Q: Thank you to everyone who participated in the Brazing Q&A quiz published in the April 2017 Welding Journal. Unfortunately, no one answered all 20 questions correctly. Participants who answered the most amount of questions correctly will receive a prize. Below are the questions and answers to help grow your brazing knowledge.

1. Which one of the following temperatures is the actual, correct, exact temperature that officially separates brazing from soldering?

A — 800°F
B — 840°F
C — 450°C

The answer is C. Metric (SI units) is the primary system of measurement in the world, and to comply with SI standards, AWS (in coordination with SI groups around the world) modified the definition of brazing back in the early 1960s, changing the official temperature from 800°F to 450°C. Please note that this temperature has no real metallurgical significance, but merely falls nicely in the open space between the melting points of zinc (420°C) and aluminum (660°C). 450°C actually converts to 842°F, but was rounded to 840°F merely for convenience.

2. Which one of the following is most important for optimal brazing results?

A — Gravity
B — Capillary attraction
C — RMS surface roughness

The answer is B. Unlike welding, which depends on the creation of a fillet, brazing depends on melting and flowing a liquid brazing filler metal (BFM) between two closely fitting, faying surfaces to create a thin bonding layer of BFM material between those faying surfaces inside the joint. Capillary attraction is the force that can draw the molten BFM into the joint, where the molten BFM can then alloy/diffuse with the base metals.

3. BAg-1 can be safely used in a vacuum furnace if?

A — Vacuum level is limited to about 10⁻¹ max.
B — A strong back fill pressure of argon is used.
C — It should never be used in a vacuum furnace.

The answer is C. The AWS A5.8 Specification shows that the chemistry of the BAg-1 BFM alloy consists of silver, copper, zinc, and cadmium, all four of which can outgas/volatilize when exposed to high temperature and a strong vacuum. Because zinc and cadmium are high vapor pressure metals, meaning they are extremely volatile when exposed to high temperatures and reduced pressures, they would readily outgas, condense on the cold walls of the vacuum furnace, and contaminate the pumping systems, ruining the furnace. Thus, they should never be used in a vacuum furnace.

4. When Ni brazing, to prevent the formation of “continuous” nonductile...
centerline eutectics in the joint, the optimal joint clearance range should be?

A — 0.000–0.003 in. (0.000–0.075 mm)
B — 0.004–0.007 in. (0.10–0.15 mm)
C — Tight clearance is not actually required because a good diffusion cycle will eliminate any continuous centerline eutectics that may have formed.

The answer is A. Many tests over the years have shown that the centerline eutectic structure in a nickel-brazed joint becomes a continuous line of hard nodularite material when the joint clearance is wider than about 0.003 in. (0.08 mm), putting the brazed joint under risk of cracking when under severe in-service stresses. Added diffusion cycles to try to diffuse away those continuous centerline eutectic materials are very difficult to accomplish when the thickness of the joint results in a continuous centerline eutectic structure. At clearances less than 0.003 in. (0.08 mm), the centerline eutectic material consists of discreet, separate, small particles (thus “noncontinuous”), surrounded by soft, ductile constituents of the BFM. Such thin joints will perform well, even in robust service.

5. The first practical nickel-based brazing filler metal (BFM) was developed shortly after WWII by evaluating which one of the following materials as a potential applicant for high-temperature brazing?

A — A thermal-spray powder
B — Oak Ridge lab metallurgists evaluated “boronizing” a special Inconel® alloy.
C — It was discovered by accident when a nickel-based superalloy began to sag due to eutectic melting when in direct contact with a graphite plate during heat treating.

The answer is A. A young engineer noticed the strength and hardness of some early Ni-Cr thermal-spray powders with which he was working, and wondered if such powders might have application inside a joint as a high-temperature nickel brazing BFM, to replace the older high-temperature BFM being used at that time, which were based on silver (Ag) and gold (Au). This Ni-Cr thermal-spray powder worked very well as a much higher temperature capability BFM than the previously used Ag-based and Au-based BFM, and was eventually adopted by AWS as the first nickel-based BFM, and given the designation of B-Ni-1.

