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Some Considerations on the Possibilities of Using Electronic Computers in the Oil Industry

This paper presents the main possibilities of using various types of electronic computers in the oil industry and expounds a series of conclusions resulting from the authors' experience.

The oil industry has developed in step with the general technical progress, permanently improving its methods of work in all domains of activity by own researches and achievements, as well as by taking over and assimilating methods, outfits and apparatus from other domains of technique. Consequently, for solving diverse specific problems of this branch, methods of operational investigation have been adopted (see [1], [2], [3]). So, for the optimization of some technological processes which call for the rapid processing of a large and complex volume of statistical data, one has now to resort more and more to the help of electronic computers. Moreover, the electronic computers prove to a greater extent their usefulness in other domains too, their use being conducive to increased efficiency of the operations of prospecting, exploitation and processing of hydrocarbons, owing to the prompt synthetizing and schematizing of the multitude of existing data.

1. USE OF COMPUTERS IN GEOLOGICAL WORK

We give as an example of computers used in the processing of geological data the P.B.W.D.S. systems — worked out in 1963 for the processing of data concerning the 240,000 drilling operations performed in West Texas and New Mexico, the R.M.W.H.C.S. (Rocky Mountain Well History Control System) which processes the data collected from 65,000 drillings, or the

G.C.W.D.S. (Gulf Coast Well Data System) processing the data resulting from 270,000 drilling operations [4].

It stands to reason that the processing of these data by conventional means is actually impossible. The technique to be adopted in this case includes, first of all, the transcription of the geological data in an appropriate way; then, the information is stored by information carriers. The cost of storage varies following the nature of the information carrier and the details transcribed, amounting on the average to 20 dollars for each oil well.

One of the difficulties occurring in this domain consists, in certain cases, in the fact that the information — such as it appears in the usual geological terminology — wants precision, scientifically speaking. For instance, the term "carbonated rock" is employed without making clear the mineralogical structure of the respective rock. Since a rock can contain some 21 component minerals, either isolated or in combinations of four or six classes (according to the grain size) and of four classes (according to their origin) it results — as hold by some authors — that there are 180,000 types of rocks.

In practice, by resorting to less detailed criteria, only 259 characteristics divided into 23 classes, have been maintained in the above mentioned experiment performed in the U.S.A. The pilot record of the International Petroleum Federation comprises 617 types of rocks.

Account must be taken also of the paleontological data and, generally, of all the available geological or geophysical characteristics.

At the French Institute of Petroleum, a test was carried out with a small geological card-index on a number of wells in the Paris basin.

The following operations can be effected with the help of card-indexes:

— the rapid drawing of maps concerning any parameter, contingent upon the parameters which feed the machine;

— the rapid access to any group of data presenting certain pursued characteristics;

— the determining of the regional gradient of a given parameter;

— the determining of anomalies;

— the quantitative analysis of the electric data;

— the interpolation of the values of parameters in less studied zones;

— statistical studies.

For the last item, mention should be made of the correlation calculus concerning, for instance, the analysis of the distribution of 50 variables on 50 tests (specimens). This work, performed by means of a medium scientific electronic computer asks for approximately one hour.

As a rule, the electronic computers are now used by geologists both in processing the data and in solving the given problem.

Proceeding from the obligatory character of the existence of sure, high quality data, and using the methods including the harmonic analysis of functions (Fourier analysis) and statistical techniques, the results achieved offer the advantage that they can be presented in visual forms entailing superior interpretations.

Thus, the analysis of the bidimensional time curves applied to the stratigraphic, sedimentary or other data, or tridimensional — used for any space variable — has as a result the separation of the regional components from local components. The Fourier analysis, which achieves the same separation,

may be used both in determining the periodicity of data, and in the analysis of curves.

The "classification" — a method based on the analysis of the common factors in many interdependent variables — is another example, which makes use of the correlated coefficients with application in geology, for determining the relations between the chemical, lythologic and biological constituents.

Therefore, the advantages offered by the use of computers in geological investigations lie in the rapid procurement of information deriving from the synthetization of a large mass of data.

The computers are widely used, too, in geophysics. In gravimetry, the multitude of existing data may be synthetized and effectively presented under the high form of order maps. In seismometry — a process witnessing outstanding development — the electronic computers gave birth to a genuine revolution, concomitantly with the introduction in practice of the analogical tape recording and, lately, of the digital tape recording.

