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Issue Article

Annaguly Rejepovich Deryaev
Scientific Research Institute of Natural Gas of the State Concern „Turkmengas"
Doctor of Technical Sciences, Senior Researcher,
Corresponding Member of International Academy of Theoretical and Applied Sciences,
Ashgabat, Turkmenistan
annagulyderyayew@gmail.com

SELECTION AND CALCULATION OF CASING PIPES OF THE PRODUCTION COLUMN OF THE DIRECTIONAL WELL

***Abstract**: the article considers the design calculation and selection of casing strings for the production column of the directional production and evaluation well for the purpose of successful drilling of well 707 at the Western Cheleken field in the coastal zones of the coastal waters of the Caspian Sea. Materials from previously drilled wells and a guidance document, instructions for calculating casing strings for oil and gas wells, as well as safety rules in the oil and gas industry were used for the design, calculation and selection.*

This work can be used to perform the tasks set when drilling directional wells and for the design of calculation and selection of casing pipes of the production column in extremely difficult mining and geological conditions at abnormally high reservoir pressures.

***Key words**: gas compressibility, nipple, packer, filter, fluidity, hydraulic fracturing, curvature, profile, straining, wellhead, stretching, margin of safety, tightness.*

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Introduction

An important role in drilling wells for oil and gas production is played by the creation of a casing string – an element necessary for fixing the horizons for development and keeping the entire well in the correct position. When creating this element, all parameters are extremely important to establish the correct length, diameter, wall thickness, therefore, the casing string is calculated beforehand, which includes calculating pressure, checking strength and tightness, as well as a number of other actions. Properly performed work will allow you to create a column that is maximally protected from external influences and capable of ensuring safe extraction of oil and gas.

The main task of casing strings is to reliably fix wells during drilling and seal productive formations from the ingress of sludge and external elements at the time of development. The casing has a composite structure: it is made of pipes, connecting to each other in series. Pipe threads for casing columns can have the shape of a cone, triangle or trapezoid, if necessary, sealing elements are used to create the most hermetic connection. The wall thickness of the casing pipe varies from 5 to 16 mm, the pipes themselves are classified depending on the strength and yield strength [1, 4].

The casing is made of steel nipple or non-nipple pipes. They differ in wall thickness and inner diameter. The threaded connection is protected from mechanical damage, so the finished structure is characterized by a high degree of strength. Non-nipple pipes have a diameter from 3.3 to 8.9 cm, and nipple pipes from 2.5 to 14.5 cm. The type of casing pipes are selected based on the depth of the productive layers, on the type of product and purpose.

The production column is the last column of casing pipes, which is attached to the well to separate the productive horizons from the rest of the rocks and extract oil or gas from the well, or, conversely, to inject liquid and gas into the layers. Sometimes the last intermediate column can be used (partially or completely) as an operational column.

The use of the last intermediate column in the place of the production column in the practice of Turkmenistan was applied at the directional well 147 on the Northern Goturdepe square with simultaneous separate operation of several horizons. A special distinguishing feature of this design from previously used structures is that in order to secure several productive layers, an increase in the depth of descent of a technical column with a diameter of Ø244.5 mm was achieved and this technical column was used as an operational column [2, 4].

The fastening of the lower productive layers in the two tested wells in the form of an operational shank without cementing is achieved with packers equipped externally on special filters, inflating under the influence of the solution used.

The development of the well design is based on the following main geological and technical and economic factors:

a) geological features of the occurrence of rocks, their physical and mechanical characteristics, the presence of fluid-containing horizons, reservoir temperatures and pressures, as well as hydraulic fracturing pressure of passable rocks;

b) the purpose and purpose of drilling the well;

c) the intended method of completion;

d) the method of drilling the well;

e) the level of organization of equipment, drilling technology and geological knowledge of the drilling area;

f) the skill level of the drilling crew and the organization of logistics;

g) methods and techniques of well development, operation and repair.

The diameter of the casing string is calculated starting from the production string, which, in turn, are calculated based on the expected productivity of the well. The increase in the internal diameter makes it possible to work with more powerful equipment, including developing several horizons and repairing the hole. Nevertheless, a large diameter of the column is not always preferable, since with a large volume, the costs of drilling mud, cementing and other works and materials also increase [5].

