APPROVED FOR RELEASE: 2007/02/08: CIA-RDP82-00850R000200070041-7

21 APRIL 1980 (FOUO 4/80) 1 OF 1

APPROVED FOR RELEASE: 2007/02/08: CIA-RDP82-00850R000200070041-7

APPROVED FOR RELEASE: 2007/02/08: CIA-RDP82-00850R000200070041-7

FOR OFFICIAL USE ONLY

JPRS L/9048

21 April 1980

USSR Report

ENERGY

(FOUO 4/80)

FBIS FOREIGN BROADCAST INFORMATION SERVICE

FOR OFFICIAL USE ONLY

APPROVED FOR RELEASE: 2007/02/08: CIA-RDP82-00850R000200070041-7

NOTE

JPRS publications contain information primarily from foreign newspapers, periodicals and books, but also from news agency transmissions and broadcasts. Materials from foreign-language sources are translated; those from English-language sources are transcribed or reprinted, with the original phrasing and other characteristics retained.

Headlines, editorial reports, and material enclosed in brackets [] are supplied by JPRS. Processing indicators such as [Text] or [Excerpt] in the first line of each item, or following the last line of a brief, indicate how the original information was processed. Where no processing indicator is given, the information was summarized or extracted.

Unfamiliar names rendered phonetically or transliterated are enclosed in parentheses. Words or names preceded by a question mark and enclosed in parentheses were not clear in the original but have been supplied as appropriate in context. Other unattributed parenthetical notes within the body of an item originate with the source. Times within items are as given by source.

The contents of this publication in no way represent the policies, views or attitudes of the U.S. Government.

For further information on report content call (703) 351-2938 (economic); 3468 (political, sociological, military); 2726 (life sciences); 2725 (physical sciences).

COPYRIGHT LAWS AND REGULATIONS GOVERNING OWNERSHIP OF MATERIALS REPRODUCED HEREIN REQUIRE THAT DISSEMINATION OF THIS PUBLICATION BE RESTRICTED FOR OFFICIAL USE ONLY.

APPROVED FOR RELEASE: 2007/02/08: CIA-RDP82-00850R000200070041-7

JPRS L/9048

21 April 1980

USSR REPORT

ENERGY

(FOUO 4/80)

CONTENTS

ELECTRIC POWER

APPROVED FOR RELEASE: 2007/02/08: CIA-RDP82-00850R000200070041-7

ELECTRIC POWER

ASPECTS OF HYDROGEN POWER, TECHNOLOGY GROWTH

Moscow TEPLOENERGETIKA in Russian No 3, Mar 80 pp 8-12

[Article by E. E. Shpil'rayn, doctor of technical sciences, S. P. Malyshenko, candidate of physical-mathematical sciences, High Temperature Institute AN USSR]

[Text] As natural liquid and gaseous fuels are becoming depleted and more expensive, their place in the balance of primary sources of energy will be taken by coal and nuclear fuel, and in the balance of raw material sources for industry -- by hydrogen and artificial liquid or gaseous hydrocarbons obtained from water and coal or natural carbonates by spending primary energy. Along with that hydrogen, and other artificial liquid and gaseous fuels obtained on its basis, will make it possible to transmit energy from nuclear sources and coal to numerous various types of users, including those who are operating on natural liquid and gaseous fuels and are not adapted to the direct use of coal and nuclear fuel. A majority of processes analyzed today and systems for obtaining artificial liquid and gaseous fuels using nuclear power and by reprocessing coal include units for obtaining hydrogen or hydrogen-containing gases in combination with a source of primary energy which determined the name of this direction in power development -- hydrogen power engineering.

Hydrogen and artificial fuels produced on its basis have many positive properties as universal power carriers in power engineering, chemistry and other areas of the national economy.

1. Water may be used as raw material for producing hydrogen, while to obtain artificial hydrocarbons coal, carbon dioxide and natural carbonates may be used, i.e., raw material reserves are practically unlimited.

2. In burning hydrogen or aritifical fuels obtained on its basis, a considerably smaller amount of harmful substances is formed and considerably smaller expenditures are required to protect the environment than when burning natural liquid and gaseous fuels, especially those containing sulfur.

APPROVED FOR RELEASE: 2007/02/08: CIA-RDP82-00850R000200070041-7

3. The obtained fuels are comparatively easy to transport, preserve and store.

4. Hydrogen and artificial fuels having it as a basis (for example, methanol) may be used in car and plane engines with comparatively small adjustments.

5. Hydrogen is used widely in modern chemistry, petrochemistry and, on a smaller scale, in metallurgy, metal processing, food and other sectors of industry and requirements for hydrogen are increasing constantly.

The problem of hydrogen power engineering proper includes the following aspects:

devlop new methods and improve existing ones for obtaining hydrogen and artificial fuels on its basis from water and mineral raw materials by electrolysis and combination cycles of decomposition of water, radiolysis, photolysis as well as methods related to coal reprocessing; in this case, arrangements using various power sources are considered;

transport, store and distribute hydrogen in the gaseous, liquid or compound states in the form of hydrides;

the use of hydrogen and artificial fuels on its basis in various areas of the national economy: chemistry, petrochemistry, power, transport, metallurgy, etc. [1-3] .

Each of these aspects includes problems of safety techniques, material technology, measuring equipment, environmental protection and many others. A great and relatively independent part of the problem are investigations and developments of new efficient intermetal compounds that absorb hydrogen reversibly and devices for their utilization in various areas of technology.

The data cited below, that characterize the state of investigations and developments of some of the above-enumerated directions and technical-economic process indicators, are based on indicators of actual installations only for processes in use today. For future methods, these evaluations are only estimates and depend greatly on the allowances made in the calculations.

At present, hydrogen is produced basically from natural gas and petroleum. In this case, the basic technological processes are catalytic steam or steam-oxygen conversion. These processes are well developed and various modifications of them are already in use. The basic indicators of these processes are indicated in the Table. In this Table, the cost of hydrogen produced is given on the basis of long-range costs of natural gas and coal in the European part of the USSR.

APPROVED FOR RELEASE: 2007/02/08: CIA-RDP82-00850R000200070041-7

Table

Technical-economic characteristics of processes for producing hydrogen in large-scale production (according to data of various authors)

Process	Efficiency, %	Characteristic temperature of process, K	Power source	Raw materials	Basic reactions or reagents	Hydrogen cost rub/ton u.t. [conventional fuel]	Literature
Steam conversion	60-75	1079-1273	Natural gas (40 rub/ton u.t.)	Natural gas (40 rub/ton u.t.)	$CH_4+H_2O \rightarrow CO+3H_2$; $CO+H_2O \rightarrow CO_2+H_2$; $CH_4+2H_2O \rightarrow CO_2+4H_2$.	60 72	
Steam-oxygen conversion at 2 to 4 MPa	67-70	1073-1173	Natural gas (40 rub/ton u.t.)	Natural gas (40 rub/ton u.t.), water, oxygen (1.7 rub/ton u.t.)	$2CH_4+O_2 \rightarrow 2CO+4H_2$; $CH_2+H_2O \rightarrow CO+3H_2$; $CO+H_2O \rightarrow CO_2+H_2$	65-70	
Target production at NPZ	60-70	1073-1000	Dry NPZ gases, natural and by-product gases, petroleum fractions	Light gasolines, dry NPZ gases, natural gas, fuel oil, petroleum, residues, oxygen steam	Steam catalytic conversion, steam-oxygen gasification, hydrocarbon dehydration	75-100 and greater	[7, 16]

Table continued

Process	Efficiency, %	Characteristic temperature of process, K	Power source	Raw materials	Basic reactions or reagents	Hydrogen cost rub/ton u.t. conventional fuel	Literature
Obtain hydrogen and hydrogen containing gases by means of coal at 0.5-10 MPa	60-80	1400-1200	Coal	Coal, steam, oxygen, etc.	Lurgi, Vinkler, Kopers, Totsek, iron-steam, etc.	90-100 and greater	[16, 7]
Electrolysis in alkali electrolyzers of unipolar and bipolar designs (of can and filter-press types)	VVER (25-25%), VTGR (25-31%)	350	Electrical power in basic mode (1 kop/kw-h), from AES (0.25 kop/kw-h), from KES (0.65 kop/kw-h)	Water	-	140-200	[4-9, 13]

Table continued

Process	Efficiency, %	Characteristic temperature of process, K	Power source	Raw materials	Basic reactions or reagents	Hydrogen cost rub/ton u.t. conventional fuel	Literature
Electrolysis in electrolyzers with solid polymer electrolyte	VVER (20-30%) VTGR (25-35%)	450	Basic Electrical power (1 kop/kw-h) from AES (0.25 kop/kw-h) from KES (0.65 kop/kw-h)	Water	-	110-150	[4, 13,] [5, 8]
High temperature electrolysis	40	1000-1300	Electric power + heat from VTGR	Water	-	90-110 at capital costs for reactor + electrolyzer 300 rub/kw (t) and 140-190 at 600 rub/kw (t)	[7, 9]

Table continued

Process	Efficiency, %	Characteristic temperature of process, K	Power source	Raw materials	Basic reactions or reagents	Hydrogen cost rub/ton u.t. conventional fuel	Literature
High temperature electrolysis	42	1000-1300	Electric power + heat from VTGR, unipolar generator	Water	-	120	[18]
Thermochemical ZnSe cycles of family LLL (Lawrence Livermore Laboratory)	40-42	1000-1200	VTGR-heat	Water	Z_nO, Se, SO_2, ZnSE, $ZnSO_4$ H_2Se, H_2SO_4, SO_3 H_2O, H_2Se, HCl, $ZnCl_2$. 5-6 and more basic reactions	260-280	[19]

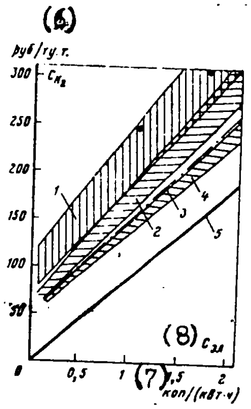
Table continued

Process	Efficiency, %	Characteristic temperature of process, K	Power source	Raw materials	Basic reactions or reagents	Hydrogen cost rub/ton u.t. conventional fuel	Literature
Thermoelectrochemical Mark-11	47	1083	VTGR-heat and electrical power	Water	SO_2 + 350K +$2H_2O \rightarrow$ H_2SO_4 + +H_2 - electrolysis 1100K $H_2SO_4 \rightarrow$ H_2O + + SO_2 + $\frac{1}{2}O_2$	165	[12]
	44	1083		"		155	[12]
	41.3	1083		"		185	[20]
	40	1083		"		210	[12]
	35-42	1100		"		230	[17]
	35-42	1100		"		155-290	[17]
Thermoelectrochemical Mark-13	37	1000	VTGR-heat and electrical power	Water	SO_2+Br_2 +350K +$2H_2O \rightarrow$ 2HBr+ + H_2SO_4 2HBr $\rightarrow$ H_2+ Br_2-electrolysis 1100K $H_2SO_4 \rightarrow H_2O$ +SO_2+$\frac{1}{2}O_2$	185-200	[12, 20]

The efficiency of these processes (ratio of the lowest combustion heat of the produced hydrogen to the power of the primary source spent on its production) is today from 60 to 75% depending upon t. purity of the hydrogen produced. In producing hydrogen from natural gas, about 40% of the initial gas is used as fuel and about 60% -- directly for producing hydrogen. The cost of the hydrogen produced in these processes is determined basically by the cost of the raw material. Methods for obtaining hydrogen from hydrocarbons at NPZ [Petroleum Refining Plant] are close to the basic reactions and methods for obtaining hydrogen from natural gas, but hydrogen produced at the NPZ is more expensive. As one of the first stages of using high temperature nuclear reactors (VTYaR) in chemistry, a possibility is considered of utilizing the high temperature heat of these reactors to compensate for the endothermic effect of the conversion reaction which will lead to a saving of 40% in the natural gas used for producing hydrogen [2] . Similar developments are being carried out in the FRG [Federal Republic of Germany] for coal gasification. The processes for producing hydrogen when reprocessing coal were developed in the first half of the Twentieth century. Later, the development of this work practically stopped because natural gas and petroleum were cheap and only recently has this work begun to develop intensively again in various countries of the world. At present, tens of various processes and arrangements are being developed in the world to reprocess coal to produce hydrogen and hydrogen-containing gases, including the use of high temperature gas reactors (VTGR). The technical-economic investigations of many authors indicate that the cost of hydrogen obtained in reprocessing coal for various processes, at present business conditions, exceeds the cost of hydrogen obtained from natural gas and is close to the cost of hydrogen produced at the NPZ (see Table). According to some forecasts, petroleum and gas prices in the world market will grow more rapidly than the price of coal and, therefore, it should be expected that in the future, the cost of hydrogen production in reprocessing coal will be found to be less than when it is produced from petroleum and natural gas. At present, in the USSR and abroad, new methods are being developed for producing hydrogen when reprocessing coal that will cost 75 to 90 rubles/ton of conventional fuel.

Electrolysis is the most assimilated method for producing hydrogen from water. At present, this method is used to obtain a relatively small amount of hydrogen (about 1.5 x $10^9 m^3$/year or 5.4 x 10^5 tons of conventional fuel/year in the entire world), at places with cheap electric power. Electrolysis hydrogen is used primarily when very pure hydrogen is required and where, for a small volume of consumption, a system for purifying conversion hydrogen becomes unprofitable. At present, many laboratories and firms in the world are carrying out investigations and developments to improve electrolyzers and making them less expensive for utilizing electrolysis in large-scale production of hydrogen using power from an AES. Bipolar and unipolar alkaline electrolyzers are being developed, as well as electrolyzers with solid polymer electolytes.

The costs of producing electrolytic hydrogen in modern electrlyzers* is 140 to 180 rubles/ton of conventional fuel and more depending on the type of the electrolyzer and the mode of its operation. For future electrolyzers (including high temperature ones) these costs will be reduced to about 110-150 rubles/ton u.t. [Conventional fuel] [4-8] (see Fig.).



Estimated costs for the production of electrolytic hydrogen (data of various authors).

1. bipolar design of electrolyzer
2. unipolar design of electrolyzer
3. unipolar design -- 1990 technology
4. electrolyzers with solid polymer electrolysis
5. theoretical limit at capital costs equal zero
6. rubles/ton u.t.
7. kopecks/(kw-hour)
8. C_{el}

Since the conversion of the energy of the primary power resources to the energy of hydrogen includes, in this case, an intermediate stage of electric power production, the full efficiency, i.e., the thermodynamic efficiency of the process is about 20% for modern AES and electrolyzers, while for high temperature gas reactors and future electrolyzers, it will not exceed 42 to 45%.

---

* Here and below the relationship of one dollar (1975) = 0.75 rubles is used when citing foreign data on capital and production costs and other economic indicators.

Numerous technical-economic investigations of producing hydrogen from water by electrolysis using electric power from various sources (AES, GES, TYaES, etc.) and using future and modern electrolyzers, operating in various modes, indicate that in the future, the estimated costs of producing hydrogen from water by electrolysis will, apparently, not become lower than 100 rubles/ton u.t. [4-9] .

Additional reserves, for reducing the cost of hydrogen may be byproducts of its production: oxygen and heavy water. In decomposing water per ton of u.t. of H_2, using any method of hydrogen production, a ton of O_2 is obtained from the water. In the case where the oxygen may be sold where the hydrogen is produced, a reduction of five to ten rubles/ ton of u.t. may be expected; however, long distance transportation of oxygen is, apparently, not profitable. In 1977, the cost of heavy water in the United States was about 100 rubles/kg. In the combination electrolytic-catalytic process, it is possible to obtain hydrogen and heavy water simultaneously, which reduces the cost of electrolytic hydrogen by 35 to 40 rubles/ton u.t. when the heavy water can be sold for 100 rubles/kg [10] . Other arrangements for obtaining D_2 as a byproduct are possible that also permit a combination with other methods for obtaining hydrogen from water, for example, low temperature rectification of the obtained hydrogen with the consequent production of D_2O.

Water may be decomposed by bypassing the electric power production stage thermochemically using the heat of the primary power source. From the thermodynamic standpoint, this method does not differ in principle from electrolysis and if all processes of converting heat into electric power, electrolysis and thermochemical decomposition were fully reversible, both processes would be fully equivalent. Hopes for obtaining higher efficiency of thermochemical decomposition of water compared to electrolysis are based on two proposals: an efficient higher upper temperature of the thermochemical cycle may be used than in modern electric power plant cycles; the degree of non-reversibility of actual processes in thermochemical cycles may be found to be lower than in the sequence of processes of obtaining electrical power and electrolysis. Thermodynamic investigations indicate that [11] in principle, it is possible, in four-five reactions, to provide acceptable outputs from a water decomposition reaction at an upper temperature of the cycle of 1000 to 1200K, that is, possible for installations with higher temperature nuclear reactors. In combination processes that also use, along with thermochemical electrochemical reactions, it is possible to reduce the number of necessary reactions in a cycle to two-three. It is also possible to implement the water decomposition process in combination cycles using photochemical, thermochemical, radiochemical, plasmochemical and other types of reactions.

