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UTILIZATION OF NON-FERROUS SCRAP METAL

Report of the Expert Group Meeting on Non-ferrous Scrap Metal

Vienna, [illegible] November 1969

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Letter of transmittal to
the Executive Director of UNIDO,
Mr. I. H. Abdel-Rahman

Dear Mr. Abdel-Rahman,

We have the honour to submit herewith our report on the "Utilization of non-ferrous scrap metal". This report was prepared during the Expert Group Meeting on the "Utilization of non-ferrous scrap metal in developing countries", organized by the Metallurgical Industries Section of the Industrial Technology Division and held from 25 to 28 November 1969, at the Headquarters of the United Nations Industrial Development Organization, Vienna.

The terms of reference given to us were to present papers on the utilization of non-ferrous scrap metal, paying particular attention to the needs of developing countries, and to discuss these papers and prepare a report containing conclusions and recommendations.

In the meeting, 26 representatives from developing countries, as well as from a number of organizations and firms from developed countries, participated as observers. They also took an active part in the discussions and offered suggestions to be included in the report. (A list of the observers is attached as annex 1.)

Mr. N. Chakrabarti was elected as Chairman of the Group, Mr. M. Spendlove as Vice-Chairman and Mr. D. Davies as Rapporteur. Mr. Christo Popov, staff member of UNIDO, was assigned to the Group to assist in its work.

Annex 3 to the report summarizes the papers presented and the discussions that took place at the meeting.

In submitting this report we have acted in a personal capacity and not as official representatives of the organizations and firms of the governments to which we belong.

We appreciate the attention which UNIDO devoted to the use of secondary non-ferrous metals and the opportunity offered to us to meet here at the UNIDO Headquarters and discuss these questions.

Yours truly,

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Foreword

1. The United Nations Industrial Development Organization convened the expert working group on "Utilization of non-ferrous scrap metal" to examine the present technological and economic status of the secondary non-ferrous metals industry; also to make recommendations for improvement of this industry in developing countries. Attention was called to the possibility of technical assistance in field operations (expert, consulting or advisory missions), which UNIDO could offer through its established programmes. This report examines the recovery of the most common non-ferrous metals - aluminium, copper, lead and zinc - from scrap and wastes.

2. A growing consumer society has been increasing its consumption of non-ferrous metals at a time when the average quality of ores mined has been decreasing. Three factors have led to the development of thriving secondary metal industries, particularly in the industrialized areas of the world: increased costs of primary metal production, periods of scarce supply, and the growing volume of scrap and residues. These secondary metal industries, which supply non-ferrous metals in amounts comparable to primary producers, assist greatly in meeting the needs of industry.

3. The consumption of non-ferrous metals in the developing countries increases from year to year. As a direct consequence, the volume of non-ferrous metals available for recovery will increase at a rate sufficient for practicable and economic recovery. Against the background of rapid depletion of easy-to-mine ore bodies, these secondary metals will be a valuable part of the non-ferrous metal resources.

4. The present report deals with the collection and classification of scrap and residues, the object of their recovery, the technologies and equipment, and the control of quality in processing and in the finished product.

1. CONCLUSIONS AND RECOMMENDATIONS

Conclusions

5. The average annual increments of consumption of the principal non-ferrous metals in developing countries for the period [illegible]6-1[illegible] were as follows: aluminium, 1[illegible] per cent; copper, [illegible] per cent; lead, [illegible].3 per cent; and zinc, 9.4 per cent. Much of this non-ferrous metal consumption is in the form of metal goods that will be scrapped after the end of their useful life and which can be salvaged, reprocessed and re-used.

6. The efficient recovery of these materials would provide developing countries with a domestic supply of non-ferrous metals for use in existing or new metallurgical industries. It is necessary for countries intent upon establishing recovery operations to survey or estimate the quantities of non-ferrous scrap and residues arising now and likely to arise in the future in order to determine the size and scope of the facilities required for their successful utilization. Governmental encouragement and assistance will be required in the early stages of the programme.

7. Melting and refining facilities are dependent upon the continuity of the supply of non-ferrous scrap and residues; an efficient scrap collection service is a prerequisite for successful operations. Similarly, the grading and classification of the salvaged materials is of fundamental importance if the best use is to be made of the recovered metals.

8. Existing secondary metal plants produce metals and alloys comparable to those of the primary metal producers; their capital costs are substantially lower than those required for similar operations in the production of primary non-ferrous metals. The established secondary metals industry has evolved its own technology and expertise on the basis of many years of experience. The transmission of this experience and knowledge to the developing countries by all practical means is desirable, even at an early stage of industrialization.

9. Secondary metal recovery lends itself to either large- or small-scale operations, thus enabling developing countries to start on a modest scale and to increase their level of activity as the volume of non-ferrous scrap and wastes increases. While the greatest proportion of secondary metal is recovered by the use of proven plants, equipment and processes, developing countries may be in a position to take advantage of the latest techniques that the industry has to offer and to improve or adapt them to fit their own economic and technical needs.

Recommendations

10. In view of the high economic value of non-ferrous metals and the likelihood of further price increases, it was recommended that:

A. The developing countries should:

(1) By governmental action, promote interest in the establishment of recovery programmes and facilities for secondary non-ferrous metals, and endeavour to promote an economic and industrial climate in which activities of this nature may be established and sustained;

(2) By legislation, when recovery facilities have been established, prevent or control the export of scrap and residues and by appropriate incentives, especially in the earlier stages of development, provide the necessary stimulus for local processing;

(3) Where conditions are suitable, establish appropriate agencies to assume responsibility for initiating and developing conditions for the maximum collection and use of national resources of non-ferrous scrap metal and residues. Governmental policies should lead to the establishment of objectives covering the salvaging, processing and use of industrial and domestic reject materials;

(4) Effect the creation of an efficient recovery programme in which the resources of both the public and private sectors can be engaged with the appropriate division of responsibility allocated by developing countries themselves;

(5) Encourage the establishment of non-ferrous metal foundries and other industries which can consume the products of the secondary metals industry;

(6) Organize a survey and assessment of the present and potential scrap and residue resources likely to be realized. In the light of the results of the survey

and assessment, policy decisions may be made not only upon the economic feasibility of establishing a scrap collection service but also on the degree of smelting and other recovery processes that would be necessary. A second objective may be the establishment of a scrap and residue collection, classification and standardization service. Special study groups or individual experts should analyse the situation in terms of scrap and residue resources, processing capability, existing industry and the size of the market for the potential products. If the results of such studies appear promising, steps should be taken to determine probable costs of production and selling prices. The acquisition of the necessary technological skills and expertise should be obtained by using the existing operating knowledge of the well established refiners of secondary metals in the industrialized countries of the world;

(7) Encourage the formation of study groups at the appropriate levels of management and technical personnel. The provision of facilities to enable such groups to receive training at existing installations abroad will be the most expedient way to assure acquisition of the necessary skills. Technical schools and centres of technology may provide short-term and extra-mural courses and guidance on the recovery of secondary non-ferrous metals. This may be the most effective means of disseminating knowledge in this field;

(8) Make full use of opportunities for technical advice and assistance which could be offered through UNIDO, such as experts, consultants, technical missions and study fellowships;

(9) Avoid the waste of non-ferrous metals by examining their current use and ensuring that it is as effective as possible and that unwanted metal, scrap and residue are not lost for industrial processing;

(10) Consider, where small quantities of different scrap metal are available, the establishment of flexible processing plants capable of dealing with this variety. Specialized plants for the production of a specific non-ferrous metal are more suitable where the quantities of raw materials are large;

(11) Establish collaboration and co-operation among themselves and with developed countries in the economic, technical and commercial activities related to the use of non-ferrous scrap metal.

B. The developed countries should:

(1) Make provision for technical education and training of personnel of the developing countries in the use of secondary non-ferrous scrap and waste;

(2) Establish and maintain contact with secondary metal experts of the developing countries to promote and implement recovery installations and operations;

(3) Make available to the governments and firms of developing countries books, pamphlets, brochures, films and visual aids and other relevant documents;

(4) Whenever possible, make available to the developing countries the latest results of research, investigation and development work in non-ferrous metallurgy;

(5) Make available upon request appropriate standards for raw materials and end-products.

C. UNIDO or the appropriate United Nations organization should:

(1) Through a special programme of its Metallurgical Industries Section assist the developing countries willing to establish or to develop their own secondary non-ferrous metals industry through expert advice, consulting services and technical missions, as well as by arranging study fellowships for nationals of those countries in plants and technical institutions in industrialized countries;

(2) Undertake studies upon request from developing countries to evaluate their potential for the development of the secondary non-ferrous metals industry;

(3) Stimulate fellowship training programmes in this branch of the metallurgical industry;

(4) Undertake studies on the methods of evaluation and determination of non-ferrous scrap metal resources;

(5) Arrange a systematic preparation and distribution of UNIDO documents and other publications dealing with problems concerning developments in the secondary non-ferrous metals industry;

(6) In due time, arrange further meetings of groups of experts, particularly on a regional basis, to identify the problems and to give concrete advice, guidance and suggestions to developing countries as well as to evaluate the latest developments in the field of non-ferrous scrap recovery;

(7) In view of the considerations expressed by the expert group, inform the ISO (International Organisation for Standardization), Geneva, of the necessity to formulate international standards to cover the classification of secondary non-ferrous scrap metal and alloys;

(8) Arrange to make available to the developing countries, the existing standards for non-ferrous scrap metal and residues.

2. PRESENT USE OF NON-FERROUS SCRAP METAL

Secondary metal in relation to primary metal

11. The world production of primary non-ferrous metals is increasing (table 1). In the past, only richer ore bodies were mined. Poorer deposits are now exploited to produce the required quantities of metal. Technological advances permit the economical extraction of these metals from the ore bodies. This is particularly true of metals like copper and tin but less applicable in the case of aluminium, of which ore reserves are the largest among the non-ferrous metals.

Table 1

World production of primary non-ferrous metals

Annual production 1956-1966 as percentage of 1963 production

1956	80
1957	82
1958	77
1959	81
1960	92
1961	94
1962	99
1963	100
1964	105
1965	108
1966	114

12. The world population growth and the constantly increasing requirements of consumer society will be responsible for heavier demands upon the world's resources of non-ferrous metals. These

needs may be partially met by the discovery and development of new ore bodies, but the rate of consumption may outstrip the production of these and existing resources.

13. A very high proportion of the non-ferrous metals used over the past 50 years was secondary metal. The maximum recovery of non-ferrous metals from discarded goods would appear to be essential if the supply of these metals is to meet the demand.

14. In the more highly industrialized countries, the use of recovered or secondary non-ferrous metals has become a substantial proportion of the total use of these metals. In the United States for example, the use of secondary lead now exceeds the use of primary lead; and the production and consumption of secondary copper is approaching that of primary copper. With the increased use of non-ferrous metals, the accumulated quantities remaining in use will tend to increase also. For many countries, they will represent the only domestic sources of these materials. In these circumstances there are pressures which make the efficient recovery of non-ferrous metals essential.

Economic aspects of the use of non-ferrous scrap

15. The extent to which non-ferrous metals may be recovered from scrap is limited by the absolute loss of metals resulting from corrosion or dispersion. These small losses are from 2 to 5 per cent; therefore, the theoretical possibility of a recovery is 95 to 98 per cent. In practice this is not so, 60 to 85 per cent being the generally accepted percentage of recovery.

16. Countries possessing large domestic scrap resources usually possess adequate facilities for production of metal products but this may not be true in many developing countries. Table 2 below indicates the extent of this situation.

17. Specialized plants of secondary smelters have often been expanded as the volume of scrap increases. In general, these plants are very economical by virtue of a high throughput. This

may not be the case for developing countries. The size of the plant required will depend upon the volume of the scrap resources; the type of plant will be determined by the particular infeed and the products to be fabricated.

Table 2

Distribution of investments to industry groups, 1938-1961
(per cent)

	Industry group	1938	1948	1953	1961
World	Light industry	52.4	44.3	39.3	37.8
	Manufacture of metal products[a]	24.1	30.1	35.2	34.7
	Heavy industry	23.5	25.6	25.5	27.5
		100.0	100.0	100.0	100.0
Developed countries	Light industry	50.8	42.2	39.5	35.9
	Manufacture of metal products	25.5	31.9	35.0	36.6
	Heavy industry	23.7	25.9	25.5	27.5
		100.0	100.0	100.0	100.0
Developing countries	Light industry	68.9	67.2	63.1	55.7
	Manufacture of metal products	9.7	10.7	11.9	16.3
	Heavy industry	21.4	22.1	25.0	28.0
		100.0	100.0	100.0	100.0

a/ This industry group includes manufacture of metal products; electrical machinery, apparatus, appliances and supplies; transport equipment and other machinery.

