

Stainless Steel Brazing

By

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Figure 1. Brazed Stainless Steel Components

Background

Atmosphere integrity and control are key to the successful brazing of stainless steel components. Due to the very high affinity that stainless has for Oxygen at high temperatures, the presence of Oxygen or moisture in the furnace will oxidize the surfaces to be brazed and result in a defective braze. Vacuum furnaces and Humpback furnaces have been the traditional systems used to braze stainless steel because of their ability to ensure an Oxygen-free atmosphere with a very low dew point. However, both furnace technologies bring with them issues that result in higher operational costs, increased maintenance costs, and other process related costs that can be avoided by using straight through continuous belt furnace technology. Recent advances in furnace design and atmosphere control have made it possible for stainless steel to be brazed in straight through continuous belt furnaces. This step forward in technology now permits continuous processing at lower operational costs, less maintenance and higher yields than realized with traditional brazing systems. Oxygen levels of less than 10 ppm and dew points as low as -85°F are common in a state-of-the-art straight through

continuous belt brazing furnace. The adoption of this technology by some of the leading producers of brazed components has allowed the industry to move forward in becoming more competitive.

Surface Cleanliness

A brazed joint is formed by the filler metal melting and flowing via a capillary effect into the pours of the closely fitted surfaces of the joint to form an alloy of the metals upon solidification.

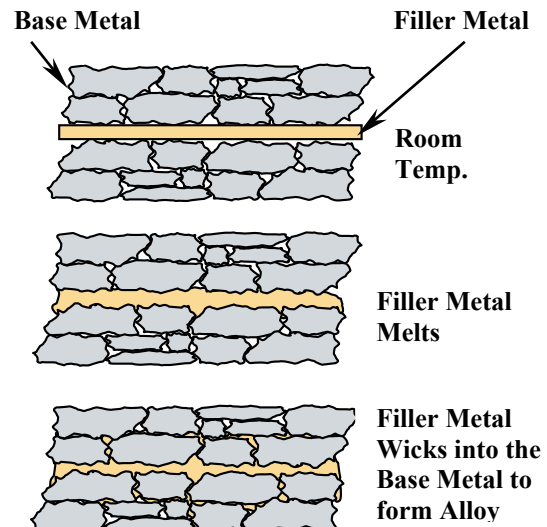


Figure 2. Brazing Schematic

The key to successfully achieving a good brazed connection is surface preparation. The presence of contaminants or oxides prevents the filler metal from coming into contact with one of the surfaces to be brazed. In the case of minor oxidation, the pours of the surfaces to be brazed will be sealed by the oxide. This prevents the capillary action and, ultimately, the brazing from occurring. Hence, the initial cleanliness of the surfaces to be brazed is extremely important, but it is equally important that the cleanliness of

these surfaces be maintained during the brazing process.

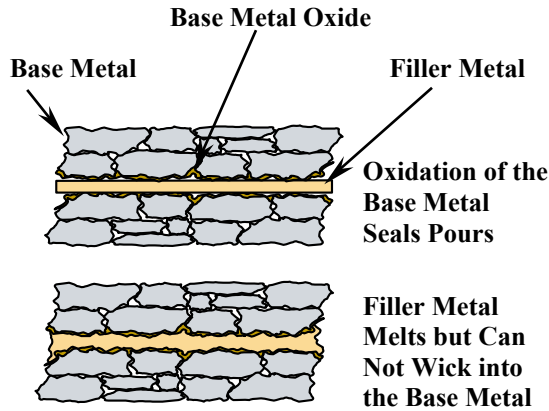


Figure 3. Effect of Oxidation on Brazing

Achieving and maintaining the necessary level of cleanliness is much more difficult for brazing stainless steel components than brazing steel components. The Chromium in the stainless steel forms a much more stable oxide at a much lower Oxygen level than iron.