In recent years, numerous thermochemical and combination cycles were proposed for implementing water decomposition reactions at temperatures possible for high temperature gas reactors. In most cases, intermediate reagents in these cycles are substances that have a great affinity to hydrogen or oxygen: haloids (for example, chlorine, bromine, iodine), elements of group VI (primarily sulfur) and metals of group II (magnesium, calcium, barium). Sometimes transitional elements are used that have a variable valency and can form various oxides (for example, iron). The theoretical thermodynamic efficiency of these cycles (ratio of the lowest combustion heat of the obtained hydrogen to the primary energy spent for its production) which, according to various authors, may reach 45 to 55%, i.e., exceeds that for the electrolysis process. However, in implementing these processes, it is necessary to solve complex problems related to providing acceptable kinetics of the reactions, separating the reaction products, heat and mass exchange at various process stages, purifying the products, material stability, etc. Experimental investigations made so far indicate that the practical implementation of these cycles is a very difficult problem and their efficiency, apparently, will be about 40% at best [12]. In this case, the total weight of the reagents participating in the thermochemical cycle in the gaseous, liquid and solid states and in the form of solutions is very great -- according to data [13], it averages about 800 tons per ton of H_2 and is not less than 300 tons per ton of H_2. For example, for an installation with a productivity of 270,000 tons of H_2 per year for $\eta = 40\%$, a minimum of 85 million tons of reagents per year participate in the chemical reactions of the cycle and minimal capital investments in the installation without taking into account the cost of the power source are about 1.25 billion rubles, which is more than double the capital investments in electrolyzers of the same productivity. For combination thermo-electrochemical cycles, the unit weight of the reagents is reduced with the increase in the share of electric power in the power balance of the cycle. For example, if 50% of the energy is spent in the form of electrical energy for electrolysis, then the minimal unit weight of the reagents is about 80 tons per ton of H_2 and the general level of capital investments is lowered, getting closer to capital investments in electrolysis production of the same productivity.

The Table shows the most authentic technical-economic characteristics of hydrogen production methods according to data of various authors. For long-range hydrogen production methods, these estimates are of a preliminary nature because they were obtained on the basis of laboratory investigations of the process and preliminary estimates of capital investments in high temperature nuclear reactors and the installations themselves are based on existing practices in power engineering and chemistry.

Technical-economic investigations of various thermochemical and hybrid water decomposition cycles indicate that thermochemical and thermo-electrochemical hybrid processes using electrolysis can hardly become more economical than electrolysis, especially of the high temperature cycle with a solid oxide electrolyte. At the same time, hybrid cycles, using along with thermochemical more intensive than electrolysis, for example, plasmochemical [14], apparently, implemented with lower capital investments and may be found to be competitive with electrolysis. At present, however, there are no reliable technical-economic estimates of the characteristics of these cycles because the work on these cycles is only beginning to develop and it will be necessary to solve complex scientific-technical problems in their practical implementation. It should be expected that at the first stages of the development of hydrogen power engineering, the most efficient methods of large-scale production of commercial hydrogen will be electrolysis and the use of coal. In this case, the costs of gaseous hydrogen produced, according to optimistic estimates, will be, apparently, not lower than 100 rubles/ton u.t. The production of liquid hydrogen involves additional power expenditures for liquefaction and orthoparaconversion of hydrogen and additional capital investments in a liquefaction plant. The theoretical expenditures of electric power for liquefaction are 10.67 Mjoules/kg H_2; with the present state of the art, however, they amount to about 45 to 50 Mjoules/kg H_2 for a large-scale liquefying plant. Estimated costs for liquefying hydrogen for a plant with a productivity of 1000 tons u.t./day of liquid H_2 are 90 to 110 rubles/ton u.t. without taking into account the costs of storage and servicing; with an increase in the productivity of the liquefying plant, the liquefication cost will decrease logarithmically. Thus, according to optimistic estimates, the cost of liquid hydrogen produced from water will be not less than 200 rubles/ton u.t. at the plant tap for a medium productivity plant.

Processes of storing, transporting and distributing gaseous hydrogen are very similar to those for natural gas. It is most economical to store large quantities of hydrogen in underground storage facilities: worked-out petroleum and gas fields, water-filled porous structures, salt-dome and other natural and artificial caverns. Experience is available on such storage of large amounts of natural gas and hydrogen under pressures of up to 10 MPa. Hydrogen storage under such conditions per ton u.t. is two to four times more expensive than for natural gas [15]. Experimental investigations have shown the technical feasibility of using existing systems of the main transport and distribution of natural gas with some modernization for transporting and distributing hydrogen. If this modernization is not done, the system will transmit 10 to 15% less energy in hydrogen than in natural gas. The cost of transporting and distributing hydrogen over pipelines under pressure of 7 MPa is 1.5 to 2 times higher than of natural gas.

In optimizing the systems for the transport and distribution of hydrogen, the diameter of the pipe must be 15 to 20% greater than for natural gas. To transport liquid hydrogen, as well as other liquid fuel, large distances (up to 1000-1500km) it is most feasible to use water transport (in tankers) and RR transport (in tanks), while for distances less than 100 to 150km -- by motor vehicles. Losses of hydrogen in the best available facilities, as a rule, do not exceed 0.5% per day and the transportation costs do not increase the cost of liquid hydrogen significantly. For example, the costs of transporting liquid hydrogen a distance of 500km, taking into account losses, are 8.8, 17.6 and 35.2 rubles/ton u.t. for river, RR and motor vehicle transport respectively [15, 7]. Long distance pipeline transport of liquid hydrogen is uneconomical due to the high cost of heat insulation of the pipeline that exceeds 100 rubles/m for vacuum-shield insulation. Storing large quantities of liquid hydrogen in cryogenic tanks with losses less than 0.3% per day is technically feasible at present. Very promising is the use of hydrides of intermetallic compound of the $LaNi_5$ and FeTi types for storing relatively small amounts of hydrogen. Such storage systems for transport installations are being intensively developed at present in the USSR and abroad and the first prototypes were created for motor vehicle transport. The cost of alloys for storing hydrogen is now 3.5 to 10 rubles/kg for lots of 500kg. Under normal conditions, such alloys absorb up to 2-3% of hydrogen by weight. Recently, alloys that absorb up 6-7% H_2 were obtained.

At present, about 160 million tons u.t. of hydrogen per year are produced and used in the world. Its basic users are petroleum refining plants and chemical industry enterprises for producing ammonia and methanol. They use about 95% of the total hydrogen produced. The remaining hydrogen is used by the metallurgical, processing, food, pharmaceutical and other industries. By 1990, it is forecast that the production and use of hydrogen in the world will increase to 200 million tons u.t. and even greater with insignificant changes in the structure of consumption. A comparison is frequently made in literature of various methods for producing hydrogen and an analysis of its long-range use in various areas of the national economy, on the basis of estimated costs for producing hydrogen by this or another method. This approach has sense only if this commercial, or "free" hydrogen goes directly to the market and to the user, when the use technology does not depend on the method for producing hydrogen. At present, and long-range, up to the year 2000, this is not the case because the transition by basic users of hydrogen from natural fuels to "commercial" hydrogen is related to the change in the technology of production of the final product and these changes depend on what kind of hydrogen ("thermochemical", "coal", "electrolytic and others) they use, on the possibility of also using, besides the hydrogen, the heat and electrical power, produced by the nuclear power plant, the

APPROVED FOR RELEASE: 2007/02/08: CIA-RDP82-00850R000200070041-7

possibility of using byproducts, etc. Therefore, it is more correct to make a technical-economic comparison of various methods of hydrogen production according to the change in the estimated costs of the final product (ammonia, methanol, etc.) by replacing in the production cycle natural gaseous and liquid fuels by nuclear heat or coal and hydrogen, and not according to the estimated costs of hydrogen. A similar situation exists also when using hydrogen as fuel in transport where the comparison must be made in accordance with the cost of the transportation and not the cost of the fuel, as well as in power engineering and other industrial sectors.

Moreover, because of the limited inexpensive natural power-resources and the necessity of their efficient utilization in the national economy, a comprehensive technical-economic optimization of power resource consumption by various sectors of industry is most efficient including the power sector, in analyzing the feasibility of changing them over to nuclear power and coal as power sources, and using hydrogen as a power carrier and as raw material. Such technical-economic investigations made at the High Temperatures Institute indicate that even at today's prices for natural gas and peak electric power, it may be found more expedient to create power-technological complexes for the production of ammonia and electric power, including peak, on the basis of modern AES with electrolytic production of hydrogen for full replacement of natural gas. Separate preliminary estimates made previously for the production of ammonia indicated that electrolytic hydrogen, produced at the AES, can be used expediently for the production of ammonia for partial replacement of natural gas at natural gas costs of about 68 rubles/ton u.t., i.e., in the fairly distant future. A more comprehensive analysis changes this conclusion essentially. Apparently, the most efficient method for introducing hydrogen power in the national economy is the creation of large interindustrial petroleum refining and metallurgical complexes based on nuclear power, and coal using hydrogen to store energy, as an energy carrier and as raw material. The optimal structure of these production facilities and their combination with the power source, and between themselves, must be established as a result of a comprehensive system analysis for individual regions.

Investigations made abroad and in the USSR indicate that hydrogen may be used expediently to transmit heat and power over long distances. Main-line long distance pipeline transport of hydrogen and the conversion of its combustion heat into electric power at the receiving end of the main-line with an efficiency coefficient of 40% is a third of the cost of transporting electric power over AC VL [Overhead line]. The advantages of hydrogen transport are preserved, although to a lesser degree, compared to DC VL. At present, processes of long distance transport of heat from high temperature nuclear reactors are being developed for home heating and technological purposes based on the endothermic reaction of converting methane and the exothermic

APPROVED FOR RELEASE: 2007/02/08: CIA-RDP82-00850R000200070041-7

process of reverse methane production. In this case, heat transport can be implemented as a heat transport process, as well as a simultaneous pipeline transport of artificial methane to the user. Technical-economic evaluations indicate that transporting heat over long distances has advantages over transporting hot water.

Hydrogen can be used in transport as basic fuel and as an additive to liquid hydrocarbons fuels to reduce the toxicity of the exhausts.

Hydrogen may be used in aviation in liquid form as fuel for supersonic and hypersonic planes. Investigations done in the United States and the Soviet Union indicate that at the cost of liquid hydrogen aboard a plane of about 300 rubles/ton u.t., direct costs for operating a supersonic plane on hydrogen fuel are close to those for a plane operating on kerosene at a cost of kerosene for the plane of about 200 rubles/ton u.t. for a flight distance of over 4000 to 5000km. Thus, the use of liquid hydrogen as fuel for long distance supersonic aviation may be found to be expected not too far in the future. A changeover to hydrogen fuel in aviation, however, involves large capital investments. For example, costs to reequip a large airport for hydrogen fuel are, according to Lockheed, about one billion dollars.

Investigations and developments in the use of hydrogen in motor vehicle transport, done in the USSR and abroad, indicate the expediency of using hydrogen as an additive to regular fuels for city motor vehicle transport even at present business conditions. When five percent hydrogen is added to the usual fuels, it is possible to reduce exhaust toxicity considerably and improve the efficiency of engine operation. By using hydride systems to store hydrogen aboard a motor vehicle in various laboratories in the world, the first prototypes of such motor vehicles were created.

At present in the USSR, FRG, United States, Japan, France, Italy and other countries, wide programs of investigations and developments are being adopted in the area of hydrogen power engineering. A broad and multifaceted development of hydrogen power engineering and technology is not expected before the first quarter of the Twenty-First Century. However, the increasing costs of liquid and gaseous fuel and the increase in the demand for hydrogen by its traditional users, especially in the NPZ, enterprises for producing ammonia and methanol and in metallurgy, may make it profitable to develop large-scale production of hydrogen and before the end of the century gradually replace natural liquid and gaseous fuels produced in the processes of petroleum refining, the synthesis of methanol and ammonia, and metallurgical production using nuclear heat and coal.

The natural power source-technological unit system for producing the energy carrier (hydrogen) may make it possible in the last quarter of the 20th Century, to solve problems related to the creation of large autonomous power-technological complexes that do not use hydrocarbon fuel, to produce power and chemical synthesis products. Already, in this sense, at the present time, the problem must be solved of creating a power technology that uses nuclear power and coal as basic power resources, while hydrogen and artificial fuels made on its basis will be used as power carriers and raw materials. Along with this, the development of large power systems based on nuclear power and coal as power sources and including numerous users of various kinds, leads to the necessity of utilizing, in the very near future, artificial fuel based on hydrogen, and hydrogen as a power carrier and for storing power, which will make it possible to design a more flexible system more adapted to the users and one that does not depend on the type of power sources.

BIBLIOGRAPHY

1. Legasov, V. A. "Universal Possibilities of Hydrogen." KOMMUNIST, 1976, No 1, pp 72-73.

2. Dollezhal', N. A.; Zaichko, N. D.; Yemel'yanov, I.Ya.; et al. "Comprehensive Utilization of Nuclear Reactor Power for Heavy Tonnage Production in the Nitrogen Industry." In book: "Voprosy atomnoy nauki i tekhniki. Atomno-vodorodnaya energetika" (Problems of Atomic Science and Technology. Atomic-Hydrogen Power Engineering), 1977, No 2 (3), pp 5-14.

3. Legasov, V. A.; Ponomarev-Stepnoy, N. N.; et al. "Long-Range Prospects of Utilizing VTGR and Basic Problems of Introducing VTGR in Technological Processes and Electric Power Engineering. In book: "Voprosy atomnoy nauki i tekhniki. Atomno-vodorodnaya energetika" (Problems of Atomic Science and Technology. Atomic-Hydrogen Power Engineering), 1978, No 1 (4) pp 3-18.

4. Shpil'rayn, E. E.; Sarumov, Yu. A.; Popel', O.S.; Zhukova, I.A. In book: "Voprosy atomnoy nauki i tekhniki. Atomno-vodorodnaya energetika" (Problems of Atomic Science and Technology. Atomic-Hydrogen Power Engineering), 1979, No 1 (5), pp 11-21.

5. Le Roy, R. L.; Stuart, A. K. Unipolar Water Electrolyzers a competitive technology. Hydr. Energy System. Ed. N. Veziroglu, W. Seifritz, Vol. 1, pp 359-376. Pergamon Press, 1978.

6. Menth, A.; Stueki, S. Present State and Outlook of the electrolytic H_2 Production Route. Hydrogen Energy System. Ed. N. Veziroglu, W. Seifrtiz. Vol. 1, pp 55-60. Pergamon Press, 1978.

7. Biederman, N.; Darrow, K.; Konopka, A. Utilization of hydrogen Rep. EPRI, RP320-1, Aug. 1975.

8. Nuttal, L. J.; Russel, J. H. Solid Polymer Electrolyte water Electrolysis Development Status. Energy System. Ed. N. Veziroglu, W. Seifritz, Vol. 1, pp 391-402. Pergamon Press, 1978.

9. Doenitz, W.; Schmidberger, R.; Steinheil, E.; Streicher, R. Hydrogen production by high temperature electolysis of water vapour. Energy System Ed. N. Veziroglu, W. Seifritz. Vol. 1, pp 403-422. Pergamon Press, 1978.

10. Hammerli, M. Heavy water as a valuable byproduct of electrolytic hydrogen. Hydr. Energy System. Ed. N. Veziroglu, W. Seifritz. Vol. 1, pp 423-450. Pergamon Press, 1978.

11. Shpil'rayn E. E. "Thermodynamic Bases of Thermochemical Decomposition of Water." IVTAN preprint No 2 -- 007, 1977.

12. Cox. K. Thermochemical production of hydrogen from water, a critical review. LASL. 1978. USA/USSR Workshop on Alternative Uses of Fusion Energy. High Temperature institute. Moswoc, No 20-24, 1978.

13. Deneure, F.; Roncato, J. P. Thermochemical or hybrid Cycles of Hydrogen Energy System. Ed. N. Verizoglu, W. Seifritz. Vol. 4, pp 2179-2204. Pergamon Press, 1978.

14. Legasov, V. A.; Rusanov, V. D. Fridman, A. A. "Nonequilibrium Plasmochemical Processes in Heterogeneous Systems." Plasma Chemistry. No 5, pp 116-147. Moscow, Atomizdat, 1978.

15. Breelle, Y.; Gelin, P.; Meyer, C.; Petit, G. Int. Journ. Hydrogen Energy, 1979, vol. 4, pp 297-308.

16. Hadden, L. D. The Economics of Producing Hydrogen from small air blown Coal Gasifier. Hydrogen Energy System. Ed. N. Veziraglu, W. Seifritz, Vol. 2, pp 983-1006.

17. Tai, A. S.; Kraskovskiy, R. A. Centralized Energy Balance, Economic considerations for thermochemical Hydrogen production from Fusion Reactor Blankets. LASL. Paper presented at the

USE/USSR Workshop on Alternative Applications of Fusion Energy. Moscow, Nov 20-24, 1978.

18. Escher, W. J. D.; Donakovskiy, T. D.; Veziroglu Ed. N. Conference Proceedings of the 1st World Hydrogen Conference Miami Beach, March 1-3, 1976, Vol. 1, pp 2A-1.

19. Krikorian. O. H. The ZnSe Thermochemical Cycle for Hydrogen Production: chemical and process design studies. Hydrogen Energy System. Ed. N. Veziroglu, W. Weifritz. Vol. 2, pp 791-808. Pergamon Press, 1978.

20. Broggi, A.; Joels, R.; Mertel, G., Morbello, M. A method for the techno-economic evaluation of the chemical process -- improvements to the "Optimo" code. Energy System. Ed. N. Veziroglu, W. Seifritz, Vol. 4, pp 2205-2230. Pergamon Press, 1978.

COPYRIGHT: Izdatel'stvo "Energiya," "Teploenergetika", 1980.

