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ELECTRIC VACUUM FURNACES FOR QUENCHING DEVELOPED IN THE USSR

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UDC 621.783:66.041.82

Increasing demands for machine parts of high quality and the development of vacuum technology have led to widespread use of heat treatment in vacuum not only for metals of high activity and high-melting metals but also many steels.

Vacuum quenching – quenching in various gases and liquids after heating in vacuum – is widely used in various branches of industry (aviation, instrument construction, automobiles, bearings, and others). In this treatment both the heating time and cooling time are limited. For this reason, the quenching furnace is of more complex design than previous furnaces for annealing, degassing, and sintering. The quality of machine parts after vacuum quenching is determined by the heating temperature and time and also by the interaction of the material with the residual atmosphere in the furnace, which depends on the degree of evacuation, the type and material of the heating elements and thermal insulation, and the operating conditions of the furnace.

In designing furnaces for vacuum quenching, the parameters ensuring the quality desired are in many cases determined experimentally from the permissible thickness of the surface layer with changes in chemical composition and structure. Such studies have been made with laboratory equipment of various types for heat-resistant, tool, and bearing steels: 2Kh13, ShKh15, 1Kh11MF, 9Kh18, Kh12M, R18, and others.

These investigations and the previous studies of the properties of vacuum furnace materials and tests of various units led to recommendations for furnace chambers on the basis of economy of operating characteristics of the materials in furnaces with an operating temperature as high as 1150°C – resistant alloys and ceramic thermal insulation (corundum or fireclay). For higher temperatures (up to 1300°) it is expedient to use graphite (dense graphite, graphitized wire and fabric). Quenchants were also investigated – vacuum oil and

Translated from Metallovedenie i Termicheskaya Obrabotka Metallov, No. 8, pp. 44-47, August, 1977.

TABLE 1

Parameter	SShV-3.3/13GM1	1SNV-5.10.5/13G	1SNV-5.10.5/11.5	SEV-3.3/11.5FM2	SEV-2.2/11.5M1
Power, kW	50	150	152	34	15
Operating temp., °C	1350	1300	1150	1150	1150
Residual pressure, mm Hg	10^{-3}	10^{-3}	10^{-3}	10^{-3}	10^{-3}
Input of cooling water, m^3/h	6,5	15	15	1,5	0,35
Dimensions of main chamber, mm:					
diameter or length	300	1000	1000	300	200
width	—	500	500	—	—
height	300	500	500	300	200
Overall dimensions, mm:					
length	2885	6336	6336	2420	1750
width	2000	4585	4585	2060	1825
height	2150	5196	5196	3060	2800
Total weight, tons	2,75	25,5	15,0	3,1	2,2

inert gases – from the viewpoint of their cooling capacity and interactions with the surface of the parts being treated.

In the case of large-scale and mass production, vacuum-quenching furnaces are usually used for quenching only in gas or in oil. For small-scale production with different steels and parts, universal furnaces are used, containing a cooling chamber and quenching tank. With heat treatment of parts of the same steel but differing in size the small parts are quenched in gas and large parts in oil.

Technical data on quenching furnaces of various types developed, manufactured, and tested in the USSR (All-Union Scientific-Research Institute of Electrothermal Equipment) are given in Table 1.

The vacuum systems of all furnaces consist of mechanical and booster pumps and ensure a pressure of 10^{-3} mm Hg in the working chamber. To reduce evaporation of components from the surface and the thickness of the defective layer the pressure can be raised to 1-10 mm Hg by letting in inert gas during heating.

The SÉV-3.3/11.5FM2 vacuum elevator furnace (Fig. 1) is designed for quenching alloy structural steels in oil as well as other types of heat treatment (annealing, tempering, normalization). It contains heating and quenching chambers arranged one above the other. The heating chamber is lined with lightweight corundum bricks. The heating elements are suspended from the walls and the roof. The batch is loaded through an opening in the lower part of the lining, which is closed with blinds during quenching to reduce the escape of oil vapor from the furnace. In the quenching chamber there is a lifting and lowering mechanism, on the table of which the container of parts is placed. The quenching chamber also has two fans with coolers to accelerate cooling in gas or for quenching small batches, a mechanism for stirring the oil, and screens to prevent the oil from getting into the heating chamber. The furnace has a programmed temperature control.

