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USSR Report

ENGINEERING AND EQUIPMENT

(FOUO 4/81)

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UDC [621.311.25:621.039]:621.181.6

USING VERTICAL STEAM-RAISING UNITS TO FURTHER IMPROVE GENERATING FACILITIES WITH VVER REACTORS

Moscow ENERGOMASHINOSTROYENIYE in Russian No 3, Mar 81 pp 2-4

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[Text] One way to improve nuclear electric plants is to increase the initial steam parameters and optimize the structure of the heating arrangement. For nuclear electric facilities with VVER [water-cooled water moderated power] reactors, without changing the parameters of the primary circuit (pressure and temperature of the coolant at reactor inlet and outlet), the parameters of the secondary circuit are determined by the minimum temperature difference in the steam-raising unit.

In the horizontal steam-raising units that are used for generating facilities with VVER reactors, the entire heating surface works as an evaporator. The feed water supplied to the steam chamber in the steam-raising unit is heated from temperature t_{FW} (at the outlet from the regenerating system of the turbine set) to the saturation point t_s^{II} corresponding to the steam pressure by condensing some of the spent steam. In this case (Fig. 1)

$$t_s^{II} = t_2 - \Delta t_{min}; \qquad (1)$$

where t_2 is the water temperature in the primary circuit at the outlet from the steam-raising unit; Δt_{min} is the minimum temperature head at the beginning of the evaporative section. At the minimum possible value of $\Delta t_{min} \sim 10°C$ accepted in the generating units of the VVER-1000 the initial steam pressure of $p_0 = 6.4$ MPa is essentially the limiting value.

In a horizontal steam-raising unit the size of the heating surface is independent of the temperature of the feed water, and therefore at fixed parameters of the primary circuit the optimum size of the heating surface is determined only by the relation between the change of electric power of the unit and the heating surface of the regenerative heaters, i. e. a value of t_{FW} close to the thermodynamic optimum is justified (at $p_0 = 6.4$ MPa, $t_{FW} \sim 225°C$). Thus when horizontal

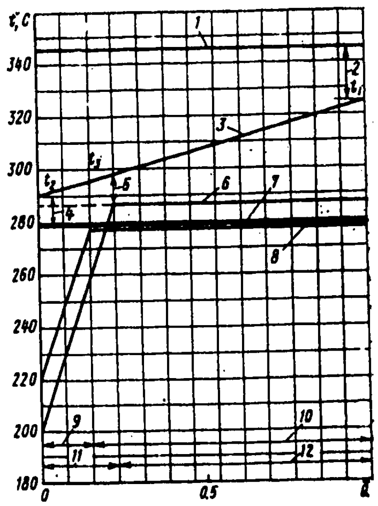

Fig. 1. t-$\bar{Q}$ diagram of the steam-raising unit ($\bar{Q}$ is the relative thermal power of the steam-raising unit): 1--saturation temperature t_s^I corresponding to the water pressure in the reactor circuit; 2--underheating of water below boiling in the primary circuit Δt_{boil}; 3--parameters of coolant in the primary circuit $t_1 = 325°C$, $t_2 = 290°C$; 4--minimum temperature difference Δt_{min} in an arrangement without economizer; 5--minimum temperature difference Δt_{min}^{ec} in a system with economizer; 6--saturation temperature in the secondary circuit $t_s^{II} = 286.4°C$ ($p_0 = 7.2$ MPa); 7--saturation temperature in the secondary circuit $t_s^{II} = 278.5°C$ ($p_0 = 6.4$ MPa); 8--water temperature in the economizer section ($p_0 = 6.4$ MPa); 9--relative thermal power of the economizer section $\bar{Q}_{ec}$ at $p_0 = 6.4$ MPa; 10--relative thermal power of the evaporative section $\bar{Q}_{evap}$ at $p_0 = 6.4$ MPa; 11--relative thermal power of economizer section at $p_0 = 7.2$ MPa; 12--relative thermal power of the evaporative section $\bar{Q}_{evap}$ at $p_0 = 7.2$ MPa.

steam-raising units are used in VVER-1000 generating facilities without changing the parameters of the primary circuit there is no possibility of further increasing the parameters of the secondary circuit.

The situation changes when a vertical steam-raising unit is used since there is a capability for segregating part of the heating surface in the zone of minimum temperatures of the coolant in the primary circuit of this steam-raising unit for the purpose of heating the feed water from t_{FW} to t_s^{II}, i. e. introducing an economizer section $Q_{ec} > 0$ (see Fig. 1).

In this case

$$t_s^{II} = t - t_{min} + Q_{ec}/G_I c_{pI}, \qquad (2)$$

where Q_{ec} is the thermal power of the economizer section, G_I and c_{pI} are respectively the flowrate and mean heat capacity of the coolant in the primary circuit on the economizer section.

Comparing expressions (1) and (2), we arrive at the conclusion that for unchanged parameters of the primary circuit and the minimum possible Δt_{min}, an economizer section can raise the pressure in the secondary circuit, and the increase is greater with increasing Q_{ec}, i. e. decreasing feed water temperature.

When the same pressure is maintained in the secondary circuit of the vertical steam-raising unit as in the horizontal unit, the minimum temperature head is greater for the vertical unit, $\Delta t^{ec}_{min} = t_3 - t^{II}_s > \Delta t_{min}$, where t_3 is the coolant temperature in the primary circuit corresponding to the minimum temperature difference in the vertical steam-raising unit. As a consequence, the mean logarithmic temperature head $\Delta t^{evap+ec}_{m\ log}$ for the vertical steam-raising unit is higher than the corresponding logarithmic temperature head $\Delta t^{evap}_{m\ log}$ of the horizontal unit, which in turn gives a gain in heating surface for the vertical unit. Calculations show that at $p_0 = 6.4$ MPa, this gain is an estimated 20% over the heating surface.

However, research has shown that the advantages of segregating the economizer section in the vertical steam-raising unit can be put to more effective use for raising the initial steam parameters rather than for reducing the area of the heating surface, as relative reduction of the average temperature head with increasing pressure in the secondary circuit is lower in the case of the vertical steam-raising unit than for the horizontal unit. Thus as the parameters of the secondary circuit are increased, there is less of an increase in the heating surface of the steam-raising unit with the economizer than without the economizer.

This ratio in the change of heating surfaces increases in favor of the vertical steam-raising unit if we consider the fact that there is some increase in the thermal power of the economizer section with increasing t^{II}_s, which leads to an increase in temperature t_3.

Thus for constant thermal power of the reactor and parameters of the primary circuit $t_1 = 325°C$ and $t_2 = 290°C$, at an initial pressure of $p_0 = 6.4$ MPa the mean logarithmic temperature difference for a horizontal steam-raising unit $\Delta t_{m\ log}$ is 24.4°C, while for a vertical steam-raising unit at $t_{FW} = 220°C$ and Δt_{min} of 16.8°C,

$$\Delta t_{m\ log} = \Delta t^{ec}_{m\ log}\bar{Q}_{ec} + \Delta t^{evap}_{m\ log}\bar{Q}_{evap} = 31.5°C,$$

where $\bar{Q}_{ec}$ and $\bar{Q}_{evap}$ are respectively the percentages of thermal power of the economizer and evaporative sections under condition of equality of the heat transfer coefficients on these sections.

Thus the difference between the heating surfaces of the two types of steam-raising units at $p_0 = 6.4$ MPa is about 29%.

As a result of the pressure increase in the secondary circuit to $p_0 = 7.2$ MPa, for the horizontal steam-raising unit at $\Delta t_{min} = 4.6°C$, $\Delta t_{m\ log} = 14°C$, whereas for the vertical unit $\Delta t_{m\ log} = 23°C$, i. e. in this case the difference between the heating surfaces will be about 64% in favor of the vertical steam-raising unit. If we consider some difference in the heat transfer coefficients on the economizer and evaporative sections, the gain in surface for the vertical unit at $p_0 = 6.4$ MPa will be about 20%, and at $p_0 = 7.2$ MPa it will be about 45%.

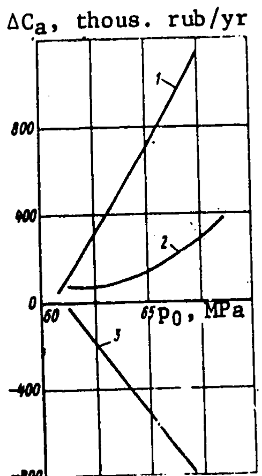

Fig. 2. Change in adjusted expenditures for a VVER-1000 generating facility with horizontal steam-raising unit as a function of the initial steam pressure: 1--for the steam-raising unit (ΔC^{SR}); 2--replaced power, for the intermediate superheater and for the regeneration system ($\Delta C_a^{el} + \Delta C_a^{SH} + \Delta C_a^{reg}$); 3--total for the unit ($\Sigma\Delta C_a$)

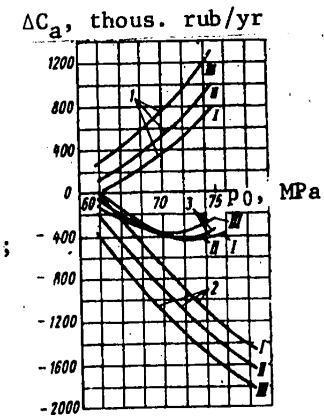

Fig. 3. Change in adjusted expenditures for a VVER-1000 generating facility with vertical steam-raising unit as a function of initial pressure p_0 and feed water temperature t_{FW}: I--t_{FW}=180°C; II--t_{FW} = 200°C; III--t_{FW} = 220°C; 1--for the steam-raising unit (ΔC^{SR}); 2--for replaced power, for the intermediate superheater and for the regeneration system ($\Delta C_a^{el} + \Delta C_a^{SH} + \Delta C_a^{reg}$); 3--total for the unit ($\Sigma\Delta C_a$)

The described situation is illustrated by a comparison of Fig. 2 and 3 from which we can see that the rate of change in adjusted expenditures for the steam-raising unit with increasing pressure is considerably greater for the horizontal steam-raising unit than for the vertical one (difference in slope of the curves for ΔC_a^{SH}).