2291
CSO: 1822

ELECTRIC POWER

SOLAR POWER STATIONS CONTEMPLATED

Moscow TEPLOENERGETIKA in Russian No 3, Mar 80 pp 5-8

[Article by F. V. Sapozhnikov, Deputy Minister of the USSR Ministry of Power and Electrification, Yu. N. Malevskiy, V. K. Gusev, Minenergo [Ministry of Power and Electrification],ENIN [Power Institute imeni G. M. Krzhizhanevskiy] , TEP [Teploelektroproyekt"]]

[Text] In recent years, work on utilizing solar power in the USSR and other countries has developed noticeably basically for supplying hot water,heating and air conditioning buildings, drying various materials and agricultural products, demineralizing water, etc.

The creation of solar electric power plants (SES), operating on the basis of machine thermodynamic cycles and capable of producing electric and thermal energy occupies a special place.

The attention and interest in developing SES in the USSR are due to the possibility of replacing some amount of fossil fuel used in traditional methods to produce power and reduce the contamination level of the environment due to the absence of chemical exhausts.

Some attention is also being devoted to this problem in the USSR in the work program on utilizing solar power. Starting in 1978, certain scientific, planning and design organizations of the USSR Minenergo (ENIN, TEP, SKB [Special design bureau] , VTI [All-Union Heat Engineering Institute imeni F. E. Dzerzhinskiy], PKB [Planning design bureau] for mechanizing power construction, PKB "Energostal'-konstruktsiya", etc.) began working to create the first experimental SES in the USSR to determine the long-range prospects of using plants of this type in southern regions of the country.

The idea of creating SES of an industrial type was proposed for the first time by Soviet engineer N. V. Linitskiy over 30 years ago. He then proposed an arrangement of a solar power plant, which is now called a solar power plant arrangement with a central receiver or tower arrangement (Fig. 1).

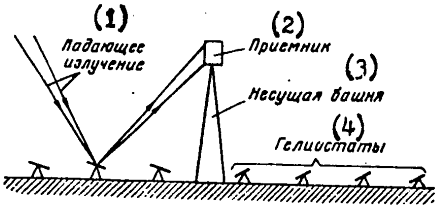


Fig. 1. Schematic diagram of a solar plant of the tower type.

1. Incident radiation
2. Receiver
3. Tower
4. Heliostats

In this system, the steam generator (solar radiation receiver) is located on a tall tower, surrounded by a field of mirror reflectors (heliostats), by means of which solar radiation is focused on the heat receiving surface of this receiver. After that, the heat energy is transformed into electrical power in accordance with the usual steam-power industrial parameter cycle. At the end of the fifties, on the basis of this concept, the ENIN developed a technical proposal for a 2.5 Mw (electric) SES which later became widely known due to publications in the scientific-engineering journals of several countries.

In the middle of seventies, the problem of utilizing renewable energy sources in industrial electric power production in the USSR began to be considered on the level of concrete evaluations.

These evaluations were made in the direction of studying the technical-economic indicators of solar electric power plants operating either independently or within power systems, as well as along the line of scientific, design and planning developments of a small capacity prototype.

The USSR has regions where the intensity of solar radiation is fairly high and stable. In the Central Asian republics, Kazakhstan, Crimea, Caucasus and Zabaykal, the sun shines 2000 to 3000 hours per year.

Taking into account the natural and economic conditions of the southern USSR, it is sound practice to consider first the importance of solar power from the standpoint of improving the power supply to numerous scattered comparatively small agricultural users of power.

As shown by an analysis made by the Sel'energoproyekt, the power required by such users is from 1.5 to 5Mw. A great number of such users are, for example, in Kazakhstan in regions south of the 50° of the northern latitude. These regions (their area is over half the area of the republic) are characterized by the fact that it is precisely here where machine irrigation is concentrated and almost all arid and semiarid pastures for sheep-raising are located that irrigation is required; here are located numerous large salt lakes and considerable reserves of underground highly mineralized waters.

In such zones, solar installations operating with flat collectors, autonomous small capacity SES may find application for comprehensive electrical and heat supply, including that for obtaining commercial steam, heating, hot water, drying, refrigerating, feeding electric pumps for irrigation systems and demineralizing water.

SES are characterized by ununiform production of heat and electric power which, to a certain extent, can be equalized by a system of a limited energy capacity storage. For this reason, the use of SES is preferable in regions where users may permit some interruption in power supply or it is possible to store the energy produced by the SES in the form, for example, of ice or elevated or demineralized water. In all other cases, either a standby power installation can be used or local 35 to 110kv electric network may be employed which, according to the Sel'energoproyekt data, have a transit capacity in the majority of zones where solar energy can be utilized.

Technical-economic calculations, made by taking into account long-range increases in fuel costs, indicate that in several regions of Southern Kazakhstan and Turkmenia, reduced costs with electric power supplied by the SES, including that operating jointly with local electric networks, may be comparable or even lower than the reduced costs for the version of power supply from sources operating on solid or liquid fuel brought in from a distance.

Autonomous condensation type SES, operating outside the system, most favorable in the load mode, are pumping stations for irrigating oases. Such pumping stations operate from April to September 12 to 13 hours during daylight, while in April-May, the electric power need changes to 30-60% of the maximum, in June-July -- 100%, decreases gradually to 60% in August-September and then to 30%. Thus, the daily schedule of pumping station operation during the year coincides with the schedule of reception of solar radiation. This fact, as well as that the use of such SES does not require standby power sources reflect positively on the technical-economic characteristics of the SES. Data analysis on the long-range development of machine irrigation in Kazakhstan indicated that there are large irrigation areas and more are planned (basically oases) located considerable distances from power system centers that, in each case, require over 1000kw of electric power for transporting water. Capital investments for competitive SES of such a capacity must be within 750 to 500 rubles/kw with the power system centers being within 300 to 50km away and fuel costs not greater than 30 rubles/ton of conventional fuel.

The trend in changing the annual schedules of the operations of the power association in some southern regions of the country attest to the fact that in the future (10 to 20 years), the annual maximum power loads will occur in the summer (i.e., in the period of maximum reception of solar radiation) due to the increasing share of power consumption for seasonal agricultural work, air conditioning and machine irrigations. This fact expands the prospects of utilizing SES in the indicated regions.

In accordance with the program for further study of the possibilities of creating, operating and utilizing SES as a power source in the country, it is planned before 1985 to build in the Crimea and to make tests of the first USSR experimental 3 to 5Mw SES, which will include all basic subsystems of a solar electric power plant with industrial parameters. Table 1 shows the basic characteristics of the plan for such an SES made by the Teploelektroproyekt on the basis of the scientific development of the Power Institute imeni G. M. Krzhizhanovskiy.

Table 1

Basic characteristics of an experimental solar electric power plant of the tower type (estimates)

Characteristic	Value
Electric power, Mw	3-5
Heat power, Mw	
maximum	21
average annual	18.5
Number of operating hours annually	2000
Annual electric power output, million kw-hours	up to 9
Heliostat field	Ring
Diameter, m:	
outer	470
inner	140
Total area of mirror surface, 1000m^2	40
Number of heliostats	1600
Size of heliostat	5 x 5
Height of tower, m	70

Table 1 contd.

Characteristic	Value
Density of radiation flux on the surface of the steam generator (7 x 7), kw/m^2:	
22 June, 12 hours:	
average	135
maximal	225
22 December, 12 hours:	
average	90
maximal	190
Steam parameters ahead of turbine:	
pressure, MPa	3
temperature, °C	232

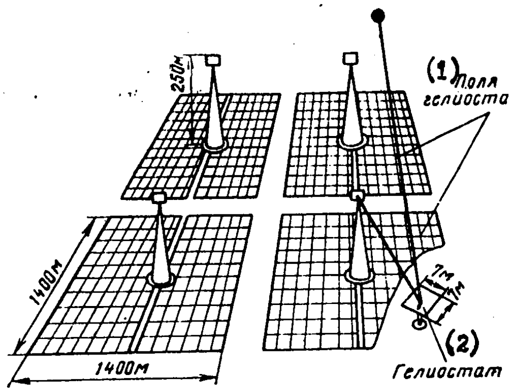


Fig. 2. Grouping of a large 300 Mw solar electric power plant arrangement consisting of four modules (75Mw each).

1. Heliostat field
2. Heliostat

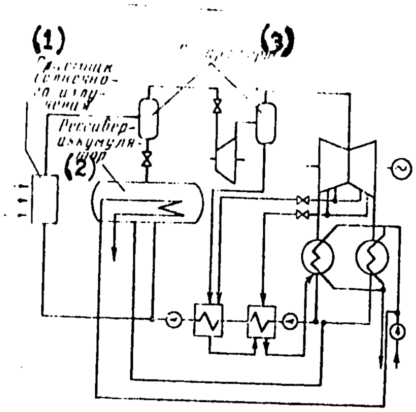


Fig. 3. Thermal arrangement of experimental SES-5 with receiver-accumulator

1. Solar radiation receiver	3. Separators
2. Receiver-accumulator	

Fig. 3. shows one possible thermal arrangement of an SES using a receiver-accumulator whose basic features are as follows:

the thermal arrangement is made on the basis of a cycle with saturated steam with the turbine operating in the condensation mode;

the solar steam generator is of the drum type with natural circulation;

a type P-6-35/5 5Mw turbine is used;

to keep the turbine hot during short interruptions in solar radiation (one to two hours) a receiver-accumulator is used in the system, filled with water at saturation temperature a reserve of which is created by a part of the steam specially condensed for this purpose, produced by the steam generator, after it becomes operative at the nominal mode. During interruptions of solar radiation and, therefore, a stoppage in the production of steam in the boiler, the thermal arrangement is kept hot due to ventilation by saturated steam evaporated from the stored saturated water.

The use of saturated steam as an operating medium, especially, at SES with the combined production of heat and electric power has certain advantages. The reduction of electrical efficiency is made up by the increase in the reliablity of the steam generator, that has to operate with the intermittent arrival of solar radiation, by a simpler arrangement of the automatic control of the SES and the accumulator and, therefore, by lower capital expenditures for this part.

The experimental SES-5 will have the possibility of testing several thermal arrangements, including one- and two-loop with a heat accumulator that makes it possible to equalize and shift the output of heat and electrical power during the day.

In the first loop of the SES, it is beneficial to use as a heat carrier a liquid with a high boiling point or a liquid metal heat carrier with high specific heat. This makes it possible to create an inexpensive heat accumulator of large energy capacity in which the pressure will not exceed 0.8 to 1 MPa. However, in the first SES, it is expedient to use water at moderate pressures of 2.5 to 4.5 MPa as a working medium that permits using as an accumulator equipment available in the power, chemical and gas industries.

Under Crimean conditions, the number of operating hours of the experimental SES per year will be about 2000. In this case, the change in the daily hours of plant operation during the year will vary from 12 (in the summer) to five (in the winter) from the moment the sun's altitude is 15° above the horizon (Fig. 4) in a solar radiation flux density range of 0.65 to 0.87 kw/m^2.

In implementing in practice the full technological arrangement for transforming solar energy into heat and electrical power, the planned power level of three to five Mw for the experimental plant is sufficient for experimental debugging of the principle of operation, the ASU [Automatic control system] , the design of the basic subsystems, their interaction and identification of special features of the operation of such electric power plants, including larger ones also.

The scientific, planning and design organizations of the Minenergo also evaluated the projected design and technical-economic characteristics of large industrial SES on an example of a 200 to 300 Mw solar electric power plant, operating within a power system.

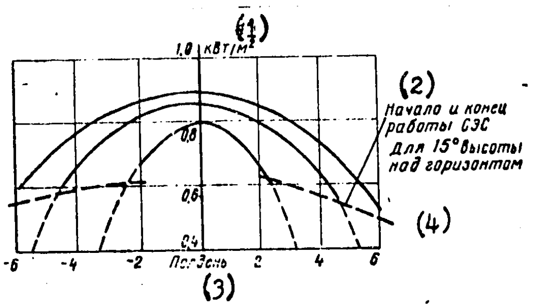


Fig. 4. Continuity of SES operation during a bright day and the change in solar radiation intensity (kw/m^2) in Crimea (45° northern latitude) for days in the summer (June), winter (December) solstice and equinox (September).

1. kw/m^2
2. Start and end of SES operation
3. Noon
4. For a 15° altitude above the horizon

The operation of a SES within a power system under USSR conditions is of independent interest. The presence of a branched power system network in the country makes it possible to utilize in various ways large solar electric power plants of various types in various climatic and economic zones, including SES operating in the mode of feeding electric power into the network during the day, and plants that have a storage system and that participate in the power balance of the power system independently, as well as in combination with thermal or hydraulic plants (hybrid version).

By a corresponding increase in the heat capacity of the storage facility, it may be possible to achieve a basic mode of SES operation which not only replaces a certain amount of fuel burned in the system by solar energy, but also corresponding fuel of a basic thermal electric power plant as a whole.

In one possible version, the SES-300 may consist of four modules each of which (with a power of up to 75Mw) represents an electric power plant operating on the "steam generator-turbine" thermodynamic principle, that has a separate heliostat field with an area of up to 2km^2 and a central tower 250m high (Fig. 3). Each SES-300 module contains about 12,000 heliostats with a mirror surface of 7 x 7m and a saturated steam pressure ahead of the turbine of 6MPa.

Table 2

Expected power characteristics of the SES-300 in southern regions

Indicator	Crimea Lower Volga	Uzbekistan Tadzhikistan Turkmenia	Kirgizia Transbaykal	Dagestan
Annual output of electric power, Mkw-hour	355-445	560-715	430-575	450-600
Hours operation per year	2000	2700	2150	2270
Saving of fossil fuel per year (1000 tons of conventional fuel)	Up to 150	Up to 245	Up to 195	Up to 200

Table 2 shows expected annual electrical power outputs of an SES-300 in southern regions of the country, the number of hours of plant operation per year and possible fuel saving. Below is given an estimate of unit costs of SES operating on a free schedule in which they can compete with traditional power plants at an average unit cost of the latter of 200 rubles/kw.

The most favorable SES cost indicators may be expected for Crimea and the Lower Volga region. This is because in the forecast 20-year period, the rated fuel costs for the indicated regions may increase almost to 50 rubles/ton of conventional fuel, while for Kazakhstan and Transbaykal lower fuel costs are expected (24 and 10 rubles/ton of conventional fuel respectively), which is characteristic for the eastern regions of the country that have rich fuel resources.

Calculations made by taking into account the possible reduction in the cost of the SES in the future with increasing fuel costs, indicate that for condensation SES operating on a free schedule without participating in the power system balance, the maximum competitive capability with thermal condensation plants is a cost per installed 1kw for the considered regions of from 270 rubles (Transbaykal) to 550 rubles (Crimea). For example, for conditions of the Lower Volga region, 300Mw condensation SES may be more economically profitable in the case where its unit cost does not exceed 530 rubles/kw.

APPROVED FOR RELEASE: 2007/02/08: CIA-RDP82-00850R000200070041-7

According to plan estimates, the unit cost of installed 1kw of large SES may vary, depending upon the region, within 750 to 900 rubles for an electric power production cost of two to four kopecks/(kw-hour). In the future, due to technological improvements of the SES system, including an increase in operating parameters of the equipment and using more optimal materials, a certain reduction in this value may be expected.

The data shown above indicates the long-range possibilities of using solar electric power plants of various types (at first of small capacities) in the southern regions of the country may, in some cases, be evaluated as positive.

Only the future will show what place solar electric power takes in the fuel-power balance of the country and what efforts will be required for its development.

Scientific research and experimental design work in this area will be directed to technological and technical-economic search for ways to increase the efficiency and competitiveness of solar electric power plants. The problem of power storage requires further investigations. It is also necessary to develop types of SES that, besides heat and electric power, can also produce products (for example, hydrogen or ethanol).

In the future, photoelements may be used widely in tower SES systems capable of operating at high densities of the radiation flux and temperatures of up to 300°C. It may be expected that the use of photoelements on the SES receiver surfaces will make it possible to increase the total efficiency of converting solar energy into electric power to 35% and higher.

BIBLIOGRAPHY

Malevskiy, Yu. N.; Tarnizhevskiy, B. V.; Fugenfirov, M. I. "Solar Power Abroad: Forecasts and the State of Art." -- In book: "Energetika i toplivo (dostizheniya i perspektiva)" (Power and fuel, achievements and prospects). No 1. Mezhdunarodnyy tsentr nauchnoy i tekhnicheskoy informatsii, 1978, pp 41-50.

The PY Energy Budget-Nuclear News, 1978, vol 21, No 4, pp 30-35.

Aparisi, R. R.; Baum, V. A.; Garf, B. A. "High Power Solar Installations." In book: "Ispol'zovaniye solnechnoy energii" (Utilization of solar energy), (symposium I) -- Izd. AN SSSR, 1957, pp 85-98.

Linitskiy, N. V. "Arrangement of a Powerful Concentrator for Solar Energy with Stationary Flat Mirrors." GELIOTEKHNIKA, 1969, No 4, pp 21-28.

APPROVED FOR RELEASE: 2007/02/08: CIA-RDP82-00850R000200070041-7

APPROVED FOR RELEASE: 2007/02/08: CIA-RDP82-00850R000200070041-7

Baum, V. A.; Aparisi, R. R.; Garf, V. A. -- High Power Solar Installation -- Solar Energy, vol 1, 1957, No 2, pp 6-10.

COPYRIGHT: Izdatel'stvo "Energiya", "Teploenergetika", 1980.

