

Moisture-Free Atmosphere System for Brazing Ferrous Metals

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A novel moisture-free brazing atmosphere system has been developed to replace the conventional humidified nitrogen-based brazing atmosphere system for brazing carbon steel components with good and consistent brazed joint quality and properties. The system involves adding a small amount of carbon dioxide to a dry nitrogen-hydrogen atmosphere to control braze flow and eliminate soot formation while brazing carbon steel components. It has been installed and commercially demonstrated in a production furnace. This article describes the development and commercial demonstration of the moisture-free brazing atmosphere system.

Furnace brazing is increasingly becoming popular for mass producing brazed components cost effectively. It involves placing a filler material between two or more components to be brazed and heating them in the presence of a protective atmosphere to a temperature that facilitates melting and flowing of the filler material to form a metallurgical bond between the filler material and the components.^[1-6] Subsequent cooling of the components allows the filler material to solidify and join the components.

The selection of the right protective atmosphere in furnace brazing is very important for producing brazed components with good brazed joint quality and properties. For example, nitrogen-based atmospheres containing nitrogen along with a controlled amount of a reducing gas such as hydrogen and an oxidant such as moisture have been routinely employed for furnace brazing carbon steel components.^[1,3] The function of a reducing gas is to keep surface of carbon steel components from oxidizing as well as to maintain reducing potential in heating and cooling zones of the furnace. The function of an oxidant is to help in regulating braze flow, facilitate removal of organic binder from the braze material, and prevent formation of soot on brazed joints. The use of high concentration of a reducing gas in the furnace atmosphere is known

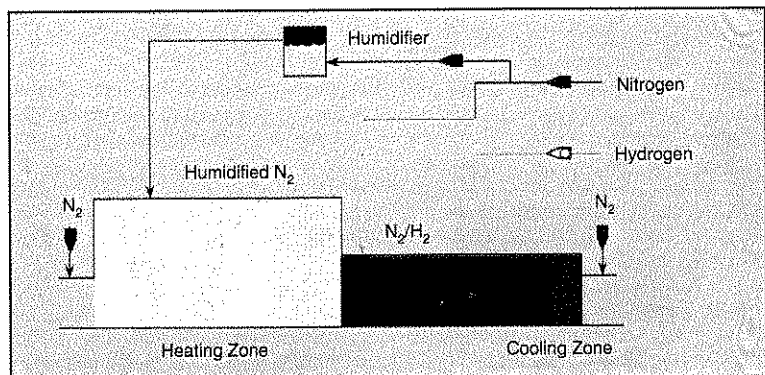


Fig. 1 Schematic of a continuous mesh belt furnace equipped with a conventional humidified nitrogen and hydrogen-based furnace brazing atmosphere system.

to cause overflow of brazing material, resulting in poor quality of brazed joints. The use of low or insufficient concentration of an oxidant is known to result in the formation of soot on brazed joints. Likewise, the use of low concentration of a reducing gas or high concentration of an oxidant is known to oxidize the braze material and components, resulting in poor braze flow and braze joint quality and unacceptable appearance of brazed components. Therefore, it is important to carefully select the composition of the furnace brazing atmosphere to produce components with good and consistent brazed joint quality and properties.

Nitrogen-based atmospheres have

been produced and supplied by exothermic generators, endothermic generators, ammonia dissociators, or by blending nitrogen and hydrogen.^[1,3] Exothermic and endothermic atmospheres are produced by thermally or catalytically combusting a controlled amount of a hydrocarbon gas, such as natural gas in air. The composition of atmosphere produced by exothermic and endothermic generators is known to change with time due to changes in the composition of natural gas and air or leaks in the system caused by high-temperature operation. They are, therefore, not often employed for furnace brazing components requiring good and consistent brazed joint quality and properties. In