18. The capital cost of primary metal is higher than the capital cost of secondary metal facilities. The high degree of mechanization required in the industrialized areas of the world adds

substantially to the capital cost; in some developing countries labour-intensive may be preferable to capital-intensive industry in the initial stage of development of the secondary non-ferrous metals industry.

19. An economic assessment of the use of non-ferrous scrap must balance the cost of acquisition, transportation, concentration and conversion against imports. The value of scrap does not remain constant; it moves with the price of the same primary metal. Its value may also fluctuate as a result of changes in supply and demand.

20. Whereas prices may change, costs do not vary greatly, and consequently the increased use of scrap will demand the creation of a highly efficient service for the acquisition and transportation of scrap, as transport charges are often an important factor in the process costs. Whether the enterprise is state-controlled or private, basic efficiency is vital.

21. The correct grading of scrap has both commercial and technical significance. Payment for supplies should be based upon grading and consistency of grading. In this way, there will be incentives for the scrapper, the collector and the grader to maximize the return of metal of known composition rather than to deliver lots of mixed metals. The value to the developing country lies in the minimum debasement of the domestic supplies, and hence the minimum requirements from the primary producers. The decision as to what extent the use of scrap will be increased may well be influenced by the future consumption of metals. Table 3 below shows the prospective growth rates for developing countries.

22. In general, the <u>per capita</u> consumption of non-ferrous metals increases with improvements in the standard of living. Using this as a broad basis for comparison, the general level of scrap resources may be roughly predicted, but more accurate estimates would be required upon which to base decisions.

Table 3

Prospective growth in the consumption of non-ferrous metals in developing countries

	Actual consumption in 1967 (thousand tons)	Average annual increase in consumption 1956-1967 (per cent)	Prospective consumption (thousand tons)	
			1975	1980
Aluminium	314	18.0	1,180	2,700
Copper	180	5.7	280	365
Lead	243	8.3	460	680
Zinc	307	9.4	630	980

23. Table 4 below gives more precise details. It suggests that the tonnages available do not merit the installation of the largest types of facilities and that small units may be preferable except in the case of aluminium. This is certainly true in the case of copper. Fortunately, the refining of non-ferrous scrap can be a very small-scale operation.

Table 4

Estimate of non-ferrous scrap resources[a/] in developing countries, 1975-1980

	Scrap resources as per cent of consumption	Estimate of scrap resources (thousand tons)	
		1975	1980
Aluminium	20	240	540
Copper	30	84	110
Lead	30	140	200
Zinc	20	126	195

a/ Including metals contained in alloys.

24. The economic viability is assured, provided the objectives are limited within reason. This situation contrasts strongly with that of the development of primary metals where large-scale operations are usually necessary and the capital investment is of the order of ten times that of operations in the recovery of secondary metals.

Sources of non-ferrous scrap

25. Non-ferrous scrap originates from industrial operations, the discarding of durable goods and the scrapping of capital plant and equipment. The range of processed scrap metal is enlarged by the increase of technical progress, greater industrialization and improvements in the standard of living.

26. Scrap from industrial operations emerge from the following processes:

(a) Rolling, forging and drawing processes in the form of ends, burrs, croppings, surface cleanings as oxides etc.;

(b) Metallurgical processes in the form of slag, leakages, spillings, sweepings, flue and bag-house dusts, cinders, ashes and drosses;

(c) From foundry scrap as teemings, risers, ashes, leakages, slags and drosses etc.;

(d) Cable manufacturing processes as wires, cable ends etc.;

(e) Mechanical processing as punchings, cuttings, turnings etc.;

(f) Tin and zinc coating processes as sludge, cinders etc.;

(g) Chemical processes;

(h) From components or parts rejected during processing.

27. Scrap resources from discarded worn-out articles and capital plant and equipment may originate from the following sources:

(a) Industry, transport, agricultural equipment and discontinued installations;

(b) Military sources such as aircraft, weapons, unprimed ammunition etc.;

(c) Domestic refuse dumps and discards.

Scrap from industrial operations is usually easily identifiable and can be readily processed into a form which allows it to be fed back into the production process without additional refining.

Classification of non-ferrous scrap metal

28. Scrap is classified into categories, groups and assortments; the classification is according to its impurity content. The United States National Association of Secondary Material Industries (NASMI) issues an internationally recognized standard classification for non-ferrous metals which precisely defines the quality of scraps under a series of headings and code names. The correct grouping of scrap is a basic necessity for optimum recovery at minimal cost; strict observance of grouping is essential from the initial formation of scrap through the subsequent storage and transport.

29. Identifiable scrap from all sources is usually made into batch form for direct use, whereas mixed scrap must be refined. Separate handling and processing lines are frequently used for different scrap. Frequently there is a feedback of scrap from the mixed batches after it has been identified during charge preparation. For aluminium-based scrap, NASMI lists 21 scrap classifications and 38 for copper-based scrap.

3. POSSIBLE USES OF NON-FERROUS SCRAP METAL

Acquisition, transportation and preliminary processing

30. A major economic factor in the secondary metals industry is the cost of transporting scrap from its source to the smelter or refinery. The location of refining facilities in developing countries must be planned within economic distances of the places where the bulk of the scrap and residue originates. Alternatively, the scrap could be treated at processing centres equipped to reduce the bulk as much as possible, thus reducing the cost of transportation. In the early stages of development, collected scrap could be subjected to a preliminary sorting operation. After a suitable labour force had been trained to sort the scrap into materials of similar composition, it could be placed in drums or other storage containers and refined domestically where possible or exported in the absence of refining facilities.

31. Scrap resources contain both large and small pieces of scrap; therefore lifting equipment should be provided. Chain pulley blocks and electric hoists are the simplest, but mobile fork lift trucks have a wider range of application. Various simple cutting equipment can break large pieces of scrap into convenient size both for transportation and for furnace charging. Unwanted material such as ferrous and non-metallic parts may also be cut from the scrap, thus enhancing its value to the refiners.

32. Mobile alligator shears are usually employed for heavy-duty cutting; old power cables, plates, heavy tubes and the like are conveniently cut up in this way. Power saws and oxy-acetylene torches may also be used. Heating over an open fire is sufficient to break large castings of bronze into pieces of manageable size. Where labour costs are low, hand-cutting operations with shears,

hack saws and the like may be used to break light scrap and to free it from unwanted material.

33. Polyethylene- and PVC-coated copper wires may be burnt to remove the coatings, but this creates black smoke, and chlorine and lead oxide fumes. Such burning, therefore, should only be practiced where there is little danger to humans or livestock.

34. Whenever scrap is stored it should be kept as dry as possible to prevent losses from corrosion. Storage on concrete or other hard surfaces is recommended to avoid losses of scrap in soft ground. Many types of scrap metal may be compacted by specially designed equipment into bales and briquettes. The advantages of compaction are that the volume is substantially reduced, resulting in lower transport costs, easier charging of the furnaces and improved melting rates.

The progressive development of a secondary non-ferrous metals industry

35. A broad general development pattern of a secondary metals industry for developing countries may be suggested. Initial development will depend to a large extent upon whether there is some industrial use of non-ferrous metals or production of non-ferrous scrap or wastes. A preliminary survey and assessment of the domestic resources of these materials would indicate the types and quantities involved. The importance of their acquisition and transportation to centres for classification and grading has already been mentioned. The first stage should, therefore, consist of elementary sorting and grading into lots of similar metals, alloys and residues. In the absence of a domestic consumer industry, these materials may be packed into drums or other suitable containers and exported.

36. Progression from acquisition and classification, the next step would be the installation of elementary melting and casting equipment to produce ingots from batches of scrap. Simple crucible gas or oil furnaces may be recommended as they are low in capital cost and are not complicated to operate. They would be eminently

suitable for small-scale operations. Simple cast iron moulds for the casting of ingots are also inexpensive.

37. As the volume of scrap and residues increases, larger furnaces and casting machines would be required to handle the increased output. When this stage has been reached, analytical facilities are necessary. Countries adopting a progressive development plan could then consider establishing simple foundries. After such basic facilities are functioning, a logical development would be to install improved methods and processes, including complex, more efficient furnaces and sophisticated and more versatile casting plants, which produce not only ingots for the foundry industry but also cast shapes for the manufacture of wrought metals. At this stage, the recovery industry would be in a position to maximize its recovery processes by introducing dust-catching equipment - such as bag houses - and thereby increase the use of non-ferrous scrap and residues.

Opportunities in the production of secondary non-ferrous metals

Extent and evaluation of potential sources

38. As previously stated, the non-ferrous metals contained in recoverable metal goods manufactured over the past four or five decades will be reclaimed in the future and will supply a large part of the total demand. As a result, new opportunities will be provided for the production of secondary metals.

39. Developing countries that establish or improve existing secondary metal operations may wish to use the opportunity to evaluate and adopt the most technically and commercially attractive processes, without spending time and money on development work or sacrificing prior investments.

40. The value of the secondary metals industry in the United States, are shown below in table 5, is an indication of the extent of the operations and the opportunities which exist in this area. Table 6 demonstrates the large accumulation of copper, lead and

zinc in use in the United States; this accumulation is expected to increase.

Table 5

Consumption of secondary metals in the United States

	Quantity	Unit	1969 value[a] ($ millions)
Copper	1,243,000	short ton	1,096[b]
Aluminium	885,000	short ton	403
Lead	554,000	short ton	161
Zinc	263,000	short ton	76
Antimony	25,568	short ton	26
Tin	22,790	short ton	71
Mercury	22,150	flask	12
Silver	59,000,000	ounce	101
Gold	2,000,000	ounce	70

Source: Bureau of Mines, Office of Mineral Resource Evaluation.

a/ Prices as cited in American Metal Market, 7 May 1969.

b/ $853 million less than the value of the secondary iron.

Table 6

Estimated tonnage of copper, lead and zinc in use in the United States, 1940-1968
(thousand short tons)

	Copper[a]	Lead[b]	Zinc[b]
1940	14,735	180	264
1945	19,933	873	1,173
1950	24,169	1,674	1,722
1955	28,615	2,490	2,525
1960	32,630	3,052	3,085
1965	37,346	3,587	3,928
1968	40,333	4,030	4,473

Source: Bureau of Mines, Office of Mineral Resource Evaluation.

a/ 1907 base of reference.

b/ 1939 base of reference.

