K H A Z A R U N I V E R S I T Y

School: **Architecture, Engineering and Applied Science**

Department: **Petroleum Engineering and Management**

Major: **Petroleum Reservoir Engineering**

MASTER THESIS

Title: Hydrocarbon Reserves Investigation With the Object Of Enhancing of Gascondensate Reservoir Further Development Efficiency

Student: **Bahtiyar Hasanov H.**

Supervisor: **Ass. Prof. Rafig Gurbanov S.**

BAKU - 2009

ABSTRACT

On the Master Thesis: "HYDROCARBON RESERVES REVISION FOR IMPROVEMENT OF GASCONDENSATEOIL RESERVOIR DEVELOPMENT"

The present thesis is devoted to topical research problem - hydrocarbon reserves more precise definition for the target of improvement the development of the VII horizon of Bulla-deniz gascondensateoil field.

The urgency target of a thesis theme is proved and the brief review of research works in the given area is made.

The brief geological and operational characteristic, current development analysis and operating well stock work conditions of the VII gascondensate horizon of field is described.

Hydrocarbon reserves more precise definition for the target of improvement of the further development of the VII horizon was carried out.

On the basis of field data hydrocarbon reserves were recalculated by applying three approaches: volumetric method, material balance method and mathematical-statistical method.

Hydrocarbon reserves calculation by the mathematical-statistical method differs from others by its more precision, less time and labor-consuming.

Based on development performances hydrocarbon recovery factor of the VII horizon were predicted.

The appropriate recommendations were suggested on the subject of improvement of the VII horizon further development.

At the end of thesis, the suitable conclusion was made.

References are shown at the end of the thesis

The results of the carried out researches can be put into practice at drawing up of the further development program scheduling, hydrocarbon reserves calculation, the analysis and the control of development of analogical type gascondensateoil reservoirs.

The thesis includes: pages, graphs, formulas and slides on the disk.

РЕФЕРАТ

Qazkondensat Layının Iшlяnmяsinin baшa чattыrыlmasının sяmяrяsini artırmaq mяqsяdilя karbhidrogen ehtiyatlarının tяdqiq edilmяsi

Щазыркы тезис Булла-дяниз йатаьынын тцкянмяйя ишлянян VII газконденсат щоризонтунун карбощидроэен ещтийатларынын дягигляшдирилмяси вя сон газвермя ямсалынын гиймятляндирилмясиня щяср олунмушдур.

Тезис мювзусунун актуаллыьы ясасландырылмыш, мягсяди вя щялл едилмиш мясяляляр эюстярилмишдир.

Булла-дяниз йатаьынын гыса эеоложи вя истисмар сяъиййяси шярщ олунмуш, VII щоризонтун ишлянмясинин ъари вязиййяти, лай тязйиги, температуру вя истисмар гуйулары фондунун иши тящлил едилмиш, газ вя газконденсатынын физики-кимйяви хассяляри щаггында мялумат верилмишдир.

VII щоризонтун карбощидроэен ещтийатлары мядян мялуматлары ясасында цч цсулла – щяъм, материал баланс вя рийази статистик цсуллары иля – щесабланмышдыр. Алынмыш нятиъяляр мцгайися олунандыр. Карбощидроэен ещтийатларынын рийази статистик цсулла щесабланмасы юз дягиглийи иля фярглянир, аз вахт вя аз зящмят тяляб едир.

Microsoft Excel-дя верилмиш programла истисмар эюстяриъиляриня ясасян VII щоризонтун карбощидроэен верим ямсалы прогнозлашдырылмышдыр.

Ишлянмя просесинин интенсивляшдирилмяси вя гуйуларын мящсулдарлыьыны артырмаг тядбирляри иряли ыцрцлмцшдцр. Чыхарыла билян галыг газ ещтийатларыны гыса бир мцддятдя ялдя етмяк цчцн истисмар фондунун фяалиййятсиз гуйуларыны истисмара дахил етмяк, истисмарда олан гуйуларын мящсулдарлыьыны артырмаг вя мящсулдар лайа йени гуйулар газылмасы тяклиф олунур.

Газ-конденсат гуйуларынын мящсулдарлыьыны артырмаг цчцн галдырыъы боруларын мцвафиг констрцксийасынын сечилмяси вя сулашмыш гуйуларда гуйу диби вя гуйу эювдясиндя топланмыш майенин гуйудан галдырылмасы мясяляляри мцфяссял тядгиг олунмуш вя файдалы тяклифляр иряли сцрцлмцшдцр.

Тезисин сонунда мцвафиг нятиъяляр ялдя олунмуш вя тядгиг олунан обйектин ишлянмясинин сямярясини артырмаг тядбирляри эюстярилмишдир.

Истифадя олунмуш ядябиййатын сийащысы верилмишдир.

Диссертасийа ишинин нятиъяляри газконденсатнефт йатагларынын ишлянмясинин лайищяляндирилмясиндя, ишлянмяйя нязарят едилмяси вя онун тянзимлянмясиндя истифадя олуна биляр.

CONTENTS

INTRODUCTION

I. Actuality of a theme. Gas and gas condensate fields exploration, appraisal and development practice needs the development program were designed on a required level, the development process control would confirm to the rules. To execute these obligations with a high reliability field geological and physical characteristic, reservoir drive mechanism and hydrocarbon reserves should be known more precisely. Geological and physical investigations of a concrete field at an appraisal stage ends with the hydrocarbon reserves calculation. Just with completion of this stage, reservoir development plan is designed.

The number of wells to be drilled on a reservoir, scope of field constructions, cumulative production rate from reservoir, field gathering, transportation and preparation of recovered product, and total capital investment is defined by the amount of hydrocarbon reserves. From this point of view, the precise estimating of hydrocarbon reserves at early development stage and its more or less precise evaluation at the further development stage provides the proper conditions for rational completion of a planned development.

II. The object of the thesis. The present thesis's main aim is based on field development data to revise the hydrocarbon reserves of long period developed reservoir. For this purpose, the following problems were considered on this thesis:

1. General geological, physical and technological field data for the investigated reservoir were gathered, processed and generalized.

2. Geological and operational characteristics, reservoir system physical and chemical properties, development current conditions and well stock operating work were analyzed.

3. Hydrocarbon reserves were revised in detail.

4. Gas recovery factor was predicted and reservoir development efficiency increasing measures were investigated.

III. Matter of thesis. The thesis includes introduction, four chapters, conclusion and reference.

In introduction the urgency of a theme is proved, the purpose and problems of the dissertation are stated.

In the chapter 1 the general field characteristic of Bulla-deniz gascondensateoil field is described. Brief geological characteristic of considered field is lighted, physical and chemical properties of gas and condensate are given. Information about reservoir pressure and temperature are introduced.

In the chapter 2 brief development history of the investigated field is described; operating characteristic of the Bulla-deniz gas condensate oil field is lighted; and analysis of VII horizon's development is carried out. Information about well stock of VII horizon is given.

<u>In the chapter 3</u> oil and combustible gases reserves classification, groups of hydrocarbon reserves and oil and gas reserves categories are introduced.

VII horizon of the Bulla-deniz field gas, condensate and oil reserves investigated in detail. Gas reserves of VII horizon calculated by volumetric, material balance and by mathematical-statistical methods.

At present in calculation of natural gas reserves provided by the two methods: volumetric and pressure drop methods. To calculate precise reserves in this thesis the third way: the mathematical-statistical method of natural gas reserves also suggested.

Graphical construction of production curve based on field data and its processing allowed describing it by appropriate mathematical expression.

For prediction of gas recovery factor the mathematical equation with high degree of accuracy has been suggested.

<u>In the chapter 4</u> VII horizon ultimate and current recovery factors were estimated.

Measures of enhancing of VII horizon of Bulla-deniz field further development efficiency has been suggested.

At the end of thesis conclusion is given and references showed

The results of dissertation can be applied in calculation of hydrocarbon reserves, estimating of gas recovery factor, development program scheduling, analyze and development process control.

The author expresses profound gratitude to Dean, prof. Ahmadov R., head of Department prof. Mammadzade A.M., supervisor Gurbanov R.S. for the rendered help at performance of the present thesis.

CHAPTER 1. GENERAL CHARACTERISTIC OF THE INVESTIGATED FIELD

1.1. General Information about the Bulla-deniz Gas condensate oil Field

The gascondnsateoil field Bulla-deniz is located in the North of the Baki Archipelago on distance of 55 kms to the South from Baki and 10 kms South-East from Sangachali-deniz-Zenbil-deniz-Khere-Zire adasi gascondensateoil field.

The seawater depth in aquatorium (water area) varies from 18 up to 30 m. The sea bottom is covered with a high-power clayey stratum.

Large-scale exploration on water area of Caspian sea were begun in the post-war period as a result of which a number of high productive stratum of oil and gas fields, including Bulla-deniz gascondensateoil field was discovered.

The presence of local structural Bulla-deniz structure first time was installed by seismic prospecting operations carried out by Marine Geophysical Office in 1950-1957. As a result of these operations the block diagram on deposits of Lower Apsheron Suite was drown up.

Then in 1960-1965 on the offshore area, the detailed seismic survey has permitted to detail a tectonic structure of anticline on strata of a pay section. A little bit later structure drilling was carried out, but its results have appeared low, as they, nothing new have brought to a geological structure in area.

In 1965 in Bulla-deniz area deep drilling works was begun and in September 1975 in well 18 from VII horizon of productive strata commercial hydrocarbon flow was received. In this well from perforation interval with head pressure 4.5 MPa through 11 mm flow bean 1 million m3pd gas and 250 tpd condensate was obtained.

After it in April 1974 in well 14 from V horizon from depth interval 4601-4578 m with head pressure 3.0 MPa through 12 mm flow bean 400 thousand m3pd gas and 70 tpd condensate was obtained.

In the middle of April of that year well № 9 which drilled-in V horizon from depth interval 4842-4811 m produced 168 tpd oil and 300 m3pd gas.

1.2. Brief Geological and Physical Characteristic of the Investigated Field

1.2.1 Stratigraphy

In geological section a structure of a Bulla-deniz field uncovered by deep wells the depositions of Quaternary period (thickness reaches up to 650 m), Apsheron (thickness 800 m) Akchagil (thickness 70 m) suites, and also sandy-aleurolite-argillaceous rocks of productive strata (pay section) (PS) of Middle Pliocene age, the thickness of which supposedly will make (4500 m). The deepest well 62 has drilled in structure up to depth of 6400 m (upper part of a VII horizon), and well 74 at with depth 5792 m drilled in deposits of Girmaki Suite more than on 100 m. More deep horizons of PS (Under Girmaki and Qala suites) on a Bulla-deniz field by exploratory wells not uncovered. The depositions of Pay Section here are introduced by two types of sediments – Kyur depression and Apsheron regions. The upper argillaceous part of PS (the not dismembered section) with thickness up to 3300 m does not contain any oil and gas pools. In bottom part of (from top of V horizon) deposits of Apsheron type, which are of interest from the point of view oil and gas, are distributed. In stratigraphic section of V and VII horizons, two independent objects are selected: V_{up} and $V_{l,}$ and VII_{up} and VII_{l}. The selected objects are separated from each other by argillaceous interlayers.

We shall result the brief description of geologic cross section of PS, within the limits of which is oil and gas saturation is presented and the objects of calculation of hydrocarbon reserves are selected.

Bottom part of PS, V horizon (analogue of VIII-IX of horizons on Apsheron nomenclature) is of interest from the point of view of oil and gas content. Deposits of V horizon with thickness of 129 m on average, are submitted interbedding of rather powerful layers of sand, sandstones and clays. Sand and sandstones from light-grey up to dark-grey color with a bluish shade, are fine and calcareous, quite often with gas reserves. Argillaceous deposits, grey with blue, brown and reddish shades, in places, a little sandy, carbonate contained.

The sand contents of V horizon, on average, makes 46 %. In section of V of horizon, according to log information two good permeable objects are distinguished, which were allocated as calculation ones (V_{up} and V_{l}). Average thickness of these objects, accordingly, makes 21 and 30 m. Within the limits of each object good permeable non-tight layers with thickness of 3-7 m, sometimes reaches up to 14 m are allocated, electric resistance of which reaches till 8-10 Ohms.

Approbation of objects V of horizon is carried out in 7 wells from which in three commercial inflow of petroleum and gas (well 9, V_l), gas and condensate (well 9, $V_{up}+V_l$; well 14, $V_{up}+V_l$, well 23, V_{up}), and from the others - inflow of water (well 16, 202, 35, 21) are obtained. Division layer V-VII is submitted by monotonous clay pack with electric resistance 2-4 Ohms and almost does not differentiate of a line. Clay is dark grey, dark-brown, and dense, carbonate contained.

The sandy content in all section makes about 10 %. Thickness of division V-VII strongly changes on the area and on average makes 369 m. The least thickness of division (up to 320 m) is marked in wells 20, 46, the greatest (557 and 575 m) - accordingly, in wells 104 and 80.

VII horizon's (similarly to "Pereriv" Suite accordingly Apsheron nomenclature), thickness is 94 m, is submitted basically by sandstones from light-grey up to dark-grey color is introduced fine, carbonate content sands with a smell of oil and gas. The section of VII horizon is the most sandy which reaches 70%. Average thickness of calculation objects makes: VII_{up} - 47 m, VII_l - 25 m. Commercial oil and gas content of considered objects is proved to approbation of a plenty of wells.