The coefficient of safety margin for excessive external pressure (crumpling) for curved and horizontal sections is assumed to be equal to:

- for sections located in vertical and curved sections with a curvature intensity of up to 3.0 degrees /10 m - 1.0;

- for sections located in vertical and curved sections with a curvature intensity from 3.0 to 5.0 degrees / 10 m -1.05;

- for sections located in vertical and curved sections with a curvature intensity from 5.0 to 10.0 degrees / 10 m - 1.10.

- for sections located within the horizontal section - 1,3 - 1,5 (depending on the stability of the collector);

When calculating the column for stretching (straining) on curved sections, increased safety factors are used – $[n'_{str}]$.

For pipe connections with triangular thread:

$$[n'_{str.}] = n_{str.}/1\text{-}[n_{str.}]\lambda_1(\alpha_{10} - 0{,}5)$$

where $[n_{str}]$ is the coefficient of safety margin for straining for a vertical borehole (Table. 1);

λ_1 is a coefficient that takes into account the influence of the size of the joint and its strength characteristics;

α_{10} is the intensity of the borehole curvature, ^{0}/10 m.

The minimum values of the coefficients of the safety margin for straining $[n'_{str}]$ for pipes with triangular threads according to GOST 632 – 80 are given in Table 1.

Table 1. Minimum values of coefficients safety margin for straining for directional wells

Casing pipe diameter, mm	Minimum value $[n'_{str}]$
114 - 168	1,30
178 - 245	1,45
273 - 324	1,60
More than 324	1,75

When calculating casing columns made up of pipes with a trapezoidal profile thread and normal coupling diameters (OTM, OTG, MSW, etc.) and imported pipes with similar connections, the following provisions are followed [5]:

- when the intensity of the curvature of wells is up to 5º/100 m for pipes with a diameter of up to 168 mm and up to 3º/100 m for pipes with a diameter above 168 mm, the tensile strength of joints is calculated in the same way as for vertical wells without taking into account bending;

- when the curvature intensity is from 3 to 5º/100 m for pipes with a diameter above 168 mm, the permissible tensile load on the joint is reduced by 10%.

The coefficient of tensile strength for a smooth pipe body on a curved section of the hole is determined by the formula:

$$[n'_{s.}] = n_{s.}/1-[n_{s.}]\lambda_1(\alpha_{10} - 0{,}5)$$

where: $[n_s]$ is the coefficient of tensile strength for a vertical well (table 1);

Calculation of the casing string for excessive internal pressure is carried out, as a rule, for the moment of its testing by hydraulic crimping in one step without a packer [6].

The excess internal pressure is generally defined as the difference between the internal and external pressure for the same point in time:

$$P_{int.exc.z} = P_{int.z} - P_{ext.z},$$

where: $P_{int.z}$ and $P_{ext.z}$ are the internal and external pressures when testing the column for tightness at the appropriate depth (Z).

The pressure at the wellhead when crimping the column must be at least 10% higher than the expected operating pressure ($P_{wellh.}$), and must not be lower than the set minimum pressure testing for a given diameter of the casing string ($P_{pr.test.min}$):

$$P_{pr.test.} \geq 1{,}1P_{wellh.}$$

$$P_{pr.test.} \geq P_{pr.test.min}$$

The values of the $P_{pr.test.min}$ are given in Table 2.

Table 2. Values of minimum pressure testing pressures ($P_{pr.test.min}$) for casing strings when checking their tightness

The outer diameter of the column, mm	The value of the minimum pressure testing pressure at the wellhead, MPa
114 -127	15,0
140 - 146	12,5
168	11,5
178 - 194	9,5
219 - 245	9,0
273 - 351	7,5
377 - 508	6,5

Pressure at the wellhead during the operation of an oil well:

$$P_{wellh.} = P_{res.} - 10^{-6} g\rho_{oil} H_{res}$$

Pressure at the wellhead during operation of a gas well:

$$P_{wellh.} = P_{res}/e^{s},$$

where:

$$e^{s} = (2+S):(2-S),$$

$$S = 0{,}034\rho_g H_{res}/\beta_{comp.}T_{cr},$$

The relative density of gas in the air (ρ_g) for the first 2-3 exploration wells is assumed to be equal to 0.6.

