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Technology of Management in Real Time

Part 2

A Textbook

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ТЕХНОЛОГИЯ УПРАВЛЕНИЯ В РЕЖИМЕ РЕАЛЬНОГО ВРЕМЕНИ

Часть 2

Допущено
Учебно-методическим объединением
высших учебных заведений Российской Федерации
по образованию в области прикладных математики и физики
в качестве учебного пособия для студентов вузов
по направлению подготовки «Прикладные математика и физика»

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The main purpose of the textbook is to provide basic knowledge about the technology of management in real time, description of the technology, tools and examples of smart industrial complexes of the first and second generations. The main features of the Scientific and Technological Revolution (STR) XXI century in the exploration and the development of the World Ocean resources, comparable in scale to the exploration of the Cosmos in the 1950s: the creation of underwater fiber gratings for the collection and transmission of the marine industries metadata; the development of the second generation of "smart" fields and wells; the standardization of data in the drilling, the use of a new generation of the high-performance computing systems and the database management systems in real time; the smart agents working in porous media; the integrated operations on land, shallow - deep - and ultra-deepwater marine environment in real time; the international standards for integrated technologies; underwater and surface robots, micro-, nano- electromechanical systems (MEMS, NEMS) and nanobots/bionanobots, the transmission of Big Data (industrial metadata) on satellite and fiber-optic communication channels, structures and physical-mechanical foundations of fiber-optic sensors.

The textbook is intended for the students, the undergraduates and the doctorates of the engineering-technical specialties of the discipline "Technology of Management in Real Time", for the engineering and technical workers of the industry and applied sciences.

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Г20 Технология управления в режиме реального времени : учеб. пособие (на английском языке) : в 2 ч.– М. : МФТИ. – Ч. 2. – 167 с. : ил.
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Основной целью учебного пособия является предоставление базовых знаний о технологиях управления в режиме реального времени, описание технологий, технических средств и примеров умных производственных комплексов первого и второго поколений. Приведены основные особенности революции XXI века в науке и технике освоения углеводородных богатств Мирового океана, сопоставимой по своим масштабам с освоением Космоса в 1950-х годах: создание подводных оптоволоконных решеток для сбора и передачи метаданных с морских промыслов; разработка второго поколения «умных» скважин и месторождений; стандартизация данных в бурении, добыча углеводородов; использование новой генерации высокопроизводительных вычислительных комплексов и систем управления базами геолого-промысловых метаданных в режиме реального времени; достоинства и недостатки умных рабочих агентов в пористых средах; интегрированных операций на суше, мелко-, глубоко- и сверхглубоководной морской среды в режиме реального времени; международных стандартов для интегрированных технологий; подводных, поверхностных, микро-, нано- электромеханических систем (МЭМС, НЭМС); нанороботов и бионанороботов; особенности передачи Big Data (производственных метаданных) по спутниковой и оптоволоконной каналам связи, конструкции и физико-механических основ оптоволоконных сенсоров.

Для бакалавров, студентов, магистрантов и аспирантов инженерно-технических специальностей дисциплины «Технология управления в режиме реального времени», для инженерно-технических работников промышленности и прикладной науки.

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CHAPTER 8. **RESERVOIR NANOROBOTS AND BIONANOROBOTS**

Abstract

The innovations and the achievements in the field of nanotechnologies, molecular, engineering and quantum calculations open the new prospects of the development of technologies, medicine, defensive and textile branches of industry. The reservoir nanorobots will become our "eyes, ears and a nose" in the layer, with their help we will be able to analyze the formation pressure, temperature, fluid type, system of pores, to collect the information in the built-in memory and to transfer the data to a surface. The development and the improvement of the reservoir nanorobots will find an extensive application in the prospecting and the development of fields, in an assessment of the reservoir and the deposit geometrization, in well spacing, in monitoring the layer, in the development control to increase the oil recovery.

Keywords: *nanorobot, microrobot, bionanorobot, underwater robots, borehole robots, nanoemulsion, nanodispersion, nanobacteria, nanoparticles, perforation, log running, sensors, borehole tractor.*

Introduction

The innovations and the achievements in the field of nanotechnologies, molecular, engineering and quantum calculations open the new prospects of the development of technologies, medicine, defensive and textile branches of industry. Not enough attention was paid to the application of nanotechnologies for the solution of subsurface problems of oil and gas industry. The first section gives the definitions of the robots in oil industry, the application of the reservoir technology, of the reservoir boundary, in a well. The second section presents the reservoir nanorobots, tasks, advantages, technical and economic parameters of the nanomaterial. The third section presents the definition of the reservoir bionanorobots, the purposes set before the robots, the tasks, the sensors, the nanoemulsion, the dendrimers. The fourth section considers the underwater robots, a concept, the main characteristics (on the example of the Chinese underwater Arctic-ARV robot), the mission and the advantages of using the underwater robots. The fifth section characterizes the borehole micro-robots, a concept, the main characteristics, the types, the movement and the management mechanism and their mission, the device and the principle of work on the example of the borehole robot of the CIRCO company. The sixth section gives the definition of the reservoir microrobots, a concept, the main characteristics and the mission, the tasks, and the purposes. The seventh section considers the microelectromechanical systems (MEMS), a concept, the main characteristics and their application in the oil and gas industry.

8.1. Robots in oil industry

The chapter presents a short review of the technologies which are considered the most influential in the last decades, namely, microrobots, nanorobots, the robots supervising the operations of pipelines and wells. Each of these technologies has a deep impact on the oil industry (see Tables 1 and 2). These technologies are applied in the reservoir, on the reservoir and well boundaries. They include the clever devices for the contact control, the analyses of autonomous regions, the passive seismic monitoring, and the input of special liquids. Though the majority of them are simply dreams, the considerable progresses which were made for achievement of these purposes are singled out. Oil industry, especially in the extracting sector, has received a lot of attention recently. Some attention was positive, and some not. This attention is caused by many factors including the growth of the global demand for energy as a whole (in particular, for oil). In the world there is a great demand for energy (Administration of power information, 2005), and the demand is expected to increase within the next several decades by 2-3% a year.

8.2. Reservoir nanorobots

The nanoparticles can be used in the drilling, the completion, the stimulation, and the injection fluids, one can drill faster, prevent or remove near wellbore damage, mineback hydraulic fractures, plug water-thief zones, reduce waterflood fingering, encourage oil production, and prevent water breakthroughs. The high-pressure/high-temperature nanoparticles can help delineate the waterflood front, identify bypassed oil location, map super-permeability zones in-situ in the oil and gas reservoirs, map tortuosities in the rock, optimize the well placement, formulate realistic geological models, optimize a well design, delineate the extent of the asset, and target delivering the chemicals to support the enhanced oil recovery objectives.

These robots of about 200–500 nanometers in diameter are entered into the reservoir to study its characteristics, and they are introduced in large amounts with the injected liquid into the reservoir (see Fig. 8.1-3). While staying in the reservoir, they will analyze the reservoir pressure, the temperature and the type of a fluid and to store this information in memory which is built in the robot. Then they will be lifted (at least the most part of them). By means of the nanorobots the oilmen have exact ideas about the reservoir, and they use the data to create the reservoir models depending on the reservoir size (the operation of nanorobots can take some months). The control of the good working order of the robots happens in real time (through the borehole telemetry). The supply is provided from the friction with liquids or from the station in a well), they also can be added into the reservoir by special nanogenerators. Imagine that it is possible to send these robots ahead of a drilling bit instead of the geonavigation, and to find the water oil contact. Several years ago it was improbable, but the opportunities are infinite. The achievements in the field of miniaturization of nanosensors happen quickly. The nanotechnologies have achieved considerable successes in the material and medical fields, but not in oil industry. Nevertheless, the efforts to achieve this progress in our branch are undertaken. For example, the SPE Expanded seminar of technology, "Nanotechnologies in E&P production: Nano-Scale revolutions of Mega-Scale calls" was held on February 3–6, 2008 for this purpose.

Many companies conduct active researches on the development and the introduction of nanorobots. The SaudiAramco has achieved some success. The Saudi Aramco analysed a core in Ghawar by 850 plugs and plotted the distributions of the pore sizes. The distribution was bimodal, but an important observation is that the majority of pores are more than about 500 nanometers. As it became clear, the cores are generally 500 nanometers in size, respectively, the bionanorobot must be smaller. Besides, the nanoparticles of a certain size and the corresponding concentration are injected into the core samples, thus analyzing the morphology of the distribution of particles and their propagation. The following step is performing a physical experiment in which the nanoparticles of a certain size and of the set concentration enter into the reservoir. Besides, all the movement of nanorobots through the pore space is modeled in the software. In other words, the first milestone in the pursuit of happiness of nanorobots is to answer the question in three ways: by supervision of a pore size distribution, carrying out an empirical experiment of the nanoparticle injection, and the software for modeling (see Fig. 8.4). All the tests are carried out by means of a scanning electronic microscope and the power-disperse spectroscopy

The tasks of nanorobots are: a reservoir limit test; a reservoir pressure analysis; a temperature measurement; an evaluation of a fluid type; the definition of the distribution of cracks and fractures in the reservoir, the definition of the ways of higher permeability; the optimization of the well spacing; the development and the creation of more realistic geological models of an asset; an address injection of chemical substances deep into the reservoir to increase the recovery of oil and gas.

The advantages of the nanorobots are as follows:

- an increase in the efficiency of the HC recovery = the growth of the quantity of the recoverable reserves (the RF growth from 35% to 50% will almost double the proved reserves);
- a detailed idea of the pool boundaries in reservoir conditions, the characteristics of the fluid saturating the formation;
- an increase of the accuracy of drilling the wells;
- the control of characteristics in real time and their adjustment if it is necessary.

The purpose of a nanorobot is the reservoir distribution to collect the information and to analyze the reservoir pressure, the temperature, the type of a fluid, the system of pores, the residual oil, the change of physical and chemical properties and others. The information received in the course of work must be transferred to the surface where, later, it is possible to solve how to use nanoparticles to increase the oil recovery.

The nanoparticles are divided into passive, active and reactive. The passive nanorobots are indicators which bear the information on various parameters such as temperature, structure, pH, concentration of ions and so on. The passive agents are bar coded with the intent to cross-correlate the injectors with the producers in the field. In some cases they can be a form of advanced DNA tracers. The active in-situ sensing agents are basically reservoir environment markers. The active agents work to capture, sense and record the reservoir environment and to perform the fluid-typing activities during their journey between the wells. The reactive agents are in-situ intervention agents that work to rectify unfavorable hydrocarbon recovery conditions. They may act as the shear-thickening agents to optimize a hydrocarbon sweep efficiency or as nanocarriers to target delivering the chemicals (polymer, surfactant etc.) deeper into the reservoir.

The waterflooding will be used to inject and to displace the functionalized hydrophilic nanoagents that can be interrogated for their 3D location and the in-situ reservoir environment and condition (see Fig. 8.5). The remote interrogation templates could include the magnetic/electromagnetic contrast agents or the acoustic/seismic noise agents. The process could postulate a nanoscale chemical delivery system to alter wettability, reduce interfacial tension, and enhance oil recovery deep into the reservoir. A number of Resbot types (chemical, pH, electrical, or thermal) can be postulated based on the functionality and the breakups of the nanotechnology definition.

A magnetically guided nanorobot is basically a simple nanoparticle comprising a ferromagnetic material. A nanoparticle can be considered as a nanorobot, because all the components and the functions that constitute a robotic system have been moved outside of the robot structure. The actuation and the propulsion could be achieved using an external magnetic field and its gradients that could apply a six degree – of–freedom magnetic force on the nanoparticle(s) (see Figure 8.5). Sensing and tracking of the nanoparticle motion could be done using the external imaging modalities such as microscopes or magnetic resonance imaging (MRI) scanners. Once the actuation and sensing have been achieved using the external magnetic field and the imaging modalities then it is possible to implement a closed loop control algorithm that will guide the nanoparticle/nanorobot at the desired location. The research in this field has been pioneered since 2003 by Sylvain Martel at the Ecole Polytechnique de Montr'eal. A systematic approach towards MRI-based guidance of nanoscale functionalized robotic capsules began for the first time in the summer of 2008 in the context of the European Project NANOMA. The researchers of the NANOMA team have successfully developed a process for producing agglomerates of ferromagnetic filled with the multi-walled carbon nanotubes (FMWCNT) that were able to be steered in a MRI system. Their process is capable of producing vertically alignedmulti-walled carbon nanotubes filled with a high aspect ratio *nickel* (Ni), *iron* (Fe), and *cobalt* (Co) with a sufficient magnetic susceptibility artifact to be detected by the MRI modality. The direction and the magnitude of the forces that are applied on the magnetic microparticles are generated according to a control law, where the feedback (i.e., the endovascular position of the microparticles) is calculated by the processing of the MRI data. The navigation techniques in combination with an appropriate chemical modification of the nanoparticles' surfaces yield a more localized and controlled treatment as well as the controlled release mechanisms. One of the limitations of the MRI scanners for being used in the guidance of magnetic nanoparticles is the generation of weak magnetic gradients that are much smaller than those required to produce the adequate propulsion forces that can move and guide the nanorobots at the nanoscale. One way to resolve this challenge is to develop specially designed electromagnetic systems that can generate strong external magnetic fields with high magnetic gradients that can be used in the manipulation of the magnetic nanoparticles at the nanoscale. A five degree-of-freedom electromagnetic manipulator has been developed in Brad Nelson's laboratory that in its newer version can steer and control the magnetic delivery nanoagents.

In order for the nanorobot to carry out the reservoir tasks set, it must correspond to the following main components: size and form; sensors; means of mobility (movement); electricity generation; data storage; telemetry and data transmission; control and navigation. It is obvious that there are a number of problems to realize it in the reservoir nano — scale (see Fig. 8.6).

8.3. Reservoir bionanorobots

The term bionanorobotics, first introduced in the year 2003, denotes all the nanorobotic systems that include the nanocomponents that are based on the biological elements such as proteins and DNA. The biological elements are used to fabricate robotic systems. Plenty of molecular machines and machine components that could be used in reservoir nanorobotics have already been developed by the scientists coming from the fields of physics, chemistry, biology, chemical and biomedical engineering (see Fig. 8.7). In an effort to bridge the gap between the physicists, the chemists, and the biologists developing bionanorobotic systems and components on the one hand and the robotics community on the other hand, the Dinos Mavroidis' group in the US and the Antoine Ferreira's group in France proposed several new bionanorobots based on a bottom-up approach inspired by the equivalent approaches in the macro-robotics field. The Mavroidis' group focused on two different protein-based nanomotors: (a) a viral-based linear nanomotor called VPL and (b) a protein-based nanogripper.

In the nature the nanorobots are of a bacterial or a chemical character, or a cumulative one. The nanorobots must be less than 200-300 nanometers, that is, less than a size of pores, various reservoir rocks, for a free movement in a pore system. To increase the oil production the active nanobacteria inject peculiar nanomicrobes which, in turn, push out the oil or improve its properties. It is necessary to reconsider and prove the technical and economic parameters of the biomaterial which will be used as a basis of the nanobacteria. The main problem in the development of bioindicators and active biorobots is that the size of such robots shouldn't exceed 500 nanometers. Most of the bacteria are of a size more than it is required, though the "nanobacteria" existence (the size 0,2–0,5 microns) which was found in a thermal source has been confirmed. The average diameter of the nanobacteria measured by an electronic microscope is less than of any known cell of an organism.

The ultrafiltrational methods give even smaller sizes. The nanobacteria can pass through the smaller pores than their own sizes and must have flexible walls of cells. It was also proved that in filtration the nanobacteria lose part of their apatite layer. Changing the structure of the environment it is possible to change the constitution of the complexes from nanoparticles, and it is possible to design the nanobacteria of similar particles by any ordered structure. Using this process the complexes which are called bions were created. The bions can imitate the biological forms which seem living. They promise to explain further how the construction of the materials consisting of tiny nanoblocks, made and collected in the nature is taking place. And the understanding of the fact how small particles were formed from the minerals in a complex with the organic molecules can clarify the emergence of life on the Earth billions years ago.

The reservoir bionanorobots can be used for the solution of a wide range of tasks:

- In the increase of the efficiency of drilling operations, the use of nanorobots in the solution when drilling wells for the purpose of data collection and for geonavigation.

- In prospecting by the bionanorobots they are injected into the reservoir through the injected well and exposing the formation can help define the boundary and the position of the oil – water contact.

- The constant analysis of the properties will allow to receive all the geological and petrophysical data in real time.

- In reservoir monitoring the bionanorobots will be able to neutralize the water show, to change the properties of a fluid.

- In the increase of the oil recovery of the reservoir the bionanorobots are used for the delivery of the active additives, the surface-active substances, the components increasing the coverage, the wettability, and forcing out the residual oil.

- In the creation of a pore network in real time thanks to small sizes the bots are able to analyze the pores and regularly to change the created model of the filtration.

The main goal in the field of bionanorobotics is to use various biological elements whose function at the cellular level is to create a motion, a force, or a signal as nanorobotic components. These components perform their preprogrammed biological function in response to the specific physiochemical stimuli, but in an artificial setting. The proteins and the DNA could act as motors, mechanical joints, transmission elements, or sensors. If all these different components were assembled together in the proper proportion and orientation they would form the nanorobotic devices with multiple degrees of freedom, able to apply forces and manipulate the objects in the nanoscale world.

The size and the form depend on the mission and an operational environment of bionanorobots. The bot in the bottomhole formation zone differs from the bot in the reservoir by the size and the form. The reservoir nanorobot of the first generation was a simple spherical ball. The last projects form the bots in the form of bacteria to improve the movement in various pore systems (see Fig. 8.8). The main criterion of the design is a minimum size for a quieter free penetration into the pores; otherwise there will occur the contamination and the decrease in the reservoir permeability. The form depends on the type of the rock and the pore system. The nuclear magnetic resonance and the accompanying researches can help determine the minimum size.

Sensors. The nanorobots for a full performance of the functions must be able to feel the change of the parameters of a well and the reservoir. Thus, they must be capable to record (a) the formation type of a fluid; (b) the reservoir temperature; (c) the reservoir pressure; (d) the key petro physical parameters; (e) the fluid factors; (e) the trajectory and the position, and so on. For the early prototypes 1-2 sensors are enough, it is a huge step forward for clever tracers. Further, the number can increase.

The means of mobility (movement) are an important factor. The early prototypes were simply of a spherical form without any mobile mechanisms. They were injected into the reservoir and moved along the natural lines of the fluid flow from the injection to the producing wells. The advantage of using the nature's machine components is that they are highly efficient and reliable. There are newest developments of vehicles, for example, Peter Krall and his colleagues from university of Illinois in Chicago developed the molecular screw with the blades formed by the flat aromatic molecules and the shaft from carbon nanotubes. The bionanorobots could be used to manipulate the nano-objects; to assemble and fabricate other machines or products; to perform maintenance, repair, and inspection operations. Figure 8.9. shows one such concept of a bionanorobot, with its "feet" made of helical peptides and its body using carbon nanotubes while the power unit is a biomolecular motor. Also, as an option, there is a movement option which copies the nature with the help of twists. The twist operated bacteria are the smallest free engine of the nature.

Any of the movement methods must be practical and conform to the following requirements: to move through a rock pore without jamming and damaging the reservoir, to move without the aid of a fluid flow under the influence of gravitational forces, overcoming the fluid viscosity, to be capable to move against a fluid flow, to change the movement direction.

One more important factor is the supply for the devices of intelligent nanorobots which will need the energy to perform the planned operations. In nano areas, depending on functions, the tension from tens to hundreds of picowatts, micro watts is required. The potential means generating the capacity for nanorobots are: the capacity from a fluid flow; the supply from the reservoir temperature; the capacity from the friction forces; the borehole fuel elements fromthe monolithic hydrocarbons; the borehole power units.

The data collection and storage are the key components of nanorobots necessary to perform the main functions. The quantum calculations can help in future nano-data storage. The telemetry and the data transmission will be one of the most difficult tasks in creating a little miracle. The last data of the tests of the researchers of UC Irvine (University of California, Irvine) – Zettl, Burke and others prove that is possible to create a radio from carbon nanotubes which have the size of some atoms in the diameter and have the opportunity to transfer the information in nano - scale.

To complete successfully the activities described above, the virtual prototyping tools based on the molecular dynamic (MD) simulators had to be developed in order to understand the protein molecular mechanics and to develop dynamic and kinematic models to study the bionano-system performance and control aspects. The ability to visualize the atom-to-atom interaction in real time and to observe the results in a fully immersive 3D environment was an additional feature of such simulations (see Fig. 8.10.) The virtual reality (VR) technology was applied in these MD simulators, which not only provided an immersive visualization but also gave an added functionality of the CAD-based design, a simulation, a navigation, an and interactive manipulation of molecular biological components. The simulation system shown in Figure 8.11 allows the manipulation, the connection, and the assembly of the bionanorobotic components in molecular dynamic simulations using real-time VR devices such as stereo glasses, 3D trackers, force-feedback devices, and a 3D graphical display.

The control and the navigation system - it is supposed to operate the bionanorobots from the surface. It is almost impossible, but who knows, and we hope in future this question will be resolved. Many of the above criteria are only the planned purposes. It can take decades to design an ideal reservoir nanorobot, but it is possible and today's technologies confirm it. Today, the oil and gas business applies the biomethods to increase the oil recovery. The basis of many of them is nanobacteria. The most widespread and the most often applied ones are nanoemulsions, nanosuspensions and dendrimers.

The nanodispersion, nanoemulsion or nanoliquid, is the liquid containing the particles and agglomerates of the particles with a specific size of 0.1 — 100 nanometers. Such liquids represent colloidal solutions of nanoparticles in the liquid solvent. Owing to the small amount of inclusions such systems possess special physical and chemical characteristics. The share of the surface in them falls to 50% of all the substances.

They possess the increased superficial energy in connection with a large number of atoms being in the excited state and having not less than one free electron at the external power level. The nanodispersions are of various nature. The polyorganosilocanes, metallic, oxide, carbide, nitride nanoparticles, carbon nanotubes etc can act as the dispersed substances. As the dispersive environment, the water or the ethylene glycol are usually used. In oil industry the nanoemulsion water in oil can transfer the products not transportable with oil, owing to their insolubility, to the areas to which it is impossible to supply large amounts of water because of the problems connected with corrosion, destructions etc. The evolution of oil and gas nanodispersions is a kinetic controlled process in which the intermediate structures are separated from the equilibrium conditions by considerable kinetic barriers. In particular, the nanoemulsions can be used as carriers of the inhibitors of corrosion, the inhibitors of asfaltene and paraffin deposits or for the acid treatment. The nanoemulsions can be used for cleaning the oil pipelines. Great prospects are connected with their use as carriers of the additives incompatible with each other or to start the reaction of polymerization or jellification in the corresponding areas of a well. At present the main problem is high cost, as a result of the need to use high-energy systems, such as homogenizers of a high pressure, to obtain them. Due to their structure and instability of the sizes of the units of the nanoemulsion, the nanodispersion, as a rule, is quite unstable. Their properties easily change and strongly depend on the external influence.

A dendrimer is a macromolecule with a symmetric tree – like structure with regular branchings. The dendrimers belong to the class of the polymeric connections which molecules have a large number of branchings. In their receiving with each elementary act of connecting the monomer, the number of branchings increases. As a result, with an increase in the molecular weight of such connections the form and the rigidity of the molecules change, that is, as a rule, accompanied by the change of physical and chemical properties of the denrimers, such as a characteristic viscosity, a solubility, a density and other changes. The dendrimers of the 3rd and higher generations are characterized by a high density of the molecular structure and have the form close to spherical. The solutions of a dendrimer possess much lower viscosity, than the solutions of other substances with the same molecular weight. The properties of the dendrimers in many respects are defined by the type of the functional groups on their surfaces. The dendrimers with the hydrophilic end groups (for example, carboxyl) are soluble in water, and with the fluororganic ones are in supercritical CO2. The dendrimers are actively investigated in connection with the possibility of their use in the most oil and gas areas. The dendrimers can serve as peculiar containers to create the system of metal nanoparticles practically of the same size which can be used as catalysts of chemical reactions. The scientists learned to hold the ions of metals on the surface of the dendrimer by means of helatny groups. Such dendrimers on the basis of gadolinium and magnesium are actively used as contrasts when carrying out the researches by the method of the nuclear magnetic resonance. The dendrimers with the photochromic groups are capable to transform the light energy that is perspective for the use in optical devices. The dendrimers are capable to form the complexes with other molecules, the stability of such complexes being supervised by a condition of the environment (see Fig. 8.12–8.13).

Thanks to the adjoining "branches" of the branched molecule, the internal cavities in which there can be various small molecules not chemically connected with a dendrimer are formed. The dendrimers can also hold the substances with the radioactive marks, used for diagnostics. Generally they find application in medicine, but the technology is applicable in oil and gas industry as well. The introduction of reservoir nanorobots in the process of oil production will help to save huge sums of money, will bring the technology prospecting, exploration and oil recovery to an absolutely new level. They will change the developed "rules of the game" in oil and gas industry, creating the systems of control, estimation, supervision, monitoring and management of the reservoir and the deposit as a whole.

The technology of the creation of the ideal reservoir nanorobot is at the conception stage, but it promises big prospects. Having taken into account the results received with the application of the nanoemulsions and the dendrimers, it is possible to state with confidence that they deserve the future. In the XX century, the reservoir flooding was introduced for the purpose of increasing the oil recovery coefficient. Today, it is a standard technique which is applied almost in all the fields. It is quite possible that in some years the reservoir bionanorobots will be applied with the same success, as the basis for this purpose has already been created.

The bacterial – based nanorobotics. This type of a nanorobotic system is based on the way the bacteria move in a porous environment. This is a "biomimetic" type of nanorobot as it uses the systems or the concepts developed by nature. The bacterial-based nanorobotic systems and some of their versions could also be as either a bionanorobotic system or a magnetically guided nanorobotic system as presented earlier. There are two different approaches in developing the bacterial-based nanorobotic systems. The first approach is using the living bacteria to serve as the nanorobotic system that will move in the porous environment and manipulate the objects in it. The other approach is developing the fully artificial bacteria-like nanorobots that are powered using an external magnetic field. The first approach is trying to take advantage of the biological engineering already in place in the living bacteria and most importantly their propulsion capability through their flagella motors. The goal is to use a team of bacteria to move forward to a small object in a porous media and be able to control this process (the speed, direction, amount of displacement, and stop on demand and resume this process). A special type of bacteria called magnetotactic bacteria (MTB) offer more possibilities for the manipulation of the objects at the micro and nanoscale. The MTB are the bacteria that possess magnetic nanoparticles on their membrane. Their main functional characteristic is magnetotaxis, i.e., they can orient along the Earth's geomagnetic field lines. The naturally embedded magnetic nanoparticles of the MTBs could be performed by the external magnetic field to generate a torque for the MTB steering control. The second approach in developing bacterial-based nanorobotic systems is a biomimetic one. The goal is to create completely artificial nanoswimmers by copying the nature's design from the bacteria. Inspired by the spermatozoa motion, Dreyfus et al. developed a microswimmer consisting of a thin paramagnetic filament. By applying an oscillating magnetic field the swimmer propelled the cell through a continuous deformation of the filament in a manner somewhat similar to an eukaryotic flagellum. The recent examples of an artificial flagellum in the form of a nanocoil that has been propelled using a rotating magnetic field have been proposed by the Brad Nelson's group (see Figure 8.14). The selfscrolling fabrication technique to fabricate the helical swimmers of a size comparable to *E. coli* which are capable of swimming in both water and paraffin oil has recently been performed as well by the same group.

8.4. Underwater robots, concept, the main characteristics (on the example of the Chinese underwater Arctic-ARV robot), mission and advantages of the use of underwater robots

The underwater Arctic-ARV robot with the system of collaboration of the automation and the remote control has been independently developed in China. The experiments and the researches armed at studying the properties and the opportunities of the use of the underwater robots in oil and gas area were carried out in conditions of the water area (under ice) being on 84 ^{0}n.e. for the first time in such high-latitudal water area. The experts from Shanghai University (Shanghai Jiao Tong University) created a robot with the remote control oriented to the depths of about 3,5 km which is one of the most advanced robots of a sort in the world, and the depth of 3,5 km the robot (the sizes: length of 3 m, height of 1,8 m, the weight of 3 t) reaches in 30 minutes.

The underwater robot is equipped with a sensor, five video cameras, six underwater searchlights and two mechanical arms, each of which is 4 times more than an arm of the person and can lift some hundred kilograms. Two searchlights can shine the area in the radius of 100 m round the robot. According to the Chinese scientists, the Arctic-ARV robot will be used mainly for the research of microorganisms and deep-water beings. The main objectives of the use of the underwater robots:

- the survey and search operations, including the search and the inspection of the sunk objects, the inspection of underwater constructions and communications (pipelines, cables, conduits);
- the prospecting operations including a topographical and photo video survey of the seabed, an acoustic profiling and a relief mapping;
- the subglacial operations including laying of pipelines, the cable at the Arctic bottom, the service of the systems of supervision and illumination of an underwater environment;
- the oceanographic researches, the monitoring of the water environment;
- the military operators, including an anti-submarine investigation, the patrol, the safety of drilling platforms, etc.

The advantages of the use of underwater robots. The absence of a man onboard the underwater machine allows:

- to lower the costs of the development of the underwater robot in comparison with the piloted devices;
- to exclude the risk of human losses;

- to exclude the restrictions determined by the physiological opportunities of the crew (the duration of autonomous swimming; a constant stress determined by the possibility of a sudden emergency situation of bearing a constant threat to the lives of the pilots).

8.5. Borehole microrobots, concept, main characteristics, types, movement and management mechanism and their mission

The device and the principle of the work are presented on the example of the borehole robot of the CIRCO company. The borehole robot of the CIRCO company is an independent intra borehole robot. The design of the borehole robot is directed at providing the research programs and the wireless monitoring of the underwater wells, the measurements of key variables in wells and the communication with the surface. This technology doesn't demand a cable to transmit the electric power and the data and allows carrying out a semipermanent monitoring of the well condition. The independent robot is capable of moving in a well to the places of carrying out measurements and to transfer or load these data into a docking station. The measurements are carried out in the positions defined in advance. Such indicators as pressure, temperature and flow velocities are measured. The device (see Fig. 8.15) consists of: the driving back and the forward wheels (driving wheel); the transmission (gearbox); an electrical motor (electricalmotor). The power supply system includes the following: a turbine (turbine); a generator (generator). The design is modular; the coupling of modules is magnetic (magnetic coupling). The main idea of the model is that the autonomy of a product is reached at the expense of the continuous inflow of energy; the product streamlining by the flow of oil/gas sets the turbine connected with the generator in motion, resulting in charging the onboard accumulator. When the energy becomes enough, the measurements (pressure, temperature, flow velocity) are carried out and the broadcast session is transmitted. The ways of the management and the control (see Fig. 8.16) are from a surface through a cable or autonomous. The classification of well robots is presented in Figure 8.17. The purpose of the robots is an inspection of the condition of wells and pipelines and the data recording in the extracting wells. The borebole tractor is a robotic vehicle for work in the well channel. The basic purpose is the delivery of various logging equipment, measuring devices and so on in various places of a well.

By the ways of movement the tractors are divided into two groups:

1. The tractors on a wheel draft (SlbTuffTrac, Sondex) are applied to work in the cased well.

2. The tractors moving as a worm (SlbMaxTRAC, SmartTrac) are applied to work in an open well.

The main domestic and foreign producers of the borehole tractors are such as the AMAK "OB" hardware and the methodical autonomous complex (development in 1996-98yy, production tests –in the year 1998). Among the domestic producers the following developments are still possible to be mentioned: the JSC NPF Geofizika; the Geotron company; the Schlumberger company tractors: the TuffTRAC and MaxTRAC; the SmartTracs (USA); the Sondex – the European company; the WellTec and the Chinese product from the China Petrolium company. Application: Perforation; Carrying out logging; Analysis of the casing; Cement and corrosion assessment. The advantages are: the reduction of the risk of jamming of the equipment; an opportunity to carry out logging in horizontal wells; the simplification of the fishing operation (fishing); carrying out the tests in running tools, against the fluid flow.

8.6. Reservoir microrobots, concept, main characteristics and mission

The microrobots are the devices from 1 mm to 16 mm, in size a device, slightly noticeable to a human eye, studies the borehole space and the stratal space if necessary. The microrobots are injected into the borehole space and into the formation to study the characteristics; they are being injected into the reservoir with the injected fluid in great amounts. White staying in the reservoir, the microrobots are capable to analyze the reservoir pressure, the temperature, the type of a fluid and to store this information in the built-in memory. After passing through the formation the microrobots are lifted to the surface in the producing wells (at least most of them). By means of the reservoir microrobots it is possible to receive the exact ideas of the reservoir characteristics which are used subsequently for the creation of models of the reservoir and the well.

