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General Ratio between the Growth of Natural Gas Output of a Country (Region), the Cost Level and the Specific Investment

The present survey analyzes the most important groups of expenses which determine the gas costs, establishing the ratios between the gas output and the cost level.

I. PRICE COST

General considerations

The level and growth of methane gas output from one period to another are dictated by the necessities of the balance of fuel resources, in steady increase, as well as by the gas demand for chemicalization. Yet, this growth is limited by the level of gas reserves, by the most rational annual coefficient of reserve consumption, which is determined, in its turn, by the way in which the exhausting of deposits is taking place. The general principle is that the layer depletion should proceed with minimum costs and maximum extraction, so that the deposit pressure be saved. For a most rational exploitation, it is necessary [1] that:

— the supply of consumers in the vicinity of the deposits should proceed from low pressure levels, through local pipes;

— the far off consumers should be supplied from high pressure levels.

Considering that these principles are observed, the growth of the gas output — related to the economic requirements of a country — may proceed on two ways: the bringing into service of new deposits, or the thickening of the number of wells on the existing deposits.

Bearing in mind all these considerations, the cost price of the natural gas will be determined by several factors, among which the most important are:

— the gas reserves and the deposit pressure;

— the efficiency of the geological work for tapping new deposits;

— the number of wells needed to meet the maximum hourly consumption;

— the annual average output per productive well and the potential (total) output per well;

— the average investments for drilling an exploitation well and for production and general equipment;

— the average exploitation cost per well/annum;

— the average cost of conveyance to the consumer.

These factors are reflected in the gas cost price, in the folowing groups of expenditures:

1. The cost of the extracted, hence of the geological work needed to secure the reserve for production;
2. the amortization of the costs of wells and production installations;
3. the routine exploitation expenses;
4. the expenses for conveyance through main pipes.

1. THE COST OF GEOLOGICAL WORK

The geological work for tapping natural gas reserves is of the same nature that the one for crude oil [2], and includes: geological investigation, prospecting and well exploration work.

By this work, the prognosis reserves (category D) are turned into ascertained reserves ($A + B$), passing through the intermediate stage of promotion of reserves, in the C_2 and C_1 categories.

The cost of geological work may be reflected in the gas cost through the repartition of the expenses involved by the geological work during a longer period (as for instance, 5 to 10 years), either on the reserves promoted to the $A + B$ category in that period, or on the extracted output in the same period.

When using the first method, only the expenses involved by the extracted reserves will be included in the gas price, the rest being tied up to the tapped yet non-extracted reserves during this interval.

The application of the second method enables the recovery through the cost price of the whole value of geological work; the gas cost will however be charged the more so as the term of ensuring reserves to production will increase and, hence, the volume of tapped reserves. On the following page is given an example which helps to better understand the influence of these two computation methods of the cost of geological work over the cost of 1,000 cu.m. of extracted gas.

It emerges from this example that the cost price of geological work is reflected in the cost of extracted gas, as follows:

a) When introduced in the cost price is only the cost per 1,000 cu.m. of tapped reserve:

— at a constant ensuring time-limit (20 years) 12 lei/1,000 cu.m.

— at an ensuring time-limit on the rise by 25 per cent in 10 years — 14.3 lei/1,000 cu.m.

b) When the whole value of geological work is introduced in the gas cost price:

— at a constant ensuring time-limit 19.2 lei/1,000 cu.m.

— at a growing ensuring time-limit 30.9 lei/1,000 cu.m.

