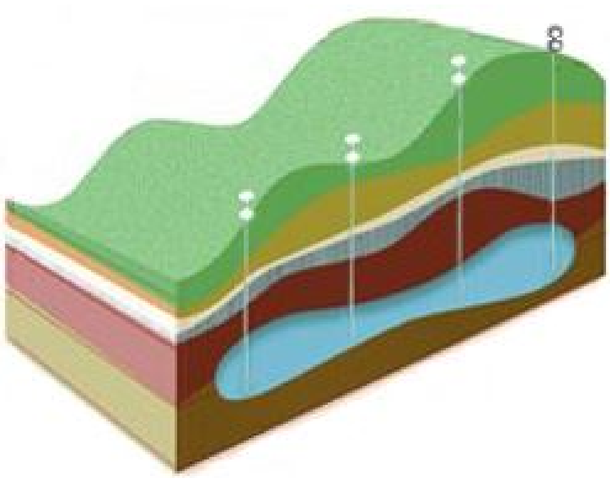

Fig. 2. Vertical wells in underground gas storage [6,8].

As horizontal drilling technology became commercially feasible for exploration and production of oil and gas in the late 1980's and the early 1990's, it became obviously that this same technology could be used to enhance the performance of natural gas storage facilities. By being able to drill laterally through the storage formation, a single horizontal well can achieve performance levels that make many depleted reservoirs feasible for gas storage that were previously considered not suitable for this activity (see Figure 3).

Several of the advantages and disadvantages of developing depleted reservoirs into underground natural gas storage fields through the use of horizontal wells are listed below.

Advantages

- All of the advantages of traditional depleted reservoir storage;
- Can be realized a high performance injection and withdrawal;
- Enables economic storage development utilizing reservoirs that would not be feasible otherwise; - Lower base gas requirements than aquifers, traditional depleted reservoir, and shallow salt cavern storage;
- Greater geographic application of storage development.

Disadvantages

- Not all geologic formations are suitable for development with horizontal wells;

- Requires the careful integration of expertise in geology, reservoir science, and drilling engineering (This isn't necessary a disavantage).

A case study, presented on going, comes to confirm the arguments previously presented and the results obtained recommend the development horizontal drilling in underground natural gas storage.

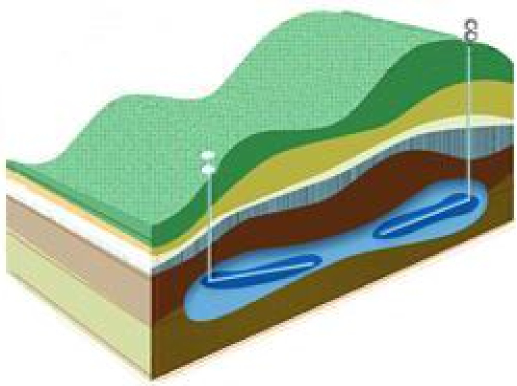

Fig. 3. Horizontal wells in underground gas storage [6,8].

Case Study

The efficiency of the horizontal wells is important in case of gas reservoirs regardless of the permeability value, which can be low or high. The flow rate of the horizontal gas well is calculated with a similar formula as for the vertical wells, with the exception that instead of the real radius of the well, r_s, it is used the effective radius of the well, r_s' [3,4,6]. The Joshi Methods were applied for a gas reservoir from Romania. The obtained results show that for the case of this reservoir the flow rate is significant to the horizontal wells, the reservoir being suitable for the submersion into an underground tank (Table 1, Figure 4). For underline how many times the horizontal well flow increased compared with the flow rate of the vertical one it was calculated the rapport

$$\omega_i = \frac{Q_{hi}}{Q_{\text{v}}},\ i = 1{,}2 \qquad (1)$$

T he i indicator refers to the two utilised methods. The growth is from several times up to several tenths times, generally it being bigger as the length of the well is bigger.

Still, if the length of the well increases up to 3000, 5000 m for a given thickness of the layer and area, as per Method I, it is noticeable that the flow rate increases mach more than the flow rate calculated by Method II. Usual, the growth of the length of the horizontal well implies an increasing of the drainage area. As per Method II, the same tendency is noticeable - the increasing of the flow linked to the growth of the length of the well, (Table 3, Figure 5). For Method II the increasing is more slowly. The two methods differ by the way which the drainage radius for the horizontal well is calculated: Method I consider the drainage area a circle and Method consider this area an ellipse.

