Construction CANADA

Photo courtesy Canadian Copper & Brass Development Association

Copper Connections

Advances in joining copper tube

By Arnold Knapp and Stephen W. Knapp

The earliest method for joining copper and brass piping systems involved threaded joints. This technique required heavy-wall pipe, which offered adequate thickness to thread pipe ends, but it also involved a significant amount of material and relatively high costs. In the 1930s, attention turned to soldering with capillary fittings. The method enabled dramatic reduction in wall thickness and a move to much thinner tubular products, making copper systems significantly less expensive. This advance paved the way for using copper in many applications previously unfeasible.

Soldering and brazing have been the most common methods of joining copper and copper-alloy tube since the '30s. At the same time, alternative joining methods have stimulated much interest. There is now a proliferation of joining techniques and products available for copper plumbing, heating, natural gas, and related mechanical systems.

Soldering

Soldering is still the main technique used for installing plumbing systems in all types of buildings, from single-family residences to multi-storey buildings, as well as commercial and institutional structures. The most significant change in soldering practices occurred at the start of the 1990s, when plumbing codes prohibited use of lead-containing solder in potable water systems. This eliminated the very popular 50-50 lead-tin solder. At first, attention focused on 95-5 tin-antimony solder, which had been used when higher internal working pressures were involved. Figure 1 compares 95-5 with 50-50 from the pressure perspective.

A number of solders were subsequently developed for potable water systems, and are available under a variety of trade names. At the same time, the copper industry has developed these soldering standards:

- ASTM B 32, *Standard Specification for Solder Metal*;
- ASTM B 813, *Standard Specification for Liquid and Paste Fluxes for Soldering of Copper and Copper Alloy Tube*; and
- ASTM B 828, *Standard Practice for Making Capillary Joints by Soldering of Copper and Copper Alloy Tube and Fittings.*

ASTM B 32 and B 813 are referenced in Article 2.2.9.2 of the 2005 *National Plumbing Code (NPC)*, and ASTM B 828 appears in Article 2.3.2.4. ASTM B 813 requires any flux residue after soldering to be water-flushable and non-corrosive. This standard includes tests for residue flushing and corrosiveness.

Brazing

Brazing (Figure 2) involves using filler metals that melt at temperatures ranging from 590 to 815 C (1095 to 1495 F), compared to solders which melt at 175 to 290 C (350 to 555 F).

Brazing filler metals are covered by American National Standards Institute/ American Welding Society (ANSI/AWS) A5.8, *Specification for Filler Metals for Brazing and Braze Welding*. The most commonly used metals are copper-phosphorus alloys, designated as 'BCuP,' and silver-containing compositions, designated as 'BAg.' It should be noted some BAg filler metals contain cadmium, which can create highly toxic fumes during the brazing process—therefore, proper safety precautions must be taken if these alloys are used.

Figure 1 shows the working pressures of brazed joints. It is important to note the maximum pressure at the lower service temperatures is the rated pressure of annealed tube, due to the high temperature involved with the brazing operation.[1]

Brazing is used in various applications, and is often required by provincial codes or regulations. For example, the joints in refrigeration installations and medical gas systems must be brazed. When installing a medical gas system, continuous purging with nitrogen is carried out to keep the tube's interior clear and oxide-free during the brazing process.

Figure 1

Recommended Maximum Internal Working Pressure (psi) for Joints in Types K, L, and M Tube

Solder of brazing alloy used in joints	Service temperature	Nominal or standard size (in.)			
		¼ to 1	1 ¼ to 2	2 ½ to 4	5 to 8
50-50 tin-lead solder*†	100	200	175	150	130
	150	150	125	100	90
	200	100	90	75	70
	250	85	75	50	50
	Saturated steam	15	15	15	15
95-5 tin-antimony solder*	100	500	400	300	150
	150	400	350	275	150
	200	300	250	200	150
	250	200	175	150	140
	Saturated steam	15	15	15	15
Brazing alloys melting at or above 593 C (1100 F)	100-150-200	Recommended maximum pressure is the rated pressure of annealed tube shown in Table 6 of CCBDA Publication No. 28			
	250	300	210	170	150
	350	270	190	150	150
	Saturated steam	120	120	120	120

* See ASTM B 32. † Not permitted in potable (*i.e.* drinking) water systems

Flaring

Flared joints have been used for many years to join soft (*i.e.* annealed) temper copper tube. This method is widely employed for refrigeration systems and, more recently, in natural gas heating systems. It is also used for certain types of fittings for underground copper water services.