Table 1

Cost of reserve tapping on a 10-year period

	Unit of measure	Constant ensuring time-limit		Growing ensuring time-limit	
		output on the rise	steady output	output on the rise	steady output
		I	II	III	IV
1. The level of gas reserves					
a) at the start of the period	thousand million cu.m.	104	104	104	104
b) at the end of the 10-year period	„ „	140	104	175	130
2. The annual gas output					
a) in the first year of the period	„ „	5.2	5.2	5.2	5.2
b) annual average rise	„ „	0.2	—	0.2	—
c) in the last year of the period	„ „	7.0	5.2	7.0	5.2
d) 10-year extracted output	„ „	61.0	52.0	61.0	52.0
3. Reserves tapped in the period (1*b*—1*a*+2*a*)	„ „	97	52	132	78
4. Ensuring time-limit of reserves					
a) at the start of the period (1*a* : 2*a*)	years	20	20	20	20
b) at the end of the period (1*b* : 1*c*)	„	20	20	25	25
5. Cost per 1,000 cu.m. of tapped reserves (6 :3)	lei/1,000 cu.m.	12	10.1	14.3	10.6
6. Cost of geological research work	million lei	11.4	526	1884	830
7. Exploration drilling	thousand m.	646	325	942	487
8. Efficiency of geological exploration drilling (3 : 7)	1000 cu.m. reserves/m	150	170	140	160
9. Cost per m.	lei/m	1800	1600	1000	1700
10. Cost geological work per 1,000 cu.m. of extracted gas (6 : 2*d*)	lei	19.2	10.1	30.9	10.7
11. Value of stocked reserves at the start of the period	million lei	1000	1000	1000	1000
12. Cost of reserves tapped in the period (according to the 6th line)	„ „	1164	526	1884	830
13. Cost of extracted reserves :					
a) with the unit cost of tapped reserves (2*d* × 5)	„ „	732	526	873	550
b) with the integral cost of geological work	„ „	1164	526	1884	830
14. Value of stocked reserves at the end of the period					
a) with the unit cost of extracted reserves (11+12—13*a*)	„ „	1432	1000	2011	1280
b) with the integral cost of geological work (11+12—13*b*)	„ „	1000	1000	1000	1000

The application of the first method is conducive to an increased value of stocked reserves (non-extracted) from 1,000 million lei to 1,432 million lei, while in using the second method, the value of stocked reserves will keep unchanged.

Below, we suppose that the value of geological work is fully distributed on the cost price of the extracted gas. In this case, the general formula of the cost of tapped reserves will be, in relation to the increase of output: [2]

$$p_d = \frac{p_r}{n} \times \frac{k_1 Q + k_2 \Delta Q}{Q + \frac{n-1}{2} \Delta Q} = \frac{p_r}{n} \times \frac{k_1 + k_2 \frac{\Delta Q}{Q}}{1 + \frac{n-1}{2} \frac{\Delta Q}{Q}} \qquad (1)$$

in which

p_d = is the cost of geological work per cubic metre of extracted gas;

Δ_Q = the annual average growth of output in the period n;

Q = the output in the basic period;

$k_1 = n_2 - n_1 + n$, n_1 and n_2 being the ensuring time-limits with reserves in the basic period and after n years;

n = the surveyed period in years.

$$k_2 = n\left(n_2 + \frac{n-1}{2}\right)$$

p_r = the cost per cubic metre of tapped reserve in the respective period.

If we take as an example:

$n_1 = n_2 = 25$ years (factor of constant ensuring);

$p_r = 10$ lei/1,000 cu.m., $n = 5$ years, hence

$$k_1 = 5, \quad k_2 = \left(25 + \frac{4}{2}\right)5 = 135$$

the expression (*1*) will become:

$$p = 10 \frac{1 + 27 \frac{\Delta Q}{Q}}{1 + 2 \frac{\Delta Q}{Q}} \qquad (1\ a)$$

On the basis of the formula (*1 a*) and of the accepted data (factor of ensuring with constant reserves) the cost of gas reserve tapping to be introduced in the cost of extraction will vary as follows, according to the increase

pointer of production, and bearing in mind that the geological work be fully included in the gas cost price.

$\frac{\Delta Q}{Q}$	p_d
0.0	10.0 lei per 1,000 cu.m.
0.1	30.8 lei per 1,000 cu.m.
0.2	45.7 lei per 1,000 cu.m.
0.3	56.8 lei per 1,000 cu.m.
0.4	65.6 lei per 1,000 cu.m.

The rise of reserve tapping cost, concomitantly with the growth of output is determined especially by the ensuring time-limit of production with reserves (n_1, n_2) which is reflected in the coeficients k_1 and k_2.

2. AMORTIZATION OF WELLS AND PRODUCTION INSTALLATIONS

The amortization of gas wells and production installations will be calculated the same as for crude oil [2]:

$$a = \frac{I_m}{p_{10}} = \frac{I_m}{10} \times \frac{N}{Q} \times \frac{1 + n' \frac{\Delta N}{N}}{1 + n' \frac{\Delta Q}{Q}} \qquad (2)$$

in which

I_m = the total average investments per productive well;
n' = the time during which the annual average output of the first ten years, on the whole area, is achieved;
P_{10} = the output of a medium well during the first ten years;
ΔN = the annual average growth of the number of wells in a period n
N = the number of productive wells, at the start of the period.