VIII horizon (upper Girmaki argillaceous Suite) is completely opened in 6 wells. Deposits of suite are submitted grey dark-grey, brown, dense clays. In a section presence of sandstones grey, fine-grained, tightly cemented, clayey sandstones, without attributes is marked.

The thickness of Upper Girmaki Suite varies from 160 m (well 70) up to 233 m (well 53) and on average, makes 201 m. VIII horizon (Upper Girmaki sandy Suite) is completely opened in 6 wells (71, 72, 56, 74, 70, 53). Because of the large depths of formation, sampling in these wells was not carried out. On electrical logging, characteristics in a geologic section two basic sandy-aleurolite formations are selected. The contents of sand in a stratigraphic section makes, on average, 46 %.

Thickness of separate sandy interlayer reaches 4-6 m with apparent electrical resistance about 10-20 Ohms. The thickness of VII horizon varies from 52 (well 72) up to 30 m (well 74) and on average, makes 37 m.

The test of VIII horizon is carried out in 4 wells. As a result of these tests are obtained: gas, condensate and oil product in wells 56 and 72, water in wells 70 and 71.

Girmaki Suite (GS) on the Bulla-deniz area was exposed in 5 wells. The maximal opened thickness of a given suite is marked in well 74 (more than 100 m) at depth of 5792 m.

Completely deposits of GS and underlying suites of PS on Bulla-deniz area were not drilled in. Deposits under Girmaki Suite, Qala Suite and underlying of Production Section on area of Bulla-deniz were not drilled in.

1.2.2. Tectonics

For studying a tectonic structure of the Bulla-deniz area geophysical works (seismic prospecting, electrical prospecting, gravity prospecting), structural - search and also deep prospecting drilling were carried out.

Seismic prospecting works carried out during 1951-1956 have allowed revealing and outlining independent anticline structure of Bulla-deniz area.

More detailed representation about a tectonic structure of a drilled area was obtained by geologic information on data of deep exploratory and development drilling. For 01.01.2000 on the Bulla-deniz area 101 ultradeep wells are drilled. These wells give complete representation about a tectonic structure of an opened part of a Pay Section.

According the materials of seismic survey and deep exploratory drilling the structure of VII horizon represents the large brachyanticline of the Northwest-Southeast of a trend which sizes on a long axis makes about 27 kms, on short - about 9 kms, height of fold on the Southeast flank reaches 1000 m. The structure is a little bit asymmetric: angles of dip on a northeast wing changes from 22^o in crest of structure up to 15^o on immersing, on a southwest side, accordingly, from 22^o up to 11^o. In periclinal parts and partially, the Northeast side of the structure through narrow syncline articulate a southwest flank of Bulla-deniz structure passes in wide Kichikdag-Andreyevski synclinori.

The Bulla-deniz structure is broken by a number of longitudinal and cross explosive dislocations on 9 tectonic blocks, from I to VI of which are oil and gas bearing blocks.

1.3. Formation Pressure

Because of large of formation depth gauging formation pressure generally was not conducted. Deep gauging of initial formation pressure only was carried out in wells V horizon. In VII horizon deep gauging were not possible because high wellhead pressure (from 30.0÷50.0 MPa) and high production rates (gas product from 700 to 1200 thousand m3pd) which prevents passage of measuring line through stuffing box. Other reasons of causing trouble to gauging of formation pressure is a large depths of wells (from 5140-6555 m), presence in wells hole hydraulic packers installed above perforation intervals from 359 to 2476 m, absence of special funnels at the bottom of tubings.

But in spite of all difficulties in wells 9, 14, 21 and 23 produced from V horizon by the help of МГН-2-600 type subsurface pressure gage run into borehole measuring of formation pressure and temperature were carried out.

Below in Table 1.3.1 the results of pressure measurements in wells of VII horizon are shown.

Current values of formation and bottom-hole pressure determined by calculation method.

Calculation method based on measuring of head pressure in shut-in wells (static state).

The results of calculations of formation of bottom-hole pressures were given in Table 2.

Table 1.3.1 Pressure measurements in wells of V horizon

Well number	Perforation interval, m	Date	Depth of measuring, m	Pressure , kg/cm2		
				Readings of presure	Static pressure at wellhead	Reservoir pressure
14	4601-4573	30.01.75	3100	431	323	485
21	5215-5185	01.01.76	3000	360	60	580
9	4842-4811	23.10.76	-	-	305	489.2
23	4711-4695	10.01.78	-	-	420	550.6
14	4560-4601	20.06.78	-	-	380	523
16	4618-4614	09.04.78	-	-	70	526

16	4618-4614	03.11.79	-	-	70	526
9	4842-4811	14.06.80	4400	266.5	190	300
14	4560-4601	14.05.80	-	-	211	300.6
14	4560-4601	14.05.80	4500	299	211	300.8
23	4711-4695	06.06.80	4400	280	-	285.7
21	5215-5185	01.01.78	-	-	60	578
21	5215-5185	03.01.79	-	-	42	560

Table 1.3.2 Calculated formation and wellhead pressures

Well number	Formation pressure, atm	Wellhead pressure, atm	Pressure drop, atm
25	380.2	301.4	78.8
28	550.5	457.5	93
29	686	640	46
31	693	632	61
32	679.3	637	42.3
34	654.7	582	72.7
39	564.7	514.7	50
42	648.3	589.8	58.5
38	657.7	547	110.7
46	563.1	480.8	82.3

1.4. Formation temperature

For definition of formation, temperatures of productive horizons of the Bulla-deniz gas-condensateoil field subinterval gauging in a hole of observant wells №16, 21 and shut in wells № 11, 62, and 32 were carried out. Using the data of gauging, the empirical formula of temperature vs depth was received; average sizes of a geothermal step and a geothermal gradient for separate intervals of a field are calculated (Table 1.4.1).

Table 1.4.1 Well temperature researches results

Depth, m	Formation temperature (t_f, ^oC) vs depth (H, m)	Geothermal gradient, $^oC/100$, m	Geothermal step, depth, m/ ^oC
0÷3750 3250÷6250	$t_f = 14,3+0.016\ H$ $t_f = 18,5+0.01484\ H$	1,60 1,47	40 68

Apparently from table 1.1, within the limits of a field two zones with growing values of a geothermal step are allocated.

Using the empirical formula given in table 1.5.1 there was an average size of temperature of separate productive horizons and blocks on their average depth of bedding. The amendment on temperature β for reduction of volume of gas standard temperature it was defined under the formula:

$$\beta = (273 + t_{st})/\ (273 + t_f)$$

where t_{st}=20 ^oC –standard temperature; t_f- formation temperature, ^oC.

1.5. Physical and Chemical Properties of Gas and Condensate

To study gas and condensate composition of Bulla-deniz field gas and condensate samples obtained from wells were examined in PVT laboratory. In Tables 1.5.1 and 1.5.2 separator gases composition on the VII horizon were introduced. As is shown in the tables 1.5.1 and 1.5.2 the VII horizons gases contain some amount of condensate. Hydrocarbon gases in mixture compose 99,60÷99,79%, carbon dioxide CO_2 – 0.21÷ 0.40% .

Absolute density of natural gas on wells varies over a range of 0.734÷0.7592, relative density- 0.5962÷0.6298.

Table 1.5.1 Composition of the separator gas on the Bulla-deniz VII horizon wells (Separator gas)

Components	Well number				
	29	**46**	**75**	**106**	**11**
C1	91.75	91.80	90.63	92.86	94.20
C2	5.86	5.13	5.49	5.05	4.14
C3	1.40	1,85	1,98	1,41	0.93
i-C4	0.22	0.30	0.45	0.20	0.16
n-C4	0.31	0.36	0.60	0.18	0.12
i-C5	0.08	0.08	0.33	0.06	0.05
n-C5	0.06	0.06	0.1	0.03	0.02
n-C6	-	0.03	0.1	-	-
CO2	0.032	0.40	0.37	0.21	0.38
ρ, q/l	0.7345	0.7347	0.7592	0.7243	0.7134
$\overline{\rho}$	0.6085	0.6180	0.6298	0.6011	0.5962

Table 1.5.2 Composition of the separator gas on the Bulla-deniz VII horizon wells (Degassed gas)

Components	Well number				
	29	**46**	**75**	**106**	**11**
C1	53.80	64.86	69.85	74.36	68.77
C2	15.65	18.85	14.65	12.36	16.53
C3	16.79	10.65	6.26	8.80	6.15
i-C4	4.40	1.80	1,65	1.03	1.87
n-C4	5.17	2.31	2.43	1.58	3.23
i-C5	1.79	0.74	1.18	0.69	1.42
n-C5	1.16	0.28	0.83	0.42	1.01
n-C6	0.35	0.1	0.93	0.19	0.65
C7	0.02	-	-	-	-
CO2	0.85	0.41	1.05	0.57	0.37
ρ , q/l	1.2450	1.0010	0.9533	0.823	0.9545
$\bar{\rho}$	1.0228	0.8302	0.7849	0.6833	0.7888

Table 1.5.3 shows condensate test results of the VII horizon. Condensate density, molecular mass, initial (bubble) end boiling point and fractional composition of condensate studied according to PVT analysis.

Table 1.5.3 Composition and physical properties of the VII horizon condensate

Title	Well number	
	20	**22**
Gas saturation,	-	-
m3/m3	1.24	1.25
Formation volume		
factor		
Stock tank conden	0.8117	0.8155
sate		
Parameters:		
Molecular mass	171	177
Initial boiling point		
10%	79^{o}	78^{o}
20%	123^{o}	123^{o}
30%	153^{o}	155^{o}
40%	190^{o}	191^{o}
50%	230^{o}	235^{o}
60%	265^{o}	273^{o}
70%	275^{o}	313^{o}
80%	300^{o}	349^{o}
Final boiling tem-	310^{o}	349^{o}
perature		

CHAPTER 2. DEVELOPMENT ANALYSIS OF THE INVESTIGATED FIELD

2.1. Brief operating characteristic of the Bulla-deniz gascondensateoil field.

The VII gascondensate horizon of Bulla-deniz field was brought into commercial development in 21.01.1975 with setting into operation well №18.

From the beginning of development up to present on horizon 54 wells were drilled in. Now operating well stock is determined by 20 wells. 14 wells for 18 operating wells produce gascondensate, 4 of them produce crude oil. Gascondensate wells production rates makes up: gas - (30÷250) thousand m3pd, condensate - (1,0÷12,0) tpd and water - (0,0÷7,0) tpd. Diameter of the flowing bean - (9,0÷24,0) mm. Flowing wellhead pressure - (0,5÷4,1) MPa, pressure in annulus space - (2,0÷ 5,5) MPa and on well bottom hole - (2,2÷9,2) MPa.

Oil wells production rate varies within limits: oil - (1,0÷36) tpd, water - (1,0÷40) tpd and gas - (0,5÷32,0) thousand m3pd.

In the Table 2.1.1 and on fig. 2.1.1 the basic parameters of development of VII horizon - dynamics of change of quantity of operating wells, gas, condensate and water yearly production, wells production rate, withdrawal rate, hydrocarbons recovery factors, on years of development are given.

Apparently, from given Table 2.1.1 process of development of VII horizon can be broken for three periods: 1975-1980, the build period of gas production; 1982-1990, the plateau period of gas production on a high level; 1991- 1999, the decline period of gas production.

Let's consider changes of performances of development on the above named periods.

In the period 1 of development the mid-annual quantity of operating wells was increased from 1 up to 12, gas recovery from 66,379 million m3 per year up to 4,169.098 million m3 per year, condensate from 20,489 thousand t per year up to 991,834 thousand t per year and water from zero up to 29,098 thousand m3 per year. By the end of the build up period the cumulative production made: gas – 14,830.107 million m3, condensate – 4,182.806 thousand m3 and water - 55,737 thousand m3. By the end I of the period 1 daily average production rate of a well on gas made 951,848 thousand m3, to a condensate – 226.44 t and water - 6,64 m3. Reservoir pressure decreased from initial 71,6 MPa up to 52,9 MPa. Withdrawal rate increased from 0,1% up to 6,34%. Gas and condensate factors were accordingly made: 0,2255 and 0,133.

Despite of significant decrease of well production on horizon in the period II of development, hydrocarbons began possible to support on a high level due to bringing into service new producing wells.

In the period I of development proceeding within 9 years, annual gas recovery decreased from 4,191.701 million m3 up to 1,883.900 million m3, condensate - from 872,568 thousand t up to 197,382 thousand m3.

By the end of period II of development in operation was 26 producing wells, the cumulative production made 42,950.518 million m3, condensate – 8,248.668 thousand m3 and water - 920,759 thousand m3. Reservoir pressure decreased from 52,9 MPa up to 18,0 MPa. Rate of recovery by the end of period II made 2,86%, gas and condensate recovery factors were accordingly made: 0,6532 and 0,222.

Since 1991 the number of producing wells decreases owing to their leaving from operation for the geological and technical reasons and to 01.01.2005 the total number of producing wells is 8.

In the period III of development annual production of gas decreased about 1,680.365 million m3 per year up to 598,357 million m3 per year, condensate - from 154,208 thousand t up to 51,642 thousand t per year. At the end of the period III daily average production rate of one well on gas was made 91,074 thousand m3 and condensate – 7.86 t. The rate of recovery on gas made: 52,957.081 million m3, condensate – 9,056.119 thousand t and water – 1,238.477 thousand m3. Reservoir pressure decreased from 18.0 MPa up to 8.6 MPa. By the end of the period III, rate of recovery equaled to 0,07%, gas and condensate factors were accordingly made 0,67 and 0,31.

