Copper Development Association

The Nickel Silvers

Design Data and Applications

1965

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Introduction

Nickel silvers are a group of copper alloys with varying additions of nickel and zinc. They are noted for their good mechanical properties, ease of fabrication, resistance to corrosion and their attractive silvery colour. The development of modern nickel silvers arose from the need in the early 19th century for an alloy closely resembling silver and yet costing only a fraction of its price. Much of the research on nickel silver was undertaken in Germany and France around 1824-25 when the investigators directed their efforts at improving the ancient Chinese copper-nickel-zinc alloy which had been brought to Europe in the 17th and 18th centuries and first analysed by the Swedish chemist Engestrom in 1776. The Chinese called their alloy 'Paktong' or 'Pakfong' - names said to be derived from 'pek' meaning white and 'tung' meaning copper. In some respects, the Chinese names were more appropriate than their modern counterparts since the nickel content is rarely above 30% , and silver, as an element, is completely absent. When the alloys were first produced in Britain a year or two after their introduction on the Continent they were called 'German Silver' - a name which was only discarded during the early part of the present century.

Originally the main outlet for nickel silver was for decorative metalwork such as jewellery, watchcases, flatware, holloware and tableware - articles where the decorative colour was of paramount importance. At that time other uses were limited because, although alloys in this group had many favourable properties, they suffered certain limitations due to difficulties in controlling impurities in the constituent metals. Improved refining techniques - in this case the electrolytic refining of copper and zinc, and the production of pure nickel - have eliminated the former production difficulties and today alloys in this group are regarded strictly as modern engineering materials capable of meeting the exacting demands of many branches of technology. Indeed, the applications of nickel silvers are now notable for their diversity, and result directly from the wide range of properties - in addition to colour - possessed by the alloys of standard composition which comprise this group of copper-base materials.

The Classification of Nickel Silver Alloys

The nickel silver alloys available in wrought forms are included in the British Standard Schedules for Copper and Copper Alloys - BS 2870 and BS 2872-4 inclusive. Each alloy is denoted by the prefix 'NS' and a number ranging from 101 to 113. The hot working alloys, NS 101 and NS102, are always known as nickel brass. BS 790: 1963 'Nickel silver sheet, strip and foil, 10-30% nickel content' and BS 1824: 1963 'Nickel silver strip and foil for the telecommunication industries' (12% and 18% nickel silver) are now both incorporated into BS 2870, and deal specifically with the alloys in rolled form.

As shown in Table 1, wrought nickel silvers can be sub-divided into three groups.

The first group have copper contents ranging from 55-65% with 10-30% nickel and the remainder zinc. These alloys have a single-phase microstructure and are known as the alpha alloys. They have excellent cold-working properties and are used for those applications which require ductility under cold-working conditions. Within this group are alloys NS 111, 112 and 113 which have small additions of lead to improve machinability, but this addition diminishes ductility.

The second group consists of two alpha alloys specified for the telecommunications industry. Both alloys - NS104 and NS107 - are included in BS 1824 dealing with nickel silver strip and foil, and of these NS107 is the more generally used.

The third group of wrought alloys possesses an alpha beta microstructure and in consequence have excellent hot working properties. For certain applications small additions of lead can be made to improve machinability. They can also be extruded and hot pressed into a wide variety of forms and shapes. The alloys in this group that are used for architectural purposes are often referred to as 'silver bronzes'.

Nickel silvers, some of which contain additions of tin (5% maximum) and lead (9% maximum), can also be used for castings. The tin lowers the melting point and moderately improves fluidity whilst the lead, as mentioned above, increases machinability.

Table 1 - Compositions and Available Forms of Nickel Silver Alloys

	B.S. Alloy No.	Nominal Composition per cent						Available Form			
		Cu	Ni	Zn	Pb	Fe (max.)	Mn	B.S. 2870 Sheet	B.S. 2872 Forgings	B.S. 2873 Wire	B.S. 2874 Rod
GROUP 1 α Alloys	NS103	60–65	10±1	rem.	0·04	0·25	0·05–0·30	+		+	
	NS104	60–65	12±1	rem.	0·03	0·25	0·05–0·30	+		+	
	NS105	60–65	15±1	rem.	0·04	0·30	0·05–0·50	+		+	
	NS106	60–65	18±1	rem.	0·04	0·30	0·05–0·50	+		+	
	NS107	54–56	18±1	rem.	0·03	—	0·05–0·35	+		+	
	NS108	60–65	20±1	rem.	0·025	0·30	0·05–0·50	+		+	
	NS109	55–60	25±1	rem.	0·025	0·30	0·05–0·75	+		+	
	NS110	55–60	30±1	rem.	0·025	0·30	0·05–0·75	+		+	
	NS111	58–63	10±1	rem.	1·0–2·0	—	0·1–0·5				+
	NS112	60–63	15±1	rem.	0·5–1·0	—	0·1–0·5				+
	NS113	60–63	18±1	rem.	0·4–0·8	—	0·1–0·5				+
GROUP 2 α Alloys (Telecom-munications)	NS104	60–65	12±1	rem.	0·03	—	0·05–0·30	+			
	NS107	54–56	18±1	rem.	0·03	—	0·05–0·35	+			
GROUP 3 α+β Alloys	NS101	43–47	10±1	rem.	1·0–2·5	0·4	—	+	+		+
	NS102	39–42	14±1	rem.	1·0–2·5	0·3	—				+

	Cu	Ni	Zn	Pb	Sn	Fe (max.)	Mn (max.)	
GROUP 4	55	12	rem.	9	2	1·5	0·5	Casting Alloys
	63	16	rem.	5	—	—	—	
	62	20	rem.	4	4	1·5	1·0	
	65	25	rem.	1·5	5	1·5	1·0	

Designing in Nickel Silver

It is not always appreciated by designers that the nickel silvers possess a range of properties differing significantly from those of the other copper alloys, and lately they have tended to be overlooked by those not familiar with their uses. The nickel silver group covers a number of compositions with distinctive characteristics, and a knowledge of their basic properties is essential for efficient design. This must also take account of the manufacturing methods applicable to these alloys when assessing the wide range of applications for which they are used. The nickel silvers in fact offer a number of definite advantages to designers of engineering assemblies as well as to architects and designers of consumer goods. The aesthetic appeal of this range of alloys is matched by the variety of their other characteristics which are outlined in this section. Discerning designers can fully grasp the opportunities afforded by the nickel silvers.

Before selecting the material for any engineering component the designer must know as accurately as possible the conditions to which the component will be subjected in service, and must consider how these conditions can best be satisfied by the physical and mechanical properties of tried and proven materials. Reference to tabulated data alone is seldom sufficient, because many additional factors, such as the variety of alloys and available forms, the fabrication and joining techniques applicable, must also be studied.