We can take $\frac{\Delta N}{N} = k_3 \times \frac{\Delta Q}{Q}$, k_3 being a coefficient characteristic to the region under exploitation; the formula (2) turns in that case:

$$a = \frac{I_m}{10} \times \frac{N}{Q} \times \frac{1 + n' k_3 \frac{\Delta Q}{Q}}{1 + n' \frac{\Delta Q}{Q}} \qquad (2\ a)$$

Taking as an example: $n' = 3$ years, $k_3 = 3.2$, $D = \frac{Q}{N} = 15$ million of cu.m. per well-year, $I_m = 2.4 \times 10^6$ the curve set upon the following

formula is obtained:

$$a = 16 \frac{1 + 9.6 \frac{\Delta Q}{Q}}{1 + 3 \frac{\Delta Q}{Q}} \text{ (lei 1,000 cu.m.)} \qquad (2\ b)$$

which permits, for the given example, the setting of the curve of the amortization cost, in relation to the growth of ouptut, on the basis of the following data:

$\frac{\Delta Q}{Q}$	a
0.0	16.00 lei/1,000 cu.m.
0.1	17.50 lei/1,000 cu.m.
0.2	17.80 lei/1,000 cu.m.
0.3	18.05 lei/1,000 cu.m.
0.4	18.20 lei/1,000 cu.m.

The rise of amortizations in step with the growth of output is determined mainly by the coefficient k_3, i.e. by the relation between the increase in the number of wells ans the increase of annual output, a relation which in this case is appreciated to be of 3.2. This means low productivity with the new wells.

3. WORKING EXPENSES

These expenses may be expressed, at natural gas just as in the case of crude oil [2] by the formula:

$$p_e = C_e \frac{N}{Q} \times \frac{1 + nk_3 \frac{\Delta Q}{Q}}{1 + n \frac{\Delta Q}{Q}} + m \qquad (3)$$

in which

C_e = exploitation cost per well-year;
m = the expenses directly proportional to the output;
n = the surveyed period of increase of output.

Taking as an example $n = 5$; $C_e = 35{,}000$ lei; $m = 2$ lei/1,000 cu.m.; $k_3 = 3.2$; $D = \frac{Q}{N} - 15 \times 10^6$ cu.m.
the formula turns into:

$$p_e = 2.33 \times \frac{1 + 16 \frac{\Delta Q}{Q}}{1 + 5 \frac{\Delta Q}{Q}} + 2 \text{ (lei/1,000 cu.m.)} \qquad (3\ a)$$

this enabling, for the given example, the setting of the curve on the basis of the following data:

$\frac{\Delta Q}{Q}$	p_e
0.0	4.33 lei/1,000 cu.m.
0.1	5.86 lei/1,000 cu.m.
0.2	6.90 lei/1,000 cu.m.
0.3	7.50 lei/1,000 cu.m.
0.4	7.80 lei/1,000 cu.m.

At this group of expenses too coeficient k_3 is the one which determines the rise of the working cost price.

4. TOTAL COST OF FREE GAS EXTRACTION

This cost results from the totalling of the examined partial costs, and hence, it is:

$$p = \underbrace{\frac{p_r}{n} \times \frac{k_1 + k_2 \frac{\Delta Q}{Q}}{1 + \frac{n-1}{2} \frac{\Delta Q}{Q}}}_{\text{I}} + \underbrace{\frac{I_m}{10} \times \frac{N}{Q} \times \frac{1 + n' k_3 \frac{\Delta Q}{Q}}{1 + n' \frac{\Delta Q}{Q}}}_{\text{II}} + \tag{4}$$

$$+ \underbrace{C_e \frac{N}{Q} \times \frac{1 + n k_3 \frac{\Delta Q}{Q}}{1 + n \frac{\Delta Q}{Q}}}_{\text{III}} + m$$

in which

I = the cost of reserve tapping;
II = amortization;
III = working expenses.

This formula expresses the variation of the gas extraction cost, in relation to the growth of output from year to year $\left(\frac{\Delta Q}{Q}\right)$. The gas cost can rise or drop as far as the coefficients of variable $\frac{\Delta Q}{Q}$ are varying.

In the above example, the formula which enables the setting of the general cost of free gas extraction will be:

$$p = 10\,\frac{1+27\,\frac{\Delta Q}{Q}}{1+2\,\frac{\Delta Q}{Q}} + 16\,\frac{1+9.6\,\frac{\Delta Q}{Q}}{1+3\,\frac{\Delta Q}{Q}} + 2.33\,\frac{1+16\,\frac{\Delta Q}{Q}}{1+5\,\frac{\Delta Q}{Q}} + 2 \qquad (4\,a)$$

on the basis of which the total cost is computed, in relation to the growth of output expressed in lei per 1,000 cu.m. of extracted gas.

