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Full Length Research Paper

A prediction to the best artificial lift method selection on the basis of TOPSIS model

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Artificial lift as a system adding energy to the fluid column in a wellbore to initiate and enhance production from the well is necessary when reservoir drives do not sustain acceptable rates or cause fluids to flow at all in some cases which use a range of operating principles, including pumping and gas lifting. Technique for order preference by similarity to ideal solution (TOPSIS) model or method is one of the most prevalent multi criteria decision making methods to solve problems involving selection from among a finite number of criteria and specify the attribute information in order to arrive at a choice. In this paper, a novel software method on the basis of technique for order preference by similarity to ideal solution model has been enabled to present the best artificial lift method selection for different circumstances of oil fields.

Key words: Artificial lift, technique for order preference by similarity to ideal solution, multi criteria decision making.

INTRODUCTION

The system that adds energy to the fluid column in a wellbore to initiate or enhance production from the well is called an Artificial Lift. When a reservoir lacks sufficient energy for oil, gas and water to flow from wells at desired rates, supplemental production methods can help. Lift processes transfer energy down hole or decrease fluid density in wellbore to reduce the hydrostatic load on formation. Major types of artificial Lift are Gas Lift (GL) design (Continuous gas lift, intermittent gas lift) and pumping (electrical submersible pump (ESP), progressive cavity pump (PCP), sucker rod pump (SRP), hydraulic jet type pump (HP).

As the well is produced, the potential energy is converted to kinetic energy associated with the fluid movement. This dissipates the potential energy of the reservoir, thereby causing the flow rate to decrease and the flow to eventually cease. It may be economical at any point in the life of a well to maintain or even to increase the production rate by the use of artificial lift to offset the dissipation of reservoir energy.

MCDM refers to making decisions in the presence of multiple, usually conflicting criteria. The problems of MCDM can be broadly classified into two categories: multiple attribute decision making (MADM) and multiple objective decision making (MODM), depending on whether the problem is a selection problem or a design problem. MODM methods have decision variable values that are determined in a continuous or integer domain, with either an infinitive or a large number of choices, the best of which should satisfy the decision maker's constraints and preference priorities. MADM methods, on the other hand, are generally discrete, with a limited number of predetermined alternatives.

By now, the usage of each of the Artificial Lift methods throughout of the world has been in a manner that for GL, ESP, SRP, PCP, HP as different Artificial Lift methods has been equal to 50, 30, 17, > 2 and < 2% respectively.

The most studies in this field have been on the basis of only experiential calculations by now and not based on the scientific MCDM methods, despite its great importance which implies one of the artificial lift selection

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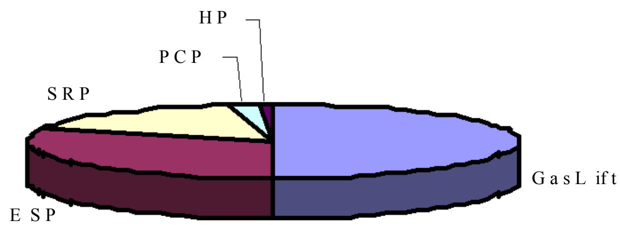

Figure 1. The recent usage of Artificial Lift methods throughout of the world.

previous procedures major imperfections.

However, about the previous Artificial Lift selection procedures, it can be said that some researchers have studied on this matter briefly expressed as the following:

Neely et al. (1981), considered the geographical and environmental circumstances as the dominant factors for artificial lift selection.

Valentine et al. (1988), used optimal pumping unit search (OPUS), a smart integrated system possessing the characteristics of artificial lift methods, for artificial lift selection.

Clegg et al. (1993), studied on some of the operational and designing factors based on artificial lift methods overall capability comparison and design.

Espin et al. (1994), used SEDLA, a computer program possessing the characteristics of artificial lift methods, for artificial lift selection.

Heinze et al.(1995), used "the decision tree" for artificial lift selection, mostly based on a longtime economic analysis.

The paper objective is to specify technique for order preference by similarity to ideal solution (TOPSIS) model as a predicted method for Artificial Lift selection for different circumstances of oil fields.

MATERIALS AND METHODS

The usage of artificial lift methods throughout the world by now has been recently reported (Figure 1), (Weatherford Com.).