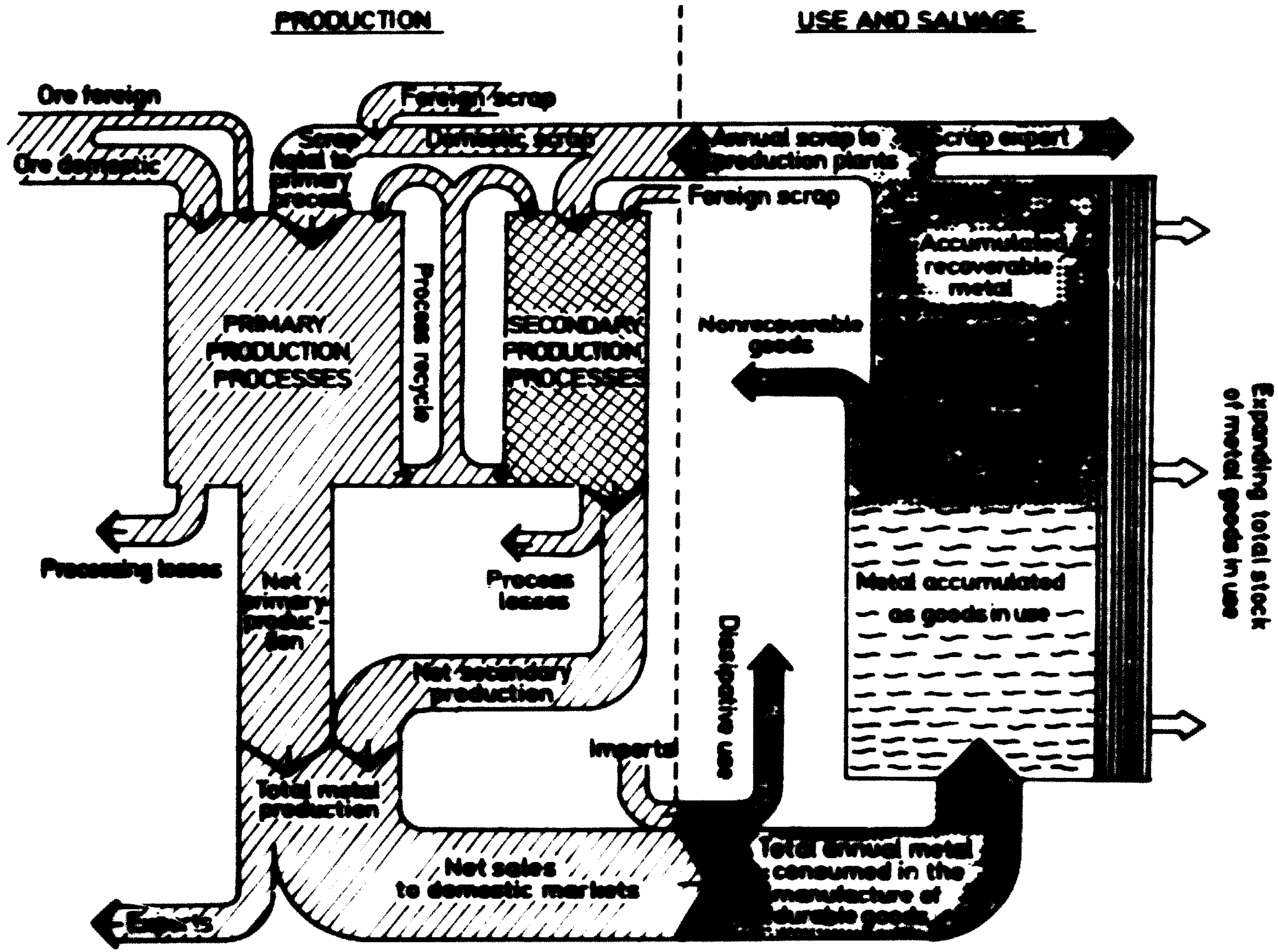
41. Complete and accurate resource data are important to ensure prudent use of secondary metals. Opportunities can best be determined from reliable information on the magnitude, location and composition of the metal goods in use, as well as from an accurate knowledge of the portion of these materials likely to become available for recovery in the near future. It is equally important to obtain current economic and technological information pertaining to salvaging, re-processing and marketing.

42. The following figure is a typical materials flow diagram and shows the sequential movement of primary and secondary metals from source through production as well as in-use salvage and re-cycling phases. The diagram shows the balance of input and output and the points at which losses occur. By applying statistical information to a flow sheet of this type, a fairly reliable evaluation of the secondary metals industry in a particular country is possible.

43. The growth of any metal processing industry is determined primarily by two factors: (a) the availability of raw materials; and (b) the marketing opportunities for the product. For secondary metals, the growth pattern follows trends in the availability of scrap, and new types of process scrap appear much later as old scrap from discarded goods and reach the refineries via breakers and salvage and scrap merchants. The quantity of materials in all phases of the use - discard cycle determines the size of the salvage and refining industry.

44. Unlike the price of primary metals, the price of secondary metals often fluctuates drastically, as does the availability and variety of scrap. Under these circumstances, periodic adverse effects may be felt in operating costs and in the capital employed in operations. Good management and accounting practice are necessary if serious pitfalls are to be avoided. The copper industry is particularly prone to problems of this nature where daily price changes are experienced as a result of London Metal Exchange dealings. Opportunities in the production of specific secondary non-ferrous metals are briefly described below.

Metal production, use and salvage cycle



Secondary aluminium

45. During the last decade, a steady growth has taken place in the production of secondary aluminium in the United States. As raw materials comprise about 75 per cent of the total cost, the most practicable materials to process are those that resemble the intended product to the greatest extent and thus require the minimum amount of processing. These types are usually in the form of common aluminium-based alloys as shown in table 7 from which it will be seen that aluminium alloys comprised 90 per cent of the recovered scrap and only 8 per cent were recovered as non-alloyed metal. Such a pattern indicates that it is not practicable to convert all scrap materials to their original composition.

Table 7

Recovery of secondary aluminium in the United States in 1967

		Short tons
From process scrap		
Aluminium-base		568,782
Copper-base		81
Zinc-base		71
Magnesium-base		313
From scrap metal		
Aluminium-base		127,681
Copper-base		70
Zinc-base		569
Magnesium-base		184
	Total	697,751
Form of recovery		
As metal		53,656
As aluminium alloys		628,848
In brass or bronze		643
In zinc-base alloys		8,304
In magnesium-base alloys		1,195
In chemical compounds		5,105
	Total	697,751

Secondary copper

46. Under the pressure of consistently rising prices, the production of secondary copper has increased rapidly during the past ten years. In most industrialized countries, secondary copper is used in nearly half of the total copper consumption.

47. Table 8 below shows the position of the United States in 1967 when the copper recovered in brass and bronze materials was more than 98 per cent of the total tonnage of secondary copper. This situation suggests that optimum segregation of scrap items is imperative for maximum processing efficiency; it also reveals the value of the NASMI classification which lists 38 different types of copper and copper-alloy scrap. The opportunities, therefore, lie not only in the recovery of copper itself but in the production of a wide range of copper-base alloys for the engineering and other industries.

Secondary lead

48. A substantial growth rate in lead production has occurred in most industrialized countries during the past ten years. Table 9 following shows the recovery of secondary lead in the United States for 1967. It will be seen that the prime source is antimonial lead in the form of battery plates, although other important sources include electric cable sheath, bearings, pipe and sheet.

Secondary zinc

49. Consumption of zinc in the United States during the past ten years has increased 1.4 times and the corresponding consumption of secondary zinc 1.3 times. Table 10 below shows the tonnages and the forms of recovery. The significant feature is that zinc- and copper-base alloys comprise the bulk of all zinc recovered in both new and old scrap.

50. Zinc scrap is classified into nine items; brass and bronze are not included. The most prominent items include five different die-cast materials, old zinc scrap, new clippings, die-cast dross and galvanisers dross. The die-cast scrap alloys are usually

refined or blended to suitable composition for new alloys, while the drosses are distilled to produce zinc metal or zinc dust and may be oxidized to zinc-oxide products.

Table 8

Recovery of secondary copper in the United States in 1967

		Short tons
From process scrap		
Copper-base		667,080
Aluminium-base		10,000
Nickel-base		157
Zinc-base		11
From old scrap		
Copper-base		476,436
Aluminium-base		5,500
Nickel-base		623
Tin-base		50
Zinc-base		50
	Total	1,159,907
Form of recovery		
As unalloyed copper:		
primary plants		343,277
other plants		79,777
In brass or bronze		700,636
In iron and steel alloys		2,805
In aluminium alloys		28,148
In other alloys		299
In chemical compounds		4,965
	Total	1,159,907

51. Flux materials from galvanizer vats and processing pots and zinc-based dusts from filters, precipitators, scrubbers and cyclones are used in the production of zinc chemicals. As few types of zinc scrap are processed by the secondary refiners, segregation problems are limited and are not as critical as for the other non-ferrous metals.

Table 9

Recovery of secondary lead in the United States in 1967

		Short tons
From process scrap		
Lead-base		71,829
Copper-base		4,500
Tin-base		578
From old scrap		
Battery-lead plates		303,258
All other lead-base		155,892
Copper-base		17,711
Tin-base		4
	Total	553,772
Form of recovery		
As soft lead:		
primary plants		2,538
other plants		147,806
In antimonial lead		288,719
In copper-base alloys		17,795
In tin-base alloys		30
In other lead alloys		96,884
	Total	553,772

Table 10

Recovery of secondary zinc in the United States in 1967

		Short tons
From process scrap		
Zinc-base		129,774
Copper-base		106,637
Aluminium-base		2,895
Magnesium-base		234
From old scrap		
Zinc-base		40,862
Copper-base		36,142
Aluminium-base		3,165
Magnesium-base		140
	Total	319,849
Form of recovery as metal		
By distillation:		
slab zinc		72,595
zinc dust		32,309
By remelting		6,366
In zinc-base alloys		17,273
In brass or bronze		146,441
In aluminium-base alloys		6,145
In magnesium-base alloys		431
In chemical products:		
zinc oxide, lead free		17,255
zinc sulphate		9,536
zinc chloride		11,236
Miscellaneous		262
	Total	319,849

Identifying opportunities

52. Similar to other business enterprises, a profit element is necessary to encourage the development of the secondary metals industry. In developing countries, profit is not only the usual pecuniary gain but it may also be expressed in terms of a reduced expenditure of foreign exchange as a result of decreased imports and an improvement of the domestic economy by encouraging the development of industry and additional employment. From both points of view however, the potential profit will be proportional to the volume of the business. Basically, the profit will be the difference between the market value of the products and the cost of the raw materials plus the operating costs.

53. The extent of the recovery operations will depend upon the continuity of the supply of raw materials. Current technology and equipment should be used; the erection of a proven plant reduces the commission time and the cost of development.

54. Flexibility is important in the design of recovery plants to allow for future changes in the in-feed material and to obtain the maximum recovery of flue dusts and other products. If the volume of the latter is small, they may be sold or stored and processed intermittently.

55. Opportunities also exist for developing countries in the adoption of new and revolutionary processes. These new processes may well reduce the working capital required as well as the operating costs. Further opportunities exist in a relaxation of product specifications and in a reduction in their number.

56. There are possibilities of mutual co-operation between developing countries, which might profitably negotiate mutual bartering or purchasing agreements. Thus a country with a deficiency of domestic scrap resources could import them from a country with a surplus. Toll conversion contracts may be considered as well as outright purchase.

Innovative processing

57. Opportunities exist for the developing countries to take advantage of new innovations in the processing field. The United States Bureau of Mines has pioneered several new processes. An outstanding example is in the improved distillation of zinc, which led to economies in fuel and retort costs and enabled gas to be used for heating instead of electricity.

58. Another recovery process for zinc uses one processing waste material as an agent to refine another waste by the reaction of zinc chloride in sal skimmings with aluminium in a melt of low-grade die-cast zinc scrap; the aluminium content is reduced to 0.01 per cent. Other innovations include the removal of solid impurities by means of a centrifuge, and, in the field of mechanical processing, the separation of metal and plastic by a very much improved method, i.e. by the recovery of metal from plastic sheathed electrical wires and cables. This method has both economic and social benefits.

59. Electrolytic methods using mercury as an amalgam have also been developed in which tin is recovered from hard-head and zinc from galvanizing dross. Additional applications of these electrolytic methods are likely to emerge.

60. The United States Bureau of Mines has developed other techniques such as ammonia-carbon dioxide leaching of copper scrap. However, commercial acceptance of them has been slower. A further process based on the use of brine and water leaches in the recovery of lead and copper from lead blast furnace matte is another good opportunity.

4. REVIEW OF MELTING TECHNOLOGY AND EQUIPMENT

61. The important aspects of processing are quality and melting losses, which are very much dependent upon good scrap segregation and charge preparation. For example, by de-greasing chips, the loss is 2 to 3 per cent less and the gas content reduced. Basically the processes employed should ensure the most complete extraction of all valuable components contained in the scrap. Therefore it should be processed into metals and alloys similar in composition.

Use of aluminium scrap and alloys

62. Process scrap is usually consistent in quality and accumulates in substantial quantities; if carefully segregated, it can be used in the works in which it originates. When available to secondary smelters, it provides a high-quality base material for incorporation into related alloys with close compositional tolerances. Examples include billet ends, extruded section and sheet off-cuts; lower grades include turnings, runners and risers.

63. Old scrap is collected from redundant or obsolete articles and equipment, including kitchen utensils, motor vehicles, wire and cable, engine components and aircraft. The scrap resources can be forecast if the aluminium content of an article is known and its life can be estimated. Most old scrap is contaminated with undesirable matter; it may be coated with paint, or it may be joined to other metal parts, plastic components or rubber. These contaminants must be removed from the aluminium scrap before recovery operations.

Preparation of raw material in scrap form

64. For the optimum use of scrap, the composition of each batch must be determined. Sampling on a statistical or controlled basis will indicate the yield to be expected and also the quantity of flux required.

65. Both physical and chemical methods are used to sort scrap. Many wrought alloys in sheet form can be distinguished from pure aluminium by a simple bend test and similarly in castings by the appearance of a fracture. More reliable chemical methods range from simple spot tests for a rough estimation or for the presence of one or two elements to the application of a visual spectroscope.

