AN EMPIRICAL APPROACH ON LABOUR COSTS FOR OIL FIELD DEVELOPMENT PLANNING

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ABSTRACT

In planning the development of an oil reservoir, the guidelines should be the annual production targets for a five-year period and for the year when development is scheduled to reach its peak. The production targets must be coordinated with the planned development of the oil industry as a whole.

The planned oil production targets for the industry as a whole must be apportioned between different oil-bearing areas and different fields within an area. The development plan for each field should ensure the most efficient production, i.e, at the lowest possible cost.

The recommended procedure is first to have a wide grid of wells so as to get a better idea of the reservoir and to finalise the spacing of the planned wells.

I. INTRODUCTION

In planning a reservoir development system, several variants of well and row patterns must be considered, the spacing of which is justified by geological and technological considerations (starting with one hectare per well in a non homogeneous solution-gas drive reservoir to 60 hectares per well in a homogeneous water-drive reservoir)[1].

The plan should provide for 10-15 % margin in the number of wells. These wells should be drilled in the later exploitation stages to recover as much of the oil as possible.

In the case of a homogeneous reservoir the well pattern will be thickest in the central part of the reservoir towards which the oil will ultimately be driven. In a nonhomogeneous reservoir the pattern will be thickest in areas where unrecovered oil has been retained due to the specific geological features of the formation [2].

In order to select the final variant of reservoir development, the variants must be compared so as to establish the one that offers the biggest economic and technological advantages.

II. THE CONCEPT OF RESERVOIRS

The concept of reservoir development efficiency embraces a whole complex of factors, of which the principal ones are:

1. The rate of development needed to meet the field production demand for oil,
2. Oil recovery factor,
3. Material and labour costs.

A. *Rate of Reservoir Development.*

The industry demand for petroleum pruducts keeps increasing and so measures must be taken to speed up production, which in turn, calls for accelerated reservoir development.

However, the shorter productive life of a reservoir the greater is the capital expenditure required. Therefore, most thorough consideration must be given to the problem of establishing the optimum productive life [3].

The productive life of a reservoir is a function of such factors:

a. The planned rate of oil production increase,
b. The geological-technical and economic conditions of a given reservoir,
c. The amount of prospected reserves, their geological location and readyness for development,

d. The technological level of oil production.

By using pressure maintenance methods, the productive life can be shortened and greater withdrawals can be maintained.

Pressure maintenance operation can ensure rapid influx to the wells even when free flow has ceased. Therefore , in many cases, subsurface pumping operations can be applied with good effect [4].

The use of subsurface electrical high-capacity pumps is most advantageous in reservoirs with high free flow pressure.

The pressure gradient between the injection and producing zones can also be increased, to increase the rate of withdrawals, by reducing the bottom-hole pressure in the producing wells by 10-15 % below the saturation pressure.

Then the area in which gas is liberated from solution will be small and, consequently, degassing will not affect the final recovery factor.

In establishing the rate of development attention must also be paid to the magnitude of pressure gradients established in the water-oil contact zone and in sections of low permeability.

The pressure gradients ensuring the highest possible recovery factor are ascertained by laboratory methods and on the basis of field data [5].

B. *Oil Recovery Factor*

In heterogeneous reservoirs the oil recovery factor increases with closer well spacing. This, however, increases development costs. Successful development methods permit 60-70 % oil recovery.

The thickness of the well grid may be ascertained through a detailed study of geological structure of the reservoir.

In development planning, it is necessary to provide, as a margin, a certain number of wells to be drilled at positions determined in the light of new geological evidence [5].

C. *Material and Labour Costs*

Material and labour costs are determined during the planning stages such as:

a. Determining the relative importance of the reservoir in total field production,

b. Apportioning the production of the whole given area between the various reservoirs it comprises,

c. Drawing up the technical plan for the development of a given reservoir to meet the planned production targets.

In planning the development of an oil reservoir the guidelines should be the annual production targets for a five-year period and for the year when development is scheduled to reach its peak [1]. The production targets must be coordinated with the planned development of the oil industry as a whole.

The planned oil production targets for the industry as a whole must be apportioned between different oil-bearing areas and different fields within an area. The development plan for each field should ensure the most efficient production, i.e., at the lowest possible cost. In formulating the economic characteristics of different development plans, the following factors should be considered such as:

- Labour productivity,
- Capital investment,
- Operating costs,
- Production costs.