In compliance with the above facts, the total cost per 1,000 cu.m. of extracted gas will be:

Table 2

$\frac{\Delta Q}{Q}$	Cost per 1,000 cu. m. of extracted gas			
	Tapping expenses (p_d)	Amortization (a)	Working expenses (p_e)	Total (p)
0.0	10.00	16.00	4.33	30.33
0.1	30.80	17.50	5.86	54.16
0.2	45.70	17.80	6.90	70.40
0.3	56.80	18.05	7.50	82.30
0.4	65.60	18.20	7.80	91.60

From the table it emerges a rise of costs concomitantly with the growth of gas output. This situation is determined by the conditions under which the exploitation proceeds, especially by the coefficients of variable $\frac{\Delta Q}{Q}$, which differ from one region to another.

In the given example the cost rise is a consequence of the fact that the coefficients of variable $\frac{\Delta Q}{Q}$ in the numerator are higher than those in the denominator, owing mostly to coefficients k_2 and k_3, the former being influenced by the ensuring time-limit of output with reserves, and the latter by the quality of deposits, which determine the relation between the increase of the number of wells and the growth of the natural gas output.

5. COST OF GAS CONVEYANCE

This cost is determined by the following factors:

a) length of pipes and their diameter;

b) the pressure at the mouth of the pipes and the pressure needed at the points of distribution, which call for the installing of compressor stations along the way or even in the gas-fields.

The conveyance costs (C_C) in relation to the growth of output shall be expressed in the formula:

$$C_C = (L + \Delta L)\, C_c + (Q_c + \Delta Q_c)\, C_g \qquad (5)$$

in which L = the length of the main pipe; C_c = the conveyance cost per 1,000 cu.m./km; Q_c = the quantity of compressed gas; C_g = the cost per cubic metre of gas compressed for conveyance.

If we consider that the increase of the length of pipes and of the quantity of gas compressed for conveyance are related to the growth of output, we, can mark:

$$\Delta L = k_4 \Delta Q \text{ and } \Delta Q_c = k_5 \Delta Q$$

and hence

$$C_C = (L + k_4 \Delta Q)\, C_c + (Q_c + \Delta Q k_5)\, C_g \qquad (5\ a)$$

k_4 and k_5 may vary commensurate to the growth of output; yet, for simplification, we shall consider them constant. Also, it can be admitted that

$$L = k_4\, Q \text{ and } Q_c = k_5\, Q$$

so that the formula (*5 a*) shall become:

$$C_C = k_4(Q + \Delta Q)\, C_c + k_5 (Q + \Delta Q)\, C_g \qquad (5\ b)$$

or

$$C_C = (Q + \Delta Q)\ (k_4\, C_c + k_5\, C_g) \qquad (5\ c)$$

the cost per 1,000 cu.m. gas conveyed ($Q + \Delta Q$ being expressed in 10^3 cu.m.) will be:

$p_t = \dfrac{C_C}{Q + \Delta Q} = k_4 C_c + k_5 C_g$ which, as is being noted, on the basis of the accepted principles, is constant irrespective of the output conveyed; this cost is however dependent on the length of pipe and the quality of compressed gas, which is mirrored in coefficients k_4 and k_5. If we take as example $k_4 = 0.4$ km/10^6 cu.m.; $k_5 = 1{,}000$ cu.m. compressed gas/10^6 cu.m.; $C_c = 30$ lei per annum, kilometer and 1,000 cu.m.; $C_g = 5$ lei per annum per 1,000 cu.m. of compressed gas, we shall have:

$$p_t = 17 \text{ lei/1,000 cu.m.} = 30 \times 0.4 + 5$$

However, generally the coefficients k_4 and k_5 are not constant, so that we could have drops or rises in the conveyance cost, in case of increased output.

6. TOTAL COST

The total cost, inclusive of conveyance expenses, in the case of the above example, will be computed upon the formula (*4 a*), to which the conveyance cost will be added (17 lei per 1,000 cu.m.) considered as constant.

The curve of the total cost is shown in Fig. 1, set off upon the data of table 2, to which 17 lei were added for conveyance.

$\frac{\Delta Q}{Q}$	p_c
0.0	47.33 lei/1,000 cu.m.
0.1	71.16 lei/1,000 cu.m.
0.2	87.40 lei/1,000 cu.m.
0.3	99.30 lei/1,000 cu.m.
0.4	108.60 lei/1,000 cu.m.