66. Experience and knowledge help in identification. Often a component is known to be composed of one or two alloys; a simple test will distinguish one alloy from another. Scrap delivered to the smelter usually requires some form of treatment due to either the size or type of contamination. Where possible, scrap is compacted into bales and bulky scrap reduced by cutting. Dross and skimmings are treated by milling in wet or dry-ball mills or by breaking in an impact crusher.

67. Swarf is usually contaminated with cutting oils and frequently with free iron such as turnings or broken tools. Iron must be removed before melting. This is done easily by magnetic separation provided the swarf is free from oil or water. The most efficient method to remove them is treatment of the swarf in a heated rotating drum to produce distillation with restricted air flow. Paper and plastic coatings must be removed from aluminium foil. Scrap cooking utensils simply require the removal of iron handles and rivets, but more complex assemblies such as automobile and aircraft engines and frame scrap require special sorting procedures and may have to be subjected to a liquation process.

68. Liquation furnaces are reverberatory furnaces designed with sloping hearths and an outside bath or ladle for receiving the liquid aluminium alloy which separates from the higher-melting-point metals. Combustibles such as paint, wood and plastic are

burnt off. Metal recovered from a liquation furnace is generally too impure for direct use and is usually brought to the appropriate specification by the addition of pure aluminium or alloys.

69. The development of large swing-hammer crushing machines has made possible the cleaning of scrap which formerly would have had to be melted in the liquation furnace. Such equipment used in conjunction with magnetic separation or sink-and-float processes enables very effective recovery to be achieved. The capital cost is high and may be justified only for large-scale operations.

Methods of melting aluminium scrap

70. In general, scrap recovery of aluminium is practiced in highly specialized plants where skills and equipment have been developed to upgrade its value in the production of specification alloy ingots for the foundry industry. Upgraded scrap can also be used in hardener alloys and deoxidants for the steel industry.

71. Scrap aluminium is obtained from fabrication processes and from discards of aluminium-containing products in population and industrial centres. It is in such locations close to raw materials and markets that scrap smelting operations have developed. The value of scrap is sensitive to supply and demand; scrap generally commands a price 20 per cent below that of virgin aluminium, although it has occasionally exceeded the price of the latter.

72. The following characteristics of aluminium are important when considering melting methods. It has a high affinity for oxygen; once formed, oxide skins prevent further oxidation. The heat capacity and latent heat of fusion are high. Aluminium forms carbides and nitrides in reaction with carbon and nitrogen. It is not reduced by carbon monoxide. Reduction smelting of aluminium as well as the oxidizing refining of its alloys is impracticable.

73. Three main groups of aluminium alloys are produced usually from aluminium scrap:

(a) Wrought alloys - containing copper, manganese, magnesium and zinc as the main alloying component;

(b) Casting alloys - containing silicon, copper magnesium, manganese, zinc nickel and others;

(c) **Deoxidizers** - destined for the steel industry and for smelting ferro-alloys, which allow high iron, manganese, silicon and magnesium content.

74. In developing countries the requirements of the national economy should be studied before considering the establishment of a secondary aluminium industry, so that the plant will be suited to produce the grades of alloy in demand. The choice of furnaces or combinations of furnaces must be made according to production requirements; different types of furnaces are considered later in this report.

Aluminium alloy scrap refining

75. Magnesium is removed by the addition of fluoride salts to cryolite; 10 kg of fluoride salts is required for each kilogram of magnesium contained in the melt. The magnesium may be reduced to 0.1 per cent by this technique. Zinc is removed most efficiently by vacuum distillation at a temperature of 800° to 900°C in a vacuum of 0.1 to 0.5 mm mercury. Non-metallic components may be removed by gaseous methods employing chlorine, hexachloroethane or nitrogen. The latter is introduced in the form of diffused bubbles, the quantity required being 1.5 to 2 m^3/ton of alloy treated. Gaseous chlorine is generally employed. The use of glass-cloth as a filter has also been adopted.

Main types of furnaces

76. Traditionally, the rotary furnace with a capacity of 1 to 15 tons has been favoured in Europe. It completely rotates on a horizontal axis and is charged at one end through an opening. The scrap is melted under a thick flux cover by the direct flame of oil or gas burners.

77. The open-well furnace developed in the United States tends to displace the rotary furnace. It is basically a reverberatory furnace with an open-well extension at one end and a capacity up to 60 tons. The use of flux in melting light scrap is confined to the open well, but the metal bath must first be produced by melting heavy scrap or by supplying liquid metal from other furnaces. The

transfer of heat from the main part of the furnace to the well is achieved by movement of the metal through the openings between the two parts.

78. The coreless induction furnace possesses advantages over fuel-fired furnaces in that there is low melt loss and the metal recoveries are higher by as much as 2 per cent. Generally, frequency-type furnaces are used with capacities of 5 to 6 tons. Clean scrap is essential, as flux treatment is undesirable due to its effect on the furnace lining and fume extraction problems. The limiting factors for these furnaces are the high capital cost, the high power cost, the relatively small size and the requirement of clean scrap in the charge.

79. Small rotary-type furnaces of 0.5 to 1 ton capacity, which are stationary during smelting but can be tilted for casting, are suitable for smelting clean scrap which does not require large quantities of flux. This type of furnace is oil or gas fired with the flue in the roof or in the end opposite the burner; charging is by a side door. Crucible furnaces with capacities up to 250 kg can be used for small-scale operations. For melting light scrap, a furnace similar to a concrete mixer with a refractory lining has given satisfactory results. It is fired by an oil or gas burner through the top opening and can be fitted for tilting outwards.

80. The choice of the type of melting furnace to be used depends on factors such as scale of production, extent of mechanization and type of scrap to be melted. In general, for large-scale production, the well furnace, which lends itself to mechanical charging, is preferred. The rotary furnace is probably better for low-yield materials, e.g. metal recovered from dross. In this case, the problem of salt fume emission is worse than in the well furnace where less flux is used and only added to the well, and where there is no direct flame impingement. Well furnaces are more flexible in operation as fluxes can be added and spent fluxes removed during a melt. In the rotary furnace, one flux bath may be used for one or more melts depending on the percentage of impurities in the charge.

81. For efficient scrap melting, agitation of the melt is necessary. This is achieved by the rotating action of the rotary furnace, but in the open-well furnace it is best accomplished by pumping the metal over a wall built into the well. Automatic temperature control is comparatively easily implemented in well furnaces by inserting thermocouples in the brickwork. It is not so practicable in the rotary furnace, but, because of the rotation, overheating is not critical. In the construction of all types of furnace refractories, the brick is at least 40 per cent alumina.

Furnaces for melting aluminium scrap

82. The following types of furnaces are available for melting aluminium scrap:

Table 11

Furnaces for melting aluminium scrap

Type	Fuel	Size (tons)	Advantages	Disadvantages
Open flame reverberatory	Solid Liquid Gas	7 - 80	High efficiency. Simple design. Easy maintenance. Low cost of repairs	Products of combustion are in contact with the bath, hence gas pick-up
Twin chamber	Solid Liquid Gas	7 - 80	Reduced contact time of aluminium with ferrous parts: Increase by 20-25 per cent. Reduced metal losses in casting	
Inclined hearth	Solid Liquid Gas	7 - 80		High losses (up to 30 per cent). Low efficiency. High fuel consumption
Reverberatory with external bath	Solid Liquid Gas	7 - 80	Firing of closed chamber only. Low oxide losses in closed chamber because metal is always under flux. Low gas contents because metal in in open bath	Necessity of removing iron from the scrap
Rotary drum	Liquid Gas		Heat transfer by contact with furnace walls as well as from flame radiation. Good mixing and low losses. (Ideal for gas treatment)	Necessity of removing iron from the scrap
Induction crucible	Electricity	1 - 10	Increased metal recovery by 2-4 per cent. Improved quality in uniform composition and density. Good working conditions. Little atmospheric pollution	Necessity of removing iron from the scrap. Requires small pieces in the charge. High specific power consumption
Induction channel			Reduction of specific power consumption by 20 per cent	Tendency of oxide to clog the channels; therefore these furnaces are useful only for melting primary base metal and pure scrap

Melting technology

83. The main difficulty in melting aluminium scrap is the thickness of the tough oxide film on the surface, which prevents coalescence of the liquid droplets. At high melting temperatures, the oxides may be particularly dense and may be suspended in the melt or sink to the bottom. As the oxides are extremely hard, they are a source of the harmful inclusions often found in castings. Good melting techniques demand, therefore:

(a) Minimal contact between scrap and flame when heating to the melting temperature;

(b) Use of appropriate fluxes to exclude air and remove oxide;

(c) Agitation of the bath to aid coalescence of metal globules.

84. It is usual to melt a heel of flux, into which scrap is charged at a rate sufficient to allow rapid melting with a minimum contact with air. Once a heel of metal has been formed, scrap is added in increasing quantities; controls ensure quick melting and that the temperature of the bath does not fall below the freezing point of the alloy. Fluxes are based essentially on sodium chloride with some addition of potassium chloride. Fluorides are also added to reduce surface tension. Alumina is not dissolved by these fluxes.

85. The major refining operation in the melting of scrap is the separation of oxides, but other refining operations may be required to remove unwanted elements. The only elements that can be removed by simple techniques are magnesium and other elements in small quantities such as sodium and calcium. Magnesium can be removed with fluxes containing fluorides or with chlorine gas. The flux method uses cryolite, sodium silico-fluoride or aluminium fluoride. The efficiency of magnesium removal in all cases is about 50 per cent; it decreases as the magnesium content is reduced.

86. Chlorine gas on the other hand is very efficient with near 100 per cent removal when the magnesium content is above 1 per cent, and 50 per cent removal when it is below 0.1 per cent. The sodium and calcium content is also reduced to low levels by chlorine

treatment. Special precautions must be taken in the handling of chlorine gas and of the fumes emitted during the chlorination process.

87. Another impurity is hydrogen, which is the cause of gas porosity in castings. It may be removed by degassing treatments using chlorine, nitrogen or a mixture of them. Hexachloroethane plunged into the melt may also be used for this purpose.

88. The melting temperatures of commercial alloys are in the range of 560° to 650°C and the normal temperature for casting ingots is between 680° and 750°C. However, in practice, even higher temperatures are necessary to allow rapid melting which is essential in order to form a heel of molten flux into which light scrap can be charged.

Facilities for laboratory control

89. The size and type of the recovery operation will determine the extent of the laboratory facilities. If the operation consists merely of melting scrap into ingot form but not into a specific alloy, the minimum requirement would be a small chemical laboratory to identify alloys by spot tests and to determine the composition of the re-melted ingot.

90. Essentially, the laboratory must be able to provide analysis in scrap identification, control analysis during melting and the final analysis of the melt. Direct-reading spectrography can be carried out by a staff of two or three. Single-channel instruments can be used; they are substantially cheaper. In the larger secondary alloy production plants, a wet-chemical section is often provided for analytical work which cannot be carried out on the spectrograph, such as the calibration of standards, the determination of unusual impurities and the composition of fluxes, fuels and effluents.

91. The sampling of scrap is usually a laboratory function. Facilities should be provided for melting the samples under conditions similar to those during actual production. Facilities for reducing the sample to a suitable size are required.

92. A metallurgical section controls the quality of the ingot in respect to its oxide content, its gas content, the grain size and other special requirements. Some alloys must undergo tensile tests on the castings produced from the ingots. The secondary refiner will require the necessary facilities to cast test bars and to test tensile strengths and other properties.

93. It is customary for larger secondary refiners to provide a technical service to customers which includes metallographic examination of castings and non-destructive tests to determine the cause of defects and to suggest means of avoiding these faults. The importance of correct sampling cannot be overstressed, and adherence to specified codes of practice is recommended.

Auxiliary equipment

94. Refined scrap must be cast into ingots of acceptable size, 5-10 kg or 15-26 kg. Small-scale production requirements can be met by hand casting into simple cast iron moulds. For large-scale production, the casting is mechanized by using water-cooled moulds mounted on a belt-type casting conveyor or wheel. The cast ingots may be pelletized and secured by steel wires or band strapping.

95. Pyrometric control during the melting is usually effected by means of chromel-alumel thermocouples with cast iron sheathers protected by a refractory coating or a non-metallic sheath. Foundry tools such as rakes, skimmers and ladles are constructed of mild steel protected by a refractory wash. Launders for the conveyance of molten metal are also of mild steel with a refractory lining which should be heated to red heat before use to ensure that moisture and combined water are evaporated.

