COMMISSION OF THE EUROPEAN COMMUNITIES
DG XII – RESEARCH, SCIENCE, EDUCATION

RAW MATERIALS

RESEARCH AND DEVELOPMENT

STUDIES ON SECONDARY RAW MATERIALS

II. RECYCLING OF NON-FERROUS METALS

February 1979

XII/108/79

SUGGESTIONS FOR FURTHER RESEARCH

(by ITE in cooperation with SGM and CERIMET)

By viewing the various products and product groups with regard to technological problems of recovery, it may be stipulated that certain common features exist in spite of many differences in size, metal input and availability of products. The major technical constraints on recycling of non-ferrous metals are concerned with their separation from materials in the waste stream, from other materials added during the manufacture of the product or from other elements in alloys.

On the other hand, regarding the efficiency of scrap collection, two different sources should be distinguished. Production waste as well as old scrap arising within the industries are usually recovered as far as feasible at given technology and prices of secondary metals. In contrast, products becoming obsolete within the household sector are normally disposed of in household refuse and therefore, at present, hardly recovered. This second source evidently offers the more important potential for additional recycling.

1. Aluminium Recycling

Some of the most important problems are: the increasing complexity of scrap to be converted into secondary alloys; the call for reduction of energy consumption and of labour requirements; the control of pollution related to some operative methods used in secondary aluminium metallurgy.

- For some methods in the field of sorting and dressing further improvements are to be expected, as additional experience from industrial practice can be used. Entirely new approaches might, however, be tried for some of the processes: For instance the results of conventional shredding applied to unsorted scrap armoured or oil-filled cables. A future development might possibly consist in adapting some of the existing methods for treating lead sheated cables by modifying the desintegration process, and complementing it with the separation of lead from the other metals. The possibility of a cryogenic grinding has to be pointed out in which lead is subject to embrittlement. Of course, the economical factors are prevailing on all other ones.

The recycling of scrapped lead in its more sophisticated forms, like batteries and cables, gives rise to a number of pollution problems, mainly air pollution, owing to the emission of sulphur dioxide and of chloridized fumes, but also water pollution, in view of the lowest lead levels in streams, tolerated by law regulations. The last referred factor might cause law infringement, when dumping materials, even slightly contaminated by lead compounds.

Under such conditions, future development might come off as follows:

- Improvements in retreatment and recovery of sulphurized-chloridized fumes, to be accomplished possibly in one plant, jointly owned by many smelters, and operating e.g. by hydrometallurgical methods.

- Replacing pyrometallurgical methods for treating battery active masses and other lead oxides and compounds, with other partially or totally hydrometallurgical methods, thus reducing air pollution and possibly hindering also water pollution.

The trend to substitute hydrometallurgical methods for pyrometallurgical ones is already to be observed in the primary lead metallurgy, though in limited amount until now.

Attempts might be made - within the hydrometallurgy research work - to produce high value lead oxides or compounds directly from recycled material, avoiding the reduction to metal, by using special selective reagents or by purifying lead salt solutions.

The economic advantages of such an approach are apparent.

3. Copper Recycling

To increase the copper recycling, main aspects are:

- To make the scrap more homogeneous, new techniques should be developed, although some new processes, like cable chopping or car shredding, are already applied on a large scale. Important progress is still to be made to generalize such methods to mixed scrap.

- A type of scrap to which more research work should be applied is low-grade "irony" scrap, such as electric motor scrap or copper-steel residues from car shredders.

- Cryogenic grinding is a new way of processing some types of scrap, but its economics are still uncertain, being too dependent on the price of the cooling agent. An estimation of the conditions under which such operations are profitable could help assessing the future of this method; scrap and copper prices, choice and price of the cooling agent, size of the cryogenic plant, etc. should be taken into account.

- For secondary copper smelters and alloyers, a reduction of the treatment costs depends primarily on furnace operations. Methods like oxygen enrichment of the air, air preheating, natural gas poling, are to be studied further to be applied on a large scale.

2

- The improvement in the recovery of by-products from copper scrap and of the proportion of copper recycled from the converter to the blast-furnace as a slag, should also be increased.

- Electrolytic refining should also be the subject for research on the way of treating anodes produced from very impure blister copper or complex scrap. In some cases, this might allow to avoid either a preliminary refining, or the production of second-quality copper that is more difficult to utilize.

4. Zinc Recycling

To increase the zinc recycling research work, one should concentrate on the recycling of galvanized products and zinc die castings. In addition zinc recycling from products such as batteries or tyres might be of interest.

- In the case of zinc recovery from galvanized products, there is at present only one direct process of recovery, the Prayon process. However, under present conditions the process is not yet applicable. On the other hand different processes for the treatment of iron dusts and sludges dusts have been developed. These dusts and sludges are of various origins:

  - blast furnaces
  - converters
  - open-hearth and electric furnaces.

  The industrially most elaborate process to retreat iron dusts consists in the direct reduction of these dusts in a WAELZ-type rotary furnace. The economics of this process would moreover require Zn-rich dusts. The processing of ordinary blast furnace dusts (4-5 % Zn) would not be economical. However, up to now only small quantities of zinc are recovered from galvanized products, mainly due to economic reasons.[1]

- Next to galvanized products, still important and yet hardly utilized sources of zinc recycling are zinc die castings which are primarily used in the motor car industry. The recycling difficulties of these products result from their widespread applications especially as small parts. So far, larger quantities have only been recovered from motor cars. Recycling from other product areas is still very small because of disposal in household refuse and separation difficulties.

- So far, zinc recycling from primary batteries has not been feasible, since obsolete cells are disposed of in household refuse and are either dumped or incinerated. Other problems are related to the mechanical separation of batteries.

- As for the zinc oxides used in tyres, there are several techniques of recycling. At present, only small quantities are recovered in F.R. Germany. How far recycling in this field will actually increase in future depends largely on the choice of technology. This decision is subject to economical factors whereby zinc recovery plays only a subordinate role.

5. Tin Recycling

By far the most important individual area of tin application - as regards additional recycling - is packaging, i.e. tinplate from old cans. For many years the new scrap resulting from the production of tinplate and especially cans has been recycled. However, much larger quantities of old tin-containing materials have remained almost unused.

---

[1] It must be pointed to the fact, that besides research for a better product from flue dust processing, there exists the need for an economically feasible method for recovery of zinc from galvanized steel scrap before this scrap enters the steelwork furnace. The economic advantage of such a process would not only lie in the zinc recovery, but also in the upgrading of steel scrap.

- They get into industrial and domestic refuse and are only rarely recycled. At present, recycling usually takes place only in the form of steel recycling. The recovery of tin from used tinplate packaging is up to now subject to research efforts undertaken in nearly all industrialized countries. The main obstacles to the salvaging of used material are the collection and processing problems; the detinning process itself seems to be less problematic, as the technique is principally the same as in the case of production wastes (new scrap).

- The tin content of alloys such as white metal (bearings), solder, bronze, etc. is already recycled to a comparatively large extent. But most tin recycling processes in this field result in "Mischzinn" or similar lead and tin containing alloys which are reused as alloys. It seems to be appropriate to emphasize the problem of high grade tin separation from tin-lead-alloys in an economic way as one of the most relevant and necessary developments in this area.

COMMISSION OF THE EUROPEAN COMMUNITIES

(Directorate General XII - Research, Science, Education)

IDENTIFICATION OF AREAS FOR R & D ACTIVITIES TO INCREASE THE RECYCLING OF NON-FERROUS METALS

Report prepared on the basis of data provided by

DEUTSCHES INSTITUT FUR WIRTSCHAFTSFORSCHUNG (DIW), BERLIN
AND INFRATEST-INDUSTRIA, MÜNCHEN

Authors

ITE : Mathias Lefeldt, Herbert van Gerpen, Knut Bäse

DIW : Detlef Filip, Renate Filip-Köhn

INFRATEST-INDUSTRIA : Arpad Geissler

Institut zur Erforschung technologischer Entwicklungslinien
Neuer Jungfernstieg, 21
2000 Hamburg 36
(Federal Republic of Germany)

January 1978

CONTENTS

TABLES

FIGURES

Introduction

In COM (75) 535, final of 29.10.75, on "Objectives, priorities and means of a common policy of research and development", the Commission proposed among other things that recycling of scarce materials be retained as Community priority for the coming five years. In this context the "Subcommittee CREST R&D raw materials" has examined the situation in the Member States and concluded that an outline of Community R&D activities should take into account the findings of techno-economic studies in this field. Among such studies one should cover the recycling of non-ferrous metals.

As outlined in the annex of the research contract underlying this study, the analysis should determine the recovery potential of used materials, on the basis of the metal content of finished products, taking into account the present technology for recovery of old scrap.

ITE, Société Générale des Minerais (SGM), Belgium, and Cerimet Italy, in joint efforts prepared a survey of recycling technologies, consisting of three volumes in total. In addition ITE developed a quantitative framework with respect to recycling potentials of aluminium, lead, copper, tin and zinc. As for the material-flow-data for the German economy ITE based this analysis upon input/output-data provided bv Deutsches Institut für Wirtschaftsforschung (DIW), Berlin, and INFRATEST-INDUSTRIA, München.

The material flow, the assessment of the potential of old scrap and, finally, the identification of areas for R&D activities to increase the recycling of non-ferrous metals are subject of this fourth volume of the complete study. It should be noted, however, that this work employing input/output-tables for following the detailed material flow through the economy had the character of a pilot-study from the very beginning. In order to keep the efforts necessary to cope with the input/output-approach in reasonable limits, this part of the study was confined to F.R. Germany, where basic data for 1972 were available. For a more recent year such as 1976 estimates can only be derived from the 1972 table upon the assumption of stable input/output-relationships. They are shown in appendix B for reference purposes.

1. Selection of non-ferrous metal containing products on the basis of input/output-tables

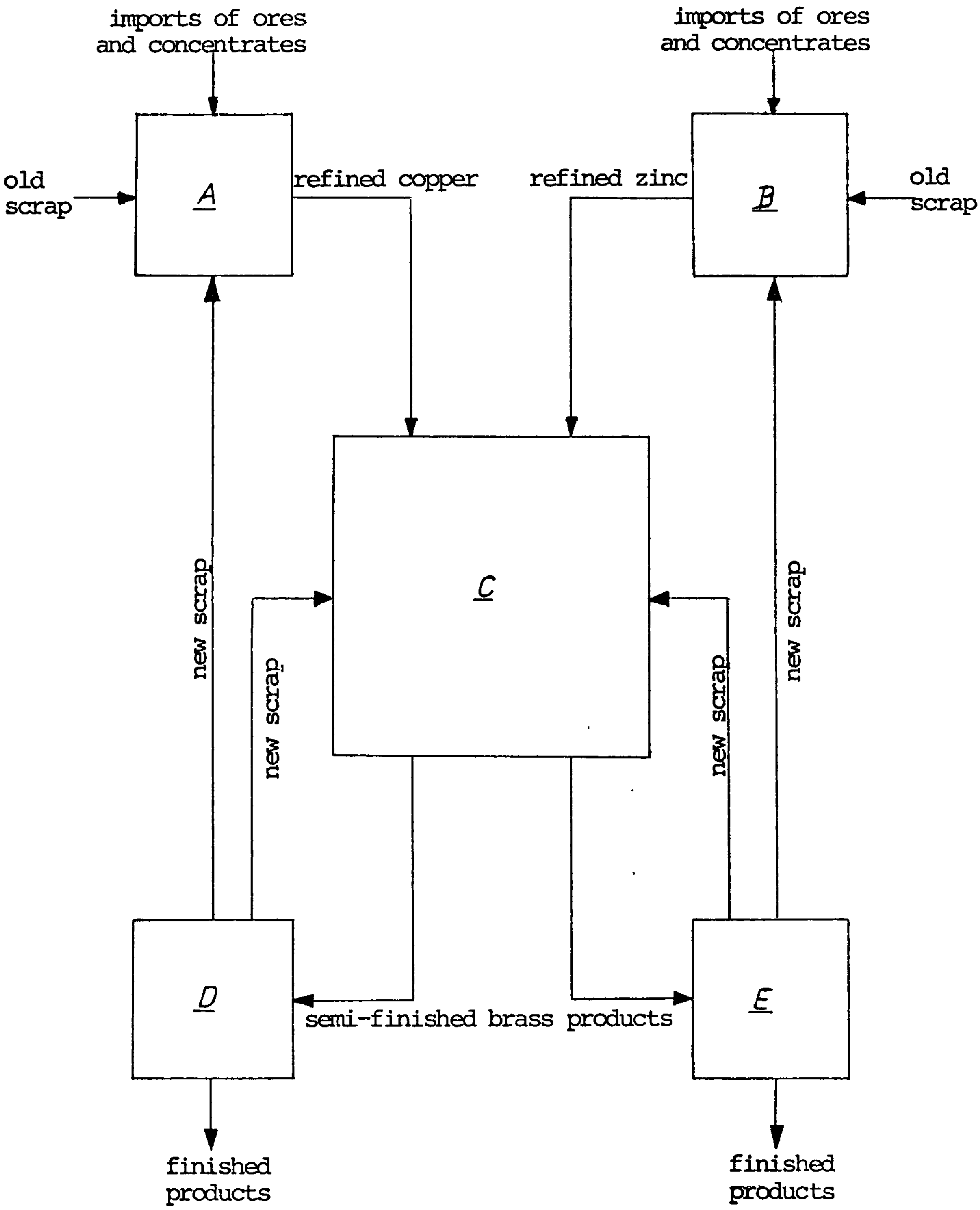
1.1. Preliminary remarks on the input/output-matrix

1.1.1. The relationship of an input/output-matrix

Each individual branch of an economy - an economic sector - is related to the other. The production of sector A - e.g. smelter production of copper - is needed for the production of sector C - e.g. the production of semi-finished goods made of brass. Besides, sector C may also have to procure products of sector B - e.g. smelter production of zinc. Such necessary procurements from sectors A and B for production in sector C are called intermediate inputs. Apart from procurement issues (as viewed by C) there are also supply aspects concerning A and B: this flow of goods will be called deliveries. However, neither is sector C only a receiver of intermediate products nor are sectors A and B exclusively delivering sectors: sector C delivers its production (semi-finished brass ware) to the sectors D and E (e.g. production of taps, cocks and valves). Yet, production scrap arises in these sectors through manufacturing and is delivered back to A and B (copper smelter, zinc smelter), if possible to C (industry of semi-finished goods). Again to the receiver this is intermediate input and to the supplying sectors deliveries (see Figure 1).

These mutual relationships between individual sectors of an economy - called intersectoral production relationship - are drawn up in a two-dimensional matrix in which all sectors are listed on the one hand as suppliers (by line) and on the other as receivers of intermediate products (by column).

Figure 1: INTERLOCKS OF DELIVERIES AND SUPPLIES BETWEEN FIVE PRODUCTION SECTORS



A = copper smelter
B = zinc smelter
C = brass-semis plant

D = production of taps, cocks and valves
E = production of locks and fittings

Table 1 gives an example of such intersectoral production relationships for five sectors.

Table 1: THE INTERMEDIATE PART OF INPUT-OUTPUT-TABLES

		Purchasing sectors					
		A	B	C	D	E	Σ
Delivering sectors	A	aa	ab	ac	ad	ae	a.
	B	ba	bb	bc	bd	be	b.
	C	ca	cb	cc	cd	ce	c.
	D	da	db	dc	dd	de	d.
	E	ea	eb	ec	ed	ee	e.
	Σ	.a	.b	.c	.d	.e	..

Apart from these intersectoral production relationships there are also so-called intrasectoral relationships. These are shown by the flow aa, bb, etc. (see Table 1). They refer to deliveries within a sector which may be caused by specialization of individual companies (e.g. a producer of semi-finished goods may deliver its manufactured copper rods to another which processes them to wire).

The sum of deliveries (a., b., ...) to other manufacturing sectors is called intersectoral or intermediate output or intermediate demand, respectively; summed up column-wise (.a, .b, ...), the aggregates are called intersectoral or intermediate input.

This intermediate section of an input/output-matrix is most important. However, it must be supplemented because

- on the one hand, not all deliveries of a sector must necessarily be transferred to another manufacturing sector; moreover, they can also be demanded by domestic and foreign consumers or investors[1] and, thus, be turned over to final use;
- on the other hand, not all intermediate products are procured from other domestic manufacturing sectors, but can also be imported.

The matrix of input/output-relationships between individual sectors of an economy, as shown in Table 1, must therefore be supplemented by sectors which account for these aspects: consumption, investment and exports are added as receiving sectors. The lines of intermediate output must be supplemented so as to include procurements from abroad (imports); in the view of the receiving sectors this is primary input.

The complete input/output-matrix is shown in Table 2. The entire raw material flow may be outlined as follows: the copper smelter A procures its raw materials partly from the foreign country M, and partly from domestic sources (e.g. new scrap from copper manufacturing industries). The intermediate products leave the smelter as blister or refined copper and are delivered partly to further manufacturers(e.g. the producers of semi-finished goods), partly for export. Only the former remains in the process of domestic manufacturing. The producers of semi-finished goods themselves process the

---

1 Intermediate products and investments are basically different: Whereas intermediate products are directly used for a product, investments serve for the manufacture of a product.

copper and deliver it to further domestic sectors, or export it. Now, the supplied sectors may produce locks and fittings, etc. Again, these are forwarded in part to intermediate demand of other sectors (e.g. mechanical engineering), but also in part to final use (consumption, investment or exports). The flow is not completed as long as deliveries are made to further manufacturing sectors: it ends when deliveries are totally turned over to final demand.

TABLE 2: BASIC OUTLINE OF AN INPUT-OUTPUT-TABLE

		Purchasing sectors						
Delivering sectors		A B C D E	Σ Intermediate demand	Consumption	Investment	Export	Σ Final demand	Total demand
	A B C D E							
	Σ	Intermediate Inputs						
	Import	Primary input		Imports for final demand				
		Gross production						

1.1.2. The role of input-output tables within the study

In a raw material flow analysis completed for the Bundesministerium für Wirtschaft (Federal Ministry of Economics), the Deutsches Institut für Wirtschaftsforschung (DIW) together with INFRATEST-INDUSTRIA drew up a comprehensive input/output-matrix for internal use. Employing the latest available input/output-table for F. R. Germany, a 56-production-sector-table for 1972, as a basis, the internal matrix holds 278 production sectors, including those relevant for aluminium, copper, lead, zinc, and tin. Referring to the data given in this comprehensive matrix, the path of an initial output such as the production of a lead smelter may be traced through the whole economy (e.g. from the lead-acid accumulator industry to the automobile industry and hence, to exports, investment or consumption).

For the original analysis of raw material flows mentioned above the availability of imported raw materials only was calculated in value terms. Thus, for the purpose of the CREST-study, it was necessary

- to transform the value data of raw materials at disposal into quantities, and
- to include both domestic primary and secondary material, apart from raw material imports.

The flow of raw materials, in quantities, was derived from the structural output data of each production sector using these materials. Although this procedure may result in some shortcomings in special cases, i. e. whenever sectoral output is inhomogeneous yet in spite of the underlying, highly disaggregated input/output-table, the approach seems acceptable in total. As for primary input from domestic sources it is aswell reflected in the sectoral output data as that of imported metals: As soon as the material has entered the domestic supply system it is of no importance whether the metal originates from inland or from foreign sources.

The primary inputs in total are compiled in Table 3. The figures cover raw material and non-ferrous products of the first manufacturing stage. By input/output-calculation these inputs were assigned to final demand, including exports of finished goods. To assess the metal quantities domestically available for recycling, it is necessary to adjust the results of the input/output-matrix by adding the metal content of

Table 3: CALCULATION OF THE PRIMARY INPUTS OF THE INPUT-OUTPUT-TABLES 1972

input-components \ metal	Al	Pb	Cu	Zn	Sn
Domestic production of primary and secondary smelters	711.9	322.2	398.5	382.5	2.4
Direct use of scrap	33.6	1o.o	147.6	34.4	9.7
Increase (-) and decrease (+) of visible stocks	- 2.5	- 1.o	- 9.2	+ 12.o	- o.4
Imports of non-ferrous metals and semi-finished products[1]	5o2.5	63.2	528.6	194.4	18.5
Total input	1245.5	394.4	1o65.5	623.3	3o.2

1 Excluding imports of new and old scrap, ores and concentrates, which are included in the production figure

Source: METALLGESELLSCHAFT AG: Metalstatistics, 1964-1974, 62. Ed., Frankfurt/Main 1975; STATISTISCHES BUNDESAMT: Fachserie G, Außenhandel, R. 2, Spezialhandel nach Waren und Ländern 1972; ite estimates.

imported finished goods, for instance the lead-content of imported lead-acid-accumulators. Apart from the flow of raw materials into final demand components (consumption, investment, exports), the metals may also be used as auxiliary materials at various production stages or disappear from the economic cycle due to production losses. Lead, for example, is incorporated in lead-acid accumulators, and through deliveries of the accumulator-industry to the automobile industry part of it shows up a metal-content of final demand for automobiles. However, lead is also used by the chemical industry as catalyzers, i. e. it is not processed directly into chemical products. This portion should therefore not be declared as the lead component of final demand for chemical products, but rather as auxiliary materials remaining within the chemical industry. DIW and INFRATEST-INDUSTRIA took account of this aspect when presenting their input/output-results.

Furthermore, the results given below were subject to plausibility controls through joint efforts of the participating institutes (ITE, INFRATEST-INDUSTRIA, DIW). In some cases of greater discrepancies between the input/output-results the basic data were revised upon indication by cross-checks with partially available data of official statistics or information provided by associations. Because of pure practical reasons, limits of computation were set, as not each and every little quantity of metal could be included in print-out of the flow pattern. By weighing the pros and cons between clarity and accuracy a raw material was regarded as having been traced through the whole of the economy when at least 90 % of the original input had been ascribed to the final demand components. The shares of original input actually recorded totalled in case of

- aluminium 95%,
- copper 96%,
- lead 93%,
- zinc 96%,
- tin 96%.

Finally, further issues that could affect the "truth" of the raw material flow to final demand categories should be pointed out here.

One distortion of the raw material flow - yet negligible in view of the problem at stake - is already caused by the fact that minor metal quantities actually required as auxiliary materials have been ascribed to the final demand components, sectors 57 to 61 of the matrix. Due to the difficulties in determining each relationship in which a certain input is employed partly or totally as an auxiliary material, a percentage of 0.3 was taken as minimum amount for following the flow. Sectoral deliveries or supplies, respectively, amounting to less than 0.3% of total raw material input have not been listed individually in the step by step scheme, but under the collective number 99999. Therefore, these deliveries or supplies could not be identified any closer and were continued to be treated as raw material quantities still within the economic cycle.

Another distortion may be caused by the fact, that individual sectors are still not sufficiently disaggregated. For it is conceivable that there are various production lines in a certain sector which feature different raw material contents and different structures of deliveries.

1.2. Examples of raw material flow

In this chapter, examples of input/output-relationships will be shown for several products elucidating at the same time the possibilities of analytical assessment. While finished products and such which are mostly delivered to final demand are only suitable for showing the intermediate input relationship, intermediate products have also been chosen. They primarily allow to demonstrate the intersectoral output relationships. Apart from the intention to analyze both input and output patterns the examples have been chosen at random.

1.2.1. Aluminium

The use of aluminium is generally wide spread, dominated by few major fields. As regards finished products the automobile sector deserves special attention. Major aluminium supplies to the sector are the foundries accounting for about 50%. These include both primary and secondary aluminium which are processed into engine blocks, cylinder heads and many other small parts. Drop forgings such as pistons, connecting-rods and wheel rims, too, originate from this input sector. Furthermore, the producers of semi-finished goods play an important role as suppliers for the motor car industry. In this case, major intermediate products are rolled products for body parts such as hoods or complete lorry bodies, and moulded and drawn articles such as profiles, rods, tubes, etc.

On the output side there is a definite concentration on final demand of which roughly 50% are exports (see Table 4).

In order to give an example of interesting output patterns a sector has been picked out which manufactures a typical intermediate product: the industry of semi-finished aluminium goods.

Table 4: STRUCTURE OF INPUTS AND OUTPUTS OF ALUMINIUM FOR THE MOTOR-CAR INDUSTRY, 1972, in 1 ooo t

Inputs = purchases from			Outputs = deliveries to		
Code	Specification	Quantity	Code	Specification	Quantity
	primary input	38,6	1o	iron and steel industry	o,1
6o	stock decrease	o,6	43	food industry	o,1
	Σ	39,2	44o21	automobile repair business	1,9
1o	iron and steel industry	o,1	45	building and civil engineering	o,5
11	iron and steel foundries	2,o	54999	miscellaneous services	o,1
12	drawing plants and cold rolling mills	o,2	21	intrasectoral deliveries	2o,8
13oo7	aluminium foundries	116,8	99999	not attributable deliveries	16,1
13o1o	semimanufactured products of aluminium	41,o		intermediate demand	39,6
14	chemical industry	o,3	57/59	domestic final demand	96,4
2ooo7	production of precision tools	o,5	61	exports	95,8
2oo12	pump and valve manufacture	o,1		total final demand	192,2
2oo33	oil hydraulics and pneumatics	o,1	62/63	auxiliary materials	1,5
24oo9	automotive electrical equipment	3,7			
26	steel forging	o,4			
27oo5	manufacture of locks and fittings	2,2			
27999	other production of tools and finished articles of metal	o,4			
34999	other plastic manufactures	o,2			

Table 4 continued :

Inputs = purchases from			Outputs = deliveries to		
Code	Specification	Quantity	Code	Specification	Quantity
45	building and civil engineering	o,3			
21	intrasectoral purchases	2o,8			
99999	not attributable purchases	5,o			
	intermediate input	194,1			
	total input	233,3		total output	233,3

Source: Calculations based on the input-output-table of aluminium.

This sector produces its supplies almost exclusively from primary smelters; the output side, however, reveals the assumed multiform structure.

Building and civil engineering is the chief consumer accounting for 24% of intermediate demand. The products include sheets for front , roof , and wall-platings; but also profiles and rods which are processed into door and window-frames and balcony balustrades. Further main users of semi-finished goods are the manufacturers of aluminium foils, strips and cans, aluminium products for electrical use as well as the motor car industry (see Table 5).

Table 5: STRUCTURE OF INPUTS AND OUTPUTS OF ALUMINIUM FOR THE PRODUCTION OF SEMIMANUFACTURED GOODS, 1972, in 1 ooo t

Inputs = purchases from			Outputs = deliveries to		
Code	Specification	Quantity	Code	Specification	Quantity
	primary input	28o,2	13o13	zinc smelters	o,8
			19oo1	wagon making	3,6
13oo9	aluminium smelters	384,2	2o	mechanical engineering	5,2
			21	motorcar industry	41,o
			24oo7	tele-communication equipment	32,o
			24oo8	automatic data-processing equipment	18,o
			24oo9	automotive electrical equipment	5,9
			24o1o	radio,television and gramophone manufacture	6,4
			24o19	production of transformers	1,9
			24o2o	aluminium products for electrical use	44,6
			25oo3	manufacture of optical instruments	12,8
			25999	other precesion engineering and optical industry	o,5
			27oo5	manufacture of locks and fittings	6,9
			27oo9	production of aluminium foils, strips and cans	61,2
			27o1o	production of tubular furniture and equipment	11,6
			27o23	production of tinplate packaging	31,3
			44o21	automobile repair business	1,2

Table 5 continued :

Inputs = purchases from			Outputs = deliveries to		
Code	Specification	Quantity	Code	Specification	Quantity
			44o27	manufacture of tools and finished articles of metal	4,4
			45	building and civil engineering	116,9
			99999	not attributable deliveries	8o,8
				intermediate demand	487,o
			61	exports	177,4
	total input	664,4		total output	664,4

Source: See table 4.

Since semi-finished aluminium goods are just intermediate products the only final demand component is exports. However, accounting for 26.7% of total output, their significance should not be underestimated.

1.2.2. Lead

The use of lead is not so widely spread as in the case of aluminium. In broad terms, this implies that the intersectoral relationships are fewer and that the relationship between smelter and final demand is closer. Therefore, as an example for input relationship a sector that is most

Table 6: STRUCTURE OF INPUTS AND OUTPUTS OF LEAD FOR BUILDING AND CIVIL ENGINEERING, 1972, in 1 ooo t

Inputs = purchases from			Outputs = deliveries to		
Code	Specification	Quantity	Code	Specification	Quantity
	primary input	o,8	45	intrasectoral deliveries	o,8
13o18	semimanufactured products of lead	17,9	99999	not attributable deliveries	2,3
13o19	lead foundries	6,2		intermediate demand	3,1
14oo2	paints and lacquers industry	1,5	57/59	domestic final demand	25,6
15	mineral oil processing	o,1	61	exports	o,2
2oo15	machines for civil engineering	o,4		total final demand	25,8
2oo23	lifting, handling and haulage equipment	o,2	62/63	auxiliary materials	2,7
2oo3o	production of taps, cocks, and valves	o,1			
21	motorcar in-dustry	o,2			
24o17	copper cables and other products for electrical use	o,4			
24o23	accumulator industry	o,6			
29	glass industry	o,5			
45	intrasectoral purchases	o,8			
99999	not attributable purchases	1,9			
	intermediate input	3o,8			
	total input	31,6		total output	31,6

Source: Calculations based on the input-output-table of lead.

Table 7: STRUCTURE OF INPUTS AND OUTPUTS OF LEAD FOR PAINTS AND LACQUERS ; 1972, in 1 ooo t

Inputs = purchases from			Outputs = deliveries to		
Code	Specification	Quantity	Code	Specification	Quantity
	primary input	o,o	14999	other chemical industry	o,3
13o2o	lead smelters	32,6	2oo15	machines for civil engineering	o,1
27o18	production of tubes and capsules of lead and tin	o,3	2o999	other mechanical engineering	o,2
			21	motorcar industry	1,1
14oo2	intrasectoral purchases	o,1	23	shipbuilding industry	o,1
99999	not attributable purchases	o,3	24	electrical engineering	o,5
	intermediate input	33,3	33	printing industry	o,9
			45	building and civil engineering	1,5
			99999	not attributable deliveries	3,6
				intermediate demand	8,3
			57/59	domestic final demand	9,o
			61	exports	15,1
				total final demand	24,1
			62/63	auxiliary materials	o,9
	total input	33,3		total output	33,3

Source: See table 6.

heterogeneous, i.e. that uses lead in most diverse forms, shall be chosen: building and civil engineering.

One outstanding feature is the dominance of semi-finished lead consumption accounting for 56.7% of total input. These include mainly sheets, belts, strips and foils which are used for architectural purposes, partly for roofs, partly for chimney and bay-window-frames. Less important is the input of lead castings (19.6% of input). The remaining 23.7% of intermediate input are shared by nine other suppliers (see Table 6).

Paints and lacquers as a second example belong to a commodity group with a relatively wide-spread delivery pattern. The main intermediate consumers of paints and lacquers are the motor car and the building and civil engineering sectors. The remaining deliveries are distributed quite evenly (see Table 7).

1.2.3. Copper

The use of copper is still more widely scattered than that of aluminium. Therefore, the input pattern - e.g. of the machine-tool industry - includes not only supplies of primary products from the first production stage, but also a number of intermediate products or even finished goods which are used as components (see Table 8). Each intermediate product plays a subordinate role - apart from products for electrical use.

As a supplier of intermediate products the machine-tool industry is only of limited importance; the major portion is passed on to final demand, in equal parts for fixed investment and exports.

Table 8: STRUCTURE OF INPUTS AND OUTPUTS OF COPPER FOR MACHINE-TOOL INDUSTRY, 1972, in 1 000 t

Inputs = purchases from			Outputs = deliveries to		
Code	Specification	Quantity	Code	Specification	Quantity
	primary input	5,3	99999	not attributable deliveries	1,4
12	drawing plants and cold rolling mills	0,1		intermediate demand	1,4
13005	semimanufactured products of copper	3,1	59	gross fixed capital formation	6,2
13006	copper foundries	2,5	61	exports	6,5
20030	production of taps, cocks, and valves	0,2		total final demand	12,7
20031	transmission engineering	0,1			
20033	oil hydraulics and pneumatics	0,1			
20999	other mechanical engineering	0,1			
24018	electric motors and generators	0,1			
24019	production of transformers	0,1			
24030	copper products for electrical use	0,9			
24999	other electrical engineering	0,2			
26001	manufacture of non-ferrous screws	0,1			
26999	other steel forging	0,1			
27008	manufacture of cupriferous sundries	0,1			
99999	not attributable purchases	1,0			
	intermediate input	8,8			
	total input	14,1		total output	14,1

Source: Calculations based on the input-output-table of copper.

Table 9: STRUCTURE OF INPUTS AND OUTPUTS OF COPPER FOR PRODUCTS

FOR ELECTRICAL USE, 1972, in 1 ooo t

Inputs = purchases from

Code	Specification	Quantity
	primary input	295,1
6o	stock decrease	o,1
	Σ	295,2
12	drawing plants and cold rolling mills	o,1
13oo5	semimanufactured products of copper	22,8
13oo6	copper foundries	o,2
13oo8	copper smelters	18,9
24oo7	tele-communication equipment	o,2
24o11	electrical heating equipment	o,1
24o13	electrical refrigerator and washing machine manufacture	o,1
24o15	production of low-voltage switchgears	o,1
24o18	electric motors and generators	o,9
24o19	production of transformers	o,7
24999	other electrical engineering	o,2
26oo1	manufacture of non-ferrous screws	o,1
24o17/24o3o	intrasectoral purchases	21,o
99999	not attributable purchases	o,9
	intermediate input	66,3

Outputs = deliveries to

Code	Specification	Quantity
2	electricity	1,6
1o	iron and steel industry	1,3
13oo6	copper foundries	o,1
14	chemical industry	1,6
2ooo1	machine-tool industry	o,9
2oo15	machines for civil engineering	1,1
2oo23	lifting, handling and haulage equipment	o,7
2oo31	transmission engineering	1,7
21	motorcar industry	11,2
23	shipbuilding industry	2,5
24oo7	tele-communication equipment	6,7
24oo9	automotive electrical equipment	3,o
24o1o	radio,television, and gramophone manufacture	3,6
24o11	electrical heating equipment	2,9
24o12	household electrical appliance manufacture	1,1
24o13	electrical refrigerator and washing machine manufacture	2,8
24o14	production of high-voltage switchgears	1,2

Table 9 continued :

Inputs = purchases from			Outputs = deliveries to		
Code	Specification	Quantity	Code	Specification	Quantity
			24o15	production of low-voltage switchgears	1,5
			24o16	production of installation equipment	1,9
			24o18	electric motors and generators	7,4
			24o19	production of transformers	5,8
			24999	other electrical engineering	7,7
			25	precision engineering and optical industry	1,2
			26oo1	manufacture of non-ferrous screws	o,1
			26999	other steel forging	o,9
			45	building and civil engineering	6,2
			24o17/ 24o3o	intrasectoral deliveries	21,o
			99999	not attributable deliveries	32,8
				intermediate output	13o,5
			57/59	domestic final demand	183,6
			61	exports	45,7
				total final demand	229,3
			62/63	auxiliary materials	1,7
	total input	361,5		total output	361,5

Source: See table 8.

The manufacturing of products for electrical use, such as cables, etc. belongs to a sector which bears interesting features both on the input side and especially on the output side (see Table 9). On principle, two different kinds of material input may be distinguished: On the one hand products of the first production stage, and on the other direct use of scrap (new scrap) for instance from cable processors. On the output side the deliveries of this sector are widely scattered to other producing sectors. Among others they comprise redeliveries to preceding production stages such as foundries.

1.2.4. Zinc

Similar to lead, the production relationships of zinc are quite limited. Deliveries from the smelter to final demand are comparatively direct. Exceptions are the building and civil engineering sector as well as the galvanized steel sheet industry.

The main suppliers of the building and civil engineering sector are the custom galvanizers accounting for 31.2% of intermediate input (see Table 10). They galvanize windows, doors, and door frames as well as bridge construction elements or drainage systems. Custom galvanizers are called upon especially for components which are not standardized but made to order.

Regarding the delivery flows the galvanized steel sheet sector is particularly interesting (see Table 11). Whereas the input pattern is ruled by the supplies from smelters, the structure of the successive production stages reveals the manifold use of this intermediate product: The major consumer is the building and civil engineering sector sharing almost 40%. However, actually it gets even more because of

Table 1o : STRUCTURE OF INPUTS AND OUTPUTS OF ZINC FOR BUILDING AND CIVIL ENGINEERING, 1972, in 1 ooo t

Inputs = purchases from			Outputs = deliveries to		
Code	Specification	Quantity	Code	Specification	Quantity
	primary input	31,2	21999	other motorcar industry	o,3
1ooo1	galvanizing steel	1o,4	53	flat-letting business	4,o
1ooo2	galvanizing seamless steel tubes	o,9	54999	miscellaneous services	o,3
1o999	other iron and steel industry	o,9	45	intrasectoral deliveries	4,1
12oo1	manufacture of welding electrodes	1,6	99999	not attributable deliveries	6,4
12oo2	production of hot galvanized steel wire	2,3		intermediate demand	15,1
13oo5	semimanufactured products of copper	1,1	57/59	domestic final demand	112,3
13oo6	copper foundries	1,1	61	exports	o,7
13o14	zinc foundries	o,5		total final demand	113,o
13o15	semimanufactured products of zinc	24,2	62/63	auxiliary materials	13,8
14oo2	paints and lacquers industry	o,5			
14999	other chemical industry	o,2			
19oo3	architectural construction	6,1			
19999	other steel construction	o,3			
2oo3o	production of taps, cocks,and valves	o,2			
24o16	production of installation equipment	o,4			
24o25	production of primary batteries	o,2			
26oo1	manufacture of non-ferrous screws	o,1			
26999	other steel forging	o,1			

Table 1o continued :

Inputs = purchases from			Outputs = deliveries to		
Code	Specification	Quantity	Code	Specification	Quantity
27oo4	manufacture of non-ferrous tools and articles for households, agriculture, and small trade	o,2			
27oo8	manufacture of cupriferous sundries	o,1			
27o16	production of construction elements of steel sheet	3,9			
27o17	manufacture of steel tube and sheet products	6,6			
27o22	custom galvanizing	34,5			
27999	other production of tools and finished articles of metal	o,1			
44o13	non-ferrous metal production and non-ferrous metal foundries	o,1			
44o19	steel and light metal construction	o,9			
45	intrasectoral purchases	4,1			
99999	not attributable purchases	9,1			
	intermediate input	11o,7			
	total input	141,9		total output	141,9

Source: Calculations based on the input-output-table of zinc.

Table 11: STRUCTURE OF INPUTS AND OUTPUTS OF ZINC FOR GALVANIZED STEEL SHEET, 1972, in 1 ooo t

Inputs = purchases from			Outputs = deliveries to		
Code	Specification	Quantity	Code	Specification	Quantity
	primary input	47,4	1o	iron and steel industry	o,6
13o13	zinc smelters	14,o	12oo2	production of hot galvanized steel wire	o,3
			14	chemical industry	o,8
			19oo2	production of containers	o,5
			19oo3	architectural construction	1,1
			19999	other steel construction	o,2
			2o	mechanical engineering	o,1
			21	motorcar industry	o,6
			24	electrical engineering	o,1
			27o11	ash cans and dust bins	o,3
			27o15	production of steel containers	1,7
			27o16	production of construction elements of steel sheet	2,2
			27o17	mining machinery	1,5
			27999	other production of tools and finished articles of metal	o,3
			45	building and civil engineering	1o,4
			99999	not attributable deliveries	5,6
				intermediate demand	26,3
			61	exports	34,o
				material losses	1,1
	total input	61,4		total output	61,4

Source: See table 1o.

Table 12 : STRUCTURE OF INPUTS AND OUTPUTS OF TIN FOR PRODUCTION OF SOLDERS, 1972, in 1 ooo t

Inputs = purchases from			Outputs = deliveries to		
Code	Specification	Quantity	Code	Specification	Quantity
	primary input	2,9	2oo19	machines for food industry	o,1
13o23	semimanufactured products of tin	1,8	2oo2o	manufacture of technical apparatus	o,5
			2o999	other mechanical engineering	o,2
			21	motorcar industry	1,4
			23	shipbuilding industry	o,3
			24oo7	tele-communication equipment	o,5
			24oo8	automatic data-processing equipments	o,7
			24o12	household electrical appliance manufacture	o,1
			24o13	electrical refrigerator and washing mashine manufacture	o,1
			24o16	production of installation equipment	o,1
			24999	other electrical engineering	o,3
			27999	other production of tools and finished articles of metal	o,2
			99999	not attributable deliveries	o,3
	total input	4,7		total output	4,7

Source: Calculations based on the input-output-table of tin.

additional indirect supplies of galvanized steel sheets. Though it is, in general, very difficult to determine the indirect delivery relationship it is in this case plain to see that construction elements of galvanized steel sheet are passed further on to the building and civil engineering sector. The same applies to the deliveries of galvanized steel sheet to the producers of steel architectural constructions which furnish the building and civil engineering sector with 97%.

1.2.5. Tin

As for tin it can be stated that the distance from the smelter to final demand is usually very short. Accordingly the interrelationships shown by the input/output-table are relatively simple. One example for more detailed output-relationship is solder (see Table 12).

1.3. Selection of non-ferrous-metal containing products

This section of the study deals with the application of the input/output-table concerning the quantities of metal in the products to be delivered to final demand. These products need not necessarily be finished products, as exports form one component of final demand. Thus, intermediate products such as semi-finished goods of copper or lead become final demand as far as they are exported. As these products are of less interest to the question in point, they are mentioned only briefly in the following and are shown as aggregates in the tables.

However, it can also be the case that technically finished products, such as solder, are not or are only partially delivered to final demand, because the material is required as input of other industries. In order to include some interesting cases the analysis will not only refer to final demand categories but will occasionally go back to intermediate products.

In some cases, in which reliable information regarding the metal content of products are available from other sources, this information has been employed in addition to the results of the input/output-tables.

It cannot be the objective of the study to deal with each and every non-ferrous-metal-containing product. The limit for including a product or product group into the analysis refers to the deliveries of individual sectors to final demand. In addition auxiliary materials, which are necessary for production but do not become part of the product, are indicated.

1.3.1. Aluminium

The limit for including aluminium containing products was set at a minimum output of 5,000 t. Thus, 24 product groups were covered. In order to show the main areas of application not only product groups but also industries were included into the analysis, i.e. the chemical industry as overall industry comprising producers for example of paints and lacquers. In this way 86,5% of the total aluminium flow will be covered. For the further investigation, however, 23% may be neglected as it concerns exports of intermediate products. Thus almost 51% of the metal flow is finally covered on the product or sector level.

The most important use of aluminium is the production of motor cars. The main products are aluminium castings (engine blocks, cylinder heads, pistons, connecting-rods, etc.) but also semi-finished goods such as rolled, forged and drawn parts (see page 13, Table 4). The second most important sector of aluminium application is the building industry where almost 11% of the total aluminium consumption is required. In architectural construction aluminium is employed for roofs, wainscots as well as for inner fittings such as banisters, shelves, sliding and folding doors. Technical installations for heating or air conditioning should also be mentioned.

The use of aluminium for cables and other conducting material accounts for 3.6% of the total metal input. Because of its light weight aluminium is substituted for copper in the case of overhead lines. In mechanical engineering, communications, automatic data processing and in the manufacture of photographical and optical instruments, aluminium is used mainly for casing.

The importance of aluminium as packaging material can only indirectly be seen from Table 13 because it refers to final demand categories. Packaging material is not only included in the quantities given for foils, strips and cans, but also in the figures for food industry, manufacture of tools and articles for household, agriculture and small trade as well as for chemical industry, i.e. for instance for packaging of cosmetics and soap.

A total of over 30,000 t of aluminium is used as auxiliary material. However, this must not necessarily be seen as being lost for recycling. For example, 3,500 t of aluminium is used for defoaming reagents in the production of detergents. During the process metallic aluminium is converted to aluminium hydroxide from which alumina can be obtained for reuse in the aluminium smelter.

In steel construction, on the contrary, aluminium is used for welding. The quantities in this and similar ways are to be regarded as lost for recovery.

Table 13: MAIN ITEMS OF FINAL USE OF ALUMINIUM, 1972

Industry/Sector		Total Final Demand[1]	
Code	Specification	in 1 000 t	in %[2]
14	chemical industry	24.5	2.0
14008	cosmetics and soap industry	4.4	0.4
19	steel construction	13.7	1.1
19001	wagon making	5.8	0.5
20	mechanical engineering	118.6	9.5
20001	machine-tool industry	9.6	0.8
20013	air conditioning and drying equipment	7.8	0.6
20014	industrial freezing equipment	5.1	0.4
20015	machines for civil engineering	7.0	0.6
20018	agricultural machinery and tractors	9.5	0.8
20019	machines for food industry	9.2	0.7
20023	lifting, handling and haulage equipment	5.0	0.4
20025	textile machines	6.4	0.5
20034	office machinery	6.4	0.5
21/44021	motorcar industry and repair business	202.4	15.7
23	shipbuilding industry	10.7	0.9
24	electrical engineering	155.4	12.5
24007	tele-communication equipment	36.6	2.9
24008	automatic data-processing equipment	23.0	1.8
24010	radio, television and gramophone manufacture	9.2	0.7
24019	production of transformers	8.7	0.7
24020	aluminium products for electrical use	45.1	3.6
25	precision engineering and optical industry	17.5	1.4

Table 13 continued:

Industry/Sector		Total Final Demand[1]	
Code	Specification	in 1 000 t	in %[2]
25003	manufacture of optical instruments	13.1	1.1
27	production of tools and finished articles of metal	61.9	5.0
27004	manufacture of non-ferrous tools and articles for households, agriculture and small trade	10.5	0.8
27009	production of aluminium foils, strips and cans	24.4	2.0
27010	production of tubular furniture and equipment	14.9	1.2
43	food industry	26.3	2.1
45	building and civil engineering	135.3	10.9
61	export of semi-finished products	286.8	23.0
∑	industries	1 o53.1	84.6
∑	sectors[3]	629.5	50.6

By way of notice: auxiliary materials

∑ industries	45.8	3:7
∑ sectors [3]	31.6	2.6

1 - Excluded auxiliary materials and material losses.
2 - Part of total input.
3 - Excluded export of semi-finished products.

Source: Calculations based on the input-output-table of aluminium.

1.3.2. Lead

In contrast to aluminium the limit for including lead containing products was not only absolutely but also relatively reduced to 1,000 t or 0.25% of total input. This is because of lead uses concentrating on fewer products. 80% of the lead flow was covered. The export of intermediate products, which are irrelevant to the further analysis, reduces this figure by almost 15%.

The most important users of lead are electrical engineering (25.9%) and the motor car industry (13.9%) (see Table 14). For both the same product group is relevant: accumulators. The 9.6% of total final demand shown for this subsector of electrical engineering reflects only the replacement quantities while the 13.9% of the motor car industry include all batteries for first equipment of new cars. Seen from the input side of the motor car industry over 80% of the lead consumption of this sector is in the form of accumulators.

Other applications of lead that should be mentioned are the lead-containing bearings in mechanical engineering, lead casings in nuclear power stations for protection against radioactivity, as well as cable sheathings and solder. Furthermore, the printing and copying industry needs lead, however, here it is used mainly as auxiliary material (typemetal).

1.3.3. Copper

The limit for including copper-containing products into the analysis is determined to be 5,000 t. This covers 28 sectors which contribute 57.4% to final demand. Relating the limit not to the product level but rather to the overall sector level and including exports of intermediate products even 93.3% of the total copper flow is covered.

Table 14: MAIN ITEMS OF FINAL USE OF LEAD, 1972

Industry/Sector		Total Final Demand[1]	
Code	Specification	in 1 000 t	in %[2]
14	chemical industry	30.2	7.6
14002	paints and lacquers industry	24.1	6.1
15	mineral oil processing	5.2	1.3
20	mechanical engineering	35.9	9.1
20015	machines for civil engineering	4.4	1.1
20020	manufacture of apparatus	11.9	3.0
20023	lifting, handling and haulage equipment	4.6	1.2
20031	transmission engineering	1.0	0.3
20035	nuclear reactor equipment	6.7	1.7
21	motorcar industry	54.9	13.9
23	shipbuilding industry	2.8	0.7
24	electrical engineering	102.1	25.9
24007	tele-communication equipment	0.5	0.1
24008	automatic data-processing equipment	0.2	0.1
24017	copper cables and other products for electrical use	45.5	11.5
24019	production of transformers	0.9	0.2
24020	aluminium products for electrical use	8.7	2.2
24023	accumulator industry	37.7	9.6
24024	production of X-ray equipments	4.5	1.1
33	printing industry	0.4	0.1
45	building and civil engineering	25.8	6.5
61	export of semi-finished products	57.6	14.7
∑	industries	315.1	79.9
∑	sectors[3]	239.8	60.7

By way of notice:	auxiliary materials		
	∑ industries	28.6	7.3
	∑ sectors[3]	23.2	5.9

1 - Excluded auxiliary materials and material losses.
2 - Part of total input.
3 - Excluded export of semi-finished products.

Source: Calculations based on the input-output-table of lead.

Table 15: MAIN ITEMS OF FINAL USE OF COPPER, 1972

Industry/Sector		Total Final Demand[1]	
Code	Specification	in 1 000 t	in %[2]
14	chemical industry	17.6	1.7
20	mechanical engineering	110.0	10.3
20001	machine-tool industry	12.7	1.2
20012	pump and valve manufacture	6.9	0.6
20015	machines for civil engineering	5.0	0.5
20019	machines for food industry	4.4	0.4
20020	manufacture of technical apparatus	6.3	0.6
20023	lifting, handling and haulage equipment	5.3	0.5
20025	textile machines	4.3	0.4
20030	production of taps, cocks and valves	12.9	1.2
21/44021	motorcar industry and repair business	59.6	5.6
23	shipbuilding industry	19.8	1.9
24	electrical engineering	546.7	51.3
24007	tele-communication equipment	33.0	3.1
24008	automatic data processing equipment	6.1	0.6
24010	radio, television and gramophone manufacture	21.8	2.0
24011	electrical heating equipment	13.3	1.2
24012	household electrical appliance manufacture	10.4	1.0
24013	electrical refrigerator and washing machine manufacture	19.2	1.8
24014	production of high-voltage switchgears	13.2	1.2
24015	production of low-voltage switchgears	12.3	1.2
24017/ 24030	copper products for electrical use	229.3	21.5
24018	electric motors and generators	27.8	2.6
24019	production of transformers	35.2	3.3
25	precision engineering and optical industry	8.9	0.8

Table 15 continued:

Industry/Sector		Total Final Demand[1]	
Code	Specification	in 1 000 t	in %[2]
26	steel forging	6.0	0.6
27	production of tools and finished articles of metal	18.6	1.7
27008	manufacture of cupriferous sundries	7.1	0.7
45	building and civil engineering	45.3	4.3
61	export of semi-finished products	161.3	15.2
∑	industries	994.9	93.3
∑	sectors[3]	611.8	57.4

By way of notice: auxiliary materials

∑ industries	43.4	4.1
∑ sectors[3]	21.7	2.1

1 - Excluded auxiliary materials and material losses.
2 - Part of total input.
3 - Excluded export of semi- finished products.

Source: Calculations based on the input-output-table of copper.

Copper is primarily used in electrical engineering for the production of conducting material. However, this is not yet reflected by the 230,000 t which are mentioned in Table 15 as final demand for copper cables. This was only 63.8% of total consumption of conducting material. The remaining 36.2% are intermediate demand of other sectors.

Conducting material, however, is not the only copper application in electrical engineering. Other items are cans, brackets, switchgear parts, switch covers, contact springs, etc. of copper, brass or other copper alloys. Along with gear wheels, bearings, pump and valve bodies main copper and copper alloy applications in mechanical engineering are tubings for lubricants, radiators and oil coolers, etc.

In the production of motor cars about 60,000 t of copper were used. Main components here are radiators, heating installations, bearings, ignition system, starter, distributors and wire assemblies. A rather small portion of total copper input in finished products is attributable to building and civil engineering (4.3%) and presumably has been underestimated in the system. Copper is required in this sector mainly unalloyed for heating and aeration installations, sanitary equipment and water pipes, as well as for roofing or for gutters, waste pipes, locks, fittings and, last but not least for conducting material.

1.3.4. Zinc

The limit for including zinc-containing products into the analysis was set at 2,000 t or 0.32% of the total zinc input. This covers roughly 30 sectors accounting for only 36.6% of the total input (see Table 16). Relating the limit to the overall industry level a coverage quota of 80,0% can be achieved. However, of this 24.2% is employed for the export of intermediate products which are of no further interest here.

The most important user of zinc-containing products is building and civil engineering. As previously mentioned in connection with the material flow example, the main uses are

Table 16: MAIN ITEMS OF FINAL USES OF ZINC, 1972

Industry/Sector		Total Final Demand[1]	
Code	Specification	in 1 000 t	in %[2]
14	chemical industry	27.4	4.4
14002	paints and lacquers industry	2.1	0.3
16002	rubber industry	0.4	0.1
19/44019	steel and light metal construction	35.9	5.8
19002	production of containers	3.1	0.5
19003	architectural construction	2.0	0.3
20	mechanical engineering	36.4	5.8
20001	machine-tool industry	5.0	0.8
20012	pump and valve manufacture	2.1	0.3
20013	air conditioning and drying equipment	2.4	0.4
20018	agricultural machinery and tractors	2.3	0.4
20023	lifting, handling and haulage equipment	2.0	0.3
20025	textile machines	2.5	0.4
21	motorcar industry	38.5	6.2
23	shipbuilding industry	6.6	1.1
24	electrical engineering	38.6	6.2
24007	tele-communication equipment	3.2	0.5
24010	radio, television and gramophone manufacture	4.1	0.7
24013	electrical refrigerator and washing machine manufacture	2.7	0.4
24017	copper cables and other products for electrical use	5.1	0.8
24025	production of primary batteries	7.5	1.2
25	precision engineering and optical industry	2.8	0.4

Table 16 continued:

Industry/Sector		Total Final Demand[1]	
Code	Specification	in 1 000 t	in %[2]
26	steel forging	5.4	0.9
27	production of tools and finished articles of metal	43.1	6.9
27011	ash cans and dust bins	2.6	0.4
27015	production of steel containers	16.8	2.7
27016	production of construction elements of steel sheet	3.4	0.5
27017	manufacture of steel tube and sheet products	5.0	0.8
45	building and civil engineering	113.0	18.1
61	export of semi-finished products	150.7	24.2
∑	industries	498.8	80.0
∑	sectors[3]	228.3	36.6

By way of notice: auxiliary materials

∑ industries	38.9	6.2
∑ sectors[3]	21.9	3.6

1 - Excluded auxiliary materials and material losses.
2 - Part of total input.
3 - Excluded export of semi-finished products.

Source: Calculations based on the input-output-table of zinc.

for galvanized steel construction elements and for semi-finished goods. A further important sector for the use of zinc is the motor car industry. Here are many fields of application for die casting items, such as carburettor casing, door handles, dashboard parts, etc. Furthermore, zinc is also used in the form of brass, for instance for radiators.

Storage and transport containers account for 2.7% of the total zinc consumption. In this case the application of zinc is nearly exclusively in the form of galvanized steel sheet. This is similar in the sector of steel construction where galvanized steel products play an important role.

As regards the use of zinc for production of rubber goods, especially car tyres, it should be noted that the 400 t of zinc attributed to the final demand of the rubber industry are obviously too low. Considering the production figures of the tyre industry and estimating the portion of replacement tyres as well as exports a quantity of at least 6,000 t zinc content appears to be more realistic. As simultaneously the zinc input figure for the chemical industry as a whole seems to be relatively high the discrepancies may well result from specific problems of statistics within the chemical industry.

1.3.5. Tin

The limit for including tin-containing products into the analysis has to be apparently much lower than in the case of the other metals under review. It was set at 200 t or 0.7% of total tin input. This covers roughly 90% of the tin material flow when the level of overall industry is chosen. Related to the sector level, however, the limit means that only 32.7% is covered. The reason for this has to be seen

Table 17: MAIN ITEMS OF FINAL USE OF TIN , 1972

Industry/Sector		Total Final Demand[1]	
Code	Specification	in t	in %[2]
14	chemical industry	700	2.3
20	mechanical engineering	5 840	19.3
20019	machines for food industry	450	1.5
20020	manufacture of technical apparatus	1 000	3.3
20030	production of taps, cocks and valves	300	1.0
20031	transmission engineering	230	0.8
21	motorcar industry	1 900	6.3
23	shipbuilding industry	310	1.0
24	electrical engineering	1 200	4.0
24007	tele-communication equipment	560	1.9
24008	automatic data-processing equipment	630	2.1
27[4)]	production of tools and finished articles of metal	1 690	5.6
43	food industry	5 600	18.5
43002	production of canned fish and meat	2 970	9.8
45	building and civil engineering	1 110	3.7
61	export of semi-finished products	7 380	24.4
Σ	industries	25 730	85.2
Σ	sectors[3]	9 870	32.7

By way of notice: auxiliary materials

Σ	industries	1 160	3.8
Σ	sectors[3]	540	1.8

1 - Excluded auxiliary materials and material losses.
2 - Part of total input.
3 - Excluded export of semi-finished products.
4 - Excluding 27023 production of tinplate packaging, as this material is not part of final demand but rather consists of semi-finished products.

Source: Calculations based on the input-output-table of tin.

in relatively high deliveries of intermediate products such as tinplate to foreign consumers.

The most important uses of tin are in the production of cans as packaging material for fruits, vegetables, meat, etc. (see Table 17). In the motor car industry tin is used both as element of bearing metals and in the form of solder. Solder is required primarily for radiators, heaters, cable connections and also for smoothening uneveness in the body work.

2. Main areas for increasing recycling of non-ferrous metals

2.1. Assessment of domestic availability

2.1.1. Preliminary remarks

The input/output-tables include on their input side imported raw materials, semi-finished products and scrap as well as scrap and primary raw materials from domestic sources. Non-ferrous-metal-containing finished goods were not included as they are mostly imported directly for final demand. There are, however, exceptions such as accumulators which are partly required for intermediate use - primarily in the motor car industry - although they are technically finished products.

Estimating the domestic availability of the relevant products obviously imports have to be included. But doing so it is not possible to distinguish between imports for final demand and intermediary uses so that minor discrepancies cannot be avoided. In the total, however, these inaccuracies remain of limited importance.

Having in mind the limits set for including product groups into the analysis only the imports of the products mentioned in Tables 13 to 17 have to be considered. A problem arises in this context from the fact that the foreign trade statistics only show gross quantities, i.e. the total weight of imported and exported products. For the purpose of this study, however, the metal content of the products is needed. The following pragmatic method has been applied:

From the input/output-table the metal content of exported products can be seen. Assuming that imported and exported goods of the same kind contain similar amounts of metal the relationship of the metal content can be derived from the import/export relationship of the gross quantities. This procedure, however, had to be modified in some cases, such as products of mechanical engineering, where only values of foreign trade are available from the statistics. Another problem concerns the discrepancies between the foreign trade statistics and the specification of the DIW-input/output-table, resulting partly from the general differences in the system of the German production and foreign trade statistics. In the case of building and civil engineering foreign trade relations are of nearly no importance and thus have been neglected.

2.1.2. Statistical survey

Table 18: CALCULATION OF THE DOMESTIC AVAILABILITY OF ALUMINIUM IN PRODUCTS FOR FINAL USE, 1972

Code	Specification	Final Demand	Import/ Export-Relation	Domestic Availa-bility
		in 1 000 t	in %	in 1 000 t
14	chemical industry	24.5	48.4	17.6
14008	cosmetics and soap industry	4.4	48.4	4.2
19	steel construction	13.7	52.2	12.7
19001	wagon making	5.8	17.6	4.8
20	mechanical engineering	118.6	24.6	67.4
20001	machine-tool industry	9.6	29.8	6.2
20013	air conditioning and drying equipment	7.8	49.9	6.4
20014	industrial freezing equipment	5.1	79.9	4.3
20015	machines for civil engineerg	7.0	67.6	5.9
20018	agricultural machinery and tractors	9.5	29.7	5.7
20019	machines for food industry	9.2	19.6	4.2
20023	lifting, handling and haulage equipment	5.0	37.7	5.9
20025	textile machines	6.4	15.3	2.0
20034	office machinery	6.4	33.9	4.0
21	motorcar industry	202.4	28.9	129.9
23	shipbuilding industry	10.7	43.9	8.2
24	electrical engineering	155.4	47.3	134.3
24007	tele-communication equipment	36.6	26.2	30.1
24008	automatic data-processing equipment	23.0	86.6	21.4
24010	radio, television and gramophone manufacture	9.2	75.6	8.4
24019	production of transformers	8.7	64.1	8.0
24020	aluminium products for electrical use	45.1	47.3	44.6

Table 18 continued:

Code	Specification	Final Demand	Import/ Export-Relation	Domestic Availa-bility
		in 1 000 t	in %	in 1 000 t
25	precision engineering and optical industry	17.5	49.8	13.2
25003	manufacture of optical instruments	13.1	69.4	11.1
27	production of tools and finished articles of metal	61.9	40.7	44.2
27004	manufacture of non-ferrous tools and articles for households, agriculture and small trade	10.5	64.2	9.2
27009	production of aluminium foils, strips, and cans	24.4	1)	8.3
27010	production of tubular furniture and equipment	14.9	69.3	14.3
43	food industry	26.3	20.2	24.3
45	building and civil engineering	135.3	-	135.3

1) Here only exports amounting to 16 100 t are to be considered; imports are already included in the primary input figure.

Source:
See Table 13 and STATISTISCHES BUNDESAMT, Fachserie G, Außenhandel R. 2, Spezialhandel nach Waren und Ländern, 1972.

Table 19: CALCULATION OF THE DOMESTIC AVAILABILITY OF LEAD IN PRODUCTS FOR FINAL USE, 1972

Code	Specification	Final Demand	Import/ Export-Relation	Domestic Availa-bility
		in 1 000 t	in %	in 1 000 t
14	chemical industry	30.2	48.4	20.4
14002	paints and lacquers industry	24.1	48.4	16.4
15	mineral oil processing	5.2	2)	2)
20	mechanical engineering	35.9	24.6	25.0
20015	machines for civil engineering	4.4	67.6	3.7
20020	manufacture of technical apparatus	11.9	24.6	7.9
20023	lifting, handling and haulage equipment	4.6	37.7	3.6
20031	transmission engineering	1.0	40.6	0.5
20035	nuclear reactor equipment	6.7	13.3	5.9
21	motorcar industry	54.9	28.9	35.2
23	shipbuilding industry	2.8	43.9	2.1
24	electrical engineering	102.1	47.3	88.5
24007	tele-communication equipment	0.5	26.2	0.4
24008	automatic data-processing equipment	0.2	86.6	0.2
24017	copper cables and other products for electrical use	45.5	40.2	41.8
24019	production of transformers	0.9	64.0	0.8
24020	aluminium products for electrical use	8.7	47.3	8.6
24023	accumulator industry	37.7	26.3	27.9
24024	production of X-ray equipments·	4.5	22.6	2.8
33	printing industry	0.4	25.0 1)	0.3
45	building and civil engineering	25.8	-	25.8

1) estimated. 2) not calculable.

Source: See Table 14, and Table 18.

Table 20: CALCULATION OF THE DOMESTIC AVAILIBILITY OF COPPER IN PRODUCTS FOR FINAL USE, 1972

Code	Specification	Final Demand	Import/ Export-Relation	Domestic Availa-bility
		in 1 000 t	in %	in 1 000 t
14	chemical industry	17.6	48.4	11.6
20	mechanical engineering	110.0	24.6	62.2
20001	machine-tool industry	12.7	31.3	8.2
20012	pump and valve manufacture	6.9	29.8	3.1
20015	machines for civil engineering	5.0	67.6	4.2
20019	machines for food industry	4.4	19.6	2.0
20020	manufacture of technical apparatus	6.3	24.6	4.2
20023	lifting, handling and haulage equipment	5.3	37.7	4.1
20025	textile machines	4.3	15.3	1.3
20030	production of taps, cocks and valves	12.9	50.5	9.3
21	motorcar industry	59.6	28.9	32.9
23	shipbuilding industry	19.8	43.9	15.2
24	electrical engineering	546.7	47.3	467.8
24007	tele-communication equipment	33.0	26.2	27.8
24008	automatic data-processing equipment	6.1	86.6	5.7
24010	radio, television and gramophone manufacture	21.8	75.6	19.8
24011	electrical heating equipment	13.3	24.4	10.9
24012	household electrical appliance manufacture	10.4	45.9	9.1
24013	electrical refrigerator and washing machine manufacture	19.2	121.2	20.7
24014	production of high-voltage switchgears	13.2	25.5	11.2

Table 20 continued:

Code	Specification	Final Demand	Import/ Export Relation	Domestic Availa-bility
		in 1 000 t	in %	in 1 000 t
24015	production of low-voltage switchgears	12.3	28.1	6.0
24017/ 24030	copper cables and other products for electrical use	229.3	40.2	207.8
24018	electric motors and generators	27.8	46.7	19.7
24019	production of transformers	35.2	64.0	32.3
25	precision engineering and optical industry	8.9	49.8	6.8
27	production of tools and finished articles of metal	18.6	40.7	12.8
27008	manufacture of cupriferous sundries	7.1	41.2	4.4
45	building and civil engineering	45.3	-	45.3

Source: See Table 15 and 18.

Table 21: CALCULATION OF THE DOMESTIC AVAILIBILITY OF ZINC IN PRODUCTS FOR FINAL USE, 1972

Code	Specification	Final Demand	Import/ Export-Relation	Domestic Availa-bility
		in 1 000 t	in %	in 1 000 t
14	chemical industry	27.4	48.4	18.8
14002	paints and lacquers industry	2.1	48.4	1.4
16002	rubber industry	0.4	102.7	0.4
19	steel construction	35.9	52.2	33.7
19002	production of containers	3.1	21.0	2.3
19003	architectural construction	2.0	52.2	1.7
20	mechanical engineering	36.4	24.6	21.2
20001	machine-tool industry	5.0	31.3	3.2
20012	pump and valve manufacture	2.1	29.8	0.9
20013	air conditioning and drying equipment	2.4	49.9	2.0
20018	agricultural machinery and tractors	2.3	29.7	1.4
20023	lifting, handling and haulage equipment	2.0	37.7	1.6
20025	textile machines	2.5	15.3	1.8
21	motorcar industry	38.5	28.9	24.0
23	shipbuilding industry	6.6	43.9	5.1
24	electrical engineering	39.3	47.3	33.6
24007	tele-communication equipment	3.2	26.2	2.7
24010	radio, television and gramophone manufacture	4.1	75.6	3.7
24013	electrical refrigerator and washing machine manufacture	2.7	121.2	2.9
24017	copper cables and other products for electrical use	5.1	40.2	4.7
24025	production of primary batteries	7.5	165.5	8.5
25	precision engineering and optical industry	2.8	49.8	2.7

Table 21 continued:

Code	Specification	Final Demand	Import/ Export-Relation	Domestic Availa-bility
		in 1 000 t	in %	in 1 000 t
27	production of tools and finished articles of metal	43.1	40.7	33.8
27011	ash cans and dust bins	2.6	78.3	2.6
27015	production of steel containers	16.8	79.2	16.4
27016	production of construction elements of steel sheet	3.4	192.6	5.8
27017	manufacture of steel tube and sheet products	5.0	44.3	2.5
45	building and civil engineering	113.0	-	113.0

Source: See Table 16 and Table 18.

Table 22: CALCULATION OF THE DOMESTIC AVAILIBILITY OF TIN IN PRODUCTS FOR FINAL USE, 1972

Code	Specification	Final Demand	Import/ Export-Relation	Domestic Availa-bility
		in t	in %	in t
14	chemical industry	700	48.4	477
20	mechanical engineering	5 840	24.6	3 334
20019	machines for food industry	450	19.6	212
20020	manufacture of technical apparatus	1 000	24.6	673
20030	production of taps, cocks and valves	300	50.5	215
20031	transmission engineering	230	40.6	111
21	motorcar industry	1 900	28.9	1 200
23	shipbuilding industry	310	43.9	238
24	electrical engineering	1 200	47.3	1 120
24007	tele-communication equipment	560	26.2	485
24008	automatic data-processing equipment	630	86.6	626
27[1)]	production of tools and finished articles of metal	1 690	40.7	1 352
43	food industry	5 600	20.2	5 345
43002	production of canned fish and meat	2 970	1 417.8	4 815
45	building and civil engineering	1 110	-	1 110

1) Excluding 27023 production of tinplate packaging, as this material is not part of final demand but rather consists of semi-finished products.

Source: See table 17 and table 18.

2.1.3. Summary of results

Because of the consideration of foreign trade with non-ferrous-metal-containing products a few shifts between final demand and inland availibility should be noted. The import/export-quota of F.R. Germany mostly is far less than one, particularly in the field of industrial products. This means that apart from a few exceptions the domestic availability is smaller than the figure representing final demand. Some drastic examples are nuclear reactor equipment, textile machines or wagons. In contrast import surplusses are recorded for example for canned food, construction elements of galvanized steel and primary batteries. Thus it has to be stated that in the case of the German economy not all metal quantities which were required for production are available for domestic recovery. For all five metals the exports of relevant products exceeded the respective imports. Related to final demand the domestic availability is as follows:

- aluminium	75%
- lead	80%
- copper	79%
- zinc	84%
- tin	77%

2.2. Identification of problem areas

2.2.1. Classification by recycling possibilities

The domestic availability gives a first indication of sectors which appear to be promising for recycling. These, no doubt, can include products from which the old scrap may be recovered quite easily. Thus, the problem is to determine products or commodity groups which are difficult to recycle under present technological standards. In order to identify these items Table 23 gives a survey of the relevant sectors for each metal under review. Among these sectors three groups may, in general, be distinguished with regard to the possibilities of recovering the metal contents:

- Sectors of dissipative use
  The main uses which are generally considered dissipative are in the chemical industry, e.g. production of pigments or lead anti-knock-compounds in fuel. Such products are usually lost for recycling.
- Sectors with recycling possibilities
  These sectors include product groups from which extensive metal recycling has been possible for a long time. The accumulator industry is a very distinct example. A major quota is also recorded for mechanical as well as electrical engineering. Generally, these products are recovered by scrap dealers and most of the non-ferrous metal contents is recycled.
- Sectors with comparatively low or no recycling
  The products of this group have metal contents which, due to technical and economic reasons are not recoverable in any notable degree. These are mostly products, e.g. packaging material or electrical appliances, used in households and are disposed of as household refuse after their useful life. In these cases the major difficulty of recycling is the separation of valuable materials from the household garbage.

Thus, the analysis concentrates in the following on products or product groups which offer a considerable metal content that may be additionally employed for recycling.

Table 23: CHARACTERIZATION OF PROBLEMS FOR RECOVERY OF THE RELEVANT NON-FERROUS METALS IN SELECTED INDUSTRIES AND SECTORS

Industries/Sectors			Recycling		
Code	Specification	Relevant Metals	dissipative use	less problematic	problematic
14	chemical industry	Al,Pb,Cu,Zn,Sn	X		
15	mineral oil processing	Pb	X		
16oo2	rubber industry	Zn			X
19	steel construction				
19oo1	waggon making	Al		X	
19oo2	production of containers	Al,Zn			X
19oo3	architectural construction	Zn			X
2o	mechanical engineering				
2oo01	machine-tool industry	Al,Cu,Zn,Sn		X	
2oo12	pump and valve manufacture	Cu,Zn		X	
2oo13	air conditioning and drying equipment	Al,Zn			X
2oo14	industrial freezing equipment	Al		X	
2oo15	machines for building and civil engineering	Al,Pb,Cu			X
2oo18	agricultural machinery and tractors	Al,Zn			X
2oo19	machines for food industry	Al,Sn		X	
2oo2o	manufacture of technical apparatus	Pb,Cu,Sn			X
2oo23	lifting,handling,and haulage equipment	Al,Pb,Cu		X	
2oo25	textile machines	Al,Cu,Zn		X	
2oo3o	production of taps, cocks,and valves	Cu,Sn			X
2oo31	transmission engineering	Pb,Sn		X	
2oo34	office machinery	Al,Zn			X
2oo35	nuclear reactor equipment	Pb	(X)		
21	motor car industry	Al,Pb,Cu,Zn,Sn			X
23	shipbuilding industry	Al,Pb,Cu,Zn,Sn		X	
24	electrical engineering				
24oo7	tele-communication equipment	Al,Pb,Cu,Zn,Sn		X	
24oo8	automatic data-processing equipment	Al,Pb,Sn		X	
24o1o	radio,television,and gramophone manufacture	Al,Cu,Zn			X
24o11	electrical heating equipment	Cu			X
24o12	household electrical appliance manufacture	Cu			X
24o13	electrical refrigerator and washing machine manufacture	Cu,Zn			X
24o14	production of high-voltage switchgears	Cu		X	

Table 23 continued:

Industries/Sectors			Recycling		
Code	Specification	Relevant Metals	dissipative use	less problematic	problematic
24o15	production of low-voltage switchgears	Cu		x	
24o17	copper cables and other products for electrical use	Pb,Cu,Zn			x
24o18	electrical motors and generators	Cu		x	
24o19	production of transformers	Al,Pb,Cu		x	
24o2o	aluminium products for electrical use	Al,Pb			x
24o23	accumulator industry	Pb		x	
24o24	production of X-ray equipment	Pb		x	
24o25	production of primary batteries	Zn			x
25	precision engineering and optical industry	Al,Cu,Zn			x
26	steel forging	Cu,Zn			x
27	production of tools and finished articles of metal				
27oo4	manufacture of non-ferrous tools and articles for households, agriculture,and small trade	Al			x
27oo9	production of aluminium foils,strips,and cans	Al			x
27o1o	production of tubular furniture and equipment	Al			x
27o11	ash cans and dust bins	Zn			x
27o15	production of steel containers	Zn			x
27o16	production of construction elements of steel sheet	Zn			x
27o17	manufacture of steel tube and sheet products	Zn			x
33	printing industry	Pb		x	x
43	food industry				
43oo2	production of canned fish and meat	Sn			x
43o99 44o43	other food industry other manufacture of food	Al,Sn			x
45	building and civil engineering	Al,Pb,Cu,Zn,Sn			x

2.2.2. Recycling problems of individual products

In this section the most important non-ferrous metal-containing products as well as the characteristics of metal input and the major problems of recycling will be briefly described. In some cases it will be necessary to recall the intermediate input structure in order to identify the form in which the metal is contained in the finished product. For example, it is not immediately clear from chemical industry's final demand for aluminium that packaging materials make up part of it.

Code No. 14, Chemical industry

Input: - Aluminium, mainly for packaging materials; also for the production of detergents, pastes and fillings;

- Lead as pigment;
- Copper in form of salts in fertilizers, insecticides, ect.;
- Zinc as pigment;
- Tin as packaging material (tinplate).

Recycling: Aluminium and tin used for packaging materials could be recovered. The main problem is the separation of household garbage. Further uses of aluminium as well as the use of lead, copper and zinc may largely be regarded as dissipative. Lead and zinc which are used for anticorrosive paints for steel constructions could be recycled to a small extent from flue dust of steel mills.

Code No. 16002, Rubber industry

Input: - Zinc is mainly used as zinc oxide for manufacturing tyres.

Recycling: At present, only small amounts are recycled in the Federal Republic of Germany. The problem of recycling is more of economic than of technical nature.

Code No. 19, Steel and light metal construction

Input: - Aluminium for wagon making and containers;

- Zinc as surface coatings for tubes, sheets and other rolled products.

Recycling: As far as these products are collected by scrap-dealers an almost complete recycling of aluminium should be achievable. Zinc, however, may only be recycled by filtering flue dusts of steel mills.

Code No. 20013, Air conditioning and drying equipment

Products: Heat exchangers, dust removing installations, drying equipment for agricultural products and for paintshops and laundries.

Input: - Aluminium for tubes, sheets, profiles;

- Zinc mainly for galvanizing steel sheets, brass.

Recycling: Apart from the already mentioned difficulties of zinc recycling from galvanized steel sheet recycling is not problematic as the material arises in relatively large pieces and is normally handled by scrap-dealers.

Code No. 20015, Machines for building and civil engineering

Products: Concrete mixers, concrete pumps, building elevators, dredging machines, road building machinery and road rollers, road graders.

Input: - Aluminium is used for high-strength brass and bearing material which is exposed to very high loads, but also for pistons, connecting-rods, cylinder heads, pumps;

- Lead for batteries and alloys for bearings (white metal, leaded bronze) and fittings (red brass);

- Copper primarily as conducting material.

Recycling: Lead from accumulators is nearly completely recycled. The recycling of the other non-ferrous metals depends mainly on the solution of separation problems.

Code No. 20018, Agricultural machinery and tractors

Products: Ploughs, drilling machines, combined harvesters, harvesters, tractors.

Input: - Aluminium for gripping arms of harvesters, parts of cultivating machines and pipelines;

- Zinc for casings and small parts (die-castings) as well as for galvanized steel sheets.

Recycling: The discarded equipment is largely passed on to scrap-dealers. The main difficulty lies in disassembling the equipment. Therefore, recycling depends on achievements of separation.

Code No. 20020, Manufacture of technical apparatus

Products: Mainly apparatus for the chemical industry.

Input: - Lead for tubes and for surface coatings;

- Copper for tubes and die-castings;

- Tin combined with lead as solder, tin tubes.

Recycling: The discarded equipment is largely passed on to scrap dealers. The main difficulty lies in disassembling the equipment. Therefore,recycling depends on achievements of separation.

Code No. 20030, Fittings

Input: - Copper is used mostly in the form of copper alloys (mainly red brass and brass).

Recycling: Since these products are usually smaller parts of large units recycling faces the problem of disassembling and collection.

Code No. 20034, Office machinery

Products: Type-writers, cash registers, table and pocket calculators, computers.

Input: - Aluminium and zinc for casings, covers, frames, types.

Recycling: In particular, the collection and disassembling of smaller articles is difficult.

Code No. 20035, Nuclear reactor equipment

Input: - Lead is for instance used for radiation shields.

Recycling: At present, the possibilities of recycling non-ferrous metals, especially lead, from the nuclear energy sector cannot be exactly determined yet. This input may be regarded as dissipative.

Code No. 21, Motor car industry

Input:
- Aluminium for wheels, bosses, wishbones, pistons, connecting rods, cylinder heads, fuel injection casings;
- Lead for accumulators, solders for radiators and heaters, car body fillings;
- Copper for electrical equipment, bearings, connecting-rods, sockets, synchronizing rings;
- Zinc for covers and casings of various motor parts and carburettors, fittings, ornamental parts;
- Tin for solders in particular.

Recycling: The recovery of passenger motor cars and vans reaching 90 - 95% is almost complete. The limits of non-ferrous metal recycling are set on the one hand by the separation technologies and on the other by the specifications for steel scrap. The separation of non-ferrous metals could be improved for instance by introducing cryogenic shredding.

Code No. 24010, Radio, television and gramophone manufacture

Input:
- Aluminium for casings, dust covers, linings;
- Copper mostly for conducting material;
- Zinc for casings, driving mechanism, record turntables.

Recycling: The greatest problem is the collection and disassembling. At the end of their useful life these products are often disposed of in household refuse or kept in households.

Code No. 24011 - 24013, Electrical heating equipment, household appliances, refrigerators and washing machines

Input: - Copper mostly for conducting material and to a small extent for bearings and casings;

- Zinc for sheets and fittings, zinc die-castings.

Recycling: These products are disposed of in household refuse whereby larger equipment such as refrigerators and washing machines are sorted out and shredded.

Code No. 24017 and 24020, Copper and aluminium products for electrical use

Input: - Aluminium for cables, wires, other conducting material;

- Lead mainly for sheathings;

- Copper for cables, wires, other conducting material;

- Zinc for galvanized corrugated steel sheathings.

Recycling: Due to the variety of products by size and quality, very costly hand sorting becomes necessary in some cases; often underground cables are not recovered because of economic reasons.

Code No. 24025 Primary batteries

Input: Zinc cans

Recycling: Old dry cells normally are disposed of in household refuse and thus are lost for recycling. Although a recovery is basically achievable, mainly collection problems have prevented it up to now.

Code No. 25, Precision engineering and optical industry

Products: Cameras, binoculars, navigation instruments, scales, watches, projectors.

Input: - Aluminium for casings, trays, indicators of scales;

- Copper and zinc (brass) are normally used for cameras.

Recycling: Only in case of larger equipment partial recycling may be expected.

Code No. 27004, Tools and articles for households and agriculture

Products: Ladders, sheets, kitchen articles, milk cans.

Input: - Aluminium and zinc are used for sheets, profiles and other semi-finished goods.

Recycling: Larger articles are partly sorted out, the remainder is disposed of in household refuse.