It is necessary to mention that sucker rod pump (SRP) is a positive displacement pump that compresses liquid by the motion of a piston. The piston is actuated by a string of sucker rods that extends from the bottomhole pump to the pumping unit at the surface. The rod or structure may limit rate at depth (Gholinegad, 2007).

A progressive cavity pump (PCP) is a kind of pump which transfers fluid by means of a sequence of small, fixed shape, discrete cavities, that move through the pump as its rotor turns.

The cavities taper down toward their ends and overlap with their neighbors, so that, in general, no flow pulsing is caused by the arrival of cavities at the outlet (Gholinegad, 2007).

An electrical submersible pump (ESP) is a dynamic displacement, multistage centrifugal turbine pump coupled by a short shaft to a downhole electrical motor. The motor is supplied with electrical power by a cable extending to the surface. ESP systems have a wide range of applications and offer an efficient and economical lift method. Even if sand production, high gas oil ratio (GOR) and viscosity are concerns, we can find the right ESP for our well and improve production. From onshore high water cut applications to complex offshore, deepwater or subsea applications, we have a system to meet our needs (Gholinegad, 2007).

A hydraulic jet type pump (HP) is an ejector type dynamic displacement pump operated by a stream of high pressure power fluid converging into a jet in the nozzle of the pump.

Downstream from the nozzle, the high velocity, low pressure jet is mixed with the well's fluid. The stream of the mixture is then expanded in a diffuser and as the flow velocity is dropped the pressure is built up. The fluid flow can carry some corrosive additives into wellbore and function as a maintenance material. The constraints to use HP are related to high GOR or contamination in the fluid flow bringing about low efficiency of pump at last (Gholinegad, 2007).

As well, about gas lift (GL), gas is injected into the tubing string to lighten the fluid column and allow the well to flow when it does not flow naturally.

The injected gas is mixed with produced fluid, decreases the flowing gradient in the production string and thus lowers the bottomhole flowing pressure. Basic objective of gas lift design is to equip wells in such a manner as to compress a minimum amount of gas to produce a maximum amount of oil (Gholinegad, 2007).

Previous artificial lift selection procedures

Neely et al. (1981) designated some Artificial Lift methods such as: SRP, ESP, HP, GL and studied about the application circumstances, advantages, disadvantages and constraints of each method. The geographical and environmental circumstances as the dominant factors for Artificial Lift selection and also some other subordinate factors such as: reservoir pressure, productivity index, reservoir fluid properties and inflow performance relationship were considered by him (Neely et al., 1981).

Valentine et al. (1988) used optimal pumping unit search (OPUS) for Artificial Lift selection. Indeed OPUS was a smart integrated system possessing the characteristics of artificial lift methods.

OPUS had the capability to control the technical and financial aspects of Artificial Lift methods. It can be said that the production system was consisted of the downhole pump up to the surface facilities (stock tank). The technical and financial evaluation of this procedure was done by means of some specific computer algorithms. Therefore, knowing the primary required investment value, costs (maintenance, equipment) and technical ability of each Artificial Lift method, Artificial Lift selection was done (Valentine et al., 1988).

Clegg (1988) mentioned some economic factors such as: revenue, operational and investment costs as the basis for Artificial Lift selection. He believed that the selected Artificial Lift method could have the best production rate with the least value of operational costs (Clegg, 1988).

Clegg et al. (1993), studied on some of the operational and designing characteristics of Artificial Lift methods categorized into 3 types based on Artificial Lift methods overall capability comparison and design, some specific operational factors and Artificial Lift methods factors probably causing some specific problems respectively (Clegg et al., 1993).

Espin et al. (1994) used SEDLA for artificial lift selection. Indeed SEDLA was a computer program possessing the characteristics of artificial lift methods. It was composed of 3 modules based on an information bank of human activities, the theoretical knowledge of artificial lift methods and the economic evaluation of artificial lift methods respectively. Therefore, the artificial lift selection was done on the basis of profit value (Espin et al., 1994).

Heinze et al. (1995), used "the decision tree" for artificial lift selection. The most major factor in it was based on a longtime economic analysis. Also, the artificial lift methods evaluation was based on operational costs, primary investment, lifetime cost and energy efficiency. Ultimately, considering these factors besides the decision maker, the Artificial Lift selection was done (Heinze et al., 1995).