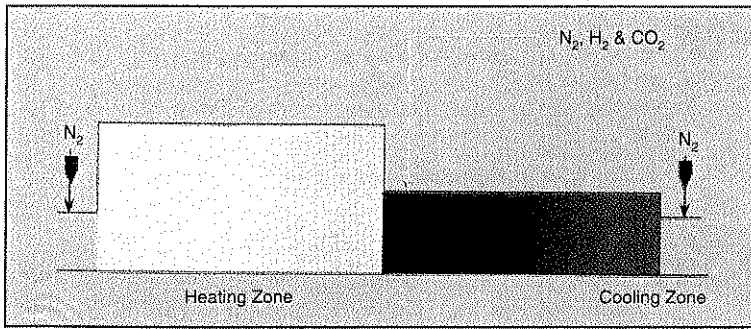


Fig. 2 Schematic of a continuous mesh belt furnace equipped with the moisture-free furnace brazing atmosphere system.

addition, due to the presence of high levels of carbon monoxide, they are not suitable for brazing stainless steel components. Atmosphere produced by dissociating ammonia can be used for brazing carbon steel components provided it is humidified prior to introducing into the furnace. It can also be used for brazing stainless steel components without humidification. However, the use of dissociated ammonia atmosphere in furnace brazing is increasingly becoming unpopular these days due to the toxic nature of ammonia.

Nitrogen-hydrogen atmosphere is produced and supplied by blending known quantities of nitrogen and hydrogen. Because the composition of nitrogen-hydrogen atmosphere can be precisely varied and controlled, it has been widely employed by manufacturers for furnace brazing carbon steel and stainless steel components requiring good and consistent brazed joint quality and properties. Although a dry blend of nitrogen and hydrogen is ideal for furnace brazing stainless steel components, it is not suitable for furnace brazing carbon steel components due to excessive flow of filler material and formation of soot on brazed joints. An oxidizing agent such as moisture is sometimes added to the nitrogen-hydrogen atmosphere prior to introducing the atmosphere into pre-heating and heating zones of furnace in an attempt to overcome these problems.^[7] Alternatively, a part of the nitrogen stream is sometimes passed through a humidifier shown in Fig. 1 and introduced directly into the pre-heating zone of the furnace to overcome the above mentioned problems.

Although a humidified nitrogen-hydrogen atmosphere is ideal for overcoming problems related to excessive braze flow and formation of soot on brazed joints while brazing carbon steel components, it is difficult to maintain

the right amount of moisture in the nitrogen-hydrogen atmosphere using a humidifier. Furthermore, it is difficult to prevent the humidified nitrogen-hydrogen atmosphere from flowing through the cooling zone of furnace and concomitantly oxidizing brazed components. Likewise, it is difficult to not only maintain the right amount of moisture in the nitrogen stream, but also to find the ideal location for introducing humidified nitrogen into the brazing furnace. Above all, it is difficult and time consuming to braze carbon steel and stainless steel components in the same furnace because of the long time required to condition the furnace while switching from brazing carbon steel to stainless steel components.

In order to overcome problems with humidifying nitrogen-hydrogen atmosphere with the right amount of moisture and finding a suitable location for introducing humidified nitrogen stream into furnace, a novel moisture-free atmosphere system has been developed and commercialized for brazing carbon steel components with good and consistent brazed joint quality and properties.^[8] Because of the moisture-free nature of the atmosphere, the system allows manufacturers to braze carbon steel and stainless steel components in the same furnace without spending a lot of time conditioning the furnace while

switching from brazing carbon steel to stainless steel components, and vice versa. The system is currently being marketed under the trade name PURI-FIRE® BR Atmosphere System.

EXPERIMENTAL

The moisture-free brazing atmosphere system for brazing carbon steel components was developed in a Watkins-Johnson continuous mesh belt experimental furnace equipped with integrated heating and cooling zones. The furnace was eight inches wide, and consisted of a heating zone made of an Inconel 601 muffle. It was heated resistively to 1,100°C to braze 1010 carbon steel test coupons using a commercially available brazing paste (CNG-1900-750) supplied by Fusion, Inc. The water-cooled cooling zone, which immediately followed the heating zone, was made of stainless steel. A mixture of dry nitrogen, 4% hydrogen and 0.0 to 0.8% carbon dioxide was employed to develop the moisture-free brazing atmosphere. The atmosphere mixture was introduced into the transition zone, which was located between the heating and cooling zones of the furnace as shown in Fig. 2. The introduction of brazing atmosphere into the transition zone eliminated all the problems that are experienced while finding the ideal spot for introducing humidified nitrogen in pre-heating zone of the furnace. A fixed belt speed was selected to provide 15 minutes in the heating zone to braze the carbon steel coupons.