Code No. 27009, Aluminium cans, strips and foils

Input: - Aluminium is used for household foils and other purposes.

Recycling: These products are disposed of almost completely in household refuse. Separation is the main problem due to the relatively small portion contained in household refuse and the magnetically neutral nature of aluminium.

Code No. 27010, Production of non-ferrous tubular furniture and equipment

Products: Office, school and garden furniture, shelves.

Input: - Tubes, sheets and profiles of aluminium.

Recycling: These products are often sorted out at waste dumps due to their size. In case of commercial use the furnitures are usually sold to scrap-dealers. Therefore, partial recycling is already being done in this field.

Code No. 27011, 27015, 27016, 27017, Ash cans, dust bins, steel containers, construction elements, steel tubes and sheet products

Input: - Zinc is used in form of galvanized steel sheets and galvanized tubes.

Recycling: A greater part of material is presumably recovered by scrap-dealers. The difficulty lies in the recycling of flue dust from steel mills.

Code No. 33, Printing industry

Input: - Lead-tin-antimony-alloys for type metal.

Recycling: No difficulties in case of re-use for the same purpose. However, demand is decreasing due to new technologies. The separation of the three metals is costly.

Code No. 43002, Canned fish and meat

Input: - Aluminium and tinplate are used for manufacturing packaging material.

Recycling: Packaging material is almost completely disposed of after use in household refuse. The most difficult problem of recycling is the separation.

Code No. 45, Building and civil engineering

Input: - Aluminium for window sills, doors, balcony frames, wall-platings;

- Lead sheets, foils,tubes, solders;

- Copper for outer wall linings, roofings, window sills, sanitary installations, conducting material;

- Zinc for eaves and roofings, brass in fittings.

Recycling: Aluminium and zinc sheets cause only minor separation problems and are largely recycled. In contrast to aluminium and zinc, copper is used more for small parts and is, therefore, more difficult to separate. Cupriferous tubes are often hard to remove from buildings without comparatively high expenses.

2.3. The recycling potential of major problem areas

2.3.1. Aluminium

As already mentioned in part 2.1.3., domestic availability of aluminium-containing products, which under quantitative aspects are of interest for recycling, is reduced by considerable export surpluses. 25% of final demand for aluminium in finished products is net exports. Additional 23% has been deducted as exports of intermediate goods.[1] Accordingly , almost half (48%) of total final demand is to be attributed to exports. This means, that roughly 645,000 t of aluminium contained in products were available for recycling after their useful life. Of these about 595,000 t have been followed up in the analysis on industry level, and about 507,000 t on the product level. Even by limiting the analysis to the problem areas outlined in the previous section of the study

1 Imports of intermediate products are already included in primary input.

the quantity still exceeds 400,000 t. The main reason for this is that the dominating applications of aluminium - motor car industry, building and civil engineering as well as packaging industry - belong to the problem areas for recycling.

In Table 24 domestic availability of packaging material

Table 24: PROBLEM AREAS FOR RECYCLING OF ALUMINIUM

Specification	Potential[1] in 1 000 t	Main Recovery Problems			
		Collection	Separation	Preparation	Metallurgical
packaging material	36.8	x	x	x	
non-ferrous tools and articles for households, agriculture, and trade	9.2	x			
instrument engineering and optical products	13.2	x			
radio, television, and gramophone articles	8.4	x			
office machinery	4.0		x		
tubular furniture and equipment	14.3		x		
motor cars	129.9		x		x
air conditioning and drying equipment	6.4	x			
machines for building and civil engineering	5.9	x	x		x
agricultural machinery and tractors	5.7	x	x		x
building constructions	135.3	x	x		
aluminium products for electrical use	44.6	x		x	
Total	413.7				

1 On the base of 1972 input

Source: See Table 18.

amounts only to 36,800 t (foils, strips and cans, packaging material for cosmetics, soaps and food). In these cases the employed packaging material can be exactly determined. However, other sectors contain additional quantities which cannot be exactly attributed to packaging material. Accordingly, estimates of roughly 60,000 to 80,000 t of domestic packaging scrap seem to be reasonable in total.[2]

The difficulties of recycling are mainly due to the fact that almost all packaging material is disposed of in household refuse. Therefore, a prerequisite for recycling is the separation of aluminium from the refuse. However, this makes sense only if all refuse is processed for collecting a series of valuable materials. Apart from the problems of collection, difficulties also arise in the preparation of the material, as impurities are to be removed. These, however, are minor problems compared with the difficulties of collection.

Since packaging material of aluminium accounts for roughly 12 % of the total recycling potential and as this share presumably will increase in future the recycling of household refuse needs further attention.

The collection of old aluminium scrap from household refuse is not only problematic in case of packaging material, but also to a certain degree in case of non-ferrous tools and articles for household and agriculture, optical instruments, radios, television sets and pocket calculators. However, by volume, these products contain only low potentials and induce even greater separation problems since aluminium is often used as a component of large equipment. Similar recycling problems arise in the case of machinery. Such equipment is often processed to recover e.g. steel and not aluminium.

---

2 See HANS-DIETER TANGERMANN: Verpackungswirtschaft - Metallkreis, in: Egon Keller (editor): Abfallwirtschaft und Recycling, Probleme und Praxis, Essen 1977, p. 297

At present, aluminium recycling from automobile scrap has the largest share in aluminium scrap recovery. This is brought about mainly by the almost complete collection of automobile scrap. However, the recovery ratio, i.e. the ratio between scrap input and recovered aluminium is not very high. In case of passenger cars and vans it can be estimated at around 30%.[3] An increase of this ratio can hardly be achieved as long as conventional shredding techniques are employed. Experts even claim that the recovery is less than in the case of hand separation.[4] By introducing cryogenic shredding the separation of non-ferrous metals from steel and other materials could be improved.[5] In view of yet unused potentials of non-ferrous metals in cars and particularly with regard to the foreseeable increases of aluminium application in this sector the relevant recycling techniques should be improved.

In building and civil engineering the collection of old scrap at present is relatively low due to the long life cycle of buildings and the fact that aluminium was only recently introduced to the building and construction industry. The aluminium parts used here nowadays are mainly large sized pieces such as sheets for wall platings, window frames, etc. Thus, separation problems hardly exist and aluminium will be recoverable almost completely when the buildings become obsolete. Some pieces may be available earlier when they are replaced.

As for the recycling of aluminium cables and other conducting material it has to be mentioned that conventional cable burning

---

3 UMWELTBUNDESAMT: Materialien 2/76, Materialien zum Abfallwirtschaftsprogramm '75, V: "Metalle und metallische Verbindungen", no place and no year given, p. 39

4 See ORGANISATION EUROPÄISCHER ALUMINIUM-SCHMELZHÜTTEN(OAE): Aluminium-Schmelzhütten Europa, Japan, USA, 1975-76, Düsseldorf 1975, p. 12

5 See SGM: A Survey of the Technology of Copper Recycling, Brussels 1977, p. 79 et seq.

is not applicable. Steel elements of the cables may even prevent the use of granulators for recycling. Thus in view of increasing employment of aluminium as conducting material more efficient recycling techniques in this sector should be developed.

2.3.2. Lead

The F.R. Germany recorded net exports of lead nearly of the same amount as in the case of aluminium. Compared with final demand domestic availability of lead-containing finished products, however, accounted for 15% so that a total of 35% of final demand was lost for domestic recycling. Of the remaining 256,000 t 83% have been followed up in the analysis on industry level, and about 76% on product level. Limiting the analysis to the problem areas mentioned in the previous section of the study only 40% of domestic availability was covered. This results from the fact that the large quantity of 95,000 t of lead in accumulators could be recycled domestically without serious difficulties.[1] Accordingly, this sector was not considered a problem area.

In comparison with the other non-ferrous metals of concern, recycling possibilities of lead, in general, are especially favourable. This might be explained by the fact that

- the greater share of input is concentrated in few areas,
- processing of old scrap is relatively simple since lead is mostly available in large pieces and retains its metallic properties due to its good resistance to corrosion.[2]

---

1 See CERIMET: A Survey of the Technologies for Recycling Aluminium and Lead, Torino 1977, p. 3 - 27.

2 See INTERNATIONAL LEAD AND ZINC STUDY GROUP: Secondary Lead and Zinc, Report by an ad hoc Working Party of the Statistical Committee, Washington, D.C. 1975, p. 4.

Table 25: PROBLEM AREAS FOR RECYCLING OF LEAD

Specification	Potential[1] in 1 ooo t	Main Recovery Problems			
		Collec-tion	Sepa-ration	Prepa-ration	Metallur-gical
machines for building and civil engineering	1.7 [2]	x	x		x
technical apparatus	7.9		x	x	
motor cars	7.o [2]		x		x
lead sheathings for copper cables	41.8	x	x		
lead sheathings for aluminium cables	8.6	x	x		
type metal	1o.3				x
building constructions	25.8	x			x
Total	1o3.1				

1 On the base of 1972 input

2 Storage batteries excluded

Source: See Table 19

12

Apart from motor cars, typemetal, and technical apparatus where technical problems impede recycling, problems arise mainly from difficulties of collection. Cable sheathings account for nearly half of the lead quantities considered problematic as far as recovery is concerned. Therefore, this sector provides the most important source to raise the recycling quota. Experts estimate that several million tons of lead sheathing and lead pipes are waiting for recovery but are presently not used because of problems of localization and costly reclaiming.

Collection problems are also partly responsible for the yet insufficient recovery of lead from machines for building and civil engineering. In addition, problems of separation exist as lead is usually applied as component of alloys used for bearings or taps, cocks, and valves. The recovery of these alloys concentrates not on lead but rather on copper (red brass) or results in "Mischzinn" (Pb/Sn-alloy) which is reused for the production of solder. An efficient separation of tin from lead is at present still problematic. However, by volume, this recycling potential is less significant for lead than for tin.

Quantitatively more important are the lead components of technical apparatus, i.e. mainly equipment for the chemical industry. Lead is appreciated primarily because of its good resistance to corrosion. Difficulties in recycling may arise from separation problems as well as from the necessary cleaning for example from acid residues.

In general, lead recycling from motor-cars is relatively high. Excluding accumulators, however, only 30% of the lead content is recovered. This might be explained by the specific kinds of application. Lead is used for solder, balancing weights, bearings, and similar small pieces scattered over the whole car.

Lead in typemetal has so far been recycled almost exclusively within the printing industry, i.e. reprocessed into the same product. However, the introduction of new printing technologies has made relatively large quantities of typemetal superfluous so that this material is available for general lead recycling. Yet, consisting of lead, tin, and antimony, the recovery of the alloy constituents is highly difficult and rather expensive.

Lead pipes, platings, etc. used in building and civil engineering can partly be removed from these buildings, however, at great cost. They are usually available when the building is pulled down. The utilization of this potential depends largely on scrap prices.

2.3.3. Copper

Due to net exports the domestic availability of copper-containing finished products is 21% lower than final demand. Additional 15% has been deducted as exports of intermediate goods so that only 680,000 t of copper remain for domestic recycling after the useful life of the products. Of these 96% have been followed up in the analysis on industry level, and still 74% on the product level. Even by limiting the considerations to the problem areas outlined in the previous sections of the study roughly 55% of the copper quantities available for domestic recycling remain.

The most important product groups are conducting material, construction material, motor cars and a few consumer durables. As in the case of lead, copper is hardly modified during its useful life due to its good resistance to corrosion and it therefore offers quite favourable conditions for recycling. Because of its good alloying properties it is often used and recycled in alloyed form.

Table 26: PROBLEM AREAS FOR RECYCLING OF COPPER

Specification	Potential[1] in 1 ooo t	Main Recovery Problems			
		Collec-tion	Sepa-ration	Prepa-ration	Metallur-gical
radio, television, and gramophone articles	19.8	x			
electrical heating equipment	1o.9	x			
household electrical appliances	9.1	x	x		x
precision instruments and optical products	6.8	x			
cupriferous sundries	4.4	x			
electrical refrigerators and washing machines	2o.7	x	x		x
taps, cocks, and valves	9.3	x	x		
building constructions	45.3	x	x		
copper cables and other products for conductor use	2o7.8	x	x		
machines for building and civil engineering	4.2	x	x		x
technical apparatus	4.2	x		x	
motor cars	32.9		x		x
Total	375.4				

1 On the base of 1972 input

Source: See Table 2o

The products scarcely used so far for recycling are electrical consumer goods and, in part, optical and small precision instruments, too, which mostly are disposed of in household refuse after use. At present only larger products such as radios, television sets, etc. are sorted out. This alone, however, does not guarantee a complete recovery of the copper contents since, on the one hnad, the quantities per unit are small (mostly conducting material), and on the other, separation problems may also occur. Large equipment such as washing machines, refrigerators, etc. are generally collected separately. They can be shredded like scrap automobiles. However, the recoverable amounts of copper in this case also depend on the separability.

To a small extent, taps, cocks, and valves, too, are disposed of in household refuse if e.g. replacements of domestic sanitary installations are done privately. In most cases, however, such work is done by plumbers who collect the exchanged parts. These products account for a considerable share of copper recycling from building and construction material. Inaccessible copper in plumbing, hardware, wiring, lighting accessories, and door furniture are seldom recovered.[1]

The most important source for copper recycling are cables and other conducting material including those quantities which are delivered as conducting material to other industries. About 320,000 t are available for domestic recovery. So far, large quantities of used cables, either subterranean or submarine, have not been recycled mostly because of economic reasons. Regarding separation, recycling technologies are gradually being modified from traditional cable incineration methods to semi-mechanical dressing and mechanical processing. Although

---

1 See L. WHALLEY, V.E. BROADIE: Non-Ferrous Metal Losses in the UK, Stevenage no year given, p. 20.

the incineration method is still more economical, these possibilities are subject to growing environmental restrictions.

Less significant in quantitative terms is the copper recycling potential of building and civil engineering machinery and equipment. The difficulties lie, on the one hand, in the insufficient collection, and on the other, in the scrapping process which does not provide for complete separation, for instance of smaller bearings from steel scrap.

In the motor-car industry there are many uses for copper. The most important are the radiator, starter and generator which usually are removed before shredding. As far as the copper remains with the steel after shredding not only is the copper lost but also the quality of steel scrap is reduced. Thus, greater efforts in utilizing automobile scrap for steel-making might also lead to a better recovery ratio of copper. Superior shredding technologies such as cryogenic shredding enable already a better separation of non-ferrous metals from steel, however, they are not yet feasible.

2.3.4. Zinc

In the case of zinc the difference between final demand and domestic availability is relatively small. While only 16% of final demand for zinc in finished products is net exports, 24% has been deducted as exports of intermediate goods. Thus, 60% of final demand or 374,000 t of zinc, respectively, are available for domestic recovery. Of these about 76.6% has been followed up in the analysis on industry level, and about 57.3% on product level. Nearly all sectors were considered as problem areas making up 53.5% of total domestic availability. This is closely connected with the fact that old scrap arisings of zinc are low compared with other non-ferrous metals.

The major recycling problems arise from galvanized products. On the other hand, the recycling potential from die casting products is also of importance. Semi-finished zinc products, sheets in particular, are largely recovered.

More than half of the domestic availability of selected products is contained in building constructions. Of this roughly 50% is shared by semi-finished zinc products and brass parts for which the recycling quota is relatively high. The remaining 50,000 to 60,000 t are used in galvanized materials, especially in steel sheets and tubes. At present, zinc used for galvanization is usually not directly recovered, because no selective collection of galvanized steel is in practice.[1] The known leaching processes are therefore not yet applied on an industrial scale.

On the other hand there are processes for the treatment of flue dusts from steel works. For several years, Lurgi for instance, is testing the processing of flue dusts with the Waelz-process. But up to now only small quantities of zinc are recovered from galvanized products, mainly due to economic reasons.

These problems of zinc recycling from galvanized products are not confined to building and construction material but also refer to other items of Table 27. However, apart from the metallurgical problems, difficulties in collecting old scrap arise in such cases as air conditioning and drying equipment.

Next to galvanized products, still important and yet hardly utilized sources of zinc recycling are zinc die castings which are primarily used in the motor car industry. Apart from these, comparatively small amounts are used for agricultural machinery and tractors, radios, television sets, and gramophones.

1 SGM: A Survey of the Technology of Copper Recycling, with a note on zinc recycling from galvanized products, Brussels 1977, Add. p. 1.

Table 27: PROBLEM AREAS FOR RECYCLING OF ZINC

Specification	Potential[1] in 1 ooo t	Main Recovery Problems			
		Collec-tion	Sepa-ration	Prepa-ration	Metallur-gical
ash cans and dust bins	2.6		x		x
steel container	16.4		x		x
construction elements of steel sheet	5.8		x		x
steel tubes and sheets	2.5		x		x
building constructions	113.o	x	x		x
large steel container	2.3		x		x
architectural con-structions	1.7		x		x
air conditioning and drying equipment	2.o	x	x		x
electrical refrige-rators and washing machines	2.9		x		
corrugated sheet steel for copper cable sheathing	4.7	x	x		x
radio, television, and gramophone ar-ticles	3.7	x	x		
primary batteries	8.5	x	x		x
precision instruments and optical products	2.7	x	x		
agricultural machinery and tractors	1.4	x	x		
motor cars	24.o		x		
tyres	6.o		x	x	
Total	2oo.2				

1 On the base of 1972 input

Source: See Table 21

The recycling difficulties of these products result from their widespread application, especially as small parts. So far, larger quantities have only been recovered from motor cars. Recycling from other product areas is still very small because of disposal in household refuse and separation difficulties.

Inspite of the high rate of collection of automobile scrap in F.R. Germany, zinc recycling from this field is still insufficient. The reason is also that zinc die castings are mostly small parts which are seldom completely removed before shredding. Even after shredding large quantities of zinc remain in the steel scrap and shredding waste.

In view of the widespread use of zinc, it is also interesting to mention the quantities used in tyres and primary batteries with respect to recycling. So far, zinc recycling from primary batteries has not been feasible, especially at the collection stage since obsolete cells are disposed of in household refuse and are either dumped or incinerated. Other problems are related to the mechanical separation of batteries.

As for the zinc oxides used in tyres, there are several techniques of recycling. At present, only small quantities are recovered in F.R. Germany. How far recycling in this field will actually increase in future depends largely on the choice of technology. This decision is subject to economic factors whereby zinc recovery plays only a subordinate role.

2.3.5. Tin

In the case of tin domestic availability is drastically reduced (23%) by considerable net exports of tin-containing finished products. In addition exports of intermediate goods, primarily tinplate, are important (24% of total demand). Thus only 53% of total demand remain available for domestic recovery. Of these 16,000 t 89% have been followed up in the analysis on industry level and about 61% on product level. Limiting the analysis to those areas in which recycling seems problematic roughly 50% of the domestically available products are considered.

By far the most important individual area of application seen from the input quantities as well as from the additional recycling potential is packaging, i.e. tinplate for cans. For many years the new scrap resulting from the production of tinplate and especially cans has been recycled. However, much larger quantities of old tin-containing materials have remained almost unused. They get into industrial and domestic refuse and are only rarely recycled. At present, recycling takes place only in the form of steel recycling. The recovery of tin from used tinplate packaging is up to now only subject to research efforts undertaken in nearly all industrialized countries. The main obstacles to the salvaging of used material are the collection and processing problems; the detinning process itself seems to be less problematic as the technique is principally the same as in the case of production wastes (new scrap).

Using old tinplate packaging as additional source of tin recycling certainly is the most promising approach for raising the recycling quota (see Table 28). For example, the total potential within F.R. Germany is estimated at about 4,800 t of tin. Even if only 60% of this quantity is recycled this would mean additional metal resources of roughly 90 million DM by value.

Table 28: PROBLEM AREAS FOR RECYCLING OF TIN

Specification	Potential[1] in t	Main Recovery Problems			
		Collection	Separation	Preparation	Metallurgical
tinplate cans	4 800	x		x	x
building constructions	1 100	x	x		x
technical apparatus	700		x		x
taps, cocks, and valves	200	x	x		x
motor cars	1 200		x		x
Total	8 000				

1 On the base of 1972 input.

Source: See Table 22.

In contrast to tin in packaging material, the tin content of alloys such as white metal (bearings), solder, bronze, etc. is already recycled to a comparatively large extent. Less important in terms of quantity is the use of tin in the form of typemetal or in the chemical industry. Apart from the mostly dissipative uses in the chemical industry the only important recycling potential in these areas might be seen in the stock of typemetal becoming available for recovery due to the changes of printing techniques.

Most tin recycling processes other than tinplate recovery result in "Mischzinn" (Pb/Sn-alloy) which is reused in the form of alloys. The separation of high grade tin from these tin/lead-alloys in an economic way obviously needs further investigation.

3. Summary and conclusions

3.1. Product life-times and scrap recovery rates

The quantitative findings of this study outline the recycling potentials of non-ferrous metals from product groups which so far are not or not sufficiently utilized. However, these recycling potentials which have been derived from domestic availability for 1972 are not yet accessible for recovery. The year in which the finished products consumed become accessible depends upon when the products become obsolete. Obsolescence is determined by each product's life-time. The life-times of products are completely different (see Table 29). For example, the production of packaging material of 1972 has become obsolete already in 1973, whereas the motor cars licenced in 1972 will become available as scrap only in the early eighties.

However, in this connection it has to be acknowledged that life-times are only of minor significance as far as the special objective of this study is concerned. As most of the products under review have entered their useful life year by year for a long time and become available consequently as old scrap each year, the identification of areas for further research on recycling can on principle be achieved without regarding the life-times of the products. This would only be a necessary prerequisite in the case of newly introduced products becoming obsolete for the first time at all.

Nevertheless, estimates of product life-times are of interest for calculating recycling or recovery ratios. Properly computed these quotas should indicate the portion of non-ferrous metals which is reclaimed from the originally

Table 29 : AVERAGE LIFETIME OF SELECTED PRODUCTS

Products	Lifetime	
	in years	classified
chemical products		
- paints and lacquers	4	○
- salts, oxides, etc.	1 - 2	○
- packaging material for chemical products	1	○
petrol (anti-knock additives)	0	
products of rubber industry		
- tyres	3	○
- other rubber products	2 - 4	○
products for steel construction		
- Al-containers	12	△
- large steel containers[1]	5 - 6	□
- wagons	20	△
- components of architectural construction	25	△
products of mechanical engineering,on average	18 - 20	△
- electrical motors and other electrical apparatus	7	□
- machines for building and civil engineering	12	△
- agricultural machinery and tractors	15	△
- taps, cocks and valves	10	□
- office machinery	15	△
motor cars	10	□
- accumulators	3 - 4	○
- tyres	3	○
shipbuilding	16	△
- accumulators	3 - 4	○
- paints and lacquers	1 - 2	○
products of electrical engineering		
tele-communication equipment	24	△
automatic data-processing equipment	12	△
radio, television and gramophone equipment	11	△
electrical heating equipment	8	□
household electrical appliances	6	□
electrical refrigerators and washing machines		
- freezing equipment	12	△
- refrigerators	12	△
- washing machines	9	□
high-voltage switchgears	30 - 40	△
low-voltage switchgears	20	△

Table29continued:

Products	Lifetime in years	Lifetime classified
copper cables and other products for electrical use	40	△
electrical motors	7	□
electrical generators	30 - 40	△
transformers	30 - 40	△
aluminium cables and other products for electrical use	40	△
accumulators	3 - 4	○
X-ray equipments	15	△
primary batteries	1	○
precision instruments and optical products	10	□
non-ferrous tools and articles for households, agriculture and small trade	12 - 14	△
aluminium toils, strips and cans	1	○
tubular furniture and equipment	18	△
ash cans and dust bins	15	△
steel containers	20	△
construction elements of steel sheet	25	△
steel tubes and sheets	25	△
typemetal	20	△
tinplate cans	1	○
building constructions	40	△
- roofing	25	△
- tubes	30	△

○ = Short term, □ = Medium term, △ = Long term

1 - Steel containers can be processed for reuse and may be employed for 5 to 6 years.

Source: BIPE: Le cycle des dêchets de metaux non ferreux, Paris 1973; H.BLUME (editor): Technologien der Rohstoffnutzung, Jahresbericht 1976 zum Programm "Angewandte Systemanalyse (ASA)" in der Arbeitsgemeinschaft der Großforschungseinrichtungen (AGF), Anlagenband II, Köln 1977; FRED V. CARILLO, MARK H. HIBPSHMAN, RODNEY D. ROSENKRANZ: Recovery of Secondary Copper and Zinc in the United States, US Bureau of Mines, Information Circular 8622, Washington, D.C. 1974; P.F. CHAPMAN: Energy Conservation and Recycling Copper and Aluminium, in: Metals & Materials, no place given, June 1974; EUROPOOL: Untersuchung über das Aufkommen an metallischem Schrott von Autowracks und Haushaltsgroßgeräten, die Möglichkeiten der Abfallbeseitigung, Weiterverarbeitung und das Recycling in den Ländern der Europäischen Gemeinschaften, no place given (1975); INTERNATIONAL LEAD AND ZINC STUDY GROUP: Secondary Lead and Zinc, Report by an ad hoc Working Party of the Statistical Committee, no place given, Sept. 1975; OECD, COMMITTEE FOR SCIENTIFIC AND TECHNOLOGICAL POLICY: The Life Cycle of Copper, Paris 1976; ORGANISATION EUROPÄISCHER ALUMINIUM-SCHMELZHÜTTEN (OEA): Aluminium Schmelzhütten Europa, Japan, USA, 1975-76, Düsseldorf 1976 employed quantities. There are two crucial points, however, which make the computing of fairly exact quotas difficult:

- First, to estimate the quantities of metals originally employed for products becoming obsolete at present, it is obviously necessary to have adequate data of production and foreign trade as well as of the metal content of relevant products for the last 30 years or so. Applying the input/output-approach yearly input/output-tables back to 1945 would be required. Such data are not available.

- Second, data on the exact composition of the actually recovered old scrap by products or product groups are not available. Only rough estimates by industry experts could be applied.

Therefore, it is not surprising that usually recovery rates of a different meaning are computed by relating the scrap available to date to present non-ferrous metal input. The different meaning becomes obvious for example in the case of lead recovery from old tubes. Relating the reclaimed metal from this source to the present day input for lead tubes results in a quota which does not indicate anything about the recovery of the originally employed lead for tubes, i.e. the efficiency of recovery. Such problems arise when the application of metals for certain products has increased or decreased substantially during the reference period.

In view of this difficulty it has been refrained from computing recovery ratios for each product in this study. With regard to the specific objectives, that is to say the determination of areas of untapped recycling potentials, it seems quite reasonable to use more or less rough estimates.

3.2. Further considerations

Part 2.3. has given a quantitative analysis of the problem areas identified as sources to increase recycling for individual metals. Recycling difficulties have also been outlined. In a concluding assessment it seems appropriate to give a general view of the relevant product groups by cumulating the different metal contents weighted by the metal prices. The findings are shown as a graph in Figure 2.

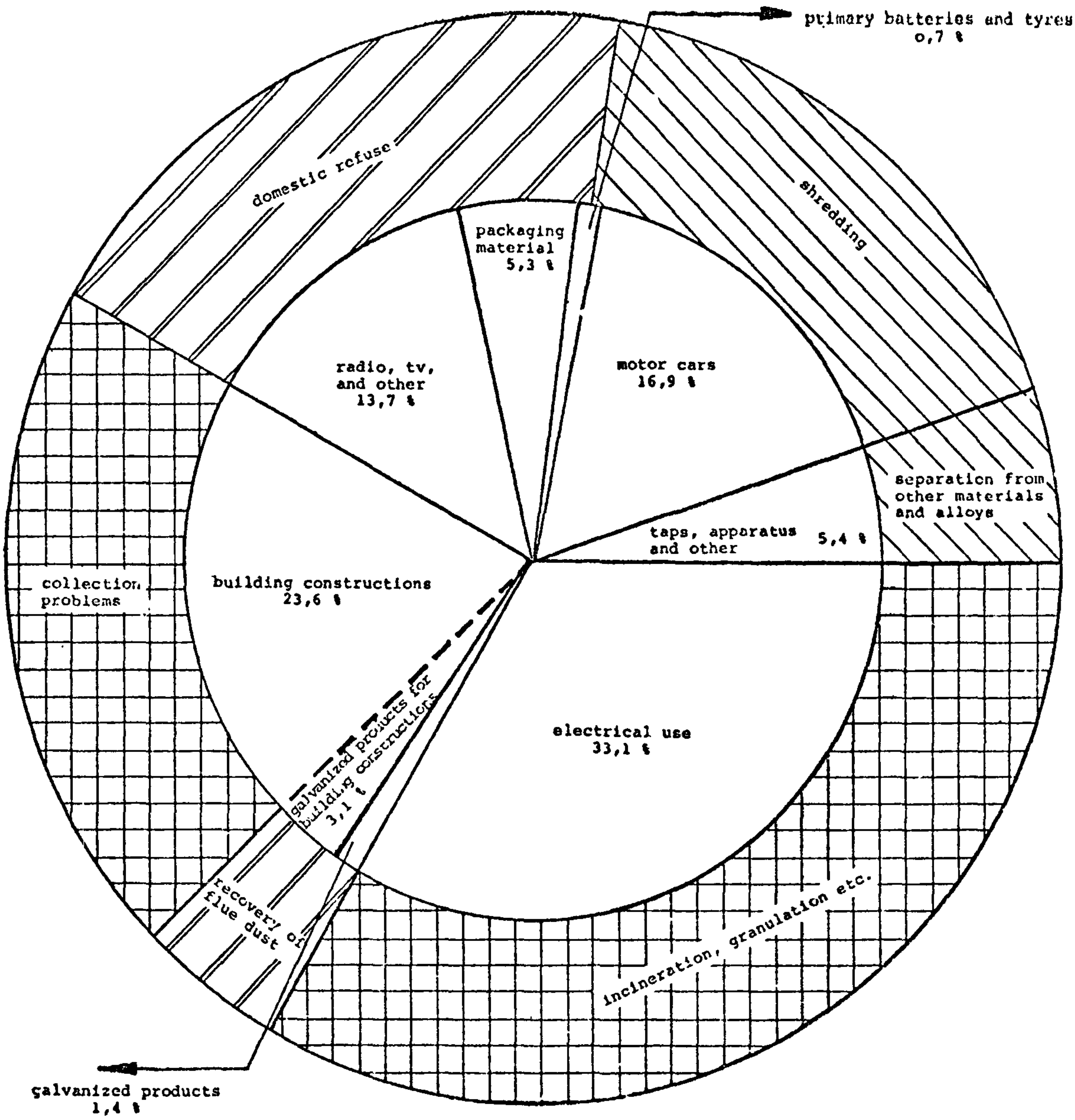
By viewing the various products and product groups with regard to technological problems of recovery it may be stipulated that certain common features exist inspite of many differences in size, metal input and availability of products. The major technical constraints on recycling of non-ferrous metals are concerend with their separation from materials in the waste stream, from other materials added during the manufacture of the product or from other elements in alloys.

On the other hand, regarding the efficiency of scrap collection two different sources should be distinguished. Production waste as well as old scrap arising within the industries are usually recovered as far as feasible at given technology and prices of secondary metals. In contrast, products becoming obsolete within the household sector are normally disposed of in household refuse and therefore, at present, hardly recovered. This second source evidently offers the more important potential of additional recycling.

Consequently the following R & D activities to increase the recycling of non-ferrous metals may be recommended:

- Domestic refuse offers a potential source of relatively large tonnages of aluminium, tin and - to a smaller extent - copper. The non-ferrous metallic components of municipal

Figure 2: TOTAL RECOVERY POTENTIAL OF MAIN PROBLEM AREAS, in value %



Present recovery activities:

(grid)	considerable
(back-hatched)	relatively low
(forward-hatched)	low or none

14

solid refuse are by far the most valuable constituents. But the economic viability of their recovery depends on the development of adequate separation and preparation techniques.

- In this context an overall aspect which must be observed is that the refuse problem of private households has so far been mainly discussed in view of disposal. If the reclamation of valuable materials contained in the refuse would be stressed the non-ferrous metals could contribute greatly towards the economics of recycling. In any case efforts should be made to introduce recovery systems for the reclamation of a series of materials rather than for the recovery of individual materials such as paper, glass, etc.

- The pyrolysis may be regarded as a promising technology to cope with these problems. This technique resulting in the recovery of the originally employed raw materials is principally applicable to household refuse as well as to cables, tyres, etc.

- It was shown that technology is often available for recovery operations, but its adoption is restricted by economic factors. Among them the prices of secondary materials seem to be most important. Any efforts to increase the level of recycling activities have to take into account that all reclaimed secondary material has to compete with primary supply.

- As for the price fluctuations experienced in the case of nearly all non-ferrous metals special emphasis should be put upon the operating flexibility of recycling equipment. This refers not only to the effects of high capital intensity on the minimum capacity employment but also to the applicability of the equipment to various input materials.

REFERENCES

BIPE: Le cycle des dêchets de metaux non ferreux, Paris 1973

BIPE, Charter Consolidated, ITE: Technical and economic analysis of the recovery and recycling of non-ferrous metals (Al, Cu, Zn, Pb, Sn) in particular in the European Community, Neuilly, London, Hamburg 1977, not published

Blume, H. (editor): Technologien der Rohstoffnutzung, Jahresbericht 1976 zum Programm "Angewandte Systemanalyse (ASA)" in der Arbeitsgemeinschaft der Großforschungseinrichtungen (AGF), Anlageband II, Köln 1977

Carillo, Fred V.; Hibpshman, Mark H.; Rosenkranz, Rodney D.: Recovery of Secondary Copper and Zinc in the United States, US Bureau of Mines, Information Circular 8622, Washington, D.C. 1974

CERIMET: A Survey of the Technologies for Recycling Aluminium and Lead, Torino 1977

Chapman, P.F.: Energy Conservation and Recycling of Copper and and Aluminium, in: Metals & Materials, no place given, June 1974

Europool: Untersuchung über das Aufkommen an metallischem Schrott von Autowracks und Haushaltsgroßgeräten, die Möglichkeiten der Abfallbeseitigung, Weiterverarbeitung und das Recycling in den Ländern der Europäischen Gemeinschaften, no place given (1975)

Filip-Köhn, R.; Filip, D.: Erdölkrise: Auswirkungen auf Preisniveau und Preisgefüge in der Bundesrepublik Deutschland im Jahre 1972, in: Wochenbericht des DIW, Nr. 1-2/1974

International Lead and Zinc Study Group: Secondary Lead and Zinc, Report by an ad hoc Working Party of the Statistical Committee, no place given, Sept. 1975

OECD, Committee for Scientific and Technological Policy: The Life Cycle of Copper, Paris 1976

Organisation Europäischer Aluminium-Schmelzhütten (OEA): Aluminium Schmelzhütten Europa, Japan, USA, 1975-76, Düsseldorf 1976

Pischner, R.; Stäglin, R.; Wessels, H.: Input-Output-Rechnung für die Bundesrepublik Deutschland 1972, Deutsches Institut für Wirtschaftsforschung: Beiträge zur Strukturforschung, Heft 38, Berlin 1975

SGM: A Survey of the Technology of Copper Recycling, with a Note on Zinc Recycling from Galvanized Products, Brussels 1977

Stäglin, R.: Aufstellung von Input-Output-Tabellen; Konzeptionelle und empirisch-statistische Probleme, DIW-Beiträge zur Strukturforschung, Heft 4, Input-Output-Rechnung, Berlin 1968

Stodieck, Helmut et al.: Substitution und Rückgewinnung von NE-Metallen in der Bundesrepublik Deutschland, Hamburg 1976

Tangermann, Hans-Dieter: Verpackungswirtschaft-Metallkreis, in: Egon Keller (editor): Abfallwirtschaft und Recycling, Probleme und Praxis, Essen 1977

Umweltbundesamt: Materialien 2/76, Materialien zum Abfallwirtschaftsprogramm '75, V: "Metalle und metallische Verbindungen", no place and no year given

Whalley, L.; Broadie, V.E.: Non-Ferrous Metals Losses in the UK, Stevenage no year given

APPENDIX A

Nomenclature of Selected Sectors of the
DIW - Input - Output - Tables

NOMENCLATURE OF SELECTED SECTORS OF THE DIW - INPUT - OUTPUT - TABLES

1o	Eisenschaffende Industrie	iron and steel industry
1ooo1	H. v.verzinktem Stahlblech	galvanizing steel sheet
1o999	Übrige eisenschaffende Industrie	other iron and steel industry
13oo5	Kupferhalbzeug-Industrie	semimanufactured products of copper
13oo7	Aluminiumleichtmetall-Gießereien	aluminium foundries
13oo8	Kupferhütten-Industrie	copper smelters
13oo9	Aluminiumhütten-Industrie	aluminium smelters
13o1o	Aluminiumhalbzeug-Industrie	semimanufactured products of aluminium
13o13	Zinkhütten-Industrie	zinc smelters
13o15	Zinkhalbzeug-Industrie	semimanufactured products of zinc
13o22	Zinnhütten-Industrie	tin smelters
13o23	Zinnhalbzeug-Industrie	semimanufactured products of tin
14	Chemische Industrie	chemical industry
14oo2	Farben- und Lackindustrie	paints and lacquers industry
14oo8	H. v. Kosmetika und Seifen	cosmetics and soap industry
14999	Übrige chemische Industrie	other chemical industry
15	Mineralölverarbeitung	mineral oil processing
16oo2	Kautschukindustrie	rubber industry
19	Stahlbau	steel construction
19oo1	Waggonbau	wagon making
19oo2	H. v. Containern	production of containers
19oo3	H.v. Hochbaukonstruktionen	architectural construction
19oo5	H. v. Weißblech u.Weißband	production of tinplate
19999	Übriger Stahlbau	other steel construction
2o	Maschinenbau	mechanical engineering
2ooo1	Werkzeugmaschinenindustrie	machine-tool industry
2oo12	H. v. Pumpen und Ventilen	pump and valve manufacture
2oo13	Lufttechnik und Trocknungsanlagen	air conditioning and drying equipment
2oo14	H. v. Kältemaschinen	industrial freezing equipment
2oo15	H. v. Bau- und Baustoffmaschinen	machines for civil engineering

2oo18	Landmaschinen für Ackerschlepper	agricultural machinery and tractors
2oo19	H. v. Nahrungsmittelmaschinen	machines for food industry
2oo2o	Apparatebau	manufacture of technical apparatus
2oo23	Fördertechnik	lifting, handling, and haulage equipment
2oo25	H.v. Textilmaschinen	textile machines
2oo3o	H.v. Armaturen	production of taps, cocks, and valves
2oo31	Antriebstechnik	transmission engineering
2oo34	Bürotechnik	office machinery
2oo35	Kernenergietechnik	nuclear reactor equipment
2o999	Übriger Maschinenbau	other mechanical engineering
21	Straßenfahrzeugbau	motorcar industry
21oo1	Kraftfahrzeugbau - VW	motorcar production of VW
21999	Übriger Straßenfahrzeugbau	other motorcar industry
23	Schiffbau	shipbuilding industry
24	Elektrotechnische Industrie	electrical engineering
24oo7	Nachrichtentechnik	tele-communication equipment
24oo8	Automatische Datenverarbeitungsanlagen	automatic data-processing equipment
24o1o	Rundfunk-, Fernseh- und Phonotechnische Industrie	radio, television and gramophone manufacture
24o11	H. v. elektrischen Wärmegeräten	electrical heating equipment
24o12	H. v. elektromotorischen Wirtschaftsgütern	household electrical appliance manufacture
24o13	H. v. elektrischen Haushaltskühlmöbeln und Waschmaschinen	electrical refrigerator and washing machine manufacture
24o14	H. v. Hochspannungsschaltgeräten	production of high-voltage switchgears
24o15	H. v. Niederspannungsschaltgeräten	production of low-voltage switch gears
24o17	H. v. Kabeln.und sonstigem Leitungsmaterial aus Kupfer	copper cables and other products for electrical use
24o18	H. v. Elektromotoren und Generatoren	electric motors and generators
24o19	H. v. Transformatoren und Stromrichtern	production of transformers
24o2o	H. v. Kabeln und sonstigem Leitmaterial aus Aluminium	aluminium products for electrica use

24o23	Blei-Akkumulatoren-Industrie	accumulator industry
24o24	H. v. Röntgengeräten	production of X-ray equipments
24o25	H. v. Primärelementen	production of primary batteries
24o3o	H. v. Leitmaterialien aus Kupfer	copper products for electrical use
24999	Übrige Elektrotechnische Industrie	other electrical engineering
25	Feinmechanische und optische Industrie	precision engineering and optical industry
25oo3	Photo- und optische Industrie	manufacture of optical instruments
27	EBM-Industrie	production of tools and finished articles of metal
27oo4	H. v. Geräten und Bedarfsartikeln aus NE-Metallen für Haus-, Landwirtschaft und Gewerbe	manufacture of non-ferrous tools and articles for households, agriculture, and small trade
27oo8	Kupferverarbeitende Metallkurzwarenindustrie	manufacture of cupriferous sundries
27oo9	H. v. Aluminiumfolien, -bändern, -dosen	production of aluminium foils, strips, and cans
27o1o	H. v. Stahl- und NE-Metallmöbeln und -einrichtungen	production of tubular furniture and equipment
27o11	Müllgefäße und Abfalltonnen	ash cans and dust bins
27o15	H. v. Lager- und Transportbehältern aus Stahlblech	production of steel containers
27o16	H. v. Baubedarf aus Stahlblech	production of construction elements of steel sheet
27o17	H. v. Rohr- und Blechkonstruktionen aus Stahlblech	manufacture of steel tube and sheet products
27o23	H. v. Feinblechpackungen (Weißblech)	production of tinplate packaging
27999	Übrige EBM-Industrie	other manufacture of tools and finished articles of metal
33	Druckerei- und Vervielfältigungsindustrie	printing industry
43	sonstige Nahrungs- und Genußmittelindustrie	food industry
43oo2	H. v. Fisch- und Fleischkonserven	production of canned fish and meat
43999	Übrige, sonstige Nahrungs- und Genußmittel-Industrie	other food industry

44o43	Sonstige Nahrungs- und Genußmittelgewerbe	other manufacture of food
45	Baugewerbe	building and civil engineer
51	Nachrichtenübermittlung (Post)	communications (post)
53	Wohnungsvermietung	flat-letting business
54oo3	Hotellerie, Gaststättengewerbe	hotel and restaurant busine
54999	Übrige, sonstige Dienstleistungen	miscellaneous services

APPENDIX B

Calculation of Final Demand and Domestic Availability in 1976 on the Basis of Input/Output-Tables for 1972

Given the inputs for 1976, the relevant final demand figures for the same year may be calculated upon the assumption of stable input/output-relationships. Prerequisites of stability are:

- absence of technological progress
- absence of changes in the composition of final demand
- absence of processes of vertical concentration
- absence of changes in the business cycle.

These assumptions, however, seem to be not realistic for the period between 1972 and 1976. Thus, results for 1976 have not been included into the study but only are shown in the appendix.

Tables for 1976 are numberized in the same way as for 1972.

Table 3: CALCULATION OF THE PRIMARY INPUTS OF THE INPUT-OUTPUT TABLES 1976

input-components \ metal	Al	Pb	Cu	Zn	Sn
Domestic production of primary and secondary smelters	991.1	338.2	446.6	326.2	2.3
Direct use of scrap	55.4	10.4	157.3	77.1	6.1
Increase (-) and decrease (+) of visible stocks	-7.2	-17.0	-45.4	+3.9	-0.3
Imports of non-ferrous metals and semi-finished products[1]	626.8	51.3	685.5	188.2	20.1
Total input	1666.1	382.9	1244.0	595.4	28.2

1 Excluding imports of new and old scrap, ores and concentrates, which are included in the production figure

Source: METALLGESELLSCHAFT AG: Metalstatistics, 1966-1976, 64. Ed., Frankfurt/Main 1977; STATISTISCHES BUNDESAMT: Fachserie G, Außenhandel, R. 2, Spezialhandel nach Waren und Ländern 1976; ITE estimates.

Table 18: CALCULATION OF THE DOMESTIC AVAILABILITY OF ALUMINIUM IN PRODUCTS FOR FINAL USE, 1976

Code	Specification	Final Demand in 1 000 t	Domestic Availability in 1 000 t
14	chemical industry	32.8	23.5
14008	cosmetics and soap industry	5.9	5.6
19	steel construction	18.3	17.0
19001	wagon making	7.8	6.4
20	mechanical engineering	158.7	90.2
20001	machine-tool industry	12.8	8.3
20013	air conditioning and drying equipment	10.4	8.6
20014	industrial freezing equipment	6.8	5.8
20015	machines for civil engineerg	9.4	7.9
20018	agricultural machinery and tractors	12.7	7.6
20019	machines for food industry	12.3	5.6
20023	lifting, handling and haulage equipment	6.7	7.9
20025	textile machines	8.6	2.7
20034	office machinery	8.6	5.4
21	motorcar industry	270.6	173.8
23	shipbuilding industry	14.3	11.0
24	electrical engineering	207.9	179.7
24007	tele-communication equipment	49.0	40.3
24008	automatic data-processing equipment	30.8	28.6
24010	radio, television and gramophone manufacture	12.3	11.2
24019	production of transformers	11.6	10.7
24020	aluminium products for electrical use	60.3	59.7

Table 18 continued:

Code	Specification	Final Demand	Domestic Availa-bility
		in 1 000 t	in 1 000 t
25	precision engineering and optical industry	23.4	17.7
25003	manufacture of optical instruments	17.5	14.8
27	production of tools and finished articles of metal	82.8	59.1
27004	manufacture of non-ferrous tools and articles for households, agriculture and small trade	14.0	12.3
27009	production of aluminium foils, strips, and cans	32.6	11.1
27010	production of tubular furniture and equipment	19.9	19.1
43	food industry	35.2	32.5
45	building and civil engineering	181.0	181.0

Source: ITE estimates

Table 19: CALCULATION OF THE DOMESTIC AVAILABILITY OF LEAD IN PRODUCTS FOR FINAL USE, 1976

Code	Specification	Final Demand in 1 000 t	Domestic Availa-bility in 1 000 t
14	chemical industry	29.3	19.8
14002	paints and lacquers industry	23.4	15.9
15	mineral oil processing	5.0	1)
20	mechanical engineering	34.8	24.3
20015	machines for civil engineering	4.3	3.6
20020	manufacture of technical apparatus	11.6	7.7
20023	lifting, handling and haulage equipment	4.5	3.5
20031	transmission engineering	1.0	0.5
20035	nuclear reactor equipment	6.5	5.7
21	motorcar industry	53.3	34.2
23	shipbuilding industry	2.7	2.0
24	electrical engineering	99.1	85.9
24007	tele communication equipment	0.5	0.4
24008	automatic data-processing equipment	0.2	0.2
24017	copper cables and other products for electrical use	44.2	40.6
24019	production of transformers	0.9	0.8
24020	aluminium products for electrical use	8.4	8.3
24023	accumulator industry	36.6	27.1
24024	production of X-ray equipments	4.4	2.7
33	printing industry	0.4	0.3
45	building and civil engineering	25.0	25.0

1) not calculable

Source: ITE estimates

16

Table 20: CALCULATION OF THE DOMESTIC AVAILIBILITY OF COPPER IN PRODUCTS FOR FINAL USE, 1976

Code	Specification	Final Demand	Domestic Availa-bility
		in 1 000 t	in 1 000 t
14	chemical industry	20.5	13.5
20	mechanical engineering	128.4	72.6
20001	machine-tool industry	14.8	9.6
20012	pump and valve manufacture	8.1	3.6
20015	machines for civil engineering	5.8	4.9
20019	machines for food industry	5.1	2.3
20020	manufacture of technical apparatus	7.3	4.9
20023	lifting, handling and haulage equipment	6.2	4.8
20025	textile machines	5.0	1.5
20030	production of taps, cocks and valves	15.1	10.9
21	motorcar industry	69.6	38.4
23	shipbuilding industry	23.1	17.7
24	electrical engineering	638.3	546.2
24007	tele-communication equipment	38.5	32.5
24008	automatic data-processing equipment	7.1	6.7
24010	radio, television and gramophone manufacture	25.5	23.1
24011	electrical heating equipment	15.5	12.7
24012	household electrical appliance manufacture	12.1	10.6
24013	electrical refrigerator and washing machine manufacture	22.4	24.2
24014	production of high-voltage switchgears	15.4	13.1

Table 20 continued:

Code	Specification	Final Demand	Domestic Availa-bility
		in 1 000 t	in 1 000 t
24015	production of low-voltage switchgears	14.4	7.0
24017/ 24030	copper cables and other products for electrical use	267.7	242.6
24018	electric motors and generators	32.5	23.0
24019	production of transformers	41.1	37.7
25	precision engineering and optical industry	10.4	7.9
27	production of tools and finished articles of metal	21.7	14.9
27008	manufacture of cupriferous sundries	8.3	5.1
45	building and civil engineering	52.9	52.9

Source: ITE estimates

Table 21: CALCULATION OF THE DOMESTIC AVAILIBILITY OF ZINC IN PRODUCTS FOR FINAL USE, 1976

Code	Specification	Final Demand	Domestic Availa-bility
		in 1 000 t	in 1 000 t
14	chemical industry	26.2	18.0
14002	paints and lacquers industry	2.0	1.3
16002	rubber industry	0.4	0.4
19	steel construction	34.3	32.2
19002	production of containers	3.0	2.2
19003	architectural construction	1.9	1.6
20	mechanical engineering	34.8	20.3
20001	machine-tool industry	4.8	3.1
20012	pump and valve manufacture	2.0	0.9
20013	air conditioning and drying equipment	2.3	1.9
20018	agricultural machinery and tractors	2.2	1.3
20023	lifting, handling and haulage equipment	1.9	1.5
20025	textile machines	2.4	1.7
21	motorcar industry	36.8	22.9
23	shipbuilding industry	6.3	4.9
24	electrical engineering	37.5	32.1
24007	tele-communication equipment	3.1	2.6
24010	radio, television and gramophone manufacture	3.9	3.5
24013	electrical refrigerator and washing machine manufacture	2.6	2.8
24017	copper cables and other products for electrical use	4.9	4.5
24025	production of primary batteries	7.2	8.1
25	precision engineering and optical industry	2.7	2.6

Table 21 continued:

Code	Specification	Final Demand in 1 000 t	Domestic Availa- in 1 000 t
27	production of tools and finished articles of metal	41.2	32.3
27011	ash cans and dust bins	2.5	2.5
27015	production of steel containers	16.0	15.7
27016	production of construction elements of steel sheet	3.2	5.5
27017	manufacture of steel tube and sheet products	4.8	2.4
45	building and civil engineering	107.9	107.9

Source: ITE estimates

Table 22: CALCULATION OF THE DOMESTIC AVAILIBILITY OF TIN IN PRODUCTS FOR FINAL USE, 1976

Code	Specification	Final Demand	Domestic Availability
		in t	in t
14	chemical industry	654	446
20	mechanical engineering	5 456	3 115
20019	machines for food industry	420	198
20020	manufacture of technical apparatus	934	629
20030	production of taps, cocks and valves	280	201
20031	transmission engineering	215	104
21	motorcar industry	1 775	1 121
23	shipbuilding industry	290	222
24	electrical engineering	1 121	1 046
24007	tele-communication equipment	523	453
24008	automatic data-processing equipment	589	585
27[1)]	production of tools and finished articles of metal	1 579	1 263
43	food industry	5 232	4 993
43002	production of canned fish and meat	2 775	4 498
45	building and civil engineering	1 037	1 037

1) Excluding 27023 production of tinplate packaging, as this material is not part of final demand but rather consists of semi-finished products.

Source: ITE estimates

APPENDIX C

Final Demand Part of the Input/Output-Table, 1972 in %

57 = Private Consumption
58 = Government Consumption
59 = Gross Fixed Capital Formation
6o = Changes in Stocks
61 = Foreign Sector (Exports)
62 = Auxiliary Materials
63 = Material Losses

ALUMINIUM IN %

CODE	57	58	59	60	61	***	62	63	***
1001	0.08	0.01	0.00	0.00	0.02	0.10	0.0	0.0	0.10
1999	0.00	0.0	0.0	0.0	0.00	0.01	0.0	0.0	0.01
2	0.08	0.01	0.02	0.0	0.00	0.12	0.0	0.0	0.12
3	0.03	0.01	0.01	0.0	0.0	0.05	0.0	0.0	0.05
4	0.03	0.00	0.0	0.01	0.04	0.08	0.0	0.0	0.08
5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
6	0.00	0.0	0.0	0.0	0.00	0.01	0.0	0.0	0.01
7	0.0	0.0	0.0	0.0	0.0	0.00	0.0	0.0	0.00
8001	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
8999	0.0	0.0	0.0	0.0	0.00	0.00	0.0	0.0	0.00
9002	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
9001	0.00	0.0	0.00	0.0	0.0	0.00	0.0	0.0	0.00
9003	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
9004	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
9005	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
9006	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
9007	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
9008	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
9999	0.0	0.0	0.01	0.00	0.01	0.02	0.0	0.0	0.02
10001	0.0	0.0	0.0	0.0	0.03	0.03	0.0	0.0	0.03
10002	0.0	0.0	0.0	0.0	0.00	0.00	0.0	0.0	0.00
10003	0.0	0.0	0.0	0.0	0.00	0.00	0.0	0.0	0.00
10004	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
10005	0.0	0.0	0.0	0.0	0.04	0.04	0.0	0.0	0.04
10006	0.0	0.0	0.0	0.00	0.03	0.04	0.0	0.0	0.04
10999	0.04	0.01	0.06	-0.01	1.03	1.13	0.0	0.0	1.13
11001	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
11002	0.0	0.0	0.0	0.0	0.00	0.00	0.0	0.0	0.00
11003	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
11999	0.01	0.00	0.06	-0.01	0.11	0.18	0.0	0.0	0.18
12001	0.0	0.0	0.0	0.0	0.00	0.00	0.0	0.0	0.00
12002	0.00	0.0	0.0	0.0	0.00	0.01	0.0	0.0	0.01
12999	0.0	0.0	0.00	0.00	0.07	0.08	0.0	0.0	0.08
13001	0.0	0.0	0.0	0.0	0.0	0.00	0.0	0.0	0.00
13002	0.0	0.0	0.0	0.0	0.0	0.00	0.0	0.0	0.00
13003	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
13004	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
13005	0.0	0.0	0.00	0.0	0.01	0.01	0.0	0.0	0.01
13006	0.0	0.0	0.0	0.0	0.00	0.00	0.0	0.0	0.00
13007	0.14	0.0	0.0	0.0	1.15	1.29	0.0	0.18	1.48
13008	0.0	0.0	0.0	0.0	0.02	0.02	0.0	0.0	0.02
13009	0.0	0.0	0.0	0.0	6.24	6.24	0.0	0.95	7.19
13010	0.0	0.0	0.0	0.0	14.26	14.26	0.0	0.0	14.26
13011	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
13012	0.0	0.0	0.0	0.0	0.00	0.00	0.0	0.0	0.00
13013	0.0	0.0	0.0	0.0	0.11	0.11	0.0	0.0	0.11
13014	0.00	0.0	0.0	0.0	0.0	0.00	0.0	0.0	0.00
13015	0.0	0.0	0.0	0.0	0.01	0.01	0.0	0.0	0.01
13016	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
13017	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
13018	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
13019	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
13020	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
13021	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
13022	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
13023	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
13024	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
13025	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
13026	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
13027	0.0	0.0	0.0	0.0	0.25	0.25	0.0	0.0	0.25
13999	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
14001	0.0	0.0	0.0	0.0	0.00	0.00	0.0	0.0	0.00
14002	0.01	0.00	0.0	0.0	0.02	0.03	0.0	0.0	0.03
14003	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
14004	0.00	0.0	0.0	0.0	0.00	0.01	0.0	0.0	0.01
14005	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
14006	0.02	0.0	0.0	0.0	0.0	0.02	0.0	0.0	0.02
14007	0.07	0.0	0.0	0.0	0.01	0.07	0.0	0.0	0.07
14008	0.33	0.0	0.0	0.0	0.03	0.36	0.0	0.0	0.36
14009	0.03	0.0	0.0	0.0	0.0	0.03	0.0	0.0	0.03
14010	0.00	0.0	0.0	0.0	0.0	0.00	0.0	0.0	0.00
14011	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
14012	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
14013	0.0	0.0	0.0	0.0	0.01	0.01	0.0	0.0	0.01
14014	0.0	0.0	0.0	0.0	0.00	0.00	0.0	0.0	0.00
14015	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

ALUMINIUM continued :

CODE	57	58	59	6o	61	***	62	63	***
14016	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
14017	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
14018	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
14019	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
14020	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
14021	0.0	0.0	0.0	0.0	0.00	0.00	0.0	0.0	0.00
14999	0.14	0.25	0.05	-0.00	0.99	1.42	0.26	0.0	1.69
15	0.04	0.00	0.0	0.0	0.00	0.04	0.0	0.0	0.04
16001	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
16002	0.01	0.00	0.00	0.0	0.02	0.03	0.0	0.0	0.03
16003	0.0	0.0	0.0	0.0	0.00	0.00	0.0	0.0	0.00
16999	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
17001	0.0	0.0	0.0	0.0	0.0	0.00	0.0	0.0	0.00
17999	0.00	0.0	0.0	0.0	0.00	0.01	0.0	0.0	0.01
18	0.0	0.0	0.0	0.0	0.01	0.01	0.0	0.0	0.01
19001	0.0	0.01	0.37	0.0	0.09	0.47	0.0	0.0	0.47
19002	0.0	0.0	0.00	0.0	0.00	0.01	0.0	0.0	0.01
19003	0.0	0.0	0.01	0.00	0.00	0.01	0.0	0.0	0.01
19004	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
19005	0.0	0.0	0.0	0.0	0.01	0.01	0.0	0.0	0.01
19999	0.01	0.03	0.49	0.02	0.06	0.61	0.01	0.0	0.62
20001	0.0	0.0	0.38	-0.01	0.39	0.77	0.0	0.0	0.77
20002	0.0	0.0	0.01	0.0	0.01	0.02	0.0	0.0	0.02
20003	0.0	0.0	0.00	0.0	0.01	0.01	0.0	0.0	0.01
20004	0.0	0.0	0.00	0.0	0.01	0.01	0.0	0.0	0.01
20005	0.0	0.0	0.00	0.0	0.00	0.01	0.0	0.0	0.01
20006	0.0	0.0	0.06	-0.00	0.14	0.20	0.0	0.0	0.20
20007	0.0	0.0	0.12	-0.01	0.14	0.25	0.0	0.0	0.25
20008	0.0	0.0	0.00	0.0	0.00	0.00	0.0	0.0	0.00
20009	0.0	0.0	0.12	-0.00	0.12	0.24	0.0	0.0	0.24
20010	0.0	0.0	0.10	-0.01	0.29	0.38	0.0	0.0	0.38
20011	0.0	0.0	0.10	-0.01	0.27	0.36	0.0	0.0	0.36
20012	0.0	0.0	0.08	-0.01	0.28	0.36	0.0	0.0	0.36
20013	0.0	0.0	0.41	-0.01	0.22	0.63	0.0	0.0	0.63
20014	0.0	0.0	0.10	-0.01	0.31	0.41	0.0	0.0	0.41
20015	0.0	0.0	0.29	-0.01	0.28	0.56	0.0	0.0	0.56
20016	0.0	0.0	0.13	-0.00	0.25	0.38	0.0	0.0	0.38
20017	0.0	0.0	0.10	-0.00	0.14	0.24	0.0	0.0	0.24
20018	0.0	0.0	0.34	-0.01	0.44	0.76	0.0	0.0	0.76
20019	0.0	0.0	0.25	-0.01	0.50	0.74	0.0	0.0	0.74
20020	0.0	0.0	0.20	-0.00	0.15	0.34	0.0	0.0	0.34
20021	0.0	0.0	0.05	0.0	0.01	0.06	0.0	0.0	0.06
20022	0.0	0.0	0.05	0.0	0.02	0.07	0.0	0.0	0.07
20023	0.0	0.0	0.26	-0.00	0.14	0.40	0.0	0.0	0.40
20024	0.0	0.0	0.16	-0.00	0.22	0.37	0.0	0.0	0.37
20025	0.0	0.0	0.10	-0.01	0.42	0.51	0.0	0.0	0.51
20026	0.01	0.0	0.04	-0.00	0.13	0.17	0.0	0.0	0.17
20027	0.0	0.0	0.01	0.0	0.00	0.01	0.0	0.0	0.01
20028	0.0	0.0	0.00	0.0	0.00	0.01	0.0	0.0	0.01
20029	0.0	0.01	0.16	0.0	0.01	0.18	0.0	0.0	0.18
20030	0.00	0.0	0.12	-0.01	0.16	0.28	0.0	0.0	0.28
20031	0.0	0.0	0.01	-0.00	0.05	0.06	0.0	0.0	0.06
20032	0.0	0.0	0.00	0.0	0.0	0.00	0.0	0.0	0.00
20033	0.0	0.0	0.0	-0.00	0.03	0.03	0.0	0.0	0.03
20034	0.02	0.0	0.21	-0.01	0.29	0.51	0.0	0.0	0.51
20035	0.0	0.0	0.05	0.0	0.01	0.06	0.0	0.0	0.06
20999	0.07	0.02	0.06	-0.01	0.02	0.16	0.0	0.0	0.16
21001	0.65	0.0	0.35	-0.01	2.81	3.79	0.01	0.0	3.80
21999	2.83	0.35	3.66	-0.05	5.10	11.89	0.11	0.0	12.00
22	0.00	0.11	0.02	-0.02	0.04	0.16	0.0	0.0	0.16
23	0.01	0.10	0.35	0.04	0.36	0.86	0.0	0.0	0.86
24002	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
24001	0.0	0.0	0.17	0.0	0.0	0.17	0.0	0.0	0.17
24003	0.0	0.0	0.0	0.0	0.00	0.00	0.0	0.0	0.00
24004	0.0	0.03	0.07	0.0	0.14	0.24	0.0	0.0	0.24
24005	0.07	0.02	0.0	0.0	0.09	0.18	0.0	0.0	0.18
24006	0.0	0.0	0.00	0.0	0.00	0.00	0.0	0.0	0.00
24007	0.02	0.02	2.27	-0.00	0.63	2.94	0.00	0.0	2.94
24008	0.0	0.0	0.87	0.0	0.98	1.85	0.0	0.0	1.85
24009	0.03	0.0	0.0	-0.00	0.17	0.20	0.0	0.0	0.20
24010	0.43	0.0	0.04	0.0	0.28	0.74	0.0	0.0	0.74
24011	0.17	0.0	0.00	0.0	0.06	0.23	0.0	0.0	0.23
24012	0.18	0.0	0.0	0.0	0.06	0.24	0.0	0.0	0.24
24013	0.20	0.0	0.0	0.0	0.11	0.31	0.0	0.0	0.31
24014	0.0	0.0	0.16	0.0	0.04	0.20	0.0	0.0	0.20
24015	0.07	0.00	0.0	0.0	0.18	0.25	0.0	0.0	0.25

ALUMINIUM continued :

CODE	57	58	59	60	61	***	62	63	***
24016	0.01	0.0	0.0	0.0	0.04	0.05	0.0	0.0	0.05
24017	0.0	0.0	0.08	0.0	0.01	0.09	0.0	0.0	0.09
24018	0.01	0.00	0.13	0.0	0.18	0.32	0.0	0.0	0.32
24019	0.0	0.0	0.54	0.0	0.16	0.70	0.0	0.0	0.70
24020	0.0	0.0	3.54	0.0	0.08	3.62	0.0	0.0	3.62
24021	0.0	0.0	0.0	0.0	0.01	0.01	0.0	0.0	0.01
24022	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
24023	0.0	0.0	0.0	0.0	0.0	0.00	0.0	0.0	0.00
24024	0.0	0.0	0.01	0.0	0.01	0.01	0.0	0.0	0.01
24025	0.00	0.0	0.0	0.0	0.00	0.01	0.0	0.0	0.01
24026	0.00	0.0	0.0	0.0	0.01	0.01	0.0	0.0	0.01
24027	0.0	0.0	0.0	0.0	0.00	0.00	0.0	0.0	0.00
24028	0.0	0.0	0.05	0.0	0.01	0.06	0.0	0.0	0.06
24029	0.0	0.0	0.0	0.0	0.02	0.02	0.0	0.0	0.02
24030	0.0	0.0	0.0	0.0	0.01	0.01	0.0	0.0	0.01
24999	0.01	0.04	0.08	-0.00	0.03	0.15	0.0	0.0	0.15
25001	0.01	0.0	0.0	0.0	0.0	0.01	0.0	0.0	0.01
25002	0.0	0.0	0.0	0.0	0.00	0.00	0.0	0.0	0.00
25003	0.24	0.0	0.30	0.0	0.52	1.05	0.0	0.0	1.05
25999	0.11	0.07	0.0	0.0	0.17	0.35	0.0	0.0	0.35
26001	0.00	0.0	0.0	0.0	0.01	0.01	0.0	0.0	0.01
26999	0.00	0.01	0.01	0.00	0.02	0.05	0.0	0.0	0.05
27001	0.01	0.0	0.0	0.0	0.0	0.01	0.0	0.0	0.01
27002	0.0	0.0	0.0	0.0	0.0	0.00	0.0	0.0	0.00
27003	0.0	0.0	0.0	0.0	0.00	0.00	0.0	0.0	0.00
27004	0.49	0.03	0.03	0.0	0.29	0.84	0.0	0.0	0.84
27005	0.02	0.0	0.0	0.0	0.16	0.18	0.0	0.0	0.18
27006	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
27007	0.0	0.0	0.0	0.01	0.03	0.04	0.0	0.0	0.04
27008	0.04	0.0	0.0	0.0	0.08	0.13	0.0	0.0	0.13
27009	0.65	0.0	0.0	0.02	1.30	1.96	0.0	0.06	2.02
27010	0.39	0.0	0.63	0.00	0.16	1.19	0.0	0.0	1.19
27011	0.0	0.00	0.0	0.0	0.0	0.00	0.0	0.0	0.00
27012	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
27013	0.0	0.0	0.0	0.0	0.12	0.12	0.0	0.0	0.12
27014	0.0	0.07	0.0	0.0	0.10	0.16	0.0	0.0	0.16
27015	0.00	0.0	0.02	0.0	0.00	0.03	0.0	0.0	0.03
27016	0.00	0.0	0.0	0.0	0.01	0.01	0.0	0.0	0.01
27017	0.0	0.0	0.00	0.0	0.01	0.01	0.0	0.0	0.01
27018	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
27019	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
27020	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
27021	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
27022	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
27023	0.0	0.0	0.0	0.0	0.00	0.00	0.0	0.0	0.00
27024	0.0	0.0	0.0	0.0	0.06	0.06	0.0	0.0	0.06
27999	0.08	0.01	0.04	0.00	0.07	0.20	0.0	0.0	0.20
28	0.00	0.0	0.0	0.0	0.01	0.01	0.0	0.0	0.01
29001	0.00	0.0	0.0	0.0	0.00	0.01	0.0	0.0	0.01
29002	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
29003	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
29999	0.0	0.0	0.00	0.0	0.00	0.01	0.0	0.0	0.01
30001	0.01	0.0	0.0	0.0	0.00	0.01	0.0	0.0	0.01
30999	0.11	0.01	0.05	0.00	0.02	0.19	0.0	0.0	0.19
31001	0.00	0.0	0.0	0.0	0.00	0.00	0.0	0.0	0.00
31002	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
31999	0.02	0.0	0.00	0.0	0.01	0.03	0.0	0.0	0.03
32	0.01	0.00	0.0	0.0	0.00	0.02	0.0	0.0	0.02
33	0.01	0.00	0.0	0.0	0.00	0.02	0.0	0.0	0.02
34001	0.00	0.0	0.0	0.0	0.01	0.01	0.0	0.0	0.01
34999	0.05	0.01	0.01	0.01	0.07	0.14	0.0	0.0	0.14
35001	0.01	0.0	0.0	0.0	0.00	0.02	0.0	0.0	0.02
35999	0.02	0.0	0.0	0.0	0.01	0.03	0.0	0.0	0.03
36001	0.02	0.00	0.0	0.0	0.00	0.02	0.0	0.0	0.02
36002	0.01	0.0	0.0	0.0	0.00	0.01	0.0	0.0	0.01
36999	0.04	0.00	0.00	-0.00	0.02	0.06	0.0	0.0	0.06
37001	0.03	0.0	0.0	0.0	0.00	0.03	0.0	0.0	0.03
37999	0.06	0.00	0.0	0.0	0.00	0.06	0.0	0.0	0.06
38	0.00	0.0	0.0	0.0	0.0	0.01	0.0	0.0	0.01
39	0.01	0.0	0.0	0.0	0.01	0.02	0.0	0.0	0.02
40	0.01	0.0	0.0	0.0	0.00	0.01	0.0	0.0	0.01
41	0.21	0.00	0.0	0.0	0.01	0.22	0.0	0.0	0.22
42	0.12	0.0	0.0	-0.00	0.00	0.12	0.0	0.0	0.12
43001	0.00	0.0	0.0	0.0	0.00	0.00	0.0	0.0	0.00
43002	0.01	0.0	0.0	0.0	0.0	0.01	0.0	0.0	0.01
43999	1.83	0.05	0.00	0.02	0.21	2.10	0.37	0.0	2.48
44009	0.00	0.0	0.00	0.0	0.0	0.01	0.0	0.0	0.01
44010	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

ALUMINIUM continued :

CODE	57	58	59	60	61	***	62	63	***
44011	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
44012	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
44013	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
44014	0.01	0.00	0.0	0.0	0.00	0.01	0.0	0.0	0.01
44015	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
44016	0.0	0.0	0.0	0.0	0.0	0.00	0.0	0.0	0.00
44017	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
44018	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
44019	0.0	0.00	0.07	0.00	0.0	0.07	0.0	0.0	0.07
44020	0.01	0.00	0.21	-0.00	0.06	0.27	0.0	0.0	0.27
44021	0.53	0.01	0.02	-0.00	0.01	0.56	0.00	0.0	0.57
44022	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
44023	0.00	0.0	0.00	0.0	0.00	0.01	0.0	0.0	0.01
44024	0.13	0.01	0.10	0.0	0.05	0.28	0.0	0.0	0.28
44025	0.12	0.01	0.03	0.0	0.01	0.18	0.0	0.0	0.18
44026	0.03	0.01	0.05	0.0	0.0	0.09	0.0	0.0	0.09
44027	0.10	0.01	0.16	0.00	0.03	0.29	0.0	0.0	0.29
44028	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
44029	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
44030	0.03	0.00	0.03	0.0	0.00	0.07	0.0	0.0	0.07
44031	0.00	0.0	0.0	0.0	0.00	0.01	0.0	0.0	0.01
44032	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
44033	0.00	0.00	0.0	0.0	0.0	0.00	0.0	0.0	0.00
44034	0.00	0.0	0.0	0.0	0.00	0.00	0.0	0.0	0.00
44035	0.01	0.0	0.0	0.0	0.0	0.01	0.0	0.0	0.01
44036	0.00	0.0	0.0	0.0	0.0	0.00	0.0	0.0	0.00
44037	0.01	0.0	0.0	0.0	0.0	0.02	0.0	0.0	0.02
44038	0.00	0.0	0.0	0.0	0.0	0.00	0.0	0.0	0.00
44039	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
44041	0.02	0.0	0.0	0.0	0.0	0.02	0.0	0.0	0.02
44042	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
44043	0.30	0.00	0.0	0.00	0.00	0.31	0.21	0.0	0.52
45	0.12	0.59	10.07	0.02	0.06	10.87	1.72	0.0	12.58
46	0.02	0.02	0.05	0.01	0.03	0.12	0.0	0.0	0.12
47	0.23	0.01	0.00	0.01	0.00	0.26	0.0	0.0	0.26
48	0.04	0.02	0.03	0.0	0.03	0.12	0.0	0.0	0.12
49	0.00	0.00	0.0	0.0	0.06	0.06	0.0	0.0	0.06
50	0.08	0.02	0.01	0.0	0.05	0.16	0.0	0.0	0.16
51	0.03	0.01	0.00	0.0	0.00	0.05	0.0	0.0	0.05
52	0.05	0.01	0.0	0.0	0.00	0.06	0.0	0.0	0.06
53	0.07	0.0	0.0	0.0	0.0	0.07	0.55	0.0	0.62
54001	0.02	0.0	0.0	0.0	0.0	0.02	0.0	0.0	0.02
54002	0.04	0.0	0.0	0.0	0.0	0.04	0.0	0.0	0.04
54003	0.34	0.0	0.0	0.0	0.0	0.34	0.0	0.0	0.34
54004	0.02	0.0	0.0	0.0	0.0	0.02	0.0	0.0	0.02
54999	0.02	0.09	0.02	0.0	0.03	0.15	0.39	0.0	0.55
55	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
56	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
57	0.20	0.0	0.0	0.0	0.0	0.20	0.0	0.0	0.20
***	13.11	2.14	29.54	-0.06	45.75	90.49	3.65	1.19	95.32

LEAD IN %

CODE	57	58	59	60	61	***	62	63	***
1001	0.04	0.00	0.00	0.0	0.01	0.05	0.0	0.0	0.05
1999	0.0	0.0	0.0	0.0	0.0	0.00	0.0	0.0	0.00
2	0.05	0.01	0.01	0.0	0.00	0.06	0.0	0.0	0.06
3	0.03	0.00	0.01	0.0	0.0	0.04	0.0	0.0	0.04
4	0.03	0.00	0.0	0.01	0.04	0.09	0.0	0.0	0.09
5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
6	0.01	0.00	0.0	0.0	0.01	0.02	0.0	0.0	0.02
7	0.0	0.0	0.0	0.0	0.0	0.00	0.0	0.0	0.00
8001	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
8999	0.00	0.0	0.0	-0.00	0.02	0.02	0.0	0.0	0.02
9002	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
9001	0.0	0.0	0.0	0.0	0.0	0.00	0.0	0.0	0.00
9003	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
9004	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
9005	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
9006	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
9007	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
9008	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
9999	0.0	0.0	0.00	0.00	0.00	0.01	0.0	0.0	0.01
10001	0.0	0.0	0.0	0.0	0.00	0.00	0.0	0.0	0.00
10002	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
10003	0.0	0.0	0.0	0.0	0.00	0.00	0.0	0.0	0.00
10004	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
10005	0.0	0.0	0.0	0.0	0.01	0.01	0.0	0.0	0.01
10006	0.0	0.0	0.0	0.0	0.00	0.00	0.0	0.0	0.00
10999	0.00	0.0	0.00	0.0	0.03	0.03	0.0	0.0	0.03
11001	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
11002	0.0	0.0	0.0	0.0	0.00	0.00	0.0	0.0	0.00
11003	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
11999	0.0	0.0	0.00	0.0	0.00	0.01	0.0	0.0	0.01
12001	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
12002	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
12999	0.0	0.0	0.0	0.0	0.00	0.00	0.0	0.0	0.00
13001	0.0	0.0	0.0	0.0	0.0	0.00	0.0	0.0	0.00
13002	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
13003	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
13004	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
13005	0.0	0.0	0.0	0.0	0.00	0.00	0.0	0.0	0.00
13006	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
13007	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
13008	0.0	0.0	0.0	0.0	0.00	0.00	0.0	0.0	0.00
13009	0.0	0.0	0.0	0.0	0.00	0.00	0.0	0.0	0.00
13010	0.0	0.0	0.0	0.0	0.00	0.00	0.0	0.0	0.00
13011	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
13012	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
13013	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
13014	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
13015	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
13016	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
13017	0.0	0.0	0.0	0.0	0.0	0.0	0.61	0.0	0.61
13018	0.0	0.0	0.0	0.0	1.73	1.73	0.0	0.0	1.73
13019	0.18	0.0	0.0	0.0	0.18	0.35	0.0	0.0	0.35
13020	0.0	0.0	0.0	0.0	12.64	12.64	0.0	0.6	13.26
13021	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
13022	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
13023	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
13024	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
13025	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
13026	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
13027	0.0	0.0	0.0	0.0	0.10	0.10	0.0	0.0	0.10
13999	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
14001	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
14002	0.41	0.08	0.0	0.00	0.81	1.30	5.04	0.0	6.34
14003	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
14004	0.00	0.0	0.0	0.0	0.00	0.00	0.0	0.0	0.00
14005	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
14006	0.01	0.0	0.0	0.0	0.0	0.01	0.0	0.0	0.01
14007	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
14008	0.02	0.0	0.0	0.0	0.00	0.02	0.0	0.0	0.02
14009	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
14010	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
14011	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
14012	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
14013	0.0	0.0	0.0	0.0	0.01	0.01	0.0	0.0	0.01
14014	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
14015	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

LEAD continued :

CODE	57	58	59	60	61	***	62	63	***
14016	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
14017	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
14018	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
14019	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
14020	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
14021	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
14999	0.03	0.06	0.01	-0.00	0.25	0.36	1.24	0.0	1.60
15	0.35	0.03	0.00	-0.01	0.05	0.43	0.89	0.0	1.32
16001	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
16002	0.00	0.00	0.0	0.0	0.01	0.02	0.0	0.0	0.02
16003	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
16999	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
17001	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
17999	0.0	0.0	0.0	0.0	0.00	0.00	0.0	0.0	0.00
18	0.0	0.0	0.0	0.0	0.00	0.00	0.0	0.0	0.00
19001	0.0	0.0	0.01	0.0	0.00	0.01	0.0	0.0	0.01
19002	0.0	0.0	0.0	0.0	0.0	0.00	0.0	0.0	0.00
19003	0.0	0.0	0.00	0.0	0.0	0.00	0.0	0.0	0.00
19004	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
19005	0.0	0.0	0.0	0.0	0.00	0.00	0.0	0.0	0.00
19999	0.00	0.00	0.06	0.00	0.01	0.08	0.0	0.0	0.08
20001	0.0	0.0	0.08	-0.00	0.09	0.17	0.0	0.0	0.17
20002	0.0	0.0	0.01	0.0	0.01	0.02	0.0	0.0	0.02
20003	0.0	0.0	0.00	0.0	0.01	0.01	0.0	0.0	0.01
20004	0.0	0.0	0.0	0.0	0.00	0.00	0.0	0.0	0.00
20005	0.0	0.0	0.00	0.0	0.00	0.00	0.0	0.0	0.00
20006	0.0	0.0	0.01	0.0	0.03	0.04	0.0	0.0	0.04
20007	0.0	0.0	0.01	0.0	0.01	0.02	0.0	0.0	0.02
20008	0.0	0.0	0.00	0.0	0.00	0.00	0.0	0.0	0.00
20009	0.0	0.0	0.00	0.0	0.00	0.00	0.0	0.0	0.00
20010	0.0	0.0	0.01	0.0	0.02	0.02	0.0	0.0	0.02
20011	0.0	0.0	0.00	0.0	0.01	0.02	0.0	0.0	0.02
20012	0.0	0.0	0.01	-0.00	0.05	0.07	0.0	0.0	0.07
20013	0.0	0.0	0.05	-0.00	0.03	0.07	0.0	0.0	0.07
20014	0.0	0.0	0.00	0.0	0.01	0.01	0.0	0.0	0.01
20015	0.0	0.0	0.57	-0.01	0.53	1.09	0.00	0.0	1.09
20016	0.0	0.0	0.01	0.0	0.02	0.03	0.0	0.0	0.03
20017	0.0	0.0	0.01	0.0	0.02	0.03	0.0	0.0	0.03
20018	0.0	0.0	0.04	-0.00	0.05	0.08	0.0	0.0	0.08
20019	0.0	0.0	0.07	-0.00	0.13	0.19	0.0	0.0	0.19
20020	0.0	0.0	1.44	-0.03	1.12	2.53	0.58	0.0	3.11
20021	0.0	0.0	0.00	0.0	0.0	0.00	0.0	0.0	0.00
20022	0.0	0.0	0.00	0.0	0.00	0.01	0.0	0.0	0.01
20023	0.00	0.0	0.75	-0.01	0.40	1.15	0.0	0.0	1.15
20024	0.0	0.0	0.04	-0.00	0.06	0.11	0.0	0.0	0.11
20025	0.0	0.0	0.02	-0.00	0.10	0.12	0.0	0.0	0.12
20026	0.00	0.0	0.01	0.0	0.02	0.03	0.0	0.0	0.03
20027	0.0	0.0	0.00	0.0	0.00	0.01	0.0	0.0	0.01
20028	0.0	0.0	0.00	0.0	0.01	0.01	0.0	0.0	0.01
20029	0.0	0.0	0.00	0.0	0.0	0.00	0.0	0.0	0.00
20030	0.00	0.0	0.09	-0.01	0.12	0.21	0.01	0.0	0.22
20031	0.0	0.0	0.04	-0.01	0.22	0.25	0.00	0.0	0.25
20032	0.0	0.0	0.00	0.0	0.0	0.00	0.0	0.0	0.00
20033	0.0	0.0	0.0	0.0	0.00	0.00	0.0	0.0	0.00
20034	0.00	0.0	0.02	0.0	0.03	0.05	0.0	0.0	0.05
20035	0.0	0.0	1.25	0.0	0.20	1.44	0.35	0.0	1.79
20999	0.18	0.06	0.16	-0.02	0.06	0.43	0.30	0.0	0.73
21001	0.53	0.0	0.28	-0.01	2.29	3.09	0.41	0.0	3.50
21999	2.25	0.28	2.91	-0.04	4.05	9.45	1.45	0.0	10.91
22	0.00	0.16	0.03	-0.03	0.05	0.22	0.0	0.0	0.22
23	0.01	0.09	0.30	0.04	0.30	0.73	0.17	0.0	0.90
24002	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
24001	0.0	0.0	0.01	0.0	0.0	0.01	0.0	0.0	0.01
24003	0.0	0.0	0.0	0.0	0.0	0.00	0.0	0.0	0.00
24004	0.0	0.0	0.00	0.0	0.01	0.01	0.0	0.0	0.01
24005	0.01	0.00	0.0	0.0	0.02	0.03	0.0	0.0	0.03
24006	0.0	0.0	0.0	0.0	0.0	0.00	0.0	0.0	0.00
24007	0.0	0.0	0.09	0.0	0.03	0.12	0.55	0.0	0.67
24008	0.0	0.0	0.02	0.0	0.03	0.05	0.73	0.0	0.78
24009	0.00	0.0	0.0	0.0	0.01	0.01	0.0	0.0	0.01
24010	0.04	0.0	0.00	0.0	0.03	0.07	0.0	0.0	0.07
24011	0.03	0.0	0.0	0.0	0.01	0.04	0.0	0.0	0.04
24012	0.13	0.0	0.0	0.0	0.04	0.17	0.0	0.0	0.17
24013	0.08	0.0	0.0	0.0	0.04	0.12	0.0	0.0	0.12
24014	0.0	0.0	0.01	0.0	0.00	0.01	0.0	0.0	0.01
24015	0.02	0.0	0.0	0.0	0.04	0.05	0.0	0.0	0.05