6. When did the practice of brazing first begin?

A — It was first used by the Vikings to produce specialized multipointed weapons.
B — The process was developed by British shipbuilders during Napoleonic wars.
C — Brazing was known and used by the ancient Egyptians.

The answer is C. Brazed artifacts, as well as wall paintings in ancient Egyptian tombs, clearly show that the Egyptians used brazing in their culture.

7. The in-service remelt temperature of some nickel-based BFM can be several hundred degrees higher than the original brazing temperature be-
cause of which specific metallic element that is part of the chemistry of the BFM?

A — Silicon
B — Chromium
C — Boron

The answer is C. Boron is a tiny atom, and due to its small size does not operate as a substitutional atom in metallurgical structures, but sits in the tiny openings (interstices) between neighboring atoms in the metal matrix of which it is a part. Thus, as an interstitial atom, it is not strongly bonded in a metallurgical matrix, and can easily escape from that metal matrix when that structure is heated and the spacing between neighboring atoms increases. Because boron is a very effective temperature lowering ingredient in many nickel-based BFMs, its escape from the metal matrix will change the melting temperature of that metal significantly. Thus, once the boron has diffused away (easily done because of its tiny size), it will require a much higher temperature to remelt that metal than when the boron content was much higher in that metal matrix.

8. When properly made, which is stronger — a welded joint or a brazed joint?

A — A welded joint should always be stronger than a brazed joint.
B — The strengths should be equal because a properly made weldment or brazement should always fail in the base metal, outside the joint.
C — Since brazing does not melt the base metal, a brazed joint should always be stronger than a weldment made on the same base metal.

The answer is B. This is very important to understand. When a metal is brazed, the temperatures used in the brazing process are such that the base metal can soften (anneal) significantly. In actual field service, these brazed components can begin to fail (stretch/yield) when it reaches the yield strength of that metal in its annealed condition. Due to the constraints of the tight side walls inside the brazed joint, tests over the years have clearly shown that the strength of the BFM in the joint can greatly exceed the yield strength of the annealed base metal. Thus failure will occur in the base metal, and not in the brazed joint.

9. Brazing fluxes help to prevent oxidation of the base metals on which it is coated. Which flux can handle higher temperatures, and for a longer time, and also be potentially more effective on refractory metals?

A — White flux (which meets AMS 3410 requirements)
B — Black flux (which meets AMS 3411 requirements)

The answer is B. The black flux is dark because of the addition of powdered boron to a white flux, which turns it dark brown/black. This boron addition enables the flux to handle refractory oxides a bit better than the standard white flux, and also gives the flux a slightly longer life and a somewhat higher temperature capability than the white flux.

10. When brazing pure copper to pure copper using the BCuP family of BFMs, is a brazing flux usually required?
A — Yes
B — No

The answer is B. The phosphorus in the BCuP alloys is a strong enough oxygen getter to be able to readily reduce (i.e., clean up and eliminate) copper oxide (a weak oxide) that forms on the pure copper surface when it is heated. The phosphorus oxides resulting from this action take on a dark color around the outside of the brazed joint, but the joint itself brazes very well by this method. The BCuP family of BFMs cannot, however, be used on any other metals (brass, bronze, etc.) without also using additional brazing flux paste coating on the joint to deal with the much harsher oxides that develop on those base metals.

11. Brazing aluminum base metals together using the BAISi class of BFMs can be easily done in a standard high-temperature vacuum furnace used by many companies for nickel-brazing aerospace components, as long as the level of vacuum is maintained at $10^{-5}$ or harder (i.e., at $10^{-6}$, $10^{-7}$, etc.).