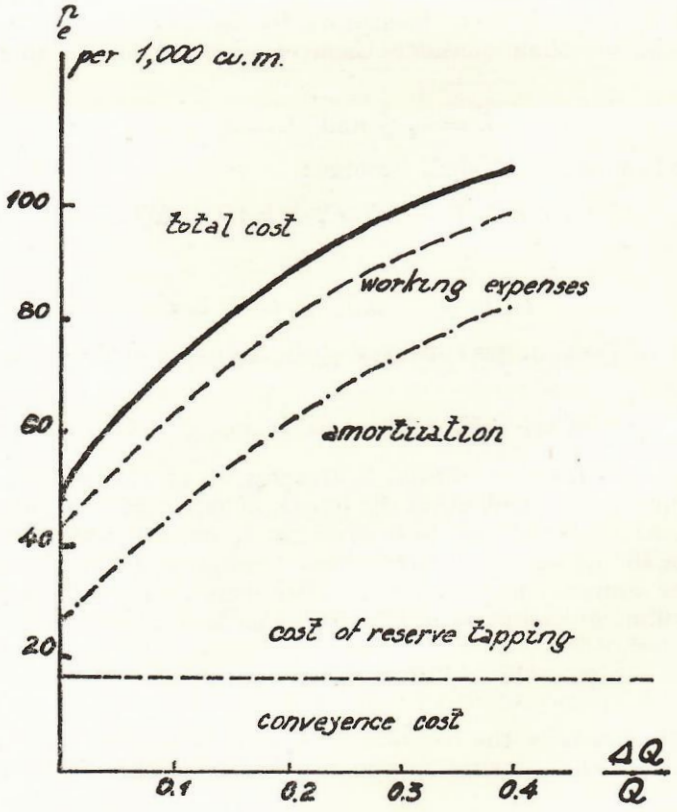

Fig.1.

In case a comparison is made with the cost of other fuels, it will be necessary to compute the costs per ton of conventional fuel, and not per 1,000 cubic metres.

II. SPECIFIC INVESTMENT

As a rule, the per branch specific investment can be considered a relation between the value of investment and the growth of annual output (capacity). Yet, bearing in mind the fact the investments ear-marked in a year do not contribute to the growth of output in the same year, it has become the practice of working out the specific investment for a greater number of years.

Consequently, the specific investment may be represented by the relation

$$s_i = \frac{\Sigma I}{\Sigma \Delta Q} = \frac{\Sigma I}{n \Delta Q} \qquad (6)$$

in which n = the analyzed interval

ΔQ = the anual average increase of output.

Actually, in the crude oil and gas extractive industry not all investments contribute to the increase of output; part of them are destined to the growth of reserves, while another part has to cover the decline, contributing in this way to keep the output level. That is why the value of investments must not be related to the growth of annual output but to the whole increase of the production capacity, expressed by the production of new wells, which serve both to cover the decline and to increase output.

With regard to the investments for the growth of reserves, we think that it must be taken into consideration in the computation only the investments needed to the increase of reserves, with the aim of maintaining the ensuring time-limit with reserves, and not the investments necessary to the increase of this time-limit. The following example established for crude oil, but which can be applied precisely to gas, shows the computation of investments according to these hypotheses.

Table 3

Computation of investment and output

	Q Annual extracted quantity (thousand tons)	of which		Investments for exploitation (million lei)	Investments for increasing reserves calculated with 40 lei per ton of output (million lei)
		Older wells * (thousand tons)	New wells		
Basic year	5,200	—	—	400	208
First year	5,400	4,700	700	500	216
Second year	5,600	4,860	740	600	224
Third year	5,800	5,040	760	800	232
Fourth year	6,000	5,220	780	1,000	240
Fifth year	6,200	5,400	800	1,200	248
Total 1—5	29,000	25,220	3,780	4,100	1,160

* We understand by older wells the wells existing on January 1st of each year.

Investments corresponding to the growth of output (the fifth year excluded, inclusive those of the basic year) 3,380 million

Investments necessary to replace the extracted reserves (established analogically) 1,120 million

Total investments for the recovery and increase of capacity 4,500 million

The increase of capacity will next be established, following the bringing into service of new wells:

Table 4

Computation of the production capacities
(thousand tons)

Output	Will produce in the years				
	1	2	3	4	5
1. From wells existing at the start of the period	4700	3880	3110	2420	1800
2. From new wells brought into service in:					
The first year	700	980	890	800	720
The second year	—	740	1040	940	850
The third year		—	760	1060	950
The fourth year			—	780	1080
The fifth year				—	800
Total annual output of which	5400	5600	5800	6000	6200
The output supplied by the new wells of the period (increase of production capacity)	700	1720	2690	3580	4400

Note: the output of the first year is estimated only for 180 days; the next year, these wells will produce for 360 days, but owing to decline, the output will be only twice the output of the first year.