The optimum initial pressure is determined from the value of

$$\min\Sigma\Delta C_a = \Delta C_a^{el} + \Delta C_a^{SH} + \Delta C_a^{reg} - \Delta C_a^{SR},$$

where $\Delta C_a^{el} + \Delta C_a^{SH} + \Delta C_a^{reg}$ is the total change in adjusted expenses for replaced power, for the intermediate superheater and for the regeneration system; ΔC_a^{SR} is the change in adjusted expenditures for the steam-raising unit.

The optimum value of p_0 corresponding to $\min\Sigma\Delta C_a$ for a vertical steam-raising unit will always be higher than for a horizontal unit since the curve for ΔC_a^{SR} with the same behavior of thermal economy with increasing p_0 for the vertical unit lies below the analogous curve for the horizontal unit, and the overall curve $\Sigma\Delta C_a$ changes sign of the derivative at a point corresponding to a higher value of p_0.

These is also a change in the optimum feed water temperature when a horizontal steam-raising unit is used. In the horizontal steam generator, expenditures had no effect on the optimum t_{FW}. In the vertical unit, the optimum feed water temperature is defined as the minimum difference of reduced expenditures ΔC_a^{el} due to the change in power of the generating unit, expenditures for the regeneration system and intermediate superheater $\Delta C_a^{reg} + \Delta C_a^{SH}$, and expenditures for the steam-raising unit ΔC_a^{SR}.

Fig. 3 shows how the adjusted expenditures vary by components as a function of pressure in the secondary circuit and temperature of the feed water in a range of 180-220°C for a VVER-1000 generating facility with vertical steam-raising unit. An increase of initial pressure in the vertical steam-raising unit shifts the optimum temperature of the feed water toward lower values.

At currently accepted parameters of the primary circuit for a vertical steam-raising unit the optimum parameters of the secondary circuit are initial pressure of 7.2 MPa and $t_{FW} = 200°C$. These parameters give an appreciable economic effect as compared with 6.4 MPa and 220°C; they can be obtained by changing the thermal arrangement somewhat.

In particular, the optimum feed water temperature (about 200°C) can be obtained by increasing the pressure in the deaerator to 1.25 MPa and by feeding the heating steam condensate from the single-stage intermediate superheater to the pressure line of the feed pumps.

Implementation of these steps requires development of a deaerator designed for increased pressure and the inclusion of an additional pump in the heating system for transfer of the condensate of the intermediate steam superheater. However, these expenditures are paid back with interest by the advantages that are obtained as compared with the heating system for horizontal steam-raising units. Let us list the most important of these advantages: feeding the condensate of the heating steam from the intermediate superheater into the feed water channel improves the economy of the generating facility by reducing the power of the feed pump and cutting losses in heat exchange; increasing the temperature difference of the heating and heated steam in the single-stage intermediate superheater (due to increased initial pressure) reduces the heating surface as compared with a two-stage superheater; three high-pressure heating stages with total heating surface of 15,000 sq. m (six shells) are eliminated from the heating system; the temperature difference ($t_s^{II} - t_{FW}$) on all working conditions of the steam-raising unit remains nearly constant because hot condensate of the intermediate superheater is fed into the feed water line; the increase in initial parameters of the secondary circuit improves the thermal economy of the generating facility by about 0.7%; the volumetric flowrate of live steam is reduced by about 17%, which reduces losses of pressure in the pipelines and the stopping and regulating equipment, and gives an additional gain in thermal economy of about 0.2%.

The use of a vertical steam-raising unit and reconfiguration of the thermal arrangement, when introduced can save more than one million rubles of capital investments and about 700,000 rubles per year in reduced expenditures, which is equivalent to a total reduction of specific capital expenditures for the generating facility with VVER reactor of about 4 rubles per kW (table) without consideration of the reduction of capital investments in the reactor department (structural part).

The use of vertical steam-raising units is in no way detrimental to the safety of reactor operation, since the water reserve in the shell of the steam-raising unit is not reduced as compared with the horizontal steam-raising unit.

Thus the use of a vertical steam-raising unit and the concomitant implementation of the enumerated steps considerably simplifies the heating system, improves the

Technical and economic characteristics of equipment making up a turbine set for horizontal and vertical steam-raising units

Equipment of existing design with horizontal steam-raising unit ($p_o = 6.4$ MPa, $t_{FW} = 220°C$)	Equipment of unified design with vertical steam-raising unit ($p_o = 7.2$ MPa, $t_{FW} = 200°C$)	Heating surface, sq. m	Mass, metric tons	Labor inputs, thous. norm-hours	Cost, thous. rubles
High-pressure heater 3	-	2 x 2500	2 x 160	2 x 11.5	2 x 150
High-pressure heater 2	-	2 x 2500	2 x 160	2 x 11.5	2 x 150
High-pressure heater 1	-	2 x 2500	2 x 160	2 x 11.5	2 x 150
-	1.25 MPa deaerator	-	2 x 140	2 x 27	2 x 155
0.7 Mpa deaerator	-	-	2 x 74	2 x 6	2 x 60
-	Single-stage intermediate steam superheater	4520	320	132	1080
Two-stage intermediate steam superheater	-	5320	540	160	1840
-	Pump for transferring condensate of the intermediate steam superheater	-	2 x 2.5	2 x 2.5	2 x 30
Mass of altered equipment making up high-pressure heaters, intermediate auperheaters, deaerators and pumps, metric tons 1648	605				
Labor inputs on altered equipment making up high-pressure heaters, intermediate superheaters, deaerators and pumps, thous. norm-hours 241	191				
Cost of altered equipment making up high-pressure heaters, intermediate steam superheaters, low-pressure heaters, deaerators and pumps, thous. rubles, with consideration of installation (ceofficient 1.2) 3440	1740				

working reliability of equipment, and enables the use of a standardized thermal arrangement with unified auxiliary equipment for generating facilities with VVER-1000, RBMK-1500 and RBM-KP-2400 reactors. In this system, the following basic equipment that makes up the turbine set is standardized: steam-generator separators, condensate pumps for the intermediate steam superheaters, heaters of the low-pressure regeneration system, deaerators and turbine feed units.

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INTERACTION OF GAS COOLANT COUNTERFLOWS IN A MODEL OF SPHERE CHARGING OF THE CORE OF THE VG-50 NON-CHANNEL REACTOR

Moscow ENERGOMASHINOSTROYENIYE in Russian No 3, Mar 81 pp 2-4

[Article by candidates of technical sciences R. G. Bogoyavlenskiy, G. V. Krasnopol'skiy and Engineer Yu. N. Pintelin]

[Abstract] Heat exchange in a spherical layer has not been as well covered in the current scientific and technical literature as heat exchange in tubular surfaces. The reason for this is that up until the early sixties the spherical layer was treated as a cap without internal heat release with the purpose of a filter or a recuperator charge.

Projects begun in the sixties on non-channel gas-cooled reactors with spherical fuel elements served as an impetus to development of research on heat exchange in a spherical layer at high Reynolds numbers. Some of the research that was done resulted in relations for the intensity of heat exchange of spheres as a function of Reynolds number at different volumetric porosities of a spherical charge [Ref. 1, 2].

A typical feature of sphere charging of the core of a gas-cooled non-channel reactor is that the volumetric porosity will not be the same throughout the core, particularly during recharging and in operation on the principles of multiple-pass or single-pass travel of the fuel elements through the core when local stacking may arise at isolated points of the spherical charge from tetraoctahedral (with porosity $m = 0,26$) to cubic ($m = 0.476$), and there may also be changes of porosity at the wall.

In experimental work by Decken [Ref. 3] an investigation was made of the nonuniformity of the average heat transfer coefficient in a layer with diameter of 20 calibers, and at different points of sphere stacking, including at the wall. Differences were found to range in limits of ±10%.

The pattern of heat exchange is particularly complicated in a non-channel core in the case where it is necessary to cool spherical fuel elements of the reactor when part of the gas flow is directed for cooling spherical fuel elements being unloaded through a discharge channel.