For 01.01.2005 residual reserves makes: gas – 21,603.465 million m3 and condensate – 1,675.413 thousand t.

Recovery of residual reserves during the term stipulated by the development plan, demands to carry out drilling in new operating wells and intensification of hydrocarbons production from VII horizon with the help of application of the equipment and advanced technologies.

Table 2.1.1 Operating performances of the wellsof VII horizon of Bulla-deniz field

N	Perforated interval	Gas ths m3 per day	Condensate m3 per day	Water m3 per day	P_f	P_{bh}	P_{ann}	T_{bh} ^oC
29	5170-5130	260	90	5	-	-	34	95.0
66	5582-5542	130	5	2	164	151.8	31	101.0
110	5476-5428	140	5	3	102	-	37	99.4
111	5754-5723	280	10	8	115.9	104.3	37/43	103.66
42	5877-5543	130	5	3	98	-	30	105.44
60	5577-5543	120	5	3	119.7	94.2	29	101.0
75	5962-5926	130	7	3	92	-	24	106.71
108	5770-5749	140	7	4	92	-	24	104.0
39	5683-5653	100	4	3	98.1	53.12	31	102.61
46	5738-5717	230	8	4	113.6	-	22	103.5
73	5582-5542	40	2	1	122	108.3	17	101.4
54	5938-5907	20	1	-	90.2		22	106.4
107		40	2	1	80			100.41

2.2. Well Stock Operation Analysis

From the time of bringing into commercial development in January, 1975 to 01.01.2005 on the area of Bulla-deniz were drilled 101 wells. 54 wells from the total number were liquidated during drilling, including 41 wells on technical and 13 wells for the geological reasons. Some more 17 wells were liquidated during operation. 9 from them for technical and 8 wells for the geological reasons.

On 01.01.2009 in total well stock in Bulla-deniz Oil and Gas Production area disposes 30 wells. 20 from them concerns to producing stock, 5 of them (55, 56, 58, 77, 114) produces oil and 15 produces gascondensate (14, 29, 39, 42, 46, 53, 54, 60, 66, 73, 75, 107, 108, 110, 111) (see Table 2.2.1). One well (25) is in nonoperating well stock. Two wells (43, 106) are observation ones. Two wells (50, 64) wait for the liquidation. 5 wells (9, 23, 38, 45, 67) wait for liquidation on an unsatisfactory condition of hydraulic engineering constructions (platforms).

Average depth of operating wells varies from 4600 m up to 6200 m. All wells provided with double casing program having combination of 6" and 5". Transition from one size of a column to another is carried out on depths 1780÷2860 m. The wells were supplied with the double string lifts. Row I of string is combined everywhere I, consists of 4" and 21/2" pipes. Depending on depth of wells, the length of the row I vary 3294÷6091 m. The length the row II varies from 1200 m up to 2450 m.

Flowing reservoir pressure in a zone of operation wells vary within the limits of 8,0÷16,4 MPa, producing bottom hole pressure from 5,0 MPa up to 6,1 MPa, but wellhead pressure varies from 1,2÷2,5 MPa. Daily average production rates of gascondensate wells make: gas 30÷250 thousand m3, condensate 1,0÷12 t and water 0,0÷4,0 t. Diameters of flowing beans are 10÷24 mm.

Operational parameters of oil wells of VII horizon are the following. Average well depth is 6000 m. In wells is run double-row lift. Row I is completed from 4" and 2.5" tubes, and row II has diameter 2.5". The average setting depth of row I and row II reaches of 5800 m and 1800 m accordingly.

On 01.01.2009 daily average production rate of oil wells make: oil 1,0÷36, water 3÷4 t and gas 12÷40 thousand m3. Surface bean diameter varies within 10÷17 mm, wellhead pressure 0,4÷3,6 MPa.

Table 2.2.1 Development performances of the VII horizon of Bulla-deniz gascondensate field

№	Development years	Number of producing wells	Yearly production				Cumulative production				Dayly average production rate per well		Water cutting of well production, %	Formation pressure , MPa	Condensate recovery factor	Rate of gas recovery	Gas recovery factor
			Gascondensate, thousand т	Water, thousand т	Total liquid, thousand т	Gas, милйон м^3	Gascondensate, thousand т	Water, thousand т	Total liquid, thousand т	Gas, million м^3	Condensate, т	Gas, million. м^3					
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
1	1975	1	20,489	-	20,489	66,379	20,489	-	20,489	66,379	59,388	192,403	-	-	0,001	0,0009	0,0009
2	1976	1	295,999	0,485	296,484	862,564	316,488	0,485	316,673	928,943	810,95	2363,18	0,1	71,3	0,012	0,0120	0,0129
3	1977	3	581,712	1,375	583,087	1.890,389	893,200	1,860	900,06	2.819,332	531,24	1.726,382	0,2	67,2	0,034	0,0263	0,0393
4	1978	4	407,174	2,403	409,577	1.541,017	1.305,374	4,263	1.309,637	4.360,349	278,88	1.055,491	0,6	62,3	0,050	0,0215	0,0607
5	1979	6	894,772	7,699	902,471	2.710,031	2.200,146	11,962	2.212,108	7.070,195	408,57	1.237,457	0,8	60,0	0,083	0,0377	0,0985
6	1980	8	990,826	14,677	1.005,503	3.590,814	3.190,972	26,639	3.217,611	10.661,009	339,32	1.229,308	1	58,9	0,121	0,0500	0,1485
7	1981	12	991,834	29,098	1.020,932	4.169,098	4.182,806	55,737	4.238,543	14.830,107	226,44	951,848	3	52,9	0,159	0,0581	0,2065
8	1982	13	872,568	82,133	954,701	4.191,701	5.055,374	137,870	5.193,244	19.021,808	183,892	883,393	9	47,4	0,192	0,0584	0,2649
9	1983	15	752,762	139,210	891,972	3.952,669	5.805,136	277,080	6.085,216	22.974,477	137,49	721,948	16	41,9	0,220	0,0550	0,3199
10	1984	20	615,899	171,373	787,272	3.926,001	6.424,035	448,453	6.872,488	26.900,478	84,36	537,808	22	36,3	0,244	0,0547	0,3746
11	1985	20	488,407	128,196	616,603	3.639,111	6.912,442	576,649	7.489,091	30.539,589	66,90	498,508	23	31,1	0,262	0,0507	0,4253
12	1986	22	387,449	69,867	457,316	3.250,741	7.299,891	646,516	7.946,407	33.790,330	48,25	404,824	15	25,9	0,277	0,0453	0,4706

13	1987	26	299,327	65,852	365,179	2.626,102	7.599,218	712,368	8.311,586	36.416,432	31,54	276,723	18	23,0	0,288	0,0366	0,5071
14	1988	26	229,863	77,588	307,451	2.421,782	7.829,081	789,956	8.619,037	38.838,214	24,22	255,193	25	21,1	0,297	0,0337	0,5406
15	1989	28	222,265	89,364	311,629	2.238,404	8.051,346	879,320	8.930,666	41.076,618	21,74	219,021	29	19,4	0,305	0,0312	0,5720
16	1990	26	197,322	41,439	238,761	1.883,900	8.248,668	920,759	9.169,427	42.960,518	20,79	198,514	17	18,0	0,313	0,0262	0,5983
17	1991	25	154,208	43,795	198,003	1.680,365	8.402,876	964,554	9.367,430	44.640,883	16,89	184,149	22	17,4	0,319	0,0234	0,6217
18	1992	23	129,365	42,635	172,000	1.521,740	8.532,241	1007,189	9.539,430	46.162,623	15,40	181,267	25	16,9	0,324	0,0212	0,6429
19	1993	23	113,596	52,751	166,347	1.325,261	8.645,837	1059,940	9.705,777	47.487,884	13,52	157,863	32	15,1	0,328	0,0185	0,6613
20	1994	24	97,509	51,685	149,194	1.163,950	8.743,346	1111,625	9.854,971	48.651,834	11,13	132,871	32	13,2	0,332	0,0162	0,6775
21	1995	22	79,513	39,169	118,682	1.095,616	8.822,859	1150,794	9.973,653	49.747,450	9,90	136,440	33	11,3	0,335	0,0153	0,6928
22	1996	22	71,336	25,456	96,792	997,102	8.894,195	1176,250	10.070,445	50.744,552	8,88	124,172	26	10,1	0,337	0,0139	0,7067
23	1997	21	59,661	22,267	81,928	927,932	8.953,853	1198,517	10.152,373	51.672,484	7,78	121,060	27	9,1	0,339	0,0129	0,7196
24	1998	17	50,621	21,990	72,611	686,077	9.004,477	1220,507	10.224,984	52.358,561	8,15	110,568	30	8,7	0,341	0,0096	0,7291
25	1999	18	51,642	17,970	69,612	598,357	9.056,119	1238,477	10.2945,96	52.957,081	7,86	91.074	26	8,6	0,343	0,0083	0,7375
26	2000	18	50,632	17,630	68,262	587,430	9.106,751	1256,107	10.362,858	53.544,348	7,71	89,411	25,8	8,5	0,345	0,0082	0,7456
27	2001	17	31,187	14,930	46,117	534, 625	9.137,938	1231,037	10.408,975	54.078,973	5,03	86,160	25,5	8,45	0,346	0,0082	0,7617
28	2002	16	29,810	13,754	43,565	490,013	9.167,748	1244,791	10.452,540	54.570,986	5,10	83,906	26,0	8,4	0,347	0,0083	0,7686
29	2003	16	30,794	11,430	42,224	382,245	9.198,542	1256,221	10.494,764	54.953,231	5,27	65,453	25,7	8,35	0,348	0,0083	0,7740
30	2004	16	32,478	11,080	43,558	328,438	9.231,020	1267,301	10.538,322	55.381,669	5,56	56,239	25,2	8,3	0,350	0,0083	0,7800

CHAPTER 3. OIL AND GAS RESERVES CALCULATION BY DIFFERENT METHODS

3.1. Oil and Combustible Gases Reserves Classification

Calculation of oil and combustible gases reserves is the important technical and economical task.

To calculate oil and combustible gases reserves requires detailed study of geological, physical and thermodynamic conditions of reservoirs. Only in this case accuracy of calculated reserves would be raised. Hydrocarbons reserves should be calculated by several methods to get fine results and choose ones that are more exact.

3.1.1. General Questions

Oil and combustible gases in most cases contain some pools. The pool can be generally coincided with the one or several reservoirs with a unified hydrodynamic system.

Oil and combustible gases pools are divided into:

a) Oil pools - when the reservoirs contain with that or other quantities of the dissolved gas. Methane content in the gases of these pools reaches 30-50%;

б) Oil and gas pools - when the reservoirs contain oil with the dissolved gas and free gas above oil (gas cap) or when the gas pools are confined (are fringed) with oil fringe;

c) Gas pools - when the reservoirs contain free gas of methane (paraffin) hydrocarbons that do not condense at the formation pressure drop. As a rule, methane content in the gases of these pools is 94- 98%. Purely gas pools do not produce liquid hydrocarbons (gas condensate) (Qalmaz gas field, in Azerbaijan is the classical example for this kind of field);

d) Gas condensate pools – when the reservoirs saturated by paraffin hydrocarbons in composition of which there are sufficiently large quantity of heavy hydrocarbons from pentane to more heavy ones (C5+) that condense and evaporating at formation pressure drop. Methane content in these gases, as a rule, makes up 70-90%. Sometimes, can take place and then oil fringe of commercial importance (Qaradag gascondensateoil field, in Azerbaijan - example for this kind of field));

e) Gas hydrate pools – when the gases in reservoir's conditions are in solid state. Gas hydrate or solid gas pools are formed under certain pressures in the Earth"s crust with low temperature.

For a commercial evaluation of oil and gas fields or separate pools reserves, productive horizons and beds configuration and area, also thickness, reservoir properties, oil and gas saturation and operating performances determination are important.

The thickness of productive horizons or separate beds vary from several centimeters up to tens, and sometimes hundreds meters.

The following thickness of productive beds are distinguished: 1) general thickness of a productive bed including all permeable and impermeable rocks thickness from top (roof) up to bottom (sole); 2) productive (effective) thickness consisting of permeable layers thicknesses; 3) oil- and gas-saturated thickness of the bed including thickness only those layers of rocks which contain oil and gas.

The porosity of productive beds depending on pores connectivity and their oil and gas saturation is divided into three types: absolute, open and effective (available) porosity.

At oil and gas reserves calculation open porosity factor is used.

The Regulations by definition of oil and combustible gases fields exploration and study degree, their reserves reference to various categories and also by definition of the oil and gas reserves preparedness degree for the substantiation of oil and gas fields development planning and investing on oil-and gasfield facilities and industrial installations them are based on the requirements stated in the document of "Oil and Combustible Gases Reserves Classification" adopted in the former USSR ("Классификация Запасов Нефти и Горючих Газов").

3.1.2. Groups of Hydrocarbon Reserves

The reserves of oil, combustible gases and accompanying components contained in them on economic view point are divided into two groups which are being the subject to separate count and taken into account: on (balance) <u>reserves</u> which development are now economically expedient and <u>resources</u> (undeveloped reserves) which development are now unprofitable but which can be considered as the object for commercial development later on.

In balance reserves of oil and gas dissolved in it, and also condensate in free gas <u>recoverable reserves</u> are distinguished and taken into account, i.e. the reserves which can be recovered at most full and rational use of up-to date engineering and technology.

