Technical and Economic Evaluation of Drainage Gas Recovery

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Abstract

For grasping the choice and input of drainage gas recovery technology scientifically and foreseeingly and improving economic efficiency, the feasibility of technical and economic evaluation must be demonstrated before technology put into production. Foam drainage, gas lift drainage and pumping drainage are comprehensively introduced in the paper, feasibility analysis and economic evaluation of scheme design are demonstrated, and finally computational formula and discriminant are proposed. And then the following factors are computed: stimulating cost, daily gas production, injection-withdrawal ratio, predicted stimulating gas volume of foam drainage technology, minimum check-valve period and payback period. After that formula and discriminant which are adopted to judge whether the old wells are worth continue operation are analyzed, and they are demonstrated by actual application with computational example being listed.

Keywords

Foam unload; Gas lift; Pumping; Drainage Gas Recovery; Economic Evaluation; Calculation Formula.

1. Introduction

For grasping the choice and input of drainage gas recovery technology scientifically and foreseeingly and improving economic efficiency, the feasibility of technical and economic evaluation must be demonstrated before technology put into production. The primary coverage of feasibility demonstration method is prediction and evaluation of economic effect.

Gas well exploitation will get through flow production period and drainage gas recovery is operated only in some phase after formation water produced, so the cost of drainage gas recovery technology is divided into 2 parts: nonprocess and process cost [1-3]. Nonprocess cost includes routine operating cost of gas recovery (labor, material, dynamic consumption, routine maintenance, etc.), depreciation cost of gas well construction and mating construction, lending interest, maintenance cost of oil field, administration cost, tax, etc. And process cost includes cost added by operating drainage technology.

For flowing wells in the same gas reservoir or block or fracture network in a gas field, their cost is basically the same, but process cost is different. So the basic method is to combine and compute the technological objective parameters and cost, then make breakeven judgment of drainage gas recovery on single well. The computation and evaluation methods of some typical drainage technology are introduced as follows [1-5].

2. Foam drainage technology

Most of foam drainage technology wells are of flowing capacity, but for gas-water producing wells with poor water carrying capacity, there is generally of low water production rate. So after foam unload technology put into production, the amplification of absolute value for water production rate is not so much. And technological production cost mainly comprises medicament cost (including foaming agent and antifoam agent) and injection cost [1-4, 6].

2.1 Cost calculation

Total cost =nonprocess cost + medicament cost +injection cost--------(1)

Stimulating cost: $\mathrm{E} = \mathrm{A} + \mathrm{B} + \mathrm{C}$--------(2)

In formula (2): E-total cost of stimulating 1m^3 of gas, yuan/m^3; A-nonprocess cost, the average production cost of similar wells in the same gas reservoir or gas field when blowing, yuan/m^3; B-medicament cost (yuan/m^3), $\mathrm{B} = B_1/q_{g1}$; B$_1$-daily consumed medicament cost, yuan /d; C-injection cost, yuan/m^3; $\mathrm{C} = \left[\frac{S_1}{330}\left(\frac{1}{N}+\frac{r}{100}\right)+S_2\right]/q_{g1}$.

So formula (2) E is :

$\mathrm{E} = \mathrm{A} + \frac{B_1}{q_{g1}} + \frac{1}{q_{g1}}\left[\frac{S_1}{330}\left(\frac{1}{N}+\frac{r}{100}\right)+S_2\right]$--------(3)

Breakeven discriminant: E<e, profit; E>e, deficit--------(4)

Derived by formula (2) and formula (3), formula (5) is obtained.

If $q_{g1} > [B_1 + \frac{S_1}{330}\left(\frac{1}{N}+\frac{r}{100}\right) + S_2]/(e-A)$--------(5)

It is profit, or deficit.

In formula (5): q_{g1}-average daily gas production in prediction period, m^3/d, obtained by the following formula (8); S_1-construction investment of injection equipment, yuan; S_2-operating cost of injection, including routine manual, traffic and maintenance cost, yuan/d; r-lending rate, %/a; N-period of depreciation for fixed assets (injection equipment), a; 330-annual production time of wells, d/a; e-price of gas, yuan/m^3.

2.2 Payback period

Referring N in formula (3) as unknown term, payback period can be computed:

$\mathrm{T} = S_1/[330q_{gl}(E - A - \frac{B_1}{q_{g1}} - \frac{rS_1}{33000q_{g1}} - \frac{S_2}{q_{g1}})]$--------(6)

In formula (6): T-payback period, a.

