Design and Installation Data:
General Considerations

It is not possible in a handbook of this type to cover all the variables a plumbing system designer may have to consider. However, in addition to the foregoing discussion, the following information may also prove helpful when preparing job specifications.

Expansion Loops

Copper tube, like all piping materials, expands and contracts with temperature changes. Therefore, in a copper tube system subjected to excessive temperature changes, a long line tends to buckle or bend when it expands unless compensation is built into the system. Severe stresses on the joints may also occur. Such stresses, buckles or bends are prevented by the use of expansion joints or by installing offsets, "U" bends, coil loops or similar arrangements in the tube assembly. These specially shaped tube segments take up expansion and contraction without excessive stress. The expansion of a length of copper tube may be calculated from the formula:

\[
\text{Temperature Rise (degrees F)} \times \text{Length (feet)} \times 12 \text{(inches per foot)} \times \text{Expansion Coefficient (inches per inch per degree F)} = \text{Expansion (inches)}
\]

Calculation for expansion and contraction should be based on the average coefficient of expansion of copper which is 0.0000094 inch per inch per degree F, between 70°F and 212°F. For example, the expansion of each 100 feet of length of any size tube heated from room temperature (70°F) to 170°F (a 100°F rise) is 1.128 inches.

\[
100°F \times 100 \text{ ft} \times 12 \text{ in./ft.} \times 0.0000094 \text{ in./in./°F} = 1.128 \text{ in.}
\]

Figure 3 shows the change in length per 100 feet of copper tube, with temperature. The previous example is shown by the dotted line.

Table 8 gives the radii necessary for coiled expansion loops, described in Figure 4. Expansion offset lengths may be estimated from Table 8.

Alternatively, the necessary length of tube in an expansion loop or offset can be calculated using the formula: where:

\[
L = \frac{1}{12} \left( \frac{3E}{p} \right)^{\frac{1}{2}} (d_e \varepsilon)^{\frac{1}{2}}
\]

WHERE:

- \( L \) = developed length, in feet, in the expansion loop or offset as shown in Figure 4.
- \( E \) = modulus of elasticity of copper, in psi.
$P = \text{design allowable fiber stress of material in flexure, in psi.}$

$\text{d}_e = \text{outside diameter of pipe, in inches.}$

$e = \text{amount of expansion to be absorbed, in inches.}$

For annealed copper tube:

$E = 17,000,000 \text{ psi}$

$P = 6,000 \text{ psi}$

Thus, the developed length $L$ is simply:

$L = 7.68 \left( \text{d}_e e \right)^{1/2}$

**Tube Supports**

Drawn temper tube, because of its rigidity, is preferred for exposed piping. Unless otherwise stated in plumbing codes, drawn temper tube requires support for horizontal lines at about 8-foot intervals for sizes of 1-inch and smaller, and at about 10-foot intervals for larger sizes.

Vertical lines are usually supported at every story or at about 10-foot intervals, but for long lines where there are the usual provisions for expansion and contraction, anchors may be several stories apart, provided there are sleeves or similar devices at all intermediate floors to restrain lateral movement, see Figure 1.

Annealed temper tube in coils permits long runs without intermediate joints. Vertical lines of annealed temper tube should be supported at least every 10 feet. Horizontal lines should be supported at least every 8 feet.

**Resistance to Crushing**

Tests made by placing a 3/4-inch round steel bar at right angles across a 1-inch annealed copper tube and then exerting pressure downward revealed that, even with this severe point-contact loading, 700 pounds were required to crush the tube to 75 percent of its original diameter. Two-inch sizes, because of their greater wall thicknesses, resisted even more weight before crushing.

Plumbing codes and good piping practice require that all excavations shall be completely backfilled as soon after inspection as practical. Trenches should first be backfilled with 12 inches of tamped, clean earth which should not contain stones, cinders or other materials which would damage the tube or cause corrosion. Equipment such as bulldozers and graders may be used to complete backfilling. Suitable precautions should be taken to ensure permanent stability for tube laid in fresh ground fill.

**Water Hammer**

Water hammer is the term used to describe the destructive forces, pounding noises and vibrations which develop in a water system when the flowing liquid is stopped abruptly by a closing valve.

When water hammer occurs, a high-pressure shock wave reverberates within the piping system until the energy has been spent in frictional losses. The noise of such excessive pressure surges may be prevented by adding a capped air chamber or surge arresting device to the system.

Arresting devices are available commercially to provide permanent protection against shock from water hammer. They are designed so the water in the system will not contact the air cushion in the arrester and, once installed, they require no further maintenance.

On single-fixture branch lines, the arrester should be placed immediately upstream from the fixture valve. On multiple-fixture branch lines, the preferred location for the arrester is on the branch line supplying the fixture group between the last two fixture supply pipes.
Collapse Pressure of Copper Tube

The constantly increasing use of copper and copper alloy tube in condensers, water heaters and other heat transfer devices for water, gas and fluid lines, and many other engineering applications where a pressure differential exists on opposite sides of the tube wall, makes accurate data necessary regarding collapse pressures. See Figure 2.

Freezing

Annealed temper tube can withstand the expansion of freezing water several times before bursting. Under testing, the water filling a 1/2-inch soft tube has been frozen as many as six times, and a 2-inch size, eleven times. This is a vital safety factor favoring soft tube for underground water services. However, it does not mean that copper water tube lines should be subjected to freezing.

