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18 September 1981

USSR Report

ENERGY

(FOUO 16/81)

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CONTENTS

GENERAL

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HYDRODYNAMIC CONVERTERS PROTECT OIL PUMPS FROM SALT DEPOSITS

Moscow NEFTEPROMYSLOVOYE DELO in Russian No 7, 1981 pp 11-12

[Article by V. N. Makarov, V. N. Sergeyev and L. N. Makarova, Tyumen' Industrial Institute: "Use of Hydrodynamic Converters to Protect Electrical Centrifugal Pumps from Calcite Deposits"]

[Text] A significant growth of the mechanized well fund is being observed in the West Siberian fields. The greater part is wells equipped with UECP [Universal Electrical Centrifugal Pump]. At the same time, the number of flooded wells is increasing and complications are developing in the operating process which result in the breakdown of the oil field equipment. Thus, at the NGDU [Oil and Gas Extracting Administration] "Nizhnevartovskneft'" there were 198 UECP breakdowns in 1979.

The main reasons for the breakdowns of the deep-well electrical centrifugal units are given below:

Reduction in resistance of insulation	111
Jamming because of mechanical admixture deposits	44
salt deposits	42
Other reasons	1

It is apparent that unit malfunctions because of salt deposits are significant. In the associations "Nizhnevartovskneftegaz." "Urayneftegaz" and "Yuganskneftegaz" the number of wells in which salt deposits are found continually rises from year to year. They numbered 418 on 1 October 1980. The main reason for the salt deposits on the running parts of the ECP is disruption in the thermodynamic balance of the water-oil-gas system during movement through the pump.

There are different methods for preventing salt deposit on the surface of the oil field equipment. They include the use of acoustic and ultrasonic fields. The effect of acoustic oscillations results in a considerable increase in the crystallization rate. This increase depends, on one hand, upon the intensive mixing of the liquid in the accoustic field and the formed crystals being washed away from the walls, and, on the other hand, upon the growth of the crystallization centers following the destruction of the crystals which had been formed. The process of crystallization thus becomes volumetric; the formed crystals are not deposit on the equipment walls but are removed by pump to the surface.

The use of acoustic fields is a promising method to protect the equipment. The range of the most optimal frequencies to influence the crystallization process is 10-18 kHz. One of the methods for producing acoustic oscillations in the UECP is the use of rotary hydrodynamic converters (RHDC)

The RHDC is a device which converts kinetic energy of a liquid stream into acoustic oscillations by periodic interruption in the stream at the moment the holes of one of the coaxial disks is covered. These disks are fixed immovably on the axis (stator) by connecting strips of the rotating disk (rotor). During rotation, the through section increases to the maximum at the moment when the openings of the rotor and stator coincide, and then diminish to zero. The oscillation frequency is determined by the number of holes and is in the range of 0.5-10 kHz. The RHDC is installed instead of one or several stages of the pump. This does not impair the working characteristics of the latter.

Analysis of the operation of the UECP with built-in converters notes that the design of the latter has a significant effect on the operation of the pump unit. The experimental models of the RHDC that were used from 1977 to 1979 in a number of cases resulted in breakage of the pump shaft because of a design imperfection. Because of the large gap between the rotor and stator, the technological ineffectiveness of the fabrication and incorrectness of the selected hole configuration of the first converters the power emitted by the converter diminished and their reliable operation declined.

Taking into consideration the shortcomings listed above, work was done to improve the RHDC design. Based on field tests, more advanced acoustic converters were developed for all type-sizes of UECP. The gap between the working surfaces of the stator and rotor was reduced; the fabrication technology was simplified; the total weight of the emitter was reduced, and the hydraulic losses in the converter were diminished. These measures increased the emitting power of the RHDC and improved their reliable operation.

The RHDC were tested in the associations "Nizhnevartovskneftegaz" and "Urayneftegaz" in 1977-1980. During this period, 11 breakdowns were observed in the wells with high mineralization because of salt deposits and shaft breakage. These are precisely the reasons which characterize the ineffecient operation of the emitter in the pumps equipped with RHDC. The average full operating time in this group of wells was 105.6 days. The lower confidence boundary of mathematical expectation with probability of 0.95 equalled 55 days.

The results of statistical processing of these data are presented in the table.

Group of wells	Average full operating time	Standard deviation, day	Confidence interval of mathematical expectation with probability 0.95, day
Equipped with RHDC	162	62	$138 \leq X \leq 186$
Operating without protection	37	19	$30 < X < 44$

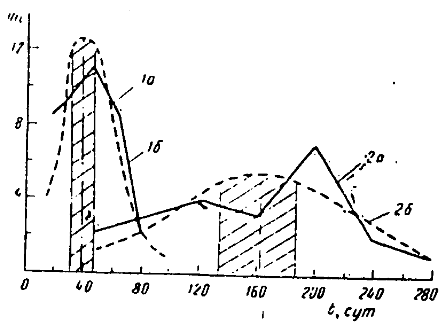
Figures 1 and 2 present the empirical and theoretical dependences of the malfunction frequency and the probability of breakdown occurring because of calcite deposits on the operating time of the UECP in wells where salt deposits are observed, with RHDC and without protection.

The presented data demonstrate the effectiveness of using RHDC to protect the UECP in wells with high mineralization and permit the conclusions that:

equipping the UECP with hydrodynamic converters in wells prevents depositing of salts in the pump and increases no less than 4-fold the full operating time of the UECP (on the average from 37 to 162 days);

the probability of the UECP breaking down because of salt deposits when the RHDC is used is much lower than the corresponding probability for the UECP without protection;

the ineffectiveness of the acoustic effect that is observed in a number of cases using RHDC can be explained both by the difference in the generated frequency from the optimal, and by the insufficient power of the acoustic field.