The gas compressibility coefficient (β_{comp}) depends on its composition and can be in the range of 0.80 – 1.40.

At the depth of the gas reservoir up to 1000 m and P_{res} < 10 MPa, as well as at P_{res} < 4 MPa and any depth of the formation, it is assumed that the internal pressure throughout the depth of the well is equal to the reservoir [7, 8].

The safety margin coefficients when calculating casing strings for internal pressure for vertical and directional wells are assumed to be the same and depend on the diameter and type of casing design (Table 3).

Table 3. Values of safety margin coefficients for casing strings when calculating for excessive internal pressures

Pipe diameter, mm	Coefficient of safety margin for internal pressure $[n'_{int}]$	
	Casing pipes according to execution B	Casing pipes according to execution A
114 - 219	1,15	1,15
More than 219	1,45	1,15

According to the obtained values of excessive internal pressures, a plot is constructed on the accepted scale.

The casing arrangement selected based on crumpling and stretching (straining) is checked for internal overpressure. For the top of each section, the actual value of the safety margin coefficient (n_{int}) is determined and compared with the normative one [9, 11].

$$n_{int.z} = P_{crit.z}/P_{int.ext.z} > [n_{int.}]$$

The values of critical internal pressures for casing pipes are calculated using the Barlow formula.

If the strength condition of the column for excessive internal pressure is met, then the selected pipes are left for the layout of the corresponding section. Otherwise, weak sections are strengthened by increasing the wall thickness or the strength group of the pipe material [10, 12].

Let's consider the calculation of an operational casing string of 244.5 mm in an obliquely directed operational evaluation well No. 707 on the Western Cheleken field (Table 4).

Table 4. Data for the calculation of Ø 139.7mm of the production column

Depth of descent of the production column	$L_{pr.}$= 2620 m (2764 m along the hole)
Reservoir pressure at a depth of 2620m	P_{res} = 445 kg/cm^2
Drilling mud density at a depth of 2620 m	$\rho_{dr.m.}$ =1,81g/cm^3
Relative density of reservoir fluid (gas) at the occurrence of gas-oil-water manifestation	γ=0,60 g/cm^3
The coefficient of safety margin of casing pipes	n_1 = 1,125; n_2 = 1,1; n_3 = 1,75

The calculation of the production column for excessive external pressure is carried out at a late stage of well operation. The calculation for excessive internal pressure is made according to the tests of the column for tightness.

We determine the internal pressure:

Calculation the highest internal pressure in the casing strings is determined at the late stage of well operation with the closed position according to the formula.

When 0 < Z < H

$$P_{int.z} = P_{res.} - 0,1 \cdot \gamma_{int} (L - H)/e^s ;$$

$$P_{int.z} = 445 - 0,1 \cdot 0,75 \cdot (2620\text{-}474)/1,03 = 276 \text{ kgf/cm}^2$$

$$S = 0,1 \cdot 10^{-3} \cdot 0,601 \cdot 474 = 0,028$$

$$e^s = 2 + 0,028/2 - 0,028 = 1,03$$

The height of the possible dissolved gas H saturated in the composition of reservoir oil $P_{sat} < P_{res}$:

$$H = L - (P_{res.} - P_{sat.})/0,1 \cdot \gamma_{sp.}$$

$$H = 2620 – ((445 - 284) / 0,1 \cdot 0,75))\ 474 \text{ m}$$

where: $\gamma_{sp.}$ is the specific gravity of reservoir oil.

The maximum internal pressure is expected when the column is compressed on an air cushion:

$$P_{pres.test} = 1,1 \cdot P_S = 1,1 \cdot 276 = 304 \text{ kgf/sm}^2.$$

We accept $P_{pres.test}$ = 305 kgf / cm^2.

