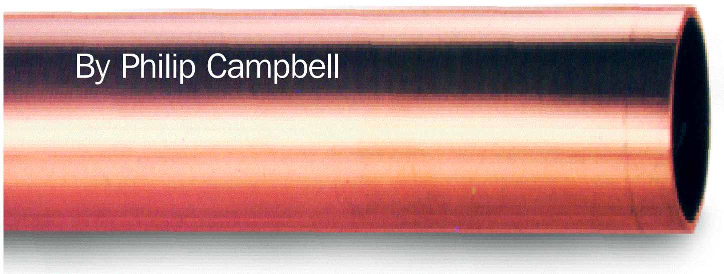
Copper Tubing Installations for Natural Gas

IAPMO Education Committee Conference Seminar



By Philip Campbell

Natural gas is a colorless and odorless gas, formed deep in the earth's crust from organic materials buried there for millions of years. This combustible mixture of hydrocarbon gases has been used by man for thousands of years. One of the first recorded uses of natural gas was for religious purposes. At the site of what would eventually be the Temple of the Oracle of Delphi *(see Fig. 1)* the ancient Greeks found an ignited natural gas spring. Believing this was a divine occurrence, they began to worship their gods there and built the temple around the spring. This is how we first became familiar with natural gas. It would escape to the atmosphere through naturally formed springs, such as the one at Delphi, and become ignited by lightning or fire and provide our ancient ancestors with light, warmth and the original barbeques.

Figure 1 – The Temple of the Oracle of Delphi

The ancient Chinese, around 500 B.C., were the first to pipe natural gas to where it was needed. Using hollowed bamboo, they piped the gas from shallow wells or springs. (There is no evidence if the installer had to be certified in bamboo joining.) These types of minor uses of natural gas continued until the 1700s when the use of natural gas, manufactured from coal, became a commercial industry in Britain.

The gas eventually found its way to our shores with the first use of manufactured natural gas for the installation of gaslights in Baltimore in 1816. It was not until 1821 that the first natural gas well was dug in the United States. *(See Fig. 2.)* William Hart dug a 27' well along the Candaway Creek in Fredonia, New York near Lake Erie. This began an industry that has led to thousands of wells, millions of miles of pipelines, and billions of BTUs used in homes and industry throughout our nation.

Figure 2 – Hart's gas well in Fredonia, New York (1821)

Natural gas from wells now accounts for 24% of the total energy used in the US *(see Fig. 3.)* Over 95% of the gas we use is produced in the US, with the remaining 5% coming from Canada and Mexico. We use this abundant gas for electricity production, heating, cooking, clothes drying and a myriad of other uses including, of course—barbeques.

Once natural gas began to be piped regularly into buildings in the early 1900s, the material of choice, at least in most of the United States, was steel pipe. Other materials have been used for this purpose including copper pipe and tubing. New materials are constantly being developed in our industry. As an example, our newest edition of the *UPC*, the 2003 edition, accepts aluminum and corrugated stainless steel pipe and tubing for natural gas purposes. However, until recently, copper pipe and tube has been questioned as to its suitability for use in natural gas systems. This is in spite of the fact that this material has been used for natural gas throughout Europe, Canada and much of the southern United States for decades. The chart in *Figure 4* shows the prevalence of copper pipe use throughout the world. In the United Kingdom, copper pipe and tube installations have been used in the vast majority of natural gas installations in that country.

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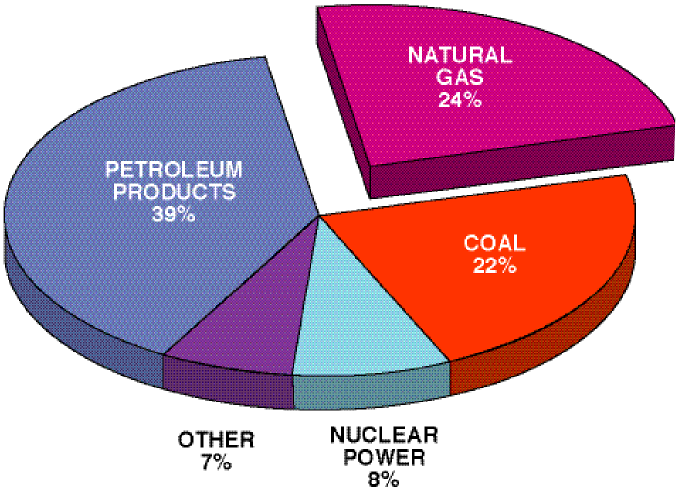