Natural gas systems strongly exemplify how advances in joining can dramatically change a market. For decades, threaded steel pipe was used for natural gas lines inside houses and buildings. Cutting and threading pipe to circumvent even the smallest of obstructions results in high labour costs.

After several years of research, it was concluded in the late 1980s that copper tube could be used to convey the natural gas commonly distributed in Canada. Canadian Standards Association (CSA) B149.1, *Natural Gas and Propane Installation Code*, was amended to permit soft copper tube with flared joints.[2] (Hard [drawn] temper tube can be used with brazed joints, but this method is not popular as it can be time-consuming and expensive.)

The change in installation practices allowed rapid growth of copper systems and natural gas projects. For example, the vertical subdivision concept became economically feasible for condominiums and apartments. Severely limited when steel pipe was the only choice, these systems became more possible when Type G copper tube and flared joints were allowed. Today, the single largest application for copper gas tube is the installation of fireplaces, followed by barbecues, in both houses and condominiums.

Society of Automotive Engineers (SAE) J513, *Refrigeration Tube Fittings–General Specifications*, covers the 45-degree flare fittings used.

Compression

With their strength and ease of installation, compression fittings have become the most popular choice for underground copper water services, replacing flare fittings. However, soft temper tube is usually supplied in coils, and the coiling process causes a slight ovality to form in the tube's cross-section. To avoid potential problems, installers should always size and round the end of a tube before making a compression or flare joint.

The current focus on eliminating lead in potable water systems is important because of its harmful effect on human health. The copper industry encourages municipal efforts to replace outdated underground lead water services in older sections of many Canadian cities. Shown in Figure 3, Types K and L copper tube are typically used for new services because of their proven performance. Additionally, corporation fittings, such as main stops, curb stops, and meter couplings are now made with lead-free copper alloys for parts in contact with potable water. The lead-free alloys recently introduced include:

- C87850;
- C89833;
- C89510; and
- C89520.

The copper industry advocates the complete replacement of a lead service. It is insufficient to only replace the section from the municipal water main to the property line, leaving a lead pipe in the owner's portion from the property line to the premises. Lead levels can spike after partial replacement; it is also difficult to document and track where parts of lead lines are left in service.

Mechanically formed tees

Article 2.3.3.2 of the 2005 *NPC* covers requirements for 'extracted tees' in which a special tool is used to form the tee. It can be used on

Types K and L copper tube in water distribution systems, but is not permitted for Type M copper tube. This type of equipment requires adequate wall thickness for the tool to form the raised collar of the extracted tee. The branch is then brazed into the collar. Soldering is not allowed because of inadequate strength due to short collar depth.

The aforementioned special tool is commonly employed in the fabrication of copper manifolds, which are widely used in hydronic and radiant heating systems. Copper headers are used in these systems, and can range between the nominal sizes of 1 and 8 in. (*i.e.* 25.4 and 203 mm) in diameter, with extruded outlets ⅜ to 6 in. (*i.e.* 9.5 to 152 mm). The range of configurations is extensive. For example, on a 1.8-m (6-ft) length, there can be 24 outlets on 3-in. (*i.e.* 76-mm) centres, 18 outlets on 4-in. (*i.e.* 102-mm) centres, and 12 outlets on 6-in. (*i.e.* 152-mm) centres.[3]

Other applications for extracted tees are found in copper plumbing systems, natural gas systems, and other mechanical system applications. Extracted tees reduce the number of joints to be brazed by the installer, reducing potential leaks and installation costs.

Roll-groove fittings

Roll-grooving and associated fittings are particularly popular for larger copper piping systems up to 8-in. (*i.e.* 203 mm) nominal size in diameter. Sentence 2.2.10.4 (1) of the 2005 *NPC* references CSA B242-M1980, *Groove- and Shoulder-type Mechanical Pipe Couplings* for pressure applications. This standard underwent extensive revision a few years ago, and the new edition was published in 2005. It is expected *NPC* will be updated to reference the revised version.