LEAD continued :

CODE	57	58	59	6o	61	***	62	63	***
24016	0.01	0.0	0.0	0.0	0.04	0.05	0.0	0.0	0.05
24017	0.03	0.0	9.97	0.0	1.54	11.54	0.00	0.0	11.55
24018	0.00	0.0	0.04	0.0	0.06	0.11	0.0	0.0	0.11
24019	0.0	0.0	0.18	0.0	0.05	0.24	0.02	0.0	0.26
24020	0.0	0.0	2.16	0.0	0.05	2.21	0.0	0.0	2.21
24021	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
24022	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
24023	3.88	0.35	1.94	-0.04	3.34	9.47	0.0	0.0	9.47
24024	0.0	0.0	0.58	0.0	0.56	1.13	0.08	0.0	1.21
24025	0.00	0.0	0.0	0.0	0.0	0.00	0.0	0.0	0.00
24026	0.01	0.0	0.0	0.0	0.01	0.02	0.0	0.0	0.02
24027	0.0	0.0	0.0	0.0	0.01	0.01	0.0	0.0	0.01
24028	0.0	0.0	0.03	0.0	0.00	0.04	0.0	0.0	0.04
24029	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
24030	0.0	0.0	0.0	0.0	0.02	0.02	0.0	0.0	0.02
24999	0.02	0.14	0.29	-0.00	0.11	0.56	0.40	0.0	0.96
25001	0.00	0.0	0.0	0.0	0.0	0.00	0.0	0.0	0.00
25002	0.0	0.0	0.0	0.0	0.0	0.00	0.0	0.0	0.00
25003	0.01	0.0	0.01	0.0	0.02	0.03	0.0	0.0	0.03
25999	0.02	0.01	0.0	0.0	0.03	0.07	0.0	0.0	0.07
26001	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
26999	0.0	0.00	0.00	0.0	0.00	0.01	0.0	0.0	0.01
27001	0.01	0.0	0.0	0.0	0.0	0.01	0.0	0.0	0.01
27002	0.09	0.01	0.0	0.0	0.04	0.14	0.0	0.0	0.14
27003	0.0	0.0	0.0	0.0	0.00	0.00	0.0	0.0	0.00
27004	0.00	0.0	0.0	0.0	0.00	0.01	0.0	0.0	0.01
27005	0.0	0.0	0.0	0.0	0.01	0.01	0.0	0.0	0.01
27006	0.0	0.0	0.0	0.0	0.12	0.12	0.0	0.0	0.12
27007	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
27008	0.00	0.0	0.0	0.0	0.01	0.01	0.0	0.0	0.01
27009	0.00	0.0	0.0	0.0	0.00	0.00	0.0	0.0	0.00
27010	0.01	0.0	0.01	0.0	0.00	0.03	0.0	0.0	0.03
27011	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
27012	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
27013	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
27014	0.0	0.0	0.0	0.0	0.0	0.00	0.0	0.0	0.00
27015	0.0	0.0	0.00	0.0	0.0	0.01	0.0	0.0	0.01
27016	0.0	0.0	0.0	0.0	0.00	0.00	0.0	0.0	0.00
27017	0.0	0.0	0.0	0.0	0.00	0.00	0.0	0.0	0.00
27018	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
27019	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
27020	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
27021	0.0	0.0	0.0	0.0	0.06	0.06	0.0	0.0	0.06
27022	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
27023	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
27024	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
27999	0.30	0.04	0.17	0.01	0.27	0.80	0.0	0.0	0.80
28	0.01	0.0	0.00	0.0	0.01	0.03	0.0	0.0	0.03
29001	0.01	0.0	0.0	0.0	0.00	0.02	0.0	0.0	0.02
29002	0.0	0.0	0.0	0.0	0.00	0.00	0.0	0.0	0.00
29003	0.0	0.0	0.0	0.0	0.00	0.00	0.0	0.0	0.00
29999	0.04	0.03	0.10	0.02	0.20	0.39	0.04	0.0	0.43
30001	0.00	0.0	0.0	0.0	0.0	0.00	0.0	0.0	0.00
30999	0.05	0.00	0.03	0.00	0.01	0.09	0.0	0.0	0.09
31001	0.00	0.0	0.0	0.0	0.0	0.00	0.0	0.0	0.00
31002	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
31999	0.04	0.0	0.00	0.0	0.01	0.05	0.0	0.0	0.05
32	0.01	0.00	0.0	0.0	0.00	0.01	0.0	0.0	0.01
33	0.06	0.02	0.00	0.0	0.02	0.10	2.62	0.0	2.72
34001	0.00	0.0	0.0	0.0	0.01	0.01	0.0	0.0	0.01
34999	0.01	0.00	0.00	0.00	0.01	0.03	0.0	0.0	0.03
35001	0.01	0.0	0.0	0.0	0.00	0.01	0.0	0.0	0.01
35999	0.01	0.0	0.0	0.0	0.00	0.01	0.0	0.0	0.01
36001	0.00	0.0	0.0	0.0	0.00	0.01	0.0	0.0	0.01
36002	0.00	0.0	0.0	0.0	0.0	0.00	0.0	0.0	0.00
36999	0.06	0.00	0.00	-0.00	0.03	0.09	0.0	0.0	0.09
37001	0.00	0.0	0.0	0.0	0.0	0.01	0.0	0.0	0.01
37999	0.01	0.0	0.0	0.0	0.0	0.01	0.0	0.0	0.01
38	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
39	0.01	0.0	0.0	0.0	0.00	0.01	0.0	0.0	0.01
40	0.00	0.0	0.0	0.0	0.0	0.00	0.0	0.0	0.00
41	0.03	0.0	0.0	0.0	0.00	0.03	0.0	0.0	0.03
42	0.01	0.0	0.0	0.0	0.0	0.01	0.0	0.0	0.01
43001	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
43002	0.00	0.0	0.0	0.0	0.0	0.00	0.0	0.0	0.00
43999	0.33	0.01	0.0	0.00	0.04	0.39	0.04	0.0	0.42
44009	0.00	0.0	0.00	0.0	0.0	0.00	0.0	0.0	0.00
44010	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

LEAD continued :

CODE	57	58	59	6o	61	***	62	63	***
44011	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
44012	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
44013	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
44014	0.00	0.0	0.0	0.0	0.0	0.00	0.0	0.0	0.00
44015	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
44016	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
44017	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
44018	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
44019	0.0	0.0	0.02	0.0	0.0	0.02	0.0	0.0	0.02
44020	0.00	0.00	0.06	0.0	0.02	0.08	0.0	0.0	0.08
44021	0.29	0.01	0.01	0.0	0.00	0.31	0.12	0.0	0.43
44022	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
44023	0.0	0.0	0.0	0.0	0.0	0.00	0.0	0.0	0.00
44024	0.02	0.00	0.01	0.0	0.01	0.04	0.0	0.0	0.04
44025	0.01	0.00	0.00	0.0	0.00	0.02	0.0	0.0	0.02
44026	0.00	0.00	0.01	0.0	0.0	0.02	0.0	0.0	0.02
44027	0.01	0.0	0.01	0.0	0.00	0.02	0.0	0.0	0.02
44028	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
44029	0.00	0.0	0.0	0.0	0.00	0.01	0.0	0.0	0.01
44030	0.02	0.00	0.02	0.0	0.0	0.04	0.0	0.0	0.04
44031	0.00	0.0	0.0	0.0	0.0	0.00	0.0	0.0	0.00
44032	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
44033	0.00	0.00	0.0	0.0	0.0	0.01	0.0	0.0	0.01
44034	0.0	0.0	0.0	0.0	0.00	0.00	0.0	0.0	0.00
44035	0.00	0.0	0.0	0.0	0.0	0.00	0.0	0.0	0.00
44036	0.00	0.0	0.0	0.0	0.0	0.00	0.0	0.0	0.00
44037	0.00	0.0	0.0	0.0	0.0	0.00	0.0	0.0	0.00
44038	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
44039	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
44041	0.00	0.0	0.0	0.0	0.0	0.00	0.0	0.0	0.00
44042	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
44043	0.06	0.0	0.0	0.0	0.0	0.06	0.0	0.0	0.06
45	0.06	0.32	5.38	0.01	0.03	5.80	0.70	0.0	6.49
46	0.01	0.01	0.02	0.00	0.01	0.05	-0.0	0.0	0.05
47	0.10	0.00	0.00	0.00	0.0	0.11	0.0	0.0	0.11
48	0.03	0.01	0.02	0.0	0.02	0.08	0.0	0.0	0.08
49	0.00	0.0	0.0	0.0	0.04	0.04	0.0	0.0	0.04
50	0.04	0.01	0.00	0.0	0.02	0.08	0.10	0.0	0.18
51	0.01	0.00	0.00	0.0	0.0	0.02	0.83	0.0	0.84
52	0.03	0.01	0.0	0.0	0.00	0.04	0.0	0.0	0.04
53	0.18	0.0	0.0	0.0	0.0	0.18	0.0	0.0	0.18
54001	0.05	0.00	0.0	0.0	0.0	0.06	0.0	0.0	0.06
54002	0.01	0.0	0.0	0.0	0.0	0.01	0.0	0.0	0.01
54003	0.06	0.0	0.0	0.0	0.0	0.06	0.0	0.0	0.06
54004	0.03	0.0	0.0	0.0	0.0	0.03	0.0	0.0	0.03
54999	0.01	0.02	0.00	0.0	0.01	0.04	0.09	0.0	0.13
55	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
56	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
57	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
***	10.64	1.83	29.65	-0.13	33.18	75.16	17.37	0.62	93.15

COPPER IN %

CODE	57	58	59	60	61	***	62	63	***
1001	0.05	0.00	0.00	0.0	0.01	0.07	0.0	0.0	0.07
1999	0.00	0.0	0.0	0.0	0.00	0.00	0.0	0.0	0.00
2	0.04	0.01	0.01	0.0	0.00	0.06	1.02	0.0	1.07
3	0.09	0.01	0.02	0.0	0.00	0.13	0.0	0.0	0.13
4	0.04	0.01	0.00	0.01	0.06	0.12	0.0	0.0	0.12
5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
6	0.00	0.0	0.0	0.0	0.01	0.01	0.0	0.0	0.01
7	0.0	0.0	0.0	0.0	0.00	0.00	0.0	0.0	0.00
8001	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
8999	0.0	0.0	0.0	0.0	0.00	0.00	0.0	0.0	0.00
9002	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
9001	0.0	0.0	0.0	0.0	0.0	0.00	0.0	0.0	0.00
9003	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
9004	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
9005	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
9006	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
9007	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
9008	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
9999	0.00	0.00	0.01	0.00	0.01	0.02	0.0	0.0	0.02
10001	0.0	0.0	0.0	0.0	0.02	0.02	0.0	0.0	0.02
10002	0.0	0.0	0.0	0.0	0.00	0.00	0.0	0.0	0.00
10003	0.0	0.0	0.0	0.0	0.00	0.00	0.0	0.0	0.00
10004	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
10005	0.0	0.0	0.0	0.0	0.03	0.03	0.0	0.0	0.03
10006	0.0	0.0	0.0	0.0	0.01	0.01	0.0	0.0	0.01
10999	0.01	0.00	0.01	0.0	0.15	0.16	0.21	0.0	0.37
11001	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
11002	0.0	0.0	0.0	0.0	0.00	0.00	0.0	0.0	0.00
11003	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
11999	0.00	0.0	0.01	-0.00	0.02	0.03	0.0	0.0	0.03
12001	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
12002	0.0	0.0	0.0	0.0	0.00	0.00	0.0	0.0	0.00
12999	0.00	0.00	0.02	0.01	0.24	0.28	0.0	0.0	0.28
13001	0.0	0.0	0.00	0.0	0.00	0.01	0.0	0.0	0.01
13002	0.0	0.0	0.0	0.0	0.00	0.00	0.0	0.0	0.00
13003	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
13004	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
13005	0.42	0.0	0.72	-0.12	4.36	5.37	0.0	0.0	5.37
13006	0.04	0.01	0.13	-0.05	0.33	0.46	0.01	0.0	0.47
13007	0.0	0.0	0.0	0.0	0.00	0.00	0.0	0.0	0.00
13008	0.0	0.0	0.0	0.0	9.31	9.31	0.0	1.00	10.31
13009	0.0	0.0	0.0	0.0	0.00	0.00	0.0	0.0	0.00
13010	0.0	0.0	0.0	0.0	0.03	0.03	0.0	0.0	0.03
13011	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
13012	0.0	0.0	0.0	0.0	0.00	0.00	0.0	0.0	0.00
13013	0.0	0.0	0.0	0.0	0.21	0.21	0.0	0.0	0.21
13014	0.01	0.0	0.0	0.0	0.0	0.01	0.0	0.0	0.01
13015	0.0	0.0	0.0	0.0	0.01	0.01	0.0	0.0	0.01
13016	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
13017	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
13018	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
13019	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
13020	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
13021	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
13022	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
13023	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
13024	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
13025	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
13026	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
13027	0.0	0.0	0.0	0.0	0.24	0.24	0.0	0.0	0.24
13999	0.0	0.00	0.00	-0.00	0.0	0.00	0.0	0.0	0.00
14001	0.0	0.0	0.0	0.0	0.00	0.00	0.0	0.0	0.00
14002	0.01	0.00	0.0	0.0	0.02	0.03	0.0	0.0	0.03
14003	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
14004	0.00	0.0	0.0	0.0	0.01	0.01	0.0	0.0	0.01
14005	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
14006	0.02	0.0	0.0	0.0	0.0	0.02	0.0	0.0	0.02
14007	0.00	0.0	0.0	0.0	0.0	0.00	0.0	0.0	0.00
14008	0.02	0.0	0.0	0.0	0.00	0.02	0.0	0.0	0.02
14009	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
14010	0.00	0.0	0.0	0.0	0.0	0.00	0.0	0.0	0.00
14011	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
14012	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
14013	0.0	0.0	0.0	0.0	0.01	0.01	0.0	0.0	0.01
14014	0.0	0.0	0.0	0.0	0.00	0.00	0.0	0.0	0.00
14015	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

COPPER continued :

CODE	57	58	59	60	61	***	62	63	***
14016	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
14017	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
14018	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
14019	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
14020	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
14021	0.0	0.0	0.0	0.0	0.00	0.00	0.0	0.0	0.00
14999	0.06	0.11	0.02	-0.00	0.43	0.62	1.82	0.0	2.44
15	0.04	0.00	0.0	0.0	0.01	0.05	0.0	0.0	0.05
16001	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
16002	0.01	0.00	0.00	0.0	0.02	0.03	0.0	0.0	0.03
16003	0.0	0.0	0.0	0.0	0.00	0.00	0.0	0.0	0.00
16999	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
17001	0.0	0.0	0.0	0.0	0.0	0.00	0.0	0.0	0.00
17999	0.00	0.0	0.00	0.0	0.00	0.01	0.0	0.0	0.01
18	0.0	0.0	0.0	0.0	0.01	0.01	0.0	0.0	0.01
19001	0.0	0.0	0.03	0.0	0.01	0.04	0.0	0.0	0.04
19002	0.0	0.0	0.01	0.0	0.00	0.01	0.0	0.0	0.01
19003	0.0	0.0	0.00	0.00	0.00	0.01	0.0	0.0	0.01
19004	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
19005	0.0	0.0	0.0	0.0	0.00	0.00	0.0	0.0	0.00
19999	0.00	0.02	0.27	0.01	0.03	0.34	0.0	0.0	0.34
20001	0.0	0.0	0.65	-0.02	0.68	1.31	0.0	0.0	1.32
20002	0.0	0.0	0.07	-0.00	0.13	0.20	0.0	0.0	0.20
20003	0.0	0.0	0.03	-0.00	0.10	0.13	0.0	0.0	0.13
20004	0.0	0.0	0.00	0.0	0.03	0.03	0.0	0.0	0.03
20005	0.0	0.0	0.03	-0.00	0.05	0.08	0.0	0.0	0.08
20006	0.0	0.0	0.06	-0.00	0.14	0.19	0.0	0.0	0.19
20007	0.0	0.0	0.07	-0.00	0.08	0.14	0.0	0.0	0.14
20008	0.0	0.0	0.04	-0.00	0.06	0.09	0.0	0.0	0.09
20009	0.0	0.0	0.06	-0.00	0.06	0.12	0.0	0.0	0.12
20010	0.0	0.0	0.06	-0.00	0.16	0.21	0.0	0.0	0.21
20011	0.0	0.0	0.07	-0.00	0.20	0.27	0.0	0.0	0.27
20012	0.0	0.0	0.13	-0.01	0.44	0.56	0.0	0.0	0.56
20013	0.0	0.0	0.18	-0.00	0.10	0.27	0.0	0.0	0.27
20014	0.0	0.0	0.09	-0.00	0.28	0.37	0.0	0.0	0.37
20015	0.0	0.0	0.35	-0.01	0.32	0.66	0.0	0.0	0.66
20016	0.0	0.0	0.08	-0.00	0.16	0.23	0.0	0.0	0.23
20017	0.0	0.0	0.06	-0.00	0.08	0.14	0.0	0.0	0.14
20018	0.0	0.0	0.19	-0.01	0.24	0.42	0.0	0.0	0.42
20019	0.0	0.0	0.17	-0.01	0.34	0.51	0.0	0.0	0.51
20020	0.0	0.0	0.39	-0.01	0.30	0.68	0.0	0.0	0.68
20021	0.0	0.0	0.01	0.0	0.00	0.01	0.0	0.0	0.01
20022	0.0	0.0	0.09	-0.00	0.04	0.13	0.0	0.0	0.13
20023	0.0	0.0	0.39	-0.01	0.21	0.59	0.0	0.0	0.59
20024	0.0	0.0	0.19	-0.01	0.26	0.44	0.0	0.0	0.44
20025	0.0	0.0	0.12	-0.01	0.48	0.59	0.0	0.0	0.59
20026	0.00	0.0	0.02	0.0	0.05	0.07	0.0	0.0	0.07
20027	0.0	0.0	0.06	0.0	0.04	0.10	0.0	0.0	0.10
20028	0.0	0.0	0.02	0.0	0.04	0.06	0.0	0.0	0.06
20029	0.0	0.0	0.01	0.0	0.0	0.01	0.0	0.0	0.01
20030	0.01	0.0	0.23	-0.01	0.30	0.52	0.0	0.0	0.52
20031	0.0	0.0	0.04	-0.01	0.22	0.25	0.01	0.0	0.26
20032	0.0	0.0	0.00	0.0	0.0	0.00	0.0	0.0	0.00
20033	0.0	0.0	0.0	-0.00	0.04	0.03	0.0	0.0	0.03
20034	0.01	0.0	0.10	-0.00	0.14	0.24	0.0	0.0	0.24
20035	0.0	0.0	0.14	0.0	0.02	0.16	0.0	0.0	0.16
20999	0.09	0.03	0.08	-0.01	0.03	0.23	0.01	0.0	0.24
21001	0.26	0.0	0.14	-0.01	1.12	1.51	0.0	0.0	1.51
21999	0.90	0.11	1.16	-0.02	1.61	3.76	0.07	0.0	3.83
22	0.00	0.09	0.02	-0.02	0.03	0.13	0.0	0.0	0.13
23	0.02	0.21	0.75	0.09	0.76	1.83	0.04	0.0	1.87
24002	0.0	0.01	0.0	0.0	0.00	0.01	0.0	0.0	0.01
24001	0.0	0.0	0.02	0.0	0.0	0.02	0.0	0.0	0.02
24003	0.00	0.00	0.0	0.0	0.00	0.01	0.0	0.0	0.01
24004	0.0	0.00	0.00	0.0	0.01	0.01	0.0	0.0	0.01
24005	0.04	0.01	0.0	0.0	0.05	0.10	0.0	0.0	0.10
24006	0.0	0.0	0.00	0.0	0.00	0.00	0.0	0.0	0.00
24007	0.02	0.02	2.40	-0.00	0.67	3.10	0.08	0.0	3.18
24008	0.0	0.0	0.27	0.0	0.31	0.58	0.0	0.0	0.58
24009	0.07	0.0	0.0	-0.00	0.40	0.46	0.0	0.0	0.46
24010	1.18	0.0	0.11	0.0	0.76	2.05	0.0	0.0	2.05
24011	0.94	0.0	0.01	0.0	0.30	1.25	0.0	0.0	1.25
24012	0.75	0.0	0.0	-0.00	0.23	0.98	0.0	0.0	0.98
24013	1.16	0.0	0.0	0.0	0.65	1.80	0.0	0.0	1.80
24014	0.0	0.0	0.98	0.0	0.25	1.23	0.0	0.0	1.23
24015	0.32	0.00	0.0	0.0	0.82	1.15	0.02	0.0	1.17

COPPER continued :

CODE	57	58	59	6o	61	***	62	63	***
24016	0.04	0.0	0.0	0.0	0.28	0.32	0.0	0.0	0.32
24017	0.05	0.0	17.17	0.0	2.66	19.87	0.12	0.0	19.99
24018	0.10	0.01	1.08	-0.01	1.42	2.60	0.02	0.0	2.62
24019	0.0	0.0	2.55	0.0	0.76	3.31	0.04	0.0	3.35
24020	0.0	0.0	0.07	0.0	0.00	0.07	0.0	0.0	0.07
24021	0.0	0.0	0.0	0.0	0.00	0.00	0.0	0.0	0.00
24022	0.0	0.0	0.0	0.0	0.0	0.00	0.0	0.0	0.00
24023	0.00	0.0	0.0	0.0	0.00	0.00	0.0	0.0	0.00
24024	0.0	0.0	0.06	0.0	0.06	0.12	0.0	0.0	0.12
24025	0.01	0.0	0.0	0.0	0.00	0.01	0.0	0.0	0.01
24026	0.03	0.0	0.0	0.0	0.07	0.11	0.0	0.0	0.11
24027	0.0	0.0	0.0	0.0	0.01	0.01	0.0	0.0	0.01
24028	0.0	0.0	0.19	0.0	0.02	0.22	0.0	0.0	0.22
24029	0.0	0.0	0.0	0.0	0.00	0.00	0.0	0.0	0.00
24030	0.08	0.0	0.04	-0.02	1.64	1.74	0.09	0.0	1.82
24999	0.06	0.37	0.77	-0.01	0.28	1.47	0.00	0.0	1.47
25001	0.01	0.0	0.0	0.0	0.00	0.02	0.0	0.0	0.02
25002	0.0	0.0	0.0	0.0	0.00	0.00	0.0	0.0	0.00
25003	0.03	0.0	0.04	0.0	0.08	0.15	0.0	0.0	0.15
25999	0.19	0.11	0.0	0.0	0.28	0.58	0.00	0.0	0.59
26001	0.09	0.0	0.0	0.01	0.14	0.23	0.01	0.0	0.24
26999	0.02	0.07	0.08	0.01	0.14	0.33	0.09	0.0	0.42
27001	0.11	0.0	0.0	0.0	0.01	0.12	0.0	0.0	0.12
27002	0.02	0.00	0.0	0.0	0.01	0.02	0.0	0.0	0.02
27003	0.00	0.0	0.00	0.0	0.02	0.03	0.0	0.0	0.03
27004	0.17	0.01	0.01	0.0	0.10	0.28	0.0	0.0	0.28
27005	0.02	0.0	0.0	0.0	0.20	0.22	0.0	0.0	0.22
27006	0.0	0.0	0.0	0.0	0.01	0.01	0.0	0.0	0.01
27007	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
27008	0.24	0.01	0.0	0.0	0.43	0.67	0.0	0.0	0.67
27009	0.00	0.0	0.0	0.0	0.00	0.01	0.0	0.0	0.01
27010	0.01	0.0	0.02	0.0	0.01	0.04	0.0	0.0	0.04
27011	0.0	0.01	0.0	0.0	0.0	0.01	0.0	0.0	0.01
27012	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
27013	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
27014	0.0	0.00	0.0	0.0	0.00	0.00	0.0	0.0	0.00
27015	0.01	0.0	0.03	0.0	0.00	0.04	0.0	0.0	0.04
27016	0.00	0.0	0.0	0.0	0.01	0.01	0.0	0.0	0.01
27017	0.0	0.0	0.00	0.0	0.02	0.02	0.0	0.0	0.02
27018	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
27019	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
27020	0.0	0.0	0.0	0.0	0.00	0.00	0.0	0.0	0.00
27021	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
27022	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
27023	0.0	0.0	0.0	0.0	0.00	0.00	0.0	0.0	0.00
27024	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
27999	0.08	0.01	0.05	0.00	0.07	0.22	0.0	0.0	0.22
28	0.01	0.0	0.00	0.0	0.01	0.02	0.0	0.0	0.02
29001	0.01	0.0	0.0	0.0	0.00	0.01	0.0	0.0	0.01
29002	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
29003	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
29999	0.00	0.00	0.01	0.00	0.02	0.04	0.0	0.0	0.04
30001	0.01	0.0	0.00	0.0	0.00	0.01	0.0	0.0	0.01
30999	0.23	0.01	0.11	0.01	0.04	0.41	0.0	0.0	0.41
31001	0.01	0.0	0.0	0.0	0.00	0.01	0.0	0.0	0.01
31002	0.00	0.0	0.0	0.0	0.0	0.00	0.0	0.0	0.00
31999	0.14	0.00	0.01	0.0	0.05	0.20	0.0	0.0	0.20
32	0.04	0.01	0.0	0.00	0.02	0.07	0.0	0.0	0.07
33	0.07	0.02	0.00	0.0	0.02	0.11	0.0	0.0	0.11
34001	0.00	0.0	0.0	0.0	0.01	0.01	0.0	0.0	0.01
34999	0.04	0.01	0.01	0.01	0.06	0.12	0.0	0.0	0.12
35001	0.02	0.0	0.0	0.0	0.00	0.03	0.0	0.0	0.03
35999	0.03	0.00	0.0	0.0	0.01	0.04	0.0	0.0	0.04
36001	0.01	0.00	0.0	0.0	0.00	0.02	0.0	0.0	0.02
36002	0.01	0.0	0.0	0.0	0.00	0.01	0.0	0.0	0.01
36999	0.05	0.00	0.00	-0.00	0.03	0.09	0.0	0.0	0.09
37001	0.09	0.00	0.0	0.0	0.01	0.11	0.0	0.0	0.11
37999	0.18	0.01	0.0	0.00	0.01	0.21	0.0	0.0	0.21
38	0.00	0.0	0.0	0.0	0.0	0.00	0.0	0.0	0.00
39	0.01	0.0	0.0	0.0	0.00	0.01	0.0	0.0	0.01
40	0.01	0.0	0.0	0.0	0.00	0.01	0.0	0.0	0.01
41	0.02	0.0	0.0	0.0	0.00	0.02	0.0	0.0	0.02
42	0.01	0.0	0.0	0.0	0.0	0.01	0.0	0.0	0.01
43001	0.0	0.0	0.0	0.0	0.0	0.00	0.0	0.0	0.00
43002	0.01	0.0	0.0	0.0	0.0	0.01	0.0	0.0	0.01
43999	0.16	0.00	0.0	0.00	0.02	0.18	0.0	0.0	0.18
44009	0.01	0.0	0.00	0.0	0.0	0.01	0.0	0.0	0.01
44010	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

COPPER continued :

CODE	57	58	59	60	61	***	62	63	***
44011	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
44012	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
44013	0.0	0.00	0.00	0.0	0.00	0.01	0.0	0.0	0.01
44014	0.00	0.00	0.0	0.0	0.00	0.01	0.0	0.0	0.01
44015	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
44016	0.0	0.0	0.0	0.0	0.0	0.00	0.0	0.0	0.00
44017	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
44018	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
44019	0.0	0.00	0.17	0.00	0.00	0.18	0.0	0.0	0.18
44020	0.00	0.00	0.18	-0.00	0.06	0.25	0.0	0.0	0.25
44021	0.30	0.01	0.01	0.0	0.00	0.32	0.0	0.0	0.32
44022	0.0	0.0	0.0	0.0	0.0	0.00	0.0	0.0	0.00
44023	0.01	0.00	0.01	0.0	0.01	0.03	0.0	0.0	0.03
44024	0.12	0.01	0.09	0.0	0.04	0.26	0.0	0.0	0.26
44025	0.06	0.01	0.01	0.0	0.01	0.08	0.0	0.0	0.08
44026	0.03	0.01	0.06	0.0	0.0	0.10	0.0	0.0	0.10
44027	0.02	0.00	0.03	0.0	0.00	0.05	0.0	0.0	0.05
44028	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
44029	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
44030	0.06	0.00	0.06	0.0	0.00	0.13	0.0	0.0	0.13
44031	0.04	0.0	0.00	0.0	0.01	0.05	0.0	0.0	0.05
44032	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
44033	0.00	0.00	0.0	0.0	0.0	0.00	0.0	0.0	0.00
44034	0.00	0.0	0.0	0.0	0.00	0.00	0.0	0.0	0.00
44035	0.01	0.0	0.0	0.0	0.0	0.01	0.0	0.0	0.01
44036	0.01	0.0	0.0	0.0	0.0	0.01	0.0	0.0	0.01
44037	0.03	0.0	0.0	0.0	0.0	0.03	0.0	0.0	0.03
44038	0.00	0.0	0.0	0.0	0.0	0.00	0.0	0.0	0.00
44039	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
44041	0.00	0.0	0.0	0.0	0.0	0.00	0.0	0.0	0.00
44042	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
44043	0.08	0.0	0.0	0.0	0.0	0.08	0.0	0.0	0.08
45	0.05	0.23	3.94	0.01	0.02	4.25	0.58	0.0	4.83
46	0.02	0.01	0.05	0.01	0.03	0.12	0.0	0.0	0.12
47	0.22	0.01	0.00	0.01	0.00	0.24	0.0	0.0	0.24
48	0.08	0.03	0.07	0.0	0.05	0.23	0.0	0.0	0.23
49	0.00	0.00	0.0	0.0	0.08	0.09	0.0	0.0	0.09
50	0.07	0.02	0.01	0.0	0.04	0.14	0.0	0.0	0.14
51	0.07	0.03	0.01	0.0	0.01	0.12	0.0	0.0	0.12
52	0.06	0.02	0.0	0.0	0.01	0.08	0.0	0.0	0.08
53	0.36	0.0	0.0	0.0	0.00	0.36	0.0	0.0	0.36
54001	0.02	0.0	0.0	0.0	0.0	0.02	0.0	0.0	0.02
54002	0.03	0.0	0.0	0.0	0.0	0.03	0.0	0.0	0.03
54003	0.32	0.0	0.0	0.0	0.0	0.32	0.0	0.0	0.32
54004	0.07	0.0	0.0	0.0	0.0	0.07	0.0	0.0	0.07
54999	0.03	0.13	0.03	0.0	0.04	0.23	0.34	0.0	0.57
55	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
56	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
57	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
***	11.39	1.89	38.45	-0.22	38.98	90.48	4.58	1.00	96.06

ZINC IN %

CODE	57	58	59	60	61	***	62	63	***
1001	0.11	0.01	0.01	0.00	0.02	0.16	0.0	0.0	0.16
1999	0.00	0.00	0.00	0.0	0.00	0.01	0.0	0.0	0.01
2	0.14	0.02	0.03	0.0	0.00	0.20	0.0	0.0	0.20
3	0.10	0.02	0.03	0.0	0.00	0.14	0.0	0.0	0.14
4	0.05	0.01	0.00	0.01	0.08	0.15	0.0	0.0	0.15
5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
6	0.00	0.0	0.0	0.0	0.01	0.01	0.0	0.0	0.01
7	0.0	0.0	0.00	0.0	0.00	0.00	0.0	0.0	0.00
8001	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
8999	0.0	0.0	0.0	0.0	0.00	0.00	0.0	0.0	0.00
9002	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
9001	0.00	0.0	0.0	0.0	0.0	0.00	0.0	0.0	0.00
9003	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
9004	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
9005	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
9006	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
9007	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
9008	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
9999	0.00	0.00	0.01	0.00	0.01	0.03	0.0	0.0	0.03
10001	0.0	0.0	0.0	0.0	5.49	5.49	0.0	0.20	5.68
10002	0.0	0.0	0.0	0.0	0.23	0.23	0.0	0.05	0.28
10003	0.0	0.0	0.0	0.0	0.00	0.00	0.0	0.0	0.00
10004	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
10005	0.0	0.0	0.0	0.0	0.02	0.02	0.0	0.0	0.02
10006	0.0	0.0	0.0	0.0	0.03	0.03	0.0	0.0	0.03
10999	0.03	0.00	0.03	-0.00	0.60	0.66	0.11	0.0	0.77
11001	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
11002	0.0	0.0	0.0	0.0	0.00	0.00	0.0	0.0	0.00
11003	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
11999	0.00	0.0	0.01	0.0	0.02	0.03	0.0	0.0	0.03
12001	0.02	0.0	0.0	0.02	0.28	0.33	0.0	0.0	0.33
12002	0.03	0.0	0.01	0.01	0.06	0.11	0.0	0.0	0.11
12999	0.00	0.00	0.02	0.01	0.24	0.27	0.0	0.01	0.29
13001	0.0	0.0	0.00	0.0	0.00	0.01	0.0	0.0	0.01
13002	0.0	0.0	0.0	0.0	0.00	0.00	0.0	0.0	0.00
13003	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
13004	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
13005	0.06	0.0	0.11	-0.02	0.65	0.80	0.04	0.0	0.84
13006	0.03	0.01	0.08	-0.03	0.21	0.30	0.0	0.0	0.30
13007	0.0	0.0	0.0	0.0	0.00	0.00	0.0	0.0	0.00
13008	0.0	0.0	0.0	0.0	2.08	2.08	0.0	0.0	2.08
13009	0.0	0.0	0.0	0.0	0.00	0.00	0.0	0.0	0.00
13010	0.0	0.0	0.0	0.0	0.01	0.01	0.02	0.0	0.03
13011	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
13012	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
13013	0.0	0.0	0.0	0.0	13.61	13.61	0.00	0.51	14.12
13014	0.24	0.0	0.0	0.0	0.02	0.26	0.0	0.0	0.26
13015	0.0	0.0	0.0	0.0	1.54	1.54	0.0	0.0	1.54
13016	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
13017	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
13018	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
13019	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
13020	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
13021	0.0	0.0	0.0	0.0	0.00	0.00	0.0	0.0	0.00
13022	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
13023	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
13024	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
13025	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
13026	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
13027	0.0	0.0	0.0	0.0	0.11	0.11	0.0	0.0	0.11
13999	0.0	0.00	0.00	-0.00	0.0	0.00	0.0	0.0	0.00
14001	0.0	0.0	0.0	0.0	0.00	0.01	0.0	0.0	0.01
14002	0.10	0.02	0.0	0.0	0.19	0.31	0.03	0.0	0.34
14003	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
14004	0.01	0.0	0.0	0.0	0.01	0.02	0.0	0.0	0.02
14005	0.0	0.0	0.00	0.0	0.0	0.00	0.0	0.0	0.00
14006	0.06	0.0	0.0	0.0	0.00	0.06	0.0	0.0	0.06
14007	0.00	0.0	0.0	0.0	0.0	0.00	0.0	0.0	0.00
14008	0.06	0.0	0.0	0.0	0.01	0.06	0.0	0.0	0.06
14009	0.00	0.0	0.0	0.0	0.0	0.00	0.0	0.0	0.00
14010	0.00	0.0	0.0	0.0	0.0	0.00	0.0	0.0	0.00
14011	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
14012	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
14013	0.0	0.0	0.0	0.0	0.01	0.01	0.0	0.0	0.01
14014	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
14015	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

ZINC continued :

CODE	57	58	59	60	61	***	62	63	***
14016	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
14017	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
14018	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
14019	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
14020	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
14021	0.0	0.0	0.0	0.0	0.00	0.00	0.0	0.0	0.00
14999	0.23	0.43	0.08	-0.01	1.71	2.45	1.61	0.0	4.06
15	0.12	0.01	0.0	-0.00	0.02	0.15	0.0	0.0	0.15
16001	0.0	0.0	0.0	0.0	0.00	0.00	0.0	0.0	0.00
16002	0.02	0.01	0.00	0.00	0.04	0.06	0.00	0.0	0.07
16003	0.0	0.0	0.0	0.0	0.00	0.00	0.0	0.0	0.00
16999	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
17001	0.0	0.0	0.0	0.0	0.00	0.00	0.0	0.0	0.00
17999	0.00	0.00	0.00	0.0	0.01	0.01	0.0	0.0	0.01
18	0.00	0.0	0.0	0.0	0.01	0.02	0.0	0.0	0.02
19001	0.0	0.0	0.02	0.0	0.01	0.03	0.0	0.0	0.03
19002	0.0	0.0	0.36	0.0	0.14	0.50	0.0	0.0	0.50
19003	0.0	0.0	0.12	0.03	0.06	0.21	0.11	0.0	0.32
19004	0.0	0.0	0.01	0.0	0.01	0.02	0.0	0.0	0.02
19005	0.0	0.0	0.0	0.0	0.01	0.01	0.0	0.0	0.01
19999	0.05	0.17	2.71	0.13	0.32	3.37	0.89	0.0	4.26
20001	0.0	0.0	0.39	-0.01	0.40	0.78	0.0	0.0	0.78
20002	0.0	0.0	0.03	-0.00	0.05	0.07	0.0	0.0	0.07
20003	0.0	0.0	0.00	0.0	0.01	0.01	0.0	0.0	0.01
20004	0.0	0.0	0.00	0.0	0.01	0.02	0.0	0.0	0.02
20005	0.0	0.0	0.00	0.0	0.01	0.01	0.0	0.0	0.01
20006	0.0	0.0	0.03	-0.00	0.07	0.10	0.0	0.0	0.10
20007	0.0	0.0	0.02	-0.00	0.03	0.05	0.0	0.0	0.05
20008	0.0	0.0	0.00	0.0	0.00	0.01	0.0	0.0	0.01
20009	0.0	0.0	0.03	0.0	0.02	0.05	0.0	0.0	0.05
20010	0.0	0.0	0.01	0.0	0.04	0.05	0.0	0.0	0.05
20011	0.0	0.0	0.02	-0.00	0.07	0.09	0.0	0.0	0.09
20012	0.0	0.0	0.08	-0.01	0.26	0.33	0.0	0.0	0.33
20013	0.0	0.0	0.26	-0.01	0.14	0.39	0.0	0.0	0.39
20014	0.0	0.0	0.05	-0.00	0.15	0.20	0.0	0.0	0.20
20015	0.0	0.0	0.14	-0.00	0.13	0.26	0.0	0.0	0.26
20016	0.0	0.0	0.05	-0.00	0.10	0.15	0.0	0.0	0.15
20017	0.0	0.0	0.03	-0.00	0.04	0.07	0.0	0.0	0.07
20018	0.0	0.0	0.16	-0.01	0.21	0.37	0.0	0.0	0.37
20019	0.0	0.0	0.10	-0.00	0.20	0.30	0.0	0.0	0.30
20020	0.0	0.0	0.17	-0.00	0.13	0.29	0.0	0.0	0.29
20021	0.0	0.0	0.05	0.0	0.01	0.06	0.0	0.0	0.06
20022	0.0	0.0	0.05	0.0	0.02	0.07	0.0	0.0	0.07
20023	0.0	0.0	0.21	-0.00	0.11	0.32	0.0	0.0	0.32
20024	0.0	0.0	0.10	-0.00	0.14	0.23	0.0	0.0	0.23
20025	0.0	0.0	0.08	-0.00	0.32	0.40	0.0	0.0	0.40
20026	0.00	0.0	0.01	0.0	0.04	0.06	0.0	0.0	0.06
20027	0.0	0.0	0.08	0.0	0.06	0.14	0.0	0.0	0.14
20028	0.0	0.0	0.01	0.0	0.02	0.04	0.0	0.0	0.04
20029	0.0	0.0	0.01	0.0	0.0	0.01	0.0	0.0	0.01
20030	0.00	0.0	0.12	-0.01	0.16	0.28	0.0	0.0	0.28
20031	0.0	0.0	0.02	-0.00	0.10	0.11	0.0	0.0	0.11
20032	0.0	0.0	0.00	0.0	0.0	0.00	0.0	0.0	0.00
20033	0.0	0.0	0.0	-0.00	0.02	0.02	0.0	0.0	0.02
20034	0.01	0.0	0.09	-0.00	0.12	0.21	0.0	0.0	0.21
20035	0.0	0.0	0.05	0.0	0.01	0.05	0.0	0.0	0.05
20999	0.09	0.03	0.08	-0.01	0.03	0.23	0.26	0.0	0.49
21001	0.34	0.0	0.18	-0.01	1.47	1.98	0.16	0.0	2.14
21999	1.00	0.12	1.29	-0.02	1.80	4.19	0.62	0.0	4.81
22	0.0	0.04	0.01	-0.01	0.01	0.05	0.0	0.0	0.05
23	0.01	0.09	0.30	0.04	0.30	0.73	0.49	0.0	1.22
24002	0.0	0.00	0.0	0.0	0.0	0.00	0.0	0.0	0.00
24001	0.0	0.0	0.01	0.0	0.0	0.01	0.0	0.0	0.01
24003	0.0	0.0	0.0	0.0	0.0	0.00	0.0	0.0	0.00
24004	0.0	0.0	0.00	0.0	0.00	0.00	0.0	0.0	0.00
24005	0.01	0.00	0.0	0.0	0.01	0.02	0.0	0.0	0.02
24006	0.0	0.0	0.00	0.0	0.00	0.01	0.0	0.0	0.01
24007	0.00	0.00	0.39	0.0	0.11	0.51	0.0	0.0	0.51
24008	0.0	0.0	0.11	0.0	0.12	0.22	0.0	0.0	0.22
24009	0.01	0.0	0.0	0.0	0.05	0.06	0.0	0.0	0.06
24010	0.38	0.0	0.03	0.0	0.24	0.65	0.0	0.0	0.65
24011	0.17	0.0	0.00	0.0	0.05	0.22	0.0	0.0	0.22
24012	0.16	0.0	0.0	0.0	0.05	0.21	0.0	0.0	0.21
24013	0.28	0.0	0.0	0.0	0.16	0.44	0.0	0.0	0.44
24014	0.0	0.0	0.08	0.0	0.02	0.10	0.0	0.0	0.10
24015	0.03	0.0	0.0	0.0	0.07	0.10	0.0	0.0	0.10

ZINC continued :

CODE	57	58	59	60	61	***	62	63	***
24016	0.01	0.0	0.0	0.0	0.05	0.06	0.0	0.0	0.06
24017	0.00	0.0	0.70	0.0	0.11	0.81	0.0	0.0	0.81
24018	0.01	0.0	0.08	0.0	0.10	0.18	0.0	0.0	0.18
24019	0.0	0.0	0.12	0.0	0.04	0.16	0.0	0.0	0.16
24020	0.0	0.0	0.01	0.0	0.0	0.01	0.0	0.0	0.01
24021	0.0	0.0	0.0	0.0	0.00	0.00	0.0	0.0	0.00
24022	0.00	0.0	0.0	0.0	0.0	0.00	0.0	0.0	0.00
24023	0.00	0.0	0.0	0.0	0.00	0.00	0.0	0.0	0.00
24024	0.0	0.0	0.01	0.0	0.01	0.03	0.0	0.0	0.03
24025	0.93	0.04	0.0	0.0	0.24	1.21	0.0	0.0	1.21
24026	0.01	0.0	0.0	0.0	0.01	0.02	0.0	0.0	0.02
24027	0.0	0.0	0.0	0.0	0.01	0.01	0.0	0.0	0.01
24028	0.0	0.0	0.01	0.0	0.0	0.01	0.0	0.0	0.01
24029	0.0	0.0	0.0	0.0	0.00	0.00	0.0	0.0	0.00
24030	0.00	0.0	0.00	0.0	0.06	0.06	0.0	0.0	0.06
24999	0.05	0.27	0.57	-0.01	0.21	1.09	0.21	0.0	1.30
25001	0.01	0.0	0.0	0.0	0.00	0.01	0.0	0.0	0.01
25002	0.0	0.0	0.0	0.0	0.00	0.00	0.0	0.0	0.00
25003	0.02	0.0	0.02	0.0	0.04	0.08	0.0	0.0	0.08
25999	0.11	0.07	0.0	0.0	0.17	0.35	0.0	0.0	0.35
26001	0.02	0.0	0.0	0.00	0.03	0.05	0.0	0.0	0.05
26999	0.05	0.16	0.21	0.03	0.36	0.81	0.00	0.0	0.82
27001	0.05	0.0	0.0	0.0	0.00	0.05	0.0	0.0	0.05
27002	0.00	0.0	0.0	0.0	0.00	0.01	0.0	0.0	0.01
27003	0.01	0.0	0.00	0.0	0.04	0.04	0.0	0.0	0.04
27004	0.16	0.01	0.01	0.0	0.09	0.27	0.0	0.0	0.27
27005	0.01	0.0	0.0	0.0	0.09	0.10	0.0	0.0	0.10
27006	0.0	0.0	0.0	0.0	0.00	0.00	0.0	0.0	0.00
27007	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
27008	0.08	0.00	0.0	0.0	0.15	0.24	0.0	0.0	0.24
27009	0.00	0.0	0.0	0.0	0.01	0.01	0.0	0.0	0.01
27010	0.02	0.0	0.04	0.0	0.01	0.07	0.0	0.0	0.07
27011	0.0	0.36	0.03	0.0	0.03	0.42	0.0	0.0	0.42
27012	0.0	0.0	0.0	0.0	0.02	0.02	0.0	0.0	0.02
27013	0.0	0.0	0.0	0.0	0.01	0.01	0.0	0.0	0.01
27014	0.0	0.11	0.0	0.0	0.16	0.28	0.0	0.0	0.28
27015	0.39	0.0	1.88	0.0	0.26	2.53	0.16	0.0	2.69
27016	0.09	0.0	0.0	0.0	0.30	0.40	0.15	0.0	0.55
27017	0.0	0.0	0.08	0.01	0.70	0.78	0.01	0.0	0.79
27018	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
27019	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
27020	0.0	0.0	0.0	0.0	0.10	0.10	0.0	0.0	0.10
27021	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
27022	0.0	0.0	0.0	0.0	0.0	0.0	0.01	0.21	0.22
27023	0.0	0.0	0.0	0.0	0.00	0.00	0.0	0.0	0.00
27024	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
27999	0.57	0.08	0.33	0.03	0.51	1.52	0.23	0.0	1.75
28	0.01	0.0	0.0	0.0	0.01	0.02	0.0	0.0	0.02
29001	0.01	0.0	0.0	0.0	0.00	0.01	0.0	0.0	0.01
29002	0.0	0.0	0.0	0.0	0.00	0.00	0.0	0.0	0.00
29003	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
29999	0.00	0.00	0.01	0.00	0.01	0.03	0.0	0.0	0.03
30001	0.01	0.0	0.0	0.0	0.00	0.01	0.0	0.0	0.01
30999	0.12	0.01	0.06	0.00	0.02	0.20	0.0	0.0	0.20
31001	0.01	0.0	0.0	0.0	0.01	0.02	0.0	0.0	0.02
31002	0.00	0.0	0.0	0.0	0.0	0.00	0.0	0.0	0.00
31999	0.05	0.0	0.00	0.0	0.02	0.08	0.0	0.0	0.08
32	0.02	0.01	0.0	0.0	0.01	0.04	0.0	0.0	0.04
33	0.16	0.05	0.00	0.00	0.05	0.27	0.0	0.0	0.27
34001	0.01	0.0	0.0	0.0	0.03	0.03	0.0	0.0	0.03
34999	0.01	0.00	0.00	0.00	0.01	0.02	0.33	0.0	0.35
35001	0.03	0.0	0.0	0.0	0.01	0.04	0.0	0.0	0.04
35999	0.03	0.0	0.0	0.0	0.01	0.03	0.0	0.0	0.03
36001	0.03	0.00	0.0	0.0	0.01	0.04	0.0	0.0	0.04
36002	0.02	0.00	0.0	0.0	0.01	0.03	0.0	0.0	0.03
36999	0.10	0.00	0.00	-0.00	0.06	0.16	0.0	0.0	0.16
37001	0.05	0.0	0.0	0.0	0.01	0.06	0.0	0.0	0.06
37999	0.11	0.00	0.0	0.0	0.01	0.12	0.0	0.0	0.12
38	0.01	0.0	0.0	0.0	0.0	0.01	0.0	0.0	0.01
39	0.01	0.0	0.0	0.0	0.00	0.02	0.0	0.0	0.02
40	0.01	0.0	0.0	0.0	0.00	0.01	0.0	0.0	0.01
41	0.02	0.0	0.0	0.0	0.00	0.02	0.0	0.0	0.02
42	0.02	0.0	0.0	0.0	0.0	0.02	0.0	0.0	0.02
43001	0.0	0.0	0.0	0.0	0.00	0.00	0.0	0.0	0.00
43002	0.01	0.0	0.0	0.0	0.0	0.01	0.0	0.0	0.01
43999	0.17	0.00	0.0	0.00	0.02	0.20	0.0	0.0	0.20
44009	0.01	0.0	0.00	0.0	0.0	0.01	0.0	0.0	0.01
44010	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

ZINC continued :

CODE	57	58	59	6o	61	***	62	63	***
44011	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
44012	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
44013	0.0	0.00	0.00	0.0	0.00	0.01	0.0	0.0	0.01
44014	0.00	0.00	0.0	0.0	0.00	0.01	0.0	0.0	0.01
44015	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
44016	0.00	0.0	0.0	0.0	0.0	0.00	0.0	0.0	0.00
44017	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
44018	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
44019	0.0	0.04	1.54	0.03	0.01	1.62	0.45	0.0	2.07
44020	0.00	0.00	0.09	-0.00	0.03	0.11	0.0	0.0	0.11
44021	0.18	0.00	0.01	0.0	0.00	0.20	0.0	0.0	0.20
44022	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
44023	0.01	0.00	0.01	0.0	0.00	0.03	0.0	0.0	0.03
44024	0.04	0.00	0.03	0.0	0.02	0.10	0.0	0.0	0.10
44025	0.04	0.00	0.01	0.0	0.00	0.05	0.0	0.0	0.05
44026	0.06	0.02	0.11	0.00	0.00	0.18	0.0	0.0	0.18
44027	0.02	0.00	0.04	0.0	0.01	0.07	0.0	0.0	0.07
44028	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
44029	0.0	0.0	0.0	0.0	0.0	0.00	0.0	0.0	0.00
44030	0.05	0.00	0.04	0.0	0.00	0.09	0.0	0.0	0.09
44031	0.02	0.0	0.0	0.0	0.00	0.02	0.0	0.0	0.02
44032	0.0	0.0	0.0	0.0	0.0	0.00	0.0	0.0	0.00
44033	0.01	0.01	0.0	0.0	0.00	0.02	0.0	0.0	0.02
44034	0.00	0.0	0.0	0.0	0.00	0.01	0.0	0.0	0.01
44035	0.01	0.0	0.0	0.0	0.0	0.01	0.0	0.0	0.01
44036	0.01	0.0	0.0	0.0	0.0	0.01	0.0	0.0	0.01
44037	0.02	0.0	0.0	0.0	0.0	0.03	0.0	0.0	0.03
44038	0.00	0.0	0.0	0.0	0.0	0.00	0.0	0.0	0.00
44039	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
44041	0.00	0.0	0.0	0.0	0.0	0.00	0.0	0.0	0.00
44042	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
44043	0.12	0.0	0.0	0.0	0.00	0.13	0.0	0.0	0.13
45	0.19	0.97	16.46	0.03	0.10	17.75	2.21	0.0	19.96
46	0.02	0.02	0.06	0.01	0.04	0.14	0.0	0.0	0.14
47	0.27	0.01	0.01	0.01	0.00	0.29	0.0	0.0	0.29
48	0.08	0.03	0.06	0.0	0.05	0.22	0.0	0.0	0.22
49	0.00	0.00	0.0	0.0	0.11	0.12	0.0	0.0	0.12
50	0.06	0.02	0.01	0.0	0.03	0.11	0.26	0.0	0.37
51	0.04	0.02	0.01	0.0	0.00	0.07	0.0	0.0	0.07
52	0.09	0.02	0.0	0.0	0.01	0.11	0.0	0.0	0.11
53	0.16	0.0	0.0	0.0	0.0	0.16	1.30	0.0	1.46
54001	0.03	0.0	0.0	0.0	0.0	0.03	0.0	0.0	0.03
54002	0.04	0.0	0.0	0.0	0.0	0.04	0.0	0.0	0.04
54003	0.26	0.0	0.0	0.0	0.0	0.26	0.0	0.0	0.26
54004	0.03	0.0	0.0	0.0	0.0	0.03	0.0	0.0	0.03
54999	0.04	0.14	0.03	0.0	0.04	0.25	0.14	0.0	0.39
55	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
56	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
57	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
***	9.50	3.53	31.28	0.21	40.35	84.86	9.79	0.98	95.63

TIN IN %

CODE	57	58	59	60	61	***	62	63	***
1001	0.07	0.00	0.00	0.0	0.01	0.09	0.0	0.0	0.09
1999	0.00	0.0	0.0	0.0	0.00	0.00	0.0	0.0	0.00
2	0.10	0.02	0.02	0.0	0.00	0.15	0.0	0.0	0.15
3	0.07	0.01	0.02	0.0	0.0	0.10	0.0	0.0	0.10
4	0.02	0.00	0.0	0.00	0.03	0.06	0.0	0.0	0.06
5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
6	0.00	0.0	0.0	0.0	0.01	0.01	0.0	0.0	0.01
7	0.0	0.0	0.0	0.0	0.00	0.00	0.0	0.0	0.00
8001	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
8999	0.0	0.0	0.0	0.0	0.00	0.00	0.0	0.0	0.00
9002	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
9001	0.00	0.0	0.0	0.0	0.0	0.00	0.0	0.0	0.00
9003	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
9004	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
9005	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
9006	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
9007	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
9008	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
9999	0.00	0.00	0.01	0.00	0.01	0.02	0.0	0.0	0.02
10001	0.0	0.0	0.0	0.0	0.01	0.01	0.0	0.0	0.01
10002	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
10003	0.0	0.0	0.0	0.0	0.01	0.01	0.0	0.0	0.01
10004	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
10005	0.0	0.0	0.0	0.0	0.03	0.03	0.0	0.0	0.03
10006	0.0	0.0	0.0	0.0	0.01	0.02	0.0	0.0	0.02
10999	0.00	0.0	0.01	0.0	0.10	0.11	0.0	0.0	0.11
11001	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
11002	0.0	0.0	0.0	0.0	0.01	0.01	0.0	0.0	0.01
11003	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
11999	0.00	0.0	0.01	-0.00	0.02	0.03	0.0	0.0	0.03
12001	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
12002	0.0	0.0	0.0	0.0	0.0	0.00	0.0	0.0	0.00
12999	0.0	0.0	0.00	0.00	0.06	0.07	0.0	0.0	0.07
13001	0.0	0.0	0.00	0.0	0.00	0.01	0.0	0.0	0.01
13002	0.0	0.0	0.0	0.0	0.00	0.00	0.0	0.0	0.00
13003	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
13004	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
13005	0.07	0.0	0.12	-0.02	0.71	0.88	0.0	0.0	0.88
13006	0.03	0.01	0.09	-0.04	0.25	0.34	0.0	0.0	0.34
13007	0.0	0.0	0.0	0.0	0.00	0.00	0.0	0.0	0.00
13008	0.0	0.0	0.0	0.0	0.10	0.10	0.0	0.0	0.10
13009	0.0	0.0	0.0	0.0	0.00	0.00	0.0	0.0	0.00
13010	0.0	0.0	0.0	0.0	0.02	0.02	0.0	0.0	0.02
13011	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
13012	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
13013	0.0	0.0	0.0	0.0	0.03	0.03	0.0	0.0	0.03
13014	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
13015	0.0	0.0	0.0	0.0	0.00	0.00	0.0	0.0	0.00
13016	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
13017	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
13018	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
13019	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
13020	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
13021	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
13022	0.0	0.0	0.0	0.0	5.79	5.79	0.0	0.27	6.06
13023	0.0	0.0	0.0	0.0	0.69	0.69	0.0	0.0	0.69
13024	0.0	0.0	0.0	0.0	0.18	0.18	0.0	0.0	0.18
13025	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
13026	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
13027	0.0	0.0	0.0	0.0	0.29	0.29	0.0	0.0	0.29
13999	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
14001	0.0	0.0	0.0	0.0	0.00	0.00	0.0	0.0	0.00
14002	0.12	0.02	0.0	0.0	0.24	0.38	0.0	0.0	0.38
14003	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
14004	0.01	0.0	0.0	0.0	0.01	0.02	0.0	0.0	0.02
14005	0.0	0.0	0.00	0.0	0.0	0.00	0.0	0.0	0.00
14006	0.05	0.0	0.0	0.0	0.00	0.05	0.0	0.0	0.05
14007	0.00	0.0	0.0	0.0	0.0	0.00	0.0	0.0	0.00
14008	0.04	0.0	0.0	0.0	0.00	0.05	0.0	0.0	0.05
14009	0.00	0.0	0.0	0.0	0.0	0.00	0.0	0.0	0.00
14010	0.00	0.0	0.0	0.0	0.0	0.00	0.0	0.0	0.00
14011	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
14012	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
14013	0.0	0.0	0.0	0.0	0.02	0.02	0.0	0.0	0.02
14014	0.0	0.0	0.0	0.0	0.00	0.00	0.0	0.0	0.00
14015	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

TIN continued :

CODE	57	58	59	6o	61	***	62	63	***
14016	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
14017	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
14018	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
14019	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
14020	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
14021	0.0	0.0	0.0	0.0	0.00	0.00	0.0	0.0	0.00
14999	0.14	0.26	0.05	-0.01	1.01	1.44	0.82	0.0	2.26
15	0.06	0.01	0.0	0.0	0.01	0.07	0.0	0.0	0.07
16001	0.0	0.0	0.0	0.0	0.00	0.00	0.0	0.0	0.00
16002	0.02	0.01	0.00	0.00	0.06	0.09	0.0	0.0	0.09
16003	0.0	0.0	0.0	0.0	0.00	0.01	0.0	0.0	0.01
16999	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
17001	0.0	0.0	0.0	0.0	0.00	0.00	0.0	0.0	0.00
17999	0.00	0.0	0.00	0.0	0.01	0.01	0.0	0.0	0.01
18	0.00	0.0	0.0	0.0	0.01	0.02	0.0	0.0	0.02
19001	0.0	0.0	0.02	0.0	0.00	0.02	0.0	0.0	0.02
19002	0.0	0.0	0.00	0.0	0.00	0.00	0.0	0.0	0.00
19003	0.0	0.0	0.00	0.0	0.00	0.01	0.0	0.0	0.01
19004	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
19005	0.0	0.0	0.0	0.0	11.70	11.70	0.0	0.35	12.05
19999	0.00	0.01	0.16	0.01	0.02	0.20	0.0	0.0	0.20
20001	0.0	0.0	0.31	-0.01	0.32	0.62	0.0	0.0	0.62
20002	0.0	0.0	0.03	-0.00	0.05	0.07	0.0	0.0	0.07
20003	0.0	0.0	0.02	-0.00	0.08	0.10	0.0	0.0	0.10
20004	0.0	0.0	0.00	0.0	0.02	0.02	0.0	0.0	0.02
20005	0.0	0.0	0.07	-0.00	0.10	0.16	0.0	0.0	0.16
20006	0.0	0.0	0.03	-0.00	0.06	0.09	0.0	0.0	0.09
20007	0.0	0.0	0.03	-0.00	0.04	0.07	0.0	0.0	0.07
20008	0.0	0.0	0.03	-0.00	0.05	0.08	0.0	0.0	0.08
20009	0.0	0.0	0.02	0.0	0.02	0.04	0.0	0.0	0.04
20010	0.0	0.0	0.03	-0.00	0.09	0.12	0.0	0.0	0.12
20011	0.0	0.0	0.03	-0.00	0.08	0.11	0.0	0.0	0.11
20012	0.0	0.0	0.08	-0.01	0.28	0.36	0.0	0.0	0.36
20013	0.0	0.0	0.31	-0.01	0.17	0.47	0.00	0.0	0.47
20014	0.0	0.0	0.10	-0.01	0.32	0.42	0.0	0.0	0.42
20015	0.0	0.0	0.14	-0.00	0.13	0.27	0.0	0.0	0.27
20016	0.0	0.0	0.04	-0.00	0.09	0.13	0.0	0.0	0.13
20017	0.0	0.0	0.03	-0.00	0.04	0.07	0.0	0.0	0.07
20018	0.0	0.0	0.09	-0.00	0.12	0.21	0.0	0.0	0.21
20019	0.0	0.0	0.39	-0.01	0.77	1.15	0.34	0.0	1.49
20020	0.0	0.0	0.99	-0.02	0.77	1.75	1.68	0.0	3.43
20021	0.0	0.0	0.01	0.0	0.00	0.02	0.0	0.0	0.02
20022	0.0	0.0	0.08	-0.00	0.04	0.12	0.0	0.0	0.12
20023	0.0	0.0	0.30	-0.01	0.16	0.46	0.0	0.0	0.46
20024	0.0	0.0	0.13	-0.00	0.18	0.31	0.0	0.0	0.31
20025	0.0	0.0	0.08	-0.01	0.34	0.42	0.0	0.0	0.42
20026	0.00	0.0	0.01	0.0	0.03	0.04	0.0	0.0	0.04
20027	0.0	0.0	0.02	0.0	0.02	0.04	0.0	0.0	0.04
20028	0.0	0.0	0.01	0.0	0.01	0.02	0.0	0.0	0.02
20029	0.0	0.0	0.02	0.0	0.0	0.02	0.0	0.0	0.02
20030	0.02	0.0	0.41	-0.02	0.53	0.93	0.07	0.0	1.00
20031	0.0	0.0	0.12	-0.03	0.67	0.76	0.01	0.0	0.77
20032	0.0	0.0	0.00	0.0	0.0	0.00	0.0	0.0	0.00
20033	0.0	0.0	0.0	-0.00	0.04	0.03	0.0	0.0	0.03
20034	0.00	0.0	0.03	0.0	0.04	0.08	0.0	0.0	0.08
20035	0.0	0.0	0.05	0.0	0.01	0.05	0.0	0.0	0.05
20999	0.27	0.09	0.24	-0.03	0.09	0.65	0.70	0.0	1.35
21001	0.09	0.0	0.05	-0.00	0.37	0.50	1.13	0.0	1.62
21999	0.31	0.04	0.39	-0.01	0.55	1.28	3.96	0.0	5.24
22	0.00	0.19	0.03	-0.03	0.06	0.26	0.0	0.0	0.26
23	0.01	0.07	0.23	0.03	0.23	0.56	0.45	0.0	1.01
24002	0.0	0.0	0.0	0.0	0.0	0.00	0.0	0.0	0.00
24001	0.0	0.0	0.01	0.0	0.0	0.01	0.0	0.0	0.01
24003	0.0	0.0	0.0	0.0	0.00	0.00	0.0	0.0	0.00
24004	0.0	0.0	0.00	0.0	0.00	0.01	0.0	0.0	0.01
24005	0.01	0.00	0.0	0.0	0.02	0.04	0.0	0.0	0.04
24006	0.0	0.0	0.00	0.0	0.00	0.00	0.0	0.0	0.00
24007	0.00	0.00	0.27	0.0	0.08	0.35	1.67	0.0	2.03
24008	0.0	0.0	0.03	0.0	0.03	0.06	2.22	0.0	2.29
24009	0.01	0.0	0.0	0.0	0.05	0.05	0.0	0.0	0.05
24010	0.17	0.0	0.02	0.0	0.11	0.29	0.0	0.0	0.29
24011	0.19	0.0	0.00	0.0	0.06	0.25	0.0	0.0	0.25
24012	0.46	0.0	0.0	0.0	0.14	0.61	0.0	0.0	0.61
24013	0.35	0.0	0.0	0.0	0.19	0.54	0.0	0.0	0.54
24014	C.0	0.0	0.07	0.0	0.02	0.09	0.0	0.0	0.09
24015	0.06	0.0	0.0	0.0	0.14	0.20	0.0	0.0	0.20

TIN continued :

CODE	57	58	59	60	61	***	62	63	***
24016	0.02	0.0	0.0	0.0	0.15	0.17	0.0	0.0	0.17
24017	0.0	0.0	0.28	0.0	0.04	0.32	0.0	0.0	0.32
24018	0.01	0.0	0.07	0.0	0.09	0.17	0.0	0.0	0.17
24019	0.0	0.0	0.13	0.0	0.04	0.17	0.0	0.0	0.17
24020	0.0	0.0	0.01	0.0	0.0	0.01	0.0	0.0	0.01
24021	0.0	0.0	0.0	0.0	0.00	0.00	0.0	0.0	0.00
24022	0.00	0.0	0.0	0.0	0.0	0.00	0.0	0.0	0.00
24023	0.00	0.0	0.0	0.0	0.00	0.00	0.0	0.0	0.00
24024	0.0	0.0	0.01	0.0	0.01	0.02	0.0	0.0	0.02
24025	0.00	0.0	0.0	0.0	0.0	0.00	0.0	0.0	0.00
24026	0.00	0.0	0.0	0.0	0.01	0.01	0.0	0.0	0.01
24027	0.0	0.0	0.0	0.0	0.01	0.01	0.0	0.0	0.01
24028	0.0	0.0	0.00	0.0	0.0	0.00	0.0	0.0	0.00
24029	0.0	0.0	0.0	0.0	0.00	0.00	0.0	0.0	0.00
24030	0.00	0.0	0.0	0.0	0.03	0.03	0.0	0.0	0.03
24999	0.01	0.08	0.16	-0.00	0.06	0.32	0.91	0.0	1.23
25001	0.01	0.0	0.0	0.0	0.00	0.01	0.0	0.0	0.01
25002	0.0	0.0	0.0	0.0	0.00	0.00	0.0	0.0	0.00
25003	0.02	0.0	0.02	0.0	0.04	0.08	0.0	0.0	0.08
25999	0.09	0.05	0.0	0.0	0.13	0.27	0.0	0.0	0.27
26001	0.01	0.0	0.0	0.0	0.02	0.04	0.0	0.0	0.04
26999	0.00	0.01	0.02	0.00	0.03	0.07	0.0	0.0	0.07
27001	0.06	0.0	0.0	0.0	0.00	0.06	0.0	0.0	0.06
27002	0.01	0.0	0.0	0.0	0.00	0.01	0.0	0.0	0.01
27003	0.00	0.0	0.00	0.0	0.01	0.02	0.0	0.0	0.02
27004	0.04	0.00	0.00	0.0	0.02	0.07	0.0	0.0	0.07
27005	0.01	0.0	0.0	0.0	0.08	0.09	0.0	0.0	0.09
27006	0.0	0.0	0.0	0.0	0.00	0.00	0.0	0.0	0.00
27007	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
27008	0.04	0.0	0.0	0.0	0.07	0.11	0.0	0.0	0.11
27009	0.01	0.0	0.0	0.0	0.01	0.02	0.0	0.0	0.02
27010	0.03	0.0	0.05	0.0	0.01	0.10	0.0	0.0	0.10
27011	0.0	0.00	0.0	0.0	0.0	0.00	0.0	0.0	0.00
27012	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
27013	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
27014	0.0	0.0	0.0	0.0	0.00	0.00	0.0	0.0	0.00
27015	0.00	0.0	0.01	0.0	0.00	0.02	0.0	0.0	0.02
27016	0.01	0.0	0.0	0.0	0.02	0.02	0.0	0.0	0.02
27017	0.0	0.0	0.00	0.0	0.01	0.02	0.0	0.0	0.02
27018	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
27019	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
27020	0.0	0.0	0.0	0.0	0.00	0.00	0.0	0.0	0.00
27021	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
27022	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
27023	0.0	0.0	0.0	0.17	5.54	5.71	0.0	0.0	5.71
27024	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
27999	1.89	0.28	1.10	0.08	1.68	5.02	0.57	0.0	5.60
28	0.01	0.0	0.00	0.0	0.01	0.03	0.0	0.0	0.03
29001	0.01	0.0	0.0	0.0	0.00	0.01	0.0	0.0	0.01
29002	0.0	0.0	0.0	0.0	0.00	0.00	0.0	0.0	0.00
29003	0.0	0.0	0.0	0.0	0.00	0.00	0.0	0.0	0.00
29999	0.01	0.00	0.01	0.00	0.02	0.05	0.0	0.0	0.05
30001	0.01	0.0	0.0	0.0	0.00	0.01	0.0	0.0	0.01
30999	0.11	0.01	0.05	0.00	0.02	0.19	0.0	0.0	0.19
31001	0.01	0.0	0.0	0.0	0.00	0.01	0.0	0.0	0.01
31002	0.00	0.0	0.0	0.0	0.0	0.00	0.0	0.0	0.00
31999	0.13	0.00	0.01	0.0	0.05	0.18	0.0	0.0	0.18
32	0.03	0.01	0.0	0.00	0.02	0.06	0.0	0.0	0.06
33	0.04	0.01	0.0	0.0	0.01	0.07	0.0	0.0	0.07
34001	0.01	0.0	0.0	0.0	0.03	0.03	0.0	0.0	0.03
34999	0.04	0.00	0.01	0.00	0.05	0.10	0.0	0.0	0.10
35001	0.05	0.00	0.0	0.0	0.01	0.06	0.0	0.0	0.06
35999	0.03	0.00	0.0	0.0	0.01	0.04	0.0	0.0	0.04
36001	0.02	0.00	0.0	0.0	0.01	0.03	0.0	0.0	0.03
36002	0.02	0.00	0.0	0.0	0.00	0.02	0.0	0.0	0.02
36999	0.10	0.00	0.00	-0.00	0.06	0.16	0.0	0.0	0.16
37001	0.03	0.0	0.0	0.0	0.00	0.03	0.0	0.0	0.03
37999	0.07	0.00	0.0	0.0	0.01	0.08	0.0	0.0	0.08
38	0.01	0.0	0.0	0.0	0.00	0.01	0.0	0.0	0.01
39	0.05	0.00	0.0	0.0	0.02	0.08	0.0	0.0	0.08
40	0.02	0.00	0.0	0.0	0.01	0.03	0.0	0.0	0.03
41	0.05	0.0	0.0	0.0	0.00	0.05	0.0	0.0	0.05
42	0.03	0.0	0.0	0.0	0.0	0.03	0.0	0.0	0.03
43001	0.00	0.0	0.0	0.00	0.00	0.01	0.0	0.0	0.01
43002	9.34	0.0	0.0	0.0	0.47	9.80	0.04	0.0	9.85
43999	5.32	0.14	0.01	0.05	0.60	6.12	1.46	0.0	7.59
44009	0.01	0.0	0.00	0.0	0.0	0.01	0.0	0.0	0.01
44010	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

TIN continued :

CODE	57	58	59	6o	61	***	62	63	***
44011	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
44012	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
44013	0.0	0.0	0.0	0.0	0.0	0.00	0.0	0.0	0.00
44014	0.00	0.00	0.0	0.0	0.00	0.01	0.0	0.0	0.01
44015	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
44016	0.00	0.0	0.0	0.0	0.0	0.00	0.0	0.0	0.00
44017	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
44018	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
44019	0.0	0.00	0.08	0.00	0.0	0.08	0.0	0.0	0.08
44020	0.00	0.00	0.08	-0.00	0.02	0.10	0.0	0.0	0.10
44021	0.17	0.00	0.01	0.0	0.00	0.18	0.0	0.0	0.18
44022	0.0	0.0	0.0	0.0	0.0	0.00	0.0	0.0	0.00
44023	0.00	0.0	0.00	0.0	0.00	0.01	0.0	0.0	0.01
44024	0.03	0.00	0.02	0.0	0.01	0.07	0.0	0.0	0.07
44025	0.03	0.00	0.01	0.0	0.00	0.05	0.0	0.0	0.05
44026	0.03	0.01	0.06	0.0	0.0	0.10	0.0	0.0	0.10
44027	0.05	0.00	0.08	0.0	0.01	0.14	0.0	0.0	0.14
44028	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
44029	0.0	0.0	0.0	0.0	0.0	0.00	0.0	0.0	0.00
44030	0.04	0.00	0.04	0.0	0.00	0.08	0.0	0.0	0.08
44031	0.02	0.0	0.0	0.0	0.00	0.02	0.0	0.0	0.02
44032	0.00	0.0	0.0	0.0	0.0	0.00	0.0	0.0	0.00
44033	0.01	0.00	0.0	0.0	0.0	0.01	0.0	0.0	0.01
44034	0.00	0.0	0.0	0.0	0.01	0.01	0.0	0.0	0.01
44035	0.02	0.0	0.0	0.0	0.0	0.02	0.0	0.0	0.02
44036	0.01	0.0	0.0	0.0	0.0	0.01	0.0	0.0	0.01
44037	0.03	0.0	0.0	0.0	0.0	0.03	0.0	0.0	0.03
44038	0.00	0.0	0.0	0.0	0.0	0.00	0.0	0.0	0.00
44039	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
44041	0.00	0.0	0.0	0.0	0.0	0.00	0.0	0.0	0.00
44042	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
44043	1.32	0.01	0.00	0.01	0.01	1.35	1.00	0.0	2.35
45	0.04	0.20	3.41	0.01	0.02	3.68	0.32	0.0	4.00
46	0.01	0.01	0.04	0.01	0.03	0.11	0.0	0.0	0.11
47	0.26	0.01	0.01	0.01	0.00	0.28	0.0	0.0	0.28
48	0.02	0.01	0.02	0.0	0.01	0.07	0.0	0.0	0.07
49	0.00	0.0	0.0	0.0	0.03	0.03	0.0	0.0	0.03
50	0.04	0.01	0.00	0.0	0.02	0.08	0.0	0.0	0.08
51	0.01	0.01	0.00	0.0	0.00	0.02	0.0	0.0	0.02
52	0.12	0.03	0.0	0.0	0.01	0.16	0.0	0.0	0.16
53	0.12	0.0	0.0	0.0	0.0	0.12	0.17	0.0	0.29
54001	0.04	0.00	0.0	0.0	0.0	0.04	0.0	0.0	0.04
54002	0.04	0.0	0.0	0.0	0.0	0.04	0.0	0.0	0.04
54003	0.13	0.0	0.0	0.0	0.0	0.13	1.68	0.0	1.81
54004	0.04	0.0	0.0	0.0	0.0	0.04	0.0	0.0	0.04
54999	0.02	0.07	0.02	0.0	0.02	0.13	0.54	0.0	0.67
55	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
56	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
57	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
***	23.25	1.77	11.80	0.12	39.12	76.06	19.75	0.61	96.43

COMMISSION OF THE EUROPEAN COMMUNITIES

(Directorate General XII - Research, Science, Education)

A SURVEY OF THE TECHNOLOGY OF COPPER RECYCLING

With a note on zinc recycling from galvanized products

SOCIETE GENERALE DES MINERAIS
Rue du Marais, 31
1000 - Brussels
(Belgium)

November 1977

CONTENTS

./.

*

*   *

*

*   *

./.

Tables

INTRODUCTION

The outstanding properties of copper make it an easily recoverable metal : its good resistance to corrosion and its use chiefly in the massive form account for the very few dissipative uses of this metal. Moreover, the normally rather high price of copper makes its recovery interesting, even when the scrap only contains a relatively low percentage of copper. In 1972 (13) it was estimated that, in the then prevailing economic and technical conditions, the lower limit of the copper content of the scrap in view of its recovery was 10 to 15 %. With the price of copper prevailing to-day, this limit is now to be put at about 20 to 25 %. But it is, however, always lower when the scrap also contains valuable secondary metals such as precious metals.

Losses in the copper circuit are low as far as metal production is concerned : discarded slags containing up to 1 to 2 % copper, industrial wastes like pickling solutions used for surface treatments, etc... Copper dissipative uses (chemicals and electroplating) represent a very small part (1 - 2 %) of the total consumption of copper. Copper alloy bearings also account for some metal dissipation.

The largest losses of copper do occur when obsolete end products should return into the production circuit through the scrap dealing sector (see fig. 1 p. 19). Some scrap that might be reclaimed is sometimes rather dumped in landfills (e.g. car bodies, appliances,...) Other types of scrap may not be recovered because of too high recovering costs (old buried cables, scrap with too low metal content, ...). Scrap with high steel and very low copper contents are rather directed to steelworks where copper will be dissolved in the steel.

It has been estimated (22) that copper losses in the circuit production - use - recovery might reach 25 to 40 %. Another source (53) reports the assessment that only 60 % of the potential old scrap in 1971 has been recovered. Some of the uncollected balance is however to be collected in subsequent years. These figures suggest that improvements of the copper recycling balance are possible.

*

*   *

This report presents a survey of the state of the art in copper recycling, concentrating on electrical engineering, mechanical engineering and building materials. As such, it does not contain many statistical data. Other reports have already been undertaken or completed in order to give a better understanding of the quantitative aspects of the material flow.

Emphasis is put on old scrap (°) which gives rise to the most difficult problems for a complete recovery. New scrap is not neglected and also receives much attention. Municipal solid waste, which may contain some amounts of copper, and industrial waste are however not dealt with.

(°) For definition of those terms, see section 1.2.

This represents an entirely new field of research (see (39) for example) and it is beyond the scope of this report.

The first chapter presents a review of the manifold uses of copper and copper-base alloys, which give finally rise to old copper scrap. This is followed by a general overview of recycling schemes for different kinds of materials.

The second chapter is devoted to a more detailed description of the machinery and the processes that are now available on an industrial scale. These processes may be roughly divided into three categories :

- non-metallurgical sorting and concentration processes;
- metallurgical processes;
- processes for direct use of scrap (alloys and chemicals).

However, the actual techniques described here are not entirely satisfactory and new processes are now being developed. This point is dealt with in the first part of the third chapter. In the second part, the economic factors, which play a key role in the recycling industry, are emphasized as well as the influence they exert on the choice of a recovery technique.

Finally, conclusions are drawn in respect to a possible R & D action towards improvement in the copper recycling balance.

*

* *

Numbers between brackets refer to the bibliography at the end of the report.

1. SCRAP OCCURRENCES AND SCRAP PROCESSING

1.1. Properties and uses of copper and its alloys

A basic feature of copper recovery is the large variety in forms and sources of scrap. In order to understand this, one must revert to the properties of copper and copper-base alloys that justify their use for a given purpose. A good reference in that respect may be found in (16).

The material utilized for any industrial application is not chosen at random. It always results from a compromise between technical requirements and economic considerations.

Copper outstanding qualities are its thermic and electric conductivity, its ductility, its mechanical resistance, its weldability, the possibility of being varnished and easily insulated. Addition of some alloying elements may have an influence, one way or another, on each of these properties and cause an increase or decrease of the price of the metal.