2.3 q_{g1} and stimulating effect prediction

Foam wells are blowing wells, so if declining rate known, stimulating gas volume after foam drainage technology can be predicted:

Stimulating gas volume in 1^{st} year $= 330q_gb(1-a_1)$

Stimulating gas volume in 2^{nd} year $= 330q_gb(1-a_1)(1-a_2)$

Stimulating gas volume in n^{th} year $= 330q_gb(1-a_1)(1-a_2)\cdots(1-a_\mathrm{n})$

N-year cumulative stimulating gas volume:

$Q_n = 330q_gb[(1-a_1)+(1-a_1)(1-a_2)+\cdots\cdots+(1-a_1)(1-a_2)\cdots(1-a_\mathrm{n})$-------(7)

n-year average daily gas production:

$q_{g1} = \frac{q_g}{n}b[(1-a_1)+(1-a_1)(1-a_2)+\cdots\cdots+(1-a_1)(1-a_2)\cdots(1-a_\mathrm{n})]$-------(8)

$\mathrm{n} -$ year stimulating value $= \mathrm{e}Q_n$-------(9)

$\mathrm{n} -$ year net added value $= (\mathrm{e}-\mathrm{E})Q_n$-------(10)

In the above formulas: b-prediction stimulation ratio after foam drainage technology, dimensionless; n-year after foam drainage technology, 1, 2, 3, ⋯; a$_1$, a$_2$, a$_3$, ⋯a$_n$-annual average declining rate; q_g-daily gas production before technology implementation, m^3/d; Q_n-cumulative stimulating gas volume, m^3.

3. Gas lift drainage technology

3.1 Cost

Total cost: $\mathrm{E} = \mathrm{A} + \mathrm{B} + \mathrm{C} + \mathrm{D} + \mathrm{S}$--------(11)
In formula (11): A-nonprocess cost, yuan/m^3; B-high-pressure injection cost per m^3 of high-pressure gas, yuan/m^3; C-processing cost of formation water, yuan/m^3; D-operation cost, the downhole operation cost per m^3 of gas, yuan/m^3; S-depreciation cost of fixed assets per m^3 of gas produced.
$\mathrm{B} = B_1/(q_z/q_{g1})$ --------(12)
In formula (12): B_1-gas lifting cost per m^3 of high-pressure gas by compression pump, yuan/m^3; q_z/q_{g1}-injection-withdrawal ratio, m^3/m^3; q_z-average gas injection volume of gas lift in predicted period, m^3/d; q_{g1}-average daily gas production in predicted period, m^3/d, referring formula (5).
$\mathrm{C} = C_1(q_w/q_{g1})$--------(13)
In formula (13): C_1-processing cost of formation water, yuan/m^3; q_w/q_{g1}-water/gas ratio of withdrawal wells, m^3/m^3; q_w-daily water production rate in predicted period, m^3/d.
In every check-valve period, the operation cost and lending interest should be called in, so:
$\mathrm{D} = \frac{D_1}{(n-m)q_{g1}}[1 + \frac{nr}{36500}]$--------(14)
In formula (14): D_1-single operation cost of publishing gas uplifting operation or checking valve and lending interest before drainage technology put into production, yuan; n-cycle of check-valve operation, d; m-average time dilatation occupied by single operation and off production, d; n-m-the exemption period of production, d; r- lending rate, %/a.
$\mathrm{S} = \frac{nS_1}{365N(n-m)q_{g1}}[1 + \frac{rN}{100}]$--------(15)
In formula (15): S_1-capital investment, including all mating construction investment added by gas uplifting operation, such as gas lifting pipeline, processing system of formation water, etc., and the sum of lending interest before drainage technology put into production, yuan; N-depreciation period of fixed assets, a; $\frac{n-m}{n}$-time correction coefficient, the number of working day = number of calendar day$\times\frac{n-m}{n}$.
So the total cost E is:
$\mathrm{E} = \mathrm{A} + B_1\left[\frac{q_z}{q_{g1}}\right] + C_1\left[\frac{q_w}{q_{g1}}\right] + \frac{D_1(1+\frac{nr}{36500})}{(n-m)q_{g1}} + \frac{nS_1(1+\frac{rN}{100})}{365N(n-m)q_{g1}}$--------(16)
Breakeven discriminant: E<e, profit; E>e, deficit--------(17)

3.2 Daily gas production

Derived by formula (11) and formula (16), formula (5) is obtained.