2291
CSO: 1822

APPROVED FOR RELEASE: 2007/02/08: CIA-RDP82-00850R000200070041-7

APPROVED FOR RELEASE: 2007/02/08: CIA-RDP82-00850R000200070041-7

ELECTRIC POWER

UDC 629.7.064.58

POWER STATIONS WITH MHD GENERATORS

Moscow TEPLOENERGETIKA in Russian No 3, Mar 80 pp 2-5

[Article by Academician A. Ye. Sheyndlin; B. Ya. Shumyatskiy and E. E. Shpil'rayn, doctors of technical sciences; and G. N. Morozow and G. M. Koryagina, candidates of technical sciences, AN USSR High Temperature Institute: "Present-Day State of the Problem of Constructing Electric Power Stations With MHD Generators[1]]

[Text] Research in the area of energy conversion by magnetohydrodynamic methods, conducted about 20 years ago in the Soviet Union and abroad, makes it possible for us at the present time to proceed to a qualitatively new stage--the commercial introduction in power engineering of thermal electric power stations with magnetohydrodynamic (MHD) generators.

The first large-scale experimental and experimental-industrial installations called upon to demonstrate the feasibility of utilizing the MHD method and to accumulate experience in operating the individual systems have been built in our country and abroad. The MHD power unit is a two-stage power installation, in the upper region of whose temperature range (2700-2000°C) the MHD generator operates and in the lower region (540-30°C) a conventional steam-turbine installation is engaged. The high initial temperature, which is practically unattainable in other types of structures, makes it possible to increase the efficiency of thermal electric power stations with MHD generators to 50-60 percent. In this way, great savings in fuel are achieved in comparison with the best modern thermal stations (efficiency of 37.3 percent). The savings are approximately 25-30 percent greater. The promise of MHD energy conversion is also determined by the fact that the MHD

---

[1] Our readers can become acquainted with the basic trends in fuel and power production resources economy in the coal industry by reading the articles in UGOL' No 3, 1980.

APPROVED FOR RELEASE: 2007/02/08: CIA-RDP82-00850R000200070041-7

generator can be utilized not only in a binary cycle with a steam power plant, but also in a multistage cycle. In this case, thermal machinery (a potash turbine, for example) can be used in the 1200-600°C temperature range. The more efficient the lower and middle stages of a combined MHD installation, the greater the thermal savings of the entire electric power station.

The utilization of the MHD generator is promising not only for increasing the savings at electric power stations where chemical fuels are employed but also at nuclear electric power installations.

A non-equilibrium plasma MHD generator with an initial inert gas temperature of 1300-1500°C is possible in combination with a high-temperature gas-cooled reactor. In the long term it will be possible to use gaseous-phase nuclear reactors with an MHD installation, which in this case will be the sole or primary source of electric energy. There are interesting proposals for the utilization of MHD generators in combination with thermonuclear installations.

An important virtue of the MHD installation is the feasibility of achieving great individual outputs from the power units. In this case, the higher the output, the greater the savings for the installation. This is due to the fact that the useful effect--the conversion of energy--is volumetric, while all the deleterious effects, such as the friction losses, current leaks along the insulating walls, etc., take place on the surfaces of the MHD generator. Consequently, it is necessary to have a sufficiently great ratio between the volume of the MHD channel and its surface in order to decrease these deleterious effects. Estimates show that open-cycle MHD generators become adequately efficient at outputs of 500-1000 MW. The overall output of the MHD unit, including the steam turbine, will comprise approximately 1000-2000 MW.

With the utilization of the MHD electric power station pollution of the environment is reduced. The enhanced efficiency of the MHD electric power station leads to a reduction of the thermal emissions with flue gases per unit of energy produced which is proportional to the reduction in the unit expenditure of fuel, that is, by 20-35 percent.

With the increase in efficiency from 40 th 50 percent the expenditure of cooling water decreases by a factor of 1.55, and by more than a factor of 2 when the increase in efficiency reaches 60 percent.

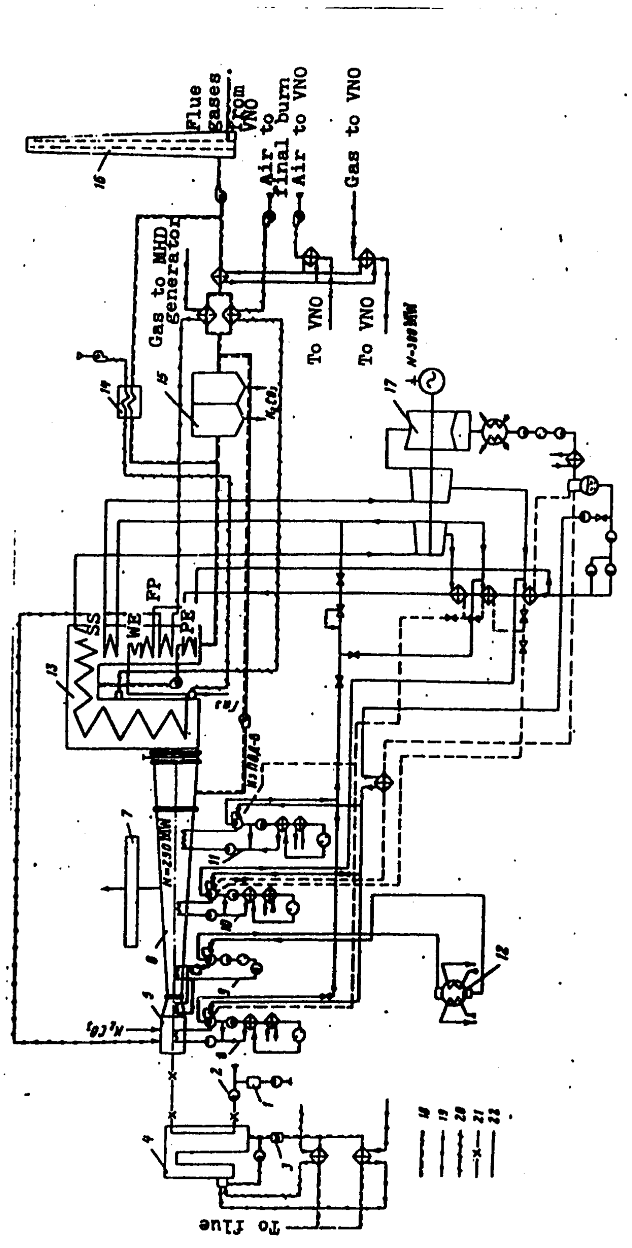
The injection of an ionizing additive--potassium carbonate (K_2CO_3)-- into the MHD electric power station's combustion products almost completely fixes the sulfuric oxides that are formed during the burning of high-sulfur coal or fuel oil. This eliminates the problem of constructing special, expensive sulfur-scrubbing equipment, the cost of which, the estimates show, reaches 30 percent of the cost of a traditional electric power plant.

By virtue of the very high temperatures at which the combustion process takes place in MHD installations, greater amounts of nitrous oxides (up to 2 percent) are formed in the combustion products.

The most widely used method of combating nitrous oxides is the two-stage combustion of the fuel. It is this method that is successfully employed at MHD electric power plants. In the primary combustion chamber the stoichiometric ratio is maintained at the 0.9-0.85 level, at which point CO and H_2 are formed, which at temperatures above 1500-1300°C dissolve the nitrous oxides by taking the oxygen from them. Later on air is fed into the combustion products and an afterburning of the incompletely consumed fuel takes place. Calculations and experimental data show that, in addition, the nitrous oxide content can be reduced to values substantially lower than those allowed by existing standards. Besides this, in certain cases it may prove to be expedient to extract the nitrous oxides from the combustion products in order to produce nitric acid.

The MHD electric power station is characterized by its great adjustability: for specific schedule determinations the load can vary from nominal to 20 percent, which significantly exceeds the control limits at conventional thermal electric power stations. Such a wide range of control is insured by the feasibility of shutting down the MHD generator and switching the steam generator over to a mode of operation using self-contained burners with consequent regulation of only the steam power unit.

The MHD open-cycle installation can utilize almost all forms of fossil fuels. Naturally, at the first stage preference was given to the utilization of "clean" fuel--fuel oil and natural gas. However, most of the coal from USSR deposits can also be effectively utilized: in particular, bituminous coal from the Kuznetskiy Basin, Kansko-Achinsk coal or semi-coke, obtained on the basis of thermal treatment of the latter. With the utilization of coal the operation of the individual systems becomes more complicated. This occurs, first of all, in the system for preheating the air, for injection of the additive


Flue gases from VNO
Air to final burn
Air to VNO
Gas to VNO
Gas to MHD generator
To VNO
To VNO
N=300 MW
N=230 MW
To flue
SS
WE
FP
PE
1
2
3
4
5
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22

BASIC EQUIPMENT LAYOUT OF THE MHD POWER UNIT AT THE RYAZAN' GRES

1. Air fractionating unit
2. Oxidant compressor
3. Catalytic reactor
4. High-temperature oxidant heaters (VNO's)
5. Combustion chamber
6. MHD generator (nozzle, channel, diffuser)
7. Inverter substation
8. Combustion chamber cooling system
9. Self-contained system for cooling the nozzle and the initial portion of the channel
10. Channel cooling system (p=2.0 megapascals)
11. Channel cooling system (p=4.5 megapascals)
12. Industrial condenser
13. Steam generator
14. Air preheater for independent operation of the steam generator
15. Cottrell precipitators
16. Flue
17. Turbine unit
18. Flue gases
19. Natural gas
20. Air
21. Oxidant
22. Steam, water

SS - Steam superheater
WE - Water economizer
FP - Fuel preheater
PE - Pre-engaged economizer

and for recovery of the additive, where the presence of scale affects the operation to a greater degree. There are, however, certain merits to the coal-fired variant: a layer of slag protects the walls of the station's high-temperature elements (the combustion chamber and the MHD channel) and the coal combustion products possess a somewhat higher electrical conductivity (in comparison with those from gas or fuel oil at the same temperature). This can substantially facilitate the solution to the problem of extended operation of high-temperature materials and can reduce somewhat the necessary level of oxidant heating.

The figure attained for the savings in fuel (or the efficiency) at an open-cycle MHD electric power station in comparison with the traditional steam-turbine electric power plants depends primarily upon the method and level of heating the air (the oxidant) in the MHD electric power plant's cycle. For example, in MHD installations in which the oxidant is heated to 1700°C by combustion products from a special (self-contained) combustion chamber, a combined-cycle efficiency of 48-50 percent can be attained. If this same oxidant preheating level is provided for through the utilization of the combustion products exiting the MHD generator, that is, through heat recovery in the MHD cycle, the combined-cycle efficiency increases to 50-54 percent. An additional increase in the degree of heat recovery (with the engagement in the system of the installation's MHD unit for the thermochemical treatment of the fuel by the heat of the gases which exit the MHD generator) increases the efficiency of the MHD installation to 55-58 percent. The higher figures for MHD installation efficiency cited in the literature (up to 60 percent) can be attained in the long term when the installation's parameters are increased (the oxidant preheating temperature to 2000°C, the magnetic field induction to 8 tons, etc.).

In the USSR the MHD installations that are best prepared and are planned for future industrial introduction are the open-cycle, gas-fired MHD plants with self-contained oxidant heating and a bottom-cycle steam turbine. The construction of a gas-fired MHD electric power plant will allow us to create the necessary production base for industry and to accumulate the operational experience which is necessary for the construction of a coal-fired MHD electric power plant. The most specialized installation elements (the MHD channel with its magnetic system, the inversion system, etc.) will undergo practically no changes in the transition to another type of fuel.

The leading position in MHD electric power plant development belongs to the Soviet Union. In addition to some large-scale scientific research installations, the U-25 experimental-industrial installation (whose MHD generator in 1974 reached its designed electric output of 20.4 MW and over the course of more than 250 hours operated continuously at loads of up to 10 MW) has been in operation since 1971 in the Soviet Union. The installation's overall operational time exceeds 6000 hours.

In the U-25 installation not only the main unit--the MHD generator--but also the other elements have been mastered: the additive injection and extractions systems, the high-temperature combustion chamber, the steam generator, a system for inverting the current drawn from the MHD generator, the apparatus for keeping the heating surfaces free from additive deposits, high-voltage electrical insulation for elements of the MHD generator and the combustion chamber, etc. Some of these elements are either totally new or acquire, in combination with the MHD installation, special characteristics that are distinct from the working specifications of traditional thermal electric power plants.

In recent years, research associated with the development in the Soviet Union of a coal-fired MHD electric power plant has been conducted at a U-02 installation where the mineral portion of the fuel is imitated through the use of ash supplied by the gas-combustion products, as well as at the Minenergo installation at Kokhtla-Yarve. Further substantial development of the utilization of coal at MHD electric power stations is planned on the existing experimental basis in Kokhtla-Yarve at the Kazakh Scientific Research Institute of Power Engineering (KazNIIenergetika) in Alma-Ata and at the U-02 and U-25 installations which will be refurbished and fully equipped. The development of coal utilization is also planned at newly constructed special stations and installations as well. Construction in the future of a coal-fired experimental-industrial MHD installation on the basis of the U-25 facility will allow us to obtain the data necessary for designing a 1000 MW hard coal-fired industrial MHD electric power plant.

In the U.S., Japan, India and Poland great attention is being devoted to the development of MHD electric power plants. Some research is being conducted in Canada, Finland, Romania, Yugoslavia and other countries. England, France and West Germany at the end of the 1960's shelved their MHD energy conversion research in view of the absence of sufficient reserves of fossil fuel and the fact that they pinned their hopes on the immediate development of atomic power.

In the U.S. more than 20 organizations from government as well as large private firms are engaged in research in the area of MHD power conversion. The largest scientific research centers participating in research into MHD power conversion are:

the U.S. National Bureau of Standards, the Massachusetts Institute of Technology, the Argonne National Laboratory, the Pittsburgh Coal Research Center, the University of Tennessee, Stanford University and other firms: Westinghouse, General Electric, Avco-Everett, Reynolds and many others. At present a special MHD power conversion institute is being organized in the U.S. in the state of Montana (MERDI), where experimental and experimental-industrial installations are being built. The transition to the practical introduction stage is characteristic of MHD electric power plant development in the United States.

The majority of research being done in the U.S. and other foreign nations (excluding Japan, which is oriented basically toward imported oil) is directed at the creation of coal-fired MHD installations. In the U.S. at the present time more than 80 million dollars are being invested yearly in this development. The first large-scale experimental coal-fired MHD facility with a 50 MW thermal output is in the final installation stage, and the start-up and adjustment operations are beginning. There are proposals for the construction in 1985 of an experimental-industrial MHD station with an output of about 125 MW, which will subsequently be increased to 250 MW.

The construction of a coal-fired 2000 MW MHD electric power plant in the U.S. is proposed for completion in 1990. A forecast done by the General Electric Company shows that, according to their technical nad economic indicators, MHD installations may prove to be the most preferred in the U.S. by the beginning of the 21st century.

Taking into account the nature of thermal electric power plant development in the Soviet Union, we are orienting the realization of a development program for MHD electric power plants in two basic steps:

the construction of several gas- and fuel oil-fired MHD electric power plants with the engagement of a pilot power unit in 1985;

the construction of a coal-fired MHD electric power plant with the engagement of a pilot power unit at the start of the 1990's.

At the present time the development of MHD electric power plants has passed the stage of technical and economic demonstration. The technical design stage of a pilot MHD power unit will be started at the Ryazan' GRES.

The following prerequisites have been prescribed as the basis of design development of a pilot industrial MHD electric power plant.

The technical-economic indicators for the MHD electric power plant's pilot power unit should be higher than those of the known alternative electric power producing installations proposed for introduction in 1985.

The technical decisions incorporated in the design should possess reliable experimental confirmation. This predetermined, first of all, the choice of fuel, since we in the Soviet Union have at the present time experience in utilizing only natural gas in MHD installations.

It seemed expedient to adopt the steam-power installation of the MHD power unit as the standard layout, since its manufacture and operation had already been mastered. On the basis of considering the limited expenditures for the pilot unit, the steam-power installation's output should be kept to a minimum, but it should not be lower than the output at which the MHD generator proves to be sufficiently economical.

The K-300-240 turbine, widely used in the Soviet Union, conforms completely with these conditions. The output of the MHD superstructure for this turbine comprises 240-260 MW, which, although it is substantially lower than the optimum figure for the MHD generator, is sufficient for demonstrating the principal advantages of the MHD method.

In connection with the characteristics of the MHD installation (increased combustion-product temperatures, the presence of additives in the combustion products, the necessity of utilizing the heat extracted from the combustion chamber cooling system and the MHD generator in the steam cycle, etc.), the MHD unit's steam generator differs in construction from the standard model.

The design development carried out has shown that all the new equipment (the super-conductive magnetic system, compressors, a system to separate the combustion products from the additive, the electric portion of the MHD generator, etc.) is on a technical level where it can be manufactured at existing industrial enterprises, using a minimum of new materials.

The oxidant preheating is done at temperatures up to 1700°C and is carried out in self-contained, high-temperature, furnace-type heaters (Cowper blast air heaters), since the higher preheating of the oxidant or a replacement of the self-contained heaters with regenerators is associated with the use of new materials, the manufacture of which demands a substantial refitting of industry.

The thermal flow sheet for the power unit of the pilot MHD electric power plant, developed in accordance with the considerations discussed above, is represented in the diagram.

The MHD generator is designed in such a way that the discharge and enthalpy of its exhaust gases are sufficient to obtain the quantity of steam necessary for the K-300-240 turbine.

The application of atmospheric air or air that is slightly enriched with oxygen (up to 27 percent) and preheated to 1700°C is planned for the oxidizing agent. The slight enrichment is foreseen as a back-up measure in case in the initial period the temperature and electrical conductivity should prove to be lower than calculated. In both cases the same equipment will be used.