Mechanical strength is increased by cold working operations, but softness can always be restored by annealing above re-crystallization temperature when further cold work is to be performed.

Appendix A lists some physical properties of copper and its alloys.

1.1.1. Pure copper

Pure copper is used in electrical engineering because of its high electrical conductivity, higher in fact than that of all other metals except silver. It is generally tough pitch high conductivity copper, of electrolytic grade, containing a certain amount of oxygen (0.02 to 0.04 %), or oxygen-free copper when the metal is to be heated in a reducing atmosphere or when it is to be welded to glass (electronics).

Copper is also appreciated for its good resistance to corrosion by chemicals, water and atmosphere, as well as for its ability to take complicated forms and to be jointed. It is thus used in plumbing installations, underground piping systems, roofing, usually as phosphorus-deoxidized copper, with or without addition of arsenic. Its excellent thermic conductivity is the reason why it is used also in heat-exchangers and in chemical engineering. Standards for such uses are less stringent than for T.P.H.C. copper, so that fire refined copper is used as well as electrolytic copper

Other uses include locomotive fire-box plates (in the past), blast furnace tuyeres, and numerous and varied articles for mechanical, chemical engineering or the building industry.

1.1.2. Copper with small additions

Small additions of some metals, usually less than 1 %, may improve some qualities of copper.

Silver (about 0.01 %) raises the annealing temperature and silver-copper is thus used for electrical engineering parts that must keep their mechanical strength after tinning, soldering or baking.

Cadmium (0.6 to 1 %) also raises the annealing temperature, strenghtens the material and does not impair the electrical conductivity of copper. Cadmium-copper is used for overhead conductors of long spans and contact wires for electric traction.

Lead, tellurium, selenium, sulphur or nickel in small quantities are added to improve the machinability of copper.

./.

Small additions of tin, with or without other elements like cadmium, silicon or aluminium, lead to the so-called conductivity bronzes with improved tensile strength but lower conductivity than pure copper. They are used for telephone and trolley wires, rotor bars and various cast parts.

Beryllium, with or without cobalt, gives a greater strength to copper and makes it particularly suitable for springs and for non-sparking tools for use when a risk of explosion exists.

Other elements may also be added to copper and all combinations are possible to impart to the alloy the desired properties.

1.1.3. Brasses

Brasses are copper-zinc alloys, the zinc content of which may vary between 2 and 50 %. According to the importance of the zinc content, one distinguishes :

- up to about 38 % Zn, "α" brass composed of a solid solution of zinc in the face-centered-cubic copper lattice;

- from 38 to 46 % Zn, "$\alpha+\beta$" brass containing, beside the α phase, a centered-cubic β phase proportionally growing with the zinc content;

- from 46 to 50 % Zn, "β" brass no longer contains any "α" phase;

- over 50 % Zn the "γ" phase appears, which is not industrially interesting because of its brittleness.

The properties of these groups of alloys are quite different as well as their applications. On the other hand, the richer in zinc, the cheaper is the alloy.

./.

1.1.3. a - "α" brasses

Like copper, "α" brasses are ductile and easily cold-worked. Their hardness is increased by cold-working. Their shade becomes lighter as their zinc content increases.

Cap copper

It contains from 2 to 5 % zinc and retains almost all the electric properties of copper. It is chiefly used as container of priming caps for ammunition.

Gilding metals

They contain from 5 to 15 % zinc and are used for jewellery and other decorative purposes. Their shade varies from red copper to "brassy" yellow.

Cartridge brass

Contains 30 % zinc and has the highest ductility which makes stamping, spinning and other cold working operations very easy. This alloy is used for cartridges and shell cases, lamp caps, door furniture and numerous other cupped articles.

Admiralty brass

Contains 70 % copper, 29 % zinc and 1 % tin; its resistance to corrosion is higher than that of cartridge brass. For a long time it was the main alloy used in marine boiler condenser tubes. It is still largely used in fresh water-cooled condensers.

Aluminium brass

It contains about 76 % copper, 22 % zinc, 2 % aluminium, sometimes a little arsenic. Presently, it is commonly used for marine tube condensers.

./.

Basis brass

It contains between 36 and 38.5 % zinc; may also contain a small quantity of the "β" phase. It is used for press work when a cheap material is required.

Clock and engraving brass

These brasses are altogether hard and easily machinable. They are obtained by adding about 1 % lead to basis brass. As their name suggests, they are used for small gear wheels and other parts of clocks and instruments and for the engraved scales of measuring devices.

Precipitation hardening brasses

They may be hardened and strengthened by heat treatments. They contain small additions of various elements, such as nickel or aluminium. They are used for machine components such as gear wheels, instruments pinions, etc...

1.1.3. b - "$\alpha + \beta$" brasses

Since "β" brasses cannot be deformed to any great extent, "$\alpha + \beta$" brasses are of intermediate properties between "α" and "β" brasses, depending on the proportions of both phases in the alloy. Essentially, "$\alpha + \beta$" brasses are hot-working materials that can be easily hot-rolled, forged, extruded and cast.

Muntz metal or yellow brass

It contains 40 % zinc. It is used in a great variety of cast and hot-worked forms.

Leaded 60 : 40 brass (turning brass)

Because of its lead content, it has an improved machinability as compared to Muntz metal. It is widely used for pressed or forged and cast parts that are to be machined. These uses include valve parts, pipe unions, clamps, brackets, etc...

./.

Naval brass

Like admiralty brass, it contains about 1 % tin, but on a 60 : 40 basis. Improved corrosion resistance makes it suitable for structural applications and for forging, especially for contact with sea water. Naval brass may also contain some lead so as to improve its machinability.

1.1.3. c - "$\alpha + \beta$" high tensile brasses (manganese bronzes)

The term "manganese bronze" is rather misleading because these alloys are no bronzes and contain only a small addition of manganese. They may contain various additions to the basic copper-zinc alloy, which give it greater strength and toughness and better resistance to corrosion. These alloys are used for large castings such as marine propellers and rudders and countless smaller castings. Hot pressing or forging parts, like high pressure valve bodies, pumps, etc... are also made out of such alloys.

1.1.3. d - "β" brasses

The only important application of "β" brasses is as brazing solder.

1.1.4. Bronzes and gunmetals

True bronzes are binary copper-tin alloys. Small additions of zinc, phosphorus, nickel, lead may confer desirable properties to bronze. Gunmetals are copper-zinc-tin alloys.

There are two main classes of bronzes: wrought alloys used for the manufacture of springs, wire-gauzes, etc.. by cold-working operations, and casting alloys for bearings and general engineering purposes like valve bodies, fittings, etc..

Wrought alloys usually contain up to 8 % tin, frequently with some phosphorus, up to 4 %. Cast bronzes are richer in tin and most often contain additional elements. Bell metal has a tin content of 20 % or more. Speculum metal, used for optical instruments and decorative purposes, contains up to 40 % tin. Leaded bronzes, with 5 to 25 % lead, form suitable alloys for bearings. Bearings may also be made out of copper-lead alloys for heavy duty purposes, or be manufactured out of tin bronze by sintering.

Admiralty gunmetal, containing 88 % copper, 10 % tin and 2 % zinc, and American gunmetal, containing 8 % tin and 4 % zinc, are used as castings for naval and engineering purposes. Admiralty gunmetal is also used for ornamental bronzework.

Leaded gunmetals are rather cheap and more resistant to corrosion than brasses. They are used for the casting of taps, valves and other water fillings.

Nickel bronzes are highly resistant to wear and to corrosion by water and steam and find their application in wearing parts of pumps for boiler feed water.

1.1.5. Cupro-aluminiums (aluminium bronzes)

Aluminium bronzes are based on copper and aluminium, and often contain additions of iron, nickel or manganese. With their good mechanical properties and excellent resistance to corrosion, they are particularly suited for service at moderately elevated temperatures.

"α" aluminium bronze, containing up to 9 % aluminium, is a cold-working material. Due to its golden color, it is used in jewellery and for various small objects like cigarette cases, lighters, etc...
It is also used for heat-exchangers and similar chemical engineering purposes.

Duplex aluminium bronzes, containing between 0 and 10 % aluminium, are made of two distinct phases like the "$\alpha + \beta$" brasses. They are used as castings for many naval and engineering purposes like pumps, propellers, hydraulic clutch wheels, etc...

1.1.6. Copper-Nickel alloys

Cupro-nickels contain these two metals only. A content of 5 to 10 % nickel gives copper a very good resistance to corrosion by sea water; such alloys are used for marine applications.

Cupro-nickels with 20 - 30 % nickel are used, among others, for marine condenser tubes and for coinage. Resistance wires are made out of cupro-nickel with 40 to 60 % nickel.

Monel alloys, containing about 29 % copper, 68 % nickel and 1.25 % both iron and manganese, are a choice material for applications in chemical engineering in very corrosive medium.

Nickel silver usually contains from 10 to 30 % nickel and 55 to 63 % copper with zinc as balance. These alloys have a silvery shade, becoming whiter as the nickel content increases. They are used for a lot of decorative applications as well as for the manufacture of forks and spoons and other pieces of silverware. Spring contacts for electrical equipments and resistance wires are also important applications of these alloys.

1.1.7. Other copper alloys

Silicon bronzes contain up to 5 % silicon. Because of their improved strength, weldability and resistance to corrosion, they are chiefly used for chemical engineering applications : storage tanks, piping systems, pickling crates, etc...

./.

Copper-manganese-aluminium and copper-manganese-nickel alloys ('manganin") are suitable for resistance wire and for springs as a substitute for beryllium copper.

*

Following tables, extracted from the C.D.A. publication (16), list the suitable copper alloys according to type of service in :

- electrical engineering
- mechanical and general engineering
- marine engineering
- chemical engineering
- building and plumbing
- paper-making, printing and textile industry
- instrumentation
- decorative and household uses

Appendix B (in French) also lists appropriate materials for typical applications in various industries.

Table 1 - Appropriate copper-base materials according to type of service (extracted from (16)).

See pages 13, 14, 15, 16 and 17 hereafter.

Table 1 - Appropriate copper-base materials according to type of service (extracted from (16))

Mechanical and General Engineering

Type of Service	Appropriate Materials
Locomotive firebox plates and stays	Deoxidised arsenical copper Copper-nickel-silicon Other special coppers with small additions
Bearings	Phosphor bronze Leaded bronze and gun-metal Copper-lead Porous bronze Graphited bronze
Turbine and supercharger blading	Special cupro-nickel Aluminium bronze Monel
Gear wheels and other mechanical parts subject to wear	Phosphor bronze Gunmetal Aluminium bronze Antimonial bronze
Pump and valve bodies, bolts, nuts and general structural applications	High tensile brass Naval brass Aluminium bronze Gunmetal Monel
Pressure-tight and general castings	Gunmetal Leaded gunmetal The $\alpha - \beta$ brasses Aluminium bronze
Radiators and oil coolers	Copper Cartridge brass Admiralty brass Cupro-nickel
Tubing for lubricants, liquid fuels, water and low pressure steam	Copper
Cylinder heads, tuyères, electrode holders and castings for applications involving relatively high thermal conductivity	Recast cathode copper Chromium copper Conductivity bronzes Cadmium copper Tellurium copper Beryllium copper Cobalt-beryllium copper

Mechanical and General Engineering—*continued.*

Type of Service	Appropriate Materials
Articles produced by extrusion and hot forging, comprising bars and sections of all shapes, pipe fittings and innumerable small parts for light mechanisms	The $\alpha - \beta$ brasses Leaded $\alpha - \beta$ brasses Aluminium bronze Copper Silicon brass
Articles produced by die casting, mainly racks, gears, brackets and small mechanical parts	Brass Aluminium bronze Naval brass
Articles produced by or involving machining, especially on automatic machines	Leaded brass Tellurium copper Leaded gunmetal
Cupped and bent articles produced by cold presswork and spinning, including cartridge cases, containers of all kinds, lamp caps and numerous bent wire products	Deoxidised copper Oxygen-free copper Tough pitch copper The α brasses The α phosphor-bronzes Cupro-nickel Nickel silver The α aluminium-bronzes Silicon bronze
Springs	Beryllium copper Phosphor bronze Brass Nickel silver Copper-manganese-nickel
Brazing alloys	Copper 60 : 40 brass 50 : 50 brass Phosphorus copper Silver solders Silicon brass
Non-sparking tools	Beryllium copper High tensile brasses Aluminium bronzes

Electrical Engineering

Type of Service	Appropriate Materials
Transmission of electricity under normal conditions	Tough pitch H.C. copper
Transmission of electricity under exacting conditions in regard to mechanical loading, vibration and wear	Cadmium copper Steel cored copper Conductivity bronzes
High conductivity applications involving moderately elevated temperatures	Silver copper Chromium copper Tellurium copper Conductivity bronzes Cadmium copper
High conductivity combined with machinability	Tellurium copper Other free-machining coppers
Castings of high conductivity, including resistance welding electrodes	Remelted cathode copper Cadmium copper Chromium copper Conductivity bronzes Beryllium copper Cobalt beryllium copper Tellurium copper
Sintered products for welding electrodes and contacts	Copper-tungsten
Contact springs	Phosphor-bronze Nickel silver Beryllium copper Cobalt beryllium copper
Resistance wires	Nickel silver Cupro-nickel Copper-manganese-aluminium Copper-manganese-nickel
Lamp caps, switch covers and similar fittings	The α brasses
Cams, brackets, switchgear parts, terminals and miscellaneous components	Brasses Aluminium bronze Gunmetal
Magnets	Copper-manganese-aluminium Copper-nickel-iron Copper-nickel-cobalt

Chemical Engineering

Type of Service	Appropriate Materials
Stills, vats, kettles, autoclaves and general coppersmithing	Deoxidised copper Deoxidised arsenical copper Silicon bronze Phosphor-bronze Cupro-nickel Aluminium bronze Monel
Piping for relatively non-corrosive liquids and gases	Deoxidised copper Arsenical copper
Piping and pipe fittings for brines and similar solutions	Aluminium brass Cupro-nickel Silicon bronze Aluminium bronze Monel
Piping for refrigerators	Copper
Pickling crates, chains and hooks	Silicon bronze Cupro-nickel Aluminium bronze Monel
Castings for valves, pumps, etc., to resist corrosion and wear	Bronze and gunmetal Nickel bronze Aluminium bronze Silicon bronze Monel
Heat exchange equipment, including condenser tubing and end plates	Aluminium brass Admiralty brass Cupro-nickel Aluminium bronze Deoxidised copper Arsenical copper Naval brass (wrought)
Castings, such as end plates for heat exchange equipment, and applications where corrosion is not particularly severe	Naval brass Gunmetal
Paper-making industry, including Fourdrinier wire cloth	Brass Bronze Aluminium bronze Silicon bronze

Marine Engineering

Type of Service	Appropriate Materials
Marine condenser tubes and plates	Aluminium brass Cupro-nickel
Piping and pipe fittings for sea-water	Aluminium brass Cupro-nickel Silicon bronze Aluminium bronze Bronze and gunmetal
Propellers and rudders	High tensile brass Aluminium bronze
Valves and pump parts, spray nozzles, etc.	Bronze and gunmetal Nickel bronze High tensile brass Monel
Nuts and bolts, chains and hooks	Aluminium bronze Bronze and gunmetal High tensile brass
Sail eyelets and miscellaneous small fittings	The brasses
Non-magnetic binnacle fittings, engine-room telegraphs, etc.	The brasses
Decorative trim	Gilding metal Nickel silver Copper Brass Aluminium bronze
Sheathing for small craft	Copper 60 : 40 brass Naval brass

Building and Plumbing

Type of Service	Appropriate Materials
Roofing, flashings, damp-proof courses, gutterings and sheet copper work generally	Copper (preferably deoxidised)
Storage tanks, cisterns and cylinders	Copper (preferably deoxidised) Silicon bronze
Piping for domestic hot and cold water services, gas and heating installations, both buried and above ground. Soil and waste pipe services	Copper (preferably deoxidised)
Plumbers' fittings, pipe unions, taps, valves, etc.	Various cast and forged brasses Bronzes and gunmetals Nickel silvers Copper
Architectural and decorative metalwork, including mouldings and glazing bars	Copper Gilding metal Various brasses Nickel silver Aluminium bronze
Wire gauze insect screens	Phosphor bronze Brass Copper
Boilers and calorifiers	Copper (preferably deoxidised)
Radiators and unit heaters for hot water or steam	Copper (preferably deoxidised)

Paper-making
Printing and Textile Industries

Type of Service	Appropriate Materials
Fourdrinier gauze	Phosphor bronze Cartridge brass
Rollers and plates for printing on textiles and paper	Copper
Singe plates	Copper Cap copper
Piping and pipe fittings for pulps and solutions	Aluminium brass Cupro-nickel Silicon bronze Aluminium bronze Bronze and gunmetal
Pumps, valve parts, beater bars and general castings or forgings to resist corrosion	Aluminium bronze Silicon bronze Bronze and gunmetal Nickel bronze High tensile brass Monel
Artificial silk manufacture (certain processes)	Mossy or granulated copper
Metallic inks	Flake powder in copper and brass

Instrumentation

Type of Service	Appropriate Materials
Plates, gear wheels and other parts for clocks, meters and similar instruments	Clock brass
Small parts demanding precision of machining	Leaded brass Tellurium copper
Springs and diaphragms, including Bourdon tubes and bellows	Phosphor bronze Nickel silver Beryllium copper Copper-manganese-nickel Monel
Diffraction gratings	Speculum metal
Fixed electrical resistances	Copper-nickel Copper-manganese-aluminium Copper-manganese-nickel Nickel silver
Magnetic alloys	Copper-manganese-aluminium Copper-nickel-cobalt Copper-nickel-iron
Capillary tubing	Cupro-nickel Copper
Coil windings and eddy current discs	High conductivity copper
Thermo-couples and compensating leads	Copper-nickel
Resistance strain gauges	Copper-nickel Copper-manganese-aluminium

Decorative and Household Uses

Type of Service	Appropriate Materials
Statuary and cast decorative metalwork, including doors and gates	Tin bronze Gunmetal Nickel silver Aluminium bronze Brass
Architectural metalwork including shop fronts, railings, etc.	Copper Gilding metal Brass Nickel silver Aluminium bronze
Jewellery, plaques, trays and decorative containers such as cigarette cases and powder compacts	The α brasses Gilding metal Various coppers Nickel silver The α aluminium bronzes
Coins and medals	Low tin bronze Cupro-nickel Nickel silver Gilding metal
Jugs, kettles, hot water cans, preserving pans, boilers, etc.	Copper (usually tinned) The α brasses
Pins, fasteners, chains, picture hooks and miscellaneous household articles	The brasses
Bells	Bell bronze Silicon brass
Decorative electro-plating finishes	Copper Brass Speculum metal
Paints and inks	Flake powder in copper and brass
Spoons, forks and tableware	Nickel silver The brasses (electro-plated)

./.

1.2. Classification of scrap

It is usual to distinguish three categories of scrap :

- home scrap;
- new scrap (or prompt industrial scrap);
- old scrap (or obsolete scrap).

Home scrap arises from a production process of semi-finished or finished products and is recycled within the same plant. This can occur in copper smelters and refineries, in foundries and brass mills and by ingot makers.

New scrap also directly results from a production process but is not reused within the manufactory. It is sent to a scrap user (see section 1.3.1.) either on a toll treatment basis, i.e. for restitution of new copper or alloy, or under a sale contract. This scrap can also be recycled via the scrap dealing sector.

Home and new scrap comprises slags and skimmings, machining swarf and all kinds of defective pieces.

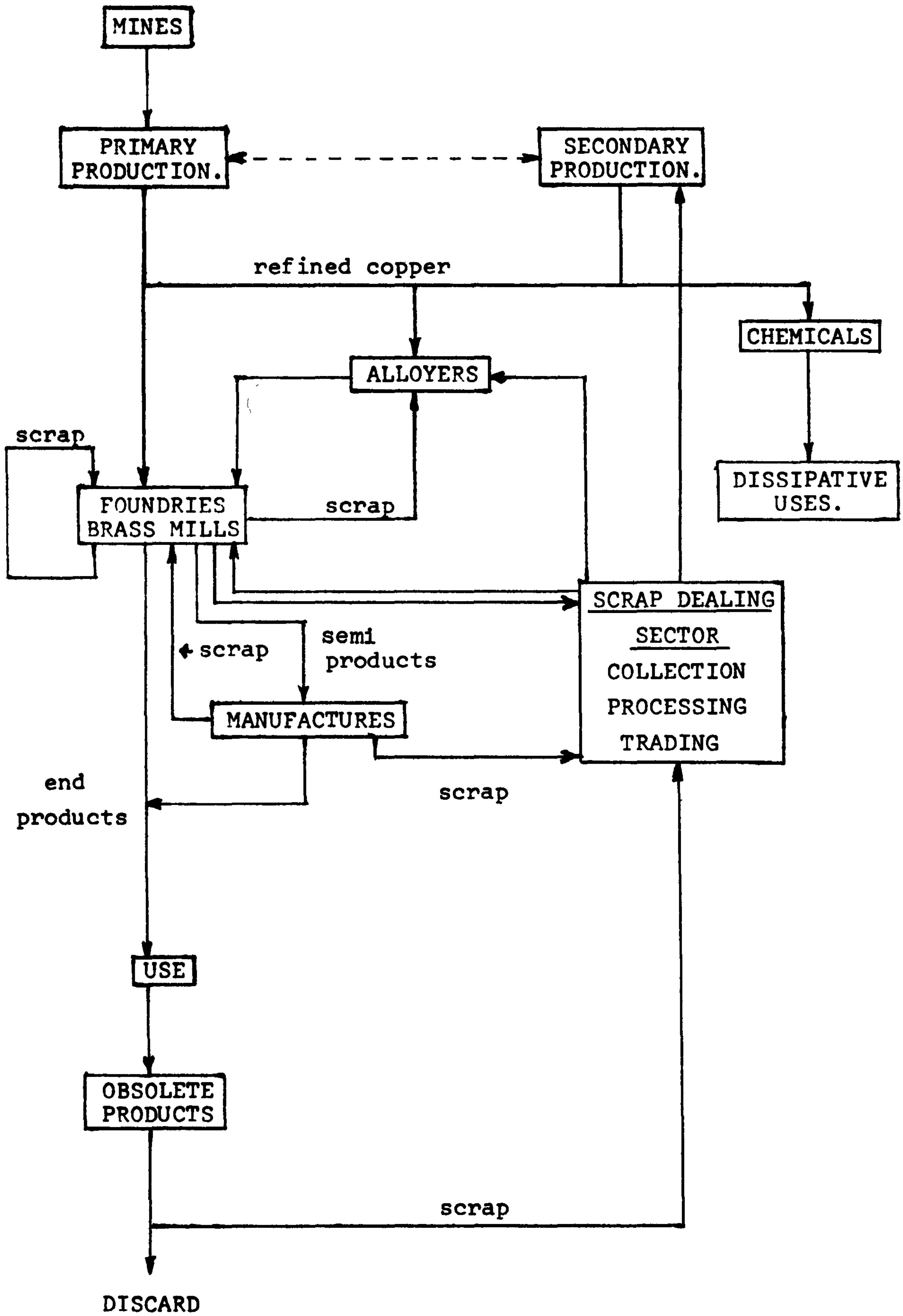
Old scrap results from the obsolescence of copper-containing products. It is always recovered through the scrap dealing sector.

Figure 1 sketches a general circuit of copper and copper-base materials from primary production to recycling. This diagram should give an idea of the wide variety of scrap flows, which is a consequence of the numerous uses of copper-base products.

Figure 2 is another diagram of this circuit, as drawn in a publication of the U.S. Bureau of Mines (47).

A good description of the organization of the scrap dealing sector (small collectors, semi-wholesale dealers, wholesale dealers) may be found in (5).

Fig. 1


MINES
PRIMARY PRODUCTION.
SECONDARY PRODUCTION.
refined copper
CHEMICALS
ALLOYERS
DISSIPATIVE USES.
scrap
FOUNDRIES BRASS MILLS
scrap
SCRAP DEALING SECTOR
COLLECTION
PROCESSING
TRADING
scrap
semi products
MANUFACTURES
end products
scrap
USE
OBSOLETE PRODUCTS
scrap
DISCARD

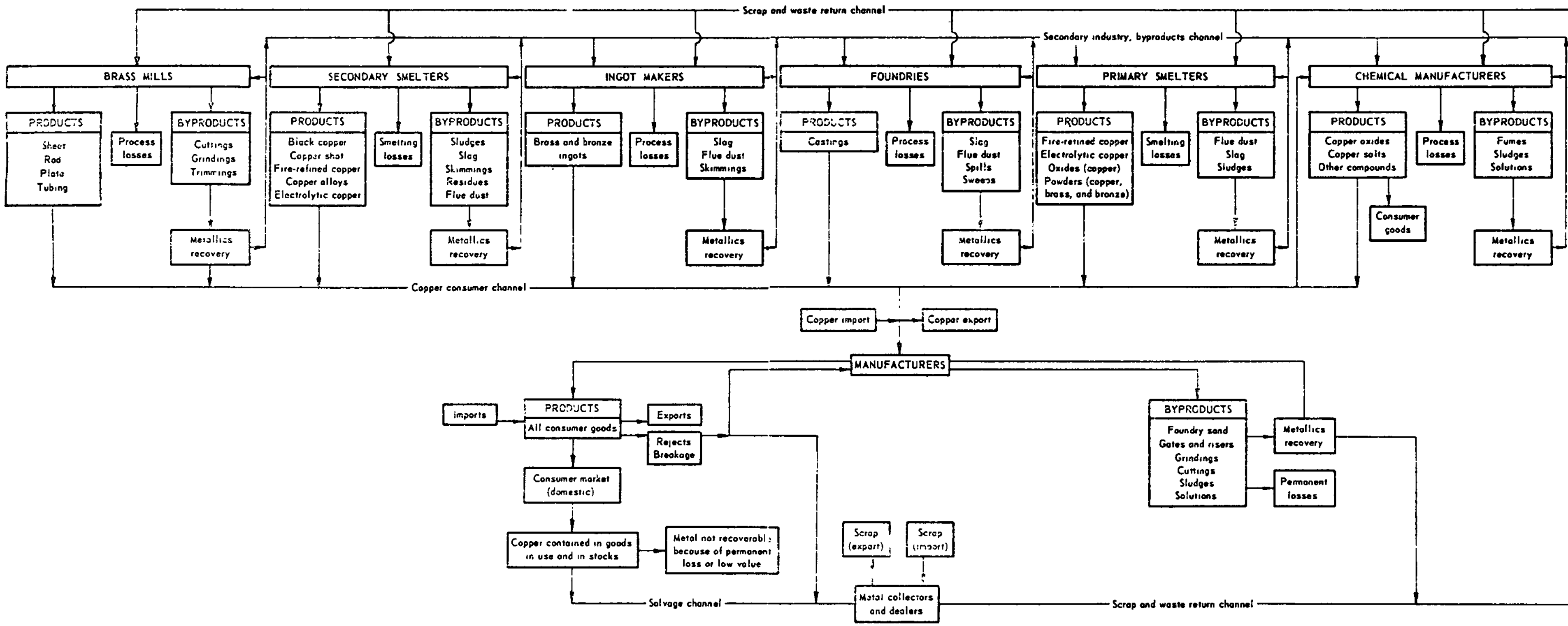


FIGURE 2. - Diagram of Materials Flow in Secondary Copper Industry. (Faces p. 4)

Old scrap is the most difficult category to deal with as far as recycling is concerned. There is always a strong economic incentive for a manufactory to sell or to recycle its new scrap, even if the effort to sort it into homogenous parcels is not always made. The only serious limitation for new scrap is the lack of an economical process for the recovery of some industrial waste like very low grade slags, waste pickling solutions, flue dusts, etc.. that must still be dumped.

On the opposite side, old scrap is to be collected, sorted, cleaned from foreign materials before being sent to a scrap user. This is the role of the scrap dealing sector. The numerous and scattered uses of copper-base products, the variety of alloy composition, the lack of incentive for some obsolescent copper-containing products owners to forward their scrap to scrap collectors instead of dumping it on landfills or mixing it with household waste, the extreme heterogeneity of some collected scrap parcels, make the task of old scrap recovery more difficult.

The problem of organizing scrap collection is not, properly speaking, a technical problem, and it is not dealt with in this report. The way scrap is sorted has important technical implications on the way it will be recycled.

When a copper alloy scrap is to be recovered, it is usually much more economical to transform it into new alloy than processing it in a copper refinery for production of pure copper which might subsequently be mixed with zinc or tin, thus returning to the original alloy composition. Furthermore, the economy in alloy recycling is still larger when the alloy scrap composition is nearest to the composition of the desired output.

./.

Likewise, it is always preferable to sort unalloyed copper scrap into parcels of rather homogenous grade (see the flowsheet of a secondary copper refinery, page 84).

The savings realized in processing high grade copper scrap of homogenous alloyed scrap, of course result in a higher price for this scrap. This added value is the commercial rationale for the sorting of scrap by manufacturers or by scrap dealers.

The sorting of new scrap is often carried out within the plant generating the scrap, especially when it has a high intrinsic value or when some toll treatment contract exists with a metal supplier. New scrap arising as turnings, cuttings, etc... and sold to scrap dealers are more likely to be mixed.

Old scrap sorting is often more complex when the scrap is supplied to dealers by many scrap collectors gathering it here and there. The extreme diversity in shape, size and quality of such scrap, makes sorting mechanization hardly possible, so that it is practically always performed manually. More details in this respect are given in section 2.1.

Shearing and baling may also be performed when sorting the scrap. Too long or too wide pieces often have to be sheared. Baling the scrap with hydraulic presses provides denser parcels which are more easily carried, handled and charged into the furnace. This baling operation is necessary for aluminium scrap, the lightness of which would otherwise cause the transport to be too costly. Copper scrap is however not always baled. Possibilities of cheating on the composition of such bales are actually large, since their outer part only is visible and since they are sold on the basis of their weight. Some cases are known when bales were loaded with bricks ! Shearing and baling, as a matter of fact, depend on demand from scrap buyers who have to take technical requirements into account and, on the other hand, to rely on the seriousness and the good reputation of the scrap supplier.

Whatever the mechanism of scrap price fixing, this price is always related someway to the copper grade and the nature of the alloy. Most often, mixed scrap and precious metals containing scrap are sampled for analysis as they arrive at the copper smelter and refinery (10). This procedure is costly, both in time and money, and various attemps have been made to establish a standard classification for metal scrap trading. In that respect, different national classifications have been proposed, in France, in Germany, in the United Kingdom, in the United States.

A standardization of the European classifications promoted by the B.I.R. (Bureau International de la Récupération) has led to the EURO norms. These norms refer to European transactions. National standards are however still currently used in each country.

American Standards issued by the N.A.R.I. (National Association of Recycling Industries, formerly known as the N.A.S.M.I., National Association of Secondary Metal Industries) apply in the United States and in international scrap trade.

EURO norms for copper and copper alloys are listed in Appendix C and N.A.R.I. norms in Appendix D. A comparison of these standards is made in (5).

Important savings are made by using these standards, not only by avoiding sampling and assaying costs, but also by a simplification of administrative operations, especially for small parcels.

Two important restrictions are nevertheless placed on a general utilization of standards. First, copper

./.

smelters and refiners usually pay their purchased scrap on the basis of the copper and other elements contents (valuable and detrimental impurities, as determined by assay. On the other hand, certain scrap categories such as too low-grade scrap, highly mixed scrap or scrap containing highly valuable metals, or some special alloys like silver-nickel (see category Niece in N.A.R.I. standards), never quite fit into the classifications and are sold by sample or analysis. But standards are always of common use among scrap dealers and scrap re-users (see next section). Scrap pricing is then based on these categories.

*

* *

1.3. Basics of recycling processes

1.3.1. Scrap users

After sorting and, if necessary, preliminary processing, copper scrap may take various routes for treatment :

- brass mills
- foundries
- secondary ingot producers
- chemicals and other miscellaneous users
- secondary copper smelters and refineries.

The scrap supply to brass mills is often limited by stringent requirements as to quality of their products. In order to most avoid pollution risks of their alloys by impurities that are difficult or costly to remove, wrought metal producers generally restrict themselves to the recycling of part of their home scrap and production scrap of their clients (like turnings, stamped sheet skeletons, ...), the alloy composition of which is well known so that the risks are lower. Anyway, scrap never constitutes 100 % of brass mills' feed, and refined metal ingots are always added in order to dilute impurities and bring the alloy to the desired composition.

When the allowance for alloy composition is greater, as is the case for leaded turning brass which is produced in large quantities, old and new scrap may have a much more important place in the supply. It is then well sorted scrap, with high metallic content and with minimum impurities.

Other productions, like for instance some copper cables and wires, require such a high quality that only electrolytic copper may be used and that even the first quality home scrap is often sold to scrap dealers or other scrap users.

Foundries face the same kind of problem as brass mills do. The more demanding the quality of their products, the lesser their possibility of using scrap. For castings with great chemical allowance, home scrap, new scrap and old scrap may constitute the main part of their metal supply. Scrap use may also be reduced to zero when castings must have a very precise chemical composition. Often too, foundries prefer to rely on alloy ingots purchased from secondary ingot producers. The choice of the type of supply always results from a balance between profit on metal price and risk regarding the quality of the product.

Secondary ingot makers, on the other hand, use old scrap of more or less good quality, in large quantities to produce alloy ingots of given composition.

The technique for recycling alloys, in brass mills or foundries as well as for ingot production, essentially consists in preparing the furnace charge, melting the scrap, removing the impurities and giving the desired composition to the alloy by adding virgin metals. This is described in section 2.3.1.

Another way of recycling copper scrap is to produce chemicals. This outlet consists mainly in copper sulphate production, and it requires high grade copper scrap with minimum about 86 % copper. The technique is dealt with in section 2.3.2.

Counter to the above direct uses of scrap (in that they do not imply bringing the copper back to the state of virgin metal), metallurgical smelting and refining processes are aimed to produce from scrap a metal that is as pure as primary copper recovered from ore concentrates. These processes, which do not essentially differ from those developed for primary production, are detailed in chapter 2.2.

If, in Europe, they are chiefly applied in secondary smelting plants, it must be underlined that the distinction between primary and secondary producers is less and less well defined. European primary copper producers actually supply their plants with copper scrap at various stages of their production. In some cases, this scrap may even constitute a very significant part of their supply.

Another feature of copper refineries, be it primary or secondary, is their ability to recover other metals, like gold, silver, platinum, palladium, rhodium, etc... that may accompany copper in certain types of scrap and that would otherwise be lost. In many cases, this recovery is even a condition of profitability of scrap processing and represents a noticeable source of supply of these metals.

As can been seen from the figure on page 84, scrap of any grade above the minimum economical limit can be introduced in the flow sheet of copper smelters and refineries. Secondary copper refiners are able to treat scrap that cannot be processed by alloyers and chemicals producers, as well as scrap that the latter can accept. Secondary copper refining appears thus as both complementary and competitive to direct use of scrap. Practically, this competition is however limited to high grade copper scrap. Recovery of good alloyed scrap is more economically performed by alloyers than by copper refiners who can only recover part of the zinc as zinc oxide, tin as brazing lead-tin alloy, and nickel as sulphate. On the opposite, too polluted alloyed scrap may not be acceptable to alloyers and are to be recycled by secondary copper smelters.

*

* *

1.3.2. Some particular problems according to types of scrap

The above considerations apply to any kind of scrap, be it stemming from electrical engineering, mechanical engineering or building materials. Certain types of scrap, however, possess special features and have led to the development of suited techniques. The corresponding machinery is described in chapter 2.1.

./.

24

1.3.2.1. Electrical engineering

1.3.2.1. a - Insulated cables and wires

Cables and wires represent a major use of refined copper. Except for overhead cables and wire windings, they are to be insulated. According to the use of the cable and the properties required from the insulation, cable sheathing may involve various materials : plastics (mainly PVC or polyethylene), lead and oiled paper, steel armour, fabrics, aluminium, tarred jute, etc... Beside the outer insulation, which is common to electrical and telephone cables, the core of the latter consists of a set of thin insulated wires. All this insulation stuff is to be removed from the copper conductors in order to upgrade the scrap and make it usable by scrap users as n°1 or n°2 copper wire.

Insulated cable and wire scrap arises both as new and old scrap, with a large variety of insulation materials and of diameters. The scrap processor is thus often faced with a very heterogenous material in size and quality, without even mentioning the possible presence of aluminium cables. As a consequence, any processing of this scrap must involve some manual sorting.

Incineration

The first method one may have in mind to have copper separated from its insulation is incineration. All combustibles, such as plastics, fabrics, tar, paper, etc... are burnt, and lead is molten and recovered in a crucible. Copper can then be easily removed from steel or aluminium armour by hand.

./.

This method is the only one which has been used for many years in spite of its drawbacks :

- The copper recovered by burning is less valuable than copper recovered by mechanical methods. It is oxidized by any excess of air in the furnace and corroded by the hydrochloric acid produced during the burning of PVC.
- Considerable atmospheric pollution is produced during burning and, in many areas, burning of cable scrap is now prohibited.
- The value of the plastic insulation is completely lost by burning. This is now of little consequence as recovered plastic has little or no value. However, processes have been recently developed for plastic waste recycling which could increase the value of this product.

However, incineration is still widely used. Improved furnaces have been designed in order to limit above inconveniences. They are described in section 2.1.4.

On the other hand, incineration is the sole method usable for some kind of cables, the treatment of which is difficult by mechanical means.

Furthermore, the cost of an incineration equipment is considerably lower than that of a complete mechanical equipment.

Mechanical processing

The alternative to incineration of cables lies in mechanical processing. Several equipment manufacturers have designed complete flow sheets for such processes. The principle, common to these flow sheets, consists in chopping the cables into small loose copper and plastic nuggets and separating them by various devices. The design of the machinery is however different according to manufacturer. Chopping mills are described in section 2.1.2.4. and separation devices in section 2.1.2.5. Complete flow sheets are given in section 2.1.3.1.

These processes have limitations at various degrees : leaded cables as well as greasy or tarry cables behave badly in chopping mills. Talcum powder allows to cope with grease and tar if they are not in too large quantities, but this means becomes unsatisfactory when the amount of greasy cables increases. Steel-armoured cables are also difficult to cut in chopping mills as they rapidly damage the knives. There also exists a lower limit for the diameter (except in the DRYFLO process) of wires likely to be mechanically separated from their insulation. Investment costs are very high and the important throughput of such machines (2 to 3 tons per hour) requires an abundant feed of a rather homogenous quality.

On the other hand, cable stripping machines (described in section 2.1.2.3.) remove the insulation by cutting it along its whole length. These machines are able to cut any kind of cable, they are rather inexpensive but continuously require one man to operate them. There also exists a minimum diameter below which wires cannot be stripped.

1.3.2.1. b - Electric motors

Electric motors, as well as car generators or alternators and small transformers, form a mixed iron-copper scrap with about 20 to 30 % copper on the average. This copper is shaped as wire windings, commutators, bushings, contacts, etc... Traditional ways to treat such scrap are either to feed it directly into a copper blast furnace or

./.

to break the armature with hammer, saw or nibbler (see section 2.1.2.2.) and then separate the copper winding from the armature. In this latter case, there always remains some copper entrapped within the steel scrap.

The copper content of car electric motors is nowadays largely recovered through car shredding operations (see sections 1.3.2.2. b and 2.1.3.2.). The case of appliances which also contain significant quantities of copper mainly in motors, is also dealt with in these sections, because of the similarity of operations.

1.3.2.1. c - Electronic_and_telephone_material

Electronic circuits, telephone exchanges, computers, etc... represent a very interesting copper scrap since they also bear a lot of precious metals. This scrap normally always goes to secondary copper smelters.

Computers and telephone centrals also include various steel or other metallic components that are not suitable for treatment in a copper smelter. These are removed either manually or by a shredding process.

1.3.2.2. Mechanical engineering

1.3.2.2. a - Swarf

Swarf may occur in many shapes (turnings, grindings, chips, ...) that are not always well suited for charging into a furnace.

The feed material for a blast furnace for instance is to be lumpy in order to achieve sufficient porosity and crushing resistance. As a consequence, there is a limitation to the use of fine dusty scrap like grindings.

This kind of material is charged in small proportion as compared to bigger pieces, or is agglomerated by briquetting or pelletization with a binding agent.

Turnings and chips are also briquetted in hydraulic presses (section 2.1.2.1. b) so as to reduce their specific volume which would otherwise be too large for an efficient charging of furnaces. When briquetting is performed within the manufacturing plant from which turning scrap arises, it also contributes to lower the transportation costs. Associated with briquetting is the problem of removing the tooling lubricants swarf is impregnated with (see sections 2.1.2.1. b and 2.3.1.).

1.3.2.2. b - Automotive scrap and appliances

Transport equipment may be included in an extended notion of mechanical engineering.

An important part of the automobile copper content is concentrated in a few removable parts : radiator, generator or alternator, starter,... An analysis of fifteen ten-year old American automobiles, made in 1969 (20), assesses the composition of a "typical composite car". It is reported in table 2. Copper accounts for 1 % of the total composite car weight. Estimates of average copper weight in cars vary from country to country. They are comprised between 2 and 8 kg per car. This represents quite a significant amount of copper when considering the number of cars being scrapped each year. This number has been evaluated at 2.1 million cars and vans in Germany in 1980 (49).

When old cars are not simply abandoned somewhere in the countryside, they are most often brought to a

Table 2

Copper content of a typical composite American car

(from (20))

Part	Copper content (pounds)
radiator (1)	13
body wiring	4
starter	2.8
generator	2.8
heater core	2.4
electric motors	0.8
dashboard wiring	0.8
battery (cables and clamps)	0.8
coil	0.5
instruments (2)	0.5
thermostat (2)	0.5
tubing	0.4
engine wiring	0.4
radio	0.3
differential (2)	0.2
voltage regulator	0.2
fuel pump (2)	0.2
carburettor (2)	0.2
horn and relay	0.2
transmission	0.2
brake drums and cylinders (2)	0.2
total :	31.2 pounds = 14.15 kg

(1) Radiators are usually made of copper and/or brass, but sometimes also, partly or entirely, of aluminium or steel.

(2) These parts contain copper as yellow brass.

./.

wrecker who can use them as a source of spare parts. After a while, when the automobile has been more or less stripped of valuable parts, it is shipped to a car scrap processor. Even if the hulk has been thoroughly stripped, there always remains some copper in body and dashboard wiring, tubing, ... (see table 2). Scrap processors may also receive abandoned automobiles.

The traditional method of processing car scrap consists in stripping the hulks of the remaining re-usable parts, incinerating them to remove non-metallic materials like fabrics, rubber, plastics, ... , removing cast iron, heavy steel and accessible non-ferrous components, and finally, compacting the hulks in the so-called "n°2 bundles". These bales are of poor quality and steelworks are generally more and more reluctant to buy them. Some copper always remains entrapped within the steel scrap and is lost. Furthermore, car incineration in the open air has been prohibited in many regions as a consequence of pollution regulations. As an alternative to baling, shearing the hulk into large loose pieces is also a common procedure.

About twenty years ago, a new mechanical process was developed, allowing a better separation of copper. Car bodies, with or without prior stripping, are shredded and reduced to fist-size pieces. After dust removal, ferrous pieces are gathered by a magnetic device. The non-ferrous reject may then be either hand-sorted by picking up the most valuable metal pieces, or processed so as to remove the non-metallics and separate aluminium and zinc. In the latter case, copper remains mixed with some stainless steel (non-magnetic !) and has to be treated in a copper refinery. This process is described more detailedly in section 2.1.3.2.

./.

Processing appliance scrap is very similar to processing car scrap. The first usual method consisted in removing the motor manually and selling it separately from the steel scrap. Incineration was seldom performed. The new trend is to shred appliances in the same mills as cars, and this may sometimes constitute up to 15 - 20 % of a shredder feed. Large quantities of copper, however, are still lost in landfills. It has been estimated in 1971 in the U.S. that about 45,000 tons of copper and 65,000 tons of zinc contained in major appliances are discarded in the U.S. every year, of which 80 to 90 % are disposed of in landfills (12).

1.3.2.2. c - Miscellaneous

Large pieces of equipment, like chemical plants or ships, are usually wrecked by specialized firms which separate the valuable metal scrap. This scrap then enters the scrap dealing sector.

1.3.2.3. Building materials

No special problem arises from building material scrap. Large copper pieces like roofing sheets, plumbing pipes, boilers,... are sold to scrap dealers. Smaller copper parts, like electrical wiring, are however difficult and costly to recover and are rather left with bricks and concrete.

./.

2. COPPER RECYCLING MACHINERY AND PROCESSES

2.1. Non-metallurgical separation and concentration processes

As for any industrial process, the choice of a metal scrap separation process represents a compromise between technical requirement and possibilities on the one part, and capital and labour costs on the other hand. The technical requirements consist of : expected separation degree, desired throughput, pollution control, etc... Such requirements may vary :

1) according to time : quality to be obtained so that the output product be marketable (see for example the market for n°2 bundles), increasing antipollution measures (see the processing of insulated wires and cables) ....;

2) according to space : size and location of the company (market, antipollution regulations, etc...).

The technical separation possibilities relate to three necessary stages of the process :

- release of homogenous constituents;
- identification of the metal;
- separation.

When scrap pieces, as is often the case, consist of various parts of different metallic nature, it is necessary to break and crush them in order to release the various constituents.

Identification and separation of the various metals are, in fact, performed in one single operation at the occasion of mechanical sorting. In this case, it is necessary to dispose of a standard separation method taking into account a physical property properly determined and sufficiently different from one metal to another, so that a scrap parcel

./.

may be separated into two fractions of different nature. A.V. Bridgewater (8) has listed the physical features of metals and their application to separation techniques. All of them do not apply to copper bearing scrap. For such scrap, the following techniques are currently used :

- density (combined with size and shape);
- magnetism;
- melting point.

These techniques, described in sections 2.1.2. and 2.1.3., in fact only allow to separate copper and/or copper alloys from other metals. The physical properties of copper alloys often vary within too small a range to allow their use, on an industrial scale, in a separation process, with the exception of some particular cases like cupro-nickel magnetic separation. It is then necessary to resort to manual sorting.

The size of the pieces to sort also plays a part in the economics of scrap sorting. Since in the case of hand-sorting the identification effort is the same whatever the size of the piece, the economic limit of profitability in hand-sorting decreases with the piece size. Small size pieces will induce to adopt mechanical sorting processes whenever possible.

2.1.1. Hand-sorting

Despite considerable improvements in the techniques of scrap treatment, hand-sorting remains an essential operation in copper recycling processes. Hand-sorting is most often applied to mixed scrap lots, in view of obtaining more homogenous parcels, usually corresponding to a standard specification, and of thereby giving the scrap a higher value.

2.1.1.1. Metal cleaning

For composite scrap, a rough liberation is made either with hammer, hacksaw and other similar tools, or by the use of semimechanized devices such as nibblers and alligator-shears. Whereas alligator-shears are built for the broad purpose of cutting metal pieces, be it ferrous or non-ferrous, nibblers are specifically designed for metal cleaning. Such machines increase the speed and the efficiency of metal liberation operations. They are described, together with other shears, in section 2.1.2.2.

2.1.1.2. Metal identification

Proper sorting requires a quick and reliable method for identification. Several methods may be used, jointly or separately (see (46), (47)).

Time consuming identification methods are not applied on each piece of a scrap parcel, but rather on several sample pieces serving as guidelines.

a/ Appearance

The recognition of the previous use of scrapped pieces often gives a clue as to its metallic composition (see e.g. copper wires, brass fittings, radiator fins,...). Colour is another criterion that is used to distinguish between copper alloys : brass colour ranges from yellow to green or brown; copper is red to green when oxidized, and so on...

b/ Nicking, filing and drilling

Identification may be based on hardness, brittleness, appearance of the cut surface and of the cuttings, colour of the fracture which is important when the surface of the piece is dirty or oxidized. For instance, a high lead content in copper alloys can be detected by using a pointed hammer, showing up a reduced hardness.

c/ Blowpipe

Samples may be identified by heating them in a blowpipe and observing the colour of the flame, the melting speed, the fume, etc... Such characters vary according to the alloy composition.

d/ Magnetic testing

Although primarily designed for the detection of ferrous metals, magnetic testing may be used for a few magnetic copper alloys : cupro-nickel, aluminium-bronze, manganese-bronze. Copper-clad steel wire will also be detected with hand magnets.

e/ Chemical spot tests

A wide range of spot tests, from simple drop tests to more elaborate ones, may be used on the sorting area to detect the presence of specific metals in alloys. A review of spot tests for the majority of industrial metals can be found in (29). For copper alloys, spot tests as well as blowpipe tests are limited to doubtful cases.

f/ Laboratory analysis

Important scrap dealers often are equipped with a laboratory where classical chemical analysis and spectroscopic analysis may be performed. These procedures are, however, time-consuming and expensive and are mainly used as a check for identification made by less accurate methods or in difficult cases. Portable handy spectroscopes have been developed for "in situ" analysis, but they are mostly used for ferrous and aluminium scrap.

Although all these copper and copper alloy identification tests are quite simple in their principles, they require a considerable amount of skill that can only

/.

be achieved by practice. A skilled scrap sorter could, for instance, recognize more than 20 varieties of copper alloys merely by nicking or drilling tests.

The U.S. Bureau of Mines (41) has undertaken some research work to develop an identification procedure for copper-base alloys by measurement of colour. Such a colorimeter could be useful for hand sorting only but, as far as we know, this method has not yet been adopted by scrap processors, at least in Europe.

2.1.2. Machinery for mechanical processes

The equipments used in the treatment of copper bearing scrap cover a larger field than just scrap sorting. They concern :

- scrap compacting;
- scrap cutting;
- granulation;
- metals separation.

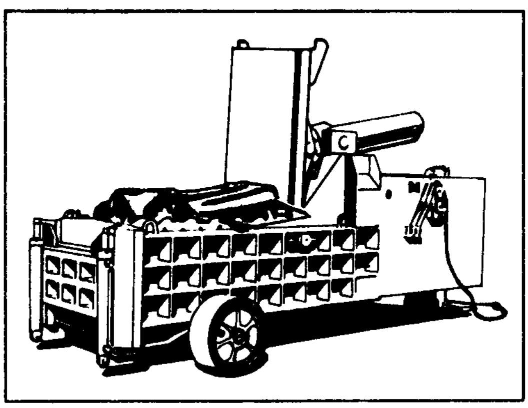
2.1.2.1. Compacting machines

Although baling and briquetting are always subject to agreement between scrap buyer and seller (see the N.A.R.I. and EURO classifications in Appendixes C and D), it is often convenient to reduce the volume and save some of the transportation costs. Furthermore, bales and briquettes are easily chargeable into furnaces. The trouble is that one can only see the outer part of the bales and must consequently trust one's supplier as far as the inner part is concerned.

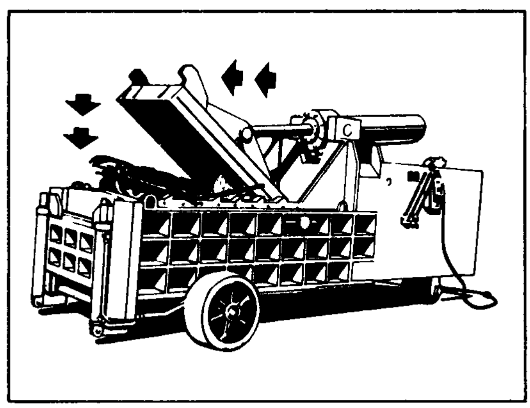
2.1.2.1. a - Baling machines

Hydraulic metal baling presses work either by biaxial or by triaxial compression. These principles are sketched in fig. 3 and 4 (°). Practical realization may however vary from one press manufacturer to another. They produce cubic or parallelepipedic bales, the section of which may be comprised between 30 x 45 and 90 x 60 cm. Their use ranges from paper and municipal waste to heavy ferrous scrap. The size and power of the machine are of course related to the kind of input. Non-ferrous and light ferrous sheet scrap balers require 8 to 50 Hp, depending mainly on the size of the bales. Car hulk balers require 100 to 700 Hp. The last figure relates to a press capable of baling simultaneously three flattened car bodies.

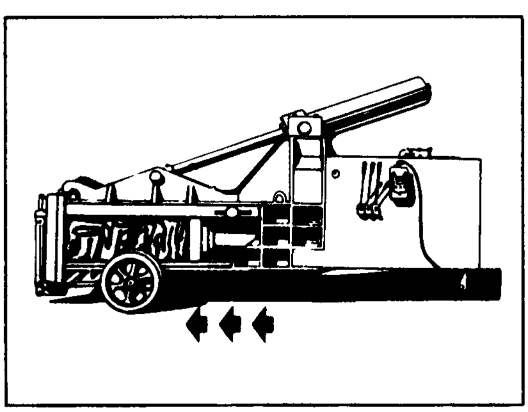
Fig. 3



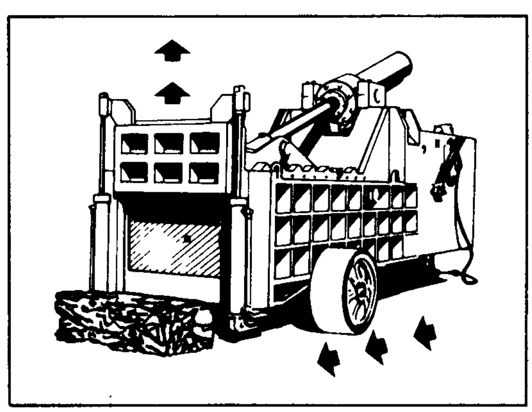
1) Press just loaded



2) Shearing and vertical compression



3) Horizontal compression

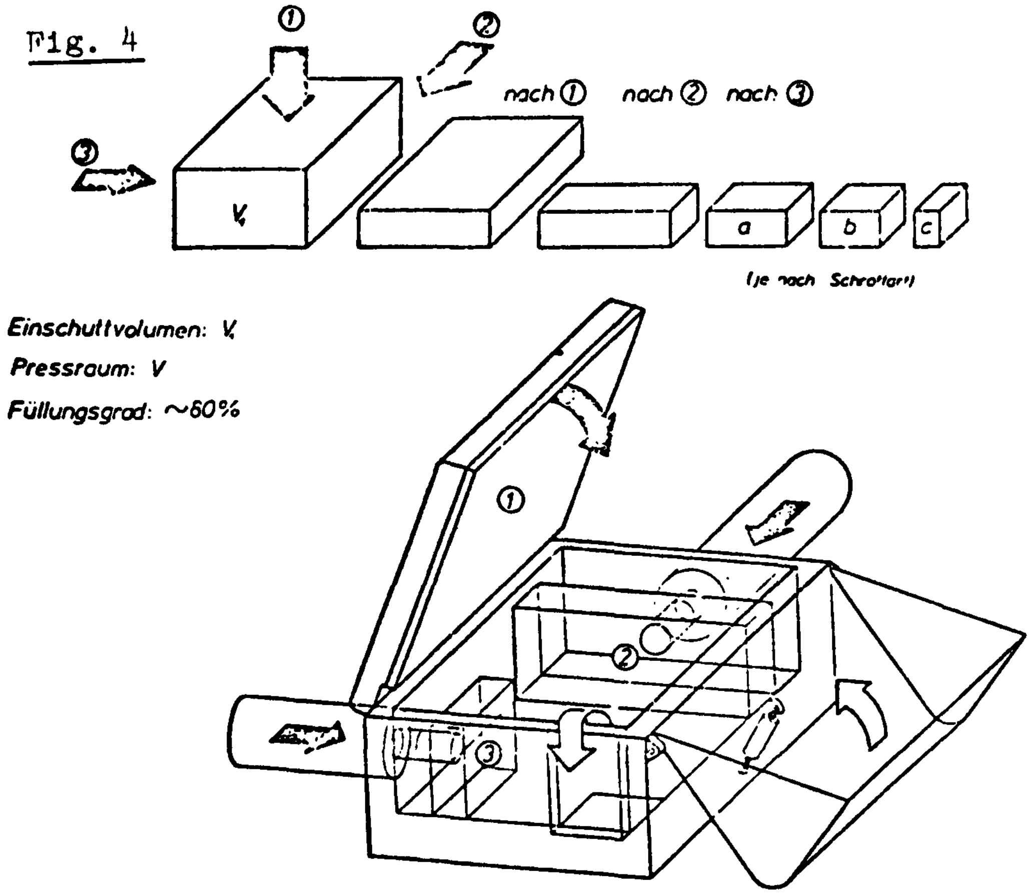


4) Pack-expulsion

(°) A list of references for figures extracted from publicity leaflets is given in appendix E. Equipment manufacturers we have been able to contact are listed in appendix F.

./.

Fig. 4



2.1.2.1. b - Briquetting presses

Briquetting machines were originally designed to treat turnings and chips arising from tooling operations. Cold-briquetting involves a preliminary elimination of cutting oil and water by centrifugation and/or drying in a furnace. The chips are then hydraulically swaged into the die of the press to form a compact cylinder of about 10 to 15 cm diameter, with 65 to 75 % solid volume. Hot-briquetting allows to dry the chips within the same machine and produces briquettes with up to 90 % solids.

Copper and copper-base alloy turnings are often too springy to allow easy briquetting and must be chopped prior to entering the briquetting press.

Briquetting may also be applied to copper nuggets produced by mechanical cable recovery systems.

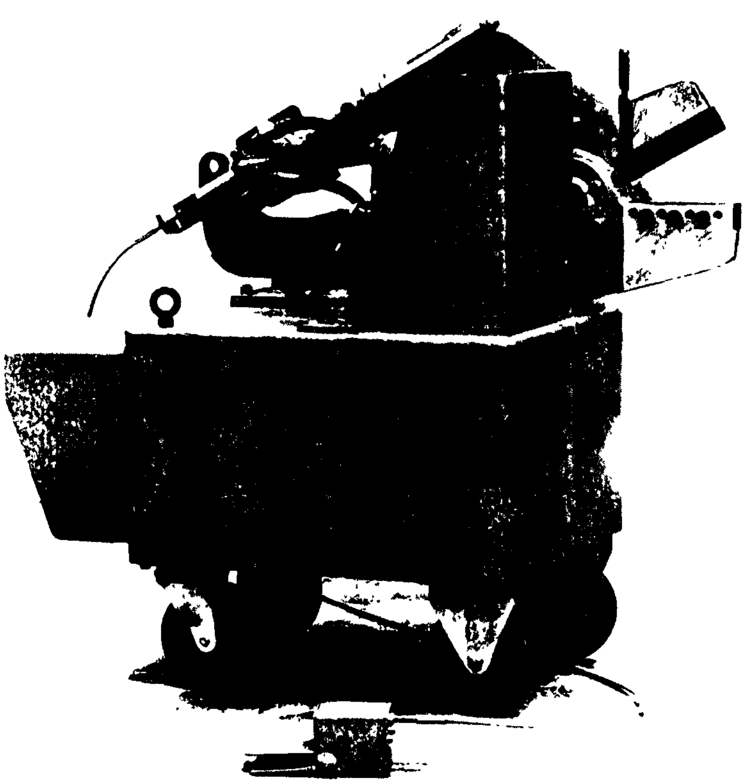
2.1.2.2. Shears

2.1.2.2. a - Alligator shears

Alligator shears are commonly used in scrap yards to cut too large pieces into the desired lengths. They may also be used for metal cleaning purposes, in order to separate composite scrap into more homogenous pieces.

Fig. 5 shows a typical alligator shear : the bottom jaw is static and the upper jaw pivots on an end boss. These machines are fed manually and are operated either by foot pressure on a pedal, or in a continuous way at constant speed. Large machines may also be fed by a conveyor belt system. The power required for non-ferrous cleaning and shearing is about 5 to 8 Hp. More powerful engines, 15 to 30 Hp, are needed in bigger machines capable of cutting mild steel pieces.

Fig. 5



./.

2.1.2.2. b - Guillotine shears

Guillotine shears, with the upper blade hydraulically powered down along a vertical line, are used to cut higher tensile and bigger bulk metals, such as entire car bodies. They can be combines with a baling device. These machines are driven by 60 to 360 Hp motors.

2.1.2.2. c - Nibblers

Nibblers (fig. 6) are metal cleaning machines, resembling alligator shears, with an horizontally V-shaped mobile upper blade. The fixed bottom blade is carved on the side of a working table. Nibblers are operated in the same way as small alligator shears. They are powered by 10 to 20 Hp motors.

Fig. 6

2.1.2.2. d - Cable cutting machines

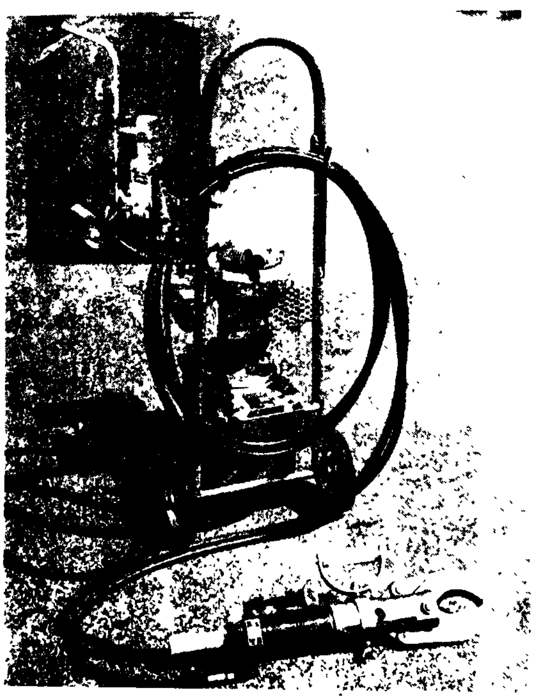
Although alligator shears may be used to cut cables to the desired lengths, special devices have been designed for that purpose.

Actually, electrical cable scrap come very often to the processing plant in the form of entangled bundles which are difficult to man-handle and which cannot be introduced in stripping machines, choppers, raspers and granulators. Moreover, the lengths of the bits of cables are generally speaking too long, which makes their further treatment difficult. When one has to deal with a lot of cables, the first operation to be performed consists in cutting them into easy-to-handle pieces before introducing them into the treatment devices.

For this purpose, the following devices are utilized :

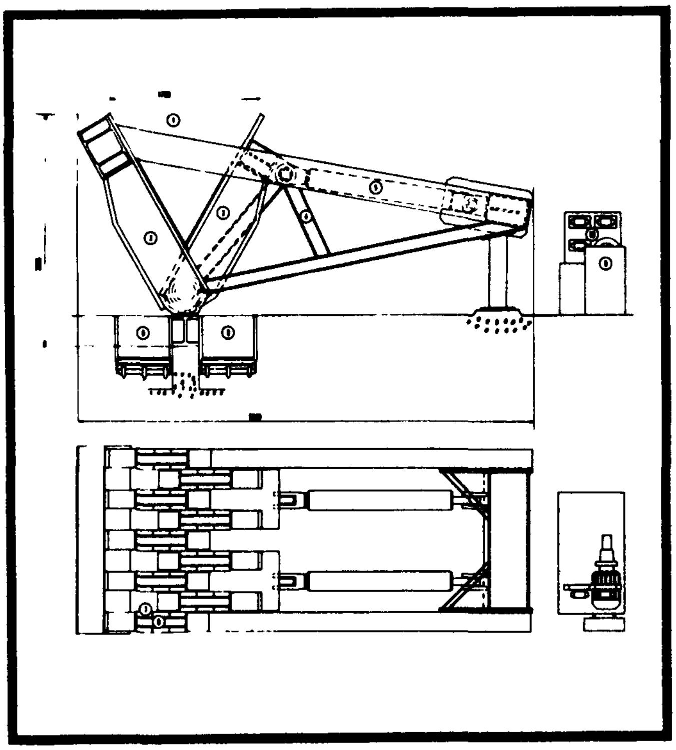
- portable cable cutters, which are very handy tools, are connected to an hydraulic system by means of sufficiently long hoses to give the operator a large area of work. For instance, the tool shown on fig. 7, developed by SISO allows the handling of cables having a diameter of up to 3.1/2";
- non-portable cable shears, to cut all types of cables in bulk form, like the one sketched on fig. 8, from PERSÖNER VERKSTAD.

Fig. 7



./.

Fig. 8



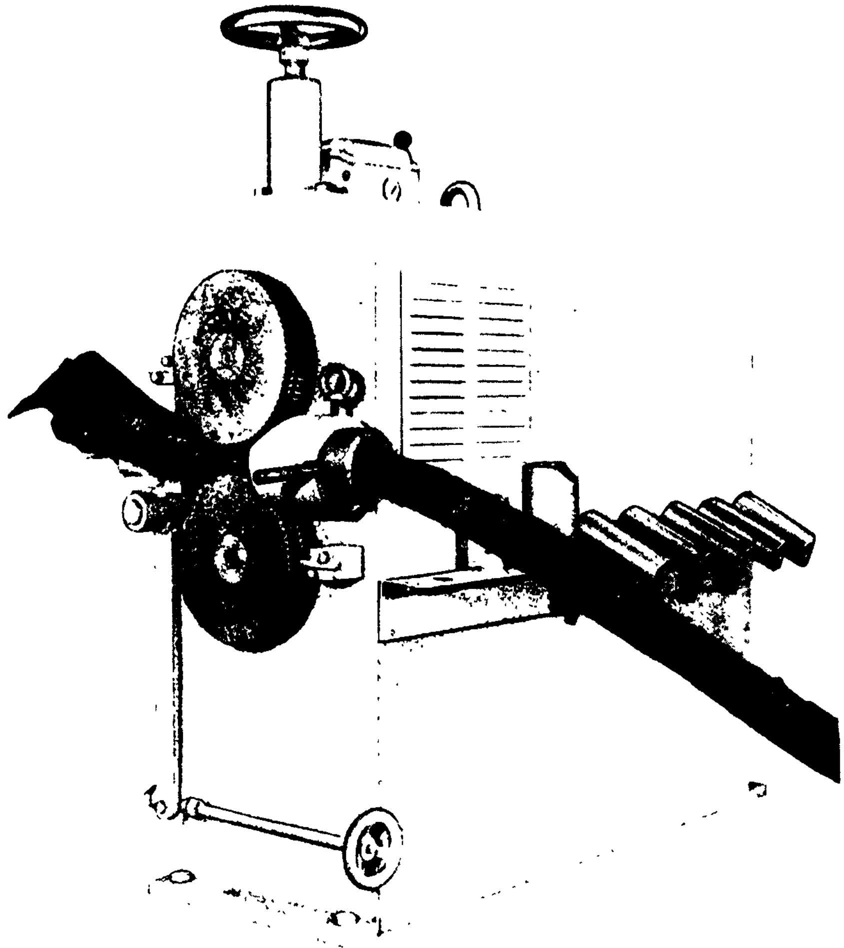
1. Loading opening
2. Fixed knife beams
3. Moving knife beams
4. Frame
5. Cylinders
6. Retaining plate
7. Cutting blades
8. Conveyor belts
9. Control panel
10. Pump unit

2.1.2.3. Cable stripping machines

Cable strippers are designed to cut the cable insulation along its length in order to remove it from the copper conductor. Stripping is often a very convenient way of processing steel armoured, lead sheathed and greasy and tarry cables.

In most of the stripping machines, the cable is pushed on a fixed cutting knife by two feed rollers, the pressure of which is adjusted by a spring loaded screw. The knife makes a slit in the insulation which is manually removed at the exit of the apparatus (fig. 9).

FIG. 9



Other machines (GREENBERG) are fitted with multiple feeders, adapted for different cable diameters and with two fixed knives which make cuts on each side of the cable.

In the machines manufactured by RIGBY, slitting knives are rotary and power driven. They make in the insulation two parallel slits, tangent to the conductor. This way of stripping results in more complete opening of the cable and reduces the amount of hand labour required to complete separation of sheathing and conductor. Machines fitted with rotary knives are not able to treat spiral wrapped metal armoured cables.

These machines must always be fed and operated manually. Some machines are self-adjusting to the cable diameter, but they are not able, in that case, to slit armoured cables.

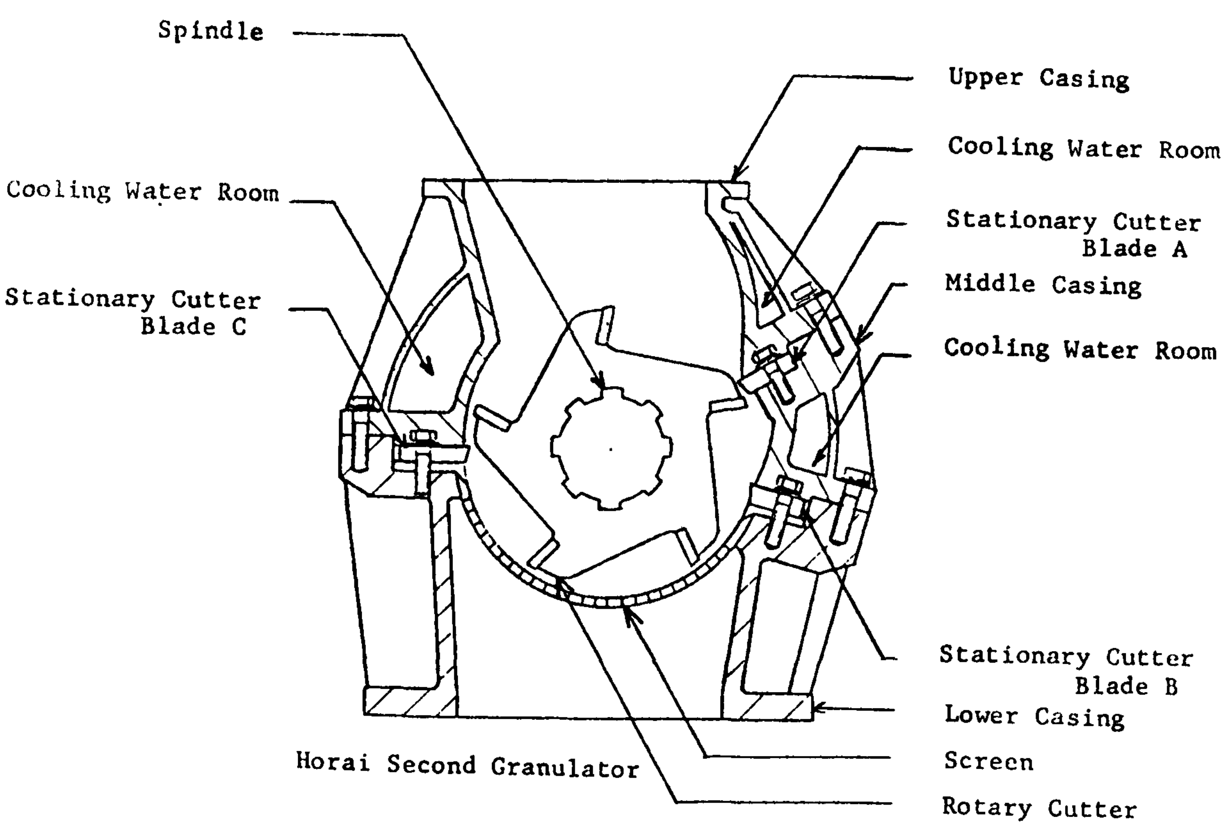
./.

Obviously, there also exists a lower limit in the diameter of wires that can be processed by such machines.

2.1.2.4. Chopping and shredding mills

The first step of any cable, car or appliances automative mechanical treatment process always consists in reducing the scrap size in order to reach a liberation degree of its constituents allowing an efficient separation. This size reduction is achieved in rotating mills. Cables are chopped in knife granulators working mainly by a shearing action and providing small copper and insulation nuggets (fig. 10). Car hulks and appliances are usually shredded in hammermills for which impact action is most important. In this case, the end product consists of fist-size pieces. All crushed or ground products are evacuated through grates with appropriate openings.

Fig. 10



./.

2.1.2.4. a - Chopping mills (granulators)

Pre-chopping

Instead of using shears to disentangle cable bundles, it is also possible to chop them in specially designed pre-choppers (raspers). Cables are reduced to pieces 1" to 3" long, and pass through the wide-mesh outlet screen. This allows for constant and controlled feed into the primary granulator of the recovery installation which, traditionally, is the bottleneck in all systems.

Pre-choppers may be fed with steel armoured cables which may subsequently be chopped by granulators. They usually have a throughput of 4 to 6 tons per hour for normal plastics, insulated cables, or of 2 tons for the lighter telephone wires, and are driven by 80 - 90 kW electric motors.

Granulators

The granulators, whichever their origin, are always mills fitted with a rotor equipped with interchangeable knives rotating against stationary knives fixed to the mill housing. The outlet is made through a screen, the mesh of which governs the sizes of the end product.

Each cable scrap recovery equipment is fitted with mills having special characteristics. The primary and finishing mills differ from one another only in the outlet screen mesh sizes, although some manufacturers propose different devices for the two milling stages.

In the CIMP (COMPTOIR INDUSTRIEL DES METAUX ET PLASTIQUES) equipment, the two mills are similar and each of them is driven by a 55 kW motor. Their 400 mm diameter rotor is fitted with 5 rows of 4 knives each, and the stator is fitted with 2 rows of 4 stationary knives.

./.

The ALPINE equipment contains 3 milling stages fitted with identical 90 kW mills equipped with a rotor of 9 rows of 5 knives each and a stator with 6 rows of 5 knives each. The rotation speed is 350 rpm, and the production reaches 3 t/h for medium cables.

DRYFLO and 3/S granulators are rather similar to these.

The HORAI granulators are, however, quite different. The first stage granulator reduces the scrap to a size of 20 - 40 mm by special twisting and shearing action. The rotor has three sets of blades working against two stationary ones. The rotor blades are erected slantwise in relation to the axis rotation and each blade is divided into four separate sections erected in echelon. By using a very low speed rotor (35 - 50 rpm), wear is greatly reduced and a greater lead angle of the blade is permitted. Moreover, the noise is greatly reduced (90 decibels, as compared to 110-130 for normal speed mills) as well as the power consumption.

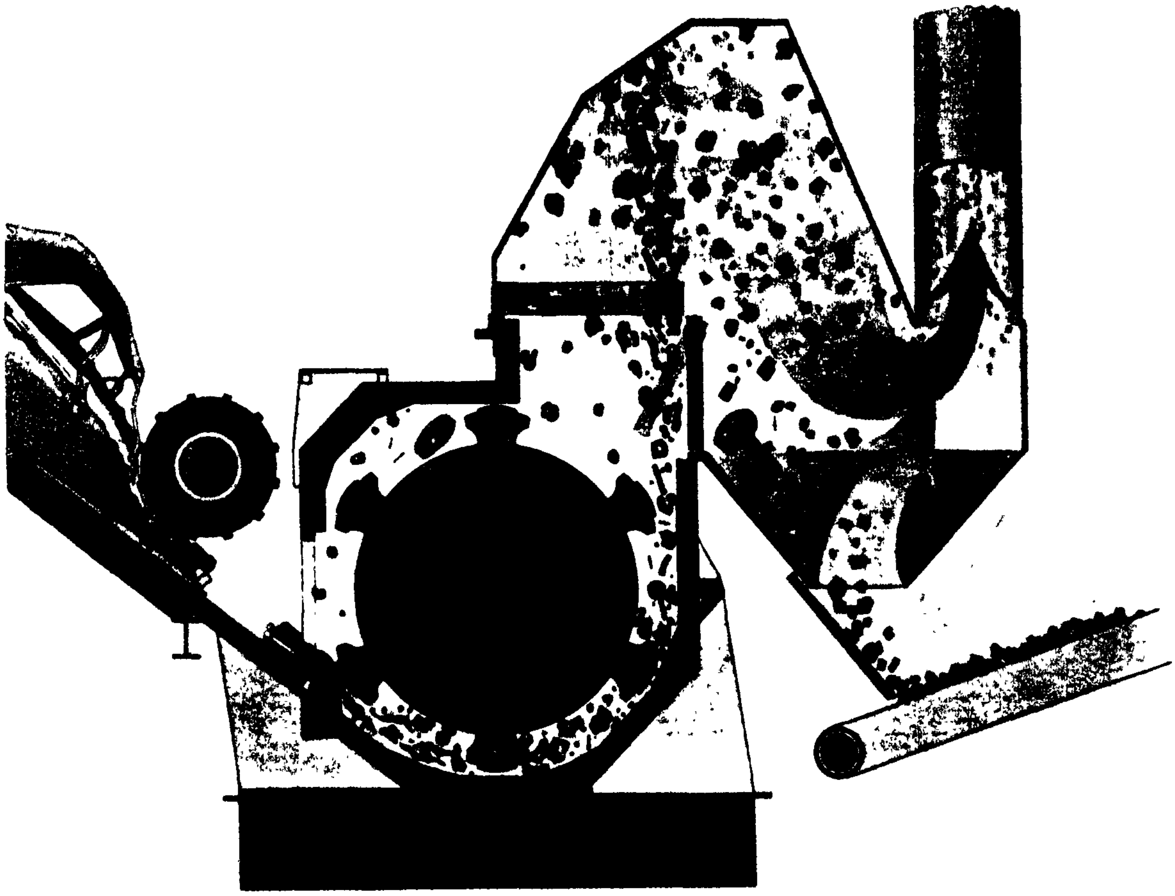
The second stage granulator (fig. 10) is especially designed to give maximum stripping efficiency with minimum blade wear. The scrap is reduced into particles, sizes of which vary between 3 and 12 mm.

Besides cable scrap, many granulators are capable of processing other copper scrap such as turnings, sheets, strips, etc... This use is however restricted to new scrap.

2.1.2.4. b - Shredding mills

The most widely used shredder is the hammermill. This type of mill has a rotor equipped with 3, 4 or even 6 axes displayed in circle, each holding a row of swinging hammers (fig. 11). The scrap is crushed by impact and shearing action. When reduced to the desired size, the pieces are evacuated from the mill through a grate having the required opening. Too big pieces pass again under the hammers. Such machines require

Fig. 11



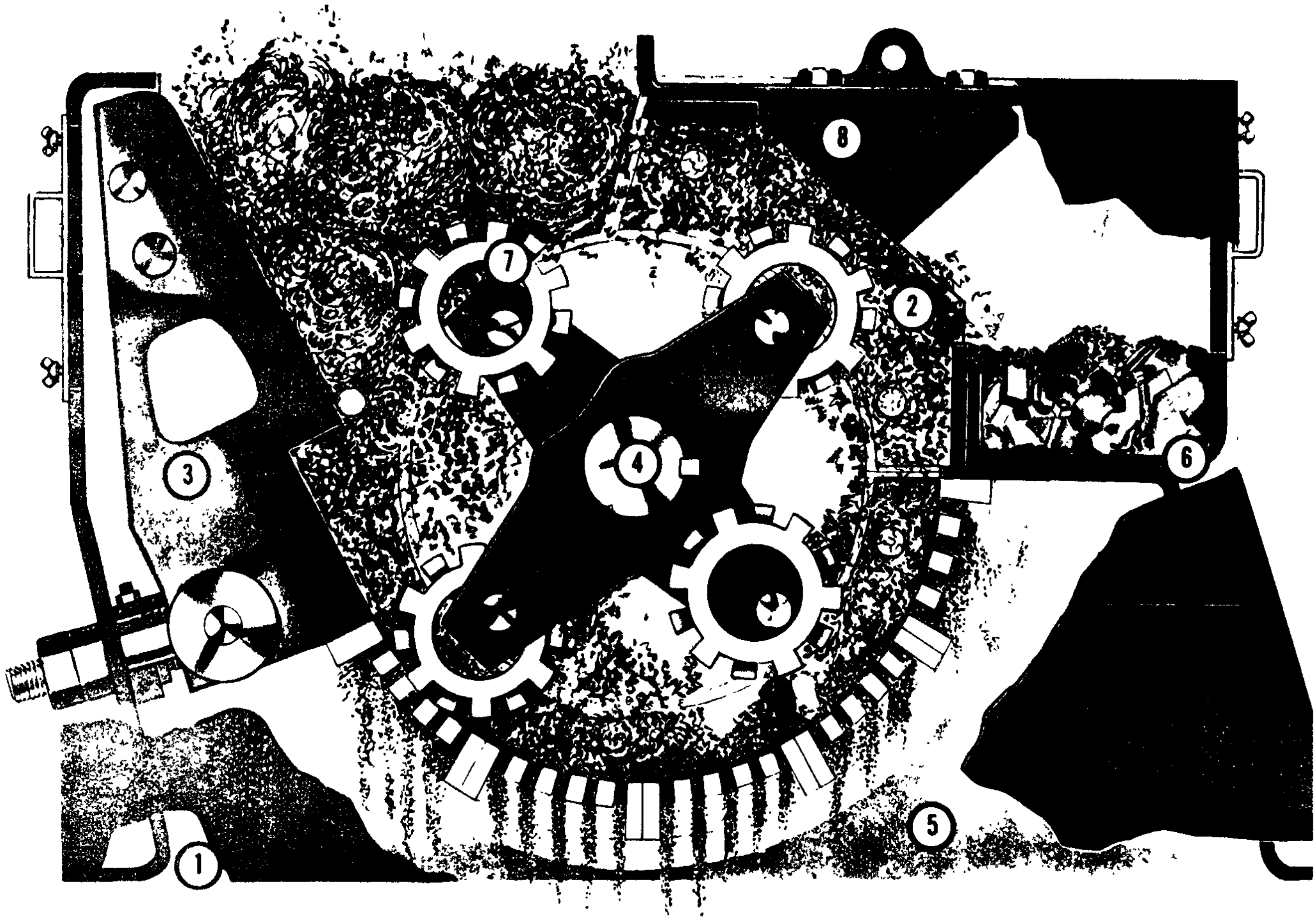
considerable power. 1000 to 4000 Hp shredders, according to the desired throughput rate, are marketed. Less powerful hammermills can crush car bodies ridded of their engine and driving gear.

