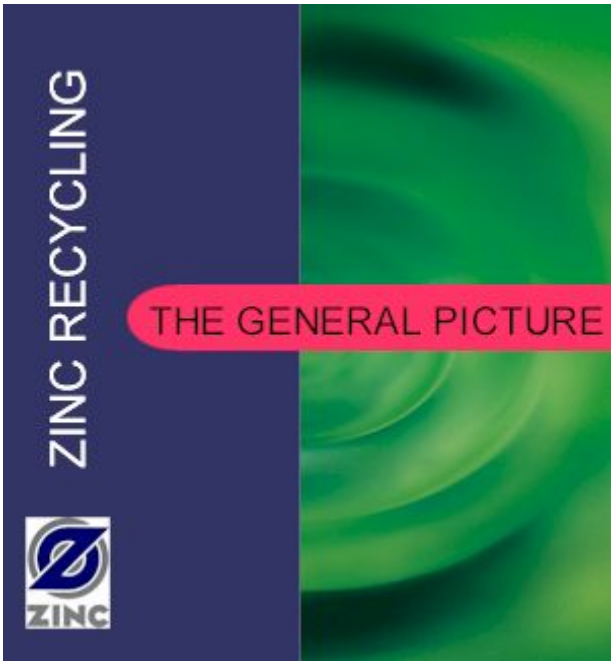

THE GENERAL PICTURE

Foreword

This booklet describes and illustrates the general picture of zinc recycling, quantifying the various routes for zinc scrap recovery.

Zinc scrap arises in a number of different forms with varying zinc content. Over the years different routes have been developed to provide the most effective and economical means of recovering the zinc from these materials. These recovery routes are described in this booklet and their relative importance is quantified.

Contents

This brochure has been produced and edited by IZA-Europe

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1. GENERAL CONSIDERATIONS

Zinc is a relative newcomer on the metals scene: while some metals have been around for 5000 years, zinc was not produced until the first century AD (in China) and in Europe not until the 18th Century.

The intrinsic properties of zinc give it a special place in today's industry and society:

- Protecting steel: there is an unique chemical and metallurgical relationship between iron and zinc, which enables zinc to protect steel from rusting. As a result nearly 50% of the zinc used in the world is for that purpose

- Alloys of zinc and aluminium: a series of alloys of zinc - principally with aluminium - are used to mass produce billions of strong, accurate castings for many different applications - from automobiles to zip fasteners

- Brasses, alloys of copper and zinc, can be cast, rolled, extruded and machined to make parts of anything from heavy engineering components to the kitchen tap • Zinc chemicals: principally zinc oxide - are used for products as diverse as tyres and other rubber products, ceramics, glass, paints and sun block creams

- Zinc for life: zinc is essential for many forms of plant and animal life, and in human nutrition. Zinc is added to fertilisers, animal feeds and to human dietary supplements

- Zinc for recycling: zinc is readily recycled and is unusual in both the number of ways in which it becomes available for recycling and in the number of recycling routes that are available.

The pattern of end uses of zinc is shown in Table 1 which, when considered in conjunction with the lifetimes of the products in which zinc is used, sets the availability - present and future - of zinc for recycling.

Table 1 : Development in zinc consumption in products 1950 - 1996*

	1950	1996
Galvanizing of steel	0.83	3.3
Production of brass	0.42	1.5
Zinc casting alloys	0.40	1.3
Chemical industry (zinc oxide & dust)	0.16	1.2
Zinc sheet (and other semiproducts)	0.28	0.6
Other uses	0.04	0.2
	2.13	**8.1**