Physical Properties

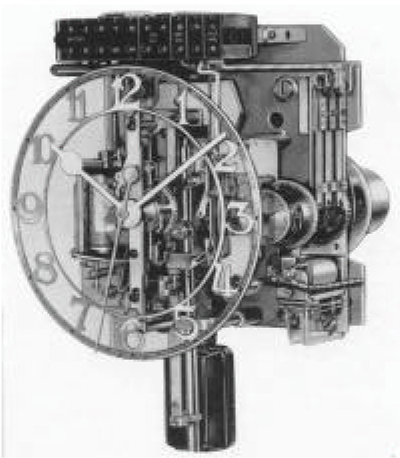
Although in some respects nickel silvers show similarities to brasses, they have definite advantages over the straight copper-zinc alloys, being generally somewhat stiffer and stronger, as well as possessing unique and subtle variations in colour.

Their physical properties vary according to composition as shown in Table 2, with the density, melting point and coefficient of expansion increasing progressively with the nickel content whilst the thermal and electrical conductivities tend to fall as the nickel percentage is increased.

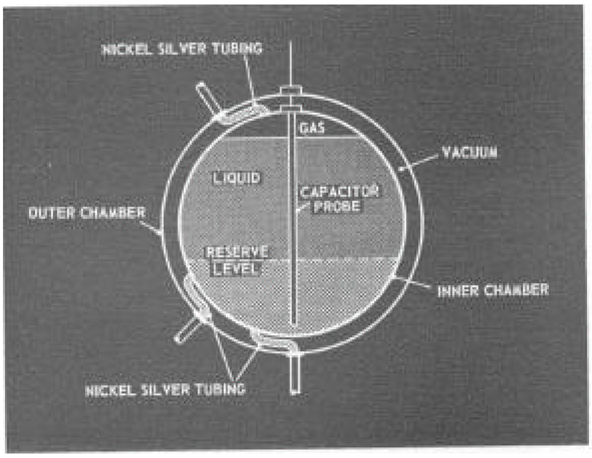
Table 2 – Typical Physical Properties of Wrought Nickel Silver Alloys

B.S. Alloy No.	Melting Point °C	Density lb/in^3	Coefficient of Thermal Expansion (0-300°C) x 10^6	Thermal Conductivity c.g.s units	Electrical Resistivity microhm-cm	Electrical Conductivity per cent I.A.C.S
NS103	1010	0.311	16.4	0.089	20.7	8
NS104	1025	0.313	16.2	0.072	22.3	7.5
NS105	1060	0.314	16.2	0.064	24.8	7
NS106	1100	0.315	16.0	0.054	27.6	6.5
NS108	1120	0.316	16.8	0.052	29.0	6
NS109	1160	0.318	17.0	0.049	33.7	5
NS110	1190	0.320	17.0	0.046	37.9	4.5

As already mentioned, the pleasing colour of these alloys is a major advantage and is substantially related to the nickel content. The lower-nickel alloys in BS 790 and 2870 containing 10-12% nickel are only slightly yellow, whilst alloys containing 15-30% nickel have the characteristic silvery appearance which has led to so many decorative applications. The graph in Figure 1 gives an indication of the variation in colour obtainable but it should be emphasised that the nickel silvers have a mellow depth of colour which is more aesthetically pleasing than is found with most other metals.

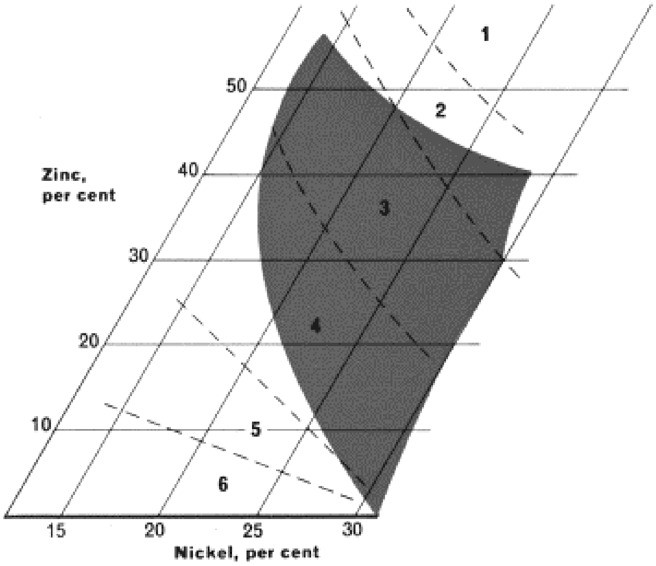


A master clock embodying a number of nickel silver springs. Nickel silver is ideal for mechanisms which have to withstand millions of cycles during a normal working life.



Aircraft liquid oxygen converter – 30 litre capacity. The container comprises two spheres, one within the other, with the space between evacuated to a vacuum. Because of its low thermal conductivity nickel silver tubing is used to connect the two chambers.

Figure 1 – Relationship between Composition and Colour



1 Definite blue cast
2 White with slight bluish cast
3 White with pale green cast
4 Definite to slight green cast
5 Definite to slight yellow cast
6 Definite to slight pink cast

Shaded area shows sensibly 'white' alloys.

Mechanical Properties

The mechanical properties of the alpha alloys show a combination of good tensile strength and excellent ductility in the annealed condition as given in Table 3. High tensile strength and hardness are obtained when the material is cold rolled to extra hard temper - i.e. 60% reduction, but there is a corresponding lowering of ductility.

Of the two alloys specified in BS 1824, the 18% nickel alloy in the work hardened condition has high tensile strength and hardness values. In temper grade 1 (extra hard) 220 HV minimum, this alloy has a typical tensile strength of about 50 ton/in^2. Both these values are the highest for any nickel silver alloy.

For applications where colour is important the alpha beta alloys in the third group have strengths similar to high tensile brass.

Table 3 lists the accepted minimum British Standard properties of wrought nickel silvers and also includes typical properties based on experimental data where minimum values are not available. Table 4 gives typical properties of casting alloys which so far have not been included in a British Standard.

Table 3 – Typical Mechanical Properties of Wrought Nickel Silver Alloys

B.S. Alloy No.	Nickel per cent	Condition	Tensile Strength		0.1 per cent Proof Stress		Elongation on 2in.	Vickers Hardness
			ton/in^2	Kg/mm^2	ton/in^2	kg/mm^2	per cent	HV
NS103	10	Annealed	26	41	9.6	15.1	43	85
		Extra hard cold rolled	43	68	35.6	56.1	3	201
NS104	12	Annealed	26	41	9.1	14.3	44	83
		Extra hard cold rolled	46	72	38.2	60.2	2	216
NS105	15	Annealed	26	41	9.8	15.4	42	86
		Extra hard cold rolled	46	72	39	61.4	2	215
NS106	18	Annealed	28	44	12.9	20.3	39.0	93
		Extra hard cold rolled	46	72	38	59.8	2.2	216
NS108	20	Annealed	27	43	10.8	17.0	38.0	90
		Extra hard cold rolled	44	69	36.8	57.9	2.8	210
NS109	25	Annealed	29	46	12.2	19.2	35.0	101
		Extra hard cold rolled	45	71	39.4	62.1	2.4	216
NS104	12	Temper Grade No. 5	26	41	9.8	15.4	41	88
		Temper Grade No. 2	45	71	38.6	60.8	1.8	212
NS107	18	Temper Grade No. 5	28	44	10.3	16.2	44	94
		Temper Grade No. 1	50	79	43.8	68.9	2.5	236

Table 4 - Typical Mechanical Properties of Casting Alloys (Sand Cast)

Composition %				**Tensile Strength**		**Elongation on 2 in.**
Cu	**Ni**	**Zn**	**Other**	**ton/in**2	**kg/mm**2	**per cent**
57	12	20	11	13-17	20-27	10-25
60	16	16	8	15-19	24-30	15-30
64	20	8	8	18-27	28-43	15-25
66	25	2	7	22-29	35-46	15-25

Properties at Elevated and Sub-Zero Temperatures

Many nickel silvers retain good mechanical properties at moderately elevated temperatures - a fact illustrated by the performance of a 10% nickel silver wire shown in Figure 2. At sub-zero temperatures nickel silvers exhibit the same characteristics as other copper base alloys with increased strength and ductility. They are in fact suitable for operations down to about minus 200°C and can be classified as an accepted material for many cryogenic applications.