Proceeding from the context of growing difficulties to get useful information, the seismometry has considerably enriched its working methods, and the registering apparatus and processing computers have marked outstanding qualitative progress, a result of the existence of possibilities to take over and adopt elements of modern electronics, applied in other research branches as well.

Today, in one form or another, the progress of the electronic technique finds its way into all the phases of seismic prospecting process, starting with the field registering of primary data and ending with their processing in an as interpretable as possible geological form. This fact has become a necessity, bearing in mind the improving of the fineness of resolution and of the accuracy of method, linked to the central problem in seismometry — that of separating the useful signal from noise.

The introduction of the analogical magnetic recording in seismic prospection has been a first qualitative leap, conducive to increased possibilities of filtration and enabling subsequent processings, for a less difficult deciphering of the useful signals and, hence, for their geological interpretation, more complete and more accurate.

The geological problems to be solved call for the necessity of watching not only over the reflection waves, but, in some cases, also over parts of the difraction waves; thus, by useful signal we understand the seismic wave, sometimes visible and sometimes distorted or obscure, corresponding to the solicited data. The coherent noise is caused by the waves which run through unwished paths (reflected-refracted and refracted-reflected, multiple-reflected, exchange waves, etc.); the incoherent noise is due to microseisms.

Improvement of the useful signal-noise relations, achieved following the introduction of analogical recording, is however not conducive to a complete spotlighting of the useful signal from the complex of unuseful signals, also registered in any geological conditions occurred.

Consequently, an accentuated tendency is now noted of combining the equipment of the analogical type with digital equipment able to solve in a superior way the problem of improving the useful signal-noise relation, due to the contributions made by the high technical features of the digital apparatus.

This can be exemplified by the factor of nonlinear distortion, which is of 0.02 per cent at digital apparatus, against 1—3 per cent at the analogical apparatus, or by the values of the dynamic scale which are of 90 dB and even 270 dB at digital apparatus, and of 50 dB up to maximum 60 dB at the analogical apparatus.

Another advantage of the digital apparatus is the fact that in having the seismic signal expressed by figures, the value of its magnitude is not changed following the processing by means of a numerical computer; thus the application of the filtering systems is more efficient, and has a direct positive influence on the relation useful signal-noise.

The computers used are big-size computers enabling over 10,000 operations per second, and sometimes are streamlined for seismic operations [5], [6].

2. USE OF ELECTRONIC MODELS FOR THE STUDY OF OIL AND GAS DEPOSITS EXPLOITATION

For the solving of hydrodynamic problems related to the prospecting or analysis of the oil and gas deposits, one can use either the mathematical apparatus of differential equations, or that of integral equations. In fact, highly important problems have been so far solved with the help of differential equations.

Necessary for solving a concrete problem is to find the solution of a differential equation with partial derivatives with limited conditions. It is known that the solutions can be obtained by means of the analytical, numerical or modelling methods. Analytical solutions may usually be found, in simple cases, for a simple geometry of the domain, and in the simplifying hypothesis concerning the fluid flow, which very seldom occurs in practice [10], [11].

An efficient means of solving such problems are the numerical methods based on the use of mathematical networks. Considering the great many computations that are to be performed, these methods are used in the programming of the numerical computers, with the aim of solving these problems.

The numerical computers used must be endowed with high working speed and a rapid, efficient storage of high capacity. Still, the operating storage capacity of modern computers is insufficient for registering all the parameters characteristic of a large oil deposit. This calls for an exchange of information between the external and the operating storage, a fact which, however, diminishes the computation speed. Moreover, the accuracy of the numerical computers is inefficiently used because the initial geological data are known with lower exactness.

Most spread among the modelling methods used in solving underground hydraulics problems is the electric modelling method, which offers additional advantages. The method is extremely intuitive and enables the easy interpretation of the results obtained; moreover, the technical means of its achievement are unexpensive, simple and precise, offering the possibility of fixing in the model a large quantity of initial data.

Very often in planning the working of oil and gas deposits various problems arise, such as:

— the choosing of a rational system of well distribution;
— the determining of the well flow;
— the study of well interference;

— the study of the contour displacement of the oil zones in case of water injection in the deposit to maintain the pressure.

All this makes even more conspicuous the finding of solutions for problems with limit conditions in multiple connex domains.

The study of the rigid working system of an oil deposit asks for the solving of an equation with partial derivatives of the elliptic type, while that of the flexible system leads to a parabolic equation, and the gas flow through porous media implies the finding of the solution of a nonlinear parabolic equation. In a practical manner, all the above mentioned systems may be found in the exploitation of large deposits.