Oil, gas and condensate recovery factors are established based on technique and economic calculations tested in practice of oil and gas fields' development.

3.1.3. Oil and Gas Reserves Categories

The reserves of oil, combustible gases and contained in them accompanying components on a degree of study are divided into four categories and which are determined by the following conditions.

Category A: – reserves of oil and gass reservoirs (or their parts) is investigated with detail ensuring full determination of the form (configuration) and extension of reservoir, formation oil and gas saturation effective thickness, reservoir properties change character, oil and gas saturation of productive formation, oil, combustible gases and accompanying components contained in them and other parameters qualitative and quantitative composition, as well as formation main features from which conditions, wells productivity, formation pressure, temperature, and permeability, and piezoconductivity of bed and other features of reservoir are depend on.

The reserves of the category A are calculated during oil reservoir development.

Category B: - Reserves of oil or gas reservoirs (or their parts), oil and gas content of which is established on the basis of obtaining commercial oil and combustible gases inflow in wells (commercial oil and gas inflow should be obtained at minimum in two wells) on various hypsometric depth and availability of favorable well logging data of samples. The configuration and extension of reservoir, formation oil and gas saturation effective thickness, character of change of reservoir properties, and oil and gas saturation of productive formations, and other parameters, as well as main features determining reservoir development conditions are approximately investigated but in a sufficient degree for a reservoir development planning; oil, combustible gases and containing in them accompanying components composition at surface and under reservoir conditions are studied in details. On gas reservoir, the oil fringe presence is established or its commercial value is determined.

Category C1: - Reserves of oil or gas reservoirs (or their parts), oil and gas content of which is established on the basis of obtaining commercial oil and combustible gases inflow in individual wells (the part of wells can be tested by the formation tester) (commercial oil and gas inflow should be obtained at minimum in one well) and favorable well logging data in a number of other wells, as well as reserves of part of reservoir (or tectonic block) adjoining to the areas with reserves of higher categories.

Oil and combustible gases occurrence conditions for a given region are established by geological and well logging methods; productive formation properties and other parameters are studied on a test of individual wells or adopted by analogy to a more investigated part of a reservoir and adjacent prospected fields.

Category C2 - Reserves of oil or combustible gases which availability are supposed on the basis of favorable geological and well logging data in individual unprospected areas, tectonic blocks and in formations of the studied fields, as well as in the new structures within the limits of oil and gas bearing regions outlined by the geological methods tested up for the given region.

Unbalanced reserves of the category C2 are not calculated.

The balance reserves of accompanying components (dissolved gas, condensate, and other components), containing in oil and gas are calculated on categories proper to the degree of study of this components reserves.

The conditions concerning to oil, combustible gases and containing in them accompanying components reserves of A, B, C1 and C2 categories counted up on separate fields and areas, for assessment of oil- and –gas provinces, areas and regions potential capabilities hypothetical (expected) reserves (Group D) are determined on the basis of general geological submissions which are tested by the oil and gas producing organizations.

The order of entering, contents and registration of materials on calculation of oil and gas reserves presented on to affirmation in the State Commission are regulated by the DIRECTIONS for use of reserves classification to oil and combustible gases fields.

3.2. Calculation of Gas Reserves of Vii Horizon of the Bulla-Deniz Field By Volumetric Method

Present day stage gas and gascondensate fields' hydrocarbon reserves are calculated by different methods of which can be named: basic volume method, pressure drop method, material balance method, mathematical-statistical methods. The first two of the above-mentioned methods (basic volume and pressure drop methods), because of availability of field data at exploration and early field development stages, are widely used in gasfield practice.

Present thesis introduces hydrocarbons reserves calculation by three methods.

Below calculation of free gas and gascondensate reserves by volume method is introduced.

Calculation of hydrocarbons reserves a field has been conducted on objects and blocks for each object. In total on a field were allocated 5 calculation objects: V_{up}, V_l, VII_{up}, VII_l and VIII horizons. On the specified objects, hydrocarbons reserves were counted up on separate tectonic blocks.

At present thesis, calculation of gas reserves has been conducted on category C1.

Free gas reserves were determined by a volumetric method under the formula:

$$V = Fhmkf(p_i \alpha_i - p_{fin} \alpha_{fin}),$$

where V - initial reserves of free gas, million m3; F – gas-bearing area m2; m – rock porosity factor; k- gas saturation factor taking into account rock residual water content; f - temperature correction for gas volume reducing to standard temperature, which is determined under the following formula:

$$f = \frac{T + t_{st}}{T + t_f},$$

Here t_{st}=20 ^oC - standard temperature; T=273 ^oC; p and p_{fin} - accordingly, initial average absolute pressure, MPa and final pressure, MPa after extracting recoverable reserves of gas and an establishing on a wellhead of absolute pressure equal on 0,1 MPa:

$$p_k = e^{1293*10^{-9}*\rho H},$$

where α and α_{fin} - corrections for hydrocarbon gases deviation from the Boule-Mariotte's low, accordingly, for pressures p and p_{fin} : $\alpha = 1/z$, where z -gas deviation factor.

For Bulla-deniz field horizons final formation pressure is equal to 1.5÷1.7 MPa.

It is known that all components included in hydrocarbon system in formation conditions refer to natural gas reserves. However, in development process with declining of formation pressure some part of components of hydrocarbons (C5+ and some part of C4) transforms into liquid phase.

Therefore, formation hydrocarbon system in surface condition changes into "dry" gas and liquid condensate.

In this connection, the formation gas reserves are calculated as "dry" gas and liquid condensate reserves. To calculate initial reserves of "dry" gas it is necessary to subtract gaseous condensate reserves reduced to the standard conditions (760 mm mercury column and $t=20^0C$ conditions) from initial formation gas reserves. To transform condensate reserves to gaseous form its reserves given in kilograms should be multiplied by the correction value of $k=(22.41/M_c)*(293/273)$ (k -the value which is replaced 1 kg condensate volume in standard conditions in m3; M_c -molecular mass of condensate).

Molecular mass of condensate is M_c=160 and the parameter that liquid condensate to gaseous one is k=0.150).

Condensate reserves have been defined by the following formula:

$$Q_k = V * \delta_{C5+},$$

where Q_k - initial balance reserves of condensate, thousand t; δ_{C5+} - potential content of hydrocarbons C5+ in initial gas, g/m3.

Initial free gas balance reserves have been determined also by the pressure drop method using the following formula:

$$V = \frac{V_c p\alpha}{p\alpha - p_{fin}\alpha_{fin}},$$

where V_c – cumulative gas production (m3) for the period of pressure drop from p to p_{fin}; α and α_{fin} - corrections for hydrocarbon gases deviation from the Boule-Mariotte’s low, accordingly, for pressures p and p_{fin} : $\alpha = 1/z$, where z -gas deviation factor.

Oil reserves have been calculated by the formula:

$$Q_{oilk} = Fhmk\rho\theta,$$

where Q_{oil} - initial balance reserves of oil, thousand t; F – oil-bearing area m2; h-oil saturation thickness, m; **m-** rock porosity factor; k- oil saturation factor taking into account rock residual water content; ρ -stock tank oil density, t/m3; θ -oil shrinkage factor, θ=1/b (b-oil formation volume factor).

Dissolved gas reserves have been determined by multiplying oil reserves to gas oil ratio (GOR) or gas solubility in oil.

The initial data for calculation of balance reserves of gas and condensate and results of calculations on separate blocks of VII horizon are introduced in Tables 3.2.1-3..4.

To calculate propane and butane reserves in tons their quantity in gr/m3 should be multiplied to gas volume in m3 and divided by 10E-06.

Table 3.2.1 Field data of VII horizon used at reserves calculation

№	Title	Value
1	2	3
1	Average depth of bedding, m	5700
2	Sizes of a deposit: length / width, m	14000/4000
3	Gas bearing area, m2	$6134 x 10^4$
4	Average gas bearing thickness h, m	29
5	Rock gas saturation factor	0,67÷0,78
6	Rock residual water saturation, parts of unit	0,33÷0,28
7	Porosity factor, m, parts of unit	0,14÷0,17
8	Current formation pressure (on 01.01.2005)	71.3
9	Formation temperature, ^oC	103
10	Relative gas density ρ, g/sm3	
11	Gas viscosity μ, Cp	0,0096
12	Balance reserves of gas, on category C1, million m3	71809
13	Balance reserves of condensate on category C1, thousand t	26367

Table 3.2.1 Gas and condensate reserves on blocks of VII horizon

Blocks	Initial condensate reserves thousand T		Initial gas reserves, million m3		Recovered		Residual recoverable reserves	
	Balance	Recover-able	Balance	Recover-able	Conden-sate, thou-sand, T	Gas, million m3	Conden sate, thousand, T	Gas, million m3
I					32,077	113		
II	9,097	3,275	24,775	24,775	1,692,139	12,331	1,582.9	12,445
III-VI	17,270	6,217	47,034	47,034	6,379,864	7,580	-71	7,579

Table 3.2.4 Oil and dissolved gas reserves on blocks of VII horizon

Blocks	Initial oil reserves, thousand T		Initial gas reserves, million m3		Recovered		Recoverable residual reserves		Total:		
	Balance	Recover able	Balance	14000/400 Recover able	Oilhs. t	Gas mln. m3	Oil ths. T	Gas Mln.m3	Oil ths. T	Gas mln. m3	Water
I	53	7	22	22	18.4	14,672	-11.4	7,328	48.4	126.7	41.4
II	5,857	827	2,514	2,477	242.6	152.3	584.4	2,324	88.1	174	13.1
III-VI	4,584	722	2,113	2,082	699.5	293	22.5	1,719			

3.3. VII horizon reservoir conditions determining and calculation of hydrocarbon reserves by material

Balance method

Having enough field material it is possible to determine reservoir drive mechanism and hydrocarbons reserves by material balance (MB) method, using the following expression:

$$G_b = G_c + G_r \qquad (3.3.1)$$

where G_b, G_c and G_r -initial, current and recovered reserves of gas, accordingly.

If in equation (3.3.1) substituting G through volume of gas Ω and density ρ we receive

$$\Omega_b \cdot \rho_b = \Omega_c \cdot \rho_c + \Omega_r \cdot \rho_{st}. \qquad (3.3.2)$$

If, $\Omega_c = \Omega_b - \Omega_r$, from imperfect gas equation we have

$$\frac{P_b \cdot \Omega_b}{Z_b \cdot R_b \cdot T_b} = \frac{P_c \cdot (\Omega_b - \Omega_w)}{Z_c \cdot R_c \cdot T_c} - \frac{Q_r \cdot P_{st}}{Z_{st} \cdot R_{st} T_{st}}, \qquad (3.3.3)$$

where P_b and P_c - initial and current formation pressures, accordingly; Ω_b - initial volume of pore space; Ω_w- water influx into the reservoir when formation pressure drops from P_b to P_c; Q_r - quantity of recovered gas at surface conditions when formation pressure declines from P_b to P_c; P_{st}=0.1033 MPa; Z_b, Z_c and Z_{st} - initial, current and standard gas compressibility factors, accordingly; R_b, R_c and R_{st} - initial, current and standard universal gas constants, accordingly; T_b and T_c- initial and current formation temperatures K, accordingly; T_{st}=293 K -standard temperature.

During gas flowing in porous medium, it is possible to accept $T_l = T_b = T = const$. Because there is no component changes in gas mixtures at development of pure gas reservoirs we may have $R_b = R_c = R_{st} = const$. The value of R could be changed at development of gascondensate fields.

In gas drive Ω_w=0 and $\Omega_c = \Omega = const$. After some transformations the equation (3.3.3) may be written as

$$P_c^* = P_b^* - \frac{Q_c}{\alpha}, \qquad (3.3.4)$$

where $\alpha = \frac{\Omega \cdot T_{st}}{T_f \cdot P_{st}}$; $P_b^* = P_b / Z_b$; $P_c^* = P_c / Z_c$.

If there is natural water influx into gas reservoir the relationship between quantity of recovered gas Q_r and formation pressure drop P_c^* is expressed as

$$P_c^* = P_b^* \cdot \frac{\Omega}{\Omega_b - \Omega_w} - \frac{\Omega_b \cdot \Omega_c}{\alpha(\Omega_b - \Omega w)}, \qquad (3.3.5)$$

where $\alpha = \frac{\Omega \cdot T_{st}}{T_f \cdot P_{st}}$.

For the gas reservoir with the gas drive, typical peculiarity is that the ratio of gas quantity recovered Q_r at $(P_b^* - P_c^*)$ is always constant, i.e.

$$\alpha = \frac{Q_c}{P_b^* - P_c^*} = const.$$

In case of $\alpha = const$, i.e. absence of water influx into the reservoir and the reservoir is developed under gas drive; otherwise, the reservoir is produced by water drive. On the other hand, equation (3.3.4) also allows determining recoverable hydrocarbons reserves from reservoir.

At the given necessary field data the VII horizon reservoir conditions determination and calculation of hydrocarbon reserves is required.

Data

Initial reservoir pressure P_i=71.6 MPa.

Reservoir temperature T=376 K (or t=103 ^{0}C)

Gas relative density $\overline{\rho}$=0.6152÷0.6275

Volume of initial gas bearing area $\Omega_b = \Omega = const$

Water influx into reservoir with gas drive Ω_w=0

Gas recovery for the different pressure drop periods is given in the Table 3.3.1.

