EziBend Tube

Information Booklet

Volume 1
For many years the tubing in automotive brake systems has been manufactured from low-carbon steel. One of more superficial coatings are applied after brazing to protect the steel substrate from corrosion, because steel has no inherent corrosion resistance to the road environment. Although coating composition has changed since the original hot-dip lead-tin coatings were used, coating flaws remain a problem. The addition of zinc-rich paints did little to improve the protection of the tube. Current aluminum-zinc coatings and added polyvinylfloride coatings are still inadequate to totally protect the steel tube.

In a recent series of tests, 90-10 copper-nickel tube (UNS C70600) was fabricated into typical brake system “shapes” which were then attached to a test trailer and conveyed through various corrosive and mechanically abusive test track environments. The tests included holding the tubes in a high humidity chamber for a portion of each 24-hour test cycle. After 40 cycles and at each 10 cycles thereafter, the individual tubes were required to pass a 20,684 KPa (3,000 psi) pressure test. Candidate tube materials had to complete 60 cycles to satisfy the minimum requirements.

Current production steel tubes passed the 60-cycle requirement but failed well before 120 cycles. The 90-10 copper-nickel tubes completed 200 cycles with essentially no reduction of their original burst strength.

Introduction
Brake tubes are located in a high-corrosion area. Although many other automotive components operate in the same hostile environment, few are less forgiving in the event of a failure. Thus, one of the major considerations in the design of an automotive hydraulic brake system is the integrity of the brake tubing which distributes the system pressure.

In 1965, an annual safety inspection of motor vehicles was introduced in Sweden and subsequently in other European countries.

This procedure included the inspection of hydraulic brake tubes for the presence of rust. Concurrently, the Swedish Motor Vehicle Inspection Company began publishing annual reports on the results of these ests.[1]

In 1969, laboratory tests were reported comparing some inherently corrosion-resistant copper alloy tube materials with the then-current production materials.[2]

Early in 1970, the Swedish Corrosion Institute approached the brake tube corrosion problem from the standpoint of using a corrosion-resistant material rather than trying to protect the surface.[1]

The European auto industry’s initial response to brake tube corrosion problems was to terminate the use of the then-current hot-dipped terne metal coating over steel tube. Laboratory testing in a 6% neutral vapor salt spray test indicated that corrosion resistance could be obtained by a 25-micron zinc coating in place of the terne coating. In the years that followed, it became apparent that the laboratory testing had not accurately reflected conditions that exist in the actual operating environment. Subsequently, various plastic coatings were applied over the zinc and some are still being used to this date.[1]

Efforts to achieve a metallurgical solution to the corrosion problem continued. Volvo began the use of 90-10 copper-nickel (“Cunifer Alloy”) tube in their 1976 model vehicles and have been using it since. **Figure-1** shows the installation at the master cylinder in a 1990 model Volvo. Audi began using this material in 1990. The other European cars using this material are Porsche and Aston Martin.[2]

Figure 1.*Copper-nickel brake lines running from master cylinder in 1990 Volvo.*

The bar graph shown in **Figure-2** depicts the percentage of vehicles failing safety inspections because of defects in the brake systems of eight-year-old Volvo passenger cars.

The 1970 model cars had terne-coated steel tubes. Tubes in the 1971 models were zinc coated. Defects other than rusted tubes are included in these values, but their effect on the data is minimal. The reduction in defects related to the introduction of 90-10 copper-nickel tube in 1976 is dramatic.

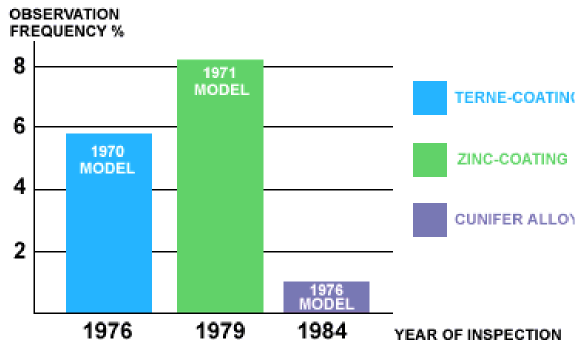


Figure 2. Annual Swedish Vehicles Safety Inspection Results. The bars indicate the percentage of 8-year old Volvo passenger cars inspected in the indicated yearwith brake liens which did not meet the inspection requirements. 1976 was the year Volvo introduced 90-10 copper-nickel tubes ('Cunifer Alloy') into their vehicles.

