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WELL COMPLETION OPTIMIZATION FOR UNDERGROUND GAS STORAGE

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Abstract: The concept of well design and completion procedures has crucial impact on the well productivity and working life. The optimal design of an effective completion involves several factors namely: prediction of well performance, specification of perforating equipment and procedures, specification of well servicing fluids, selection of tubing and components, and identifying of completion sequence and running procedure.

The scope of the paper is to design optimal production and injection system for underground gas storage wells.

1. Introduction

Underground gas storage wells are special in the use because their purpose is to enable gas production from the storage and gas injection to renew needed supplies. Much more through the life time there is the need for occasional chemical treatments. Well completion design must be done according to algorithm in fig. 1.

The selection of tubing string requires the specification of: the internal and outside diameter of the tubing, the length of each section of production tubing which comprise the total string, material of construction, thread and connection type and maximum tubing movement expected or tubing to packer forces if anchored.

The maximum size of the tubing which could be run in the well is defined by the production casing schedule. However, the optimum diameter will be defined by the minimum pressure loss which can be achieved under stable flow conditions for a prescribed flow rate defined by the inflow performance of the reservoir.

The selection of tubing material of construction is determined by the abrasion and corrosion properties of the fluid, internal fluid properties and calculations of the mechanical and hydraulic loadings on the completion string under a range of envisaged operating conditions, e.g. stimulation, injection and production conditions.

Such tubing stress calculations will allow specification of threaded coupling type, and materials of construction as well as identifying the possible need for a dynamic seal assembly to accommodate tubing movement if tree axial tubing stress calculations indicate possible tubing failure.

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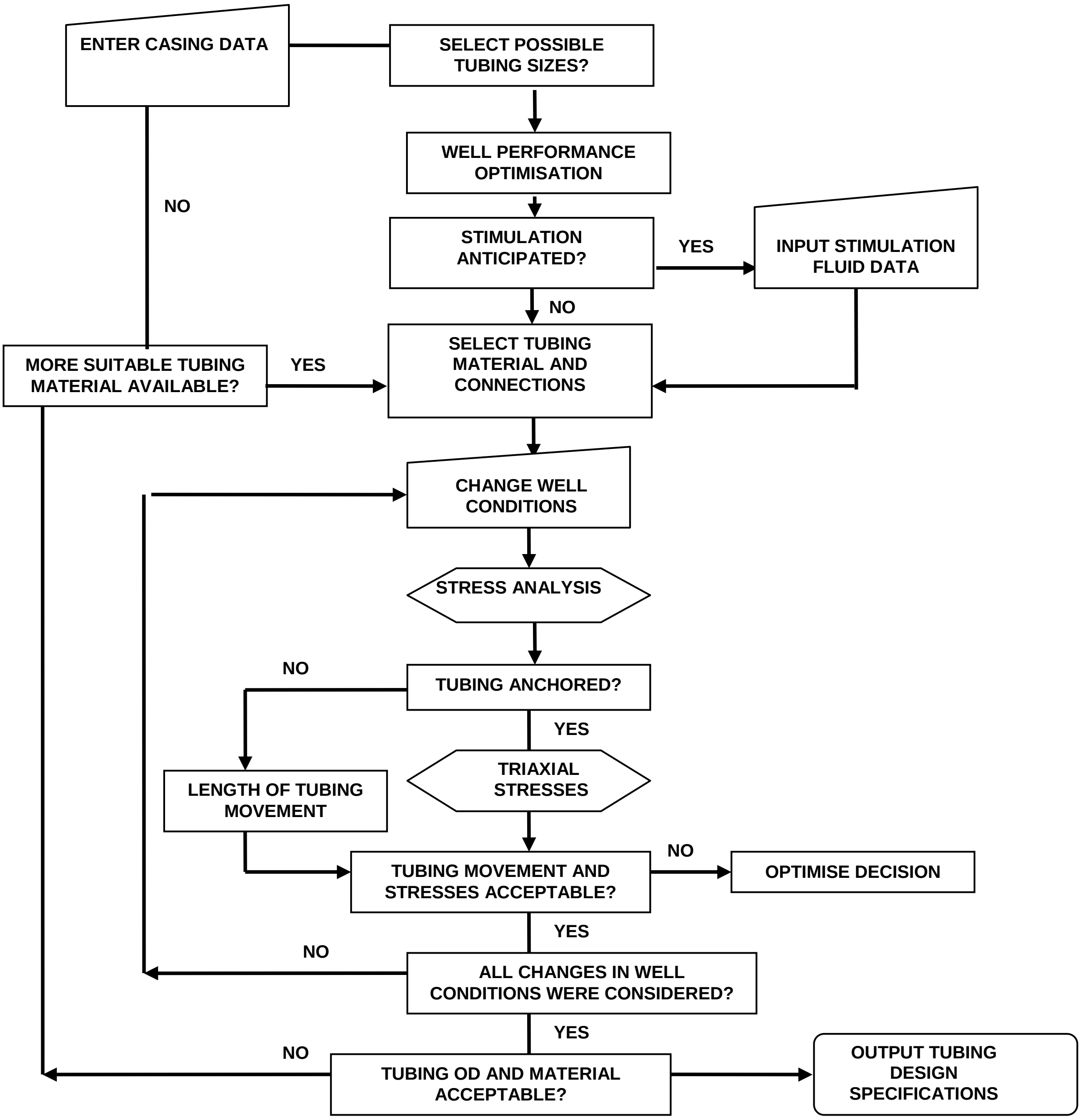