There are as yet no methods in the scientific and technical literature for calculating gas flows in spherical packing in the presence of counterflows of different intensity.

In the simplest case we can consider the encounter of a main flow of gas coolant penetrating through the sphere charge of a non-channel core with the gas flow leaving the unloading channel counter to the main flow. After mixing in the sphere layer, both these flows are removed from the core to the hot gas collector situated at some distance from the walls of the channel for unloading the spherical fuel elements. It is natural to assume the existence of some region in the charge where the velocities of the flows are mutually cancelled, and consequently there is appreciable detriment to heat transfer and an associated effect of overheating of fuel elements that have sufficient heat release in this region.

The research plan included getting data on the magnitude of heat exchange in a sphere charge in the region of mixing of counterflows of different intensity. In addition it was necessary to determine more precisely the dependence of heat exchange on Reynolds number for the region outside the flow mixing zone. With consideration of data cited on the possible variation of porosity through the core during recharging, recurrent measurements must be made, i. e. they must be statistical insofar as possible.

The experimental study was done on a VNIIAM stand [expansion not given], which is a closed circulation loop with gas blower, an experimental section and auxiliary heat exchangers (Fig. 1). Provision is made in the loop for separating the coolant into two streams and feeding them to the experimental section. Each of the coolant streams is provided with instrumentation for determining the flowrate, and with choking devices for regulating the flowrate.

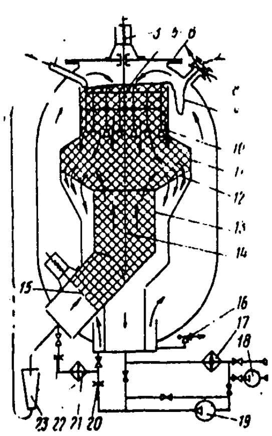

Fig. 1. Diagram of stand: 1. sphere duct; 2--tube for feeding spheres into experimental section; 3--mechanism for raising the calorimeter unit; 4--calorimeter unit position indicator; 5--calorimeter unit; 6--power shell; 7--lines to measurement instrumentation; 8--sealed electric entrance; 9--flexible thermoelectrodes; 10--upper cylinder of model with hemispherical displacers; 11--central chamber of the model; 12--perforated bottom of the central chamber; 13--lower cylinder of the model; 14--sphere charge of the model; 15--electrically driven sliding grate; 16--safety valve; 17--water type gas cooler; 18--compressor; 19--gas blower; 20--total stream flow meter; 21--electric gas heater; 22--flowmeter for the counterflow; 23--storage hopper

The experimental section is a cutaway model of the reactor core including the unloading channel. It is made in the form of two coaxial cylinders of different diameters. The main upper cylinder, 1200 mm high and 580 mm in diameter (13 calibers) is interfaced with the lower cylinder, 405 mm in diameter (9 calibers) by a cylindrical chamber 300 mm high (6.5 calibers) and 850 mm in diameter (19 calibers).

The lower part of the chamber has a tapered transition to the lower cylinder without holes to a diameter of 580 mm, and then perforated up to a diameter of 850 mm. Beginning at the perforated section of the chamber bottom is a gas collector that takes the gas out of the model. In the bottom of the lower cylinder is an electrically driven sliding grate. The upper and lower cylinders and the cylindrical chamber are filled with graphite spheres 45 mm in diameter. The model is filled with the spheres from the top through a tube 50 mm in diameter with lower end dropping below the level of the upper cylinder. The model is emptied by opening the sliding grate, the spheres dropping into a collector: an inclined pipe with diameter of 4.5 calibers. To prevent direct leakage of gas along the upper wall, hemispherical displacers are installed in the upper cylinder that simulate an infinite layer.

The main gas flow enters from the power shell that accommodates the pressure-relieved experimental section. Via the open end of the upper cylinder the gas flows downward through the sphere layer and out to the collector through the perforations in the tapered bottom of the chamber.

The gas that cools the fuel elements in the unloading channel is fed through the sliding grate into the lower channel and moves counter to the main flow, and then after mixing with the main flow above the unloading channel, this gas also flows out to the collector.

Located in the sphere layer is a calorimeter unit that can be moved vertically along the axis of the model (Fig. 2) [photo not reproduced]. The unit is raised by a special lifting mechanism, and lowered together with the sphere layer when the spheres are partly unloaded from the model by moving the sliding grate. The calorimeter unit is assembled so as to cover the cross section of the model as completely as possible.

Each calorimeter in the unit is a sphere 45 mm in diameter made up of two copper hemispheres 1 mm thick (Fig. 3) [photo not reproduced]. The hemispheres are joined by a copper core on which a tubular electric heater is installed with a power of 300-350 W. Welded to the surface of the sphere are three KhA (KTMS) thermocouples. The free part of the sphere is filled with molten lead to improve uniformity of distribution of the heat flux over the surface of the calorimeter. The thermoelectrodes of the thermocouples and the electric leads of the heater are brought out through a stainless steel tube 16 mm in diameter with wall thickness of 1.25 mm connected to the sphere with solid solder. This tube holds the calorimeter in the unit. On the other end of the tube is a terminal block through which all electrodes are connected by flexible leads to the sealed entrance from the power shell, and thence to the measurement instrumentation and power transformers.

To prevent gas leakage along the calorimeter holder tube, on the outside are ten freely moving drilled graphite spheres of the same diameter as the charge (45 mm). The location of the calorimeter unit in the layer is shown by a special indicator that can be observed on the outside of the shell. Connected in the section of the tube for feeding the counterflow is an electric heater for raising the gas temperature by 20-30°C over the unheated main flow.

The measurements made in the experiments included gas pressure in the shell, flowrate and temperature of the main flow and couterflow, temperature of the gas flowing around the calorimeters, temperature of the walls and power of the calorimeter heaters. The experiments were done under conditions of stabilization of flowrates, pressures and temperatures of both airflows, and the temperature of the calorimeters. Temperature stability was monitored from the readings of an EPP-09 automatic chart-recording potentiometer.

The first distinguishing feature of these experiments was measurement of the temperature of the gas impinging on the calorimeter and the temperature of the calorimeter wall by the same thermocouples installed on the surface of the sphere with the heaters of the calorimeter disengaged and engaged respectively. The second feature is lowering of the calorimeters together with the layer of spheres, which enabled measurement with the same calorimeters at different points heightwise of the layer. The features give a more reliable picture relative to the distribution of gas temperature and intensity of heat exchange in the volume of the sphere charge where the calorimeters are located.

The experiments were done in two series. In the first series an investigation was made of the way that the intensity of convective heat exchange depends on Reynolds number for the spheres located in the layer under conditions of unidirectional flow. Experiments of this series were done with the calorimeter unit in the upper position and with feed of only the main airflow at different flowrates. The resultant experimental data in the form of the Nusselt number (Nu) as a function of Reynolds number Re (Fig. 4) calculated with respect to gas velocity in the full cross section without consideration of blocking of the channel by spherical elements, and with respect to the diameter of a sphere as a characteristic dimension show that over a range of Reynolds numbers of $3 \cdot 10^3$–$20 \cdot 10^3$ with error of 15% we can use the formula

$$Nu = 0.8Re^{0.65},$$

and for Reynolds numbers of $20 \cdot 10^3$–$50 \cdot 10^3$ with error of 7% we can use the formula

$$Nu = 0.48Re^{0.7}.$$

The indicated errors are determined mainly by nonuniformity of the distribution of heat transfer intensity in the sphere packing cross section

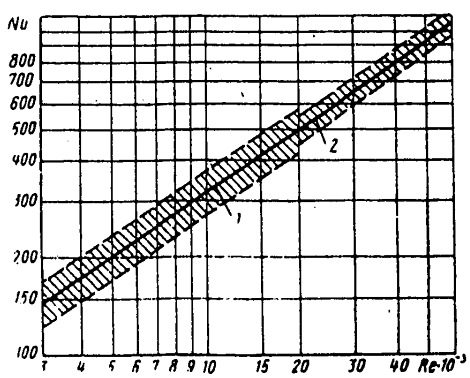

Fig. 4. Relation $Nu = f(Re)$ in the case of unidirectional flow: 1--$Nu = 0.8Re^{0.65}$; 2--$Nu = 0.48Re^{0.7}$

The experiments of the second series were done with lowering of the calorimeter unit from the upper position to the mouth of the channel for unloading the spheres. This arrangement included feed of both the main (upper) gas flow, and the (lower) counterflow via the unloading channel. The main flow was the "cold" gas, and the counterflow had a temperature 20-30°C higher than the main flow.

The wall temperature of the calorimeters on each of the levels heightwise over the mouth of the unloading channel was measured first without engagement of the heaters (to determine the temperature of the air flowing over the calorimeter). Then the heaters of the calorimeters were energized and after stabilization had been reached (the calorimeters were heated), repeat measurements were made of the emf of the calorimeter thermocouples.

These emf's were used to determine wall temperature, which in combination with measurement of electric power and with consideration of thermal losses as a result of heat transfer to adjacent unheated spheres enabled determination of the heat transfer coefficient, and consequently the Reynolds number for each of the calorimeters.