The equipment layout at the MHD electric power plant is completed with compressors that are driven by synchronous motors. A more economical solution is the installation of a compressor driven by a special turbine which receives a portion of the steam from the primary turbine's TsVD (high-pressure cylinder) after intermediate superheating. In this case, however, the development of a new primary steam turbine would be required for the electric generator drive, since the flow rate of steam within it would be different before and after the intermediate superheating. Such a solution would not be adopted for the pilot unit, but it is proposed that when the MHD electric power plant goes into commercial production this solution be reviewed and that we make the transition to a steam drive for the compressor.

One of the complex problems is the efficient utilization of low-potential heat in the MHD cycle. In contrast to conventional steam-turbine plants, the cooling of exhaust gases in MHD electric power plants in the temperature region below 300°C cannot be carried out by the oxidant, since it exits the compressor at a higher temperature. In addition, 7-9 percent of the burned fuel's heat is extracted from the combustion chamber's cooling system and from the MHD generator at temperatures no higher than 250-260°C. Low-potential heat can be utilized only under conditions of partial displacement of the steam regeneration; for utilization of the heat of the exiting gases to heat the fuel and preheat the air that enters the self-contained high-temperature heaters; and for other purposes. The design developments that have been carried out show that the application of MHD electric power plants instead of steam-turbine electric power stations provides a 21-22 percent savings in fuel. With the cost of fuel at 30 rubles per ton of conventional fuel this makes it possible to reduce the calculated expenditures for the output produced by 6-7 percent.

The designing of the MHD power unit for the Ryazan' GRES is being carried out by the Moscow branch of the "Teploelektroproyekt" Institute. In the development of equipment for the MHD power unit, the largest scientific research institutes and design organizations of the USSR Minenergo, Minelektrotekhprom, Minenergomash, the USSR Minchermet and Minkhimash are participating, as well as from other departments, such as the Leningrad "Elektrosila" union, the NPO TsKTI (Scientific-Industrial Union of the Central Scientific Research and Design-Construction Turbine Boiler Institute imeni I. I. Polzunov), Ukrgipromez and others.

The plans for 19 long-range, special-purpose programs relating to new developments in the area of power engineering have been examined by a permanent commission for the formulation of a long-term, complex program of development of a fuel and power-production complex for the Soviet Union. This permanent commission is under the control of the USSR Gosplan, the USSR Council of Ministers State Committee for Science and Technology and the AN USSR. A preliminary analysis has shown that, even with consideration given to all the allowances made for the possible deviations in the program's results, the gas- and solid fuel-fired MHD electric power plants occupy one of the first places among the new power-production technologies with respect to the expenditures cited.

COPYRIGHT: Izdatel'stvo "Energiya," "Teploenergetika," 1980

9512
CSO: 1822

APPROVED FOR RELEASE: 2007/02/08: CIA-RDP82-00850R000200070041-7

ELECTRIC POWER

UDC 621.3.019.3

RELIABILITY TESTING PROCEDURES FOR POWER STATION EQUIPMENT

Moscow IZVESTIYA AKADEMII NAUK SSSR ENERGETIKA I TRANSPORT in Russian No 1, Jan-Feb 80 pp 11-18 manuscript received 17 May 79

[Article by G.I. Gladyshev, Moscow: "Methods of Estimating the Reliability of the Main Thermal Power Equipment of Electric Power Stations"]

[Text] Diagnostic monitoring and statistical probability methods of estimating the reliability of the major thermal power engineering equipment of electric power stations are treated. The efficiency of their utilization in various operational periods is analyzed. The theoretical capability of utilizing the data of monitor diagnostic measurements for statistical probability estimates and forecasting the reliability of equipment is demonstrated. Figures 5; references 7; pp 11-18.

Equipment which is in service subject to both obsolescence and physical aging. Physical aging is expressed in a loss of operability by parts and assemblies which operate under conditions of creep, under cyclical loads, as well as in cases of corrosion and erosion.

Processes which lead to a loss of operability continue throughout all operational periods of the equipment, and some, for example, corrosion processes, also continue when the equipment is not operating. Thus, physical aging is continuously taking place. This circumstance determines the necessity of ascertaining the time intervals for parts, assemblies and units of a whole, during which their performance does not fall below some previously specified level which assures the execution of the specified functions. For individual types of equipment, such time intervals are stipulated during the design. For the components of boilers, turbines and piping which operate at high temperatures (more than 400° C for carbon steels, more than 450° C for alloy steels and more than 525° for austenitic nickel-chrome steels), the time factor is taken into account by a conventional long term strength limit at the design temperature, which corresponds to fracture after 10^5 hours, as well as with a conventional limit of creep, also after 10^5 hours. Within the range of this time

APPROVED FOR RELEASE: 2007/02/08: CIA-RDP82-00850R000200070041-7

period, which is the design time period, the functional time--long term strength and time--creep relationships are known, since provisions are made for design margins of strength [1].

The accounting for long term strength and creep at temperatures above 400° C is due to the fact that with the action of the applied loads and the stressed state arising as a consequence of this, the performance of heat resistant steels and alloys, which is determined by the resistance to deformation and fracture under conditions of creep and the capability of deformation during delayed fracture, varies with time. The mechanism for the change in the performance of steels and alloys, from which the parts and assemblies of thermal power engineering equipment are fabricated, is determined by the degree of alloying of the base, the quantitative ratio of components in the solid solution and the parameters of the excess strengthening phase (carbide and intermetallic). Structural and phase changes are constantly taking place in a metal and are accompanied by a reduction in its strength characteristics in time [2].

The loss in the strength of 12MKh and 15 KhM steels due to the transition of molybdenum to carbides at various accrued operating times is shown in Figure 1. It can be noted that the influence of temperature in the stressed state within a range of 10^5 hours is taken into account sufficiently completely, although it is necessary to continue research on a number of problems [3].

In assessing the influence of cyclical loads on the long term service life, only some of the factors are taken into account in the design calculations: the change in the pressure of the working medium during startups and shutdowns, fluctuations in the working pressure, fluctuations in the external loads, cycles during temperature stresses during the time of startups and shutdowns and oscillations during operation. The impact of water-chemical modes is not taken into account, which, as is well known, have a catalytic action with the occurrence and development of defects in components, and in a number of cases, are the decisive factors in the formation and spread of damage, for example, in the bends of unheated pipes and the drums of boilers.

Corrosion is taken into account in the calculations for the piping of heating surfaces in the case of high temperature processes. Other kinds of corrosion and erosion processes are not taken into account.

Thus, physical aging and consequently, the loss of performance can be determined by calculations only on the basis of a few criteria for a part of the equipment of electric power stations and in a number of cases, only for its individual components and assemblies in a range of accrued operating time of up to 10^5 hours. In the case of operation which exceeds this timeframe, physical aging is estimated either by physical or by probablistic statistical methods of checking, or by both methods simultaneously. The possibilities of each of the methods is to be assessed as well as the promise for their use in power engineering.

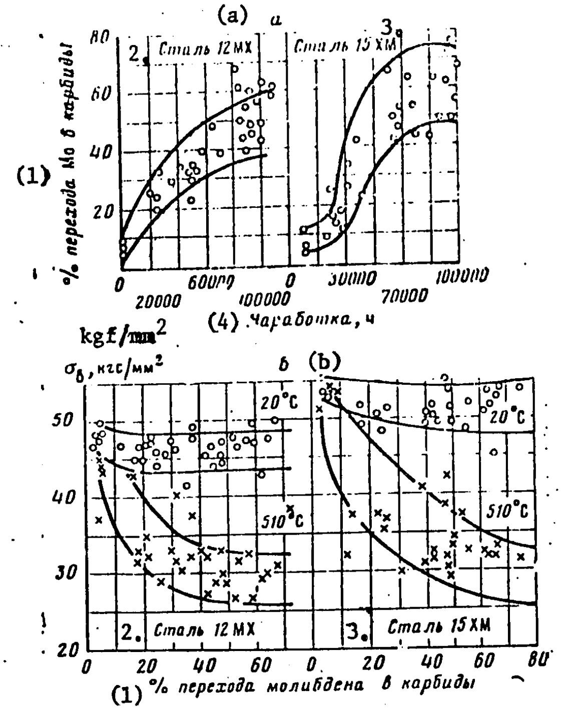


Figure 1. The loss of strength in steels with a change in the molybdenum content in the carbides.

Key:
1. Percentage of transition of Mo into carbides;
2. 12 MKh steel;
3. 15 KhM steel;
4. Accrued operating time, hours.

The level of equipment reliability, which at every point in time corresponds to its physical state, is characterized by several determinate criteria, which can be quantitatively estimated [4]. The major ones of them are the following: the short term mechanical properties of the metal at room and working temperatures, the long term strength, chemical composition, density, structure, residual deformation, the presence and nature of defects and stress concentrators, as well as the rate of corrosion and erosion wear. The magnitude of the criteria is estimated by means of instrumented diagnosis: ultrasonic and magnetic flaw detection, X-ray and gamma ray radioscopy, measurements of residual deformation, mechanical properties and chemical composition, etc.

The high precision of measurement of the criteria using diagnostic instrumentation makes it possible at any fixed point in time to confidently estimate the actual performance of assemblies and components on which the measurements are made. However, the results obtained cannot always be extrapolated to identical components on which the diagnostic procedure was not performed. This circumstance substantially reduces the effectiveness of physical methods of checking. Thus, during the ultrasonic flaw detection of the bends of unheated boiler pipes, a batch of 36,179 bends of 133 x 10 mm fabricated from carbon steel was tested for the purpose of estimating their reliability. Of the entire number of those tested, flaws were found in 725 bends (2 percent). In this case, defective bends were not detected at all in some of the boilers, and in some others, the rejection figure exceeded 10 percent. It is obvious that the extrapolation of the results obtained by ultrasonic flaw detection from some units to others is precluded in practice.

There are even fewer possibilities for ultrasonic flaw detection in the forecasting of changes in the criteria being measured. In fact, as a result of testing the 36,179 bends and finding 725 flawed bends among them, an answer was obtained concerning the reliability at the moment of testing. However, it remained unclear when and at what rate flaws would occur and spread in the remaining parts. At the present time, this drawback is localized in practice at periodic control checks, which are made at time intervals specified by regulations, and on which considerable material and personnel resources are expended.

However, using some instrumented diagnostic procedures, it is possible to predict reliability (residual deformation, long term strength, hardness and a number of others). To do this, repeated measurements are needed at definite, rather lengthy intervals of time.

As a rule, the diagnosis is performed on parts and assemblies, the damage or destruction of which cannot be allowed because of conditions for disruption of the power supply to consumers, the safety of servicing personnel and the maintenance of the equipment. Since an estimate of the level of reliability at every point in time of the measurements is rather high, while the possibilities of prediction based on the data obtained are limited, the monitor diagnostic work is carried out systematicallly at specified time intervals, during which the probability of failure or damage is low.

Monitor diagnostic measurements for the purpose of estimating the reliability of equipment are made systematically on a one-time basis. The necessity of making one-time measurements is determined by the resolution of various individual problems which arise during the operational process. The essence of such problems consists in determining the level of reliability based on individual criteria at definite points in time. The systematic performance of the measurements is directed towards estimating the dynamics of the reliability level, which is measured using one or several criteria. Systematic monitor diagnostic operations are performed at the present time primarily on turbines, boilers and high pressure steam lines [5].

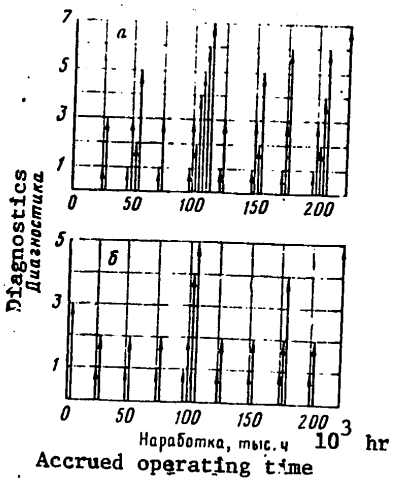


Figure 2. The periodicity, kinds and volumes of monitor diagnostic operations on the casing components of turbines.
a) The housings of check valves: 1. Visual inspection of the surface at a temperature of the metal of 450° C and above (100% of the surface); 2. Visual inspection of the surface at a temperature of the metal below 450° C (100% of the surface); 3. Magnetic powder flaw detection of all of the radial transitions at a temperature of the metal of 450° C and higher; 4. Magnetic powder flaw detection of all radial transitions at a temperature of the metal below 450° C; 5. An investigation of the mechanical properties of one notch sample for 35 KhML and 30 KhML steels; 6. An investigation of the mechanical properties of one notch sample for 15 Kh1M1FL steel; 7. An investigation of the mechanical properties of one notch sample for 20 KhMFL steel;

b) The housings of cylinders: 1. Visual inspection of the surface, 100%; 2. Magnetic powder flaw detection of all radial transitions; 3. Non-sample measurement of the mechanical properties (no less than 50 points); 4. An investigation of the mechanical properties of four notch samples for 15 Kh1M1F steel; 5. An investigation of the mechanical properties of four notch samples for 20 KhMFL steel.

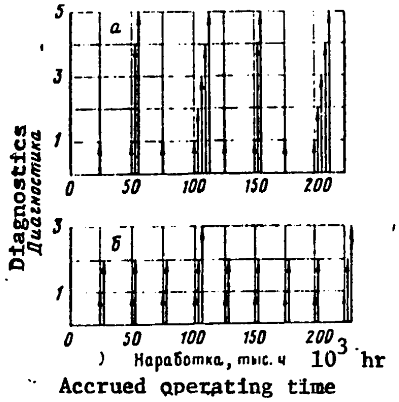


Figure 3. The periodicity, kinds and volumes of monitor diagnostic operations for the flow-through portion of turbines.

a) Parts which operate at a temperature of 450° C and above: 1. Visual inspection of the surface, 100%; 2. Ultrasonic testing of the weld joints of the shaft, 100%; 3. Color flaw detection of the surface of the heat grooves, 100%; 4. Ultrasonic flaw detection of fastenings with diameters of 42 mm and more, 100%; 5. Measurement of the firmness of fastenings with diameters of 42 mm and more, 100%;

b) Parts operating at temperatures below 450° C: 1. Visual inspection of the surface, 100%; 2. Ultrasonic testing of the rotating blades of the ChND [low pressure section], 100%; 3. Ultrasonic testing of the weld joints of shafts, 100%.

The housings of cylinders, check and control valves and nozzle cages, as well as the weld joints of cast parts between each other and with forged parts are checked in turbines. The components of the flow-through section are also checked: rotors, the weld joints of rotors, the thermal grooves of shafts, disks, rotating blades, diaphragms, stator blades and fastening with diameters of 42 mm and more are likewise checked. The most complete measurements are made on those components and assemblies, the working temperature of which exceeds 450° C. Nonetheless, diagnostic work is also performed on medium and low pressure cylinders.

The periodicity and kinds of ckeck diagnostic operations, performed on the housing compcnents of turbines, are shown in Figure 2. In the original state, the hardness of the metal of the cylinders is checked no less than at 50 points in the zone of the regulating stage and the flange joints outside the seating positions. The entire internal surface of cylinders is inspected and magnetic powder flaw detection (MPD) is performed on the radial transitions and repair samples after every 25,000 hours of operation. The assessment of the mechanical properties of the metal based on the samples is made after 100,000 hours of accrued operating time for all turbines. Repeat measurements and an estimate of the mechanical properties are made for the housings of cylinders, fabricated from 15 Kh1M1FL steel every 175,000 hours, and for the housings of cylinders made of 20 KhMFL steel, every 220,000 hours.

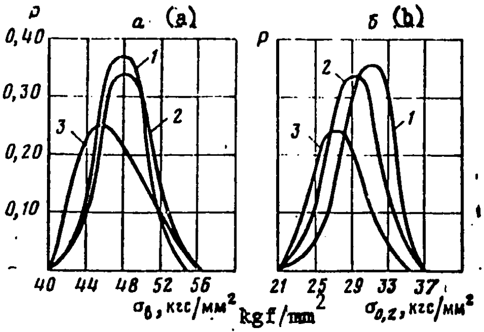


Figure 4. The distribution probability for the ultimate strength and the conventional yield limit: 1. In the original condition; 2. After 45,000 to 65,000 hours of accrued operating time; 3. After 85,000 hours of accrued operating time; a. The distribution probability for the ultimate strength; b. The distribution probability for the conventional yield limit.

The mechanical properties are not determined for medium pressure cylinders; only magnetic flaw detection and an inspection are performed. Visual inspection is made of low pressure cylinders.

The same kinds of monitor diagnostic operations are provided to evaluate the housings of check valves.

The components of the flow-through section, which operate at temperatures of more than 450° C, are sujected to a 100% visual inspection every 25,000 hours. Ultrasonic flaw detection of all seams is made for welded joints of shafts after 100,000 and 200,000 hours. Color flaw detection is used to check the condition of the thermal grooves of shafts at these same intervals.

Fastenings with diameters of 42 mm and more, which operate at temperatures of 500° C and above, are checked every 50,000 hours using ultrasonic flaw detection equipment (UZD). Moreover, the firmness of the fastening is measured.

The components of the flow-through section, which operate at a temperature below 450° C, are visually inspected every 25,000 hours. The rotating blades of the low pressure section in the turbines of power units with a capacity of 150 MW and above are fully checked once every 25,000 hours using ultrasonic flaw detection. Ultrasonic flaw detection is performed on all the welded joints of the shafts after 100,000 and 200,000 accumulated hours of running time (Figure 3).