Fig. 1 *Production/injection system design*[1]

Each well on the storage is completed according to the scheme on the fig. 2.

To determine the optimal tubing system configuration it was necessary to run hydrodynamic and thermodynamic calculations with specific input data. The maximal production needed is determined to be 390000 m^3/day, and when injecting it should be up to 350000 m^3/day with maximal pressure drop at the formation depth of 30•105 Pa. Formation pressure at the end of the gas injection is 196•105 Pa. Hydrodynamic and thermodynamic calculations were done in the PROSPER 11.0 computer program (Petroleum Experts Ltd.).

When well is killed, tubing and annular space are filled with brine (brine density is 1130 kg/m3). During production, injection or chemical treatment annular space is filled also with brine. When producing, tubing is filled with gas, and when acidizing, tubing is filled with acid (acid density is 1123 kg/m3). Possible production from particular well can be predicted from the PC – performance curve. The operational point is derived from the intersection of IPR - inflow performance relationship and TCP – tubing performance curve.

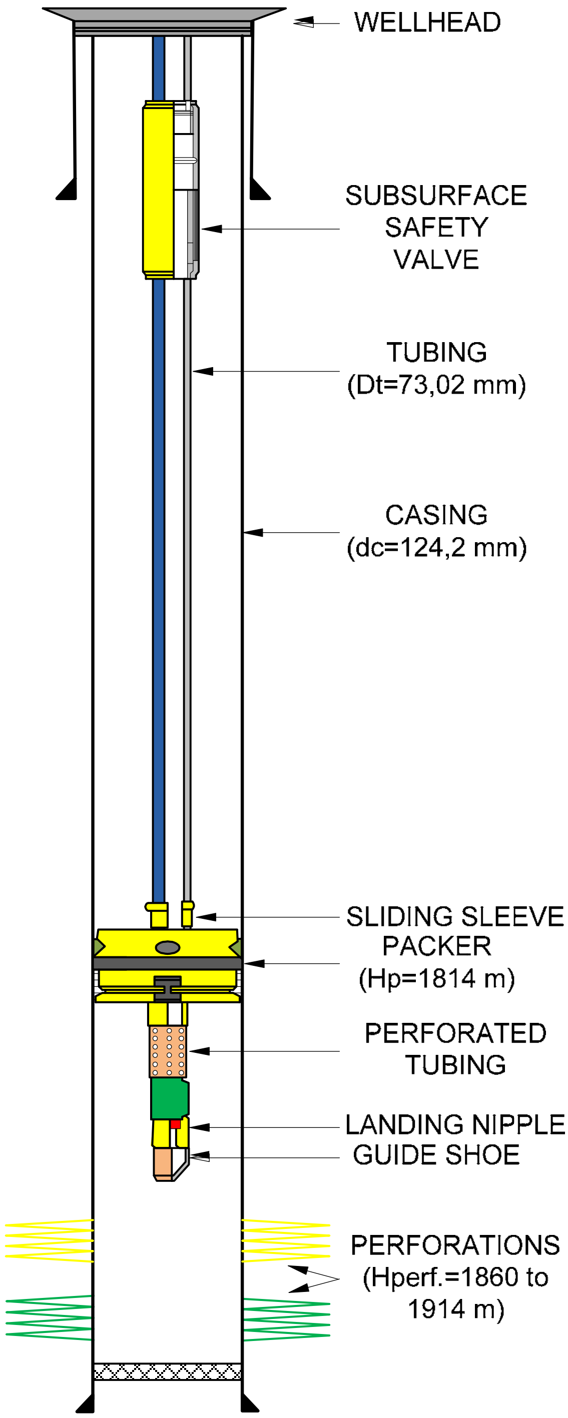

Fig. 2 *Well completion design.*

Tab. 1 *Possible (chosen) well states.*

Well state	Tubing		Casing			
	Well head pressure (10^5 Pa)	Pressure at packer depth, (10^5 Pa)	Well head pressure (10^5 Pa)	Pressure at packer depth, (10^5 Pa)	Well head temperature, (°C)	Bottomhole temperature, (°C)
Production	121	201	10	201	79	105
Chemical treatment	100	285	150	351	10	50
Well killed	0	201	0	201	15	105
Injection	196	201	10	201	35	95

Inflow performance relationship (IPR - inflow performance relationship curve) for any well illustrates the rate at which the well will flow at a particular bottom hole flowing pressure. The shape of curves and realized production depend on changes in:

- well bore and production equipment characteristics,
- reservoir characteristics and
- inflow performance characteristics.

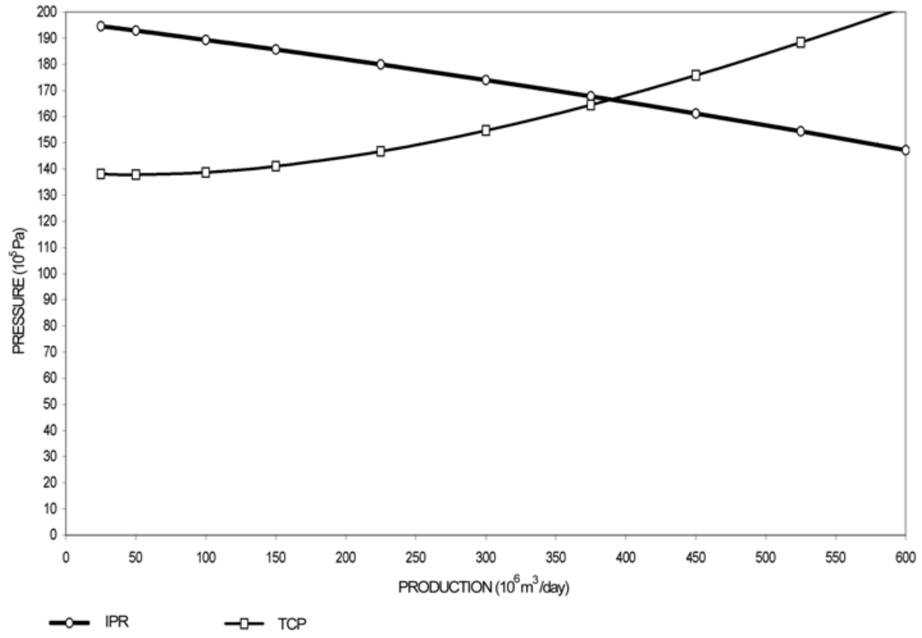

Fig. 3 *Inflow performance relationship for the well Ok-28 during production[2].*