In the assembled form the microrobots represent the devices of 160 mm high and weighing 0,06 kg. By the data of the Saudi Aramco it is observed that most of the practical microrobots are made of wire in the form of round balls which, in turn, is very convenient, for example, for welding long seams with a small amount of extension. The previously prepared seams in general can't often be welded by a direct (straight) wire. Such a wire is possible to weld, but only very short connections.

The sensitive part of the manometer represents a glass cylinder in which the heater from a tungsten wire with the diameter of 0,01 mm and with the resistance of 80 Ohms is placed. To increase the sensitivity of the manometer in the range of high pressures it is necessary to use a straight wire.

The tasks of microrobots are as follows: the temperature measurement in the borehole space, the pressure measurement, the address injection of the chemical substances into the borehole space and into the reservoir, the assessment of a fluid, the optimization of the well spacing.

8.7. Microelectromechanical system (MEMS), concept, the main characteristics and their application in the oil and gas industry

The MEMS is a set of micro devices of the most various design of application in which production the modified processing methods of microelectronics are used (see Fig. 8.18). The micro electromechanical systems are produced by a combination of mechanical elements, sensors and electronics on the general silicon basis by means of the micro production technologies. All the elements can be realized in the form of a uniform product, and at once ten miles by hundreds, as chips on a silicon plate. The basis of it is the approved traditional production technology of semiconductor integrated chips. Their development began by the early 1960s, but the commercial application began since the 90s, and the earliest applications of the MEMS were the sensors of the pressure printing heads of stream printers and micromirrors of digital projectors quite recently, by the early 2000s, of these 3 segments more than 80% of all production of the MEMS was necessary. Today they already work as important elements in automobile, medical and electronics industries.

In most cases the devices unite all the siliconless chips which are carrying out "brain" functions of the system with the micro mechanisms serving for it as "eyes" and "hands" with the MEMS. Such devices differently react to the environment surrounding them. The sensors detect the temperature, mechanical, chemical and optical changes whereas the components of the power drive are physically established in a standard position and measure and regulate various elements of the environment. The national scientific fund defines the "micro" - range from 1 micron to 1 mm, and the "nano" - range begins already outside 1 micron. For comparison, a diameter of a human hair is usually equal to 50-100th (nm). No wonder these arguments in favor of the application of the MEMS technologies in the area of prospecting and development of fields are generally reduced to their sizes.

The small sizes have their advantages. The MEMS blend the limited space, such as the wellbore or the bottomhole tool, and take a very little place where the free space is of paramount importance. Their need for power supply is comparable with that for the silicon electronic chips and is low in comparison with the ordinary macroscopic devices which are carrying out the similar tasks. Besides, after a careful development of an effective mastering of manufacturing techniques of the MEMS the mass production of devices with the MEMS can become profitable. In industry the MEMS have already proved the reliability and an ease of integration in the designed systems.

Thanks to the production of the integrated schemes, silicon has been studied well. The level of the properties of silicon is ideal in view of its crystal structure like diamond with an elementary cell (the smallest repeating part of a crystal) of a cubic type. By the mechanical properties pure silicon is suitable for the MEMS creation, and after alloying with admixtures, we apply it in the production of the integrated schemes, its electric properties are possible to modify according to the proper constructive requirements.

The understanding of the properties of a crystal form of silicon is of key importance in the mechanical micro processing. The symmetry in regard to three main axes of its crystal and the communication between three crystallographic planes can define the geometry of etching and, finally, the MEMS functionality. Being the basic structural element of the MEMS creation, silicon in the crystal form is made in the form of plates and has rather a low prime cost. The polycrystalline and the amorphous forms of silicon are usually deposited in the form of thin films and also are often used in the production of the MEMS. The polycrystalline silicon (polysilicon) has become an especially useful material for the production of micromechanical structures and the creation of electric connections in the devices with the MEMS.

The standard process of the production of the devices with the MEMS consists of three main stages. On a suitable pallet, usually from silicon, sometimes from sapphire, thin films are grown up or deposited. It is followed by the process of lithography by means of which a drawing is made, and then by the etching process which creates a three-dimensional structure. This sequence can be reiterated so as to create more complex structures.

Sometimes the stages of sedimentation or etching are passed, a photoresist as a rule, a photosensitive emulsion or a polymer layer is used as a consumed layer in the creation of free suspended structures or templates for the selective cultivation of a new material. In the course of production of the MEMS the fourth stage, that's, seaming of two and more plates together is possible.

All these processes must take place in the purest conditions, as on such a scale even the smallest foreign particles can result in the defects, capable to worsen the product characteristics. In pure apartments there are carefully controlled the concentration of natural pollutants, including the dust, microbes transferred by air, aerosol particles and vapors of chemicals which are capable to create complications in the MEMS production. In pure apartments the extensive complex systems of filtration, circulation and a transition of the air through the locks are working, and also scrupulous procedures of maintenance of purity by the working personnel are introduced. In most cases on one plate a set of devices is created. Then the plate is cut by a high-precision tool, resulting in the MEMS party.

On the increased scale – the ready plate containing 800 devices, though 50 of these chips are not functional control structures. The chips from this plate will be used for the production of pressure sensors on the basis of the MEMS of a joint development of the Schlumberger company and Californian institute of technology (Caltech). The diameter of the plate is 100 mm (4 inches), and each sensor microchip is of 2×2 mm in size. The MEMS devices can feel, think, work and communicate. It is possible to divide all the MEMS devices into two groups depending on their appointment: the sensors and the executive mechanisms-activators. They redirect the light, inject and mix the fluids, and also defect the molecules, the heat, the pressure or the movement. The interaction of the electronics, mechanics, the light or the working liquids operating together make up the micro electromechanical systems, or the MEMS.

There exist 3 main types of the MEMS:

- Pressure sensors.
- Chemical sensors.
- Motion sensors (accelerometers and gyroscopes).

The MEMS are widely used in the medical sphere, in production of cars, and also in the military, space, power, transport, oil and gas and construction industries. The MEMS are used in power industry. The power branch is developing,with the role of the use of the MEMS technologies increasing. The MEMS can promote the development of the new advanced technologies to seize the new markets, to increase the efficiency of the existing markets. The MEMS can be used as the basis for the new power sources:

- the improvement of already existing industrial components;
- the increase of efficiency of the oil and gas companies, namely prospecting and development of fields.

The oil and gas industry studies the new ways of images, monitoring and research of conditions directly on the remote field facilities. The MEMS propose the perspective solutions for this segment, being highly sensitive sensors which are of small sizes and reliable. One of the examples of the application is the seismic image of deposits which can be made by means of the MEMS devices. The use of the MEMS offers the productivity improvement in addition to essential economy of means and time for a wide range of technologies for the oil and gas industry. Thanks to the possibility of a continuous control, these technologies can become a basis of smart fields.

Conclusion

The introduction of robots into to the process of formation saves huge sums of money, will bring technological exploration and oil recovery to quite a new level. They will change the established "rules of the game" in the oil and gas industry, a system of monitoring, evaluation, supervision, monitoring and management of the reservoir and the formation as a whole. The technology to create the perfect formation of nanorobots is still at the stage of conception, but it has great prospects. Taking into account the results obtained with the use of the nanoemulsion, we can surely say that they merit the future. In the XX century there was introduced the waterflooding reservoir to increase oil recovery. At present, it is a standard procedure which is used almost in all fields. It is possible that in a few years the reservoir nanonorobots will be applied as well, because the basis for this has already been created.

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MEMS – Electro-mechanical systems: CIRCO – autonomous borehole robot; Arctic ARV – Underwater robot; CIN – Oil Recovery increase; SPE – Wide seminar on technology.

Fig. 8.1. Nanorobots in pore space

Рис. 8. 1. Нанороботы в поровом пространстве

Fig. 8.2. The size of the nanobot is one thousandth of the thickness of a human hair

Рис. 8.2. Размер наноробота составляет 1/1000 от толщины человеческого волоса

Fig. 8.3 Distribution of nanoparticles in the sample of carbonate rock
Рис. 8.3 Распределение наночастиц в образце карбонатной породы

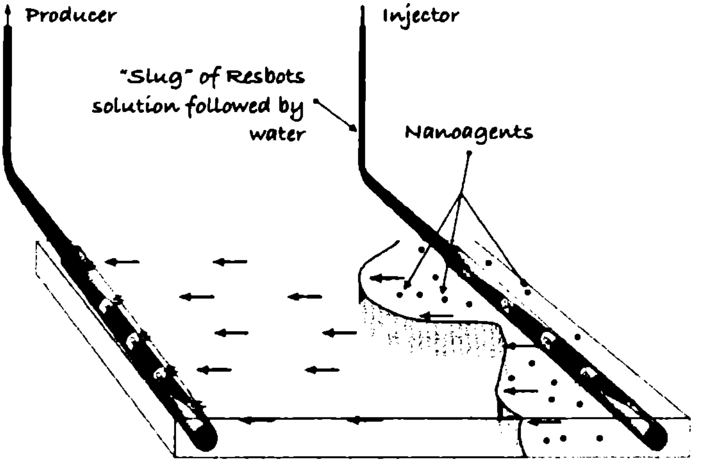
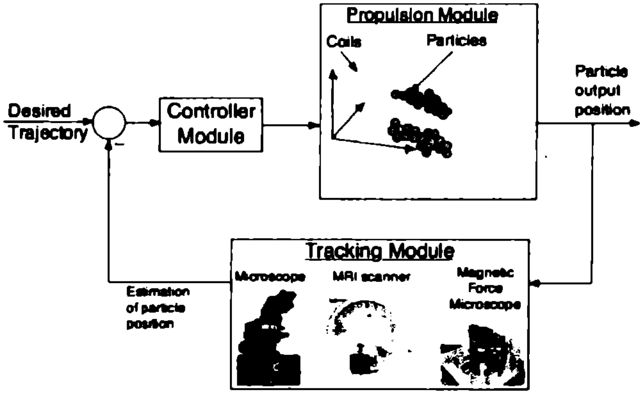


Fig. 8.4. Injection of nanoagents (Resbots) into the reservoir [14]
Рис. 8.4. Нагнетание наноагентов (Resbots) в пласт [14]



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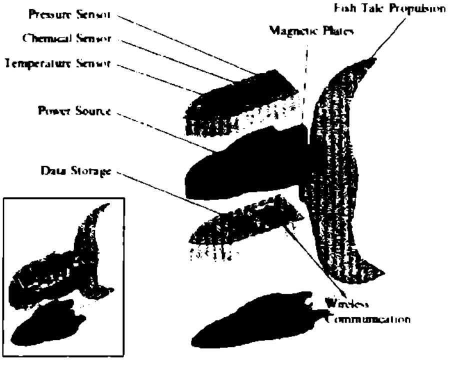

Fig. 8.6. A fully functional, autonomous nanorobot for in- situ monitoring and its individual components [11]

Рис. 8.6. Полностью функциональный, автономный наноробот для пластового мониторинга и его отдельные компоненты [11]

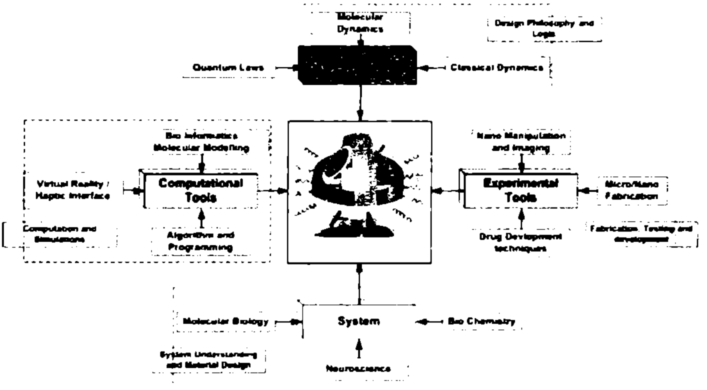

Fig. 8.7. Nanorobotics—a multidisciplinary field

Рис. 8.7. Наноробoтика - междисциплинарная область знаний

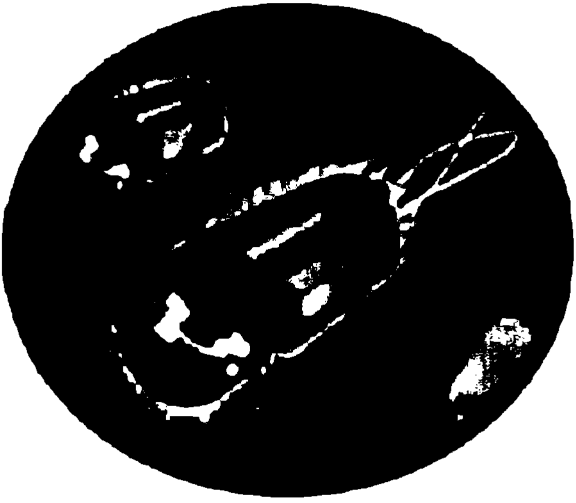

Fig. 8.8. The bots in the form of bacteria to improve the movement in various pore systems

Рис. 8.8. Боты в виде бактерий для улучшения движения в различных пористых системах

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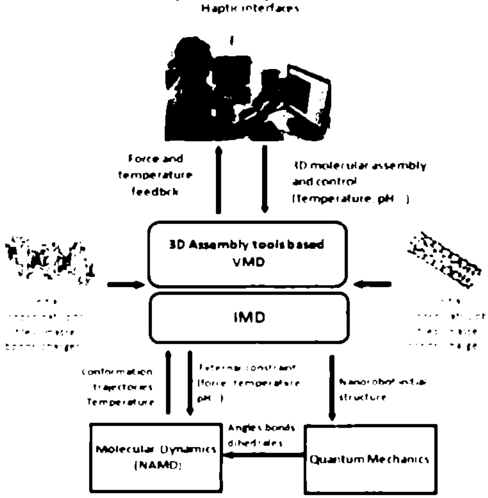

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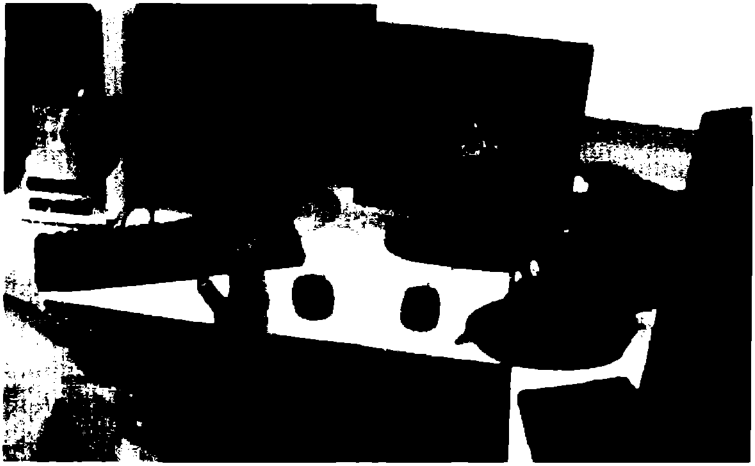

Fig. 8.11. Experimental interactive simulation platform using virtual reality interfaces. In the virtual molecular dynamics (VMD) environment, the user applies forces to simulated bio-nanorobotic structures via a force feedback haptic interface while manipulation is performed through a virtual hand. The head tracker is mounted on a pair of shutter glasses for operator immersion

Рис. 8.11. Экспериментальная интерактивная платформа моделирования с использованием виртуальных интерфейсов реальности. В виртуальной молекулярной динамике (VMD) окружающей среды, пользователь прикладывает силы к искусственным био-нанороботным структурам с помощью тактильного интерфейса с обратной связью по усилию во время манипуляции виртуальной рукой. Поворотное устройство смонтировано на защитных очках для погружения оператора. Головной манипулятор/трекер, крепится на защитных очках для погружения оператора в виртуальную среду

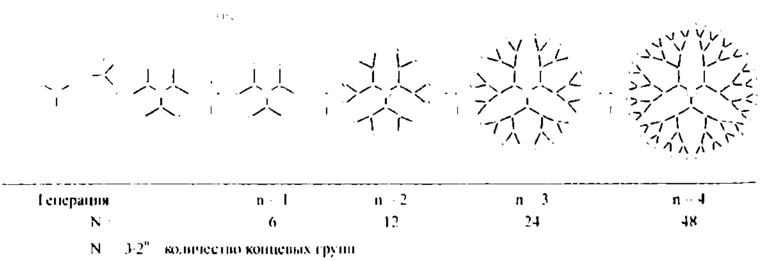

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Рис. 8.12. Схема синтеза дендримера, растущего с сердцевины (двумерная проекция)

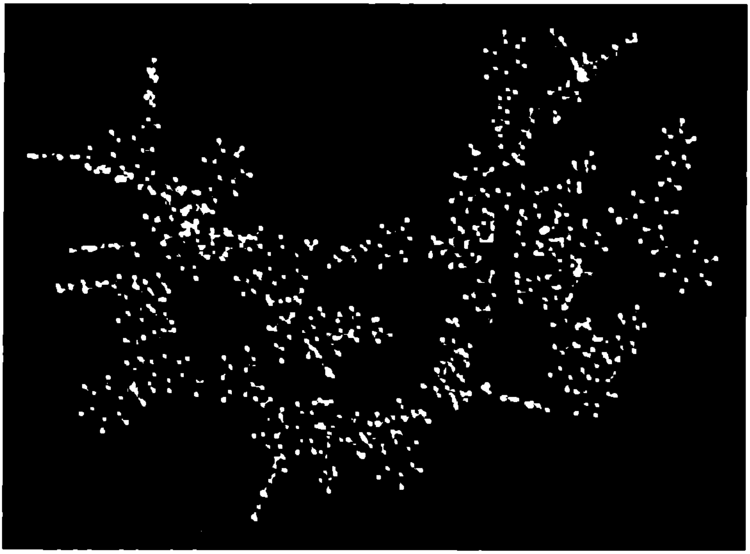

Fig. 8.13. The synthesis of dendrimer
Рис. 8.13. Синтез дендримера

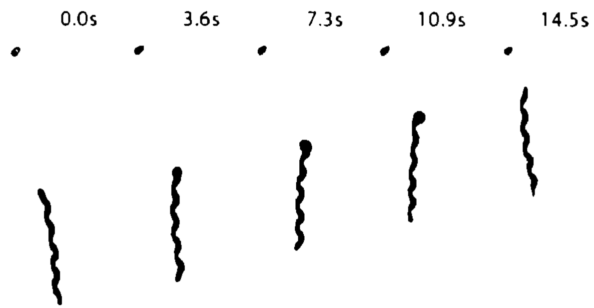

Fig. 8.14. Artificial bacterial microswimmers developed at ETH Zurich. By adjusting the rotating speed and direction of the external magnetic field, velocity and direction of the motion of the helical swimmers can be tuned in a controlled fashion [B.J. Nelson, ETH Zurich]

Рис. 8.14. Искусственные бактериальные микропловцы,разработанные в ETH Zurich. Регулируя скорость вращения и направления внешнего магнитного поля, скорость и направление движения спиральных пловцов может быть настроена в управляемом режиме. [BJ Нельсон, ETH Zurich]

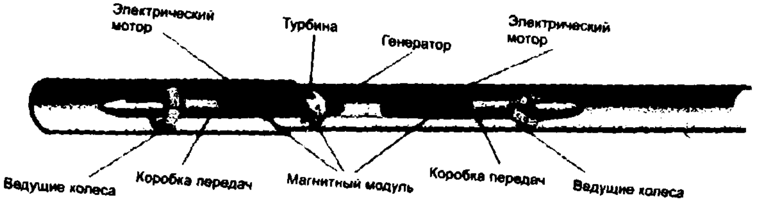

Fig. 8.15 Driving gear
Рис.8.15 Транспортный привод

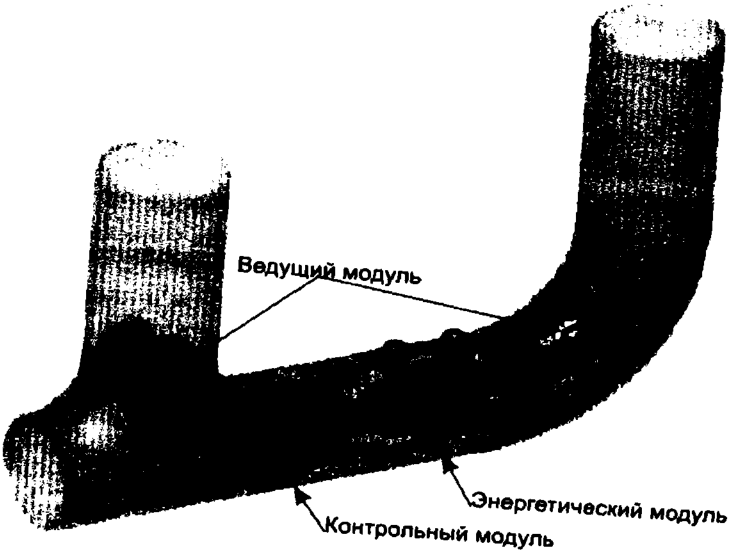

Fig.8.16 Control mode
Рис. 8.16. Способ управления

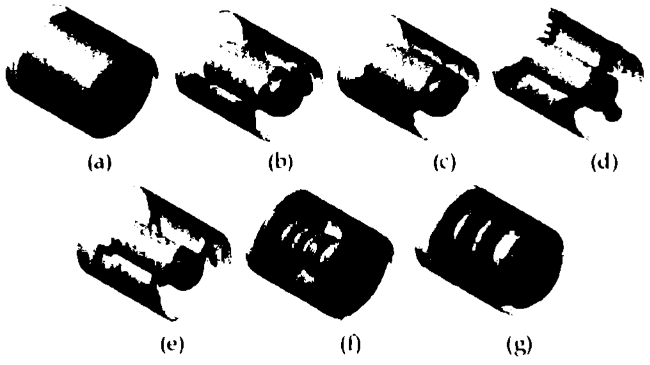

Figure 8.17. Classification of robots: (a) type of pig, (b) type of wheel, (c) type of track, (d) type of spring, (e) type of pacing, (f) type of screw, (g) type of spiral

Рис. 8.17. Классификация роботов: (a) типа болванки, (b) колесный тип, (c) гусеничный тип, (d) пружинный тип, (e) шагающий тип. (f) червячный тип, (g) винтовой

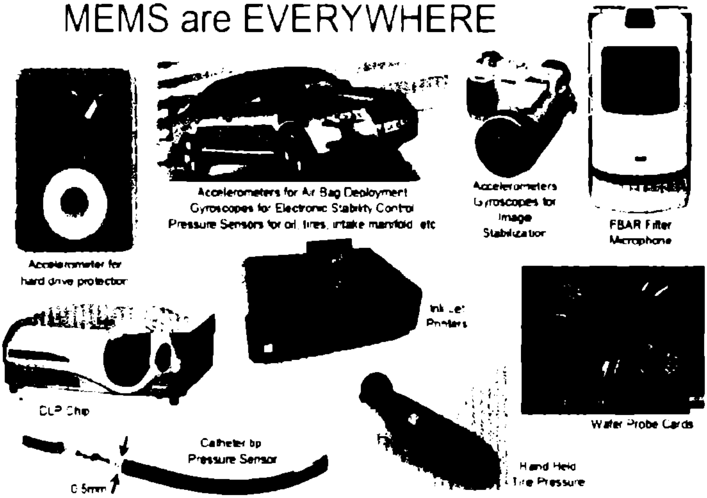

Fig. 8.18. Using of MEMS in diversity sphere

Рис. 8.18. Использование МЭМС в различных сферах

Area	Industry Needs	Nanotech Solutions
Exploration	Less invasive methods of exploration, remote sensing Methods to "sniff" for new pockets of oil Enhanced resolution for subsurface imaging and computational techniques Improved temperature and pressure ratings in deep wells and hostile environments Improved instrumentation for gas adsorption Improved 1D, 2D, 3D and 4-D seismic resolution	Nanosensors and imaging
Reservoir management	Enhanced remote imaging, real-time continuous monitoring of flow-rate, pressure and other parameters during production, wireless telemetry, *in situ* chemical sensing Accurate early warning detection and location of leaks (preventing environmental hazards) Improved reservoir illumination and characterization, including improved signal-to-noise ratio of subsalt events, improved velocity-modeling accounting for anisotropy	Nanosensors
	Improved sand exclusion and mobility of injectant Controlled agglomeration of particles Ability to capture and store CO_2	Nanomembranes
	Improved stability and pressure integrity and heat transfer efficiency Ability to minimize damage to formation of offshore platforms, reduce their weight requirements, and increase their sturdiness	Nanomaterials, fluids and coatings
Drilling	Increased effectiveness and longevity of drilling components, making cheaper, lighter and stronger pipes and drill bits Extended lifetime of equipment with corrosion resistance, adhesion enhancement and wear resistance Improved strength-to-weight ratio for an expanding range of geological settings Expandable tubulars for deeper wells without needing to telescope the well, or casingless wells Improved cement integrity - light density and high strength, hole quality and well placement, hermetic seals Innovative drill engines that can be sent deep into the shaft, improved elastomers Ability to prevent bio-fouling	Nanomaterials and coatings
	Improved drilling fluids and thermal conductivity Removal of toxic metals (mercury, cadmium, lead) Ability to prevent drilling mud invasion, separating mud filtrate and formation water	Nanofluids and nanomembranes

Table 8.1. Nano technologies for exploration, reservoir management and drilling [16]

Таблица 8.1. Нано технологии для разведки, разработки месторождений и бурения [16]

Area	Industry Needs	Nanotech Solutions
Production	*In situ* sensing and control, monitoring of stresses in real-time	Nanosensors
	Ability to direct fracturing and withstand high temperatures to go deep into challenging resources of wellbore deep reading of oil-water interface	
	Chemical detection with no active components downhole	
	Enhanced measurements in the borehole (pressure, temprature, composition, conductivity)	
	Accurate detection and location of leaks (pipeline, downhole)	
	Improved understanding of matrix, fracture, fluid properties and production-related changes	
	Increased wear resistance	Nanomaterials and coatings
	Self-healing materials	
	Pressure integrity, improved robustness	
	Enhanced hydro-phobic or hydrophilic behavior for waterflood applications	
	Improved water filtration (for industrial, agricultural and potable use)	Nanomembranes
	Filtration of impurities from heavy oil and light gas	
	Desulfurization, inhibiting H_2S producing bacteria	
	Cost-effective CO_2 sequestration	
	Sand exclusion	
	Effective water-shutoff	
	Scale/wax removal	
	Easy separation of oil/water emulsion on the surface	
	High-strength/lightweight proppants	Nanofluids
	Environmentally friendly fluids	
	Enhanced oil recovery: enhanced fluid viscosity and molecular modification,	
	Improved production rates and water disposition	
	Reversible/reusable swellables	
	Ability to manipulate the interfacial characteristics of rock-fluids relationship	
	Reversible and controllable making and breaking of emulsion or foam	
	Improved combustion and enhanced prevention of fouling and corrosion	

Table 8.2. Nano technologies for the oil and gas production [16]
Таблица 8.2. Нано технологии для добычи нефти и газа [16]

CHAPTER 9. **SMART PROCESSING AND TRANSPORT**

Abstract

The smart field is based on the technology, the essence of which is that the installed borehole equipment makes it possible to carry out the automated measurements and to transmit them from the site to the control station in real time. The operators constantly receive the relevant information enabling them to manage the well operation more effectively. Based on these measurements, the models are created, which help to calculate various options to reduce the cost of the development, the optimization, the production and the water injection into the reservoir. Using a constant flow of the integrated data, the effective solutions for the entire life of the well can be made. The pipelines operate at high pressure, and the violation of their integrity results in the emissions of the products pumped. The sensitivity of the system, its accuracy and high speed, i.e., the ability to detect the small leakages and mechanical damages in the shortest time, are the most important requirements. Small, but time-consuming leakages can, as the experience shows, result in significant environmental and financial consequences.

Key words: *Production control system in real time, advanced process control, smart wells, subsea production systems, subsea separators, wellhead valves for water injection, underwater separation, pressure reduction and injection station, water injection pump, multiphase pump, sand removal station, monitoring of production processes, distribution control system, information and communication systems, enterprise production environments, automated control system, production relational database management system, gas collection and treatment system management in real time, intelligent process control over the system for gas treatment in real time, underwater field, spiral-axial multiphase pumps, underwater compressor units, automated process control system of primary oil treatment, a system of supervisory control and the data acquisition, remote terminal, the central control room (dispatch center), soft-real-time mode, human-machine interface, ergonomic operator's work, the information security of the enterprise, integrated communication system, a remote object, the central control panel, the data exchange in real time, the sensor network, the technology of self-*

organizing wireless networks, smart pipelines, multiphase pipelines, monitoring, fiber-optic monitoring, subsea risers, distributed temperature sensor, risk management system of pipelines, main pipeline, compressors.

Main topics of the chapter:

The management of intra-field processing and transport of hydrocarbons in real time. Smart intra-field pipelines, gas and condensate pipelines. The control systems of intra-field transport of oil, gas and condensate in real time. Underwater and surface systems of multiphase intra-field transport of products. The features of fiber-optic cable installation field pipelines. The advantages of using fiber-optic monitoring system. Gas leak detection system. The main causes of gas leakage during transportation. Management of the intra-field oil transport in real time. The pipeline risk management system (PRMS). Vibroacoustic system of continuous monitoring of an extended structure (SAMPO). The monitoring of the condition of intra-field pipelines using robotic systems.

Introduction

This chapter deals with the modern technical equipment and the software in the field of information and process automation and the production management that enable to solve a wide range of tasks to improve the efficiency of the development of oil fields. The proposed concept of the company is based on the smart field technology the essence of which is that the installed borehole equipment makes it possible to carry out the automated measurements and to transmit them to the site in the control station in real time. The operators are constantly receiving the relevant information, enabling them to manage the processing and transport operations more effectively. In addition, it minimizes the number of visits to their multiple processing units and transport intra-field pipelines, and hence it reduces the costs and risks of accidents. Based on these measurements, the models are created, which help to calculate various options to reduce the cost of the development, the optimization, the production and the water injection into the reservoir. Using a constant flow of the integrated data, the smart companies take more effective solutions for the entire service of the processing units and transport intra-field pipelines.

9.1. Intelligent management system of the infield gathering and preparation of hydrocarbons in real time

The modern information systems allow you to get in a convenient form for the operator the data from the wells, gathering stations, storage tanks, primary oil treatment plants, and the booster group pumping stations in real time. The material basis for the collection of the information is provided by the modern controllers and the database management systems that allow you to store and process the data from the infield gathering and preparation systems in real time, and from the relational databases. On the pyramid (Fig. 9.1 levels of automation) they are levels L1 - L2. As part of the monitoring functions of the production processes and the dispatch management in modern information systems including, the following tasks are solved. The user gets the basic values of the monitored parameters (flow rate, pressure, temperature, etc.) of the wells, a group of metering stations, the processing plants, the surface facilities, the storage and the delivery of the products, etc. in real time. In this case the visualization of the bottlenecks is carried out: the screen provides the current values in comparison with their established limits in the controlled processes. The well operation data are processed and issued upon the request in the format required. The user is supplied with the *rich by the opportunities* the report generator that allows to design the reports in a standard format in different directions: changeable and daily production reports, reports on the production and the delivery of hydrocarbon, the injector volumes, the well status, etc.

The monitoring and the reports on the events, the data of which come from the distributed control system (DCS) and the sensor systems security, are carried out. The sequence of the events that triggered the alarm are recorded and analyzed. A continuously verification of the safety valves on the potentially dangerous areas of gathering and the initial treatment of oil and gas is executed and on its basis the reports of any changes in their conditions are made up. For example, Fig. 9.2 (Window of application control of the valves) presents a list of standard reports generated by a specific application of Safety Valve Scout Honeywell on the control of valves. The monitoring and the analysis of all the equipment shut-downs directed at fixing all the reasons for shutdowns, the shut offs on the basis of restoration in the history of the process of all the actions that led to the shutoffs are conducted.

The reports are prepared based on the made analysis (Figure 9.3 Window of application of monitoring disconnections of technological facilities). A separate subsystem, along with the subsystems of fire and explosion dangers, is the subsystem control of pipeline leaks. Today one of the most promising areas is the acoustic systems to detect and locate the leaks. The advantages of such systems are the ability to operate at all the stages of the pipeline operation (start / stop pumps, changing the values of flow rate, etc.), a low rate of false actions which is very important for the purposes of automated data protection, an easy maintenance and a high reliability of the operation. An important requirement for a modern security system is its integration with a distributed control system, which allows to respond to potential threats and emergency situations, and to operate the equipment in a safe mode [4].