The application of the moisture-free brazing atmosphere system was commercially demonstrated in a humpback mesh belt commercial furnace designed by Designed Metal Products, Mansfield, OH. The furnace was similar to the one shown in Fig. 3, measuring 24 inches wide with three independent gas-fired heating zones, and operating at a maximum temperature of 1,145°C. The furnace was used to braze stainless steel components (300 series) in dry 25%

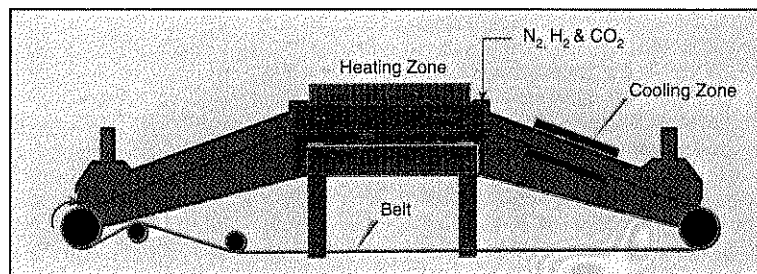


Fig. 3 Schematic of a continuous Humpback mesh belt furnace equipped with the moisture-free furnace brazing atmosphere system.

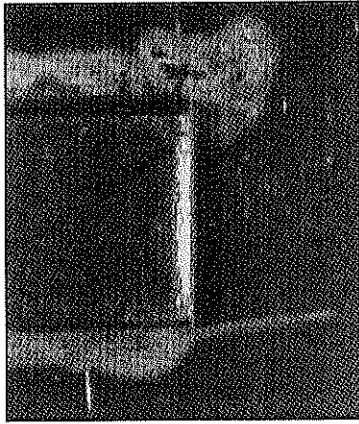


Fig. 4 Carbon steel coupon brazed in a dry nitrogen and hydrogen atmosphere showing excessive braze flow and soot formation on brazed joint.

nitrogen - 75% hydrogen atmosphere using BNi-1 nickel preforms supplied by Lucas-Milhaupt. It was also used to braze SAE type 1010 and 12L14 carbon steel components using CDA 521 copper preforms and 102 oxygen-free copper. A mixture of dry nitrogen, 6.5% hydrogen and 0.5% carbon dioxide was used to braze carbon steel components. The gaseous mixture was introduced at the end of the heating zone (see Fig. 3) to braze stainless steel and carbon steel components. A fixed belt speed was selected to provide 20 minutes in the heating zone to braze stainless steel and carbon steel components.

RESULTS AND DISCUSSION

Initially a mixture of dry nitrogen and 4% hydrogen was introduced into the furnace through the transition zone of the furnace to braze carbon steel coupons using a commercially available brazing paste. The use of a dry nitrogen-hydrogen atmosphere resulted in brazed coupons with a bright surface finish, but with an unacceptable brazed joint quality, as evidenced by excessive braze flow and formation of soot on brazed joint (see Fig. 4). The use of a dry nitrogen-hydrogen atmosphere was instrumental in reducing the surface tension between the base metal and filler material, thereby causing excessive braze flow. Likewise, the dry nitrogen-hydrogen atmosphere was not effective in removing organic binders from the brazing paste, thereby forming soot on the brazed joint.

The addition of 0.2% oxidant in the form of carbon dioxide to the nitrogen and 4% hydrogen atmosphere was helpful in reducing both the excessive

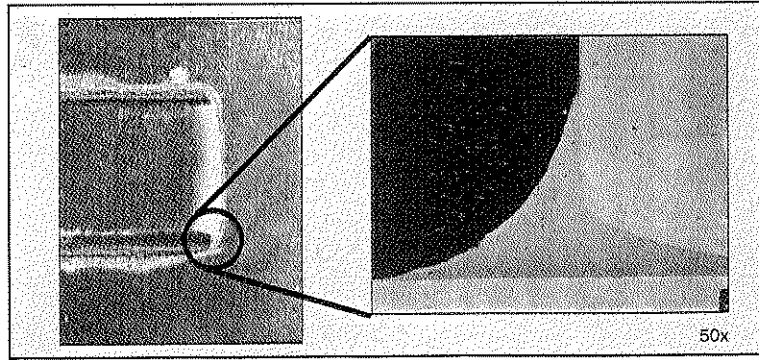
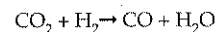