Some engineering applications of TOPSIS model used up to now

Application of TOPSIS model as a data classifier, the proposed model could provide additional efficient tool for comparative analysis of data sets. TOPSIS model has been applied in Multiple Criteria Decision Analysis based on Wu's data mining model. It has been applied in supply chain complexity evaluation and simulation has been used to validate the proposed model (Jiang et al., 2007).

Application of TOPSIS model as a new model for mining method selection of mineral deposit based on fuzzy decision making, the fuzzy decision making (FDM) software tool has been employed to develop a fuzzy TOPSIS based model. Application of this model with various values (crisp, linguistic and fuzzy) of the deposit eliminated the existing disadvantages of other methods (Samimi, 2008).

Application of TOPSIS model in initial training aircraft evaluation under a fuzzy environment, the study has applied the fuzzy MCDM method to determine the weights of evaluation criteria and to synthesize the ratings of candidate aircraft. Aggregated the evaluators' attitude toward preference; then TOPSIS has been employed to obtain a crisp overall performance value for each alternative to make a final decision (Wang and Chang, 2007).

Application of TOPSIS model as a Multi Criteria Decision Analysis of alternative fuel buses for public transportation, the result has shown that the hybrid electric bus has been the most suitable substitute bus for Taiwan urban areas in the short and median term. But, if the cruising distance of the electric bus extends to an acceptable range, the pure electric bus could be the best alternative (Tzeng et al., 2005).

Some other certain scientific programs based on MCDM models are listed as below, but because TOPSIS model has been validated with several certain oil fields Artificial Lift selection operations results and a considerable accordance between their final results has been gained, this model has been chosen for Artificial Lift selection. As well, this model gives an appropriate solution that is not only the closest to the best alternative, but also the farthest from the worst alternative:

- TOPSIS (technique for order preference by similarity to ideal solution) model
- SAW (simple additive weighting) model
- ELECTRE (elimination et choice in translating to reality) model
- WPM (weighted product model)
- VIKOR (VIsekriterijumsko KOmpromisno Rangiranje), compromise ranking model.

DISCUSSION

In this paper, a software method (with Visual Basic.net code) based on TOPSIS model has been presented for Artificial Lift selection in oil industry that has been essential to mention to the mathematical and logical strategy of this method.

Technique for order preference by similarity to ideal solution (TOPSIS) model

This model was developed by Hwang and Yoon (1981). This model is based on the concept that the chosen alternative should have the shortest Euclidean distance from the ideal solution and the farthest from the negative ideal solution (Hwang and Yoon 1981; Pimerol et al., 2000).

The ideal solution is a hypothetical solution for which all alternatives relative to criteria attribute values (V_{ij}) correspond to the maximum attribute values in the database comprising the satisfying solutions; the negative ideal solution is the hypothetical solution for which alternatives relative to criteria attribute values (V_{ij}) correspond to the minimum attribute values in the database. TOPSIS thus gives a solution that is not only closest to the hypothe-tically best, that is also the farthest from the hypothetically worst alternative (Rao, 2007). The main procedure of TOPSIS model for the selection of the best alternative from among those available has been described thus:

At first it was required to allocate suitable quantities scaled from 0 through 10 for the alternative relative to the criteria qualities, (higher each of their qualities, more its value out of 10), (Rao, 2007). The relative scores of different methods relative to Production, Reservoir and Well constraints as well as Produced fluid properties and Surface infrastructure constraints, (Figure 2), have been based on Schlumberger Company certain practical reports. The value of 1 (good to excellent) has been considered as 7 out of 10, the value of 2 (fair to good) has been considered as 5 out of 10 and the value of 3 (not recommended and poor) has been considered as 3 out of 10 in the following (Schlumberger Com.). On the whole, it is believed that the calculations results and the related figures shown as (Figure 3) through (Figure 6) vary in different circumstances of oil fields.

But here, (Figure 3) through (Figure 6) have been related to the condition that ESP application has been the best choice as the shown result in (Figure 3).

In the matrix the number of the alternatives and the number of the criteria have been considered as the number of matrix rows and matrix columns respectively.

Then, the normalizing of the resulted alternatives relative to the criteria quantities matrix had to be done (Rao, 2007).