Corrosion

Copper water tube is corrosion resistant. It is very infrequent that waters or special conditions are encountered which can be corrosive to copper tube. When they are encountered, they should be recognized and dealt with accordingly.

Since World War II, over 18 billion pounds of copper plumbing tube has been produced in the United States, 80% of which has been installed in water distribution systems. This translates into more than 7 million miles of copper tube. The rare problems of corrosion by aggressive water, possibly aggravated by faulty design or workmanship, should be viewed in the context of this total record of outstanding service performance. In general, widespread use of copper plumbing tube in a locality can be taken as good evidence that the water there is not aggressive to copper.

When corrosion problems do occur, they usually stem from one of the following causes:

1. aggressive, hard well waters that cause pitting;
2. soft, acidic waters that do not allow a protective film to form inside the copper tube;
3. system design or installation which results in excessive water flow velocity or turbulence in the tube;
4. unacceptable workmanship;
5. excessive or aggressive flux;
6. aggressive soil conditions.

Aggressive pitting waters can be identified by chemical analysis and treated to bring their composition within acceptable limits. Characteristically, they have high total dissolved solids (t.d.s.) including sulfates and chlorides, a pH in the range of 7.2 to 7.8, a high content of carbon dioxide (CO2) gas (over 10 parts per million, ppm), and the presence of dissolved oxygen (D.O.) gas.

A qualified water treatment professional can specify a treatment for any aggressive water to make it non-aggressive to plumbing materials. In general, this involves raising the pH and combining or eliminating the CO2 gas. Sometimes simple aeration of the water (e.g., spraying in the open air) is treatment enough.

Pitting can also be caused or intensified by faulty workmanship which leaves excessive amounts of residual aggressive flux inside the tube after installation. If the joints have been overheated during installation and the excess residual flux has polymerized, the pitting problem can worsen.

Soft acidic waters can cause the annoying problem of green staining of fixtures or "green water." Raising the pH of such waters to a value of about 7.2 or more usually solves the problem, but a qualified water treatment professional should be consulted. A typical treatment for an individual well water supply is to have the water flow through a bed of marble or limestone chips.
Excessive water velocity causes erosion-corrosion or impingement attack in plumbing systems. As explained in the discussion of pressure system sizing beginning on page 10, to avoid erosion-corrosion (and noise) problems, the water velocity in a plumbing system should not exceed 5 to 8 feet per second—the lower limit applying to smaller tube sizes.

Velocity effects can be aggravated if the water is chemically aggressive due to pH or gas content as outlined above, or if solids (silt) are entrained in the flow. The combination of a velocity that is otherwise acceptable and a water chemistry that is somewhat aggressive can sometimes cause trouble that would not result from either factor by itself.

Erosion-corrosion can also be aggravated by faulty workmanship. For example, burrs left at cut tube ends can upset smooth water flow, cause localized turbulence and high flow velocities, resulting in erosion-corrosion.

Any metal pipe laid in cinders is subject to attack by the acid generated when sulfur compounds in the cinders combine with water. Under such circumstances, the tube should be isolated from the cinders with an inert moisture barrier, a wrapping of insulating tape, a coating of an asphaltum paint, or with some other approved material. With rare exception, natural soils do not attack copper.

Copper drainage tube rarely corrodes, except when misused or when errors have been made in designing or installing the drainage system. An improper horizontal slope can create a situation where corrosive solutions could lie in the tube and attack it. If hydrogen sulfide gas in large volume is allowed to vent back into the house drainage system, it can attack the tube.

### Vibration

Copper tube can withstand the effects of vibration when careful consideration is given to the system design.

Care should be taken when installing systems subject to vibration to assure that they are free from residual stresses due to bending or misalignment. Residual stresses coupled with vibration can cause fatigue at bends and connections where such residual stresses have been built into the system.

### Durability

Under normal conditions, a correctly designed and properly installed copper water tube assembly will easily last the life of the building. Throughout its existence, the assembly should function as well as it did when originally installed.

### NSF Certification

The U.S. Safe Drinking Water Act (1996) and the Lead and Copper Rule (1991) require public water suppliers to provide non-corrosive drinking water to customers. Typically, this is accomplished through the use of pH adjustment (pH 6.5 to 8.5) and through the addition of corrosion inhibitors such as ortho- and polyphosphates. The resultant tap water concentrations of lead and copper must be below the action levels of 15µg/L and 1300µg/L, respectively.

NSF International has certified several copper tube and fittings manufacturers to ANSI/NSF Standard 61. All have the limitations of being certified for use in non-corrosive aqueous environments. Specifically, the pH must not be below 6.5. Otherwise, resultant copper concentrations in tap water may exceed the action level established by the EPA.

ANSI/NSF Standard 61 requires products evaluated to conditions other than those specified in the standard (such as pH 5 and 10 exposure water) to be labeled with a limitation statement, as follows:

*Copper tube (Alloy C12200) is Certified by NSF to ANSI/NSF Standard 61 for public water supplies meeting or in the process of meeting the EPA Lead and Copper Rule (56FR 26460, June 7, 1991). Water supplies with pH less than 6.5 may require corrosion control to limit copper solubility in drinking water.*

NSF Certified copper tube must bear the NSF Certification mark and the limitation statement. The length of the
limitation statement makes it difficult to place on the tube itself. Additionally, current inking technology results in smearing and low legibility. For these reasons, NSF certification policies allow copper tube manufacturers to place the limitation statement on a tag attached to bundles of copper tube, or on the boxes of coiled copper tube. Placing "NSF" on the tube itself is still required.