Copper-Nickel Brake Tubing in the Automotive Industry

CDA Information Sheet 49, 1990

Copper-Nickel Brake Tubing in the Automotive Industry

CDA Information Sheet 49

June 1990

Acknowledgements

Copper Development Association gratefully acknowledges the assistance given by IMI Yorkshire Alloys Ltd, Volvo Car Corporation, Volvo Concessionaires and AB Svensk Bilbrovning.

Copper Development Association

Copper Development Association is a non-trading organisation sponsored by the copper producers and fabricators to encourage the use of copper and copper alloys and to promote their correct and efficient application. Its services, which include the provision of technical advice and information, are available to those interested in the utilisation of copper in all its aspects. The Association also provides a link between research and user industries and maintains close contact with other copper development associations throughout the world.

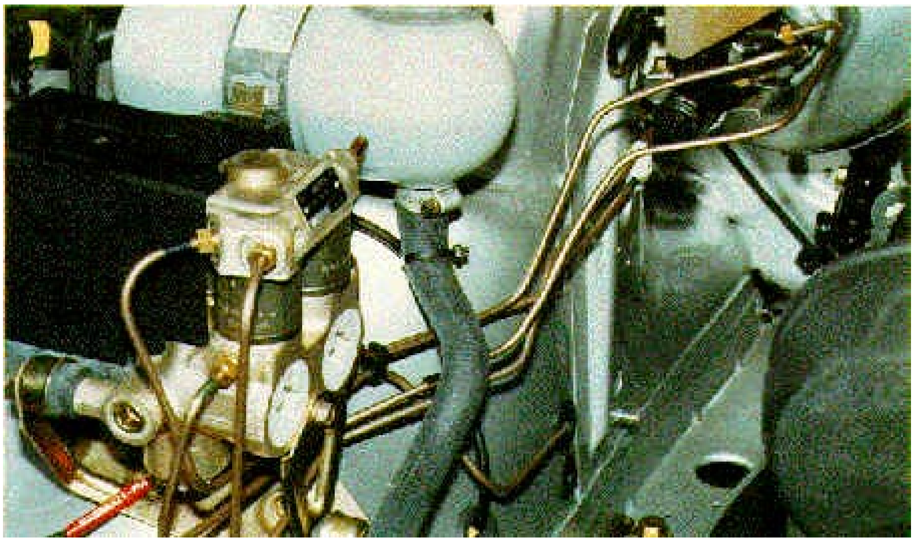
Website: www.cda.org.uk

Email: helpline@copperdev.co.uk

Contents

Introduction

The braking system in road vehicles is one of the most critical items for safety. Tubing, transmitting hydraulic pressure from the central master cylinder to each of the slave cylinders at the wheels, is particularly at risk to pecking damage from stones and corrosion by salt thrown from road surfaces. For some years now, 90/10 copper-nickel tubing has been used consistently to replace steel tubing which has failed in the application. Also, it is installed as original brake tubing by an increasing number of manufacturers wishing to maintain a reputation for reliability.



Types of Tubing

Copper tubing was used for reliability in the 1930s but with increasing mass car production after the second world war a cheaper alternative was sought. Brazed steel tubing became the popular choice. This is produced from continuous copper-coated steel strip in the cold rolled, soft annealed condition formed into a fully overlapped, resistance brazed, tube. The final tube will have a copper coating on its internal and external surface to a depth of 5 - 50µm.

The introduction of this tubing was coincidental with salting of roads as a means of clearing ice and snow. Later, salting was also carried out in anticipation of icy conditions. The steel tube alone was found to have inadequate corrosion resistance in these aggresive conditions. To give some extra protection the finished tube may be coated externally with zinc or terne (a lead/tin alloy with 5 - 25% tin).