The calorimeters were lowered together with the spheres of the layer as some of the spheres were discharged through the unloading channel. The experiments with lowering of the calorimeters were done at only one mass velocity of the main flow (in the upper cylinder). The mass velocity of the counterflow was measured over a wide range (from 50 to 125% of the mass velocity of the main flow, nominal velue of 75%).

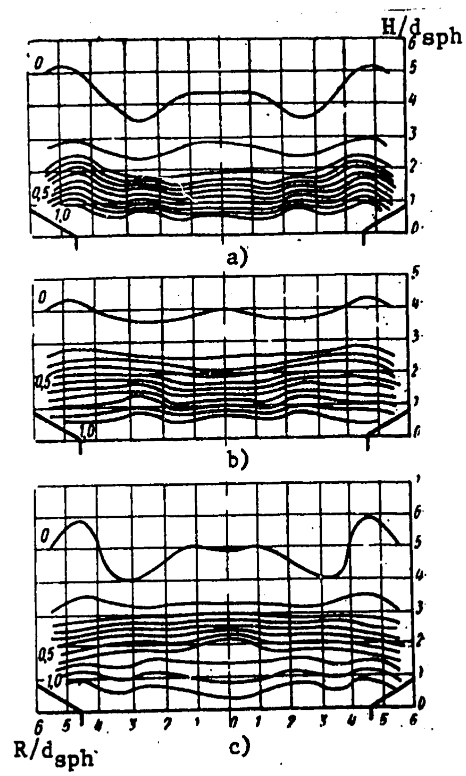

Fig 5. Diagram of mixing of main flow and counterflow in the form of the relation $(t_0 - t)/(t_0 - t_{cf}) = f(H/d_{sph};\ R/d_{sph})$ at different ratios of the mass velocities of the main flow and counterflow; a--0.5; b--0.75; c--1.25

In the experiments of this series one can determine the course of mixing of the main flow and the counterflow, and delineate the so-called "mixing zone" [Ref. 4] by using the temperature field of the gas in the layer as determined from measurements without heating of the calorimeters. The mixing zone is that part of the volume of the sphere layer above the mouth of the unloading channel where the flow over the spherical fuel elements in each elementary volume consists partly of the gas of the main flow (arriving from above) and partly of the gas arriving from below (from the unloading channel). The ratio of these gases ranges from 0 to 1.0, and the surfaces where these extreme values occur are the boundaries for the mixing zone.

It can be seen from the graphs of Fig. 5 that the position of isotherms in the form of relations $(t_0 - t)/(t_0 - t_{cf}) = f(H/d_{sph};\ R/d_{sph})$ that reflect equal degrees of mixing of the main flow and counterflow changes with a change in the ratio of their mass velocities.

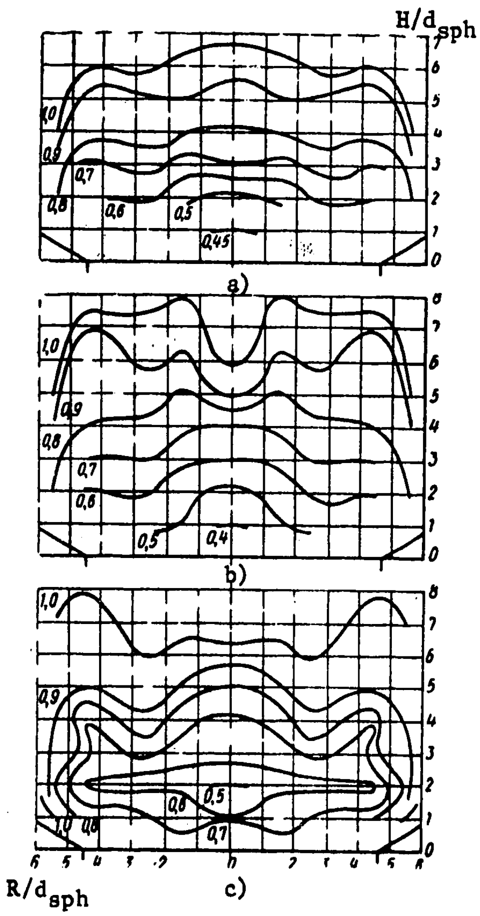

Fig. 6. Diagram of distribution of heat exchange intensity above the mouth of the unloading channel $Nu/Nu_0 = \phi(H/d_{sph}; R/d_{sph})$ for different ratios of the mass velocities of the counterflow and the main flow: a--0.5; b--0.75; c--1.25

The mixing zone increases with an increase in the mass velocity of the counterflow. Besides, the region of the mixing zone where intermixing of the flows takes place most intensively, i. e. where the isotherms are most densely spaced, shifts up noticeably (by nearly 1½ sphere calibers) with increased mass velocity of the counterflow as compared with nominal conditions. At the same time, there is an increase in the overall height of the mixing zone, especially on the edges, where the gas velocity at the wall is considerably greater than the average due to a jump along the wall of the unloading channel. Errors in placement of the isotherms due to reduction of the temperature of the counterflow caused by heat losses through the wall of the central chamber do not exceed 5%.

The experiments of the second series also enable us to single out the "zone of impaired heat exchange" which is the part of the volume of the sphere layer above the unloading channel where we observe a reduction in the intensity of heat exchange as compared with the overlying sphere layer due to a reduction in the mean velocity at which the coolant flows over the spherical fuel elements, which is caused by the interaction of the opposed flows in combination with a change in the direction of flow determined by the configuration of the walls of the funnel and the location of the point where the coolant leaves the model of the reactor core.

Fig. 6 shows graphs of the distribution of lines of equal intensity of heat exchange $Nu/Nu_0 = \phi(H/d_{sph}; R/d_{sph})$ plotted in the scale of the average Nusselt number (Nu_0) in the sphere layer above the zone of mixing of the flows and the zone of impaired heat exchange. It is clear from these diagrams that the minimum relative values of the Nusselt number are 0.4-0.45, and are situated at low velocities of the counterflow close to the mouth of the unloading channel. When the mass velocity of the counterflow is increased, the region with minimum Nusselt number (0.5) "floats" upward nearly two calibers above the mouth of the channel, and its volume decreases considerably.

There is a noticeable correlation between the diagrams of mixing and heat exchange, especially at high velocities of the counterflow, with respect to non-uniform distribution of velocities in the unloading channel. Therefore it is of interest to study the inside of the unloading channel. The form of the diagrams may also be considerably influenced by points of location of coolant discharge.

Our research enabled qualitative investigation of one of the possible ways of controlling the zone of impaired heat exchange close to the mouth of the channel for unloading fuel elements from the reactor core by altering the ratio of mass velocities of the main flow and counterflow. In doing this, we have established that for the investigated model and designs geometrically similar to it, doubling the mass velocity in the unloading channel (as compared with the nominal value) increases the minimum intensity of heat exchange, reduces the volume where it occurs, and reduces the temperature of the coolant flowing over the fuel elements in the zone with impaired heat exchange conditions. This reduces the danger of exceeding the permissible fuel element temperature and improves conditions of heat exchange on the approach to the unloading channel where cooling is to tkae place.

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CSO: 8144/1087

UDC [621.311.25:621.039]:621.182.14-11.001.2

ENLARGEMENT OF HIGH-PRESSURE HEATERS FOR HIGH-POWER GENERATING FACILITIES IN NUCLEAR ELECTRIC PLANTS W'' H VVER REACTORS

Moscow ELEKTRICHESKIYE STANTSII in Russian No 2, Feb 81 pp 12-13

[Article by candidates of technical sciences V. M. Marushkin, Ya. L. Polynovskiy and G. T. Shkol'nik, Ural Affiliate of the All-Union Scientific Research Institute of Heat Engineering imeni F. E. Dzerzhinskiy]

[Text] A characteristic feature of the current stage of nuclear power development is an increase in unit capacities of facilities made in the form of individual generating units including a reactor, steam generators and a turbine. It is quite natural to expect that the effect of this trend would be maximized by enlarging all types of equipment in the electric power plant.

However, the enlargement of certain kinds of equipment presents rather complicated problems. This applies in particular to high-pressure heaters. Difficulties in enlargement of such heaters are due to high flowrates of the feed water at the same time that water velocity is restricted to less than 2 m/s in the elements of the heating surface; another source of problems involves limitations on overall dimensions of the heaters. The water velocity constraint is a result of technical and economic factors, and also the limits of resistance of heater coils to corrosion and erosion, as operating conditions permit the use of relatively inexpensive grade 20 steel for making high-pressure heating coils for generating facilities with VVER [water-cooled water-moderated power] reactors.

The 220 MW generating units now being used in nuclear electric plants with VVER reactors according to All-Union Standard OST 24.271.28-74 [Ref. 1] are equipped with PV-1600-92 vertical collector heaters designed by Krasnyy Kotel'shchik Production Association. The heater shell has 2600 mm inside diameter and a height of 10.6 m.

Having reached the limit with respect to capabilities for further enlargement in the design features incorporated into the PV-1600-92, Krasnyy Kotel'shchik tried making horizontal high-pressure heaters of chamber type [Ref. 1] in developing heaters for the fifth generating unit of Novovoronezhsk Nuclear Electric Plant with two K-500-1500 turbines. However, for technological reasons these heaters could be made only from austenitic steel even though working conditions did not require it.