Hence the wells existing at the start of the period drop their output from 4,700 thousand tons to 1,800 thousand tons after five years. The difference up to the output of 6,200 thousand tons in the last year of the period is covered by the wells brought into service in the course of five years, which will supply in the fifth year a 4,400-thousand tons output, this representing the increase of production capacity.

From this example, the specific investment per ton of increased capacity can be computed in one of the following variants:

— If we consider the increase of the annual output alone

$$\frac{4,500,000}{6,200 - 5,200} = 4,500 \text{ lei/t}$$

— If we consider the cumulated output of the new wells (held as new only in the year of their commissioning, according to table 3)

$$\frac{4,500,000}{3,780} = 1,190 \text{ lei/t}$$

— If we consider the output of last year given by the wells brought into service during the whole 5-year period

$$\frac{4{,}500{,}000}{4{,}400} = 1{,}023 \text{ lei/t}$$

In the opinion of the author, the third method is the best, because the whole increased capacity of these wells is taken into consideration. In this case, the specific investment is to be calculated on the basis of the relation

$$I_s = \frac{\Sigma I_R + \Sigma I_P}{\Sigma Q_n} \tag{7}$$

in which: ΣI_R = the value of investments necessary to the increase of reserves for keeping a constant ensuring factor.
ΣI_P = the investments for the exploitation drilling and the commissioning of the wells.
ΣQ_n = the annual output of the new wells, after n years.

In the formula (7) the investments necessary to the replacing of the extracted reserves will be:

$$\Sigma I_R = p_d \, \Sigma Q$$

in which: p_d = the cost per ton of tapped reserve, to which by introducing the value of p_d according to the formula (1), it results:

$$\Sigma I_R = \Sigma Q \frac{p_r}{n} \times \frac{k_1 + k_2 \dfrac{\Delta Q}{Q}}{1 + \dfrac{n-1}{2} \times \dfrac{\Delta Q}{Q}} \tag{7 a}$$

Knowing that:

$$\Sigma Q = nQ + \frac{n(n-1)}{2} \Delta Q = nQ \left(1 + \frac{n-1}{2} \times \frac{\Delta Q}{Q}\right)$$

We obtain:

$$\Sigma I_R = p_r Q \left(k_1 + k_2 \frac{\Delta Q}{Q}\right) \tag{8}$$

The investments for the drilling and endowment of wells with production equipment are being computed as follows:

$$\Sigma I_p = I_m N (n-1) \frac{\Delta N}{N} \tag{9}$$

The number of new wells brought into service over the whole period will be:

$$\Sigma \Delta N = (n-1) \, \Delta N$$

This has been computed in the hypothesis that the activity of the new wells proceeds with an average number (ΔN) of wells put into operation during the whole surveyed period n.

I_m is the average investment per new well put into operation, including both the drilling and endowment of wells with production equipment.

If we mark $\frac{\Delta N}{N} = k_3 \frac{\Delta Q}{Q}$, the total investments for the wells equipment will be:

$$\Sigma I_p = I_m N (n-1) k_3 \frac{\Delta Q}{Q} \qquad (9\ a)$$

Total Specific Investment

Taking into consideration the formulae (*8*) and (*9 a*) the total specific investment calculated per capacity of new wells, in the last year of period Q_n will be:

$$I_s = p_r \frac{Q}{\Sigma Q_n}\left(k_1 + k_2 \frac{\Delta Q}{Q}\right) + I_m \frac{N}{\Sigma Q_n} \times k_3 (n-1) \frac{\Delta Q}{Q} \qquad (10)$$

which expresses the specific investment in relation to the increase of output.

If we mark by D the annual average output per well, in the first year of the period, hence $N = \frac{Q}{D}$, the formula (*10*) becomes:

$$I_s = \underbrace{p_r \frac{Q}{\Sigma Q_n}\left(k_1 + k_2 \frac{\Delta Q}{Q}\right)}_{\text{I}} + \underbrace{\frac{I_m}{D} \times \frac{Q}{\Sigma Q_n} k_3 (n-1) \frac{\Delta Q}{Q}}_{\text{II}} \qquad (11)$$

in which the first term represents the investment for the increase of reserves, and the second term the investment necessary to the drilling and equipment of exploitation wells.