The chief input of the shredders consists of automobiles, up to 80-90 %. Various types of appliances, also containing a certain amount of copper, make up the difference (see section 1.3.2.2. b).

Similar mills may be fitted with toothed rings for the shredding of turnings (fig. 12). The tooth-shaped tools prevent springy turnings from clogging at the bottom. Evacuation grids have to be placed at the bottom. The weight capacity of such mills varies according to the size, the power, the turning speed, the nominal chip size and the nature of the turnings.

./.

Fig. 12



WILLIAMS markets ring mills with 15-20 Hp up to 1000-1500 Hp, or even up to 6000 Hp on request. More powerful mills tend to have a slower rotation : 600 to 900 rpm for a 1000 Hp mill against 1200 to 1800 rpm for a small 20 to 60 Hp mill.

BECKER has developed ring mills with 75 to 500 Hp with a constant speed of 980 rpm.

The throughput of a ring mill is about twice as large for brass turnings as for mild steel. It is still less for stainless steel, high alloy steel or aluminium. For brass turnings, a small 15-20 Hp mill would have a capacity of 1.5 to 2.5 t/h with a grid hole size of 2" and 1 to 2 t/h if the opening is 1" wide.

./.

CLESID has developed recently a knife-shredder capable of processing automobile hulks and appliances. It consists of a shredding drum equipped with stationary teeth-like knives, enclosed in a stator equipped with moving and retractable knives mounted on jacks. This shredder has a capacity of 5 t/h.

2.1.2.5. Concentration and classification devices

The problem of separating mixed pieces or particles according to their nature is solved in a number of ways. Procedures adopted for metal scrap processing usually derive from ore dressing techniques. Only the most important ones as regards copper recycling will be dealt with here.

Any separation device makes use of one or several physical properties of the materials to be sorted. Ferromagnetism is used in magnetic separation. Particles may be separated according to their density in hydrocyclones, pneumatic and fluidized bed separators. The size of the particles may however interfere with their density in the separation. However, heavy media separation relies only on density. Classification according to size is performed in dust cyclones.

Liquation (or preferential melting), although not being a purely mechanical process, will also be cited here as a means of separating metals according to the difference in their melting points.

2.1.2.5. a - Magnetic separation

The required magnetic flux for the separation is generated by electromagnets or, more often, by permanent magnets.

./.

The simplest magnetic separator consists of a grid through which passes the material to be treated, the magnetic bars collecting the iron particles. Another type of simple magnetic separator consists of a set of suspended magnets having also to be freed periodically from the retained iron.

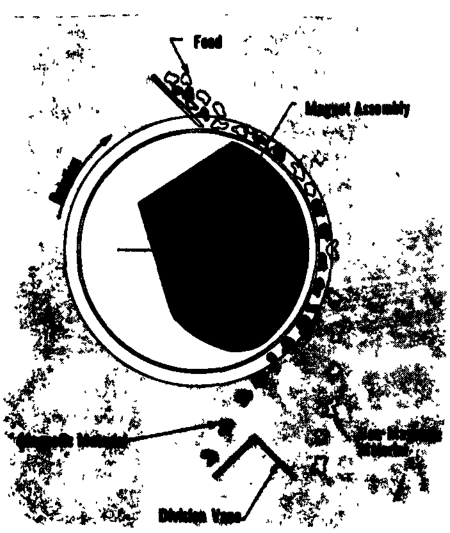
Crossbelt magnetic separators allow to evacuate automatically the retained ferrous particles (fig. 13).

Magnetic pulleys also carry out an automatic separation (fig. 14).

The magnetic particles are strongly attracted by the magnet assembly and held to the drum through the length of the magnet arc and thus deflected from their normal trajectory. They pass on one side of the division vane while the non-magnetic particles pass on the other side.

Fig. 13

Fig. 14



Although mainly used to remove ferrous metals from non-ferrous materials, magnetic separators måy also be utilized for copper alloys. Actually, cupro-nickel, manganese-bronze, aluminium-bronze and some copper-base alloys containing iron are magnetic too, though much less than iron and steel. The intensity of the magnetic field is thus to be increased.

2.1.2.5. b - Pneumatic separation

Air elutriation

In pneumatic separators the materials to be separated are introduced in an upward air flow. The light materials are carried upwards with the air flow whilst the heavy ones drop by gravity. Various means are used by the different manufacturers in their designing in order to generate sufficient turbulence within the air flow needed for a proper separation, but it may happen that heavy material, due to its small size, moves with light material and is lost. The efficiency of such separators is thus dependant not only upon the specific gravity difference but also upon the size ratio. They are unable to discriminate between small pieces of copper and large pieces of plastic.

The majority of this type of separators use a large quantity of air, being used not only for the separation but also for the transport of the light material from the separators to a suitable collector.

A pneumatic separator which is utilized for the recovery of copper from electrical cables is the ALPINE MULTIPLEX ZIGZAG CLASSIFIER. In this device, the upward air flow follows a zigzag course. The separator is fed at mid-height with material to be separated. The heavy part of the treated products is collected at the bottom while the light one escapes with the air flow through the top outlet. This separator can only be used for a first rough separation followed by a more accurate sizing in another type of device (see the ALPINE flowsheet, section 2.1.3.3.). (Fig. 15, page 57)

The DRYFLO SCALPING TOWER consists of a vertical column in which air is introduced so as to create a turbulent effect. By suction at the top of the column, paper and textile dust and fine copper powder are extracted and the heavy material descends by gravity to a conveyor.

./.

WILLIAMS V.I.P. separator

This system, depicted in fig. 16, may be used for the separation of metallic and non-metallic fractions in non-ferrous residue from automobile shredding, as well as for the separation of bar ends, lost tools, etc... from turnings, bushings and similar metal scrap, prior to crushing. Recovery of metals from municipal solid waste is also possible with this equipment.

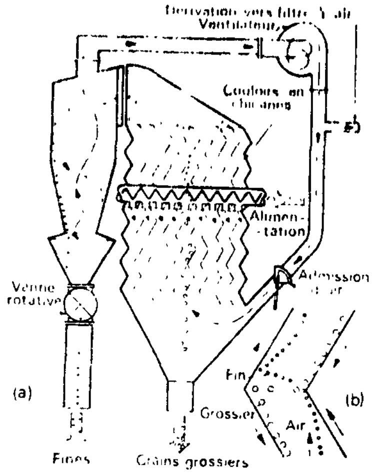
The mixed input is poured on a vibratory feeder which causes an initial disassociation and stratification of the heavy material at the bottom of the feeder, and of the lighter components in the upper layer. The whole material is then discharged into a high velocity air stream arising from a fan. This stream acts like an air knife and blows the relatively light materials into a crusher hopper. The heavy pieces drop into a reject spout and are removed. The light fraction is crushed and evacuated through a screen. Heavier parts which could have been blown with the light fraction, either because of their large surface or because of entanglement with light non-metallic items, are more difficult to shred and are recycled centrifugally back to the vibrator feeder.

We have no figures about throughput and efficiency of such a device, but its manufacturer claims that it can recover up to 98 % of recyclable metals from a typical municipal solid waste feed.

Pneumatic table

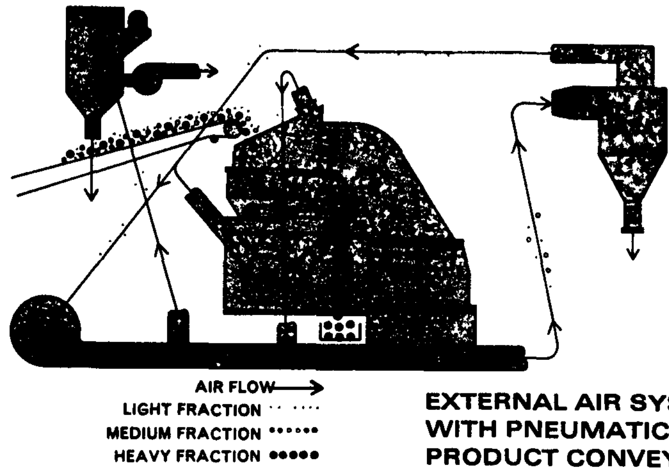
The HORAÏ pneumatic table (fig. 17) separates the particles according to their specific gravity by a blast of air and conveys them in opposite directions thanks to vibrations magnetically produced . Plastic and copper particles are discharged at opposite ends of the bed. According to information given by the company, 98.5 % of the copper, 100 % pure, is recovered. The pastic insulation separated contains less than 0.2 % copper.

Fig. 15



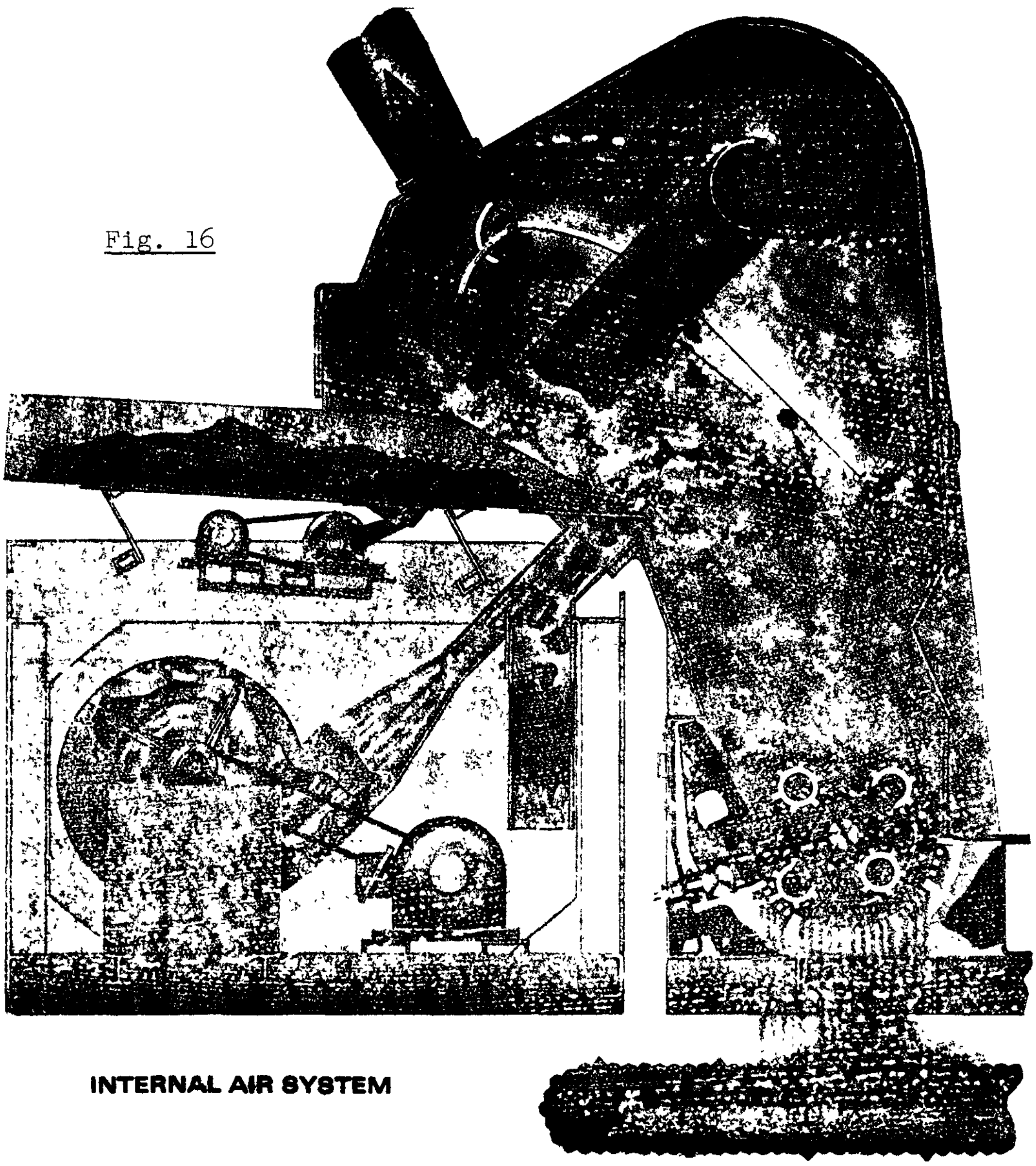
Sélecteur Zick-Zack (Alpine)

(a) coupe de l'appareil ; (b) coupe d'un couloir.



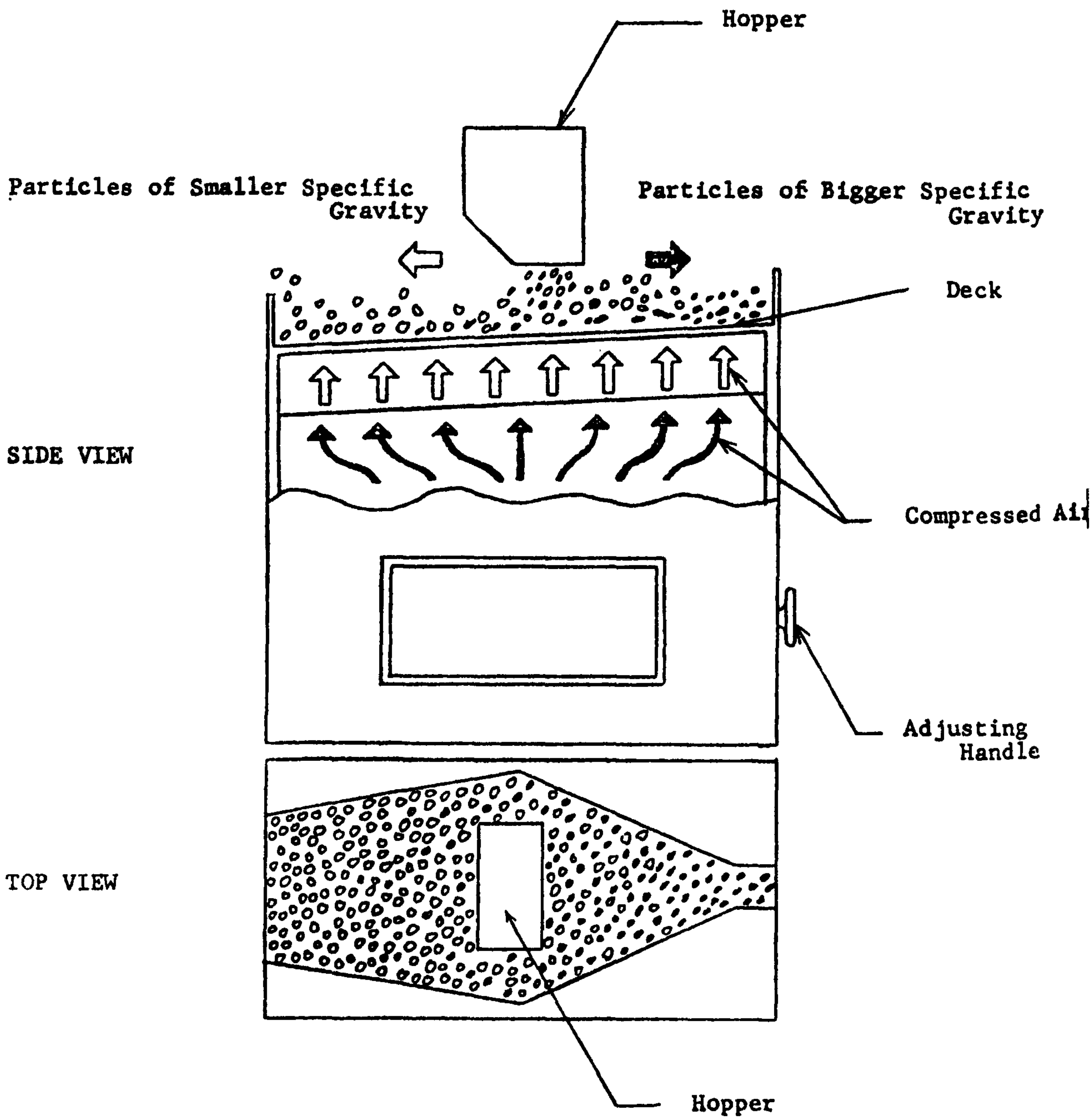
EXTERNAL AIR SYSTEM WITH PNEUMATIC PRODUCT CONVEYOR

Fig. 16



INTERNAL AIR SYSTEM

Fig. 17



The CIMP separator consists of a vibrating sieve over which the materials having to be separated are spread. Air is blown upwards under the sieve in order to form a fluidized bed. The light materials gathering above the bed are removed from one side of the sieve by air blown sidewise, while the heavy materials are evacuated by gravity via the other side. The flows and the distribution of air are adjustable. With such separator 99 % of copper, about 100 % pure, is recovered.

In the 3/S fluidized bed separator, the separation is made by passing the product mixture over a vibrating, flat, porous deck sloped in two directions. As the mixture is introduced into the narrow side of the trapezoidal deck, low-pressure, fluidizing air stratifies the material according to the terminal velocity of each particle. "Heavy" particles sink to the bottom of the material bed and are conveyed up to the heavy discharge by the deck's vibration, while "light" particles, lifted by the air stream, float off the lower end of the deck. Intermediate particles are discharged as "middlings" between the two extremes.

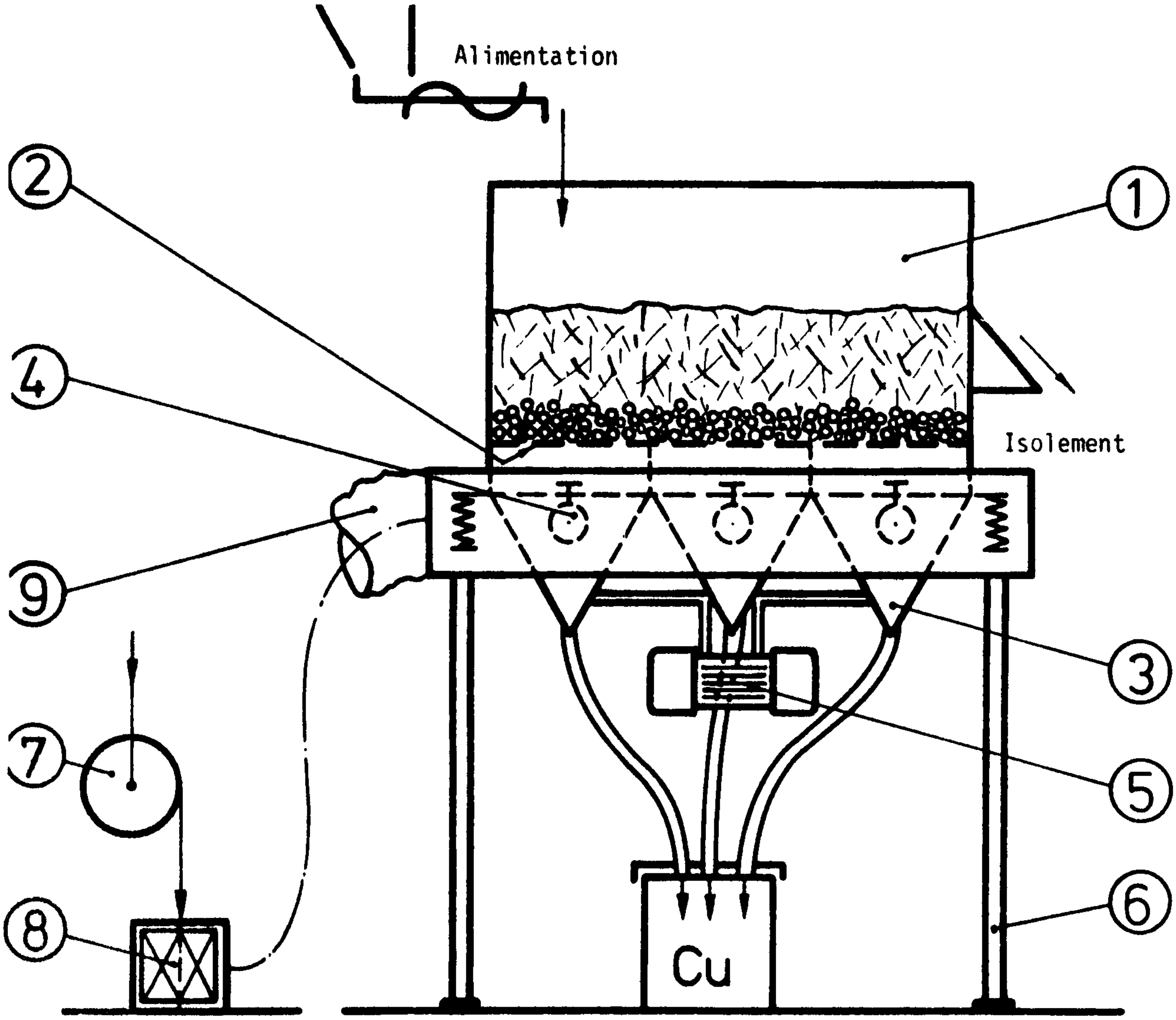
The ALPINE air jig mainly consists of the housing (1), the sieve (2), the hopper with discharge openings (3), the adjustable air feed lines (4), an unbalanced generator (5), installation trestle (6), ventilator (7), rotary slide valve (8) and hose line (9).

Like pneumatic tables, this system is designed for cable processing (fig. 18). The housing is filled up to a certain height with small glass balls lying on a sieve. The mixture of copper and insulation nuggets is fed above the glass ball layer. A pulsatory air flow comes from beneath the sieve and gets the mixture of wire and insulation into a swinging up and down which results in the deposit of the copper on the balls and the gathering of the insulation in the top part of the bed. The unbalanced generator then causes the housing to oscillate vertically. Thanks to these oscillations and thanks to the weight of the copper layer, the balls dislocate in upward direction and play the role of a kind of separating layer, through which copper goes down and is gathered in containers below the sieve. The light material of the insulation is not able to dislocate the glass balls and remains on the top. It is discharged out of the housing.

99 % of the copper present in the charge is recovered by this method, with a purity of 99.7 %.

./.

Fig. 18



Cyclones

The well known cyclone is able to extract particles as fine as 10 microns from air, but it can only discriminate between gasses and solids and is not to be relied upon to separate different solids. It is mostly used for removing the dust from the air utilized for the pneumatic carriage of the solids or drawn over the different devices of the equipment.

Cyclones may also be used to separate dust particles according to their size. The critical size should be in the 5 to 50 micron range.

./.

2.1.2.5. c - Iron powder fluidized bed separator

The DRYFLO SEPARATOR consists essentially of a porous bed, over which the copper and plastic material is fluidized using an iron powder medium. When the mixture is fluidized, the plastic tends to float on the surface whilst the copper will tend to sink to the bottom. The material is split into three fractions:

1) clean conductor;
2) clean waste plastic or rubber;
3) a middling product consisting of a small amount of material where the insulation is still wrapped around the conductor.

According to the information published by the maker of this equipment, the main advantage of the method is that it is able to extract simultaneously not only the heavy coarse copper but also the fine wires that might otherwise have been lost together with the plastic. The principle of the method is analogous to that of a wet heavy medium separator in which the separation is due only to the relative difference in specific gravity. The iron powder medium is able to accommodate the fluctuations that inevitably arise due to the fact that the cable being fed into the system is constantly varying both in dimensions and in relative copper/plastic ratio. Without the iron powder media, constant adjustment of the separator would be necessary to take into account the varying size of granulated copper and plastic.

After separation, the iron powder is recovered by a magnetic device.

Treatment of mixed gauge copper wire gives an average recovery varying from 99.36 to 99.75 %. Recovered copper has a purity of 99.97 %. Separated insulation contains 0.55 to 1.10 % copper.

2.1.2.5. d - Hydrocyclones

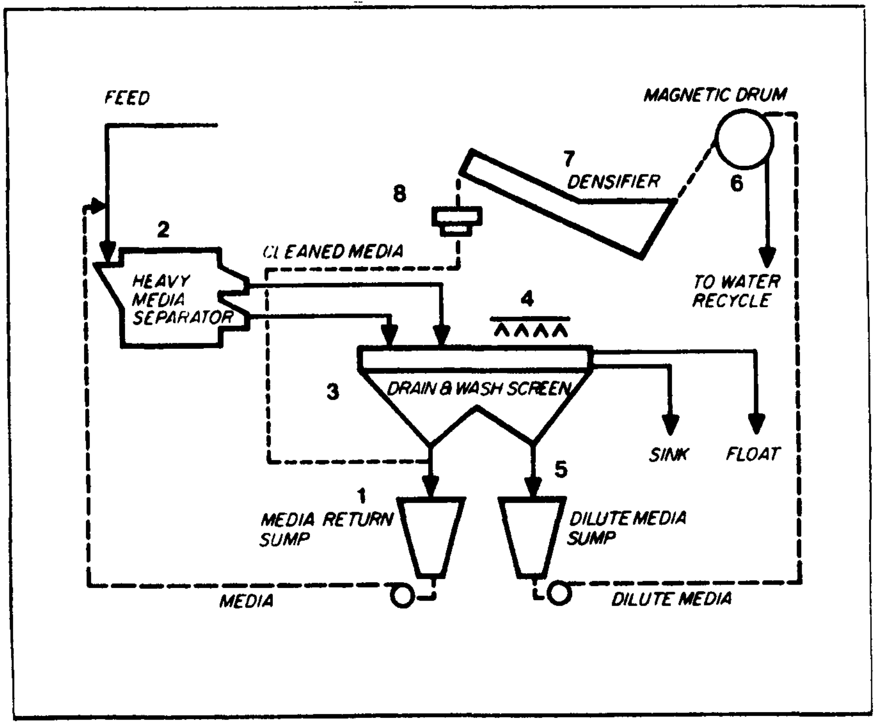
Hydrocyclones are very similar to cyclones, except that the feed is mixed with plain water. As a scrap recovery system, their sole application is, to our knowledge, in the STAMICARBON washing-separating process designed for the treatment of the non-ferrous reject of car shredders. The centrifugal force allows to obtain a density separation point of 1.8. The overflow contains non-metallic particles only, whereas the bottom discharge contains mixed non-ferrous metals and glass.

2.1.2.5. e - Heavy media separators

Heavy media separation is based on the principle that cork floats on the water and that stone sinks. It is mainly used in scrap processing to separate hard rubber and aluminium from other metals in the non-ferrous car shredder reject, after removal of light non-metallics. As the density of water is below that of aluminium, use is made of a "heavy medium" i.e. a suspension of magnetite and/or ferrosilicon in water. These materials allow to reach high densities, are inexpensive and easily reclaimed by a magnetic separator and cleaned for re-use.

Densities from about 2 up to 7.9 may be reached with various concentrations of this material in water. Aluminium having a density of 2.7 will float in a heavy medium of density 3. Fig. 19 shows a typical flowsheet for a heavy media separation system.

Fig. 19



2.1.2.5. f - Preferential melting (sweating)

Lead melts at a temperature of 327° C, zinc die casts (96 % Zn and 4 % Al) at 381° C, aluminium at 660° C, copper at 1083° C and steel at about 1500° C. It would thus be possible to achieve a separation by melting mixed scrap selectively for each metal at a controlled temperature. This is actually done with car shredder reject for zinc and aluminium, and for aluminium collection from heavy scrap. The temperature required to melt copper is too high : melting is then accompanied by oxidation and alloying with iron. Lead sweating is also performed in cable incineration chambers when the cables have a lead sheathing.

Sweating may be done in small home-built furnaces as is the case for many small scrap processors, as well as in specially designed furnaces marketed by several manufacturers providing the stricter control of temperature needed when several low melting point metals are present together. These furnaces may be heated by gas or fuel oil.

./.

2.1.3. Flowsheets for mechanical processes

2.1.3.1. Systems applied to cables

The following flowsheets, marketed by different firms, integrate the devices described in the previous sections.

2.1.3.1. a - C.I.M.P. flowsheet (fig. 20)

The mixed cables are first manually sorted in order to separate them in three lots :

- cables containing copper conductors with a diameter < 0.3 mm which cannot be treated;
- lead and/or steel armoured cables and tarred/greased cables which cannot be treated in the granulation equipment; such cables are treated by a stripping machine;
- the other PVC, rubber, paper, etc.. insulated cables which can be introduced normally into the circuit.

They are fed into a pre-chopper or cut by a portable cable shear.

The cut cables are freed from the steel particles they might contain by a magnetic pulley. They are then loaded into the primary granulator via a conveyor. A pneumatic conveyor carries the product leaving the granulator to the two finishing mills. The air utilized in the conveyor is freed from its dusts, paper and textile wastes, in a cyclone.

Pneumatic carriers, also fitted with a cyclone, carry the products to the two pulsed air fluidized bed separators with vibrating sieve, where copper and plastic are separated. The inlet of this device is fitted with a magnetic grid retaining the last small ferrous particles.

./.

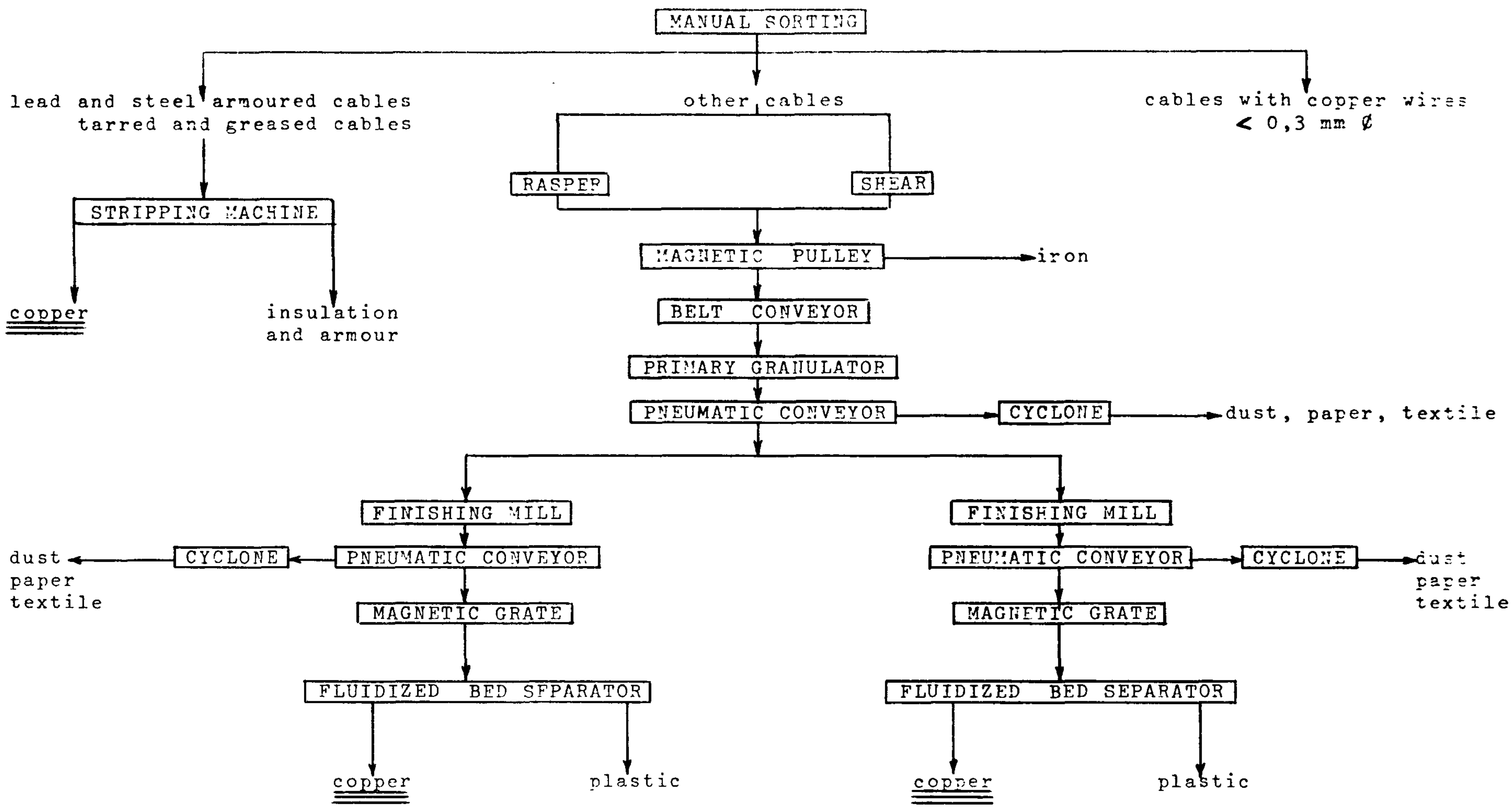

MANUAL SORTING
lead and steel armoured cables
tarred and greased cables
other cables
cables with copper wires
< 0,3 mm Ø
STRIPPING MACHINE
copper
insulation
and armour
RASPER
SHEAR
MAGNETIC PULLEY
iron
BELT CONVEYOR
PRIMARY GRANULATOR
PNEUMATIC CONVEYOR
CYCLONE
dust, paper, textile
FINISHING MILL
PNEUMATIC CONVEYOR
CYCLONE
dust
paper
textile
MAGNETIC GRATE
FLUIDIZED BED SEPARATOR
copper
plastic
FINISHING MILL
PNEUMATIC CONVEYOR
CYCLONE
dust
paper
textile
MAGNETIC GRATE
FLUIDIZED BED SEPARATOR
copper
plastic

FIG. 20 C.I.M.P.

2.1.3.1. b - HORAI flowsheet (fig. 21)

The HORAI equipment can treat cables containing copper wires having a diameter above 0.15 mm. It cannot accept either tarred and greased cables or steel armoured cables. The treatment of lead armoured cables is impossible at the moment, it is however being studied.

Consequently, a preliminary manual sorting is necessary and the lead sheathed and/or steel armoured cables, as well as greasy and tarry cables will be treated by means of a stripping machine. Before being introduced in the first stage granulator, the cables must be cut into pieces 0.5 to 1 m long by means of a portable or stationary shear.

At the outlet of the first granulator, the products are taken away by a belt conveyor fitted to its head with a magnetic pulley. At the same time, dusts are collected and carried into a cyclone. The conveyor carries the products to the second granulator, at the outlet of which they are taken away by a pneumatic conveyor to a double deck vibrating sieve. The air leaving the pneumatic conveyor is freed from its dusts by a cyclone. Above the double deck vibrating sieve, an exhaust fan sucks the paper and textile wastes up, collected in a cyclone.

From this sieve onwards, the too large fragments are recycled at the head of the second granulator while copper and plastic are carried to the fluidized bed separator by a belt conveyor fitted with a magnetic pulley which removes the last ferrous particles. At the outlet of the fluidized bed separator, copper and plastic are recovered separately, the latter being carried away to the plastic collector cyclone.

./.

(29)

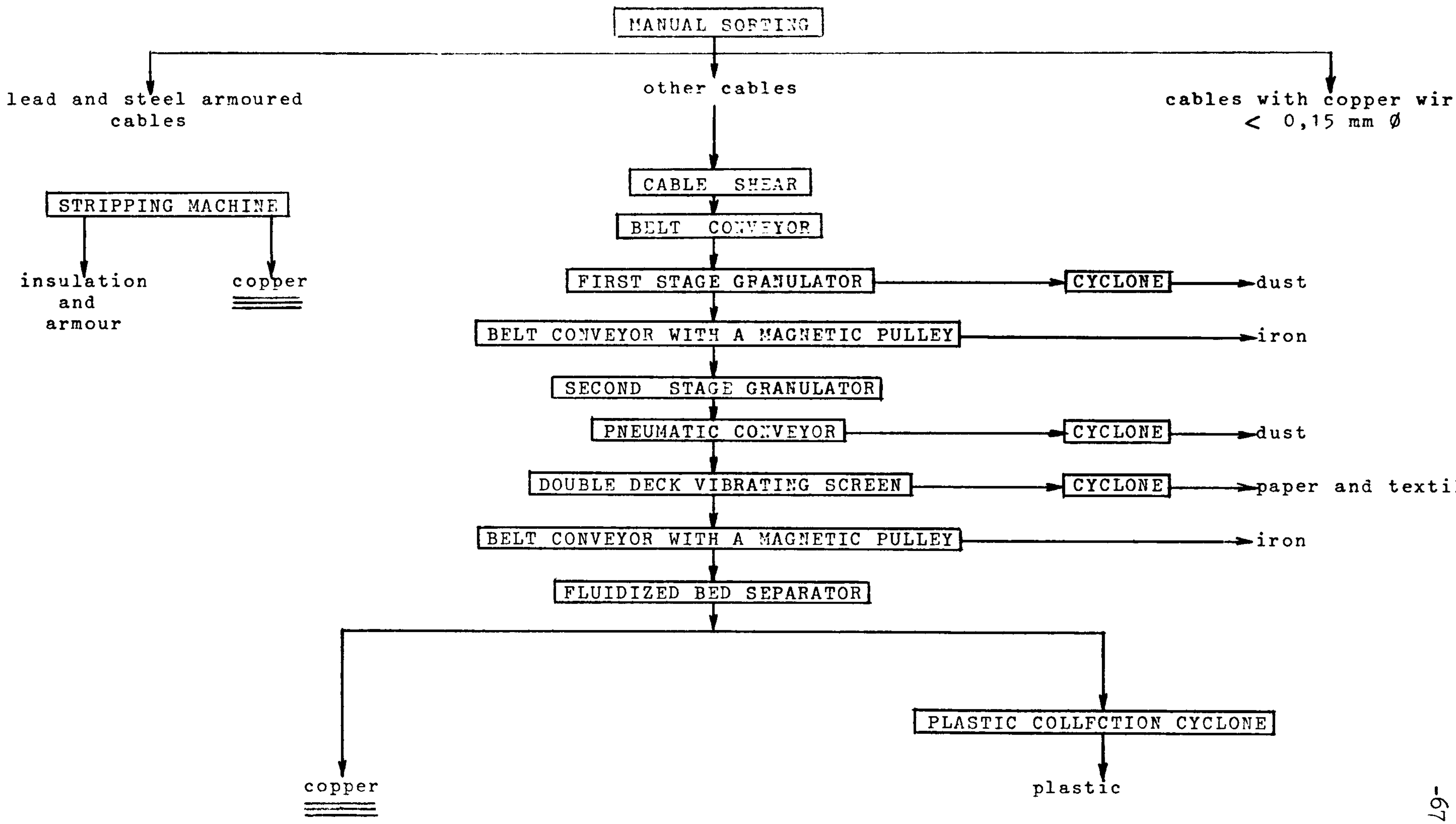


FIG. 21 HORAI

2.1.3.1. c - ALPINE flowsheet (fig. 22)

The ALPINE equipment can treat cables containing copper wires with a diameter above 0.2 mm. Tarry and lead cables are excluded. However, steel armoured cables can be treated if the equipment is fitted with a pre-chopper. Once more, a manual sorting is consequently indispensable.

The cables are cut by a shear into pieces 0.5 to 1 m long which pass on a magnetic pulley. If a pre-chopper exists, the steel armoured cables are sent to it. Otherwise, they are sent to the stripping machine where they are processed together with lead sheathed and tarry cables.

The primary mill is fed by a conveyor belt. Dusts resulting from the milling are sucked up and they are sent to a cyclone. The products leaving the mill pass on a Multiplex Zig Zag Classifier. The air leaving this device through its top carries away paper, textile wastes and also part of the plastic, which are collected in a cyclone. The heavy part recovered at the base of the Multiplex is sent to the second stage of the milling consisting of a mill identical to the first stage one, except for the sieve.

The milled products then pass into a second Multiplex Zig Zag, adjusted so as to collect at its base the heaviest copper pieces. At the top of this device, the fine copper particles and the plastic leave for a cyclone, holding back the copper and the heaviest insulation pieces, the fine plastic particles being carried away to another cyclone.

The heavy plastic and the copper are admitted to the third stage of the milling, consisting of two parallel mills identical to the previous stages ones, except for the sieves. The outlet of each of the above mills is fitted with a third Multiplex Zig Zag, at which top another deal of plastic is eliminated through a cyclone.

Finally, the mixture collected at the base passes on an ALPINE Air Jig where the remaining copper and insulation are separated.

ALPINE has also devised two other flowsheets especially suited for thin or massive cable supply.

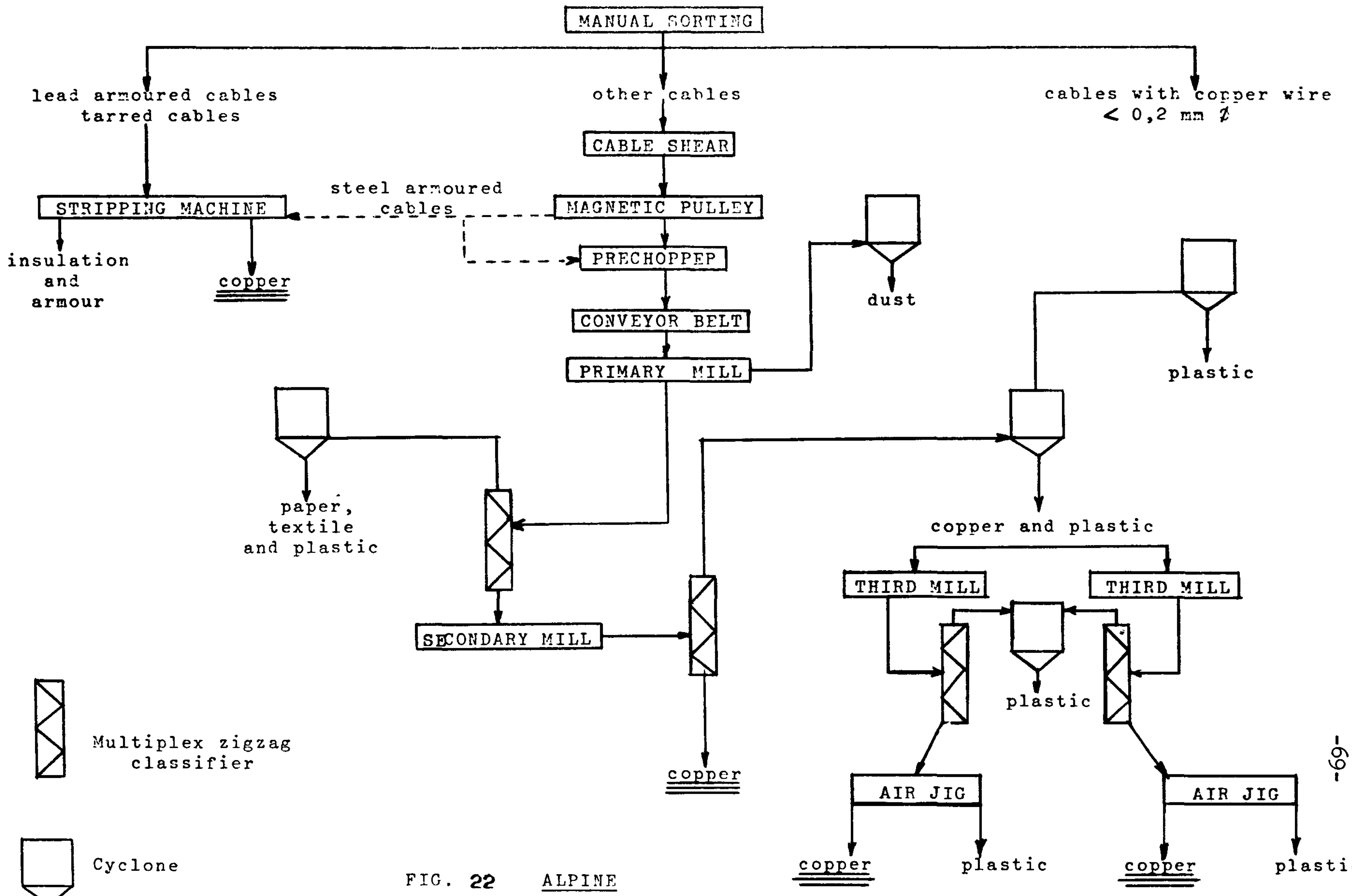


FIG. 22 ALPINE

2.1.3.1. d - DRYFLO flowsheet (fig. 23)

Here again, armoured cables and cables containing lead, grease and tar, cannot be treated. Sorted cables are reduced to a length of about 250 mm in a pre-chopper. They are thus carried by a conveyor belt to the primary granulator. A cross belt magnetic separator is placed above this conveyor.

The cables are chopped down to a length of less than 12 mm by the primary granulator, the outlet of which is fitted with air sweep fan units which suck air through the mill and extract the chopped material. The latter is pneumatically conveyed to a cyclone where dust is removed. Cleaned, chopped material falls into the secondary granulator where it is reduced to 4 mm. The secondary granulator is also fitted with air sweep fan units which pneumatically convey the material to a pan feeder.

The DRYFLO Scalping Tower at the top of which textile and paper are extracted, is fed by the pan feeder. At the base, the material falls on a belt conveyor fitted with a cross belt magnetic separator which removes any iron which may be released.

The first DRYFLO separator, which is operated with iron powder as fluidized bed, is fed by the conveyor belt. Material which flows out of the latter is split into three fractions, namely :

- copper;
- plastic or rubber waste, still containing some copper;
- a middling product consisting of a small amount of material where the insulation is still wrapped around the conductor.

The iron powder which is present in each of these fractions is screened out and recycled. Plastic wastes are sent by a conveyor belt to a second DRYFLO separator where the remaining copper is separated from clean plastic and the middling product.

./.

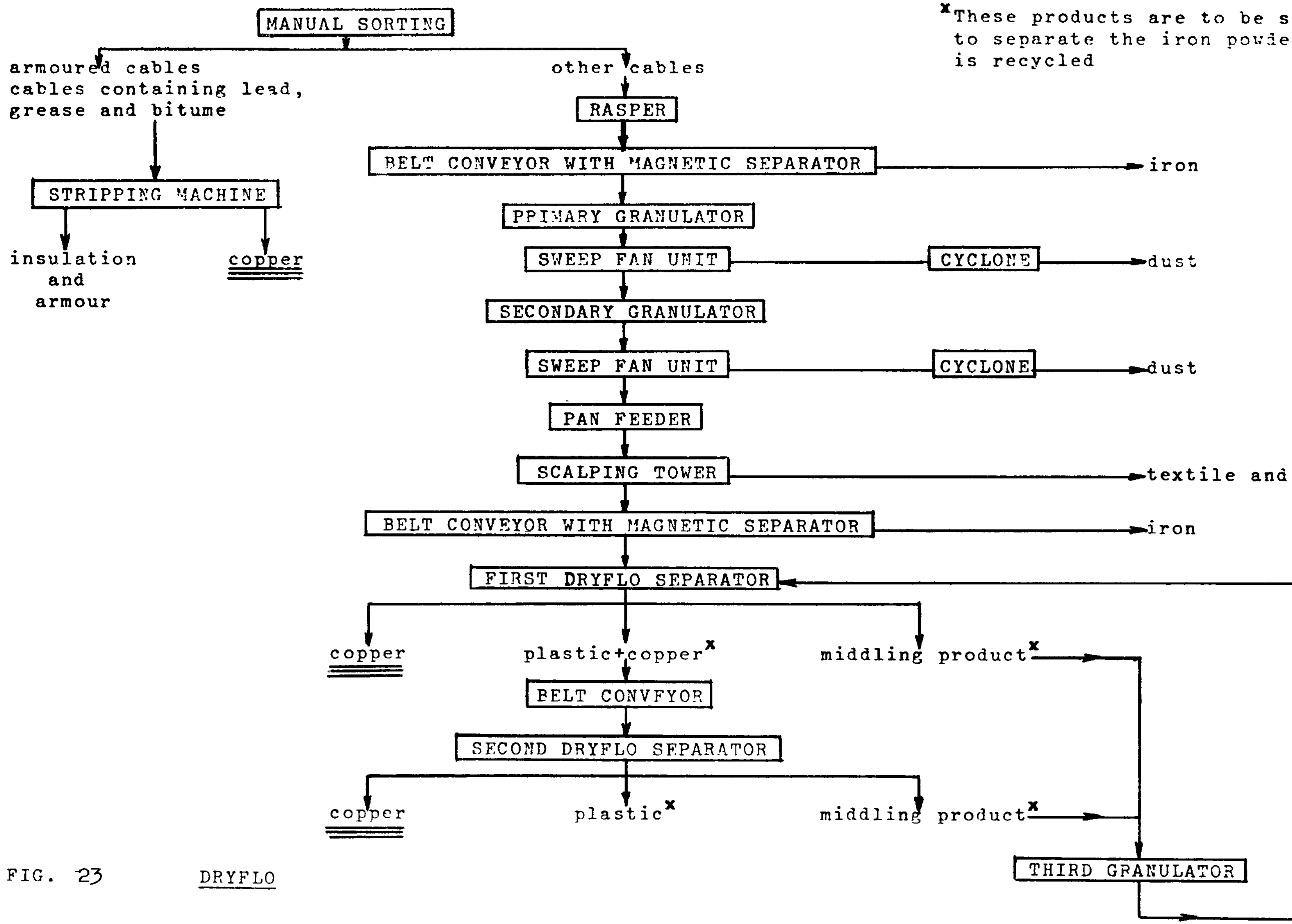


FIG. 23 DRYFLO

*These products are to be screened to separate the iron powder which is recycled

Middling products from the first and the second separators are treated by a third granulator, the chopped material leaving it is sent to the first separator together with that from the second granulator.

This equipment, as its manufacturer claims, is the only one which is able to process cables of any diameter, even fine wires.

2.1.3.1. e - TRIPLE/S flowsheet (fig. 24)

As for the preceding processes, the mixed cables must first be manually sorted in order to separate those which cannot be treated by the equipment. The other cables are fed into a shear or into the 3/S Rotagator pre-chopper. Pre-chopped cables are loaded into the primary granulator and into the secondary one successively. After granulation, a magnetic separator removes the steel particles which the product may contain.

The mixture of chopped wire, insulation and some unstripped wire from the secondary granulator, then passes to the separation section of the system. First, a high speed vibrating screen sizes the mixture into coarse and fine fractions. This separation is made in order to avoid losses of fine copper in the tailings of subsequent operations.

The two sized fractions are carried separately by two constant feed conveyors which feed, at a constant rate, two fluidized bed separators. These separate the mixture into four fractions :

- clean copper;
- clean plastic;
- a milling fraction which is re-circulated to the high speed vibrating system;
- unstripped wires which are sent to the third stage granulator for re-chopping and, from there on to the high speed vibrating system.

./.

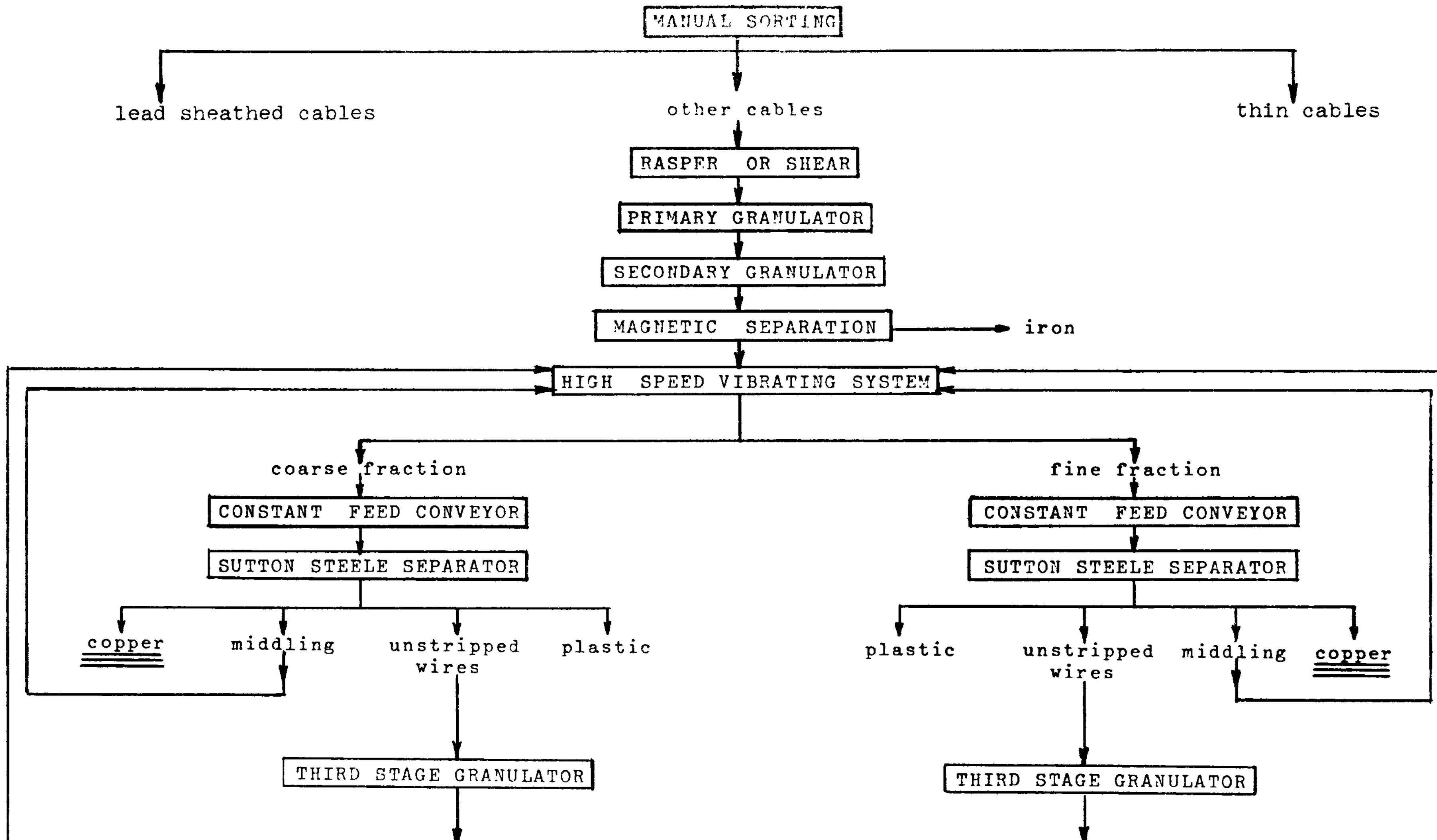


FIG. 24 TRIPLE S

2.1.3.1. f - Cost estimation

Treatment costs have been evaluated for each of the above flowsheets, the 3/S excepted. Following facts were taken into account :

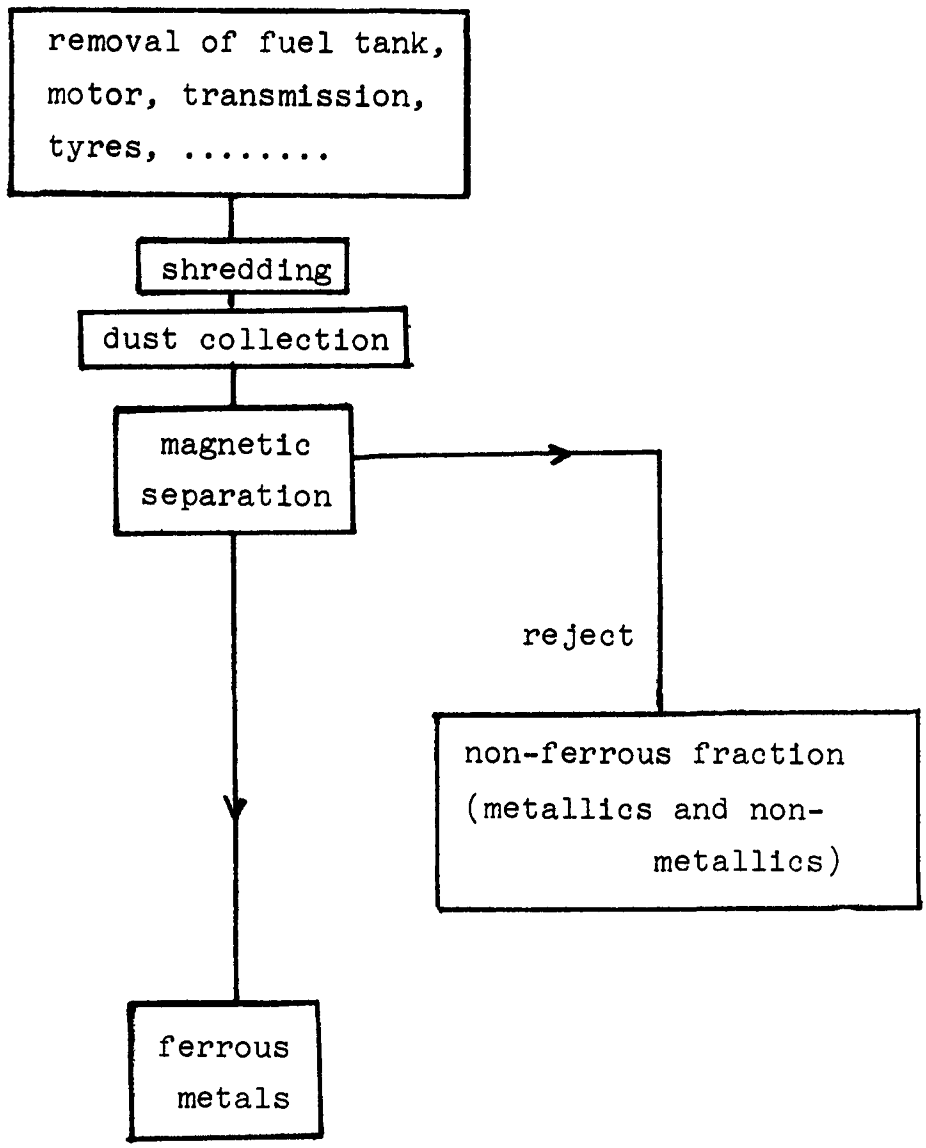
- nominal hourly capacity : 2 or 3 tons of cables per hour;
- investment amortization : 5 years;
- financing costs : 10 % interest rate;
- operating charges :
  - 2 shifts of 4 or 5 men according to the equipment;
  - electric power;
  - maintenance;
- salary costs : Bf. 400 per man-hour;
- buildings are not taken into account.

The calculation, based on data valid in 1976, gives a recovery cost of Bf. 4.1 to 5.6 per kilo of copper. These figures correspond to a feeding of mixed cables having medium dimensions. It stands to reason that a higher hourly production could be reached with larger cables, the cost price being consequently appreciably lowered. On the other hand, a charge composed of a majority of cables containing small wires would reduce the production, thus entailing an opposite effect on the cost price. The calculated values must consequently be considered as averages.

2.1.3.2. Systems applied to cars

The typical flowsheet of car hulks processing comprises the following steps (fig. 25). Before being charged in the shredder, the car body is always ridded of its tank, considering the risk of explosion. The magnesium cast engines

Fig. 25


removal of fuel tank, motor, transmission, tyres, ...
shredding
dust collection
magnetic separation
reject
non-ferrous fraction (metallics and non-metallics)
ferrous metals

./.

are also removed from the car body. To various degrees the body may also be ridded of the engine, the transmission, the tyres, the battery, the radiator, etc... The degree of stripping depends on technical considerations (possibility for the shredder to crush the heavy parts in cast iron, wanted quality of the ferrous scrap,...) as well as on economic considerations (cost of the stripping, price of the removed parts, treatment cost of the non-ferrous fraction of the shredder, etc...). As a rule, the high capacity shredders having a large throughput crush the car bodies as they arrive, after removal of the tank.

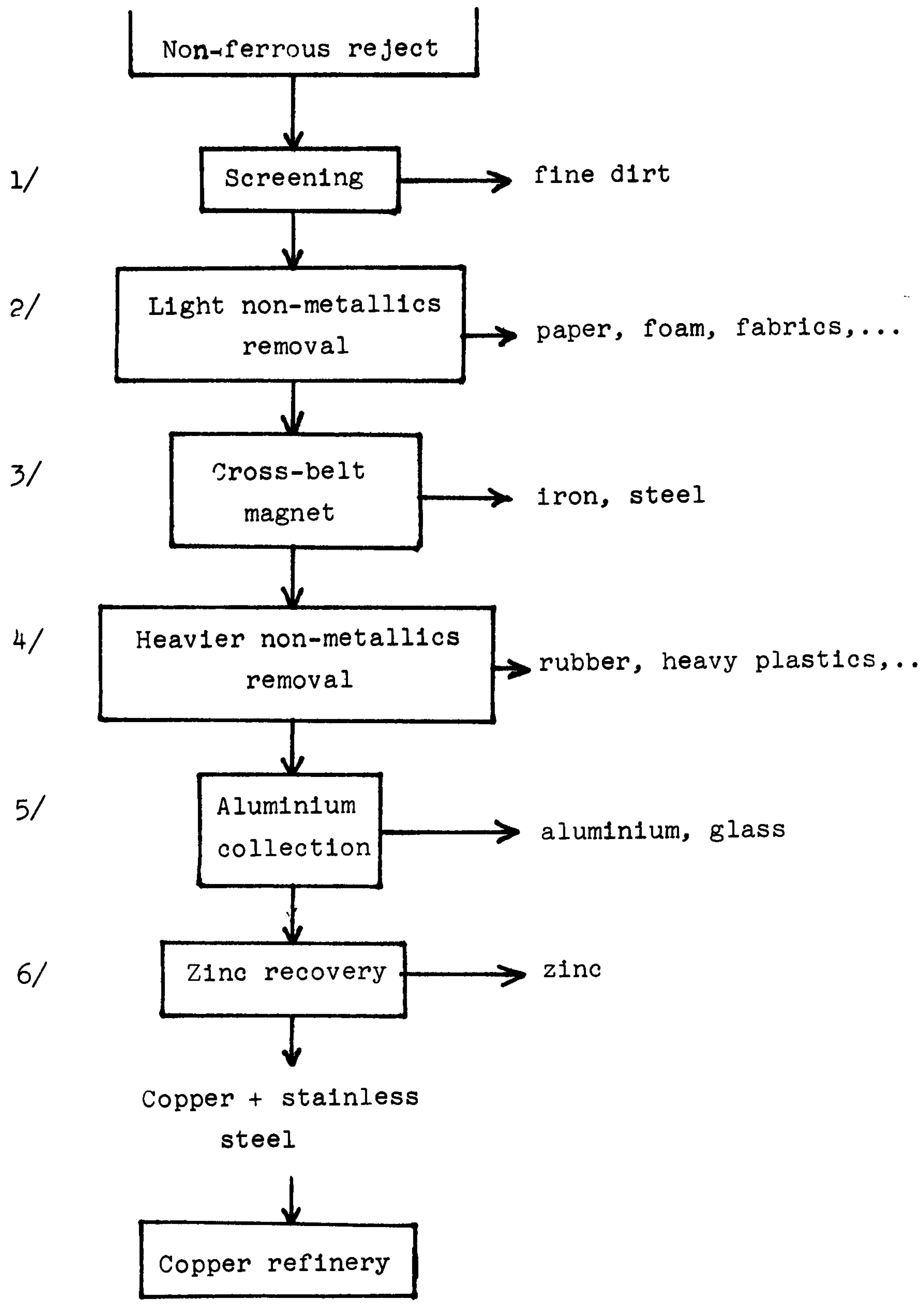
A cyclone system is always installed at the outlet of the shredder to collect dust.

Ferrous metals are collected by a magnetic separator, leaving a fraction of non-ferrous materials comprising non-metallic materials (fabrics, glass, rubber, ...) and a mixture of metals (zinc, aluminium, copper, brass, stainless steel).

Most of the shredding operators merely hand-pick the copper, brass or other non-ferrous pieces, big enough to be easily spotted when passing on the conveyor belt at the outlet of the magnetic separator. The balance of the non-ferrous fraction is then re-sold to another scrap processor. It has been estimated (42) in the United States that of the 2 - 3.5 % of non-ferrous metals contained in car scrap, about 1 to 1.25 % is already recovered by simple hand-picking. A much lower figure is reported in (17) : hand-picking would allow a recovery of 14 % only of the red metals coming out of the shredder. The composition of the recovered non-ferrous metals is however different from that of the global metallic shredder reject, since there is a tendency to pick the bigger pieces of metals, where zinc and aluminium tend to break into smaller pieces than copper.

The actual practice in processing the non-ferrous shredder reject may vary from plant to plant, although it rests on the same basic principles. A typical flowsheet would run as follows (fig. 26) :

Fig. 26


Non-ferrous reject
1/
Screening
fine dirt
2/
Light non-metallics removal
paper, foam, fabrics,...
3/
Cross-belt magnet
iron, steel
4/
Heavier non-metallics removal
rubber, heavy plastics,...
5/
Aluminium collection
aluminium, glass
6/
Zinc recovery
zinc
Copper + stainless steel
Copper refinery

./.

1/ Screening : shaking the material through a screen allows to filter out the fine dirt.

2/ Light material removal : paper, light plastic, fabrics, foam, etc... are cleaned out by a water flotation or an air elutriation system. The heavy residue, mostly metallic, sinks to the bottom of the system.

3/ Cross-belt magnet : tramp iron is separated from the residue by a second magnetic device.

4/ Rubber, heavy plastics,... removal : remaining non-metallics are collected in a heavy medium system of density 1.8 to 2.1.

5/ Aluminium collection : a second heavy medium system, with a density of 2.7 allows to float aluminium. Glass is also collected together with aluminium. Operations are often halted at that stage in shredding plants. The remaining mix of zinc, copper and stainless steel is then shipped to another scrap processor specialized in zinc recovery. Such recovery may, however, sometimes be made within the same plant.

6/ Zinc recovery : zinc is sweated out of the mix by a preferential melting system. Lead that might be present, is also recovered at this stage. Copper and stainless steel are left in the sweating furnace and usually shipped to a secondary copper smelter

Departures from this general flowsheet are numerous and consist either in other separation systems or in the succession of the operations. Non-metallics may be removed in one stage after screening, with a WILLIAMS V.I.P. separator or with a hydrocyclone in the STAMICARBON process, for instance. Screening may also take place after removal of light non-metallics. But the most important feature from a copper recycling point of view is the presence or absence of a hand-picking step in the process. Some scrap processors still maintain this step, either before or after the removal of non-metallics, as long as the cost of this operation is paid by the value of a purer copper scrap. The final mix, in this case, is of course richer in stainless steel. Furthermore, many shredding operators, like in other scrap processing fields, have developed own improvements of the existing technology with a view to achieving a greater separation efficiency. These improvements, however, are most often kept secret.

According to (42), the non-ferrous metal content of car scrap is about 2 to 3.5 %. It was generally agreed, during the first years of shredder production in the U.S., that the mix consisted of approximately 65-68 % zinc die cast, 21-25 % aluminium, 2-3 % stainless steel, balance 7-8 % copper. Since that time, the aluminium and stainless steel contents seem to have increased, the copper proportion remaining constant. The copper content is thus markedly lower than that indicated in (20) (see section 1.3.2.2. b). This discrepancy may result from the difficulty of assessing an average copper content, and mainly from the fact that shredding operators receive partly stripped hulks as well as entire cars, and sometimes do strip the cars themselves before shredding.

Cryogenic shredding

Cryogenic shredding is operated since 1971 by GEORGE & Cie. The basic principle of this method is to cool the scrap bales down to a temperature when they become brittle, so that a less powerful hammermill will suffice to cause them, literally speaking, to explode.

In this INCHSCRAP process, the hulks are first baled. No part of the car bodies needs to be removed, not even the gas tank. The bales are conveyed along an insulated tunnel where they are cooled down to about -7° C by cold nitrogen gas. At the end of the tunnel, they are immersed in a liquid nitrogen bath at -196°C t The bales enter a 500 Hp hammermill at the temperature of -140°C, where they explode into pieces of different sizes, according to their nature. Fabrics and dirt are first eliminated by a fan. Other products are classified by size and pass through magnetic separators. Further processing of the non-ferrous fractions is similar to the treatments described above.

Similar cryogenic systems have been studied for other kinds of scrap, like cables and electric motors, but they are not yet developed to a fully operational stage. They will thus be mentioned in chapter 3.1.

2.1.4. Incineration

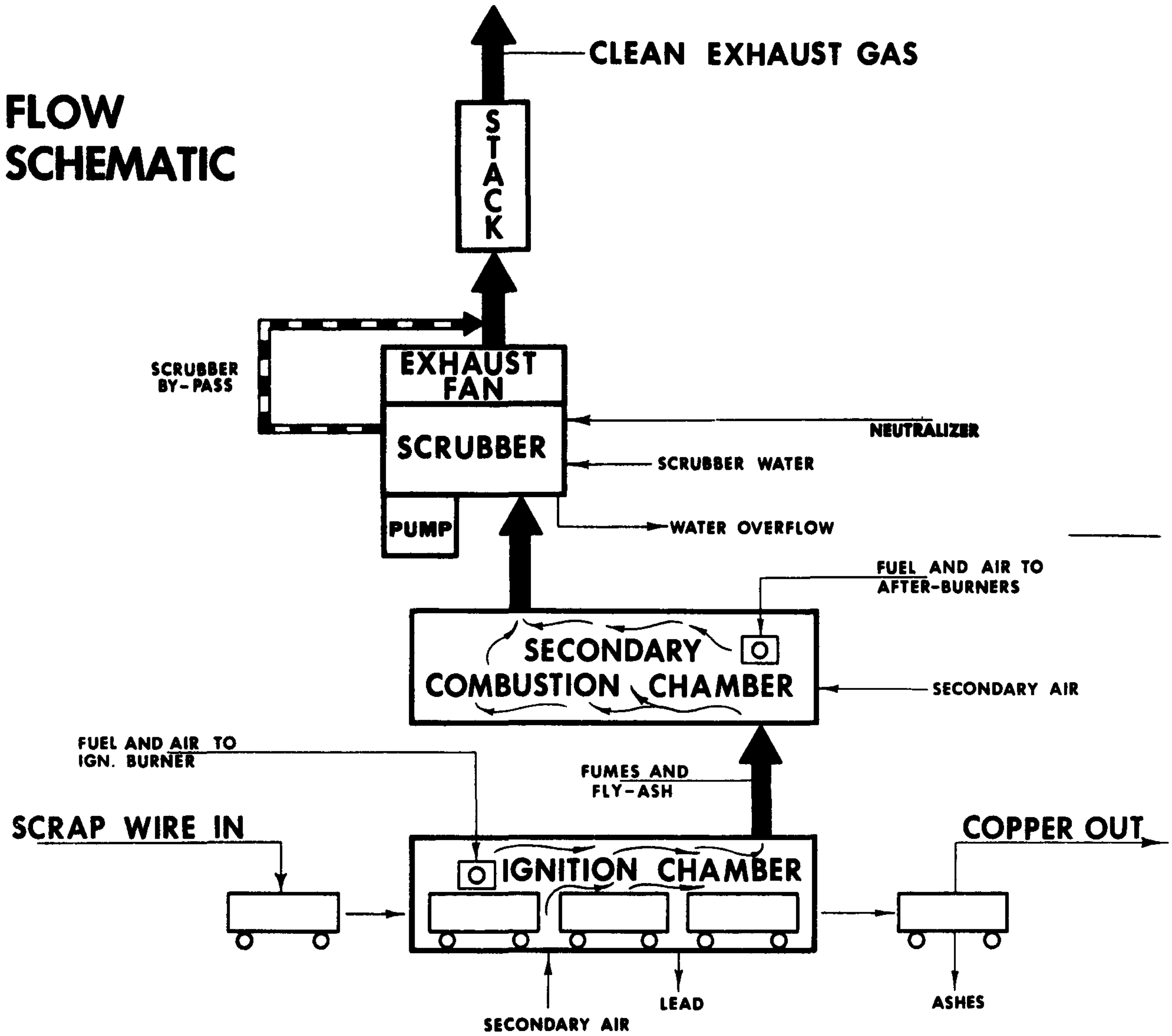
Strict antipollution regulations and the desire to obtain good quality copper scrap from cable burning, have led to the design of furnaces fitted with afterburners and gas scrubbers. Furnace manufacturers market various designs of such devices, but they all rest on the same basic principles. The PECO furnace is taken here as an example (fig. 27).

Insulated copper wires are loaded into the furnace in movable baskets. The insulation is ignited in the ignition chamber and burns up until it is all consumed. The burners operate only for a short time when a new batch of cables is introduced. By restricting the air inlet and limiting the temperature, excessive oxidization of copper is avoided. If lead sheathed cables are introduced into the furnace, the molten lead, sweated from the cables, flows over a shaped furnace floor into a heated port for convenient recovery outside the furnace.

After complete elimination of the insulation, the wire is withdrawn, quenched and cleaned of ash. Fumes and smoke generated in the process pass into the secondary chamber (after-burner) where they combine with additional air and burn completely in a high temperature environment. During normal operation, these combustion fumes are often sufficient themselves to maintain the required temperature of the after-burner without need of additional fuel.

Fig. 27

WIRE RECYCLING FURNACE



./.

Exhaust gasses from the furnace subsequently pass into a gas scrubber where fly ash, soluble acids and other pollutants are washed out prior to their emission through the stack. The hydrochloric acid (HCl) resulting from the combustion of PVC insulation is neutralized by soda (NaOH) and is transformed into salt (NaCl) and water.

Other equipments vary in the conception of their loading device, after-burners and gas scrubber systems.

The treatment costs of cable scrap by incineration have been evaluated on the same basis as in the case of mechanical processing (section 2.1.3.1. f). With a furnace capacity of 0.625 ton of cables per hour, the cost per recovered kilo of copper is about Bf. 3.70.

It must be noted that despite the fact that oxidization of copper is considerably reduced as compared with simple burning, some superficial oxidization is still difficult to avoid, especially for small diameter wires, and that the copper cannot be sold at the same price as copper nuggets obtained by efficient mechanical separation processes.

Incineration furnaces may however be loaded with any kind of copper cable scrap, and is still, together with the DRYFLOW system, the only way to remove plastic insulation from thin wires.

*

* *

2.2. Metallurgical processes for copper smelting and refining

Metallurgical processes applied to the treatment of copper scrap and residues do not basically differ from those applied to primary copper production. The approach of the problem is however rather different and has been leading, for the last twenty years, to a faster development in the case of primary copper. Primary copper smelters actually receive very important quantities of constant quality ore concentrates. It is thus possible to work on a large scale and to optimize each step of the process. Regular supply, in quantity as well as in quality, has led to the development of continuous roasting and smelting processes, with higher heat and metallurgical efficiency.

On the contrary, secondary copper smelting is faced with a much more diversified source of supply. This diversity in quality is accompanied with a greater uncertainty about availabilities, which mainly depend on copper prices. As a consequence, secondary copper smelters are operating more classical plants with smaller capacity. A good knowledge of the processes and small units allowed to keep the flexibility required for the survival of this sector.

Whereas the basic technology of copper smelting and refining remained essentially unchanged, secondary metal recovery improved. As already stressed, the complexity of supplied scrap (alloys, electronic scrap, ...) in many cases makes this recovery essential to the profitability of the whole operation.

2.2.1. Pyrometallurgy

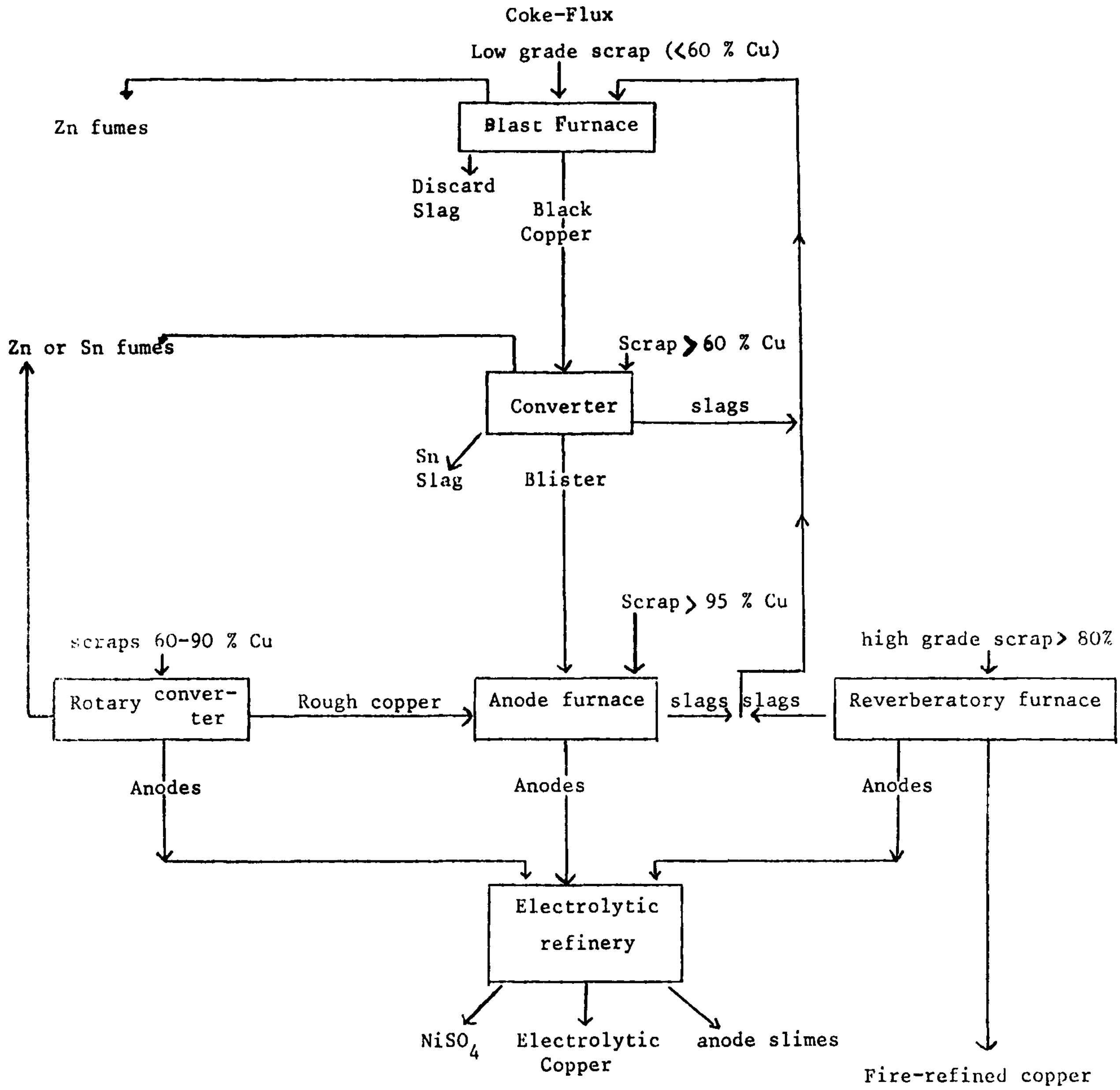
Unlike ore concentrates, most of the copper scrap and residues do not contain any sulphur, so that it is never necessary to perform a desulphurizing roasting, and smelting is the first pyrometallurgical step.

The classical equipment used by the majority of secondary copper smelters, may be illustrated by all or part of the flowsheet as per fig. 28. This is the conventional way, with a succession of metallurgical steps, each one of which is aimed at removing certain impurities, recovering secondary metals and increasing the copper grade up to the final electrolytic refining step.

./.

Fig. 28

Flow-sheet of recovery of copper from secondary sources



./.

Table 3 lists the range of variation of input and output at each step. Typical energy requirements are also listed in table 4.

Table 3

Increase of the copper content of low grade scrap and residues.

	Cu content feed %	Cu content product %
Blast furnace	30 - 35	70 - 80
Converter	70 - 80	97 - 98
Anode furnace	95 - 98	98,5- 99
Electrolytic refining	98,5- 99	> 99,9

Table 4

Typical energy requirements for the production of one ton of cathode copper from secondary material.

	Electricity Kwh	Fuel oil l	Coke tonnes
Blast-furnace	242	90	0,60
Converter	178	90	0,16
Anode casting	36	100	-
Electrolytic refining	460	-	-
Total	916	280	0,76

With some specific departures, each secondary smelter disposes of part or whole of this general flowsheet. Most of them are using a blast furnace for low-grade scrap and/or reverberatory furnaces for high-grade scrap smelting. On the other hand, electrolytic refining seems to be more and more the indispensable ultimate step allowing to meet the requirements of copper users.