The cost of a set of such heaters per 500 MW turbine unit was 2.4 million rubles (specific cost of 400 rubles per sq. m). Despite this high price tag, the optimum temperature of the feed water according to data of Ref. 2 is 200°C for a single-pass steam generator with economizer when the live steam parameters are 7 MPa (70 kgf/cm²) and 310°C. By contrast, Ref. 2 points out that the optimum temperature of the feed water would be about 220°C when using a high-pressure heater with heating surface costing 100 rubles per sq. m, giving an annual savings of about 150,000 rubles.

According to our own analysis, this temperature could be attained by using PV vertical collector high-pressure heaters based on the PV-2300-380 units currently installed in the generating units of 500 MW fossil-fuel electric plants [Ref. 3]. The feed water in such high-pressure heaters can be heated to 220°C when the pipe system is made up of collectors with diameter of 377 x 24 mm, and the flat coils are formed from tubing with diameter of 32 x 4 or 32 x 3.5 mm, assuming an inside diameter of the shell of 3200 mm and height of 14 m in an arrangement with two high-pressure heater stages with 0.7 MPa (7 kgf/cm²) deaerator, the condensate from the water separator and superheater being fed into the water feed line.

Krasnyy Kotel'shchik is nearly ready to start manufacturing such heaters. A cost analysis by the All-Union State Institute for the Design and Planning of Electrical Equipment for Heat Engineering Installations shows that a set of two heaters with consideration of delivery and installation will cost 500,000 rubles (specific cost of 120 rubles per sq. m).

Such heaters in a two-channel model and with three-stage heating of feed water have now been accepted for the generating unit of the 1000 MW South Ukrainian Nuclear Electric Plant. A number of organizations have proposed a heating arrangement with 1.2 MPa (12 kgf/cm²) deaerator, a single high-pressure heater stage in the high-pressure regeneration system and an auxiliary PND-5 low-pressure heater for generating units of this same power.

We feel that this idea is not as sound as two-stage heating of water in a high-pressure heater with 0.7 MPa deaerator, since with equal economy and capital outlay it requires development of new equipment: the 1.2 MPa deaerator, and a feed pump with inlet water temperature of 200°C.

Research projects done in recent years by the Ural Affiliate of the All-Union Scientific Research Institute of Heat Engineering imeni F. E. Dzerzhinskiy, Krasnyy Kotel'shchik Production Association [Ref. 4] and the scientific production association of the Central Scientific Research Design and Planning Boiler and Turbine Institute imeni I. I. Polzunov indicate the feasibility of considerably reducing metal inputs and dimensions of the described heaters, and developing two-channel high-pressure heaters within acceptable overall dimensions for 2000 MW generating units. Judging from Ref. 4, the major way to enlarge the high-pressure heaters in the generating units of fossil-fuel and nuclear electric facilities is to switch to making the elements of the heating surface from small-diameter tubing (20 x 3 or 22 x 3 mm for nuclear electric plants).

The following results are achieved by designing the high-pressure heaters of high-power generating units in nuclear electric plants around the engineering features suggested in Ref. 4 for single-shell high-pressure heaters of the generating units in 800 MW fossil-fuel electric plants. Vertical single-channel PV

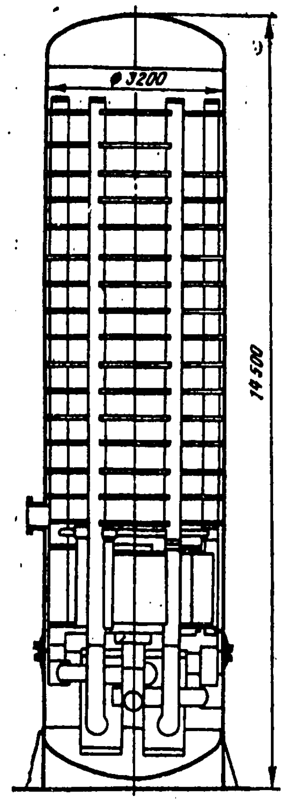

Fig. 1. Structural diagram of a single-channel PV collector high-pressure heater for generating units of a 1000 MW nuclear electric facility

collector high-pressure heaters can be made for 1000 MW generating units in a shell 3200 mm in diameter and 14.5 m high (Fig. 1) with heat-engineering characteristics ensuring attainment of a feed water temperature of 200°C with two-stage heating and 0.7 MPa deaerator.

The 4000 sq. m heating surface in these high-pressure heaters consists of a built-in condensate cooler and a single-pass condensation zone, and by analogy with the recommendations of Ref. 4 it is made up of sections in the form of two double-tube flat coils placed one over the other and formed from grade 20 steel tubing with diameter of 22 x 3 mm welded to intermediate elements with diameter of 45 x 5 mm. The sections, as recommended in Ref. 4, are welded to the collector in two staggered rows; the step to each row is 104 mm, and the average spacing between coils heightwise of the high-pressure heater is 26 mm. The collectors are made of tubing with diameter of 377 x 24 mm.

In this arrangement, the maximum velocity of the water in the coils will be less than 2 m/s, while that in the collectors will be about 6 m/s. The maximum length of the tubing in a coil will be 13 m, and the high-pressure heater will mass 250 metric tons. The estimated cost of a single heater is 350,000 rubles.

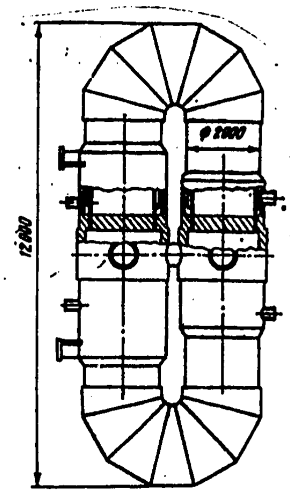

Fig. 2. Structural diagram of a doubled single-channel chamber high-pressure heater for generating units of a 1000 MW nuclear electric plant

Even greater capabilities for enlargement of high-pressure heaters open up with the acquisition of chamber heaters. A possible design of a single-channel chamber high-pressure heater for a 1000 MW generating facility is shown in Fig. 2.

When U-tubes with diameter of 16 x 2 mm and length of 10 m are used for the elements of the heating surface in such a heater with total heating surface of 4000 sq. m, it can be made with a shell diameter of 2000 mm and length of about 12 m. The grade 20 steel tube plate is 300 mm thick. The heater masses 180 metric tons.

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PLANNING AND BUILDING NUCLEAR ELECTRIC PLANTS

Moscow OSOBENNOSTI PROYEKTIROVANIYA I SOORUZHENIYA AES in Russian 1980 (signed to press 4 Dec 80) pp 2, 188

[Annotation and table of contents from book "Particulars of the Planning and Construction of Nuclear Electric Plants", by Leonid Mikhaylovich Voronin, Atomizdat, 4000 copies, 192 pages]

[Text] The book discusses the major problems that come up in working out plans for nuclear electric facilities with different kinds of reactors. Methods and stages of construction and installation on the facility are examined. The major emphasis is on questions of features that are inherent only to nuclear electric plants. A central place is given to questions of ensuring high quality of the building, assembly and installation jobs, which is especially important for reliable operation of nuclear electric facilities. The material is based on experience in the planning, construction and operation of Soviet nuclear electric plants with water-water and channel reactors.

For specialists in the field of planning, building and using nuclear electric facilities. May be of use to students majoring in the appropriate fields in engineering colleges. Tables 15, figures 73, references 53.

Contents

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DECONTAMINATION OF THE EQUIPMENT IN NUCLEAR ELECTRIC POWER STATIONS WITH VVER-440 REACTORS

Moscow ELEKTRICHESKIYE STANTSII in Russian No 4, Apr 81 pp 6-8

[Article by Yu.V. Balaban-Irmenin, candidate of the engineering sciences and A.L. Teplitskiy, engineer, All-Union Thermal Engineering Institute]

[Text] The long-term operation of AES equipment leads to the constant accumulation of radioactive contaminants on the internal surface of the radioactive loops of AES's, as well as on the outer surfacesof equipment and walls (floors, ceilings) of rooms. This process can occur at different rates depending on the AES technology, the application of various preventive measures, etc., but in any case, there is an increase in the gamma radiation level from the AES equipment with time, which complicates and increases the cost of its repair and metal monitoring, and in a number of cases, even prevents normal operation of the electric power station. For this reason, it is necessary to periodically decontaminate, i.e., remove radioactive contaminants from equipment and room surfaces.

An analysis of the radiation exposure of personnel at AES's shows that the personnel dosage expenditures are primarily related to equipment repair [1, 2] and at the present time, the radiation exposure of personnel is 70 to 90 percent governed by the radioactive contamination of the internal surfaces of the primary loop equipment, which comes in direct contact with the coolant.

Various methods of removing radioactive contaminants can be used at AES's depending on the decontamination purposes and facilities: chemical, electrochemical, chemical-mechanical and others [3].