The latest edition was expanded to address several kinds of metallic and non-metallic piping materials. For copper tube, nominal sizes from 2 to 8 in. (*i.e.* 51 to 203 mm) are covered. The minimum wall thickness of a copper tube that can be roll-grooved corresponds to the wall thickness of Type DWV copper tube.

These couplings are used for a wide variety of mechanical and industrial applications. A car wash in Burlington, Ont., illustrates these couplings in action. Copper tube in sizes from ¾ to 4 in. (*i.e.* 19 to 102 mm) was used for the carwash piping system, plumbing, compressed air lines, and portions of the in-floor heating system. A combination of solder fittings and mechanical couplings was employed for joining purposes, depending on the size and role of the piping run.

Press-connect joining

Press-connect joining is a newer technology for fabricating copper piping systems. It involves using a powerful crimping tool and special fittings with an internal O-ring to maintain a seal when the joint is made. A torch is not required, eliminating the risk of fire associated with soldering or brazing operations. Press connections are typically rated for 200 psig (*i.e.* pound-force per square inch gauge) at 121 C (250 F).

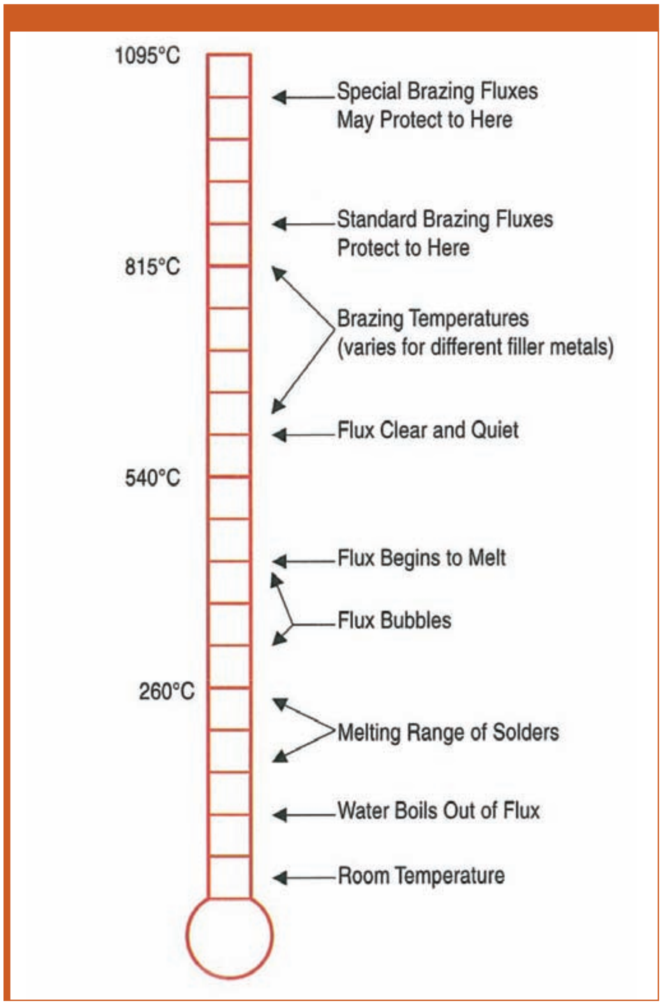
The American Society of Mechanical Engineers (ASME) B 16 Subcommittee J is developing a standard for this method of joining copper tube. In 2007, the ANSI LC4/CSA 6.32, *Press-Connect Copper and Copper Alloy Fittings for Use in Fuel Gas Distribution Systems* was published. To the authors' knowledge, it is not yet cited in Canadian natural gas and propane installation codes, but will likely be considered in the near future.

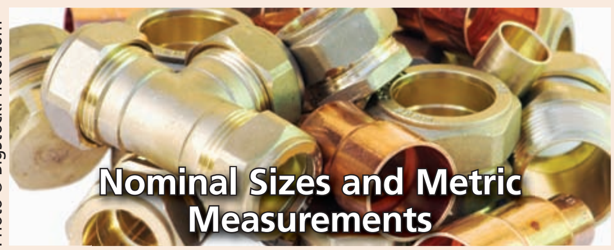
Push-connect joining

Push-connect is a type of joining method that has received considerable attention. It does not involve a pressing operation to achieve the joint. The tube's end is simply prepared according to the manufacturer's instructions and then inserted—and pushed—into the fitting's socket. Like press-connect joining, it eliminates torch use and associated risks.