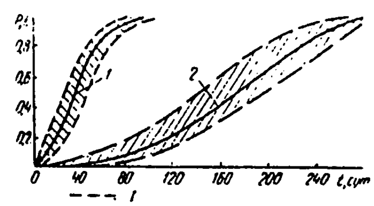


Fig. 1. Dependences of empirical (a) and theoretical (b) frequencies of UECP breakdowns due to salt deposits in electrical centrifugal pump on operating time in wells where salt deposits are observed: 1. electrical centrifugal pump without protection, 2. electrical centrifugal pump with RHDC

Fig. 2. Dependence of probability of UECP breakdown due to calcite deposits in electrical centrifugal pump on operating time in wells where dalt deposits are observed: 1. electrical centrifugal pump without protection, 2. electrical centrifugal pump with RHDC, I. confidence interval with level of reliability 0.95.

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POLYMER COATING PREVENTS SALT DEPOSIT FORMATION

Moscow NEFTEPROMYSLOVOYE DELO in Russian No 7, 1981 pp 13-15

[Article by L. Kh. Ibragimov and I. Z. Akhmetshina, I. M. Gubkin Moscow Institute of the Petrochemical and Gas Industry: "Laws Governing the Formation of Complex Salt Deposits"]

[Text] It is known that salt deposits contain organic oil components. Studies by methods of electron microscopy, infrared spectroscopy and spectrophotometering in the ultraviolet and visible parts of the spectrum have made it possible to establish the presence of two types of organic oil compounds in these components: asphaltenes, resins, paraffin hydrocarbons; aromatic compounds, alcohols, oil acids and their salts, halide compounds, and organosulfurous compounds.

Compounds of both types are found in the salt deposits on any section of the oil field equipment used in fields whose working is complicated by sedimentation.

The organic compounds in the structure of the salt deposits over the field can be divided into adsorbed and crystal-bound.

The water-soluble part of the organic compounds which is part of the deposits is of especial importance. Its content fluctuates from 10 to 40% of the weight of the entire organic compounds. Below are the results of a quantitative analysis of the water-soluble organic compounds in the salt deposits of the oil-saturated rocks of the deposit water and the oil of the Samotlor field.

Name of sample	Weight content of active organic compounds ,%
Salt deposits from	
well 4646	0.394
well 4264	0.276
Deposit water from	
well 2048	0.034
well 4528	0.037
Oil from	
well 4521	0.027
well 4634	0.031
Oil-saturated rock from	
well 4264	0.334
well 5024	0.297
well 1544	0.318

The organic compounds were extracted from the oil-saturated rock by Seyfert's technique, from the salt deposits, by the technique of Giprotyumenneftegaz, and from water and oil, by chloroform.

The studies showed that the organic substances that were extracted from the oil, oil-saturated rock and salt deposits were identical in composition. Their feature is high surface and chemical activity which is manifest in the capacity to reduce solubility of inorganic salts in water, to bond metal ions with the formation of organometallic compounds, to be adsorbed on the surface of the interface, and to reduce the interphase tension.

The oil components probably have a significant effect on the kinetics of crystallization of inorganic deposits and their properties. Special laboratory studies were made on the process of salt depositing under dynamic conditions in order to verify this hypothesis.

Aqueous solutions of salts Na_2CO_3 and $CaCl_2 \times 2H_2O$ that dissolve well in water were prepared separately in two vessels and of calculated concentrations. Using dosing pumps, the solutions were continually fed to five mixers with the same velocity. A chemical reaction occurred practically instantaneously in the mixers between the sodium carbonates and the calcium chloride with the formation of $CaCO_3$. The latter, being a compound which is difficult to dissolve, is capable of creating supersaturated aqueous solutions.

In the experiments, the coefficient of supersaturation of the solution in the mixer equalled 10 and corresponded to the results of computing the supersaturation of the deposit waters of the Samotlor field.

Solutions were pumped from the mixers through thermostatically controlled steel pipes with temperatures of 30, 50 and 80°C. The pipes were periodically taken from the "casings" and dried at room temperature. The quantity of deposits was determined by repeated weighing on analytical scales and by computing the average arithmetical results for five pipes.

The second series of experiments was conducted by adding extracted organic compounds to the mixer with a small quantity of solvent (in a 1:1 ratio).

The results of the studies at 30°C are presented in the figure. It is apparent that with an increase in the quantity of organic compounds in the solution, the rate of sedimentation rises. Examination of the inner pipe surfaces under an electron microscope revealed films of organic compounds onto which salt crystals precipitated with oil components adsorbed on them. Real salt deposits were often located on a continuous oil film that was adsorbed on the metal surface and which included complex structural units, aromatic hydrocarbons, oil acids and their salts.

Thus, the active oil components promote intensification of salt accumulation. In addition, by adsorbing on the interface, they increase the adhesion between the particles and the surface of the equipment.

With a drop in temperature of the experiments, the quantity of deposits also diminished slightly. This is explained by the rise in the quantity of equilibrium concentration (solubility) of the calcium carbonate.

Of especial interest is the fact that in the presence of organic compounds, the quantity of deposits formed on a glass surface drastically increases. It is common knowledge that with high supersaturations, homogeneous nucleation dominates over heterogeneous. The oil components wet the quartz glass, forming a film on it and the salt particles that develop in the stream adhere to it.