For error method determination it was used the relationship

$$\varepsilon = \frac{Q_{h1} - Q_{h2}}{\max[Q_{h1}, Q_{h2}]} \qquad (2)$$

In figure 6 is showed the error versus the length of the well for different drainage areas. This error show the difference between the two calculating methods.

Tab1e 3. Flow rate of horizontal and vertical wells in the same conditions [7].

Sda	L, m	Q_{h1}, Nm^3/s	Q_{h2}, Nm^3/s	Q_v, Nm^3/s	ω1	ω2	ε
1	2	3	4	5	6	7	8
1	150	9.49	9.36	3.608	2.631	2.596	0.013
2	200	10.57	10.40	3.608	2.929	2.884	0.015
3	300	12.45	12.08	3.608	3.450	3.349	0.029
4	400	14.16	13.58	3.608	3.926	3.765	0.041
5	500	15.81	14.97	3.608	4.383	4.150	0.053
6	600	17.45	16.24	3.608	4.836	4.502	0.069
7	750	19.94	18.09	3.608	5.527	5.015	0.093
8	900	22.53	19.88	3.608	6.246	5.512	0.118
9	1000	24.35	21.04	3.608	6.748	5.832	0.136
10	1200	28.23	23.29	3.608	7.825	6.457	0.175
11	1300	30.32	24.45	3.608	8.405	6.778	0.194
12	1400	32.53	25.61	3.608	9.018	7.098	0.213
13	1500	34.87	26.71	3.608	9.666	7.403	0.234
14	1750	41.33	29.60	3.608	11.457	8.204	0.284
15	1900	45.68	31.33	3.608	12.662	8.684	0.314
16	2100	52.07	33.70	3.608	14.433	9.341	0.353
17	2400	63.03	37.28	3.608	17.470	10.335	0.408
18	2700	75.70	40.98	3.608	20.984	11.360	0.459
19	3000	90.13	44.80	3.608	24.983	12.418	0.503
20	3300	106.30	48.67	3.608	29.465	13.491	0.542
21	3600	124.17	52.72	3.608	34.421	14.613	0.575
22	4000	150.60	58.15	3.608	41.746	16.119	0.614
23	5000	229.07	72.43	3.608	63.498	20.077	0.684

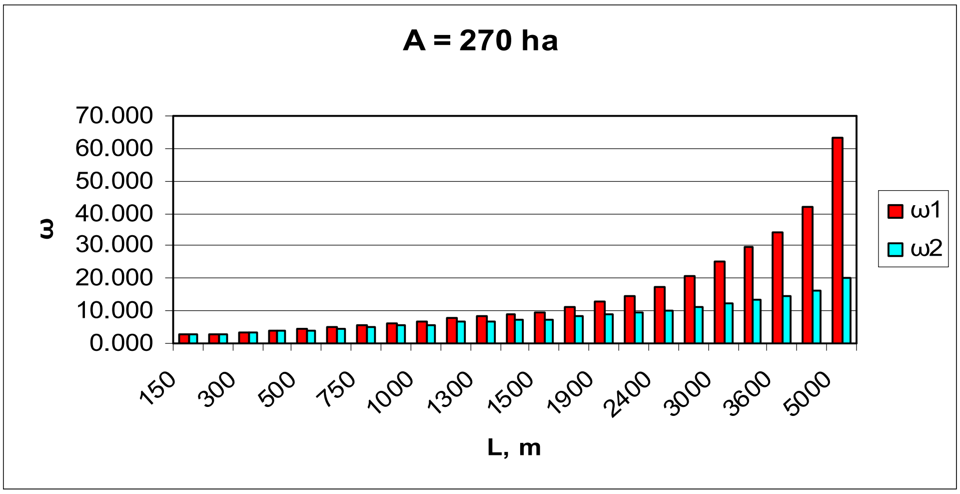

Fig. 4. Growth of horizontal well's flow rate comparing vertical well's flow rate.