A — True
B — False

The answer is B. Because the BAISi class of BFMs have melting temperatures that are very close to the melting points of the aluminum base metals being joined, any brazing furnace must have extremely tight temperature controls (+/- 5°F maximum) so that the base metals will not melt when the aluminum BFMs are finally molten and ready to do their job. Standard high-temperature aerospace-type vacuum furnaces used for nickel-brazing have typical brazing tolerance spreads of up to +/- 25°F, which is far too large to adequately control for aluminum brazing. A second reason not to do this in a high-temperature aerospace vacuum furnace used for nickel-brazing is the outgassing of aluminum and magnesium, which would coat the furnace walls and contaminate its pumping systems, ruining the vacuum furnace.

12. Because many people feel that a braze fillet contributes significantly to the overall strength of a brazed joint, it is therefore wise to specify a minimum fillet size on engineering drawings and in process specifications/procedures, so that brazing personnel and engineers will know how big a braze fillet they should produce.

A — True
B — False

The answer is B. A brazing fillet (meniscus) is merely the after-effect of any brazing process, and is a non-controlled surface. There is no way to effectively control its actual size to any specific dimension. I always strongly advise designers and engineers to never dimension a braze fillet. That is what I call “weld-think,” in that it may apply to the world of welding, but has no place in the world of brazing. Too many variables in brazing processes can cause fillet size to vary widely from part to part or process to process.

13. In a similar vein, it is usually a good recommendation to build up a large braze fillet in the corner of two parts being brazed together at right angles.
(in which there is a 90-deg corner at that joint edge), because the large fillet is an excellent way to help spread the stress that would otherwise try to concentrate in that sharp corner.

A — True  
B — False

The answer is B. Never use a braze fillet in a design to help spread the stress. A brazing filler metal is only supposed to flow into a joint to join the two faying surfaces. External fillets in brazing are castings, and the larger they are, the more potential for casting imperfections to weaken that fillet, possibly resulting in premature failure of the joint. If the designer wants to spread the stress at the sharp corner, then it is his/her job to design curved base metal surfaces to handle that corner stress, but never depend on braze fillets to do that work.

14. When vacuum brazing, which is more important?

A — Level of vacuum in the furnace  
B — The leak-up rate of the vacuum chamber

The answer is B. Every vacuum furnace is leaky because of the many fittings and connections involved in its construction and operation. Air will leak into the furnace through one or more of these connections (the furnace door seal is the most common), and the pressure inside the furnace will start to go back up towards atmospheric pressure. This leak-up rate must be regularly measured and dealt with in every vacuum brazing furnace. For most metals, leak-up rates less than 10 microns/h is acceptable. For titanium bearing metals, it should be less than 5 microns/h.

15. When brazing with a torch, the adjustment of the torch flame is important. For most applications, it is recommended to adjust the flame so that it is?

A — Slightly oxidizing  
B — Neutral  
C — Slightly carburizing

The answer is C. Such a flame will be fuel rich. Since the fuel gases are hydrocarbon fuels, this means sending excess carbon against the face of the joint that you are trying to torch braze. When base metals are heated, their hot surfaces want to react more with oxygen, forming oxides on their surface. When these excess surface oxides encounter the excess carbon being sent their way by the fuel-rich torch flame, the carbon and oxygen readily react to form CO/CO₂, and the surface of the metal will quickly become bright and clean. Thus, such a torch setting can also be called a “self-fluxing” flame, or a “reducing” flame, since it does “reduce” the surface oxides.

16. When vacuum brazing a 304-type base metal, it is recommended that only 304L be used rather than standard 304 material, because the 304L has far less carbon in it. This is important because?

A — With less carbon, there is much less chance of carburizing the brazed joint.  
B — Carbon wants to react with the chromium in the stainless steel at elevated temperatures to form chrome carbides that migrate to grain boundaries, thereby reducing the amount of chromium oxide on the surface of
the stainless steel to keep it corrosion resistant.
C — BFMs react adversely with carbon-containing materials, thereby preventing adequate "wetting" of the joint faying surfaces, thus causing excessive voids in the joint, and sometimes "leakers."