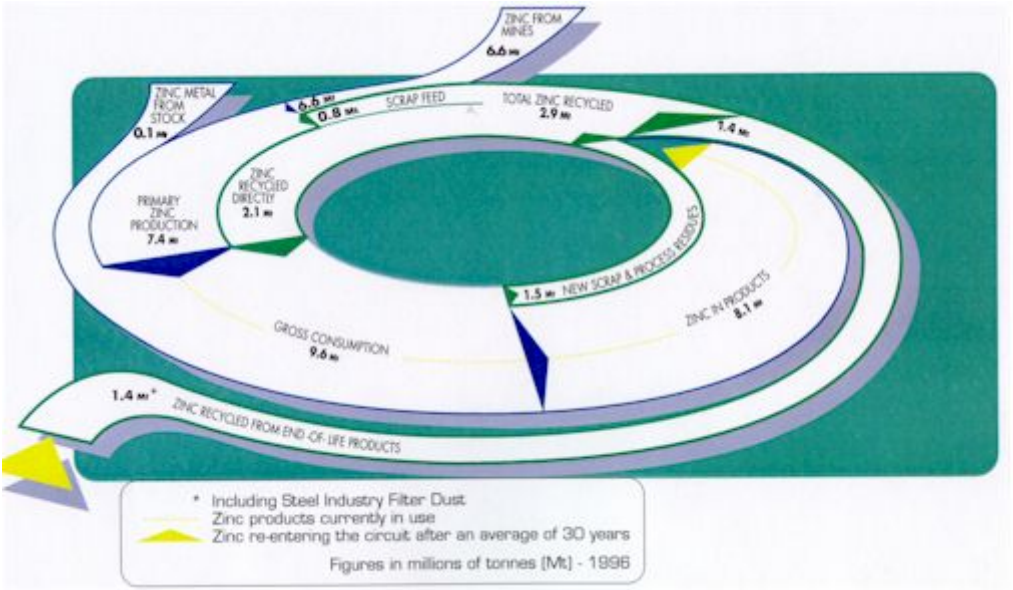
* in millions of tonnes (Mt)

Zinc, in common with all elements, can be and is recycled continuously unlike synthetic materials for which incineration for energy recovery is often the only treatment possible.

Some scrap arises immediately from the production or processing of products containing zinc. This is "new" or "process" scrap, and is recycled almost immediately. Other zinc arises for recycling only at the end of the life of the product into which it is incorporated. This is "old" scrap. As will be seen later, the interval between the incorporation of zinc into a product, and its return as old scrap can in some cases be well over a century.

The relative importance of new and old scrap can be seen in the outline recycling circuit for zinc shown in Fig.1. That diagram also illustrates the need to define clearly what is meant by consumption of zinc. Currently some 6.6 Mt of zinc produced from mined ores are used annually, together with 2.9 Mt of zinc from secondary sources. This, together with 0.1 Mt of zinc metal from stock, indicates a gross consumption of 9.6 Mt. However, in processing this 9.6 Mt, 1.5 Mt are returned as new scrap and process residues, so that the amount actually incorporated into products is close to 8.1 Mt.

Fig.1: Outline recycling circuit for zinc



Consumption of zinc rose steadily in the 19th Century, reaching about 0.5 Mt by 1900, and it has continued to grow in the 20th Century. The 8.1 Mt of zinc which

enters products makes it the fourth most important metal after iron, aluminium and copper.

Detailed information on how zinc is used and how it is recovered and recycled has become more readily available and more reliable in recent years. At the turn of the century the principal uses of zinc were in sheet for roofing, in brass and to some extent in hot dip galvanizing. Brass, zinc sheet and galvanizing continued to be the most important applications. From the 1930's onwards the use of zinc casting alloys became increasingly important, as they are particularly well suited to use in mass produced goods - such as cars and appliances. By 1950 the end use pattern had been established in more detail. This is shown in Table 1, on page 2, in comparison with current consumption patterns.

For zinc, in contrast to synthetic materials, recycling is not a new concept. The value of zinc scrap has always been recognised and its price set according to zinc content and to the costs of recovering it in a useful form. The different forms of zinc scrap are well defined and characterised and a European standard for them is in course of preparation.

Recycling does not mean that scrap must be returned to its original form - refined zinc metal ingots. Conversion to other zinc products can be - both technically and economically - the most efficient way of treating some forms of scrap.

Published statistics - for both production and consumption - generally refer to primary zinc. That is metal which has been produced by an electrochemical or chemical reduction process from upgraded and concentrated metal ores, together with increasing quantities of scrap and residues which are most economically recovered in this way. Secondary zinc metal is obtained from scrap by remelting and - if necessary - treatment of the resulting molten metal. No reduction process is involved.