If $q_{g1} > \frac{\frac{D_1}{(n-m)}(1+\frac{nr}{36500})+\frac{nS_1}{365N(n-m)}(1+\frac{rN}{100})}{e-[A+B_1\left(\frac{q_z}{q_{g1}}\right)+C_1(\frac{q_w}{q_{g1}})]}$--------(18)

It is profit, or deficit due to very small daily gas production.

3.3 Injection-withdrawal ratio

If $\left(\frac{q_z}{q_{g1}}\right) < \left\{e - \left[A + C_1\left(\frac{q_w}{q_{g1}}\right) + \frac{D_1}{(n-m)q_{g1}}\left(1 + \frac{nr}{36500}\right) + \frac{nS_1}{365N(n-m)}\left(1 + \frac{rN}{100}\right)\right]\right\}/B_1$---(19)

It is profit, or deficit due to too much injected gas volume needed to produce per m^3 of gas.

3.4 Payback period

The payback period of fixed assets and downhole operation (T) after drainage technology put into production can be derived:

$\mathrm{T} = \frac{nS_1}{365N(n-m)} \times EA_1$--------(20)

$EA_1 = 1/\{\mathrm{e}q_{g1} - \mathrm{A}q_{g1} - B_1 q_{g1}\left(\frac{q_z}{q_{g1}}\right) - C_1 q_w - \frac{D_1}{(n-m)}\left(1 + \frac{nr}{36500}\right) - \frac{nrS_1}{36500(n-m)}\}$-------(21)

3.5 Minimum check-valve period (n)

Under the circumstances that no depletion for gas uplift technology, the minimum check-valve period (n) can also be derived:

$\mathrm{n} = \frac{m \times eA_1 + \frac{D_1}{q_{g1}}}{eA_1 - \frac{D_1 r}{36500 q_{g1}} - \frac{S_1}{365N q_{g1}}(1+\frac{rN}{100})}$--------(22)

In formula (22): $eA_1 = e - A - B_1\left(\frac{q_z}{q_{g1}}\right) - C_1\left(\frac{q_w}{q_{g1}}\right)$--------(23)

4. Pumping drainage technology

4.1 Cost

Total cost: $\mathrm{E} = \mathrm{A} + \mathrm{B}_1 + \mathrm{B}_2 + \mathrm{C} + \mathrm{D} + \mathrm{S}$--------(24)

In formula (24): B_1-labor cost per m^3 of gas produced, yuan/m^3; B_1-dynamic and other cost per m^3 of gas produced, yuan/m^3; C-processing cost of formation water, yuan/m^3; D-operation cost, the downhole operation cost per m^3 of gas, yuan/m^3; S-depreciation cost of fixed assets per m^3 of gas produced; C, D and S refer to formula (11).

$\mathrm{B}_1 = \frac{nxy}{365(n-m)q_{g1}}$--------(25)

In formula (25): x-number of workers on single well pumping technology; y-average cost per worker per year, yuan/per man.

$\mathrm{B}_2 = \frac{0.002724 r_w HG q_w}{\eta q_{g1}}(1 + b_1)$--------(26)

In formula (26): r_w-relative density of liquid; H-total delivery head of pumping and drainage system, m, H=delivery head of pump +that of surface petroleum pump; G-the price per kilowatt hour, yuan/kWh; η-total energy efficiency of the system; b_1-the ratio of other consumption cost (material, maintenance, etc.) and dynamic consumption cost, gained from technology type and empirical data.

So the total cost E is:

$\mathrm{E} = \mathrm{A} + \frac{nxy}{365(n-m)q_{g1}} + \frac{0.002724 r_w HG q_w}{\eta q_{g1}}(1 + b_1) + C_1\left(\frac{q_w}{q_{g1}}\right) + \frac{D_1}{(n-m)q_{g1}}\left(1 + \frac{nr}{36500}\right) + \frac{nS_1}{365N(n-m)q_{g1}}\left(1 + \frac{rN}{100}\right)$--------(27)

Breakeven discriminant of total cost: E<e, profit; E>e, deficit--------(28)

4.2 Daily gas production

Derived by formula (27) and formula (28), formula (29) is obtained.

If $q_{g1} > \frac{\frac{nxy}{365(n-m)} + \frac{0.002724 r_w HG q_w}{\eta}(1+b_1)}{e-A} + \frac{C_1 q_w + \frac{D_1}{(n-m)q_{g1}}\left(1+\frac{nr}{36500}\right) + \frac{nS_1}{365N(n-m)}\left(1+\frac{rN}{100}\right)}{e-A}$--------(29)

It is profit, or deficit due to very small daily gas production.