The 1SNV-5.10.5/11.5F electric vacuum chamber furnace was developed for quenching larger batches of die, bearing, and other steels in inert gases and in oil (Fig. 2).

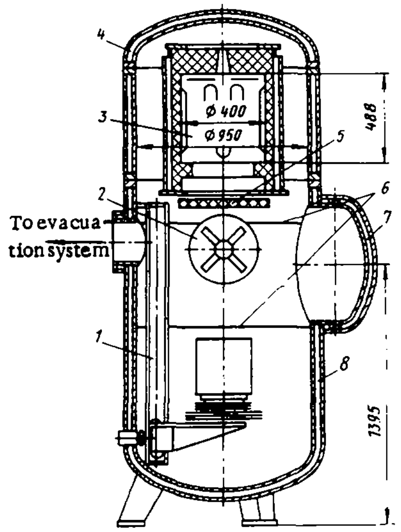

Fig. 1. SÉV-3.3/11.5FM2 electric vacuum elevator furnace. 1) Mechanism for transferring the batch; 2) fan; 3) heating chamber; 4) upper door; 5) blinds; 6) screens; 7) side door; 8) frame.

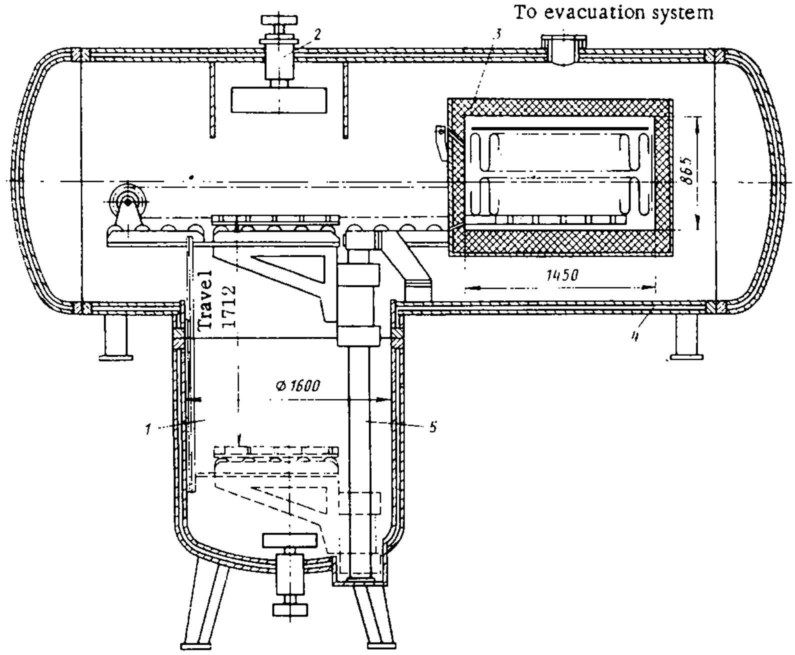

Fig. 2. 1SNV-5.10.5 / 11.5F electric vacuum chamber furnace. 1) Quenching tank; 2) fan; 3) heating chamber; 4) frame; 5) mechanism for transferring the batch.

The furnace has three chambers, the first containing a fan to circulate the inert gas. The second chamber, perpendicular to the first, is a quenching tank with mechanisms for lowering the batch and stirring the oil. In the third chamber, lined with lightweight fireclay bricks, the parts are heated to 1150°. The tray of parts is loaded through the door in the first chamber and moves to the heating chamber on a roller conveyor. After heating and holding, depending on the cooling rate required, the parts are quenched in gas in the first chamber or dropped into the quenching tank in the second chamber. The possibility of varying the cooling rate (cooling down in the heating chamber or in the cooling chamber with or without circulation of the gas) permits the furnace to be used for various types of heat treatment – annealing, normalization, quenching, and tempering, and also for sintering several metals and alloys based on copper, silver, and others.

