HIGH-TEMPERATURE VACUUM BRAZING OF PLATE-AND-RIB HEAT EXCHANGERS
OF COMPRESSOR UNITS

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The creation of highly efficient compact plate-and-rib heat exchangers for compressors [1] has made necessary a method of brazing them in large-scale production. In the production of plate-and-rib heat exchangers only a method of flux-free brazing may be used since removal of the products of the reaction and flux residues from the long thin gas channels involves significant difficulties. As experience indicates [2], in the production of lamellar structures, similar in many respects to the design of plate-and-rib heat exchangers, brazing in a medium of protective gas or in vacuum is primarily used. In [3, 4] the advantage was shown of using brazing in vacuum rather than brazing in a protective gas.

Depending upon the purpose of the compressor, plate-and-rib heat exchangers are made of low-carbon or 12Kh13, 20Kh13, 12Kh18N9, 17Kh18N9, or 12Kh18N9T high-alloy steels or aluminum and its alloy AMts. The basic parts of a plate-and-rib heat exchanger (Fig. 1), the spacer sheet 1 and the fins 2, are made of thin metal sheet or strip, the thickness of which, depending upon the operating pressure in the heat exchanger, is 0.2-1 and 0.1-0.3 mm, respectively. The operating gas channels of the plate-and-rib heat exchanger are formed by stamping or bending of the spacer sheet or by placing of additional elements 3. The parts of the plate-and-rib heat exchanger are joined by brazing. The collector plate 4 may be brazed simultaneously with the heat exchanger parts. The fin of sinusoidal or triangular profile is formed by rolling sheet with a toothed roll. The height of the fin profile is 0.1-0.2 mm more than the height of the channel in which it will be installed. As a result of elasticity of the fin, which is deformed in assembly by this amount, the tight fit of the plate-and-rib heat exchanger parts necessary for the creation of capillary gaps in brazing is provided.

For welding of steel heat exchangers in vacuum, copper is used as the brazing metal. The tensile strength of joints of low-carbon and high-alloy steels made with copper is 36-39 and 40-44 kgf/mm², respectively. The brazing is done in 1.059.007, OKB8085, SEV-5.5/16, SEV-11.5,5/16, and other vacuum furnaces having an operating temperature of not less than 1100°C and a vacuum in the chamber of 10⁻⁴ mm Hg. Regardless of the type of steel from which the plate-and-rib heat exchanger parts are made, in brazing with copper the part is heated to 1100°C and held at this temperature for 10 min after fusion of the braze metal.

Brazing of plate-and-rib heat exchanger parts of low-carbon steel is done in a vacuum of 10⁻¹-10⁻³ mm Hg, while brazing of high-alloy steel plate-and-rib heat exchangers even in a vacuum of 10⁻⁴ mm Hg involves certain difficulties related to the poor wettability of steel by copper as a result of the presence on the steel surface of chromium and titanium oxides [5]. In heating to 600°C the oxide film thickness increases as a result of the action of oxygen contained in the residual gases at a vacuum of 10⁻⁴ mm Hg. With further heating the oxide film thickness decreases as a result of an increase in the rate of dissolution of oxygen in the heated metal. The surface of steel parts is freed of the oxide film at a temperature above 1200°C [6]. However, such overheating is unacceptable in brazing with copper because of its active evaporation and increased flowability. It is possible to decrease the temperature of disappearance of the oxide film from the surface of alloy steels in heating in vacuum by decreasing the partial pressure of oxygen in the residual gases in the brazing zone. A method of additional screening is used for this purpose [7]. The technological approach to reducing the partial pressure of oxygen in the brazing zone is chosen depending upon the type of steel used in production of the plate-and-rib heat exchanger. Brazing of low-carbon steel plate-and-rib heat exchangers does not require additional procedures. In brazing 12Kh13, 20Kh13, 12Kh18N9, and 17Kh18N9 high-alloy plate-and-rib heat exchangers screens of thin steel sheet fastened by contact welding around the

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Fig. 1. Block of a plate-and-rib heat exchanger formed by stamping or bending of the spacer sheet (a) and with the use of bars (b).

Fig. 2. Plate-and-rib heat exchanger block assembled for brazing with welded collector and production strips.

In brazing a plate-and-rib heat exchanger of 12Kh18N9T, which is alloyed with titanium, metal packages with manganese powder with a particle size of 50-150 μm are fastened to the surface of the screen exposed to the heat exchanger. The quantity of manganese is based on a calculated 0.004 g per cm³ of volume enclosed by the screens.

The quality of brazing of plate-and-rib heat exchangers depends upon the dimensions of the brazed joints between the parts. In the plate-and-rib heat exchangers assembled for brazing, the copper strip used as the brazing metal is inserted from both sides of the spacer sheet. Depending upon the size of the plate-and-rib heat exchanger, the strip thickness is 0.02-0.05 mm. In fusion of the braze metal the dimensions of the brazed joints may change as a result of displacement of the plate-and-rib heat exchanger parts under the action of their own weight. To avoid this, special mechanisms [3] or devices, which are heated together with the heat exchanger parts to the brazing temperature, are used. However, experiments showed that the reliability and effectiveness of these devices at a brazing temperature of 1100°C are low and their weight and dimensions are significantly greater than those of the plate-and-rib heat exchanger blocks.

In assembling steel plate-and-rib heat exchangers it is desirable to use a method of rigid fastening of all parts with securing of the brazed joints by welding. Before welding, the heat exchanger parts are degreased in benzene and dried in air. The rust is first removed from low-carbon steel parts by any of the known methods. The plate-and-rib heat exchangers assembled in a device are tightened under a press to eliminate gaps between the brazing metal strip, the spacer sheets, and the bars, and they are held on the assembly plate by threaded tie rods. Strips, which are parts of the collector, are welded on the angles of the heat exchanger by argon-arc welding. The weld joint is made continuous over the whole height of the heat exchanger, connecting all of the bars and spacer sheets with the strip. In addition, production strips are welded around the perimeter of the heat exchanger with a spacing of 150-180 mm (Fig. 2). In assembling heat exchanger blocks without the use of bars (Fig. 1b) the spacer sheets forming the gas channels are fastened to the collector strips and the position of the fins is fixed by welding the production strips. In assembling a heat exchanger with fixing of the gaps by welding the maximum utilization of the volume of the vacuum furnace working chamber is provided.

The method of assembling aluminum alloy plate-and-rib heat exchangers is somewhat simpler than that for steel ones as a result of the use of spacer sheets of AMts alloy clad in rolling on both sides with eutectic Silumin, which is used as the brazing metal [8]. The brazing of aluminum alloy plate-and-rib heat exchangers is done at a lower temperature, which makes it possible to use comparatively simple equipment consisting of threaded tie rods and support sheets for forming them. With the use of such equipment it is possible to perform up to 50 brazing cycles without repair of it.

The complexity in brazing aluminum heat exchangers is caused by active oxidation of the aluminum in heating and the resistance of its oxide film. For flux-free vacuum brazing of aluminum the majority of works recommend placing magnesium in the brazing zone. This method