Table 5 and Table 6 give data for several nickel silver alloys at elevated and sub-zero temperatures. The information relates to work carried out on several non-standard alloys but a similar performance can be expected from the equivalent British Standard nickel silvers.

Figure 2 – Elevated temperature properties of 10% nickel silver wire

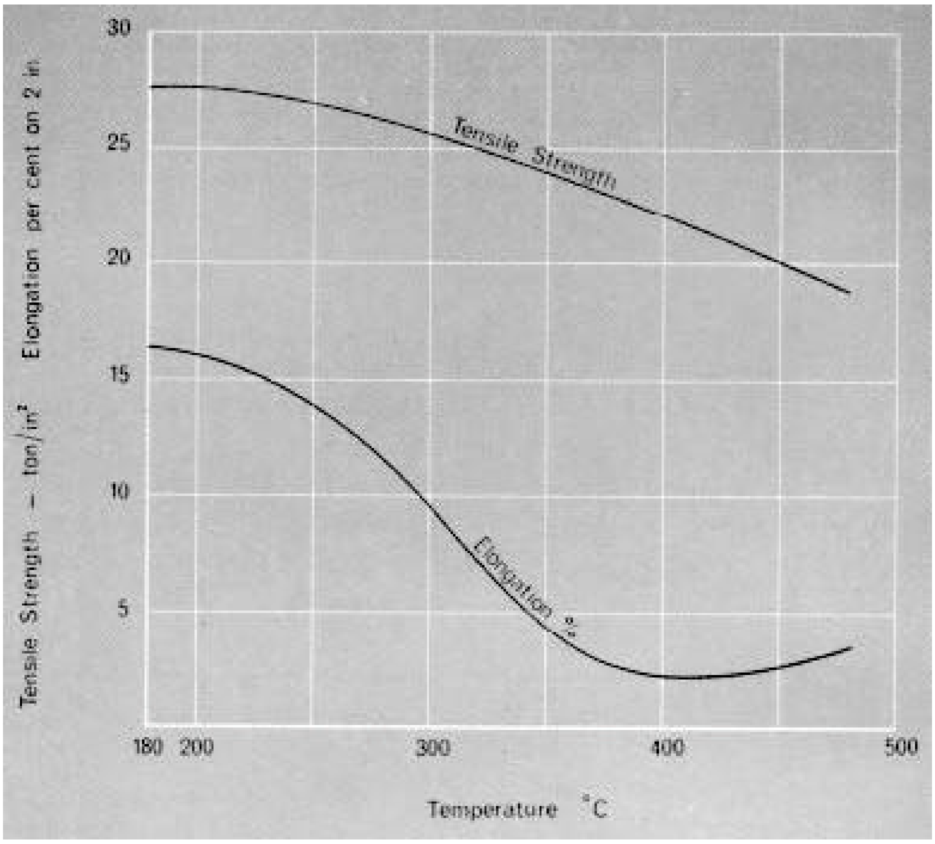


*Table 5 – Mechanical Properties of some Nickel Silver Alloys at Elevated Temperatures**

Composition %					**Temperature**	**Tensile Strength**		**Elongation on 2 in.**
Cu	**Ni**	**Zn**	**Other**	**Condition**	**°C**	**ton/in^2**	**kg/mm^2**	**per cent**
74	20	5	1	Cold drawn and annealed at 650°C	27	23	36.2	51.0
					320	20	31.5	28.5
					400	18	28.3	37.0
66	10	24	-	Wrought	27	28	44.1	14.0
					180	28	44.1	16.5
					290	26	40.9	10.5
					340	21	33.1	1.0
					400	21	33.1	2.0
					480	19	29.9	3.5
46	13	39	2	Cast	27	32	50.4	26.5
					260	25	39.4	8.6
					290	27	42.5	4.5
					320	21	33.1	0.4

* These are not British Standard alloys - the data are derived from ASTM - ASME 'Compilation on Creep' and ASTM STP181.

Table 6 – Mechanical Properties of 30% Nickel Silver at Sub-zero Temperatures *

Temperature	**0.1% proof stress**		**Tensile Strength**		**Elongation on 2in.**	**Izod**	
°C	**ton/in^2**	**kg/mm^2**	**ton/in^2**	**kg/mm^2**	**per cent**	**ft lb**	**kg m**
20	12.5	19.7	33.6	52.9	33	80	11.1
-10	12.4	19.5	34.5	54.3	32	-	-
-40	12.8	20.2	34.9	55.0	34	87	12.0
-80	12.3	1934	37.1	58.4	39	83	11.4
-120	12.9	20.3	40.1	63.2	38	80	11.1
-190	12.7	20.0	46.5	73.2	41	87	12.0