The paper[2] presented at the SAE Annual Meeting in January 1970 dealt with the then "state of the art" in tube coatings; the data presented in that paper are still pertinent. Voids, poor adhesion, discontinuities and physical damage to the superficial coatings used today can result in accelerated, localized corrosive attack which renders useless the value of any intact coating elsewhere on the tube.

An incident reflecting the latter condition was recorded in an SAE paper presented in 1991.[3] A brake line which should have burst when tested at 115,832 to 158,579 kPa (16,800 - 23,000 psi), in fact, burst at 4,825 kPa (700 psi). The paper states, "This particular tube portion was located at the end, above and behind the rear axle, and showed a great deal of corrosion, perhaps due to gravel impingement."

Against the background summarized above, a test program was undertaken by the Copper Development Association Inc., with the cooperation of an automotive vehicle manufacturer, to evaluate thoroughly the applicability of Copper Alloy C70600 tube, 90-10 copper-nickel, for automotive brake line application.

Trailer Corrosion Test

The design test procedure generally used today to evaluate the corrosion resistance and integrity of motor vehicle body and chassis components consists of 100 cycles of controlled humidity soaking and drying, salt spraying and mileage accumulation over various road surfaces with test samples mounted on a trailer.

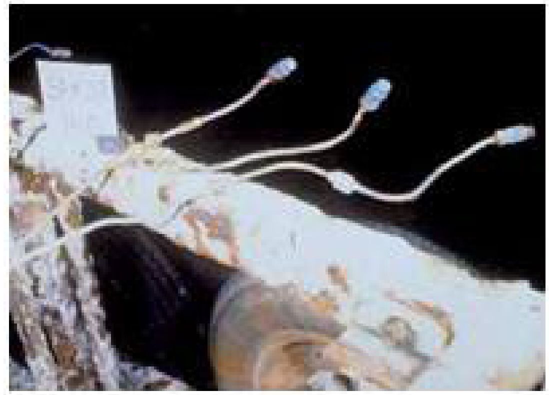


Figure 3. *Brake line samples attached to test trailer.*

The trailer is exposed to salt, dust and stone pecking as well as temperature and humidity variations. The total humidity soak time is approximately 2,600 +/-25 hours. The total drying chamber soak time is 375 +/-25 hours. The test trailer accumulates approximately 13,800 km (8,600 miles) during the full test cycle. Total test time is approximately 26 weeks
Figure 3 shows test samples attached to a typical test trailer.

The tube size used for the test was 4.76mm (0.1875 in.) outside diameter, 0.7mm (0.028 in.) wall thickness. It was fabricated into typical brake system configurations with flares and tube nuts. The ends were encapsulated to allow subsequent pressure testing. These test specimens were then attached to various areas of the test trailer to assure exposure to all test elements at various degrees of intensity.

Beginning with the 40th cycle, and at 10-cycle intervals thereafter, each tube is subjected to an internal pressure test of 20,684 kPa (3000 psi). Candidate materials must complete 60 cycles to satisfy the minimum requirement. **Figure-4** shows the test equipment on which the hydrostatic pressure tests were made.

This performance would be expected even if a measured superficial abrasion had been inflicted on the tube as a condition for the evaluation of the tube surface.

Test Results

The data in **Table-3**[4] reveal that after 200 test cycles, which exceeds three times the minimum benchmark of 60 cycles, the copper-nickel material retained more than

Figure 4. *Equipment used to test hydrostatic pressure in brake tube.*

89% of its initial average burst strength. Also noteworthy is the narrow spread in post-test burst pressure. This attests to the uniformity of copper-nickel's strength and physical properties, a feature which is not present in the currently used coated carbon steel tube.