Figure 3 – Total energy used in the United States

Country	Materials Used For Transmission/Distribution Pipes	Materials Used For Domestic Supply Pipes
Belgium	Steel and Polyethylene	Copper
Brazil	Steel and Cast Iron	
Croatia	Steel	
Estonia	Russian Steel	
Eire	Polyethylene and Copper	
Finland	Steel and Polyethylene	Copper and Steel
France	Copper, Polyethylene, Cast Iron and Steel	
Japan	Steel, Ductile Iron and Polyethylene	
Netherlands	Steel and Synthetics	Copper and Steel
New Zealand	Galvanized Iron, Copper and Nylon	
Palestine	Mild Steel	
Romania	Steel	
Sweden	Steel and Copper	
The Czech Republic	Czech Standard Steel	
United States	Steel and Polyethylene	Aluminum, Copper and Brass

Note: Where only one material is listed, the country did not specify whether this was for domestic or transmission pipes
Source: WS Atkins survey of IGU members

Figure 4 – Materials used for gas piping internationally

As a matter of fact, copper pipe was used in localities that accepted the *Uniform Plumbing Code* when it was first issued by the Western Plumbing Officials. In the second edition of the *Uniform Plumbing Code* (1946), copper pipe was one of the accepted materials for natural gas distribution.

Section 1513 states:

All pipe used for the installation, extension, alteration and/or repair of any house gas piping shall be standard weight wrought iron or steel pipe, or brass or copper pipe of iron pipe size, and such pipe shall either be new or shall previously have been used for no other purpose than for the conveying of gas. All such pipe shall be free from internal obstructions, splits, or other imperfections, which would render it unfit for the purpose intended, and the ends thereof shall be properly reamed.

All fittings used in connection with the above piping shall be of malleable iron, brass, copper or equal.

It was not until 1955 that the Western Plumbing Officials amended the code, calling for "internally tinned copper" to be used. *Section 1212* reads:

(a) All pipe used for the installation, extension, alteration, and/or repair of any gas piping shall be standard weight wrought iron or steel, yellow brass (containing not more than 75% copper), or internally tinned or equivalently treated copper of iron pipe size.

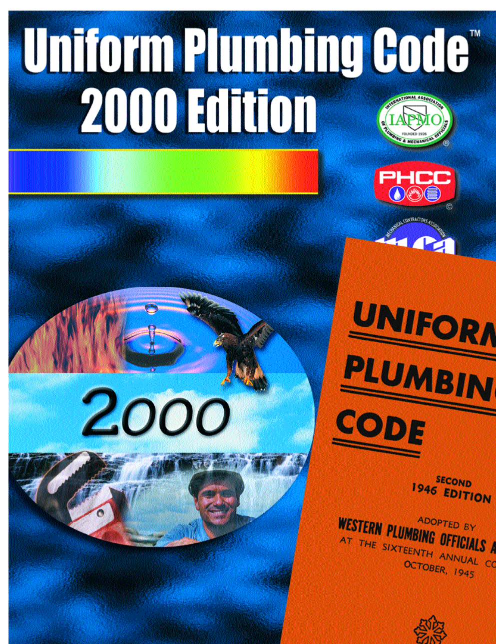
(b) All such pipe shall be either new, or shall previously have been used for no other purpose than conveying gas; it shall be in good condition and free from internal obstructions. Burred ends shall be reamed to the full bore of the pipe.

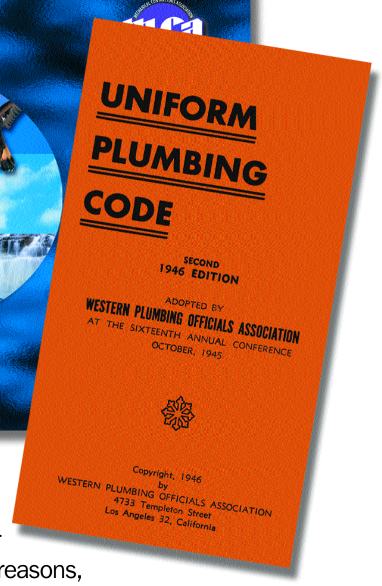
(c) All fittings used in connection with the above piping shall be of malleable iron or yellow brass (containing not more than 75% copper).