The modern production management system or the MES (Manufacturing Execution System) is the information and communication system of the production environment of the enterprise. In the structure of the automated enterprise management the MES is connected with the process control systems (ERP Enterprise Resource Planning). The MES, collecting and processing the data in real time from the processing facilities and control systems and the historical data from the production relational databases, the MES supports the automatic or manual control of decision making. Simultaneously, the MES prepares and transmits the information in the required form to the ERP. Currently, the following areas of the MES in oil companies can be identified.

The present level of the introduction of the methods and the software to manage the design and the development of oil fields enable you to formulate and solve complex optimization problems of the field development. On the basis of a mathematical hydrodynamic model of the formation, which allows to take into account the mutual influence of the hydraulic wells; the problem of selecting the optimum production rate of the recovery and the injection wells. As an optimization criterion we refer to the technical and economic criteria such as minimizing the volume of associated water, subject to the limitations on the borehole pressure and the implementation of the plans of oil production. Currently, to solve such problems an effective mathematical apparatus based on the methods of mathematical programming, and considerably taking into account the specific character of the mathematical model of the problem has been developed [6]. While investigated and proposed were the methods of solving a more general organization of the problems which along with the production rates include the optimum multitude of the newly commissioned wells from the infinitely many possible drilling locations. The selection of the optimum option of the construction of the surface field facilities is performed. Given a set of indicators of field development options, calculated by solving the above problems, the problems of the optimal development of the ground-based arrangement are solved. To solve the problems that arise at this stage, special methods of integer programming [7] are used.

To date, the number of refineries and petrochemical plants of Russian systems use the advanced control - the APC (Advanced Process Control) [9]. The implementation of such systems at the facilities of the gas treatment and processing has not carried out yet, despite the suitable conditions for such as a number of technological problems, reducing the negative effect that can be achieved through the use of the advanced control systems. In this paper we propose a variant of the complex gas treatment plant (CGTP) with the help of the advanced control. The sections [10, 11] describe the features of the process facilities of the CGTP in the Cenomanian Urengoy gas field. In addition, the presence of similar problems at the CGTP for the Yamburgskoye Cenomanian gas field is pointed out in the review [12], thus enabling to make a conclusion about their generality and the abundance at the Russian field gas treatment facilities.

The functions of the Advanced Process Control. The CU (advanced control) is a set of software and algorithmic tools for the centralized management and the technical-economic optimization of complex systems. The advanced control includes three main concepts:

- The multicoupling regulation, based on the model predictive control (MPC - Model Predictive Control).
- The virtual analyzers (inferential measurements) - empirical - neural network or regression - models that reflect the relationship of the immeasurable parameter and the indirect factor.
- The technical and economic optimization in real time.

The multicoupling control unit (for example, a column with a coupled heat exchanger, a process furnace, etc.) can be realized with a single multiply controller regulating the PID control knobs that represent the basic automation system, or directly the actuators.

The virtual analyzers acting as the conventional measuring devices can be used instead of them or in conjunction with them. As the immeasurable parameter often characterizes the performance of the entire automation system and wider the process facility in general and may be included in the objective function of the optimization or the restriction (e.g., the quality of the output product, the dew point temperature, etc.), the virtual analyzers are a basis of the construction of the optimization system. The technical and economic optimization is usually calculated for the whole unit (for example, distillation, catalytic cracking, etc.) and is implemented as a larger unit that controls a set of multiply regulators. The control through the APC system is used to solve the problems of two classes: a high quality stabilization process based on the minimization of the integral criterion of the quality of the transition process and the optimization of the process as the higher-level tasks.

SCADA (abbreviated from English. Supervisory Control And Data Acquisition) is a system of supervisory control and data acquisition. The SCADA-systems enable the development of a control system in a client-server or in a distributed architecture (DCS abbreviated from English Distributed Control System). The SCADA-system consists of three components:

1. The remote terminal, called in English Remote Terminal Unit (RTU). The complete processing of data information in real time passes through. This terminal may be differently designed. For example, it may represent the most primitive sensors that read the information from the process at specified intervals. The fault-tolerant multiprocessor computing devices are sometimes used as remote terminals. They process the information already in hard real time.

2. The main central terminal or a master station. In English it is called Master Terminal Unit (MTU), Master Station (MS). It performs data processing and management at the highest level. The soft real-time is used here. The main task of the structural component of the SCADA-system is the creation of a human-machine interface, providing the ergonomic work of the operator of control systems. Depending on the tasks to create the HMI, there are used both a single computer which receives all the information from different points of the economic facilities and the entire computing system that integrates all the local control panels. That is, in creating a central control panel, the problems of the information security of the enterprise are solved.

3. The channels of communication or the integrated communication system, which in English stands for Communication System (CS). Its purpose is to create the links between the remote sites and the central control unit [21].

9.2. Intelligent control of surface structures in the Salym Petroleum Development company

The company has introduced new process methods, using advanced data collection tools to get the maximum recovery in the Salym fields. There have been formed specialized teams of technical experts from various fields, including the specialists in reservoir engineering, the field experts and the groups of international experts to develop the effective reservoir management programs. As a result of the extensive well operations and thanks to the samples of the core and reservoir fluids, as well as the best logging practices, the most valuable information was renewed to understand the reservoir. This information is used for the following purposes: the improved well design, the optimization of drilling and well completion activities within the program Drilling the Limit, establishing of a common strategy to extract more oil at lower volumes and the impact of drilling operations on the environment.

In December 2006, the SPD began the work on the creation of the first in Russia "smart" wells in the Vadelyp field. The SPD started this project only with the installation of the flow meters for the automatic measurement of inflows in real time, but in case of the further inflow changes the well had to be physically shut-down. Subsequently, the company will equip the well with the control valves. After testing this technology in the Vadelyp field, the technology of "smart" wells will be transferred to other fields of the Salym project.

The data on the reservoir, resulting from the construction and maintenance of wells, and, more recently, from the "smart" wells, are stored and analyzed in a high-precision production database created by the engineers of the company. In the year 2007, the SAP developed the first three-dimensional sector models of high resolution in the West Salym field. The models are based on the large amount of data on the structure of the reservoirs collected for the previous three years. The models make it possible to visualize the dynamic fluid flows in three dimensions, and thus the engineers and the employees responsible for making decisions can better understand the behavior of the reservoir and improve the development of mineral resources to ensure a maximum recovery of oil. Now the corresponding group in the SAP is working on a complete integrated model of the West Salym field.

The technology of "smart" fields and well-coordinated work of many specialists would have been impossible without a modern communication system. This system ensures the reliable data transmission between the base camps, all the major objects in the Salym and the export oil pipeline valving. In is used in the integrated protection system that provides round the clock surveillance, the system of admission and the operation of the protection systems. The existing infrastructure of the information technology system meets the needs of the SAP in the modern means of communication, computerization and automation, and for many years to come it will suit to the requirements of the company. In constructing the field facilities, there have also been installed the fiber-optic communication lines, only in the West Salym their length being about 100 km. In the coming decades, the data from the Salym fields will be used in the future developments to enhance the oil recovery factor. The basis of the telecommunication infrastructure is the microwave transmission system provided by seven communication masts of up to 82 meters. The wireless communication is connected to the general commuted telephone network, a cellular communication system in the field. This is one of the first digital systems in the main telephone service in Russia and the first similar system in the Khanty-Mansi Autonomous Okrug [18].

The advantages of the integrated innovative technology "Smart Field" SAP are: a large-scale project of the management of wells and reservoirs directed at the development of systematic approaches and ensuring the sustainability of the field development in the DR, regular monitoring of the rate of oil production and water injection into the bed, water cutting and pressure, the effective use of the stock, limiting the operating costs, optimization of water injection, increased production, improved planning and a more efficient oil recovery. The smart fields technology is a reliable basis for the projects of the incremental oil production, resulting in the fact that the system is allowed to close the well control cycle and reservoir, and the operators in the PPB receive the information, process it using the tools of the integrated management of the well stock, determine the correlation of the parameters and the operators in the PPB as well regulate the operation of each well using an automatic control system, reducing of unplanned downtime, a longer trouble-free operation of the borehole equipment, reducing the chemical consumption, reducing the number of trips in the field and reducing the cost of transport, increasing the staff efficiency in the oilfield, the boreole production increases by an average of 2–2.5% per year, the operator spends most of his time in the control room serving 30-40 wells, the communication information transfer from the multiple well platform to the control zoom is performed in real time, the operators more quickly respond to the behavior of the borehole equipment, the smart technology on the intake, the water injection and treatment using the Fieldware Water Injection System, the system which is available both from the Salym platforms and from the office in Moscow [19].

9.3. Management of subsea data gathering and treatment of oil and gas in real time

The experience in the development of the North Sea and the Beaufort Sea fields demonstrates an active development of the offshore technology of the field development and preparation of well production. For the development of the Russian offshore technology it is necessary to attract actively the domestic scientific potential using the foreign one. The technology of the underwater treatment significantly enhances the flexibility in the recovery of well production. Big operating companies with private capital, such as Shell, Exxon, Total, BP, Woodside, Statoil and Petrobras, are leaders in promoting the elaborations and applications of new offshore technologies in the injection and the treatment of the borehole fluid. They actively contribute to the development of all the areas of offshore technologies, despite the potentially high risk when investing in new elaborations. Norway has managed to create simultaneously a national innovation system and to make it part of a global one, it could make the foreign corporations operating in the local market spread the localization of their technologies in the country, or pass them to the Norwegian research institutions. The way of using the offshore field is considered as the most promising direction in developing the fields in such conditions as freezing and non-freezing seas using the equipment of treatment and injection of fluids in the submarine performance, including multi-phase pumps, separators, compressor units and subsea drilling rigs (Figure 9.5–6).

The underwater treatment of hydrocarbons includes the separation of reservoir fluid, the injection of sea water and gas compression. To enable the underwater treatment of production and a high-voltage electrical supply over long distances, the modern system of control and management of the processes, the cost-effective installation, the maintenance and the equipment removal are performed. The advantages of the underwater treatment of production are to improve the productive capacity of the pay to accelerate the recovery to the reduced capital and operating costs. The above advantages are becoming especially important in developing the fields in the Arctic because of deep-water deposits, the fields are large distance from the shore fisheries, the lack of infrastructure and harsh environmental conditions.

To date, the use of the multiphase pumps has become a real and viable solution for the efficient movement of multi-phase gas-liquid flows from the wells at the bottom of the sea through the field pipelines and the risers onto the top structures of the platform or the onshore facilities. Several types of pumps that are used both on the deepwater fields of the Alaska shelf, and in the fields of the Gulf of Mexico, South America and Australia have been elaborated. The spiral-axial multiphase pumps can pump large amounts of borehole products and exceed the rotary pumps by gas ratio, and the piston pumps by performance. One of the latest developments is a high pressure pump of the High-Boost MPP company Framo with the capacity of up to 1600 m3 / h at pump pressure of up to 20 MPa which can operate at gas-oil ratio of 95%, which is a breakthrough technology in the possibilities of field development at depths of 2–3 km. Of wider application are the two screw pumps manufactured by Bornemann, Flowserve, Nuovo Pignone, etc., which are mainly used to pump the produced fluids with a high content of the gas phase. These pumps refer to one of the volumetric displacement categories and remain operational even when the volume content of the gas phase is up 95%. The Bornemann company in recent years has made a significant step forward in the development of the subsea multiphase pumps. So, in the year 2007, the BP company, setting two deepwater subsea pumps Bornemann MPC-335 in the King Field in the Gulf of Mexico, immediately broke two world records: its the depth (1700 m) and for the distance from the platform (29 km).

The main disadvantages of the modern multiphase pumps include a low (30 to 50%) efficiency of units. The work on improving the performance of the multiphase pumps, conducted since the 1990s, enables to hope for a significant progress in the coming years, given that the current efficiency of centrifugal pumps is 60–70% and of compressor ones is 70–90%.

Originally they were intended for the use in the development of small offshore fields in the North Sea, and then they found their applications in the fields with the existing platforms, from which the management of the subsea systems and supply are performed.

The world's first real working installation of the subsea separation of production and the effective water injection into the reservoir mounted on the Troll field, 80 km away from Bergen. The system consists of a horizontal gravitational separator, wherein the hydrocarbon flow is separated into gas, oil and water. The structure of the subsea installation of the division of the reservoir products, in addition to the multi-phase pump and separator, includes wellhead equipment of the injection of produced water into the reservoir and the manifold for the distribution of the borehole flow. The separated water is pumped into the reservoir by the multiphase pump developed by the Framo firm, and oil and gas are transported together into the upper structures of the platform. The control system allows you to monitor and control the level of the phases in the separator, to change the performance of the multiphase pump. The analysis of the underwater separation plants of Troll Pilot and VASPS identified the need to further improvement of their performance. Thus, the technical solutions used in the Troll C field do not include the mechanical impurities separation system, since this equipment has a maximum size and the weight characteristics corresponding to the equipment used on land. The separator has been designed with a diverter line for a gas phase and the separation system of oil, water and sand (for installation in the Tordis field (Fig. 9.7)).

The use of the separators under water can bring tangible benefits, including the increasing of the life of the field, reducing the probability of problems of hydrotizing in the marine risers and reducing the size of the equipment for the treatment of the products on the platform. These factors contributed to an increase in the number of projects of underwater separation which are often integrated with the pump and compressor units. The presence in the well production of a significant amount of sand will require the improvement (upgrading) of the design of underwater separators, especially when used in conjunction with the underwater gas compression units, resulting in the increased demands for the quality of treatment. The use of the underwater gas compression technology will extend the life of the fields at the late stage of development on the falling pressure schedule and the active water inflow.

The beginning of the development of research in the field of underwater compression can be considered the year 1990 associated with the fist compressor module (850 kW) constructed by the company GE's Oil & Gas, and tested in the year 1992 in industrial conditions. In the year 2001, GE's Oil & Gas and Aker Kvaerner signed a contract and joined the Norwegian government program Demo 2000, under which the projects for the construction and testing of subsea modules of 2.5 and 12 MW were launched. The installation of 12.5 MW (vertical centrifugal compressor GE's Oil & Gas driven by an electric motor) is an experimental model on the way to the introduction of the subsea compression technology in the Ormen Lange field. In constructing the Ormen Lange field facilities (Fig. 9.8) in the year 2016 it is planned to use an underwater compressor unit consisting of four identical lines (one is a reserve). Three of them will be commissioned during the first year of field development. Each of the four modules provides the increased pressure to 6 MPa and the capacity of about 60 million m3 per day, and the electricity will be supplied from the shore substation. The similar developments in the field of underwater compression are implemented by the Siemens and MAN Turbo companies in the project for Statoil's in the Asgard field. In Norway there was tested the MAN Turbo's Hofim-type installation, and in the year 2009 the Siemens ECO-II compressor was tested. Within the "Asgard" project the laboratory owned by Statoil and Aker Solutions was carrying on a program to test the subsea compressor units. This is due to the fact, that the Statoil company is planning to install two compressor units (8-10 MW) in the Mikkel gas-condensate deposits from which the products are transported to the Asgard B platform. It is expected that, due to the installation of the compressor modules, it will be possible to increase the recoverability of the products up to 70-80%.

The compressor station (CS) of the Aker Solutions for the Asgard field will include the processes of separation of liquid from gas and the pressure rise of each phase separately. As noted above, to launch the project "Asgard" in the year 2014 with a maximum capacity of 10–18 million m^3/day, two MAN Turbo compressor units of 10 MW are used. Each of them provides an increased pressure to 5 MPa and the capacity of approximately 25 million m3 per day, and the electricity will be supplied from the Asgard B platform. The compressor unit of the centrifugal design is intended to work with wet gas, and has been developed with a high-speed motor (without gears and couplings), on magnetic bearings (without grease). The Statoil is planning to place the underwater CS in the Gullfaks South field in cooperation with the Aker Solutions' Framo Engineering. Such a solution is an alternative to a special platform designed for the compressor module. Nevertheless, under these conditions, there may be difficulties associated with the power transmission (20–40 mW) over long distances (about 140 km) [19].

9.4. Smart oil and gas transportation

Petroleum products consist of a variable mixture of oil, condensate (light oils), natural gas, formation water, and formation solid particles (sands). Many technological challenges associated with petroleum production in the deep sea areas are a result of the action of these components. In particular, the presence of water along with gas in the product flow increases the potential for hydrate formation and subsequent clogging of the pipelines. A recent MMS (Minerals Management Service, USA) study classifies the subsea piping systems into four categories/types based largely on the degree of separation of the components of crude oil that is achieved in future. The four classifications are: Type 1 – multiphase mixture transportation is carried out directly, Type 2 – partial separation of the production flow, Type 3 – complete separation of the production flow in subsea conditions, and Type 4 – export pipeline of high quality oil and gas. Type 1 and 2 systems are currently being used by the oil industry to produce oil and gas in the subsea environment. Type 3 and 4 systems are under development and may be used by the oil industry to create oil and gas production activities.

The multiphase pumps are the crucial subsea processing technology. The multiphase pumps involve the use of a pump/boosting system to transport the multiphase mixture through pipelines on the floating production vessels, platforms, or to shore. There is no separation of the multiphase mixture until it reaches the processing platform or facility.

The formation water and sands are pumped to the processing facility along with the other fluids. This makes it the most economically affordable and achievable system for subsea processing. These types of systems are applied to overcome the pressure losses associated with long pipelines and to enable flow rates outside the plugs (FMC Technologies). By eliminating the problems associated with plugs and high pressures, the rate and the uniformity of flows in the pipelines will increase.

The multiphase pumping systems are a proven technology for subsea processing that has been used in the oil industry for several years around the world. There are three main types of multiphase pumps: helical-axial, twin-screw, and piston. The helical-axial pump technology has been the established industry leader. In Brazil the PETROBRAS initially attempted to install the Leistritz SMBS-500 of a twin-screw multiphase pumping system in 2006. Due to the damage during the initial installation, the final installation was delayed until November/December 2007, or later. The "Type 2" system provides a partial separation of crude oil and fluid. These systems typically combine a separator unit with a multiphase pumping system or the gas compression system to pump the separated liquids and gases to the surface. These systems are the most technologically advanced systems currently applied in the subsea processing. "Type 2" systems can be based either on a two-phase (gas/liquid) or three-phase (oil/gas/water) separation processes. These systems have the potential to significantly reduce costs on the offshore platforms by placing the equipment, necessary to separate the reservoir products on the seafloor. By placing the equipment on the seafloor, the capacity to process oil on the platform should increase and the need to separate potentially large volumes of produced water on the platform is eliminated. The separation and the removal of produced water are especially important at the end of the field producing life when the water fraction increases. Separating the produced water on the seafloor also keeps the produced water from entering the riser and the flowline system, which, in turn, reduces the well back pressure and allows to increase oil production. The produced water can be a major contributing factor for gas hydrate formation in flow lines. The separation of the produced water will help to control the gas hydrate formation in the oil flows (Devegowda and Scott, 2003). Reducing the volume of produced water entering the flowlines may also lead to reductions in the amount of chemicals used to control the hydrate and wax formation in flow lines.

"Type 2" technologies can be combined with the injection and the stimulation. There are three options for the disposal of produced water: to pump to the surface along a separate flow line, reinject into the reservoirs, and to discharge into the surrounding water. Current applications typically pump the produced water and sands to the surface where they receive further treatment prior to disposal according to the existing regulations.

The injection of the produced water and sands can be eliminated at the expense of pumping these materials to the surface (FMC Technologies 2006b). By reducing the total volume of fluids, the injections may also allow the use of smaller and fewer flowlines and risers to the platform (Bringedal et al, 1999). The injection of the produced water can also be used as a method of enhanced oil recovery. When produced water is injected into the reservoir, the pressure within the reservoir can be increased, which will lead to an increase in the amount of the oil produced. The injection is limited by reservoir conditions, and the water quality, required for the injection, should meet the certain standards.

The direct discharge of produced water to the ambient seawater is the simplest method of disposal. The separation of produced water from the oil is not complete, and the direct disposals would result in releasing of oil and other chemicals (emulsifiers, etc.) into the sea. The deep reservoirs may potentially have high concentrations of hydrogen sulfide (H2S), which can significantly increase the toxicity of produced water. In addition, the high partial pressure of gasses in deep sea conditions will increase their concentrations in produced water, potentially resulting in hydrate formation at a high depth. The only practical method of discharge of produced sands is to mix them with the produced water and transport the sands to the surface for separation and disposal according to the current regulations. The technologies have not been developed to fully remove the oil and other chemicals from the produced sands. Furthermore, current regulations prohibit the discharge of produced sands. At present, "Type 2" systems have seen a limited use. Two large applications of this type of system are the Troll C in the North Sea field and the Vertical Annular Separation and Pumping System (VASPS) developed by PETROBRAS and field tested off the coast of Brazil. The VASPS is comprised of a centrifugal subsea separator combined with an electrical submersible pump (ESP) The system is a two-phase separation process that separates the liquid and gas phases of the product. After the gas/liquid mixture, the liquid phase is separated and pumped to the platform by the ESP and the gas is vented to the platform. The VASPS have proven to be a feasible solution to increase subsea production from the marginal and mature fields.

"Type 3" systems involve a complete separation of the production flow in subsea conditions. This system assumes the use of both the separator and the scrubber stages for the production slow. As was with a "Type 2" system, the separation system is combined with a pump (multiphase or single) or a gas compressor to move the product to the surface. The majority of the produced water are removed from the production stream and is either pumped to the surface, injected, or discharged into the sea.

"Type 4" systems will produce the quality of export pipeline of oil and gas. This system involves the use of a multi-stage separator with the additional fluid treatment to produce oil and gas of export quality. The separation system is combined with single-phase pumps or compressors to move the product to the surface. All of the produced water would be removed and either pumped to the surface, injected, or charged into the sea.

"Type 3 and 4" systems have the possibility of extending the economic life with the subsea development. These systems help to reduce significantly the costs associated with the lifting of large volumes of water to the surface (Scott et al. 2004). These systems are still under development and are not being used yet. They may be applied in the future. Because of their unproven status, there has been some resistance to the full use of subsea oil and gas. Any application of these types of technologies will likely require cooperative efforts in oil industry. With the Type 3 and 4 systems of the subsea processing, the issues connected with the displacement or disposal of sand in this system have not been taken into account.

The subsea multiphase pumping is one of the most real and vital solutions for the effective oil recovery from subsea tie-backs. In boosting applications, seabed pumps improve production economics by reducing backpressure on the reservoir which increases flow rates, and the total recoverable reserves. In other applications, where there is poor sweep efficiency or low reservoir drive, single phase pumps can be used to inject water (seawater or produced water) into the well to increase pressure in the reservoir and sweep hydrocarbons from the formation, raising recovery and enabling the increased production rates. The benefits are: accelerates production; increases recovery and extension of field life; facilitates production from low energy reservoirs; reduces OPEX; improves flow assurance performance; faster and safer start-up of low energy wells.

Leveraging our experience as a subsea system integrator, the FMC Technologies has developed a vast knowledge of pumping applications and the know how to apply the right technology to maximize the performance of the subsea system. To further the development of "state of the art"of pumping technology, FMC Technologies is collaborating with Sulzer Pumps Ltd., one of the leaders in pumping solutions, to fully qualify a new multiphase 3.2 MW 5,000 psi helico-axial pump system for high boost applications. This new solution will leverage Sulzer Pumps' field-proven pump hydraulics coupled with the FMC Technologies's advanced high-speed permanent magnetic motor technology and subsea system design and integration experience. The product family will include: helico-axial multiphase pumps, hybrid pumps, and single-phase centrifugal pumps.

The subsea boosting has been proven as an effective means to increase production rates and ultimate recovery. The key to achieving these goals is reducing back pressure on the well. This becomes increasingly more challenging in deepwater developments where back pressures are higher due to the fluid gradient and in long step-outs where frictional pressure losses are inherently greater. FMC Technologies and Sulzer Pumps Ltd. have collaborated on a new, high speed 3.2 MW, 5,000 psi helico-axial pump solution that addressed these challenges. Helico-axial pumps operate on a rotor-dynamic pumping principle and are a cross between a centrifugal pump and an axial compressor. The pump consists of multiple stages of impellers (helico-axial-type rotor) and circles of guide vanes (diffuser-type stators). The compression of the fluid is achieved through the transfer of kinetic energy from the rotating impeller blades through the fixed diffuser vanes. The technology has been developed to handle hydrocarbon flow at high gas volume fraction (GVF). The pump is capable of generating a differential pressure up to 200 bar (2,900 psi) depending on the GVF and suction conditions. The pump is driven by a power-dense permanent magnet motor which offers higher speeds, power, and efficiency than an equivalent induction.

One of the most effective ways to control the integrity of the pipeline and the timely detection of leaks and the delivered product is the development and implementation of specialized JMA - leak detection systems. Such systems are intensively developed both in our country and abroad. There are about 20 of these developments:

1. Acoustic system: SNKGN-1-2 SNKGN imaging Institute at Tomsk Polytechnic University (Tomsk, Russia); A "Trap" system of LLC "Project-resource" (Russia, Nizhny Novgorod).

2. Parametric systems:

- Leak Detection System of the Company Process Automation Systems (PAS, Czech Republic);

- «LeakSpy» Company "Energoavtomatika" (Russia); «Leak Detection System» of Company SEIC (Italy);

- «Pipeline Leak Detection System» of Tokyo Keiso-KROHNE Pte. Ltd. (Singapore);

- «ATMOS (TM) Pipe» company ATMOS (UK); «Leak detection and location system» of Simulation Software Limited (UK).

3. Based on the fiber-optic cable: Vibroacoustic monitoring system based on the fiber-optic cable LLC "Hughes" (Russia); the Fiber-optic sensor (cable) for the detection of leaks of oil products of the JSC spills and oil "Management Company" Constellation "with IPM RAS (Russia); "The Rapid remote control of leaks (ODC)" of CJSC "MosFlowline", based on the measurement of conductivity of insulating coating line;

4. «Secure Pipe» of Australia's «Future Fibre Technologies».

Currently, the pipelines are operated by a number of systems, which are based on different physical principles. The acoustic system records in the acoustic frequency the range of the waves generated by leaks. Parametric systems are based on the measurement of pressure and flow rate of the product. There are also systems that work on other physical principles, among which; in particular, the monitoring system based on the fiber-optic cable should be pointed out.

The fiber- optic monitoring system is intended for the continuous monitoring and visualization in real time of the vibration state and the integrity of the pipeline. The vibration monitoring system enables to detect the changes around and within the pipeline to discover the conducting of various technical operations close to it, e.g, the construction equipment operation, an attempt to dig or try to damage the gas pipeline. As a sensitive element (vibrosensor) in the vibration monitoring system,use is made of the seamless fiber- optic cable, located along the gas pipeline (buried in the ground, and so on a hidden location) or mounted directly on the surface of the pipeline (clear placement). For best results, the distance from the sensor to the pipe walls should not exceed 1 meter. The installation and the mounting of the cable is performed by the licensed professionals.

A cable sensor contains no electric conductors and no special requirements for the placement. The construction of a cable sensor is typically 4-6 km in length. They are connected together by special protected joints for the fiber-optic cable. Connecting of the cables and their subsequent repair in case of the rupture are performed by welding of optical fibers.

Functionally, the vibration monitoring system consists of a vibrosensor and the software and hardware unit, which includes the source and the receiver of the secondary transmitter and the computer with a special software. The software and hardware unit are assembled at the monitoring site. The designed software displays the processed signal in real time and provides a permanent record in the memory. The communication between the modules of protection is performed through the «Ethernet» - it is the most common standard of local networks at present.

The advantages of the fiber optic monitoring system are: a continuous analysis of the pipeline condition, an instant reaction to the event; high accuracy (+ - 5 m) of determining the place of the failure. The possibility of classifying the following types of failures are as follows: a mechanical effect on the metal of the pipeline, a broken cable, gas leakages, vehicle access to the pipeline or the excavation nearby; the high sensitivity of the system. The registration of the impact in the displacement of the sensor by 3x10-7, the length of the area controlled by one operating module is up to 150 km. Relatively recently there has been developed a system of distributed integrity monitoring (DTS) pipeline, in which a fiber-optic cable is used as a sensor, which allows you to control temperature change (delta T °) and tension ($\Delta\varepsilon$) at every point along the entire length of the pipeline. The change of the delta T ° and / or $\Delta\varepsilon$ in any section of the pipe results in changes of the parameters of the adjacent optical fiber, which is continuously receiving the probe pulses from the meter. When the probe pulse reaches the problem area, part of the optical signal is reflected back.

The localization of the events is based on the use of the principle of the radar, that is, the length of time between the moment of start of the optical pulse in the optical fiber sensor and the receiving time of the back reflected pulse to the photographic recorder of the measuring device. Knowing the speed of light propagation in the optical fiber and the time elapsed between the sending of a signal and its return, it is easy to determine the distance to an obstacle, from which the light waves are reflected. If the back reflected pulse returned after 2 sec, the distance to the obstacle is approximately 300 m, because the light has covered this route twice - from the transmitter to the obstacle and from the obstacle to the transmitter.

The PRMS (*Pipeline risk management system*) users are subdivided into three categories. The first category comprises the employees with limited access to the system functions. Such an employee may view all the pipeline data, but he or she may only edit the sections accessible to him or her. The second category comprises the performance unit (PU) administrators. Such administrators may edit the data on any facility or event within the certain PU. An administrator may close a reporting period, but may not open such a period. Once the reports are closed, any changes to the system may only be made as agreed by a higher level administrator.

The third user category consists of the Corporate Center (CC) administrators who have access to all the system functions. A CC administrator may edit the references, assign the system roles, view the event logs, and edit all the sections, open and close reports. In addition, the CC administrators track the operations of the PU administrator and make sure that the PU administrators close any reporting periods in a timely fashion.

Pipeline risk management system structure. In terms of the structure, the PRMS is a modular system consisting of five modules. Its key module is "Pipelines"; in addition, there are such modules as "Import", "Reports", "References", and "Settings". In future it is planned to increase the functional possibilities of the PRMS in pipeline operations. The "Pipelines" module lists all the pipelines with the selection filtering capability. The parameter display field sorts the data alphabetically for the text values, and for numerical values they are sorted from minimum to maximum (or vice versa). The standard filters include the performance unit names, status and the purpose of a given pipeline, year of commissioning of the pipeline, etc. In addition, the user can see the technical condition of the facility and the degree of risk involved in operating the pipeline at present. Each risk category is color-coded. Red means a very high risk, orange indicates the need for extra actions on the pipeline, yellow shows that the pipeline needs attention even though the actions may be deferred, while green refers to a problem-free pipeline.

The "Sections" sub-module of the "Pipelines" module contains the information on the pipeline sections, river crossings, and the properties of the product pumped through any pipeline. The specialized sections on "Leaks", "Technical diagnostics", "Maintenance", and "Corrosion prevention" contain the information regarding relevant events, linked to the time interval and the relevant facility. These sections allow for files to be attached as text documents (MS Word, Excel or PDF), images, or photos. Furthermore, an operating risk module has been created within the PRMS using the priority setting model. It may be used to change the preset calculation algorithms, to update automatically the calculation results, and to save any changes made to the system. Any change made in this way results in a recalculation of the risk level assigned to the relevant pipeline; this value is always up-to-date. Currently, the discussions are under way to see if the information may be entered into the PRMS at an earlier date, i.e., on the occurrence of any event, rather than on the completion of the relevant reporting period. For instance, in case a leak occurs, the information regarding such a leak must be input into this system right away. The "Reports" module makes it possible to generate reports automatically. Meanwhile, whereas the reports are used to be generated once a month, nowadays reports may be uploaded as of the current point in time, covering any PU and any topic, such as pipelines, pipeline sections, leaks, technical diagnostics, repairs, corrosion protection, river crossings, etc. In order to expedite the information input, the system features an Import module. The information may be imported as MS Excel files matching a preset template, or keyed in manually. The Reference module contains reference information regarding the Company's organization, pipeline characteristics and actions, corrosion protection status, estimation references. The reference information is changed only by a CC-level administrator at the request of any user of a group. Finally, the Settings module enables to manage the users' access control, the event logging, and the system visit statistics, along with the calculation and official services. In its turn, the Period Lock sub-module enables to restrict the data entry and to edit the information within a preset time interval.

9.5. Systems of smart Flexible pipelines

A visualiser of subsea risers. Drilling of wells on land and on the sea requires such equipment that would ensure the safe and cost-effective operations as a whole. On the sea the offshore drilling of oil and gas wells is much more complex, because it uses specific technical devices and systems, which are never used on the land.