Table 3.	Trailer Corrosion Test Results [4]	
	Hydrostatic Brust Pressure	
Sample No.	kPa	psi
Before Test Exposure		
1	114,108	16,550
2	113,079	16,400
Average:	113,591	16,475
After 200 Test Cycles		
3	104,111	15,100
4	102,732	14,900
5	100,663	14,600
6	99,974	14,500
Average:	101,870	14,775

Additional Testing
Figure-5 shows the engine compartment of a 1976 model Volvo four-door sedan. The vehicle was located in the storage yard of a used automobile parts dealer. The engine had already been removed and the actual mileage is not known. However, using the corrosion in the engine compartment as a criterion, it can be concluded that the uncorroded copper-nickel brake tubes which can be seen exiting from the master cylinder had, indeed, survived a hostile, corrosive environment.

Figure 5. *Engine compartment of 1976 Volvo showing uncorroded copper-nickel brake lines.*

The brake tubes were removed from this vehicle and hydrostatic burst tested with the following results:

Tube No. 1	111,694.95 kPa	(16,200 psi)
Tube No. 2	106,868.62 KPa	(15,500 psi)

These real-world data are welcome confirmation of the trailer test results.

Summary and Conclusions
The automobile industry faces many challenges in the market place and on its test tracks. It must produce vehicles that will compete in a world market on the basis of quality, safety, reliability, durability and cost. The test results presented above demonstrate that 90-10 copper nickel tube is a significantly better choice for automotive brake lines than low-carbon steel because:

1. The use of an inherently corrosion resistant material is the best protection against long-term brake tube corrosion. This has been demonstrated by Volvo, which uses 90-10 copper-nickel tube in automobiles they have produced during the last 15 years.

2. The results of trailer corrosion testing indicate that 90-10 copper-nickel tube (UNS 70600) is a superior product compared to the coated steel tube used for brake lines in today's U.S.-made vehicles.

3. Current double-wrapped, brazed and coated steel tubing is susceptible to brazing voids, coating voids, poor coating adhesion and discontinuities. These susceptibilities, combined with random service damage, mean the actual service life of the brake tube materials presently used in U.S.-manufactured vehicles should be considered unacceptable.

It must be recognized that all underbody components, including the brake tubes, wll be struck by objects thrown up by the tires. Such random damage must be considered the most vulnerable link in the chain.

The tubing designer generally specifies the addition of a metal or plastic sleeve to the tube areas believed to be most vulnerable to stone damage. However, an inherently corrosion-resistant copper-nickel tube provides the surest protection against such random service damage, especially compared to a coated steel tube.

REFERENCES:
[1] Svenson, G.E., Swedish Motor Vehicle Inspection Company, Brake Pipe Corrosion - the Situation 1986, Except from ISO Document 150/22/2WG 8N 82, February, 1986.

[2] Ingram, A. G. and Miner, D. K., Hydraulic Brake Line Corrosion; An Initial Investigation of the Problem, SAE Technical Paper 690530; presented at the SAE Annual Meeting, Detroit, Michigan, May 1969.

[3] Bologna, D.J., Accelerated Corrosion Tests and the Evaluation of New Automotive Brake Line Coatings, SAE Technical Paper 912292, Conference, Dearborn, Michigan, October 1991.

[4] Brantigan, J., Control Power Company, Hydrosatic Burst Test Results, September 11, 1992.

Volume 2

A vehicle's braking system is as crucial to a vehicle's performance as its engine and drive train. The tubing carrying pressurized air or fluid through the system is the vital link between master cylinder and slave cylinders at the wheels.

Brake system tubing is vulnerable to the pressures of air or fluid flowing through it, to corrosion from road mud and salt, and to damage of any protective coatings on is surfaces from stone pecking where it is exposed under the chassis.

Prior to 1930, copper and brass, having excellent inherent pressure containing and anti-corrosion characteristics, were the materials of choice for brake tubing. By post World War Two, automotive industry mass production economics dictated adoption of a low-cost form of double wrapped, furnance-brazed steel tubing that is still in use today worldwide.