It can be seen from the data given on monitor diagnostic operations, that they are used to estimate the level of reliability of the major components of turbines after specified intervals of time. The primary goal of the diagnostic work is to ascertain flaws which occur in the assemblies and components during the operational process, as well as to observe the change in the properties of the metal at various accrued operating times.

The heating surfaces, unheated pipes, drums, collectors and weld joints of boilers, as well as high pressure steam lines are checked in a similar manner. The individual components of feed lines are likewise checked.

The cost of performing monitor diagnostic operations is rather high, and at the present time, is estimated to be 10-20 percent of the cost of major overhauls of equipment in power units.

Along with the diagnostic work, statistical probability methods are used to estimate the reliability of equipment with various accrued operating times. The problems solved using these methods are different from those described above. The main one of them is the estimation of the reliability of a group of units, components or assemblies, which are made into a sample and which are characterized by a definite statistical homogeneity: the kind of fuel, the accrued operating time, the type of equipment and its parameters, etc. The accuracy of the estimates and the representativeness of the results obtained in this case are determined by the correctness and the volume of the generated sample. Up to the present time, information on the operation and downtimes of equipment, which makes it possible to compute the following various indicators have been taken as the basis for the determination of the reliability level using statistical probability methods: the readiness and operational readiness factors, the running time, the forced downtimes, the average restoration time, the mean time between failures and a number of others [6]. The change in these indicators in the case of various accrued operating times can likewise characterize the physical wear on the equipment. However, the data obtained in this case concerning the reliability level can be extrapolated to other samples with different confidence levels, which depend primarily on the agreeement or lack of agreement between the conditions characterizing both samples.

The computation of the probability of failure-free operation of thermal power engineering equipment based on the true mean time between failures can obey various laws. Exponential and normal distributions are encountered more frequently than the others. All of the main components of the boiler heating surfaces have an exponential distribution.

Among other reasons, failures can arise as a result of the physical aging of components and assemblies. This circumstance makes it possible to draw the conclusion that at certain accrued operating times, after which changes in the metal characteristics are ascertained from data of a physical check, one can compute the probability of a change in the properties of the metal. The generation of a sample in this case should not be made based on the mean cycles between failures, but rather on the basis of the mean time until a change in the properties, in which case, all of the attributes of sample homogeneity are preserved, and in a number of cases, are specified more precisely. The latter condition can be explained as follows. If sufficient conditions for the generation of a sample for the purpose of determining the probability distribution of failure free operation of steam lines are the identity of the nominal steam parameters, pipe diameter and types of steel, then additional conditions on the observance of the temperature modes, including overshoots of the temperature above the nominal level, are needed to determine the probability of a change in the properties of the metal.

It is obvious that in generating a sample, to observe the conditions for its homogeneity, factors which have an impact on the change in the metal properties must be taken into account: temperature, pressure, compensation and cyclical loads, the variation in the chemical composition and physical properties, as well as the variation in the structure. The factors can be considered separately and in groups, depending on the problems which are to be solved by means of the information obtained from the generated sample.

As a result of such an approach, it is possible to combine the results of monitored diagnostic measurements with the reliability indicators determined by statistical probability methods.

The distribution probabilities for the ultimate strength and the conventional yield limit, obtained in tests of samples cut from steam lines (12 Kh1MF steel) at various accrued operating times are shown in Figure 4. In other words, the distribution probabilities were obtained on the basis of samples of the "accrued operating time until a change in properties" type generated on the basis of monitored diagnostic measurement data. Two circumstances are noted. The first is that the distributions obey a normal law; the second is that with an increase in the length of operation, the probability of the occurrence frequency of the appearance of samples with good properties falls off. It follows from this that by knowing the law governing the distribution probability of the frequency of the change in the metal properties of parts and assemblies for different accrued operating times, one can predict the reliability level of the equipment. Thus, there is the theoretical possibility of establishing a relationship between the results of monitor diagnostic operations and statistical probability estimates of equipment reliability [7]. Such relationships are obviously more clearly expressed in the case of long accrued operating times, since many reliability indicators are markedly degraded only in the aging period of the equipment.

It can be seen in Figure 5 that ascertaining relationships between the results of monitor diagnostic measurements and an estimate of the equipment reliability level by means of the failure flow parameter is preferable in the case of long accrued operating times. The failure flow parameter varies substantially only in the run-in and aging periods. The distribution probability of the frequency of the change in metal properties has a marked drop only after an accrued operating time close to or exceeding 100,000 hours. This confirms the expediency of combining both methods for long running equipment.

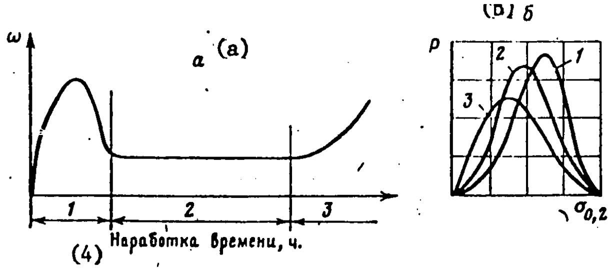


Figure 5. The variation in the failure flow parameter and the distribution probability for the conventional yield limit at various accrued operating times.

a) The variation in the failure flow parameter;
   1. The run-in period;
   2. The normal operational period;
   3. The ageing period.

b) The variation in the conventional yield limit:
   1. The original condition;
   2. After 45,000 to 65,000 hours;
   3. After 85,000 hours;
   4. Accrued operating time, hours.

In all probability, only by combining monitor diagnostic operations with statistical probability estimates for equipment reliability can the problems of determining the maximum permissible service lives of components assemblies and units as a whole be solved for thermal power engineering equipment of electric power stations.

The utilization of the accumulated statistical data on equipment reliability and the results of monitor diagnostic measurements of the state of a metal make it possible, particularly when they are combined, to reduce the labor outlays and material expenditures for the estimation of the reliability of equipment which has been left in service beyond the design period.

The requisite conditions for the development and implementation of programs directed towards optimizing the diagnostic volumes and periodicity are essentially being created.

An important measure related to boosting the efficiency of determinate methods of reliability estimation can become the supplementation of the stock of measurement equipment with new instruments, and particularly, with ultrasonic flaw detectors. The existing flaw detection instruments and the methods of their utilization do not permit the reliable checking of the reliability of contact weld joints of the heating surfaces of boilers, the weld connections of steam lines made of austenitic steels and certain other components of thermal power engineering installations. There are practically no means of estimating the depth and shape of cracks which propagate from the surface into the depth of a part. Instruments are lacking for checking the shafting of turbine rotors from the axial channel side.

There is no need to continue the enumeration of the assemblies and parts, to evaluate the reliability of which physical testing tools should be refined or redesigned. It can be seen from the examples cited here that such a problem exists, and its solution will allow for the optimization of the volumes and timeframes for the performance of monitor diagnostic operations.

Thus, ways of optimizing the estimation of reliability consist in combining diagnostic and statistical probability methods, in refining the existing measurement tools and in developing new and more refined ones.

It must be noted that for the estimation of the reliability of long running thermal power equipment, the tools and procedures utilized on installations operating within the limits of the design service period are altogether suitable.

Conclusions. 1. The evaluation of the reliability of thermal power equipment using diagnostic tools is characterized by a high level of measurement precision and a wide range of evaluation criteria, but has limited capabilities for prediction and extrapolating the results obtained.

2. Statistical probability methods make it possible to predict the change in the reliability level with time, and to extrapolate the results of calculations for homogeneous samples, but yield greater errors in the estimates in the case of small volumes of raw data. This precludes the use of probabilistic criteria in the calculation of the reliability of individual assemblies and parts, for which a small number of events have been accumulated during the operational process.

3. In the case of long accrued operating times, the change in the probability and determinate indicators is rather well pronounced in the ageing period of the equipment, because of which there is the theoretical capability of establishing a quantitative relationship between both methods. The esistence of a relationship creates the conditions for predicting the

results of diagnostic measurements, and for their extrapolation for homogeneous samples.

4. Combining the results of diagnostic work and probability estimates can reduce the volume of periodic testing of the reliability level of equipment which is in service. Moreover, the confidence level of the forecast in the determination of the additioanl operational time will be increased for thermal power installations left in service beyond the design service period.

BIBLIOGRAPHY

1. OST 108.031.02-75, "Kotly statsionarnyye parovyye i vodogreynyye i i truboprovody para i goryachey vody. Normy rascheta na prochnost'" ["Permanent Steam and Hot Water Boilers, and Steam and Hot Water Lines. Strength Design Standards"], Implemented 7 April, 1977, Minenergomash Publishers, 1977.

2. I.R. Kryanin, L.P. Trusov, "Perlitnyye stali v templovoy energetike" ["Perlitic Steels in Thermal Power Engineering"], TEPLOENERGETIKA [THERMAL POWER ENGINEERING], 1978, No 10.

3. P.A. Antikayn, B.M. Estrin, "Svoystva metalla paroprovodov iz staley 12MKh i 15KhM posle ekspluatatsii 90-100 tys. ch." ["The Properties of the Metal of Steam Lines made of 12MKh and 15KhM Steels after 90,000 to 160,000 Hours of Operation"], TEPLOENERGETIKA, 1973, No 10.

4. V.K. Adamovich, A.I. Levchenko, et al., "Opredeleniye resursa dal'neyshey ekspluatatsii energooborudovaniya iz khromomolibdenovoy stali posle 170-200 tys. ch ekspluatatsii" ["The Determination of the Service Life for Further Operation of Power Equipment Made of Molybdenum Chrome Steel after 170,000 - 200,000 Hours of Operation"], TEPLOENERGETIKA, 1978, No 10.

5. G.P. Gladyshev, "Otsenka nadezhnosti teploenergeticheskogo oborudovaniya otrabotavshego raschetnyy srok sluzhby" ["Estimating the Reliability of Thermal Power Engineering Equipment Operated Beyond the Design Service Life"], Report to the All-Union Seminar "Puti povysheniya nadezhnosti ekspluatatsii elektrostantsiy i setey" ["Ways of Increasing the Operational Reliability of Electric Power Stations and Networks"], VDNKh [Exhibition of National Economic Achievements] Publishers, 1972.

6. "Rekomendatsii k metodikam prognozirovaniya nadezhnosti pri proyektirovanii energeticheskog oborudovaniya" ["Recommendations for Procedures to Predict Reliability when Designing Power Engineering Equipment"], TsKTI [Central Scientific Research and Project Planning and Design Institute for Boilers and Turbines imeni I.I. Polzunov] Publishers, 1975.

APPROVED FOR RELEASE: 2007/02/08: CIA-RDP82-00850R000200070041-7

7. G.P. Gladyshev, "Nauchno-tekhnicheskiye issledovaniya problem nadeshnosti pri ekspluatatsii teploenergeticheskogo oborudovaniya, otrabotavshego raschetnyy srok sluzhby" ["Scientific and Engineering Research on Problems of Reliability in the Case of Thermal Power Equipment Operated Beyond the Design Service Life"], Report to the All-Union Seminar on "Prognozirovaniye i optimizatsiya pokazateley nadezhnosti turbogeneratorov" ["Predicting and Optimizing Reliability Indicators for Turbine Generators"], VNIIElektromash Publishers, 1979.

COPYRIGHT: Izdatel'stvo "Nauka", "Izvestiya AN SSSR, energetika i transport', 1980.

8225
CSO:1822

APPROVED FOR RELEASE: 2007/02/08: CIA-RDP82-00850R000200070041-7

ELECTRIC POWER

UDC: 621.311.21-827

KISLOGUB TIDAL POWER STATION DESCRIBED

Moscow ENERGETICHESKOYE STROITEL'STVO in Russian No 1, Jan 80 pp 64-67

[Article by Doctor of Technical Sciences L. B. Bernshteyn and Candidate of Technical Sciences I. N. Usachev: "Significance of the Kislogub Tidal Power Station for Hydraulic Engineering and Power Engineering Construction"]

[Text] The tough energy balance, caused by the rise in world crude oil prices and limited reserves of natural fuel, has led to an intensified search for new sources of energy, including tidal power. In spite of a certain stagnation in construction of PES [Tidal Power Stations] since construction of the French tidal power barrage at Rance, recently there has been noted a realistic solving of the problem, expressed in the forthcoming construction of two large PES in Canada (1 and 3.8 million kilowatts), South and North Korea, as well as in elaboration of PES projects in England, Australia and other countries. The USSR is examining the possibilities of building in the White Sea and Sea of Okhotsk PES with a total generating capacity of 120 million kilowatts, annual electric power production at which would provide savings of 100 million tons of coal per year at thermal electric power plants.

On the basis of 10 years' experience of operating the Kislogub PES [1], one can state with full justification that such a turning point occurred not only as a consequence of the above-stated objective factors but also to a significant degree thanks to new technical solutions implemented and tested at the Kislogub experimental PES. This experiment was based on full-scale testing of a new lightweight building design, making it possible to employ a floating technique.* The strength of this design is provided by the three-dimensional structural performance of thin-walled elements (15-20 cm in section), and barrage stability -- by sand ballast. This solution made it possible to erect the PES building under the favorable conditions of a coastal industrial center and to deliver it in finished form, together with installed equipment, to the barrage site, which frees construction crews from the necessity of erecting costly

---

* Certificate of Invention 135028 (USSR). Building for a Low-Head GES/ L. B. Bernshteyn. Published in B. I., No 1, 1961.

cofferdams and from the necessity of working in the sparsely-populated, difficult-access, harsh-climate area of the barrage site.

The floating method of construction has long been known and is extensively employed in the erection of floating drilling rigs, underwater tunnels, water intakes and other structures sited at fairly large depths. Nowhere in the world, however, had hydroelectric power stations been constructed in this manner. Therefore the solution we proposed evoked many objections and doubts.

Today, after successful erection, delivery, insertion at the barrage site and 10 years of studies, we can confidently state that the proposed design and method of erection are entirely reliable. It was established following thorough and extended study of the readings of 20 reinforcing rod dynamometers placed at precisely calculated points in the structure that when the barrage site was flooded, tensile forces in the reinforcing rods of the block walls increased by 30-40 kN without any abrupt bursts and reached 200 kN (substantially below calculated figures). When a block was lowered onto a temporary bed, a rehearsal of insertion at the barrage site, forces reached 280 kN, that is, remained within allowable limits. During wave action fluctuations of forces did not exceed 15-20 kN. Under operating conditions measurements of forces in the reinforcing rods when the structure took a head showed extremely small fluctuations (2-5 kN) during the tide cycle. Analysis of observational data indicates that under operating conditions, when the average daily head absorbed by the structure varies insignificantly (within a range of 20-30 cm), forces in the reinforcing rods, with some shifting in time, are determined only by change in ambient air temperature. Stresses in the slab and sidewalls change in conformity with change in temperature of the concrete. Forces in the sidewalls increase in an upward direction and from the interior axis toward the periphery. Forces change by 1-2 kN with a temperature change of 20°C.

Dynamic studies conducted with the aid of pulsation and vibration sensors, conducted by Gidroproyekt's Scientific Research Station during critical conditions indicated that the Kislogub PES building, in spite of its open construction, possesses a high degree of rigidity, exceeding that of the Saratov GES building, which is constructed of monolithic components.

Analysis of pressure fluctuation on a structure in the process of operation under specially created critical conditions indicates that the Kislogub PES building is also on the basis of its dynamic properties a relatively more rigid structure than, for example, the Kiev GES building, which is also equipped with capsule units, but the section of the building components of which is three times as large. The dimensionless natural frequencies of the first form of oscillation for the Kislogub PES building fall within the range 33.5-43.6, and for the Kiev GES -- 22-27.2. Within the range of disturbing frequencies excited by passage of water through the PES, vibrations of structural components are negligibly small.

We should particularly note that the design of the turbine mounting, which caused the greatest concern as it seemed highly fragile, proved to be entirely reliable. Analysis of the vibration characteristics of the principal components of the turbo-set indicated that the vibration load on them is 2-4 mkm in reverse pumping mode, which is the most difficult mode for the generator, 2-6 for the capsule, 5-20 for the thrust bearing, and 7-24 for the runner chamber, which is substantially below standard values.

Design of the unique Kislogub PES, with the floating erection technique, required solving a great many technical problems: development of new and upgrading of existing structural materials, methods of protecting them, and construction of an underwater foundation.

Let us examine the proposed solutions and their reliability.

Particularly high frost-resistant concrete was unquestionably that decisive material which determined the viability of the Kislogub PES design.

A concrete composition of particularly high frost resistance was specially developed for the Kislogub PES building [2]. The fact is that, as was indicated by studies performed prior to initiation of PES construction, the few concrete structures on the Murmansk coast began disintegrating in the tidal zone from the very first year of their existence with an intensity (by depth) of 10-40 mm per year. It is understandable that under these conditions, with a 20 millimeter protective layer of concrete in the 15-centimeter PES structures, the PES building would cease to exist within a few years. Calculations established that, taking into account homogeneity of concrete in frost resistance and reserve strength factor, concrete for the PES should be grade Mrz1000, which exceeded by twofold that allowed by the GOST.

Concrete compositions proposed by various institutes were tested by accelerated methods under actual Kola Bay site conditions. Based on test results, preference was given to a composition with a combined addition of sodium abietate and sulfite-alcohol malt residue proposed by the Central Construction Scientific Research Institute [2]. Features of this concrete include a limited quantity of water (water-cement ratio=0.376, OK=1-3 cm) and the necessity of maintaining 2-3% air of a specified quality in the poured concrete in order to maintain a high degree of frost resistance -- required development of a special on-site process, which was elaborated by Gidroproyekt. This concrete was poured in the PES building, and over a period of 10 years of operation it was thoroughly tested at various experimental sites. The results of study of this concrete in the tidal zone by Schmidt instrument on core samples and specimens indicated that at the most critical sites (average level 6,800 cycles) it does not sustain disintegration or losses in mass, its compressive strength with a designed M400 was 70.1-83.7 MPa, watertightness V10-V14, water absorption 0.65-0.73%, and frost resistance Mrz1000.