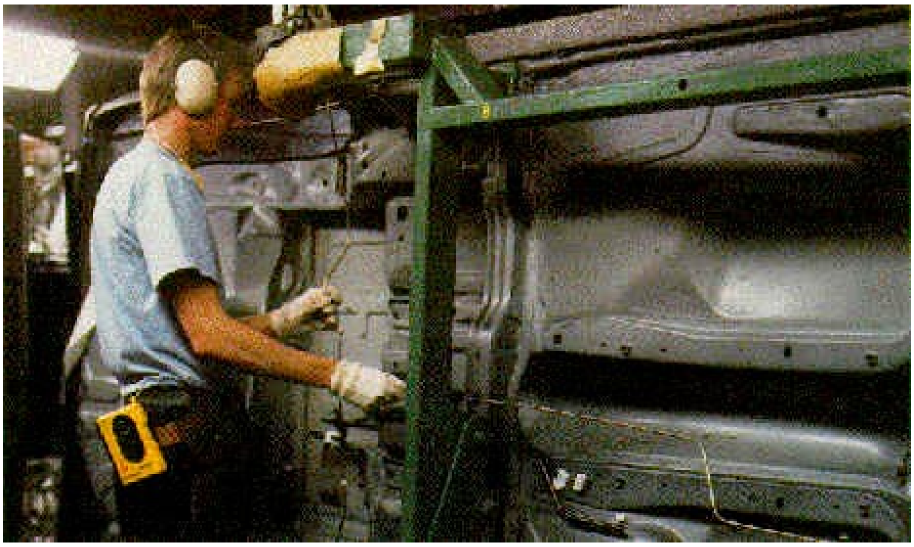
Zinc normally has a low corrosion rate in neutral or alkaline environments but if the pH acidifies to less than 4 the corrosion rate is significantly higher. In a crevice corrosion situation such as may be found at joints or under clips, the pH drops, leading to local degeneration of zinc and accelerated corrosion.

Other metallic or organic coatings are satisfactory only if not damaged during flaring for assembly or by stone pecking in service. Such perforations lead to accelerated corrosion of the substrate tubing. Stainless steels have also been tried but have their usual disadvantages in terms of susceptibility to localised pitting and crevice corrosion in the presence of chloride environments.

Applications

Volvo, Lotus, Aston Martin, Porsche and Audi all now fit copper-nickel brake tubing as standard equipment. It is also fitted as standard in most passenger service, freight and military vehicles, fire tenders, JCB's and other heavy vehicles.

For the replacement market, copper-nickel brake tubing is widely available supplied in coils or straight lengths.



Installation of 90/10 copper nickel brake tubing during vehicle manufacture at Volvo Car Corporation

Brake Tubing Requirements

Brake systems depend on the transmission of either pneumatic or hydraulic pressure. Brake tubing is a particularly vulnerable component, being mainly in an exposed condition under the vehicle. Externally it has to survive a wide range of environmental conditions whereas internally it must withstand pressurised air or brake fluid. Failure of brake tubing is an obvious safety hazard.

The outer tube surface needs to be resistant to extremes of seasonal climatic changes such as temperature and humidity and also resistant to regional atmospheric conditions including chlorides inherent to coastal regions and industrial pollution. Even more importantly, it should show good corrosion resistance towards salt thrown up from the roads. Salt/dirt mixtures can accumulate in crevices, trapping and retaining moisture even in dry condtions. Stones thrown from road surfaces can induce mechanical damage and vibration can lead to surface fretting against retaining clips and other vehicle components.

Internally, the tubing has to be strong enough to withstand transmission pressures even in panic braking situations and also to be resistant to corrosion from the transmission medium. The low water and oxygen contents of brake fluid and its poor conductivity as an electrolyte means that it is not normally particularly corrosive. Many brake fluids also contain corrosion inhibitors.

Installation of the tubing involves flaring the tube ends to make connections and bending to position along the contours of the vehicle.

Overall the requirements for a brake tubing material are:

- Good corrosion resistance especially against chlorides
- Strength
- High burst pressure
- Ease of formability
- Smooth, clean tube bores to allow non-restricted flow
- Good fatigue/corrosion fatigue resistance
- Good resistance to surface fretting and stone pecking
- Readily available in required sizes
- Realistic cost

The Move to Copper-Nickel Tubing

In the late 1960s and 1970s corrosion of motor vehicles had become alarming and was estimated to cost the motorists £250,000,000 in the United Kingdom alone. Brake tubing was a particularly critical item of concern and so an alternative material was again sought. Copper had been proved since the early days to have many good atributes It is easy to bend and had very high corrosion resistance but there was concern about its low fatigue strength.