Although some data are published on the production and use of secondary zinc, these are by no means comprehensive. The information in Table 2 has been prepared from published data supplemented by information from International Zinc Association - Europe. This shows clearly the importance of recycling to the zinc industry.

Table 2 : Sources and overall consumption of zinc*

		1996
Primary Zinc		
from mine production	6.6	
from secondary scrap feed	0.8	
from stocks	0.1	7.5
Zinc in secondary forms		
remelted zinc	0.3	
secondary alloys	0.2	
chemical industry	0.5	
brass	1.1	2.1

Gross consumption	9.6
Less new/process scrap produced	*-1.5*
Net consumption - zinc in products	**8.1Mt**

Proportion of zinc in gross consumption coming from secondary sources (2.9Mt/9.6Mt)	**31%**

* in millions of tonnes (Mt) - 1996 data

2. SOURCES AND RECOVERY ROUTES FOR RECYCLED ZINC

Total recovery of zinc within the non ferrous metals industry amounts to 2.9 Mt, of which 1.5 Mt are new scrap or process residues and 1.4 Mt are old scrap. Both old and new are valuable and are used by primary smelters, secondary metal producers, or makers of zinc products, depending on their physical form, as well as their content of zinc and of other metals (for instance copper in brass).

The sources of zinc for recycling are given in Table 3 and illustrated in Fig. 2. The industries using arisings of scrap are given in Table 4 and Fig. 3.

Fig. 4 illustrates the comprehensive recycling circuit for zinc-both arisings and their use.

Table 3 : Sources of currently recycled zinc

Source	Mt (zinc content) new	old	total	%
Brass Scrap	0.7	0.50	1.2	42
Galvanizing residues	0.8	-	0.8	27
Die casting scrap	≪0.1	0.4	0.4	16
Steel industry filter dust	-	0.2	0.2	6
Zinc sheet/semiproducts	≪0.1	0.2	0.3	6
Chemical industry	≪0.1	0.1		2
Other (incl. dumps)	≪0.1			1
	1.5	**1.4**	**2.9**	**100**

Fig. 2 : Current sources of recycled zinc (old & new scrap)

Table 4 : Principal industries using zinc in secondary forms*

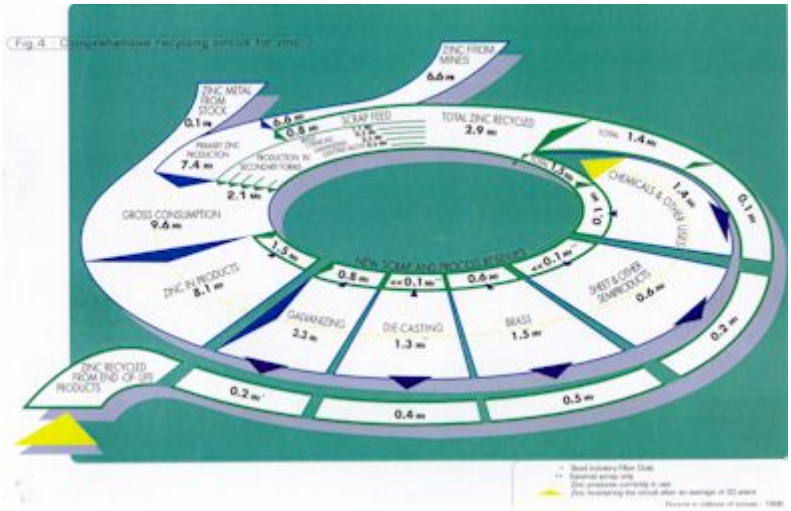
Primary zinc production	0.8
Brass industry (1)	1.1
Galvanizing (2)	0.3
Die Casting (3)	0.2
Chemical industry and other	0.5
	2.9

(1) Zinc content in secondary brass of which 0.08Mt is secondary (remelted) zinc
(2) Almost entirely secondary (remelted) zinc
(3) Secondary (remelted) alloys

** in millions of tonnes (Mt)*

Fig. 3 : Principal consumers of secondary zinc in all forms

Fig.4 : Comprehensive recycling circuit for zinc



Brass scrap

With its high value and high copper content (generally >60%) brass scrap, whether old or new, is recycled almost exclusively within the brass and copper industries. Any other route would be uneconomical. This means that any zinc used in brass production leaves the zinc recycling circuit for ever and is completely recycled within the brass / copper circuits. However, this material isincluded on the data and calculations given in this booklet.