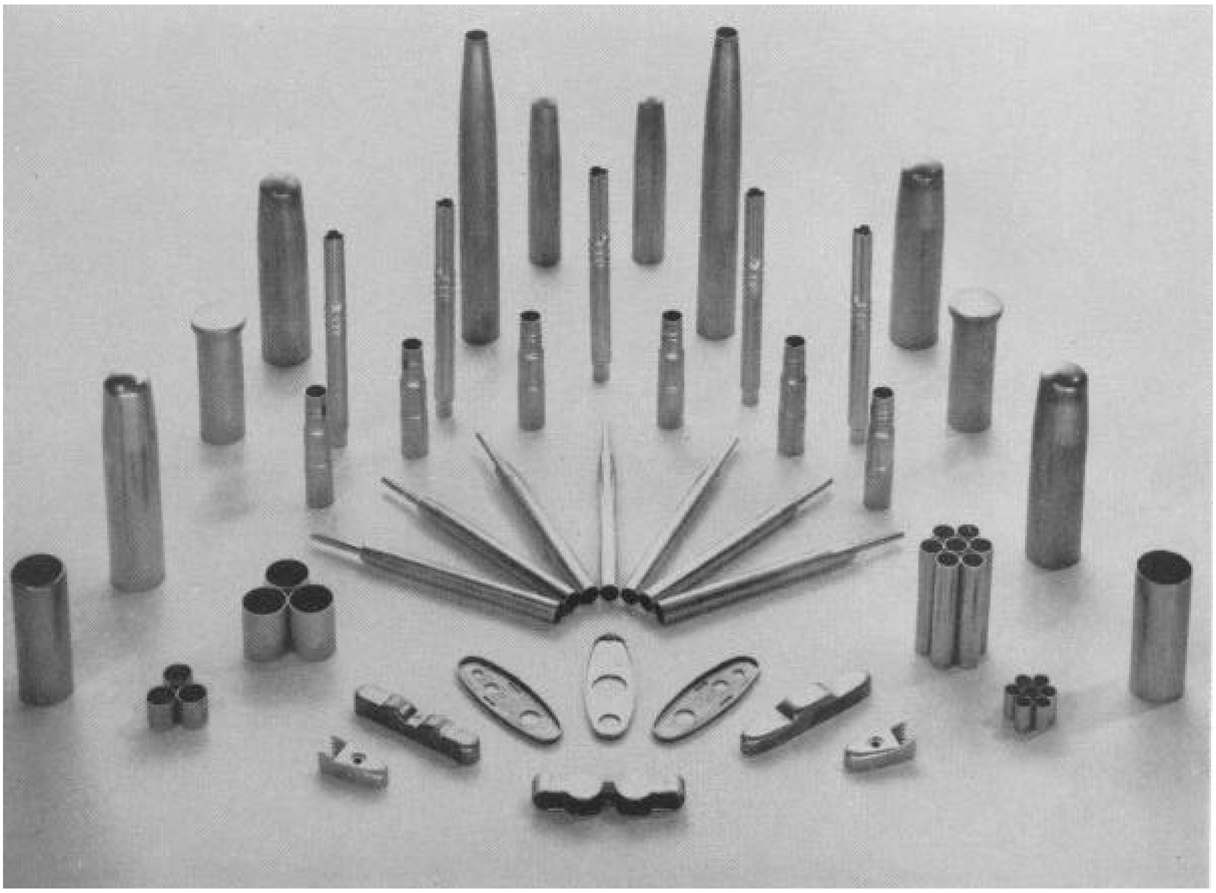
* Data from American sources; this alloy is equivalent to NS110.

Corrosion Resistance

Nickel silvers have a very good resistance to industrial, rural and marine atmospheres and the alloys have been successfully used in these environments for many years. For exterior architectural metalwork periodic maintenance has always been necessary to retain the lustre of nickel silver but a new lacquer coating, 'Incralac', is now available which reduces the need for after-treatment to an absolute minimum.

The resistance of nickel silver to corrosion in fresh and salt water is also very good. This is a common feature of all copper-base alloys and nickel silvers are generally superior to high tensile brass in this respect. The tremendous expansion in the growth of the chemical engineering industries now means that an increasing variety of substances have to be handled, sometimes under very unfavourable conditions. Information on the behaviour of nickel silvers in specific environments is generally available through the alloy producers and fabricators, and through bodies such as the Copper Development Association.

In common with certain other copper-base alloys and indeed with many other metals, nickel silvers that have been extensively cold worked can be susceptible to the well-known form of failure - season cracking. This can occur spontaneously when very small concentrations of certain corrosive agents are in contact with a metal possessing internal stresses. As with other copper-base alloys, ammonia in quite small traces may be responsible for failures of stressed components, but in practice removal of the internal stresses by low temperature annealing eliminates the risk of failure without adversely affecting the mechanical properties of the alloy. Oxidizing acids also attack nickel silvers but organic acids and many neutral salts have no adverse effect on the metal. The resistance to organic acids is particularly important since the absence of corrosion residues means that nickel silvers have long been regarded as 'hygienic materials' and has led to a number of applications in food processing industries.



The excellent formability of nickel silver is demonstrated in this collection of pressed components. The assembly includes ball point pen ink reservoir cartridges, lipstick containers, propelling pencil and fountain pen parts, pressure stove burner jets and eraser holders. These are more traditional uses of nickel silver but the electronics industry is also represented with a number of transistor cans for which nickel silver is particularly suitable.

Fabricating Techniques

Table 1 shows that by varying the percentage of the constituent elements a standard range of nickel silvers has been produced. Each alloy exhibits special characteristics but within the group alloys can be found which are amenable to all the common fabricating techniques.

The wrought nickel silvers can be sub-divided into two classes - cold and hot working materials.

Cold working

The single phase alpha alloys possess good ductility and can be cold worked without difficulty.

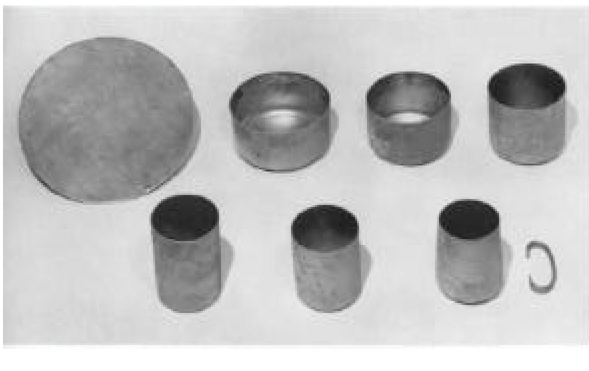
Alloys NS103, NS104, NS105 and NS106 containing 60-65% copper are all generally suitable for severe forming operations. The deep drawing characteristics of nickel silvers are similar to those of the brasses and the tools for the operation are interchangeable. Alloy NS 107 developed for spring applications such as in telecommunications equipment, contains 55% copper and is less ductile, and therefore not recommended for severe forming operations. Minimum bending radii for this alloy in sheet and strip form are given in Table 7.

As with other cold worked materials, nickel silver possesses directional properties which mean that in practice it can be bent more easily across the rolling direction than parallel to it without the risk of cracking. The lead containing alloys are less ductile and should be bent only when bends of very generous radii can be accommodated.

Nickel silvers are capable of being deep drawn - generally with characteristics similar to those of the deep drawing brasses, and with similar tooling procedures. The deep drawn examples illustrated in the brochure are typical of the kind of cold working operation applied to the nickel silvers. The non-leaded alloys with copper contents of 65% are particularly suitable for deep drawing, but the correct grain size must be specified when purchasing metal for these operations. The other standard cold working processes - spinning, upsetting, stamping and embossing - can be readily applied to nickel silver as also can the various expanding and contracting operations such as necking.

Hot working

The two nickel brasses NS 101 and NS 102 have been specially developed for their hot working properties. Both these alloys contain controlled additions of lead and are available as bars and section, whilst alloy NS 101, which has the lower nickel content, can also be obtained as forging stock. This alloy is used for hot pressings and can be worked almost as easily as 60/40 brass. The hot stamping of components in certain nickel silver alloys is undertaken on a small scale, principally in North America.



Stages in the manufacture of a nickel silver tankard. The blank is subjected to a series of cupping operations with interstage annealing at about 700°C.