Internal overpressure

The internal overpressure when the column is pressed on water is determined by the formula:

$$P_{int.ov.} = P_{pres.test} + 0,1 \cdot \gamma_o \cdot Z - P_{res};$$

At Z = 0, P_{res} = 0; $P_{int.ov}$ = $P_{pres.test}$ = 305 kgf /cm^2.

At Z = 2620m, P_{res} = 445 kgf /cm^2;

$P_{int.ov}$ = 305+0,1·1,02·2620-445 =127 kgf/ cm^2.

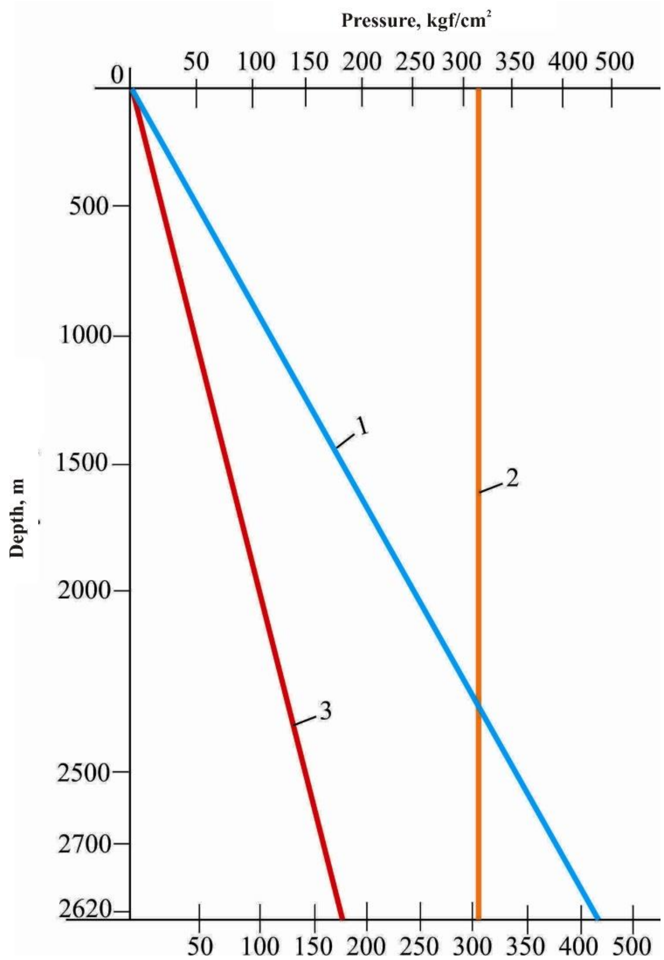

Figure 1. Calculation of excess external and internal pressures in the production column 139.7 mm

1. Reservoir pressure
2. Internal overpressure when testing the column for tightness
3. External overpressure

External overpressure

The external overpressure is determined by the formula:

$$P_{ex.ov.} = P_{res.} - 0{,}1 \cdot \gamma_o \cdot Z;$$

at Z = 2620 m

$P_{ex.ov.}$ = 445 – 0,1 · 1,02 · 2620= 178 kgf / cm^2

In accordance with the above calculations and graphical constructions, casing pipes Ø 139.7 mm are designed for descent into the well. with a wall thickness of 10.54 mm, N-80 steel strength group, Batress thread, with a normal coupling, according to the API standard.

The weight of the casing pipes in the air to be lowered to the well is:

Q_c = 33.7 · 2764 (along the hole) = 93.1 tons.