Use of lead and zinc scrap, alloys and wastes

96. Not all products made of lead and zinc yield scrap and residues for use by the secondary refiner; sometimes they are completely consumed by use. The major uses of lead are in the manufacture of lead acid batteries, cable sheathing, pigments, and in construction and plumbing. To a lesser extent, lead is

used in printing metals, bearing metals, tetra-ethyl lead and in sound insulation. The applications above are given in their order of importance. Zinc is used mostly for galvanizing, die-casting and production of brass, wrought zinc and pigments; significant quantities of scrap and residues are available for the secondary metals industry.

Recovery of secondary lead

97. Lead from batteries provides 50 to 60 per cent of the metallic lead, antimony and lead oxides; the remainder is lead sulphate. Lead is recovered in the form of an alloy of antimony by processing the scrap either alone or with other lead-bearing residues. The recovered alloy is re-used for batteries after its antimony content has been adjusted.

98. The furnaces may be simple melting pots, reverbatory furnaces, barrel furnaces, blast furnaces or electric furnaces. Simple melting cannot recover lead in the form of oxides and other compounds, therefore smelting is required. This consists of treating the scrap with suitable reducing agents and fluxes; the latter help to collect the metal, and the former reduce the oxides to metal.

99. The lead contents of old batteries may be removed manually or, where large quantities are concerned, by crushing and separation processes based on the difference in density between lead and other materials. In the first instance, wet or dry sieving is employed, in the second instance a separation vessel is used containing a liquid of the appropriate specific gravity to achieve separation of the lead.

100. The principal thermal methods of recovery vary to some extent but most of them employ a flux and a reducing agent. Recoveries may be low due to losses in fumes and slag matte resulting from the sulphur content of the scrap, although the sulphur may be removed by washing the scrap in a concentrated solution of sodium carbonate. The washed scrap is then smelted in a reverberatory furnace at 800° to 900°C using anthracite as a reducing

agent and a flux of soda ash, borax and fluorspar. There is a 98.5 per cent recovery of the lead and antimony contents with negligible losses to the fumes and slag.

101. In a Japanese patent for the processing of old battery plates and half their weight of antimony slimes (55 per cent antimony), they are heated at 700°C with 5 per cent wood charcoal, 10 per cent sodium carbonate and 10 per cent coal tar. The resulting yield is about 92 per cent with 18 per cent antimony in the alloy.

102. An electric furnace i used in another Japanese patent; 93.5 per cent of the lead is recovered without pre-treatment for the elimination of sulphur. Sulphur dioxide is led from the furnace through a bored graphite electrode.

103. Both natural draft and electric shaft furnaces have also been operated successfully with recoveries of 87 per cent of the lead. In lower temperature operations at 360°C, the melt is mechanically stirred with a flux of sulphur and sodium hydroxide. The advantages of this type of recovery are the relatively low temperature, the high purity of the reclaimed metal, the absence of fumes, low losses and no special apparatus required.

104. Rotary furnaces operating at temperatures of about 850°C can be used. The charge of battery plates is melted with 2 per cent sodium carbonate, 2 per cent coke, charcoal or anthracite, 0.5 per cent sodium chloride and 0.5 per cent cast iron filings. Losses to fumes are high, but if they are recovered in a bag-house and remelted, the yield may be improved.

105. In a rotary drum furnace operation, the charge of battery scrap lead containing 20 per cent (by weight) lead oxides is treated with solid carbon (10 per cent of the charge weight) using 10 per cent sodium carbonate as a drossing agent. The dross-free molten lead is pumped into a refining furnace and treated with sulphur to remove copper. After removing the copper dross, the metal is refined further by treatment with a mixture of sodium hydroxide and sodium nitrate.

106. Electrolytic methods to reclaim battery lead are operative on a laboratory or pilot-plant scale. There may be an opportunity

for developing countries to adopt the electrolytic recovery method in the future.

107. Cable sheath lead resources are fewer and more sporadic than battery scrap. Cable factories tend to use their own process scrap; the scrap that reaches the secondary refiners has usually been stripped from old cables. In this case it is necessary to remove the impurities.

108. In developed countries resources of lead from sheet and pipes, and other miscellaneous uses are steadily received by the refiners, but in the developing countries, these resources are small because these uses of lead are not as widespread. Due to the inhomogeneity of this class of scrap, it is given a comprehensive refining treatment to remove all the common impurities, such as copper, iron, arsenic, antimony and tin.

109. The refining treatment consists of melting the charge in a large cast iron basin equipped with a mechanical stirring device. The dross formed during melting is skimmed off and treated separately. The molten lead is transferred to a refining kettle where copper and iron are removed by the action of sulphur and ammonium chloride. Arsenic, tin and antimony are removed by a sodium hydroxide base flux. Depending upon the scale of operations, the fumes may be treated to recover additional metal.

110. Other patented processes and techniques are available for treating scrap in the form of powder, filings, borings, other miscellaneous scrap and scrap containing other less common impurities. High-bismuth, lead and copper-base waste material may be treated by these methods. Using both aqueous solutions and fused salts as electrolytes, two electrolytic methods have been developed to remove several impurities such as bismuth, antimony, copper and silver.

111. Lead is the principal constituent of foundry type used in the newspaper industry. This is re-cycled several times a day with a progressive depletion of the lead content. After a number of cycles it is returned to the smelter and the composition is adjusted by the addition of suitable alloys.

112. Recovery operations lead to the formation of as much as 25 per cent dross. Several processes have been developed for treating dross. Heating in a reverberatory furnace with sodium hydroxide can produce lead of 93 to 97 per cent purity, while a 65 per cent recovery of lead may be achieved in a rotary drum furnace with sodium carbonate and calcium fluoride. Blast furnace slags have been treated with powdered coal and air and the reduced metals vapourized and oxidized to obtain high percentages of recovered zinc and lead. Slags containing lead oxide have been treated successfully with barium oxide, sodium carbonate and sodium chloride at 200^{o} to $300^{o}C$; the lead separates at the bottom. Fusion treatment of slags with calcium sulphate and sodium sulphate is effective.

113. A two-stage process involves the use of an electric furnace. In the first stage, copper and noble metals are extracted into a matte, while zinc, cadmium, lead and the rare metals are volatilized. In the second stage, the remaining lead and zinc are extracted. Other processes include cementation with carbon-saturated liquid cast iron, electrolytic treatment of slag at high temperatures and leaching with an alkali solution. In the latter process, arsenic, tin and antimony are converted to their respective sodium salts; lead is recovered from the residue.

114. The metallurgical wastes of slimes, tailings, fumes and dusts have widely varying lead content and contain impurities difficult to remove. Although these wastes are difficult to collect, they are of sufficient significance to warrant their treatment. There is a number of thermal, hydrometallurgical and electrolytic processes and patents for recovery methods.

<u>Recovery of secondary zinc</u>

115. The residues formed during galvanizing are dross, ash, flux skimmings and steam blowings when tubes are manufactured. Zinc dross is the most important as it contains a high content of zinc which can readily be extracted. Ash is used in zinc compounds.

116. Dross contains as much as 95 per cent of zinc and is thus a rich source for extraction of the metal. It may be used directly

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for the manufacture of zinc dust by melting and distillation; this simple and low-cost operation requires good control techniques.

117. For the recovery of pure zinc, distillation processes are generally used. The dross is heated to a temperature above the volatilization temperature of zinc, and the escape vapours are collected as liquid metal in a condenser. There are few impurities in the metal; relatively pure zinc with recoveries of up to 95 per cent is obtained.

118. The aluminium process is not widely used. It is based on the principle that aluminium has greater affinity for iron than zinc and can thus displace zinc from the zinc-iron alloy. Aluminium is added to a bath containing zinc scrap and forms compounds with the iron which float on the surface of the molten zinc. A clean separation of the zinc is not possible but separation is improved by a lead treatment. The yield is good if the process is continuous. The equipment required is simple and inexpensive. A centrifuging technique has been developed in connexion with this process.

119. There are other processes for dross such as sweating cut the zinc by liquidation or heating and then decanting the supernatant liquid metal. The methods are simple, but the yield is low and the metal is usually contaminated with iron.

120. The zinc content of galvanizer's ash varies between 70 and 90 per cent. Galvanizer's ash also contains lead, iron, chlorides and other matter. Much of the zinc is in metallic form. The coarser fractions are usually returned to the galvanizing pot through an open cylinder located in a corner of the bath. The heat of the galvanizing pot melts the metal in the ash. The metal then runs into the bath with an 80 to 90 per cent recovery.

121. Generally, however, ash is treated in externally fired crucibles or rotary furnaces with a suitable chloride based flux at a temperature of 400° to 500°C. The ash is stirred gently to break the exterior oxide surface and to allow the molten zinc to coalesce. Recoveries of 80 per cent have been claimed. The spent

ash can be used by the chemical industry to manufacture chemical compounds or by the smelters to recover the zinc.

122. Flux skimmings are residues from the wet galvanizing process and are composed of zinc oxides, zinc chlorides and other chlorides, and some metallic zinc. Generally they are consumed by the chemical industry, but high-purity zinc can be obtained from them. One process involves the reaction of the skimmings with lime, as a result of which zinc chloride and other metals are converted into oxides, and calcium chloride is obtained as a by-product. After treatment in a ball mill with petroleum coke and burnt pebble, the oxide is heated in a graphite crucible containing molten calcium chloride. Zinc oxide is reduced and the metal collected in a condenser.

123. Scrap of old die-castings is usually tested for the recovery of zinc by distillation or used to manufacture zinc oxide.

124. Flashlight battery cells are probably the largest source of scrap zinc sheets, but their collection is a problem. Other residues include sludges from the chemical industry and from alloying and smelting operations in the metallurgical industry. Often, special methods or a combination of techniques are required for an economical recovery.

Economic aspects of the recovery of lead and zinc

125. The economic aspects of the recovery of lead and zinc differ very little from those relative to other non-ferrous metals. There are, however, some special factors involved.

126. Problems in the acquisition of scrap are important in the economics of the secondary metals industry. To illustrate this point, exhausted flashlight batteries are not collected, whereas automobile batteries are collected because the value of the metal they contain makes this worthwhile. Efforts should be increased to recover more of them. There should be growing resources of die-cast scrap, but some is lost because frequently it is mixed with assorted metallic scrap. However, the residues are uniform and command a fair price.

127. In addition to the costs of acquisition and transport, there are costs for sorting and removal of impurities. Good clean scrap requires little sorting and a simple refining treatment. Intermediate operations are necessary prior to the actual recovery processes for lead batteries and also for assorted scrap from machine shops that are mixtures of various metals. The cost of these operations may be the decisive factor in economical recovery.

128. Certain manufacturing processes require virgin metal, and reclamation of articles from these processes produces secondary metal that cannot be fed back and other outlets must be found. An example is die-casting of zinc alloys. In this case, it is necessary to produce zinc or oxides by distillation to compete with other equally suited raw materials such as dross and ash.

129. In general, scrap and residue prices follow the prevailing price for virgin metal; there is a relatively stable balance regardless of fluctuations and scarcity in the market. In some zinc-importing countries, the price of residues is frequently higher than the price of imported virgin zinc in times of scarcity. This situation is often created by the pressure of demand in another consuming industry such as brass manufacture, which may use drosses in its process and is prepared to pay the higher prices. In this event, zinc recovery would be unprofitable.

130. In large countries the freight charges for transport of zinc and lead scrap may be prohibitive, especially if the scrap-producing industry is distant from the secondary metal refiners. Then a plant could profitably establish its own refinery rather than sell its residues.

131. A number of developing countries have a low *per capita* consumption of metals, particularly lead and zinc. They include countries of Latin America, Africa, the Middle East, India and South-East Asia. In their industrial expansion, the consumption of lead and zinc is increasing at a faster rate than that of the world average - from 225,000 tons of zinc in 1961 to an expected 700,000 tons by 1975 and from 180,000 tons of lead to 500,000 tons. These figures indicate the potential of the secondary metals industry in these areas.

132. It is expected that *per capita* consumption of these developing countries will be very much in line with the consumption of the industrialized countries in a decade. In a number of developing countries battery grids are imported, but in others the complete battery is manufactured. The former have little use for the battery scrap resources, while the others use them. Because the collection and reclamation industries have not been developed, less secondary lead is used than in industrialized countries. An opportunity for secondary metal recovery, therefore, may exist, but its economic development is retarded due to the lack of adequate facilities.