*Table 7 – Minimum Bending Radii of 18% Nickel Silver * (NS107)*

Condition	**Tensile Strength**		**Nominal Thickness**	**Vickers Hardness**	**Minimum Bending Radii in.**		
	ton/in^2	**kg/mm^2**	**in.**	**HV**	**Across Grain**	**45° to Grain**	**With Grain**
½H	35.0-41.0	55.0-64.5	0.01	170-210	S†	S†	S†
			0.045		1/16	1/16	1/16
			0.06		1/16	1/16	1/16
			0.10		1/8	1/8	-
H	41.0-51.0	64.5-80.0	0.010	-	S†	S†	S†
			0.045		1/16	1/16	3/32
			0.06	220	3/32	3/32	>1/8
			0.10		>1/8	>1/8	>1/8
EH	45.0-51.0	71.0-80.0	0.010	220-250	1/64	1/64	1/64
			0.045		1/8	5/32	3/16
			0.06		5/32	3/16	3/8
			0.10		3/8	3/8	3/8

* Other lead-free wrought nickel silver alloys conform closely to these figures.
† Can be bent sharp.

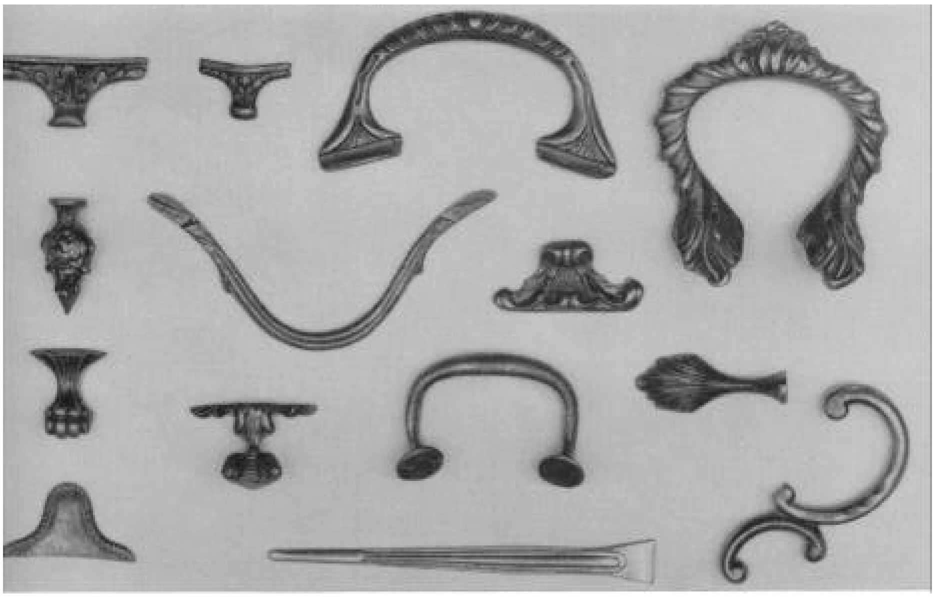
*Table 8 – Minimum Bending Radii of 18% Nickel Silver * (NS107)*

BS Alloy No	**Group**	**Cold Working**	**Hot Working**	**Hot Working Temp Range °C**	**Annealing * Temp Range °C**	**Machinability Rating †**
NS103-NS110	1	Excellent	Poor	-	600-750	25
NS107	2	Good	Poor	-	600-750	25
NS101 NS102	3	Poor	Excellent	700-850	-	80
Casting Alloys	4	-	-	-	-	60-70

* See 'Heat Treatment' in relation to mass and time cycles
† Free cutting brass = 100

Casting Properties

Most nickel silver castings are produced by the sand cast process which offers the greatest flexibility in shape and size, but the casting alloys listed in Table 1 can also be used for gravity diecasting and centrifugal and investment casting. Diecastings in nickel silver have an excellent surface finish and require only a minimum of polishing and buffing. When designing castings the high shrinkage rate of nickel silver must be taken into account by providing generous fillets and avoiding abrupt changes in the cross-section thickness of the casting. Attention should also be given to the correct positioning of gates and risers, and de-oxidation of the melt should be carried out, prior to pouring, by adding recognized de-oxidants such as manganese and phosphorus-copper.



A selection of small nickel silver sand castings for decorative holloware manufacture. Fine-grained oil-bonded sand is used for the moulds to give an exceptionally fine finish which requires only a minimum of after treatment. A 10% nickel alloy is used containing 2% lead and up to 1% tin

Machinability

Millions of keys are produced annually from lead-bearing nickel silver alloys which are easily machinable and can withstand continuous wear coupled with high torsional stress

The deliberate addition of lead to certain wrought nickel silver alloys (Table 1) has resulted in materials that are specified for applications such as key blanks and screws for which their ready machinability makes them particularly suitable. With high speed steel tools the lead-containing nickel silvers NS111-113 and NS101-102 can be turned at speeds comparable with other free-cutting copper-base alloys, such as free-machining brass, tellurium copper and the leaded bronzes. The non-leaded nickel silvers are more difficult to machine, as will be seen from Table 9, and therefore it is recommended that the highest practical cutting speed be used with a relatively light feed and a moderate depth of cut.

The casting alloys containing lead are not difficult to machine, although tool life is extended if speeds are reduced when machining the outer surface of sand castings.

Table 9 – Recommendations for Machining *****

Operation	Surface Speed ft/min		Feed in/rev		Tool Angle degrees			
	A	B	A	B	A		B	
Turning	75-150	300-700	Roughing 0.015-0.040 Finishing 0.005-0.020	Roughing 0.006-0.020 Finishing 0.003-0.015	Side rake Back rake Side clearance Front clearance Lead angle	20-30 10-20 10-20 10-15 15	Side rake Back rake Side clearance Front clearance Lead angle	0.3 0 0-5 6 10-15
Parting	75-150	300-700	0.005	0.0015	End cutting edge Back rake Side clearance Front clearance	25 7-15 2-4 5-10	End cutting edge Back rake Side clearance Front clearance	15 0 2-4 5-10
Milling	50-150	200-300			Rake Clearance	0-15 5-10	Rake Clearance	0-10 10-15
Drilling	50-125	200-500	0.003-0.020	0.003-0.020	Clearance Drill point Cutting edge Full rake (do not flatten)	12-20 100-110	Clearance Drill point Cutting edge (flatten approx. 6-8% of dia.)	12-15 118 0 rake

* Using high-speed steel tools A = Non-leaded alloys B = Leaded alloys

Heat Treatment

According to the grade of nickel silver to be annealed, a temperature range of between 600°-750°C is suitable, but it should always be remembered that the time cycles, temperature and mass are related, and the best results are obtained by annealing nickel silvers at the lower part of the range for a longer time than using the maximum temperature for a shorter period. Operations of this nature should preferably be carried out in controlled atmosphere furnaces or in closed containers. Precautions should be taken to keep the sulphur content in the furnace atmosphere as low as possible. The time factor is important since re-crystallization begins when the metal is raised to annealing temperature, and when re-crystallization is completed it is followed by growth in grain size if the heating time is prolonged. Grain size is of fundamental importance in controlling the properties of the material; as grain size increases, strength and hardness decrease and ductility conversely increases. Excessive grain growth is undesirable as it not only adversely affects the tensile properties, but may cause surface roughening and fracturing when the metal is subsequently cold worked. The amount of cold work performed on the metal before annealing also has a bearing on grain growth, as severe cold work lowers the temperature at which re-crystallization begins. Much depends on user's equipment but manufacturers of the alloy will always be pleased to advise when necessary.