These technical devices are: a system for anchoring and positioning of marine units (IPU), the underwater wellhead and the blowout preventer, the compensation pitching system unsupported by the offshore drilling units (MODU), etc. A riser is a column of pipes (steel, flexible), stretching from the ship to the bottom, the wellhead. The risers have been used since 2003 in the offshore of Brazil and the Gulf of Mexico. A marine producing riser is a thin, flexible structure that connects the wellhead on the sea bottom with the stationary or movable platform or a ship, a kind of a pipe that transports the internal flow of hydrocarbons during production.

The design of the complex technical systems, such as, the floating offshore rigs, and in a more general sense, all the offshore oil and gas systems is impossible without the preliminary strength and dynamic analysis of critical components. The ocean currents, the lateral movement of the floating marine devices, wind and wave loads, accidental disconnection of the marine riser and offshore drill pipes from the underwater wellhead have a decisive impact on the dynamics and reliability of the underwater marine drill string and thus the safety of all the activities in the sea as a whole. A recent implementation of the fiber-optic control built-in flexible riser is an important step on the path of the formation of a riser monitoring structure. Sharing the optical sensor point and a fully distributed optic-fiber opens new possibilities to monitor different characteristics and technological actions such as break of the outer shell, transporting of condensate polymer temperature and pipe temperature measurements during the shut ins, wear and broken wires.

Some of the benefits of the fiber-optic sensor systems for use in monitoring of risers are: multiplexing (mixing in English) sealing the channel, i.e., sending multiple streams (channels) with a lower data rate (bandwidth) for one channel, which is higher than the most conventional electronic sensors and requires fewer number of cables, as well as their resistance to electromagnetic interference. The fiber-optic sensors are passive sensors, and use only the low power light signals for more accurate measurements and the data transmission over the fiber-optic cable.

The new advances in optical technology and the methods of producing risers mean that a set of real-time monitoring can provide a much more accurate picture of the riser condition during the operation. This improves the decision-making, enabling to solve the structural and temperature issues to be detected at an early stage, and to eliminate most effectively meeting the safety and regulatory requirements and to ensure the maximum performance of the field.

The risers can be used in various configurations with the buoyancy of the module and other accessories in order to customize the system for specific conditions. A typical configuration of the deepwater platforms is a freely hanging chain line, where the flexible riser is attached directly to the mounting surface to the seabed.

The unbonded flexible pipes of the composite structures constitute several concentric layers of steel and polymers, with the main layers (from central bore outward): the frame is made of profiled steel strip to lock, for the main purpose of resisting the external pressure; the inner liner is made of a polymeric material, which is the main fluid barrier in forming the bore; the armor pressure is typically C- or Z-shaped steel wire previously connected with each other, mainly to resist the internal pressure in the bore; the anti-wear tape between various metallic layers; the outer sheath made of a polymeric material to protect the pipes from the marine environment.

The flexible risers are used to supply gas and liquid products which vary in temperature and pressure depending on the operating conditions and on external pressure at varying loads. A failure in operation will result in stoppage of production and hence a significant economic losses.

The real-time monitoring can provide a far more accurate picture of the riser condition during the operation. This improves and solves the structural and temperature issues to be detected at the earliest possible stage and enables to eliminate them in the most efficient manner, ensuring the maximum oilfield productivity. Within the last few years a number of techniques have been developed for monitoring the flexible pipelines (Carneval et al. 2006; Marinho et al. 2008; Pipa et al. 2010; Weppenaar et al. 2008). Most of these techniques were developed for monitoring the integrity of the outer sheath or the integrity of the tensile of sheathing wires. One of the most promising technologies for real-time monitoring is building- in the optical fibers in flexible risers. The optical fibers have shown very good properties especially for measuring temperature and strain in the longitudinal direction along the length of the fiber. This technology has been utilized for many years in other industries, and its support is an extensive range of the installed equipment and the procedures from the optical telecommunications industry. Building- in the optical fiber has the advantages as there are no protrusions on the outside of the pipe and it is not affected by the changes in the pipe diameter, for example in tuning the limiters, so that the optical fibers can be used to monitor anywhere along the pipe. The technique has been developed to expose optical fibers in grooves in the tensile sheathing wires, which are then incorporated into the flexible pipe (Andersen 2001).

The temperature control. The temperature monitoring of the annulus region of a flexible pipe (the section between the inner and outer sheath) can yield important information about the operational condition of the pipe system. In the monitoring operation the temperatures can assist with the process control in case of a temporary shut-in of the flow in the bore. For certain production materials the hydrate plug can be formed if the temperature drops below a certain point. These plugs are very difficult to dissolve, once formed in the pipe. With a temperature monitoring system in the flexible pipe the information can be obtained for deciding whether to turn the flow back or to leave it at the same level with the fluid dissolvent.

Another operational application is the monitoring of the flexible pipeline for hot spots with auditioned insulation on the pipe. This can be in the region of the pipe immediately under the floating vessel where a bend of stiffness is mounted on the top of the riser to protect from the bend. If a well is running at a high temperature, these hot spots may reach the temperatures which increase the susceptibility to aging for some of the polymer materials.

Since corrosion is severely aggravated by the supply of fresh seawater, it is important to be able to detect a second failure or a fault in repairing on the already flooded risers. With a built- in fiber-optic temperature monitoring system, the outer sheath failure can be detected both under the wet annulus conditions and the dry ones.

The detection of an outer sheath failure with a temperature monitoring system is based on the temperature difference which is typically present between the bore and the ambient ocean water. The thermal design of a flexible pipe line is such that the main temperature drop will be through the two polymer layers (inner liner and outer sheath). The temperature profiles of the outer wall of a typical flexible pipeline are shown for four different temperature differences between the bore and the medium in Figure 9.8. If any failures appear in the outer sheath, the temperature will be lowered in relation to the temperature of the medium locally at the position of the failure, as shown in Figure 9.8.

The temperature monitoring system is based on the optical fiber sensors built- in in the annulus of the flexible riser. To be able to detect an outer sheath failure, the monitoring system must be able to detect the temperature continuously along the entire length of the instrumented pipe, and to reveal the coherent data of temperature, time and position. The main specifications for a temperature measurement system are: sensing range of -40 to +130 °C.; temperature resolution of 0.2 °C.; spatial resolution of 1m, sampling rate 1/minute.

The distributed temperature sensor (DTS). The unique feature of the distributed temperature sensor (DTS), shown in Figure 9.9, is that the system can obtain the profile measurement along the entire length of the sensing cable, at intervals of every 1 m, over a range of 10 km, giving the temperature measurements at 10,000 individual sensing points. The DTS illuminates the glass core of the optical fiber with a laser pulse of 10 nanoseconds in duration (this corresponds to a 1m pulse). As the optics, the pulse propagates down the fiber and it undergoes scattering, even in the absence of impurities and structural defects. Part of this scattered radiation is known as Raman scattering, for which some of the light travels back towards the analyzer with a wavelength that is shifted either side of the original (see in Figure 9.8a). The ratio of the two components has a well-defined function of temperature. It is this ratio, in conjunction with the time the moment of an optical pulse, which is used to determine the temperature of the fiber at a given point. The DTS can provide very accurate temperature measurements, depending on the measurement parameters, it can have resolutions of better than 0.01 °C. A measurement time of 30 seconds is required to achieve a temperature resolution better than 0.05°C along the full length of 2 km of fiber. A long range of versions of the DTS (>40 km) will operate at a wavelength of 1550 nm. The shorter wavelength versions are limited to ~10 km but are likely to be more suitable for use in risers as they are more resistant to a differential loss caused by hydrogen darkening.

DTS of the monitoring systems have been used in a variety of field for temperature profile monitoring, particularly for the pipelines and oil and gas wells. The best performance is provided by installing a multimode optical fiber, when the specifications are within the raisers required for outer sheath failure monitoring. The DTS can be both with intelligent alarms including the general system alarms, fiber break, zoning temperature limit max/min or alarms trend and hotspot/cold spots of alarm (point of deviation from average) to provide an automatic outer sheath failure monitoring and feedback for the process control.

The data management and visualization. In order to make the main technologies accessible to the end users, an integrated data management system is not required. While we have discussed in detail the benefits of the new monitoring technologies, a disadvantage can be the volumes of data (Big Data) generated by such systems. Bearing in mind the DTS as a rule, the generations in one reading per meter of a riser with multiple fibers may have the order of 20,000 temperature readings for every survey. The temperature of the survey can be generated as often as every 10 seconds, the dynamic strain being several times a second.

In the office the domain individual databases exist for the distributed data sets (DTS, strain and others), as well as the data referring to the sources. A full client interface combines different monitoring data and correlates with the operating information available from the servers such as the production data historian. This gives the experienced users an easy access to all the different types of information they may need. The web browser can support the configurable alarms and a control board display which was preconfigured to show the users the real time data and health in the system providing a single, easy to use interface for all the monitoring systems.

The system has been designed to be fully compatible with the secure network environments operated by most major operating companies. The configuration and communication network is shown in Figure 9.10.

Conclusion

Modern information systems allow you to get, in a convenient form for the operator, the data from wells, gathering stations, storage tanks, primary oil processing plants, booster and group of pumping stations in real time. As part of the monitoring functions of production processes and dispatch management, the modern information systems solve the following tasks as well. The user gets the basic values of monitored parameters (flow rate, pressure, temperature, etc.) of the wells, group metering stations, processing plants of surface facilities, storage and delivery of products, etc. in real time. To date, the number of units of refineries and petrochemical plants Russian systems use the advanced process control, the APC. The CU (advanced control) is a set of software and algorithmic tools for centralized management and technical-economic optimization of complex systems. The control via the CU system is used for solving the problems of two classes: a high quality stabilization process by minimizing the integral criterion of the quality of the transition process and optimizing the process as a higher-level task. Using a constant flow of integrated data, the SPD takes more effective solutions for the entire life of the well. The data on the reservoir, resulting from the construction and maintenance of wells and, more recently, of "smart" wells, are stored and analyzed in a high-precision production database created by the engineer of the company. Now the corresponding group in the SAP is working on a complete integrated model of the West Salym field. To date, the use of multiphase pumps has become a real and viable solution for the efficient movement of multi-phase gas-liquid flows from the wells at the bottom of the sea through the field pipelines and risers on the platform top structures and onshore facilities. Several types of pumps that are used for deepwater offshore in Alaska, and in the fields of the Gulf of Mexico, South America and Australia have been developed. The main disadvantage of the modern multiphase pumps is a low (30 to 50%) efficiency. The process control system for oil (PCS) is designed to automate the OTP process, the automation control of the specialists, activities and the management of technological processes and production, to ensure timely information control (monitoring) of the technological mode of devices and installations of the OTP, high-performance process control of the OTP. Smart Wireless solutions provide access to all the valuable information available to the company. It will be possible to add new points of measurement, where previously it was not possible or required too much work to connect. Smart Wireless solutions provide the ability to connect directly the measuring devices in a wireless network, and then to get the information to the control system via a wireless gateway. Each sensor is equipped with its own antenna, and an autonomous power source for maintaining the efficiency for a long time. Using the smart pipelines enables us to reduce significantly the risk of emergency cases with the environmental consequences of the accidents in the pipeline; to comply with the requirements of the legislation, the international treaties, the standards and regulations in the field of environmental management, the environmental protection and the ecological safety; to raise the status of the customer as an environmentally focused company, based on the trust of international environmental organizations, partners, customers and the population in the regions where the Customer operates; the increased recovery; the reduced capital and operating costs. These advantages become especially significant in deeper sea fields; at greater distance from the field to the shore; with the lack of infrastructure; in more severe environmental conditions.

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RTD – Real time; DCS – Distribution Control System; APC – Advanced Process Control;SPD – Salym Petroleum Development; MPP – Multiphase pump; OTP – Oil treatment plant; AMS TP – Automative management system for technologic process; CS – Control station; MES – Manufacturing Execution System; APCS – Advantages of Process Control Systems; CGTP –Complex Gas Treatment Plant; MPC – Model Predictive Control; DEG – Diethylene glycol; OGCF – Oil-gas-condensate field; SCADA – Supervisory Control And Data Acquisition; RTU – Remote Terminal Unit; MTU – Master Terminal Unit; CS – Communication Systems; PRMS – pipelines risk management system ; MFE – marine floating equipment; FDR – Floating drilling rig; BHA – bottom hole assembly; MWD – measurement while drilling; MRT – Mode of Real-time; DTS – Distributed temperature sensor.

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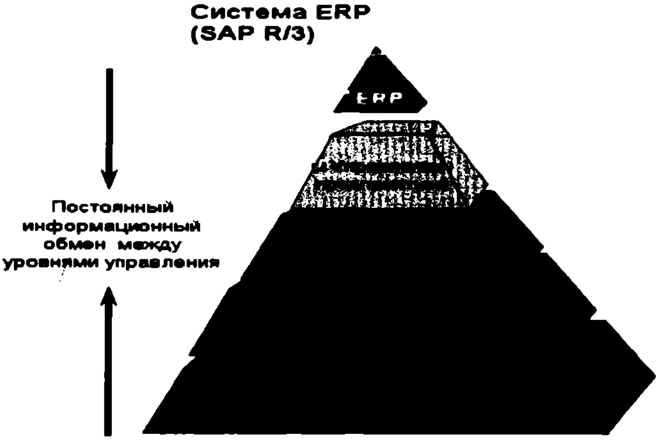

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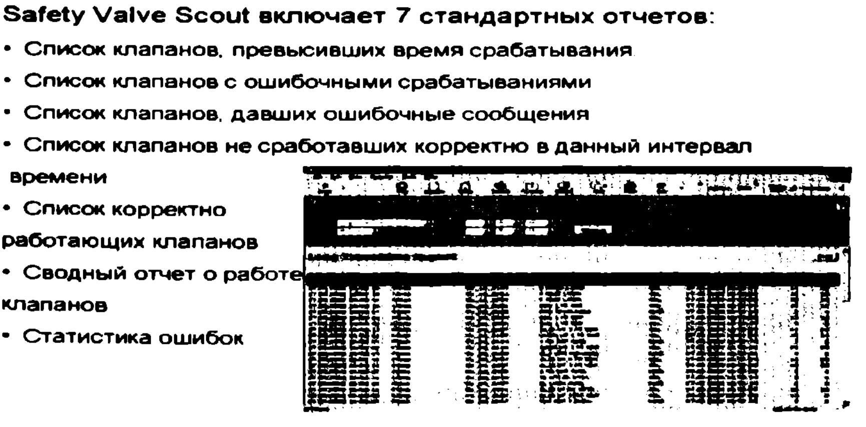

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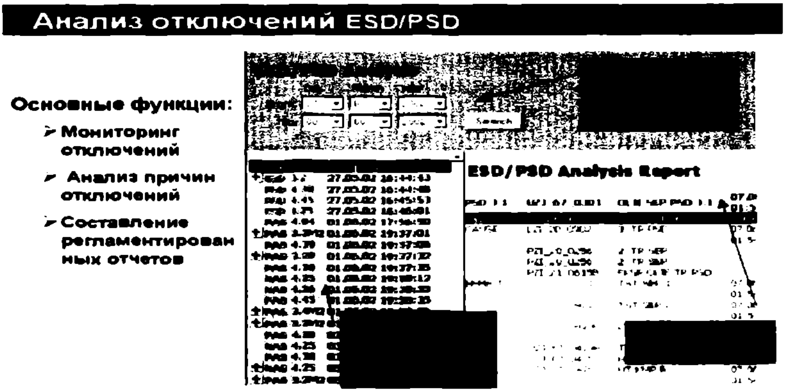

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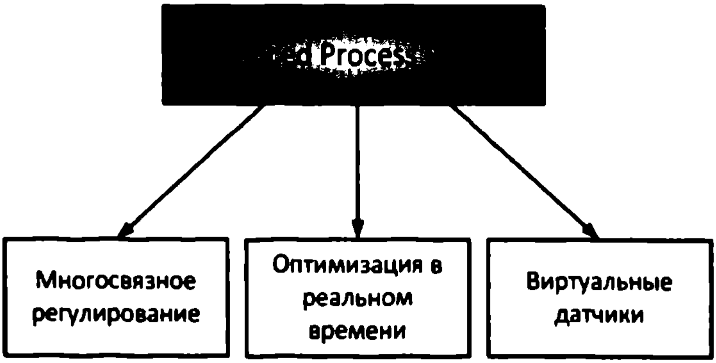

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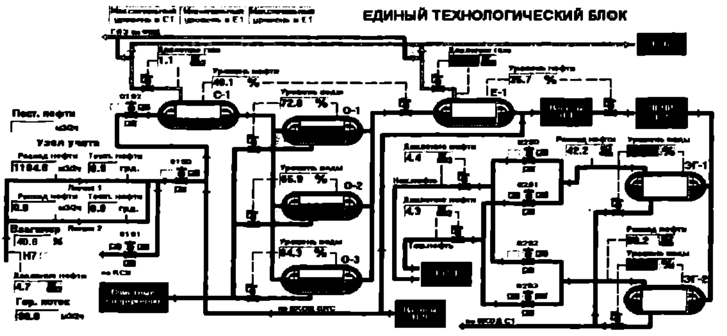

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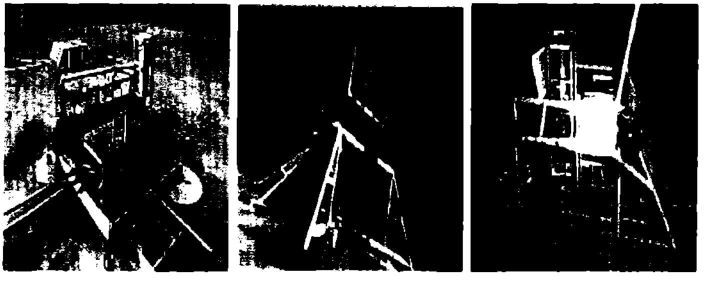

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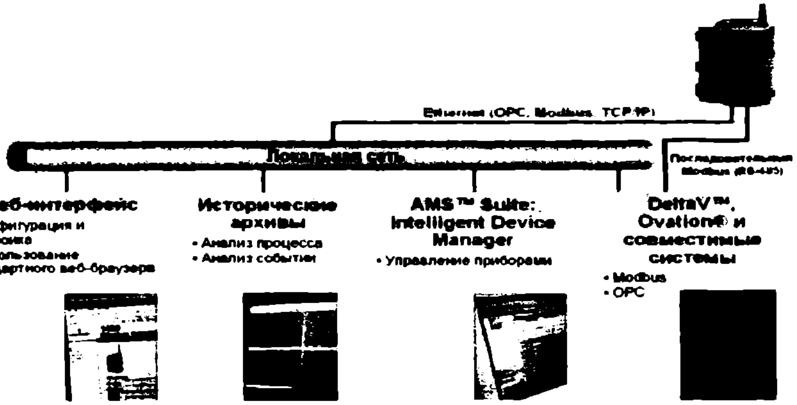

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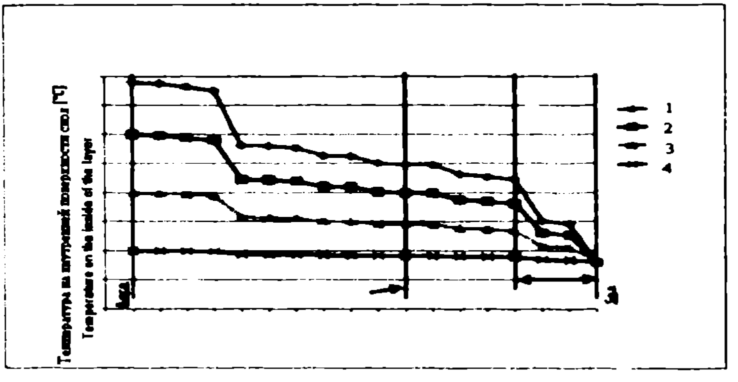

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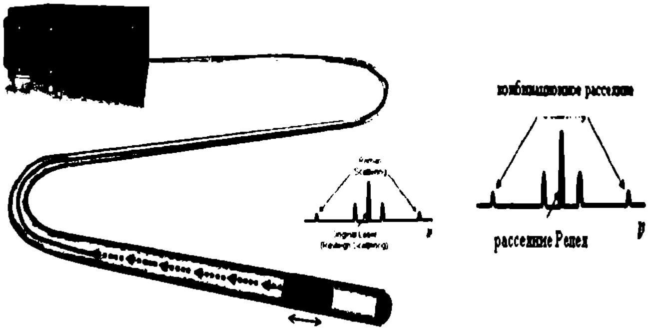

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CHAPTER 10. **ECOMONITORING IN REAL TIME**

Abstract

Oil and gas industry has a strong and complex impact on the environment. Since oil spills will inevitably involve any operations on its production and transportation, the scales of leakages are very different, and can be relatively minor and easily accumulate with ecosystems, as well as catastrophic, destroying the entire marine biota. The extraction and the use of oil and gas lead to anthropogenic impacts on the environment during the entire production cycle, from exploration, extraction and transportation of oil to the recovery and consumption of petroleum products. The construction, development and operation of wells in the uninhabited areas undermine the natural ecosystem. One of the most significant ecological violations occurs due to the drilling wells when carrying out prospecting, exploration and exploitation of oil and gas fields. The research is needed in order to find an ecologically expedient balance maintained at a level that gives the maximal ecological, social and economic effect in the development of the area of the depths containing hydrocarbons. The ecological monitoring in real time is an indispensable element in a comprehensive program of socio-economic development of different regions, territorial production complexes and individual enterprises. The ecological monitoring of oil and gas fields in real time is considered as a set of integrated tools for monitoring anthropogenic and natural sources of impact, the environment, the dynamics of the changes taking place in it, the forecast of the development and the management of the situations. The bases of the monitoring are systematic observations of the ecological effects and the interaction between the nature, the people and the petroleum industry.

Keywords: *Ecological monitoring in real time, multi-level ecological monitoring, robotic control, aerospace monitoring, remote sounding of the earth, satellite ecological monitoring, information provision of eco-monitoring, unmanned flying machines.*

Main topics of the chapter:

The ecological monitoring of the extraction of oil and gas in real time, the main characteristics of the system of the multi-level ecological monitoring of oil and gas field development in real time and the types of subsystems, the robotic monitoring of the technical state of the surface and the subsea oil and gas facilities to predict the degree of their injury, the comprehensive ecological monitoring of the potentially dangerous surface, the water and marine facilities; the aerospace monitoring of the field, the aerospace monitoring of the processes of oil and gas field development in real time: the concept, the goals, the objectives, a structure, the processing steps of aerospace information in real time on the example of monitoring of oil spills in the Gulf of Mexico after the accident on April 20, 2010 ecological monitoring of oil spills in real time, remote sounding of the earth for the tasks of monitoring of oil spills and pollution in real time - the goals and the objectives, the main advantages of satellite subsystems of ecological monitoring of oil spills in real time, the main tasks of the subsystem of information support of oil spill monitoring in real time, the use of unmanned flying machines (UFM) in the oil and gas business, the goals and the objectives; the advantages of the unmanned flying machines over the pilot flying machines (PFM) and the examples of the use of unmanned flying machines in the oil and gas business; ecological monitoring with the use of drones, the unmanned helicopters and balloons in real time, for example, the Samotlor field.

Introduction

The ecological monitoring of oil and gas fields in real time is considered as a set of integrated tools for monitoring anthropogenic and natural sources of an impact, the environment, the dynamics of changes taking place in it, the forecast of the development and the management of situations. Subsection 10.1. analyzes the current trends of the development of ecological monitoring of the extraction of oil and gas in real time, the main characteristics of the system of multi-level ecological monitoring of oil and gas development in real time and the types of subsystems, the robotic control of the technical state of the surface and subsea oil and gas facilities to predict the degree of their injury, the complex systems of ecological monitoring in real time, the potentially hazardous surface, water and marine facilities. Subsection 10.2. gives a detailed description of practical application of aerospace monitoring of the field in real time. Separately, there were analyzed the methods of aerospace monitoring of the processes in oil and gas fields in real time: the concept, the goals, the objectives, the structure The description is given to the use of remote sounding of the earth for the monitoring problems of oil spills and pollution in real time, the main advantages of satellite ecological monitoring subsystem of oil spills in real time. Subsection 10.3. presents the concept of the ecological monitoring of oil spills in real time, the main problems of the information security subsystem, the processing steps of aerospace information in real time. as an example, the monitoring of oil spills in the Gulf of Mexico. Subsection 10.4. demonstrates the possibility of using unmanned flying machines (UFM) in the oil and gas business, the goals and the objectives, describes the advantages of unmanned flying machines over the pilot flying machines (PFM), provides the ecological monitoring data with the use of drones, unmanned helicopters and balloons in real time, the Samotlor field as an example.

10.1. Ecological monitoring of oil and gas extraction in real time

Falling of oil and its components into the environment, the air, the water, or the soil causes a change in their physical, chemical and biological properties and characteristics disturbing the flow of natural biochemical processes. During the transformation the oil hydrocarbons are capable of forming toxic compounds possessing the properties hazardous to human health, including carcinogenic ones, characterized by resistance to microbial decomposition. The monitoring of oil pollution in the environment is one of the most difficult tasks. The variety of petroleum products encloses the complexity of the problem of their monitoring: each product having its own conditioned chemical composition has an individual solubility and biodegradation.

Maximum permissible concentrations (MPC) of oil pollution in various ecological objects depend on the type of oil products or water utility and are as follows: water from - 0.001 (phenol) to 3 mg / l; the accepted total content of oil products in accordance with OST 38.01378-85 is 0.05 mg / l and for the soil - 0.1 mg / kg. The maximum permissible concentration of total content of oil products in soil is not standardized; the maximum permissible concentration for certain oil products are: benzene - 0.3 mg / kg; toluene - 0.3 mg / kg; xylene - 0.3 mg / kg; for air - 0.05 - 5 mg / m.

In the development special attention is given to the observations of the macro benthic communities, because their composition is dominated by the long-living species with long life cycles. Thanks to these forms, the structure of communities preserves the traces of anthropogenic impact, which is very valuable in terms of the long-term monitoring. In their infrared range oil and oil products have their individual absorption spectra. The infrared analysis of hydrocarbons uses a range of 0.7 to 25 microns, which is usually divided into three regions: near - 0.7 - 2.5 microns, the area of main frequencies - 2.5-6 microns, far - 6-25 microns. The far-infrared area is used primarily to identify the source of contamination. On this basis there were created the instruments for infrared spectroscopy, a fundamentally new step being the elaboration of the laboratory of infrared spectrometers based on the Fourier transform. The majority of domestic and foreign portable infrared analyzers of oil products perform the measurements of the concentrations of oil pollution on the same wavelength. The fluorescent methods are characterized by a high speed and sensitivity, which allows them to be used for the systematic monitoring of the biosphere and hydrosphere, and for determining the micro elements, as well as the total content of the contaminating organic substances and individual organic compounds. The fluorescent analysis is also used in determining in the air the polyaromatic hydrocarbons and their derivatives. The instruments for the fluorescent analysis can be divided into two groups: fluorimeters and spectrometers. The fluorimeter uses filters, and the fluorescence spectrometers use diffraction lattices.

The main characteristics of the system of multi-level ecological monitoring of oil and gas field development in real time and types of subsystems. The system of continuous monitoring of subsurface structures in the sea water areas should provide the information on the key parameters of the marine environment in real time to assess the current impact, on the one hand, on the objects of subsoil structures and, on the other hand, on the most important components of marine ecosystems. The main objective of the integrated ecological monitoring in real time is to monitor the possible man-made pollution. An early detection of leaks of pollutants is required to take timely measures to prevent the major accidents. The long-term monitoring data are used to monitor the status of key ecological parameters and to distinguish the human factors on the background of natural trends.

The ecological monitoring system in real time has the following characteristics: it has a multi-layered structure; provides the continuous information on changes in the key parameters of the state of the interacting natural environments: the surface layer of the atmosphere, the sea surfaces, of the water mass, of the seabed including the sedimentary layer and the Earth's crust, it uses the multisensor approach applying the modern remote and contact technical means and methods, it is cost-effective, and is mainly based on the domestic technologies, it is regionally-adapted with account of specific regional characteristics of the shelf zone, the local structure and the dynamics of ecosystems and the nature of the anthropogenic pressures, as well as taking into account the features of the regional climate. In this case, it uses the new scientific and technological solutions, including the automation of measurements, the robotics, and the case processing methods of satellite data and signal recognition. The technical complex of the multi-level ecological monitoring in real time includes the following subsystems: hydrometeorological monitoring, monitoring of the presence of oil pollution in the marine environment; geodynamic monitoring, monitoring of subsurface structure from a vessel; satellite monitoring, information provision.

The robotic technical inspection of the underwater oil and gas facilities to predict the degree of their injury. An active elaboration of the world ocean by the developed countries necessitates the intensive conducting of underwater operations both at small and average-depths and at the deep-sea depth, at various facilities and in various conditions. The Underwater work is a complex of operations with the utilization of the widest range of technical means. Such means include the remotely operated unmanned underwater vehicles (ROUUV) (Fig.10.1.). The world experience in using these devices says that without the use of the teleported unmanned under water vehicles it is impossible to imagine the development of offshore oil and gas industry in the shelf region. The Modern self-propelled unmanned underwater vehicles (UUV) are a separate class of robotic objects with the inherent tasks, the specific features of the technology, the composition of the systems and the functional properties. All the self-propelled unmanned underwater vehicles are divided into two subclasses: the non-autonomous (anchored) unmanned underwater vehicles and the autonomous unmanned underwater vehicles (AUUV). The non-autonomous unmanned underwater vehicles include the self-propelled or anchored underwater vehicles. The non-autonomous underwater vehicles principally require the presence of the power supply wire channel and the remote control (cable bundle). In a class of non-autonomous unmanned underwater vehicles of interest are the self propelled vehicles (vehicles with the propulsion system). The autonomous unmanned underwater vehicles are the selfpropelled unmanned underwater vehicles with the autonomous power supply system and, as a rule, the wireless remote control and a channel of communication. The unmanned underwater vehicles with the autonomous power supply system, but with a wire pilot channel and the communication channel (usually on the basis of the fiber-optic line), constitute a class of semi-autonomous units. Depending on the tasks, the remote-control unmanned underwater vehicles can be equipped with a sensor system to measure the hydrochemical, hydrobiological, hydrophysical parameters: the temperature, the salinity, the transparency, the oxygen and phytoplankton concentrations, and the electrical conductivity.

The complex of the remote-control unmanned under water vehicles includes the acoustic positioning system, which allows to determine their position in relative coordinates, and with the help of the satellite navigation system on board, the vessel to define the accurate absolute coordinates the remote control unmanned underwater vehicles and the faculties under study. The optional equipment of remote- control unmanned underwater vehicles in addition to the sensors and data acquisition systems may include: a view sonar-circular, a side-scan sonar, a profiler, a multi-beam sonar, an ultrasonic thickness gage or flaw detector, a laser size meter able to scale video, laser detection system of oil spills, the locator, the 4, 5, 6 or 7-functional manipulators, the underwater electric and hydraulic tools, the inertial navigation system, the special equipment and sensors on request of the customer.

Complex systems of ecological monitoring of natural environments. Complex systems of ecological monitoring are carried out at three main stages: the stages of construction, operation and abandonment of the deposit. A common requirement is the precise coordination of the monitoring component,namely, physical, geochemical and biological measurements are performed at the same station grid. The first stage of the comprehensive ecological monitoring includes the ecological baseline survey before the start of drilling exploration wells. Synchronously with the process of drilling exploration wells on a regular grid of stations and the standard procedure, the first monitoring survey is performed. Its main task is to ensure the ecological safety of the drilling operations. At this stage of the field development, as a rule, there is no confirmed information on the characteristics of stocks, the development scheme.

During all the field development a long term monitoring is performed. In this case, the monitoring surveys conducted by ships over a large area are advisable to be carried out every three years. The satellite monitoring of the water should be conducted on a monthly basis during this period (in the ice-free seasons). The monitoring of hydrological, hydro-chemical, biological, geophysical parameters of the environment in the area of the producing complex is performed almost continuously by the autonomous cable at the bottom and at the submerged plants. For the purposes of ecological safety, it is necessary to conduct a continuous monitoring of the technical parameters of the industrial facility with the appropriate sensors.

