UTILISATION OF NON-FERROUS SCRAP

Every year in New Zealand significant quantities of scrap metal are produced both as industrial off-cuts and when metal products wear out. As there are no economically viable sources of essential metals in New Zealand, it is often more sensible to recycle this metal than to import fresh stock. This is especially true of non-ferrous metal as it is more expensive than iron to buy, and thus recycling is usually a cheaper option.

Collection
The metal is collected by waste products dealers directly from industries, from tips and from roadside collections. It is then transported to metal refineries for sorting.

Sorting
The scrap is sorted into different pure metals, including copper, aluminium, nickel and zinc, and a variety of alloys. The metal is sorted primarily by hand by people trained to recognise the different substances, but for some alloys chemical tests are done to ascertain their exact composition. Precision is important because many of the final products require a specific mixture in the alloy for reliable function.

Uses
Once the metal has been sorted it is combined into a variety of alloys and cast into ingots prior to sale to various metal industries. These include the copper-based alloys of brass (zinc in copper), bronze (tin in copper) and gunmetal (zinc, tin and lead in copper) as well as some pure metals.

INTRODUCTION

New Zealand uses significant quantites of non-ferrous metal every year and as yet no economically workable deposits of base metal ores have been locally found. This means that all our requirements of such vital base metals as copper, zinc, tin, lead and nickel have to be imported. It is therefore desirable that the maximum amount of these expensive metals appearing in the form of scrap should be re-cycled internally to reduce import requirements.

COLLECTION

The collection of scrap starts with the waste products dealer, who does a remarkably efficient job of scouring the country for any metal that will return a reasonable profit. The price of non-ferrous scrap is such that it will usually stand the cost of collection and transportation to the point of use. By contrast, the much lower price received for ferrous scrap frequently makes its collection uneconomic. Copper and copper alloys comprise a large proportion of non-ferrous scrap, amounting to tens of thousands of tonnes a year. Significant amounts of lead, zinc, aluminium, tin and their alloys are also recovered and re-cycled.

Sources of scrap metal

Scrap metals arise from two sources. Process scrap is produced in a number of manufacturing industries and consists of off-cuts, machinings, punchings, grindings and rejects from rod, wire, sheet, etc., used in the fabricating of metal articles. This material is usually clean and of consistent composition and thus is easily reused. Obsolescence scrap is a much more variable material and consists of metal objects that for one reason or another have reached the end of their useful life, either through wear, breakage or redundancy.

Sources of obsolescence scrap include:

For copper-based alloys
- Car radiators
- Old castings
- Hot water cylinders
- Copper wire

For aluminium alloys
- Aluminium cans
- Lithography plates
- Old castings such as lawn mower bodies
- Aluminium wire

Scrap metal that cannot be processed in New Zealand is sent overseas for processessing, thus there is very little wastage of metal.

SORTING

Scrap is usually hand sorted into pure metal (e.g. copper, lead, etc.,) and various alloy types. This requires a large measure of skill and experience to distinguish such alloys as the various types of brasses, gunmetals and bronzes. Some objects are composed of a mixture of metals and alloys which cannot be economically separated; e. g. motorcar radiators usually contain copper, brass (copper-zinc) and solder (tin-lead). While much of the scrap can be sorted visually, it is often necessary to use chemical tests to identify the alloy constituents.

A certain amount of scrap is too intimately mixed with incompatible metals or is of too low a grade to be economically sorted. Slags and residues from melting and other industrial processes also contain metal which is not recoverable by processes available locally. These materials find a ready market with large overseas smelters and are sold on the basis of their content of the particular metal in which the smelter is interested.

USES

Having sorted the scrap into a range of classes of which the composition is known within reasonable limits, a decision can be made as to its best use. Often this will involve mixing it with fresh metal and then including it in a regular process, such as the pure recovered copper which is mixed with fresh copper and used by McKechnie Bros. in New Plymouth in the manufacture of copper tubes.