133. In developing countries, realization of the need to improve the use of scrap and residues is increasing, but in the absence of technical know-how it is difficult to establish a stable secondary metals industry. Nevertheless, profitable industries have developed, albeit by trial and error, but the rate of progress has been slow even where suitable technical personnel were available. This may be attributed to the reluctance of industrialists to finance unproven projects. The situation will undoubtedly change as larger volumes of secondary metals become available.

134. Lack of foreign exchange prevents imports of lead and zinc in many developing countries. While this suggests a favourable situation for the establishment of secondary metal refineries, there are other inhibiting features such as lack of know-how, instability of prices and uncertain supply conditions; as a result, residues are exported or not used effectively.

Use of copper scrap

135. Copper scrap resources from industrial processes include cuttings, punchings, wire, tube ends, extrusion discards and the like. Little refining is required; this scrap may be melted in crucible, reverberatory, rotary or induction furnaces and used for ingots or shapes. Copper from heavy electrical cables may also be included if it is stripped from the insulation and sheathing and its soldered joints and connexions removed.

136. Plumbers scrap forms a high proportion of domestic scrap. It includes lengths of pipe and tube, cistern balls, water cylinders and boilers and water heaters. Hot-stamped brass, cast brass or gun metal fittings are often attached. Tee-pieces soldered onto the tube and soldered joints are frequently found; if they are melted in the charge, the resulting tin, lead and zinc require additional refining. Where labour costs are low, such components may be cut from the scrap, thereby upgrading it, saving the costs of refining and the waste of tin and lead. The solder-bearing pieces may be melted for the production of gun metal alloys.

137. Where larger quantities of solder are to be found, a simple sweating process, in which the components are heated to a temperature above the melting point of the solder, may be employed to recover as much solder as possible. After sweating, the scrap may be fire-refined to copper or incorporated in the production of gun metals.

138. Tinned copper is found in scrap electrical cables and wires, utensils, and food and drink manufacturing equipment. To avoid waste of the tin, this scrap should be used in the production of bronze for the foundry industry; lead and zinc must not be in the charge.

139. Automobile radiators represent an ever increasing source of copper and copper alloy scrap. They may be sweated to recover solder and afterwards used in the production of gun metal or foundry brass.

140. When labour costs are low, electrical switchgear and bus-bar installations may be broken into small pieces and the non-metallic portions removed. Soldered ends, tinned ends and cable connectors may be cut from them to obtain lengths and pieces of uncontaminated copper. The ends may be used for the production of foundry alloys.

141. Insulated copper wire is a valuable source of copper scrap, but its recovery presents problems of environmental pollution. Mechanical stripping may be used, but the most elementary process is to burn the wire in the open air or in a furnace. Large volumes of black smoke are produced, which are undesirable in densely

populated areas. If the wire is insulated with PVC, chlorine, phosgene and lead oxides are emitted. Under no circumstances should the emitted lead oxides fall upon agricultural land. After burning, the residue is riddled to separate copper from ash. The disadvantages of burning are losses of small particles of copper and severe oxidation of the remaining copper unless the temperature is kept as low as possible.

142. Occasionally locomotive fire-box plate is received at the refineries. As it usually contains arsenical copper with 0.3 to 0.5 per cent arsenic, it can be remelted and used for the production of water pipes.

143. The major resources of copper-bearing residues are from industrial processes and include slags, sweepings, skimmings, flue-dusts and scales. In the secondary copper industry, it is usual to screen the residues and heat them in a simple blast furnace with scrap iron, limestone and coke. The residues may be subjected to agglomeration and charged. The basic operation consists in oxidizing the copper in the furnace and reducing it with the iron of the furnace burden. A black copper is produced which is passed to the converter for further processing, to blister and finally to cathode by electrolysis.

144. Because high-purity mill scales are essentially copper oxides, they can be directly smelted in reverberatory or rotary furnaces using reducing agents.

145. If labour costs are low, electric motors can be broken and the metallic copper removed manually for processing. Otherwise they are processed in a blast furnace. Contaminated brass, bronze and the like are also treated in a blast furnace.

Technology and equipment

146. The use of copper scrap has become a major industry in the industrialized countries and provides almost half of their requirements of copper. Concurrently, with the recovery of pure copper by fire-refining technology and by electrolytic methods, copper alloys such as bronze and gun metal are manufactured and sold as

ingots to the foundry industry. The technology used in the processing plants enables competitive production of secondary and primary metals.

147. Much of the process scrap generated by the wrought non-ferrous metals industry is consumed internally in a refinery's own melting and casting shops, and very little reaches the secondary metal smelter. This scrap is usually rigorously segregated and sold as parcels of uniform quality. It requires little treatment and is used for the production of high-quality rolling slabs and extrusion billets.

148. Scrap from worn out and discarded equipment and consumer goods is generally low grade and is contaminated with tin, lead, iron, zinc, cadmium and non-metallic components. The extent of the contamination determines whether it is to be fire-refined or electrolytically refined.

Sorting and grading of copper scrap

149. Scrap may be delivered to the refineries already sorted and graded to standards prescribed by internationally recognized authorities such as the United States National Association of Secondary Metal Industries (NASMI). Consignments are usually checked to ensure compliance with the standard of scrap purchased. Samples of mixed scrap are melted and assayed. The purchase price is based on copper content, therefore accuracy in sampling and assaying is very significant.

150. Scrap in which the percentage of impurities is low and confined to elements such as lead and tin which are easily removed by fire refining is segregated, batched and refined as a parcel. It is suitable for the production of shapes. Low-grade scrap may be similarly treated for the manufacture of ingots for remelting and alloying purposes. Heavily contaminated scrap and residues in which the percentage of impurities is high (especially elements not removed in fire refining such as nickel), are usually fire-refined to produce a batch of metal that will be homogeneous in character for ultimate electrolytic refining. Where converter facilities exist, scrap may be processed directly in the converter.

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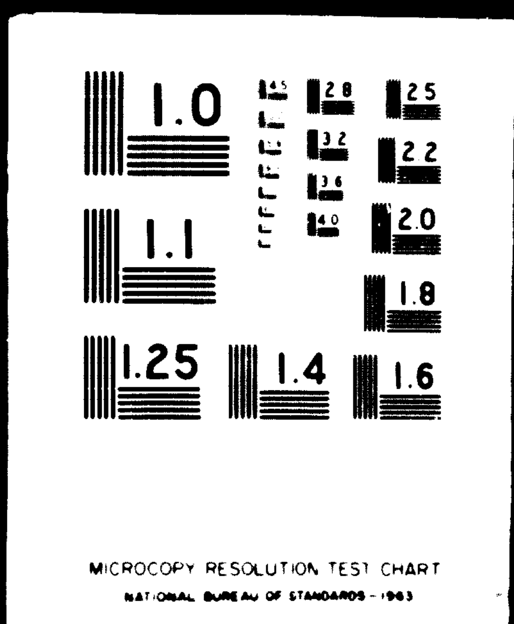
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MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS - 1963

151. Gun metal, brass, bronze and other alloys of copper are generally sorted by the collector and sorted further into batches by the refiners for the production of ingots. Occasionally, the copper, tin and zinc content may be recovered. Other materials of high copper content are concentrated in batches; their copper content and impurity levels determine the most economical refining method, i.e. fire refining or electrolytic refining.

The technology of fire refining

152. The major foreign elements in copper scrap are tin, lead and iron; the quantities present may be reduced in each case to tolerable limits by fire refining. Among the minor elements, cadmium and sulphur are readily eliminated but the removal of arsenic is a rather more complex process. Nickel, on the other hand, cannot be eliminated. The analysis of the parcels of scrap will indicate whether there are non-removable elements in it and the necessary degree of refining.

153. A large refinery will have recourse to linear programming techniques using a high-speed computer to optimize the use of scrap; but this is not necessary in smaller refineries. The composition of the charge is very important; a successful result is obtained only if the sampling and assay have been carried out accurately.

154. The fire-refining process is based on the oxidation of impurities by blowing air through a bath of molten copper. Elements such as cadmium and sulphur volatilize and are eliminated through the furnace flue. Refractory tin, lead and iron oxides float on the surface of the bath and are collected in a slag. The efficiency of the process is controlled by the degree of oxidation; excessive oxidation causes unnecessary loss of copper in the slag. The oxygen content is usually limited to 1.2 per cent for the removal of tin and 0.8 to 1.0 per cent for the removal of lead.

155. Sand is usually the carrier slag for these treatments. It must be completely molten and is completely dispersed in the bath by blowing air through the melt. Once the oxygen content of the bath has reached the figures quoted above, no further blown air is

introduced and the slag is skimmed off. Further blowing merely increases slag losses without oxidation of additional impurity. The melt is now saturated with cuprecus oxide.

156. The cuprecus oxide is reduced to metallic copper by the "poling" process in which green tree trunks are stuck into the molten copper; as they burn under the surface of the melt, the oxygen in the melt combines with the carbon and is released as a gas. An assay is made to determine whether further treatments are necessary. The poling ceases at 0.1 per cent oxygen and blowing is recommenced. The treatments are continued until the impurity levels are satisfactory. After the final poling the tough-pitch copper should have 0.03 to 0.05 per cent oxygen. It can be deoxidized by the addition of phosphorus, if a phosphorus-deoxidised copper is required. Arsenic can be removed by adding sodium carbonate to the melt after the tin and lead have been removed and allowing it to react for about 30 minutes.

The casting of copper

157. Although many secondary copper refineries use continuous and semi-continuous casting methods for shape production, the bulk of wire bars and ingots are cast into horizontal moulds of copper and carried on large casting wheels. These bars and ingots are easy to make, require a minimal amount of machining, and at the end of their useful life they are returned to the furnace. For lower-volume production, high-grade cast iron moulds can be used for ingots, billets and cakes. However, for the latter products, water-cooled copper moulds are preferable. These moulds are coated with a slurry of bone ash for the casting of tough-pitch copper and with a mineral oil and carbon dressing for deoxidised copper.

158. The casting temperature is strictly controlled by the use of immersion pyrometers with precious metal thermocouples; if the product is cast directly from the furnace, a reducing atmosphere is maintained. During casting, the oxygen content of the melt is carefully controlled and the set of the surface of the product carefully observed. In order to cast sound billets and cakes, care and attention must be given to the pouring temperature, the

rate of rise in the moulds, the purity of the metal and the shape of the pouring stream.

Main types of furnaces

159. In general use are rectangular, reverberatory furnaces of up to 400 tons capacity that are fired by oil or pulverized fuel. The burners are located at one end and the up-take at the other. Charging doors are on one side; a poling and skimming door is at the up-take end. A tap hole is on the side opposite to the charging door. A suspended or sprung-arch roof is constructed. The chrome-magnesite hearth usually has spall-resistant fire-brick above the metal line. Self-proportioning burners are generally used with heavy fuel oil for firing; provision is often made in addition for gas oil supply for use during poling and casting.

160. Another popular furnace is the rotary furnace which is extremely versatile and can be used intermittently or continuously. Furnaces of this type are cylindrical and are mounted on rollers to permit rotation, thus increasing the thermal efficiency by bringing the charge into contact with the hot furnace wall. The refractories are similar to those used in reverberatory furnaces, and the refining procedures are carried out in the same way.

161. A third type of furnace is the [illegible] Sklenar furnace, which is essentially a small tilting reverberatory furnace with an interrupted up-take. Oil burners are located in the opposite wall to the up-take; slagging and working doors are on one side wall and a tap door in the other. The charge is lodged in the truncated up-take, where it melts and flows into the hearth. The refractories are similar to those in reverberatory furnaces; the up-take is lined with a high-grade fire-brick. Melting is extremely rapid; a 5-ton-capacity furnace on a 3-hour cycle will readily melt 40 tons/24 hours. The depth of the hearth, however, is not sufficient for rapid poling. This is best accomplished in a holding furnace.

Quality control

162. The metallurgical and economic success of the fire-refining process depends upon the quick and accurate control of impurity levels and oxygen contents. A multi-channel direct-reading spectrograph enables a rapid analysis and an assessment of the efficiency of the refining process. Optical oxygen determinations are easily and quickly carried out to check the proper oxidizing and reducing processes. The secondary copper refinery should also have complete facilities for wet-chemical analysis of other elements than those for which the spectrograph is used. Absorptiometric analysis equipment is useful in the determination of phosphorus. Copper intended for electrical use will require that the conductivity be measured on an electrical bridge. Facilities for etching and examining sections of castings are necessary to ensure the quality of the cast products.