Fig. 5 Carbon steel coupon brazed in the moisture-free brazing atmosphere system showing good braze flow and fillet formation along with absence of any soot on brazed joint.

braze flow and formation of soot on the brazed joint, but the concentration of carbon dioxide was too low to eliminate soot formation and provide acceptable brazed joint quality. On the other hand, the addition of 0.5 to 0.8% carbon dioxide to nitrogen and 4% hydrogen atmosphere provided excellent brazed joint quality in terms of braze flow and fillet formation, as shown in Fig. 5. It was also instrumental in eliminating soot formation on brazed joint.

Besides using a minimum concentration of carbon dioxide in the moisture-free brazing atmosphere, it is important to introduce the moisture-free brazing atmosphere either into the transition zone or at the end of the heating zone of the furnace to produce brazed components with a bright surface finish. This is because a part of the atmosphere introduced into the furnace flows through the heating and pre-heating zones and exit the furnace through the feed vestibule. The remaining part of the atmosphere moves through the cooling zone and exits the furnace through the discharge vestibule. The part of the atmosphere exiting the furnace through the feed vestibule is heated while passing through the heating zone, causing a

portion of the carbon dioxide present to react with hydrogen to produce carbon monoxide and moisture in-situ according to the following reaction:



Consequently, there are two oxidizing agents (carbon dioxide and in-situ produced moisture) present in the atmosphere entering the pre-heating zone from the heating zone. These oxidizing agents are responsible for controlling braze flow, removing the organic binder from the brazing paste, and eliminating soot formation on brazed joint. More importantly, since one mole of hydrogen is reacted to produce one mole of carbon monoxide, the reducing potential of the atmosphere is maintained both in the heating and pre-heating zones of the furnace. The maintenance of reducing potential both in the heating and pre-heating zones of the furnace is important to braze carbon steel components with the desired bright surface finish.

The part of the atmosphere exiting the furnace through the discharge vestibule is not heated while passing through the cooling zone. Consequent-

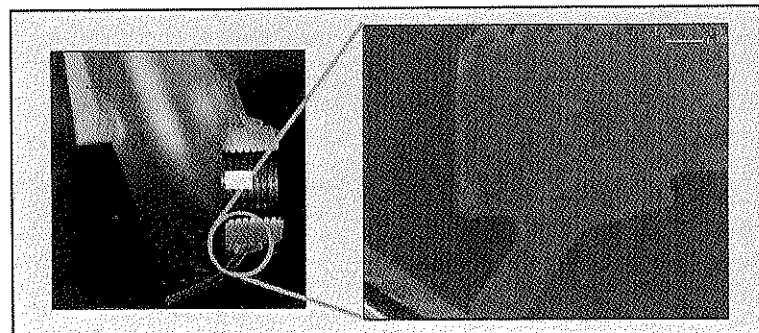


Fig. 6 Carbon steel component brazed in the moisture-free brazing atmosphere system showing good braze flow, fillet formation, and brazed joint quality.

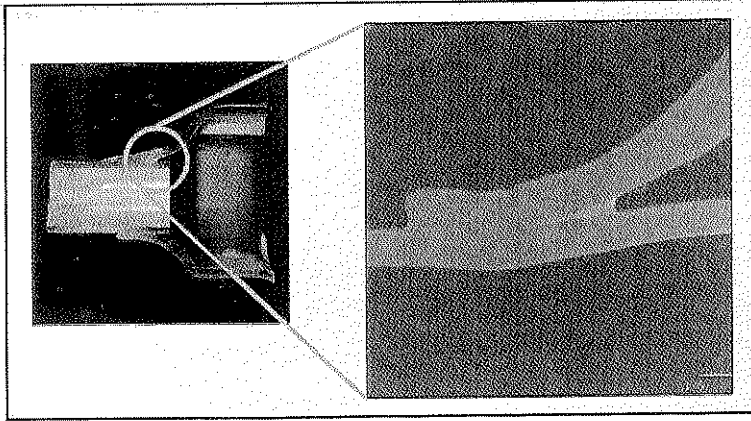


Fig. 7 Carbon steel component brazed in the moisture-free brazing atmosphere showing good braze flow, fillet formation, and brazed joint quality.