A considerable tonnage of copper chemicals (including copper sulphate, oxy-chloride and oxide) is manufactured locally for use in the formulation of fungicide sprays and copperised fertilizers. These chemicals require a copper of fairly high purity, and scrap copper wire is the chief basis of the industry. The balance of the copper and sorted alloys are converted into a wide range of alloys of carefully controlled compositions. Alloys based on a mixture of approximately 60% copper and 40% zinc are mixed with small quantities of lead, tin, copper, aluminum, nickel, manganese and silicon. The mixture is then cast into billets which are extruded easily at a red heat through dies into lengths of rod, bar, tube and sections. These alloys have a wide range of compositions, with copper contents varying from about 55% to 95%, and this allows for a wide range of scrap to be used provided adequate sorting and testing facilities are available. Not only is all the copper for these alloys obtained in scrap form, but most of the other ingredients also come from scrap sources of one type or another. Of all the metals used in the manufacture of copper-based alloys produced in New Zealand foundries, less than 5% have to be specially imported.

Some of the alloys that are commonly made from non-ferrous scrap metal are listed below under the general headings bronze, brass and gunmetal. A summary of the alloy constituents is given in **Table 1**.

Bronze
The term bronze refers to an alloy of ca. 10% tin in copper, often also including 5% lead and small quantities of other metals. The following bronzes are made from recycled copper.

Aluminium bronze - AB1 and AB2
These alloys are rarely surpassed for marine use such as propellors etc. Excellent corrosion resistance and strength.

Phosphor bronze
Alloys containing copper, tin and phosphorus used in the manufactue of bearings and bushes.

Brass
Brasses consist of up to 40% zinc in copper.

Diecasting brass
Used in the manufacture of brass taps for domestic use.

High tensile brass (manganese bronze)
These alloys are copper and zinc in which the strength normally associated with straight copper-zinc alloys is very considerably increased by the addition of elements such as aluminium, manganese, tin, iron and nickel.

The structure of the brasses (copper-zinc-alloys) containing up to about 36.5% zinc, consists of a single phase, alpha[1]. With more than 36.5% zinc a second phase, beta, is formed which increases in proportion as the zinc increases, until at about 46.5% zinc the alloy consists of beta phase only. In beta brass the ‘zinc’ need not actually be zinc, but can be one of a range of other alloying elements.

Some of the added elements (e.g. aluminium and tin) have a considerable influence in the structure in that they act in equivalence to zinc and alter the proportion of the alpha and beta phases; others, particularly manganese and iron can, if present in sufficient quantities, lead to the formation of separate phases. Normally the amount of manganese added is not sufficient to form a separate phase, but it is important that sufficient iron is present to produce the iron-rich phase which is essential to proper grain refinement.

[1] Note that: -α brass is consists of a face-centred cubic structure and is soft and ductile
- β brass has a body-centred cubic structure and is hard and extremely strong
- brasses that contain both these structures are known as duplex brasses

Table 1 - Compositions of some common alloys

Element / %	Aluminium bronze $CuAl_{10}Fe_3$	Phosphor bronze $CuSn_{11}P$	Phosphor bronze $CuSn_{10}P$	High tensile beta brass $CuZn_{28}Al_5FeMn$	High tensile brass $CuZn_{35}AlFeMn$	Diecasting brass $CuZn_{40}$	Gunmetal $CuSn_7Pb_3Zn_3$
Copper	83.0 - 90.0	84.9 - 88.9	86.4 - 89.5	55.0	57.0	59.0 - 63.0	82.8 - 90.0
Tin	0.0 - 0.1	11.0 - 13.0	10.0 - 11.5	0.0 - 0.2	0.0 - 1.0	—	6.0 - 8.0
Zinc	0.0 - 0.5	0.0 - 0.3	0.00 - 0.05	30.0 - 40.5	32.9 - 41.7	36.25 - 41.00	1.5 - 3.0
Lead	0.00 - 0.03	0.0 - 0.5	0.00 - 0.25	0.0 - 0.2	0.0 - 0.5	0.00 - 0.25	2.5 - 3.5
Phosphorous	—	0.15 - 0.60	0.5 - 1.0	—	—	—	—
Nickel	0.0 - 1.0	0.0 - 0.5	0.0 - 0.1	0.0 - 1.0	0.0 - 1.0	—	0.0 - 2.0
Iron	1.5 - 3.5	0.0 - 0.1	0.0 - 0.1	1.50 - 3.25	0.7 - 2.0	—	0.0 - 0.2
Aluminium	8.5 - 10.5	0.00 - 0.01	0.00 - 0.01	3.0 - 6.0	0.5 - 2.5	0.0 - 0.5	0.00 - 0.01
Manganese	0.0 - 1.0	—	0.00 - 0.05	0.0 - 4.0	0.1 - 3.0	—	—
Antimony	—	—	0.00 - 0.05	—	—	—	0.00 - 0.25
Arsenic	—	—	—	—	—	—	0.00 - 0.15
Silicon	0.0 - 0.2	0.00 - 0.02	0.00 - 0.02	0.0 - 0.1	0.0 - 0.1	—	0.00 - 0.01
Bismuth	—	—	—	—	—	—	0.00 - 0.05
Magnesium	0.00 - 0.05	—	—	—	—	—	—
Sulphur	—	0.0 - 0.1	0.00 - 0.05	—	—	—	—