5. QUALITY CONSIDERATIONS IN THE RECOVERY OF NON-FERROUS SCRAP METAL

163. The desired quality of the refined product is determined by the intended end-use and is controlled by the appropriate manufacturing specification. Scrap and wastes of various origins are treated to obtain products of acceptable quality, but there is always an unavoidable scatter in the chemical composition of the principal elements as well as of the impurities. This precludes the use of these materials for the production of wrought products to a large extent, so that the foundry industry is the main customer for such scrap. This is, of course, particularly true for aluminium alloys, brass, gun metal and bronze.

164. The chemical composition must be controlled in order to produce the following required properties:

(a) Good castability and other casting properties;

(b) Machinability;

(c) Mechanical properties;

(d) Corrosion resistance;

(e) Tightness.

Aluminium casting alloys

165. Aluminium casting alloys may be grouped into four major classes for foundry purposes:

(a) Alloys for general purposes;

(b) Corrosion-resistant alloys;

(c) Heat-resistant alloys;

(d) Special alloys for particular uses.

166. In alloys for general purposes machinability and good casting properties are required. Higher hardness generally

improves machinability; this may be engendered by the presence of alloying elements. Non-metallic inclusions must be avoided. These alloys exhibit tendencies to hot-cracking and shrinkage; good foundry practice can prevent these problems.

167. Iron is an undesirable impurity in some casting methods. For castings in sand moulds and permanent moulds other than for pressure die-castings, the iron content must be as low as possible. Levels of 1.0 to 1.5 per cent iron are usually employed when pressure die-casting, as the iron prevents the casting from sticking in the mould. In the manufacture of the ingots for pressure die-casting of secondary materials, the iron content is increased, if necessary, or is retained when present in satisfactory quantities.

168. Copper is a valuable alloying element when it is present between 1.0 and 5.0 per cent with a mean tolerance of about 1.5 per cent. Magnesium increases both the elastic limit and the hardness, but it decreases elongation values and is reputed to impair casting properties. The refiner must control the consistent magnesium content in deliveries because of its effects during casting in the customer's foundry. Other elements, including manganese, nickel, lead, tin and chromium are usually found at allowable limits, 3 per cent zinc may be allowed.

169. Metals that are more noble than aluminium present a danger to corrosion resistance. Copper, nickel and zinc fall in this category, and their contents are strictly limited to 0.05 per cent, 0.10 per cent and 0.15 per cent respectively. The magnesium and silicon contents must be constant to avoid variations in casting properties.

170. Heat-resistant alloys are required in the automotive industry, and consistent quality is important both in the foundry and during service. Good deformation resistance and a thermal expansion similar to that of cast iron are necessary. These requirements are met by alloys containing copper, nickel, magnesium and iron, together with a high silicon content. The Y-alloys are typical. Deoxidants are the only special alloys for particular uses that are made from scrap.

171. Chemical composition is best determined by the direct-reading spectrograph, using standards based on the alloy being tested rather than on standards extrapolated from those for pure materials. These standards should be cast into specimen standard sets under foundry conditions. Analysis of actual ingots should be avoided because of the wide compositional scatter. Other controls are the measurement of gas content and the machining and polishing of sections for the detection of hard spots. Mechanical properties may be controlled by tensile test bars cast in permanent dies.

Copper-base foundry alloys

172. Copper of high conductivity is rarely used in the foundry industry. When copper is used, the usual method is to sort, melt and oxidize the scrap to reduce the zinc and phosphorus content. Tin is rarely removed. The cuprous oxide dissolved in the melt is reduced by the addition of magnesium in the form of 50 per cent copper-magnesium alloy at the rate of 0.05 per cent of the weight of the charge. If this is insufficient, further additions at the rate of 0.01 per cent are made. The copper content is usually 99 to 99.5 per cent.

173. Bronze usually contains 9 to 13 per cent tin. The tin content is carefully controlled because of its high price, and the bronze must be reasonably free of lead. As this element is not easily removed by melting, leaded bronze scrap and lead must not be present in the charge. Zinc scrap is similar in this respect. Other harmful elements are silicon, aluminium and sulphur; iron must also be restricted but nickel is considered equivalent to copper. The presence of gas in bronze is harmful to foundry workers.

174. Brass is used in the foundry for sand casting and for die-casting. Typical compositions are as follows:

> For sand casting, the copper content ranges from 63 to 67 per cent; the lead content is 1.0 per cent; the maximum tin content is 1.0 or 1.5 per cent; the content of silicon, sulphur and aluminium is 0.05 per cent each.

For die-casting, the brass contains more zinc than those for sand casting with a deliberate addition of aluminium to moderate zinc volatilization. The usual copper content is 59 to 64 per cent; the maximum content of lead is 2 per cent; the maximum content of tin and aluminium is 0.8 per cent each.

175. The increasing popularity of copper aluminium alloys bears the risk of their contamination of other alloys. Therefore, these alloys must be carefully sorted from other alloys. Various copper aluminium alloys are used for sand and permanent mould casting. The latter are usually made from virgin metal, however there is a market for secondary ingots used in sand casting. These castings may contain iron, nickel and manganese, but zinc and tin contents must be avoided. The total impurity content may not exceed 0.8 per cent. The maximum aluminium content is 1.0 per cent.

Quality control in the preparation of scrap for recovery

176. The main method to sort discarded articles is manual; the experience of the sorter is very important. The tin content of bronze may be determined by measuring the hardness on a Brinell machine:

Brinell hardness	Tin
Below 80	Below 8
80-95	8-12
95-115	12-14
Above 115	Above 14

Rapid analysis techniques may also be helpful to sort scrap; they include drop testing, electrochemical potential and spectrography, and electrical conductivity measurements.

177. Automatic sorting is used mainly to separate white metal and copper-base alloys. Agitation and screening at a temperature between the melting points of the alloys in a furnace fitted with a rotating screen is very effective.

178. Moisture and cutting oils may be removed by centrifuging, followed by a hot-water wash with cleansing agents. Frequently

the scrap is further dried in a kiln. The magnetic separation of ferrous materials from dry scrap is a cheap and effective sorting method.

179. Briquetting is popular in the copper industry; high-pressure baling presses are in general use. Although it is claimed that baling reduces melting losses, this is open to question. The main advantage of briquetting is that furnace charging is faster, furthermore storage space and handling are more economical for briquettes.

Quality control in smelting and refining

180. Quality control of the fire-refining process for copper scrap has been discussed in paragraph 162 of this report. The bronze refining process of oxidation and reduction is similar to the refining of copper. The process may be employed with or without slag, but better ingots are produced with a slag layer, 5 to 10 cm thick. The slag can be used for several melts; its fluidity is maintained by the addition of fluorspar. A typical slag is formed from the following chemicals:

	per cent
Borax	15
Calcium carbonate	25
Sodium carbonate	35
Silica	25

Without slag, the refining process proceeds by progressive oxidation by air of iron, zinc, silicon, manganese and aluminium. Some oxides that adhere to the lining are removed by washing the furnace with a flux of sodium carbonate and silica; the metallic silicates are reduced by the addition of pulverized coal, and the metals recovered. The final reduction is achieved with phosphorus additions. The sulphur is removed by sodium carbonate or by the addition of magnesium.

181. Careful control of refining is necessary, particularly at the oxidizing stage, to prevent the loss of tin, zinc and lead.

182. brass is generally melted in batches by the smelter. The process is simple as there is no gas pick-up. Sodium chloride added at the end of the melt is a good cleansing agent.

183. Aluminium copper alloys are melted under slags of cryolite or calcium fluoride. If manganese is present, manganese chloride is used as a slag; it degasses strongly and may therefore introduce more manganese into the melt. As impurities are not eliminated, the sorting of scrap must be accurate.

184. There are several aspects to quality inspection. To ensure homogeneous composition, all ingots of a single delivery to a foundry should be from the same charge or melt. The direct-reading spectrograph is recommended to control chemical composition. Because of its speed, it is useful to determine changes in the composition. Solidification under a reduced pressure of 150 grams of liquid metal from the melt is useful to check whether degassing has been completed. The surface of the ingot bar must be inspected to ensure that splitting has not occurred. Fracturing a slice from an ingot may reveal spots, blow-holes and the presence of slag.

Annex 1

LIST OF PARTICIPANTS

Apart from the experts participating in the meeting, the following 26 persons attended as observers. The four UNIDO representatives who participated are also listed below.

Observers

ALGERIA:	Tahar Abdelmoumem Saad Nasri
AUSTRIA:	Walter Bazant-Hegemark Gerhard Czadek Heinrich Götz Hans Reichert Friedrich Schäfer Julius Stainer
HUNGARY:	Fülöp Balazs
INDIA:	Parmeshwari Dayal
ITALY:	Luciano Marchesi Giordano Vitali
POLAND:	Roman Balaj
ROMANIA:	Petre Marcu
SPAIN:	Jose Luis Sobrino Vicente Fernando Toca Abascal
TURKEY:	Tumer Özenc
USSR:	I. K. Bakheev
YUGOSLAVIA:	Franc Drozg Radovan Pikojević Jelena Kabilic Dragan Perišić Dragomir Putnik Ferdinand Repovš Žarko Stajić Marija Tomašek

United Nations Industrial Development Organization

I. H. Abdel Rahman, Executive Director

Igor Rothblum, Deputy Director,
Industrial Technology Division

L. Correa da Silva, Chief,
Metallurgical Industries Section

Christo Popov, Member of the Staff,
Metallurgical Industries Section

Annex I

LIST OF PAPERS PRESENTED TO THE MEETING 1/

ID/WG.46/1	Agenda
ID/WG.46/2	Problems of secondary lead and zinc utilization, by M. Parthasarathi
ID/WG.46/3	Opportunities in the production of secondary non-ferrous metals, by M. Spendlove
ID/WG.46/4	Search after appropriate quality for ingots of secondary non-ferrous metals and alloys destined for casting, by C. Hacord
Add.1	Policies, incentives and programmes
ID/WG.46/5	Problems of quality in processing secondary non-ferrous scrap metal, by N. Chakrabarti
Add.1	Pattern of future development of the secondary non-ferrous metals industries in developing countries
ID/WG.46/6	Utilization of copper scrap: technology and equipment, by D. Davies
Add.1	Possible policies and measures for the creation of copper scrap facilities in developing countries
ID/WG.46/7	Sources of non-ferrous scrap metal and alloys and their preparation for melting and reclamation, by L. Prunescu
Add.1	Recommendations and proposals
ID/WG.46/8	Utilization of aluminium scrap: technology and equipment, by J. Jakubi
Add.1	Specific suggestions for establishing scrap recovery facilities

1/ A limited number of copies are available upon request.

ID/WG.46/9	Economic aspects and significance of the utilisation of non-ferrous scrap in developing and developed countries, by J. Ditko and K. Tomko
ID/WG.46/10	Methods of melting non-ferrous scrap metal and possibilities of their application in developing countries, by M. Istrin

[illegible]

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Problems of secondary lead and zinc utilisation

by M. [illegible]

Availability of raw materials for secondary lead and zinc depends on the consumption of primary metals for various applications and also on the proportion of scrap or residues arising from each of the end-products. Lead acid batteries and cable sheathing are the chief sources of secondary lead, while galvanising residues, die-casting scrap and zinc sheets are the important sources for secondary zinc.

A major portion of the secondary lead is derived from battery scrap. The collection of batteries is a well organised sector of the secondary metals trade which receives a steady supply of old batteries for the reclamation of lead. Numerous patents and processes are available for the recovery of lead from battery scrap either as a metal or as an alloy of antimony. These include thermal and electrolytic processes: each of them has advantages, disadvantages and a limited application. Plumbing fixtures and strippings of cable sheathing and old sheet are also good sources of secondary lead; the refining of such scrap is usually simple. Treatment of other lead-bearing residues such as dust, fumes, slags and the like is complicated and very often requires expensive preliminary processing and complex smelting and refining procedures.

Although galvanising residues such as zinc dross and ash are good sources of secondary zinc, they are often used as raw materials for the production of zinc dust, zinc oxide and other compounds of zinc. Production of secondary zinc from galvanising residues is predominantly confined to thermal techniques, although electrolytic processes are also occasionally employed. Zinc sheet scrap is easily processed by simple refining techniques, while die-casting scrap is usually treated by the same methods adopted for zinc dross. Zinc from flashlight batteries is generally not

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recovered because of difficulties in collection and separation of the metal.