1. Labour Costs

Labour costs are subdivided as follows:

- Drilling labour costs
- Oil-field operation labour costs
- Pressure maintenance operations labour costs
- Utilities labour costs
- Construction labour costs

a. Drilling Labour Costs

The calculation of labour costs for drilling producing, injection and test wells is based on the dependence between the cost of drilling 1,000 metres and the drilling speed. The higher the commercial drilling speed, the lower the labour costs per 1,000 metres [1]. An empirical expression for the relationship between the labour costs per 1,000 metres (man-year) and the commercial rate of drilling (metres/rig-month) is:

$$Y = 21{,}850\ Cdr^{-1.2} \quad \text{.................................} \quad (2.1)$$

where :

Y = number of workers per 1,000 metres drilled in a man-year,

Cdr = commercial drilling rate, metres/rig/month.

The starting point for computing drilling labour costs is the number of producing, test, and injection wells and their depth.

From the reckoned drilling speed the index of labour required per 1,000 metres of wells drilled is found. This is multiplied by amount of drilling required for each development plan which determines the drilling labour costs.

After the amount of the labour required in other departments (electrical shop, automotive transport, plugging, erection, housing and utilities department and others) is determined.

The labour costs of these services amount to 60 % of the labour employed in the drilling division. The labour costs of the technical, administrative and other personnel are calculated on the basis of factor indicating the ratio between the number of employees in these categories and the total personnel of a given trust.

The labour costs of the technical administrative and other personnel are determined by multiplying the labour costs of the drilling personnel by a factor of 0.154. Drilling labour costs are the sum of the costs given above.

b. Oil-field Operation Labour Costs.

The number of workers required varies depending on the thickness of the well grid. The wider the spacing the greater the relative amount of labour required per well and, therefore, the greater per-well labour costs.

An empirical expression of the dependence between the number of oil-field workers (Y) per well and the free area of the field (F) per well in hectares may be presented as:

$$Y = 0.543\ F^{0.434} \qquad \text{...................................... (2.2)}$$

On the basis of average statistical data, the engineering technical staff and other personnel amount to 10% of the total number of field workers.

c. Labour Costs in Reservoir Pressure Maintenance Operations.

The number of workers employed per injection well in the reservoir pressure maintenance division may be determined from the following empirical formula:

$$Y = \frac{41}{Ninj} + 3 \qquad \text{... (2.3)}$$

where:

Y = specific amount of labour,

Ninj = number of injection wells.

In pressure maintenance operations the technical personnel amount to 12% of total labour.

d. Labour Costs in Auxiliary Departments

The componen of this labour will include: electricity, water treatment, supply department, machine shops, warehouses, overhaul shop, control and measuring instrument, construction and erection, motor transport, housing, and utilities departments [1].

The dependence between the number of workers employed in the services in field operation and in the pressure maintenance operations (K) and the total number of operating wells (N) may be determined from the empirical relationship:

$$K = \frac{1}{0.000388\ N + 0.478} \qquad \text{............................. (2.4)}$$

Field experience shows that technical staff should amount to 25 % of the total number of workers in the auxiliary departments.

e. Labour Costs in Construction and Erection Departments

Labour costs are determined on the basis of capital investment in construction. Field experience the construction and erection labour costs are about 62 % of the total construction labour costs.

To determine labour productivity, all the labour costs (Item a through e must be summarized).

2. Determining Capital Investment

The breakdown of capital investment is as follows :

1. drilling and producing wells,
2. field facilities,
3. drilling of injection wells,
4. flooding facilities (these costs depend mainly on the number of injection wells, and their pattern),
5. auxiliary facilities (generator and power, electrical department, automotive transport, etc),
6. housing and public amenities,
7. road construction,
8. water supply and treatment.

The item 5 to 8 do not depend on the development plan and are practically the same for all the variants of

Table 2.1
Relationship between K and F.
(Predicion in 1956)

F (Hectares/Well)	K (US Dollars
10	25,000
12	26,000
15	28,000
20	30,000
30	35,000
40	40,000
50	45,000
60	50,000

the development plan. The costs of drilling production and injection wells depend on the depth of the formation, the type of wells, and the drilling conditions in a given area.

The construction of field facilities depends on well pattern density. The density of the spacing determines the length of the discharge lines, the number of measuring tanks and traps, and the oil-tankage capacity.

The relationship between the capital investment into facilities K and the area per well F is given in the Table 2.1 on the basis of data from oil fields in general. (Prediction in 1956) [(1)]

Investment in flooding facilities includes the following items:

1. water intake facilities,
2. water pumping and conditioning plan,
3. water mains,
4. pumping stations serving clusters of wells,
5. distribution mains.