A considerable number of gas bubbles are observed in many real samples of salt deposits, especially carbonate. This is evidently associated with the great rates of deposit formation and with the release of carbon dioxide when the pressure drops and the water-soluble bicarbonates break down into calcium carbonates which are difficult to dissolve.

Gas bubbles, like complex structural units of oil, are active crystallization centers. They are capable of disrupting the laminar sublayer and of creating heterogeneous solid-liquid-gas interfaces on which, as is known, more favorable conditions exist for nucleation of salt crystals.

The process of forming mixed salt deposits is mass crystallization from salt-saturated accompanying water under complex hydro- and thermodynamic conditions in the presence of oil components, gases and other admixtures which have a significant effect on the kinetics of crystallization and the properties of the deposits.

The study results make it possible to assume that in order to prevent salt depositing, lyophobic coatings should be selected, and not hydrophobic as is customary. Materials with smaller critical surface tension of wetting have lower wettability with liquid. Below are reference data on the critical surface tensions of wetting of certain polymers.

Polymer	σ_{kp}, mJ/m^2
Polyvinyl chloride	40
Polymethyl methacrylate	39
Polystyrene	33
Polyethylene	31
Polytetrafluoroethylene	18

Polytetrafluoroethylene probably should be the most effective of them.

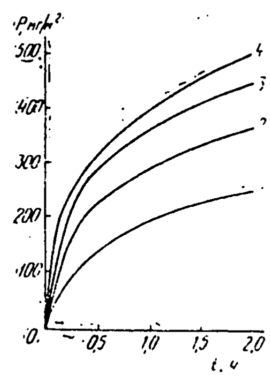
Supersaturated water-salt systems were pumped according to the technique presented above through thermostatically controlled pipes that were covered by the aforementioned polymers for 45 h. Electron microscopic studies of the inner pipe surfaces at the end of the experiments showed the absence of salt deposits in them.

In the next series of experiments, supersaturated solutions of salts treated with additives of organic compounds in a quantity of 1% of the weight of the entire solution that were extracted from the salt deposits, were pumped through thermostatically controlled pipes with coatings made of the same polymers. Examination of these pipes after the experiments revealed individual accumulations of salt crystals from 3 to 9 μm in size on the surfaces of the polymethyl methacrylate, polystyrene, polyethylene and polyvinyl chloride. The rate of sedimentation on them changed from 25 to 117 mg/m^2 x h. After removal of the salt crystalline particles, organic films were found on the surface of the polymers. Salt particles formed in the liquid evidently also adhered to them.

Jointly with D. S. Odnorog we conducted field tests of coatings made of polytetrafluoroethylene. Pipe test samples with coatings applied to them were installed in a common collector at the outlet from the measured unit "Sputnik" of GU-1 of the Zhetybay field at the site of greatest stream turbulence (bending of the collector on which, according to field data, salt deposits to 5-8 mm thick form in 10-15 days). The test samples were in the stream for 17 days. Their examination at the end of the testing did not reveal any salt deposits on the polymer-covered surface. At the sites of cutting the test samples where the metal surfaces were not covered with polymer, dense layers of barium sulfate precipitated with a small quantity (less than 6%) of calcium sulfate, calcium carbonate and organic oil components. These layers reached thickness of 8 mm.

Thus, the amount of critical surface tension of wetting can be considered one of the chief criteria in selecting the coating for the inner surface of equipment on a certain field section whose working is complicated by precipitation of salt deposits.

In order to prevent salt deposits in the system of collection, preparation and transportation of oil, gas and water on the Zhetybay field, application of coatings made of polytetrafluoroethylene to the inner surface of the equipment can be recommended.



Dynamics of the process of sedimentation from supersaturated water in the absence of organic oil components (1) and when organic compounds are added to the solution that were extracted from real salt deposits in a quantity of 0.3 (2), 0.6 (3) and 1% (4)

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GENERAL

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BOOK DESCRIBES ATOMIC ENERGY DEVELOPMENTS, PROBLEMS

Moscow ATOMNAYA NAUKA I TEKHNIKA--NARODNOMU KHOZYAYSTVU in Russian 1981 (signed to press 5 Dec 81) pp 146-156

/Conclusion from book "Nuclear Science and Technology for the National Economy" by Andranik Melkonovich Petros'yants, chairman of the USSR State Committee for the Utilization of Atomic Energy, Energoizdat, 24,000 copies, 157 pages/

/Text/ During the postwar years, and especially during the 1960's, atomic energy acquired all the rights of "citizenship" and became a part of the life of man as a new source of energy, which had never been used before. Atomic energy became an irreplaceable assistant of man in many areas of his peaceful activity. It is impossible, of course, also to forget the potential use of atomic energy for military purposes, which is disastrous for mankind. During World War II the explosion of atomic bombs showed how terrible, destructive and savage a force nuclear weapons can become in the hands of militarists and aggressors.

This destructive power is so great (taking into account the stockpiles of nuclear weapons in the countries having a nuclear arsenal) that this factor alone is in a certain manner a restraining force, an obstacle to the use of nuclear weapons for military purposes. Aggressors should understand that they cannot forget the retaliatory nuclear strikes of the opponents. However, it is clear that this circumstance alone is not sufficient to check the military threat. That is why our party and the Soviet Government are coming forward with peace initatives and are making many radical suggestions to the United Nations on arms reduction, the halt of underground tests and the production of nuclear weapons, and subsequently the complete elimination of all stockpiles.