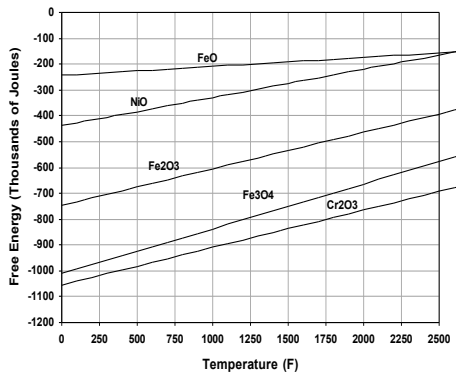


Figure 4. Oxide Stability

The oxides present on the surface must be reduced prior to the part reaching the melting temperature of the filler metal. The reduction is typically achieved through a reaction of Hydrogen with the Oxygen present in the oxide to form water vapor.

Oxide Reduction

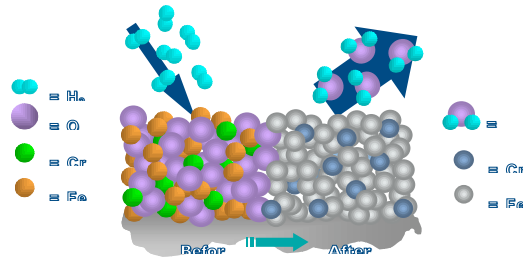


Figure 4. Oxide Reduction Mechanism

The presence of too much water vapor or Oxygen in the system will prevent the reaction from proceeding. The dew point is used to determine the amount of water vapor in the system at given conditions. The dew point is the temperature at which an amount of water vapor in the system will saturate the atmosphere. The typical dew point required for brazing stainless steel joints in 100% Hydrogen is -50°F .

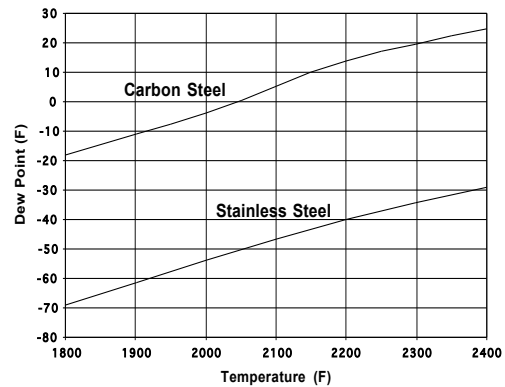


Figure 5. Dew Point Requirements

Equipment

The equipment used to braze stainless steel has changed over the years. These changes have been a result of technological advancements in the areas of atmosphere control and furnace design.

The traditional method of brazing was to use a vacuum furnace. The low Oxygen level was achieved by removing the atmosphere from the furnace while heating up the components to be brazed. The lack of atmosphere eliminated the opportunity for oxidation of the stainless

steel and reduced any oxides that were already present on the surface of the base metal.



Figure 6. Seco/Warwick Vacuum Furnace

Although effective, this method of brazing has a number of disadvantages. The capital cost of a vacuum furnace is two to four times that of competing technologies. The process is a batch process. The furnace must be heated and cooled with each batch of product. The result is wasted time and energy due to the large mass of the vacuum furnace. The reduced volume of production and the significantly higher capital cost for such a system make it more applicable to high value niche products.

To braze larger volumes of products, the continuous belt furnace is used with a reducing atmosphere. The most common gas used in these atmospheres is Hydrogen. If the amount of Oxygen that is entering the furnace is small, the Hydrogen can react with it and prevent the oxidation of the base metal.

There are two types of the continuous belt furnace: the hump-back furnace and the straight through continuous belt furnace.

In the past, the hump-back furnace was the most common method of continuous stainless steel brazing because the arched form of the muffle took advantage of the very low density of the Hydrogen in relation to that of Oxygen. The stratification of the atmosphere inside the furnace provided a very low dew point for the control of the oxides and effective brazing.

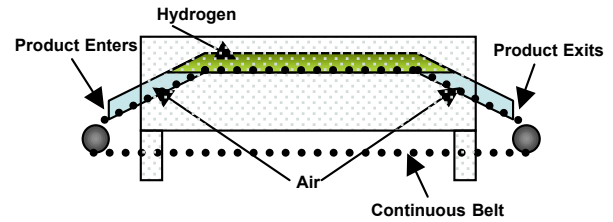


Figure 7. Schematic of a Hump-Back Furnace

The hump-back furnace affords the producer the ability to braze larger volumes of product with equivalent quality, higher production rates and higher thermal efficiency than the vacuum furnace.