Investigation of concrete in the zone of total immersion with the aid of remote-control radio devices, as well as determination of concrete strength with a PIBG-2 underwater gun with ball punch and an ABG-1 aquaconcretescope enabled us to establish that disintegration of concrete under aquatic growth biomass does not occur. Its strength in this zone was 67-72 MPa. The obtained positive result of extended tests of Mrz1000 concrete made it possible to adopt a national regulation on its employment in harsh conditions and to recommend its adoption.

Of course the investigations are not ending with development of Mrz1000 concrete. A search is in progress in this area for a composition with a longer service life in the North, which can be achieved by the incorporation of a number of special additives. For large PES presently on the drawing boards, the structures of which will be subjected to the effects of large ice fields more than 2 meters thick with high ice strength, it is necessary to develop a concrete capable of withstanding the abrasive action of ice. We cannot model ice action in laboratory conditions, and therefore the possibility of conducting continuous (for a period of 8 months) tests on structural fragments for ice abrasion in the basin of the Kislogub PES is of exceptional importance. Tests of the ice abrasion resistance of concrete structures have been in progress for 6 years, at the PES. Specimens of concretes impregnated with various compounds, plastic coatings and epoxy compositions are being tested on-site. Tests are being conducted on a new method of protecting reinforced concrete structures from ice, proposed by the Georgian Scientific Research Institute for Hydroelectric Power Construction, a method which calls for coating them with a polymeric heater.

Insulation and waterproofing. Design studies indicated the importance of temperature stresses occurring in the upper part of the structure as well as that part periodically exposed by overfall. In order to eliminate these stresses, in place of the usually employed "fur coat" (wood plate-asphalt), which is quite heavy, foam epoxy insulation and watertight sealant was adopted to maintain buoyancy, applied from slabs 5 meters in thickness [3].

Investigations of this coating indicated that its heat conductivity diminished by 10-20% during the first 2 years (under the condition of coating integrity when subjected to mechanical action), evidently as a result of shrinkage, and subsequently heat conductivity remained constant. This positive result made it possible to apply foam epoxy insulation and watertight sealant on a commercial scale in construction of Dneproges-II, the Nurek, Ust'-Ilimskaya and Sayano-Shushenskaya GES, as well as the Karaganda Canal. In future utilization of epoxide-foam watertight sealant one should bear in mind that as a result of protracted measurements under "winter-summer" conditions it was established that due to the thermal inertia of the water washing a structure in the tidal zone, at the contact point with the structure there exists a microclimate which decreases the calculated temperature gradient by 30-40%.

Future investigations should also resolve the as yet unresolved problem of increasing the strength of insulation and watertight sealant under the effect of mechanical abrading loads.

Protection of PES structures and equipment from marine plant overgrowth also proved to be a very difficult problem. In the PES zone there are 53 species of fouling organisms, the biomass of which reaches 10 kg/m^2 in a year. Many of these species attach so firmly to the surface of a structure, forming a layer 2-5 centimeters thick, that they can withstand high water flow velocities (up to 8 m/s) and low air (down to -30°C) and water (down to -1.5°C) temperatures.

Since such intensive fouling of the turbine blading, just as on a ship's hull, can seriously deteriorate operating conditions, we employed here the best of the marine paints: equipment was protected by the French-manufactured coating Cellobrase, while structural components were protected with Soviet-manufactured non-fouling paints: KhS-79 (blue) and KhV-750 (green), as well as KhV-712, recognized as one of the finest in the world. Their service life (together with anticorrosion coatings) of 4-5 years is considered entirely acceptable. Subsequently, however, it is necessary to restore the coating which, in contrast to a ship, in conditions of structures permanently immersed in water, is extremely complex and costly.

In order to find more effective solutions, study has been conducted for 12 years now at the Kislogub PES of new coatings on test frames which are totally and alternatingly submerged. Alongside these studies, a search is in progress for new ways to protect structures. On the basis of a proposal by A. N. Usachev, for example, studies have been conducted at the Kislogub PES since 1972 with the aim of developing a concrete with antifouling properties, by introducing a number of bactericide additive agents to its formulation. These additives are introduced in the concrete in the form of aqueous solutions together with the mixing water in an amount up to 0.2% of the cement by weight [4]. A concrete formulation with lantanox additive was selected and tested at the first stage of this project. Tests at the PES indicated that under conditions of the Barents Sea this concrete does not become fouled by marine organisms for a period of 6 years. In addition, the cost of implementing this method of achieving a nonfouling effect is almost 15 times less than the cost of restoring nonfouling coatings. In addition, installation of equipment to protect the suction pipes from fouling with the aid of electrolytic chlorination, with seawater used as raw material, has now begun at the PES. We can assume that adoption of this method will substantially advance solution of problems of biological protection not only of PES on the drawing boards but also protection of large-diameter water pipes on various water engineering structures operating in the sea.

Hydrophobic soil in the form of a batched mixture of sand with high-strength residual oil was employed for ballasting the floating structure in the zone of variable levels. Investigations of this ballast, which is contained both in enclosed cavities within the structure proper and on test fragments, indicated that after more than 8000 cycles of alternating thawing and freezing, the hydrophobic properties of this ballast remain unchanged, which confirms its reliability.

Cathode protection [5] of the Kislogub PES, following the design of Gipromorneft' and Azneftekhim, encompasses both the structural part (reinforcement, reinforced concrete and sheet piling metal cathode box in the rock-fill linking barrages) and the equipment, where it operates jointly with imported (in the turbine unit) paint coatings.

Cathode protection of reinforced concrete structures is effected from a powerful source -- a VSA 300/600 rectifier; protection is provided by two tubular anodes placed on the bottom of the head bay, and 32 anodes installed in the PES building. Turbine protection is provided from a type KSS-Sh power-line cathode station, an automatic control system, service lines and comparison electrodes for monitoring effectiveness of protection. For this system the foreign supplier company installed on the turbine unit 30 built-in platinum-plated anodes. The cathode protection of the hydroelectric power equipment has preserved it throughout the 10 years of station operation in extraordinarily aggressive corrosion conditions of ocean-salinity seawater. As operating experience has shown, protection of the gates, provided with built-in magnesium sacrificial anodes, is effective only in the zone of total immersion.

The underwater foundation was especially thoroughly examined, since it constituted the most important condition making it possible to erect a PES without cofferdams. The foundation was laid out in the form of a half-meter layer of sand-gravel, poured down after excavation of marine sediments to the specified depth. The required antifiltration and suffosion properties of the bed were determined by the composition of the local soil, selected by the All-Union Scientific Research Institute of Hydraulic Engineering, screening out particles more than 50 mm in diameter, as well as by the effect of a frame (blades in the shape of a 250 mm angle bar), framing the block's reinforced concrete bottom. Poured in place by the clamshell of a floating crane, the bed was leveled by specially built devices.*

Thorough studies of the foundation were conducted during the entire 10-year period of PES operation. Observations employing piezometers placed at the base of the foundation indicated that change in water levels on the sea and basin sides of PES are rapidly recorded by piezometers, which attests to the absence of stagnation zones, while the pressure head gradients varied within limits of 0.08-0.15, which produced a filtration flow rate of 0.12-0.15 m^3/s. Regular annual measurements of approach channels

---

* Certificate of Invention 268279 (USSR). Device for Forming Underwater Beds/V. G. Gavrilov. Published in B. I., No 13, 1970.

indicated the absence of dangerous deformations and any suffosion of material from the bed.

The most indicative for the state of the foundation were the results of observations of settling of the PES building, performed on a regular basis by precision leveling: at first annually, and subsequently once every 2-3 years. During the first three years settling averaged 20 mm at the four corners (maximum difference 3 mm), while subsequently settling stabilized to 1 mm per year uniformly at the four corners. All these data attest to the suffosion filtration reliability of the foundation and enable us to recommend it for large PES and other floating structures. In particular, such a foundation bed was prepared for the floating foundations of the towers of the 330 kilovolt overhead line in the Kakhovka Reservoir.

Power generation studies. Studies of hydroelectric power generating operations were not for the purpose of obtaining any new solutions, since they were performed by the supplier (the French (Neyrpik) Company) on the basis of development of the hydroelectric generating unit installed at the Rance Tidal Power Station, where these units have demonstrated their exceptional efficiency, obtaining from the flood (ebb) tide a maximum quantity of electric power and transforming generation of tidal power from a lunar to a solar cycle. Studies of the power equipment at the Kislogub PES conducted by the Gidroproyekt Scientific Research Station confirmed these capabilities as well as the possibility of generating at the PES the designed quantity of electric power while operating in a mode of maximum yield and specified power output: 0.75 of installed generating capacity during peak demand hours, regardless of tide phase.

A new innovation in this area was development of a variable rpm unit. This proposal was presented in 1961 by L. B. Bernshteyn [6] and based on the fact that in PES operating conditions pressure heads on the turbine change between five and seven times during a cycle. Maintaining constant rpm leads to substantial energy losses. Study of ways to solve the problem of obtaining constant generator rpm (required by its AC power line hookup) resulted in selection of an induction-synchronous motor-generator (ISMG) proposed by M. M. Botvinnik, Yu. G. Shakaryan, and N. N. Blotskiy [1], equipment which, due to a variable state or magnetic field rate, makes it possible to convert the turbine's variable rpm to generator rotor constant rpm. This unique equipment, built at the Elektrosila LPEO [expansion unknown] with a control system built at the Uralelektrotyazhmash Production Association, was installed at the PES (in place of an imported synchronous generator) and, upon completion of testing, demonstrated a capability to increase PES power generation by 10%. which opens up realistic prospects for increasing the efficiency not only of tidal power stations but also river hydroelectric power stations which experience considerable head fluctuations.

Ecology, commercial fishing. These studies are of decisive significance for designing large PES. Studies conducted by a number of organizations indicated that the ecological properties of the PES basin did not undergo change during the entire 10-year period of PES operation. This is due to preservation of the natural water exchange between basin and sea at the PES site.

It was established that the PES rectilinear-axis blading promotes the passage of commercial fish not only through the water passage openings but also through the turbine without causing injury [7].

In the process of these studies it was established that there is a favorable potential for utilizing a PES base for development of commercial fishing. This was demonstrated by establishment in the Kislogub PES basin of a fish farm for breeding Atlantic and Quinnat salmon.

Investigation of side recovery of trace elements from seawater. We know that world reserves of rare elements are rapidly becoming exhausted, while some are close to disappearance. Under these conditions the age-old problem of extracting these elements (including gold, silver, etc) is being studied today in a number of countries. Determining in this study is the development of efficient sorbents and organization of passage of very large quantities of seawater. Independent resolution of the second part of this problem requires building extremely costly water-passing dams spanning entire straits or narrows. Academy of Sciences Corresponding Member Yu. V. Gagarinskiy advanced the idea of secondary utilization of PES structures for this purpose [8]. On-site studies conducted at the Kislogub PES demonstrated the practical possibility of such a solution, which requires installation of frames with sorbents in the water-passage and turbine penstocks, which leads to corresponding relatively small additional expenditures and loss of several percent of PES power generation. The effectiveness of this solution can be established upon obtaining high-productivity sorbents, a search for which is in progress.

It becomes obvious from the figures cited above that construction of the Kislogub PES and the studies conducted at it are opening up the possibility of well-substantiated designing of large tidal power stations (Lumbovskaya -- 0.4 million kilowatts; Mezenskaya, 10 million; Tugurskaya and Penzhinskaya -- from 35 to 100 million kilowatts). The significance of the Kislogub PES, however, is certainly not limited to this. New technical solutions obtained during its construction and verified in the process of subsequent studies have found application in various areas of hydraulic engineering and power engineering construction.

We should mention first of all construction of a 330 kilovolt overhead power line crossing on the Kakhovka Reservoir, employing 100 meter towers brought to the on-water site on floating foundations. This project was carried out on the basis of experience gained from construction of the Kislogub PES and provided savings of 8 million rubles [9].

By decision of a USSR Gosstroy expert commission, a variant design is presently being developed on the basis of this experience, for construction by the floating method of spillway gates in a Leningrad flood control dam.

Considerable savings have also been obtained by employing the structural materials of the Kislogub PES (extremely high frost-resistance concrete and efficient epoxide foam insulation and watertight sealant).

The Kislogub PES played a very important role in development in the USSR of an efficient capsule hydroelectric turbine and its extensive adoption at low-head GES.

In 1959, during study of the French experience of building a capsule unit for a PES in the USSR, the proposal was first made calling for extensive employment of these units for specific low-head GES which were on the drawing boards at that time [10]. A thorough study and investigations made it possible to implement this proposal on a broad scale. At the present time 54 capsule units with a total generating capacity of 1.26 million kilowatts have been installed and are successfully in operation, which has produced savings of 57 million rubles on capital investment.

In addition, Soviet machine builders have mastered the manufacture of this equipment so well that they have been able to take an important step forward in the evolution of these units, building the world's largest encased unit with an encased suspended wheel diameter of 7.5 meters, with eight such units sold to other countries.

Thus we can make the entirely warranted conclusion that the Kislogub PES, located far beyond the Arctic Circle along the rugged coastal cliffs of the Barents Sea, has proven itself and has become a laboratory of advanced technology in hydroelectric power construction not only in the Arctic but also in various other parts of this country.

BIBLIOGRAPHY

1. "Kislogubskaya PES" [Kislogub Tidal Power Station], Moscow, Energiya, 1972, 263 pages.

2. Usachev, I. N. "New Materials for Water Engineering Construction," STROITEL'NYYE MATERIALY I KONSTRUKTSII, No 4, 1978, pp 11-15.

3. Certificate of Invention 234666 (USSR). Method of Producing Epoxide Foam/ V. I. Sakharov, A. A. Igonin. Published in B. I., No 4, 1969.

4. Usachev, I. N. "Protection of Water Engineering Structures in the Barents Sea," in the book "Primeneniye polimernykh materialov v gidrotekhnichskom stroitel'stve" [Employment of Polymeric Materials in Water Engineering Construction], Leningrad, Energiya, 1972, pp 143-148.

5. Trifel', M. S.; Plizade, G. Ya.; and Mamedov, A. K. "Electrochemical Protection at the Kislogub PES," GIDROTEKHNICHESKOYE STROITEL'STVO, No 4, 1972, pp 20-26.

6. Bernshteyn, L. B. "Pogruzhnyye gidroagregaty" [Submersible Hydroelectric Turbines], Moscow, TsINTIMash, 1961, 211 pages.

7. Pasternak, V. S., and Surkov, S. S. "Distribution and Behavioral Features of Commercial Fish in the Zone of Influence of the Kislogub Tidal Power Station," in the book "Biologicheskiye osnovy upravleniya povedeniyem ryb v svyazi s primeneniyem rybozashchitnykh i rybopropusknykh sooruzheniy" [Biological Principles of Controlling Fish Behavior in Connection With Employment of Fish Protection and Fish Passage Structures], Moscow, 1971, pp 20-23.

8. Gagarinskiy, Yu. "The Ocean Through the Eyes of Chemists," PRAVDA, 17 March 1973.

9. Bernshteyn, L. B., and Gavrilov, V. G. "Construction of a 330 Kilovolt Overhead Power Line Crossing on Floating Reinforced Concrete Foundations," ENERGETICHESKOYE STROITEL'STVO, No 8, 1977, pp 26-29.

10. Bernshteyn, L. B. "Increasing the Efficiency of Low-Head Hydroelectric Power Stations," GIDROTEKHNICHESKOYE STROITEL'STVO, No 9, 1959, pp 36-42.

COPYRIGHT: Izdatel'stvo "Energiya", "Energeticheskoye stroitel'stvo", 1980

3024
CSO: 1822

APPROVED FOR RELEASE: 2007/02/08: CIA-RDP82-00850R000200070041-7

ELECTRIC POWER

UDC 621.3.019.3:621.314.212.001.14

METHODS OF TESTING POWER TRANSFORMER RELIABILITY

Moscow IZVESTIYA AKADEMII NAUK SSSR ENERGETIKA I TRANSPORT in Russian No 1, Jan-Feb 80 pp 19-25 manuscript received 28 May 79

[Article by V.V. Sokolov and V.A. Lukashchuk, Zaporozh'ye: "Questions of Estimating and Providing for the Reliability of Power Transformers"]

[Text] Questions of quantitatively evaluating the reliability of power transformers are treated. Results of an analysis of the level of reliability of transformers are given using nontraditional methods of processing the statistical data. A classification is given for the causes of transformers failures in light of the design of a diagnostic system. Approaches to the assurance of transformer reliability are formulated. Figures 4, tables 1, bibliographic citations 6. pp 19-25.

The growth in the power and working voltages of electrical installations is confronting transformer construction with the problem of further improving the technical and economic indicators of transformers and improving their operational reliability. These requirements are to a certain extent contradictory, since making a design efficient leads to an increase in the specific working loads on materials, something which entails an increase in the sensitivity to the degradation of the condition of the transformers in operation. Operational experience with foreign transformers shows that the reliability of modern transformers proves to be lower in a number of cases than those produced 15 to 20 years ago, where the specific number of failures [1] increases with an increase in the voltage class (Figure 1). Moreover, the failure of a large transformer leads to considerable losses, related to the failure to deliver electrical power and the cutoff of generator capacity, as well as expenditures for repair, which frequently amount to more than 60 percent of the original cost. All of this makes it necessary to increase the requirements placed on tranformer reliability as well as the methods for estimating and assuring it.