Table 3.3.1

Gas recovery vs time periods

Development periods	Quantity of gas recovered, Q_r ,billion m3	Current formation pressure, P_c^* ,MPa
I	0.928943	71,3
II	4.360	62.3
III	10.661	58.9
IV	19.021	47.4
V	26.900	36.3
VI	33.790	25,9
VII	38.838	21.1
VIII	42.960	18.0
IX	46.162	16.9
X	48.651	13.2
XI	50.744	10.1
XII	52.957	8.6

Solution

Determination of gas compressibility factor Z for the different development periods is required.

For the engineering calculations when gas relative density is changed within limits of $\overline{\rho} = 0.5 \div 0.9$ for determination of pseudo-critical pressure P_{pc} and critical temperature T_{pc} the expressions below are used

$P_{pc} = 49.5 - 3.7 \cdot \overline{\rho}$ and $T_{pc} = 93 + 176 \cdot \overline{\rho}$. (3.3.7)

As in the given case $\overline{\rho} = 0.62$, then

$P_{pc} = 49.5 - 3.7 \cdot \overline{\rho} = 49.5 - 3.7 \cdot 0.62 = 47.21$ and

$T_{pc} = 93 + 176 \cdot \overline{\rho} = 93 + 176 \cdot 0.62 = 202.12$. (3.3.8)

Studies of gas compressibility factors for natural gases of various compositions have shown that compressibility factors can be generalized with sufficient for most engineering purposes when they are expressed in terms of the follo9wing two dimensionless properties: pseudo-reduced pressure and pseudo-reduced temperature.

These dimensionless terms are defined by the following expressions:

$$P_{pr} = \frac{P}{P_{pc}} \text{ and } T_{pr} = \frac{T}{T_{pc}}, \qquad (3.3.9)$$

where P-system pressure, MPa; P_{pr}-pseudo-reduced pressure, dimensionless; T-system temperature, K; T_{pr}-pseudo-reduced temperature, dimensionless; P_{pc}, T_{pc}-pseudo-critical pressure and temperature, respectively, and defined by the following relationships:

$$P_{pc} = \sum_{i=1}^{i=n} y_i \cdot P_{ci} \text{ and } T_{pc} = \sum_{i=1}^{i=n} y_i \cdot T_{ci} \qquad (3.3.10)$$

It should be pointed out that these pseudo-critical parameters, i.e., P_{pc} and T_{pc}, do not represent the actual critical properties of the gas mixtu7re. These pseudo properties are used as correlating parameters in generating gas properties. As gas relative density is known for calculation pseudo-critical pressure and temperature expressions

$$P_{pr} = \frac{P}{49.5 - 3.7 \cdot \overline{\overline{\rho}}} \text{ and } T_{pr} = \frac{T}{93 + 176 \cdot \overline{\overline{\rho}}}, \qquad (3.3.11)$$

are used.

For the reservoir pressure P=71.6 MPa and temperature T=376 K pseudo-critical parameters will be

$$P_{pr} = \frac{P}{49.5 - 3.7 \cdot \overline{\overline{\rho}}} = \frac{716}{49.5 - 3.7 \cdot 0.62} = 15.17 \quad \text{and}$$

$$T_{pr} = \frac{T}{93 + 176 \cdot \overline{\overline{\rho}}} = \frac{376}{93 + 176 \cdot 0.62} = 1.86;$$

For the reservoir pressure P=71.3 MPa and temperature T=376 K pseudo-critical parameters will be

$$P_{pr} = \frac{P}{49.5 - 3.7 \cdot \overline{\overline{\rho}}} = \frac{713}{49.5 - 3.7 \cdot 0.62} = 15.10 \text{ and}$$

$$T_{pr} = \frac{T}{93 + 176 \cdot \overline{\overline{\rho}}} = \frac{376}{93 + 176 \cdot 0.62} = 1.86.$$

The same way for the other values of reservoir pressure and temperature, the magnitudes of pseudo-critical pressure and temperature are calculated.

Based on the concept of pseudo-reduced properties, Standing and Katz (1942 presented generalized gas compressibility chart as shown in Figure (3.3.1). This chart represents compressibility factors of sweet natural gas as a function of pseudo-reduced pressure P_{pr} and pseudo-reduced temperature T_{pr}. This chart is generally reliable for natural gas with minor amount of nonhydrocarbons. It is one of the most widely accepted correlations in the oil and gas industry.

From the chart introduced in Figure 3.3.1 depending of pseudo-critical parameters, we found Z-factor values. For example, for pseudo-reduced pressure P_{pr}=15.17 and pseudo-reduced temperature T_{pr}=1.86 it makes Z=1.41. For

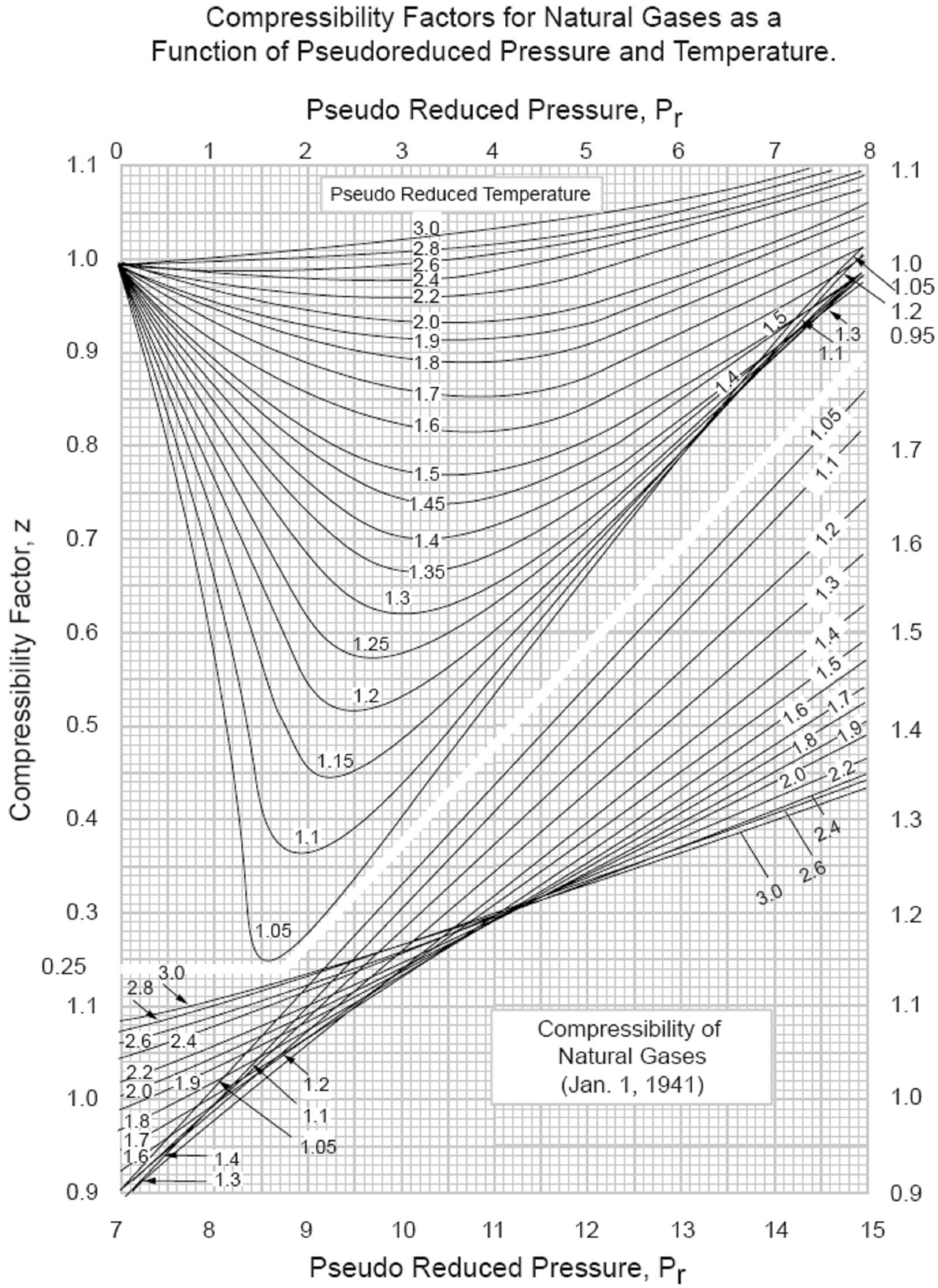

Figure 3.3.1. Standing and Katz's gas compressibility chart

pseudo-reduced pressure P_{pr}=14.2 and pseudo-reduced temperature T_{pr}=1.86 it is Z=1.37. The additional diagram Z-factor vs P_{pc} and T_{pc}, $Z = f(P_{pc}, T_{pc})$ (3.3.2) was constructed by us.

The same we determine Z-factor values from Standing and Katz's Chart (Figure 3.3.1) and put down Table 3.3.1.

To determine gas reservoir drive material balance equation is used:

$$\frac{P_b}{Z_b} - \frac{P_c}{Z_c} = \frac{Q_r}{\alpha}, \qquad (3.3.12)$$

Hence, $\alpha = \dfrac{Q_r}{\dfrac{P_b}{Z_b} - \dfrac{P_c}{Z_c}}$.

All calculations results have been introduced in the Table 3.3.1 and Figure 3.3.2.

It became possible determining reservoir drive and initial gas reserves from the graph $P/Z = f(Q_r)$ plotted based on data given in Table 3.3.1. In the given case dependence $P/Z = f(Q_r)$ presents the straight line. If extend it until axis of abscissa, the cumulative $\sum Q_r = 72.0$ billion m3 will be equal to VII horizon initial gas reserves in place.

It should be remembered that initial gas reserves of VII horizon calculated by the volume method makes 71.809 billion m3.

Therefore, the difference between calculated and graphically determined values of initial gas reserves of VII horizon is 0.04%.

As is shown in the Table 3.3.1 values of parameter α beginning from the 13th year of development up to the 25th year is equal to $\alpha = 0.13 \div 0.14$, which shows pure gas drive for the VII horizon.

Table 3.3.1 The results of reservoir drive mechanism and hydrocarbon reserves calculations by the material balance method

Development years	P, MPa	$\sum Q_r$	P_{pc}	T_{pc}	Z	P/Z, MPa	$P_b/Z_b - P_c/Z_c$	α
1	2	3	4	5	6	7	8	9
1	71.6	0	15.2	1.86	1.41	507.8	0	-
2	71.3	1.93	15.1	"	1.41	503.7	2.1	0.44
3	67.2	2.82	14.2	"	1.37	490.5	17.3	0.16
4	62.3	4.36	13.2	"	1.32	472.0	35.8	0.12
5	60.0	7.07	13.7	"	1.30	461.5	46.3	0.15
6	58.9	10.7	12.5	"	1.28	427.1	57.0	0.19
7	52.9	14.8	11.2	"	1.22	400.0	67.0	0.22
8	47.4	19.0	10.0	"	1.14	368.3	76.9	0.25
9	41.9	23.0	8.9	"	1.06	348.3	126.9	0.18
10	36.3	26.9	7.7	"	1.05	315.6	177.8	0.15
11	31.1	30.5	6.6	"	0.97	300.0	187.2	0.16
12	25.9	33.8	5.5	"	0.94	275.5	232.3	0.15
13	23.0	36.4	4.9	"	0.91	252.7	255.1	0.14
14	21.1	38.8	4.5	"	0.90	234.4	233.4	0.14
15	19.4	41.1	4.1	"	0.89	218.0	289.8	0.14
16	18.0	43.0	3.8	"	0.89	202.3	305.5	0.14
17	17.4	44.6	3.7	"	0.88	197.7	310.1	0.14
18	16.9	46.2	3.6	"	0.89	191.0	316.8	0.15
19	15.1	47.5	3.2	"	0.89	189.7	318.1	0.15
20	13,2	48.7	2.8	"	0.90	146.7	361.1	0.14
21	11.3	49.8	2.4	"	0.91	124.2	383.6	0.13
22	10.1	50.7	2.1	"	0.92	109.8	398.0	0.13
23	9.1	51.7	1.9	"	0.92	8.9	408.9	0-.13
24	8.7	52.4	1.8	"	0.92	94.6	413.2	0.13
25	8.6	53.0	1.8	"	0.92	93.5	414.8	0.13