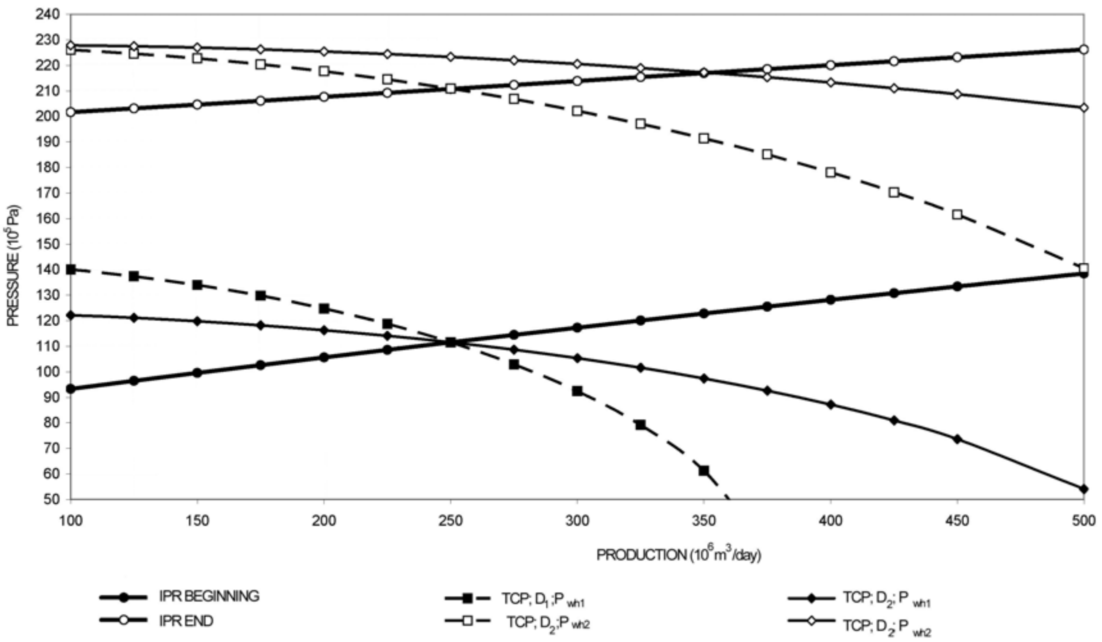

Fig. 4 *Injection performance relationship for the well Ok-28[2].*

2. Three axial stresses

Distortion energy theory of failure is based on material yield strength and shows that material is going to release and not that pipe will be damaged. For this purpose the stresses in the tubing during production were determined. The tubing in the well has an outside diameter of 0,073 m; inside diameter 0,062 m and the yield strength of material is $551{,}6 \cdot 10^6$ Pa.