This resulted normalized matrix had to be weighted by means of a specific weights calculating mathematical method such as Entropy method, (Rao, 2007). Multiplying the normalized matrix by the alternatives relative to the criteria resulted weights diametrical matrix, the normalized weighted matrix has been obtained (Rao, 2007).

Then, the positive ideal (best) and the negative ideal (worst) of each criterion had to be obtained in this step, (Rao, 2007).

$$V^{+} = \{ (\max_{i} V_{ij} / j \in J), (\min_{i} V_{ij} / j \in J') / i = 1,2,\ldots N \}, = \{ V_1^{+}, V_2^{+}, V_3^{+}, \ldots V_M^{+} \} \quad (1)$$

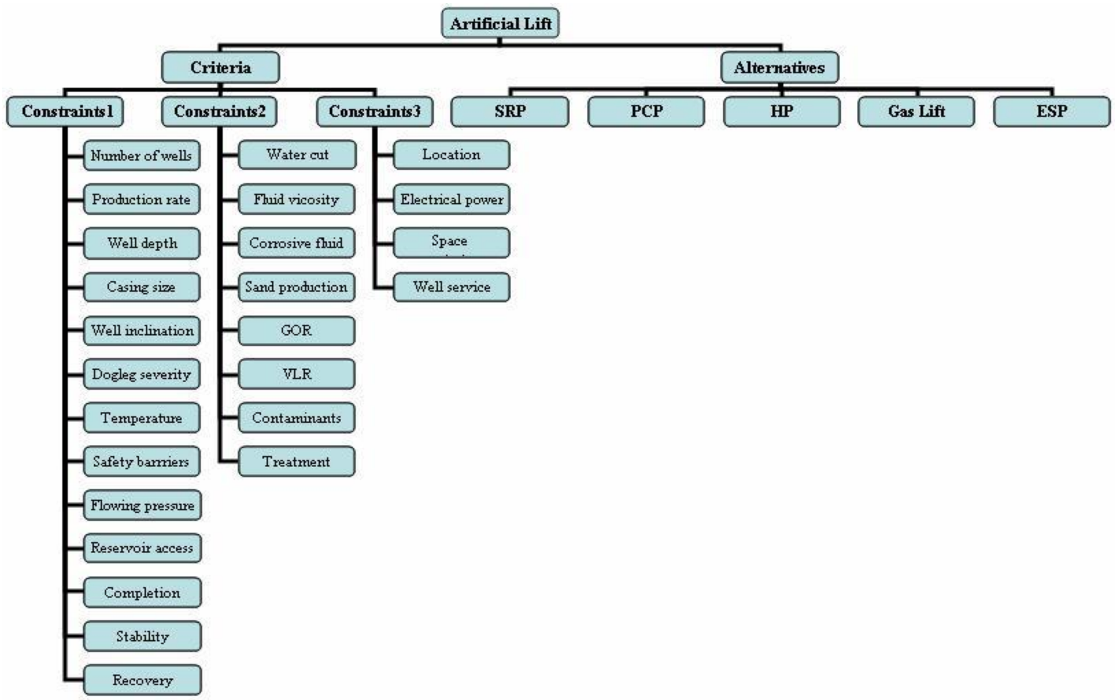

Figure 2. The Alternatives versus the Criteria for Artificial Lift selection

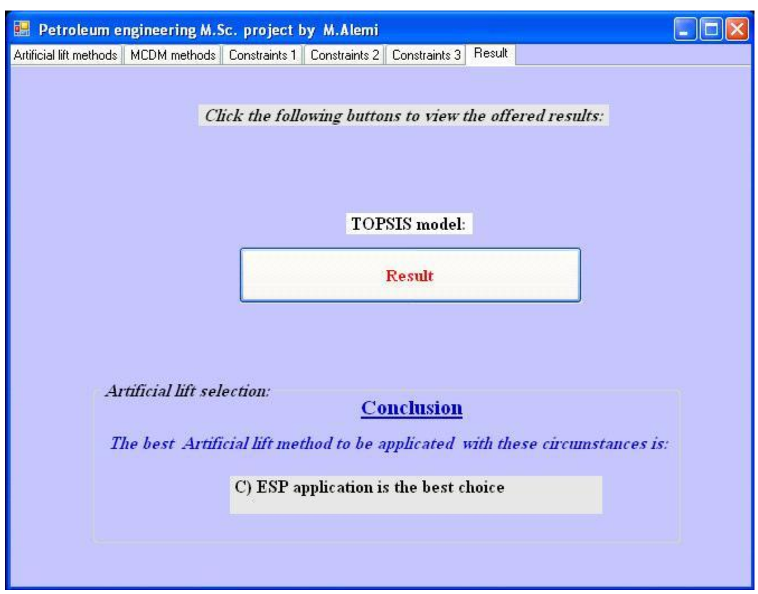

Figure 3. Artificial Lift selection result by the designed computer program (The obtained final result due to the sample input data).

$$V_i^{-} = \{ (\min_i V_{ij} / j \in J), (\max_i V_{ij} / j \in J') / i = 1,2,...N \}, = \{ V_1^{-}, V_2^{-}, V_3^{-}, ...V_M^{-} \} \quad (2)$$

Where; J = (j =1, 2, M)/j is associated with beneficial attributes. J'= (j =1, 2, M)/j is associated with non-beneficial attributes.