As it has been noted, the first term is affected by coefficients k_1 and k_2 which reflect the degree of ensurance (n_1 and n_2) of production with reserves, during the period n.

The level of the second term is determined by the annual average delivery per well (D) and by coefficient k_3, which shows the quality of new structures (deposits) brought into being. When the rate of increase of the number of wells is lower than the growth of production, this term will contribute to the lowering of the specific investment, concomitantly with the increase of production.

This formula of the specific investment may be applied both to crude oil and to free gas.

In the case of the extractive industry of free gas (methane) by using the data showed in the example calculated for the cost price, namely:

$$p_r = 10 \text{ lei/1,000 cu. m.}; \; k_1 = 5; \; k_2 = 135; \; n = 5$$

$$k_3 = 3.2; \; D = 15 \times 10^6 \text{ cu.m.}; \; I_m = 2.4 \times 10^6 \text{ lei}$$

the specific investment for an 1,000 cu.m. increase of capacity due to new wells is obtained

$$I_s = \underbrace{10 \frac{Q}{\Sigma Q_n}\left(5 + 135 \frac{\Delta Q}{Q}\right)}_{\substack{\textit{investments for rising} \\ \textit{reserves}}} + \underbrace{\left(\frac{2.4}{15} \times 1{,}000 \times 12.8 \frac{\Delta Q}{Q}\right) \times \frac{Q}{\Sigma Q_n}}_{\substack{\textit{investments for} \\ \textit{exploitation}}} \qquad (12)$$

which will be the more reduced, the lower is the relation $\frac{Q}{\Sigma Q_n}$ and, consequently, the last year's contribution of the new wells (ΣQ_n) brought into service during the period will represent a higher proportion in the total output of the first year (Q).

If we consider $\frac{Q}{\Sigma Q_n} = 2$ which is supposed to be constant for all the values of $\frac{\Delta Q}{Q}$ the specific investment can be calculated, in the given conditions, in relation to the increase of output as against the basic year, as follows:

$$I_s = 100 + 6{,}800 \frac{\Delta Q}{Q}$$

expressed in lei per 1,000 cu.m. increase of annual output supplied by the new wells.

The specific investment is a linear function in relation to the increase of output, which however varies according to annual delivery and coefficient k_3 in each region.

In the conditions shown by the accepted figures, the specific investment per 1,000 cu.m of increased capacity will vary according to the growth of output, as follows:

$\frac{\Delta Q}{Q}$	I_s lei/1,000 cu.m.	of which:	
		for reserve tapping	for exploitation
0.0	100	100	—
0.1	780	370	410
0.2	1460	640	820
0.3	2140	910	1230
0.4	2820	1180	1640

The curve in Fig. 2 has been worked out on the basis of these data.

It stands to reason that such high rates of increase cannot be conceived year after year. The figures, however, show how very important investments must be ear-marked when a high rate of increase of gas output is planned.