Investment into water flood facilities may be determined using the formula:

$$Kw = \frac{954}{(Ninj)^{0.5}} \quad \text{..} \quad (2.5)$$

where:

Kw = capital investment per well, hundred of thousands US dollars,

Ninj = number of injection wells.

Capital investment appears in the production costs in the form of depreciation calculated against a well life of 15 years. Sometimes capital investment is depreciated against the whole productive life.

3. Determining Operation and Production Costs

The total costs of marketable production can be determined from the following groups of cost items [(1)] :

Group-I: Well maintenance costs, which depend on the number of wells and their spacing. This group includes:

a. wages of production personnel and social insurance contributions (8% of the wages),
b. expenditure on well maintenance,
c. overhead charges.

Depending on the number of wells in field N, well maintenance costs (Y_1) in hundreds US dollars, are determined using formula :

$$Y_1 = 530{,}000\ N^{0.5} \quad \text{......................................} \quad (2.6)$$

Group-II : Costs depending on the current rate of oil production.

This group includes oil pumping and storage costs. Depending on the current rate of oil production (Q) in tons, the costs (Y_2) in US dollars for pumping one ton of oil are determined using the following formula :

$$Y_2 = 0.53\ Q^{-0.567} \quad \text{..} \quad (2.7)$$

Group-III : Costs depending on the quantity of working agent injected into the reservoir and on the number of injection wells.

These costs are connected with measures needed to increase recovery (mainly by means of pressure maintenance projects).

The costs (Y_3) in US dollars per 1 (one) cubic meter of water depending on the volume (V) in millions of cubic meters injected are determined from the formula:

$$Y_3 = 1.4\ V^{-0.758} \quad \text{..} \quad (2.8)$$

Group-IV : Cost depending on the number of producing wells in a reservoir (or its area), expressed as overall field cost.

The overall field costs (Y_4) in hundreds of US dollars per well per year depending on the field area (F) in hectars per well are determined using equation:

$$Y_4 = 7{,}676\ F^{0.3543} \quad \text{.......................................} \quad (2.9)$$

Group-V: Depreciation of well and other fixed capital. Depreciation of the initial cost of wells Dpw is determined using the formula:

$$Dpw = Cpw. \frac{M}{E\,M} \quad \text{....................................} \quad (2.10)$$

where:

Cpw = cost of all the producing wells,

M = number of well/years in a stage,

EM = total productive life of a reservoir in term of well/years.

The same expression may be applied to determine depreciation for injection wells. The costs of major well overhauls and also of the repair of any equipment are determined from the relationship:

$$Kpw = M.Cpw.H \quad \text{....................................} \quad (3.11)$$

where:

Kpw = cost of major overhaul,

H = standard allocations for major overhauls.

Group-VI: Demulsification costs.

These depend on the amount of fluid handled and other factors.

To determine oil production costs, it is necessary to add depreciation and current expenditures and devide the result by the ultimate recovery. Such calculations are made for all different development plans (different row and well spacing, different injection front and producing well bottom-hole pressure).

The variant giving the optimal overall characteristics (recovery, producing life, and production costs) is then chosen.

III. CONCLUSIONS

* The shorter productive life of a reservoir the greater is the capital expenditure required.
* In heterogeneous reservoirs the oil recovery factor increases with closer well spacing.
* The well spacing depends upon geological and economic considerations, the wider the spacing the greater the relative amount of labour required per well and therefore, the greater the labour costs per well.
* The higher the commercial drilling speed, the lower the labour cost per 1000 metres.
* By using pressure maintenance methods, greater withdrawals can be maintained.
* The production targets must be coordinated with the planned development of the oil industry as a whole.

NOMENCLATURES

Cdr = Commercial Drilling Rate, metre/rig/month

Cpw = Cost of all producing wells

Dpw = Depreciation cost of well, US dollars

EM = Total productive life of a reservoir, well/year

F = the field area per well, ha/well

H = Standard allocation for major overhaul

K = Pressure maintenance operation costs

Kpw = Cost of major overhaul

Kw = Capital investment per well, US dollars

M = Total well per year in a stage

N = Total producing wells

Ninj = Total of injection wells

Q = Current rate of oil, tons

V = Volume of water injected, million of cubic meters

Y = Total of personels per 1000 meters drilled, man/year

Y_1 = Well maintenance costs, US dollars

Y_2 = Costs of pumping 1 ton of oil, US dollars

Y_3 = Costs per 1 cubic meter of water

Y_4 = Overall field costs, US dollars/well/year

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