Copper-nickel was introduced, having similar corrosion resistance to copper together with higher strength and better fatigue strength. Its good formability allows ease of flaring for the joints and bending for the tube runs. Although the metal price is slightly higher than that of the steel alternatives it is easier to install, safer and more cost-effective during the vehicle's lifetime.

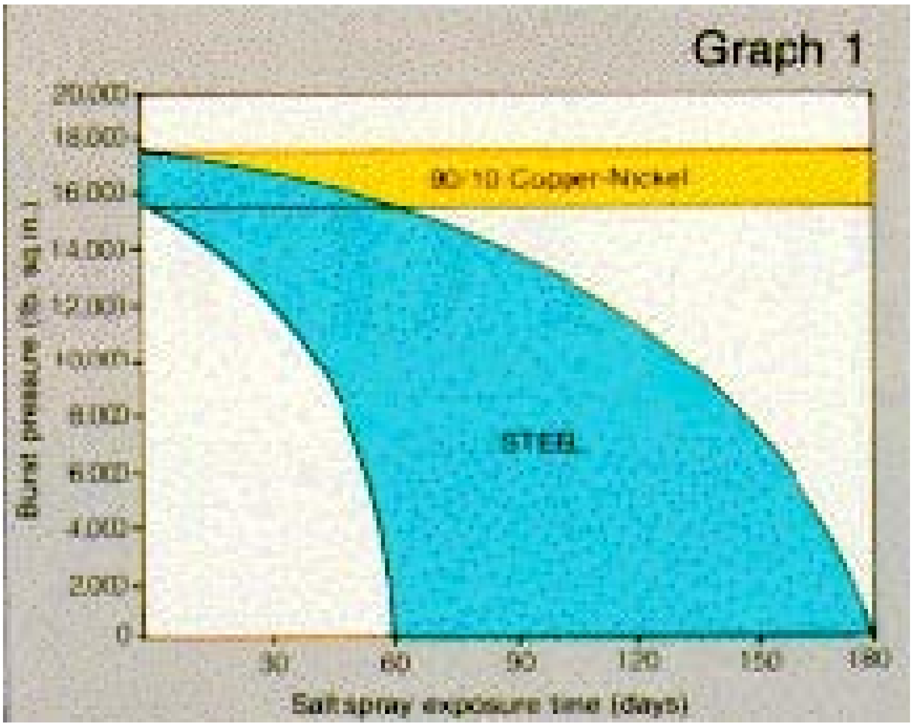
Properties of Copper-Nickel Brake Tubing

The copper-nickel alloy used for brake tubing typically contains 10% nickel with iron and manganese additions of 1.7% and 0.8% respectively. The composition conforms to BS 2871 Part 2, CN 102 designation while dimensions, tensile stress, proof pressure, formability and internal cleanliness conform to international specifications for automotive applications such as SAE J527, ASTM A254 and SMMT C5B. Also, the tubing satisfies the requirements of pressure containment, fabrication and corrosion resistance for ISO 4038 and SAE J1047.

Corrosion Resistance

In addition to being a brake tube material, 90/10 copper-nickel had been used in ships, power station condensers, hydraulic lines on tankers and had shown excellent resistance to saline conditions. Early tests also showed copper-nickel tubing to have almost the same resistance to burst pressure as steel tubing. The latter, however, when exposed over 180 days to salt spray, decreased significantly whereas the copper-nickel remained the same (graph 1).

Graph 1 – Results of tests on copper-nickel



For tubes covered with a moist salt-laden mudpack for six months, brazed steel was severely corroded to perforation of the wall, whereas only superficial general corrosion was found on the copper-nickel.

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 a least equal to 25µ of zinc. In all cases 90/10 copper-nickel easily exceeds the required corrosion resistance.

Copper-nickel is more galvanically noble than other vehicle components with which it is in contact. These are normally aluminium or steel and so corrosion of the less noble alloys was feared. Experience has shown this not to be a problem.

Clips do not suffer accelerated corrosion as might have been anticipated probably because they in turn are connected to larger steel members. An advantage has been found in that it is easier to disconnect copper-nickel tube from brake cylinders. Naturally, some corrosion of the steel nut occurs but it appears there is less tendency for the nut to bind onto a copper-nickel than a steel tube.