Having excellent, initial pressure bearing characteristics, steel tubing is, however, susceptible to corrosion. To retard its inherent corrodibility, coatings of various materials, e.g., zinc-rich paint, terne (a lead/tin alloy) and epoxy, have been applied to steel tubing exteriors. However, no coating has proven to be totally impervious to pitting, scuffing and chipping due to flawed manufacture, careless installation and exposure to hostile environmental conditions like loose gravel. A penetrated coating allows the corrosion process to begin.

An inherently corrosion-resistant tubing material is the only way to insure continuing effective corrosion resistance.

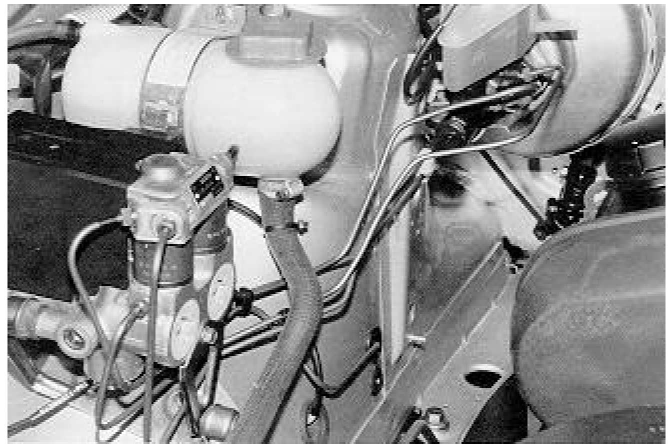
Copper-nickel alloy C70600, an alloy of 90% copper and 10% nickel, is inherently corrosion resistant to road salt, and its use as brake tubing is increasing used on: (1) Changing life-expectancy for automotive vehicles; (2) Worldwide service-experience data on brake tubing wear; and (3) Increasing cost of corrosion-retarding coatings for steel brake tubing.

Automobile Life-Expectancy

More cars, 10 years old and older, are on the road today than ever before. Automobile Manufacturers Association data indicate that road worthy, 10-year-plus vehicles increased in number from 10 million in 1975 to 35 million in 1989.

Automobile use habits serve as an unspoken directive to manufacturers to continue their efforts in providing cars with extended lives.

The adoption of extended warranties by the automotive industry compels design engineers to pursue the 10-year-life goal as the new standard of total vehicle reliability. In the case of subsystems like brakes, a 20-year component life is desirable to ensure that critical subsystems long outlast the vehicle of which they are a part.



Worldwide Data on Wear

In 1965, 251,000 automobile accidents in the USA involved brake failures. In that same year, at a major meeting of the Society of Automotive Engineers (SAE), the problem of brake loss due to steel tubing damage was identified as both dangerous and costly. By 1969, the SAE published a study, Hydraulic Brake Line Corrosion: An Initial Investigation of the Problem (A.G. Imgram and D.K. Miner, Paper 690530, Mid-Year Meeting, May 1969). Indications were clear: corrosive deterioration of steel brake tubing created maintenance problems and could be hazard to safety. The report revealed that steel brake tubing was highly erratic after 4-6 years in service. It also identified Copper-Nickel alloy C70600 tube as outstandingly superior to conventional steel brake line tubing in laboratory salt-spray-exposure burst tests. Copper and four copper alloys also out-performed the double wrapped steel tubing in the tests.

Sweden, with a national program of vehicle inspection since the mid 1960's has been a consistent source of the most accurate data on the problem. The Swedes frequently ban vehicles from the road due to badly corroded steel brake tubing. As in the USA, roads in Sweden during the winter are salted for snow and ice removal.

In spite of corrosion-retarding coatings that are applied in accordance with specifications requiring a minimum coating weight per square foot of tubing surface area (not an overall coating thickness), little protection may result in local areas.