Much has already been done on the political level. There are a number of international agreements which limit the conducting of nuclear weapons tests, the production of strategic offensive weapons and so forth. In July 1979 the Strategic Arms Limitation Treaty was signed between the two largest countries--the USSR and the United States. This treaty was signed on the part of the USSR by General Secretary of the CPSU Central Commitee and Chairman of the Presidium of the USSR Supreme Soviet Comrade L. I. Brezhnev and on the part of the United States by the U.S. President. The draft of a trilateral Universal Nuclear Test Ban Treaty is being prepared. The parties of this draft are the Soviet Union, the United States and Great Britain.

However, not everything has yet been done by the peoples of our planet for the sake of peace on earth. And our party, our Soviet people and all peace-loving peoples are exerting every effort to solve this most important task for the purpose of the rejection of the use of nuclear weapons, the repudiation of wars, achieving a peaceful solution of controversial questions by direct negotiations, without the use of weapons, especially nuclear weapons.

In this book we attempted in a very concise form to show what potentials atomic energy, which is used for peaceful purposes, holds. The advantage of atomic energy is that its potentials are truly unlimited; moreover, they are still far from exhausted. The numerous examples cited in the book clearly confirm this.

Atomic energy has received the most extensive use in the generation of electric power, in the construction of nuclear steam-generating plants, including for transportation purposes. Nuclear electric power stations, having begun their path with the first nuclear electric power station in the world in the Soviet Union (the 25th anniversary of which was celebrated in June 1979), have been or are being built in more 40 countries of Europe, Asia, America and Africa.

In the middle of 1980, according to the data of the International Atomic Energy Agency, more than 225 nuclear electric power stations (blocks) with a total electric power capacity of 120 million kW were in operation throughout the world. And in all with the nuclear electric power stations in operation, under construction and planned to be built, according to the data of the IAEA, by the middle of 1980 there were nearly 500 nuclear electric power stations with a total electric power capacity of more than 400 million kW. In order to comprehend better the scale of construction of nuclear electric power stations in the countries of the world, let us recall: the power capacity of all the electric power stations in the USSR in 1979 was 260 million kW, that is, more than the capacity of the electric power stations of Great Britain, France, Italy and the FRG taken together. However, it is impossible not to point out that the construction of nuclear electric power stations in a number of countries of the world is proceeding under difficult conditions. Nuclear electric power stations have many friends, but there are also opponents. On the basis of the assumption that atomic energy is potentially the most dangerous form of energy, its opponents are hindering in every possible way the construction of new nuclear electric power stations, are organizing protest demonstrations and are making attempts to destroy the objects of nuclear electric power stations, which are being built and are in operation. Industrial monopolies of traditional types of primary energy are also playing a certain role in the organization of such protests of the public against nuclear electric power stations. It is also impossible to deny that in certain countries government agencies in some instances support the opponents of the construction of nuclear electric power stations, in other instances the opposition political groups support them. That is how it was, for example, in Sweden during the elections, when the opposition parties defeated the Social Democratic Party, having advanced the campaign promise to halt the construction of new nuclear electric power stations and to shut down the operating ones. Incidentally, after coming to power, these parties were not able to keep their promises: the nuclear electric power stations continue to generate electric power. This is understandable, since they provide 20 percent of all the electric power generated in Sweden.

An international conference, which was organized by the German Society of Foreign Policy and the Federal Ministry for Research and Technology, was held in May 1979 in the Federal Republic of Germany. The most diverse groups of the public, scientists, members of parliaments and representatives of the governments of more than 20 industrial and developing countries took part in this conference. The conference participants came to the conclusion that in face of the fact of "the decrease of petroleum reserves throughout the world the development of atomic energy is becoming simply necessary."

The need of nuclear energy for power supply was illustrated, in particular, by the following example: 1 billion tons of hard coal would have to be burned annually to obtain a third of the energy consumed per capita in Western Europe. Meanwhile, in the United States, for example, only 600 million tons are mined annually, while in the Federal Republic of Germany--100 million tons.

The accident at the Three Mile Island nuclear power plant on 28 March 1979 in the United States, near Harrisburg, Pennsylvania, caused great anxiety of the world public.

According to press reports, the accident occurred due to the damage of one of the reactor core cooling systems. During the accident the formed gas bubble, which contained hydrogen, which could cause the explosion of the reactor in the presence of a large amount of oxygen, was the main threat. But the amount of gas decreased rapidly and by 3 April it had declined to a safe level (from 28.3 m^3 on 31 March to 1.36 m^3). It should be noted that this accident caused no injuries, while the level of irradiation as a result of the venting of radioactive gases was negligible and came to 1-2 millirem.* Meanwhile, this accident caused very great reprecussions in the world, since it was the most serious of all the ones that had ever occurred at nuclear electric power stations. Some "especially hot heads" demanded in this connection the shutdown of all operating nuclear electric power stations and the halt of construction of new ones.

The U.S. President appointed a high-level commission to investigate the causes and consequences of the accident at Three Mile Island. The commission, which was given extensive powers, under the chairmanship of J. Kemeny came to the following conclusion.

1. As a result of the accident three of the operating personnel received a dose of radiation in the range of 3-4 Rem, which slightly exceeded the dose permissible over 3 months.

2. The possible consequences of the irradiation of the surrounding population were negligible. The total collective dose of radiation within a range of 50 miles (about 80 km) was only 2,000 man-Rem, with a dose of the natural radiation background (for this area) of 240,000 man-Rem.

