Vacuum Furnace Brazing Large Segments Of Heat Exchanger For Nuclear Fusion Reactor

By CHARLES F. BURNS JR.
Manager of Quality Control and Brazing
Solar Atmospheres Inc.
Affiliate of Vacuum Furnace Systems Corp.
Souderton, PA 18964

Five large heat exchanger segments for an experimental power reactor (Tokamak) for Princeton Plasma Physics have been successfully vacuum furnace brazed. Each segment was brazed, one at a time, in a vacuum furnace (Model HL66) at Solar Atmospheres, Inc., an affiliate company of Vacuum Furnace Systems Corp., Souderton, PA (see Figs. 1 and 2).

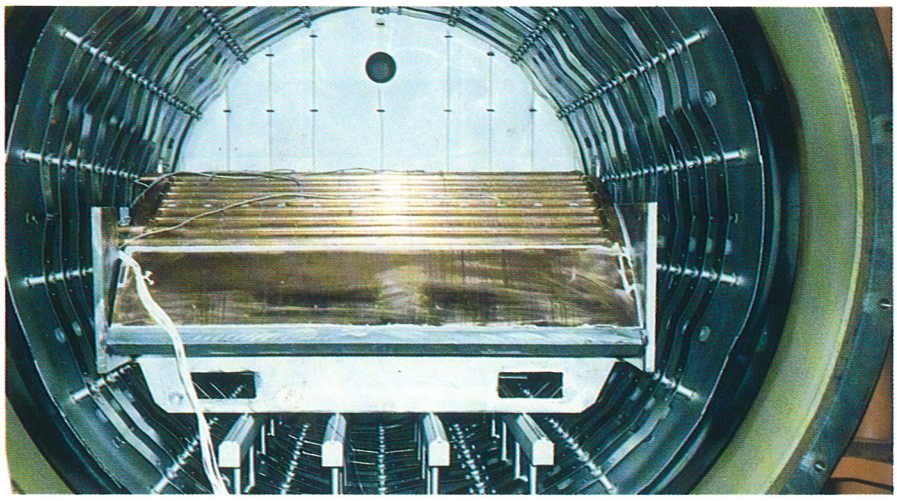

Fig. 2 Fixtured heat exchanger segment in vacuum furnace ready for the brazing cycle. Work thermocouples positioned throughout the assembly are being readily connected to a common jack to allow temperature monitoring.

Furnace Facility Design

The vacuum furnace is designed with molybdenum heating elements and a composite graphite foil/graphite felt insulated hot zone. Appropriate vacuum is achieved through use of a roughing vacuum pump (Busch Model EE), two cascade vacuum blowers (Roots type) and a 32 in. high vacuum diffusion pump (Varian). Temperature control is via a programmable controller (Honeywell Model DCP 700) coupled to a 360 kW variable reactance power supply (Hunterdon). A data logger (Honeywell DPR) provides for data acquisition.

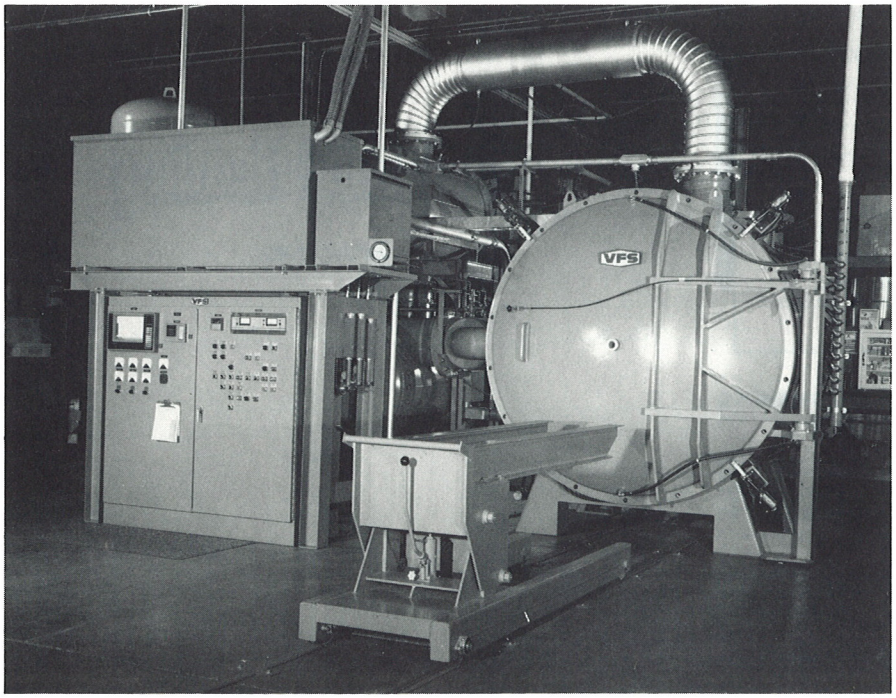

Fig. 1 Vacuum furnace facility used for silver brazing copper tubing on segment of heat exchanger for nuclear fusion reactor.

Heat Exchanger Segment

A stainless steel fixture, Figs. 2 and 3, holds the heat exchanger segment during the brazing cycle. Each hemispherical segment is 52 in. wide by 68 in. long by 36 in. high and weighs 2260 lb. The copper segment is 2 in. thick with approximately 30 one-inch diameter tubes forming a manifold assembly for cooling purposes. The copper tubes are brazed to the copper plate using a 72% silver - 28% copper braze alloy with a special binder to reduce residue (Handy and Harman 721). Fig. 4 shows application of the brazing alloy in paste form, prior to the vacuum furnace brazing operation.