Material	Ultimate Tensile Strength 1000 psi (MPa)	Yield Strength 0.5% Ext. under Load 1000 psi (MPa)	Elongation % in 2 in.	Fatigue Strength (10x7 cycles) 1000 psi (MPa)	Burst Pressure* 1000 psi (MPa)
Copper-brazed Steel	48-55 (0.330 - 0.380)	28 - 34 (0.190 - 0.235)	30 - 40	30 (0.210)	19.05 (0.135)
C12200 - Phosphorus deoxidized Copper	32 - 38 (0.220 - .265)	10 - 14 (0.070 - 0.100)	45 - 60	10 (0.070)	12 (0.083)
C70600 - Copper Nickel 90 - 10	48 - 54 (0.330 - 0.370)	16 - 22 (0.110 - 0.150)	40 - 55	15 (0.100)	19 (0.130)
*For typical 3/16 in. tubing, 0187 in. (4.7mm) o.d. and 0.028 in. (0.71mm) wall thickness.					

Table 1. *Mechanical properties of materials used for hydraulic brake tubing*

Since the 1970s, observed brake tubing faults have diminished with improved coatings. Still, in 1988, over 90,000 Swedish vehicles failed testing due to damaged steel brake tubing, most of which was corrosion related. West Germany, which instituted mandatory vehicle inspections in 1970, has collected data in line with Sweden. Data from the United Kingdom reveal 20% failure rate of brake systems. However, there is no indication of what part of that is attributable to tubing damage.

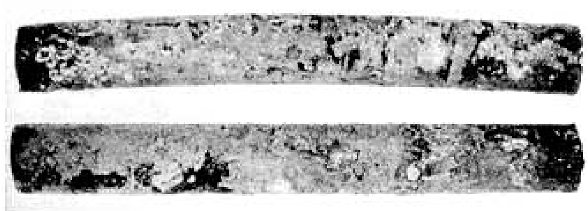


Figure 1: *Results of brake tubing inspections of Volvo vehicles with different brake tubing materials*.

The Swedish data cover the period during which Volvo upgraded the material it used for brake tubing. Prior to 1971, Volvo had used terne coated steel tubing. In 1971 they changed the coating to zinc. The zinc coating was eventually supplemented by epoxy, and in 1976, Volvo adopted copper-nickel alloy C70600. In **Figure 1,** the performance of these four materials are compared on the basis of the percentage of observed occurrences of corrosion damage to brake tubing over 12 years of service. Copper-nickel is shown as the most reliable material by far.

Users of copper-nickel brake tubing in addition to Volvo include world-class vehicle manufacturers like Rolls Royce, Lotus, Aston Martin, Porsche and, most recently, Audi. Copper-nickel is also used in military, fire fighting and other heavy vehicles.

Added Cost Of Coatings

The steel tubing in predominant use is produced from continuous steel strip in the cold-rolled and annealed condition, which is formed into a fully-overlapped tube and copper brazed. The introduction of steel tubing was coincidental with salting of roads as a means of clearing ice and snow and in anticipation of icy conditions. As steel tube alone does not have adequate corrosion resistance, it requires coating. Three coatings in wide use have been zinc, terne (lead and tin alloy with from 7%-14% tin) and epoxy.

Zinc Coating

Zinc has a low corrosion rate in neutral or alkaline environments. If the pH is less than 4, the corrosion rate is higher. In a crevice corrosion situation, pH drops, resulting in degeneration of the zinc and exposure of the copper brazing metal. Galvanically, copper is more noble than zinc, and once exposed, zinc corrosion accelerates. For example, if the steel is exposed due to damage to the coating from stone pecking or other penetration, the copper, being galvanically more noble, creates a large cathodic/anodic area ratio that accelerates the corrosion of the steel resulting in perforation.

Terne Coating

Terne metal has good corrosion resistance, but once damaged it is also noble to the steel, and a large cathode/anode area ratio is created that accelerates corrosion of the steel.

Epoxy and Plastic Coatings

Epoxy and plastics (including teflon) are acceptable until perforated, whereupon localized corrosion of the underlying steel occurs. Perforation can result from stone pecking, from flaring, or when tightening nuts during installation

Other Types of Tubing

Coated seamless or welded steel tubing have been used, but once the coating is perforated, the problems are very similar to those of copper brazed steel tubing. Stainless steel has also been used, but has disadvantages in terms of susceptibility to localized pitting and crevice corrosion especially in chloride-containing environments. With successive attempts to upgrade the performance of coatings, cost has been added to the manufacture of steel brake tubing. In the late 1960's and 1970's, corrosion of motor vehicles was estimated to cost motorists nearly $500,000,000 in the United Kingdom alone. Brake tubing was a particular area of concern, so an alternative material was once again sought.