The answer is B. Carbon wants to react with the chromium in the stainless steel at elevated temperatures to form chrome carbides that migrate to grain boundaries, thereby reducing the amount of chromium oxide on the surface of the stainless steel to keep it corrosion resistant.

17. When furnace brazing, it is often necessary to have one or more built-in "holds" at various temperatures on the way up to brazing temperature to allow for thermal equilibrium to occur in the furnace chamber. These "holds" are necessary because?

A — The heating rates used are too rapid, thus causing thinner parts to heat up faster than heavier parts in the load.
B — The intermediate holds are timed so that the total brazing cycle meets minimum cycle times for the base metals being joined.
C — At each intermediate "hold" point, metallurgical reactions are allowed to occur that cannot efficiently be completed at other temperatures.

The answer is A. This is a challenge I constantly give to all furnace brazers: "Why are you using the heating rate you're using?" The answers are usually either "I don't know" or "We've always done it that way." Neither answer is good enough to justify the continuance of the rapid rates being used. Technically speaking, you should never have to use any holds on the way up to brazing temperature. You should find the fastest heating rate (by experimentation) that will allow you to get up to brazing temperature with no holds. Challenge question — why do you put holds in your furnace cycles? Let me know your thoughts.

18. When vacuum brazing, one of the terms used to describe the level of vacuum is the word "Torr." Where does this word come from?

A — In honor of Jonathan Torr berson, a man who claimed to invent the first practical vacuum furnace back in 1919.
B — An abbreviation for "torrid," a term describing the extreme temperatures used in a vacuum furnace when brazing.
C — Named after Evangelista Torricelli, an Italian scientist in the early 1600s.

The answer is C. Torricelli is given credit for developing our understanding of barometric pressure via his experiment in 1643 with an inverted glass tube of mercury in a shallow dish. Atmospheric pressure kept the mercury suspended in that tube (the top end of the tube was sealed) to a height of 760 mm (29.92 in.) at sea level, which has become known as one standard atmosphere of pressure. In honor of this, scientists have abbreviated each 1 mm of height of that mercury as 1 torr of pressure. Thus, one atmosphere has 760 torr of pressure.

19. When induction brazing a round steel bar assembly that is placed inside a circular induction coil, the “coupling distance” of the induction coil is very important. Coupling distance is?

A — The distance between the electrical junctions in the power head of the inductor where it is connected inside the power unit, always inversely proportional to the coil diameter.
B — The distance between the ID of the induction coil and the OD of the part being heated inside the coil.
C — The distance between the outside edge of the induction coil to the nearest piece of conductive metal in the immediate vicinity of the induction brazing unit.

The answer is B. For effective induction heating, the coupling distance of the induction coils should be kept uniform around the part being heated/brazed. If the part is not properly centered in the coil, then one side of the part will get hotter much faster than the other side. That's because the closer the coupling distance, the more intense the surface heating of the part. The greater the coupling distance, the less surface heating since the magnetic flux field around the coils becomes less efficient as the distance to the surface of the part being heated gets greater.

20. When brazing a tube into a fitting where the tube and fitting are made from two different kinds of metals with different coefficients of thermal expansion, it would usually be best (from a brazed-joint integrity perspective) to select those base metals so that the higher-expanding metal is?

A — The outer member (the fitting)
B — The inner member (the tube)

The answer is A. All metals expand at different rates, and it is very important to take that into consideration when designing joints to be brazed. This is especially true when different metals are to be brazed together. When a tube is being brazed into a fitting, the higher expanding metal should be on the outside (the fitting) so that the joint will open up when heated. Then, after brazing is completed, the outer member will shrink faster than the inner member, putting the joint into compression, which is desirable. When the inner member is made of the higher-expanding metal, the joint tends to close up when heating to brazing temperature. Then, after brazing, the inner member wants to shrink faster and more than the outer member, thereby causing the joint to want to open up, thus putting that joint into tension. Brazed assemblies have sometimes cracked open when this tension gets too high. There are enough metals out there so that designers can always design joints to go into compression on cooling.