The economics of the recovery of secondary lead and zinc are largely dependent on three important aspects of the secondary metals trade. These include the collection of scrap, the separation of the metallic content from other substances and, lastly, refining or smelting of the scrap and residues. Each of these stages contributes to the final cost of the secondary metal; there are instances where secondary metal recovery is uneconomical due to excessive cost or practical difficulties in connexion with one or more of the above aspects. In addition to these main considerations, factors such as the end-uses of the secondary metals, stability of price and freight charges have an important bearing on the method of use of scrap or residues.

The pattern of consumption of lead and zinc and, consequently, the use of scrap in developing areas differs from that in highly industrialised countries. A number of developing countries experience a shortage of the two metals. Thus, while conditions are favourable for the reclamation of secondary lead and zinc, there are numerous factors that obstruct the establishment of a stable secondary metal industry such as an inadequate supply of raw materials, erratic prices, lack of know-how and equipment, and foreign exchange difficulties. However, various steps can be taken to overcome these obstacles. Government assistance and encouragement may be needed.

Opportunities in the production of secondary non-ferrous metals

by M. Spendlove

Recently discarded durable metal goods manufactured some ten to fifty years ago comprise a substantial part of the raw materials currently processed by secondary smelters. Opportunities in the current industry must be found therefore for processing these old materials as well as the new scrap being generated by manufacturing plants. Since the scrap materials of tomorrow are being manufactured as durable goods today, the potential future benefits are considered. It is shown that these metal materials are accumulating as goods-in-use in the United States and are collectively reaching enormous proportions. They comprise a growing metal resource. Documented data on the actual quantity of scrap materials processed annually show that these materials supply a large part of the total metals consumed. The record also shows that primary and secondary metal production rise and fall approximately in unison, and, for some commodities, the fraction of metal supplied from scrap appears even to be increasing slightly more rapidly than primary metal production. Such data may be useful for estimating the profitable scale of operations in a developing country simply by comparing its level of industrialization with comparable reliable data published by other countries. The ratio of profitable secondary metal production for two countries should be approximately proportional to the ratio of their levels of industrialization. Such a comparison of data would simply indicate the total volume potential, but the economic potential could then be estimated in accordance with domestic capabilities and other assets. Accordingly, opportunities in the production of secondary metals would be found through several means, such as judicious management, adopting only the most advanced and efficient technology and possibly negotiating suitable trade agreements. Several typical examples of interesting possibilities are discussed including distillation, electrometallurgy, mechanical separations and chemical processes.

Search after appropriate quality for ingots of secondary non-ferrous metals and alloys destined for casting

by C. Mascré

The economic and juridical aspects are considered to be of great importance for the recovery of secondary non-ferrous metals. The foundry industry can use alloys of relatively scattered composition and is, therefore, an important consumer of secondary non-ferrous metal alloys. The qualities of different aluminium- and copper-base alloys are described in the paper. The influence of a number of chemical elements on these qualities is discussed. In addition, the sequence of technological requirements for the production of ingots from different non-ferrous alloys is explained in some detail. The equipment and furnaces used are also briefly described. The paper deals mainly with the quality, inspection and control of ingots destined for the foundry industry.

Problems of [illegible]
non-ferrous [illegible]

[illegible]

For effective recovery and use of secondary non-ferrous scrap metal, the necessity and importance of maintaining judicious quality control in every step from the beginning of collection, identification and segregation to the melting has been discussed and highlighted in the paper.

One of the striking features of the rapid growth of the non-ferrous metals industry in recent years is the effective recovery and use of secondary metal to an extent of 20 per cent and more of the total production of important primary non-ferrous metals such as aluminium, lead, copper, zinc, tin and nickel. In the United States, secondary metals account for 42 per cent of the total production. With an ever-increasing necessity for recovering secondary non-ferrous scrap metal, more attention is being paid to the questions of acquisition, identification, segregation and processing of the available resources. Non-ferrous ore deposits in India are small. Therefore the current Indian production of major non-ferrous metals is negligible, and the bulk of the country's demand is satisfied through imports. After an analysis of the country's future demand and production pattern, the paper stresses the importance of a planned programme for effective recovery and use of secondary non-ferrous scrap metal by all possible means. This problem was correctly approached by the National Metallurgical Laboratory of India at Jamshedpur by considering, on a priority basis, research and development work on the recovery of aluminium from dross and other scrap sources, as well as copper from secondary materials by melting and electro-metallurgy. This work may serve as a guide to large-scale industrial recovery of secondary aluminium and copper. The paper then describes the various sources of aluminium and copper scrap and alloys and discusses their characteristics and qualities. Several methods of extraction and recovery are suggested. Various methods of recovering metal or alloy aluminium from dross and skimmings, furnace scrap, rolling scrap, fabrication scrap, cold aluminium wire, foils, discarded utensils including various aluminium-alloy scrap from borings, turnings, drilling, millings and Duralumin have been discussed. The operation of suitable types of furnaces is also discussed. The paper includes similar discussions on the availability of fabrication copper scrap and other mixed copper-bearing scrap containing 15 to 75 per cent copper and processes for their recovery. The effect of furnace atmosphere during melting of scrap metal, with particular reference to hydrogen, oxygen, water vapour and refractory lining in relation to product quality has been clarified. Finally, the paper stresses the importance of maintaining meticulous quality control in processing non-ferrous scrap metal at every stage of operation from the initial source of the scrap through the manufacture of the finished product. This should be accomplished through the application of modern metallurgical testing equipment such as metal spectroscopy, direct-reading spectrometer, X-ray florescence spectrometer or through a conventional analytical-chemical laboratory set up under the guidance of an experienced metallurgist.

Utilization of copper scrap: technology and equipment

by D. Davies

The paper is essentially a practical guide for the recovery of copper from scrap. An attempt has been made to reveal the potential use of fire-refining methods as compared to electrolytic refining for the production of copper shapes for subsequent working. In this way, the maximum use of a valuable asset is to be realized with its considerable contribution to the copper-consuming sector of the economy.

The fire-refining process is well known and is well documented in metallurgical literature; therefore, no attempt has been made in the paper to deal with the purely metallurgical considerations of the process. Emphasis has been placed upon the practical aspects of the operations to suggest the scale of operations required and to indicate the ancillary and supporting activities of scrap collection and sorting, which must precede the actual refining process.

An indication has been given of appropriate equipment for the establishment of a refining operation for certain levels of activity. In this regard, the paper has been generalized to present a common form of good practice that is appropriate for very small to comparatively large installations.

Sources of non-ferrous scrap metal and alloys and their preparation for melting and reclamation

by L. Frumosu

The paper deals with sources and the importance of non-ferrous scrap metal. It is particularly important to determine the origin and classification of scrap metal in order to ensure adequate storage and transport after collection.

In the most effective use of secondary metals, the manufactured end-products are similar in composition to the material salvaged.

Better extraction yields can be obtained by:

(a) Knowledge of source and composition of scrap metal;

(b) Classification of scrap metal in accordance with quality standards; (This proves the importance of compulsory classification standards. A standard for non-ferrous scrap should consider the quality requirements demanded by the processing plant.)

(c) Procedures for acceptance, handling, transport and storage to avoid any possible contamination;

(d) Organization of enterprises for collection and delivery of scrap metal to the processing plants;

(e) Organisation of preliminary treatment of scrap metal to ensure quality requirements for full reclamation of useful metals.

Some of these points are applicable to the source of scrap, some to the collecting enterprise and others to the processing plant.

The paper discusses the scrap collected in Romania, its sorting by collecting enterprises and the specialised scrap processing plants. The following groups of scrap metal are discussed:

(a) Copper and its alloys;

(b) Zinc and its alloys;

(c) Tin and its alloys;

(d) Lead and its alloys;

(e) Aluminium and its alloys.

The characteristics of scrap metal in the following three forms are given:

(a) Scrap metal in pieces;

(b) Cuttings;

(c) Scrap oxides.

The preparation of scrap metal for melting and reclamation is the main theme of the paper and therefore the preparation schedule of the base metal is presented in detail. The technology and a flow sheet of the process are given; future trends are outlined.

The experience of the specialized NEFERAL plant for scrap processing is described; the efficiency of its technology is indicated. Scrap metal of aluminium- and copper-based alloys is prepared by pyrotechnical control, sorting, dismantling and baling by special equipment. Cuttings of aluminium- and copper-based alloys are prepared by the following steps: breaking, degreasing, removal of iron and briquetting. Due to deficiencies in the degreasing technology using rotary drums, modern methods of degreasing with solvents have been tested.

In the preparation of lead and lead alloy scrap, special equipment is used to dismantle power cables and to crush tubes. Oxide scrap containing copper and lead is prepared by agglomeration or briquetting; oxide scrap containing aluminium is prepared according to mechanical or hydromechanical technology. Old batteries are usually prepared by dismantling and sorting. Physical-chemical methods for quick analysis have been introduced parallel with the application of modern technology.

In conclusion, it has been noted that rational primary preparation is vital for an economic reclamation of non-ferrous metals. The importance of these activities in developing countries has also been pointed out.

Utilization of aluminium scrap: technology and equipment

by J. Jakobi

This review of the aluminium scrap smelting industry deals with the nature and origin of the raw materials. Methods of preparation are described to show how to upgrade scrap in order to make alloys of higher values than would be possible from the unprocessed scrap, thus providing uniform furnace charges and achieving maximum productivity. The various furnaces in current use and the metallurgical aspects of smelting and alloying are described.

Recommendations are made for the disposition of scrap depending on the volume of the resources and the scale of operations planned. Although quantities mentioned are in respect to aluminium scrap, it is suggested that some facilities can be designed to treat other non-ferrous metals; then more advanced equipment can be justified where the resources of aluminium alone are insufficient. Similarly, partial preparation of scrap in a number of areas prior to transport to one smelting unit may be desirable in developing countries. If there is only a small market for foundry alloys, rough re-melt ingots may be the most suitable product to export for the production of a variety of higher-value ingots. For quantities of less than 500 tons *per annum*, direct sale to the best market should be encouraged.

The size and scope of the industry in developing countries will grow in proportion to the general industrial development, but they will be particularly dependent on the manufacture and consumption of such articles as durable consumer goods, aluminium components in modern buildings and aluminium-based electrical transmission equipment. The gradual increase in scrap generation will limit the size of the scrap smelting industry.

As foundries are established to meet the demands for aluminium alloy castings, the output of smelters will change from the early stages of simple re-melt ingots for subsequent processing and alloying to production of specification alloy ingots that require close control and up-to-date techniques. The number and size of individual plants will depend on the geographical distribution of industrial concentrations; smaller and more numerous operations will be desirable if the distances between centres are great. A few large factories will be more viable if the centres are close to each other.

The furnaces, handling and processing equipment, production techniques and laboratory control mentioned in this paper have all been developed in Europe and the United States to meet their operating and commercial requirements. For plants in countries where they would be entirely new ventures, local conditions may present opportunities and problems that could well lead to modifications and improvements in existing practices. The circumstances and the types of scrap available are continually changing. It is therefore important that an installation should be capable of adaptation to suit the widest range of demands that may be made.

Economic aspects and significance of the utilization of non-ferrous scrap in developing and developed countries

by J. Dutko and K. Tomko

Non-ferrous scrap metal in various forms is an important source for the production of secondary metals. In general, developments in this branch of metallurgy have resulted from a decrease in the percentage of valuable metals in the existing ore reserves as well as from the increase in demand and market prices.

The most effective means of establishing a domestic metal supply as a base for further development of industry in the developing countries is considered to be the collection and processing of non-ferrous scrap metal.

The technology of processing the scrap into usable metal is generally a simple one. In a number of cases it does not require large capital investments; the total expenses for processing usually is only about 25 to 35 per cent of the expenses necessary for production of the primary non-ferrous metals.

This paper points out the economic aspects and possibilities for the development of a secondary non-ferrous metals industry in the developing countries.

Methods of melting non-ferrous metal scrap and possibilities of their application in developing countries

by W. Petrie

The paper presents statistical data on the increment of production of non-ferrous metals in developing countries, the prospective growth of the consumption of non-ferrous metals and the present and possible future sources of secondary non-ferrous metals in these countries.

Various methods of melting scrap and wastes of non-ferrous metals and some technological requirements are also briefly described. The paper deals primarily with the equipment and furnaces employed in the processing of non-ferrous scrap metal of different origins and sizes. In each case, specific mention is made of the equipment most likely to be suitable for the conditions prevailing in a particular developing country. Some technical characteristics of the furnaces in use are also given.

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