2.2.1.1. Copper blast furnace (water jacket furnace)

This kind of furnace is similar to the iron blast furnace, but it has a rectangular section and is much smaller, with a surface of 3 to 7 m^2 at the level of the tuyeres (fig. 29). A reducing smelting with coke (8 to 12 % of the charge) yields a "black copper" and a slag.

The charge is essentially composed of low-grade copper-bearing scrap and residues and converter and anode furnace slags, that are mixed with sand and lime if necessary. All kinds of scrap and residues designated as "drove" in the N.A.R.I. standards are fed into the blast furnace : electronic scrap, skimmings, foundry ashes, irony scrap, ...

The charge must of course contain enough valuable metals in order to pay for the smelting and the subsequent refining costs. Scrap with less than about 20 % copper is thus ruled out, and is to be concentrated by mechanical processes, for instance. From that point of view, the use of copper in more and more complex components creates a new problem. The plastics content in the charge is also to be limited so as to avoid a too early combustion of the charge. This also makes a preliminary mechanical processing or incineration necessary.

The copper blast furnace operation is difficult to stabilize. The equilibrium is to be maintained between copper oxide reduction and oxidation of iron and aluminium which are removed within the slag. This constraint makes it

./.

necessary for each smelter to balance his supply between the various kinds of scrap. Besides, it should stir up some new research for the recovery of copper which is more and more often combined with iron and aluminium. This type of use is, in fact, growing and the quantities that could be recycled in blast furnaces will remain limited.

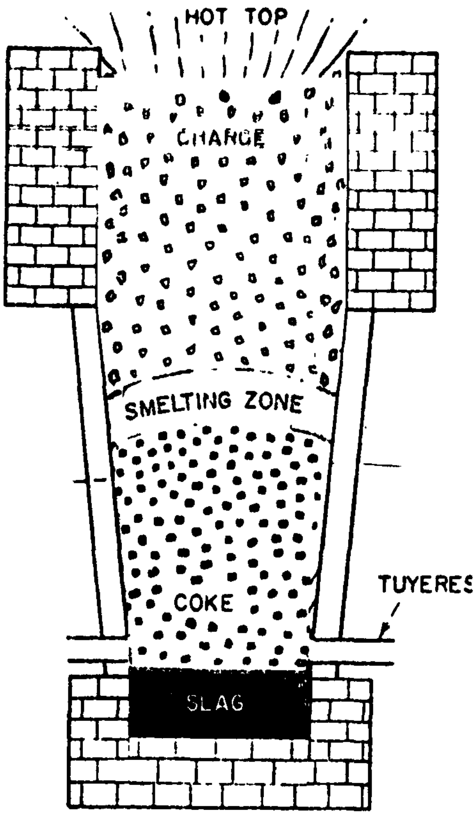
The liquid phases, metal and slag, come out of the furnace continuously and are separated in a crucible. The black copper contains 70 to 80 % copper, the balance being mainly tin, nickel, iron, lead and zinc in varying proportions, depending on the furnace feed and the operating conditions. This metal is treated subsequently in a converter. The slag, containing about 1 to 2 % copper, is lost as well as some tin, nickel and lead, and 5 to 10 % zinc. This unavoidable copper loss represents about 5 % of the processed copper.

The blast furnace gas cleaning gives mainly a zinc and/or tin-bearing dust. Some blast furnaces are working in "hot top" conditions, i.e. with the furnace top maintained at high temperature. This allows a better recovery of zinc and tin in the dust since their condensation at the top is avoided, and they do not pass into the slag.

Some smelters separate zinc-bearing charges from tin-bearing charges, the latter being composed of converter slags. This aims at producing a zinc-rich dust (50 to 60 % zinc) or a zinc-lead-tin dust which will be either sold or treated within the same plant for the production of zinc oxide and lead-tin solder alloy.

Economically, the copper blast furnace keeps an unquestionable dominant position due to the wide range of scrap and residues it is able to treat. Some technical improvements have been achieved during the last years, particularly air enrichment with oxygen, which contribute to reduce coke consumption and to increase the smelting rate. Most small units, however, have too modest requirements and cannot, therefore, obtain oxygen at interesting prices. Other techniques, like air pre-heating and fuel injection in tuyeres, have been studied but are not yet applied on a large scale.

Figure 29



2.2.1.2. Converter

The liquid black copper coming out of the blast furnace undergoes a first refining step in a converter similar to those used for blowing copper matte, but of smaller size. It is a cylindrical furnace, with a nominal capacity of 10 to 40 tons, equipped with a horizontal line of tuyeres through which air is blown into the bad. Gasses are evacuated either by the charging opening (Peirce-Smith converter) or sideways (Hoboken siphon converter, fig. 30). The air causes a selective oxidation of the metals accompanying copper, and the oxides pass either into a slag or into flue dusts. The composition of converter products is given in table 5.

./.

Figure 30

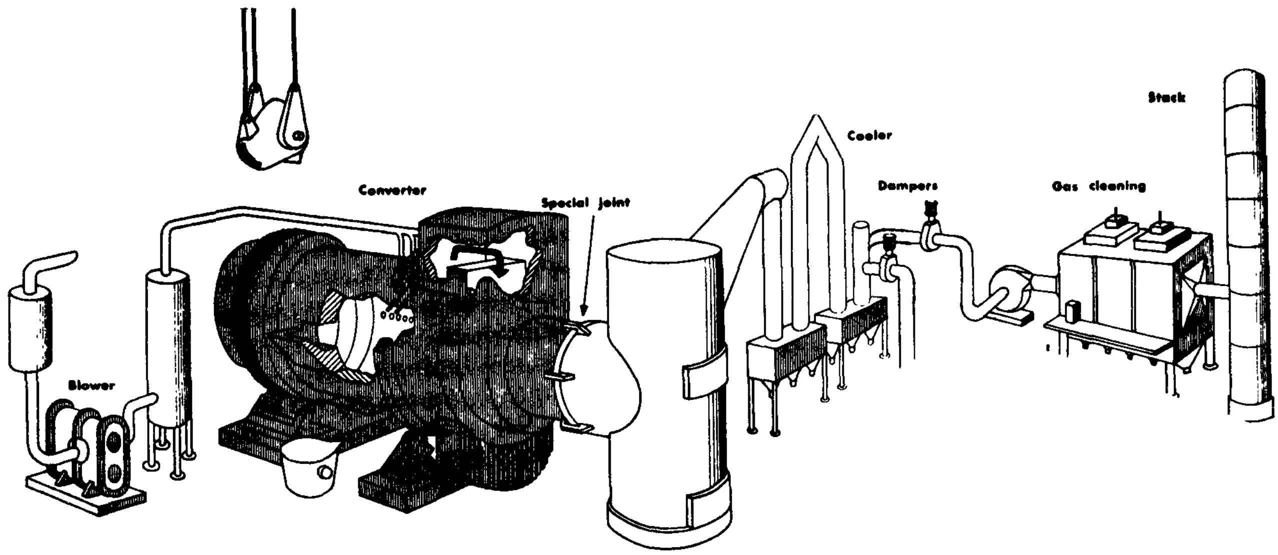


Table 5

Black Copper converter - Typical compositions.

	Feed	Products		
	Black Copper	Blister	Slag	Oxide
Cu	70 - 80 %	98 %	30 - 40 %	2 - 5
Pb	4 - 6 %	0,3 %	5 - 10 %	2 - 25
Zn	4 - 6 %	-	2 - 10 %	30 - 40
Sn	1 - 5 %	-	2 - 10 %	5 - 25
Fe	4 - 6 %	-	10 - 20 %	
Ni	1 - 4 %	0,4 %	1 - 8 %	
SiO_2			15 - 25 %	

./.

The thermal balance of the converter reactions is theoretically positive : the heat produced mainly by iron and zinc oxidation should compensate for losses by radiation and gasses. However, as it is a discontinuous process, some fuel or coke is used in order to hold the copper liquid before blowing or even to melt scrap during the charging. If the heat balance makes it possible, 60 to 80 % copper scrap is also charged during air-blowing, particularly tin-bearing scrap like "drink", "ebony" or "grape" N.A.R.I. categories when tin recovery in dusts or slag is aimed at.

Iron, zinc, tin, lead and nickel are collected in the slag. This slag is returned to the copper blast furnace, except when its tin content justifies a separate processing. Part of the zinc, tin and lead also passes into dusts which are collected for recovery. Complete removal of lead requires, however, too long a blowing, bringing about a too large quantity of slag incorporating some copper. Besides, it is impossible to bring the nickel content below 0.30 %. Crude copper (or "blister" copper) from the converter will subsequently be electrolytically refined, which is all the more justified as its precious metals content often represents a significant source of revenue for secondary smelters.

The most immediate modernization is the oxygen enrichment of the air blown through the tuyeres, or the blowing of pure oxygen by "top blowing" or by an immersed nozzle. These techniques aim to improve the heat balance and to accelerate the operation. Unfortunately, once again small secondary smelters will have to pay a too high price for oxygen which cannot be bulk delivered, as consumption is too low.

The role of the black copper converter in the copper recovery process is well defined : it is a refining step which is rapid (3 to 4 hours for a nominal furnace charge),

./.

efficient (copper grade increases from 75 to 98 %) and, if the furnace is well designed and operated, thermically self-sufficient.

Endly, the advisability of matte blowing in the primary smelters, should be emphasized with respect to scrap treatment. In this case, the heat balance is clearly positive and the quantity of solid scrap that may be loaded into the converter without extra melting cost is much more important.

2.2.1.3. Rotary converters

Several types of rotary converters (including the Kaldo), inspired by the technique applied in the converters, have been set up in order to process copper scrap. They are used to smelt and refine scrap rich enough to avoid the blast furnace-converter circuit. Their field of application is, however, not yet well defined : these units are, in fact, competing with the converter processing the 60-80 % copper scrap and with the reverberatory furnace processing the 85-95 % copper scrap.

Their main advantages are : the flexibility of smelting with natural gas or fuel, the easy regulation of working conditions (continuous or discontinuous use) and, above all, the possibility of having them turn round their axle at a rather low speed (for instance 30 rpm). This rotation ensures a mixing and a movement of the charge, making the smelting and the practice of "top-blowing" or blowing by immersion particularly efficient, no matter the injected product (air, oxygen or reagents).

As in the case of the converter or the reverberatory furnace, the principle of the operation is to oxidize and to slag the impurities after smelting. The resulting slags are remelted in the blast furnace, except when they undergo a separate treatment to recover other metals.

The operating flexibility of rotary converters allows to treat rather complex copper scrap, for instance with lead and zinc recovery by elimination in dust. Poling (copper reduction) is also performed, in some applications, before copper is cast into anodes or even as fire-refined copper.

The rotary converter, which is the most recent furnace used in the copper recovery industry, was submitted to many tests. However, each smelter using this process according to his own technique, we cannot speak of "one" rotary converter. Because of its small dimensions, it will be reserved for specific applications. It is a subject of important research work and improvements in the case of complex scrap (50 to 85 % copper).

The use of tilting furnaces should be mentioned here (like the Sklenar furnace), which combine some characteristics of both the rotary converter and the reverberatory furnace. This rectangular furnace is equipped on one side with burners, and on the other side it has a large opening for scrap charging and gas exhaust. Gas passing through the charge allows a very quick melting, but the bath is not deep enough to allow an efficient refining. It is well suited for remelting clean scrap intended for alloy production.

2.2.1.4. Reverberatory furnace

Secondary melting reverberatory furnaces may have a capacity of up to 200 tons. Heated with fuel or natural gas, the reverberatory furnace is used either for the smelting and the fire refining of high quality copper scrap subsequently cast into commercial formats, or for a first refining of scrap and blister copper from the converters, before casting into anodes and electrolytic refining.

At that stage, the reprocessed scrap includes categories 2 to 9 of the N.A.R.I. classification, the most important ones being "Berry" and "Birch".

Contrary to the furnaces mentioned previously, the recovery of secondary metals is here quite accessory, because of the degree of purity of the blister copper to be refined. Slags produced by this furnace (30 to 40 % copper) are returned to the blast furnace.

The immediate refining of copper scrap in a reverberatory furnace is of course the most economical way of recycling it. One operation only - smelting, oxidation and slagging of the impurities, deoxidization and casting of copper - produces commercial copper. To reach this result, it is however necessary to take into account the possibilities of eliminating the various impurities and, therefore, to choose carefully the scrap to be processed (> 85 % copper). Such elements as cadmium, part of the zinc and inorganic materials, are volatilizing. Tin, lead, iron, aluminium and the remaining part of zinc are removed by oxidation and collected in a slag.

The elimination of lead is however difficult and requires an important overblowing of the bath leading to a too large amount of copper losses in the slag. Besides, below 0.3 %, nickel cannot be eliminated. Arsenic and, to a lesser extent, antimony can be removed by adding lime or soda to an overblown bath. Lastly, it should be mentioned that some impurities, uncommon in the ordinary scrap (though not in the blister copper), such as bismuth, selenium, tellurium and precious metals, are almost never removable at that stage.

These various requirements do not allow the treatment of high grade scrap containing large quantities of lead, nickel or antimony for the production of fire-refined copper. This scrap will be cast into anodes to be refined later.

After removal of the impurities, the copper oxide contained in the bath is reduced by the poling process, in which tree trunks are introduced under the liquid copper surface and burn while combining with oxygen. Copper is then cast, either in commercial formats, or in anodes.

./.

The fire-refining process in the reverberatory furnace took advantage of the research work performed by primary copper refiners to increase capacity and quality of anode furnace production. Oxy-fuel burners and natural gas, propane or ammonia desoxidization number among the most important developments.

Basically, copper scrap fire-refining tends to decrease. The use of this type of copper, which is relatively impure, is more and more restricted to the making of products for which the electric and mechanic properties of pure copper are not required.

2.2.2. Hydrometallurgy

2.2.2.1. Electrolytic refining

Electrolytic refining more and more constitutes the normal continuation and the last step of copper processing. It consists in dissolving copper at the anode and depositing it to the cathode under the influence of an electric current. If the impurities in the anode are nobler than copper, they do not dissolve and, if they are less noble, they do not deposit. Cathode copper is more than 99.9 % pure.

The electrolytic refining technique is basically the same in secondary copper refineries as in primary copper refineries. European primary refineries generally have a rather important supply of high grade copper scrap. This scrap is mixed with blister copper in the anode furnace. On the other hand, many secondary smelters have no electrolytic refinery and their black copper or their blister copper is also sometimes sent to primary refineries.

The few refineries that specifically treat secondary copper, generally produce a more impure anode copper than primary refineries do. These anodes often bear important quantities of lead (0.3 to 0.4 %), nickel (0.3 to 0.4 %), antimony and, sometimes, tin. It has thus been necessary to control the behaviour of these impurities in order to produce good quality copper. This copper does however not meet the present most stringent standards for some impurities. In fact, lead and tin do not dissolve in the electrolyte, but a too high concentration of these elements in the anode could pollute the cathode through mechanical drive.

Precious metals are recovered in the electrolysis slimes and are, later on, processed for silver, gold and possibly platinum-group metals recovery. A typical composition of such slimes would be as follows :

silver	1 - 5 %
gold	0.05 %
lead	20 - 30 %
copper	10 - 20 %
antimony	3 - 10 %
tin	3 - 10 %

and sometimes occurrence of selenium, tellurium and bismuth.

Nickel is another impurity frequently found in the anodes (0.3 to 0.4 %). It dissolves in the electrolyte and a continuous bleed-off is therefore operated. The bleed-off is first electrolized to remove copper, then, if necessary, purified from its arsenic content and, finally, concentrated by evaporation. Nickel sulphate crystals are precipitated and are either sold as they are or purified in the refinery.

Modernization efforts during the last few years concerned copper cathode quality, mechanization of the operations (including casting into anodes) and increase of current density in the electrolysis cells by means of periodic current reversal. These improvements are obviously not exclusively fitted to the secondary copper industry.

./.

2.2.2.2. Leaching processes

An entirely different route may be imagined for copper scrap and residue recycling : copper dissolving by leaching and direct recovery of the metal from the solution. This very simple principle is however facing economical and technical difficulties which, up to now, have been only partly overcome, although such processes are already applied on a large scale to the treatment of some copper concentrates.

Copper scrap leaching consists in dissolving the different metals in order to extract them separately afterwards. The chief characteristics of leaching processes are :

- no dust or air pollution;
- good selectivity as regards certain impurities;
- possible automatization of the processes.

On the other hand, some difficulties that have restrained the industrial development of these processes must also be pointed out :

- low recovery yield;
- low speed of leaching operation;
- lack of flexibility regarding the various kinds of scrap.

A lot of research work was devoted to leaching processes during the last few years, but one only is applied on an industrial scale. A classical flowsheet would read as follows :

- leaching;
- solvent extraction with possible bleed-off for precipitation or purification;
- in the case of solvent extraction, elution of the exhausted electrolyte and solvent regeneration;
- recovery of metals, most often by electrowinning.

The principal leaching agents are :

- sulfuric acid;
- hydrochloric acid, with or without ferric chloride;
- ammonia and ammonium salts.

Except in certain particular cases, a general tendency seems to favour the use of hydrochloric acid. Some examples are given in the following figures :

- Universal Minerals and Metals Process (fig. 31)
  Copper scrap leaching is made in the open air. After filtration and precipitation of lead and tin, the solution is reduced with hydrogen until copper powder is obtained.

- Björling process (fig. 32)
  This process is applicable to the treatment of radiators. Copper is recovered as cathodes by electrowinning.

- The cupric chloride process (fig. 33)

Among the processes using chlorides, the D.K.H. process (fig. 34) should be mentioned, which is the only one known to be applied on an industrial scale for certain copper residues. After leaching and elimination of a residue, copper chloride is precipitated and oxidized as Cu_2O. This copper oxide is leached again and the solution is electrowinned after purification.

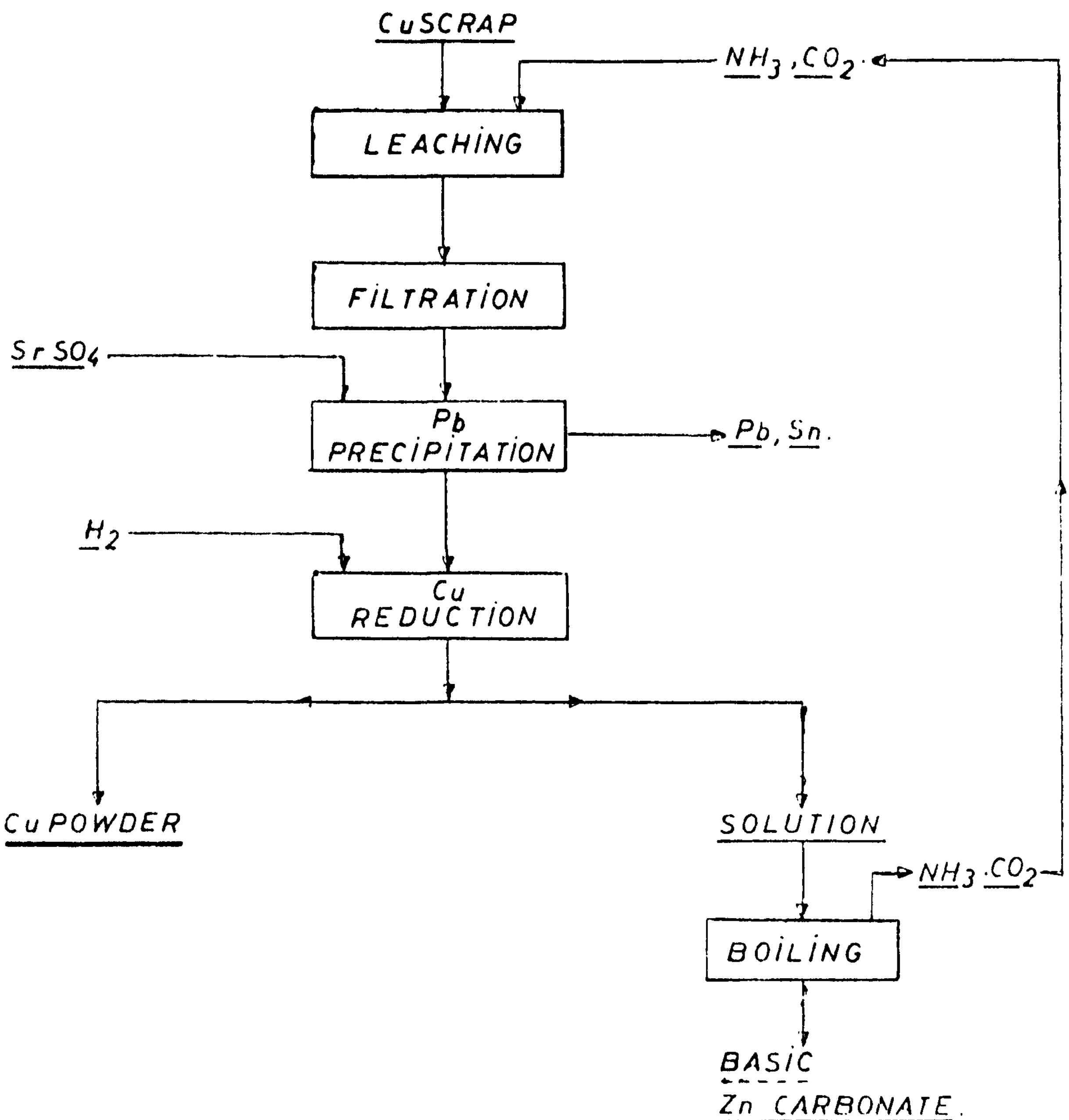
*

* *

./.

Figure 31

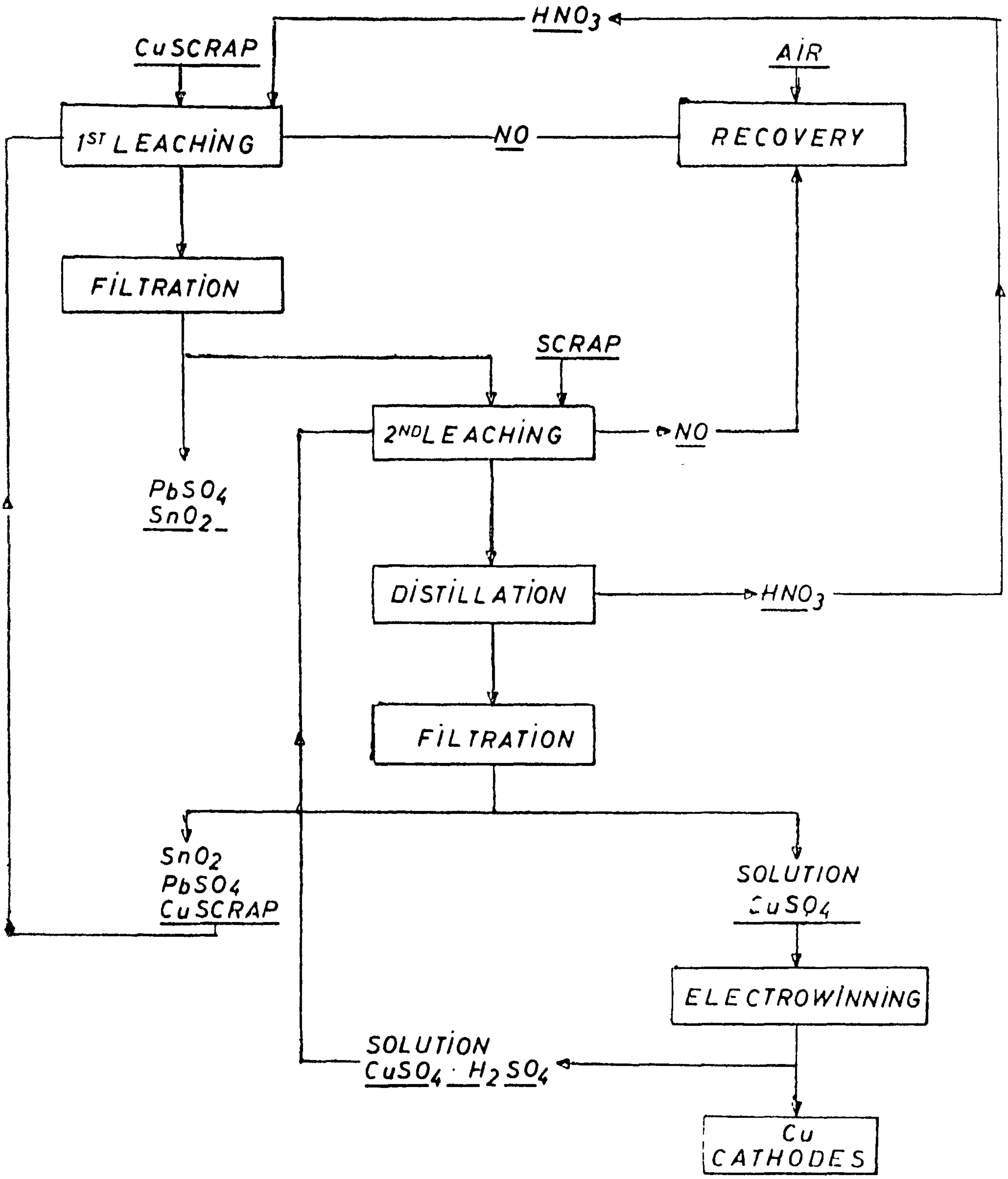
UNIVERSAL MINERALS AND METALS.



./.

Figure 32

BJÖRLING.



./.

33

Figure 33

Cupric chloride process

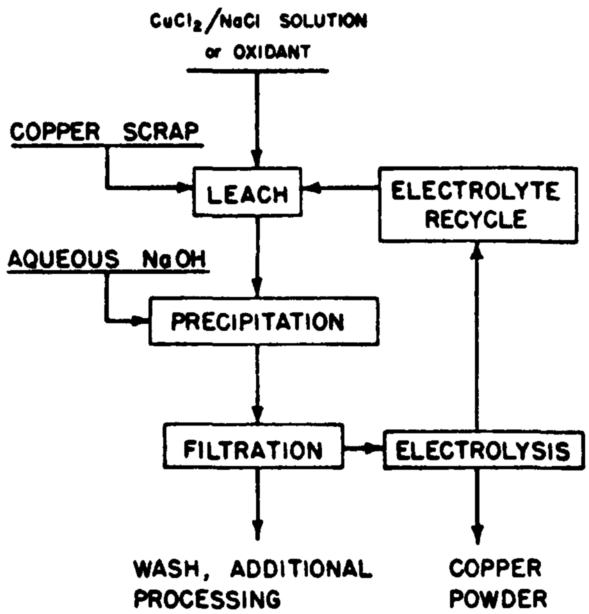
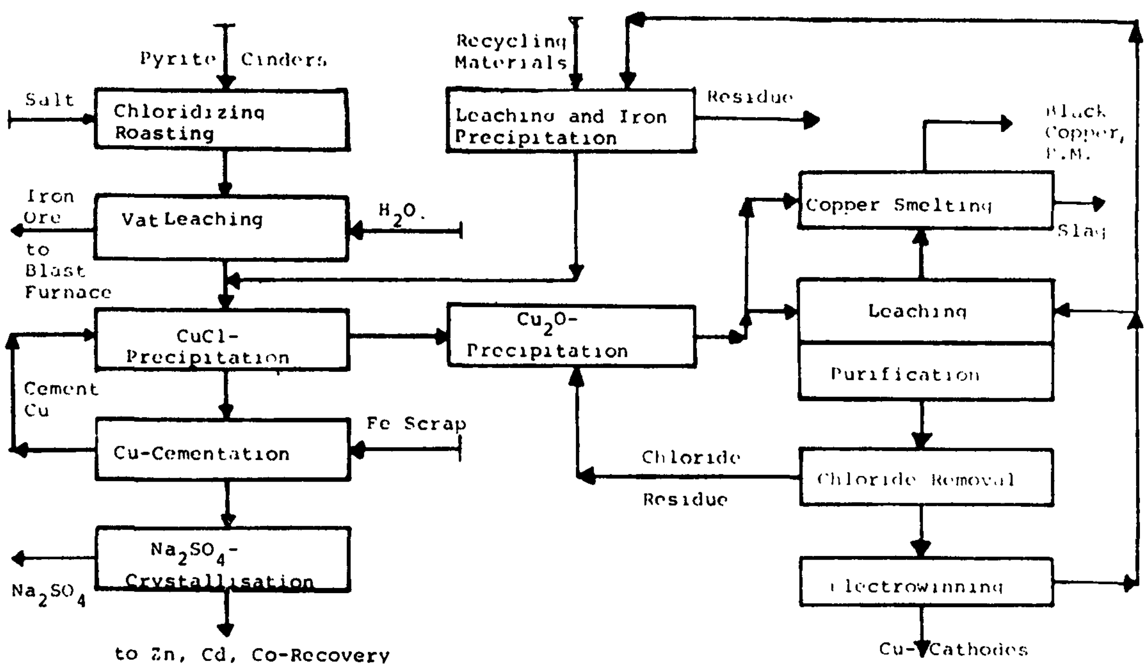


Figure 34

The D.K.H. Process.



./.

2.3. Processes for direct use of scrap

2.3.1. Alloys

As in the case of secondary copper smelters, there exists no strictly defined flowsheet that would be followed by all alloy recyclers. Each one of them, be it a brass mill, a foundry or a secondary ingot maker, rather adjusts his technique to the kind of material he is supplied with and, above all, to the requirements about his products. The basic principles of alloy recycling are, however, the same for the whole sector. This technique accounts for about two thirds of the whole copper secondary production.

2.3.1.1. Furnace charge composition

In order to produce a certain alloy with scrapped alloy material, some combination of two different techniques is used : dilution and refining. Dilution consists in bringing any element of the alloy to the desired content by mixing different parcels of material, and particularly, in bringing, by so doing, undesired impurities down to a content that is no longer harmful. Refining consists in reaching the same goals by removing elements, either by oxidization with air blowing or by fluxing. The operations are performed in a furnace, and the composition of the bath, after analysis, is finally adjusted by adding virgin metals.

It is always more economical to calculate the furnace charge so as to minimize the amount of necessary dilution or refining and be the closest possible to the wanted final composition, given the available qualities of supply and the quantity and quality of desired alloy. Blending different kinds of scrap rests first on a good knowledge of the scrap lot composition and thus on a careful sampling and analysis. The experience of foremen in charge of this operation, who are able

./.

to spot unwanted material in a scrap parcel, here plays a part of prime importance. A good scrap sorting is also essential as the added cost of sorting is offset by the savings in refining and dilution.

Some years ago, the use of a computer has appeared in order to optimize the charge blending according to the composition, price and availability of raw materials. This procedure has nevertheless not yet been adopted everywhere, and some alloy recyclers still prefer to rely on their skilled workers, especially when their range of products is not too large.

It should still be emphasized that the use of scrap in the making of alloys depends on the composition tolerance of the final products and that, in many cases, brass mills and foundries are reluctant to buy old scrap or even new scrap (see section 1.3.1.).

2.3.1.2. Furnace operation

When an alloy recycler operates by dilution only, the problem essentially consists in making an excellent charge blending and in avoiding to buy poor quality scrap. The charge is then molten in the furnace in order to homogenize it and adjust its composition with some pure metal ingots. Some fluxes may be used, like glass or borax, to cover the bath and reduce the volatilization of zinc.

If the charge is to be refined, air blowing can oxidize some impurities like iron, manganese, aluminium, ... and remove them to a slag. This operation is very similar to those performed in pyrometallurgical processes for secondary copper recovery (section 2.2.1.). Blowing is however not satisfactory in the case of high zinc alloys, since it would cause zinc to volatilize as zinc oxide.

Chemical fluxes are used to remove impurities, to protect the surface of the bath or to give desired properties to the melt or the slags. Various non-metallic and metallic fluxes are used in this respect, for instance : lime to remove tin, phosphorus to remove lead and deoxidize the melt, charcoal to provide a reducing atmosphere at the surface of the bath, sand to thicken the slag or borax to make it more fluid, and so on... The kind of flux varies with the desired effect and the nature of the alloy. Copper-base alloys can also be used as fluxes in order to add some element to the melt.

The amount of refining is generally not very high when the scrap is properly sorted and the charge properly blended, so that impurities are already diluted. Furthermore, some impurities, like aluminium or silicon, are difficult to eliminate by refining to the extent required for some kinds of brasses, and here again, the calculation of the charge is of primary importance.

Alloy melting always gives rise to various residues (slags, skimmings, ashes, ...) that are rather rich in copper and that are sent to a secondary copper smelter for recovery.

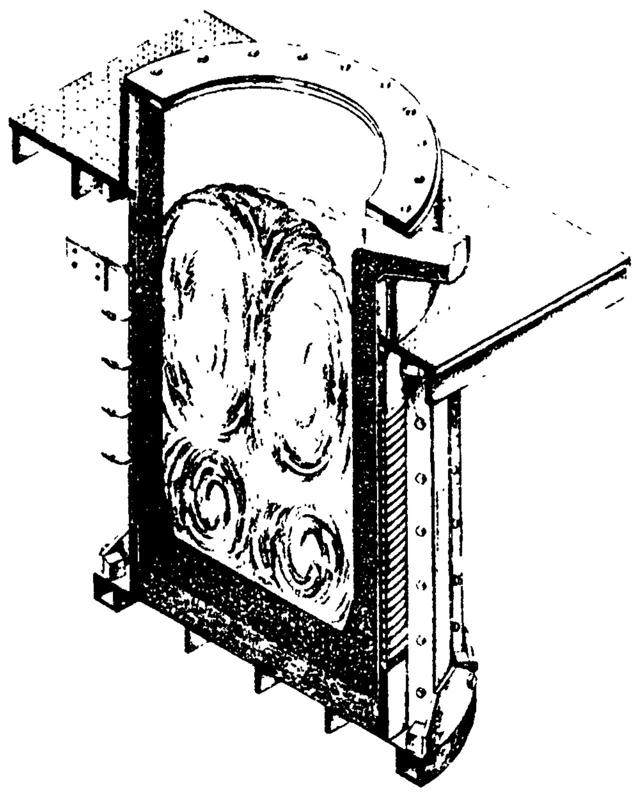
Reverberatory furnaces are used when the amount of refining is rather important. The design and operation are similar to the secondary copper reverberatory furnace (section 2.2.1.4.), but the capacity is somewhat lower, about 10 to 100 tons.

Rotary furnaces, be they simply rotating or end-tilting units, are more flexible. They are also more easily operated and have a better heat efficiency.

Induction furnaces also are very flexible units and tend to be preferred now. The basic principle is the same for coreless and channel furnaces : heat is generated by high eddy-currents induced in the charge by a high or low-frequency magnetic field from an induction coil (fig. 35); convection flows within the crucible ensure a good mixing of the charge.

Figure 35

High-frequency coreless induction furnace (from (47))



Other types of furnaces include arc furnace, crucible end-tilting furnace, crucible rotary furnace. A good description is given in (44) and (47).

Anyway, the choice for a furnace depends on the nature of the alloy and on the operations to be performed, the desired capacity and flexibility, heat efficiency, refractory lining resistance, etc... Often, a compromise is necessary : one must choose between capacity and flexibility, since big furnaces allow a better productivity for important quantities of a like alloy, and flexibility is desired to cope with the large variety of scrap composition and product requirements.

./.

2.3.2. Chemicals

Copper sulphate by far represents the most important chemical outlet for copper. It can be produced from copper pyrites, cement copper, impure sulphate solutions as a by-product of copper refining, and copper high-grade scrap. The copper content of scrap is usually required to be at least 86 %. On the other hand, some copper sulphate manufacturers are reported to use electrolytically refined copper, which is certainly much more expensive but provides a higher safety as regards the quality of the product.

The production processes of copper sulphate from scrap are rather simple and are cited here briefly. More details can be found in (18). All of them are variants of the same basic process which comprises three steps :

- granulation;
- oxidation and dilution by a sulphuric solution;
- crystallization of the copper sulphate, rinsing and packaging.

The purpose of granulation is to increase the specific surface of the metal and to facilitate by this means the dissolution of copper. The scrap is melted at 1200° C in a rotary or a reverberatory furnace, where the impurities pass into the slag. It is then poured into cold water, so as to obtain copper shots with about 99.8 % copper.

The granules are placed in a lead or stainless steel-lined tower where they react with steam and sulphuric acid to form diluted copper sulphate at about 90-100° C.

The liquor is then sent to crystallization pools where sulphate crystals precipitate. These are finally rinsed, dried and packaged.

3. FURTHER CONSIDERATIONS AND CONCLUSIONS

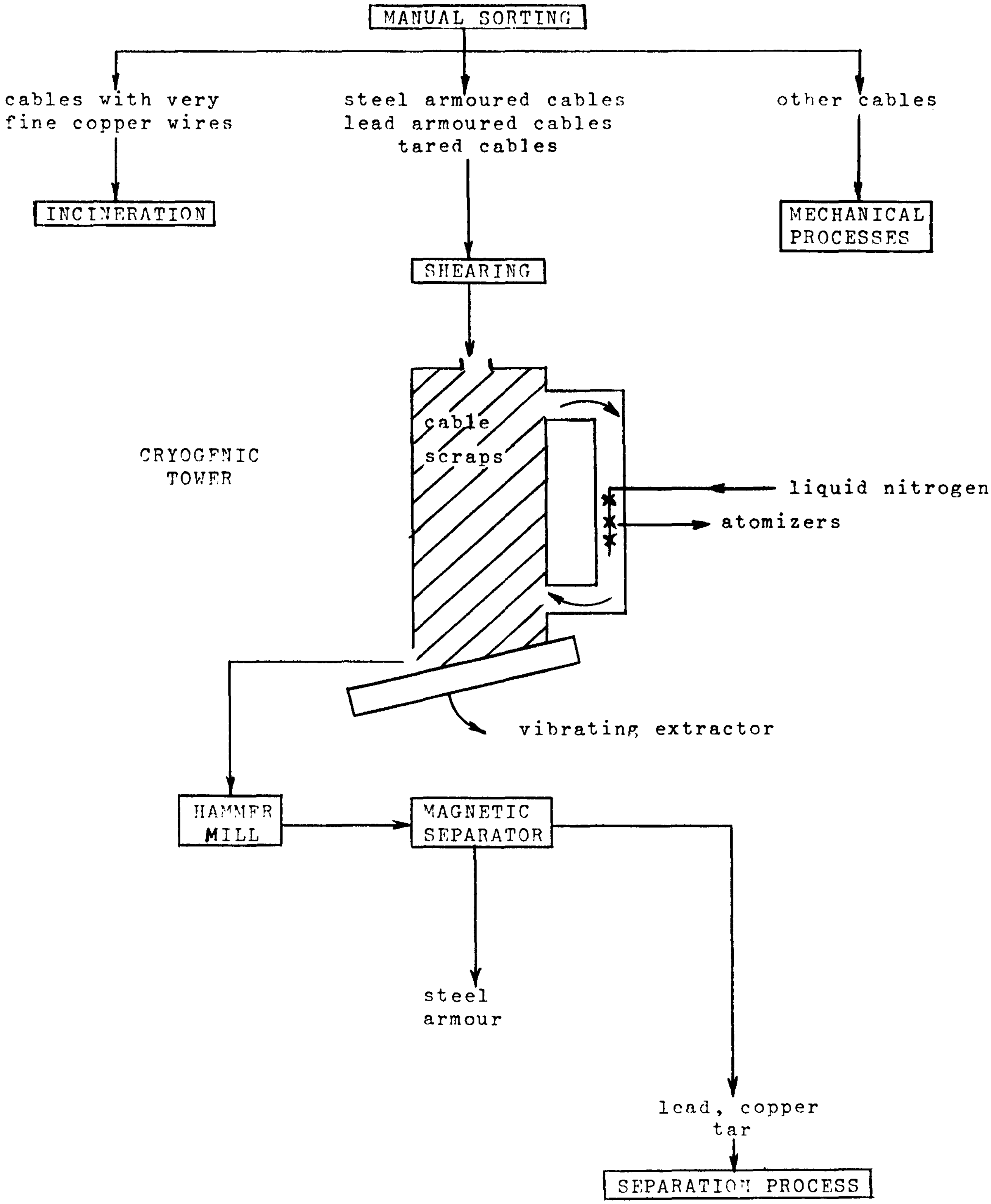
3.1. Areas of present research

The present research work regarding either technical improvements of existing recycling techniques or development of new processes, is carried out by both public organizations, be they governmental institutions like the U.S. Bureau of Mines or the Warren Spring Laboratory in the U.K., and private companies. Whereas developments introduced by the formers are always aimed to reach the market, private companies when they do not want to patent and market their processes, often do not disclose their technology so as to keep the advantage of their inventiveness over their competitors.

Problems in cable scrap recycling have already been mentioned in chapter 2.1. The new incineration furnaces with after-burner and scrubbers are theoretically non-polluting and do not oxidize the copper wires. They need to be carefully operated for that purpose and this may be contradictory to the desire of the furnace operator to achieve a higher throughput by not controlling too strictly the incineration conditions. We have actually seen in a yard, a parcel of brittle oxidized copper wires being incinerated in a modern furnace.

Cable chopping devices, on the other hand, are less flexible as regards their cable feed, and treatment of steel-armoured, lead-sheathed, greasy and tarry cables in chopping mills is still difficult. Nowadays, such cables are incinerated or skipped. A new development would be to apply a cryogenic chopping to those cables. This technique has already been tested on a small scale. A principle flowsheet is given fig. 36. After having been cooled down with liquid nitrogen, steel, lead, tar, plastic, are sufficiently brittle

./.



CRYOGENIC PROCESS

.../.

to be crushed by a hammermill. There remain, however, some problems to be solved before implementing such a process on an industrial scale for, after crushing, the tar rapidly becomes pasty and makes further separation difficult. Moreover, cryogenic processing of cables appears not to be very cheap. It has been calculated on the same basis as for mechanical processing (section 2.1.3.1. f), with a capacity of 2 tons of cables per hour, that the recovery cost of the cryogenic process would be about Bf. 4.80 per kilo of copper, with half this amount representing the price of liquid nitrogen solely. Cryogenic crushing is also developed in some plants, after dipping cables free of tar or grease in a liquid nitrogen bath. This brings about few technical problems, but the economic future of this process depends on the relative price of copper and nitrogen. The U.S. Bureau of Mines (54) has investigated the possible use of other cooling agents, like dry ice or methanol. Their preliminary results showed that a liquid CO_2-dry ice system could also be used for insulated wire processing.

An entirely different method to remove insulation from cables, that has been contemplated in Germany by three private companies (7), is pyrolysis. The basic principle of pyrolysis is to heat wastes containing organic compounds in a neutral atmosphere so as to decompose them into gasses and vapor, and to produce a carbonaceous residue. Polluting products are washed and neutralized and other pyrolysis products may serve as fuel. The application of pyrolysis to municipal sold wastes has already been studied in Japan and by the Warren Spring Laboratory, but the German process would be the only one applicable to all types of cables as well as to other kinds of industrial organic wastes. The economics of the process has, however, not yet been studied.

./.

Another type of scrap to which much research work is devoted is low-grade "irony" scrap, such as electric motor scrap or copper-stainless steel residue remaining after processing non-ferrous car shredder rejects.

Cryogenic grinding of these materials has also been studied. The U.S. Bureau of Mines (4) performed some tests on cryogenic processing of non-ferrous residue from automobile shredder, but it only succeeded in separating zinc from the copper and aluminium components. Pilot installations for cryogenic processing of electric motors are also tested by a French scrap processor and they seem to prove efficient. As for cables, the main problem seems to be the cost of the cooling agent.

Research work aiming to extend the sweating process (see section 2.1.2.5.) to iron-bearing copper scrap has also been undertaken by the U.S. Bureau of Mines (37). The process is based on preferential melting in molten salt bath at 1150 to 1250° C. The role of the salt bath is to prevent copper oxidation and to promote heat transfer. Barium or calcium chloride is used preferably. A pre-treatment of the scrap with sodium sulphate or sodium silicate to prevent copper from alloying with iron, allows to achieve a better separation. This process, however, seems to be very costly : an estimation made in 1973 was about US$ 0.20/lb.

Another research of the Bureau of Mines focussed on an efficient hand-breaking system for electric motors with power hand-tools, presses and hand-saw (21). Similar research was devoted to manual car dismantling (20).

Processing of electric motors by cupric-ammonium carbonate leaching has been investigated too (48) but, as far as we know, none of the processes devised by the U.S. Bureau of Mines has been commercially adopted up to now.

./.

Mechanical separation processes are also currently investigated in various laboratories. Most of them are however being studied for application to municipal solid waste sorting systems. Eddy-current separators and devices for classification according to friction coefficient could be used for copper scrap. A magnetic liquid consisting of a colloidal suspension of tiny magnetic particles in water has been developed in Japan (?). By applying a magnetic field of a given value to this "ferrofluid", it is possible to obtain a controlled apparent density and to have the magnetic liquid act like a "heavy medium" allowing separation of metals that differ in density by as little as 0.3. We do not know whether such device has already been tested or used in Europe until now.

Concerning metallurgical processes, most of their developments have already been mentioned in chapter 2.2. As regards pyrometallurgy, efficiency improvements include enrichment of air with oxygen, pre-heating of air, oxy-fuel burners, etc... Many leaching processes have already been proposed, but economical feasibility has still to be demonstrated for most of them. The use of hydrometallurgical processes might be particularly interesting for certain types of scrap which set real problems as far as pyrometallurgical treatment is concerned: copper scrap mixed with aluminium, copper with some toxic metals (cadmium, beryllium, ...), poor recovery of secondary metals. The flexibility of hydrometallurgy, a good pollution control and the possibility of regenerating the re-agents, are attractive.

It is, however, not conceivable to have a single process which would allow to treat any kind of scrap in optimal conditions. In this field, processes that are specific to well-determined scrap categories are to be developed. The advantage would be the selectivity and the expected recovery yields, and the drawback, the lack of flexibility due to the application limits.

./.

One may imagine that some combination of a basic pyrometallurgical processing followed by a subsequent hydrometallurgical treatment, could constitute a new orientation. Unfortunately, no promising industrial realization has been achieved yet in this field.

*

* *

3.2. Consequence of economic factors on the technique

A basic fact, that should never be forgotten when dealing with scrap recycling, is that this activity belongs to a competitive sector, where every cost in the reclamation process must be paid for by the price of the recovered products. In other words, recycling operations must be profitable to the scrap processor to enable him to continue his operations. This influences the outlet for some scrap as well as the recycling technique itself.

As we already pointed out, the outlet for certain types of scrap is fixed by technical requirements : low grade scrap for instance can be recovered by secondary smelters only. For other scrap, its price as compared to that of pure copper may influence its outlet. For high grade copper scrap, direct users are competitors to secondary copper smelters and refiners, as this kind of scrap is a fair substitute for pure copper as regards their purposes. N°1 and n°2 copper scraps have thus their own market governed by the supply/demand rule. The price of this scrap is related to the price of pure copper, but can rather independently move away from it. The scrap suppliers try to sell at the highest possible price, as long as this price covers their costs, and the direct users of scrap buy it as long as the discount versus pure copper is higher than

./.

the costs involved by the use of scrap, since they always have the alternative possibility of using refined copper. On the contrary, copper refineries will purchase high grade scrap as long as the refining costs are lower than the difference between pure copper and copper scrap prices, so that the whole operation allows them to make some profit. Some other factors may cloud this picture : a tight copper supply may compel direct users of scrap to pay for it more than the nominal copper price as the metal is difficult to obtain, or a refiner may buy copper scrap at a high price, without any profit, to keep his plant running when the metal is in short supply, and so on....

We have already stressed that, as far as brass scrap is concerned, the discount as compared to the copper and zinc prices, is too low to allow copper smelters to purchase it regularly, since the zinc loses most of its value. It did, however, happen in time of copper shortage that brass scrap was processed for copper refining, the usual discount on account of the presence of zinc being wiped out by the need for copper.

Other factors than relative prices have an influence on the outlet for high grade scrap. Commercial relations between sellers and buyers may work in various ways : contracts for toll-treatment of new scrap by the supplier of raw materials, connections between different contracts with the same partners, ... The location of the scrap user determines transport costs which, in turn, also determine the total price of scrap.

If the discount for scrap against refined copper may determine its outlet, the need for an evolution in the technique is mainly related to the absolute price of copper. On a long period, the recovery rate of copper has not basically increased, as the price of copper did not follow the recycling costs, and the positive effect of technical improvements has

./.

been offset by higher costs of energy and manpower. As scrap processing at the first stages involves a lot of manual operations, like breaking the scrap and sorting it, it is presently possible only with pieces having enough value. If the price of scrap is too low, as is the case now, the cost of collection and manual processing makes it unprofitable and a lot of metal may thus be unrecovered. Due to the increasing cost of manpower, there is also a strong tendency towards mechanization whenever possible, and towards building ever bigger machines. In the case of mechanical processing machines as well as furnaces, small capacity units tend to disappear from the manufacturers' catalogues in favour of ever more gigantic ones. This results in a lower specific cost in manpower, but also in larger overhead costs and in the need for a sufficient supply. Some scrap processors, however, still believe that smaller units with greater flexibility in their use and smaller investment costs, may prove more viable when the market is depressed and the copper scrap scarce.

Another economic aspect related to copper recycling is the importance of energy savings when comparing secondary and primary copper production. Energy consumption has been estimated to be, on an average, about six times lower for secondary copper. Although it is not properly related to the metal balance in Europe, the "energy" aspect of copper recycling is not without importance for the Community.

*

* *

3.3. Conclusions and recommendations

The problem of increasing copper recycling rate may be viewed as a two-dimension one. The first direction would be to increase the quantities of recovered scrap with a copper content that is already high enough to make its reclaiming economically relevant, and the second one to lower the minimum copper grade beneath which the recovery is not profitable. We speak here only of "classical scrap". The recovery of copper from municipal solid wastes or from industrial wastes is already the subject of important developments , and there exist in these fields strong non-economic incentives stemming from environmental worries. The effect of this research work can anyway only be positive on the non-ferrous metals balance.

Increasing the quantity of recycled copper is related to both treatment costs and copper price. About copper price, it is to be noticed that low prices, which are detrimental to the production of secondary copper and copper alloys, both because of a bad price-costs relationship and because people try to withhold their scrap until the price is higher, are normally caused by a serious oversupply situation of the copper market. On the contrary, when the copper supply is tight and the price high, copper availability for recycling increases, because treatment costs are now more easily paid by the price of copper, and also because holders of copper scrap stocks try to take advantage of the higher prices. From this viewpoint, copper recycling has, to a certain degree, a kind of regulation effect on the metal supply. This effect is, however, not strong enough to prevent any large price fluctuation, or to insure a thorough exploitation of the European copper scrap resources. A higher copper price would certainly increase the copper recovery rate, but it might also not be wished from other points of view. Anyway, as copper belongs to a world market where efforts are already undertaken with great difficulties to stabilize its price, it seems hardly feasible to artificially maintain this price at a high level in the short-term.

./.

Improving the recycling rate of copper scrap thus makes other measures necessary, as lowering the processing costs, improving the scrap collection organization or setting up some economic or psychological incentives to the recovery of metals. Lowering processing costs could also reduce the minimum limit of copper content for profitable recovery, but it is hardly probable that it would drastically increase that way the amount of recycled scrap. On the other hand, this allows scrap processors to pay more for their scrap, so as to induce holders of new scrap parcels to sell them more rapidly and to pay higher collection costs for old scrap. Processing costs should be reduced by lowering the energy consumption in furnaces and by improving the methods of scrap sorting, which are still very empirical. By the way, the reduction in energy consumption could also be aimed at from a general point of view as far as energy balance is concerned.

The problem of organizing the collection of old scrap is very important, since almost all the new scrap is already recycled. Nowadays, old scrap is collected for a large part by small scavengers as long as the time they spend on it is paid by the price of scrap, taking their transport costs into account. Presently, this occupation tends to disappear as the price for scrap is very low for the time being, so that much old scrap remains uncollected, some being easily recoverable later, some being lost within huge quantities of waste. A methodic organization of scrap collection, together with some incentives for people discarding copper-base products to have them recovered, could probably improve the situation very much.

It should also be remembered that such measures could also be applied to other metallic scrap and that they would also affect the recovery of secondary materials associated with copper.

Mention must also be made of the so-called "Non-Waste Technology", the purpose of which is to avoid the arising

./.

of new scrap by a better piece design or production process. This would not have any important effect on the copper balance since almost every piece of new scrap is already recovered. It is, however, an interesting development for manufacturers who want to reduce the cost of their raw materials.

As a consequence, some guidelines can be set and some fields of research determined, in order to increase the recovery rate of scrap.

- First, it would be useful to study further what are exactly the scrap resources in the European Community, in what conditions they occur, what is their grade and which factors can affect their potential for recycling. Part of such a study is already undertaken for new scrap with an input-output analysis by the German I.T.E. under contract with the European Commission.
  Some studies on old scrap occurrences, with estimation of a mean lifetime, have also been published. They, however, do not point out where the losses in the copper circuit occur, or where they could be the most easily avoided. Such study would, however, be rather difficult, when considering the large amount of small copper-base pieces present in every kind of equipment.

- The organization of scrap collection should be studied more thoroughly, with a view to selecting some policy of economic or psychological incentives for a large recovery of metals. It has been suggested for example, to set up a tax on cars which would be reimbursed when the car is sold to a wrecker rather than abandoned along some road. Our intention is not to judge here such measures, but to suggest to study them more deeply.

./.

- The sorting of scrap is still a very empirical operation which, however, determines the quality of the final scrap parcels. New methods for homogenizing these parcels are still to be found, although some new processes, like cable chopping or car shredding, are already applied on a large scale. Important progress is still to be made to generalize such methods to mixed scrap.

- Although many manufacturers try to take the best possible advantage of their scrap by sorting it at its point of occurrence, new scrap is still often mixed, especially for swarf. A way of coping with the problem of scrap sorting would be to induce these manufacturers to separate it into homogenous categories through a selective collection. This might prove profitable as the scrap would have a higher value, but there certainly is a scale effect on this operation.

- Cryogenic grinding is a new way of processing some types of scrap, but its economics is still uncertain, being too dependent on the price of the cooling agent. An estimation of the conditions under which such operations are profitable could help assessing the future of this method: scrap and copper prices, choice and price of the cooling agent, size of the cryogenic plant, etc... should be taken into account.

- For secondary copper smelters and alloyers, a reduction of the treatment costs depends primarily on furnace operations. Methods like oxygen enrichment of the air, air preheating, natural gas poling, are to be studied further to be applied on a large scale. An automatic analysis of impurities content in fire-refining could also lead to significant savings, as, presently, people are used to blow air longer than necessary in order to be sure to have a pure enough copper. The improvement of the heat efficiency of any type of furnace should also lead to important reductions in energy consumption. In a general way, a better knowledge of all furnace parameters can only prove to be useful for a more economical recovery.

- The improvement in the recovery of by-products from copper scrap and of the proportion of copper recycled from the converter to the blast-furnace as a slag, should also be increased.

- Electrolytic refining should also be the subject for research on the way of treating anodes produced from very impure blister copper or complex scrap. In some cases, this might allow to avoid either a preliminary refining, or the production of second-quality copper that is more difficult to utilize.

It should finally be stressed that an important part of these researches has already been undertaken or simply contemplated by various companies belonging to the scrap dealing sector, to direct scrap users, to secondary smelters or refiners, and to the equipment manufacturing sector. Instead of starting this research from scratch again, it would be advisable to make some enquiry among those people with new ideas, in order to find out which ones would need the help of the European Community, or would be ready to work in cooperation with it. This help could be of financial order, but perhaps also in the form of a market analysis to assess what could be outlook for the new process. A new pattern for the copyrights of processes developed with the help of the Community might also be necessary in order to protect the rights of the people developing the idea, as well as the rights of the people supporting the project through the European Commission.

This enquiry should be directed to large-scale as well as to small-scale operators, the optimal operation size not yet being well determined. From this point of view, an estimation of the optimal capacity of scrap processing plants might also be very useful, taking into account the need for flexibility and the cost structure in the process.

*
***
*

A P P E N D I C E S

Appendix A

Some physical properties of Copper and Copper Alloys

(extracted from (16))

Metal	* Electrical conductivity at 20° C. % I.A.C.S.	Thermal conductivity cal/sq. cm./cm./sec./°C.	Melting-point or melting range °C.	Coefficient of linear expansion at normal temperature per °C. × 10^{-4}
High Conductivity Copper (tough pitch)	100–102	0·92–0·94	1083	× 10–4
Oxygen-free High Conductivity Copper	100–102	0·92–0·94	1083	
Tellurium (or Selenium) Copper (free cutting)	94–98	0·85	1075	
Cadmium Copper	80–85	0·9	1040–1080	
Phosphorus Deoxidised Copper (0·04% P)	80	0·75	1080	
Chromium Copper (heat treated)	80	0·75	1073–1080	0·16–0·17
Chromium Copper (prior to heat treatment)	45	0·4	1073–1080	
Copper Nickel Phosphorus (Ni 1%, P 0·25%)	60	0·62	1080	
Conductivity Bronze (0·5–1% Sn)	55–75	0·55–0·7	1080	
Arsenical Copper (tough pitch)	40–50	0·42	1075	
Deoxidised Arsenical Copper (phosphorised)	about 40	0·42	1080	
Gilding Metal (90 : 10)	43	0·45	1020–1045	0·18
Gilding Metal (85 : 15) (Red Brass)	37	0·36	990–1020	
Gilding Metal (80 : 20)	32	0·34	960–1000	0·19
Aluminium Brass (76 : 22 : 2 Al)	23	0·24	950–980	
Cartridge Brass (70 : 30)	27	0·29	920–955	
Admiralty Brass (70 : 29 : 1 Sn)	25	0·26	920–950	
Yellow Brass (65 : 35)	27	0·29	905–930	
Basis Brass (63 : 37)	26	0·29	900–910	
Naval Brass (Tobin Bronze) (62 : 37 : 1 Sn)	25	0·26	850	0·20
Yellow Metal (Muntz Metal) (60 : 40)	28	0·3	885–905	
Free Cutting Brass (58 : 39 : 3 Pb)	25	0·26	875–900	
H.T. Brass (Manganese Bronze) (typical composition)	10–25	0·1–0·26	875–900	0·21

./.

Appendix A

Some Physical Properties of Copper and Copper Alloys *(continued)*

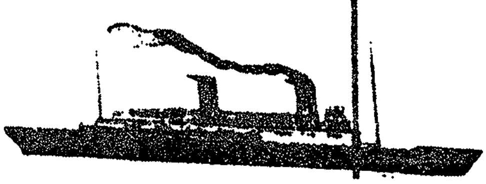
Metal	* Electrical conductivity at 20° C. % I.A.C.S.	Thermal conductivity cal/sq. cm./cm./sec./°C.	Melting-point or melting range °C.	Coefficient of linear expansion at normal temperature per °C. × 10⁻⁴
Aluminium Bronzes with fractional percentages of other elements	12–18	0·13–0·2	1040–1080	0·17
Duplex Aluminium Bronzes	6–12	0·07–0·13	1040–1080	
Gunmetals (88 : 10 : 2 : 0, 86 : 7 : 5 : 2, 83 : 3 : 9 : 5, 85 : 5 : 5 : 5, Cu : Sn : Zn : Pb)	10–15	0·1–0·15	850–1000	
Phosphor Bronzes (Wrought) (3–10% Sn)	11–27	0·1–0·25	800–1000	0·18
Phosphor Bronzes (Cast) (10–18% Sn)	6–11	0·07–0·12	800–1000	
Silicon Bronzes (1·5% Si)	12	0·14	970–1060	
Silicon Bronzes (3% Si)	6	0·10		
Cupro-Nickels (95 : 5)	23	0·28	1090–1120	0·15
Cupro-Nickels (80 : 20)	6	0·09	1130–1190	
Cupro-Nickels (70 : 30)	5	0·09	1170–1240	
Nickel Silver (10%)	8	0·09	1050–1110	0·16
Nickel Silver (15, 20, and 25%)	3–6	0·04–0·06		
Beryllium Copper (1·7% Be, 0·3% Co), heat treated	25–35	0·25	870–950	
Beryllium Copper (1·7% Be, 0·3% Co), prior to heat treatment	16–18	0·20	940–1020	0·17
Beryllium (Cobalt) Copper (0·4% Be, 2·6% Co), heat treated	45–50	0·5	1000–1050	
Beryllium (Cobalt) Copper (0·4% Be, 2·6% Co), prior to heat treatment	20	0·3		
Silver	105	1·0	960	0·19
Aluminium	62	0·53	660	0·24
Magnesium	39	0·37	651	0·27
Zinc	29	0·27	419	0·39
Nickel	25	0·22	1455	0·13
Iron	17	0·17	1538	0·12
Tin	15	0·16	232	0·23
Lead	8	0·08	327	0·29

* *Note.*—With the exception of the figures for High Conductivity Copper and Cadmium Copper, all the values in this column are approximate and not covered by British Standard.

Appendix B

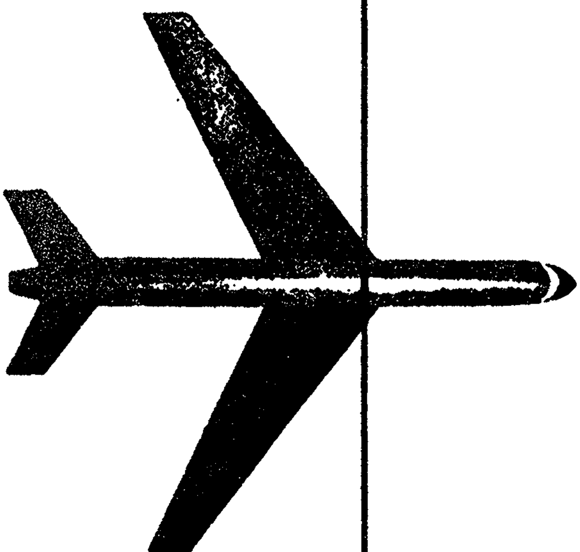
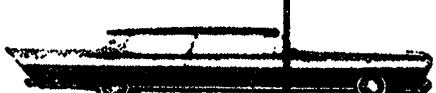
Appropriate copper-base material according to application
(extracted from (15))

SPECIALITES	INDUSTRIES	APPLICATIONS	ALLIAGES APPROPRIES
TRANSPORTS	MARINE	Pièces chaudronnées	cupro-silicium cupro-aluminium
		Arbres porte-hélices	cupro-aluminium
		Planches de doublage pour petits bâtiments	cuivre, laiton 60/40, laiton amirauté
		Pièces de chaudières	cuivre désoxydulé
		Barres d'entretoises (pleines ou creuses)	cuivre au manganèse
		Réchauffeurs (pour pétroliers)	laiton 85/15 laiton à l'aluminium
		Tuyauteries de circulation d'eau de mer	cuivre, cupro-aluminium, cupro-nickel 95/5, cupro-silicium
		Circulation d'huile, conduite de fuel, pétrole	laiton 85/15 cuivre
		Tubes et plaques condenseurs	laiton à l'aluminium 76/22/2 cupro-aluminium cupro-nickel (avec ou sans fer)



./.

Appendix B

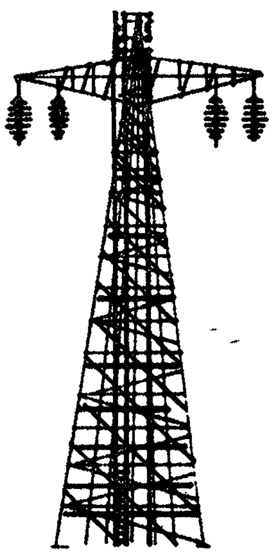
SPECIALITES	INDUSTRIES	APPLICATIONS	ALLIAGES APPROPRIES
TRANSPORTS (SUITE)		Tubes d'évaporateurs, d'échangeurs, pièces d'injecteurs	laiton 60/40 cuivre
		Vis et écrous, boulonnerie, rivets, œillets pour voiles, crochets	laiton H.R. (à haute résistance) laitons 60/40, 85/15, 90/10 cupro-aluminium 95/5 cupro-silicium
		Armatures de compas	laiton 60/40 maillechorts
		Installations sanitaires	cuivre désoxydulé (ou non) cupro-silicium
		Garnitures : « ferrures » Quincaillerie de bâtiment : serrurerie Décoration	laiton 65/35 cupro-aluminium laitons 95/5, 90/10
	AVIATION	Tuyauteries, tubulures de presse hydraulique (trains d'atterrissage)	cupro-silicium (laiton spécial au nickel silicium)
		Tuyauteries de carburant	cuivre
		Douilles de bougies aviation	cuivre au chrome
		Circuits de refroidissement Boulonnerie	cupro-nickel cuivre au nickel silicium
	AUTOMOBILE	Carcasses de radiateurs Conduites d'eau	cuivre laitons 65/35, 67/33, 85/15
		Réservoirs Carburateurs (flotteurs) Rondelles et pièces estampées	laiton 65/35
		Appareillage électrique	cuivre, laitons, maillechorts, cuivre au tellure
		Engrenages, pistons hydrauliques pour freins, tubes loockheed,	laiton 60/40 cuivre
		Pièces décoratives (chromées) Serrures et profilés	laiton 85/15 laiton 65/35 laiton 70/30
	CYCLES	Appareillage électrique	cuivre laitons
		Brasures pour cadres	laiton à l'étain et au silicium soudo-brasure
		Pompes de bicyclettes	laiton 70/30

Appendix B

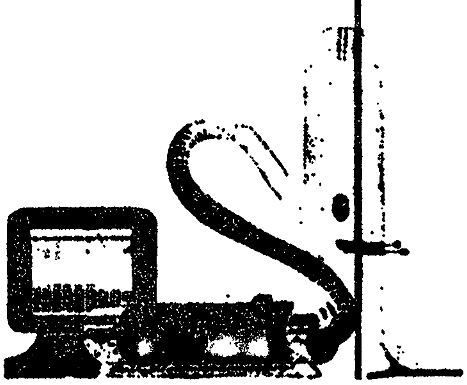
TRANSPORTS (SUITE)	**Chemin de fer**	Plaques de foyer	cuivre désoxydulé cuivre à l'arsenic cupro-nickel
		Pistons hydrauliques pour freins	cuivre laiton 60/40
		Tubes condenseurs, échangeurs température	laiton à l'aluminium cupro-nickel laiton Amirauté
		Circuits de graissage	cuivre cupro-nickel laiton 85/15
		Locomotive électriques Petits appareillages, connexions, contacteurs	cuivre laitons cuivre au tellure cuivre à l'argent
		Supports de caténaires	laitons bronze d'aluminium
		Installations sanitaires des wagons	cuivre cupro-silicium
		Décoration, serrurerie	laitons 85/15, 65/35
BATIMENT	**Toiture**	Couverture, gouttières (feuilles, tuiles)	cuivre ou cuivre plombé
		Accessoires de couverture : crochets et agrafes	cuivre
		Paratonnerres	cuivre plombé (ou non)
	Installation sanitaire	Conduites d'eau chaude et froide (colonnes montante, évacuation)	cuivre
		Installations de bains Chauffe-eau, chauffe-bains (brûleurs, vannes)	cuivre ou laiton 90/10
		Accessoires de plomberie (raccords...)	laiton 60/40, bronze phosphoreux coulé, tubes façonnés
		Installations de gaz butane et propane	cuivre désoxydulé laiton 65/35, 60/40
		Colonnes montantes et canalisations de gaz	cuivre
	Chauffage	Chauffage par rayonnement (tubes noyés dans le plâtre, le béton) Radiateurs paraboliques	cuivre désoxydulé
	Décoration	Quincaillerie de bâtiment, serrures, charnières, boutons de porte, plaque de propreté, vis	laiton 65/35
		Profilés, devantures, vitrines, interrupteurs, lustres, enseignes	cuivre, laitons, maillechorts, bronze

./.

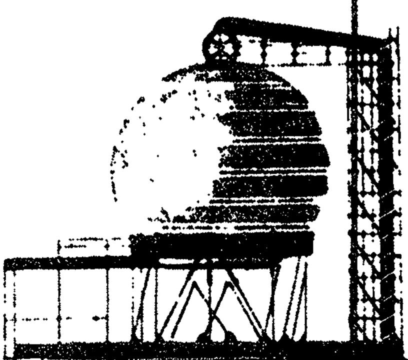
Appendix B



ELECTRICITE	**APPAREILLAGE**	**Fils, câbles, barres de connexion**	**cuivre**
		Fils de résistance	**constantan, nickeline, maillechorts**
		Fils de bobinage	**cuivre émaillé**
		Culots et douilles de lampes	**laitons 65/35, 70/30**
		Pièces de construction d'appareillage électrique	**laiton 65/35 cuivre au tellure**
		Interrupteurs électriques	**cupro-aluminium cuivre au nickel silicium**
		Contacteurs, cosses de connexion, raccords, supports fusibles, fiches mâles et femelles	**laiton 65/35 cupro-nickel cuivre au nickel silicium cuivre au béryllium**
		Coussinets de moteurs électriques	**bronze phosphoreux**
		Boulonnerie électrique	**cupro-nickel cuivre au tellure cuivre au nickel silicium**
	RADIO-ELECTRICITÉ	**Postes de T.S.F. (cosses)**	**cuivre**
		Téléphone (fiches)	**laiton étamé (ou non)**
		Télévision (fils)	**maillechorts**
		Radars (coupelles, guides d'ondes)	**cuivre H.C. exempt d'oxygène**
	CENTRALES THERMIQUES	**Condenseurs, échangeurs de température**	**laiton à l'aluminium cupro-nickel laiton amirauté**
MATERIEL MENAGER et ELECTRO MENAGER	**MATÉRIEL DE CUISINE**	**Batterie de cuisine Brocs, marmites, casseroles**	**cuivre (en général étamé)**
		cuillers, fourchettes, couverts, shakers, gobelets, coutellerie, ronds de serviettes	**laiton 65/35 maillechort, alpacca, laiton**
	APPAREILLAGE	**Machines à laver (pièces diverses)**	**bronze phosphoreux cuivre**
		Réfrigérateurs (évaporateurs, tubes frigorifiques)	**laitons 60/40, 80/20 cuivre**
		Fers à repasser (à réserve d'eau) Bouilloires électriques	**laiton 60/40**
		Toutes pièces décolletées	**laiton 60/40 au plomb cuivre au tellure**
		Cuisinières et fours (robinetterie, brûleurs)	**cuivre laitons**
		Ballons d'eau chaude	**cuivre, cupro-silicium cupro-nickel**
		Chauffe-eau, chauffe-bain	**cuivre laiton 90/10**



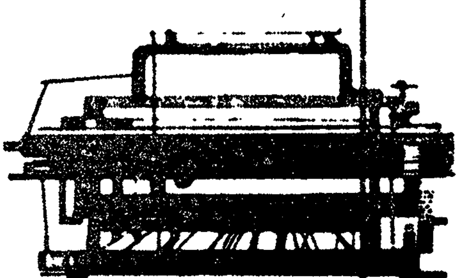
Appendix B

ARMEMENT 	Munitions de guerre ou de chasse	Enveloppes de balles, amorces, coiffes de fusée	laiton 95/5
		Bandes pour obus, amorces	laiton 90/10
		Enveloppes de cartouches pour armes légères et pour artillerie	laiton 70/30
		Barrettes pour ceintures d'obus	cuivre
INDUSTRIES CHIMIQUES 	Acides et Alcalis Alcools Vernis Résines Huiles et Graisses	Pièces chaudronnées et appareillages divers pour acides sulfurique, acétique, alcalis, trichloréthylène	cupro-nickel cupro-silicium cupro-aluminium
		Conduites pour liquides et gaz peu corrosifs	cuivre désoxydulé
		Evaporateurs, colonnes de distillation	cuivre, laitons, bronzes
		Condenseurs, échangeurs de température	laiton à l'aluminium cupro-nickel laiton amirauté
		Tuyauteries pour réfrigérateurs	cuivre désoxydulé
		Robinetterie industrielle, vannes, arbres et pièces de pompes	cupro-aluminium
		Rivets, boulons, vis...	cupro-nickel laiton aluminium cupro-aluminium cuivre au nickel silicium
	Industrie Pétrolière	Pièces chaudronnées	cuivre, laiton 85/15 cupro-aluminium cupro-nickel
		Condenseurs, échangeurs de température	laiton à l'aluminium cupro-nickel laiton amirauté
		Réchauffeurs	laiton à l'aluminium cupro-aluminium cuivre
INDUSTRIES ALIMENTAIRES 	Brasserie Distillerie Conserverie Confiturerie Confiserie Sucrerie Malterie	Cuves de fermentation Colonnes de distillation Récipients de cuisson Evaporateurs, appareils de concentration Ecumoires Circuits de réfrigération	cuivre laitons
		Convertisseurs (pour le glucose)	bronze phosphoreux

./.

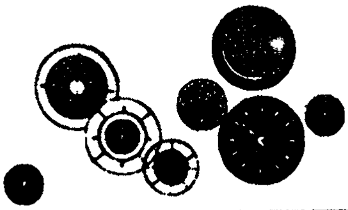
Appendix B

INDUSTRIES ALIMENTAIRES (SUITE)		**Echangeurs de température, condenseurs**	**laiton à l'aluminium cupro-nickel laiton amirauté**
		Tamis métalliques	**bronze phosphoreux laitons**
	LAITERIE	**Récipients de pasteurisation**	**cuivre étamé**
		Echangeurs de température	**cuivre étamé**
		Evaporateurs (lait concentré, condensé, en poudre)	**cuivre**
INDUSTRIES TEXTILES	**MATÉRIEL ET APPAREILLAGE**	**Plaques de flambage pour le coton**	**cuivre**
		Cylindres de séchage chauffés à la vapeur	**cuivre laitons, cuivre au béryllium**
		Rouleaux, calandres d'essoreuses	**cuivre**
		Cylindres de repassage	**cuivre**
		Récipients pour bains de coloration	**cuivre**
		Bobines, flasques	**laiton 70/30**
		Pots de centrifugation pour fils	
	FABRICATION DES TEXTILES ARTIFICIELS	**Toiles métalliques (tamis)**	**bronze phosphoreux laiton 70/30 ou 85/15**
		Filières pour soie artificielle	**cuivre**
INDUSTRIE PAPETIERE	**MATÉRIEL**	**Tuyauteries pour pâte à papier et solutions**	**laiton 70/30 laiton à l'aluminium cupro-nickel cupro-silicium**
IMPRESSION	**IMPRESSION SUR PAPIER TEXTILES**	**Rouleaux et plateaux d'impression sur papier et sur textiles**	**cuivre (gréné ultérieurement)**
		Pièces forgées ou matricées devant résister à la corrosion	**cupro-aluminium cupro-silicium**
		Clichés pour « offset » Clichés pour « typo »	**cuivre**
		Encres métalliques	**poudres et pâtes de bronze-cuivre, laiton**
INDUSTRIES DE PRECISION	**HORLOGERIE**	**Platines et ponts Barillets Roues d'horlogerie**	**laiton horlogerie, laiton de décolletage rapide**



./.

Appendix B

INDUSTRIES DE PRECISION 		Cadrans, aiguilles	
		Boîtiers	laitons 67/33, 64/36
		Pièces décolletées	
	Optique et Appareils de Mesure	Microscopes, jumelles, appareils de précision, de projection (cinéma)	laiton, maillechorts (chromés et nickelés ultérieurement)
		Boussoles	laitons 70/30, 65/35
INDUSTRIES DIVERSES	Industrie Atomique	Echangeurs thermiques	cuivre
		Condenseurs	laiton à l'aluminium cupro-nickel laiton amirauté
	Travaux Publics	Travaux en béton : joints de dilatation	cuivre
	Mines et Carrières	Outils non étincelants	bronze au béryllium cupro-aluminium
		Câbles électriques	cuivre bronzes téléphoniques
	Mécanique	Tuyauteries de circulation d'eau, refroidisseurs sur différentes machines	cuivre laitons
	Agriculture	Pièces de machines agricoles	cuivre laitons
		Robinetterie, appareillages pour pulvérisateurs	cuivre, laitons, cupro-aluminium
	Bijouterie	Bijouterie fantaisie	laitons 95/5, 85/15, 80/20 cupro-aluminium 95/5
		Articles de Paris : étuis à rouge, boîtes à poudre	laitons 90/10, 85/15
	Monnaies	Monnaies, médailles, plaques, jetons	laiton 95/5 cupro-aluminium cupro-nickel
	Articles Métalliques	Boutons, agrafes, fermetures à glissières...	laiton tombac laitons, maillechorts
		Toiles métalliques	laitons 67/33, 72/28 bronze phosphoreux bronze à l'étain
	Musique	« Cuivres »	laitons 80/20, 70/30
	Sports	Crosses de golf	laitons
	Divers	Extincteurs Coffres-forts	laiton 65/35 bronze au béryllium

./.

Appendix C

EURO Standards

EUROPEAN CLASSIFICATION FOR NON-FERROUS METAL SCRAP (E U R O)

(Prepared in collaboration with the consumers of non-ferrous Scrap metal in Europe and various national and international Associations included in which are the Organisation of European Aluminium-Smelters (OEA), the International Wrought Copper Council and the Fédération Internationale des Associations de Négociants en Acier, Tubes et Métaux (FIANATM).)

Definitions

Furnace Chargeable:	Material of maximum dimensions 100 × 50 × 40 cm, weights of more than 200 kg only according to special agreement.
Crucible Chargeable:	Material of maximum dimensions 35 × 25 × 15 cm, weight max. 50 kg.
Small Pieces:	Material less than 10 × 10 × 0,2 mm.
„Fines":	Material through 20 mesh sieve (0,84 mm aperture).
Foreign Substances:	Material, whether metallic or nonmetallic, which does not fall within the specification.
Coated Material:	Material with any kind of coating including paint, varnish, print, plastics, anodic oxide and other metals however applied, including Cr, Ni, Sn, Pb, Al etc. Includes also material with adhering metal: e. g. solder.
Plastics:	Unless otherwise agreed the scrap has to be generally free of plastics.
Compacted Material:	Unless otherwise agreed the scrap shall not be delivered in hydraulically compressed bales or briquettes.

./.

I. COPPER

EURO I/1 "cabin"

Bright copper wire

Clean, unburnt, bright, unalloyed copper wire with a minimum diameter of 1 mm, also copper bus bars and collector bars.

Free of coated material and other substances.
Furnace chargeable, unless otherwise specified.

EURO I/2 "cabro"

New copper sheet cuttings

New unalloyed copper sheet cuttings with a minimum thickness of 0,2 mm.

Free of coated material and other foreign substances.

Tol.: 10 % clean, homogenous copper punchings.
Furnace chargeable, unless otherwise specified.

EURO I/3 "cadet"

Unalloyed copper wire

Unalloyed copper wire with a minimum diameter of 1 mm.

Free of coated material and other foreign substances, also wire that is brittle or wire resulting from burning of PVC-cables.

EURO I/4 "calyx"

Unalloyed copper wire scrap minimum diameter 0,15 mm

Unalloyed copper wire with a minimum diameter of 0,15 mm.

Free of coated material and other foreign substances, also wire that is brittle or wire resulting from burning of PVC-cables.

EURO I/5 "caper"

Mixed copper wire scrap

Unalloyed copper wire with max. 15 % tinned, mixed-tinned, soldered wire.

Free of hair wire or wire, which is brittle or wire resulting from burning of PVC-cables.

EURO I/6 "cerro"

Heavy-copper

Copper scrap with a minimum thickness of 1 mm.

Tol.: Max. 1 % nonmetallic foreign substances.
Crucible chargeable.

EURO I/7 "cider"

Mixed copper scrap

Mixed, coated and/or uncoated copper scrap with a minimum thickness of 0,5 mm, wire minimum 0,15 mm.

Free of wire, which is brittle or oxidised by burning or wire resulting from burning of PVC-cables.

Tol.: Max. 1 % foreign substances.
Furnace chargeable.

EURO I/8 "colon"

Light-copper

Pieces of tubes and sheets, mixed copper wire including hair wire, copper-utensils of all kinds, minimum 88 % Cu.

Free of electrotype shells, radiators and galvanos.

Tol.: Max. 3 % other foreign substances.

./.

EURO I/9 **Other copper scrap**

"coral" Sold on basis of copper content with a minimum of 85 % Cu.
In case the copper content is between 80—85 %, the buyer cannot reject the delivery, but the price has to be reduced by negotiation, variations to be agreed beforehand.
Furnace chargeable.

EURO I/10 **Copper turnings**

"cycle" Unalloyed copper turnings arising from any process, but free of grindings, fillings and planings.
Tol.: Max. 3 % iron, grease and moisture.

All types not specified above, such as trolley wire, telephone wire and firebox with and/or without stay bolts, also Cu-Te, Cu-Al, Cu-Mn, Cu-Be, must be sold by special arrangement.