Push-connect joints are typically rated at 200 psig at 82 C (180 F), which is slightly lower than press-connect joints. Fittings are available for smaller nominal sizes of copper tube, typically from ½ to 1 in. (*i.e.* 12.7 to 24.5 mm). ASME B 16 Subcommittee J is also considering development of a standard for these fittings. Push-

Figure 2





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Copper plumbing tube and fittings are still known by their nominal 'inch' sizes only, as covered in the standards issued by ASTM, the American Society of Mechanical Engineers (ASME), and other organizations. There are no metric sizes for copper tube and fittings for use in North America. To avoid confusion, the Canadian Copper and Brass Development Association (CCBDA) advises construction professionals to not soft-convert the inch nominal sizes to metric.

Figure 3

Dimensions and Weights of Types K, L, M*, and DWV† Tube

Nominal or standard size (in.)	Outside diameter (in.)	Wall thickness (in.)			
		K	L	M	DWV
¼	0.375	0.035	0.03		
⅜	0.5	0.049	0.035	0.025	
½	0.625	0.049	0.040	0.028	
⅝	0.75	0.049	0.042		
¾	0.875	0.065	0.045	0.032	
1	1.125	0.065	0.05	0.035	
1 ¼	1.375	0.065	0.055	0.042	0.04
1 ½	1.625	0.072	0.06	0.049	0.042
2	2.125	0.083	0.07	0.058	0.042
2 ½	2.625	0.095	0.08	0.065	
3	3.125	0.109	0.09	0.072	0.045
3 ½	3.625	0.12	0.1	0.083	
4	4.125	0.134	0.11	0.095	0.058
5	5.125	0.160	0.125	0.109	0.072
6	6.125	0.192	0.140	0.122	0.083
8	8.125	0.271	0.2	0.212	
10	10.125	0.338	0.25	0.212	
12	12.125	0.405	0.28	0.254	

* ASTM B 88, *Standard Specification for Seamless Copper Water Tube*
† ASTM B 306, *Standard Specification for Copper Drainage Tube* (DWV)

connect products include mini-ball valves, shutoffs, supply stops, and related items.

Adhesives

A brief word is in order about adhesives for joining copper tube and fittings. An assortment of adhesive formulations have been developed and tested, typically using capillary solder fittings with copper tube. A two-part, fast-curing epoxy performed well in trial installations of water supply systems for decades. New adhesive-type products are expected to become part of the copper-joining options in the future.

Future advances

In the years ahead, other fittings and techniques will be developed for joining copper and copper-alloy piping systems. Each new advance will be tested, scrutinized, and, if successful, become an acceptable method permitted by Canadian codes and regulations.

While performance in service will be a key factor in determining a product's success, the installation cost will be an equally important consideration for copper to continue as a major candidate when designing and specifying materials for mechanical applications.

Photo courtesy CCBDA

Brazing a 5-inch Type K copper vacuum line in a hospital.

Notes

[1] Extensive data on the rated internal working pressures for Types K, L, and M copper tube is available in Table 6 of "Copper Tube & Fittings," Publication No. 28. It covers nominal tube sizes from ¼ to 12 in. (*i.e.* 6.4 to 305 mm), at temperatures from 38 to 205 C (100 to 400 F), in both annealed (soft) temper and drawn (hard) temper. Visit the Canadian Copper and Brass Development Association (CCBDA) website at www.coppercanada.ca.

[2] Natural gas and propane installations are covered by CAN/CSA B149.1, which is generally adopted with or without amendments by the provinces and territories.

[3] Metric conversions are provided only for illustrative purposes. As noted, there are no metric sizes for copper tube and fittings for North America. CCBDA recommends design professionals do not soft-convert the inch nominal sizes to metric in practice.

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A Disclaimer on Copper Joining

This article contains general information on the different methods of joining copper tube and fittings for various applications. Such applications are typically regulated by codes and related regulations. Reference should be made to such codes and regulations to confirm which materials and processes are permitted in specific localities.

While every effort has been made to use the latest information, advances in joining methods are occurring rapidly. Therefore, readers may encounter newer data at any time. Interim regulatory variations may also permit certain products and methods to be used before they are referenced in applicable codes.

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