The Move To Copper-Nickel Tubing

Copper had been proved since the early days to have many good attributes. It was easy to bend and had very high corrosion resistance, but there was concern about its low corrosion-fatigue strength. When copper-nickel was introduced, it displayed corrosion resistance similar to copper, higher general strength and better fatigue strength. Good formability allows ease of flaring and bending, and although the metal cost is greater than that of steel alternatives, copper-nickel is very attractive in view of its extra life, trouble-free installation and safety/reliability characteristics.

Properties of Copper-Nickel Brake Tubing

The copper-nickel alloy used for brake tubing typically contains 10% nickel, with iron and manganese additions of 1.4% and 0.8% respectively. The product conforms to ASTM B466 (American Society for Testing and Materials), which specifies dimensions, tensile strength and yield strength. Formability and internal cleanliness conform to specifications SAE J527, ASTM A254 and SMMT C5B (Society of Motor Manufacturers and Traders). Also, the alloy meets the requirements for pressure containment, fabrication and corrosion resistance for ISO 4038 (International Standards Organization) and SAE J1047. The mechanical properties of alloy C70600 in comparison with steel and copper are shown in **Table-1**.

Alloy C70600 is normally supplied as redrawn tubing in the annealed condition. The combination of strength and good ductility give excellent formability. As copper-nickel is softer than steel, it was first feared that fretting might be a problem. Experience has shown this is not the case.

Corrosion Resistance

For many years prior to its application as a brake tubing material, alloy C70600 had been used in ships, power station condensers and hydraulic lines on tankers, and had displayed excellent resistance to saline conditions. Early tests revealed that copper-nickel has almost the same resistance to burst pressure as steel. In testing, however, when exposed to salt spray over 180 days, steel's burst strength decreases significantly. The copper alloy remains consistently resistant.

For tubes covered with a moist, salty mud pack for six months, brazed steel was severely corroded resulting in perforation of the tubing wall; whereas, only superficial general corrosion was found on the copper-nickel tubing. ISO 4038 and SAE J1047 include a corrosion resistance requirement referring to ISO 3768 asking for a minimum burst pressure of 110 MPa after 96 hours in neutral salt spray. Swedish requirements include a resistance at least equal to 25μ of zinc. In all cases alloy C70600 easily exceeds the required corrosion resistance.

The Right Tubing For The Job

Even the best tubing will be unsatisfactory unless it is used properly. The following considerations are necessary for establishing the specifications for brake system tubing installations:

- Since tubing may suffer damage and/or loss of corrosion resistance as a result of gravel impact, it should be adequately protected in areas of potential damage.

- Tubing should be adequately protected against hoist or towing fixture damage.

- Tubing should be routed or otherwise protected so that under no condition can the tubing or its protective conduit come in contact with any vibrating or moving component. (That is, if the tubing is attached to the frame, the underbody is considered to be a "vibrating component.") The tubing should never intersect an exhaust pipe, muffler or catalytic converter, unless it is adequately protected against excessive movement of the pipe, muffler or catalytic converter, even if a hanger failed.

- Tubing should be routed so that its stress limits will not be exceeded during flexing.

- Tubing should be routed so that it will not be in or form a pocket that will trap salt or other de-icing chemicals.

- Tubing should avoid or be protected from exhaust systems or other areas of extreme heat. The design engineer should take into account possible electrolytic corrosion resulting from contact between dissimilar metals, for example, brake tubing and protective conduit, clips, fittings and mounting surfaces.

•The design engineer should determine the brake tubing's minimum inside diameter based on brake system actuation time. The factors affecting actuation time are:

1. Brake fluid viscosity,
2. Operating temperature,
3. Tube length, and
4. Fluid flow rate as determined by wheel cylinder displacement requirements.

Copper-nickel brake tubing provides superior reliability and assures both manufacturers and vehicle owners improved durability for effective long-life functioning of the brake system.