Thus, according to the conclusion of the commission the consequences of the radioactive contamination of the surrounding area of the nuclear power plant were "negligible." The commission made a number of suggestions on organizational questions, which concerned the Nuclear Regulatory Commission, on the issuance of

*REUTER APPL. ATOM. NEWSLETTER, No 1220, 1979, pp 1-2; NUCLEONICS, No 1892, 1979, pp 9323-9324.

licenses for the construction of new nuclear power plants and on their operation; it expressed its opinion on the shortcomings of the design of this nuclear power plant.

The accident at the Three Mile Island nuclear power plant could not but attract the attention of specialists, political figures and the scientific community of many countries. What happened at this nuclear power plant, even though there were no injuries and contamination of the environment, should not be repeated. The point is not that the operators of the nuclear power plant made some mistakes and even that the reactor cooling system broke down, but that the opponents of nuclear power engineering are attempting to use every slip, every omission for their own purposes in order to ban nuclear power.

Meanwhile, this new source of energy is also necessary especially against the background of the depletion of such natural resources of fuel as petroleum and gas. At the same time a number of countries, especially of the Western world, are dependent upon petroleum imports. It is possible to cite France as a example.

France meets 75 percent of its needs for petroleum by imports from the Arab countries. In 1973 the main petroleum suppliers for France were Saudi Arabia and Iraq, which supplied it with 36 percent of all its petroleum, while in 1978 their share had increased to 52 percent. That is why nuclear power engineering found a stable place in France and that is why France is developing nuclear power engineering in earnest. In the past decade France has invested more than $30 billion in the construction of 37 new nuclear electric power stations in addition to the 10 nuclear electric power stations previously in operation.

The increase of petroleum prices has sharply intensified the interest of France in nuclear power engineering. In conformity with the program of the development of power engineering, which is designed for 15 years, in France it is planned by 1985 to build nuclear electric power stations with thermal reactors with an electric power capacity of 35,000 MW and with a (Superfeniks) breeder reactor with an electric power capacity of 1,200 MW and to increase the total electric power capacity of nuclear electric power stations to 40,000 MW. At present 26 nuclear electric power stations are being built in the country.

At the time when the stir over the Three Mile Island accident was at its height, the French Government, having declared such an accident to be impossible in France, issued an order to speed up the construction of nuclear electric power stations and laid the foundation of the 48th reactor. France at present receives 14 percent of its electric power from nuclear electric power stations, while by 1985 it plans to increase this proportion to 30-40 percent.

Speaking at the International Conference on Nuclear Energy in Hamburg (1979), FRG Chancellor Helmut Schmidt said that "...no country in the world can afford to reject an additional energy source, as nuclear power is.... If in the future battles begin on a world scale over the distribution of the ever decreasing reserves of power raw materials, the poorer developing countries would be in a worse situation as a result of this.... This, in turn, could also cause a confrontation of the largest states. Thus, a sufficient supply of energy would become an essential component of the maintenance of peace on earth...."

"It would be foolish to deny," Schmidt stated further, "that the accident at Three Mile Island did any harm to the faith in science and technology. Nevertheless, hasty and rash conclusions should not be drawn from this. Everything must be discussed thoroughly, and it is better to do so on an international basis."

In Switzerland a referendum on whether or not to have nuclear power in the country was held in early 1979. The people voted for nuclear power. And now the proportion of nuclear energy with respect to the generation of electric power is nearly 30 percent of its total generation by all Swiss electric power stations. This is the greatest generation as compared with that of all the western countries.

In the Soviet Union nuclear power engineering is being developed on the basis of thermal reactors; great gains have been made with respect to breeder reactors. Such large industrial nuclear electric power stations as the Novovoronezhskaya, Leningradskaya, Chernobyl'skaya, Kol'skaya, Kurskaya, Armyanskaya and other AES's are in operation in the USSR. Nuclear electric power stations have been built and are being operated with the technical assistance of the USSR in Czechoslovakia, the GDR, Bulgaria and Finland. In Hungary the start-up of the first nuclear electric power station was carried out in 1980. The construction of nuclear electric power stations in these and other countries with the assistance of the Soviet Union is continuing.

The significant of atomic energy for the USSR and the countries of the socialist community is great.

In October 1980 in his report "According to Lenin's Behests, by the Path of October" Chairman of the USSR Council of Ministers Comrade N. A. Tikhonov said:

"An enormous advantage of socialism is that it has turned to the benefit of progress and peace the enormous achievements of human genius. We have the right to be proud of the achievements of science, of the fact that we were the first to begin using atomic energy for peaceful purposes, the first to go into space....

"The increase of the rate of development of atomic energy, the decrease of the proportion of petroleum, which is used at electric power stations, the rapid increase of the production of gas, the more efficient use of traditional and new types of energy, the development and introduction of highly productive and economical equipment and energy-saving technologies will make it possible to ensure the more stable supply of the national economy with fuel and power...."

On 2 December 1980 the CPSU Central Committee published the Main Directions of USSR Economic and Social Development for 1981-1985 and the Period to 1990, in which the directives of our party on the development of all the sectors of the national economy and science are set forth.

In Section III "The Development of Science and the Acceleration of Technical Progress" it is indicated: "In the area of the natural and technical sciences to concentrate efforts on the solution of the following most important problems:

"...the development of the physics of elementary particles and the atomic nucleus for the purpose of further knowledge of the structure of matter;

"the development of nuclear power engineering and the creation of the bases of thermonuclear power engineering."