The primary method which makes it possible to curtail the dosage expenditures of AES personnel both during a repair period and in a decontamination period is the decontamination of the loop equipment while assembled. The traditional, so-called two bath method is usually used abroad for this operation, which consists in the sequential flushing of the primary loop first with a rather concentrated solution of alkaline permanganate and then with an acid solution (predominantly oxalic) with an intermediate flushing with condensate. The complex configuration of the primary loop and the necessity of careful removal of the resiudes of the decontaminating solutions from it in this case produce a large amount of radioactive water (up to 70 times the volume of the decontamination loop) and require considerable expenditures of time, which have a direct influence on the duration of the power generator downtime [4]. For this reason, the primary loop is rarely decontaminated using the two bath method.

Soviet specialists, in conjunction with specialists from the GDR, have developed a new technology for primary loop decontamination. The dissolution of the oxide film, including radionuclides, is accomplished in this case by successive exposure of the film to a solution of potassium permanganate and an etching solution made of ethylenediaminetetraacetic and citric acids. The first test of the new technology was made in 1978 during the decontamination of the primary loop of a standard power unit with a VVER-440 reactor [5].

The reactor vessel and the volume compensator, which are made of nonalloy steels, as well as three loops (of six) with steam generators were decontaminated. The core was unloaded for the purpose of providing for the inspection of the reactor vessel. The duration of the decontamination was 54 hours. Some 84 hours was expended on the preparatory work. All of the operations were performed with regular equipment, without the installation of additional hardware.

Some 605 Ci were removed from the loop as a result of the decontamination, including 28 percent fission products while the remainder were corrosion products. The following were removed through the dissolution of the oxide films from the metal surfaces: 86.5 kg of iron, 7.3 kg of chromium and 6.3 kg of nickel. The reduction in the dosage expenditures of the personnel as a result of the decontamination was governed not only by the reduction in the level of the gamma radiation doses from the equipment (the decontamination factor reached 25 for the steam generators), but also by the reduction of the time needed to prepare the metal for testing, by virtue of removing the oxide film during the decontamination. No corrosion damage to the equipment or traces of secondary corrosion following the decontamination was detected.

One of the advantages of this technology is the small amount of waste. The quantity of primary wastes was a total of three times greater than the loop volume; the volume of concentrated waste amounted to 17 m^3.

At the present time, the technology described here has been used to decontaminate the primary loop of two power units with VVER-440 reactors. The results of the trial have shown that the application of this method can be permitted five times for the decontamination of one power unit without the danger of corrosion to the equipment.

In the case of short term shutdowns of power units and a limited amount of repair and metal testing, decontamination of the entire primary loop is not expedient. For this reason, independent decontamination systems are widely used at AES's for individual components of the core loop. Independent decontamination makes it possible to clean that equipment which requires an increased amount of inspection and monitoring work, as well as to employ the most efficient solutions in the least amount and the corresponding minimal quantity of waste.

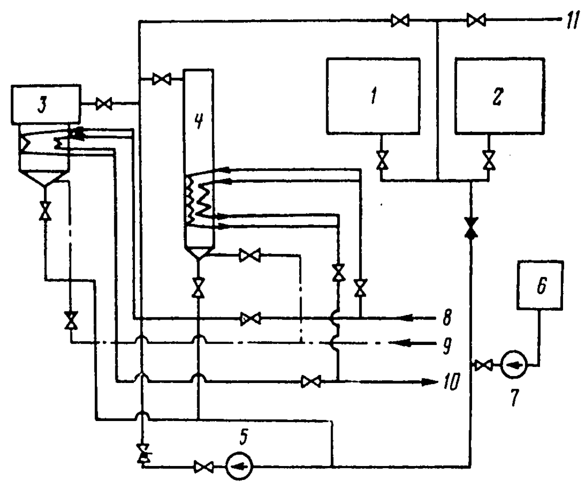

Figure 1. Configuration of the decontamination unit for the main circulation pumps.

Key: 1,2. Tanks for preparing the solutions;
3. Decontamination bath for the removed portion of the MCP;
4. Decontamination bath for the rotor of the MCP;
5. Circulation pump;
6. Tank for the hydrogen peroxide solution;
7. Pump for the hydrogen peroxide solution;
8. Steam feed;
9. Compressed air feed;
10. Condensate drain;
11. Condensate feed.

The main circulation pump (GTsN) [MCP] is that component of the primary loop which is most often subjected to inspection and repair. To decontaminate it, special decontamination units have been created at AES's, which included [6]: storage tanks for the working acid and alkaline solutions; a decontamination bath for the removed portion of the MCP; a decontamination bath for the rotor of the MCP; a solution circulation, feed and return pump; and a control panel (Figure 1).

The outside portion of the MCP is delivered through easily removable covers in the central room to the decontamination unit and is installed in a special bath. The construction of the bath makes it possible to treat only the lower most contaminated portion of the MCP, which has come in direct contact with the coolant. To decontaminate the MCP rotor, a special bath is also set up, where to avoid deformation, the rotor is decontaminated in a suspended position.

The solutions are prepared in tanks; the solutions are fed to the bath with the equipment by means of a pump. The solutions are heated up to the requisite temperature in a heat exchanger, where the temperature of the solutions is registered by a thermocouple and the readings are fed out on the control board.

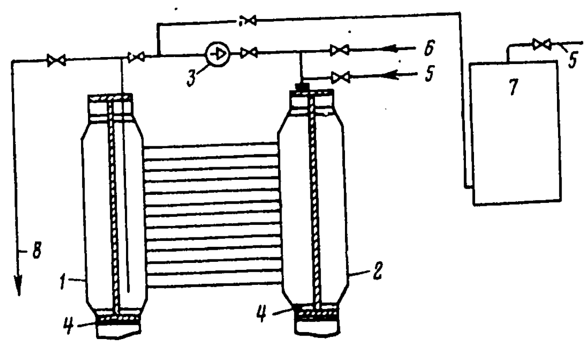

Figure 2.

Figure 2. Configuration for the decontamination of the steam generators.

Key: 1. Cold header of the steam generator;
2. Hot header of the steam generator;
3. Pump;
4. Blank flange;
5. Water feed;
6. Compressed air feed;
7. Tank for the preparation of the solutions;
8. Discharge to the special sewerage system.

The decontaminating solution is circulated by means of the same pump. To achieve the greatest intermixing rate, compressed air is fed into the baths. The framework of the unit provides for washing the entire system with pure condensate, as well as repeated use of the solutions. If a chemical reagent does not reach its saturation after the decontamination cycle is completed (something which is determined by analysis), it is expedient to repeat its application, and this reagent is pumped into storage tanks for the decontaminating solutions.

The structural design of the decontamination baths makes it possible to treat not only the removed portions of the MCP, but also other small equipment and parts. A basket which is placed in the large bath is used for this purpose. The equipment to be decontaminated is loaded into the basket. The usually attainable decontamination coefficients fluctuate from 10 to 100.

A rather typical case of independent decontamination of equipment when assembled is the decontamination of the steam generators for the VVER-440, the schematic of which is shown in Figure 2 [7].

The following equipment was assembled to create this configuration: blank flanges in the pipe where D_u = 500 mm on the side of the main circulation pump, which prevent the decontaminating solution getting into the piping; flanges on the header of the steam generators to introduce and circulate the decontaminating solutions; a tank with a capacity of 2 m^3 to prepare the solutions (at the same time, this tank was used as a "breather"); a pump with a delivery of 45 m^3/hr. The decontaminating solutions were preheated on the side of the steam feed secondary loop (a pressure of 8 to 12 kgf/cm^2) from the turbine room into the continuous purging line of the steam generators.

TABLE

Operation	Temperature °C	pH	Concentration, g/l: Alkali	Oxalic acid	Iron	Overall activity with respect to the dry residue, Ci/l
Alkalization (first cycle)	70	13.21	16	-	-	$1.4 \cdot 10^{-5}$
Acid stage (first cycle)	80	1.11	-	25.2	0.325	$2.0 \cdot 10^{-3}$
Alkalization (second cycle)	80	13.20	10.4	-	-	$6.2 \cdot 10^{-6}$
Acid stage (second cycle)	72	1.31	-	21.0	0.230	$3.1 \cdot 10^{-5}$
Flushing with a weak solution of nitric acid	78	1.76	-	-	0.125	$4.2 \cdot 10^{-6}$

Note: The concentration of the potassium permanganate during alkalization was equal to 3 g/l and the nitric acid concentration during the etching was 0.3 to 1 g/l.

The decontamination technology included treatment with an alkaline solution (KOH at 30 g/kg and $KMnO_4$ at 3 g/kg) for the case of solution circulation and a temperature of up to 90 °C (the alkalization was carried out simultaneously with the warming-up of the steam generator). Then, after flushing with water, a treatment was made with a solution of oxalic (15 g/kg) and nitric (1 g/kg) acids. The final flushing was accomplished with a slightly alkaline water (2 g/kg KOH), and then with pure water, the decontamination coefficient was equal to 8.5.