The fatigue resistance of copper-nickel is lower than that for brazed steel yet higher than that for copper. With correct flaring and fitting and by using the frequency of clipping used for steel, fatigue can be avoided. With time the steel tubing starts to corrode and the fatique strength is reduced, whereas the copper-nickel remains unimpaired.

Copper Nickel Sheathing Gas platform - Morcambe Bay - Designed for 40 year life in severe marine environment.

Mechanical Properties

The mechanical properties of 90/10 copper-nickel in comparison with steel and copper are compared in table 1. The copper-nickel is normally supplied as seamless tubing in the annealed condition. The combination of strength and good ductility give excellent formability. It has been estimated that 30 - 40% less effort is required to fabricate and shape the copper-nickel compared to steel. A possible time saving of 15 minutes per vehicle should be achieved. It is easier to bend and flare and also, being seamless, has less risk of splitting. As copper-nickel is softer than steel, it was also feared that fretting might be a problem. Again, experience has now shown this not to be the case.

Table 1 - Mechanical Properties of Materials Used for Hydraulic Brake Tubes

Material	Ultimate Tensile Strength psi x 10^3 (N/mm^2)	Yield Strength or 0.5% Proof Stress psi x 10^3 (N/mm^2)	Elongation % on 2 in.	Fatigue Strength (10^7 cycles) psi x 10^3 (N/mm^2)	Burst Pressure * psi x 10^3 (N/mm^2)
Copper – brazed steel	48 - 55	28 - 34	30 - 40	30	19.5
	(330 - 380)	(190 - 235)		(210)	(135)
Phosphorus de-oxidised copper	32 - 38	10 - 14	45 - 60	10	12
	(220 - 265)	(70 - 100)		(70)	(83)
90/10 Copper-Nickel	48 - 54	16 - 22	40 - 55	15	19
	(330 - 370)	(110 - 150)		(100)	(130)

* Burst pressure for typical 3/16" tubing, 0.187in (4.7 mm) o.d. and 0.028in (0.7 mm) wall thickness.

Guarantee

One brake tube manufacturer, IMI Yorkshire Alloys Ltd. is so convinced of the performance and reliability of the product that they provide guarantee that it will last the lifetime of the vehicle to which it is fitted.