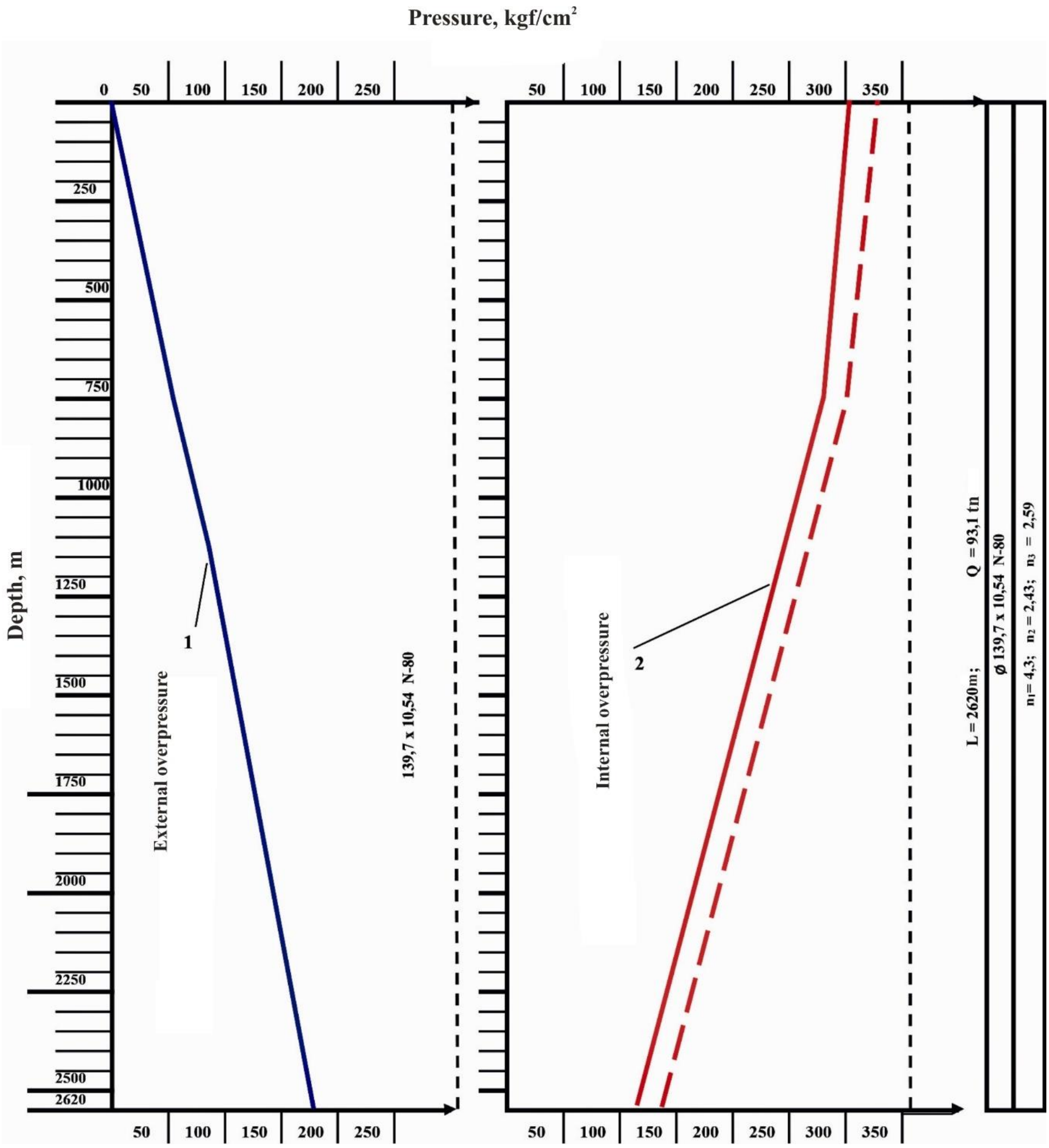

Figure 2. Calculation of excess external and internal pressures in the production column 139.7 mm

We determine the value of the safety factor when calculating the external overpressure for casing pipes designed for descent:

$$n_1 = P_{cr.} : P_{ex.ov.} = 785 : 183 = 4{,}3 > 1{,}125;$$

We determine the value of the safety factor when calculating the internal overpressure for casing pipes designed for descent:

$$n_2 = P_T : P_{pres.test.} = 742 : 305 = 2{,}43 > 1{,}1;$$

We determine the value of the safety factor when calculating the tensile strength for casing pipes designed for descent:

$$n_3 = P_{st} : Q_{c.} = 241 : 93{,}1 = 2{,}59 > 1{,}75$$

Graphic calculation of the Ø 324mm intermediate column for excessive external and internal pressures is shown in Fig.1, 2.

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