Sintered Powder Components

Advantage can be taken of the high production rates of the compacted and sintered powder process to manufacture small parts in nickel silver. Alloy NS106 containing 18% nickel is most widely used for powder metallurgy but other alloys in powder form are also suitable. The recommended sintering temperature for the 18% nickel powder is about 980°C. Components made by compacting and sintering nickel silver powders have a durable and lustrous finish which requires very little after-treatment: scratch brushing followed by burnishing in a tumbling barrel is sufficient to attain a permanent light satin finish.

*Table 10 - Properties of Nickel Silver Powder Products**

Composition %				**Sintering Temperature °C**	**Tensile Strength**		**Elongation on 2 in.**	**Vickers Hardness**
Cu	**Ni**	**Zn**	**Pb**	**°C**	**ton/in²**	**kg/mm²**	**per cent**	**HV**
64	18	18	-	980	14.3	22.5	15	50
64	18	16.5	1.5	880	12.5	19.7	10	48

* Compacted to a density of 7.5-7.8.

Joining Techniques

All nickel silver alloys can be easily joined by one or more of the standard joining processes:

Soldering

In common with other copper alloys, nickel silvers can be soldered without difficulty and, because of the low temperature involved, the tensile strength and hardness of cold worked material are hardly affected. The 50/50 tin/lead solder to BS 219, which has a melting range between 183°-212°C, is used for most soldering operations with nickel silver but experience has shown that the higher tin content solder (60/40) is more satisfactory for joining thin sheet. Zinc chloride fluxes or 'killed spirits' can be used provided the normal precautions are taken to wash off the flux residues after the operation is completed. A number of resin-based fluxes, including many proprietary compositions, are also available and these have the advantage of being non-corrosive. When work hardened components such as pressings are to be soldered, it is advisable to heat treat to relieve stresses beforehand as a precautionary measure to avoid a rapid form of stress corrosion cracking due to intergranular solder penetration. Likewise a stress should never be induced in a component when molten solder is being applied as similar adverse results may occur.

Brazing

With the exception of the lead-containing alloys all nickel silvers can be brazed or silver soldered without difficulty. Brazing is not recommended for the leaded alloys although they can be joined by these processes provided the operation is carried out quickly. Either copper-zinc brazing alloys or silver solders to BS 1845 can be used. The former have melting ranges around 860°-890°C and should not be used with thin gauge material. The melting ranges of silver solders vary between 620°-830°C. The silver-bearing filler metals have excellent fluidity and in general are the most suitable for rapid production work. Another point in their favour is that with the lower brazing temperature some degree of work-hardening can be retained although this is dependent on the speed of the operation. They also give a good colour match with the base metal. Fluxes are again essential: borax is used with the copper-zinc brazing metals whilst a number of proprietary fluxes are available for use with silver solders.

Table 11 – Suitability of Joining Methods

Alloys	Soft Soldering	Hard Soldering Brazing	Oxy-acetylene Welding	Argon-arc Welding	Electrical Resistance Welding
Group 1	Excellent	Excellent	Fair	Fairly good	Good
Group 2	Excellent	Excellent	Fair	Fairly good	Good
Group 3	Excellent	Excellent	Fair	Fairly good	Good
Group 4	Excellent	Fair	Fair	Fair	Not normally applicable

Note. The leaded single phase wrought nickel silver alloys (NS111, NS112 and NS113) and the leaded cast alloys are highly susceptible to hot cracking during welding. This effect appears less marked in the duplex alloys.

Electroplated nickel silver tankards. Component parts such as handles and bases can be easily brazed in position.

Welding

A number of different welding processes can be used to join nickel silver, notably resistance, tungsten-arc and oxy-acetylene welding. Because of their relatively high electrical resistivity due to the nickel content, nickel silvers can be easily joined by resistance welding provided the mating surfaces are clean and free from oxide films. Unlike tungsten-arc and oxy-acetylene welding, this technique is very suitable for rapid large-batch production of small components. The use of the other techniques has been limited in the past but interest in them has revived recently following the increases in the architectural applications of nickel silver rolled metal and extruded sections. Results of recent welding trials using sheets of varying nickel content and different thicknesses show that welds with strengths closely akin to the parent metal can be obtained with both processes. Recommendations for oxy-acetylene welding are similar to those for brass and a slightly oxidizing flame has been shown to give the best results.

*Table 12 - Recommendations for Tungsten-arc Welding Nickel Silver Sheet **

BS Alloy No.	Sheet Thickness		Type of Joint	Welding Current
	in.	**mm**		**amp. D.C.**
NS103 }	0.064	1.6	A	50-60
NS104 }				
NS105 }	0.160	4	B	120-root run
NS106 }				140-2nd run

A = Square butt, no gap B = Single vee, 90° angle, 3/32 in. root gap.

* These recommendations, which are based on laboratory tests undertaken by the International Nickel Co Ltd, are quoted as a general guide. The joints were made in a thick mild steel jig preheated to 280°C.

*Table 13 - Recommendations for Oxy-acetylene Welding Nickel Silver Sheet **

BS Alloy No	Sheet Thickness		Type of Joint	Flux	Burner Size †
	in.	**mm**			
NS103 }	0.064	1.6	A	Anti-porosity ‡	No. 3
NS104 }				Monel ex. A	
NS105 }				Monel ex. B	
NS106 }	0.160	4	B	Anti-porosity	No. 10

A = Square butt, 3/32 in. gap. B = Single vee, 75° angle, 1/16 in. root gap.

* These recommendations, which are based on laboratory tests undertaken by the International Nickel Co Ltd, are quoted as a general guide.

† Slightly oxidizing flame.

‡ All proprietary fluxes were used.

Surface Finishing

Pickling

Where oxide scale is formed on nickel silver during annealing it can be removed by immersing the parts in a pickling bath containing a solution of 10% (vol.) sulphuric acid and maintained at about 50°C. This results in a rather dull matt finish which can be brightened by further dipping in a cold dichromate brightening solution with the customary intermediate rinsing and drying.

Cleaning and Polishing

All the usual metal finishing techniques such as barrel tumbling, caustic soda degreasing, aqua-blasting etc. can be used with nickel silver components, whilst the natural lustre of the alloys can be further enhanced by polishing and buffing with felt mops dressed with a polishing compound such as tripoli. Nickel silver components can also be electro-polished in proprietary electro-brightening solutions. The solution is operated at a temperature of 28°-43°C and the immersion time ranges from 6 to 10 minutes depending on the finish required.

Plating

The ease with which nickel silver can be silver plated with standard electro-plating techniques has led to widespread usage for holloware and flatware. A number of proprietary plating solutions are available for use in the silver plating of nickel silver. The basis of all these solutions is usually the double cyanide of silver and potassium with a slight excess of free potassium cyanide and various other addition agents. Operating conditions vary according to the solution used: in a typical example the solution is used at room temperature but not below 15°C, and the current density is 2-3 amp/ft^2. The anodes are silver of 99.99% purity and the silver is deposited at the rate of 0.001 in. in just over two hours. For the best quality hotel plate and flatware a deposit of 0.002 in. is normally given and sometimes special plating techniques are adopted to build up an extra thickness on the backs of spoons and forks where wear is most likely to occur.

Whilst silver plating predominates for these applications, chromium and bright nickel plating if desired, can also be used with attractive results.