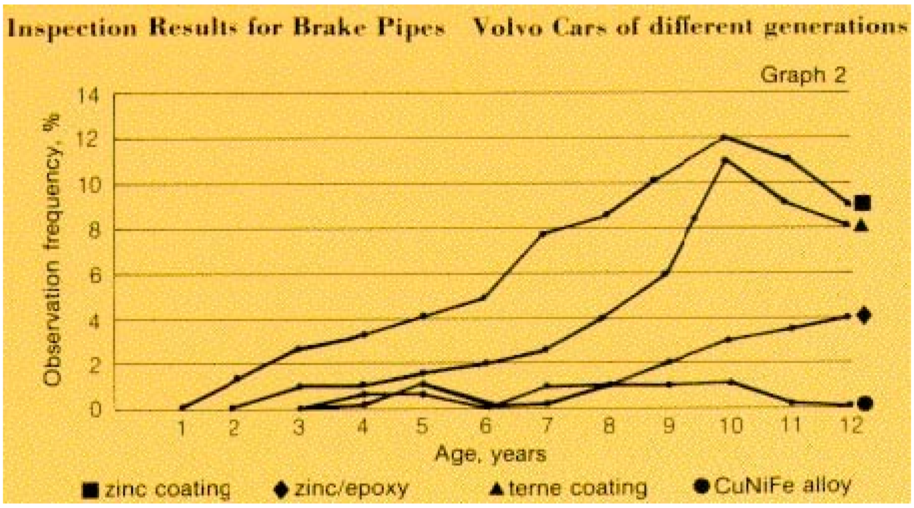
Experience

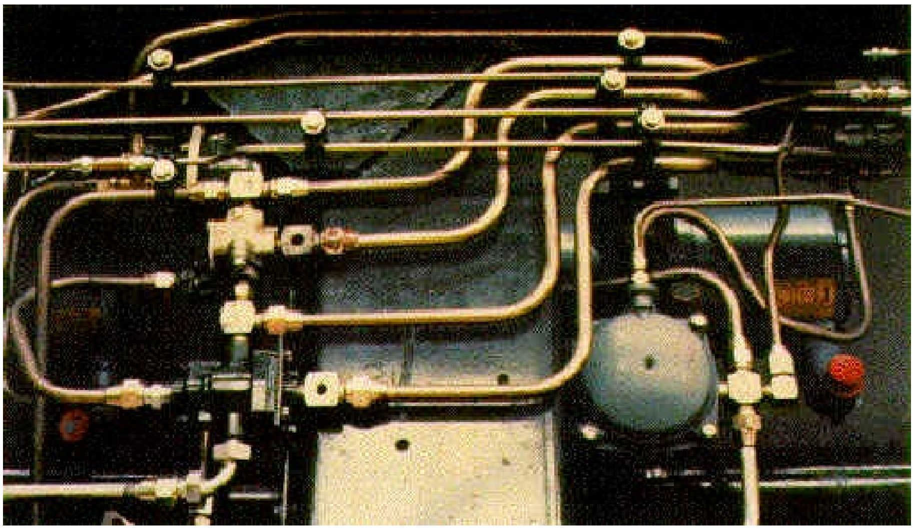
Since 1965 in Sweden, and 1970 in West Germany, annual inspection of all motor vehicles and trailers exceeding a certain age has been compulsory. Since that time comprehensive information has been collected for observed faults found. Their data have shown that over the years the frequency of failures due to brake tubing has diminished, probably because of early replacement and improvements in brake tubing.

Even so, in 1988 over 3 million passenger cars were inspected in Sweden and of these nearly 90,000 (3%) failed because of damaged brake pipes. Most were due to corrosion damage but other types of damage such as chafing and deformation were also found. In the UK, the MOT test is not so comprehensively monitored as Swedish and West German inspections but about 20% of failures currently are due to brake defects. Information is however, not made available to show what proportion of these are due specifically to brake tubing.

Based on Swedish data an interesting comparison can be made for Volvo cars who have over the years used various types of brake tubing culminating in the current use of copper-nickel. Up to 1971 Volvo used terne coated steel tubes but to ensure they met Swedish corrosion requirements they changed to 25µ of zinc as the coating from 1971. Later, the zinc coating was supplemented by epoxy coating and from 1976 models used copper nickel. Graph 2 shows how the four generations of brake tubing coped with corrosive environment for age of vehicle. The copper-nickel shows excellent reliability even after 12 years.

Graph 2 – Inspection results for brake pipes





Under a heavy road transport truck, an installation of 90/10 copper nickel brakeline tubing.

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 distort the tube or damage it by over-tightening in a vice.
3.	The sawn faces should be dressed to remove burrs from the outside edges.	DO NOT allow slivers of metal to enter the tube.
4.	The appropriate single or double flare can be formed using a good quality flaring tool.	DO NOT use worn punches or dies.
5.	Ensure the tube is gripped 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. It should emerge cleanly from the nut without bearing against it.
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 overtighten the nut. From hand tight the degree of tightening should generally be between 1 and 1 ½ turns.
4.	All brake tubes should be supported at regular intervals along their length using either steel clips with a resilient insulating lining or by the plastic snap-on type clips each attached to the body or the chassis of the vehicle. When tube runs follow the axle casings or suspension arms which can induce vibration of the tube, adequate, secure fixing is essential. Clips should be spaced at least at the recommended distance for steel, although a spacing of 12 - 13" is preferred for copper nickel alloy tubing.	

Recommended working pressures

90/10 copper nickel tubing can be used for brake tubing up to the following recommended working pressures:

Imperial Range

O/D	**X**	**Wall Thickness**	**Recommended Maximum Working Pressure**	
in.		**in.**	**lb/in^2**	**bar**
3/16	X	0.028	3120	215
1/4	X	0.028	2250	155
5/16	X	0.028	1740	120
3/8	X	0.028	1450	100
1/2	X	0.028	1090	75
5/8	X	0.048	1450	100

Metric Range

4.75	X	0.7	3050	210
6	X	0.7	2320	160
8	X	0.7	1740	120
10	X	0.7	1305	90
12	X	0.7	1090	75

Copper Development Association
5 Grovelands Business Centre
Boundary Way
Hemel Hempstead
HP2 7TE

Website: www.cda.org.uk
Email: helpline@copperdev.co.uk