For a number of reasons, power transformers are not subjected to tests for reliability, and the effectiveness of designer efforts to increase the reliability can be quantitatively assessed only from the results of

APPROVED FOR RELEASE: 2007/02/08: CIA-RDP82-00850R000200070041-7

transformer performance in service. But estimating transformer reliability based on operational results also has its own specific features.

Group 15-05 of CIGRE proposed a procedure for estimating the reliability of tranformers, according to which the indicators are defined as the averaged figures over a specified period, specifically, the failure rate is defined as:

$$FR_m = n/NT$$

where n is the number of transformers which have failed, N is the number of installed tranformers and T is the observation period.

Consdiering the fact that the average service life of transformers amounts to 20 to 30 years, it is recommended that the observation period be specified in a range of 2 to 3 years. Such an approach is convenient for a comparative analysis, but of little effectiveness in resolving the questions of forecasting failure free service within the limits of the specified time periods, planning observations, establishing guarantee periods, etc.

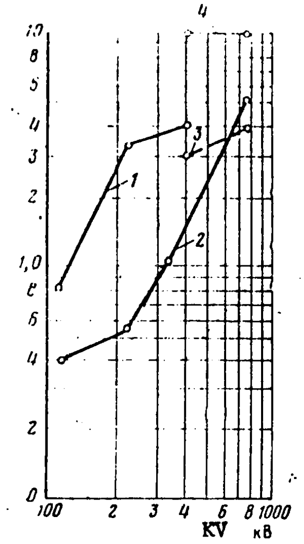


Figure 1. Number of failures per 100 years of transformer service of foreign transformers as a function of the voltage class.

Key:
1. The combined power systems of the Federal Republic of Germany;
2. Hydro-Quebec (Canada);
3 ,4. Block transformers and autotransformers as evaluated by committee No. 12 of the CIGRE.

Power transformers number among the higly reliable static devices with service lives of tens of years, where an insignificant fraction of the installed transformers either fails or is damaged within the period between maintenance servicing, something which does not make it possible to use traditional methods of probability theory and mathematical statistics to process data on failures and requires the use of nontraditional methods [2-5].

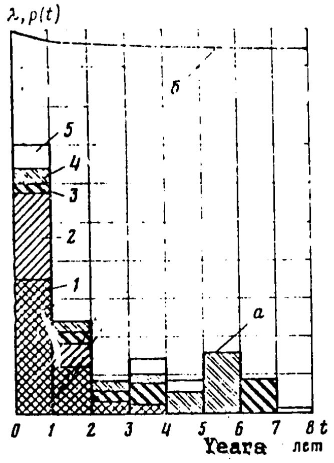


Figure 2. Histogram of the rate (a) and the curve for the probability of failure free service (b) of 110 KV power transformers.

Key:
1. Insulation failures due to moisture;
2. Insulation failures (interwinding breakdown);
3. Heating of current carrying connections;
4. Short circuit;
5. Other.

In analyzing the reliability of various groups of transformers, an intermediate characteristic is employed: the failure rate, where fixed volumes of tests and test times are not required to derive this figure. The calculations of $\lambda(\tau_j)$ are made from a formula which takes into account the change in the volume in a finite time interval $\Delta t_j = \tau_j - \tau_{j-1}$ because of products which have failed and those which were dropped from the tests for reasons not related to failures [5]:

$$\lambda(\tau_j) = \frac{n_j}{\left[N - \sum_{k=0}^{j-1} (N_{1k} + n_k - n_{1k})\right] (\tau_j - \tau_{j-1})}, \qquad (1)$$

where N is the original volume of the sample, N_1 is the number of products removed from testing, n is the number of failed products, and n_1 is the number of products which have failed from among those removed from testing.

The following function is defined in a similar manner

$$r(\tau_j) := \sum_{1}^{j} \lambda_j \Lambda t_j, \tag{2}$$

which has come to be called the accumulated rate [3], by means of which the values and form of the distribution function are established.

To establish the form of the distribution function, a graphical method was used which was based on the utilization of linearized distributions in the form of functions of the type

$$\psi(\tau) = c + hg[r(\tau)], \tag{3}$$

where $\psi(\tau)$ and $g[r(\tau)]$ are certain (known) functions of the mean time before failure and the accumulated rate respectively, c and h are distribution parameters (transformed in the well known manner).

The selection of the distribution law is likewise made, being governed by the objective measure of closeness of the sample function between the mean time before failure and the accumulated rate to a linear function. Used as this measure was a sample correlation coefficient between the indicated functions [3]:

$$\rho = \frac{\Sigma\psi_j g_j - (\Sigma\psi_j)(\Sigma g_j)/k}{\sqrt{[\Sigma\psi_j^2 - (\Sigma\psi_j)^2/k][\Sigma g_j^2 - (\Sigma g_j)^2/k]}}, \tag{4}$$

where ψ_j and g_j for certain distributions are found as parameters of linear functions of type (3) from the table.

The parameters c and h of the linear function of the selected law were evaluated by the method of least sqares. The resulting estimates were specified more precisely by the method of maximum likelihood. Used as the maximum likelihood function in this case was the product of the sample densities of all of the observed mean times between failures and the probabilities of failure free operation of all of the products which had not failed.

The likelihood equations were solved by iteration with a certain precision specified in advance.

Histograms and curves for the probability of failure free service of sets of low power 110 KV transformers with a capacity of more than 80 MVA are shown in Figures 2 and 3, which were obtained by means of the methods described, and characterize the change in the reliability over a period of 8 to 12 years. The results of the calculations made it possible to establish the correspondance between the statistical data and Weibull distribution:

$$F(t)=1-e^{-(t/a)^b}, \tag{5}$$

where a is a scale factor and b is a form factor.

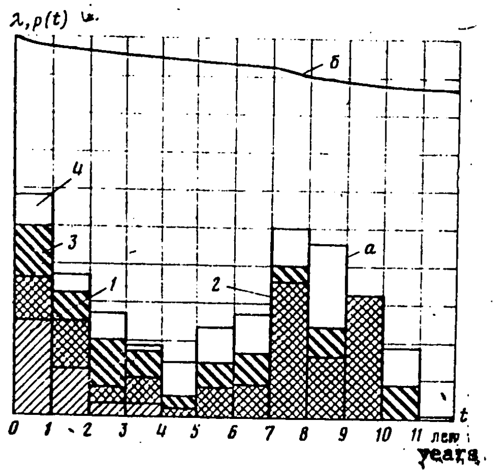


Figure 3. Histogram of the intensity (a) and curve for the probability of failure free service (b) of power transformers with a capacity of more than 80 MVA.

Key:
1. Sudden failures due to defects in structural design and production technology;
2. Failures due to degradation and breakdown of the insulation in operation;
3. Developing failures, due to increased heating of current carrying connections and structural components of the active section;
4. Failures due to the effect of a short circuit and other short term elevated effects.

This conclusion agrees with the resuls of similar studies by other authors [6]. The distribution curve for 110 KV transformer failures (Figure 2) has a form factor of b = 0.371, something which attests to the considerable increase in reliability with the expiration of the run-in period, the steady length of which is two years from the start of operation. Characteristic of these transformers is the rejection of transformers with weakened insulation in the first years of service. The percentage of the two other kinds of failures - because of heating of current conducting connections and because of the action of short circuit currents - increases slightly by the sixth year of operation.

Параметры Parameters	Distribution Laws законы распределения			
	(1) экспоненциальный	(2) Вейбулла	(3) логарифмически-нормальный	(4) нормальный
g	τ	$\ln \tau$	$\Phi^{-1}(1-e^{-r})$	$\Phi^{-1}(1-e^{-r})$
ψ	r	$\ln r$	$\ln \tau$	τ

Key: 1. Exponential;
2. Weibull;
3. Log-normal;
4. Normal.

While low power 110 KV transformers are not so much subject to the influence of service quality, sensitivity to operational violations is well seen in the aggregate of transformers with capacities of more than 80 MVA (Figure 3). The distirbution curve for the failure of high power transformers has a form factor of b = 0.754, while the histogram for the rates has three clearly pronounced sections.

In the first section, defects in the fabrication and installation while other factors remain practically constant are ascertained over a period of three years. At the end of this period, there is a slight stabilization of the indicators. Upon the expiration of the six year period, an increase in the failure rate is observed, which is due to the manifestation of degradation and violation of the insulation due to servicing deficiencies, as well as the manifestation of the cumulative effect of short circuit currents which occurs over this period. Failures occur over this same period because of some developing effects, which are not ascertained because of deficiencies in traditional methods of diagnosis. In the third section, the failure rate agains falls off as a result of the rejection of defective transformers.

As calculations perform for sets of transformers of different design levels have shown, the introduction of refinements for the purpose of eliminating specific kinds of failures reduces the information content of the samples and makes it difficult to obtain unambiguous probability functions and estimates. However, the results obtained make it possible to define some extremely important approaches to increasing reliability, besides constantly improving technology.

For the purpose of reducing the failure rate in the initial operation period, i.e., for the purpose of eliminating the run-in period, it is expedient to implement testing for the long term impact of nominal currents and voltages both on individual assemblies and components as well as on the completely assembled transformer.

To eliminate failures due to impermissible short term actions, it is essential on one hand, to study the cumulative effect of short term actions, and on the other, to seek out possibilities of controlling the cycles and numbers of short circuits in power systems.

Increasing the reliability of large transformers should likewise take the approach of simplifying the structural design, in particular, in certain kinds of transformers it is necessary to limit the use of winding switching devices (in block transformers, those for ultrahigh voltage classes, etc.).

An important trend in increasing the reliability of ultrahigh voltage transformers is the implementation of measures to maintain stable insulation characteristics in service by means of constant removal of wear products. For modern transformers, with their large volume of insulation materials, refinement of the diagnosis of the condition by means of developing methods for continuously monitoring moisture, gas saturation, local insulation hot spots, etc., all acquire considerable importance.

For the purpose of ascertaining the governing relationships in failures and establishing the system tasks for diagnosing transformers, more than 6,000 transformers with capacities of 16 MVA and higher were studied, ranging in voltage from 35 to 500 KV with an overall service life of more than 35,800 transformer years. Some 623 failures were considered and analyzed over a six year period.

As analysis has shown, more than eight percent of the failures were caused by internal (hidden) damage; the majority (about 60 percent) of the failures was related to distruction of the electrical insulation, while the remaining were caused by a disruption of the electrical conductivity (breaks in the current carrying circuitry and hot spots due to current flow), as well as by a mechanical strength failure. The adopted classification of failures conforms to the task of designing optimal diagnostic systems.

The assignment of failures to one of the following groups is of substantial importance for establishing the possibility of diagnosis by means of periodic tests: developing damaging; damage due to defects of a wear nature; sudden damage.

Experience shows that an average of about 40 percent of the failures are due to developing damage (Figure 4), which can be eliminated in an early stage of development. The percentage of such failures increases markedly among transformers of higher voltage classes and for the 500 KV class, amounts to about 80 percent. In 35 and 110 KV transformers, the major kinds of developing damage are heating of current carrying connections of taps and switching devices. It was likewise determined that damage to insulation by partial discharges occurred primarily as a consequence of dirt contamination of the insulation by various impurities following comparatively long term operation (7 to 13 years). This indicates the promise of warning of failures by means of monitoring wear defects.

Moisture intrusion is the most frequent of the wear type defects. In 35-110 KV transformers, the causes of dangerous moisture intrusion are predominantly related to circumstances which precede their going into service, or which exist in the initial operational period. In 220-500 KV transformers, such causes exist practically throughout the entire operational period. A study of failures related to contamination of insulation by moisture and solid impurities showed that the rate of such failures obeys a Weibull distribution with a form factor of b = 1.05.

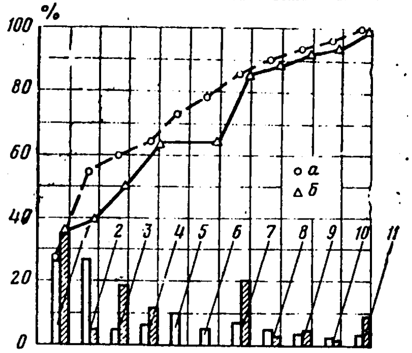


Figure 4. Causes of the failures of high power transformers at 220-500 KV (a) and 35-110 KV (b).

Key:
1. Sudden damage;
2. Heating of the structural components of the active section;
3. Heating of the current carrying connections of switching devices;
4. Heating of the current carrying connections of taps;
5. Partial discharges in the insulation;
6. Partial deformations of the windings;

[Key to Figure 4, continued]:

7. Moisture infiltration;
8. Ageing;
9. Dirt contamination;
10. Gas saturation;
11. Violation of the insulation spacings (and other insulation violations).

An analysis of the causes of failures confirms the comparatively slight influence of thermal oxidation ageing on reliability, given the existing state of high power transformers.

A study of the condition of the insulation of a group of transformers with capacities above 80 MVA likewise show that the problem of high power transformer ageing is primarily determined by the increased wear of individual heated sections, given the satisfactory condition of the bulk of the insulation. A substantial role in the process of insulation destruction is played by oil decomposition products.

More than 20 percent of the failures (Figure 4) is caused by damage of a sudden nature, the early diagnosis of which is not expedient in practice. Numbered among them are failures due to short term increased effects during operation, as well as some other kinds of failures due to hidden defects, which lead to shorted turns in the windings. The results of studying the length of the development of damage using models for the interwinding insulation have shown that the overall time for the development prior to breakdown ranges from units to several tens of hours. Consequently, the diagnosis of such faults is possible only with continuous long term monitoring of the insulation.

Thus, with the design of a sufficiently efficient diagnostic system, there can be forewarning of about 70 percent of failures, while at the present time, slightly more than 20 percent of the failures are detected, in which case, the majority of them are detected by unconventional methods. The primary tasks of such a system should be the detection of insulation defects which lead to an intolerable reduction in the electrical strength during operation, and the detection of developing defects at an early stage of development. For the most important transformers, it is expedient to implement continuous diagnostic procedures.

Conclusions: 1. The procedure used to analyze the failures of transformers makes it possible to estimate the reliability of the transformers being manufactured, and creates the conditions for the development and implementation of standards for reliability indicators.

2. It was established as a result of the calculation that the distribution of the failures of power transformers obeys a Weibull distribution law with

form factors of from 0.3 to 0.75. Production improvement is characterized by the form of the distribution approaching an exponential one.

BIBLIOGRAPHY

1. A. Bossi, L. Giannuzzi, G. Manzoni, F. Coppadoro, G. Sigaudi, "Chice of the Characteristics of Power Transformers for UHV Systems", CIGRE, Aug. 30 - Sept. 7, 1978, Paper No. 12-11, RZh VINITI "ELEKTROTEKHNIKA I ENERGETIKA" [JOURNAL OF ABSTRACTS, ALL-UNION INSTITUTE FOR SCIENTIFIC AND TECHNICAL INFORMATION, "ELECTRICAL AND POWER ENGINEERING"], 1979, No 1, Abstract 1I270.

2. D.Ye. Kadomskiy, "Opredeleniye zakona razpredeleniya dolgovechnosti elementov v sluchaye ogranichennoy prodolzhitel'nosti ispytaniy na razlichnykh ob"yektakh" ["The Determination of the Distribution Curve for the Service Life of Components in the Case of Limited Test Duration for Various Objects"], IZV. NII POST. TOKA, "Peredacha energii postoyannym i peremennym tokom" [PROCEEDINGS OF THE DIRECT CURRENT SCIENTIFIC RESEARCH INSTITUTE, "Direct and Alternating Current Power Transmission"], Collection 11, Energiya Publishers, 1965.

3. A.S. Agapov, "Opyt primeneniya nekotorykh metodov statisticheskoy otsenki nadezhnosti promyshlennykh izdeliy" ["Experience with the Use of Certain Statistical Estimate Procedures for the Reliability of Industrial Products"], the series, "Uluchsheniye kachestva promyshlennoy produktsii (standartizatsiya, povysheniye nadezhnosti, zashchitnyye pokrytiya, tekhnicheskaya estetika)" ["Improving the Quality of Industrial Products (Standardization, Improving Reliability, Protective Coatings, Engineering Esthetics)"], Leningrad, LDNTP Publishers, 1977.

4. I.A. Korol', "Otsenka kharakteristik nadezhnosti po usechennym vyborkam s razlichayushchimisya narabotkami neotkazavshikh izdeliy" ["Estimating Reliability Characteristics based on Truncated Samples with Differing Accrued Operating Times of Products which have not Failed"], NADEZHNOST' I KONTROL' KACHESTVA [RELIABILITY AND QUALITY CONTROL], 1977, No 11.

5. D.Ye. Kadomskiy, "Opredeleniye kharakteristik nadezhnosti elementov po dannym nachal'nogo perioda ekspluatatsii" ["The Determination of the Reliability Characteristics of Components based on Data from the Initial Operating Period"], IZV. NII POST. TOKA, "Peredacha energii postoyannym i peremennym tokom", Collection 12, Energiya Publishers, 1966.

6. V.A. Nepomnyashchiy, "Uchet nadezhnosti pri proyektirovanii energosistem" ["Accounting for Reliability in the Planning of Power Systems"], Energiya Publishers, 1978.

COPYRIGHT: Izdatel'stvo "Nauka", "Izvestiya AN SSSR, energetika i transport", 1980.

8225
CSO:1822

END