After a complete elimination of the marine industrial facility, it is necessary to perform at least two geo-ecological surveys of the former field with a gap of several years. This period is determined by the duration of the processes of natural restoration in the region. If the consequences of the elimination of the facility continue to be observed, the monitoring from the ship should be extended. In the presence of the underwater pipelines or the tanker transportation of the product, the measurements along the route are carried out regularly, preferably with a resolution of 5-10 km. If during the measurement the presence of a strong or previously expected impact is observed an operative local regular grid of stations with a space of 200-500 m is established for the purpose of an exact localization of the source.

The technical particularities of oil field development on the shelf are difficult to estimate and to prevent a possible impact on the fragile Arctic ecosystems during the oil field development. The environmental protection in the Arctic Regions is ensured by the legal environmental protection. The legal base of the oil and gas field development in the offshore of the Russian Regions is insufficient to promote the environmental protection in the Arctic. The authors present the measures of a legal base development which will provide the environmental protection of the Arctic Zone of the Russian Federation in future. The existing state system of the ecological monitoring and the experience of the "United Monitoring System" programs are presented. It is very important to estimate the ecological damage and liquidate it in time. The responsibility for nature pollution must be strictly defined by the special norms of legal documents. The results of the study can be used for the maintenance of the environmental protection in the perspective regions of oil resources development and for the improvement of regional and international systems of oil spills response in the Arctic.

10.2. Aerospace monitoring of the field in real time

The aerospace monitoring of oil and gas fields in real time is a system of space-time observations of the territory in order to assess their condition and prognosis, implemented by the aerospace systems of the remote sensing of the Earth using integrated geographic information systems. The aerospace monitoring is divided into the remote monitoring - a set of aviation and space monitoring. Sometimes this notion includes tracking the environment with the instruments installed in the almost impassible places of the earth (in the mountains in the Far North), their readings being transmitted to the monitoring centers using the methods of long-distance transmission of information (by radio, through wire, the satellites, and so on). The aviation monitoring is carried out by aircraft, helicopters, airships and other flying machines (including floating balloons, etc.) not rising to the height of the space (mostly from outside the troposphere). The space monitoring is the monitoring from space surveying.

In the Jet Propulsion Laboratory (JPL) the robot of the spacecraft is operating million of miles from the Earth. The capabilities of the robotics developed at the JPL have been applied to the Mars Pathfinder, Mars Exploration Rover, Deep Space 1, EOS1 and other space missions and are used at many JPL of the research projects conducted for the NASA, the US Department of Defense and the private industry. Although developed for space applications, these technologies are also highly relevant to the problems in oil and gas field development and production. The benefits from the introduction of these technologies include a greater precision, an increased reliability, a reduced uncertainty, an increased productivity, a reduced cost, and the accelerated development and the schedules of the completion of the tasks. The instruments and the Earth-orbiting satellites developed at the JPL study the geology, hydrology, ecology, oceanography, gravity and the climate of the Earth. There are a number of similarities between the applied space technologies and the applications in the oil & gas industry (Oxnevad, 2010). In both cases, the systems will be deployed at remote locations with the limited access for the intervention, maintenance or repair. The operational environments often encounter harsh temperatures, pressures and material corrosion. The reliability of the systems is extremely important in space and in the oil and gas industry. The failures can be catastrophic both financially and in the public perception, thus weakening the support for the programs.

Aerospace monitoring of oil and gas development process in real time: the concept, goals, objectives, a structure. In organizing the space monitoring in the interests of the oil and gas industry it is necessary to use the principles inherent in complex information systems. The process of aerospace monitoring of the oil and gas bearing areas and the facilities of the oil and gas complex forms the initial information (space images, and other data of the remote sensing and the geophysical information as well.) When using the air services for monitoring, the operational processing of information in some cases may be carried out on board the aircraft and its results can be transmitted to the consumers in real time or can arrive at the ground processing devices. The information from different satellites can be effectively relieved at the antenna complexes of land receiving centers. To monitor the oil, gas and product lines efficiently, the radio tomography method is used based on the multi-frequency radio sounding.

Remote sounding of the Earth for the tasks of monitoring of oil spills and pollution in real time. The Remote sounding of the earth is the observation and measurement of the energy and polarization characteristics of the radiation of facilities in various ranges of the electromagnetic radiation in order to determine the location, type, and properties of temporal variability of the environmental structures without any direct contact of the measuring device with them. In the last decade, much attention was paid to the study of the world ocean by means of remote sounding (RS), which facilitates the monitoring of the global anthropogenic pollutions of waters. Each year the oil pollution scale is significantly increasing because of the increased volume of production and the transportation of oil products. A timely detection in satellite images of the places in real time, subject to this kind of pollution, prevents the risk of damage to the environment. The remote radar sounding can be used for the detection and monitoring of oil pollution on the sea surface. In the pictures the oil field appears as dark spots of the reduced intensity of the backscattered signal. The problem is that in the light winds these spots are not easy to distinguish from, for example, some types of organic films, the wind shadow areas, ice, upwelling zones (the process of upwelling to the surface). The oil spilled in the sea forms the films of different thicknesses, as crude oil and products of its processing are complex mixtures. In the form of aggregates, in the emulsified form and in films oil can exist in the ocean for a long time. The largest number of oil films is detected in the summer months, so in this period the observation should be done with great care and frequent regularity for the prompt and an efficient detection of the accidents connected with oil pollution of waters. On the radar images the oil spills are characterized by a form (oil pollution is characterized by a simple geometric form), the edges (smooth boundary with a higher gradient than the slicks of natural origin), the size (too large spots are usually slicks of natural origin, such as algae or plankton colonies); the geographical location (primarily the oil spills occur in the oil production areas or oil transportation routes). The processing of the data obtained from the radar remote probe is conducted by the experienced technologists and experts, and the efficiency of the data processing is essential for a rapid response to an emergency.

Since May 2010 the Petrobras has been using space sensors of the remote sensing for its sea surface monitoring program in the Campos, Santos and Espírito Santo Basins of the southeastern Brazilian coast. The data of the ocean color (SeaWiFS and MODIS), the thermal infrared radiation (NOAA/AVHRR), a scatterometer (QuikSCAT) and a synthetic bottom hole radar (RADARSAT-1 and ENVISAT) were integrated in order to detect and characterize different sorts of marine pollution and meteo-oceanographic phenomena. The near real time processing and delivery of the SAR data allow to check and process timely the samples of remotely registered areas. The satellite sensors operating in the visible part of the spectrum are used to monitor the ocean color variations and the biomass changes associated with them. The thermal infrared radiometers are ideal to monitor the featuressuch as oceanic fronts and upwelling lines. The major limitation for both types of sensors is the extensive and persistent presence of clouds in the monitored area. Such microwave sensors of the image of space SAR can collect the oceanic images, regardless of the cloud cover. With the space SAR systems available it is possible to have almost a daily synoptic view of large areas with a suitable spatial resolution for the detection of different natural and men-made events. The integrated analysis of these data presents an important decision tool for emergencies, as well as for the elaboration of the plans and the evaluation of the impacts of the oil industry activity.

The main advantages of the satellite subsystems of eco- monitoring of oil spills in real time. The subsystem of the satellite monitoring of oil pollution should be primarily based on radar satellites. It provides the detection of oil spills and their sources of origin in the vast water area, the estimation of the direction and velocity of the oil spill moving. A wider application of satellite techniques using color scanners, infrared radiometers, altimeters and scatter meters allows to estimate the concentration of the suspended matter and chlorophyll, the primary production in the near-surface layer of the sea, and the sea surface temperature, speed and direction of the near-water wind, sea surface level anomalies. The satellite observations provide a regular sequence of spatial distributions of each of the above parameters and allow a timely detection of the occurring changes and to identify their causes. The satellite observations make it possible to track the sources of the detected contaminants and thereby to distinguish the pollution caused by the oil and gas producing activities from the pollution not associated with this activity.

10.3. Ecological monitoring of oil spills in real time

With increasing of oil production from year to year an issue of ecological protection and the elimination of the consequences of oil spills on land, in rivers and seas is becoming sharper. The information on oil spills and pipeline breaks in the largest oil producing and refining companies is insufficient. The problem of detection, localization of oil spills and liquidation of their consciences in real time is complex. In the oil and gas industry a threat to oil spills may be an emergency, an accident, a failure to comply with the technical standards of safety. A modern approach to the application of geographical information systems (GIS) in ecological monitoring has been proposed. There are a number of foreign developments of geographical information systems that solve a variety of industrial or regional problems. Such information systems are focused on the study and monitoring of the same objects, for example, the Tactical Response Plan and Florida Marine Spill Analysis Systems aimed at the study and protection of water area and the coastal zone of the Gulf of Mexico. In Norway, Thailand and Japan there have been developed the geographical information systems to assess the ecological condition of the facilities and to simulate the emergency situations.

At present, the global trend is to create an open Internet of the modules of the geographical information systems for monitoring the ecological safety of oil and gas complexes in real time. An example of these geographical information systems can be the interactive maps in real time from the Google and Yandex companies. To get this platform, it is necessary to develop the database of the geographical information system that will include the information on oil and gas facilities in view of their attributes, such as, the type of the facility, the area and the power. In integrating the open geographical information system developed by the Google with the developed database, the obtained result can be used in monitoring the oil and gas facilities in real time. In creating of special units of the information processing, the system can act as a platform for forecasting and oil spill liquidation. To work with the user, it is necessary to create the WEB interface. The scheme of the received information system is presented in Figure 10.2.

The stages of processing of aerospace information in real time on the example of monitoring the oil spills in the Gulf of Mexico after the accident on April 20, 2010. The subject treatment was carried out online and involved the following stages: masking the land, isolation of cloud, isolating the region of interest, selecting the optimal parameters for the classification of the area of interest using the algorithm ISODATA; allocation of the classes corresponding to two levels of the oil pollution of the water surface; tracing the results and their integration into the geographical information systems. Fig. 10.3. presents an example of processing the multispectral satellite image taken on May 31, 2010 from the board of the Terra satellite. The same Figure shows the result of the classification by the cluster analysis and a map with the area of the oil image propagation displayed in the Google Earth system. Compiling the maps of oil pollution on the results of the Modis data processing in the program Modis Earth Map and Google Earth resulted in creating a map of the distribution of spots. With the ENVI 4.5. program, the following pictures (MODIS) (Fig. 10.4.) were processed. As a result, one can clearly see the dynamics and the area of propagation of the oil slick in real time. The most informative are the data obtained by the MODIS spectroradiometer, mounted on the TERRA and AQUA satellites (Figure 10.5.). The space optical images obtained by using the MODIS, have extremely high information for their comprehension level and are freely available. As part of this work, there were used the MOD02HKM seven-channel images with a spatial resolution of 500 meters. The product loading of the MODIS data from the web-server of the operator, as well as their preliminary and subject processing were performed at the Research Center of Aerospace Monitoring "Aerospace" during the implementation of the operational monitoring of the effects of the accident in the Gulf of Mexico.

The main tasks of the subsystem of the information support of the eco-monitoring of oil spills in real time. The main purpose of the information subsystems is to provide the following: the collection and processing of the data from different subsystems of observations (stationary, ship's, satellite), the analysis of the information and the transmission of the information products created on its basis to the corporate bodies of management of industrial and ecological safety, and public authorities of the management of natural resources and the ecological protection. It's reasonable for the information products to include the following information: the evaluation of the anthropogenic impact, the forecast of possible adverse changes in the corresponding elements of the natural environment and the natural complex in general, the recommended measures that reduce the negative effects and localize the human activity.

The functioning of the information subsystem should be performed in two modes: operational in real time mode and reserving the aggregate information.

10.4. Using unmanned flying machines (UFM) in the oil and gas business, goals and objectives

An unmanned flying machine (sometimes abbreviated as UFM, which is often colloquially called as "drone" in English) is a flying machine without a crew on board. In the oil and gas business the drones can be used in the cases when the working conditions are unsafe for a man. We refer here also to the work in full darkness, in conditions of sandstorms and at extremely high and low temperatures. These are flies over the sea in the Arctic and in the deserts, it is necessary to make regular flights along the same route. To use drones is economically profitable. The drones consume up to 20% less fuel. The average price of a mile of shooting drops from $ 15 to $ 3, compared with the manned vehicles. Unmanned systems offer a higher quality material than the systems controlled by a man. This is due to the fact that they have lower metal mass, thus providing a lower level of noise and interference in the measurements of the magnetic and gravitational fields. A drone can take on board up to 50 kg of equipment and work within 14 hours. The drones have almost no restrictions concerning the working height. One of the best examples of such a case is patrolling the pipeline. It can be realized with the help of the satellite, but the relation of "price / quality" will give a way to the drones very much. This method will greatly depend on the time, because the satellite is not always over the object of interest. For this purpose Chevron Texaco company uses the Israeli unmanned flying vehicle Aerostar, successfully applying it in their facilities in Angola and Nigeria. The unmanned systems offer a higher quality material than the systems controlled by man. This is due to the fact that they have lower metal mass, thus providing a lower level of noise and interference in the measurements of the magnetic and gravitational fields.

Ecological monitoring with the use of drones, unmanned helicopters and balloons in real time on the example of the Samotlor field. The TNK-BP is planning to use the unmanned flying vehicles to monitor the Samotlor field. The experimental production testing of drones, specially designed for the TNK-BP in the Center for Space Research in Korolev near Moscow, is currently being performed in Western Siberia. A high-tech drone, equipped with a digital camera and a video recorder, as well as a thermovision, is adapted for the use in harsh environments and can be off-line to provide overall monitoring of the situation, to assess the ecological situation and to identify the irregularities in the infrastructure and pipelines in remote areas of the field. According to a source in the company, it is expected that already in 2012-2013 yy the unmanned flying vehicles will be flying around the clock over the entire pipeline system within the license areas of the TNK-BP to monitor cuttings in, breakthroughs and unauthorized approach to the pipelines. The

Samotlor field needs 6 drones which will explore every part of the pipeline 4 times a day.

This method of monitoring will be used in the field of almost 2 million square kilometers in area where the unmanned flying vehicles (UAV) are used. The flight range is 100 km, and the non-stop flying over the territory of the facilities and fields can last up to four hours. In the case of oil leakage in the pipeline, the machine will see and give the coordinates with a precision of centimeters. All the data in real time enter the control room. It also accumulates the information obtained through the GPS sensors established on the drilling rigs. The Samotlor oil field has become the first field in Russia, modeled in 3D. Thanks to the virtual simulation of the field, the experts see the field facilities in small detail and have a full understanding of its condition, choose the optimal methods of the production process control. The modern tracking system allows you to receive the regular information on the volumes of recovery and hydrocarbon reserves, to control the integrity of the production facilities, the availability of breakthroughs or illegal cuttings in.

Conclusion

Falling of oil and its components into the environment, in the air, the water, the soil causes a change in their physical, chemical and biological properties and characteristics disturbing the flow of natural biochemical processes. During the transformation the oil hydrocarbons are capable of forming toxic compounds possessing the properties hazardous to human health, including carcinogenic and characterized by resistance to microbial degradation. In the infrared range oil and oil products have their individual absorption spectra. On this basis there were created the instruments for infrared spectroscopy, a fundamentally new step being the elaboration of the laboratory of the infrared spectrometer based on the Fourier transform. The aerospace monitoring is divided into the remote monitoring - a set of aviation and space monitoring. The aviation monitoring is carried out by aircraft, helicopters, airships and other flying machines (including floating balloons, etc.) not rising to the height of the space (mostly from outside the troposphere). The space monitoring is the monitoring of space surveying. Tracking the natural environment by using the instruments installed in the impassible places of the earth (in the mountains, in the Far North), their indications are being transmitted to the monitoring centers using the methods of long-distance transmission of information (by radio, through the wire, the satellite, etc.). The global trend is to create an open internet of the modules of the geographical information systems for monitoring the environmental safety of oil and gas complexes in real time. The main oil-producing and oil refining companies are already oriented to the use of geoinformatics in their information system. The geographical information system is a means of creating an integrated platform for the monitoring and modeling of oil spills in real time. The mapping basis of the geographic information systems can be the open interactive maps from the Google and Yandex companies. An unmanned flying marching ((UFM) is sometimes abbreviated as (UFM), which is often colloquially called as «drone" in English) is a flying machine without a crew on board. In the oil and gas business the drones can be used when the working conditions are unsafe for a man. The drones have almost no restrictions concerning the working height. To use drones is economically profitable. The drones consume up to 20% less fuel. An unmanned flying machine (a drone) can take on board up to 50 kg of equipment and work within 14 hours. The average price of a mile shooting drops from $ 15 to $ 3, compared with the manned machines. The unmanned systems offer a higher quality material than the systems controlled by man. This is due to the fact that they have lower metal mass, thus providing a lower level of noise and interference in the measurements of the magnetic and gravitational fields.

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List of Abbreviations

MPC-maximum allowable concentrations; UFM -unmanned flying machines; PFM-pilot (aircraft) flying machines; UUV- unmanned underwater vehicles; ROUUV-remotely operated unmanned underwater vehicles; AUUV- autonomous unmanned underwater vehicles; GIS-geographic information systems.

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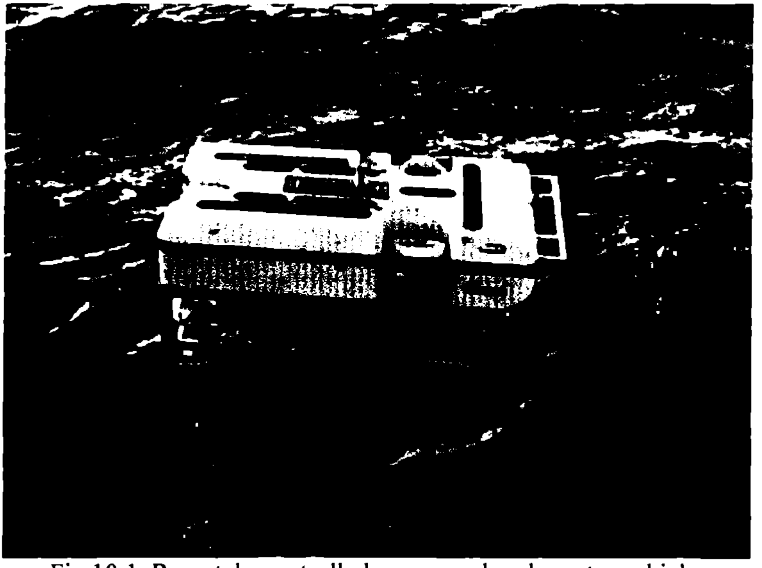

Fig.10.1. Remotely controlled unmanned underwater vehicle
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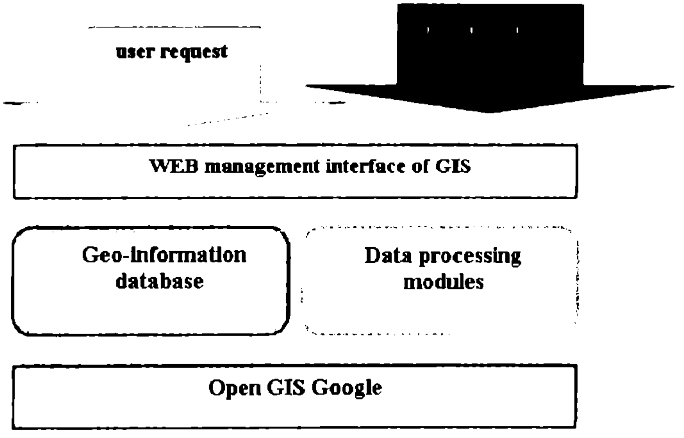

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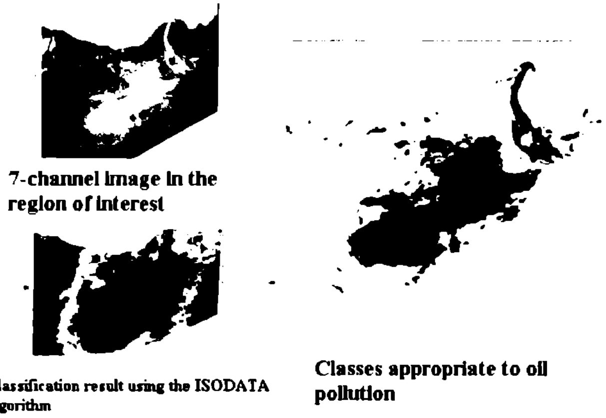

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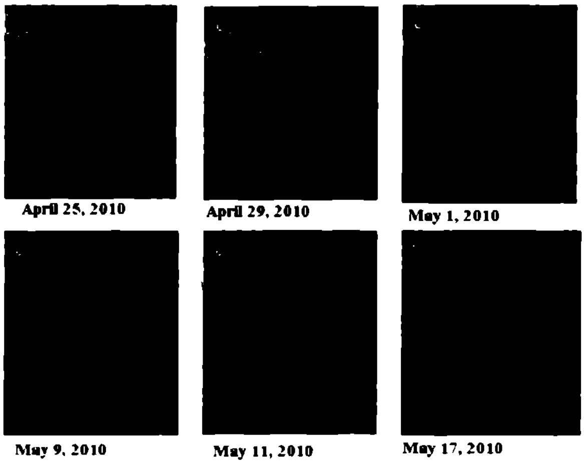

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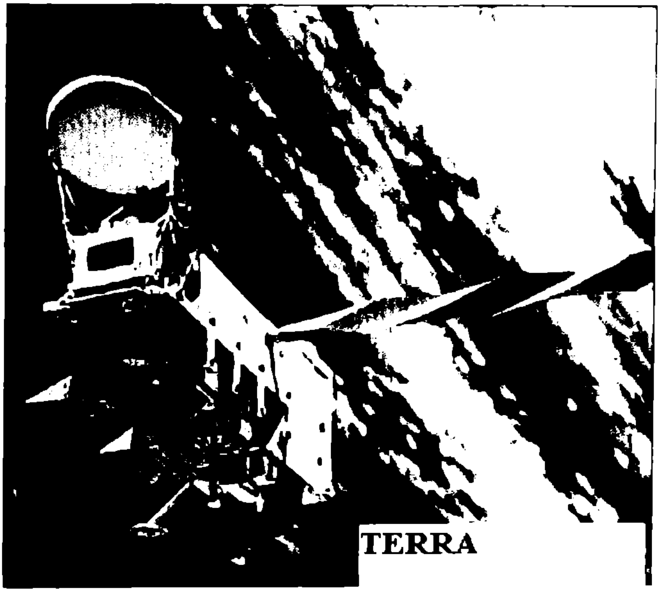

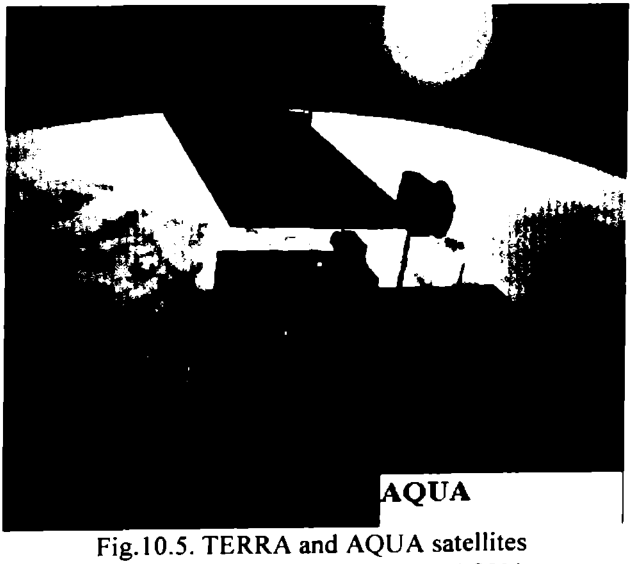

Fig.10.5. TERRA and AQUA satellites
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CHAPTER 11. SMART ASSET OPERATIONS

Abstract

The chapter is devoted to the effective management of the assets of oil companies in real time being an actual problem at present. The assets of oil companies include wells, pumping equipment, tanks, surface facilities, pipelines, separators, etc. Natural resources become an economic asset of oil and gas companies when it comes to their rational use, a deliberate choice of the most preferred and practical option among all the entire set of alternative uses. This paper provides examples of asset management systems, and special attention is paid to the analysis of the effectiveness of new systems for evaluating the assets of oil companies. By the year 2013 the packages of such programs as IBM Maximo, Avocet, etc. of evaluation of the cost of assets of the company in real time had been elaborated.

Key words: *Asset management in RTM, the assets of the enterprise in RTM, current assets, the interaction of the team, effective data management, efficient operation of enterprises in RTM, liquid assets, enterprise resource planning, enterprise asset management.*

Introduction

This chapter consists of 5 sections: management of oil and gas assets of the company in real time - the concept, goals and objectives, types of assets of oil and gas companies, the decision of IBM Maximo for Oil and Gas industry, the Avocet integrated asset management, the interaction of the team, the impact of the level of experts on decision-making on the management of oil and gas assets.

Section 11.1. describes the concepts of oil and gas assets, the goals and objectives of asset management of the oil and gas companies in RTM, section 11.2. lists the types of productive assets, including oil and gas assets. Sections 11.3. and 11.4. present the ways of solving the asset management in RTM and the last section 11.5. analyzes the impact of the level of experts on decision-making on the management of oil and gas assets.

11.1. Asset Management in oil and gas company in real time — concept, goals and objectives

Nowadays, natural resources are used efficiently enough. There are not clear and transparent conditions of use of the natural resources. In this case the structure of the exhaustible natural resources is steadily worsening. Natural resources are not only the basis for the development of the economy and the social sphere, but also the guarantee of the normal vital functions of future generations. The resources become an economic asset when it comes to their rational use, a deliberate choice of the most preferred and practical option among all the set of alternative uses. In today's oil and gas company there is a close correlation of the asset valuation represented by the reserves of hydrocarbons in the depths, with the major cost and technological indicators of the activities of the oil and gas company. The assets of oil and gas companies include wells, pumping equipment, tanks, surface facilities, pipelines, separators, etc. The most important task is to develop the organizational and economic system capable of ensuring the efficient use of assets. The management of oil and gas assets (economic assets) in real time means an efficient use of natural resources of oil and gas companies using software packages (IBM Maximo, Avocet) to assess the value of the companies that had been established by the year 2013. These are systems of strategic management of the production company that can operate at a global level and with a simple adaptation to local requirements. It is necessary to solve complex problems in managing the assets of the oil and gas companies. The most important of them are the following:

- the formation of organizational and economic system capable to ensure an efficient use of the assets in the oil and gas companies PPB;
- the creation of the necessary of technological infrastructure that would ensure the operation and continuous improvement of the managements system assets of the company;
- the formation of the team able to successfully meet the challenges of a sustainable use of the assets in the difficult and controversial economic conditions of the modern economy.

The three main components of the growth in the value of assets must be closely related: the definition of the objectives and their qualitative and quantitative identification, and analysis of the value chain in order to increase the return of each element of the chain. The formation of the integrated management in RTM is a rather complicated process of adoption and implementation of solutions developed by the experts. It is necessary to link together various parts of the organization, providing a strategy, an elaboration, the implementation of current plans, as well as the technological development. The element of the integrated management is the formation of an asset management system related to the hydrocarbon reserves in the depths with effective work.

11.2. Types of Assets in oil and gas companies

The operational and financial assets are defined. The financial assets are cash and various forms of the requirements for the right to earn the income. The production assets are divided into tangible and intangible. The tangible assets are: hydrocarbon reserves in the depths, the fixed capital stocks (wells, pipelines, storage facilities, processing plant, etc.). The intangible assets include the qualifications of the personnel of the company, patents, inventions, technical innovations, reputation of the companies. The optimization of the company's assets is made at different hierarchical levels of the company (from the wellhead choke to the development system), on different time scales from seconds to the life of the field. All the assets of the company can be divided into the following hierarchy levels:

Level 1: compressors, pumping stations, steam generators, electric centrifugal pumps;

Level 2: the gathering and treatment of products;

Level 3: the field (reservoir, wells, surface facilities, transportation of products);

Level 4: a group of fields;

Level 5: a vertically integrated oil and gas company.

The reserves of mineral resources in the bowels refer to the basic productive assets. Hydrocarbon reserves relate to tangible assets, they are actually involved in the production process and are the subject of the application of efforts by various mining companies, but they are public property. Subsoil users are those who develop natural resources, that is, oil and natural gas, and quickly, on time, deliver the product to the market. An asset in the eyes of the investor is a balance value of the wells, equipment, as well as an integrated company. The valuation of assets of the company, presented by the hydrocarbon reserves in the depths, has a significant impact on all the major resulting performance of its activities. The resulting performance of the oil and gas companies involves:

the volume of production; the cost of production; the value of the assets of the company; the profit on the current operations; the value of the shares; the capitalization of assets etc. All these indicators are closely related to each other as the profits on current operations affect the value of the assets of the company, the supply of reserves also directly affects the level of capitalization of the company, etc.

The analysis of the asset management in the oil business can more clearly represent some of the key features of this process. Namely, the role of asset management systems presented by the hydrocarbon resources in the depths is valid and even increases.

11.3. IBM Maximo Solution for Oil and gas Industry

The IBM is actively developing the innovative solutions for the oil and gas industry which will enable the system, as a whole, to adapt better, to be more efficient, safer and smarter. The IBM Maximo Asset Management is a product of the IBM automating the processes of the operations management, maintenance and repair of technological equipment and the facilities of the transportation and operation infrastructure of the company. A distinctive feature compared to other systems of this class is the extended functionality of the service management and service relationships. The effective business depends on the reliability of equipment and on the degree of the influence of the occurring failures on the market losses. In this case, the condition of the equipment may result in not only direct but also indirect losses, so you need to evaluate the technical condition qualitatively. You can get the estimates of the current state of the equipment, while the further development of the tools will enable to assess the risks, predicting a change in the state and the extent of occurring arising defects. The critical state of the equipment, the condition forecast with the risk assessment are the key points in the formation of influence to maintain the readiness for the operation. A comparison of the costs and their impact on the effective business of the programs allows you to create repair or modernization, technical re-equipment.

The system provides the following functionality: managing the lifecycle of production equipment; planning of repairs and maintenance, the renovation and replacement of fixed assets; management of the production staff; the creation of a unified system of management of the production document action.

The new generation technologies are an integrated model of asset management, a field, and in a variety of companies they are called as: "Optimization of an intelligent field and a remote management»,an intelligent field and remote control management / inform, «The integrated model of asset management» - Integrated Asset Operation model (IOAM). These systems are similar in aims and objectives, they are designed to simulate various scenarios for the development of the situation in the production and give a solution.

The petroleum engineers can communicate with the control center from anywhere in the world using a computer, analyze the information on the field and make a decision on the optimization its operation. Creating such a system requires careful gathering of information about the wells and the field, the experience of many experts. Today parts of the system are functioning in old fields. And at present the newly designed (new) fields have such an opportunity. It was presented at the SPE conference, in the report made by Andrew Mebian from the Salym Petroleum Development Company. Andrew Mabian, deputy director of the production department of CPAs, received a regional reward (Russia and the Caspian region) from Ganesh Thakur, the President of the International Society of Petroleum Engineers (SPE). It marked the achievements of Mabiana in improving the safety and efficiency of extraction and exploitation of the oil field with the help of "smart fields", which today in Russia are recognized as one of the best in the monitoring and control of the well stock and is considered for the implementation in the fields of other companies.

11.4. Avocet Integrated Asset Management

The Avocet provides a single solution for the entire life cycle of the field which integrates the production stratum, wells, surface infrastructure and the equipment for processing, as well as the operating parameters of field facilities, financial performance and economic conditions into a single management environment of production, collection and transportation of hydrocarbons. The success of the implementation of the technical solutions depends on the technology and the staff. Since the geography of oil and gas companies is becoming increasingly diverse, the companies must rely on the experts who are far away from the oil fields as well as on each other. With the use of the Avocet IAM the experts in different areas, regardless of where they are located, build the models, the results of which are transmitted to the end integrated model. Working together, they identify and eliminate the constraints that could lead to an increase in the cost or a decrease in the performance. The integrated models based on economic indicators clearly show the effectiveness of the project and help to extend the life cycle of the asset. The Avocet IAM allows to improve the quality of decisions at the planning stage of the field development, to optimize the production and to control the costs.

11.5. The interaction of a team, the influence of the competence of specialists on decision-making on the management of oil and gas assets

A person joining the team must be prepared to meet the challenges of both the professional and interpersonal values. In other words, he must be able to perform the respective roles of specialist, a colleague, a mentor, etc., which are the basis for taking him or her to the team. The analysis of the operation of various teams enables to identify the following qualities of the professionals, the manifestation of which contributes to the creation of successful teams: responsibility for their work and the whole team; the knowledge and professional skills; the quality of the execution of activities; the desire for cooperation, trust in colleagues; the reliability; the ability to accept criticism; a willingness to a compromise, communication skills. These qualities deserved the maximum rating in the cause of extensive studies of maximum rating. But apart from them there are mentioned dozens of qualities with lower rating values, but also playing an important role.