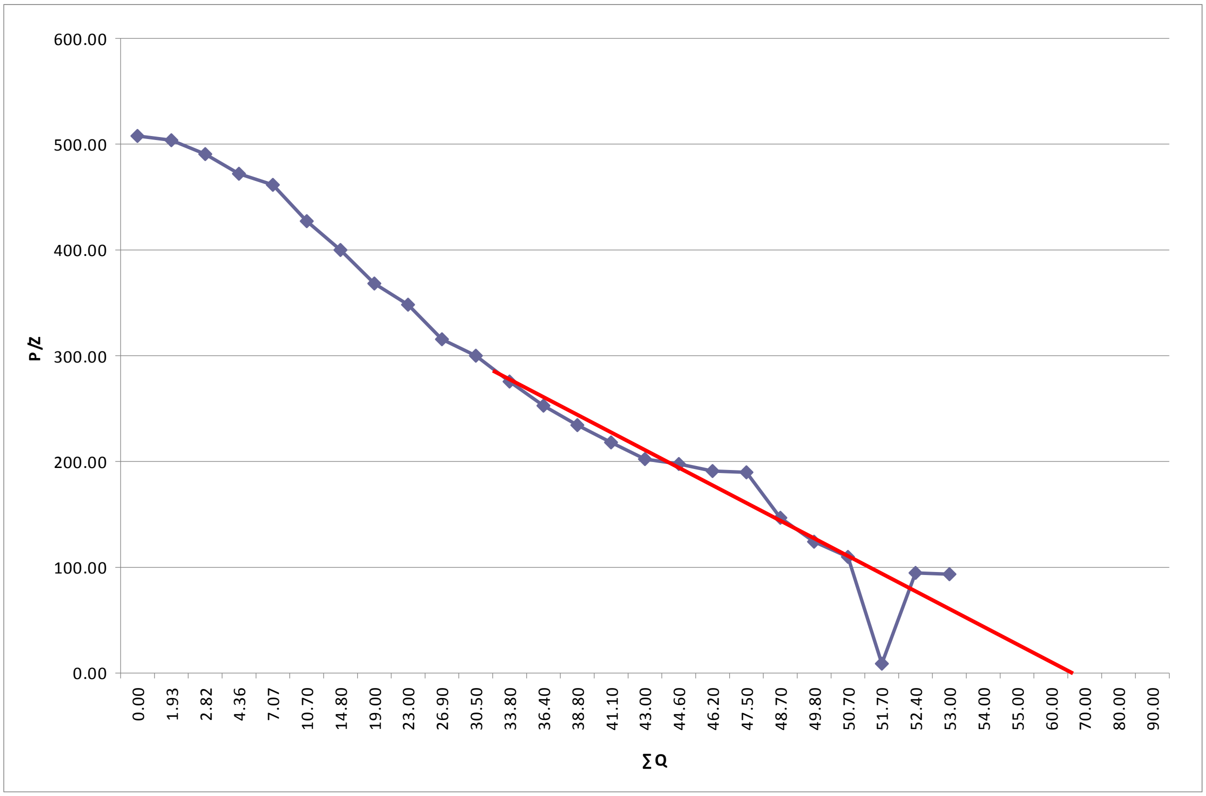

Figure 3.3.2. Redused pressure p/z **vs cumulative gas production rate** $\sum Q$ **.**

3.4. Calculation of gas reserves of VII horizon by mathematical-statistical method

Hydrocarbon reserves calculation by mathematical-statistical method is based on mathematical processing of field data. First in oil industry, V.V. Bilibin introduced oil reserves calculation by statistical method [2]. By the help of mathematical-statistical method, using production decline curve, it is possible to calculate hydrocarbon reserves with large accuracy. Construction of different curves with purpose of determining factors influencing to wells and formations production rate it is necessary to use field statistic material concerning all periods of development.

Introducing of statistic methods in most cases requires using field materials concerning middle or declining periods of reservoirs development. Before using statistic methods, it is necessary to construct special tables in which should be introduced numerical values of function depend on numerical values of argument.

Functions presented in such way could be required differentiating or integrating in further operations.

In processing of Tables data it would be required determining argument's intermediate values not shown in the Table (interpolation problem) or argument's out of Tables values (extrapolation problem).

3.4.1 Graphical construction of production curve based on field data it's processing

To carry out statistical studies it is required gathering, generalization and systematization of field data. This work is performed for VII horizon and introduced in Table 3.4.1. Based on data of Table 3.4.1 production curve for VII horizon was constructed (Figure 3.4.1) and another Table 3.4.2 was drown up.

Table 3.4.1 Field data for calculation of gas reserves of VII horizon by statistical method

Development years	Number of develop-ment year, t	Cumulative Production of gas, million m3	$\frac{t_i}{\sum Q}$	t_i	$\frac{t_i}{\sum Q} \cdot t_i$
1	2	3	4	5	6
1975	1	66,379	0.01506		
1976	2	928,943	0.00215		
1977	3	2,819.332	0.00106		
1978	4	4,360.349	0.00092		
1979	5	7,070.195	0.00071		
1980	6	10,661.009	0.00056		
1981	7	14,830.107	0.00047		
1982	8	19,021.808	0.00042		
1983	9	22,974.477	0.00039		
1984	10	26,900.478	0.00037		
1985	11	30,539.589	0.00036		
1986	12	33,790.330	0.000355		
1987	13	36,416.432	0.000357		
1988	14	38,838.214	0.00036		
1989	15	41,076.618	0.000365		
1990	16	42,960.518	0.000372	256	0.005958
1991	17	46,640.883	0.000381	289	0.006477
1992	18	46,162.623	0.00039	324	0.007020
1993	19	47,487.884	0.00040	361	0.007600
1994	20	48,461.934	0.0041	400	0.00822049
1995	21	49,747.450	0.000422	441	0.008862
1996	22	50,744.552	0.000433	484	0.009537
1997	23	51,672.484	0.000445	529	0.010235
1998	24	52,358.561	0.000458	576	0.01992
1999	25	52,956.918	0.000472	625	0.011800
2000	26	53,544.348	0.000486	676	0.0126
	$\sum$ 205		$\sum$ 0.0041	$\sum$ 4285	$\sum$ 0.0867

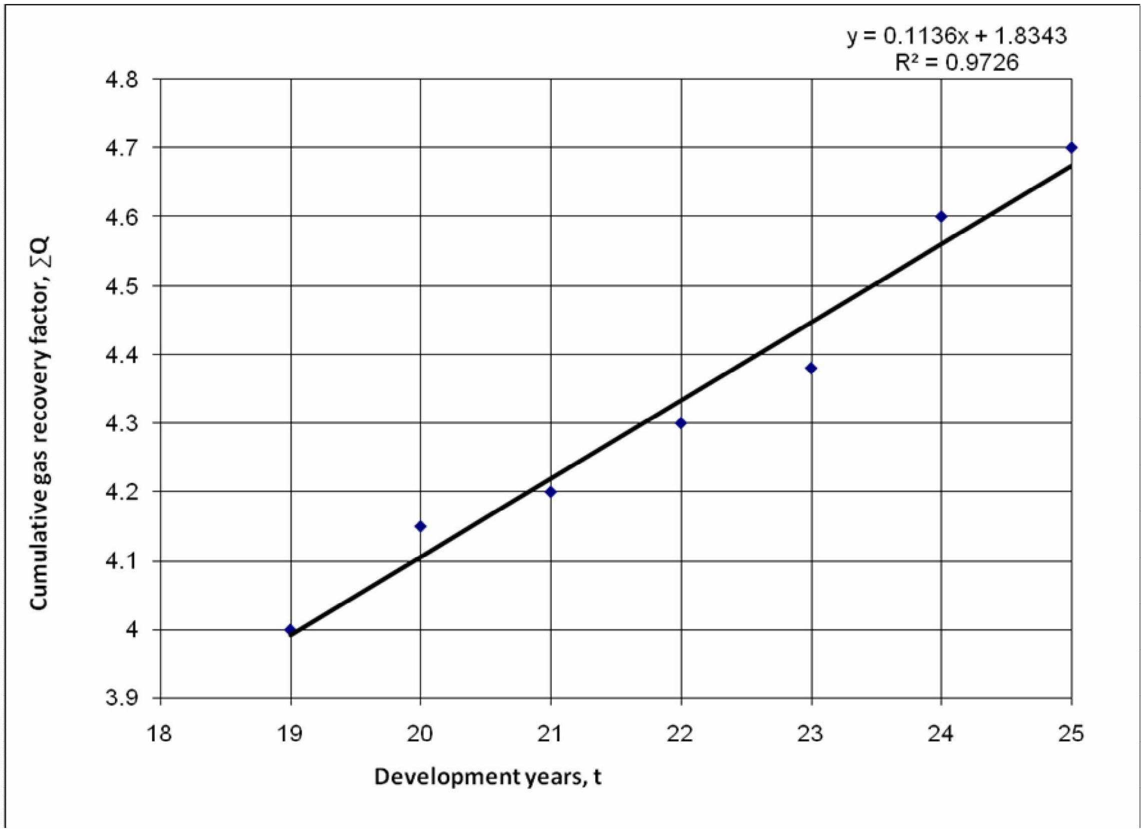

Figure 3.4.1 Cumulative gas production vs time.

To plot production curve of VII horizon of Bulla-deniz field, Table 3.4.2 showing cumulative production on reservoir vs. development years, were drown up. Based on data put in Table 3.4.2 cumulative gas production vs development years curve $\sum Q = f(t)$ was constructed (Figure 3.4.1). As is shown in Figure 3.4.1 production curve has parabolic nature. Beginning from 1990 decreasing of cumulative production is observed. It results due to sufficiently formation pressure drop, removing some producing wells from service and not bringing into service new producers. As is illustrated in Table 3.4.1 and in Figure 3.4.1 yearly production rates on VII horizon for the last period becomes more or less constant and therefore beginning from 1990 production curve $\sum Q = f(t)$ has rectilinear character. To determine gas production for the next years and also cumulative gas production for infinite time period (it means hydrocarbon reserves) based on data put in Table 3.4.2 the values of parameter $t/\sum Q$ was calculated and the diagram $t/\sum Q$ vs development years t was constructed (Figure 3.4.2). As is clear from Table 3.4.2 and Figure 3.4.2 beginning 1990 the value of parameter $t/\sum Q$ increases. It is required to choose functional relationship for expression

$t / \sum Q = f(t)$. Composition of equation for the curve plotted based on field practical data is called choosing of empirical formula. The curve $t / \sum Q = f(t)$ shown in Figure 3.4.2 describes the linear function, which intersects some segment from y-axis and forms some angle with x-axis. Therefore, we can write

$$y = a + bx \tag{3.4.1}$$

So, practically, smoothing of the curve is carried by equation $y = a + bx$. To determine coefficients a and b in equation (3.4.1), method of least squares has been used. In a function of $y = a + bx$ as a measure of common error, deviation for all experiments, would be expressed as

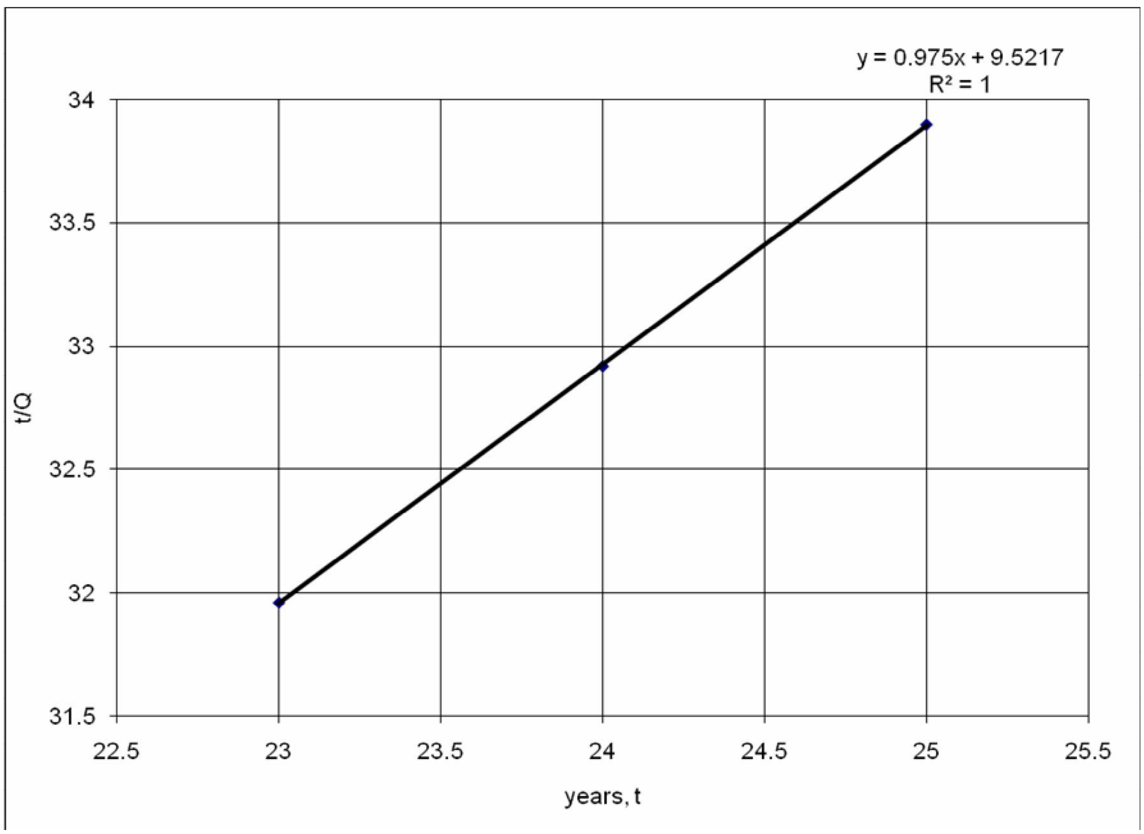

Figure 3.4.2 t/Q parameter vs time

$$G = \sum (y - a - bx)^2 = \min . \qquad (3.4.2)$$

Providing minimum of the sum of all deviations G determining of coefficients values in equation (3.4.2) is called the method of least squares.

In a small values of a common error G to calculate constant $b = b^*$ it is required to differentiate it on a and b coefficients provided that $\frac{\partial G}{\partial a} = 0$ and $\frac{\partial G}{\partial b} = 0$.