New brass scrap includes reject components, swarf or trimmings produced during machining processes, and offcuts of sheet, tubes or wire. Old scrap consists of brass products or components that have reached the end of their useful lives.

Galvanizing residues

These comprise a range of different materials, all of which contain large amounts of entrained metallic zinc. Zinc ashes (or skimmings) are skimmed from the top of general galvanizing baths. They contain oxides formed on the surface of the bath together with entrained metal. The overall metal content is generally >70%. Zinc drosses (hard zinc) are removed from the bottom of general galvanizing baths (bottom dross), or from the pots of continuous galvanizing lines (top dross). In either case they contain >90% metallic zinc, together with zinc-iron intermetallic compounds formed from the reaction of the steel and zinc during the galvanizing process. In tube galvanizing a further residue, blowings, is formed as excess zinc is removed from the surfaces by compressed air.

Zinc drosses are used in the production of zinc oxide, zinc dust and other zinc chemicals. Ashes are physically separated to produce secondary zinc ingot with the non-metallic fraction used as feedstock, alongside ores, in the production of primary zinc.

Galvanized steel products at the end of their lives are recycled in the steel industry and the zinc is captured in the dust filters.

Zinc die cast scrap

New zinc die cast scrap consists of new reject castings, and process scrap - parts of the cast metal that are trimmed off the finished casting. These materials are recycled directly, either in the die casting plant or by toll treatment in an alloy plant.

Old scrap arises when products containing zinc castings are themselves broken up and recycled. A relatively small amount of die cast scrap is remelted to produce secondary zinc alloy. Most end-of-life cars and domestic appliances are shredded. The non-ferrous fraction of the shredded materials is the main source of zinc die cast scrap.

Technology is available to separate zinc from other metals. The resulting zinc alloy fraction is an important source of secondary refined zinc, secondary zinc casting alloys and zinc chemicals.

Scrap zinc sheet

This is largely old scrap, zinc sheet from roofs, cladding, gutters, downpipes, etc…, which are being replaced. There is also a relatively small quantity of new scrap in the form of off-cuts from new sheet being used for building purposes. Whether old or new, zinc sheet scrap is highly valued and much of it is remelted to produce secondary zinc ingots. It is also an ideal material from which to produce zinc oxide and zinc dust.

Steelmaking arisings

The use of zinc for galvanizing has grown very substantially over the last 40 years, but due to the long life of many of the products containing galvanized steel, this has only relatively recently appeared in substantial quantities in scrap. It should be borne in mind that a large proportion of the zinc applied to the steel is likely to remain on the surface when it is scrapped.

When steel is being produced from scrap, the zinc remaining on the feedstock is volatilized and captured in the flue dust which is filtered out from the furnace gases. Considerable effort has been and is being devoted to the economic recovery of zinc from these materials. Substantial quantities of these dusts are upgraded and then used as feedstock for the production of primary zinc. Where this treatment is not economic, the dust is currently put in regulated dumps, awaiting technical developments. Industry is aware of the potential for further recovery of zinc and is increasing the amount of

these materials that are treated to recover the zinc content.

Other arisings

Zinc residues also arise in smaller quantities in several different ways: from the treatment mine and smelter dumps; filter dusts from brass works; and in various parts of the chemical industry. These are largely recycled in the chemical industry or through primary zinc production.

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3. WHO ARE THE RECYCLERS?

The scrap metal trade

Where large quantities are involved, zinc scrap is purchased directly by the company which will recycle it. Smaller quantities may be handled by the scrap metal trade, which provides an invaluable service by buying, sorting and grading scrap in order to build up economic quantities from numerous small sources. These bigger lots are then sold to the appropriate user - secondary zinc producer, chemical industry, semifabricator or primary smelter.

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4. WHERE DOES THE ZINC SCRAP ARISE AND WHERE IS IT RECOVERED?