Proceeding from the analogy between Ohm's and Darcy's laws, the distribution of the isobar and of the current lines can be determined at the modelling of large deposits on the basis of the distribution of tensions and currents in the nodes and branches of an electric network formed of resistors or of resistors and capacities ; some zones may be more thoroughly studied thanks to the limited dimensions of the network. Contingent upon this, the whole deposit is first of all modelled at a low scale with an equipotential line enclosing the zone we are interested in put into evidence. Then, the delimited zone is represented on the deposit, on a bigger scale.

Diverse technological variants of water injection for the maintenance of pressure in the deposit can be studied on the electric network. In this case, the following problems may arise :

— to find the optimum distribution of injection wells, the pressure and the injected fluid flow, the displacement of the contour line of the oil-bearing zone for a given deposit pressure ;

— to find the flows of the exploitation wells and the contour of the oil-bearing zone for pressures or flows of the given injection wells.

Besides the above mentioned problems, the opposite problems may be solved, too, on the electric network, namely the establishment and pinpointing of the geological parameters of the deposit following the reproduction on the model of the exploitation story.

By using the electric networks in planning the oil and gas deposits exploitation, some circumstances of the exploitation can be taken into consideration, as for instance the order of the introduction into exploitation of the extraction and injection wells.

Studied have been with the help of electric networks matters related to the piston type biliquid flow in nonhomogeneous porous media, under the conditions of liquids with differing viscosity and density indexes, as well as to the capillary pressure at their separating point.

The importance of the solving of problems related to the planning of the exploitation of oil deposits determined the building in the USSR of specialized modelling installations, such as the EIS installation (in 1957) and the USM installation (in 1961). In spite of their complexity, the cost of these installations was redeemed since the solving of the first problems.

Practice has shown that the electric networks provided with 1,000—2,000 nodes and made from own resources (as for instance at the Drilling and Extraction Research Institute at Cîmpina) are yielding very good results when employed by organizations streamlined for the planning of exploitation of small-size oil deposits as well as for a series of theoretical pro-

blems in this domain. Great attention is being paid of late to the production of hybrid installations resulting from the interconnection of electric networks with numerical computers. Of practical interest in this case are the big electric models of the network type destined to the study of large deposits with hundreds of extraction and injection wells. The computers are used for carrying out automatic control of the network run, the automation of the process of determining the strata parameters on the basis of the exploitation data, the automation of computations related to the study of the shifting of the oil zone, the drawing of isobar lines.

The algorithms have been established for the approximate computation of the phenomena of the oil discharge having dissolved gas and of the oil dislocation due to water, by taking into account the basic permeability with the hel pof hybrid devices.

It must be noted that there are large numbers of problems of bidimentional and tridimensional discharges in nonhomogeneous media, of unstable flow of oil with dissolved gas in various exploitation conditions, at pressures below the saturation point, as well as other problems of discharges of fluid mixtures with diverse properties which have been solved with the help of big numerical computers.

There are, however, problems still unsolved by means of computers, as for instance the general case of the well interference in the dissolved gas discharge regime.

Practice has shown that at present problems highly important for planning the exploitation of oil deposits can be solved by electric modelling and with the help of numerical computers [7], [8], [9].

3. ELABORATION OF OIL DEPOSIT MODELS

The scientific exploitation of an oil deposit supposes, on the one hand, a most accurate knowledge of the way in which the oil-bearing rock strata are disposed in the soil and, on the other hand, the suitable siting of the wells needed for the exploitation of the deposit. Account must, however, be taken of the fact that never can be the structure of the deposit determined on the spot. The digital computation method used for processing geological data may permit the elaboration of a number of deposit models.

Generally, estimates are made on the deposit, namely models comprising a series of parameters are elaborated, determined by the exploitation data, as well as of other parameters which are credited with plausible values. The model is permanently improved by means of the data on the time evolution of the extracted oil flow.

The present tendency in this matter is to use the computers for the forecast of the deposit behaviour under certain exploitation hypotheses.

Many investigations are aimed at the bettering of theoretical methods, methods of mathematical physics concerning the fluid discharge through porous media. Along this line too, the Romanian researchers have made important contributions.

It must be stated that, generally, the models just as the whole computation method will lead to results all the more nearing reality as the equations describing the studied phenomena correspond better to the concrete situation.

4. USE OF COMPUTERS IN DRILLING OPERATIONS

The drilling operation is performed with a view of exploiting deposits sometimes located at great depths (3,000—4,000 m. and even more).