Hence, according to condition (3.4.2) system of equation is given

$$\left.\begin{aligned} \frac{\partial G}{\partial a} &= 2\sum_{i=1}^{i=n} (y_i - a - bx_i) \cdot (-1) = 0 \\ \frac{\partial G}{\partial b} &= 2\sum_{i=1}^{i=n} (y_i - a - bx_i) \cdot (x_i) = 0 \end{aligned}\right\} \qquad (3.4.3)$$

These two conditions allows for determining of coefficients a and b to set up equations systems shown below

$$\left.\begin{aligned} &\sum_{i=1}^{i=n} y_i - na - b\sum_{i=1}^{i=n} x_i = 0 \\ &\sum_{i=1}^{i=n} x_i y_i - a\sum_{i=1}^{i=n} x_i - b\sum_{i=1}^{i=n} x_i^2 = 0 \end{aligned}\right\} \qquad (3.4.4)$$

It is not difficult to calculate values of a and b coefficients from equations system (3.4.4). For this purpose, to be short, assume that

$$m_1 = \sum_{i=1}^{i=n} x_i ; \qquad m_2 = \sum_{i=1}^{i=n} x_i^2 ; \qquad q_1 = \sum_{i=1}^{i=n} y_i ; \qquad q_2 = \sum_{i=1}^{i=n} x_i \cdot y_i .$$

Then equation system (3.4.4) can be written, as

$$\left.\begin{aligned} m_1 \cdot a + m_2 \cdot b &= q_2 \\ m_1 \cdot b + na &= q_1 \end{aligned}\right\} \qquad (3.4.5)$$

Solving equation system (3.4.5) can be received:

$$\left.\begin{aligned} a &= \frac{m_2 \cdot q_1 - m_1 \cdot q_2}{m_2 \cdot n - m_1^2} \\ b &= \frac{q_2 \cdot n - q_1 \cdot m_1}{m_2 \cdot n - m_1^2} \end{aligned}\right\}. \tag{3.4.6}$$

There is another approach to the considered method. Equation $y = a + bx$ as a function between two variables x and y being considered linear expression would be written such way that allowed calculating of unknown coefficients a and b. Using the experimental data, depending on these parameters equation system can b $q_1 = \sum_{i=1}^{i=n} y_i$;e written:

$$\left.\begin{aligned} y_1 &= a + bx_1 \\ y_2 &= a + bx_2 \\ &\cdots\cdots\cdots\cdots \\ y_n &= a + bx_n \end{aligned}\right\}. \tag{3.4.7}$$

Having experimental data it is easy to calculate a and b coefficients. However, taking into consideration that parameters x and y were measured by some error, then we believe that those errors influence to the a and b coefficients values. On the contrary, a and b coefficients calculations will be more accuracy with increasing experimental measurements, in other words, with increasing equation numbers. Therefore, errors of separate measurements will compensate each other, and therefore, applying the method of least squares will be more reasonable. It should be noted if there is not linear relationship between x and y variables, and existed more complicated relationship, solving the problem would be more sophisticated. In practice, in this case, for choosing of mathematical expressions graphical approach is used.

To calculate hydrocarbon reserves of VII horizon of Bulla-deniz field the model shown in [8] has been used:

$$\sum Q = \frac{t}{a + bt}, \tag{3.4.8}$$

If expression (3.4.8) being written for the case time approaches to infinite, i.e. $t \to \infty$ we receive:

$$\sum Q \,|_{t\to\infty} = \frac{1}{b}. \tag{3.4.9}$$

In reality, the inverse value of the Y-intercept of the rectilinear constructed between parameter $t/\sum Q$ and time t is characterized the gas reserves in place. From graph shown in Figure 3.3.3, we obtain $b = 14.2 \cdot 10E06$.

In this case $1/b = 0.0704225 \cdot 10^6$ has been received.

Finally, gas reserves in place calculated by above considered method makes $\sum Q = 70.422$ billion m3.

The difference between gas reserves calculated by statistic and volume methods is 1.387 billion m3, i.e. 2%. The poor drainage of some zones and sections of reservoir could explain this fact.

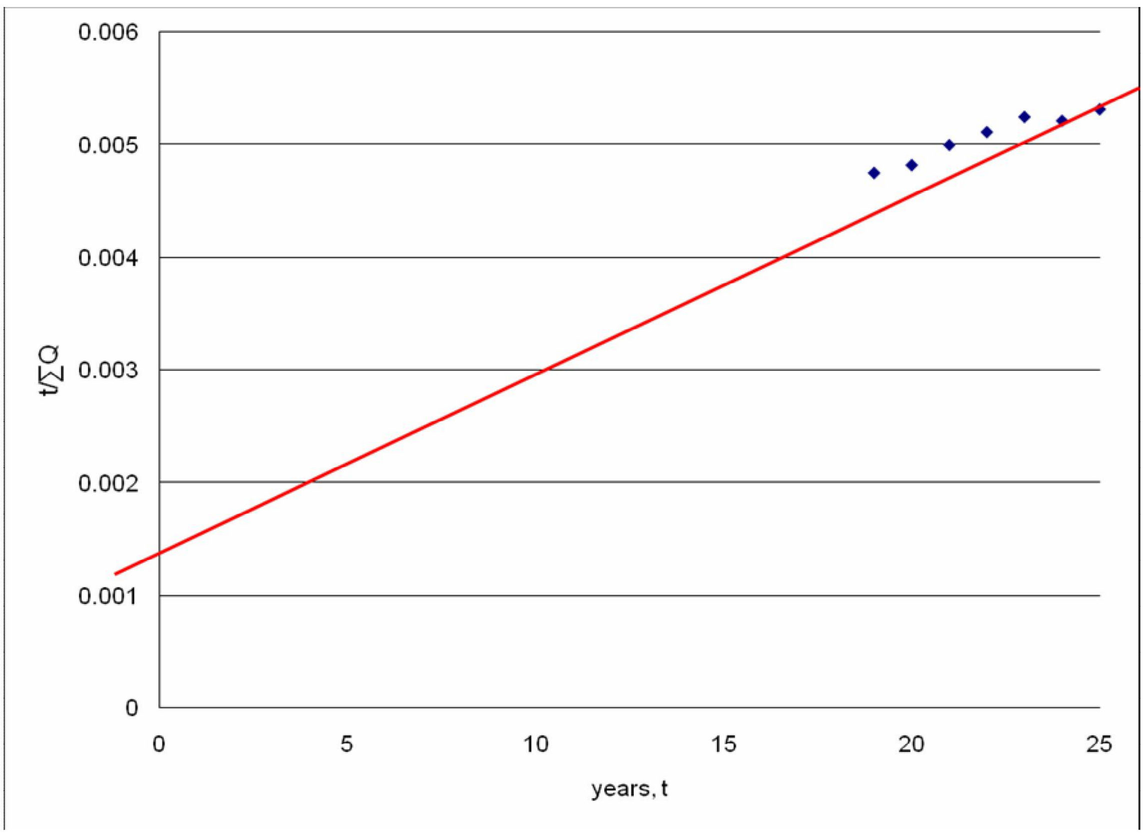

Figure 3.3.3. t/∑Q parameter vs development years t.

CHAPTER 4. MEASURES OF ENHANCING OF VII HORIZON OF BULLA-DENIZ FIELD FURTHER DEVELOPMENT EFFICIENCY

4.1. General questions

For the gas and gascondensate reservoirs developed long period and a large portion of hydrocarbon reserves which was recovered to increase of the development efficiency for the next period, appropriate corrections should be done in its further development plan.

Further development period is the longest period with worsening of reservoir performances that is characterized by formation pressure declining, decreasing of producers' production rate, water encroachment of pool, liquid hydrocarbons separation, well production problems and their shutdowns for some reason or other; all these problems cause sufficiently declining of recovery rate. Before further development program scheduling the following tasks should be done:

1. As a result of gathering, generalization and processing of field datareservoir development process should be analyzed;

2. Development control information should be analyzed.

3. To increase development efficiency preparing measures of its intensification should be provided.

In the second chapter of this thesis short development analyze of VII horizon was realised. On the third chapter of thesis based on processing field information reservoir hydrocarbon reserves by different methods were calculated.

4.2. Estimating of VII horizon ultimate gas recovery factor

Below in Table 4.2.1 drown up by field data gas reserves recovery factors of VII horizon from beginning of development up to 2001are shown.

Table 4.2.1Field data on calculation of ultimate gas recovery of VII horizon

Development years	Number of development year, t	Cumulative gas recovery factor, η	Ratio of development year to the cumulative gas recovery factor, t/η
1	2	3	4
1975	1	0.0009	1,111.11
1976	2	0.0129	155.04
1977	3	0.0393	76.34
1978	4	0.0607	65.90
1979	5	0.0985	50.76
1980	6	0.1485	40.40
1981	7	0.2065	33.90
1982	8	0.2649	30.20
1983	9	0.3199	28.13
1984	10	0.3746	26.70
1985	11	0.4253	25.86
1986	12	0.4756	25.50
1987	13	0.5071	25.64
1988	14	0.5406	25.90
1989	15	0.5270	26.22
1990	16	0.5983	26.74
1991	17	0.6217	27.34
1992	18	0.6429	28.04
1993	19	0.6613	28.73
1994	20	0.6775	29.52
1995	21	0.6928	30.31
1996	22	0.7067	31.13

1997	23	0.7196	31.96
1998	24	0.7291	32.92
1999	25	0.7375	33.90
2000	26	0.7456	34.87
2001	27	0.7617	35.45
2002	28	0.7686	36.43
2003	29	0.7740	37.47
2004	30	0.7800	38.46

Based on Table 4.2.1 information In Microsoft Excel the graph of $\frac{t}{\eta} = f(t)$ function was plotted (Figure 4.2.1).

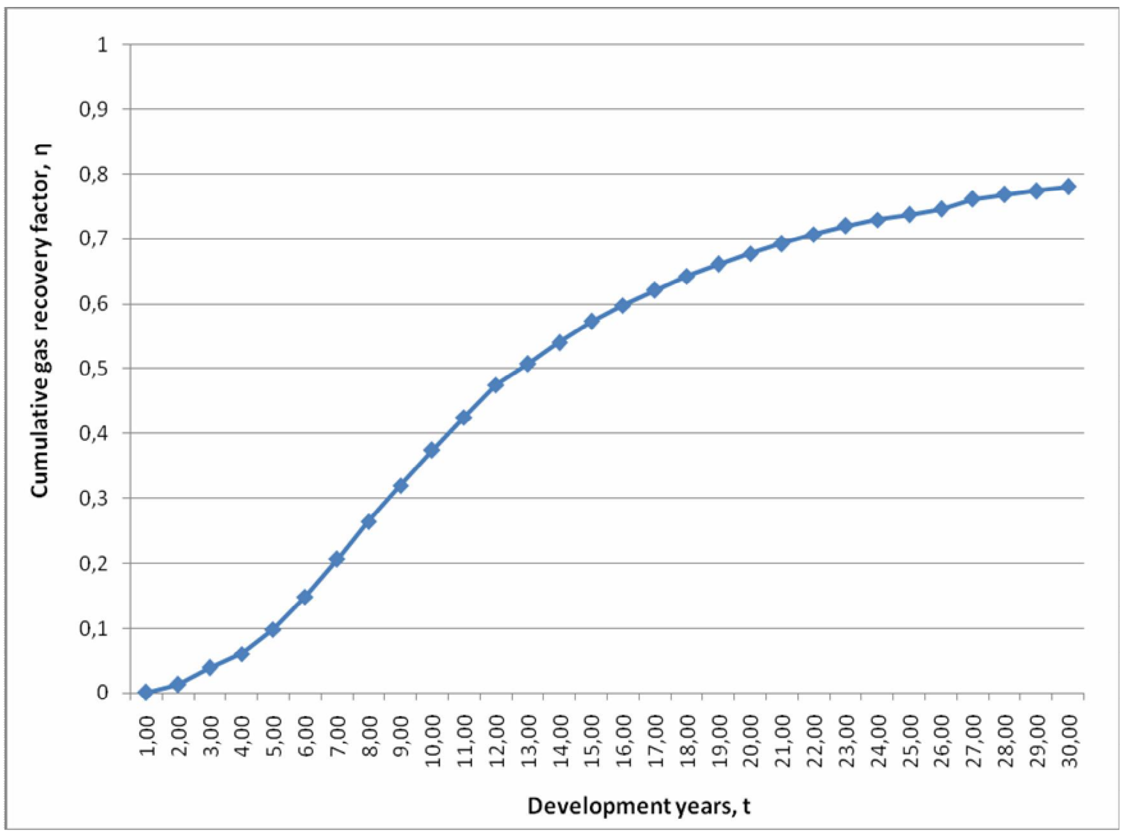

Figure 4.2.1. Gas recovery factor vs. time.