Zinc is recovered all over the world. Its geographical distribution is shown in Table 5. Europe has the highest share, because "older" industrialised countries have much higher historical consumption making quantities of old scrap available that much higher. However, the significant proportion recovered in Asia depends on the export of scrap from Europe and North America.

That trade is encouraged by such factors as

- lower treatment costs enabling buyers in those countries to compete strongly for scrap
- lack of indigenous sources of zinc

This means that recyclers in industrialised countries do not have access to all the scrap which they would wish to recycle.

Table 5 : Analysis of secondary zinc recovery by continent and industry*

Continent	Primary production	Secondary production	Secondary casting alloys	Secondary input into: Brass	Chemical industry	Total	%
Europe	0.28	0.13	0.09	0.50	0.17	1.17	40
Africa	-	<0.01	-	<0.05	<0.05	<0.02	<1
America	0.18	0.05	0.05	0.25	0.12	0.65	22
Asia	0.25	0.16	0.08	0.33	0.18	0.99	34
Australasia	0.05	-	-	0.01	<0.01	0.07	<1
	0.76	**0.34**	**0.22**	**1.10**	**0.5**	**2.90**	**100**

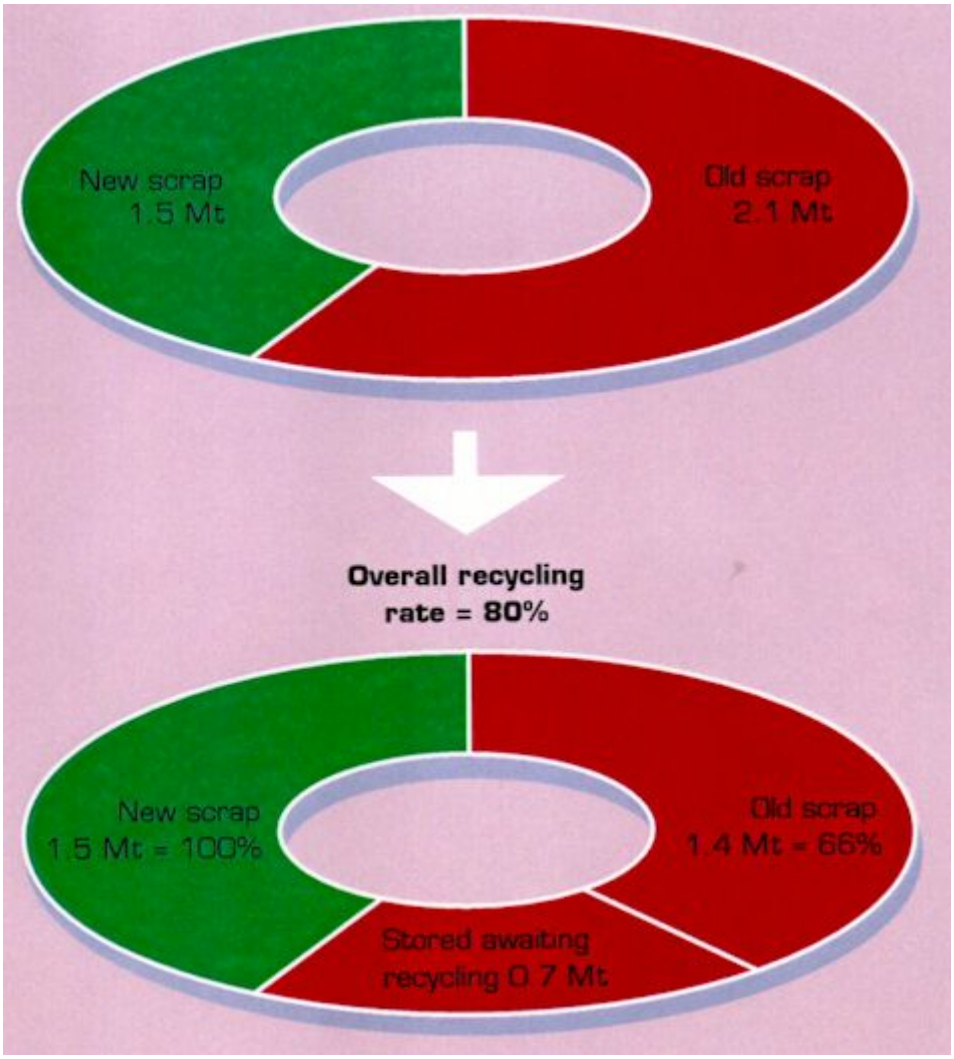
* in millions of tonnes (Mt)