One of the major reasons for the relatively low decontamination coefficients in this case is obviously the low liquid velocities. For this reason, the All-Union Institute of Thermal Engineering imeni F.E. Dzerzhinskiy and the Kol'skaya AES proposed a special device which makes it possible to produce a liquid mass rate of flow through the steam generator of a VVER-440 reactor of about 1,600 m^3/hr when the pipes where D_u = 500 mm are cut off from the steam generators.

A two bath method was used in the decontamination (see the Table). Just as in the variant described here, the solutions were warmed up at the secondary loop side.

As a result of the first decontamination cycle, 6.685 kg of iron oxides, refigured for Fe_2O_3, were washed out in dissolved form and radioactive nuclides amounting to 11.16 Ci were removed. An examination of the headers showed that the surface of the cold header was completely cleaned of the oxide film; 70 percent of the hot header surface was coated with a gray colored oxide film. The gamma radiation dose in the collectors was reduced by a factor 9-10.

The second decontamination cycle was carried out using the same technology as the first cycle. Additionally, following the acid stage, a weak solution of nictric acid (0.7 g/l) was used as a rinse. The duration of the second cycle 16.5 hours.

As a result of the second decontamination cycle, 5.2 kg of iron oxides, refigured for Fe_2O_2, were washed out of the steam generators in dissolved form and radioactive nuclides amounting to 1.78 Ci were removed. The examination of the headers after the second decontamination cycle showed that the surface of the hot header was likewise fully cleaned of the oxide film.

After the second cycle and the disassembly of the device, the D_u = 500 mm piping along with the steam generators were flushed with condensate.

The gamma radiation dose rates from the steam generator (in the headers and above the pipe still), measured after the completion of the second decontamination cycle, were sharply reduced as compared to the initial level. The decontamination coefficient of the various sections of the equipment averaged: 49 with respect to the cold header; 25 with respect to the hot header and 32 with respect to the pipe still.

Similar results were obtained for the case of decontamination in two cycles of the steam generators of another power unit. In the case of one cycle decontamination, the decontamination coefficient was equal to 10.

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NON-NUCLEAR ENERGY

UDC 621.499;661.961.621;621.438.9

ENERGY-STORING MATERIALS AND THEIR USE

Kiev ENERGOAKKUMULIRUYUSHCHIYE VESHCHESTVA I IKH ISPOL'ZOVANIYE in Russian 1980 (signed to press 28 Jul 80) pp 2, 238-239

[Annotation and table of contents from book "Energy-Storing Materials and Their Use", by Il'ya L'vovich Varshavskiy, Institute of Machine Building Problems, UkSSR Academy of Sciences, Izdatel'stvo "Naukova dumka", 1000 copies, 240 pages]

[Text] The monograph discusses problems of using certain substances as secondary energy carriers. Energy-storing materials are classified, and their energy capacity is analyzed as well as methods of producing them. An evaluation is made of the feasibility of using energy-storing materials to get hydrogen from water.

The book is intended for scientists and engineering-technical personnel specializing in the field of power engineering, machine building and transportation.

Contents

6610
CSO: 1861/102

CONSTRUCTION

UDC 624.13

CONTINUOUS-ACTION EXCAVATORS

Moscow EKSKAVATORY NEPRERYVNOGO DEYSTVIYA in Russian 1980 (signed to press 12 Sep 80) pp 2, 302-303

[Annotation and table of contents from book "Continuous-Action Excavators. Second Revised and Enlarged Edition", by Zalman Yeremeyevich Garbuzov, Viktor Mikhaylovich Donskoy, Nikolay Vasil'yevich Karev (deceased) and Leonid Yermolayevich Podborskiy, **Izdatel'stvo "Vysshaya shkola", 35,000 copies, 304 pages]**

[Text] The book describes the power equipment and drives of continuous-action excavators (chain and rotary trenchers, drain-ditching excavators, transverse diggers, rotary and auger-rotary channel diggers, boom-rigged rotary excavators), their construction, technical operation and organization of excavation work.

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CSO: 1861/97

UDC 355.58

FIRING GROUND-TO-AIR MISSILES

Moscow STREL'BA ZENITNYMI RAKETAMI in Russian 1980 (signed to press 10 Mar 80) pp 292-295

[Annotation and table of contents from book "Firing Ground-to-Air Missiles", by Fedor Konstantinovich Neupokoyev, Voyenizdat, 12,500 copies, **296** pages]

[Text] The theoretical principles of firing ground-to-air guided missiles are presented in the book, based on information from Soviet and non-Soviet open-source literature.

The general characteristics of ground-to-air missile systems are given; an examination is made of fields of application of various missile guidance techniques; factors that determine errors of missile homing on a target are analyzed as well as parameters of the coordinate law of striking a target; methods are outlined for calculating the indices of firing effectiveness, and for estimating the space and time capabilities of a ground-to-air missile complex.

The book is intended for specialists in problems of combat utilization of ground-to-air missile complexes.

Contents

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CSO: 1861/104

FLUID MECHANICS

UDC 681.833.4.062.004.5

OPERATION OF MARINE HYDROACOUSTIC STATIONS

Leningrad EKSPLUATATSIYA SUDOVYKH GIDROAKUSTICHESKIKH STANTSIY in Russian 1980 (signed to press 19 Sep 80) pp 2, 189-191

[Annotation and table of contents from book "Operation of Marine Hydroacoustic Stations", by Vladlen Anatol'yevich Pokrovskiy and **Gennadiy Aleksandrovich Shcheglov**, Izdatel'stvo "Sudostroyeniye", 3500 copies, 192 pages]

[Text] The book gives major characteristics of hydroacoustic stations. A description is given of standard measurement instrumentation used in technical servicing of these stations. An analysis is made of factors that influence the output functional characteristics of hydroacoustic stations, and a technique is offered for quantitative evaluation of efficiency in using them.

The book is intended for marine radio navigators, and can be used by students in institutions of higher and intermediate education that train hydroacoustics specialists, and also by engineering and technical workers engaged in the design and utilization of hydroacoustic facilities.

Contents

6610
CSO: 1861/103

MECHANICS OF SOLIDS

UDC 539.313

PLATES AND SHELLS WITH DISCONTINUOUS PARAMETERS

Leningrad PLASTINY I OBOLOCHKI S RAZRYVNYMI PARAMETRAMI in Russian 1980 (signed to press 4 Apr 80) pp 2-5

[Annotation and table of contents from book "Plates and Shells With Discontinuous Parameters", by Boris Kuz'mich Mikhaylov, Ministry of Intermediate and Higher Special Education, RSFSR, Izdatel'stvo Leningradskogo universiteta, 1304 copies, 196 pages]

[Text] The book presents methods of calculating shells and plates with ribs, breaks, cuts and holes subjected to distributed and concentrated loads, based on generalized (discontinuous) functions. Solutions are presented for problems that come up often in computational practice.

The book is intended for engineers and scientists who deal with strength calculations of thin-walled three-dimensional structures and specialize in the thoery of thin shells.

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CSO: 1861/101

UDC 534.232.001.11

DYNAMIC-ENERGY RELATIONS OF OSCILLATORY SYSTEMS

Kiev DINAMIKO-ENERGETICHESKIYE SVYAZI KOLEBATEL'NYKH SISTEM in Russian 1980 (signed to press 14 Jul 80) pp 2, 186-187

[Annotation and table of contents from book "Dynamic-Energy Relations of Oscillatory Systems", by Aleksandr Yevgen'yevich Bozhko and Nina Moiseyevna Golub, Institute of Machine Building Problems, UkSSR Academy of Sciences, Izdatel'stvo "Naukova dumka", 1000 copies, 188 pages]

[Text] This monograph gives the results of studies of the interrelation between dynamic and energy processes that take place in oscillatory systems with free and forced oscillations. Harmonic, polyharmonic and unsteady forces are considered as forces of excitation. These studies are extended to a broad class of oscillatory systems: linear and nonlinear, with one, two and n degrees of freedom.

Examples are given relating to systems of reproducing vibrations and active vibration protection based on electrodynamic exciters.

The book is intended for scientists, engineers, graduate students majoring in the field of vibration equipment design and vibration testing of machines and instruments, and also for advanced students in engineering colleges. Figures 26, references 36.

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CSO: 1861/100

TESTING AND MATERIALS

UDC 629.7.036:539.4

EROSION STRENGTH OF COMPONENTS OF FLIGHTCRAFT ENGINES AND POWER PLANTS

Moscow EROZIONNAYA PROCHNOST' DETALEY DVIGATELEY I ENERGOUSTANOVOK LETATEL'NYKH APPARATOV in Russian 1980 (signed to press 4 Oct 80) pp 2, 243-245

[Annotation and table of contents from book "Erosion Strength of Components of Flightcraft Engines and Power Plants", by Roman Grigor'yevich Perel'man, Izdatel'stvo "Mashinostroyeniye", 1000 copies, 248 pages]

[Text] The book outlines the theoretical and engineering aspects of erosion strength when fluid particles interact at high velocities with a solid. The characteristics of erosion strength are given for some materials, as well as methods and examples of digital computer calculation of blades in compressors of gas turbine engines and nuclear turboelectric space vehicle power plants. Some recommendations are made on designing items with required erosion strength.