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EziBend Tube Chart – Following is a chart that maps out the capacity of each size tube. This is based on the alloy and temper of the BrakeQuip EziBend tube with .028" wall thickness up to 200° F.

EziBend Tubing	3/16" OD	1/4" OD	5/16" OD	3/8" OD
Minimum Working Pressure PSI	3,062	2,214	1,740	1,429
Minimum Burst Pressure PSI	15,310	11,070	8,700	7,145
Minimum Tensile Strength PSI	45,000	45,000	45,000	45,000

Nickel - www.nidi.org
Copper - www.copper.org

TIPS on preparation and installation of copper-nickel brake tubing

Preparation		
1.	Determine the length of brake tube using string, flexible tape or the old brake tube as a pattern.	
2.	Cut off the required amount using a fine tooth pitch hack saw ensuring that the sawn ends are square.	DO NOT over-tighten the tube in a vice.
3.	Remove burrs from the outside edges.	DO NOT allow slivers of metal to enter the tube.
4.	A single or double flare can be formed using a good quality flaring tool.	DO NOT use worn punches or dies.
5.	Grip the tube securely without deforming the tube section or indenting its surface.	DO NOT use serrated grips.
Installation		
1.	The nutted and flared tube should be bent carefully into shape so that it will fit easily into position.	DO NOT kink or strain the tube into position.
2.	Bends should be smooth and have a radius of at least 3 x tube O.D.	
3.	A small quantity of brake fluid on the bearing surfaces of the flare will ensure that it and the nut can be tightened without twisting the tube.	DO NOT over-tighten the nut. Hand tighten between 1 and 1-1/2 turns.
4.	All brake tubes should be supported at regular intervals with steel clips with insulating lining or with plastic snap on type clip attached to the body or the chassis. Spacing of 12-13 inches is preferred.	

Copper Nickel C70600 Specifications

Property Results	
Related Metals	90-10 Cupro Nickel
	Copper Nickel, C706
Chemistry Data:	
Iron	1 - 1.8
Lead	0.05 Max
Manganese	1 Max
Nickel	Includes Co
Remainder Each	Cu, including Ag
Remainder Total	Cu + sum of named elements 99.
Zinc	1 Max

Standards					
ASME	ASTM	DIN	MIL	SAE	UNS
SB111	B111	2.0872	C-15726	J461	C70600
SB171	B122		T-15005	J463	
SB359	B151		T-16420		
SB466	B171		T-22214		
SB467	B359				
SB543	B395				
	B432				
	B466				
	B469				
	B543				
	B608				

Principal Design Features
Copper Nickels (Copper-Nickel), Copper-Nickel, (90-10). Excellent corrosion resistance, especially in marine environments. Moderately high strength, good creep resistance at elevated temperatures. Properties generally increase with nickel content. Relatively high in cost compared with copper-aluminum and other alloys with similar mechanical Properties.

Applications - Copper-nickels are mainly used for seawater service as forged and machined valve and pump components, fittings and hardware. Used where high corrosion resistance is required and where concern over chloride stress-corrosion cracking prevents use of stainless steels.

Machinability - The machinability rating of this alloy is 10. (Where Alloy 360 FC Brass is 100.)

Welding - Soldering of this alloy is rated as “excellent”, brazing is rated as “excellent”, oxyacetylene welding is rated as “fair”, gas shielded arc welding is rated as “excellent”, coated metal arc welding is rated as “good”, spot welding is rated as “good”, seam welding is rated as “good”, and butt welding is rated as “excellent”.

Forging: The hot forgeability rating of this alloy is unknown. (Forging Brass=100). The recommended hot working temperature for this alloy is between 1550 and 1750 F.

Hot Working - Rated as “good” .

Cold Working - Rated as “good”.

Annealing temperature - is between 1100 & 1500 F.

Physical Data - Density (lb./Cu. in.) 0.323; Electrical Resistivity (microhm-cm (at 68 Deg F) 112.9; Modulus of elasticity tension is 18000.

Mechanical Data - There is no mechanical data available for this grade.