The high tensile brasses which are in general use, i.e. HTB1 and HTB2, have alpha-beta structures, throughout which is distributed the complex iron-rich phase. There is a third higher strength alloy, HTB3, which is of all beta structure (also with the grain refining phase) which is susceptible to stress corrosion cracking, as are all the beta alloys.

Whilst these alloys have excellent strength characteristics, which can be superior to those of the aluminium bronzes (particularly with regard to proof stress), the fatigue and corrosion fatigue values cover a considerable range from not quite as good as aluminium bronze to very much inferior. These alloys are characterised by a rapid falling in properties with increase in temperature and should, therefore, not be used for applications involving temperatures in excess of 150°C.

These alloys can be tinned although some compositions are more suitable than others. They are all slightly ferro-magnetic to varying degrees. HTB1 is suitable for sand and die-casting, HTB2 and HTB3 can be sand cast only.

HTB1 and HTB2
Typical applications for which high tensile brasses are employed are:
- Components highly stressed at normal temperatures
- Marine propellers and cones
- Rudders and rudder posts
- Gun mountings
- Hydraulic equipment
- Water turbine equipment
- Locomotive axle boxes
- Pump casings
- Marine castings and fittings

HTB3
The high strength all beta alloy, HTB3, is used for:
- Heavy rolling mill housing nuts
- Rolling-mill slipper castings
- Spur and gear wheels which are heavily loaded and slow moving

The warning is repeated that HTB3 is susceptible to stress-corrosion cracking, that is, if it is subjected simultaneously to the influence of stress and corrosion (including certain atmospheres) it is liable to crack and for this reason great caution must be exercised in its use.

Gunmetal
Alloys of copper, zinc, tin and lead used in the manufacture of water pressure-tight valves and fittings.

THE ROLE OF THE LABORATORY

The foundry chemist is primarily responsible for analysing the samples of scrap and controlling the quality of alloys produced. The amounts of some metals in the alloy are very critical and require sophisticated methods such as the use of an atomic absorption spectrophotometer for accuracy. For this specialised work the chemist needs to be tertiary qualified in analytical chemistry and also possess some knowledge of metallurgy. Knowledge of the suitability of various alloys for each client's requirements is gained from experience.

Some alloys require the determination of up to 20 elements. Molten metal is typically controlled using direct reading computer controlled atomic emission and X-ray fluorescence spectrometers. This type of equipment allows for the precise analysis of up to 60 elements within 4 minutes from the time the molten metal is sampled.

As well, wet analysis using ICP[2] and flame atomic absorption techniques are commonly employed to control the accuracy of direct reading spectromters and also to analyse samples that need to be taken into solution. ie. samples that are to small to fit on a spectrometer.

Written by G. S. Lambert and P. J. Wilcox (Hayes Metal Refineries) with reference to:

- Association of Bronze and Brass Founders; *Copper and Copper Alloy Casting*; Association of Bronze and Brass Founders; 1961

Edited by Heather Wansbrough

[2] More correctly ICPOES, meaning inductively coupled plasma optical emission spectroscopy, a technique