Radiators

EURO III/18 Brass Radiators

"bully" Unsweated brass radiators or parts of radiators.
Free from Aluminium and free iron.

EURO III/19 Composite Radiators

"burim" Unsweated radiators or radiator parts, consisting of Copper and Brass, minimum content 67 % Cu and 3 % Sn in the average of the parcel.
Free from Aluminium and free iron. To be stated, whether with or without tank.

EURO III/20 Radiators-Copper

"busby" Unsweated radiators or Radiator Parts, consisting completely of copper. Copper Water Tanks are accepted.

P.S. Material, consisting partly of Euro III 18 and 20 can be sold as per Euro III 19, but have to be specified beforehand according to conditions.

Other cuttings and borings, such as brass with manganese, brass with aluminium, brass with silicium etc. should be sold as per sample or analysis or according to specially agreed terms.

II. RED BRASS AND BRONZE

EURO II/1 "racer"
Commercial Quality Red Brass Cuttings
Pieces with a minimum content of 85 % Cu and Sn. Sn minimum content 4 %, maximum content of Lead 6 %. The contents mentioned refer to the average of the parcel.
Free of pieces of other alloys.
Tol.: Max. 1 % free Iron. Crucible.

EURO II/2 "radar"
Cuttings from Red Brass Taps
Pieces, containing minimum 78 % Cu plus Sn. Minimum content 3 % Sn.
Free of Leaded Bronze, aluminium alloys and manganese alloys. Tol.: Maximum 1 % free Iron. Crucible.

EURO II/3 "rally"
Red Brass Turnings
Turnings and Millings from Red Brass with a minimum content of 70 % Cu and 3 % Sn.
Free of Swarf or Filing and Grinding operations. Sale as per sample and/or Analysis.

EURO II/4 "rebel"
Pure Bronze Sieves
Sieves out of Copper-Tin-Bronze, smooth and in coils with wire of different gauges.
Tol.: 2 % non-metallic components. In such cases where the weight of the non-metallic components exceed 2 %, an appropriate deduction in weight will take place.

EURO II/5 "river"
Mixed Bronze Sieves
Sieves, smooth and in coils and /or perhaps in packets, with wire of different gauges, the weft however will consist of tombac.
Minimum content 88 % Cu plus Sn, thereof Sn min. 3 %.
Tol.: 1 % Lead, 2 % non-metallic components. In such cases where the weight of the non-metallic components exceed 2 %, an appropriate deduction in weight will take place.

Other bronze cuttings and turnings, such as phosphor containing bronze, lead bronze, silicium bronze etc. are to be sold as per sample or analyse.

II. BRASS

EURO III/1 **New unleaded Sheet Cuttings**
"babel" Production cuttings from brass sheets and strips out of lead-free alloys with a maximum of 10 % homogeneous punchings. Cu-content has to be minimum 63 %.
Free from coated material and other foreign matter.
Furnace chargeable.

EURO III/2 **New leaded Brass Sheet Cuttings**
"babis" Production cuttings from Brass Sheets and Strips out of lead-containing alloys, with a maximum of 10 % homogeneous punchings. The Cu- and Pb-content has to be stated.
Free from coated material and other foreign matter.
Furnace chargeable.

EURO III/3 **Brass Rodends**
"bacon" Brass Rodends with a minimum content of 57 % Cu, max. 0,3 % Sn, max. 0,2 % Fe in the alloy.
Free of Rods out of Special Brass and coated material.
Furnace chargeable.

EURO III/4 **Brass Rodborings**
"bacus" Turnings and Millings from brass rods, free from Grindings, Filings and Planings as well as Borings of Special Brass. The parcel must contain minimum 57 % Cu, max. 0,3 % Sn, max. 0,1 % Al and max. 0,2 % Fe in the alloy.
Tol.: Max. 4 % moisture, grease and free iron, however max. 1 % magnetic iron. Excess moisture, grease and free iron have to be deducted by weight.

EURO III/5 **Brass Turnings**
"bamel" Brass Turnings, Millings and Borings of various types. Attention is drawn to the post script regarding special alloys.
Free from Grindings.
Tol.: Max. 4 % iron, moisture and grease, but max. 1 % free iron. Recommended to sell the material as per sample or analysis.

EURO III/6 **Brass Shell Cases without Primers**
"baron" Clean Brass Shell Cases without primers, not exploded or muffled, alloy 70/30. Any other alloy has to be specified.
Free from primers and foreign matter, especially explosives. Diameter minimum 37 mm.

EURO III/7 **Brass Shell Cases with Primers**
"basin" Clean, fired Bress Shell Cases with primers, which may be muffled, alloy 70/30. Any other alloy has to be specified.
Free from foreign matter, especially explosives. Diameter minimum 37 mm.

Ms 1

./.

EURO III/8 Fired Brass Cartridge Cases

"basty" Clean, fired Brass Cartridge Cases, various types, not muffled, excluding Aluminium alloyed cases.

Free from foreign matter, especially explosives. Diameter minimum 6 mm.

EURO III/9 Muffled Brass Cartridge Cases

"belly" Clean, muffled Brass Cartridge Cases of various types. Broken Cartridges subject to special agreement.

Free from bullets, iron and any other foreign matter.

EURO III/10 Brass Primers and Primer Caps

"berto" Brass Primers and Primer Caps muffled and/or fired.

Free from iron and other foreign matter.

EURO III/11 Scrap Brass Tubes

"bezel" Scrap Brass Tubes, free of aluminium and tin in the alloy.

Free from plated material.

Tol.: Max. 2 % sediment.

EURO III/12 Brass Scrap Condenser Tubes with Tin or Aluminium

"bingo" Brass Scrap Condenser Tubes alloyed with Tin or Aluminium. The alloy has to be specified.

Free from plated material.

Tol.: Max. 2 % sediment.

EURO III/13 Mixed Scrap Brass Condenser Tubes

"bison" Mixed Scrap Brass Condenser Tubes.

Free from plated material.

Tol.: Max. 2 % sediment.

EURO III/14 Old Rolled Brass

"blade" Old Rolled Brass Scrap and Scrap Brass Tubes conforming to EURO III/11, uncorroded, free of condenser tubes.
In furnace sizes.

EURO III/15 Heavy Brass Scrap

"bogie" Heavy Brass Scrap various types, containing maximum 15 % metal-plated and/or sweated material.

Free from Aluminium and/or Manganese alloys, Lead- and solder adherements, radiators and radiator parts as well as iron and other foreign material. Crucible.

EURO III/16 Mixed Brass Scrap

"bravo" Brass Scrap, containing about 40 % Heavy Brass.

Free from aluminium and/or manganese alloys, radiators and radiator parts, as well as lead and solder adherements.

Tol.: Max. 1 % free iron. In furnace sizes.

Ms 2

EURO III/17 Light Brass Scrap

"bulbo" Light Brass Scrap, plated and non-plated, free from lead filled material and gaskets.

Free from aluminium and/or manganese alloys.

Tol.: Max. 3 % iron. Furnace chargeable.

Appendix D

NARI CIRCULAR NF-77

Standard Classifications

For

Nonferrous Scrap Metals

EFFECTIVE MAY 1, 1977

National Association of Recycling Industries, Inc.
330 Madison Avenue, New York City, N. Y. 10017

./.

Apple 1.—DELIVERY

a. Delivery of more or less on the specified quantity up to 1¼ per cent is permissible.

b. If the term "about" is used, it is understood that 5 per cent more or less of the quantity may be delivered.

c. Should the seller fail to make deliveries as specified in the contract the purchaser has the option of cancelling all of the uncompleted deliveries or holding the seller for whatever damages the purchaser may sustain through failure to deliver and if unable to agree on the amount of damages, an Arbitration Committee of the National Association of Recycling Industries, Inc. may be appointed for this purpose, to determine the amount of such damages.

d. In the event that buyer should claim the goods, delivered on a contract, are not up to the proper standard, and the seller claims that they are a proper delivery, the dispute may be referred to an Arbitration Committee of the National Association of Recycling Industries, Inc. to be appointed for that purpose.

e. A carload, unless otherwise designated, shall consist of the weight governing the minimum carload weight at the lowest carload rate of freight in the territory in which the seller is located. If destination of material requires a greater carload minimum weight, buyer must so specify.

f. A ton shall be understood to be 2,000 pounds unless otherwise specified. On material purchased for export shipment a ton shall be specified as either a Gross Ton of 2240 lbs., or a Metric Ton of 2204.6 lbs.

g. If, through embargo, a delivery cannot be made at the time specified, the contract shall remain valid, and shall be completed immediately on the lifting of the embargo, and terms of said contract shall not be changed. When shipments for export for which space has been engaged have been delivered or tendered to a steamship for forwarding and through inadequacy of cargo space the steamship cannot accept the shipment, or where steamer is delayed in sailing beyond its scheduled time, shipment on the next steamer from the port of shipment shall be deemed a compliance with the contract as to time of shipment.

h. In case of a difference in weight and the seller is not willing to accept buyer's weights, a sworn public weigher shall be employed and the party most in error must pay the costs of handling and reweighing.

i. When material is such that it can be sorted or segregated, consignee cannot reject the entire shipment if the percentage of the rejection does not exceed 10%. The rejected material must be located in such a manner that it can be readily sorted or segregated. The disposition of the rejected material, including the cost of sorting, packaging, and reloading to be subject to negotiation between buyer and seller. Seller is responsible for freight costs on rejected material. Replacement of, or financial adjustment for rejected material, will be subject to mutual agreement between buyer and seller.

Upon request of the shipper, rejections shall be returnable to the seller on domestic shipments within 10 days and on foreign shipments within 30 days from the time notice of rejection is received by them and provided government regulations permit such return.

j. PACKAGES

Shall be good strong packages suitable for shipment and each package shall be plainly marked with separate shipping marks and numbers and with the gross and tare weights so that the packages may reach their destination and their weights can be easily checked.

Barley 2.—No. 1 COPPER WIRE

Shall consist of No. 1 bare, uncoated, unalloyed copper wire, not smaller than No. 16 B & S wire gauge. Green copper wire and hydraulically compacted material to be subject to agreement between buyer and seller.

Berry 3.—No. 1 COPPER WIRE

Shall consist of clean, untinned, uncoated, unalloyed copper wire and cable, not smaller than No. 16 B & S wire gauge, free of burnt wire which is brittle. Hydraulically briquetted copper subject to agreement.

Birch 4.—No. 2 COPPER WIRE

Shall consist of miscellaneous, unalloyed copper wire having a nominal 96% copper content (minimum 94%) as determined by electrolytic assay. Should be free of the following: Excessively leaded, tinned, soldered copper wire; brass and bronze wire; excessive oil content, iron, and non-metallics; copper wire from burning, containing insulation; hair wire; burnt wire which is brittle; and should be reasonably free of ash. Hydraulically briquetted copper wire subject to agreement.

Candy 5.—No. 1 HEAVY COPPER

Shall consist of clean, unalloyed, uncoated copper clippings, punchings, bus bars, commutator segments, and wire not less than 1/16 of an inch thick, free of burnt wire which is brittle; but may include clean copper tubing. Hydraulically briquetted copper subject to agreement.

Cliff 6.—No. 2 COPPER

Shall consist of miscellaneous, unalloyed copper scrap having a nominal 96% copper content (minimum 94%) as determined by electrolytic assay. Should be free of the following: Excessively leaded, tinned, soldered copper scrap; brasses and bronzes; excessive oil content, iron and non-metallics; copper tubing with other than copper connections or with sediment; copper wire from burning, containing insulation; hair wire; burnt wire which is brittle; and should be reasonably free of ash. Hydraulically briquetted copper subject to agreement.

Clove 7.—No. 1 COPPER WIRE NODULES

Shall consist of No. 1 bare, uncoated, unalloyed copper wire scrap nodules, chopped or shredded, free of tin, lead, zinc, aluminum, iron, other metallic impurities, insulation, and other foreign contamination. Minimum copper 99%. Gauge smaller than No. 16 B & S wire and hydraulically compacted material subject to agreement between buyer and seller.

Cobra 8.—No. 2 COPPER WIRE NODULES

Shall consist of No. 2 unalloyed copper wire scrap nodules, chopped or shredded, minimum 97% copper. Shall be free of the following: aluminum and excessive insulation. Other impurities, maximum 1% each, with total metal impurities not to exceed 2%. Hydraulically compacted material subject to agreement between buyer and seller.

Dream 9.—LIGHT COPPER

Shall consist of miscellaneous, unalloyed copper scrap having a nominal 92% copper content (minimum 88%) as determined by electrolytic assay and shall consist of sheet copper, gutters, downspouts, kettles, boilers, and similar scrap. Should be free of the following: Burnt hair wire; copper clad; plating racks; grindings; copper wire from burning, containing insulation; radiators; fire extinguishers; refrigerator units; electrotype shells; screening; excessively leaded, tinned, soldered scrap; brasses and bronzes; excessive oil, iron and non-metallics; and should be reasonably free of ash. Hydraulically briquetted copper subject to agreement. Any items excluded in this grade are also excluded in the higher grades above.

Drink 10.—REFINERY BRASS

Shall contain a minimum of 61.3% copper and maximum 5% iron and to consist of brass and bronze solids and turnings, and alloyed and contaminated copper scrap. Shall be free of insulated wire, grindings, electrotype shells and non-metallics. Hydraulically briquetted material subject to agreement.

./.

Code Word	Item

Drove 11.—COPPER-BEARING SCRAP
Shall consist of miscellaneous copper-containing skimmings, grindings, ashes, irony brass and copper, residues and slags. Free of insulated wires; copper chlorides; unprepared tangled material; large motors; pyrophoric material; asbestos brake linings; furnace bottoms; high lead materials; graphite crucibles; and noxious and explosive materials. Fine powdered material by agreement. Hydraulically briquetted material subject to agreement.

Ebony 12.—COMPOSITION OR RED BRASS
Shall consist of red brass scrap, valves, machinery bearings and other machinery parts, including miscellaneous castings made of copper, tin, zinc, and/or lead. Should be free of semi-red brass castings (78% to 81% copper); railroad car boxes and other similar high-lead alloys; cocks and faucets;closed water meters; gates; pot pieces; ingots and burned brass; aluminum, silicon, and manganese bronzes; iron and non-metallics. No piece to measure more than 12" over any one part or weigh over 100 lbs.

Enerv 13.—RED BRASS COMPOSITION TURNINGS
Shall consist of turnings from red brass composition material and should be sold subject to sample or analysis.

Eider 14.—GENUINE BABBITT-LINED BRASS BUSHINGS
Shall consist of red brass bushings and bearings from automobiles and other machinery, shall contain not less than 12% high tin base babbitt, and shall be free of iron-backed bearings.

Eland 15.—HIGH GRADE — LOW LEAD BRONZE SOLIDS
It is recommended these materials be sold by analysis.

Elbow 16.—BRONZE PAPER MILL WIRE CLOTH
Shall consist of clean genuine Fourdrinier wire cloth and screen having a minimum copper content of 87%, minimum tin content of 3%, and a maximum lead content of 1%, free of stainless steel and Monel metal stranding.

Elias 17.—HIGH LEAD BRONZE SOLIDS AND BORINGS
It is recommended that these materials be sold on sample or analysis.

Engel 18.—MACHINERY OR HARD BRASS SOLIDS
Shall have a copper content of not less than 75%, a tin content of not less than 6%, and a lead content of not less than 6%—nor more than 11%, and total impurities, exclusive of zinc, antimony, and nickel of not more than 0.75%; the antimony content not to exceed 0.50%. Shall be free of lined and unlined standard red carboxes.

Erin 19.—MACHINERY OR HARD BRASS BORINGS
Shall have a copper content of not less than 75%, a tin content of not less than 6%, and a lead content of not less than 6%—nor more than 11%, and the total impurities, exclusive of zinc, antimony, and nickel of not more than 0.75%; the antimony content not to exceed 0.50%.

Fence 20.—UNLINED STANDARD RED CAR BOXES (CLEAN JOURNALS)
Shall consist of standard unlined and/or sweated railroad boxes and unlined and/or sweated car journal bearings, free of yellow boxes and iron-backed boxes.

Ferry 21.—LINED STANDARD RED CAR BOXES (LINED JOURNALS)
Shall consist of standard babbitt-lined railroad boxes and/or babbitt-lined car journal bearings, free of yellow boxes and iron-backed boxes.

Grape 22.—COCKS AND FAUCETS
Shall consist of mixed clean red and yellow brass, including chrome or nickel-plated, free of gas cocks, beer faucets, and aluminum and zinc base die cast material, and to contain a minimum of 35% semi-red.

Code Word	Item

Greet 23.—MIXED BRASS SCREENS
To consist of clean mixed-copper, brass and bronze screens, and to be free of excessively dirty and painted material.

Honey 24.—YELLOW BRASS SCRAP
Shall consist of brass castings, rolled brass, rod brass, tubing and miscellaneous yellow brasses, including plated brass. Must be free of manganese-bronze, aluminum-bronze, unsweated radiators or radiator parts, iron, excessively dirty and corroded materials.

Ivory 25.—YELLOW BRASS CASTINGS
Shall consist of yellow brass castings in crucible shape, no piece to measure more than 12 inches over any one part; and shall be free of brass forgings, silicon bronze, aluminum bronze and manganese bronze, and not to contain more than 15% nickel plated material.

Knife 26.—OLD ROLLED BRASS
Shall consist of old pieces of yellow sheet brass and yellow light tubing brass, free from solder, tinned and nickel plated material, iron, paint and corrosion, rod brass and condenser tubes.

Label 27.—NEW BRASS CLIPPINGS
Shall consist of the cuttings of new unleaded yellow brass sheet or plate, to be clean and free from foreign substances and not to contain more than 10% of clean brass punchings under ¼ inch. To be free of Muntz metal and naval brass.

Lace 28.—BRASS SHELL CASES WITHOUT PRIMERS
Shall consist of clean fired 70/30 brass shell cases free of primers and any other foreign material.

Lady 29.—BRASS SHELL CASES WITH PRIMERS
Shall consist of clean fired 70/30 brass shell cases containing the brass primers and which contain no other foreign material.

Lake 30.—BRASS SMALL ARMS AND RIFLE SHELLS, CLEAN FIRED
Shall consist of clean fired 70/30 brass shells free of bullets, iron and any other foreign material.

Lamb 31.—BRASS SMALL ARMS AND RIFLE SHELLS, CLEAN MUFFLED (POPPED)
Shall consist of clean muffled (popped) 70/30 brass shells free of bullets, iron and any other foreign material.

Lark 32.—YELLOW BRASS PRIMER
Shall consist of clean yellow brass primers, burnt or unburnt. Free of iron, excessive dirt, corrosion and any other foreign material.

Maize 33.—MIXED NEW NICKEL SILVER CLIPPINGS
Shall consist of one or more nickel silver alloys and the range of nickel content to be specified, free of chrome or any other plating material. Leaded nickel silver clippings should be packed and sold separately. Not to contain more than 10% of clean punchings under ¼ inch.

Major 34.—NEW NICKEL SILVER CLIPPINGS AND SOLIDS
Shall consist of new, clean nickel silver clippings, plate, rod and forgings, and other rolled shapes, free of chrome or any other plating material. Must be sold on nickel content specifications such as 10% — 12% — 15% — 18% — 20%. Leaded nickel silver clippings should be packed and sold separately. A description as to its physical characteristics should be made in offering all nickel silver material.

Malar 35.—NEW SEGREGATED NICKEL SILVER CLIPPINGS
Shall consist of one specified nickel silver alloy. Not to contain more than 10% of clean punchings under ¼ inch.

./.

CODE WORD ITEM

Malic 36.—OLD NICKEL SILVER
Shall consist of old nickel silver sheet, pipe, rod, tubes, wire, screen, soldered or unsoldered. Must not be trimmed seams alone and it is also to be free of foreign substances, iron rimmed material or other metals.

Melon 37.—BRASS PIPE
Shall consist of brass pipe free of plated and soldered materials or pipes with cast brass connections. To be sound, clean pipes free of sediment and condenser tubes.

Naggy 38.—NICKEL SILVER CASTINGS
To be packed and sold separately.

Niece 39.—NICKEL SILVER TURNINGS
To be sold by sample or analysis.

Night 40.—YELLOW BRASS ROD TURNINGS
Shall consist of strictly rod turnings, free of aluminum, manganese, composition, Tobin and Muntz metal turnings; not to contain over 3% free iron, oil or other moisture; to be free of grindings and babbitts; to contain not more than 0.30% tin and not more than 0.15% alloyed iron.

Noble 41.—NEW YELLOW BRASS ROD ENDS
Shall consist of new, clean rod ends from free turning brass rods or forging rods, not to contain more than 0.30% tin and not more than 0.15% alloyed iron. To be free of Muntz metal and naval brass or any other alloys. To be in pieces not larger than 12" and free of foreign matter.

Nomad 42.—YELLOW BRASS TURNINGS
Shall consist of yellow brass turnings, free of aluminum, manganese and composition turnings; not to contain over 3% of free iron, oil or other moisture; to be free of grindings and babbitts. To avoid dispute, to be sold subject to sample or analysis.

Ocean 43.—MIXED UNSWEATED AUTO RADIATORS
Shall consist of mixed automobile radiators, to be free of aluminum radiators, and iron finned radiators. All radiators to be subject to deduction of actual iron. The tonnage specification should cover the gross weight of the radiators, unless otherwise specified.

Pales 44.—ADMIRALTY BRASS CONDENSER TUBES
Shall consist of clean sound Admiralty condenser tubing which may be plated or unplated, free of nickel alloy, aluminum alloy, and corroded material.

Pallu 45.—ALUMINUM BRASS CONDENSER TUBES
Shall consist of clean sound condenser tubing which may be plated or unplated, free of nickel alloy and corroded material.

Palms 46.—MUNTZ METAL TUBES
Shall consist of clean sound Muntz metal tubing which may be plated or unplated, free of nickel alloy, aluminum alloy, and corroded material.

Pants 47.—PLATED ROLLED BRASS
Shall consist of plated brass sheet, pipe, tubing, and reflectors, free of soldered, tinned, corroded, and aluminum painted material, Muntz metal and Admiralty tubing, and material with cast brass connections.

Parch 48.—MANGANESE BRONZE SOLIDS
Shall have a copper content of not less than 55%, a lead content of not more than 1%, and shall be free of aluminum bronze and silicon bronze.

Racks 49.—SCRAP LEAD — SOFT
Shall consist of clean soft scrap lead, free of all foreign materials such as drosses, battery lead, lead covered cable, hard lead, collapsible tubes, foil, type metals, zinc, iron and brass fittings, dirty chemical lead. Free of radioactive materials.

CODE WORD ITEM

Radio 50.—MIXED HARD/SOFT SCRAP LEAD
Shall consist of clean lead solids, free of foreign materials, such as drosses, battery lead, lead covered cable, collapsible tubes, type metals, zinc, iron and brass fittings, dirty chemical lead. Free of radioactive materials.

Rails 51.—BATTERY PLATES
If cells (plates, separators, and lugs) or battery plates, must be reasonably free of rubber. May be bought and sold by assay or as agreed between buyer and seller.

Rains 52.—DRAINED WHOLE BATTERIES
Batteries to be free of liquid and extraneous material content. Aircraft (aluminum or steel cased) and other special batteries subject to special agreement.

Rakes 53.—BATTERY LUGS
Shall be free from battery plates, rubber and foreign material. A minimum of 97% metallic content is required.

Ranks 54.—PEWTER
Shall consist of tableware and soda-fountain boxes but should contain a minimum of 84% tin. Siphon tops to be accounted for separately. Material must be free of brass, zinc, and other foreign metals.

Ranch 55.—BLOCK TIN
Block Tin must assay minimum of 98% tin, and to be free of liquids, solder, and brass connections, pewter, pumps, pot pieces, dirt.

Raves 56.—HIGH TIN BASE BABBITT
Shall contain a minimum of 78% tin and be free of brassy or zincy metals.

Relay 57.—LEAD COVERED COPPER CABLE
Free of armored covered cable, and foreign material.

Rents 58.—LEAD DROSS
Should be clean and reasonably free of foreign matter, iron, dirt, harmful chemicals or other metals. Free of radioactive materials. Assay basis, or as agreed between buyer and seller. Other metals present such as antimony, tin, etc. to be accounted for as agreed between buyer and seller.

Ropes 59.—LEAD WEIGHTS
May consist of lead balances with or without iron, as may be specified. Free of foreign materials.

Roses 60.—MIXED COMMON BABBITT
Shall consist of lead base bearing metal containing not less than 8% tin, free from Allens metal, ornamental, antimonial and type metal. Must be free from all zincy and excessive copper in the alloy.

Saves 61.—OLD ZINC DIE CAST SCRAP
Shall consist of miscellaneous old zinc base die castings, with or without iron and other foreign attachments. Must be free of borings, turnings, dross pieces, chunks, melted pieces and skimmings. All unmeltables, dirt, foreign attachments, and volatile substances (such as rubber, cork, plastic, grease, etc.) are deductible. Material containing in excess of 30% iron will not constitute good delivery.

Scabs 62.—NEW ZINC DIE CAST SCRAP
Shall consist of new or unused, clean, zinc base die castings. Castings to be unplated, unpainted, and free from corrosion.

Scope 63.—NEW PLATED ZINC DIE CAST SCRAP
Shall consist of new or unused clean, plated zinc base die castings, free from corrosion.

Scoot 64.—ZINC DIE CAST AUTOMOTIVE GRILLES
Shall consist of clean, old or used zinc base die cast automotive grilles, free from soldered material. All foreign attachments and extraneous material are deductible.

Code Word Item

Score 65.—OLD SCRAP ZINC
Shall consist of clean dry scrap zinc, such as sheets, jar lids, clean unalloyed castings and anti-corrosion plates. Borings and turnings are not acceptable. Material must not be excessively corroded or oxidized. All foreign attachments and extraneous materials are deductible.

Screen 66.—NEW ZINC CLIPPINGS
Shall consist of any new pure zinc sheets or stampings free from corrosion. To contain no foreign material or attachments. Printers zinc, such as engravers zinc, lithograph sheets and addressograph plates subject to special arrangements. Printers zinc to be free of routings.

Scull 67.—ZINC DIE CAST SLABS OR PIGS
Shall consist of melted zinc base die cast materials, in smooth clean solid slabs or pigs. Material to be free from drosses and to contain a minimum zinc content of 90%. To contain a maximum of 0.1% nickel and maximum of 1% lead. Blocks are acceptable upon mutual agreement.

Scribe 68.—CRUSHED CLEAN SORTED FRAGMENTIZERS DIE CAST SCRAP, AS PRODUCED FROM AUTOMOBILE FRAGMENTIZERS
To be clean, free of dirt, oil, glass, rubber, and trash. To contain a maximum of 5% unmeltables such as free iron, copper, aluminum and other metals.

Scroll 69.—UNSORTED FRAGMENTIZERS DIE CAST SCRAP
Material to contain 65% zinc-bearing scrap. Trash, dirt, glass, rubber, oil, iron and other unmeltables not to exceed 5%. Quality to be determined by mutual agreement between buyer and seller.

Scrub 70.—HOT DIP GALVANIZERS SLAB ZINC DROSS (Batch Process)
Shall consist only of galvanizers unsweated zinc dross in slab form from hot dip galvanizing (Batch Process) with a minimum zinc content of 92% and shall be free of skimmings and tramp iron. Broken pieces under 2" in diameter shall not exceed 10% of the weight of each shipment. Slabs shall not weigh over 100 pounds each. Heavier pieces acceptable upon mutual agreement between buyer and seller. Material from continuous galvanizing operation is not acceptable. Blocks are acceptable upon mutual agreement.

Seal 71.—CONTINUOUS LINE GALVANIZING SLAB ZINC TOP DROSS
Shall consist of unsweated zinc dross removed from the top of a continuous line galvanizing bath, in slab form not weighing in excess of 100 pounds each, with a minimum zinc content of 90%. Heavier pieces acceptable upon mutual agreement between buyer and seller. Shall be free of skimmings. Broken pieces under 2" in diameter shall not exceed 10% of the weight of each shipment.

Seam 72.—CONTINUOUS LINE GALVANIZING SLAB ZINC BOTTOM DROSS
Shall consist of unsweated zinc dross removed from the bottom of a continuous line galvanizing bath, in slab form not weighing in excess of 100 pounds each, with a minimum zinc content of 92%. Heavier pieces acceptable upon mutual agreement between buyer and seller. Shall be free of skimmings. Broken pieces under 2" in diameter shall not exceed 10% of the weight of each shipment.

Shelf 73.—PRIME ZINC DIE CAST DROSS
Shall consist of metal skimmed from the top of pot of molten zinc die cast metal. Must be unsweated, unfluxed, shiny, smooth, metallic and free from corrosion or oxidation. Should be poured in molds or in small mounds weighing not over 75 pounds each. Zinc shall be minimum of 85%.

ANY OTHER GRADES OF ZINC-BEARING MATERIALS NOT MENTIONED ARE SUBJECT TO SPECIAL ARRANGEMENT.

Code Word Item

Table 74.—NEW PURE ALUMINUM CLIPPINGS
Shall consist of new, clean, unalloyed sheet, clippings and/or aluminum sheet cuttings, free from oil and grease, foil and any other foreign substances and from punchings less than ½" in size.

Taboo 75.—MIXED LOW COPPER ALUMINUM CLIPPINGS AND SOLIDS
Shall consist of new, clean, uncoated and unpainted low copper aluminum scrap of two or more alloys and to be free of 7000 series, foil, hair wire, wire screen, dirt, and other foreign substances. Grease and oil not to total more than 1%. Also free from punchings less than ½" in size. New can stock subject to arrangement between buyer and seller.

Tabor 76.—MIXED OLD ALLOY SHEET ALUMINUM
Shall consist of clean old alloy sheet aluminum of two or more alloys and to be free of 7000 series, foil, venetian blinds, castings, hair wire, screen wire, food or beverage containers, pie plates, dirt, and other foreign substances. Oil and grease not to total more than 1%. Up to 10% painted sidings and awnings permitted.

Taint 77.—SCRAP SHEET AND SHEET UTENSIL ALUMINUM
Shall consist of clean, unpainted old 2S or 3S aluminum sheet and sheet utensils, free from hub caps, radiator shells, airplane sheet, foil, food or beverage containers, pie plates, oil cans and bottle caps, dirt, and other foreign substances. Oil and grease not to total more than 1%.

Take 78.—NEW ALUMINUM CAN STOCK
Shall consist of new low copper aluminum can stock and clippings, clean, lithographed or not lithographed, and coated with clear lacquer but free of lids with sealers, iron, dirt and other foreign contamination. Oil not to exceed 1%.

Talc 79.—OLD CAN STOCK
Shall consist of clean old aluminum cans, decorated or clear, free of iron, dirt, liquid and/or other foreign contamination.

Tale 80.—PAINTED SIDING
Shall consist of clean, low copper aluminum siding scrap, painted one or two sides, free of iron, dirt, corrosion, fiber backing or other types of foreign contamination.

Talent 81.—COATED SCRAP
Shall consist of awnings, venetian blinds, vinyl, plastic, etc. Shall be subject to special arrangements between buyers and sellers.

Talk 82.—ALUMINUM COPPER RADIATORS
Shall consist of clean aluminum and copper radiators, and/or aluminum fins on copper tubing, free of brass tubing, iron and other foreign contamination.

Tall 83.—E. C. ALUMINUM NODULES
Shall consist of clean E. C. aluminum, chopped or shredded, free of screening, hair-wire, iron, insulation, copper and other foreign contamination. Must be free of minus 20 mesh material. Must contain 99.45% aluminum content.

Talon 84.—NEW PURE ALUMINUM WIRE AND CABLE
Shall consist of new, clean, unalloyed aluminum wire or cable free from hair wire, wire screen, iron, insulation and any other foreign substance.

Taste 85.—OLD PURE ALUMINUM WIRE AND CABLE
Shall consist of old, unalloyed aluminum wire or cable containing not over 1% free oxide or dirt and free from hair wire, wire screen, iron, insulation and any other foreign substance.

CODE WORD ITEM

Tarry 86.—ALUMINUM PISTONS

(a) Clean Aluminum Pistons
Shall consist of clean aluminum pistons to be free from struts, bushings, shafts, iron rings and any other foreign materials. Oil and grease not to exceed 2%.

(b) Aluminum Pistons with Struts
Shall consist of clean whole aluminum pistons with struts to be free from bushings, shafts, iron rings and any other foreign materials. Oil and grease not to exceed 2%.

(c) Irony Aluminum Pistons
Should be sold on recovery basis, or by special arrangements with purchaser.

Teens 87.—SEGREGATED ALUMINUM BORINGS AND TURNINGS
Shall consist of clean, uncorroded aluminum borings and turnings of one specified alloy only and subject to deductions for fines in excess of 3% through a 20 mesh screen and dirt, free iron, oil, moisture and all other foreign materials. Material containing iron in excess of 10% and/or free magnesium or stainless steel or containing highly flammable cutting compounds will not constitute good delivery.

Telic 88.—MIXED ALUMINUM BORINGS AND TURNINGS
Shall consist of clean, uncorroded aluminum borings and turnings of two or more alloys and subject to deductions for fines in excess of 3% through a 20 mesh screen and dirt, free iron, oil, moisture and all other foreign materials. Material containing iron in excess of 10% and/or free magnesium or stainless steel or containing highly flammable cutting compounds will not constitute good delivery. To avoid dispute should be sold on basis of definite maximum zinc, tin and magnesium content.

Tense 89.—MIXED ALUMINUM CASTINGS
Shall consist of all clean aluminum castings which may contain auto and airplane castings but no ingots, and to be free of iron, dirt, brass, babbitt and any other foreign materials. Oil and grease not to total more than 2%.

Tepid 90.—WRECKED AIRPLANE SHEET ALUMINUM
Should be sold on recovery basis or by special arrangements with purchaser.

Terse 91.—NEW ALUMINUM FOIL
Shall consist of clean, new, pure, uncoated, unalloyed aluminum foil, free from anodized foil, radar foil and chaff, paper, plastics, or any other foreign materials. Hydraulically briquetted material by arrangement only.

Testy 92.—OLD ALUMINUM FOIL
Shall consist of clean, old, pure, uncoated, unalloyed aluminum foil, free from anodized foil, radar foil and chaff, paper, plastics, or any other foreign materials. Hydraulically briquetted material by arrangement only.

Thigh 93.—ALUMINUM GRINDINGS
Should be sold on recovery basis or by special arrangements with purchaser.

Thirl 94.—ALUMINUM DROSSES, SPATTERS, SPILLINGS, SKIMMINGS AND SWEEPINGS
Should be sold on recovery basis or by special arrangements with purchaser.

Throb 95.—SWEATED ALUMINUM
Shall consist of aluminum scrap which has been sweated or melted into a form or shape such as an ingot, pig or slab for convenience in shipping; to be free from corrosion, drosses or any foreign materials. Should be sold subject to sample or analysis.

CODE WORD ITEM

Tooth 96.—SEGREGATED NEW ALUMINUM ALLOY CLIPPINGS AND SOLIDS
Shall consist of new, clean, uncoated and unpainted aluminum scrap of one specified aluminum alloy only and to be free of foil, hair wire, wire screen, dirt, and other foreign substances. Oil and grease not to total more than 1%. Also free from punchings less than ½" in size. New can stock subject to arrangement between buyer and seller.

Tough 97.—MIXED NEW ALUMINUM ALLOY CLIPPINGS AND SOLIDS
Shall consist of new, clean, uncoated and unpainted aluminum scrap of two or more alloys free of 7000 series and to be free of foil, hair wire, wire screen, dirt, and other foreign substances. Oil and grease not to total more than 1%. Also free from punchings less than ½" in size. New can stock subject to arrangement between buyer and seller.

Tread 98.—SEGREGATED NEW ALUMINUM CASTINGS, FORGINGS AND EXTRUSIONS
Shall consist of new, clean, uncoated aluminum castings, forgings, and extrusions of one specified alloy only and to be free from sawings, stainless steel, zinc, iron, dirt, oil, grease and other foreign substances.

Trump 99.—ALUMINUM AUTO CASTINGS
Shall consist of all clean automobile aluminum castings of sufficient size to be readily identified and to be free from iron, dirt, brass, babbitt bushings, brass bushings, and any other foreign materials. Oil and grease not to total more than 2%.

Twist 100.—ALUMINUM AIRPLANE CASTINGS
Shall consist of clean aluminum castings from airplanes and to be free from iron, dirt, brass, babbitt bushings, brass bushings, and any other foreign materials. Oil and grease not to total more than 2%.

ITEMS NOT COVERED SPECIFICALLY IN ALUMINUM SCRAP SPECIFICATIONS SHOULD BE DISCUSSED AND SOLD BY SPECIAL ARRANGEMENTS BETWEEN BUYER AND SELLER.

Wafer 101.—MAGNESIUM CLIPS
Shall consist of clean magnesium clips in crucible size, free of copper, aluminum, and zinc flashings and excessive oil and grease. To be free of all foreign attachments.

Walnut 102.—MAGNESIUM SCRAP
Shall consist of magnesium castings, magnesium engine blocks and transmission casings, bomber and car wheels, extrusions, and sheet. Material to be free from brass and copper inserts and all foreign attachments. To be free of anodes, hollow castings and explosives. Percentages of and penalties for dirt, oil, grease, and iron to be subject to agreement between buyer and seller. Excessively large pieces to be negotiated between buyer and seller.

Wine 103.—MAGNESIUM ENGRAVER PLATES
To be free of copper, aluminum, zinc, and electrotype plates. To be clean and free of all foreign attachments. Magnesium plates shipped loose by agreement between buyer and seller.

Wood 104.—MAGNESIUM DOCKBOARDS
Shall consist of clean magnesium dockboard cut or broken to size agreed upon by buyer and seller. To be free of all foreign attachments.

World 105.—MAGNESIUM TURNINGS
It is recommended that these materials be sold by special arrangement between buyer and seller.

Wrench 106.—FRAGMENTIZED MAGNESIUM SCRAP
Shall consist of clean crushed magnesium scrap free of brass, copper and other foreign material.

- - .1.

CODE WORD ITEM

Aroma 107.—NEW NICKEL SCRAP

Shall consist of clean new sheet, plate, bar, tube, and any other wrought nickel scrap solids. Nickel minimum 99%. Free of castings, as well as any foreign attachments or other contamination.

Burly 108.—OLD NICKEL SCRAP

Shall consist of old and/or new sheet, plate, bar, tube, and any other wrought nickel scrap solids. Material to contain a minimum of 98% nickel. This grade to be free of castings, soldered, brazed, sweated, or painted material, other metallic coating, foreign attachments, and any other contamination.

Cache 109.—MISCELLANEOUS TYPES OF NICKEL SCRAP

Shall consist of miscellaneous types of nickel scrap, such as carbonized scrap, castings, strippings, peelings, baskets, and/or turnings. Particulars regarding physical description, assay, and packaging to be agreed on between buyer and seller.

Dandy 110.—NEW CUPRO NICKEL CLIPS AND SOLIDS

Shall consist of clean, new, segregated (normally accepted analysis grades) either 70/30, 80/20, or 90/10 cupro nickel tube, pipe, sheet, plate, or other wrought solid forms. Must be free of foreign attachments or any other contamination.

Daunt 111.—CUPRO NICKEL SOLIDS

Shall consist of old, and/or new, segregated (normally accepted analysis grades) either 70/30, 80/20, or 90/10 cupro nickel tube, pipe, sheet, plate, or other wrought solid forms. Maximum 2% sediment allowable. Any other forms of cupro nickel solids such as castings, gates, risers, spills, etc., packaged separately, may or may not be included, only upon agreement between buyer and seller. Must be free of foreign attachments and all other contamination. Other particulars concerning physical description, analysis and packaging to be agreed upon between buyer and seller.

Delta 112.—SOLDERED CUPRO NICKEL SOLIDS

Shall consist of segregated (normally accepted analysis grades) either 70/30, 80/20, or 90/10 cupro nickel solids, soldered, brazed, or sweated, must be free of trimmed seams and edges and all other contamination.

Decoy 113.—CUPRO NICKEL SPINNINGS, TURNINGS, BORINGS

Shall consist of clean segregated (normally accepted analysis grades) either 70/30, 80/20, or 90/10 cupro nickel spinnings, turnings, or borings. Particulars concerning physical description, analysis, packaging, to be agreed upon between buyer and seller.

Hitch 114.—NEW MONEL CLIPPINGS AND SOLIDS

Shall consist of clean, new, Regular and/or R-Monel sheet, plate, bar, rod, tube, pipe, or any other wrought scrap, free of any foreign attachments or any other contamination.

Ideal 115.—OLD MONEL SHEET AND SOLIDS

Shall consist of new and/or old clean Regular and/or R-Monel sheet, pipe, plate, rod, and all other wrought scrap solids. Must be free of foreign attachments or any other contamination. (To exclude soldered, brazed, and unclean sweated material.)

Indian 116.—K-MONEL RODS AND OTHER SOLIDS

Shall consist of clean K-Monel rods and other solids.

Junto 117.—SOLDERED MONEL SHEET AND SOLIDS

Shall consist of soldered and/or brazed, Regular or Miscellaneous grades of Monel Alloys (with basic minimum 63% Nickel contained in any alloy itself), in either wrought or cast form. Must be free of trimmed seams and edges, nonmetallic filling, foreign attachments, and all other contamination. Particulars concerning physical description, assay, and packaging to be agreed upon between buyer and seller.

CODE WORD ITEM

Lemon 118.—MONEL CASTINGS

Shall consist of various types of clean Monel castings, assaying minimum 60% nickel. Must be free of foreign attachments, or any other contamination.

Lemur 119.—MONEL TURNINGS

Shall consist of mixed Monel turnings and borings containing a minimum of 60% nickel content, on a dry basis.

Pekoe 120.—200 SERIES STAINLESS STEEL SCRAP SOLIDS

Shall consist of all types of clean AISI Series Stainless Steel Scrap Solids, which contain a maximum of .5% copper, free of foreign attachments and other contamination.

Sabot 121.—STAINLESS STEEL SCRAP

Shall consist of clean 18-8 type stainless steel clips and solids containing a minimum 7% nickel, 16% chrome, and have a maximum of .50% molybdenum, .5% copper, .045% phosphorous, and .03% sulfur, and otherwise free of harmful contaminants. Particulars concerning physical description, grading, additional analysis, and preparation to be agreed upon between buyer and seller.

Ultra 122.—STAINLESS STEEL TURNINGS

Shall consist of clean 18-8 type stainless steel turnings containing a minimum of 7% nickel and 16% chrome, and to be free of nonferrous metals, non-metallics, excessive iron, oil and other contaminants. Particulars concerning physical description, assay, packaging to be agreed upon between buyer and seller.

Rusten 123.—11-14% CHROME STAINLESS SCRAP

Straight chrome stainless scrap shall contain 11-14% chrome, phosphorous and sulphur .03% maximum, and shall not contain over .50% nickel and otherwise be free from harmful contaminants. Material to be prepared to individual consumer's specifications.

Rusthirty 124.—14-18% CHROME STAINLESS SCRAP

Straight chrome stainless scrap shall contain 14-18% chrome, phosphorous and sulphur .03% maximum, and shall not contain over .50% nickel and otherwise be free from harmful contaminants. Material to be prepared to individual consumer's specifications.

Vaunt 125.—EDISON BATTERIES

To be sold free of crates, copper terminal connectors, and drained free of excess liquid, to be free of type "B" batteries.

ANY OTHER PARTICULARS IN THE NICKEL ALLOY GROUP CONCERNING PHYSICAL DESCRIPTION, ASSAY, AND PACKAGING TO BE AGREED UPON BETWEEN BUYER AND SELLER.

MIXED NONFERROUS METALS FROM RESOURCE RECOVERY FACILITIES

Shall consist of mixed metals containing predominantly zinc, brass, copper, lead, aluminum and stainless steel. Metals shall be relatively free of foreign attachments and all pieces should be capable of passing over ½" mesh screen. Mixture should not contain more than 3% iron and no more than an additional 3% foreign, nonmetallic substances. Material should be loaded loosely in drums, boxes or other containers and should not be briquetted, baled or otherwise hydraulically compressed.

GENERAL NOTE

It has been the purpose in revising these specifications to provide for those materials which are most frequently dealt in. Any items for which classifications are not specified should be subject to negotiations between buyer and seller.

GUIDELINES FOR WEIGHING, PACKING, SHIPPING AND RECEIVING NONFERROUS SCRAP METALS

A. Detailed weights and commodity description advice should accompany all truck shipments and be mailed sufficiently in advance of all rail deliveries. This document should show order number and should list each item separately, indicating number of pieces in each item, and show separate gross, tare and net weights for each item shipped. If unable to include packing list with some shipments (e.g., some commercial trucks and piggybacks) then air mail on the same day shipment leaves.

B. A packing list and diagram showing location of each item within a shipment should be attached to wall inside boxcars and trucks. Such a diagram can, of course, accompany vendor's trucks.

C. Trailers should be weighed (both gross and empty) dropped, if possible, and such scale tickets should accompany shipment, or be made part of the documents in paragraph A.

D. Open top trailers should be covered with a tarpaulin.

E. All trucks and boxcars should be sealed and seal numbers supplied with documents in paragraph A.

F. Boards should be placed across doors on both sides of railroad boxcars, to prevent material from leaking out, and so that doors may be easily opened.

G. Railroad cars should be uncoupled and at rest (if possible), before determining either gross or tare weight.

H. Careful attention by consumers should be given to all shipment advices, documents and packing lists.

I. Shipper should be notified immediately by telephone or wire whenever there is a weight discrepancy in excess of 1%.

J. When there is a discrepancy between shippers' and consumers' weights and/or classifications, all settlements should be accompanied—to whatever extent practical—by scale tickets, weight manifests, or other documents which describe how settlement weights were determined. Prompt notification should be made where consumer grading is different from detailed shipping documents.

K. Shipper should assure that any truck or boxcar being loaded is clean, in good shape, and free of holes which could jeopardize unloading operations or result in cargo spillage.

L. Different lots in any car or truck should always be properly segregated to avoid comingling and should also be tagged or marked adequately to assure appropriate identification and weighing of each lot at consumer's plant.

M. Packed material should always be in sound bales or containers (drums, boxes, etc.) and should be securely bulkheaded within conveyance to prevent breakage of packages during transit.

(These Guidelines were developed by NARI's Dealer-Smelter Relations Committee to aid scrap processors when shipping material to nonferrous metal consumers.)

./.

Appendix E

Reference list for figures extracted from publicity leaflets.

Fig. 3 from LOLLINI.

Fig. 4 ORENSTEIN und KOPPEL.

Fig. 5 McINTYRE (Machinery).

Fig. 6 SAMSON.

Fig. 7 SISO.

Fig. 8 PERSÖNER.

Fig. 9 SISO.

Fig. 10 HORAÏ.

Fig. 11 NEWELL.

Fig. 12 WILLIAMS.

Fig. 13 STEARNS MAGNETIC.

Fig. 14 STEARNS MAGNETIC.

Fig. 16 WILLIAMS.

Fig. 17 HORAÏ.

Fig. 18 ALPINE.

Fig. 19 WEMCO.

Fig. 27 PECO.

Appendix F

EQUIPMENT MANUFACTURERS

This appendix lists the manufacturers of recycling equipments whom we have been able to contact, either directly, or via a sales' agent. This list is certainly not complete, because we could not get all the addresses of equipment manufacturers, especially in Japan, and because some of those we tried to contact did not give any answer. The firms cited here often produce other equipments than copper-recycling equipments.

\- - - - - -

ADDAX (St.Etienne, France) : cable strippers.

ALPINE (Augsburg, Germany) : complete mechanical cable processing systems, cable strippers.

British Jeffrey Diamond (Wakefield, U.K.) : car shredders.

C.E. CAST Equipment (Cleveland, Ohio, U.S.A.) : briquetting presses.

CHAMOTTE Rijkaart Industrieel (Gerldermalsen, Netherlands) : incineration furnaces.

CLANDON Scientific Ltd. (Aldershot, U.K.) : spectroscope.

CLESID (St.Etienne, France) : car shredders.

College Research Corporation - CORECO (Butler, Wisc., U.S.A.) : all types of furnaces.

D & S Manufacturing Co. (Auburn, Mass., U.S.A.) : knives and screens for chopping mills.

DRYFLO Separators (New Barnet, U.K.) : complete mechanical cable processing systems.

FRANZ ARNOLD'S Soehne (Voesendorf, Germany) : baling presses, car compactors, shears, briquetting presses.

GREENBERG Engineering Co. (Bala Cynwyd, Pa., U.S.A.) : cable strippers, magnetic separators.

./.

HAMMERMILLS Inc. (Cedar Rapids, Iowa, U.S.A.) : car shredders, ring mills.

HARRIS (Marlow, U.K.) : baling presses, shears.

HORST ANDERS Apparatebau (Berlin) : spectroscopes.

Impact Industrial Holdings (Sunderland, U.K.) : cable strippers.

LEFORT (Gosselies, Belgium) : shears, baling presses, nibblers.

Ets. LESAUVAGE (Aubervillers, France) : sales' agent for C.I.M.P. : complete mechanical cable processing systems.

LINDEMANN (Dusseldorf, Germany) : baling presses, shears, shredders.

Ing. A. LOLLINI S.p.A. (Zola Predosa, Italy) : shears, baling presses, sweating furnaces.

MAC Corp. (Dallas, Texas, U.S.A.) : balers, car flatteners.

Maschinenfabrik BECKER und Co. (Dortmund, Germany) : baling presses, shears, shredders, ring mills.

J. McINTYRE (Machinery) Ltd. (Dunkirk, U.K.) : shears, baling presses.

MOSLEY Machinery Co. (Waco, Texas, U.S.A.) : shears, baling presses, car flatteners.

NEWELL Manufacturing Co. (San Antonio, Texas, U.S.A.) : shredders.

ORENSTEIN und KOPPEL (Dortmund, Germany) : shears, baling presses.

PERSÖNER Verkstad A.B. (Ystad, Sweden) : baling presses, shears.

PLANTERS Division of Entwisle and Gass Ltd. (Bolton, U.K.) : baling presses, briquetting presses.

Progressive Equipment Co. - PECO (Glastonbury, Conn., U.S.A.) : incineration furnaces.

PROMOTEC B.V. (Amersfoort, Netherlands) : car shredder reject processing system.

PURETHERM (Burlington, N.J., U.S.A.) : briquetting presses.

REHSIF (Petit-Lancy, Switzerland) : sales' agent for HORAÏ : complete mechanical cable recovery system.

./.

RIGBY Manufacturing Co. (South Portland, Maine, U.S.A.) : cable strippers.

SAMSON Machinery Co. (Warley, U.K.) : baling presses; nibblers, cable strippers, shears.

SISO A/S (Copenhagen, Denmark) : shears, cable strippers, pre-choppers.

STEARNS Magnetics (Spy, Belgium) : magnetic separators.

STRUNZ Gesellschaft (Nuremberg, Germany) : incineration furnaces.

TOLL TRECK Ltd. (Droitwich, U.K.) : swarf drying furnaces.

TRIPLE/S Dynamics (Dallas, Texas, U.S.A.) : complete mechanical cable processing systems.

The UNITED Corp. (Topeka, Kansas, U.S.A.) : incineration and sweating furnaces.

Officine VEZZANI (Milan, Italy) : baling presses, shears.

WEMCO G.B. (London, U.K.) : heavy media separators.

WILLIAMS Patent Crusher & Pulverizer Co. (St.Louis, Miss., U.S.A.) : ring mills, air separators.

REFERENCES

B.I.P.E. : Bureau d'Informations et de Prévisions Economiques, Paris.

B.I.R. : Bureau International de la Récupération, Bruxelles.

C.B.I.C. : Centre Belge d'Information du Cuivre, Bruxelles.

C.D.A. : Copper Development Association, London.

C.I.D.E.C.: Centre International pour le Développement du Cuivre, Genève - London.

N.A.R.I. : National Association of Recycling Industries, New York.

U.S.B.M. : United States Bureau of Mines, Washington.

*

* *

1 - Anon. : Le déchiquetage des ferrailles par cryogénie - Procédé Inchscrap.
Journal du Four Electrique, n°3, 1975.

2 - Anon. : Hitachi High Density Metal Separation Technique Using Magnetic Liquid.
Temp Trol, Tokyo, August 1976.

3 - M.B. Bever : The Recycling of Metals - II : Non-Ferrous Metals.
Conservation and Recycling, vol. 1, Pergamon Press, 1976.

4 - J.H. Bilbrey Jr. : Use of Cryogenics in Scrap Processing.
Proc. of the 4th. Mineral Waste Utilization Symposium, Chicago, 1974.

5 - B.I.P.E. : Le cycle des déchets de métaux non ferreux, 1974.

6 - P. Blazy : La valorisation des minerais.
Presses Universitaires de France, 1970.

7 - K.P. Bracker & H.H. Riemann : Vorteile pyrolytischer Rohstoffrückgewinnung.
Metall, May 1977.

./.

8 - A.V. Bridgewater : Metal Recovery from Waste.
Paper presented at the Recycling Course,
University of Nottingham, 1977.

9 - W.R. Burson, F.B. Morgan III : Recovery and Utilization of
Copper Scrap in the Manufacture of High Quality
Cathode.
Proceedings of the 4th. Mineral Waste Utilization
Symposium, Chicago, 1974.

10 - T. Caeymaex, M. Bosmans, J. De Keyser : Réception et
échantillonnage de scraps non ferreux.
A.T.B. Métallurgie 13 (2), 1973.

11 - O.N. Carlson et al. : Studies on Upgrading of Automotive
Scrap by Vacuum Melting and Electroslag Remelting.
Proc. of the 4th. Mineral Waste Utilization Symposium,
Chicago, 1974.

12 - F.V. Carrillo, M.H. Hibpshman & R.D. Rosenkranz :
Recovery of Secondary Copper and Zinc in the U.S.
U.S.B.M., I.C. 8622, 1974.

13 - C.B.I.C. : Influence of the Copper Scrap on the Copper Market.
Publication n°43, 1972.

14 - C.B.I.C. : Le cuivre et ses alliages dans l'industrie.

15 - C.B.I.C. : Les usages électriques du cuivre et de ses alliages.

16 - C.D.A. : Copper and its Alloys in Engineering and Technology.
C.D.A. publication n°43.

17 - C.J. Chindgren, K.C. Dean & L. Peterson : Recovery of the
Non-Ferrous Metals from Auto Shredder Rejects by
Air Classification.
U.S.B.M., TPR-31, 1971.

18 - C.I.D.E.C. : Copper Sulphate Manufacture.
Report n°147, 1967.

19 - D. Davies : Energy Utilization in the Smelting and Refining
of Copper.
Metals and Materials, March 1974.

20 - K.C. Dean & J.W. Sterner : Dismantling a Typical Junk
Automobile to Produce Quality Scrap.
U.S.B.M., RI 7350, 1969.

21 - K.C. Dean & J.W. Sterner : Metal Recovery by Dismantling of
Scrapped Starter Motors, Auto Generators and
Alternators.
U.S.B.M., RI 8110, 1976.

./.

22 - T.W. Farthing & M.J. Leedham : Review of Production Processes for Copper Scrap, the Economic Uses and Future Trends. The Institute of Metals, Spring Meeting, 1973.

23 - R. Fischer : Recycling ein Modewort ? Erzmetall, Jan. 1976.

24 - A.W. Fletcher : Metal Recycling from Scrap and Waste Materials. Proc. R. Soc. Lond., A.351, 1976.

25 - L.J. Froisland et al. : Recovering Metal from Non-Magnetic Auto-Shredder Reject. U.S.B.M., RI 8049, 1975.

26 - D.A. Harrison, P.C. Newdick & P.J. Bowles : Recovery of Non-Ferrous Metals from Car Scrap. Metals and Materials, January 1974.

27 - M.E. Hemstock : The Recycling of Automobiles. Paper presented at the Recycling Course, University of Nottingham, 1977.

28 - E. Herman : Anwendung des Dryflo-Wirbelbettverfahrens zur Zerlegung von Kupferkabel-Schrott. Erzmetall, Dec. 1971.

29 - International Nickel Co. : Rapid Identification (Spot Testing) of some Metals and Alloys. New York, 1951.

30 - J.S. Jacobi : Recovery of Copper and Associated Metals from Secondary Sources. The Institution of Mining and Metallurgy. Symposium, April 1976.

31 - J.S. Jacobi : Reclamation and Recycling of Copper and its Alloys. Paper presented at the Recycling Course, University of Nottingham, 1977.

32 - R. Kammel & H.W. Lieber : Metallrückgewinnung statt Schlammdeponie ? Metall, March 1977.

33 - H.H. Kellog : The Role of Recycling in Conservation of Metals and Energy. Journal of Metals, December 1976.

34 - H. Kudelka, R. Dobbener, N.L. Piret : Copper Electrowinning at Duisburger Kupferhütte. CIM Bulletin, August 1977.

./.

35 - U. Kuxmann : Entwicklungstendenzen der Verfahren zur Gewinnung von Kupfer.
Erzmetall, February 1974.

36 - S.M. Langer, T.D. Kaun, M.A. Namets : The Cupric Chloride Hydrometallurgical Process for Copper Recovery from Scrap.
Journal of Metals, July 1976.

37 - V.G. Leak, M.M. Fine, H. Dolezal : Separating Copper from Scrap by Preferential Melting.
U.S.B.M., RI 7809, 1973.

38 - L.R. Mahoney & J.J. Harwood : The Automobilie as a Renewable Resource.
Resources Policy, Sept. 1975.

39 - E.C. Mantle : Waste Water in the Non-Ferrous Metals Industries. The Scope for Recycling.
Pure & Appl. Chem., 45, 1976.

40 - M.G. Manzone, W.R. Opie : Recycling Copper Scrap at USMRC.
CIM Bulletin, August 1977.

41 - A.W. Maynard & H.S. Caldwell : Identification and Sorting of Non-Ferrous Scrap Metals.
Proc. of the 3rd. Mineral Waste Utilization Symposium, 1972.

42 - N.A.R.I. : Wire and Cable Chopping and Recovery of Metals from Shredding Operations. New York, 1977.

43 - W.R. Opie : Problems in Smelting Copper Scrap.
Effective Technology for Recycling Metal.
N.A.S.M.I.

44 - W.J. Roscrow : Furnaces and Processes for Non-Ferrous Metal Recovery.
Metallurgia and Metal Forming, August 1976.

45 - W. Ryan : Non Ferrous Extractive Metallurgy in the U.K.
The Institution of Mining and Metallurgy, London, 1968.

46 - E. Scheuer : The Sorting of Scrap Metals and Alloys.
Metallurgical Reviews, vol. 1, part. 3, 1956.

47 - M.J. Spendlove : Methods for Producing Secondary Copper.
U.S.B.M., IC 8002, 1961.

48 - W.L. Staker, C.J. Chindgren & D.K. Dean : Improved Cupric Ammonium Carbonate Leaching of Copper Scrap.
U.S.B.M., RI 7554, 1971.

./.

49 - C. Steinsiek et al. : Autowracks und Altreifen.
Battelle-Institut, Frankfurt/Main, 1974.

50 - H. Stewart : Pollution-Free Reclamation of Copper from Insulated Wire.
A.I.M.E. Annual Meeting, San Francisco, 1972.

51 - S.G. Temple : The Effective Use of Energy in the Melting and Casting of Copper and its Alloys.

52 - A. Van Peteghem, C. Feneau : Hydrometallurgica Treatment of Non-Ferrous Waste.
International Symposium Brussels, November 1973.
Centre Belge d'Information du Cuivre.

53 - L. Whalley & V.E. Broadie : Non-Ferrous Metal Losses in the U.K.
Warren Spring Laboratory.

54 - W.J. Wilson, E.G. Valdy & K.C. Dean : Use of Cryogenics to Reclaim Nonferrous Scrap Metals.
U.S.B.M., RI 7716, 1973.

PROCESSUS FOR ZINC RECOVERY

FROM GALVANIZED PRODUCTS

PROCESSES FOR Zn-RECOVERY FROM GALVANIZED PRODUCTS

ABSTRACT

- For the time being, zinc used for galvanisation is usually not separately recovered, except for dusts resulting a.o. from the processing in electric and martin furnaces of iron scrap containing galvanized steel and die-cast materials.

- At present, we know only one specific process for the recovery of zinc from galvanized steel, i.e. the Prayon process, but in the present state of the scrap recovery cycles, it cannot be applied. A system for selective collection of galvanized steel scrap should be developed.

- Various processes for the treatment of iron dusts and sludges dusts have been developed. These dusts and sludges are of various origins :
  - blast furnaces
  - converters
  - open-hearth and electric furnaces.

- Iron dusts are either
  - stored in basins
  - sold to cement mills
  - partly recycled on the sintering belts for furnace charges (in as much as Zn, Pb and alkaline contents are not too high : Zn max. 1,5 %)
  - reprocessed to obtain
    - Fe-rich material which can be recycled
    - Zn- and Pb-rich dusts, which can be treated in Zn and Pb smelters.

- The industrially most elaborate process to retreat iron dusts consists in the direct reduction of these dusts in a WAELZ-type rotary furnace. The economics of this process would moreover require Zn-rich dusts. The processing of ordinary blast furnace dusts (4-5 % Zn) would not be economical.

- Reprocessing units applying the WAELZ-furnace are operating in Japan, a country where dusts are generally richer in Zn. One pilot plant is operating in Germany (Berzelius/Duisburg).

DETAILED INFORMATION

1. DIRECT PROCESS

The Prayon process (Belgian patents n°s 773905 and 789772) consists in leaching the galvanized scrap with a sulphuric acid solution, containing a colloid like e.g. gelatine, dextrine, floculating agents such as polyacrylamide, etc...

The presence of a colloid allows a selective Zn-dissolution from the iron substrate.
The sulphuric acid solution can be spent electrolyte of a zinc tankhouse.
When zinc is dissolved from the galvanized scrap, the solution could be fed again in the main circuit for the hydrometallurgical treatment of zinc concentrates.
Since there is presently no suitable circuit for the selective recovery of galvanized scrap, this process is not yet applied on an industrial scale.

2. METHODS TO PROCESS IRON DUSTS

2.1. WAELZ-type processes

2.1.1. General principle

All these processes are characterized in that dusts of various origins are, after preparation, introduced in a rotary tubular furnace where the charge is reductive. In the actual charge Zn- and Pb oxides are reduced, these metals volatilize and are drifted with the fumes under the influence of which they oxidize again. The greater part of Fe contained in the charges is also reduced and the residue is a strongly metallized Fe concentrate, which can either be fed again in the shaft furnace after separation of the carbon in excess, or if it is poor in S and gangue, be used in steelmaking. The presence of C in the calcinated pellets produces no inconvenience in subsequent processing.

2.1.2. Alternatives and examples of application

a) LURGI

This process was tested in 1975 in the WAELZ-plant of BERZELIUS (Duisburg) with the contribution of E.E.C., where were treated

- slimes from blast furnace mouths, containing 5.1 to 19.8 % Zn
- slimes and dusts from LD steel works containing 0.8 to 2.4 % Zn
- Ruhr coal.

After pelletization on trays, crude pellets containing 50 % Fe, 3.5 % Zn and 4 % C were fed together with a reducing agent into a rotary furnace withour preliminary drying nor firing.
Tests at Berzelius yielded on the one hand a 97.5 % metallised ferrous residue containing an average of 0.06 % Zn and < 0.5 % Pb, which is perfectly suitable for blast furnaces, as well as an oxidized Zn-Pb concentrate containing approx. 30 % Zn, 13 % Pb and 28 % Fe perfectly suitable for ISF furnaces.
The ferrous residue still contained 2 % S, which made it unsuitable for direct use in steelmaking, notwithstanding its high metallisation rate. Ref. : Annex 1.

b) NIPPON KOKAN - Fukujama - Japan

is operating since the end of 1974 a plant yielding 350,000 mt/per year of iron sponge in a WAELZ-type furnace. A usual charge consists of 30 % blast furnace dusts, 30 % dusts from LD steel works and 40 % iron ore. This mixture is pelletized on granulating trays in presence of bentozite coal (?) and water. Iron ore is added to make granulometry of the mixture even coarser and to allow drying and prehardening of pellets on a movable grate without any risk of splintering.
Dusts containing 25 % Zn are processed by Nissan Smelting.
Pellets still containing much S can be recycled in blast furnaces.

c) KAWASAKI Steel Corp

is processing since 1968 in its Chiba plant (Japan) 120,000 mt/per year of dust containing 0.6 % Zn, which is a mixture of dusts from blast furnaces, from LD steel works and from sinter plants.
Principle : Granulation on trays without binder, drying + preheating on grate and reduction in a rotary furnace in the mouth of which coke-dust is fed.
Pellets containing 0.01 to 0.02 % Zn, 0.01 % Pb and 0.2 % S are fed again into the blast furnace. Dusts containing ± 32 % Zn are sold.
Since 1973, Kawasaki is operating in the MIZUSHIMA plant a similar unit with a production capacity of 480,000 mt/per year of dust.
Kawasaki has signed a contract with Dofasco regarding the technical know-how and the construction of a unit with the same production capacity as the Mizushima plant (Annex 2).

d) KRUPP developed a related process together with Inland Steel (USA) and with the support of the German Research and Technology Ministry.
The Krupp process starts with the preparation of a mixture of slimes from LD steel works and SM steel works (previously dried), of dry dusts from LD and SM steel works and of scale. This mixture is humidified and pelletized on trays, and the pellets are dried on a movable grate. Coke-dust and dolomite or lime are fed into the mouth of the rotary furnace. Temperature in the furnace reaches 1,150 to 1,200° C and due to the presence of dolomite on the one hand and to the high temperature on the other hand. Zn and Pb are eliminated but so is sulphur. Pellets can after separation of excess C be bricked and used in steelmaking.
Crude pellets containing 53.5 to 62.8 % Fe, 2.8 to 11.8 % Zn, 0.35 to 1.9 % Pb used as feed material, yield reduced pellets containing 85 to 91 % Fe, 0.1 to 0.3 % Zn and < 0.01 % Pb.
In 1973 Heckett Engineering Co considered the construction in the Chicago district of a unit with a production capacity of some 400,000 mt per year of dust.

e) SUMITOMO developed two processes, the SDR and the SPM methods.
The SDR process (i.e. Sumitomo Dust Reduction) is nearly the same as the Kawasaki process. A plant with a production capacity of 240,000 mt/per year of dusts in operation.
The SPM process (i.e. Sumitomo Prereduction Method) is characterized in that dust (dried at ± 10 % H2O) and anthracite are directly fed into the rotary reduction furnace. There is accordingly no preliminary pellitization, while sintering and reduction are performed simultaneously in the furnace.
The size > 7 mm of the ferrous "residue" can be fed into the blast furnace, while fines are recycled. Sumitomo is operating a SPM unit with a production capacity of 216.000 mt per year of dust, which raises serious problems of gas/solid materials separation (Annex 3).

2.2. Other processes

2.2.1. EAFR - University of Toronto

The "Extended Arc Flash Reactor" process which has not yet been applied on an industrial scale consists of flash reduction in an electric arc furnace stabilized by injection of a suitable gas. According to its promotors, it would suit perfectly well for the processing of iron dusts (Annex 4).

2.2.2. UDDACON-UDDEHOLM process (Sweden)

The Uddacon process allows direct reduction of oxides injected in a (C-rich) cast iron bath, by which liquid cast iron is kept in a reactor under high temperature (1,450° C) by means of a channel inductor.
Oxides are injected through a nozzle located just under the level of the molten metal; they are reduced by C dissolved in cast iron. The consumption of C for purposes of reduction is balanced by injection of coal with oxides.
When oxides from steel-works (possibly enriched with Zn in a WAELTZ-type furnace) are processed, the yields are cast iron on the one hand and a very rich Zn and Pb containing product (in the fumes) on the other hand, which can be processed, after elimination of Cl and alkalines by washing, in the Zn and Pb smelters.

2.2.3. Bureau of Mines

The Bureau of Mines has tested a process aiming at the recovery of Zn and Pb included in the flue dusts resulting from the remelt of automobile scrap.
The objective was to obtain Zn metal meeting the Prime Western specification. It was obtained by a double distillation under vacuum, consisting of

- granulation of a mixture of dust (30 to 35 % Zn, 4.7 to 4.9 % Pb, 21 to 22 % Fe) and coke (5 %) with water in a drum
- volatilization and condensation under partial vacuum and sweeping off methane, a Zn-Pb composite product
- redistillation of Zn from the composite product (still under partial vacuum).

2.2.4. Atomenergi-Sweden seems to have examined a process of "fluid extraction" from gases in steel-works stacks. Further details are lacking.

2.2.5. Tecnicas Reunidas-Spain has developed a process based on solvent extraction and subsequent electrowinning.

REFERENCES

- Dr. Rausch - E. Gory (Lurgi) : Procédé Waelz-Berzelius de traitement des boues et des poussières sidérurgiques en vue de récupérer le plomb et le zinc

- W. Janke und H. Serbent : Verarbeitung von eisenhaltigen Hüttenwerksstäuben nach dem SL/RN - Verfahren - 1974

- M.O. Holowaty : A process for recycling of zinc-bearing steelmaking dusts - August 1972

- C.A. Pickles, A. McLean, C.B. Alcock, R.S. Segsworth : Investigation of a new technique for the treatment of steel plant waste oxides in an extended arc flash reactor - April 1977

- Tsuyoshi Miyashita : Recovery of Zinc from Steelmaking Dust - September 1976

- E.G. Valdez and K.C. Dean : Experiments in Treating Zinc-Leads Dust from Iron Foundries - 1975

- S. Sakurai (Kawasaki Steel) : Recyclage de poussières oxydées dans des hauts fourneaux et dans des fours d'aciérie

- Helmut Maczek, Heinrich Rellermeyer, Günter Kossek, Duisburg und Harry Serbent, Frankfurt : Versuche zur Verarbeitung von Hüttenwerksabfälle nach dem Wälzverfahren in einer Betriebsanlage - Dezember 1976

- Günter Kossek, Helmut Maczek, Heinrich Rellermeyer und Harry Serbent : Verarbeitung von Hüttenwerksnebenprodukten nach dem Wälzverfahren - Juni 1976

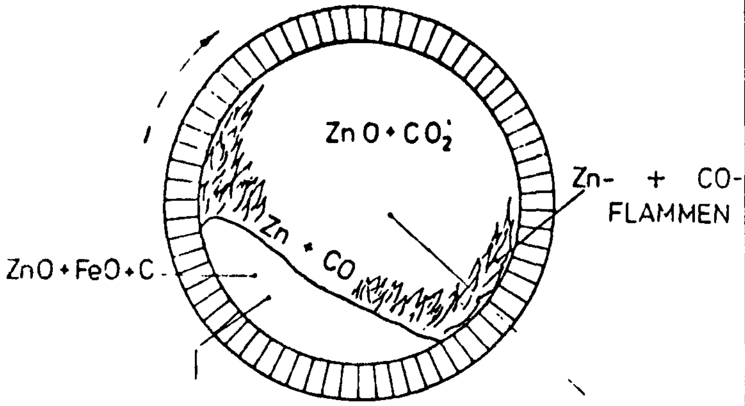
- Kiyoshi Sugasawa, Yasuteru Yamada, Osaka, Shojiro Watanabe, Kazumasa Kato, Wakayama, Kazuo Masuda, Kashima, Yoshimasa Sato, Niihama, Toshihiko Kawabata, Tokio (Japan) : Direktreduktion von Hüttenwerksstäuben - Dezember 1976

- Dr. D. Engledow : Metal Recovery from Dusts and Fumes - 1975

- John C. Hogan (Armco Steel Corp.) : Caractéristiques physiques et chimiques de poussières provenant de fours d'aciérie et de creusets à l'oxygène

- G. Meyer, K.H. Vopel, W. Janssen : Untersuchungen zur Verwertung von Stäuben und Schlämmen aus den Abgasreinigungen von Hochofen- und Blasstahlwerken im Drehrohrofen - Dezember 1976

ANNEX 1



Réactions :

dans la charge

1. $ZnO + CO \rightleftharpoons Zn + CO_2$
2. $CO_2 + C \rightleftharpoons 2CO$ } +

3. $ZnO + C \rightleftharpoons Zn + CO$

1. $FeO + CO \rightleftharpoons Fe + CO_2$
2. $CO_2 + C \rightleftharpoons 2CO$ } +

3. $FeO + C \rightleftharpoons Fe + CO$

dans les fumées

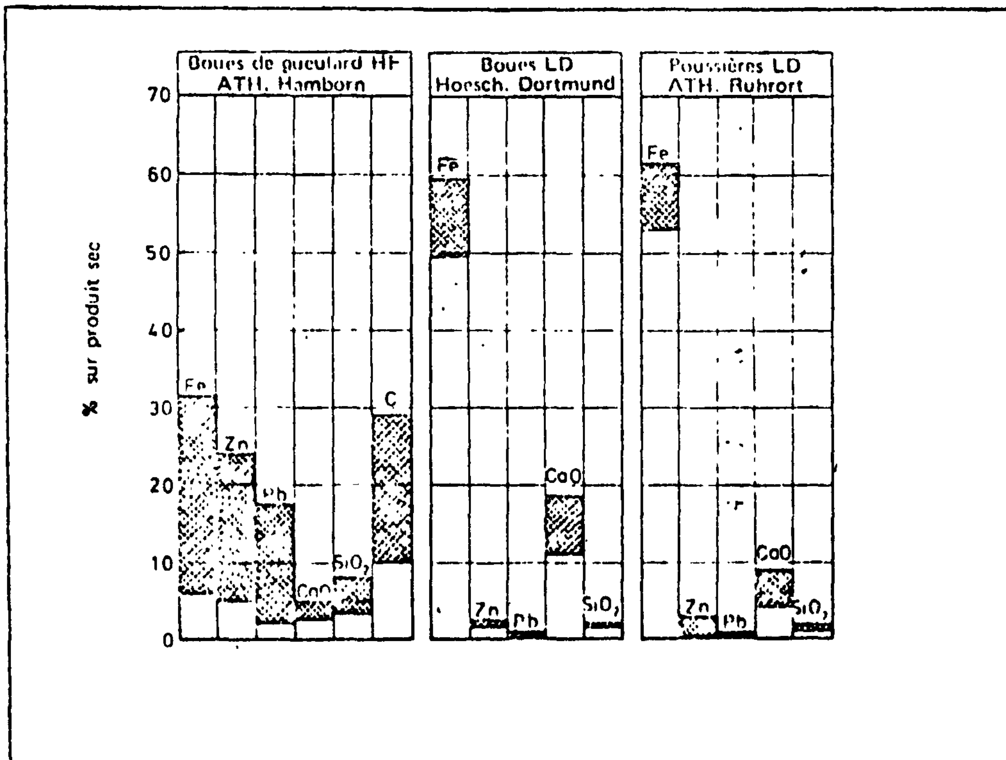
1. $Zn + \frac{1}{2}O_2 \rightarrow ZnO$
2. $CO + \frac{1}{2}O_2 \rightarrow CO_2$

LURGI

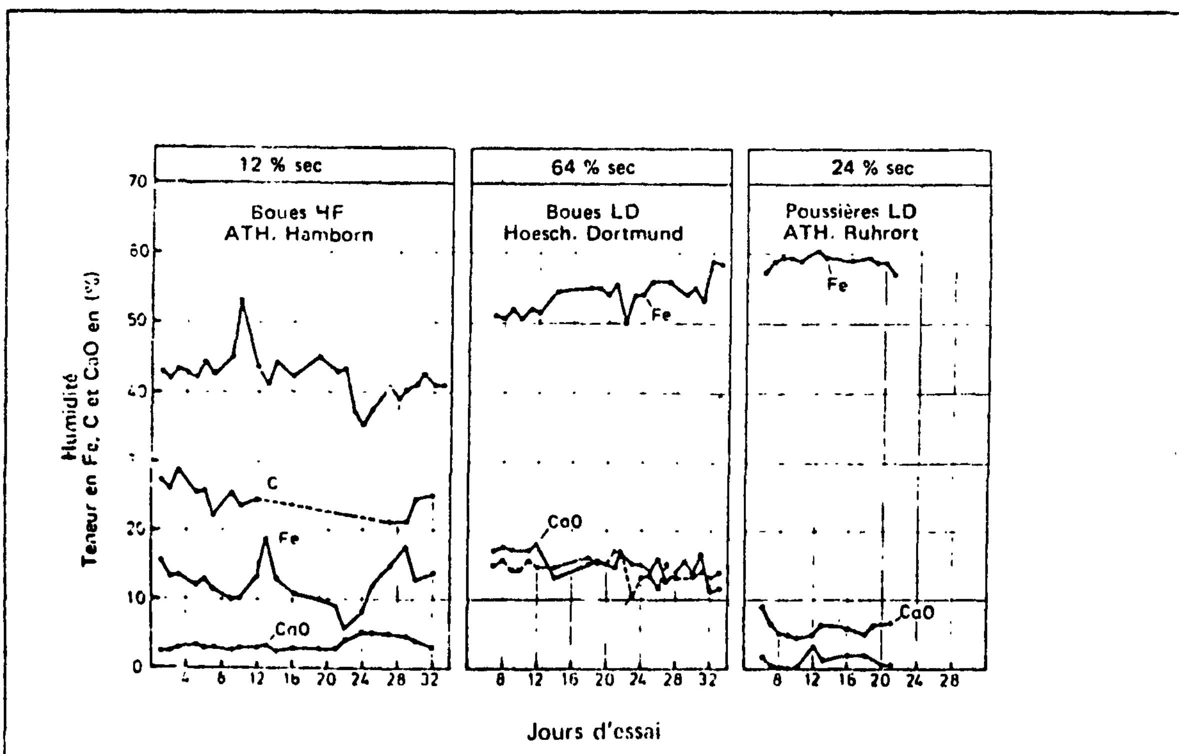
Bilan schématique des réactions d'évaporation du zinc et de la réduction des oxydes de fer dans un four rotatif

Selon F. JOHANNSEN

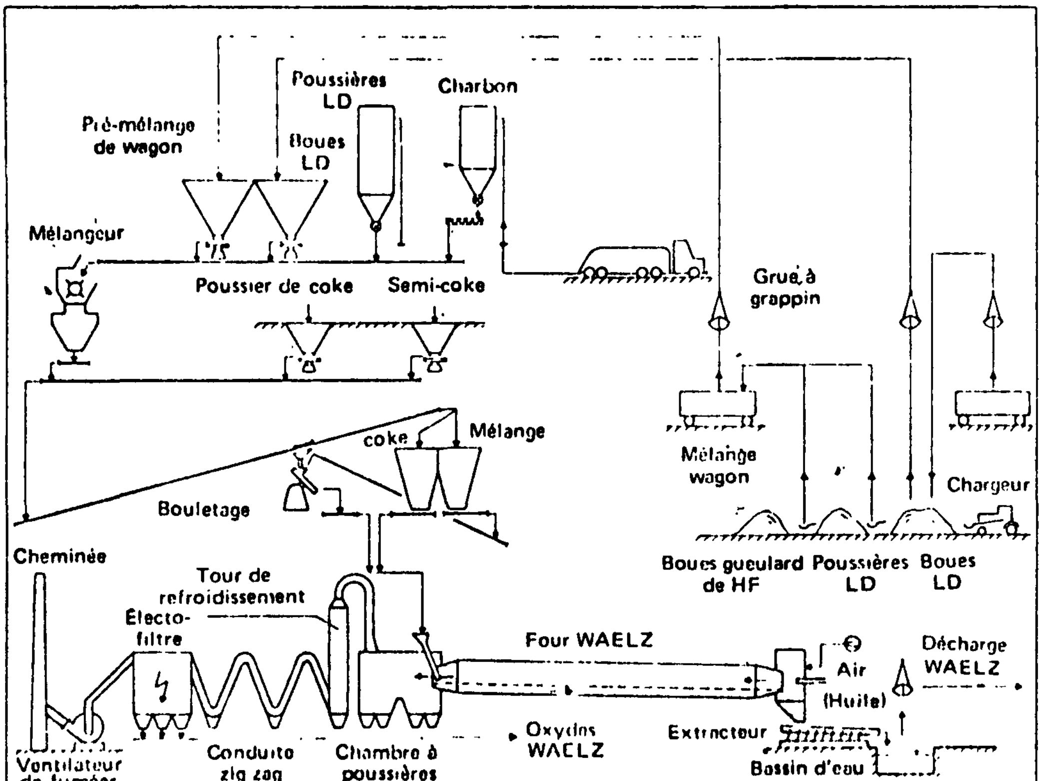
C74 - 1116



LURGI	Variations des composants les plus importants des matériaux utilisés	C76-1144