Brazing Cycle

The brazing cycle includes a high vacuum bake-out cycle for 8 hr at 1100°F with vacuum into the mid 10^{-5} Torr range to remove dissolved oxygen (see Fig. 5). Bake out is followed by the introduction of hydrogen flowing at 80 SCFH. The programmed cy-

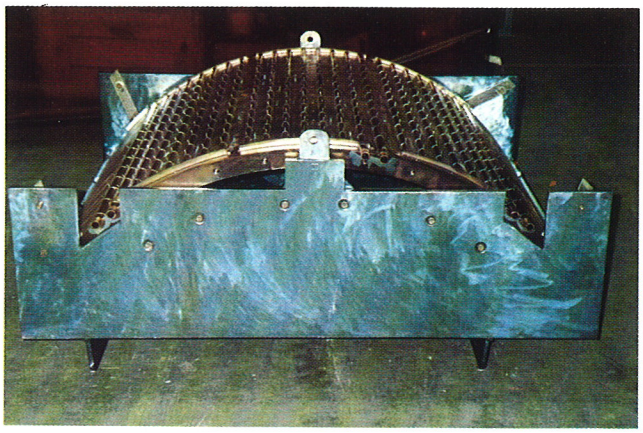

Fig. 3 Copper heat exchanger segment is held in the stainless steel fixture during the brazing cycle.

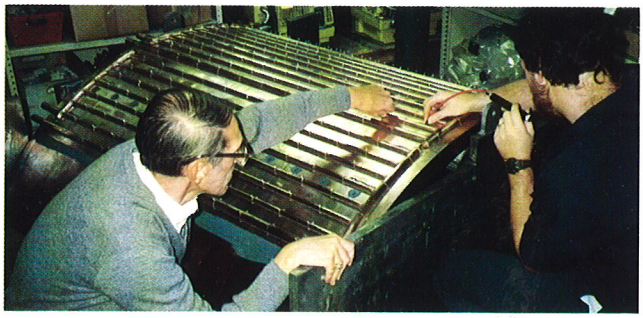

Fig. 4 Application of the 72% AG - 28% Cu brazing alloy paste to the copper heat exchanger segment for vacuum furnace brazing of tubing to the plate.

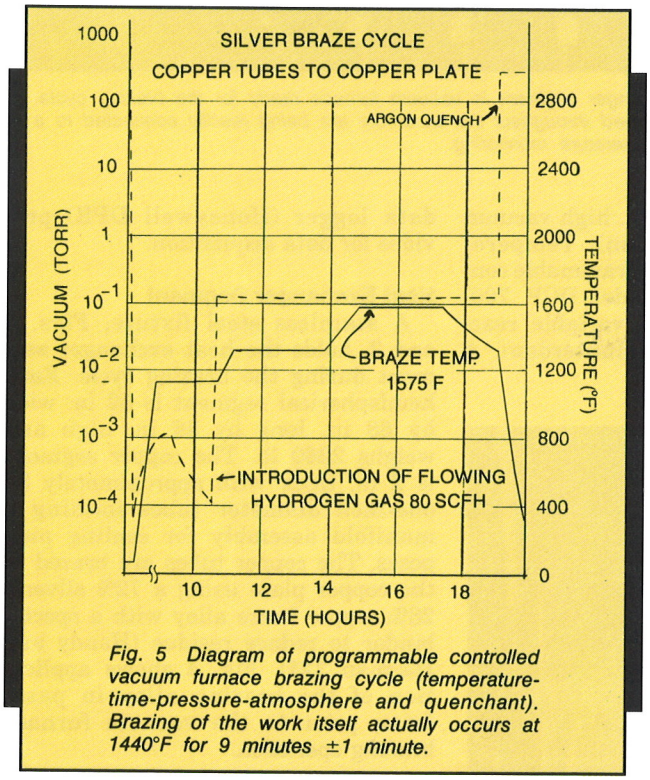

Fig. 5 Diagram of programmable controlled vacuum furnace brazing cycle (temperature-time-pressure-atmosphere and quenchant). Brazing of the work itself actually occurs at 1440°F for 9 minutes ±1 minute.

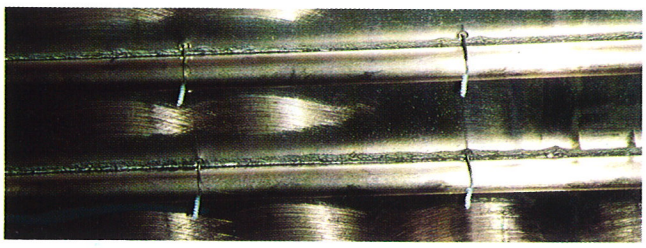

Fig. 6 Copper tubing joined to the copper plate of the heat exchanger segment, by vacuum furnace brazing.

cle then proceeds with heating to about 1300°F and held at that temperature to achieve overall temperature uniformity, prior to reaching the furnace brazing temperature of 1575°F while still under the partial pressure hydrogen atmosphere. Operating pressure is maintained by the vacuum blowers and the backing pump.

The work itself is brazed at a temperature of 1440°F for 9 minutes ±1 minute. This actual flow temperature for the brazing alloy is measured by means of a thermocouple connected to the braze alloy in a separate cup processed along with the work.

Following brazing, the heat exchanger segment is cooled with recirculating argon gas to ambient temperature. The entire furnace cycle is approximately 20 hours from work load to unload of the furnace.

Temperature Control And Braze Quality

To insure proper temperature monitoring of the heat exchanger segment, 12 type "K" thermocouples were positioned throughout the assembly (see Fig. 2). Temperature uniformity at the braze was within 5°F as measured on the assembly. The braze flow and wetting were excellent and well within expectation (see Fig. 6).

Reprinted from

Industrial Heating

January 1990