"To develop atomic energy at a leading rate," it is indicated in Section IV "The Development of Industry." And later: "In electric power engineering to increase the generation of electric power in 1985 to 1.55-1.6 trillion kWh, including to 225 billion kWh at nuclear electric power stations. To ensure the increase of the generation of electric power in the European part of the USSR mainly at nuclear electric and hydroelectric power stations. To put into operation 24-25 million kW of new capacities at nuclear electric power stations. To continue the work on the development of breeder reactors and the use of nuclear fuel for the generation of thermal energy.

"In power machine building to ensure a considerable increase of the production of equipment for nuclear electric, hydroelectric and thermal electric power stations, including atomic reactors with a capacity of 1-1.5 million kW and power blocks with a capacity of 500,000-800,000 kW for thermal electric power stations which run on low-grade coals. To complete the production and delivery of the first atomic reactors for the supply of large cities with heat. To develop new designs of power blocks with breeder reactors with a capacity of 800,000-1,600,000 kW.

"In the RSFSR to place into operation the capacities of the Smolenskaya, Kalininskaya and Kurskaya AES's.

"In the Ukrainian SSR to increase in 1985 the generation of electric power to 280-290 billion kWh, to obtain the basic increase of it by means of nuclear electric power stations. To launch the construction and place into operation the first units at the Khmel'nitskaya, Zaporozhskaya and Krymskaya AES's and the Odesskaya Nuclear TETs, to ensure the increase of the capacities at the Chernobyl'skaya, Yuzhno-Ukrainskaya and Rovenskaya AES's.

"In the Lithuanian SSR to ensure the placement into operation of the first section of the Ignalinskaya AES."

The policy of developing atomic energy as one of the main tasks on increasing the power supply of all the sectors of the USSR national economy is clearly expressed in this draft of the CPSU Central Committee for the 26th CPSU Congress.

The socialist countries have also embarked on the path of the use of atomic energy for peaceful purposes and first of all for obtaining electric power at nuclear electric power stations. This was reflected in the collective decisions of the Council for Mutual Economic Assistance (CEMA) and in the adopted long-term goal program of cooperation in the field of power engineering. The agreement on the creation of the Unified Power System of the European socialist countries, which was concluded several years ago, is aimed at this. All the collective measures of the CEMA countries in this most important area attest to what an enormous role socialist cooperation and economic integration are playing in the solution of the most important problems of power engineering.

In the socialist world, in the world of the community of socialist countries science has become accessible to the peoples of all the countries which have been united in the Council for Mutual Economic Assistance. The scientific, technical and economic cooperation of the CEMA member countries has assumed an extensive scale.

The 30 years of CEMA activity have been marked by enormous achievements. The Comprehensive Program of Socialist Economic, Scientific and Technical Integration was adopted by the CEMA member countries. This detailed program is a plan of multilateral integration measures of the CEMA member countries, which includes the most important economic, scientific and technical problems connected with development, the construction of projects and the creation of additional production capacities.

One of these problems is the development of the fuel and energy base of the CEMA member countries and the meeting of their steadily increasing needs for the main types of fuel, power and raw materials. The Comprehensive Program of the Further Intensification and Development of Socialist Integration, which was drafted and is being implemented by CEMA, covers more than 200 problems in all areas of the national economy and science. It is intended for stage-by-stage implementation over the next 15-20 years.

International socialist economic, scientific and technical cooperation is a historically governed and natural process of the development of the world socialist system. The brilliant foresight of V. I. Lenin that in contrast to capitalism, socialism creates "new, higher forms of human community life, when the legal demands and progressive aspirations of the working masses of every nationality will be met for the first time in international unity,"* is being realized during our times.

Today the CEMA member countries are demonstrating the great vital force of socialist internationalism, which was bequeathed by Lenin.

The community of socialist states rests on the uniform economic basis created in the CEMA member countries--the public ownership of the means of production and a similar state system, the power of the people headed by the working class, on a single ideology--Marxism-Leninism, and on a single goal--the building of communism.

In his report at the 25th CPSU Congress General Secretary of the CPSU Central Committee Comrade L. I. Brezhnev spoke about the close ties of the Soviet people with the peoples of the socialist countries.

"Our alliance, our friendship and our cooperation are the alliance, friendship and cooperation of sovereign, equal states which are united by common goals and interests, by the bonds of comradely solidarity and mutual assistance. We are advancing together, helping each other, uniting our efforts, knowledge and resources for the quickest possible progress.

"We have adopted a policy of the joint solution of the problems of raw materials, fuel and power, foodstuffs, transportation. We are intensifying specialization and cooperation, especially in machine building, on the basis of the latest achievements of science and technology. We will solve these problems reliably, economically and in the long run. We will solve them with an understanding of the interests and needs of each fraternal country and the entire community."

Precisely these principles determine the entire subsequent course of cooperation with the member countries of the Council for Mutual Economic Assistance.

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*V. I. Lenin, "Poln. sobr. soch." /Complete Works/, Vol 26, p 40.

The scientific and technical cooperation of the socialist countries in the area of the use of atomic energy for peaceful purposes has undergone extensive development among the CEMA member countries. The achievements of our Soviet scientists and the enormous experience gained in the Soviet Union were the basis of this cooperation. At the first stage of cooperation in the area of nuclear science and technology nine nuclear reactors, six cyclotrons and seven radiochemical and physics laboratories furnished with modern equipment and instruments were built and put into operation in the socialist countries with the technical assistance of the Soviet Union.