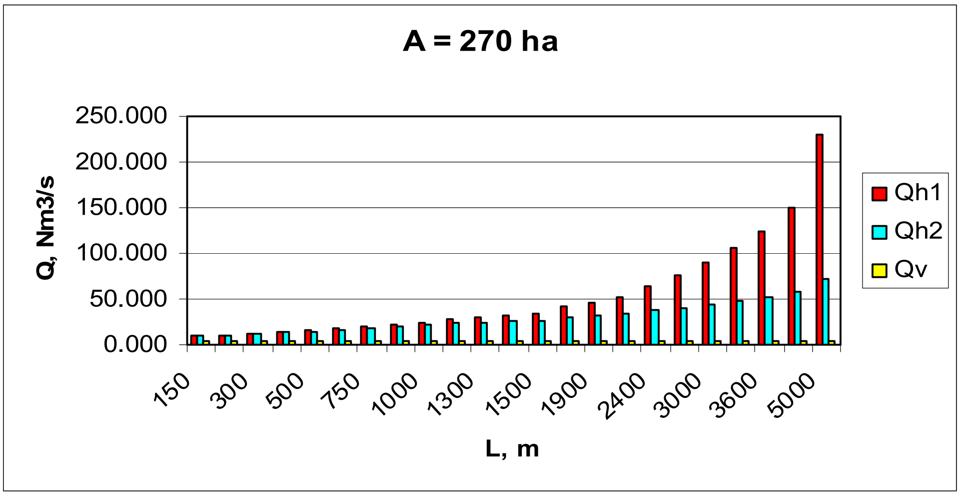

Fig. 5. Variation of horizontal well's flow rate versus well's length.

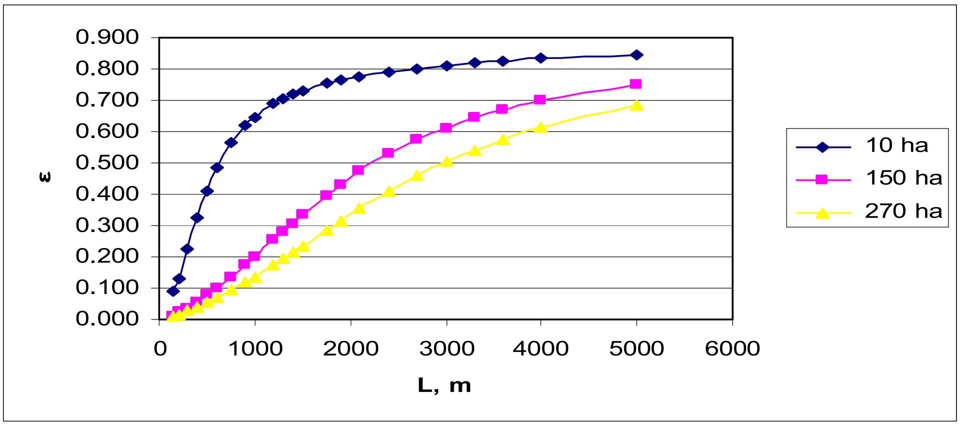

Fig. 6. The error of the method versus long of the well.

Conclusions

1. Horizontal wells assure the growth of gas flow rate compared with vertical wells.
2. Case study presented denotes flow rates several tenths times greater than vertical wells, in similar conditions.
3. There are differences between the two methods, more and more important if the length of horizontal well increasing; for small length (until 1300 – 1500 m) the differences are minim.
4. The differences between the two methods are decreasing with increasing of drainage area.

References

1. **Schwartz, David H.** - *Successful Sand Control Design for High Rate Oil and Water Wells*, JPT, Sept. 1969
2. **McLennan,J.R.S.,a.a.** - *Underbalanced Drilling Manual*, G. R. I, Chicago, 1997
3. **Joshi, S. D.** - *Horizontal Well Technology*, PennWell Books, Publishing Co. Tulsa, Oklahoma, 1991.

4. **Stoicescu, Maria** - *Hidraulica subterana si hidrotehnica*, Editura Universitatii Petrol – Gaze din Ploiesti, 2005.
5. *** *Integrated Drilling Design Process*, Reference Manual, 1998.
6. **Gheorghitoiu, M., Stoicescu, Maria** - *Sonde performante pentru depozitele subterane de gaze naturale*, Editura Universitatii Petrol-Gaze din Ploiesti, 2010.
7. **Gheorghitoiu, M., Stoicescu** - *Performant Wells which Attendances Underground Deposits of Natural Gas*, International Symposium from Sankt Petersburg, April, 2010.
8. *** Online Sources – Internet.
9. **Evans, D. J., Chadwick, R. A.** - *Underground Gas Storage*, The Geological Society of London, 2009.

De ce sonde orizontale pentru depozitele subterane de gaze?

Abstract

Pornind de la idea că în viitorul apropiat suprasarcinile curente de gaze naturale vor fi tot mai frecvente, este necesar ca depozitele subterane de gaze să fie adaptate la o exploatare în cicluri cu o frecvență mult mai mare. La nivelul actual al tehnicii, numai sondele orizontale, vrem să spunem sondele orizontale performante pot răspunde acestei provocări.