Two parameters are available for this operation, namely the protection force and the rotation speed of the bit. The optimization is aimed at the directing of the drilling operation so that a certain criterion, of an economic nature (a minimum cost) or of another kind (for instance, the shortening to the minimum of the drilling time) may be achieved.

This optimization may proceed by involving the drilling element and the transducer motor, which will feed a computer with certain data. On the basis of the information received, the computer constantly determines the optimum regime of the motor and the bit.

5. OPTIMIZATION OF OIL EXTRACTION

Various procedures are used in oil extraction. Below, we have in view especially the pumping method.

The electronic computers may be used in this case, first of all at the pumping installations design. To this end, the situation corresponding to the well that is to operate by pumping method is worked out on the model. The different pumping regimes are modelled, characterized by a certain surface stroke, a special set of sucker rods, a special pump and a certain set of tubings. The number of strokes per minute, that is the pumping frequency, is submitted to variations. Contingent upon these elements, the maximum force and minimum force emerging in a drilling cycle is determined, the same as the real bottom stroke, this providing the oil flow. By means of these elements, the theme of design for the maker of the pumping plant is determined [12], [13].

The model of the pumping plant can be used for the elaboration of a dynamometric diagram catalogue which enables the finding of certain faults occurring in the installation, so that remedial measures might be taken in time.

6. FURTHER USES

The electronic computers are successfully used in solving problems reducible to binary decisions [14], [15], concerning the optimum siting of refineries. Likewise, for solving programming problems in the optimum designing of the pipeline system, the optimum control of the technological processes at oil refineries, etc.

In one of these cases, important successes have been achieved in our country, as resulting from the quotations in the references.

Yet, taking into account, on the one hand, the importance of the oil industry in our national economy as a whole, and on the other hand, the possible applications of the computers in the oil industry, we think that, on this line too, a wide sphere of activity rests open. The training of the personnel is necessary, which by making use of the existing means could use to the best the possibilities offered by cybernetics in the domain of the oil industry.

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CONSIDERATIONS SUR LES POSSIBILITES D'UTILISER DES CALCULATEURS ELECTRONIQUES DANS L'INDUSTRIE PETROLIERE

Cette étude présente les principales possibilités d'utilisation des différents types de calculateurs électroniques dans l'industrie pétrolière.

On étudie à tour de role la façon dont les calculateurs digitaux, analogues et hybrides peuvent être utilisés dans les différentes branches de l'industrie pétrolière et dans certains domaines annexes.

On analyse ainsi, dans cet article, la situation dans les domaines principaux suivants: développement mathématique automatique des données géologiques; développement mathé-

matique automatique des donnés provenant de prospections géophysiques, élaboration de modèles de gisements, exploitation optimum des gisements pétroliers, amélioration optimum du processus de forage, amélioration optimum des principaux systèmes d'extraction du pétrole et du gaz, amélioration optimum des processus technologiques exécutés dans les raffineries, amélioration optimum de l'emplacement des réseaux de pipe-lines et son exploitation optimum.

En plus de la présentation critique de certaines données de la littérature de spécialité, l'article expose une série de conclusions provenant de l'expérience des auteurs dans certains des domaines énumérés.

О ВОЗМОЖНОСТЯХ ИСПОЛЬЗОВАНИЯ ЭЛЕКТРОННЫХ ВЫЧИСЛИТЕЛЬНЫХ МАШИН В НЕФТЯНОЙ ПРОМЫШЛЕННОСТИ

В этой статье изложены главнейшие возможности использования различных типов электронных вычислительных машин в нефтяной промышленности.

Последовательно рассматриваются способы использования ручных, аналоговых и гибридных вычислительных машин в различных отраслях нефтяной промышленности и в некоторых связанных с ней отраслях.

Так, в данном труде анализируется положение в следующих, наиболее важных отраслях: автоматическая обработка геологических данных; автоматическая обработка данных геофизической разведки; разработка моделей залежей; оптимальная эксплуатация нефтяных залежей; оптимизация процесса бурения; оптимизация главных систем добычи нефти и газа; оптимизация технологических процессов на нефтеочистительных заводах; оптимизация размещения сети нефтепроводов и ее оптимальная эксплуатация.

Наряду с критическим разбором ряда данных из посвященной этой специальности литературы, приводится также и ряд выводов, сделанных авторами на основании накопленного ими опыта по некоторым из этих отраслей.