BY DAN KAY

Q: When we brazed Inconel® 718 components in our vacuum furnace, the initial results were marginal at best. The parts are not bright and the filler metal did not flow well. Someone suggested we may need to more effectively clean the furnace prior to brazing and use some titanium material as a "getter" in the furnace beforehand. Please explain what a getter is, and how its use may help us.

A: By definition, a getter is a deposit of reactive material that is placed inside a vacuum system for the purpose of completing and maintaining the vacuum. When gas molecules strike the getter material, they combine with it chemically or by adsorption. The use of clean titanium as a getter prior to vacuum brazing sensitive base metals is recommended, since all vacuum chambers have leaks from the many fittings, connections, and seals.

Clean titanium machine turnings (Fig. 1) make excellent getters because they present extensive surface areas to react with any oxygen present in the vacuum chamber.

The metal/metal-oxides curves (Fig. 2) charts vacuum furnace temperature vs. vacuum pressure. Each curved line charts a particular metal oxide. The chrome-oxide (Cr_2O_3) curve near the center of the chart indicates we can get rid of Cr_2O_3 if we are positioned to the right side of the Cr_2O_3 curve. Thus, a vacuum furnace operating at about 2000°F (1100°C) and at a vacuum level of about 10^{-1} torr, would "thermodynamically reduce" (get rid of) the oxide of chromium, leaving the chromium free to alloy with the BFM.

Note that this chart also indicates that operation at temperatures to the left of the Cr_2O_3 curve is more oxidizing, i.e., the combination of temperature and vacuum level is not sufficient to remove oxides, but is high enough to cause significant formation of that metal oxide. Thus, during heating in a vacuum furnace, the oxides continue to form as the metal gets hotter. The rate of oxide formation slows down as it approaches the oxide line for that metal, and then as it moves to the right side of that oxide line, only then can that particular oxide be reduced.

Notice the oxide curve for titanium (TiO curve) indicates that as titanium heats up in a vacuum furnace it will steadily oxidize, but for that oxide to be eliminated it must get to the right-hand side of that curve. If you operate the vacuum furnace at about 10^{-4} torr, it would have to run above 2700°F (1500°C) to accomplish that. This is not possible in shop vacuum brazing furnaces, therefore, when titanium oxidizes in such a furnace, it will hold onto that oxide layer strongly.

This is the reason titanium is an effective getter. By placing titanium in the vacuum furnace chamber, it will steadily oxidize during heating, removing much of the oxygen present in the chamber. Since that oxygen is tied up as an oxide on the titanium surface, it is not available to oxidize the parts being brazed in the furnace. The larger the surface area of the titanium exposed to the furnace atmosphere, the greater will be its oxygen-scavenging capability, which is why titanium turnings (Fig. 1) are more effective than the titanium pieces; and titanium-sponge materials work even better — Fig. 3.

During vacuum furnace cycles, some contaminants will outgas from the parts being brazed and condense on the chamber surfaces. The outgassed materials may come from brazing-paste binders (organic materials) or some of the alloyed metallic components in the base metals or from the BFMs. When reheated in subsequent furnace runs, these contaminants may revolatilize off the furnace walls and contaminate the parts being brazed.

Because of the high reactivity of titanium to many of these outgassing contaminants, titanium can be a very effective getter of these materials when any of these contaminants come in contact with titanium in the furnace chamber. Although pure titanium would be optimal, any titanium alloy can be used with great effectiveness as a getter. And, since the TiO curve is so far to the right side of the metal/metal-oxide chart, the titanium oxides, once formed, cannot be reduced, i.e., broken down into titanium and free oxygen during any regular vacuum brazing run. Thus, once scavenged by the titanium, those contaminants, including oxygen, will remain permanently bonded to the titanium surfaces.

Fig. 1 — Ti-turnings have much greater surface area than larger sheet stock.

It should be noted, too, that this contamination of the titanium surface will normally cause the darkened titanium getters to become extremely fragile and can easily crumble when handled. Deeply discolored titanium material should be discarded and not reused.