The separation of each alternative from the ideal one has been given by the Euclidean distance in the following equations (Figure 4 and 5), (Rao, 2007).

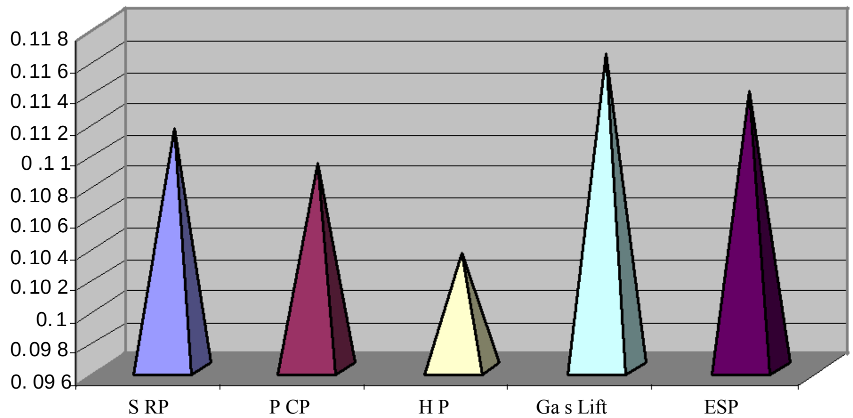

Figure 4. The resulted separation of each alternative from the positive ideal given by the Euclidean distance (obtained from the sample input data).

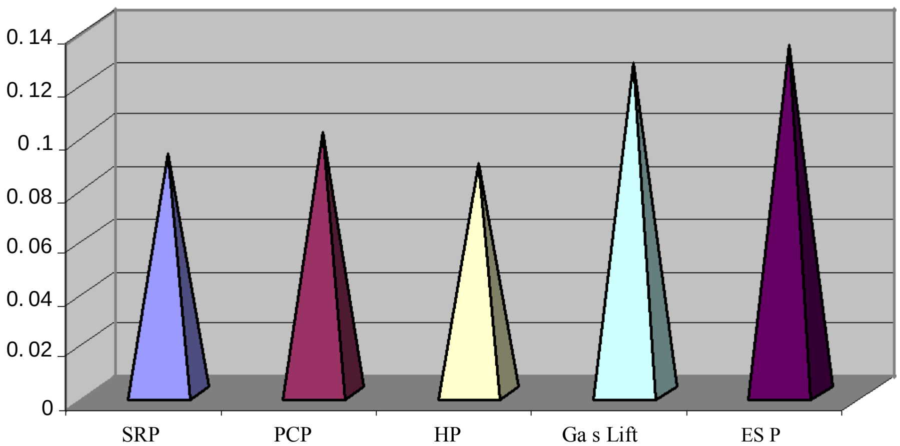

Figure 5. The resulted separation of each alternative from the negative ideal given by the Euclidean distance (obtained from the sample input data).

$$S_i^+ = \{\sum_{J=1}^{M} (V_{ij} - V_j^+)^2\}^{0.5},$$

$$S_i^- = \{\sum_{J=1}^{M} (V_{ij} - V_j^-)^2\}^{0.5}, \qquad (3)$$

$$S_i^+ = \{\sum_{J=1}^{M} (V_{ij} - V_j^+)^2\}^{0.5},$$

$$S_i^- = \{\sum_{J=1}^{M} (V_{ij} - V_j^-)^2\}^{0.5}, \qquad (4)$$

$i = 1, 2, ..., N$

The relative closeness of a particular alternative to the ideal solution, P_i, could be expressed in this step as follows:

$$P_i = S_i^- / (S_i^+ + S_i^-) \qquad (5)$$

The higher value for P_i shows the better choice to be selected (Figure 6), (Rao, 2007). The (Table 1) shows the sample input data too.