The book is intended for aviation industry engineers.

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CSO: 1861/99

UDC [621.311.25:621.039.002.5]:546.3:65.012.7.004

IMPROVING THE EFFICIENCY OF SELECTIVE TESTING OF THE METAL OF NUCLEAR ELECTRIC POWER STATION EQUIPMENT

Moscow ELEKTRICHESKIYE STANTSII in Russian No 4, Apr 81 pp 8-10

[Article by V.N. Gulyayev, candidate of the engineering sciences, "Energiya" Scientific Production Association of the USSR Ministry of Energy]

[Text] High reliability of the metal and the welded joints of equipment should be assured in the operation of nuclear electric power stations.

Monitoring during the operational process must be set up so that primarily those parts or their zones which are the most dangerous from the viewpoint of the possibility of the occurrence of damage are inspected with selective monitoring with minimal expenditures and so as not to violate existing instructions, where there is a maximum of confidence in the reliability of the results of selective checking.

The efficiency of selective monitoring can be increased, when the factors considered in the following are taken into account.

There is a considerable scatter in properties in parts, especially those made of thermal strain hardened steels. This scatter in properties is customary in world practice and is explained both by the fluctuations in the actual chemical composition of the steel (or alloy) within the range of a brand of steel and the application of standard heat treatment schedules at the plants, these schedules are specified as a whole for a standard steel composition for a given specific product.

For example, the processing of the certificate data on 205 pipes of 47 melts, intended for the boiler plants of thermal electric power stations, showed that the scatter was as follows: 25 kgf/mm^2 for the yield stress; 20 kgf/mm^2 for the ultimate strength; 12.5 percent for the relative elongation; 30 percent for the contraction ratio and 14.7 $kgf \cdot m/cm^2$ for the impact toughness.

Operational experience with conventional thermal electric power stations shows that the equipment components undergo brittle rupture primarily in the case of

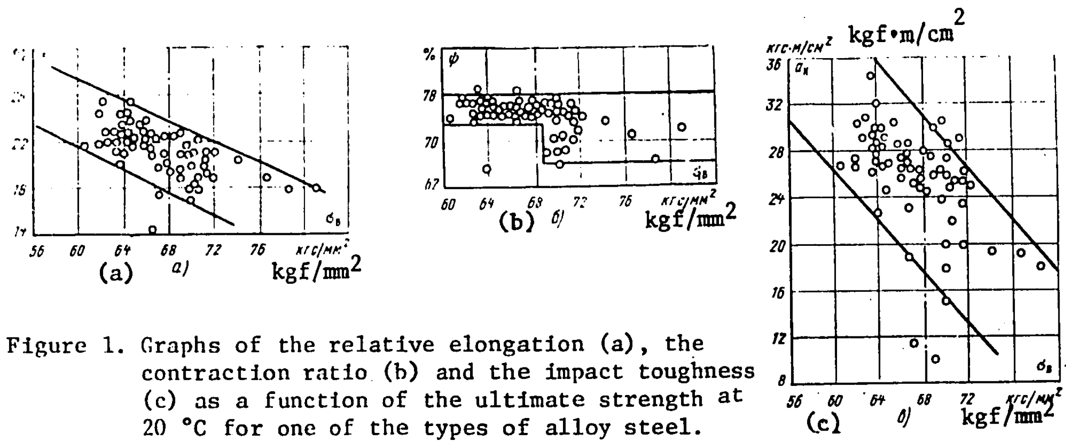

Figure 1. Graphs of the relative elongation (a), the contraction ratio (b) and the impact toughness (c) as a function of the ultimate strength at 20 °C for one of the types of alloy steel.

inadequate metal ductility. Since increasing the strength and hardness is, as a rule, accompanied by a reduction in plasticity, ascertaining especially high strength and hardness indicators during the input quality control in individual products or regions of them can be evidence of inadequate ductility and a tendency to brittle fracture, i.e., the most dangerous damage.

Various steels, depending on the alloy, have various ductilities for the same level of strength [1]. For products which have already been fabricated, it is necessary to take into account the ductility and the impact toughness of the metal when monitoring and sampling dangerous regions (from the viewpoint of possible damage).

The relative elongation, the relative contraction ratio and the impact toughness are shown in Figure 1 for one of the brands of alloy steel. For the case where the upper ultimate strength is limited to a value of 68 kgf/mm^2, the indicators for the plastic properties and the impact toughness increase.

The conclusion can be drawn that in the case of selective monitoring, primarily those products or regions of them should be checked, the metal of which has the highest strength and hardness indicators.

To reduce the probability of damage to metal, the following requirement is stipulated in the rules of the State Committee of the Council of Ministers for the Supervision of Industrial Safety and Mining Inspection [2]: the value of the ratio of the yield stress to the ultimate strength (σ_S/σ_B) at room temperature should not exceed 0.6 for carbon steels, 0.7 for alloy steels and 0.8 for alloy reinforcement steels.

In actual products, the value of σ_S/σ_B for a metal can vary in a rather wide range. Thus, pipes, the scatter in the properties of the metal of which was given earlier, were distributed as follows with respect to the value of σ_S/σ_B:

σ_S/σ_B	Number of Pipes	Percentage of the Total Number
≤ 0.7	33	15.1
> 0.7--≤ 0.75	29	14.1
> 0.75--≤ 0.8	100	48.8
> 0.8--≤ 0.85	39	19.0
> 0.85--≤ 0.875	4	2.0

The role of the σ_S/σ_B criterion is rather clear when Figure 2 is considered, from which it can be seen that there is a linear relationship between the value of σ_S/σ_B and the number of cycles before destruction in tests for short-term fatigue at a specified deformation amplitude [3]. A similar linear function is likewise characteristic of tests for thermal fatigue. The greater the value of σ_S/σ_B, the fewer cycles the metal sustains for destruction.

An analysis of a number of faults in the primary metal and welded joints at conventional TES's [3, 4] has shown that damage was primarily observed where the requirement concerning the value of the ratio σ_S/σ_B was not met. Since AES's are used to carry the base load and operate with a smaller number of starts and shutdowns of the equipment than conventional generator sets with capacities of up to 200 MW and nonmodular TES installations, higher ultimate values of the ratio σ_S/σ_B can be permitted for the metal of AES equipment.

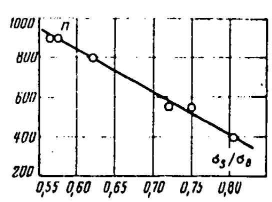

Figure 2. The graph of the relationship between the number of cycles before destruction in the tests of 15 GNM and 22 k steels for short-time fatigue for the case of a deformation amplitude of 1 percent and the ratio of the yield point to the ultimate strength.

Regardless of the setting of these ultimate values, the effectiveness of selective monitoring of the metal and welded joints of AES equipment is improved if those elements or regions of them where the values of σ_S/σ_B are maximum are given priority in the testing.

The values of the ultimate strengths σ_B can be taken from the certificates or determined based on hardness measurements during input quality control during the equipment installation period. The yield stress σ_S is likewise in the certificates for the primary metal or can be determined using nondestructive techniques [5, 6].

When determining the regions of equipment which require increased attention during testing, it is likewise necessary to take into account the possible change in the metal properties due to transformations which take place in it at the working teperatures during operation.

At conventional TES's, pipe bends are the most subject to damage, besides welded joints [7], where the operability of pipe bends depends not only on the properties of the metal and the thermal treatment following bending, but also on the ovality, since with an increase in the ovality, the actual stresses in the bends increased [8]. This circumstance predetermines the expediency of measurements during the acceptance testing for the ovality of bends and the priority monitoring during operation of those bends which have the maximum ovality.

Piping made of austenitic stainless steel has found widescale applications at AES's. The quality of the weld joints of such pipes and their functional capability during operation depend on the ferrite phase content in the metal of the pipes and in the deposited weld metal. Because of this, it is necessary to check the ferrite content in each pipe during input quality control.

It should be noted in conclusion that the large volume of data on metal properties obtained during the input quality control makes it difficult to use them in an operationally timely manner when testing during the operational process. Because of this, the problem arises of designing a monitor system around computers. The latter, based on the metal properties from the certificate and documents of the input quality control which are stored in their memory, as well as the values of the existing stresses, should feed out recommendations for specific equipment or regions in it which are to be given priority in monitoring during operation.

Conclusions

It is expedient to do the following for the purpose of improving the efficiency of selective monitoring of metal and weld joints during operation:

--Determine the equipment components or regions of them, the metal of which is the most inclined to brittle failure, during input checking based on the analysis of certificate data as well as the results of hardness and yield stress measurements;

--Use nondestructive techniques to determine the ultimate strength and yield stresses of individual regions of weld joints and bends, as well as for the primary metal in some cases;

--Give priority to the checking during the operational process of those components or regions of them by nondestructive methods, where reduced values of the ductility and impact toughness, as well as high values of the strength properties and the σ_S/σ_B ratios are combined with the maximum acting stresses;

--Take into account the ferrite content in the metal of pipes for the weld joints of piping made of austenitic steel.

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