This section remained virtually untouched until the *2000 Uniform Plumbing Code* when the section was amended to accept copper tube for natural gas installations. It states in *Section 1210.1*:

1210.1 *All piping used for the installation, extension, alteration, or repair of any gas piping shall be standard weight wrought iron or steel (galvanized or black), yellow brass (containing not more than seventy-five (75) percent copper), or copper tube or Types K, L or ACR. Approved PE pipe may be used in exterior buried piping systems.*

1210.1.1 *Copper alloy tubing shall not be used if the gas contains more than an average of 0.3 grains of hydrogen sulfide per 100 standard cubic feet of gas (0.7 milligrams per 100 liters).*





We have seen that copper installations were once accepted in our code. What then were the reasons, either perceived or real, that led to the removal of copper pipe from the code and the reluctance of many

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plumbers to trust copper in natural gas installations? There seem to be three possible reasons for this reluctance:

- Installation problems—the perceived vulnerability of copper tube and pipe;
- Corrosion of the exterior of pipe and tube;
- Corrosion of the interior of pipe and tube.

We will deal with each of these issues in turn and discuss how the *Uniform Plumbing Code* solves these problems.

Photo Courtesy of CCBDA

Installation Problems

After 50 years of using mostly black iron steel pipe for natural gas installations, it is difficult for many of us old plumbers to accept any other material for this use. We know the volatility of the material within the pipe and, rightly so, want to protect the building and its occupants from danger. Explosions from leaks or damage to black iron pipe are fairly rare and we of course want to keep it that way. This does not mean, however, that this should be the only material that should be used. When the code was amended in 2000 much consideration was given to the two types of damage seen involving gas piping:

- Damage to the pipe at installation—either from being struck, bent or pierced by screws, nails or staples (by other crafts of course);
- Damage to the pipe by the owner / occupant (the Tim Allen Syndrome)—repairing or adding to the system when you don't know what you are doing or, the ultimate nightmare, hanging a picture and puncturing the gas pipe behind the drywall;
- Sizing problems—confusion on types of tube and OD.

The precautions contained in the 2000 *UPC* to rectify the first category of damage to copper installations are in *Sections 1211.8* and *1211.9*. *Section 1211.8* identifies copper gas pipe to differentiate it from other possible copper installations in the building. *(See Fig. 5.)* The section reads as follows:

1211.8 *Copper tubing systems shall be identified with an appropriate label, with black letters on a yellow field, to indicate the piping system conveys fuel gas. These labels shall be permanently affixed to the tubing within one (1) foot (304.8 mm) of the penetration of a wall, floor or partition and at maximum six-foot intervals throughout the length of the tubing runs. Labels shall be located to be visible to facilitate inspection.*

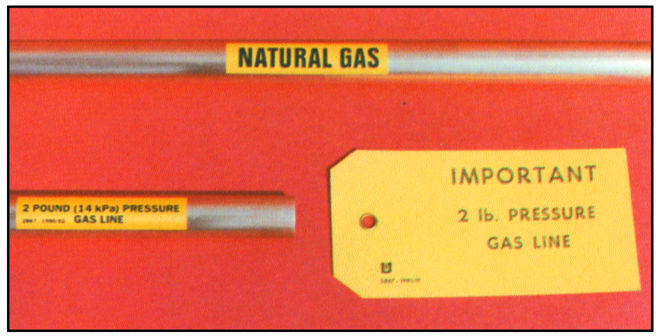

Photo Courtesy of CCBDA

Figure 5 – Copper pipe identification

If the plumber follows these guidelines, the accidental use or repair of the wrong line should not occur. With this labeling on during construction, other workers should take precautions around this piping and reduce the occurrence of punctures or damage to the material. It should be noted that black iron pipe is not required to have this labeling and therefore as much care may not be taken during construction with this material as with copper.