It is preferable to use titanium getters as part of your shop's furnace maintenance procedure during clean-up cycles rather than waiting to use it during a brazing run. This ensures your vacuum furnace is clean, with a very low leak-up rate, and is oxygen-free before you begin brazing. Some brazers include titanium getters in-

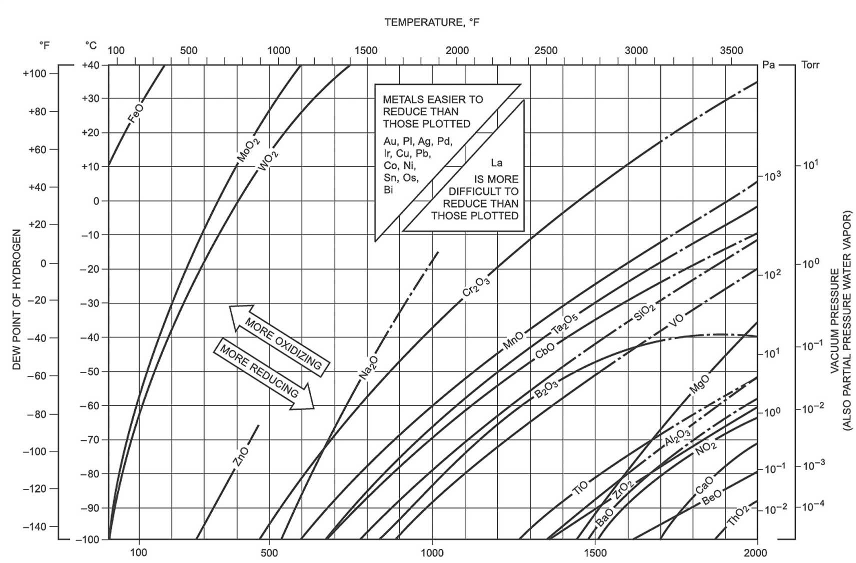

Fig. 2 — Metal/metal-oxides curves, including titanium. From AWS Brazing Handbook, *5th edition, p. 120.*

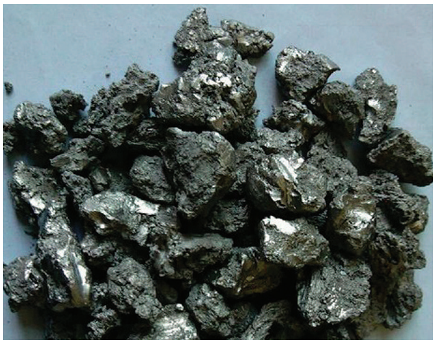

Fig. 3 — Ti sponge exposes the most surface area for maximum gettering effect.

side their hot zone during the brazing run, to further protect the parts being brazed. This is also quite acceptable if you want to do that.

Note, it is important to prevent the titanium getter material from coming into direct contact with any nickel-containing metals, including stainless steels, since this may cause a eutectic reaction between the titanium and nickel. A low-melting eutectic alloy can readily form at about 1750°F (955°C) when titanium and nickel alloys touch. You can use ceramic (alumina) sheets or crucibles to keep these metals separated.

Following our first furnace cleanup cycle, we discard the dark titanium turnings then repeat the cleanup cycle using a fresh load of titanium turnings. These usually come out much lighter in color than the turnings in the first run. When necessary, for a very dirty furnace, we run a third cleanup cycle using fresh Ti turnings with a thin sheet of titanium placed on top of the turnings. If that titanium sheet can then be folded back on itself without breaking, we know the vacuum chamber is very clean.

For further reading, see *Vacuum Heat Treatment* by Daniel H. Herring, 2012, Getter Materials, pp. 305–309; BNP Media II, LLC.♦

This column is written sequentially by TIM P. HIRTHE, ALEXANDER E. SHAPIRO, and DAN KAY. Hirthe and Shapiro are members of and Kay is an advisor to the C3 Committee on Brazing and Soldering. All three have contributed to the 5th edition of AWS Brazing Handbook*.*

Hirthe (timhirthe@aol.com) *currently serves as a BSMC vice chair and owns his own consulting business.*

Shapiro (ashapiro@titanium-brazing.com) *is brazing products manager at Titanium Brazing, Inc., Columbus, Ohio.*

Kay (Dan@kaybrazing.com), *with 40 years of experience in the industry, operates his own brazing training and consulting business.*

Readers are requested to post their questions for use in this column on the Brazing Forum section of the BSMC website www.brazingandsoldering.com.