The 20th anniversary of the organization of the CEMA Permanent Commission for Peaceful Uses of Atomic Energy was marked in October 1980. The active participation in the work of the commission of CEMA member countries: Bulgaria, Hungary, the German Democratic Republic, Poland, Romania, the Soviet Union, Czechoslovakia, Cuba and Vietnam, made it possible to make a very significant contribution to the development of multilateral and bilateral cooperation in such important directions of the use of atomic energy as atomic power engineering, nuclear instrument making, radioactive and stable nuclides, tagged compounds, radiation safety, protective equipment, the use of radioisotope instruments and apparatus in various sectors of the national economy, science and medicine.

This cooperation promoted the creation in the CEMA member countries of atomic scientific research centers, the development of scientific research and engineering developments and, what is the main thing, the establishment of national scientific and technical personnel in such a leading sector as nuclear science and technology are.

The creation of the conditions and the organization of assistance in the building of nuclear electric power stations in the CEMA member countries is an especially favorable fact in the activity of the CEMA Permanent Commission for Peaceful Uses of Atomic Energy.

The achievements of the economy, science and technology, the steady extension and improvement of socialist democracy and the increase of the standard of living of the workers clearly demonstrate the superiority of socialism as a social system and are conducive to the increase of its attractiveness.

Along with the flourishing of each socialist nation and the strengthening of the sovereignty of the socialist states, their interrelations are becoming closer and closer, more and more elements of community are arising in their politics, economics and social life.

The Soviet Union is making a great contribution to the development of international economic relations of a new type and to the strengthening of the positions of world socialism. The achievements of the Soviet people in the building of communism and the consistent struggle for the strengthening of peace and for detente are having a profound influence on the entire course of world events.

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ELECTRIC POWER

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ANALYSIS OF EQUIPMENT FAILURE AT ACTIVE SOVIET NUCLEAR POWER STATIONS

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[Article by F. Ya. Ovchinnikov, L. M. Voronin, B. B. Baturov, A. A. Abagyan and S. A. Lesnoy]

[Text] One of the major trends in development of nuclear power in the Soviet Union is construction of nuclear electric facilities with water-cooled water-moderated power reactors [VVER]. The first power facility with a VVER-210 was put into industrial operation in 1964 at the Novocherkassk Nuclear Electric Plant. A large series of power facilities with VVER-440 reactors has been put into operation since 1971 in the USSR and several other nations (East Germany, Bulgaria, Finland, Czechoslovakia) with technical assistance from the Soviet Union.

Operation has confirmed the correctness of engineering decisions in design developments, as well as conformance of the actual working characteristics of power facilities to the projected levels. Operational experience has also enabled determination of ways to further improve equipment and technological systems in accordance with increasing requirements for safety and reliability of nuclear electric plant operation.

Safety problems for normal working conditions can be considered completely solved. However, for emergency conditions these problems need further research. International experience in the development of nuclear power shows that the very concept of "safety" and the methods of achieving it are undergoing continuous changes in connection with massive construction of nuclear power facilities and the search for rational, technically feasible means of ensuring safety. VVER reactors of the first generation had shielding and localizing systems corresponding to the limited scale of a maximum credible accident that was accepted at the time. Considerable emphasis was placed on the factor of keeping the nuclear electric plant far from populated areas. The safety systems in power facilities with unified VVER-440 reactors that are now being introduced are designed for counteracting more extensive damage up to and including a break in the pipelines of the main circulation loop with maximum diameter for which the consequences of an accident are potentially more serious. Obviously it is very difficult to solve this problem by technical means alone, i. e. by using hardware to meet all safety requirements in building a nuclear electric plant that does not subject the surrounding environment to at least a slight risk of contamination. All efforts in the area of safety should be directed toward reducing the degree of risk. Such efforts will be fruitful only upon condition of inseparable combination of technical safety facilities with a high level of organization in utilizing these facilities.

Experience in the operation of nuclear electric plants throughout the world shows that while we are developing and constantly improving hardware for preventing and localizing large accidents (up to and including instantaneous transverse rupture of maximum-diameter pipelines), we need to be just as serious in working out and perfecting methods and means of preventing and clearing up so-called "minor accidents." In large part, these methods and means are the same as those aimed at ensuring the reliability of nuclear power plants as sources of energy, since any disruptions in the operation of major equipment that are due to failures and defects lead to power limitations for purposes of preventing deviations of the parameters of the facility beyond safe limits. In other words, to ensure safety, a reduction in reliability predetermines the necessity of placing constraints on the working conditions of a facility.

Comprehensive in-depth analysis of equipment operation to find the weakest links in technological systems of nuclear electric plants and improve their reliability has been a matter of course since the startup of the first VVER power facilities. Since 1977, a unified system has been in operation in the USSR for collecting data on failures and defects of nuclear electric plant equipment. The acquisition of reliable information enables isolation of the most typical failures that lead to emergency outages, unplanned down time and reduced economic efficiency of nuclear electric plants. Timely determination of the causes of equipment failures and defects (especially for the equipment of systems having to do with the safety of a nuclear electric plant) means that effective work can be done on improving this equipment from the design stage to final operational use. For the sake of convenience of such analysis and evaluation of the influence of failures and defects on the operational reliability and safety of nuclear electric plants, equipment has been divided into groups in accordance with functional designation. The table shows the spectrum of distribution of failures of equipment by percentages as typical of power facilities with VVER-440 reactors.