Conclusion

In this paper, a novel software method based on TOPSIS model was presented for artificial lift selection in different circumstances of oil fields. The validity of this scientific designed program has been checked and validated with several certain oil fields artificial lift operations results by

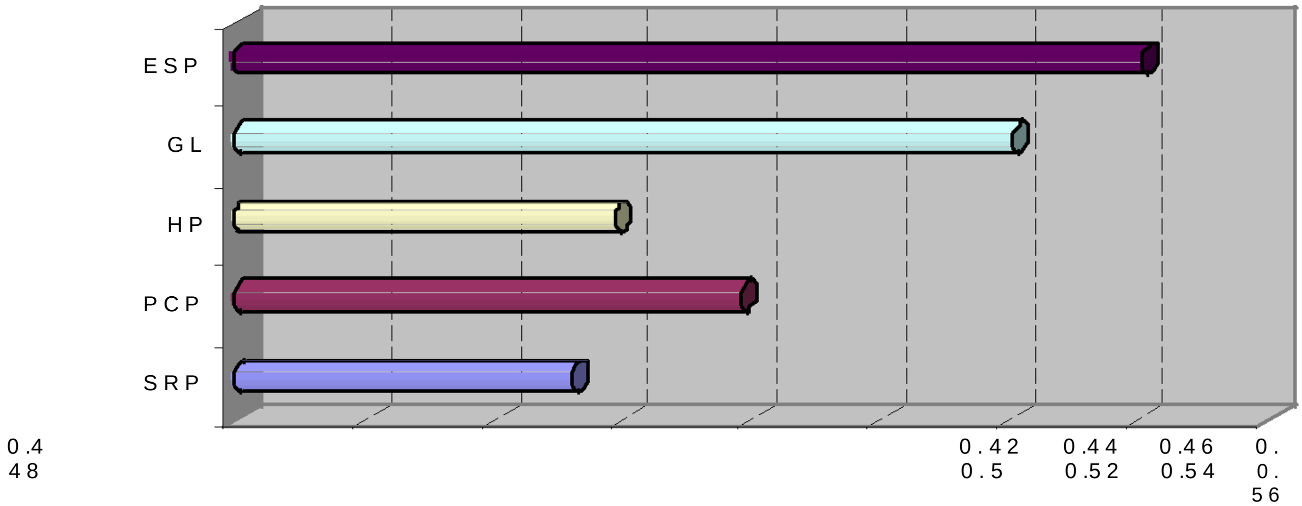

Figure 6. Artificial lift selection result (for the sample input data).

Table 1. The designed software sample input data

Condition	Oil field
Production, reservoir and well constraints	
Number of wells	50
Production rate	56000 STB
Well depth	8000-11000 ft
Casing size	9 5/8"
Well inclination	All of cases
Dogleg severity	0-10 per feet
Temperature	180-210 F
Safety barriers	1
Flowing pressure	Greater than 1000 psi
Reservoir access	Required
Completion	Simple
Stability	variable
Recovery	Secondary waterflood
Produced fluid properties	
Water cut	70%
Fluid viscosity	Less than 100 cp
Corrosive fluid	No
Sand and abrasives	Less than 10 ppm
GOR	650
VLR	Less than 0.1
Contaminants	Scale
Treatment	Acid
Surface infrastructure	
Location	Offshore
Electrical power	Utility
Space restriction	Yes
Well service	Pulling unit

means of the comparison between them. Finally it has resulted that between this designed programs final results and the related oil fields Artificial Lift operations results, a considerable accordance has been available. Indeed, the paper objective has been a prediction study for Artificial Lift selection (with Visual Basic.net code) in oil industry.

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