Fig. 5 : Geographical breakdown of overall zinc recovery

5. RECYCLING RATES AND HISTORICAL CONSUMPTION

Recycling rates for material are sometimes expressed as the ratio of secondary to primary materials in current consumption. This is meaningless as a way of describing the efficiency with which a material is recovered and re-used, because the arisings or recoverable residues are largely governed by consumption of the material several - perhaps many - years ago.

Fig. 6 : The recycling rates



The total of zinc consumed - 9.6 Mt - gives rise to 1.5 Mt of new scrap and process residues, 100% of which are recycled almost immediately.

The wide range of product lifetimes makes a precise calculation of old scrap arisings very difficult. However, a reasonable evaluation can be made by considering the average lifetimes of each of the main products in which zinc is used, and the historical tonnage of zinc in each of those products. Such a calculation suggests that the weighted average lifetime of zinc products is about 30 years. This would suggest that close to 3.0 Mt of zinc should arise from old scrap each year.

Of the arisings of 3.0 Mt about 0.7 Mt are in the chemical industry and are not available for recycling in the non-ferrous

metals industry. Of that, about 50% is in the form of zinc oxide in rubber, 20% in ceramics, glass and paint. These materials are either recycled in the industries or permanently encorporated in a non dispersible form (e.g. cement, glass). The remainder includes agro-chemicals, pharmaceuticals, and many other smaller uses.

A further 0.2Mt is not available for recycling. It is estimated that one third of this is held on a long term basis (for instance in collectors' items), one third contained in household waste and the remainder dispersed during or after use (for instance in run-off due to atmospheric corrosion, tyre wear, use of agricultural and pharmaceutical products, etc…). Taking these factors into consideration, the quantity really accessible for recycling is 2.1 Mt.

Of this, 1.4 Mt (66%), is recycled. Taking new and old arisings together indicates that 80% of the available materials are recycled.

The balance of 20% consists mainly of zinc contained in steelworks filter dusts. As already pointed out (p.9) this material is a secondary "zinc mine" awaiting

exploitation.

6. ZINC IN THE ENVIRONMENT

Zinc is a natural constituent of the earth's crust. Due to natural processes, background concentrations of zinc are observed in all environmental compartments. Zinc is an essential element which is required for the optimal growth and development of all living organisms from micro-organisms to man.

Man-made inputs of zinc into the environment are well controlled and of the same order of magnitude as natural inputs. These man-made inputs are continuously decreasing as emissions from industrial point sources are progressively more closely controlled. An additional and indirect benefit arises from the decreasing acidity of ambient air, which decreases atmospheric corrosion of zinc.

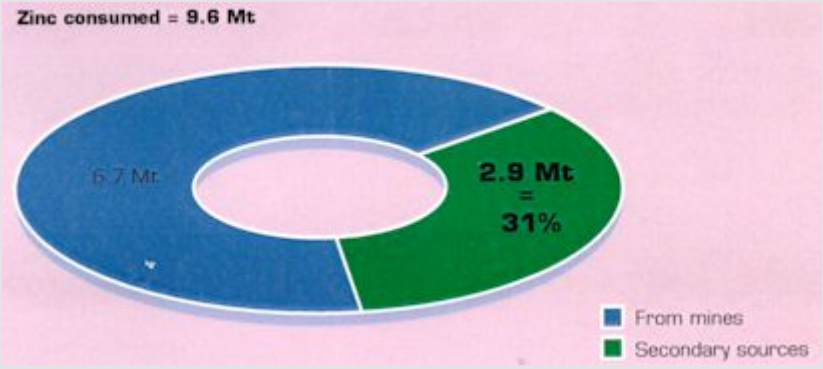
For further information, reference should be made to 'Zinc in the Environment' published by the International Zinc Association.