In analyzing the information, consideration was taken of all kinds of failures, both complete and partial, that lead or may lead to limitations in the operation of major equipment, as well as those failures that do not affect normal operation of power facilities due to the secondary nature of equipment, or built-in redundancy. The table shows that 11.3% of the failures pertain to equipment of the primary circuit having the greatest significance from the standpoint of ensuring reliability and safety of the nuclear electric plant. Failures of reactor equipment, including the control system, amount to ~4%, failures of steam generators 3.5%, and of pipelines--less than 1%. This shows the fairly high level of reliability of the main circulation loop. The remaining 88.7% of failures and defects pertains mainly to equipment that is not specific to nuclear electric plants and is typical of conventional power facilities.

A large number of failures (~38%) pertain to monitoring and control instrumentation. However, this has almost no effect on the reliability of the power facility since it most frequently involves instruments and communication lines with adequate backup. Analysis of the statistics of equipment failures for 1977-1979 showed that

Distribution of Failures and Defects of Equipment in Nuclear Electric Plants With VVER Power Facilities According to Functional Groups and Individual Kinds of Equipment

Equipment Group	Number of Failures per Unit per Year	Percent
Primary Circuit Equipment:		
reactor equipment	5	4.3
steam generator equipment	4	3.4
main circulation pumps	2	1.7
main shutoff gates	1	0.9
pipelines	1	0.9
For the Group	13	11.3
Turbine-Unit Group:		
turbines	1	0.9
condensers	3	2.6
steam-superheater separators	3	2.6
regenerative heaters	6	5.2
For the Group	13	11.3
Pump Equipment of All Kinds	9	7.8
Fittings (Except for Main Shutoff Gates	10	8.7
Blower Equipment	7	6.1
Compressor Equipment	4	3.5
Electrical Equipment:		
turbogenerators	1	0.9
electric pump drives	3	2.6
electric drives of control assemblies	2	1.8
breakers, disconnects	9	7.8
For the Group	15	13.1
Monitoring and Control Instrumentation:		
primary instruments	9	7.8
secondary instruments	23	20.0
communication lines	12	10.4
For the Group	44	38.2
TOTAL	115	100

the most characteristic defects are welding flaws (up to 32%) and hidden flaws in materials (up to 28%). Failures and damage through fault of servicing personnel amount to less than 7%, which is evidence of a rather high skill level.

To work out requirements for equipment reliability (which are especially necessary on the stages of design and manufacture), reliability indices are calculated on the basis of statistical data on equipment failure. One such very important index for restorable items is the parameter of failure rate $\omega(t)$. Because of the comparatively small volume of the statistical sample, only point values of $\omega(t)$ have been obtained, without estimation of the confidence level. Nevertheless, these values of $\omega(t)$ establish a lower limit of reliability and can be used as primary normalized data in the design, manufacture and utilization of equipment. For example $\omega(t)$ in hr^{-1} for the reactor is $(1.6-2.1)\cdot10^{-5}$, for the steam generators --$8.2\cdot10^{-5}$, for the reactor control system--$6.2\cdot10^{-4}$, for the main circulation pump--$2.6\cdot10^{-5}$, for the turbine--$8\cdot10^{-5}$. Comparison of these data with those available for equipment of non-Soviet nuclear electric plants shows that they are completely comparable if consideration is taken of the fact that ordinarily only total failures are considered in calculations of $\omega(t)$ in non-Soviet practice.

The given information shows that failures and flaws apply mainly to subsidiary equipment, or to auxiliary systems of major equipment. Therefore these is no reduction in the reliability and safety of the nuclear electric plant as a whole. This is evidenced by the stable and high level of the coefficient of utilization of installed power of VVER-440 power facilities: in 1970 this index was 72.6%, in 1978--80.7%, in 1979--73.8%.

We point out that the optimum coefficient of utilization of installed power for power facilities with VVER-440 reactors in the USSR is 80%, which corresponds to 7000 hours of operation of the equipment at rated power per year. This is determined by established periodicity and standards of duration of repairs of major equipment (reactor equipment, turbines and so on).

Analysis of the structure of the coefficient of utilization of installed power shows that underuse of installed capacities associated with unplanned repairs and equipment defects, i. e. due to down time having a direct relation to reliability and safety of the nuclear electric plant, amounts to no more than 3.7%, whereas this index was 8% in the early years of operation of VVER-440 reactors. This is evidence of an appreciable improvement in the reliability of major equipment over the elapsed period.

Continued work in the following major areas will ensure retention of the attained reliability level and further improvement:

perfection of equipment design;

improving the quality of the equipment during manufacture and the quality of installation as a basis for operational safety and reduction of the probability of failures and damage. Programs of quality control have been developed and implemented at the manufacturing plants for major equipment. All equipment arriving at the nuclear electric plant goes through a pre-instllation entry inspection. Improvements are being made in the technology of installation and welding processes, and in methods and equipment for quality control on welding jobs;

checking the condition of equipment during utilization with application of up-to-date methods for early detection of defects;

improving and increasing the technical level of utilization;

improving the efficacy of supervision for observance of directive and normative-technical documents in the process of manufacture, installation and utilization of nuclear electric plant equipment;

improving the skill of personnel working in the nuclear electric plant, and systematic personnel safety training in accordance with specially developed comprehensive programs.

On the whole, experience in utilization of VVER-440 power facilities brings us to the conclusion that they are sufficiently highly reliable and safe.

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