The ability of employees to work in a team is as important as their professional knowledge. The management team needs highly responsible, creative and professional people. And moreover it is important that not only the head but also the team members themselves should be aware of it. The team not only collectively generate the criteria for the selection of the personnel, but also focuses on the individual characteristics of each of the participants, delegating the functional tasks according to a person's ability and not vice versa, as it is the case in the bureaucratic structures. Very often at the first stage of the formation there appears an exaggerated idea of the team members themselves as professionals, everyone expects himself well-trained and able to solve any problem. The joint work pretty quickly brings the realization of inconsistencies of their ideas and real possibilities, and this happens independently and is an additional incentive to the education. The education in this team is considered necessary both for the team, and for the specialist as increasing the personal skills. The staff provides the constant changes and the transformation of the organization necessary for its success. Thus, the formation of a team is also the development of the ability of its members to educate themselves on the basis of practice, coordinating the pace of their personal development, the transition from periodical improving of their qualifications to the concept of human resource development of the team.

The team form of the organization of the work is a departure from the traditional forms caused by the unforeseen technical violation of the habitual style of the work (a sharp reduction of terms, a manifestation of unexpected obstacles, new things, etc.).

Conclusion

The effective business of oil and gas companies depends on the reliability of equipment and on the degree of the influence of the occurring failures on the market losses. In this case the condition of the equipment may result in not only direct but also indirect losses, so you need to evaluate the technical condition qualitatively. You can get the estimates of the current state of the equipment, while the further development of the tools will enable to assess the risks, predicting a change in the state and the extent of occurring defects. The critical state of the equipment, the forecast with the risk assessment is the key point in the formation of influence to maintain the readiness for the operation. A comparison of costs and their impact on the effective business enables to elaborate the programs of repair or modernization, technical re-equipment.

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List of Abbreviations

RTM – Real-time mode; SPD – Salym Petroleum Development.

CHAPTER 12. **POSC STANDARDS**

Abstract

Some of the international standards of data exchange were developed in oil and gas industry, part of them was integrated into EC practice at the end of the year 2011: ISO 15926, "Integration of data for total operation of the refineries including the gathering and treatment systems of oil and gas";POSC standards (Petrotechnical Open Software Corporation); WITSML (Wellsite Information Transfer Standards Markup Language) – standards in the drilling; PRODML – standards in the production; RESQML –standards in the development. Nowadays there is a complex of operations for integration of standards in pipeline transportation [1].

Key words: *Smart oil and gas fields, industrial standards, WITSML standard of oil and gas data in the drilling, PRODML standard of oil and gas data in production, RESQML standard of oil and gas data in the development, Petrotechnical Open Software Corporation (POSC), Data storage, Data base, POSC exchange format, Model of the Epicenter data, User's interface, Digital platform, Extendable markup language, Reservoir modeling, Data format, Modeling and analysis, Visualization in real time, Solutions of applied tasks, Monitoring of drilling processes, Server.*

Main topics of the chapter:

Standards of oil and gas data. Petrotechnical Open Software Corporation's standards (POSC). WITSML standards of oil and gas data in the drilling. PRODML standards of oil and gas data in the production. RESQML standards of oil and gas data in the development –. PRODML production standard – the purposes, development history. Characteristics of Data according to PRODML. Advantages and disadvantages of using PRODML.WISTML drilling standard - purpose, advantages and disadvantages. Characteristics of the processes covered by the WITSML standard. RESQML development standard. The purpose of the RESQML standard. Extendable markup language for reservoir modeling. Features of RESQML development standard. The main causes and requisites of creating POSC – the main advantages of creating POSC.POSC data storage -data models and exchange format. The object of POSC activities. Examples of POSC business benefits.

Introduction

When the engineers work with smart fields they are faced with huge amounts of information. In today's smart fields these volumes can simultaneously be tens or hundreds of petabytes (PB) / pebibytes (PIB). The work with such amount of data may be realized only with the availability of standardized forms of their presentation. To ensure the uniform standards base, several major oil and gas companies in the U.S. and Europe founded the Petrotechnical Open Software Corporation (POSC) in October 1990. From the beginning it was a non-profit, neutral organization to the suppliers. Its work is dedicated to providing a unified set of specifications that will allow the data to flow easily between software products manufactured by different organizations, and the user to easily switch from one application to another. The presence of common standards ensures that the results of different researches of intelligent wells will be in a format compatible with the rest of the data received at the next stages of the study of wells and fields in general. With the guaranteed compatibility of data, the engineers can more effectively use a variety of applications. Another advantage of having standards is the fact that they allow the sharing of products from different vendors. Finally, the exchange of information, or at the request to the database the standards will enable the geoscientists to differentiate the "raw" curves and treated curves easier, and also to distinguish the other features of the data, such as the type of treatment that has been applied, the performers of the treatment, etc. The identification of such bend marks is particularly relevant for smart companies with the automated work with databases.

12.1. Standards of Petrotechnical Open Software Corporation (POSC)

The main advantages of creating POSC. Previously, oil and gas companies faced the problems of data management and dramatically increasing additional costs of the computer systems. Hidden costs manifested, for example, because of the need to develop the software to transfer the acquired application to a format corresponding to one functioning in the applications of the company. The effective development of software required considerable costs for training the personnel and, in extreme cases, it was necessary to create something like the "Department of reformatting" [2] to facilitate the data transfer between different applications. It is not profitable for the intelligent companies to keep extra units of the staff and to allocate the funds for reformatting. In addition, the problems associated with the information processing lead to a decrease in the velocity of analytical processes, which complicates the work in real time. Under these conditions, any method that ensures the software a free access to the properly formatted input data will result in a significant increase in labour productivity. This method is the software standardization.

The main advantages of creating the POSC are: the removal of barriers to the purchase of computer technology from different vendors, and the ability to communicate with each other and with the corporate databases from different applications, the ability to use multiple applications together, facilitating the user's activities, increasing the labor productivity, the rapid deployment of new and the better use of existing technologies, reducing the design cycle time, reducing additional costs and income growth, the rationalization of economic and investment portfolios.

POSC data storage -data models and exchange format. There is a clear need to maintain and manage the technical data of the E & P beyond a variety of applications. Among the POSC the data storage location is called a POSC data warehouse (POSC Data Storage - DS). The DS specification allows different organizations to distribute their data in different ways. The POSC specifications provide all these configurations and ways to multiple data storages, so that they could have an access to each other at any time. Each DS may comprise many different types of data. They need to be identified, determined and assigned to a certain type of structure. The POSC has created such a structural model called the "Epicenter", it is defined independently of any application and comprehensively describes the required DS content. The Role of the Epicenter Zero is to determine in what form the software interface will present the data from the DS to the applications. The Epicentre is the only commercial data model that provides an access to the data about the data and the information sharing throughout the life cycle of the asset. The applications also need access to the data that are not yet part of the data warehouse of the POSC. These amounts of the data must be available for a number of softwares created by different companies. Consequently, there is a need in the general, physical format to share all the types of the E & P data and to archive them for the future reference. The benefits of having the POSC exchange format are that the employees will have fewer problems in passing the data between the specialized systems, *for the application* to have a single format will reduce the need to support a large number of the exchange ones, the consumers will be able to determine the compliance of the standard model format, and also to download and to get access to the data without any translation.

*The object of POSC activities.*Some time later, after introducing the Epicenter, the intellectual Texaco company decided to apply the commercial standards to its main Kern River project (an oil field in California, USA). This project was created for their perforation of wells to increase the production by 10%. The field was in the third stage of development and produced more than 11 tons of oil per day. At that the time the costs were only spent to provide the steam injection to displace the heavy oils. Decreasing of water saturation by 1% led to the increased profits by $ 45 million a year. The field was managed by 2 geologists. They decided to integrate on the market the current software with the Epicenter model. The total cost of the project, visualization and access data system amounted to more than $ 0.5 million. As a result of the integration, an enhanced production was to 14 tons / day, which made it possible to complete the project 12 months ahead of schedule. The total cost of the project was paid off in 9 days after increasing the production. The asset management team attributed these results to the improved data management and visualization. These two ingredients for success are the most fundamental of all the smart technologies. After the success with the Kern River, about 25 other companies began to demand for the Epicenter model. These and other projects cost less than $ 30,000 and were implemented for 1 day [3, 4, 5].

The use of the POSC standards enables to achieve not only a significant economic but also a technological effect. That is, it contributes to increase profits, not only by reducing the finance and the time spent on the work with the data, but also by enhancing oil production, which becomes possible thanks to more efficient work with the data and, as a consequence, to the adoption of more effective solutions of the management of smart fields.

12.2. Standards of oil and gas data in the drilling — WITSML

WISTML drilling standard - purpose, advantages and disadvantages. The year 2000 marked the beginning of the development of the WITSML standards to transfer the data in a serial form, and their integrations from different rigs in the XML format. The pioneers in this project are the BP and the Statoil. The Energetic company provides an independent support to the WITSML standards from the beginning of the year 2003, when a specialized group, the WITSML Special Interest Group (SIG),was formed. The planned development allowed the group to include the representatives from all major and many other oil and service companies. The WITSML is primarily the implementation of WITS on the contemporary language, transportation and program basis: through the XML, Internet and Web services. The WITSML is designed to improve the decision-making, thanks to the continuous flow of real-time data. The WITSML,developing thanks to the Energistics company, has more than 50 member companies, members of a special team engaged in solving the specific problems, as well as it was included into over 40 software products and applications used by oil and gas companies around the world.

Most oil companies have already implemented the WITSML technology to transmit the data in real time from the drilling rigs and from their archives, or are planning to do so in the near future. The volume of software compatible with the WITSML is increasing in response to these demands, and the standard itself is considerably becoming a treaty obligation already, especially when it relates to the new fields. At the moment a number of reasons cause the deployment of the WITSML. The standard provides the intelligent tools for the data integration and is the basis for the technology of the drilling centers. At the moment, the latest version of WITSML 1.4 supports the optimization of the automated use of the scenarios to minimize the user's intervention in the processing of data streams. It is supplemented with the new data objects for a more flexible description of the coordinate reference system (Coordinate Reference Systems), while the operator (as opposed to the vendor - a company that develops and distributes software) focuses on the daily drilling report. In the preparation process of the version there were processed over hundreds of requests for optimization. One of its main advantages is the ability to expand and to supplement easily to support the future technologies of the well engineering. The advantages of using a standardized approach to the information exchange on drilling are an intuitive to most engineers, drillers and drilling authorities and are usually characterized by the following aspects:

1. The WITSML enables to increase the return on the investments in high-tech areas, and opens up the new possibilities for the automation and optimization of the energy companies that would otherwise be impossible or difficult.

2. The WITSML reduces the cost of information exchange between the software applications within a company - developer and between companies - developers, joint ventures, partners, contractors and regulatory bodies.

3. The WITSML reduces the costs for the replacement or substitution of the software, and as a result, improves the functionalities.

At the same time, its adoption and implementation contribute to the increased level through the promotion of branch standards. The published specifications of the WITSML exchange formats of a specific integrator (the customer) are always available. The undersigned client receives the data of the integrator, to whose published procedure it is connected. To retrieve the historical data if the connection is lost (for example, faults on the satellite link), the WITSML provides a special type of the «GetFromStore» request using the non-state Web-protocols. The «GetFromStore» enables not only to receive the data stream, but also to perform the application request to the available objects, such as "well", "well bore" and to retrieve the data sorted by the mnemonics, intervals, updates, etc. This flexibility requires special efforts to ensure the information security. The basic data of the field geophysics can be only obtained during and immediately after drilling (before the column cementing). They are expensive. The well data can enable to evaluate the reserves and hence the cost of the fields. This is extremely valuable business information. To protect it, the network constraints do not usually permit to enter the corporate network from the external environment. So that the companies engaged in the aggregation of data could search for and check their data directly while drilling of wells, they need a remote access inside the data center of the service company engaged in drilling. Alternatively, they can provide a place on your intranet to the service companies, but in this case it is necessary to support the multiple systems of different service companies with their infrastructure of interaction and security.

The WITSML document is presented in a convenient XML format. From the people who know the English terminology of well logging, it does not require great skills of sight-reading. According to the Petrolink company 95% of the integration problems is associated with the gathering and coordination of the data of well drilling. The WITSML can obviously help to improve the situation. But there are some cons: the WITSML is still not well known and is more difficult to use in the field treatment. Due to the lack of the universally recognized industrial sample, the WITSML flexibility is potentially fraught with confusion and duplication in the data types. In theory, the work with the WITSML data scheme should be quite simple, on the relationship of the objects:

Well → Wellbore → The borehole inclination (path for hole) → log structure.

But every service company implements this scheme in its own way. One company stores both path logging data, and the information on the inclination in the same structure, the standard ML request will not work. Another company does not follow the normal WITS authorization procedure of point-to-point connection, etc. In contrast to the WITS replicated many times and long configured, the practical experience in implementing and applying the WITSML hasn't been established yet.

The WITSML was 'invented' by the customers, producing and major service companies which decided to save money on the integration of the data available to them from various sources. The implementation depends on the service operators directly involved in drilling and data collection. For them, the transition to the new format is fraught with additional costs. The Service companies may have private data and internal formats, the access of the third parties to which is undesirable.

The integration with the customers in the overall network online, required to implement a secure service-oriented architecture of the WITSML, contradicts the rules of the internal security of many companies. The WITSML development costs have not been in vain. Not replacing the WITS in the coordination of businesses, the WITSML proved a very useful tool for cross-program and cross-system integration, especially in the globally distributed companies. Instead of connecting in pairs the programs and corporate databases, there appeared a possibility to display all their internal circuits on the WITSML circuit, saving significant efforts on the analysis and the development. To date, at the market there appeared the ready WITSML — adapters widely spread in the world of geophysical software systems.

Characteristics of the processes covered by the WITSML. The processes covered by the standard are: the assembly / disassembly of the equipment, drilling, making a connection, the welbore enlargement, the pilot borehole drilling, core sampling, drilling mud treatment, the drill string assembly running into the well, the pulling out of the string, the preventive maintenance of drilling equipment, the repair of drilling equipment, hauling the tackle system, wire-line directional survey logging, casing running, casing cementing, plugging-back, cementing under pressure, molding, waiting on cement, drilling out of cement, mounting / dismounting of anti – aircraft defence, pipe formation testing, fishing operations, well orientation operations, killing the well, stitching the pipes, the expectation of weather conditions, underwater operations, wellhead overflow test, the column pressure testing, determination of the rock strength under the shoe, absorption, a short drill stem assembly running, a short drill stem assembly pulling out.

Some energy companies,such as Statoil and Saudi Aramco, have long recognized the benefits of using the WITSML and as a result, their master service agreements stated that the WITSML should be used for the provision of drilling data in real time. This does not apply to a wider sector of the oil and gas industry. The introduction of the new technology simply because of the efficiency is mainly perceived in the industry as a solution that "it would be nice to accept" rather than "it is necessary to accept". In the case of a new well design, there are two distinct stages - planning of the well and preparing the well for the operation. Both stages require the support of the service team, working in the well- performed by the depth and drilling disciplines of the service, as shown in

Fig. 1. A number of software tools will be used by the engineers - specialists and the crew in the well to support the planning and preparing the well for the operation. This structure will be more valuable for the business with planning in advance. The individual processes are clearly represented by the majority of oil and gas companies, but to what extent they are related to the effective sharing of the data is significantly different depending on the project. The main reason for this is the use of the approach "do it the way we did before," and, besides, there is no planning of full information flow. The exchange of information is sometimes considered as a necessary evil rather than is treated as an opportunity to increase the full effect in the work of project managers and team leaders at the wells.

The situation is more complicated in using the software from different vendors, which happens very often. Despite the fact that to date the WITSML offers only a partial solution of the problem, the standard moves towards a significantly increasing the efficiency of the data exchange in the future, since the development is accelerated due to the demand of the end. In conclusion, it should be noted that the subject of the information exchange should be a critical aspect of the well preparing system for operation and the use of the WITSML is likely to have a major impact on the value of the project. There are fixed documented cases when the WITSML significantly increased the profitability of the project, but often the standardization is not part of the project strategy. It may be so that those who are responsible for making decisions on the project do not have the technical expertise in the field of WITSML and do not imagine what important role it can play. Under these circumstances, the result in the best case will be achieving some profit despite the ineffectiveness of data exchange. The key issue in this case is what could be the return on the project, if the WITSML was a part of the overall strategy. And what is more important is the fact, how much there will be the overall return from the oil and gas industry in the universal introduction and use of the WITSML.

12.3. Standards of oil and gas data in the production — PRODML

PRODML production standard — the purpose, development history. The PRODML is a commercial initiative designed to provide standard interfaces between different software products which is used to monitor, manage and optimize the production of hydrocarbons. The purpose of the PRODML is an optimization in real time, that is, an instant process of the implementation of the technology and any decision in the current recovery process. The PRODML also enables to deploy a plan of a field in electronic form for a unified control and to provide a single source of reliable information by the optimization cycles. Version 1.0 was developed in the year 2005 as a result of concentrated and joint efforts on the part of the five oil companies: BP, Chevron, ExxonMobil, Shell and Statoil. At the moment, the working group of the community has more than 30 companies developing the standards for production.

Characteristics of the data according to PRODML. At the request, the data transfer of the following nature can be performed in the following ways:

• Passing volumes of the extraction and injection with account of the conditions everywhere. You can take into account the measured, modeled, recommended, and other types of data.

• Testing of the well.

•Distributed fiber-optic temperature measurements (Distributed Temperature Sensing DTS) and other data from the well sensors and transmitters.

•Operational reporting on internal operational, partner and state standards.

Advantages and disadvantages of using PRODML. Both the operators and the vendors benefit from the data of these standards. The operators are guaranteed a high degree of compatibility between different vendors' software products and the reduction of the integration costs. They are also guaranteed the improvement of the production efficiency and cost reduction through a more efficient use of information. With an access to more timely information, the operators will be able to support the system working at the well better and to contribute to the optimization of production and its internal processes. The vendors will get an opportunity to integrate more easily their software products into the architecture of the customer while reducing the cost of the recovery and the development.

Ultimately, the industry gets an advantage due to the improved standards which permit the resource owners, the operators, the customers and the regulators to exchange easily the data with greater operational reliability. The operators can exchange the information and collaborate with the partners, the government and the service providers more efficiently, ensuring the observance of the contractual, corporate and other liabilities. There is also noted an increase in the operation security: the possibility of remote monitoring, collaboration and instant intervention to solve the problems are added up to a reduction of risks to the personnel and the safer working conditions.

12.4. Standards of oil and gas data in the development — RESQML

RESQML development standard-The purpose of the standard. Modeling of the deposits is a multi-stage, multi-disciplinary and interdisciplinary process. The "literate" modeling requires geophysical, geological, geochemical and petrophysical data. Up-to-data models of the tanks are sufficiently detailed and can display important geological features, and can weigh up to tens of terabytes. Fast and high-quality data exchange is a key point in the workflow. The problems in the absence of a single standard are:

- the data are often lost, because only part of them can be exported or imported between different software packages;
- the Multi format data transmission is a time-consuming process requiring that the user should have a lot of experience and patience;
- the absence of a unified standard of data storage and transmission acts as a barrier to the introduction of new applications and the work flow integration.

The Standard allows a quick and an effective exchange of data without losses and the real-time interaction of all the E & P processes.

Extendable markup language for reservoir modeling. The standard development (RESQML) is an extendable markup language for modeling the reservoirs. This is a format with the extension used for storage, export /import of data. It allows you a quick and reliable transmit of three-dimensional models with multi-million cells. The standard is designed by the Energistics, a global on-profit organization, managing the open data and the standards in the development and production of hydrocarbons. The standard has been applied since January, 2012.

Features of RESQML development standard. The RESQML allows us to represent the model as a framework consisting of horizons, faults, areas of disagreement and chronological relationships between them. The support of multiple geometric representations of each item, including a set of points, a regular two-dimensional grid, a triangular surface and sets of curves has been realized. The transmission of the information on the horizons and faults does not require any communication with the three-dimensional grid. The application of the standard ensures a quick and easy data import / export, as regardless of the amount of information, the transmitted files will be only two, namely, the main document with the extension and an additional one with the extension.resqml.h5; a simple updating of the model, for example, when necessary, to transmit only a fault, or a structural surface, not the entire model, the improved features of the grid, which operate in the construction of multi-million-cell model, all the elements of the reservoir have their own coordinates, and the integration with the WITSML and the PRODML is supported with the following WITSML objects: a well, the wellbore, a trajectory, a formation marker, a well log; etc.

12.5. Standardization barriers in oil and gas industry

The aging of the workforce in the industry and the increased exploration and production of oil and gas in harsh environmental conditions will raise the need of the urgent adoption of standards. Because of the reduction of experienced engineers working at the well sites and also the rising costs of the personnel maintenance at these sites, the petroleum companies will rely more on their data processing centers that will process the information coming from these remote sites, require the data in standard formats and use the standard protocols to be cost-efficient. The industry can benefit from the experience of other industries and move straight to a standardized environment. The lagging industries are able to develop their position by the immediate adopting of advanced technologies rather than by replicating the previous technological areas. The strategy must be built around the status of the lagging oil industry so as to use it as an advantage. This will require that the oil industry should understand the character and the driving forces of the industry and also spread the industrial processes and technologies. An important part of adopting of standards is finding the ways to coordinate with other firms and to set a growth strategy for the transition from the current methods to the improved standards. Using the efforts of contractors, operators, and governmental entities, the improvements in reporting on the exploration and production activities, a better reaction to the world market and the environmental condition can be achieved. The compatibility of the data allows making better decisions – throughout all the processes, drilling and well completion, development and production, and finally operations and maintenance. This also will ensure the governmental bodies a better control of the environmental impact and the production monitoring with fewer personnel.

Conclusion

Standards allow us to accept more effective solutions on managing smart fields in real time due to more qualitative information obtained through the improved access to full information, and with the ability to work more effectively with this information. The presence of standards leads to a significant increasing of the final business results, i.e. reduction in the finance and the time on the spent work and the increasing profits by enhancing the production of oil or gas and a more rational utilization of mineral resources. The industry gets an advantage due to the improved standards which permit the source owners, operators, and regulators customers to exchange easily the data with greater operational reliability. The operators can exchange the information and collaborate with the partners, the government and the service companies more efficiently, ensuring the observance of the contractual, corporate and other liabilities. There is also noted an increase in the operations security: the possibility of remote monitoring, collaboration and instant intervention to solve the problems are added up to a reduction of risks to the personnel and the safer working conditions. The use of the POSC standards enables to achieve not only a significant economic but also a technological effect in the management of smart fields.

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List of Abbreviations

POSC – Petrotechnical Open Software Corporation; WITSML – Wellsite Information Transmit Standards Markup Language; PRODML – Production Markup Language; RESQML – Reservoir Characterization Markup Language; DS – Data Storage.

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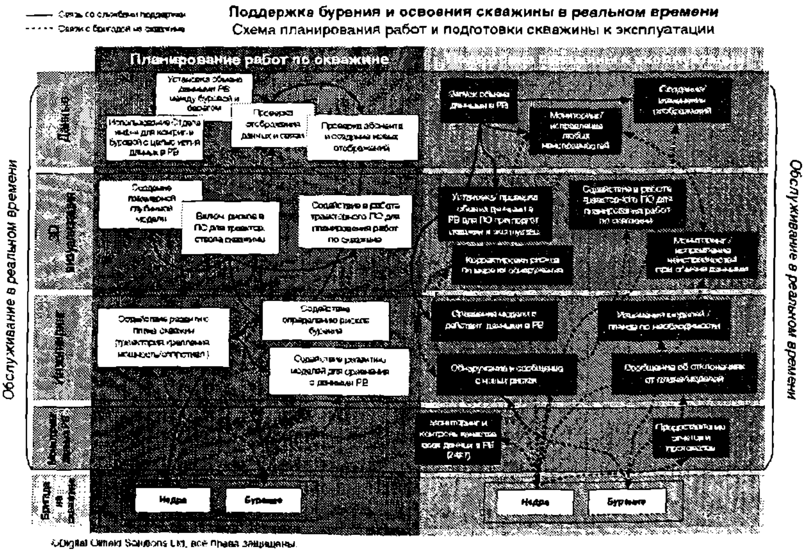

Fig.12.1. Requirements of data exchange in the planning works and preparation well for operation

Рис. 12.1. Требования к обмену данными при планировании работ и подготовке скважин к эксплуатации

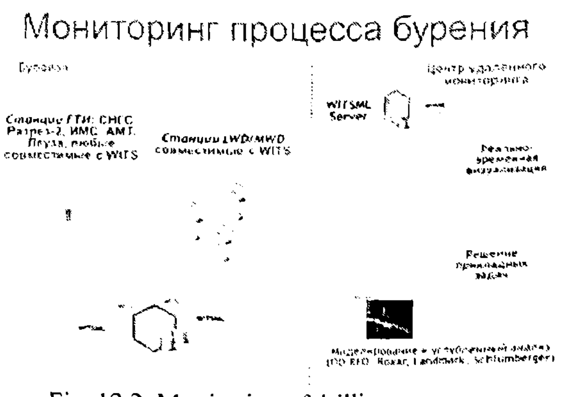

Fig. 12.2. Monitoring of drilling process

Рис. 12.2. Мониторинг процесса бурения

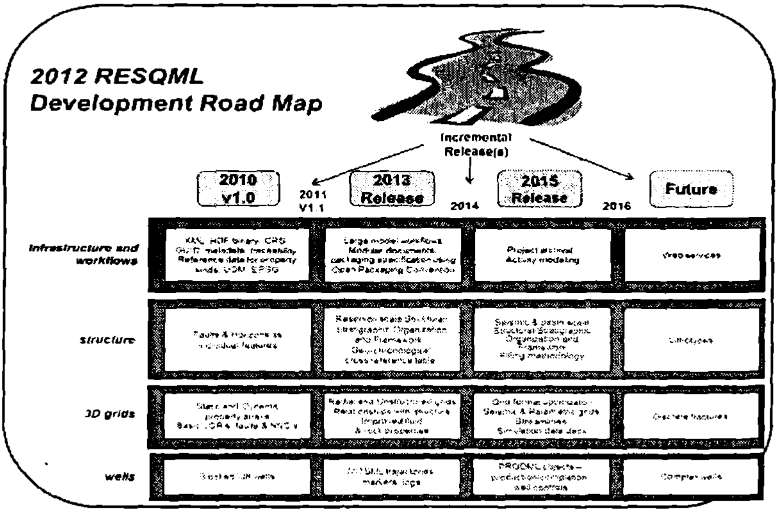

Fig. 12.3. RESQML development road map
Рис. 12.3. Программа развития стандарта RESQML

CHAPTER 13. **HIGH PERFORMANCE COMPUTER**

Abstract

In the reservoir development the oil companies faced the task of an effective extraction of raw materials. The investigations and computer simulations should be executed before drilling of new wells, choosing the method of oil and gas production. The simulation of oil and gas field model and its analysis by modern software is required before proceeding to the development in practice. The simulation is also necessary in the working out of the measures to increase the productivity of the existing wells, as the bad-considered actions can cause more harm than benefit.

Keywords: *3D visualization, supercomputer, real-time regime (RTR), a database of the extremely big data, parallel computing, high-performance computing system (HPC), simulation, sound channel, reservoir, gigabyte system.*

Introduction

In the given chapter the technology of creating of three-dimensional digital models of oil and gas fields and the formation of the design and technical solutions on this base are described. Presented are the basic program software products of the world's leading Vendors that provide the given technology to optimize which the additional algorithmic and software products are offered. The concept of extremely big oil and gas data (Big Data), the solution of which is an actual topic in our time of high technology, has been revealed. The description is given to the concept of a database management system in real time, the main functions of the database in real time are enumerated. The Section "3D modeling and design" includes a description of the methods and technologies for the creation of models, their scope, goals and objectives. The 3D visualization section includes the types of the data required to create the visualization, its functions, progress of the 3D visualization over the past decades. The technology of the casing visualizer is presented,as well as its actuality and application in practice.

13.1. The concept of the problem Big Data

The big data in information technology is a series of approaches, tools and methods for processing of structured and unstructured data of large amounts and a significant diversity to gain the human-readable results, effective in conditions of the continuous increase, the distribution through the numerous computer network, formed in the late 2000s, the alternative traditional database management systems and the solutions of the Business Intelligence class. The series includes the means of massive and parallel processing of indefinite structured data, first of all, the decisions of the NoSQL category, algorithms, MapReduce, software frameworks and the libraries of the Hadoop project. As the defining characteristics for the big data there are pointed out "three Vs»: volume (Engish volume, in terms of value of the physical volume), speed (Eng. velocity in terms of both the rate of an increase and the need for high-speed processing and getting the results), diversity (Eng.variety, in the sense of the possibility of simultaneous processing of different types of structured and semi-structured data). It is most frequently indicated as a basic principle of processing the big data SN-architecture (Eng. Shared Nothing Architecture), providing massive and parallel processing, scalable without degradation into hundreds or thousands of processing centers. At the same time, McKinsey, except for the NoSQL, MapReduce, Hadoop, R, technologies considered by most analysts, includes the context of applicability to handle the big data and the Business Intelligence technologies and relational database management systems with the SQL language support. In December 2010, the ORACLE company issued the first in the world open database management system in real time. For example, using the sensors mounted on the equipment in the field, the field system can collect the operating data and analyze the key parameters of the wells. This helps to control the operation of a more proactive way of planning the preventative servicing plan and avoiding breakdowns of the equipment.

The knowledge management systems allow you to record the experience of the employees and to create "virtual experts" to manage the actions of the operators in relatively simple situations. As a result, part of the load is removed from the actual experts who can be engaged in more important and complex cases. In the construction of a smart field there are its own problems. If in many new fields the modern control equipment is installed, the older ones often provide only a limited set of data. In fact, part of the key information, as before, is collected in the paper. And even if the data are collected electronically, most companies store them in the isolated computer systems, which are often difficult to "communicate" with each other.

The solution is to find a way to integrate all the systems and to make the technology infrastructure a source of profits, not disappointment. To be effectively analyzed, the data must be stored in one location and in a standardized form. This will enable to avoid conflicts arising from the storage of data in the isolated systems. A smart field is not just the data. With the help of modern technology the original data from the field are converted into the meaningful information, based on which, the experts can increase production, reduce costs and optimize operations. The Oracle is a leader in the processing of big data. Figures 13.1, 13.2, 13.3 describe the brief schemes of the traditional data processing and the processing of big data by the Oracle [4].

13.2. Systems of data base management in real time

Systems of data base management. The principal ideas of modern information technology are based on the concept of databases (DB). The systems of data base management in real time, in contrast to the conventional database management, have time constraints on the transaction execution, that is, the data must be actual and return at a clearly defined period of time, not to lose their value by the time the transaction is completed. A particular type of the database management systems in real time are the systems with a multi-level access security (Multi Level Security), the users of which have different levels of access and work only with the groups of objects of a definite level of confidentiality. Such systems are used in the ministries of defense, aviation systems and automated process of trading in stock markets. When designing a database management system in real time with the MLS, it is important not only to achieve the criteria of security, but also the preservation of the existing criterion of efficiency, that is, the amount of the missed deadlines.

The purpose of the systems operating in real time is the interaction with the objects of the external (relative to the system) world in the rate of processes taking place in these objects. This is due to the fact that the input signal in such systems usually corresponds to some changes in the physical process, and the output signal (most often a process control signal) must be associated with these changes at a certain period of time. This time is often referred to as the response time of the system, it is used to describe the SRT. The external events to which the system responds, in general, occur at random times. The processing of any upcoming events is to perform a sequence of actions, in advance limited by time frames. For example, an external event may be the availability of the data from the asynchronously operating device, which is not directly controlled by the operator.

The main functions of the systems of data base management in real time.

Defining the data. The database management system should allow the definition of the data (external schemes, conceptual and internal schemes of corresponding images). For this purpose the database management system includes a language processor for various languages of the data definitions.

Data processing. The DBMS should handle the requests of a user for the selection and modification of the data as well. For this purpose the database includes the components of the language processor of the data processing.

Data security and integrity. The DBMS should monitor the requests and prevent the attempts to break the security and integrity.

Data recovery and duplication. The DBMS should provide the data recovery after disturbances.

Data Dictionary. The DBMS must provide a function of the data dictionary. The dictionary can be considered as a system database that contains the information about the data of the user's database, that is, contains definitions of other objects in the system. The dictionary is integrated into the database, defined by it and contains a description of it.