Protective Lacquer Coatings

Although a degree of tarnishing of nickel silver surfaces can occur in industrial atmospheres, this can now be avoided by applying a new thermoplastic resin lacquer which has recently been produced and is now commercially available. This new lacquer coating, known as 'Incralac,' has been developed by the International Copper Research Association and although intended for use on all copper-base alloys it has special significance for the nickel silver architectural applications where immaculate appearance without costly maintenance is a prime consideration. Site tests in London and elsewhere have yielded most encouraging results and it is expected that 'Incralac' coatings, which contain special additives and are easy to apply, will have a useful service life far in excess of any previous protective lacquering system.

Colouring

It is not always appreciated that the nickel silvers can be coloured with films that are quite permanent, for example those produced by arsenide solutions. These are particularly appropriate on castings and on heavily embossed work, the highlights being brought up again to the original colour by polishing. There is an interesting revival in this means of enhancing the aesthetic appeal of nickel silvers.

Nickel Silver Applications

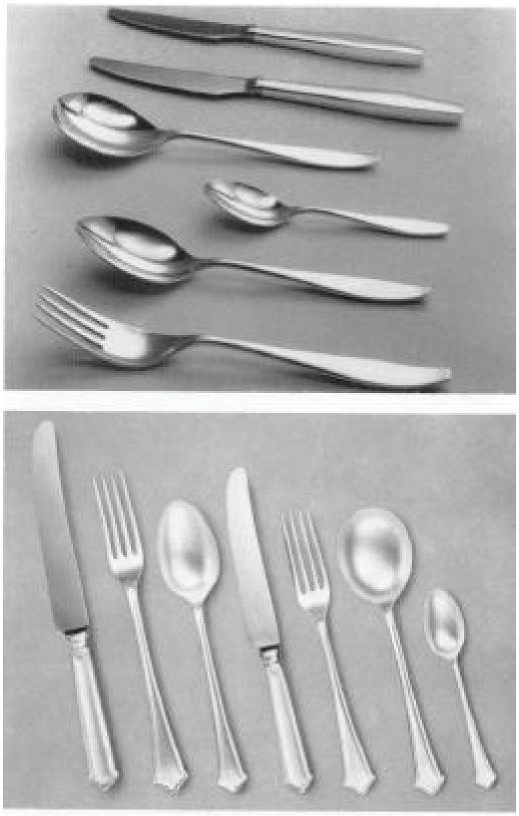
The range of physical and mechanical properties and the aesthetic characteristics of the nickel silvers indicate that they can be used in a wide range of applications. In particular, they are established for many small but essential components in telecommunications equipment, for tableware and for major decorative features in building, particularly when prestige is important, and for a less familiar range of uses in general and mechanical engineering, chemical engineering and in food manufacturing equipment.

Telecommunications

Maximum reliability is an essential prerequisite for telephone and automatic exchange equipment; and design, production and materials must be of the highest order. For over forty years nickel silver alloys have been used for contact springs, wiper blades and other items of telephone exchange equipment - their use for this application has in fact become virtually standard practice all over the world. Two alloys, NS 104 and NS 107 in this connection, are included in BS 1824, 'Nickel silver strip and foil for the telecommunication industries.' These contain 12% and 18% nickel respectively and possess the inherent corrosion resistance and cold working properties of the alpha nickel silver alloys. Of these alloys, NS107 is more widely used and has been specially developed with closely controlled constituent elements, namely 17-19% nickel, 54-56% copper, to meet the exacting requirements specified throughout the world which have to take into account the varying climatic conditions. This alloy in the grade 1 (extra hard) temper has a typical tensile strength of 50 ton/in^2, and when used for its spring properties in relay springs etc. for telecommunications purposes it is regularly subjected to life tests involving one million or more make and break movements.

Further development in the telecommunications field incorporating transistorized components has created an additional demand for nickel silver which offers many advantages as a canning material because of its good cold working properties. The alloy generally specified is NS106.

Flatware and Holloware



Traditional or modern! Nickel silver is equally suitable for simple contemporary flatware designs as it is for the elegant and perennially popular traditional styles.

The familiarity of the letters EPNS, which stand for Electroplated Nickel Silver, testifies to the widespread use of nickel silvers for flatware, holloware and tableware. This application dates back many years and can be considered a logical development of Sheffield Plate which involved the plating of copper with silver before the invention of electro-deposition. The popularity of electroplated nickel silver can be attributed to the colour of the alloys. The outstanding feature is their close resemblance to silver and if, after long use, the silver wears off, the effect is barely noticeable. Nickel silvers offer the added advantage that the parent metal is unaffected by organic acids present in certain food stuffs and therefore the life of EPNS flatware is virtually indefinite. The excellent cold working properties of the alpha alloys afford considerable scope for designers of flatware, holloware, tableware and other items such as ash trays and presentation cups which are made by stamping, pressing, spinning and other standard processes. Flexibility is the keynote in this respect and nickel silver can be used for traditional designs which usually require a considerable degree of forming as well as the more austere, yet equally elegant contemporary styles which may be less demanding.

Architectural Applications

Colour is an important consideration in the selection of architectural metalwork and a unique feature of nickel silver is the subtle variation in tone which is obtained by altering the nickel content of alloys in the group. This factor, coupled with a good corrosion resistance and ready availability in sheet, strip and a variety of sections, has led to widespread usage for doors, balustrading, handrails, door furniture and light fittings in banks, shops and offices in the United Kingdom and overseas. The architectural applications of nickel silver shown in these pages are from buildings which represent many of the best features of modern architecture. In every case the metalwork contributes to the overall conception of permanence and dignity and also harmonizes with other aspects of the general decorative schemes. This can be applied generally to well-designed architectural metalwork but only the nickel silvers, or silver bronzes as they are referred to in this context, offer a combination of colour variation without recourse to plating or other forms of surface treatment.

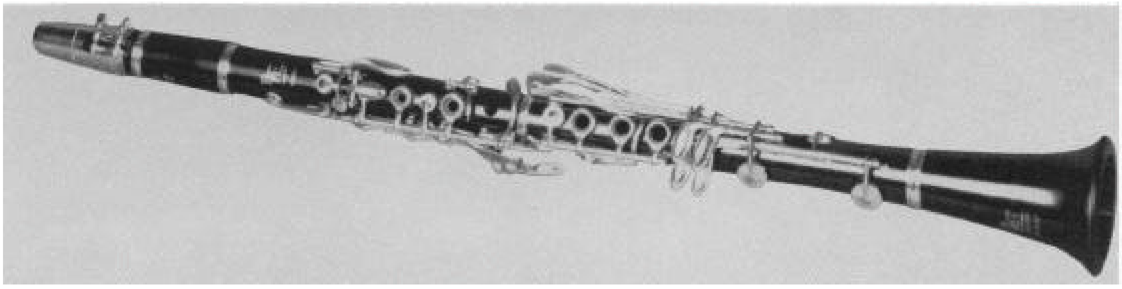
Already a well-known London landmark, the Shell Centre at South Bank, like many other prestige buildings, has nickel silver entrance doors

Keys, Locks and Small Machined Components

The fact that the leaded-nickel silver alloys NS 111, NS112 and NS113 can be machined with ease has led to their use for a variety of components where machinability and colour are principal requirements, together with strength and hard wearing properties. These include latch type keys, lock parts, screws, gears and pinions for clocks and instruments, optical components, parts for cameras and binoculars.