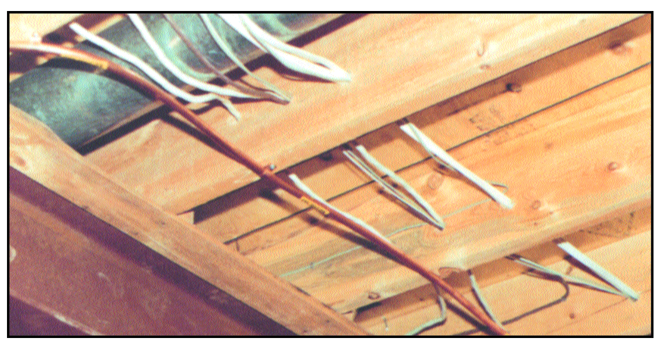

Photo Courtesy of CCBDA

Figure 6 – Copper tubing support

Section 1211.9 and the subsections *1211.9.1-3* provide for the support of the material and the protection of the installation from problems during construction. *(See Fig.6.)* The code reads as follows:

1211.9 *Copper tubing systems shall be supported and protected as follows:*

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1211.9.1 *Copper tubing running parallel to joists shall be fastened to the center of the joist at a maximum of (six) 6 foot (1829 mm) intervals.*

1211.9.2 *Copper tubing running at an angle to joists shall be installed either through holes in the joists that are at least 1-1/2 times the outside diameter of the tubing or fastened to and supported at a maximum of (six) 6 foot (1829 mm) intervals.*

1211.9.3 *Copper tubing running through holes in joists that are closer than one and three quarter (1-3/4) inches (44 mm) to the exposed face of the joist shall be protected with a steel striker plate at least 0.0508-inch (16 gauge) thick.*

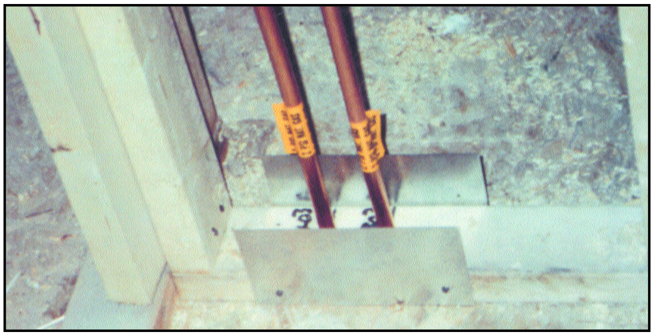

Photo Courtesy of CCBDA

Figure 7 – Steel striker plates

The requirements for the enlarged bored hole of 1-1/2 times the diameter of the pipe and the placement of steel striker plates on the face of the horizontal joists and at floor and ceiling plates as in *Figure 7*—and as we will see in *Section 1211.9.4*—protect the piping from puncture damage. The enlarged hole will allow movement of the pipe within the hole to avoid puncture. *(See Fig. 8.)*

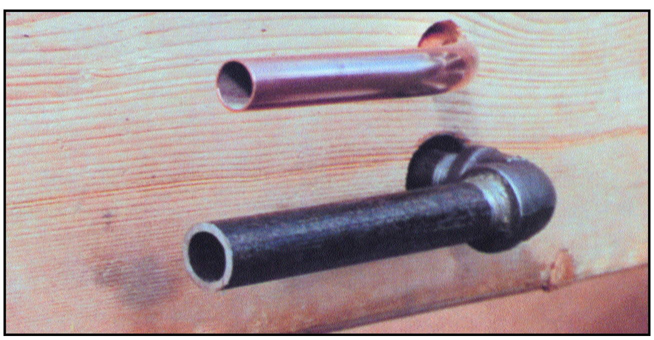

Photo Courtesy of CCBDA

Figure 8 – Enlarged bored holes

The above sections and the following section protect the copper natural gas system from the "Tim Allens" of the world. *Section 1211.9.4* states:

1211.9.4 *Copper tubing running vertically through partition walls shall not be supported within the wall space, except at the floor or ceiling. Steel striker plates or steel pipe of at least 0.0508 inch (16 gauge) thick and extending a minimum of 4 inches beyond concealed penetrations of floor/ceiling plates, wall studs, fire stops, etc. shall be installed between the tubing and the finished wall.*