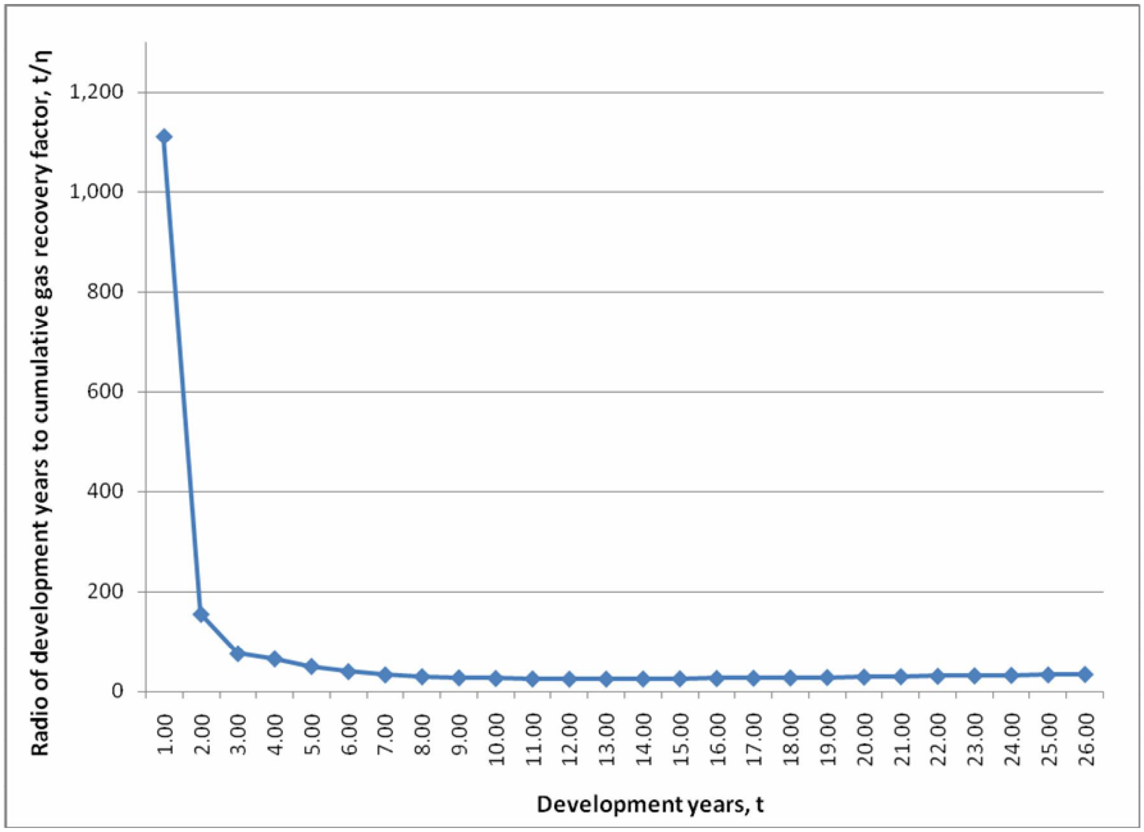

Figure 4.2.2. t/η **parameter vs. time.**

As is clear from Figure 4.2.1 plot t/η as a function of t has a rectilinear character and is described as

$$\frac{t}{\eta} = 0.975t + 9.5217. \qquad (4.2.1)$$

Degree of approximation accuracy is $R^2 = 1$.

Dividing of both sides of equation 4.2.1 by t we receive

$$\frac{1}{\eta} = 0.975 + \frac{9.5217}{t}. \qquad (4.2.2)$$

If the expression (4.2.2) would be written for the case of $t_{\to\infty}$, then the following dependence can be received

$$\frac{1}{\eta} \;|_{t\to 0} = 0.975. \qquad (4.2.3)$$

Hence, will be $\eta = \dfrac{1}{0.975.} \approx 1$.

So, inverse value of a portion of plotted relationship of t/η as a function of time t intersected from y-axis is characterized of ultimate gas recovery factor. From here in becomes clear that ultimate gas recovery factor will be $\eta \approx 1$.

It should be noted that in one variants of VII horizon's development program ultimate gas recovery factor was received $\eta = 1$.

4.3. Estimating of VII horizon current gas recovery factor

To predict reservoir current gas recovery factor, information given in Table 4.2.1 were used. Based on data shown in Table 4.2.1 relationship $\eta = f(t)$, plot gas recovery factor η as a function of development years t was constructed. Based on Microsoft Excel program the previously mentioned function was approximated and the equation below was received:

$$\eta = 0.0105t + 0.4762. \qquad (4.3.1)$$

Reliability of approximation is $R^2 = 0.9859$.

For confirmation of reliability of equation (4.3.1) calculation of gas recovery factor on the 26th year is needed:

$$\eta = 0.0105t + 0.4762 = 0.0105 \cdot 26 + 0.4762 = 0.273 + 0.4762 = 0.7492.$$

Therefore, gas recovery factor calculated by the equation and real one are the same. Therefore, prediction of gas recovery factor for the next development years using expression (4.3.1) is reasonable.

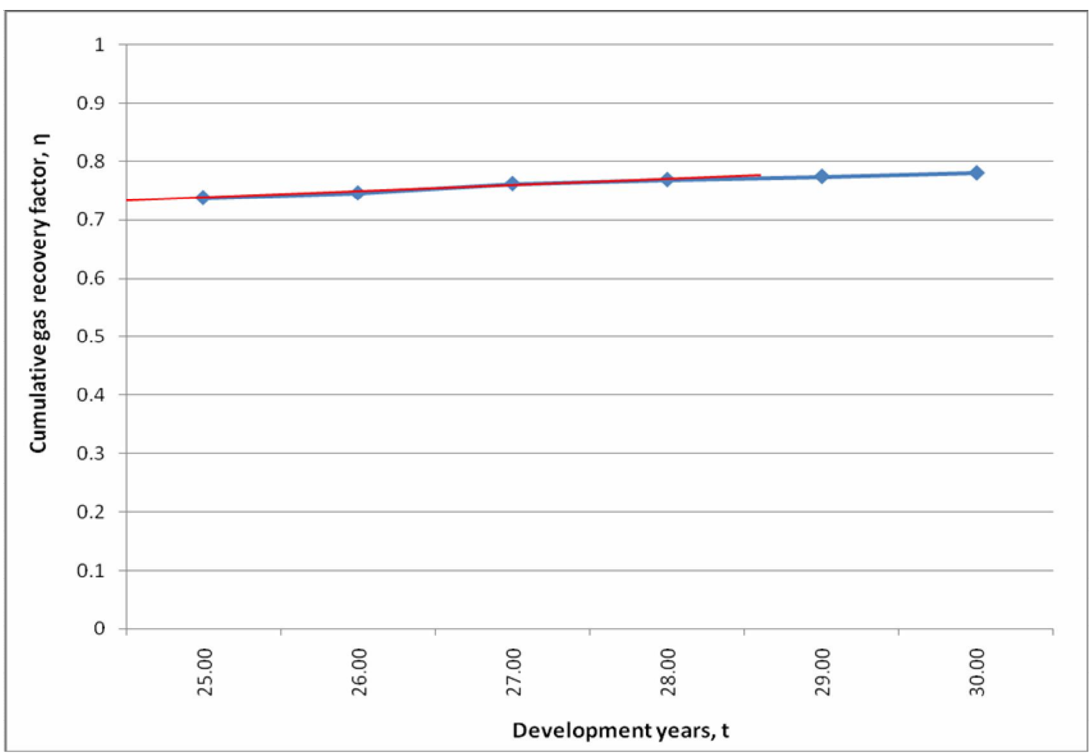

Figure 4.3.1. Gas recovery factor vs. time.

4.4. Procedures on intensification of VII horizon development process

VII horizon of Bull-deniz field is produced by reservoir pressure depletion. The initial gas reserves is 71,809 million m3. Up today more than 60,000 million m3 was recovered. Initial reserves of condensate is 26,367 thousand t. For the present time 9,350 thousand t was produced. Current gas recovery factor is 0.77, condensate recovery factor is 0.35. Recoverable gas reserves makes 11,771 million m3 and condensate recoverable reserves is 2,515 thousand t. In one variants of development program of VII horizon gas recovery factor was accepted 0.83, condensate recovery factor - 0.5.

I think that for gascondensate reservoir produced in formation pressure depletion and does not subject to sufficiently water influx such gas recovery factor is to a considerable extent is small. In all probability gas recovery factor VII horizon will be more than 0.90. If development process will be continued such way as today, for recovering of residual reserves 20-25 years are needed. To that time, it is highly probable, hydraulic facilities will go out of service.

Thermodynamic studies provided in field conditions shown that in separate wells initial condensation pressure for investigated reservoir varies 7.5÷11.3 MPa. On VII horizon initial reservoir pressure from 71.3 MPa declined to 8.7 MPa in 1998. It means that yet beginning from 1998 well bottom and formation pressures were less than initial condensation pressure separation that resulted condensate (liquid C5+) separation first in borehole, then in formation conditions.

At present, the formation pressure is 8 MPa. It is natural that because of sufficient declining of reservoir pressure wells and formation water influx is going on. All these facts service condensate loss in formation and declining of wells output. On the other hand, to keep up production rate constant, instead of 18 producers, only 14 wells are in operation. Wells number is not enough to maintain designed production rate and increase it. If at the beginning of development production rate per well was 500÷1,000 thousand m3 and condensate - 40÷400 t, now gas production rate per well is 90 thousand m3, condensate – 8 t. Percentage of well stream watering makes 28. Deterioration of flowing process in reservoir conditions and water accumulation in well bore are the reasons of restraining of development intensification process.

To keep gas recovery rate constant and increase it to a certain extent other measures realization in practice are needed. These procedures if could not influence of flowing of gas in formation, nevertheless, could improve flowing process in well bottom-hole and decrease flow resistance in well borehole. To these procedures may be referred method of liquid drainage (removing) from well bore by methanol injection into it. Other way for liquid removing from well bore is foaming agent injection into well and choosing appropriate type of lift construction.

To improve development process whether by drilling-in wells or applying well's Economic efficiency rule states that capacity stimulation methods, should be based on economic efficiency.

Economic efficiency rule states that if marginal benefits of applying oil stimulation methods exceeds the marginal costs, do it. So, problem is complicated, but is solvable.

CONCLUSION

The thesis is considered problematic task revision of hydrocarbon reserves of VII horizon of Bulla-deniz gascondensateoil field.

General characteristic and brief geological description of the Bulla-deniz gascondensateoil field has been lighted.

Physical and chemical properties of gas and condensate based on thermodynamic investigations are given.

VII horizon of Bulla-deniz gascondensateoil field hydrocarbon reserves detailed studies were carried out and existing gas and condensate reserves were revised. Hydrocarbon reserves recalculation was conducted by three methods. It was established that hydrocarbon reserves are:

1. Volumetric method-gas reserves is 71.809 billion m3 and condensate - 26.367 thousand ton;

2. Material balance method (pressure drop method) - gas reserves make up 72,000 billion m3 and

3. Mathematical-statistical method. Gas reserves is 70,422 billion m3.

It should be noted that State Reserves Committee for calculation of combustible gas reserves two approaches are required: volumetric and pressure drop methods.

To calculat6e gas reserves by these methods the formation rock properties and many other parameters characterized formation system, field and laboratory studies are required.

Depending on the accuracy of parameters determination or insufficiency information there will be some errors in hydrocarbon reserves calculation. Hydrocarbon reserves calculation by above-mentioned methods also is labor- and time-consuming.

To avoid this undesirable phenomena calculation of hydrocarbon reserves by complex approach is suggested. In particular, adding to those remembered methods mathematical-statistic one.

In calculation of hydrocarbon reserves by the mathematical-statistic method one only need information about gas production during development years and some others in short, more less than other methods. However, accuracy of used data is necessary.

The main task is to choose good processing technique for experimental information processing. For this purpose, based on field data cumulative gas production vs. time relationship is plotted and due to empiric distribution, the appropriate mathematical expression has been chosen.

Taking into consideration all above-mentioned facts in calculation of gas reserve the mathematical-statistical method is suggested.

For prediction of gas recovery factor the mathematical equation with high degree of accuracy has been suggested.

Finally, to improve further development process intensification, production recovery stimulation methods are considered. To them may be included measures of keeping recovery rate constant, facilitation of fluid filtration to bottom-hole formation zone and other well capacity stimulation methods.

I think, I achieve the results that I have planned to do in my thesis.

REFERENCES

1. Жданои М.А., Лисунов В.Р., Гришин Ф.А. Методика и практика подсчета запасов нефти и газа. М.; Недра, 1967, 403 с.

2. Жданои М.А. Нефтегазопромысловая геология и подсчета запасов нефти и газа. М.; Недра, 1981, 453 с.

3. Инструкция по комплексному исследованию газовых и газоконденсат-ных пластов и скважин. Под ред. Г.А. Зотова, З.С. Алиева. М.; Недра, 1980, 264 с.

4. Коротаев Ю.П., Закиров С.Н. Теория и проектирование разработки газовых и газоконденсатных месторождений. М.; Недра 1981, 294 с.

5. Газоконденсатное месторождение Булла-море. Геологическое строение, исследование и разработка. 1975-1980. Баку, НГДУ "Булла-море", 1980. Методы вскрытия и освоения неоднородных газовых и газоконденсатных пластов. Прогнозирование извлекаемых запасов углеводородов. АзИНФТЕХИМ имени М. Азизбекова.

6. Анализ и обобщение геолого-физического материала по газоконденсат-ному месторождению Булла-море с целью уточнения тектоники и харак--тера изменения фильтрационно-емкостных параметров М. V, VII и VIII горизонтов продуктивной толщи по площади, направлений доразведки и запасов газа, конденсата и нефти (по состоянию на 01.07.1987). Книга I, II и III. ИПГНГМ, Баку, 1987. НГДУ им. Н.Нариманова. Геологический отдел НГДУ.

7. Пути совершенствования разработки газоконденсатного месторождения Булла-море. АзИНФТЕХИМ имени М. Азизбекова. Баку 1985-1986.

8. Зельдович Я.В., Мышкис А.Д. Элементы прикладной математики. М.; Издательство Наука, 1972, 592 с.

5. Гурбанов Р.С., Нясибов Н.Б. Эцняшли йатаьы фасиля лай дястясинин нефт еһтийатларынын һесабланмасы. "БИЛЬИ" Дярэиси, "Техника" №3. АР "Тяһсил" ямиййяти. Баки, 2002.