Other Applications

One of the largest applications for nickel silver wire is the manufacture of metallic slide fasteners where its colour, strength and hard wearing properties make it particularly suitable for high quality fasteners.



Keys for many woodwind instruments such as clarinets and saxophones are made in nickel silver

In addition, many other familiar articles are made from nickel silver such as spectacle sidewires and hinges, watchcases, costume jewellery, cigarette lighters, medallions and tokens as well as musical instruments. A common requirement in the manufacture of these articles is that of easy fabrication at moderate cost, without sacrificing appearance and durability. Whilst some of these requirements may be exacting, they can be admirably met by the nickel silver alloys.

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Appendix 1

Typical applications of nickel silver

Group 1 **NS103-NS110**	Holloware, tableware and flatware (spoons and forks), knife handles, costume jewellery, metallic slide-fasteners, optical fittings, instrument parts, cigarette cases, ashtrays, trophies, surgical instruments, culinary equipment, rivets, screws, springs, nameplates, watchcases, buttons, medals, light fittings, finger plates and door kicking plates
Leaded alloys **NS111-NS113**	Key blanks, gears, pinions, watch parts, camera and binocular parts, screws, musical instrument components
Group 2 **NS104 and NS107**	Springs and contacts in telephone equipment
Group 3 **NS101 and NS102**	Architectural sections for entrance doors, balustrading, handrails, grilles, door furniture, forgings
Group 4 **Casting alloys**	Casting alloys decorative architectural metalwork, food processing equipment, dairy equipment, musical instrument keys

Appendix 2

Weights of Some Nickel Silver Semi-Fabricated Products

Table 14 – Weight of Nickel Silver Rod

Rod diameter in.		*mm*	Weight lb/ft
$\frac{1}{64}$	0·0156	*0·397*	0·0007
$\frac{1}{32}$	0·0312	*0·794*	0·0028
$\frac{1}{16}$	0·0625	*1·588*	0·0113
$\frac{3}{32}$	0·0937	*2·381*	0·0253
$\frac{1}{8}$	0·125	*3·175*	0·045
$\frac{5}{32}$	0·1562	*3·969*	0·0702
$\frac{3}{16}$	0·1875	*4·762*	0·1013
$\frac{7}{32}$	0·2187	*5·556*	0·138
$\frac{1}{4}$	0·250	*6·350*	0·180
$\frac{9}{32}$	0·2812	*7·144*	0·228
$\frac{5}{16}$	0·3125	*7·938*	0·2815
$\frac{11}{32}$	0·3437	*8·731*	0·3406
$\frac{3}{8}$	0·375	*9·525*	0·4054
$\frac{13}{32}$	0·4062	*10·319*	0·4757
$\frac{7}{16}$	0·4375	*11·112*	0·5517
$\frac{15}{32}$	0·4687	*11·906*	0·6333
$\frac{1}{2}$	0·500	*12·700*	0·721
$\frac{17}{32}$	0·5312	*13·494*	0·8135
$\frac{9}{16}$	0·5625	*14·288*	0·912
$\frac{5}{8}$	0·625	*15·875*	1·126
$\frac{11}{16}$	0·6875	*17·462*	1·363
$\frac{3}{4}$	0·750	*19·050*	1·62
$\frac{25}{32}$	0·7812	*19·844*	1·76
$\frac{13}{16}$	0·8125	*20·638*	1·9
$\frac{7}{8}$	0·875	*22·225*	2·207
$\frac{15}{16}$	0·9375	*23·812*	2·534
1	1·000	*24·606*	2·882

Table 15 – Weight of Nickel Silver Sheet and Wire

S.W.G. No.	Thickness in.	mm	Sheet lb/ft²	Wire lb/100 ft	S.W.G. No.	Thickness in.	mm	Sheet lb/ft²	Wire lb/100 ft
7/0	0·500	*12·700*	21·850	74·1	18	0·048	*1·219*	2·098	0·682
6/0	0·464	*11·786*	20·280	63·8	19	0·040	*1·016*	1·750	0·473
5/0	0·432	*10·973*	18·880	55·3	20	0·036	*0·914*	1·574	0·384
4/0	0·400	*10·160*	17·480	47·4	21	0·032	*0·813*	1·400	0·303
3/0	0·372	*9·449*	16·258	41·0	22	0·028	*0·711*	1·225	0·232
2/0	0·348	*8·839*	15·208	35·9	23	0·024	*0·610*	1·049	0·171
0	0·324	*8·230*	14·159	31·1	24	0·022	*0·559*	0·962	0·143
1	0·300	*7·620*	13·110	26·7	25	0·020	*0·508*	0·874	0·118
2	0·276	*7·010*	12·062	22·6	26	0·018	*0·457*	0·787	0·096
3	0·252	*6·401*	11·013	18·8	27	0·0164	*0·416*	0·717	0·079
4	0·232	*5·893*	10·142	15·9	28	0·0148	*0·376*	0·647	0·065
5	0·212	*5·385*	9·267	13·3	29	0·0136	*0·345*	0·595	0·055
6	0·192	*4·877*	8·392	10·9	30	0·0124	*0·315*	0·542	0·046
7	0·176	*4·470*	7·692	9·17	31	0·0116	*0·294*	0·507	0·040
8	0·160	*4·064*	6·995	7·58	32	0·0108	*0·274*	0·472	0·035
9	0·144	*3·658*	6·294	6·14	33	0·0100	*0·254*	0·437	0·030
10	0·128	*3·251*	5·598	4·85	34	0·0092	*0·233*	0·402	—
11	0·116	*2·946*	5·070	3·99	35	0·0084	*0·213*	0·368	—
12	0·104	*2·642*	4·546	3·20	36	0·0076	*0·193*	0·333	—
13	0·092	*2·337*	4·020	2·51	37	0·0068	*0·172*	0·298	—
14	0·080	*2·032*	3·497	1·90	38	0·0060	*0·152*	0·262	—
15	0·072	*1·829*	3·148	1·53	39	0·0052	*0·132*	0·227	—
16	0·064	*1·626*	2·798	1·21	40	0·0048	*0·122*	0·210	—
17	0·056	*1·422*	2·450	0·929					

Appendix 3

Ordering Nickel Silver

It is always helpful when ordering nickel silver in wrought form to state the following:

- Quantity required - by weight if possible. Give the nickel content and specification number if known.
- Condition - in accordance with British Standards Specifications.
- Dimensions - these should be clearly stated in inches or decimal parts of an inch, and when a gauge number is used this must be specified and the gauge standard indicated.
- Form - State whether required in coils, random or exact flat lengths.

If there is any doubt about quality, hardness or specification, manufacturers will be pleased to advise on receipt of full information regarding the intended application of the metal.

Architectural sections can be ordered from standard profiles or made to special order. The composition of billets for castings should be specified, but prior consultation with the metal suppliers is recommended to ensure selection of the most suitable alloy.

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