The disadvantages of the hump-back furnace are two fold. The height of the product must be restricted to ensure that the hump is effective in maintaining the seal through the stratification of the atmosphere. As well, the hump presents many problems with respect to product tipping and general furnace maintenance.



Figure 8. Abbott Furnace Company Hump-Back Furnace

A straight through continuous belt furnace avoids many of the issues presented by the hump in the hump-back furnace. The belt rides on a horizontal surface throughout the furnace. Product stability and height issues are minimized along with the added maintenance that is seen in the hump-back furnace.

Until recent years, it was thought that the atmosphere control and dew point could not be controlled to a level sufficient to braze stainless steel in a continuous belt furnace without the use of a flux. Due to advances in atmosphere technology and furnace design, this is now a very common approach to brazing stainless steel without a flux.



Figure 9. Abbott Furnace Company Straight Through Continuous Belt Furnace

Controlling the time, temperature and atmosphere relationship that is experienced by the product is the ultimate key to this process. Due to the many zones of control in this type of furnace, the temperature and the atmosphere may be varied throughout the furnace to optimize the brazing process.

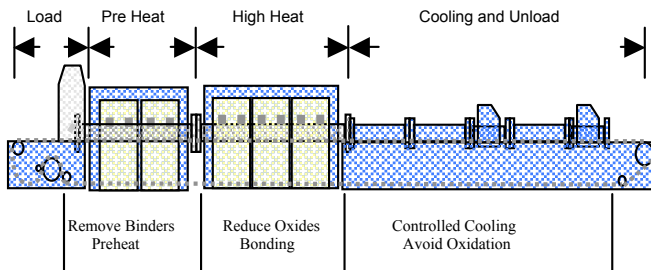


Figure 10. Schematic of a Straight Through Continuous Belt Furnace

The degree of this control is demonstrated in Figure 11. Each step of the brazing process is dealt with separately. The temperature and atmosphere needed for each of these steps are provided for the appropriate amount of time to reach completion.

Optimal atmosphere control is achieved through zoning, composition, multiple injection points throughout the furnace, flow rate and overall directionality of the atmosphere flow in the furnace. Approximately 80% to 90% of the total atmosphere that is introduced into the furnace should flow toward the front of the furnace. Forward atmosphere flow provides optimal heating and a minimization of atmosphere usage to flush any volatiles from the product.

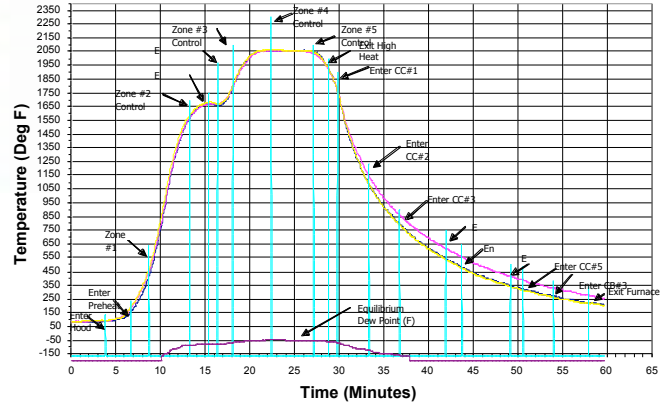


Figure 11. Equilibrium Dew Point

Important variables that must be considered in making such a system are quality of the construction, selection of the appropriate sealing materials and incoming atmosphere integrity. Once a very pure atmosphere has been delivered to the furnace, the purity of the atmosphere must be maintained throughout its use. Mechanical additions to the furnace in the form of curtains and uniquely designed stacking aid in this control.

Advancements in the area of muffle design and muffle composition have greatly improved the performance of these systems. No longer are designers restricted to steel as the primary material for muffles. Advanced ceramics, with the many desirable properties with regards to thermal stability and wear, are now a common material for muffles.

Summary

Advancements in materials, manufacturing techniques, furnace designs and a better understanding of the stainless steel brazing



process have made it possible to take advantage of the lower cost and higher throughput of a straight through continuous belt furnace; therefore, providing brazing houses with another tool to become more competitive.