The continuing growth in the use of zinc means that increasing quantities will become available for recycling over the coming years. Throughout the world, zinc products and downstream industries are investing in the plant and equipment required to treat these increasing quantitites of zinc scrap and residues. Zinc arisings are well characterised, their value appreciated, and in most cases their optimal recycling routes are well established.

7. CONCLUSION

Zinc is used in so many different ways - from agriculture to zip fasteners - that it is a major challenge to know, control and where possible recycle all of it. It is therefore a remarkable achievement that industry recycles or controls virtually all available zinc.

It should be stressed also that, as a result of the continuing increase in recycling, today some 31% of the zinc consumed is produced from secondary sources. The trend will continue, conserving even greater amounts of natural resources and of energy.



GLOSSARY

Explanations of a few of the terms used in this booklet :

Primary zinc :

metallic zinc produced by a chemical or electrochemical reduction process mainly from zinc concentrates.

Zinc concentrates :

zinc ores which have been ground and treated to raise the zinc content, generally to 50 % or more.

Primary zinc smelter :

a plant producing primary zinc by reduction of essentially non-metallic zinc-bearing materials (either from ores or from secondary sources) with carbon (coal/coke). The ISF (Imperial Smelting Furnace) process is the most frequent form of smelter.

Primary electrolytic zinc refinery :

a plant producing primary zinc by electrolysis of a solution of zinc sulphate which is produced by roasting zinc concentrate and then dissolving it in acid.

Secondary zinc :

metallic zinc produced by remelting and, where necessary, chemical treatment of metallic zinc residues.

Zinc sheet :

zinc or an alloy of zinc (generally with small amounts of copper and titanium) rolled into thin sheets suitable for forming into roofing and cladding and other applications.

Zinc alloy :

a metallic material based on zinc, but with specified additions of other metals. In particular zinc die casting alloys contain 1-27 % aluminium, 0-7 % copper, 0.03 - 0.06 % magnesium.

Secondary zinc alloy :

a zinc alloy (generally zinc die casting alloy) produced by remelting, chemical treatment where necessary, and adjustment of composition, from scrap arisings of essentially the same alloy *.

Pressure die casting :

a process for producing strong accurate parts in large quantities, by forcing molten metal under pressure into a steel die.

Zinc die castings :

zinc alloy parts produced by the pressure die casting process

Brass :

a metallic material based on copper and zinc, together sometimes with other metals. There are a very wide range of brasses with zinc contents up to 42 %. Brasses are used as castings and in a wide range of other forms (sheet, wire, tube, extrusions ...)

Scrap arisings :

any materials which may be used for the recycling of zinc. These may be :

new (or process) scrap : zinc-bearing material which arises during the transformation of zinc and/or its incorpo-ration into a product. Examples include : off-cuts of zinc sheet ; machining and turning swarf ; castings and their feeding systems ; drosses from hot dip galvanizing.

old scrap : zinc-bearing material from products which have reached the end of their useful life

Galvanizing :

producing a coating on zinc or iron or steel by dipping in molten zinc. The term is also loosely used to describe other processes for producing zinc coatings on steel, particularly electrogalvanizing in which the coating is produced by electrolytic deposition.

Dross : (hard zinc)

a mixture of metallic materials contained in a matrix of zinc. In particular the zinc-iron and zinc-iron-aluminium compounds with a high proportion of entrained zinc whic are formed in the hot dip galvanizing process. Top dross and bottom dross are so named depending on whether they float to the surface or sink to the bottom of the galavanizing bath.

Ash :

oxidised zinc or zinc alloys, generally, containing large amounts of entrained metal. Ashes generally are formed on the surface of molten metals exposed to the air, for instance on hot dip galvanizing baths, zinc casting alloy melting and holding pots, etc.

* Zinc casting alloys require close control over certain impurities, particularly lead, tin and cadmium. For this reason, secondary alloys should only be produced from new or process scrap.

DATA SOURCES

The data presented in this publication have been developed from :

- published statistics of the International Lead and Zinc Study Group (ILZSG)

- IZA Europe members