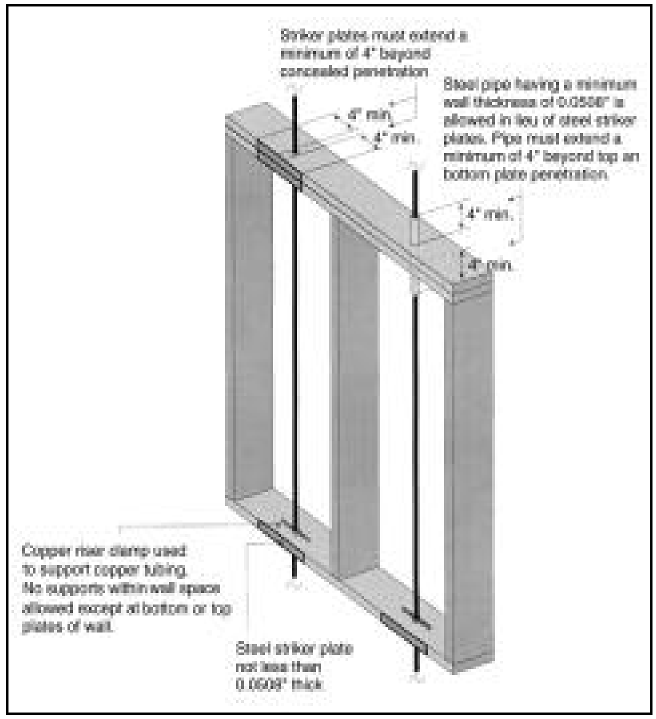

Figure 9 – Sec. 1211.9.4 of the UPC Illustrated Training Manual

The restriction of not strapping the copper within the vertical wall space provides for the free deflection of the piping away from any possible puncture point. As the point of any screw, nail or staple begins to strike the surface of the copper, the pipe or tube can move horizontally away from the point and not be punctured. Is this a foolproof method of protecting the copper pipe or tube? No, however, I think we have all seen steel pipe damaged and punctured by screws or drill bits. We must remember it will be impossible to protect any system from accidents or fools all of the time.

Corrosion – Exterior

The *UPC* does not provide for protection from this type of corrosion for it does not need to. Many people mistakenly think that the dark brown color of exposed copper pipe is due to corrosion and that the pipe will eventually "rust away." However, the reverse is true. The dark brown color or even the blue-green patina that occurs on copper is copper oxide. Instead of corroding copper, this compound actually protects copper by creating a protective film outside and even inside of copper pipe and tube. This film then protects copper from further corrosion or erosion, which is why we can find copper pipe over 5000 years old in the pyramids in Egypt that could still be used. Jim Weflen of the Copper Development Association can verify this. He was there when it was installed. Copper pipe and tubing is one of the most corrosion-resistant materials we have in the plumbing industry.

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Corrosion – Interior

Typical Composition of Natural Gas		
Methane	CH_4	70-90%
Ethane	C_2H_6	0-20%
Propane	C_3H_8	
Butane	C_4H_{10}	
Carbon Dioxide	CO_2	0-8%
Oxygen	O_2	0-0.2%
Nitrogen	N_2	0-5%
Hydrogen Sulphide	H_2S	0-5%
Rare Gases	Ar, He, Ne, Xe	Trace

Figure 10 – Typical Composition of Natural Gas

Corrosion on the interior of copper pipe and tube in natural gas installations is the most serious of the above concerns. This corrosion is created because of the properties of natural gas itself. As *Figure 10* shows, natural gas is a mixture of many other hydrocarbon gases and other elements. The problem occurs with the amount of hydrogen sulfide contained in the gas. Hydrogen sulfide (H_2S) will react with copper, creating a coating of black or dark brown "dust" referred to as sulfidation. This sulfidation is perceived to cause two possible corrosion problems in the copper natural gas system:

- Continual flaking of the copper sulfide, thinning the pipe and eventually causing pinholes and thus leaks;
- Continual flaking of the copper sulfide, causing the flakes themselves to fall and be carried into the appliance and possibly block burners or be deposited into gas valves causing the valve to foul.

Two extensive studies have been done on the sulfidation of copper in natural gas installations that have shed light on these two problems. The first was a study completed in 1996 in the United Kingdom entitled, "*Safety Aspects of the Effects of Hydrogen Sulfide Concentrations in Natural Gas*," prepared by WS Atkins Environment for the British government. The second was a study completed in 2002 entitled, "*Copper Tubing in a Natural Gas Environment*," work performed by Wayne T. Yuen, engineer for a joint effort by the Copper Development Association and the Southern California Gas Company. The first study, the UK study, investigated sulfidation in the existing copper systems in the United Kingdom along with analysis of other existing systems or studies. The second study, the SCG study, examined the use of copper tubing in a natural gas installation, simulating the flow of gas in a typical residence for up to 15 years.