ly, there is no reaction between carbon dioxide and hydrogen, and the reducing potential of the atmosphere flowing through the cooling zone is also maintained. The maintenance of reducing potential in the cooling zone of the furnace is also important to braze carbon steel components with the desired bright surface finish.

Commercial Demonstration of the Moisture-Free Brazing Atmosphere System

In the commercial demonstration, the use of the dry 25% nitrogen - 75% hydrogen atmosphere resulted in excessive braze flow and soot formation while brazing carbon steel components. In order to improve brazing of carbon steel components, the furnace operation was modified simply by introducing carbon dioxide along with nitrogen and hydrogen atmosphere at the end of the heating zone, as shown in Fig. 3. No operational changes were made for

brazing stainless steel components.

The addition of a mere 0.5% carbon dioxide to the nitrogen-hydrogen atmosphere containing 6.5% hydrogen resulted in significantly improved quality and consistency of brazed joints, as shown in Figs. 6 - 8. The addition eliminated excessive flow of braze material and formation of soot on brazed joints. Furthermore, it provided excellent penetration of brazing material and fillet formation, as shown in Figs. 6 - 8.

Since brazing of carbon steel components required using a mixture of dry nitrogen, hydrogen and carbon dioxide, it was very easy to switch to a mixture of dry nitrogen and hydrogen required for brazing stainless steel components. Furthermore, since moisture required for brazing carbon steel components was produced in-situ by reacting carbon dioxide with hydrogen, it was easy and less time consuming to condition or dry the furnace while switching from brazing carbon steel components to brazing

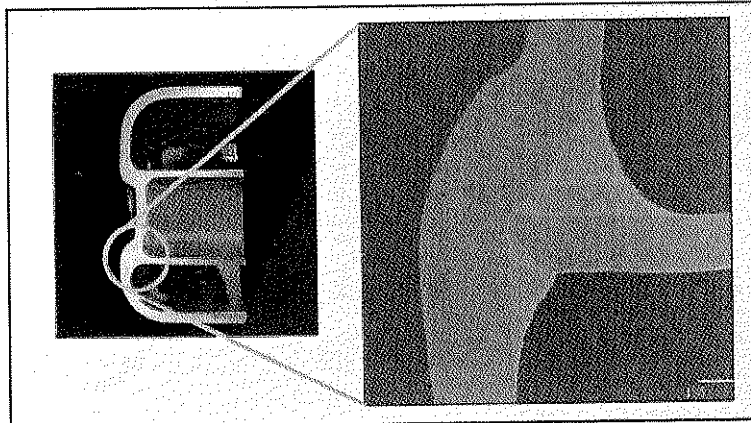


Fig. 8 Carbon steel component brazed in the moisture-free brazing atmosphere showing good braze flow, fillet formation, and brazed joint quality.

stainless steel components. This provided operators freedom to switch between brazing carbon steel and stainless steel components without spending a lot of time conditioning the furnace.

CONCLUSIONS

This article describes the successful development and commercial demonstration of a novel moisture-free atmosphere system for furnace brazing carbon steel components. A small amount of carbon dioxide can be added to the dry nitrogen-hydrogen atmosphere to produce moisture in-situ that is required to control braze flow and eliminate soot formation while brazing carbon steel components. The results also show that the addition of a small amount of carbon dioxide is instrumental in overcoming problems normally experienced with conventional brazing atmospheres such as humidifying a nitrogen-hydrogen atmosphere with the right amount of moisture and finding suitable location for introducing humidified nitrogen stream into the brazing furnace. Finally, because of the moisture-free nature of the brazing atmosphere, the system provides flexibility for furnace operators to switch easily from brazing carbon steel to stainless steel components in the same furnace without spending a lot of time conditioning the furnace.

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