The DBMS must function at the peak performance. Usually the modern database management system contains the following components: nucleus, which is responsible for data management in the external and operative memory and logging; CPU database language that optimizes the requests to retrieve and update the data, and to create, as a rule, the machine-independent executable native code; the subsystem of the support of the execution time that interprets the programs of the data manipulation, creating a user's interface with a DBMS; as well as the utilities (external utilities), providing a number of options for the maintenance of the information system.

Means of database organization. The database management enables to organize the operation with the remote offices within a single information space in order to obtain the information about the state of affairs in the geographically remote subdivisions of the organization, and for the employees to obtain promptly the necessary information from the central computer. The requirements for the database include: the monitoring of the integrity of the transmitted data; the use of various communication channels; the ensuring of the efficient loading of the whole system; a completeness of the data, the presentation, that is, the data in the database should adequately represent all the information about the object and they should be sufficient for the data processing systems; the insurance of the preservation of the information when processing it; the provision of the access to the data; the integrity of the database, that is, the data must be stored in their processing by the data processing systems; the flexibility of the data structure, that is, the DB should allow to change the data structure without disturbing its integrity and completeness when the outer conditions change; the feasibility. There should be an objective presentation of a variety of objects, their properties and relations; the availability, that is, the database must provide a differentiated access of the users to the data.

The DBMS processes the information that is in the database. It must meet the following requirements:

1. data independence, flexibility, data protection;
2. the support to both centralized and distributed database;
3. protection of the database from the mismatch in the mode of public access.

The main tools in the database management systems are: the job descriptions of the database structure; the construction of the screen forms for data entry, viewing and processing in on-line; the tools for creating the requests to retrieve the data under specified conditions; means of reporting from the database to print the processing results in the user's form; means of reporting from the database to print the processing results in a user's form; the language of tools - macros, a built-in algorithmic language (Dbase, Visual Basic, etc.), a request language (SQL), etc.; the tools for creating the user's applications (application generator, tools for creating menus and control panel applications) that enable to fix various operations with the database in a single process.

The database management system can have the including or basic programming language. In the DBMS with the host language, its own algorithmic language is used allowing to except the data manipulation operations to perform various calculations and data processing. The standard relational request language is a SQL structured request language [2], [4].

13.3. Supercomputer in modeling

The year 1976 can perhaps be called the beginning of the era of supercomputers, when the first Cray vector system 1 appeared. Working with a limited set of applications at that time, the Cray 1 showed such impressive results, when compared to the conventional systems, that it deserved the name "supercomputer" and determined the development of the industry of high-tech performance computing for many years. But more than two decades of the joint evolution of the architectures and the software systems on the market, there appeared the systems with radically different characteristics, so the concept of the "supercomputer" became a multi-valued and had to be revised repeatedly.

The attempts to define a supercomputer relying only on the performance have led to the need to continually raise the bar that separates it from a workstation or even from a common desktop computer. Only in the last 15 years, the conditions have been changed several times. By definition of the Oxford Dictionary of Computer Science in 1986, in order to get this proud name, the capacity should be of 10 Mflops (millions of operations with a floating comma per second). In the early 90's the mark of 200 Mflops was overcome followed by 1 GFLOPS.

Oil, gas and supercomputers. The efficiency of operations in the oil and gas industry is directly related to the use of powerful supercomputers to solve large-scale computational tasks ensuring the quality of the search and exploration of oil and gas fields, the increase of the productivity of the existing wells and the reduction of environmental damage in their development. Nowadays all over the world, everyone is well aware that the improved efficiency of oil and gas industry is directly dependent on the power of the applied high - efficient computing systems. Out of 500 most powerful supercomputers in the world their application in geophysics by oil and gas service companies in exploration, prospecting and development ranks third in the use. In order to find and develop oil and gas fields effectively, the geophysicists analyze the results of applying various physical methods of remote sensing data jointly with the data of prospecting, exploration and production wells, as well as the diverse geological information.

Among the geophysical research methods seismic, electromagnetic and gravitational ones can be noted. At present the seismic exploration in the search for oil and gas is mainly used. The idea of the method is that on the earth surface (or the sea surface) the artificial, for example, by explosion elastic waves, are stimulated, which are then recorded on the earth surface by the geophones, special devices. The waves reflected from the boundaries of the rocks with different physical properties carry the information about these properties.

The process of extracting information from the seismic data is as follows. First of all, it is necessary to suppress the coherent and incoherent noise, the so-called wave-interferences. Then it's necessary to build a velocity-depth model of the environment describing the propagation of waves at the macro-level, a three-dimensional depth image of the part of the earth's crust in the area under study. Finally, it's necessary to attempt to analyze the composition and the properties of rocks and to predict the presence of deposits of oil and / or gas. During the processing of the information recorded in the seismic survey, rather a complex and diverse mathematical tool is used. The suppression of the interference waves requires the application of various single-measured and multi-dimensional filters, both in time and in frequency domain and also in the Radon transformation. During the construction of the velocity-depth model use is made of the tomographic methods which are reduced to the solution of large systems of linear equations. Finally, in the process of constructing of the depth imaging of the medium there are used these or other means of direct or opposite wave field continuation, i.e., to obtain the estimates of the wave equation solutions. There are applied both the numerical methods, including the method of finite differences or finite elements, and the numerical analysis when the Kirchhoff integral device is used.

It's possible to make a conclusion justified by serious and costly computations such as, after analyzing the cost of well drilling. The on-land drilling of one well costs the oil company on average US $5 million, while the offshore drilling using a drilling platform or a vessel may exceed US $100 million. That is why the leading foreign oil service companies and research centers are actively investing in the development related to the supercomputing technologies. After all, the speed and the quality of the calculations directly affect the time and the quality of search for fields, the accuracy of exploration and development drilling, the efficiency of oil and gas recovery during the field development life. The success of the prospecting drilling is enhanced through the high-performance processing and interpretation of seismic data, and the effectiveness of subsoil use is increased through a high-precision hydrodynamic simulation. In particular, in the old, depleted fields, these methods can significantly improve the oil recovery factor. According to the CERA energy consulting agency (USA), in the next 3-5 years, the use of supercomputer calculations will provide: an increase in the number of the oil produced in the field by 2-7%; the reduction of the cost of oil production by 10-25%; an increased production rate of 2-4%.

The stage of oil and gas production is called field development. In order to extract oil from the porous country rocks, several wells are drilled which are injected under pressure. A variety of solutions, hot steam and can arrange a controlled fire at a depth of several kilometers in order to reheat the solid fractions of hydrocarbons. In order for these processes to be effective and productive, according to the initial results of the seismic data and well testing (on a computer build), the volumetric geological and hydrodynamic models of the fields are built on the computer that are constantly specified and verified. For such models the complex mathematical algorithms are used taking into account hundreds and thousands of different parameters simultaneously, which requires the use of the most powerful supercomputers. The more powerful and the better used design algorithms are the higher quality and accuracy of the model building and, the quality of the decision-making, that directly affect the efficiency and lifetime of the producing fields of hydrocarbons.

A particular problem is that the volume of the original seismic data of the exploration of one field can be tens of terabytes. As an example, a study case can be mentioned: the forming of a depth image on a 1000 km2 using the algorithm of reverse time migration, which is reduced to a two-fold solution of the wave equation by the method of finite differences in the space-time domain, it takes 6 months using the 1024 processing cores [3].

13.4. Fiber-optic measuring system

In the last 5–7 years the fiber - optic measuring system has been widely used in the following areas: measurement of temperature and pressure characteristics; downhole flowmetering; continuous well monitoring; 4C and 4D development monitoring of the visualizer of the casing and the cementing process. The fiber - optic cable consists of a glass or quartz core for a direct data transfer, and the surrounding sheath and it can transmit the signal without losses of information. The fiber- optic systems are "transparent" with respect to various data coding systems and are compatible with the systems of many electronic device manufacturers (Kalatel, Sensormatic, Philips, Panasonic, etc.). The range of the fiber- optic equipment is from -40 to +75 ° C. The equipment design ensures a reliable operation of a fiber-optic system in the event of failure of any element. The faulty module in the block will not affect the operation or performance of the other modules in this block. When transferring video signals over small and large distances, the fiber- optic systems do not require electrical or optical adjustments. The fiber-optic connection guarantees minimum noises and a high security. The plastic fibers are used in the grip length of not more than 100 m and at a restricted speed (<50 MHz). Recently, there have been developed plastic fibers suitable for the transmission at the rate of 40 Gbit / c with a cable length of 30 m and at a rate of 5.35 Gbit / c with a cable length of 220 m (Lightware N4 2007). The probability of an error in the fiber-optic transmission is <i0-i 0, which in many cases makes it unnecessary to control the integrity of the messages.

Downhole fiber- optic sensors. A real time is an information and communication stage of oil and gas field development technology, the main production products of which are information and knowledge. The information and communication stage of oil and gas science development, namely, geophysics (4D seismic), geology and oil and gas field development (4D monitoring) is different from the past by the necessity to operate a meta volume of geological field data. In the oil and gas industry the process of the avalanche flow of information has begun. The progress has been made in the technology of receivers (4C seismic sensors, fiber - optic sensors in the wells, the system of gathering, treatment and transportation of oil and gas). The production technology of the fiber-optic receivers (sensors) is continuously improved, which leads to the further increase of data. The 3D geological and hydrodynamic models also generate huge amounts of synthetic data. In modern oil and gas science the geological and field analysis of terabytes and even petabytes of seismic, geophysical, field-test data has become a routine task.

The first fiber-optic sensor was installed in the well in the year 1996. The leading foreign companies working with the fiber-optic sensors are Schlumberger, Shell, and Halliburton. The Schlumberger has established such sensors in more than 300 wells with a total length of the fiber-optic over 600 km. The fiber-optic downhole sensors represent a system that includes an optical fiber which is located in a borehole in the test interval, and a computer data acquisition and processing unit, installed on the surface. The fiber-optic is both a distributed temperature sensor (pressure) and a transmission information channel from the wellbore to the surface. The device operates on the principle of transmitting the light impulses generated by the laser through the optical fiber and processing the reflected signals under a certain program. The technology based on Bragg grating allows you to combine the sensors inside the fiber-optic channel, turning a monolithic structure into one continuous sensor.

The variations in temperature, pressure or stress on the fiber-optic change the length of the reflected light wave. The fiber - optic sensor is able to withstand high temperature, pressure and vibration. The fiber-optic sensor allows to measure the temperature profile in the well in the range from -40 to +350 ° C, with an accuracy of ± 1° C. It provides a distributed metering system at an interval of 1 m, to the depth of 5000 m.

The fiber-optic sensors are classified according to the type of action: amplitude; interferential; distributed (direct and inverse scattering); fluorescent; inter-fiber lattice; combined. The sensor of the temperature or the pressure is a single-mode or a multimode optical fiber, protected by the outside sheath of steel wires. Such a sensor designed in the form of a carrier cable ensures it a good flexibility and, simultaneously, a high tensile strength with the gravity of about 350 g / m. The fiber- optic sensor can be installed in the producing and the injection wells. The fiber-optic cable is mounted on the outer side of the tubing or the outside of the production casing. When installing the fiber-optic cable on the tubing, the life of the system corresponds to the interrepair period of the well operation from 1 to 5 years while in the cable installing on the production casing, the well lives up to 20–30 years.

When mounting on the outside of the tubing, the protected fiber-optic is laid along the perforated portion of the pipe. The optical fiber is put through the structural elements of the downhole equipment (packer) and along the body of the submersible electrical pump. When installing the fiber-optic cable on the outside of the production casing, the latter is mounted above the roof of productive strata on the technology of the collar cementing. The lower part of the column in the area of the productive strata is equipped with the sectional filters. The optical fiber is laid on the outside of the column filters with a pass through the structural elements of the managed packers, sleeves and the collar cementing packer.

The steel pipe for placing the optical fiber is mounted on the outer side of the casing above the cementing basket assembly and is cemented together with the column. The time of measuring the temperature profile and / or pressure of one well is 2 min. According to the «Sensa» company, which today is one of the leaders in the introduction of the fiber-optic technology, only through the use of the information in PPB, the company has achieved the productivity increase of a number of wells in the Gulf of Mexico by 36%.

The distinctive features of the fiber-optic sensors in comparison with the traditional methods of the thermopiezometry are: measurement of the thermal field and / or the pressure field (profile) along the wellbore in real time; high reliability and long life of the fiber- optic sensor; high stability of the system of the thermopiezometry for the interrepair time or the life of the well; immunity to electromagnetic interference; remote control (up to several kilometers); measurement with high accuracy; inertness to chemicals. The fiber-optic sensors of the downhole survey and monitoring of wells in PPB provide: the control of the layers in the process of production and injection under steady-state and the dynamics of operation conditions of the well; the control of the dynamics of movement of inter- fluid contacts; the monitoring of the movement of the fluid along the tubing to identify the areas of possible formation of paraffin plugs and gas hydrate blocks; the monitoring of the technical condition of the production casing and the tubing, the definition of nongermetic zones and casing cross flows; the monitoring of the submersible pump or gas lift valve system. The advantages of using the fiber-optic sensors are: the measurement of the parameters of the well operation in real time; a small number of components resistant to vibration; a high sensitivity and a wide working range; a flexibility, a distributed reading system, the consideration of many parameters.

To ensure the well monitoring using the fiber-optic technology in PPB, use is made of the following equipment: a submersible fiber optic (armored) cable; the data acquisition and processing unit; a wellhead interface cable for a cable outlet to the surface; the cable connectors; the tubing mandrel for a fiber-optic sensor. A submersible armored fiber-optic cable allows to receive and to transmit to the surface in real time the highly accurate continuous information on the following well parameters:the pressure, the temperature, the flow rate, the phase composition of the mixture, the temperature distribution in the borehole, the seismic data. A standard cable consists of two single-mode (for measuring pressure, flow rate and seismic vibrations) fibers and one multimode fiber for temperature measurement in the wellbore. The period of use of this sensor is comparable with the lifetime of the well [4].

13.5. High-performance computing in real time

The high-performance computing (HPC) is in the use of parallel processing for running the advanced programs efficiently, reliably and quickly. The term especially applies to the systems that function above a teraflop or 1012 floating-point operations per second. The term HPC is occasionally used as a synonym for supercomputers, although technically a supercomputer is a system that currently performs a high operational rate for computers. The software has been written for a serial computation: to be couched on a single computer with a single central processing Unit (CPU). A problem is split into a discrete series of instructions. The instructions are executed one after another. Only one instruction may be executed at any moment (Fig 13.6). From the simplest point of view, the Parallel computing is the simultaneous use of multiple computing. It will work using several processing resources to solve a computational problem: the problem is broken into the discrete parts that can be solved concurrently, Each part is further broken into a series of instructions, the instructions from each part execute simultaneously on different CPUs (Fig 13.7).

The computing resources may be: a single computer with multiple processors; an arbitrary number of computers connected to a network; a combination of both. The computational problems should be able: to be broken into discrete pieces of work that can be solved simultaneously; to execute multiple program instructions at any moment; to be solved in less time with multiple computing resources than with a single computing resource.

The parallel calculation algorithm. The parallelization of the calculation is provided in two ways simultaneously. It is the use of a parallel simulator and the separation (preprocessing) of the field model into sectors, followed by a parallel calculation of these sectors. If a serial simulator is used, the parallelization is limited to a sector division. The software for parallel calculations is shown in Fig. 13.8 and consists of blocks: a control C ++ code; a parallel C + + code with the MPICH2 library; an Eclipse Parallel Simulator with a MPI / Pro library; the analyzer of the supercomputer loading C + +; the data (warehouse) storage. The managing C + + code is responsible for running all the other units, including the executor of the parallel code, the optimizer of the model with post-and preprocessors, a log analyzer, the exchange of boundary conditions, the analyzer of supercomputer loading, as well as a user interface. The model optimizer divides the model into the sectors (their number is ns), then it integrates into the entire model. The separation is carried out in a staggered manner so that the calculation of one sector did not depend on the calculation of the other, that is, it had no boundary conditions. The simulation of the sector depends on the results of modeling of the neighboring sectors, so the exchange of boundary conditions takes place when the calculation results of the related sectors are ready. Each sector has its own catalog for storing the initial, settlement computes and boundary data.

The Contractor of the parallel code starts the computing sectors, i.e., individual Eclipse Parallel streams. The Eclipse Parallel Simulator uses the standard MPI / Pro library. The launch of the simulator with the parameters is controlled by the "parallel C + + code », which carries out the launch of the simulator with the specified input parameters. After reaching the required accuracy of the calculation, the merging of the sectors in the entire model (post-processing) is performed.

The leading analyzer performs a continuous monitoring of the utilization of the supercomputer hardware resources (CPU loading, RAM, hard disk, etc.) and records measurements in a log. This and other journals (Journal of Eclipse, a log of all C + + codes) are processed by the log analyzer, and by the results of this analysis the control messages are generated. A user can react these messages and intervene in the process of calculation, for example, spending additional separation of the sector, or to stop the flow with poor calculation parameters [4].

13.6. 3D Simulation of oil and gas processing

The reservoir simulation is another important application of the HPC systems. It helps us to understand the flow processes in the reservoir. The seismic interpretation of the core data and the well logs are used to create geological or static models. A high resolution of reservoir models has provided many insights into the reservoir processes in large reservoir models. Because of its obvious benefit, there is a great motivation to build very many high resolution models for an accurate capture of the heterogeneity in the reservoirs. Fig. 13.9 schematically shows the main stages of creating three-dimensional models of oil and gas fields. All the stages are interrelated and mutually supplementary as it processes the information on the formation and saturating fluids. The interpretation of the geophysical data and petrophysical parameters can distinguish the faults often occurring in carbonate reservoirs, for example, a vertical fracture with the help of a detailed XMAC acoustic logging (Baker Hughes). The construction of the structural model of the pore space allows finding out the distribution of the vertical and horizontal fractures and, as a consequence, to determine the predominant flow along or perpendicular to the bedding.

Constructing a static reservoir model allows us to determine the distribution of fluids in the reservoir, the dependence of the main parameters of the liquid and gas on the specific geological and physical conditions. With account of the environment of sedimentation and facies architecture, the facies analysis of the productive strata contributes to the building of a more detailed geological and static reservoir model. The analysis of the results of the hydrodynamic research enables to reveal the distribution of the basic properties of formations both vertically and laterally.

The results of the above studies are taken into account in the construction of a hydrodynamic model of the filtration of fluids in a particular reservoir. The construction of a defined dynamic model is based on the selection of typical flow elements, which mainly depend on the texture of sedimentation. This is particularly important for carbonate rocks, as the carbonate texture has a significant impact on the variability of permeability and distribution of bound water.

The optimized scenario of the development or the further development of the deposit using modern computer technologies certainly differs by a lower degree of risks and high profitableness.

The method of tagged points is adapted to describe the distribution of discontinuous small barriers within the sand body. The discrete stochastic method is used to simulate the geological features of the deposit, discrete by its nature of clay or sand bodies, facies bodies. It is based on a probabilistic assessment of the sizes of clay inter-layers, which are determined by using the cumulative distribution frequencies. This method basically allows you to describe the form of sand and clay bodies, the most characteristic of the simulated sedimentary environments (channels, bars, etc.). But the researchers are increasingly turning to the more simple geometric forms, such as rectangles and squares. The method of tagged points is similar to the procedure proposed by Haldorsen, Lake (1984). For the 3D model each clay interlayer is generated by random setting of six numbers: three of them define x, y and z coordinates of the center of the body, and the other three - thickness, height and length. The generation of clay layers lasts as long as a certain amount of clay layers for the selected zone of the formation is achieved. This proportion is defined from the data analysis of the borehole drilled in the area. These functions describe the probability that the next clay interlayer will appear at a certain distance from the point coordinates (x, y, z) of the current clay interlayer. This approach is particularly effective for the sedimentary environments, in which the appearance of clay layers is not purely random by nature (rivers, aeolian, the distal cones of deepwater marine sediments).

On the basis of the tagged points, the SESIMIRA program has been developed. It consists of two stages: the generation of reservoir geometry, the elements of sedimentation, faults and any fixed geological features; an accidental filling of the remaining space by the discrete elements of a smaller scale. The body shapes are usually presented either rectangular or ellipsoidal.

The Boolean sets are used for modeling the unconformities (lenses, facies and faults) in the sandy block. In this case, the lenses and facies are represented as random points in space of the reservoir. This method depends on several parameters: the lenses density destitution in volume; center shapes of lenses and facies (constant or variable); their dimensions and orientation of the compass. These models also allow you to display the form of geological bodies not only in the form of rectangles and squares, but also in the forms that are similar configurations to the beds of paleorivers, the bars. The disadvantages of this approach should be explained by the fact that there is assumed an independence of facies distributions from each other. The krigging method is used to interpolate the correlated surfaces between the wells.

Monte Carlo sampling. A random distribution of small clay inter layers within the formation can be generated using the Monte Carlo probabilistic modeling procedure. In this case the Monte Carlo method is used for a direct probabilistic modeling. It is based on the computer simulation of probability distributions using a pseudo-random numbers. An important role is played by the assumptions regarding the probability of the lateral dimensions of clay. For the first time the procedure was proposed by H. Haldorsen, L. Lake (1984). In it the random number generator determines the random location, the width of the clay layer. The Monte Carlo sampling is also used to assign the random probabilities continuity of clay layers in the space between the holes. If this probability is less than the probability determined by an expert, it is believed that the clay interlayer is continuous between these wells. Otherwise, a random number of cells containing sand is generated on the line connecting these wells. The effectiveness of the Monte Carlo method slightly depends on the size and the geometric features of the reservoir structure, and this is its obvious advantage. The trained Artificial Neural Network was used as a proxy function for a Monte Carlo simulation. The probability distributions for the input parameters are being established. A total of 10,000 trials are carried out during the Monte Carlo simulation. Fig. 13.14 shows the resulting probability distribution. The result was a logarithmic-normal probability distribution with a 50% - probability of recovery of 122 200 m. The sensitivity analysis showed that the permeability had the greatest effect on the results, followed by the maximum GOR achieved at the maximum optimal, size of the gas drive [4].

Simulation of random Markov fields. The Markov field model (Ripley, 1987) is used as an alternative to the traditional compiling of clay maps to describe the distribution of clay layers that correlate between two and a large number of wells. A model based on a probabilistic assessment of the continuity of clays between the pairs of wells enables to simulate river channel erosion of clay layers. The simulation of Markov fields can generally present more realistic models from geological point of view. From the point of view of the local distribution of the parameters, a less realistic situation is modeled. In particular, unrealistic are the forms of clay barriers such as rectangular, square. The number of randomly simulated sand cells between the wells has also a strong effect on the model of clay barriers. The Markov field model includes a description of the distribution of facies and the use of clay thicknesses in terms of Markov transition probabilities. The Markov process is a process in which the current state depends only on the previous state.

The Gaussian random fields are one of the methods of construction of continuous stochastic models (porosity, permeability). Before constructing the Gaussian field, the layer is divided into the basic elements of sedimentation by vertical and lateral (up to 10 items). Each element of sedimentation is determined by: the mathematical expectation (average) for each petrophysical value, the interval change of each petrophysical value for the element of sedimentation; the inter-value correlation matrix, the spatial correlation function (spherical, exponential, or fractal). These values are determined from the well data, or are based on the expert data. The distribution function of each facies in space relies on the subordinate of the normal (Gaussian) distribution.

The ReO software includes a number of solutions for simulation and optimization of the ground-field equipment and the operating infrastructure which practically include all the items from the wellhead equipment to the processing plants. This application simulates the entire production system as a whole and simultaneously optimizes the manufacturing process considering the economic model defined by the user. The COM interface allows you to connect to the package any independently developed program to model the wells and the treatment processes including even the Excel spreadsheet. The ReO software package simulates the behavior of any reservoir fluid considering its fractional composition and a wide range of temperatures and pressures. The construction of the model of black oil provides a set of standard commercial ratios of pressure / volume / temperature (PVT), such as the Standings, Glaso, Petroski-Farshad ratios, etc. For the mixed media the DOT model is constructed using the equation of state. Six equations of state, including the Peng-Robinson and the Soave-Redlich-Kwong equation, are integrated in the ReO package. The database of formation fluids supplied with the application campuses the characteristics of the components contains up to C45, including the standard inorganic compounds which can be detected in them. All this allows the user to enter the data on the DOT quickly. The software supports all the major equipment used in the standard systems of oil and gas recovery, namely, fittings, field pipelines, risers with the upstream and downstream flows, pipe fittings, manifolds, multi-phase separators, heat exchangers, gas compressors, pumps, CO2 and H2S absorbers etc.

The built-in object-oriented object-store database stores all the configurations of the production systems and networks together with the calculated results. This allows you to create, evaluate, and easily compare different scenarios. The ReO forecast allows you to build a complex model of the underground and ground network for an accurate prediction. It connects ReO with a model, the program of the underground part through the WellFlo package. The model of the underground part of the network is a MatBal software module used to calculate the material balance. The ReO can also interact with other layers simulators (Figure 13.10).

Reservoir modeling/simulation. When run, every reservoir simulator requires the input data that define the model. The input data should generate the output data that represent the results of the performed calculations. In spite of different reservoir simulation codes having different formats for entering the data, they all have some basic components in common. All the further modeling process will depend on these data. The input file must be set up before starting the simulation process. The data file may be set up by manual editing (if it is in ASCII format), or by using a Graphical User Interface (GUI). Whichever method is used, most data files will be divided into certain key sections such as: model dimensions; grid and rock properties; fluid properties; initial conditions; output requirements; production schedule. The additional (optional) sections may allow the manipulation of the imported grid structures and the subdivision of the grid in the regions.

The pre-processors may be used: to define grid and rock properties; to define fluid properties; to convert the results of special core analysis data to a form that can be used in the simulation; to upscale the rock data so that to define the sizes of grid cells; with their help used; to define vertical flow performance tables; to set up the production schedule. The output of the reservoir flow calculations is usually performed in two forms which in both cases results in the creation of files that can be stored and read at a later date. The first category of output data is typically referred to as "summary" data and the second type of output consists of field grid data. The two types are as follows:

a) The summary data consisting of calculated parameters such as oil, water and gas flows, well bottom or well head pressure, etc. These data may be plotted as charts, usually as a function of time, either by using a specialized post-processing software, or by using a standard graphing software such as Microsoft Excel or Lotus 1, 2, 3;

(b) The grid data consisting of such values as pressure or saturation for each cell so as to characterize them at any moment. These files are typically in a binary format which means that they may only be read by the appropriate post-processing software.

Fig. 13.11, Fig. 13.12 show a pattern of a reservoir, an example of modeling and mapping of each cell.

Treating the *uncertainties in Reservoir-Performance Prediction (Artificial Neural Network).* Very often, the simulation of models is performed to design the field development plans. Because of the low level of the available information during the early development stage, a range of uncertainty in the prediction must be considered. Such uncertainties can be handled with the Artificial Neural Network (ANNs). The mathematical prediction models (simulation models) are detailed and powerful predictive tools that can answer many questions regarding the subsurface engineering. Due to the large uncertainties, the prediction results will have a broad range especially in the early development phase. To take into account the whole range of possible outcomes of the reservoir simulation, it is necessary to treat the mathematical models by a successive optimization processing thousands of times. There is a requirement of finding a solution which will meet both the standards of the subsoil uncertainties and the economic considerations with the greatest profiles. Because of the computational time involved, these methods are not often used. The formations of a response surface that can predict many possible outcomes of a mathematics simulation by processing a large variety of input parameters could provide a solution to this problem. The response surface must cover the non-linear dependencies of the input and output parameters.

The experimental design and the response surface modeling have been used to delineate the subsurface uncertainties. Common applications include the probabilities of the toted oil reserves in the geological model, estimating the uncertainty in the predevelopment or redeveloped projects, in predicting the production performance in different cases of field development, and in the optimization the of the well sparing to maximize the profits.

Methodology. Fig. 13.13 shows the proposed workflow. First of all, a limited number of simulation operations is carried out to define the most sensitive input parameters. In these operations the parameters are transformed into the minimum or to the value one at a time after selecting the most influential input parameters, three values (minimum, best-estimated, and maximum) are defined. The experimental design aims at obtaining the maximum information with a minimum number of simulation runs. An own minimum number of testing processes is required for the Artificial Neural Network to get the accurate data. With these data sets containing output and input parameters and the corresponding output of several additional runs, an Artificial Neural Network is trained and tested. After defining the probabilities of every input parameter, the Artificial Neural Network is used as a proxy function for a Monte Carlo simulation. The use of the probability distributions of the input variables, together with the proxy function, provided the opportunity of realizations for thousands of solutions and, thus, the possible final solutions have been defined.

Reservoir Model. The given oil reservoir contains a gas cap and a small aquifer. While the depth of the gas/oil contact (GOC) is known by the wells, the gas-cap size is uncertain. The exact point of the oil/water contact (OWC) is not known, only there is the deepest oil-bearing horizon. The gas/oil ratio (GOR) was steadily increasing since the first production. As the aquifer is small, it generates little energy. The gas cap and the dissolved gas drive are the main driving forces of oil recovery. The single case of the production of the free gas in the GOC zone is enough to obtain a low oil recovery factor. An additional well aimed at deeper areas of the reservoir can provide the opportunity to recover more oil down the bed dip. To increase oil recovery even more, there is opportunity to inject water down the angle of the fed dip or gas up the dip. One of the crucial questions is the time of shutting in of the up dip well to maintain a sufficient pressure formed by a gas-cap drive for maximizing the recovery factor.

Definition of Uncertainties. After carrying out a limited number of simulation runs, four parameters were identified as the most sensitive relative to the cumulative oil production: gas-cap size; the position of downdip well producing oil and which depends on the position of the OWC; the permeability; the maximum GOR. The minimum, most probable and maximum values for different parameters were defined.

Experimental Design and Neural Network. The central composite experimental designs were set up with 25 simulation runs. Five additional runs were set up to test the model. The Artificial Neural Networks consisted of the four stated input parameters and five neurons in the hidden layer. The cumulative production after 15 years was defined as the network output data. With the defined minimum, best estimated, and maximum values for the input parameters, the cumulative production after 15 years was in the range of from 104 000 to 173 000 m. The test results showed the maximum deviation of 7%.

13.7. 3D Visualization of Oil and Gas Processing in Real Time

The availability of reliable and timely information on the course of any operating process, its "visualization" is obviously the key to managing this process both by the operator and by the automated control. The information systems used in the oil fields are becoming more advanced, and the realization of value and convenience of the information they collect is constantly improving. The modern information systems allow you to get in a convenient form for the operator the data from the wells, gathering stations, storage tanks, primary oil treatment plants, booster and group pumping stations in real time. The material basis for the collection of information is provided by the modern controllers and database management systems that allow you to store and process the data of operating processes both in real time and from relational databases. On the pyramid (Figure 13.15) these are levels L1 - L2. The user gets the values of the basic monitored parameters (flow rate, pressure, temperature, etc.) of the wells, group metering stations, processing plants of surface facilities, storage and delivery of products, etc.

in real time. In doing this, the visualization of the bottlenecks the screen displays the current values in comparison with their established limits in the controlled processes. The data of the well tests are processed and issued upon the request in the required format. The user is supplied with the inherently rich report generator that allows to design the reports in a standard format in different directions: changeable and daily production reports, reports on the production and delivery of hydrocarbon injection volumes, status of wells, etc.

The graphical visualization began to be widely used since the mid 80s. The 3D visualization of seismic data, GIS and the development enabled to get quickly the horizontal and vertical slices of the structure scanned by rotating, animation, glossing over with smooth color transitions. Using this technique, the specialists have got the opportunity to analyze the 3M models of the oil reservoir from the top, the bottom, the side and the inside. The logging data, contour maps, seismic sections, and even color photographs of the core can be sent from one data center to another in a few minutes. The computers can simultaneously correlate over 30 wells. The synthesis of a variety of data with a simultaneous visualization allows you to analyze and geological aspects and the development process both on the macro-and the micro-scale. The computer visualization is a tool enabling to reflect the 3D images of the reservoir structure and for multiphase fluid flow inside this structure. In the construction of 3D models, the following data types are used: scalar, vector, matrix. The scalar data (pressure, saturation, rock types, facies) are more often known by the results of well tests and are averaged (or expert estimated) for the reservoir. The vector data (to sand content, clay content, porosity) can be obtained on the basis of GIS data by loggings. The matrix data (2, 3,.., n-dimensional) are the estimated data of numerical reservoir models and the development processes. The color scheme in the case of discrete types of data is strongly tied to the appropriate value (for example, red is the porous reservoir type, blue is the fractured reservoir type). The color scheme (in the form of a rainbow) for continuous data types may reflect a quantitative change in the parameter (oil saturation, porosity, etc.) from the lower (cool colors) to high values (warm colors). The modern computers can reflect more than one million tones, half-tones and shades. There are several ways to build 3D images of the formation and the development processes. The most common of them is a method of isoline or isosurface measurement. To show the rate of the change of the parameter in the 3D space isogradient the maps are prepared.