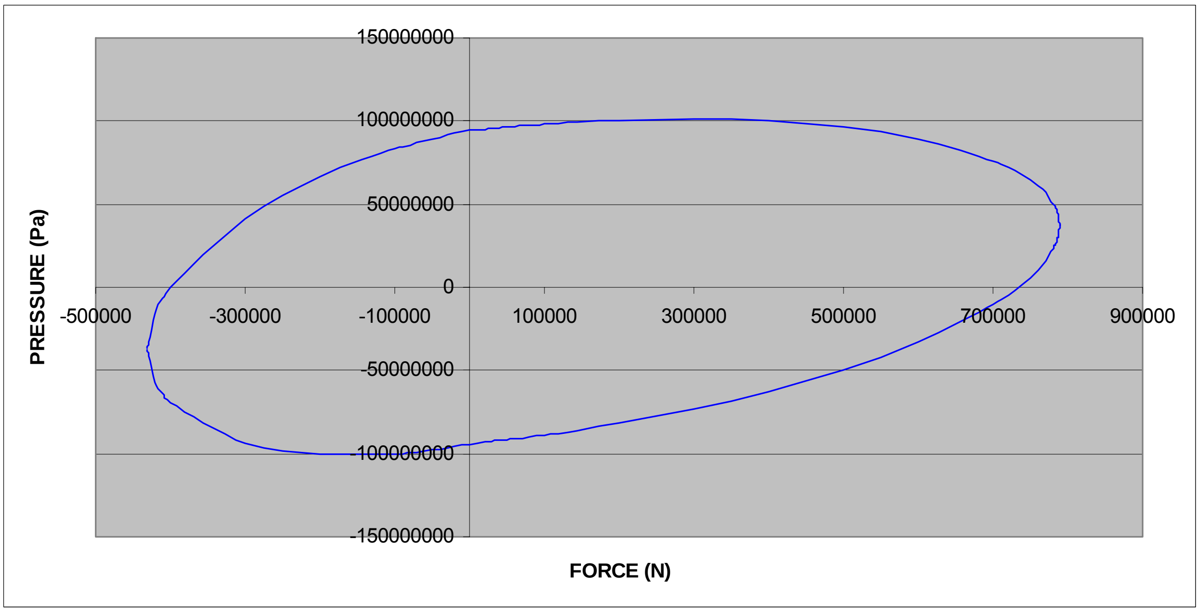

Fig. 3 *Ellipse of elasticity/plasticity for the well Ok-28 during production*[3]

3. Movements and forces in tubing/packer system

Stresses due the loads in different working conditions define tubing selection.

Data needed to calculate stresses are:

- packer fluid density (fluid in annulus),
- tubing fluid density,
- wellhead annulus pressure,
- wellhead tubing pressure,
- surface temperature,
- bottom hole temperature,
- pressure drop due the fluid flowing friction.

When tubing is suspended in the well with the activated packer; forces, stresses and length changes must be determined; determining adequate forces, determining proper length changes, determining stresses due the length changes if there is a connection between packer and tubing that allows no tubing movement.

Length changes that are realized, result from several effects:

- **piston-like or (Hooke's law) effect** – is the elongation or contraction effect due to pressure being applied to the horizontal surfaces; changes in diameter between packer and adjacent tubing;
- **helical buckling effect** – is the contraction of tubing into a helical configuration due to the tubing pressure, exceeding the annular pressure;
- **ballooning effect** – is lengthening or contraction due to swelling or compressing the tubing due to radial pressure force;
- **thermal effect** – is the contraction or elongation of a tubing string that occurs whenever the temperature of the tubing string deviates from its normal temperature.

When **packer allows no movement** (threaded connection between tubing and packer), change in pressures and temperature, results always as force between tubing and packer.

Table 2 represents calculated movements and forces for the well Ok-28 during production, injection and chemical treatment.

***Tab. 2** Movements and forces for the well Ok-28 during production, injection and chemical treatment.*

	Production	Gas injection	Chemical treatment
Length change due to piston effect (m)	**0,288**	**0,295**	**0,315**
Length change due to buckling (m)	**0**	**0**	**0**
Length change due to ballooning (m)	**- 0,052**	**- 0,039**	**0,155**
Length change due to change of temperature (m)	**0,685**	**0,676**	**0,451**
Packer to tubing force (N)	**- 54595,8**	**119573**	**122486**

4. Conclusion

Optimal configuration of production equipment is such that for defined formation conditions and surface production facilities ensures best hydrodynamic and thermodynamic behavior of the systems. That means that there will be the minor energy loses, with respect to maintenance of mechanical integrity of the production system.

Based on the calculations, tubing of 73,02 mm external and 60,3 mm internal diameter was chosen (2 7/8“; 9,52 kg/m, New Vam L-80). The dimensions of the available flow area provide optimal path for fluids during production, injection and in special conditions as is chemical treatment. Selected material with yield strength of $551,6 \cdot 10^6$ Pa is capable to withstand maximal internal and external pressure differences and at the same time axial compressive and tensile forces that are applied or are acting on the cross section of the tubing. The tubing is also checked according to corrosion resistance and the resistance of abrasion or erosion that should impact the system behavior.

Because the packer to tubing connection allows no movements, packer to tubing forces for defined states were calculated, to show that tubing and packer will withstand forces and stresses when changing system states.

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