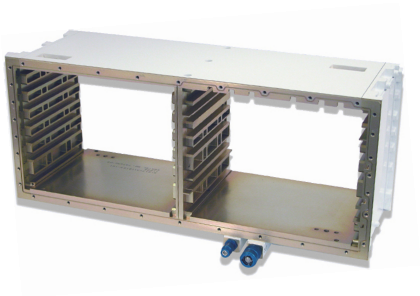
THERMAL DIVISION OF BOYD CORPORATION

VACUUM BRAZING OF ALUMINUM COLD PLATES AND HEAT EXCHANGERS



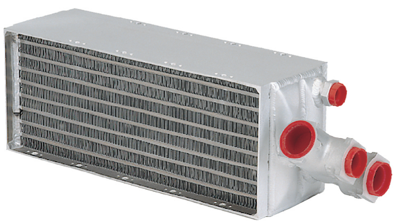
Vacuum brazing is a high-end joining technology because it results in parts with extremely strong joints and with no residual corrosive flux. It is a process in which two base metals, such as aluminum plates, are joined together using a filler metal that has a melting point below that of the base metal. The filler metal, also known as a braze alloy, is drawn into the closely mated parallel surfaces of the aluminum plates by capillary action. The attributes of the vacuum brazing process include uniform heating, tight temperature control, no post cleaning processes, and process repeatability.

Aluminum cold plates, plate-fin heat exchangers, and flat tube heat exchangers are three products that are often vacuum-brazed. Aluminum vacuum-brazed cold plates consist of corrugated aluminum fin brazed into a cavity between two aluminum plates. Plate-fin heat exchangers have fin-filled passages that are separated by flat plates. The fin is brazed to the plates, which are multi-layer aluminum sheets with braze alloy on both sides. The braze alloy that is selected for plate-fin heat exchangers depends on the base metal's alloys as well as the application's specific requirements. Flat tube heat exchangers, also known as oil coolers, have fin between flat tubes. For both flat tube heat exchangers and cold plates, the braze alloy generally doesn't vary.

Before vacuum brazing, cold plate and heat exchanger components must first be cleaned. Removing grease, oil, dirt, and oxides ensures that there is uniform capillary action, which is needed to achieve the highest quality braze joints.

After components are cleaned they are stored in sealed containers and placed in a temperature and humidity controlled room for assembly. This ensures that components are protected from additional oxidation and contamination prior to assembly and brazing. During assembly, protective gloves are worn to further protect components from contamination.

Once parts are cleaned and assembled, they are secured in brazing fixtures. The brazing fixtures hold the parts together as well as keep them aligned during the brazing process. Low thermal mass fixtures reduce the brazing cycle time. If magnesium is not present in the alloy, it generally will be added to the furnace as a "getter" of any remaining oxygen molecules.



Virtually every cold plate and heat exchanger requires a slightly different furnace profile to achieve the highest quality braze. This furnace profile is known within the industry as a vacuum brazing "recipe." The recipe specifies the temperature, vacuum level, and cycle time. Brazing of cold plates and heat exchangers usually takes place at approximately 1100°F (593°C) and a vacuum level between 5 to 6 Torr. However, the recipe depends in large part on the alloys, the total mass in the furnace, and the vacuum furnace being used. The furnace controller monitors vacuum levels and temperatures and automatically advances to the next segment as programmed in the recipe until the cycle is complete.

Compared to other metallurgical techniques for joining aluminum, vacuum furnace brazing offers numerous technical advantages:

- High-strength, void-free, leak-free joints approaching parent metal strength, with proof pressures up to 800 psi and burst pressures up to 1300 psi
- Temperature resistance up to 350°F (176°C)
- Consistently reproducible results with tightly toleranced joining surfaces
- Uniform thermal conductivity
- Extremely clean parts with no residual corrosive flux due to the flux-free process (unlike dip brazing)
- Ability to fill long, otherwise inaccessible joints
- Minimal distortion due to uniform heating and cooling
- No surface deterioration during processing

Single process production of complex assemblies with multiple joints can also lower cost while increasing product quality. Yields of 80% are typical for the vacuum brazing process, but 98% or better yields are possible in a carefully controlled process. With high yields for complex fabrications, vacuum brazing is the preferred joining process for manufacturing high performance aluminum cold plates and heat exchangers.

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