Both studies found that the first possible problem, the thinning of the copper wall and eventual failure or pin holing of the pipe, is unlikely ever to occur. The UK study found no failures of piping in installations in the UK. The study stated that although the copper sulfide coating may flake or fall off the wall of the pipe and could continually do this "the corrosion rates suggest failure of the copper pipe due to sulfidation should not represent a concern.... Even at high concentrations [of H_2S] the pipe would have a life expectancy of 100 years." The SCG work took pipe samples and inspected them after different lengths of time in use. In inspecting the longest use sample, the 52-week sample, minute pits were found after the copper sulfide flaked off. However, "the projected wall loss at 20 years of service life for bare copper tubing is well below the 10 mils limit. Based on a uniform wall loss assumption, the data suggest that bare copper tubing will maintain structural integrity for the duration of its "service life."

The second problem with sulfidation, the possible continual flaking and thus the plugging of burners and the fouling of valves, is the serious concern with these copper systems. Both studies found evidence of flaking. The UK study stated that "Approximately 21,000 properties in Great Britain are estimated to be affected by the presence of hydrogen sulfide in gas. 90% are estimated to be associated with blockage of burners and about 5% with central heating boiler gas valve failure." However they also stated, "Only one accident has been reported due to gas valve failure caused by sulfidation." It should be noted that almost all natural gas systems in Great Britain are installed in copper. It was also noted that the sulfidation problem had been only in the previous few years before the study. The problems began to occur once new natural gas terminals from the North Sea that contained higher concentrations of hydrogen sulfide came on line. Most of the problems were occurring in the North of Great Britain where the new gas was being delivered.

The UK study also found that the rate of movement of the gas affected the stability as well as the growth of the copper sulfide flakes. "Lower flow rates of flow resulted in thinner layers of copper sulfide formation but the layers appear to be more stable and less likely to flake off." They also found that bends causing turbulence actually slowed the copper sulfide reaction and disturbed its growth.

The SCG study subjected bare copper tube and tinned copper to flows of over 3.5 million cu ft of gas for varying periods, the longest of which was 52 weeks. This was equivalent to the flow of gas in a typical residence of 15.96 years. In each of the samples tested—4 weeks, 12 weeks, 24 weeks, 52 weeks—*(see Figure 11)* hydrogen sulfide deposits were found in the bare tube, as can be seen in *Figure 12*. In the 24-week sample, the strainer filters downstream of the tube

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had deposits, as did the 52-week sample, but not enough to cause blockage. It is also interesting that in the 24-week sample of the tin-lined copper, the lining had flaked off in two small areas, which had begun to produce copper sulfide. However, the report stated, "Tin-lined copper tubing did not exhibit susceptibility to sulfide corrosion while the tin coating was intact. It was clearly more resistant to corrosion than bare copper tubing.... Also, the results indicate that the tin-lined copper tubing should not exhibit any significant potential for blockage of orifices, valves, or burners due to the release of significant amounts of friable corrosion products."