4.3 Payback period

The payback period of fixed assets and downhole operation (T) after drainage technology put into production can be derived:

$\mathrm{T} = \frac{nS_1}{365 \times (n-m)} \times EA_2$--------(30)

$EA_2 = 1/[\mathrm{e}q_{g1} - \mathrm{A}q_{g1} - \frac{nxy}{365(n-m)} - \frac{0.002724 r_w H G q_w (1+b_1)}{\eta} - C_1 q_w - \frac{D_1}{(n-m)}\left(1 + \frac{nr}{36500}\right) - \frac{nrS_1}{36500(n-m)}]$-------(31)

4.4 Minimum check-valve period (n)

$\mathrm{n} = (m \times eA_2 + \frac{D_1}{q_{g1}})/[eA_2 - \frac{\mathrm{xy}}{365 q_{g1}} - \frac{D_1 r}{36500 q_{g1}} - \frac{S_1}{365 N q_{g1}}(1 + \frac{rN}{100})]$--------(32)

In formula (32): $eA_2 = e - A - \frac{0.002724 r_w H G q_w}{\eta q_{g1}}(1 + b_1) - C_1\left(\frac{q_w}{q_{g1}}\right)$--------(33)

5. Application demonstration and analysis

(1) No matter the computation formula of gas uplift or that of pumping technology, the parameters include technological objective parameters (such as q_{g1}, q_z, q_w, n, m, H and η), cost parameters (such as A, B_1, b_1, D_1, S_1, x, y and G), parameter of physical property r_w and lending interest r. And all the parameters are necessary for the same kind of technology which is also of the same formula composition. So the formula of gas uplift is feasible to gas uplift, gas jet pump and plunger gas uplift, called “the gas-lift-type formula”; the formula of pump is feasible to deep well pump, electric submersible pump, hydraulic jet pump, hydraulic piston pump and progressive cavity pump, called “the pump-type formula”.

(2) Study and implementation results on engineering should display the economic effect, and the discriminant suggest that to cut the cost should lower A, B_1, b_1, D_1, S_1, m, $\frac{q_z}{q_{g1}}$, $\frac{q_w}{q_{g1}}$, x, y and increase q_{g1}, n and η.

(3) Taking some parameters of the discriminants as variables and other parameters as known constants, sensitiveness of the parameters to E, q_{g1}, T or $\frac{q_z}{q_{g1}}$ is analyzed. Computing example is as follows:

For a drainage technology well with new pump, known that A=0.4, C_1=3.5, D_1=250000, G=0.45, H=1600, N=10, m=10, x=4, y=20000, b_1=0.05, η=0.4, r_w=1.0, q_w=50, S_1=900000, r=10, e=0.65.

By formula (27), (29) and (31), the relationship of check-pump period with cost E, q_{g1} and payback period T is showed in Table1.

Table1 the relationship of check-pump period with cost E, q_{g1} and payback period T

n (d)	180	270	365	730	1095	Fixed value
E (yuan/m^3)	0.673	0.620	0.594	0.557	0.545	q_{g1}=10000, N=10
q_{g1} (yuan/m^3)	10925	8825	7764	6285	5803	N-10
T (a)	83.36	4.65	3.11	2.12	1.92	q_{g1}=10000

It is obvious that high cost for the short check-pump period, required gas production rate being high, the payback period being long, E of check-pump period being 180 days is more than e so it is defective; low cost for the long check-pump period and required gas production rate being low, the payback period will be much shorter.

Under the set of parameters, if q_{g1}=10000, N=10, it can be computed by formula (27) and (28) that the minimum check-pump period without deficit is 211 days.

(4) The cost of old drainage gas recovery wells will increase due to the descending gas production rate and pressure, the rising water/gas ratio and increasing downhole fault. For the old wells which have recouped the fixed assets, during every exemption period of production, operation cost of check-valve or check-pump should be recouped once. So the discriminant judging whether it is worth to

keep on operation for old drainage gas recovery wells is gained by removing the term, the fixed assets investment, from discriminant.

(5) All the formulas are not complex and can be programed for extensive computation and judgement. Many parameters of the formulas depend on empirical data, so attention should be paid to gathering, conditioning and accumulating relevant data.

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