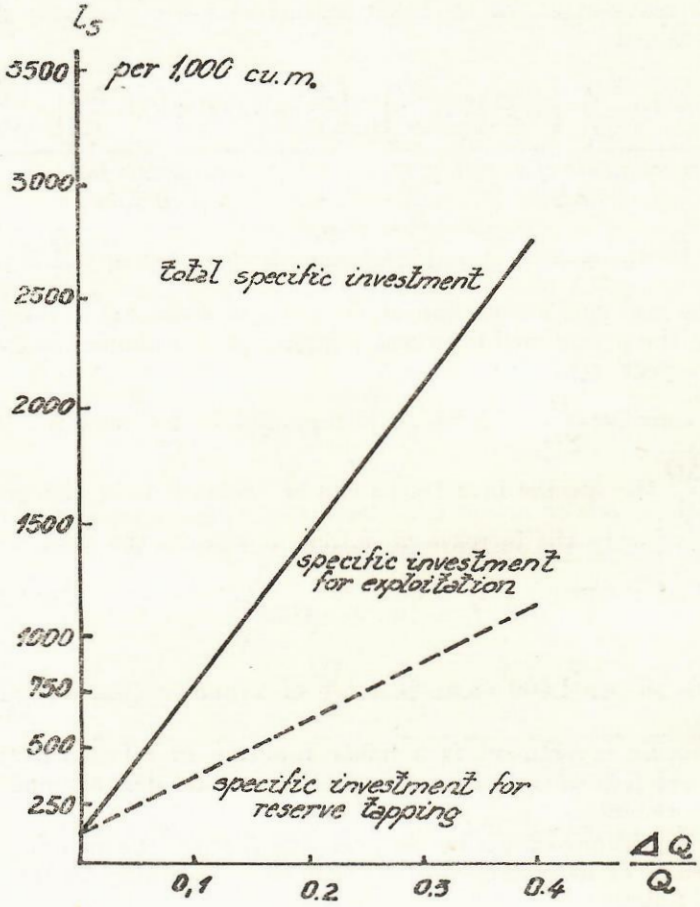

Fig. 2

Of course, it would be interesting to establish for each geological zone the formula of increase of the specific investment and the characteristic indicator, especially the k_3 coefficient and the annual average delivery of wells (D) which, as seen above, has an important role in establishing the level of both cost price and specific investment.

These formulae could next serve to the elaboration of the mathematical model needed by the optimization calculus of the crude oil and gas output level in the conditions of a region or country, having as objective a minimum of cost price or specific investment.

In setting out the mathematical formula of variation of the cost price and the specific investment for crude oil and gas, we shall be able to approach the optimization of the balance of primary energy per ton of conventional fuel, for coal and other resources of primary energy, in relation to the increase of output, determining for each period the optimum proportion of various resources of primary energy, which will be conducive to the lowest cost or lowest specific investment per ton of conventional fuel.

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RELATIONS GENERALES ENTRE L'AUGMENTATION DE LA PRODUCTION DE GAZ NATUREL D'UN PAYS (D'UNE REGION), LE NIVEAU DU PRIX DE REVIENT ET LES INVESTISSEMENTS SPECIFIQUES

Cet article analyse les groupes de dépenses les plus importants qui déterminent le prix de revient du gaz, établissant une relation entre l'augmentation de la production de gaz et le niveau du prix de revient.

On montre ainsi l'influence du coût des travaux géologiques sur le prix de revient du gaz et on étudie deux variantes: la première, dans les conditions d'un terme constant pour assurer des réserves à la production, et la seconde, dans les conditions où ce terme augmente.

Afin de déterminer l'influence de l'investissement spécifique et,par conséquent, de l'amortissement sur le prix de revient, parallèlement à l'augmentation de la production, on établit sertaines formules générales de calcul, qui sont applicables par zone géologique ou par pays.

Les dépenses d'exploitation sont également analisées en rapport avec l'agumentation de la production, des formules générales étant établies, applicables dans l'industrie d'extraction du gaz méthane.

En ce qui concerne le transport du gaz on propose une formule qui tient compte de la longueur des conduits de transport et de la pression dans ces conduits, nécessaire pour l'alimentation des consommateurs.

Finalement, on établit des formules générales pour le calcul du prix de revient et pour l'investissement spécifique, qui contiennent, comme variable, l'indice d'augmentation de la production.

Afin de faciliter la compréhension et le mode d'application des formules on emploie une série de données pouvant être rencontrées dans la pratique.

ОБЩИЕ СООТНОШЕНИЯ МЕЖДУ РОСТОМ ДОБЫЧИ НАТУРАЛЬНОГО ГАЗА В ДАННОЙ СТРАНЕ (ИЛИ РАЙОНЕ), УРОВНЕМ СЕБЕСТОИМОСТИ И СПЕЦИФИЧЕСКИМИ КАПИТАЛЬНЫМИ ВЛОЖЕНИЯМИ

В работе анализируются главные группы расходов, определяющие себестоимость газов и устанавливается соотношение между ростом добычи газа и уровнем себестоимости.

Так, например, указывается влияние стоимости геологических работ на себестоимость газа и рассматриваются два варианта: первый, в условиях неизменяющегося срока обеспечения производства запасами газа и второй, — в условиях роста этого срока.

Для определения влияния, оказываемого специфическими капитальными вложениями и, следовательно, амортизации на себестоимость по мере роста продукции, устанавливается ряд общих вычислительных формул, которые могут быть применены либо по геологическим зонам, либо по странам.

Также в соотношении с ростом продукции анализируются и расходы по геологической разведке и устанавливаются общие формулы, применимые в промышленности добычи газа метана.

Что касается доставки газа, предлагается формула, учитывающая длину газопроводов и давление в газопроводе, необходимое для снабжения газом потребителей.

В конечном разделе работы устанавливаются общие формулы для вычисления себестоимости и специфического капитального вложения, в которых переменной величиной является индекс роста производства продукции.

С целью облегчения понимания формул и способа их применения, приводится ряд данных, встречающихся на практике.