The 1SNV-5.10.5 / 13G furnace, with an operating temperature of 1300°, is similar in design to the furnace shown in Fig. 2, with use of carbon–graphite materials.

The SShV-3.3 / 13G electric shaft furnace (Fig. 3) was developed for vacuum quenching of tools made of high-speed and die steels. Heating and quenching occur in the same chamber without movement of the parts.

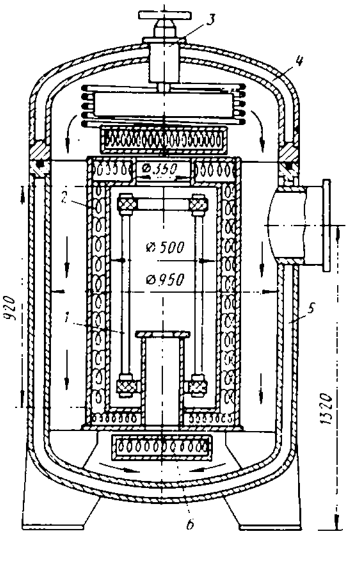

Fig. 3. SShV-3.3 / 13G electric vacuum shaft furnace. 1) Heating element; 2) thermal insulation; 3) fan; 4) cover; 5) frame; 6) blind.

The fact that the heated parts are not moved reduces distortion, which is the advantage of this design. A mechanism for raising and turning the cover is mounted on the frame, along with a fan and an electric motor. Thermal insulation in the sidewalls is provided by a graphite cylinder wrapped with several layers of graphite felt and bound with two metal halfcylinders.

The ends are thermally insulated with graphite rings and graphite felt. The heating elements are graphite rods suspended from two molybdenum brackets. In the process of heating, the openings in the upper and lower parts of the thermal insulation are closed with blinds. A diffuser placed under the lower blind directs the main gas flow into the working space during quenching. The gas-cooling system is placed at the end of the frame. The furnace is powered by a reducing transformer and thyristor regulator. The temperature is controlled by a programmed device.

Laboratory and production tests have confirmed the main advantages of the vacuum-quenching process:

1) The reduction of distortion due to reduction of the thickness of the surface layer with changes in chemical composition;

2) a bright surface, due to which pickling or sandblasting is unnecessary, and reduction of mechanical operations (for example, grinding of bearings);

3) an increase in the service life of parts due to the improvement in the quality of the surface, higher ductility due to degassing, and so forth;

4) better working conditions and the absence of toxic substances in the atmosphere.

EFFECT OF THE CONDITION OF THE SURFACE LAYER ON COMPLEX (BULK) PROPERTIES OF METALLIC MATERIALS

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UDC 621.785.5:620.18

Most of the physicochemical processes that occur during operation of machine parts are concentrated primarily in surface zones of the metal. This is observed not only in those cases were the free surface of the metal is subject to the direct influence of chemical and electrochemical corrosion, erosion, friction against a counterbody, and sublimation due to high-energy particles, but also under the influence of mechanical stress fields. Stresses are usually distributed unevenly through the section of a part and induce deformation and fracture primarily in surface zones. Changes in the chemical composition, structure, and properties also occur in the surface zones of alloys under the influence of high temperatures and surrounding media.

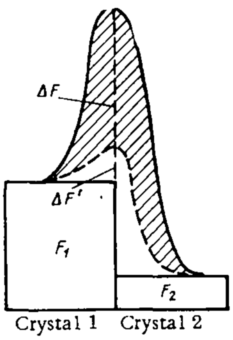

Fig. 1. Change in free energy at the boundary between two crystals in the process of diffusional interaction. ——) Before saturation; – – –) after saturation.

Moscow Institute of Civil Aviation Engineers. Translated from Metallovedenie i Termicheskaya Obrabotka Metallov, No. 8, pp. 47–49, August, 1977.