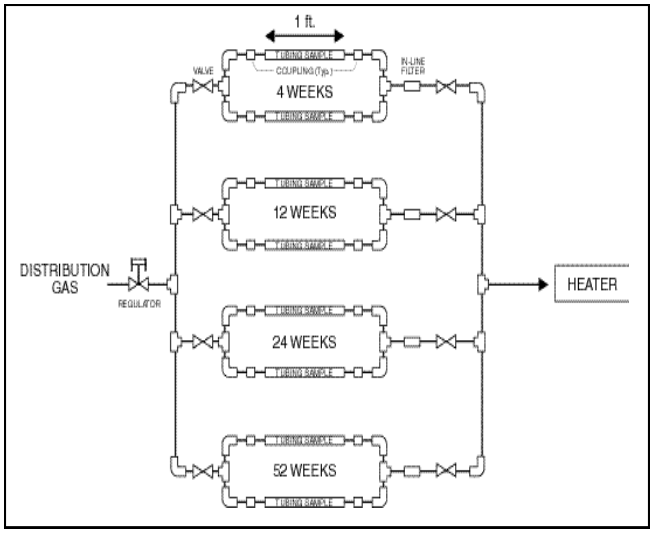

Figure 11 – Test-rack assembly

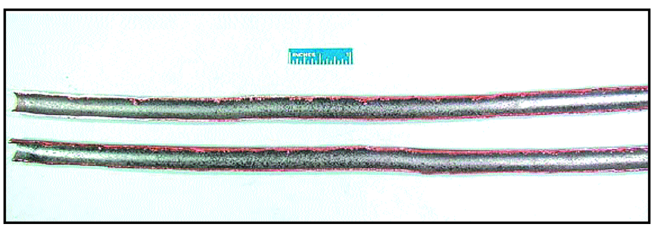

Figure 12 – Tube Samples

The conclusion of the SCG study states, "Both the bare copper tubing and the tin-lined copper tubing evaluated in this test met the performance criteria to indicate that they will maintain structural integrity even though there were clear signs of sulfide corrosion. The extent of the observed corrosion was not severe enough to cause concern with through-the-wall type corrosion in the context of a 20-year useful life. However, a suggested area for further study is the evaluation of the copper sulfide corrosion products to determine if they are of sufficient size or consistency to present the possibility of creating blockage in system components."

It is obvious from reading these two studies that there can be problems with high amounts of hydrogen sulfide in natural gas. Even low amounts can cause copper sulfide corrosion. The UK study found that high amounts of oxygen can cause increased corrosion. Also the mercaptan—the compounds added to natural gas to produce that rotten egg smell—can also have an affect on the amount of copper sulfide corrosion.

The remedy then, if one uses copper for natural gas, is to ensure that low amounts of hydrogen sulfide are contained in the gas. The 2000 *UPC* contains this requirement. Section *1210.1.1* states:

> ***1210.1.1*** *Copper alloy tubing shall not be used if the gas contains more than an average of 0.3 grains of hydrogen sulfide per 100 standard cubic feet of gas (0.7 milligrams per 100 liters).*

It is also recommended that you consult with the supplying gas company to ascertain if the gas meets this requirement and will meet it into the future. This may be difficult to obtain in that most gas companies are reluctant to guarantee this content, not knowing if or when they may change gas suppliers.

Another cause for possible concern with copper tube natural gas installations is the confusion that may occur when using the different types of tubing. Type L and K and type ACR copper have different size designations. Type L and K tube use inside diameter designations such as 1/2", 3/4", 1" and so on. ACR tubing uses outside diameter designations such as 3/8", 5/8" and 7/8" and so on. The *UPC* solves this dilemma by using all of the designations and the appropriate CFH maximums in Table 12-11 and 12-12. Note that the table requires the use of the outside diameter of the tube for sizing.

Table 12-11

Copper Tube – Low Pressure

Maximum Delivery Capacity* of Cubic Feet of Gas Per Hour of Copper Tube Carrying Natural Gas of 0.60** Specific Gravity at Low Pressure (Less than 14 inches Water Column) Based on Pressure Drop of 0.50 Inch Water Column:

Length of Tube, feet	Outside Diameter of Tube, Inches						
	3/8 (10 mm)	1/2 (15 mm)	5/8 (18 mm)	3/4 (20 mm)	7/8 (22 mm)	1-1/8 (28 mm)	1-3/8 (34 mm)
10	24	50	101	176	250	535	963
20	17	34	69	121	172	368	662
30	13	27	56	97	138	295	531
40	11	23	48	83	118	253	455
50	10	21	42	74	105	224	403
60	9.1	19	38	67	95	203	365
70	8.4	17	35	62	84	187	336
80	7.8	16	33	57	81	174	313
90	7.3	15	31	54	76	163	293
100	6.9	14	29	51	72	154	277
125	6.1	13	26	45	64	136	245
150	5.6	11	23	41	58	124	222
175	5.1	11	21	38	53	114	205
200	4.8	10	20	35	50	106	190
250	4.2	8.7	18	31	44	94	169

*Includes 20% factor for fittings.
**For other pressure drops values see Table 12-12.

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Table 12-12
Specific Gravity
Multipliers to be Used with Copper Tube when Specific Gravity of Gas is other than 0.60.

Specific Gravity	Multiplier	Specific Gravity	Multiplier
.35	1.31	1.00	.78
.40	1.23	1.10	.74
.45	1.16	1.20	.71
.50	1.10	1.30	.68
.55	1.04	1.40	.66
.60	1.00	1.50	.63
.65	.96	1.60	.59
.70	.93	1.70	.58
.75	.90	1.80	.56
.80	.87	1.90	.56
.85	.84	2.00	.55
.90	.82	2.10	.54

Adjustment for a gas with an average specific gravity (relative density) other than 0.60 is achieved by multiplying the CFH values of Tables 12-11, 12-13, or 12-14 by the appropriate multiplier.