Creating the high-performance computing systems has set the scientists a new challenge nakedly, the development of the 3D systems for the visualization of geological and field processes in real time. The use of the digital technologies will increase the efficiency of the development thus resulting in the reduction of the operating costs by 5% and capital costs by 10%; additional recovery of residual oil in old fields; the achievement of 50% recovery factor through the introduction of innovative technologies (see Fig. 13.16).

The data on the geology and the development of oil and gas resources can be both statistical (time-independent) and dynamic (time-varying). For the dynamic parameters (oil saturation, pressure) the distribution maps may be reproduced at regular time intervals. The analysis of the results of mathematical modeling requires powerful tools for visualizing the 3D flows in complex, irregular and dynamic lattices. These tools can help a reservoir engineer to build quickly a lattice to describe the flow of fluids in a complex constructed environment. Typically, such an operation for a large, complex system of reservoirs with fractures (Gullfaks, Norway) takes several months. The development of the tools of the integrated approach (Figure 13.19) is currently more important than the efforts to increase the computing power and performance. Fig. 13.18–13.22 show the process of visualization in real time of the Halliburton, Schlumberger, Conoco Philips, Paradigm companies.

Vizualizer of the casing. Shell and Baker Hughes Incorporated companies have developed a system which allows to monitor the deformation of the sand screen and the casing shape in real time using fiber optics. This system is a visualizer of the casing and the cementing process in real time (VCPB). The VCPB uses the Bragg grating sensors embedded in the sand screen, instrumentally related to the fiber-optic cable to monitor the deformation and displays three-dimensional images of high-resolution deformation on the screen. The nature of the deformation of the hole over its cross section depending on the properties of the occurring unstable rocks is divided into two types: the increasing cross-sectional area of the wellbore or reducing it. The first is the result of cavings and collapses of well boreholes. The second type of deformation of the wellbore (narrowing) is associated with the occurrence in well section of the montmorillonite clays, capable of constant flux till the complete shutoff of the well. Tens of thousands of sensors are arranged spirally at a distance of 1 cm from each other, each of which is capable of measuring submicron deformations. They provide a continuous real-time monitoring of the pipe deformations, sealing the oil and gas reservoir well integrity, without any external intervention. They all also fix all the pipe stresses, including the axial load, collapse of pipes, pressure and temperature.

The VCPB is currently used for both the casing and the 9 5/8-inch gravel peak. The first successful real- time test of the casing was held in the Pinedale field (Wyoming, USA, the Shell company, 2008). The system was used for the section of two 7-inch casings from different angles of winding fiber-optic on the casing, the winding angle determining the sensitivity of a particular deformation condition. The key points of cementing of casing (cement injection, the movement of the bridge plugs) were clearly displayed on the screen.

The latest developments in the field of smart sensors enable to carry out a "subtle" monitoring of the operating equipment that allows preventing the faults before they occur. A huge number of tiny sensors were installed next to all the equipment. If the vibration of the engine exceeds the permissible level, the sensor detects a change of the motion rate, and the data are transmitted from one sensor to another until they reach the computer. The computer includes an alarm signal system, and the working crews begin to repair the engine prior to the damage. [1, 3, 4].

13.8. A Multimodal Reservoir Simulation

Saudi Aramco's Multimodal Simulation Environment (Muse) is an environment that integrates a voice-advisory system with the multimodal visualization. This environment provides a stereo- compatibility of the 3D visualization, the force feedback using the haptic devices, and the data ultrasonic processing. A new-generation reservoir simulators are capable of handling millions of cells and imply that the geological details can be handled without a intensive scaling up which can lead to a direct seismic integration of the hydrodynamic simulation. Unfortunately, the ability to analyze the information doesn't keep pace with these advances in full measure. Recently, the devices that function as a "3D mouse" with haptic (i.e., touch) capabilities have appeared. These devices have the ability to move and to study the models inside the Earth models.

Multimodal Data Analysis. In contrast with the conventional software systems that provide only the 3D visualization as the means for the data interpretation and analysis, this system uses two additional "channels" for the sensor interaction: a sensing element (haptics) and a sound (sound tracking). The reservoir simulation results, that are loaded into the system, can be attached to more than one of these three channels.

The number of the data (i.e., simulation of variables) that can be loaded is limited only by the volume of addressed memory system, as a result, only three volumes can be attached to the channels. The other volumes available in the system can be searched over the channels at any time. All the loaded volumes, whether they are attached to the channels or not, can be monitored by the system using the rules prescribed by the engineers.

For example, the engineer can visualize a 3D pressure distribution, feel the permeability changes with the haptic device and hear changing of oil or gas saturation through the loud speakers. The values of these properties are fixed for a range of 0 to 255, similar to a typical color map. Also, the simulation results of such as 3D distribution of the mole fraction of hydrogen sulfide (H2S) or the acoustic impedance from an elastic model can be tracked as the events, even if they are not directly attached to any channel.

Visualization Channel. The so-called "rainbows" are color maps which are typical (e.g., blue for low values, red for high). The color map panel is fully editable, and the engineers can choose the upper and lower limits to concentrate on specific value ranges, if so desired. Fig. 13.23 shows typical 3D displays of different simulation of output variables (pressure, gas saturation, and H2S mole fraction).

Haptic Channel. The system uses a 3D mouselike haptic device that can be moved in six directions inside the data volume. The device provides the engineer with a force-feedback sensation. The amount of the force resistance is passed on to the haptic device and is felt by the engineer's hand when moving of the stylus and is reflected in "haptic maps". A great resistance can be assigned to the high-value ranges (e.g., high HS concentration) or a low-value ranges (e.g., low permeability), as desired. The zero-resistance or low-resistance ranges can be assigned to low or average values that are of less interest to the analysis/interpretation.

Sound Channel. The sound map has been designed so that each value corresponds to a given note of a musical instrument. The choice of musical instruments follows the standard of musical instruments of the digital interface tables. Three sliders can provide a musical note, volume, and an instrument. The musical note ranges from 0 (C00) to 127 (G9), spanning 10 octaves, where each octave contains the notes to G with the accompanying flats and sharp objects. The volume ranges from 0 (silent) to 127 (very loud). The instrument ranges from 0 (grand acoustic piano) to 127 (gunshot). For example, a high gas saturation can be assigned to a trumpet in C-sharp, a low gas saturation to a flute in B-flat, and a very low gas saturation (and regions below the gas/water contact) to a French horn in F. The rule based on the automated interpretation of the system has the ability to analyze all of the data on the basis of the rules set a priori by the engineers. As a temporary in advances, the new state of the simulation is analyzed by the set of the rules and the certain events. These events currently use only the visual and sound channels.

A specific message can be included in the rules so that the text to the utility speech is the message to warm the engineer when certain conditions occur. The scope of the search can be confined to specific wells, all the wells, or the full 3D grid. The system searches throughout the entire data set and identifies the wells or cell locations where the condition occurs. For example, the rule "Find all the wells in which pressure of <6,000 psi" will result in the following: the system will report "Pressure below 6,000 at Well R-2", whenever this condition occurs at Well R-2 during the simulation. Similarly, the rule "Find all the blocks in which oil saturation is >0.05" will result in the system reporting "Condensate dropout at gridblock 45, 85, 65" whenever this condition occurs during the simulation. In setting up these rules, the engineer has a full control over the message that should be spoken, with the system automatically adding the result of the search into the message [4].

Conclusion

The rapid development of computer simulation technology has made the field simulation more widespread. Most of today's oil and gas companies are using digital 3D-modeling in the design and the development of new fields, in determining the best way to extract the resources, and also apply the permanently operating geological and technological models for managing the development of oil and gas fields in real time. A characteristic feature of the modern development of the exploitation of hydrocarbons (HC) is the computerization and the widespread use of information and communication technologies. The course paper points out the obvious achievements of the information and communication technologies and the computerization of oil and gas field development. The paper considers the problem of optimizing the 3D-modeling of oil and gas field by using the HPC. The using of the 3D-simulation model is proposed for a rapid analysis of large models without desensitization is presented. Creating the 3D static and dynamic models is a long process that takes from several months to a year or more. In this regard, presently the issues of the development and the improvement of the information and communication technologies still remain relevant. There is a special demand for the modeling system using the gigacells generated as the result of dividing the model into large amount of cells. Processing of the information received from each cell, requires a modeling system with advanced possibilities. Such systems are necessary for considering the geological data of the cells, when the hydrodynamic models of the reservoir unite the cells to facilitate the processing.

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List of Abbreviations

IRT – in real time; DBMS – data base management system; HPC – high performing computing; ANN – artificial neural systems; WT – well testing; HC – hydrocarbons; GPEW – geological prospecting and exploration works; RF – oil recovery factor; HCh – haptic channels; SCh – sound channels.

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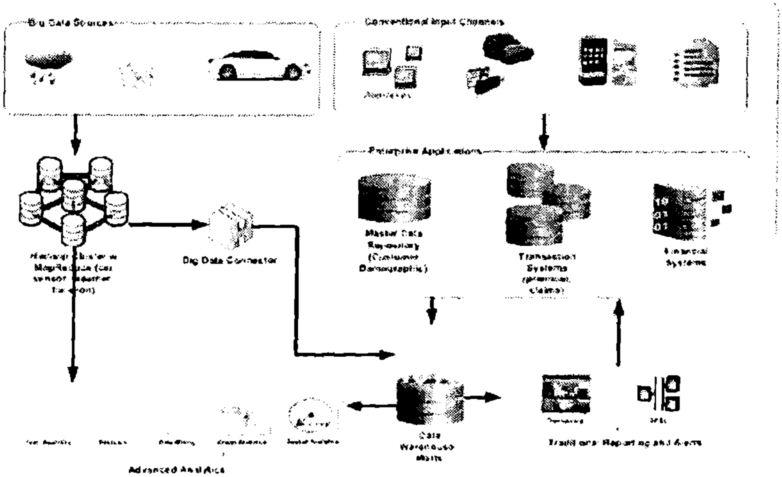

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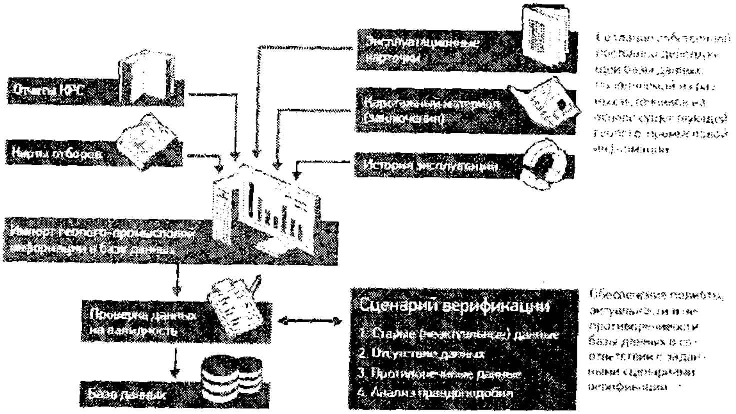

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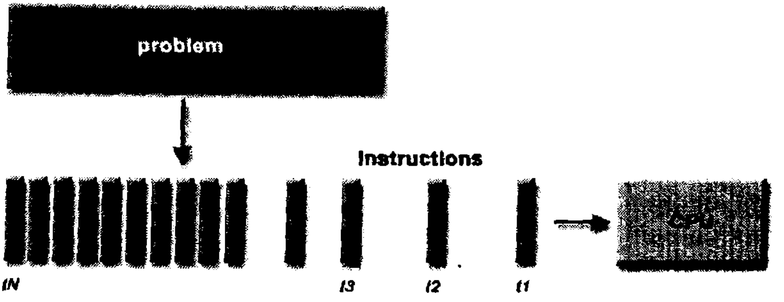

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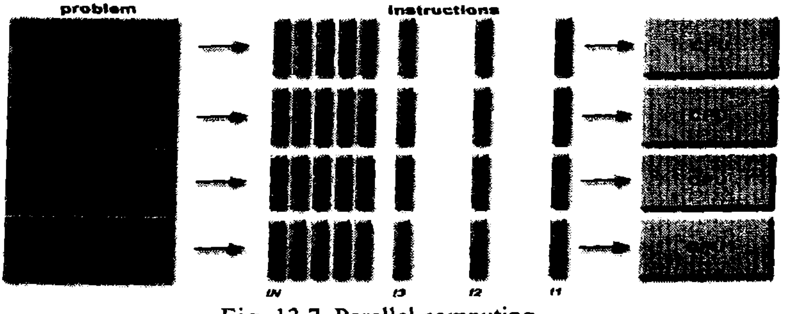

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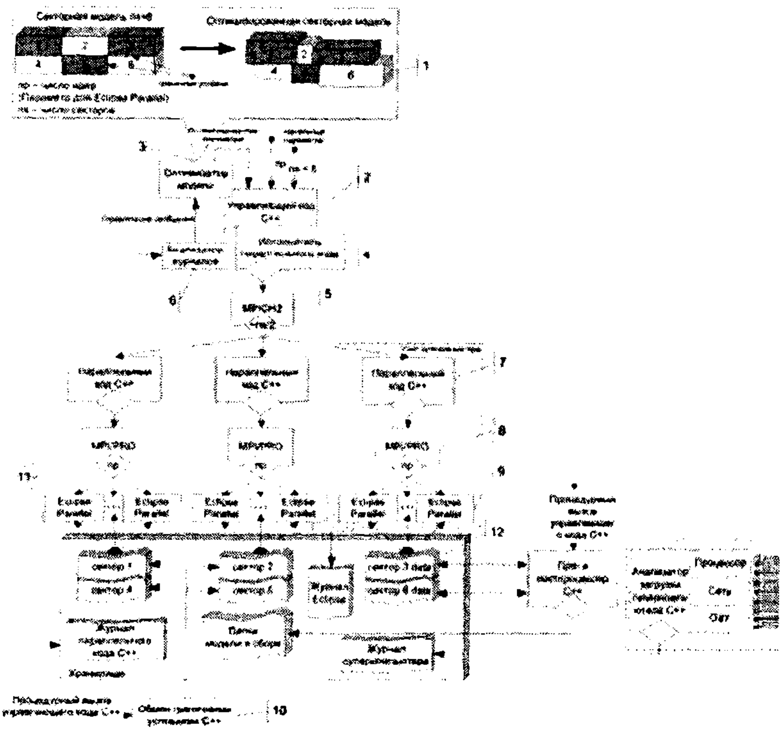

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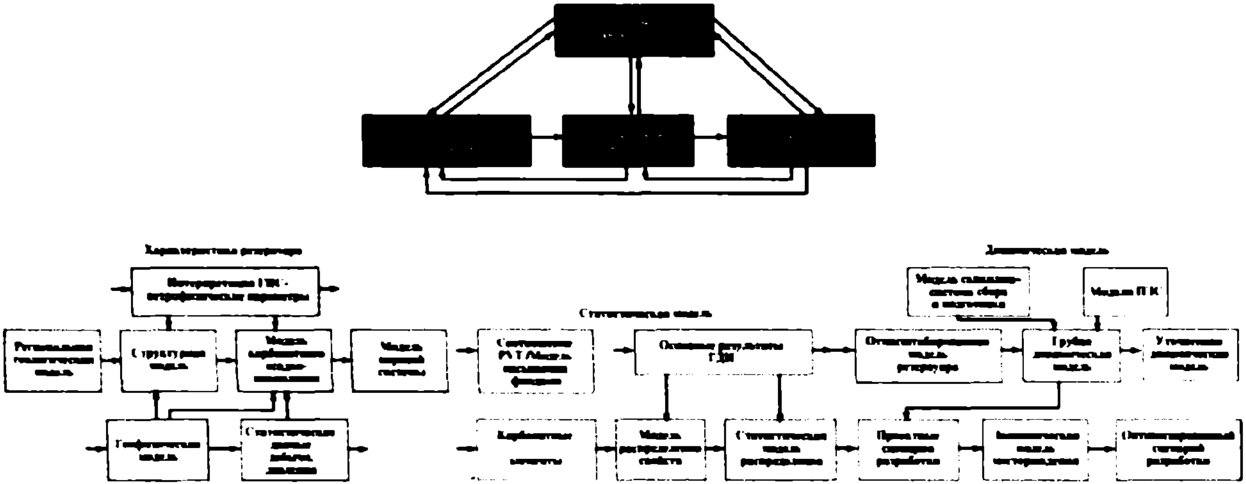

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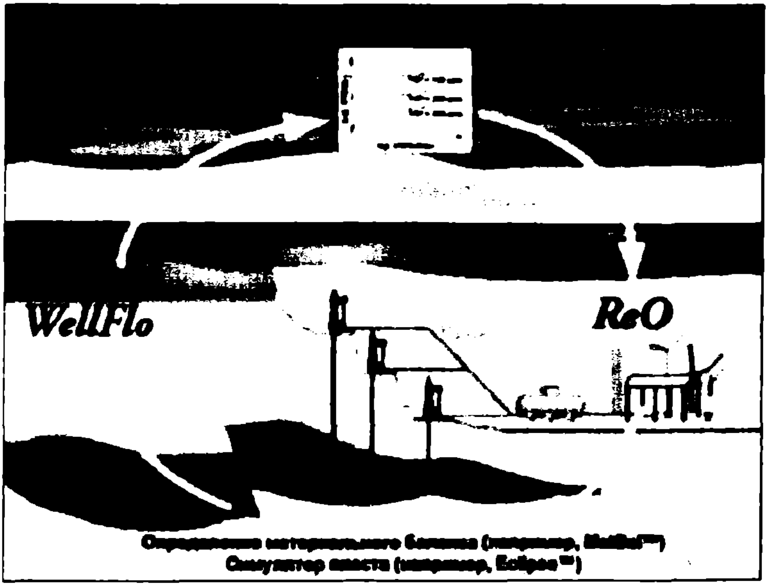

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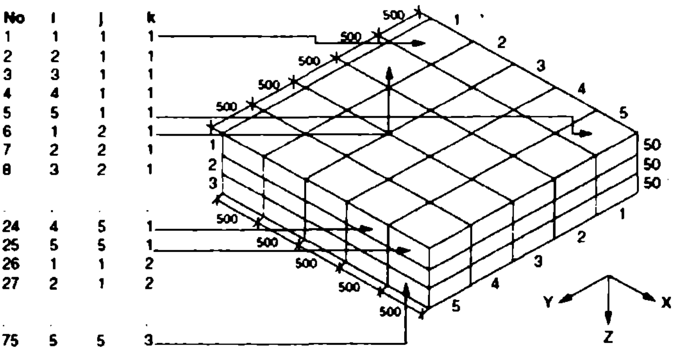

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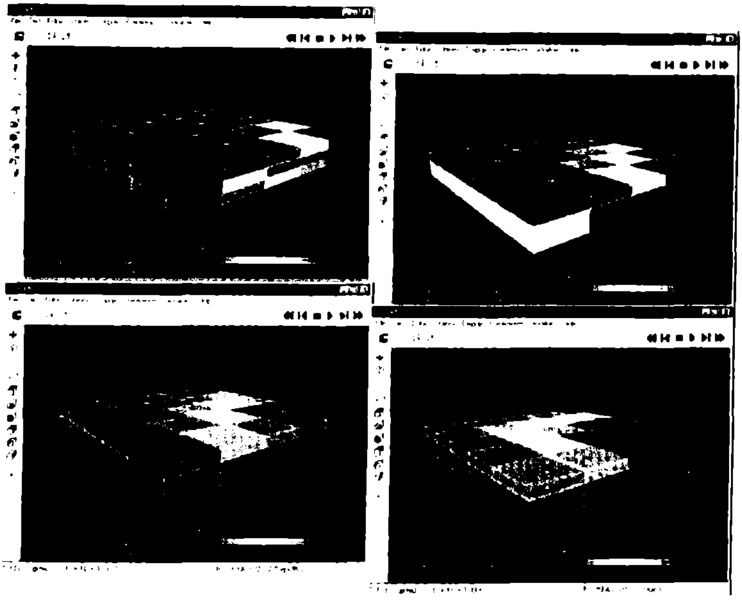

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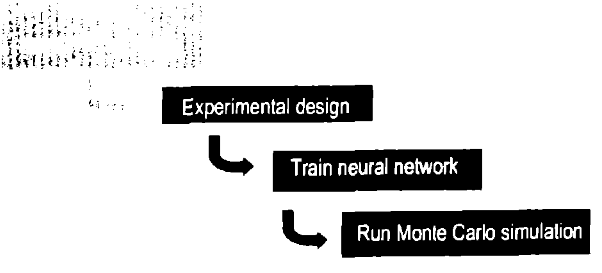

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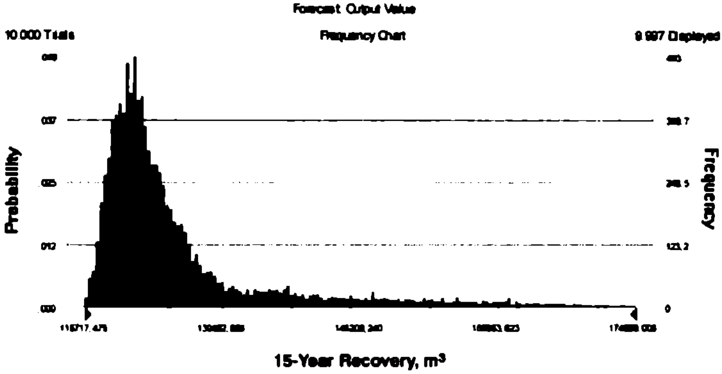

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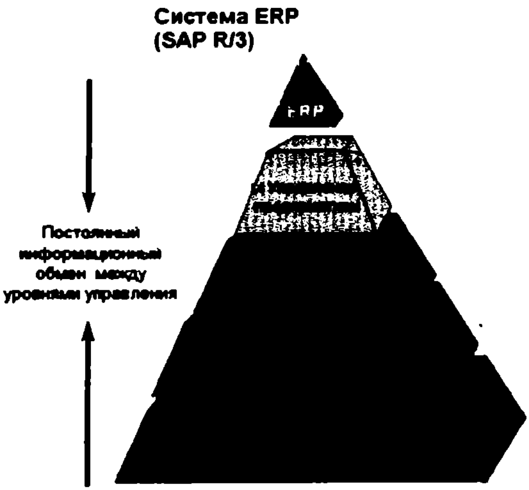

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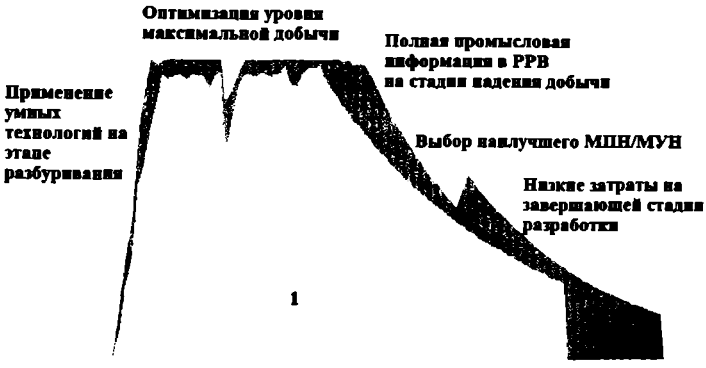

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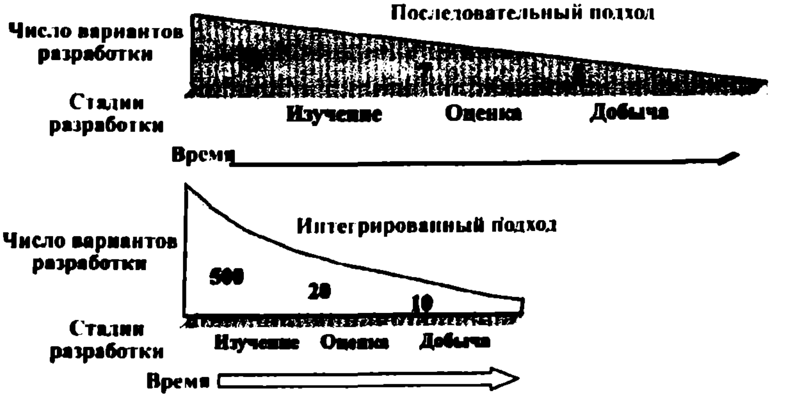

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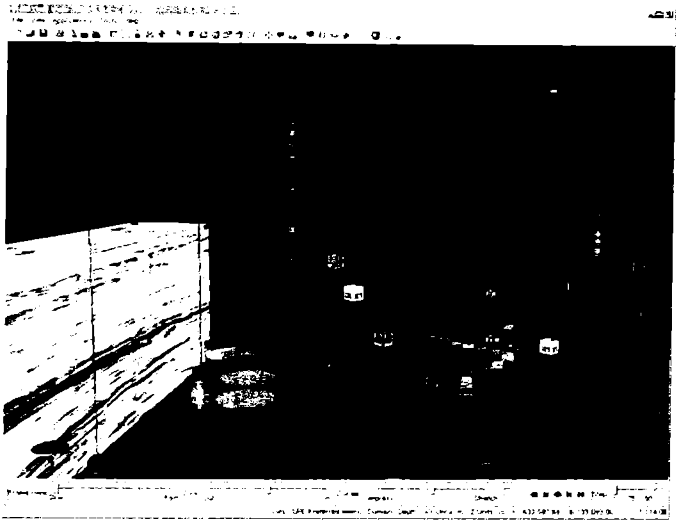

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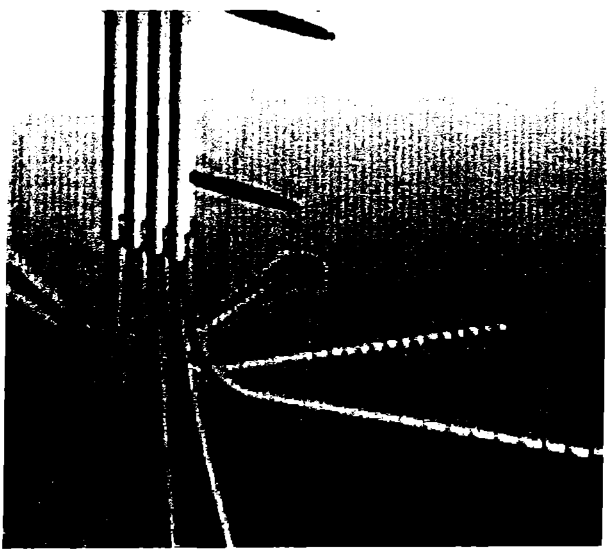

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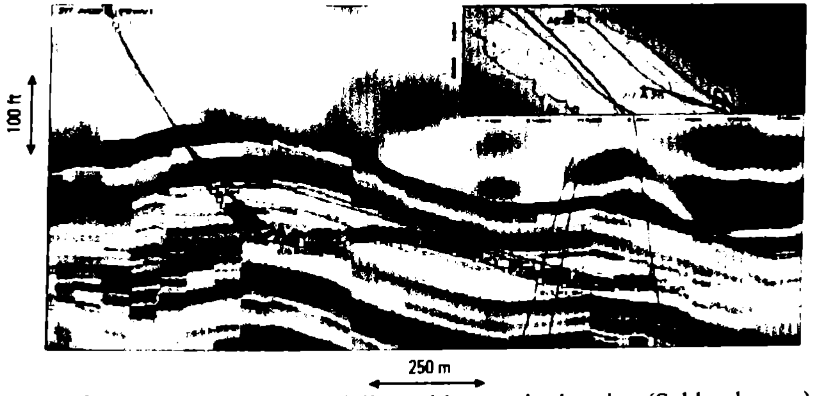

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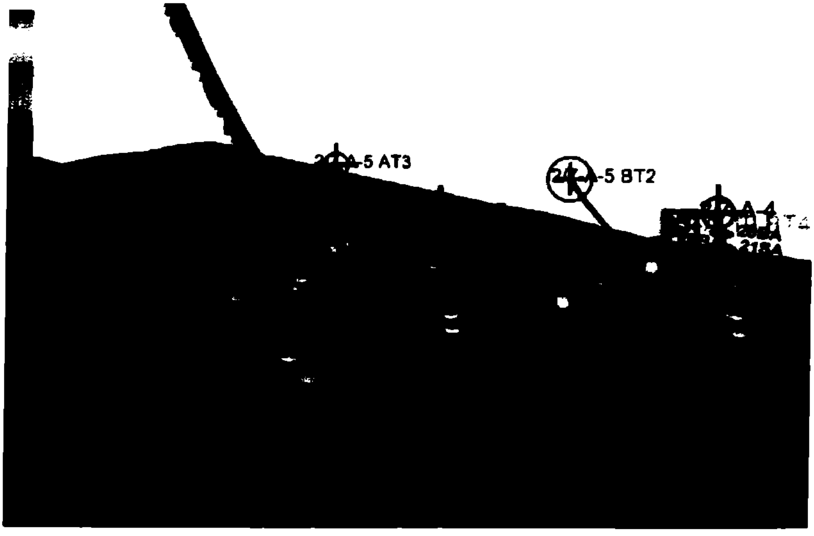

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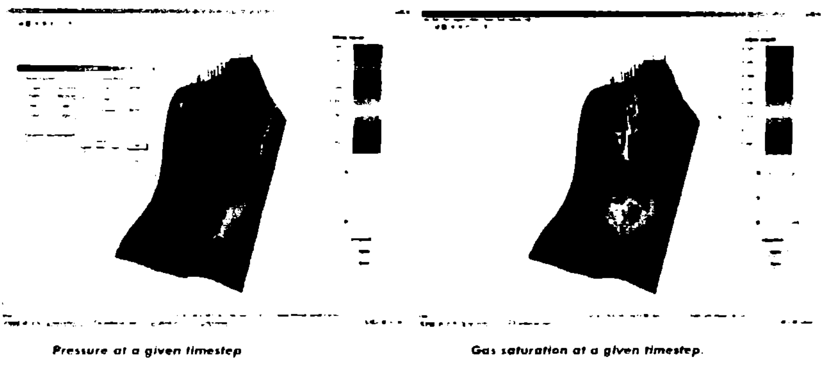

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Conclusion

The main trends of the modern development of the smart manufacturing complexes are:

1. Creating a unified system of management and decision-making in real time.

2. Unification of collecting production data from millions of sensors, preparation, processing and transmission of the industrial metadata on the basis of common standards, data formats and communication protocols.

3. Smart management processes of the environmentally friendly use of energy, transport, roads, weather, resources - metal, water, air, land; logistics supply of physical and chemical reagents, spare parts, equipment, marketing products in the industrial complexes in real time.

4. Simulation of mechanical, physical, chemical, technical, technological, industrial, environmental, financial processes, training, transport, processing and sale of products in the mode, as close to real time: 2015 – quarterly, 2025 - monthly, 2035 - weekly and 2045 - daily regimen.

5. The transition to a fully automated (unmanned) technology to new industrial complexes to the years 2025-30.

6. The transmission of information on the state of intelligent manufacturing company on the Russian stock exchanges in real time.

7. Provision of annual hourly labor productivity growth in smart manufacturing companies from 5 to 7% (annual hourly labor productivity growth in the U.S. engineering and technical personnel is 6%; increasing in the annual hourly wage of the engineering and technical personnel in the U.S. is 1%).

In modern conditions, industry should improve the technological, manufacturing, and information and communication processes to meet the long-term productivity growth in OECD countries. Few of the existing manufacturing companies will survive the requirements of the time. These tasks require the production companies the maximum concentration of its efforts on the implementation of smart technology at every stage of the cycle. The introduction of the smart technologies in the production cycle of the key companies should be supported by the Government of the Russian Federation in the form of a state program for the period 2015-25 years. Otherwise, the Russian production companies may be companies with high capital and operating costs and unattractive for investment. This will lead to a loss of position in the global market and the difficulties in developing the resources of the World Ocean, Eastern Siberia and the Far East.

Key manufacturing companies can realize the gradual restructuring of the industrial complex through the use of smart technologies in real-time to upgrade fixed assets, retrain the scientific and technical staff, a major control centers and link them to the places of production, preparation, processing and transportation of products and stock exchanges. In a highly competitive global market demands time withstand those companies that are able to look at two steps forward.

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На обложке: Snake robot for the subsea pipeline inspection, Robotnor; Змееподобный робот для инспекции подводных трубопроводов компании Robotnor, Норвегия

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