If there is a possibility for problems to occur in copper natural gas systems, why would one choose to use copper pipe and tube in the first place? The answer is twofold.

- Ease of use
- Economics

Most plumbers are already familiar with the installation of copper systems. *Section 1211.2* of the *UPC* states:

> ***1211.2*** *All copper tubing joints shall be brazed, flared or screwed joints.*
> ***1211.2.1*** *Brazed joints shall be made by certified brazers in accordance with the applicable standard(s) in Table 14-1 and with approved material having a melting point not less than 1000°F (538°C) and containing not more than 0.05 percent phosphorus.*
> ***1211.2.2*** *Flared joints shall be made with approved gas tubing fittings and shall not be used in concealed or inaccessible locations.*

All of these joining methods are familiar to journeyman and apprentice plumbers. (A brazed natural gas line is shown in *Figure 13*.) And at least for this old plumber I would rather braze or flare copper than thread and screw black iron pipe. It is just simply easier to install (not to mention cleaner). This is just the author's opinion, not IAPMO's.

Many studies have been done on the economics of using copper. Most have found that due to its ease of use and variable joining methods, copper has a distinct advantage over black iron pipe in labor savings. As to cost of materials, the graph in *Figure 14* shows a comparison of bids for the same work using three different materials: steel, CSST, and copper. This survey was prepared by the Canadian Copper and Brass Development Association. We can see that copper was the least expensive installation.

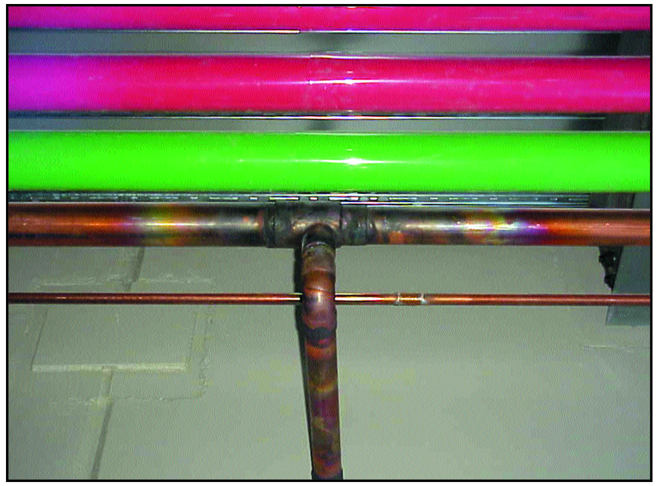

Figure 13 – Brazed natural gas line

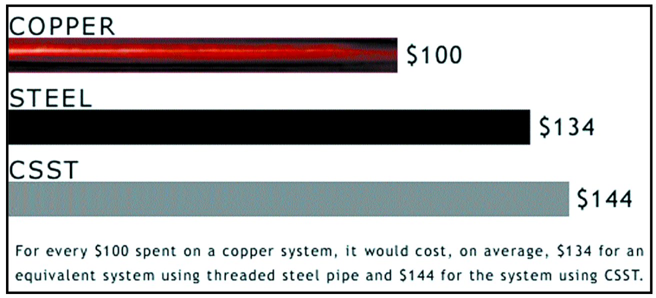

Figure 14 – Cost of materials

Is economics alone a good enough reason to use copper pipe or tube for natural gas installations? The answer is no. We members of IAPMO have never been swayed by economics alone. Our mission in 1946 and our mission in 2003 are one and the same—protecting the health and safety of our nation. If the problems with copper sulfidation were great enough to put that mission at risk, copper would not have been accepted for use in natural gas systems. With the requirements contained in Chapter 12 of the *Uniform Plumbing Code* for copper installations, we believe that the system is safe. If the hydrogen sulfide content can be kept at or below the requirement, copper natural gas systems should serve the owner for the life of the building and beyond. Who knows, in 5000 years another plumber may be giving a seminar on copper systems and noting that the copper found in an ancient training center could still be put into use.

Thanks to the Canadian Copper & Brass Development Association for use of their images. Some of the other images provided have been taken from the UPC *as well as it's supporting publications. The remaining images have been provided from the author's personal archives.*

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