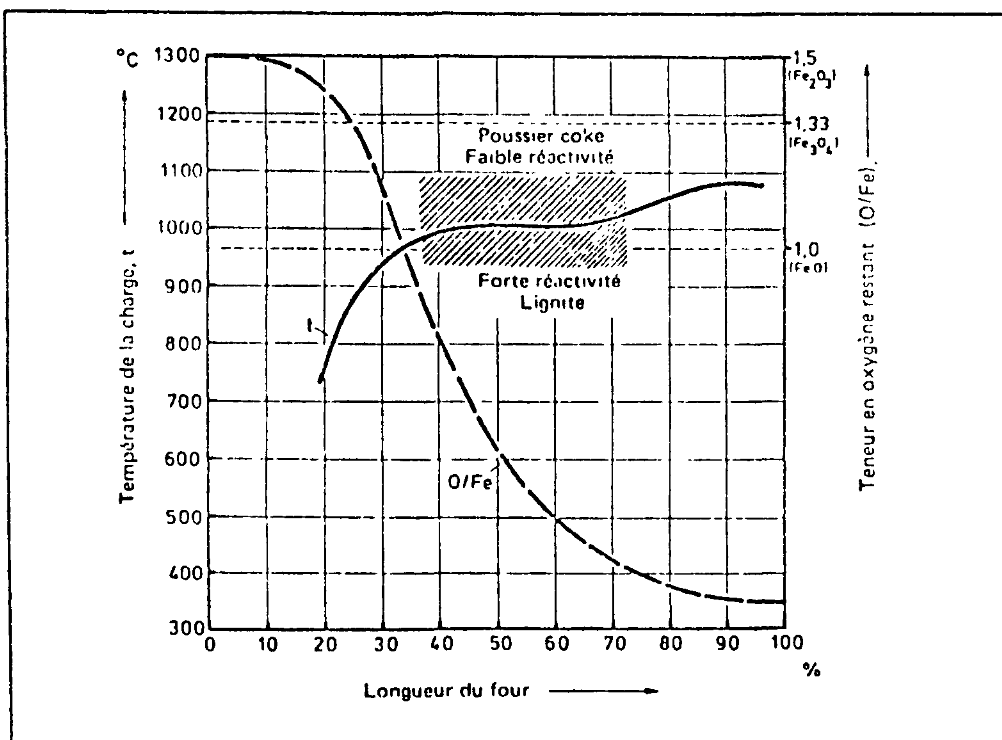
LURGI	Variations des principaux constituants des déchets sidérurgiques traités	C76-1145



LURGI

2ème essai de traitement des poussières sidérurgiques

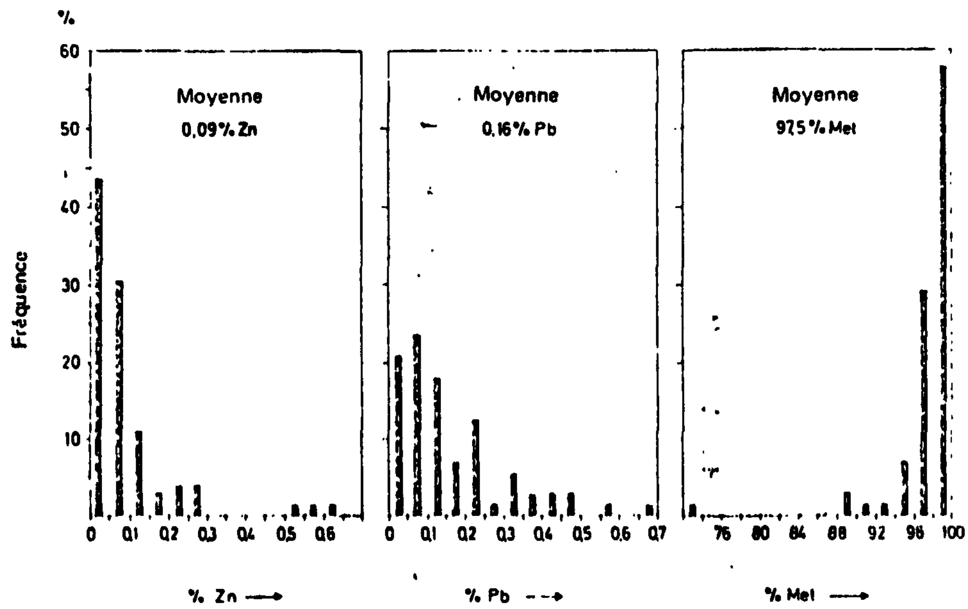
C76-1205



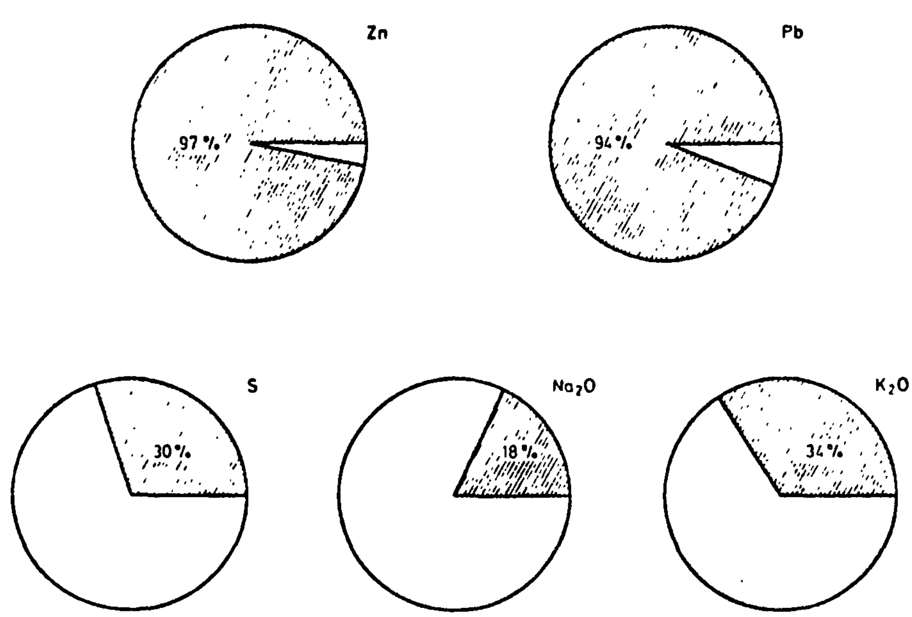
LURGI

Température du produit dans le four tournant en fonction de la réactivité de l'agent réducteur

C 75 - 1134 D



LURGI	Teneur résiduaire en zinc et plomb ainsi que degré de métallisation du fer dans la décharge du four	C76-1204



LURGI	Volatilisation des différents composants lors du traitement au four tournant d'un mélange de déchets sidérurgiques	C76-1206

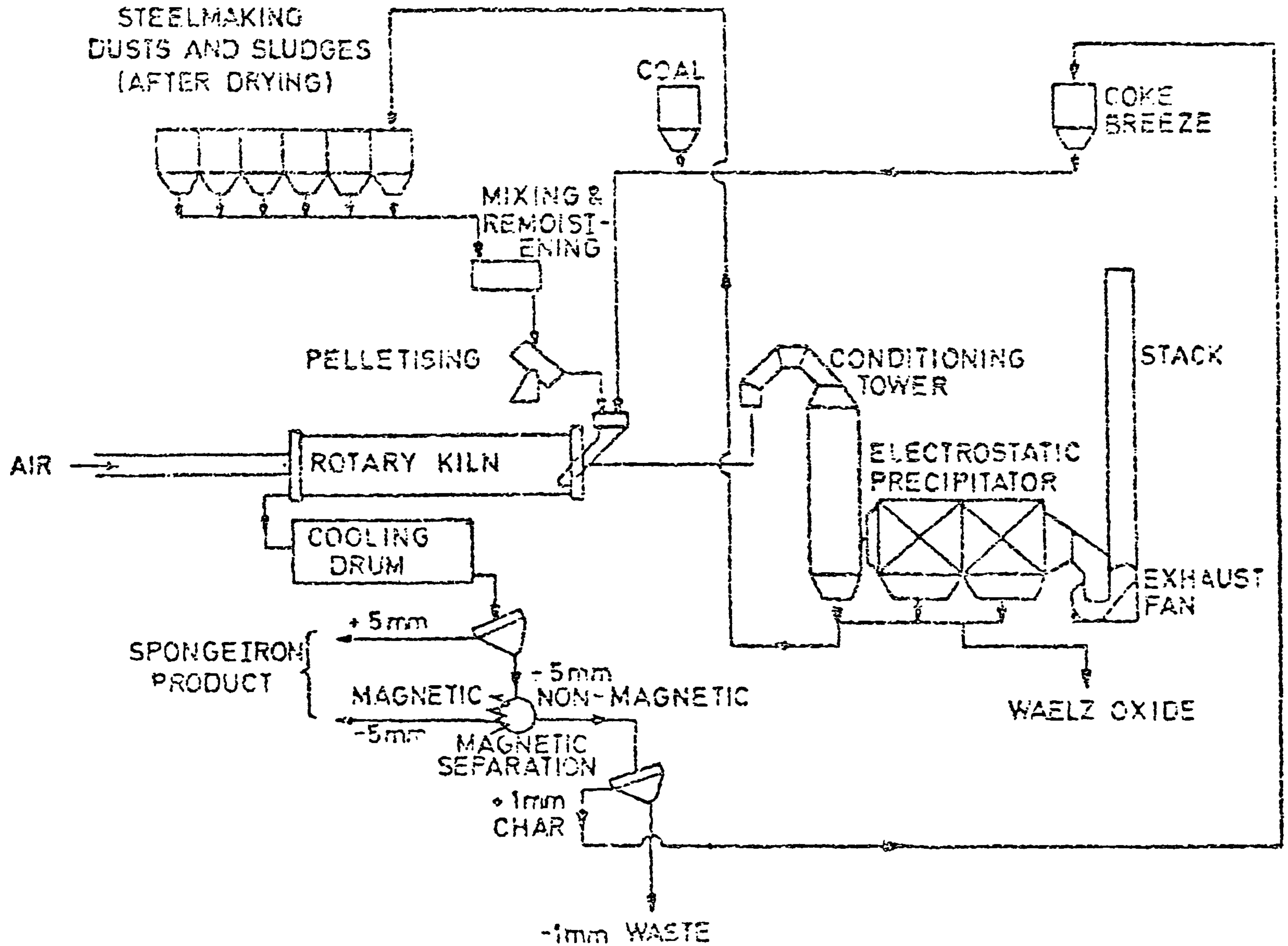
	% (produit sec)
Zn	28-33
Pb	11-15
Fe tot.	23-31
C	2-7
S	env. 2
CaO	7-8
SiO_2	3-4
Métaux alcalins (comme oxydes)	2-4
Halogènes	env. 1

LURGI

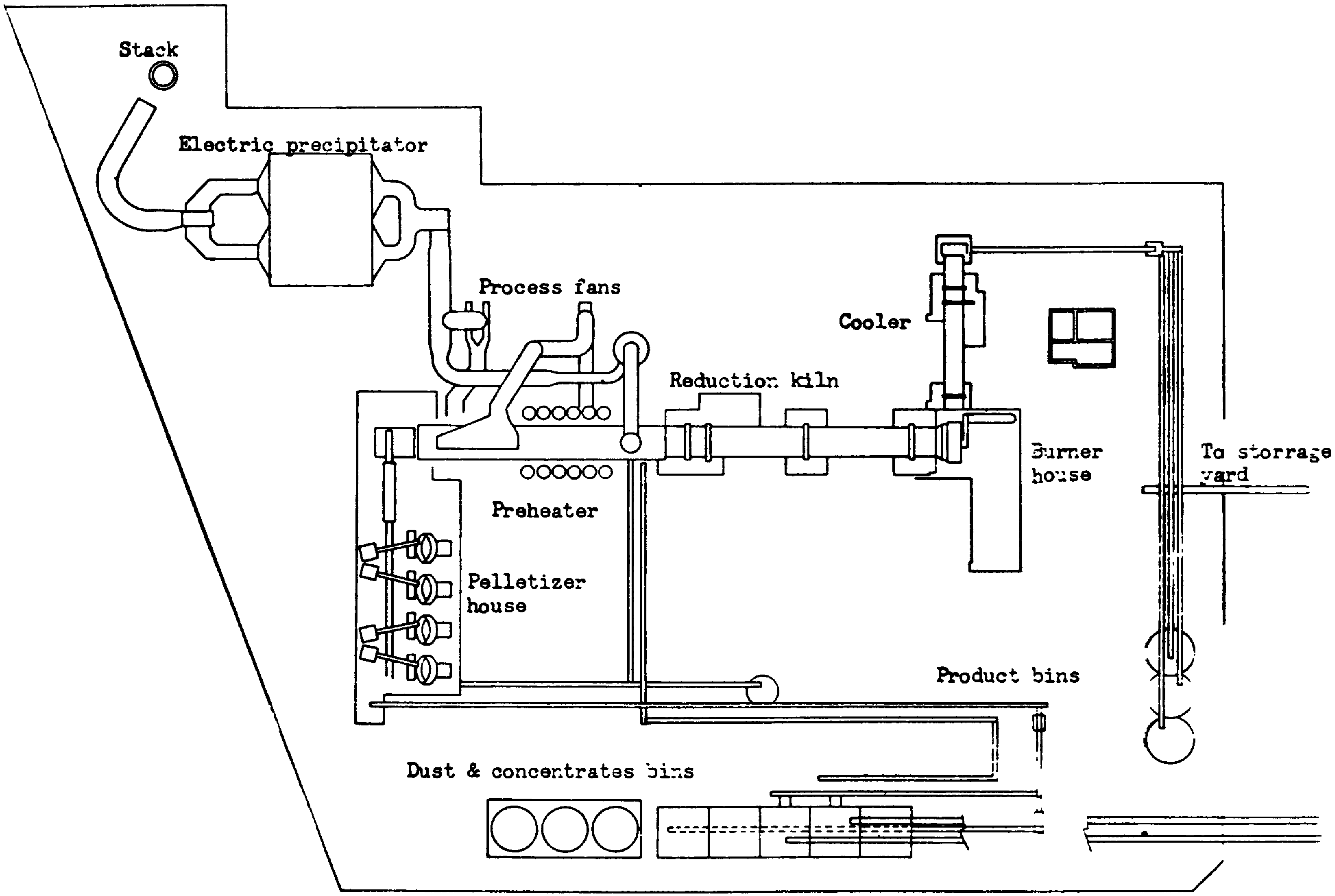
COMPOSITION CHIMIQUE DE L'OXYDE WAELZ
(POUSSIÈRES D'ÉLECTROFILTRE)

C76-1225 F

WAELZ PROCESS



ANNEX 2

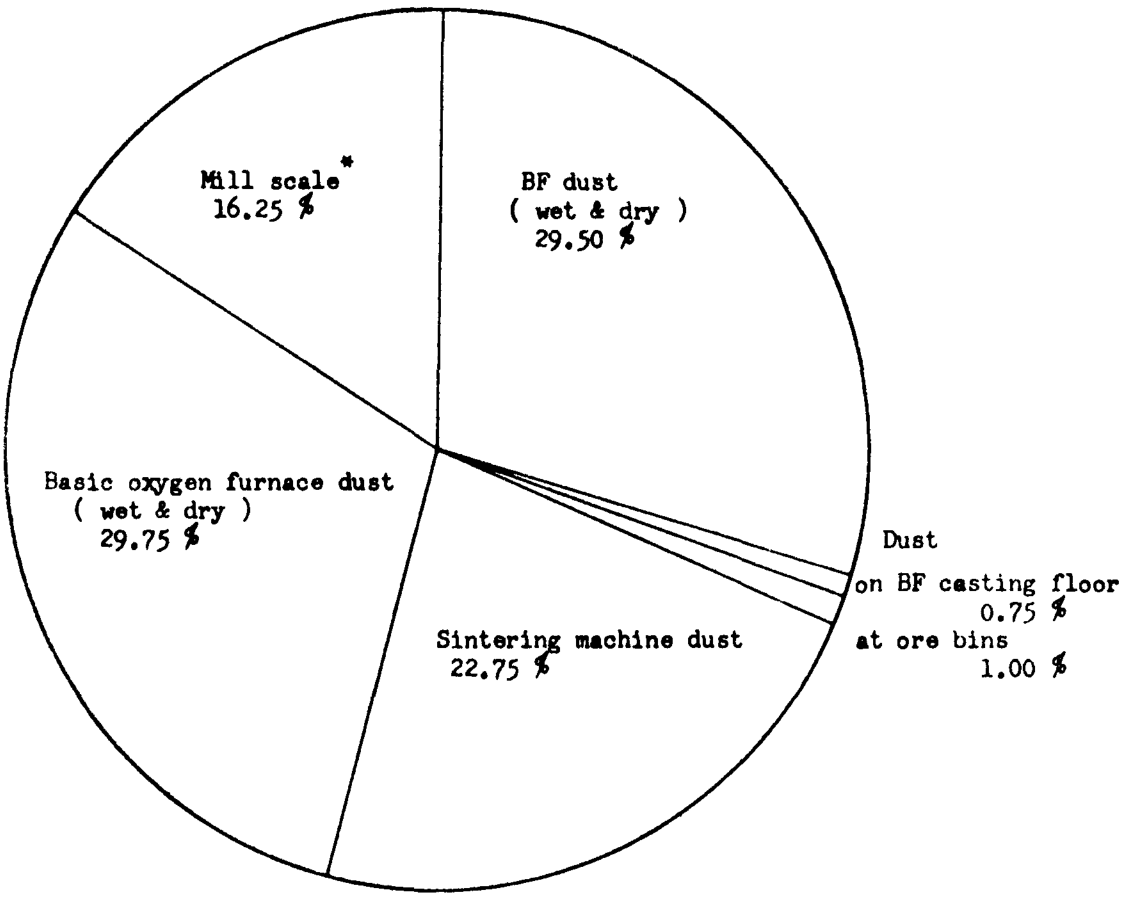


General layout of 240,000 ton product/year plant at Mizusawa

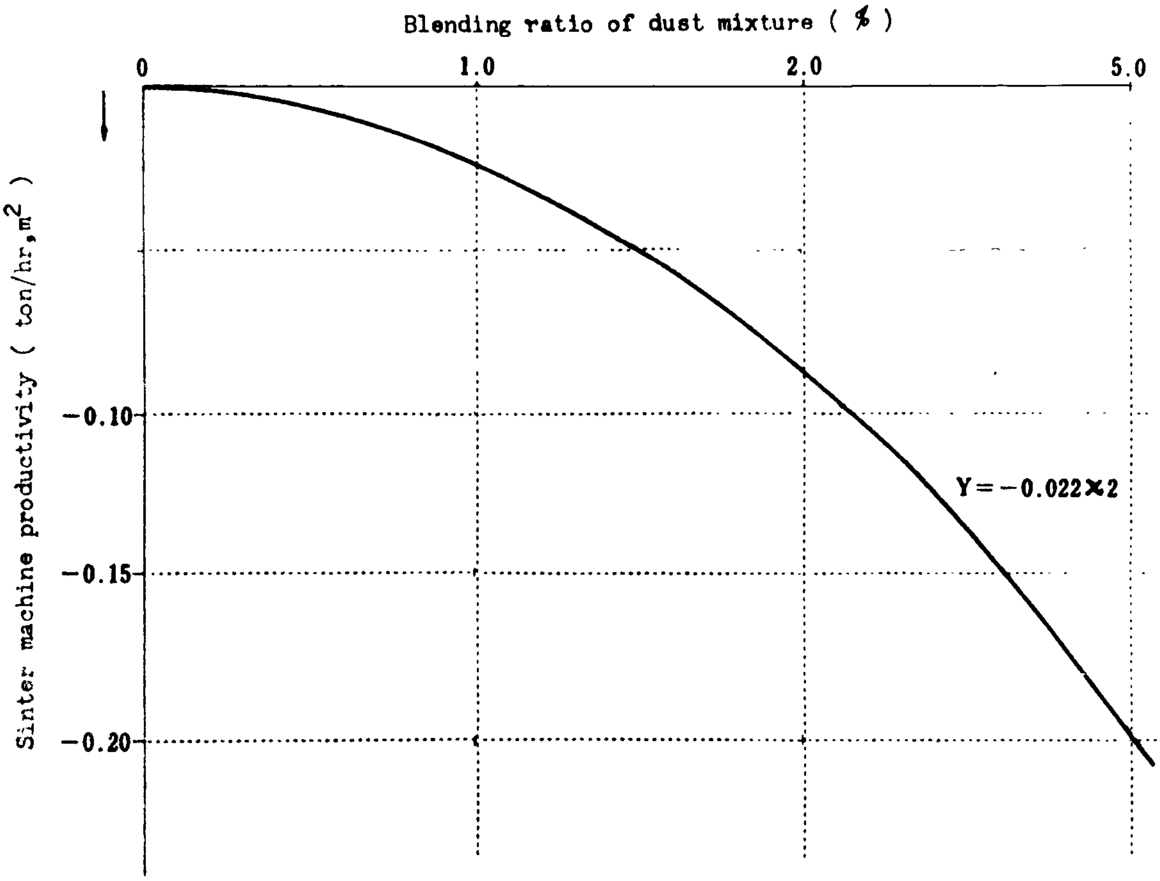
TEST RUNNING OF THE BLAST FURNACE WITH REDUCED PELLET CHARGE

Operation Variables

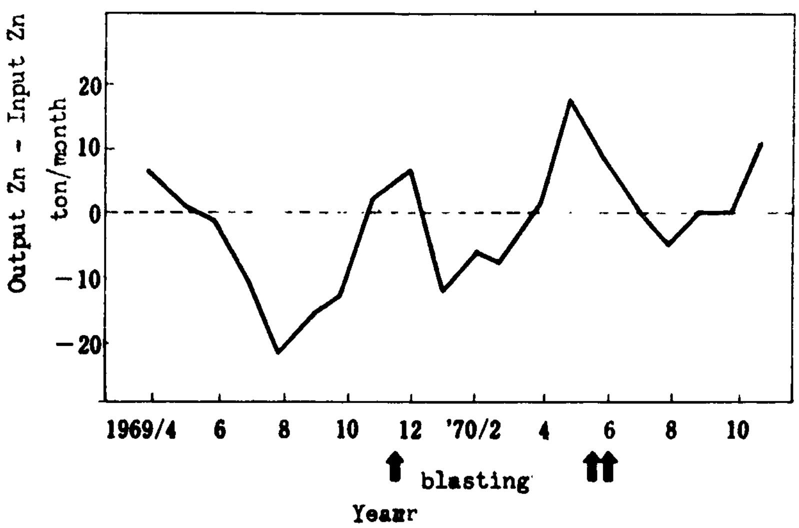
Period		9/5-14	9/28-10/4	10/7-12	10/15-19
Reduced pellet (wet)	t/charge	0	1.3	2.6	3.3
Reduced pellet (dry)	%	0	5.1	9.3	13.6
Reduced pellet	kg/t. pig	0	76	145	137
Production	t/d	1,935.4	1,993.2	2,069.0	2,032.4
(correct. 0_2 & Delay)	t/d	1,935.4	2,012	2,091	2,072
Coke rate	kg/t	479.2	447.6	424.6	426.4
Coke (corrected)	kg/t	479.2	449	425	425
Oil rate	l/t	51.5	50.5	46.2	47.5
Blast volume	m^3/min.	1,753	1,783	1,751	1,768
Blast volume	m^3/t. pig	1,308	1,288	1,219	1,253
pressure	g/cm^2	1,312	1,362	1,409	1,454
P/V		0.75	0.76	0.80	0.82
temperature	^oC	1,011	992	1,016	997
moisture	g/m^3	29.6	28.6	29.6	29.4
0_2 enrichment	%	1.00	0.69	0.65	0.46
Sinter	%	35.3	27.6	33.1	31.6
Pellet	%	45.8	49.7	43.7	43.6
Slag rate	kg/t	328	294	314	323
Si	%	0.51	0.52	0.48	0.49
S	%	0.047	0.048	0.047	0.043
Coke ash	%	11.1	10.6	10.8	10.3
No. of slips	time/d	20	16	18	10
Delay time	min.	0	0	0	22



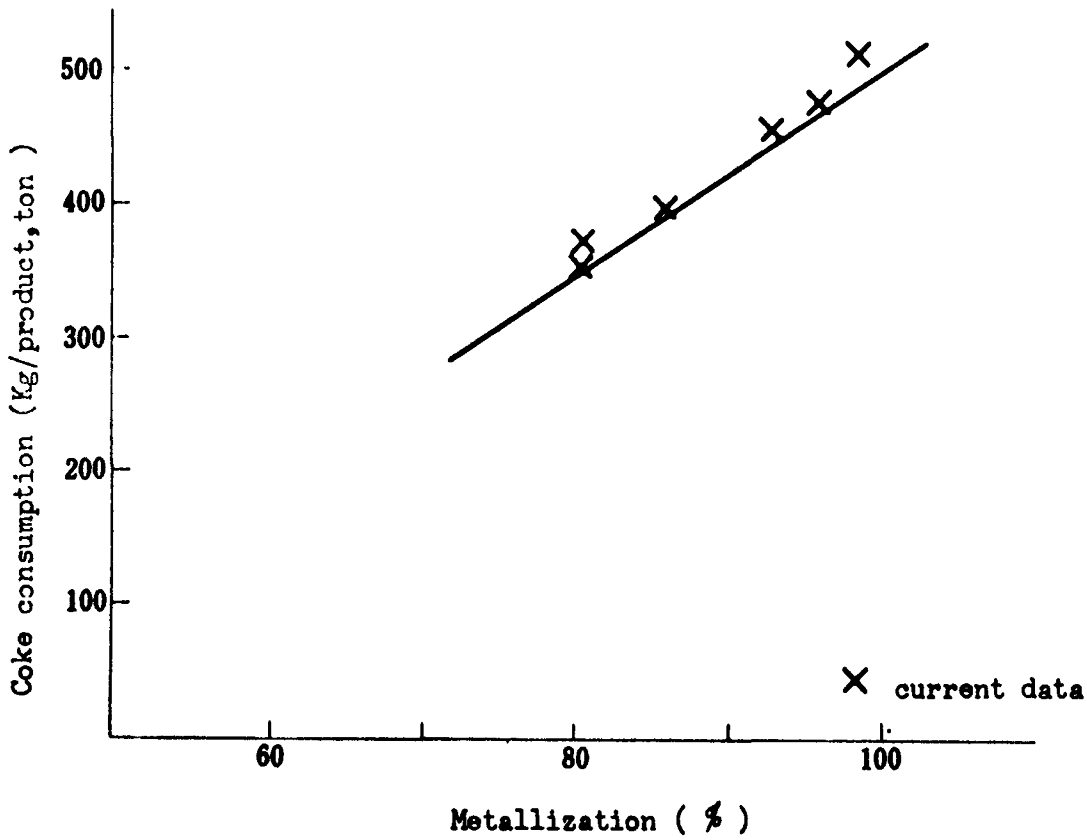
Various dust generation at an integrated steel plant
(The sign * denotes a fine portion of mill scale amenable to the dust treating plant which is about 15 pct in weight of the total mill scale.)



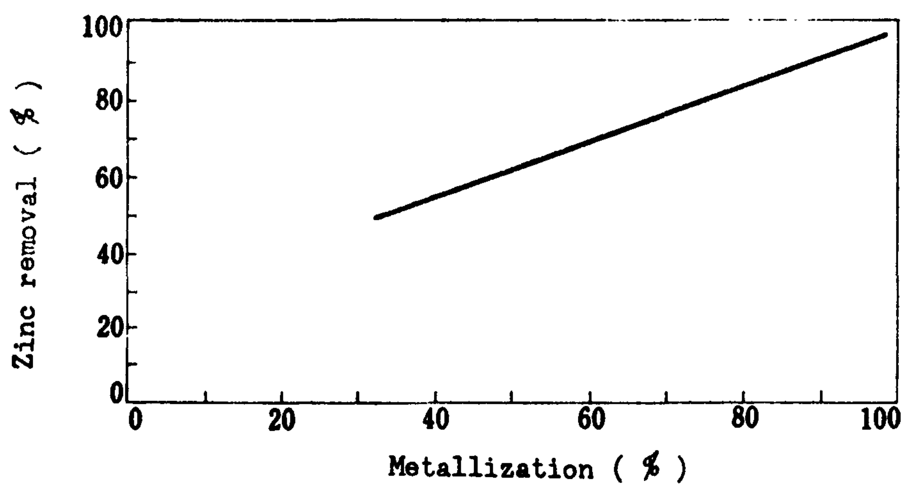
Blocing effect of dust on sinter bed gas permeability



Effect of zinc accumulation in the blast furnace on scafford formation

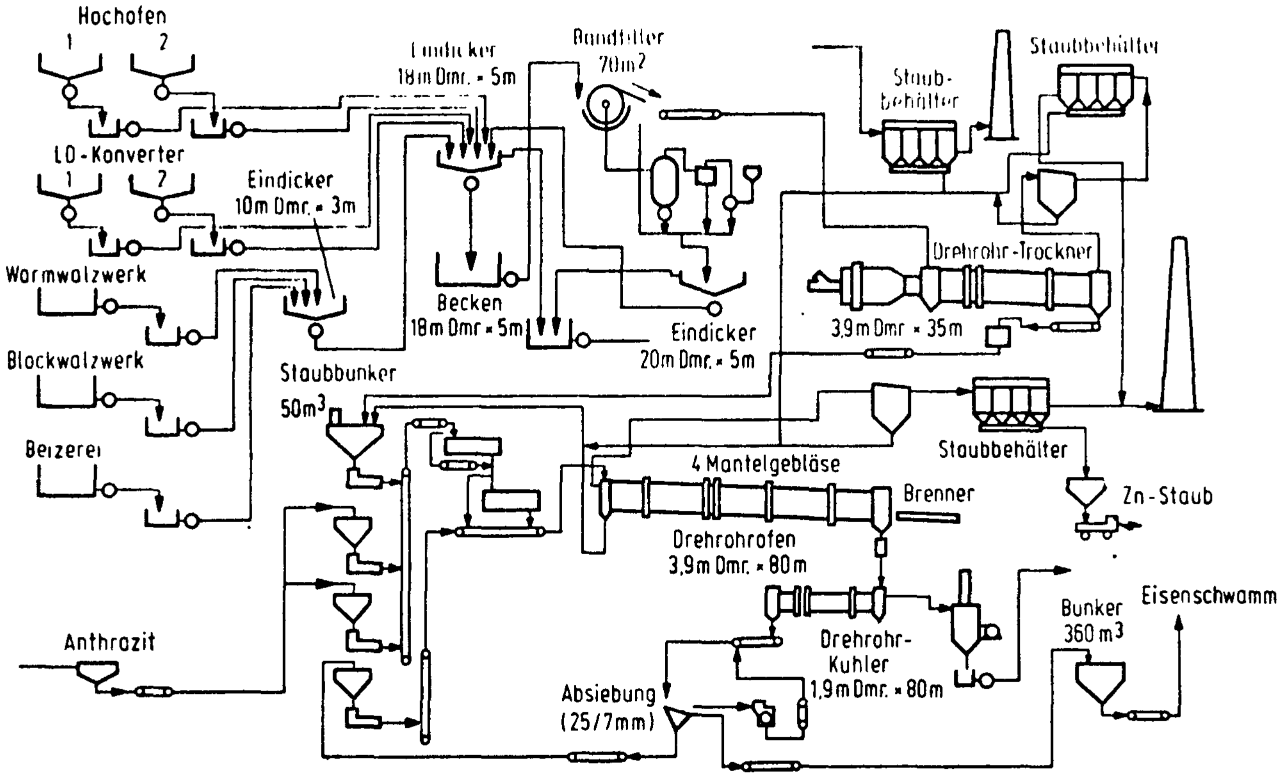


Metallization of pellet vs. coke consumption

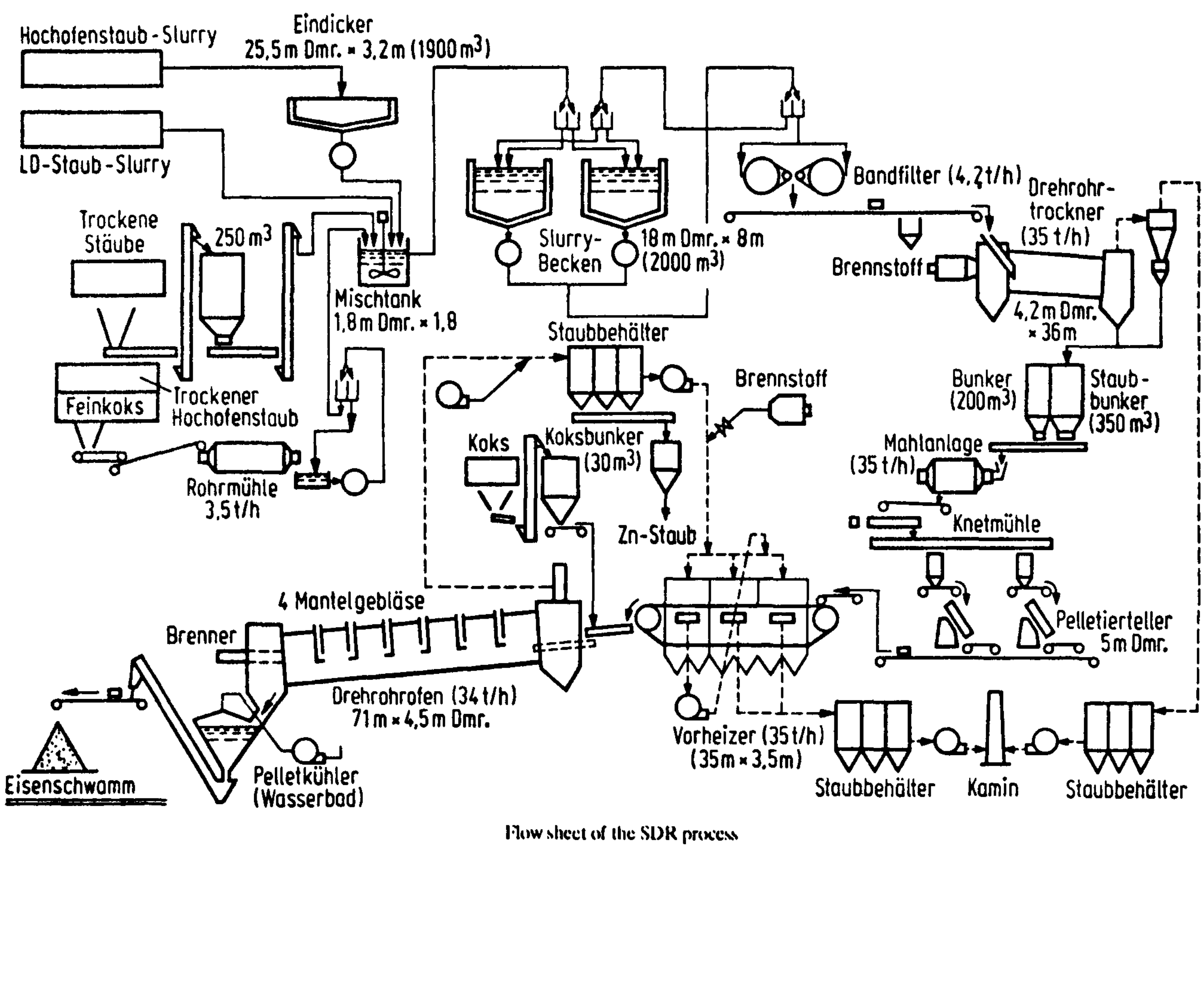


Zinc removal vs. degree of reduction

ANNEX 3



Flow sheet of the SPM process



Flow sheet of the SDR process

ANNEX 4

The extended arc flash reactor*

The electrical characteristics of the conventional carbon arc can be improved dramatically by the introduction of an appropriate gas into the arc zone. This technique provides an alternative to both the conventional 'plasma' furnace, where the plasma is generated in a 'gun', and the usual carbon arc furnace. It has the advantage that the power supply can be identical to the relatively uncomplicated arrangement used in arc furnaces, with the further advantage that it imposes less strain on the electrical system. The added complexity required to provide and control the gas is minimal. Also, the amount of gas required is quite small and only a minor item in the cost of operating such a furnace. With the added versatility provided by gas injection, different electrode configurations and new furnace applications become feasible. The extended arc flash reactor (EAFR) and its application for the treatment of waste oxides is the subject of the present paper.

The stabilized arc arrangement is less expensive than the more conventional plasma-gun furnace. It employs a simple and more efficient power supply arrangement. Normally, it requires lower gas consumption, less cooling water and a less sophisticated control system. With the configurations that have been tested in the EAFR, it is clear that an acceptable level of thermal efficiency can be obtained, which is usually difficult or even impossible with most plasma-gun arrangements.

For optimum results the type of gas and the manner in which it is introduced are both critical. In general, argon is usually preferred, although carbon monoxide or nitrogen can be used to advantage in particular applications. It has been found that the most effective method of introducing the gas is through axial holes drilled in the electrodes. In any given situation both the velocity of the gas stream and the volume of flow must be selected with care to achieve the full potential of this technique.

The modified or extended arc that can be created between electrodes or, alternatively, between electrodes and the charge in the furnace is much more stable than the conventional 'carbon' arc. From an electrical point of view it has more of the characteristics of a resistance and generates much less of the irregular waveform, which is a deleterious characteristic of the conventional arc. These characteristics are illustrated in the oscillograms of the arc current, power and voltage reproduced in Fig. 2. Although these particular oscillograms illustrate the operation of the arc in a 5-kg indirect arc furnace, the same effects have been observed and recorded in a conventional scrap melting furnace (25 000 kVA) equipped with gas-injection facilities. The results of this work have been described in detail elsewhere.[35, 36]

For any given applied voltage and equivalent power, the stabilized arc will be longer than a corresponding plain carbon arc. This creates the relatively diffuse and large volume of hot plasma that makes the EAFR possible. Carbon monoxide generated during reduction reactions, dissociation and ionization of various species and temperature all enhance stabilization of the plasma.

The general outline of the EAFR as developed in the laboratory is illustrated in Fig. 3. A relatively high-grade magnesia refractory ramming mix is used for the furnace lining. The hearth diameter is about 20 cm. The graphite electrodes are 2.2 cm in diameter. In a typical test run the power input is 20–25 kW, three-phase, with about 60–80 V, 60 Hz line to line, and a current of 150–200 A. The effective arc length (tip to tip) would be 8–15 cm.

In operation, the raw material, mixed with an appropriate amount of carbon, is fed into the preheater at a rate of about 10 kg/h. This material flows countercurrent to the hot gases evolved from the reaction zones – first, through a preheater, through the column or flash reactor, then through the plasma zone, and, finally, collects in molten form in the hearth. From there it may be withdrawn continuously or intermittently, as required. After solidification the metal and slag phases are readily separated.

An extensive laboratory programme has determined that this arrangement offers a number of features that could be exploited to advantage in a commercial application.

(a) The feed material does not require extensive preparation, such as pelletizing or briquetting. In general, it should be relatively fine (100% -35 mesh).

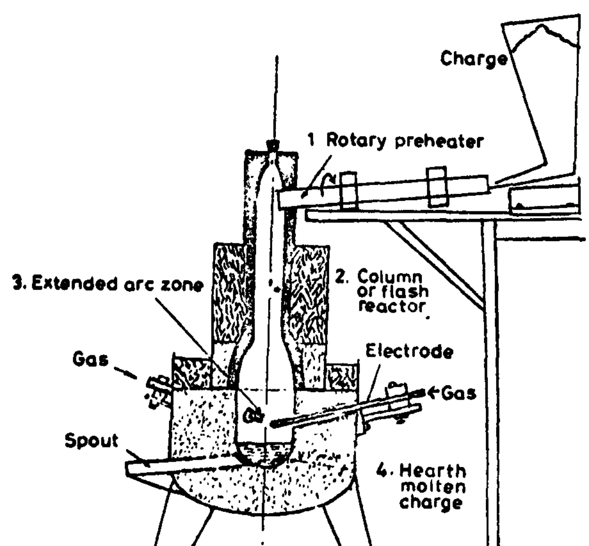
(b) The process is not sensitive to the analysis of the raw feed. Steel plant waste oxides, fly-ash concentrates and similar materials, which would not ordinarily be considered amenable to treatment by conventional routes, can be readily processed in the EAFR.

(c) The process is not sensitive to the carbonaceous material. Bituminous coal, anthracite, coke, coke breeze and graphite have been employed as reductants.

(d) Aside from the previously outlined operating details of the furnace, no new technology is involved. Power supply, materials handling, etc., are conventional. Metallurgical control of the product also follows well established procedures.

(e) The plant required is relatively simple and not capital-intensive. It is considered that an operation should be economically viable, even on a relatively modest scale.

The treatment of steel plant waste oxides in the EAFR is discussed in more detail below.



Schematic of three-phase extended arc flash reactor (EAFR) (25 kW)

* Patent pending.

COMMISSION OF THE EUROPEAN COMMUNITIES

(Directorate General XII - Research, Science, Education)

A SURVEY OF THE TECHNOLOGIES FOR RECYCLING ALUMINIUM AND LEAD

by

A. Vaschetti and M. Civera
(Cerimet)

CERIMET S.p.A.
(Centro Ricerche Metallurgiche)
Lungo Dora Voghera 82
10153 Torino
(Italy)

December 1977

43

Part A

ALUMINIUM

(by A. VASCHETTI)

CONTENTS

RECYCLING OF ALUMINIUM - GENERAL REMARKS

The recovery of aluminium or of its alloys from old and new scrap, foundry drosses and slags concerns a large industrial branch, which has risen up to a high degree of technological development.
Its share is considerable in contributing to reduce the dependence of EEC countries upon foreign sources, not only of ore, but also of fuel: as it is well known, for producing 1 ton of primary aluminium, beside 0,5-0,6 T of coke for electrodes and minor amounts of other chemicals, 4 to 4.8 tons of bauxite are required, as well as 8,400 kWh of thermal energy for producing alumina and 13,000 to 14,000 kWh of electrical energy for the recovery of aluminium metal (1.1); the total is equivalent to the consumption of about 4 tons of fuel oil. On the contrary, in the aluminium recycling processes energy consumption is reduced down to 1/6 or even to 1/20 of that amount, according to the type of materials treated.
In 1974 900,000 tons of secondary aluminium alloys were produced within EEC (1.2), corresponding to a reduction in imports in the order of 3 million tons of oil and 4 million tons of bauxite. From the ecological point of view advantages are also very important, but some more difficult to be expressed by figures.
Different from primary industry, which depends on well located supplying sources with known reserves and production capacities, secondary smelters receive their raw materials from "above ground mines", whose typical features are remarkable dispersion and quality heterogeneity, as well as

supply flows liable to fluctuations often impredictable, also related to market trends as well as to complexity and fragmentation of supply circuits.

The ever and ever growing complexity of scraps coming into the yards of the secondary smelters compels them to choose sophisticated techniques for sorting,melting and control of pollution a factor favouring the growth of plant size: plant capacities higher than 20,000 tpy are now frequent within Europe. On the other hand, the interest is growing in primary smelters to this field, and in all EEC countries integrated plants have been set up.

Owing to the properties of aluminium, which cause it to be difficult to refine the metal, secondary smelters supply mainly the casting alloy market, in percentages reaching up to 80-90% of the amounts needed: these alloys show higher contents of alloying elements and wider tolerances in composition. A smaller portion of production consists of aluminium alloys used in deoxidizing steel, and of powder for aluminothermy; besides, some byproducts are obtained, like scrap of steel and of other nonferrous metals (copper, zinc, magnesium), and aluminium oxides.

A) USES OF ALUMINIUM IN INDUSTRY

Pure aluminium metal is used in electrotechnical industry, chemical plants and packaging, but aluminium is more frequently used in the alloyed state, i.e. such metals as silicon, magnesium, copper, zinc, are added to it in amounts up to 13 - 15%.
For special purposes, minor additions are made of manganese, titanium, nickel, cobalt, chrome, bismuth, lead, and cadmium.
Each alloying element causes peculiar changes to aluminium basic properties; e.g.:

- silicon improves castability and reduces thermal expansion coefficient
- magnesium improves corrosion resistance in alkaline waters and sea water
- copper improves mechanical strength, especially at higher temperatures
- zinc, when associated with magnesium, gives higher mechanical strength.

Quaternary Al-Zn-Mg-Cu wrought alloys in the heat treated state have tensile strength levels comparable with those of steel, and the advantage of less than half its specific weight.
Cu-Al and Al-Zn-Mg alloy rolled products may be plated with pure aluminium or Al-Zn alloys in order to improve their resistance to corrosion.
In Tables I and II compositions and properties are listed of the most typical wrought and casting aluminium alloys produced in Italy.

Alloys similar in composition are mentioned in standard specification of other EEC countries (4.1) (5)
Indicatevely a list is reported - unavoidably not complete owing to the width of application field of the metal - of the aluminium - base manufactured goods in the different industrial sectors, some of them are dealt with in this report.

Buildings

Window frames are made almost totally of Al Mg Si alloys, usually surface-treated by anodysing: oxidised layer must be at least 12 microns thick for outside exposed parts and 7 microns thick for interiors. The use of decorative panels made of pure aluminium or AlMg alloys coated with PVC or polyethylene is also growing, both for interiors-walls, doors, tables, furniture and for outside decorative panels.
AlMn alloys are widely employed for roofings.
Other applications include radiators, venetian blinds, lighting fixtures, home and office furniture etc.

Transportation equipment

High strength AlCuMg and AlZnMgCu alloys are used in airplane structural parts, sheathings, propellers, wheels, etc.
For railroad equipment AlMgSi and AlMg alloys with improved corrosion resistance are preferred: the latter alloy class is widely employed in naval superstructures.
In some truck parts - caissons, chassis, tanks - AlMgSi 1 and AlZnMg 1 find more and more wide acceptance for the possibility of making substantial savings in fuel during the service life of the equipment.
The same advantages are recognised for cars, with the conse-

./.

quence that consumption of aluminium alloys is foreseen to be increased in next future not only for the engine parts, made mainly of casting alloys, but also for body parts.

Electrotechnics

Aluminium is widely used for the high voltage overhead lines: cable conductors are used for this purpose, consisting of aluminium wires wound around a galvanized steel wire core Aluminium is also used in ever increasing amounts for power insulated cables and low voltage insulated conductors with cross section area down to 5 mm^2; moreover in bus bars of electrolytic plants, power substations and squirrel cage motors. Other applications include transformer windings, condensators, lighting equipment, panels and frames for switch boards, television sets etc.

Mechanical engineering

Main application items are machinery bodies and accessory parts where aluminium die casting alloys are preferred, owing to their low weight coupled with good mechanical properties. These applications are so numerous that an exhaustive list of them is nearly impossible to be made.

Domestic Appliances

Aluminium is widely used for manufacturing pots and pans: for this purpose pure aluminium or its alloys with magnesium and manganese are used.
Other important applications are to be found in sets for recreation and sports.

./.

Chemical plants

Pure aluminium (99,7 - 99.8) is usually chosen, or less frequently AlMg or AlMgSi alloys, for constructing tanks, heat exchangers, distillation columns, tubes, drums, bins, valves, pumps, etc.

Packaging

Pure aluminium is used in thin foils (less than 0, 2 mm) lacquered or bonded to paper or plastic for food preservation and transport: small non returnable containers for beverages and aerosols are made of AlMnMg or AlMg alloys. For larger returnable containers AlSiMg or AlMg alloys are preferred.

Other uses (mainly dissipative)

- As a deoxidizing agent for steel. For this purpose high iron aluminium alloy can be employed, obtained during the treatment in sweating furnaces (see C 1.4) of scraps heavily contaminated by iron. This consumption has been evaluated to 1 kg per ton of steel produced (3.3).
- In aluminothermic processes
- As a pigment for heat resisting paints
- As alloying element for magnesium, copper, zinc base alloys
- For chemicals, mainly for producing $AlCl_3$ widely used in organic chemistry.

Indicative data are given in Table III of the spectrum of aluminium consumption (in thousands of metric tons) for 1974 in the different industrial branches of some EEC countries.

When grouping the figures of the table for the four referred countries, the fact may be observed, that aluminium consumption for the industrial branches considered in this contract accounts for 73% of total consumption;

(thousands of metric tons)

a) transportation	617.5 (26.1 %)
b) mechanical engineering (chemical,domestic and office appliances included)	470.8 (19.9 %)
c) Electrical Engineering	264.9 (11.2 %)
d) Building	375.7 (15.9 %)
total items a) b) c) d)	1.728.9 (73.1 %)
grand total (direct exports deducted)	2.365.1 (100.0%)

The use of aluminium or aluminium alloys in the above mentioned industrial branches is mainly non dissipative; however only a part of this metal is beeing currently recovered from old scraps as it will be later explained (Section B.2) Inadequacy of some technologies employed for recovering the metal is only partly responsible for this situation.

B) ORIGIN AND QUALITIES OF ALUMINIUM SCRAP

As for the other nonferrous metals, for aluminium too the distinction is fundamental between old and new scraps: their origin affects actually in a considerable manner both their commercial value and the subsequent treatment they require for recovering the metal.

B.1) New Scraps (and home scraps)

They come both from primary and secondary metalworking. In view of the multifarious uses of aluminium, their appearance and composition varies widely: rejected or broken castings; sprues; feeding heads; trimmings; scraps from extruded parts, wires or tubes; sheet or plate cutoffs; punchings; coated or uncoated foils; turnings; borings etc. The semis manufacturers and the foundries recycle directly the most part of their scraps, i.e. their "home scraps": their share in the charge of melting furnaces may reach up to 30-40% of the total.(37) The following materials are frequently not included in this direct recycling:

- Skimmings and drosses coming from melting operations: their amount may be estimated to 3-4% of the total metal treated. They contain yet considerable quantities of metallic aluminium (30 to 70%) more or less finely dispersed into a phase consisting mainly of aluminium oxide.
- Metallic residues coming from machining operations: their fineness and high content of heterogeneous materials (lubricating oils, water, ferrous metal turnings etc.) require usually some pre-treatments

before melting.
The two above sorts of materials are sold directly to secondary smelters, or dealt with in the collecting system consisting of a complex chain of small collectors, middlemen, wholesale traders, having at their disposal a more or less complex technical equipment for a preliminary sorting of the different metallic scraps and for their shipment to utilizers.
A comprehensive discussion of the structure of the above said technical-commercial organization - which is vital for providing for an adequate flow of scrap to recycling plants - goes beyond the scopes of this survey: an exhaustive survey on this matter is included in the recent report of Charter-BIPE-ITE made on behalf of the Environment and Consumers Protection Service of EEC. (6)
New scraps are also originated from fabricators using products of the aluminium primary working.
The most selected ones are often sold to primary smelters, to foundries, and in smaller amounts to semis manufacturers. Lower grades with heterogeneous inserts, turnings and swarves are supplied to secondary smelters, either directly or through the above mentioned collecting system.
More than 90% of new scraps generated in the different manufacturing activities is estimated to be recycled: therefore a little chance is left to improve such a high percentage.

B.2) Old Scraps

They originate from dismantling of manufactured goods

after their period of useful service.
The actual share of secondary aluminium recycled from old scraps depends upon the amount of metal used in the different manufacturing products in the past years, upon their durability, and upon economical stimulus to its collection. As for the durability of the different manufactured articles and the percentages of aluminium recovered from old scraps coming from different industrial branches, estimates are available which do not always agree each other; some of them are listed indicatively in Table IV.
In a recent OEA report (3,4) we may see that the estimated percentage of aluminium recovered from old scraps within EEC by 1974 accounts only for 35-40% of the potentially available amount, originated by the discarding of the different manufactured goods; another estimate dealing only with Federal Germany (18) gives a much lower figure - 22% - for this item. Even if we take into account the uncertainties involved in these estimates, such low percentages show that possibilities are yet open for improving the recovery of old scraps.
On the technological side their treatment gives rise to more problems than that of new scraps.
The raw material is often a mixture of different alloys polluted by dirt and other materials and with oxidized, painted or anodized surfaces; very often the pieces - widely varying in size - include metallic or non metallic inserts difficult to separate.
Many important technological advances have been ma-

de just in the stage relating to the dressing and classification of scraps, where some typical ore dressing methods have been adapted to hese materials.

In fig. 1 is shown, in somewhat semplified way, the main flows of new and old scraps between the various producers and secondary refiners.

B.3) Classification of Aluminium Scraps

In order to facilitate the international trade of non ferrous metals scrap, some more or less widely accepted classification and grading standards have been set up, which have beenadded to those already available within the different Countries.
The first of such standards - which can be applied in all international agreements - is the American NASMI Specification Circular No. 66 (see appendix B).

Subsequently the Bureau International de la Récuperation (BIR) has set up the Euroclassification, more suited to the requirements of the European market and applicable to agreements between European countries (see appendix A).
This classification is now beeing revised in order to make it more suitable to the fast changing market of aluminium alloys and to reach a better agreement with the American Specifications.
NASMI standards list 21 different grades of aluminium scraps, Euroclassification lists 18. Many scrap sorts and grades are not yet included in these standards,and

their commercial rating is made only after a careful sampling of the lot under question.
The weight of the sample may range between 0,5 to 10% of the whole lot of scrap, according to its homogeneity; it is melted in a crucible under a salt flux and the metal obtained is weighted and analysed.

B4) Influence of Economics on Aluminium Recycling

As previously pointed out, the main marketing outlet of secondary smelters consists of foundry alloys, especially of die casting Al Si12 Cu Fe and Al Si8 Cu3 Fe alloys.

Their sale price is somewhat related to the price of primary aluminium, which is their main component, and amounts to 90 - 95% of this price; however, in some cases anomalous market conditions, owing to unbalances between demand and offer, lift the prices of these alloys upwards, at levels remarkably higher than primary metal prices.
On the contrary, a tighter interrelation is between the price of secondary alloys and the price paid by refiners for aluminium scrap: e.g., if quotation trends are considered in the '74-'75 period, for "carter" alloy -typical feed of secondary smelters and consisting mainly of Al Si Cu alloy die casting scrap - we may see that they amount to about 60% of quotations of the corresponding secondary alloys (3.3).
The same ratio is to be observed for more recent quotations found in the Metal Bulletin.

The difference between the two prices may be taken as an index of the margin available for refiners for the transformation of a reasonably selected scrap; such a margin must be sufficient to meet the costs related to melting and refining operation, and to provide for an adequate reward for invested capitals.

According to estimates made by Organization of European Aluminium smelters (OEA) for the 64-74 period and referred to a 20,000 tpy secondary smelter, investment costs had risen up to 180-210 $ per yearly ton capacity, owing to the higher mechanization of operations and to higher plant installation costs, mainly due to antipollution equipment (3.1).

In the same time, labour productivity had risen from 77 tpy per worker in the sixties up to 130-150 tpy and the average labour cost had increased from 100 $ to 200 $ per ton of secondary alloy.

The above reported basic quotation for carter scrap are liable to increase considerably in the case of well selected new scrap, having low contents of some impurities (Cu, Zn, Pb), or to decrease for scraps - e.g. turnings, scrap with ferrous inserts etc. - requiring further selecting treatments at the refiners plant, or liable to have heavy melting losses when treated in the as-received state.
The relatively high cost of the final refining treatment affects the price paid by dealers and collectors to the owners of scrapped goods or to dismantlers: the commercial system must actually meet the often high cost of

collecting, sorting,storage, and shipment to refiners. It will then be readily realized that in many instances little stimulus is left to metal collection - for some hardly recoverable low aluminium scrap or for scrap available in small scattered lots - so that the metal follows the destiny of the main scrap component, or is wasted.

The improvement of the different technologies applied in aluminium recycling, though it be necessary, may prove not to be decisive in increasing metal recovery yields: actually, in past years its main effect was in counterbalancing the increasing costs of energy, labour and investment, related to selecting and transforming operations.
Other factors must be considered beside the technological ones.

Among them may be mentioned: the rationalization of the collecting system; the attenuation of some speculative trends connected to the said system; the generation of a higher sensitiveness of consumers with regards to recycling problems; suitable measures for favouring industrial branches interested to recycle and for discouraging the use of some hardly recoverable articles.

The discussion of their influence on the improvement of recovery rate for aluminium is anyhow outside the scope of this work.

C) REVIEW OF TECHNOLOGIES APPLIED FOR RECYCLING ALUMINIUM

Aluminium scraps and rejects look extremely heterogeneous as for appearance and composition: they come both from primary metalworking concerns (foundries and semis manufacturers) and manufacturers of aluminium-bearing articles, as well as from old junked manufactured goods.

In the previously mentioned BIPE-Charter-ITE report (6) we can see that in some EEC countries (France, Germany, U.K.), where more detailed statistical data are available, old scraps account for 30 to 35% of the recycled aluminium, balance including 35 to 38% of new scraps, 18 to 20% of turnings, and 15% of drosses. Similar figures are reported elsewhere (2.11) for the composition of raw materials of secondary smelters.
According to that report, the share of the total supply of old and new scraps for the above mentioned countries between the various users is the following:

Secondary smelters	(old and new scraps)	~ 85%
Primary smelters	(mainly new scraps)	~15% (Primary smelters, Foundries, Semis manufacturers, Other users)
Foundries	(mainly new scraps)	
Semis manufacturers	(mainly new scraps)	
Other users		

Therefore, secondary smelters are the biggest users of aluminium scraps of every kind, and usually they apply the most advanced technologies for dressing, melting and refining these materials; foundries, semis manufacturers, and primary smelters add usually selected aluminium new scraps in limited amounts to the charge of their melting furnaces.

The different types of scraps will be briefly reviewed here, which originate from the different industrial branches within the scope of this work.

Building Industry

We may estimate that, at least in Europe, the most readily removable aluminium components, like roofings, window frames, venetian blinds, furnitures, lighting fixtures, radiators, etc. are recovered before building demolition; other items may be lost, e.g. tubings and electrical cables, but they do not account for large amounts of this metal.

The treatment of these scraps - more or less thoroughly sorted - does not originate special problems, except for the necessity, in some instances, of preliminary shearing and baling operations before the shipment to refiners. For materials with ferrous inserts or plastic coatings, shredding may be advisable before melting. (see C 1.3).

Transportation Equipment

The most part of aluminium scraps originating from aircraft, railway equipment, ships and trucks are recovered by dismantlers; however, some aluminium parts not readily removable are lost together with ferrous scrap.

A particular problem is to be faced in the recovery of aluminium and generally speaking of non ferrous metals from junked automobiles; a special technology has been developed for this purpose (see C 1.3.2.1).

Electrical Engineering

The recovery of aluminium from the different sorts of cables is accomplished by methods similar to those applied for the correspondent copper articles, which account yet for the most part of scrapped materials.

Losses consist mainly in underground cables, which are left in situ at the end of their service life; the lower value of their aluminium content impairs also the stimulus to recovery.

As for other applications of aluminium in electrotechnics, its recovery may vary widely, according to type and position of the articles; however we may estimate that the most part of the aluminium is recovered, when dismantling large or middle size installations for the generation or utilization of electric power.

Mechanical Engineering

The wide variety of application of aluminium in this industrial branch gives problems for a detailed description of scraps originating from them.

As a rule, we may estimate that the most readily removable and sufficiently large-sized aluminium parts of

machinery are removed by middle and small dismantlers and shipped to the recovery system.
Electrical household appliances - in which aluminium is intermingled together with non-ferrous and ferrous metals, as well as plastics - are similar in condi-- tions to automobiles, and can be treated by the same methods and often in the same recycling plants.

A not negligible portion of old scraps consists of kitchen pots and pans, and of other small household articles, and their collection is often hindered by their great scattering.

The poor selection at the original places of some sorts of scraps - old scraps, turning, drosses - and some unbalances in the availability of the different materials, causes often the secondary smelters to have at their disposal metal mixtures different in composition with regard to the alloys that they intend to produce, though wider tolerances for alloy composition and higher tolerances for impurity levels are allowed in specifications and standards for secondary smelting products.

Unlike copper and lead, the complete refining to metal of aluminium alloys remelted from scrap is too expensive: aluminium affinity towards oxygen and halogens is indeed higher than that of all alloying elements and impurities usually present in its alloys - except for magnesium - so that pyrometallurgical refining techniques cannot be applied.

Aluminium refining by molten salt electrolysis is used by primary smelters only for production of limited amount of high purity aluminium, but cannot be applied by secondary smelters, owing to economical reasons (cf. D 2.3).

So, secondary smelters - after a thorough sorting of raw materials - just make a suitable mixing in the melting stage, in order to achieve the compositions of the alloys they usually produce, mainly casting alloy for which market supply they account for 80-90%.

A proper knowledge of composition of the different sorts of available scraps - which may often be achieved only by costly sampling by fusion - is a condition required for applying linear programming techniques: they give the means for producing alloys with the desired composition by using the cheapest materials and taking into account availability limitations and other factors related to the production processes.

The calculations involved, often cumbersome owing to the great number of variables, can be quickly accomplished by electronic computers, which are also widely used for other routine operations like store manage-- ment for raw materials and finished products, cost accounting etc.

So, refining treatments can be reduced down to a minimum: they consist mainly of magnesium removal by treatment with chlorine and degassing with chlorine and/or inert gases.

Before final ingot casting, alloy composition adjusting may be done by adding aluminium and/or master alloys: the required analytical controls are made quickly and accurately by quantometer spectrography.

In figure 2 the different operations are shown, which are used - all or in part - by secondary smelters (2.1): in the whole processing the following basic stages may be outlined:

C1) Sorting and charge dressing
C2) Melting
C3) Refining
C4) Casting

Moreover, in section C5 the ecological implication will be examined, related to the above operations, as well the means chosen for controlling solid, liquid, and gaseous pollutants.

C.1) Sorting and Charge Dressing

A number of alternatives are applicable in this stage, according to raw materials to be treated. They may be grouped as follows:

- Hand sorting
- Shredding and following operations (air and magnetic classification, heavy media separation)
- Sweating furnaces for scrap heavily contaminated with iron

- Dressing of turnings, borings, etc.
- Dressing of drosses
- Dressing of electrical cables
- Dressing of aluminium foils with various coatings.

The above grouping of the different processes is merely descriptive: actually the same material may be treated by more than one of the above methods. E.g. hand sorting may frequently precede or follow the shredding or shearing operations accomplished on mixed scraps.

C.1.1. Hand Sorting

This method is widely applied at all levels of the scrap collecting system - including waste collectors, small traders, middlemen, wholesale traders, with an intensity decreasing from the former to the latter ones - and also by secondary smelters.

The cost of required equipment is low, so it is readily available also for small and middle concerns.
The success of operation depends mainly upon the skill of labourers; so their wages are steadily increasing owing also to the uncomfortable working conditions. The possibilities of improving the selection of materials by technical aids which make the detection of the different metals and alloys easier are rather scarce, at least for aluminium-base scrap. Devices have been set up, based on measurement of arc emission, thermoelectric power, resistivity, electrolytic potential, magnetic permeability, or chemical spot test, which give

the means to discriminate the different aluminium alloys and, above all, foreign metals (2.2) (41).
So far, they have found limited applications.
The new, highly mechanized sorting methods - which will be described in the following sections - are gradually replacing hand sorting. But their use, owing to the high investment costs, is not readily within reach of all recyclers; on the other hand, even when such equipment is used, a preliminary sorting for removing the most readily detectable heterogeneous stuffs makes considerably easier the subsequent operations.

C.1.2. Shearing, Baling, Briquetting

For large-sized aluminium scraps, like those obtained from dismantling of aircraft, ships, land vehicles, buildings, industrial plants, etc., a preliminary shearing treatment is required.

A typical machine used for this purpose is the guillotine shearing device(*): the scrap is fed into a large container, e.g. 3-6 meter long and 1.8-2.5 meter wide, and is pre-pressed by movable side walls hydraulically driven, then is pushed at a constant speed under the vertical hydraulically driven shear; cutting force reaches up to some hundred tons, and cutting ra-

---

(*) Some manufacturers: Lindemann KG (W.Germany); Maatschappij Bronneberg Helmond (Holland); Harris Press & Shear Corp. (USA); Copex (France); Ing.Alessandro Lollini (Italy); Beker & Co.Kg (W.Germany); Thyssen Henschel (W. Germany).

te is some cuts per minute. The scrap is reduced down to a size of some decimeters.
A similar equipment is the alligator shearing device (**): its blade does not slide vertically between guide rails, but is hinged at one end, the other one being free. They may be large-sized, performing similarly to guillotine shears, but also portable, hand-driven devices are available, specially suited for cutting tubes, bars, shapes, cables, etc.
Another treatment frequently used for aluminium scrap before shipment to secondary smelters, or before charging into melting furnaces, is baling: hydraulically driven machines are used, which press the material into brick-like blocks (bales) side size some ten cm, apparent density 1.2 to 1.5. The capacity of these semi-automatically controlled machines is about 1-2 tph (***).
Aluminium turnings and chips are more frequently subjected to briquetting (****): cylindrical disks are thus obtained, which can be readily transported and fed into melting furnaces.

C.1.3. Shredding and subsequent Separation Treatments

Bulk scrap not classified at origin, and consisting mainly of old scraps, include heterogeneous, more or less readily separable materials: we may find metallic parts or inserts, mainly cast iron or steel, as well as

(**) Some manufacturers: Maatschappij Bronneberg Helmond (Holland); Lefort Gosselies (Belgium); Tezuka (Japan); Harris Press & Shear Corp. (USA).

(***) Some manufacturers: Lindemann KG (W.Germany); Ing. Alessandro Lollini (Italy); Logemann (USA); MAC Corp. (USA); D.& J.Press Co. (USA).

(****) Some manufacturers: Tezuka (Japan); D.&.J.Press Co. (U.S.A.); Logemann (USA).

./.

organic materials, like plastics, wood, paper, paints, besides various heterogeneous stuffs originating from dismantling and collecting, e.g. earth, grease, rags. Data given by a plant equipped for the mechanical sorting of aluminium scraps of various origins (8) show percentages ranging 0 to 25 for metallic inserts, and 0 to 15 for non-metallics, averages values being 8 and 5%.

In some special scraps, like those obtained from aircraft dismantling, the percent of ferrous metals may reach up to 25%.

Such scraps are subjected to pre-desintegration, in order to separate heterogeneous materials, as far as possible. For their removal two alternatives are chosen:

- Wind separation of light parts, followed by magnetic separation of ferrous parts
- Magnetic separation of ferrous parts, followed by heavy medium separation, for removing fractions having sp.gr.lower than 2 or higher than 3.

C.1.3.1. Shredding, wind separation of light fractions, and magnetic separation of ferrous parts

As an example the main features are given here of a plant, capable of treating 8 to 12 tph of aluminium scrap, costructed by Becker & Co.KG of Dortmund (W.Germany), and operating at Rackwitz (E.Germany) (8).

The raw material is passed through a pre-disintegrator, consisting of three parallel shafts, positioned at a triangle and fitted with teeth, which reduces the size of the material, and effects a preliminary separation of inserts; on the belt conveyor,feeding the subsequent shredding mill the most readily detectable heterogeneous

./.

parts are removed by hand sorting.
This machine looks like an hammer mill, but instead of hammers it has toothed rings, freely turning around peripheral pins , so that a shearing action is obtained, combined with mechanical impact.
The shaft turns at 1000 rpm, and is driven by a 700 HP motor; scrap size is reduced down to the 30-80 mm range.
An intensive air stream - in the order of 45,000 Nm^3/h - is forced to pass by aspiration through the rotor chamber, for removing pneumatically the most part of light components (wood, plastics, paints) together with a small amount of metallic powder, which is then separated by means of cyclones and bag filters.
The metallic parts discharged from the shredder are subjected to magnetic sorting by means of high field intensity drum magnet , which retains all parts containing more than 5% of iron. The average aluminium content of this fraction is rather high, namely 25%; so, a further treatment is required, i.e. passing them under low field intensity magnet, which gives two fractions:

- A ferrous material-base fraction containing less than 5% aluminium, which is sold to steelworks
- An aluminium-rich fraction which may be recycled to shredding or sent to de-ironing furnaces.

The main non-magnetic fraction may contain up 0.2 to 0.3% iron, and is passed under a special magnetic probe - a peculiar feature of this process - which operates a baffling device, thus recycling to crushing all parts containing more than 0.1% iron. Then, a crushed scrap is obtained, containing only 0.07% iron, which can be melted in rotary furnaces under molten salt cover, with a 91-95% yield.

Electrical power consumption is in the order of 50 kWh per ton, and labour requirement is 2 operators per shift, if no hand sorting is made. Maintenance and repairs - including changes of disintegrating rings - account for 30% of the total nominal working time.

A plant similar in capacity (5 to 7 tph) but operating under a slightly different principle has been constructed by Thyssen Henschel (9). Unsorted aluminium scrap, sizing up 30x60x100 cm, are fed by conveyor belt into a vertical shaft mill. After it has entered the barrel via the feed chute, the scrap is torn up by breaker arms into pieces until these are small enough to be seized by the grinding wheels. This size reduction causes ferrous pieces to be separated from non ferrous pieces. Due to high kinetic energy and a moltitude of working edges the materials continue to be torn up and fragmentized. This size reduction is further enhanced by the tapered space between the barrel and grinding wheels, where the scrap goes down in a spiral way. In addition to beeing size reduced, the pieces of scrap have also their sharp cornered contours rounded off (see fig. 3).

The mill is driven by two 250 kW motors, coupled to main shaft through a double hydraulic and belt driving device.

The shredded material is thrown through the discharge housing where a fan generates an air turbulence to facilitate the separation of the heavy pieces from dirt and dust. Air cleaning is accomplished in a cyclone and in a scrubber; the slimes settling down in the wet cleaning device are removed by means of a special conveyor and discharged in a container for the shipment to dump.

The metal, cleared of light fraction and fines and reduced down to a 5 to 20 cm size, passes in drum-type or belt-type magnetic separators. The plant requires two operators per shift. A special shredder for aluminium scrap operating under similar principles (10) has been constructed by Jack--sonville Blow Pipe Co. and is active by North American

Smelting Co. (NASCO): the hammer mill is driven by a 400 HP motor and can treat up to 9 tph of unsorted scrap Non-metallics are separated pneumatically and ferrous materials magnetically; the final product is sorted manually before shipment to melting furnaces (*).

C.1.3.2. Shredding - Magnetic Separation - Heavy Medium Separation

The methods described in the previous paragraph give the means for removing the lighter non-metallics and the magnetic fractions; however they are not suited for separating parts, consisting of magnesium-base alloys or heavy non-magnetic metallics (stainless steel, zinc, lead or copper-base alloys), which can only be removed in a more or less complete manner by final hand sorting. The use of heavy media consisting of an aqueous suspension of ferrosilicon of specific gravity ranging 2 to 3 gives the means of overcoming such limitations: the actual density of aluminium alloys ranges 2.5 to 3, so that they can be rather readily separated from lighter or heavier fractions, provided that a sufficient liberation has been achieved in the preliminary disintegration.

The equipment is similar to that usually chosen for ore dressing (though a number of details is confidential): a drum is used, rotating at some rpm, half filled with ferrosilicon suspension; the raw material is charged at a drum end by means of a vibrating feeder, and is divided into two fractions: the lighter one floats and flows over a weir, whereas the heavier one is lifted

(*) Other manufacturers of shredding plants: Hammermill Inc. (USA); Harris Press & Shear (USA); American Pulverizer Co. (USA); Lindemann KG (W.Germany)

./.

up by internal baffles of the drum and falls into a discharge hopper, positioned in the upper drum half. Ancillary devices are used for recovering any heavy medium carried away by treated materials.
The operative stage are as follows:

- Shredding of raw scraps down to a size suited for heavy medium separation (25 to 75 mm).
- Magnetic separation of cast iron and steel
- Screening of fines
- Feeding into a <2.5 sp.gr. medium to float wood, plastics, magnesium alloys
- Treatment of sink in 3 sp.gr. medium for floating aluminium base alloys

The sink of the second heavy medium separation consists of zinc, lead, and copper alloys, as well as of stainless steel.
All processed materials are thoroughly washed for minimizing losses of ferrosilicon, which are most heavy in process cost accounting.
Moreover, aluminium scraps are dried in a rotary kiln.
A further alternative - less frequently applied - of the method consists of the separation of aluminium alloys into two fractions in a 2.7 sp.gr. medium: float consists of Al-Mg, Al-Si, Al-Mg-Si, Al-Mn alloys; sink consists of Al-Cu-Si, Al-Cu-Zn, Al-Cu, Al-Zn-Mg, Al-Zn-Mg-Cu alloys.
In Europe the Vénot Pic process (11) (12) has been widely accepted: plant capacity ranges 4 to 8 tph according to scrap quality.

The above methods perform satisfactorily, but investment costs are heavy, and plant operation is rather cumberso me, especially in controlling medium density and ferrosilicon losses; so, they cannot be adopted by all recyclators.

C.1.3.2.1. Recycling Aluminium Alloys from Junked Cars

This is a sort of scrap which is becoming increasingly important, as shredding is becoming more popular in motor car junking plants.
So, the correspondent equipment deserves a more detailed description.
According to data given by different sources, average, aluminium content is 1.5% (by weight) in American cars, and 3 to 3.5% in European cars; as trends are for manufacturing lighter and less consuming cars, such percentage shall yet increase in the near future.
After dismantling of car bodies in shredding plants - their technological features are not outlined in this section - and after magnetic separation of the ferrous fraction, which is the main product (70 to 84% by weight) a residual fraction is obtained, consisting of miscellaneous metallics (stainless steel, zinc, aluminium, and copper alloys) and non-metallics (rubber, plastics, fabrics). This fraction was formerly dumped, after a low-yield hand sorting to recovery the larger metallic parts.
The application of more advanced treatment techniques gave the means to improve recoveries of metallic fraction, but also to separate the different parts from each other.
The method (13) consists of a preliminary screening to separate fines; then a hydraulical classification follows for removing lighter fractions (wood, fabrics, pla

stics, and the most part of rubber).
The heavy fraction (containing metallics) is first treated in 2.1 sp.gr. medium: the residual rubber goes in float. Sink is furtherly treated in 2.7 sp.gr. medium, so aluminium base alloys go in float, whereas sink consists mainly of zinc and copper alloys and of stainless steel.
Plants operating under such principle are already active in the U.S. and in Europe (Eumet, Frankfurt a.Main, W.Germany): raw materials are supplied by car shredders active in the surroundings. According to practical data given by American plants, the nonferrous metallic fraction recovered ranges 2 to 3.5% of the ferrous fraction. It consists of 55-57% zinc base alloys; 32-33% aluminium alloys; 7-8% copper alloys; 2-6% stainless steel (14). A comprehensive technical and economical analysis of this subject is given in (30).

C.1.4. Sweating Furnaces

Their operating principle depends upon the difference between melting points of aluminium and its alloys (lower than 650°C) and those of cast iron or steel (higher than 1150°C).
Metals like lead, zinc, tin and their alloys melt at lower temperatures than aluminium (less than 420°C), and can be separated from it in the first operative stages, though that is less frequently practiced.
For a correct performing it is essential that time required for melting aluminium be as short as possible, to minimize both oxidizing and pollution by impurities, mainly iron, owing to diffusion and alloying processes. Therefore, a very large heat energy transfer is requi

./.

red, by using high power oil or gas burners impinging directly onto the material; only small overheating danger does exist until some aluminium is yet left to be melted. Organic substances are burnt by flames, but that does not prevent emissions of fumes and dusts, mainly in the first operating stages.

Such furnaces may have very different features; a common element is the inclined bottom, on which aluminium flows down and is collected in a separate hearth.

A rather simple furnace, used for treating large parts like motor blocks, is shown schematically in figure 4 a.

The raw material is fed into the main furnace hearth by a crane, after removing the furnace roof. Heating is accomplished by two tangential burners, and aluminium is collected in a smaller hearth separated by the main one by a refractory partition wall.

The removal of ferrous residues is made from above by means of lifting magnets.

A similar furnace is shown in figure 4 b: scrap charging is also made from above after removal of roof, whereas ferrous residues are removed from a side door.

Maximum capacity of these furnaces averages 5 tph and can double when using oxygen-enriched air for combustion.

Smaller hearth or rotary furnaces are also used frequently in intermediate collecting concerns for pre-casting into ingots the alloys to be shipped to secondary smelters. (x)

Heat efficiency amounts to 15-20%, corresponding to a consumption of 1,3-1,7 10^6 Cal per ton of recovered a-

---

(x) Some manufactures: The United Corp. (USA); College Research Corp. (USA).

./.

luminium.
These furnaces have to be operated by skilled workers; then results obtained may be comparable to those of other furnaces fed with pre-dressed scraps.
98% fusion recoveries are quoted (2.3) when treating scraps not excessively contaminated. Even contamination by iron may be kept within acceptable limits: when treating e.g. aircraft scraps heavily contaminated by iron, the following products could be obtained

69%	of total of alloys with	less than 0.5% Fe
28%	" " " "	0.5 to 0.7% Fe
3%	" " " "	more than 0.7% Fe

If we take into account that secondary smelters have their largest market in AlSi12CuFe and AlSi8Cu3Fe die casting alloys, tolerating iron contents up to 1.3%, contamination is kept within reasonable limits. The fraction more heavily contaminated by iron is used for desoxidation of steel.

C.1.5. Treatment of Turnings, borings etc. (2.4)

Such scraps originate mainly from the secondary working of aluminium, i.e. cutting, milling, turning, boring, grinding of semifinished products. Owing to their high specific surface, low apparent density, and considerable content of impurities - mainly water, oil and ferrous turnings - they are usually subjected to the following pre-treatments, before melting:

- Disintegration
- Drying
- Magnetic sorting, possibly briquetting

./.

Disintegration is effected when raw material is received in form of skeins, as frequently occurs with aluminium alloys.

Special disintegrating machines are used consisting of a funnel chamber with a central vertical shaft; both chamber and shaft have oblique, readily interchangeable knives.

However, this operation is more frequently accomplished in special rotating ring mills, operating at 980 rpm, motor power ranging 75 to 500 HP. Capacity may range from 2-3 to 35-45 tons of chips per hour (System American Pulverizer).

The product thus obtained is free flowing, and can be transferred by belt or bucket conveyors, and stored in bins.

Drying of chips, turnings etc. is done in rotary kilns, fired either directly or indirectly.

An advantage of direct-fired furnaces is constructional simplicity, and a disadvantage is the difficult control of volatilization of oil contained in scrap, which in catching fire may cause localized overheating and therefore partial fusion or oxidation losses.

The operation of indirectly fired kiln dryers can be more readily controlled (x).

One of the most advanced methods, working under the above principle, is Intal process.

It uses an inclined rotary kiln, its upper end rotating within a chamber heated by a burner; owing to heat received from outside, in a controlled temperature range between 300° and 400°C water vaporization and a partial combustion of oil take place, complete combustion of

---

(x) Some manufacturers: Dumfort & Elliot (U.K.); Coreco (USA).

oil being made outside the kiln. Exhaust gases pass over an after-burner, which increases their temperatu re up to 700°C to destroy all trace of fumes, then through a washing device, to remove dust.
The material made free from water and oil in the upper part of the kiln is cooled by air stream while descending towards the discharge end. The plant is wholly automated, and gives virtually oxide-free chips, owing to the accurate temperature control in the drying zone: either water or light fuel oil is added to the charge, when temperature is increasing or decreasing, respectively.
According to data, heat consumption ranges 150,000 to 200,000 kcal per ton of treated chips, the larger share being required for operating the after-burner.
After drying, the material is subjected to magnetic sorting and to screening, to separate fines under 0.5 mm, which are sent to melting under molten salt cover, or sold for aluminothermy applications.
The coarser, almost oxide-free fraction can be melted without any further pre-treatment in induction furnaces (15) - which shall be dealt with in section C.2.4., or alternatively may be briquetted before melting.

C.1.6. Recovery of Aluminium from Drosses

Such material consist of metallic aluminium - its content ranges 30 to 70% - in a matrix consisting mainly of aluminium oxide. A number of methods are used to treat it, but the first stage is always dry milling, in which advantage is taken from the different behaviour of the relatively malleable metal and of the brittle oxide. Special ball mills can be used, fitted with

./.

grid mantle (*) for removing dusts.
An alternative (16) - advantages being a higher productivity and a lower degradation to dust of the metallic fraction - is the treatment of drosses in hammer mills. Dusts, consisting of aluminium oxide contaminated by other substances, is separated by suction and collected in a cyclone. The heavier metallic fraction is screened and divided into two fraction: the coarser one may be shipped to melting, after magnetic sorting. The finer fraction may be used directly, mainly for aluminothermy purposes (see fig. 8 b).

C.1.1. Dressing of Electrical Cables

In such articles, where wide differences are to be seen as for size, structure and metal content, according to their field of application, the use of aluminium is gaining ground in the place of copper. The electrical resistivity of pure aluminium is higher than that of copper - 0.028 Ohm · mm^2/m against 0.017 Ohm · mm^2/m - and consequently cables of larger cross-section are required; however the lower cost of aluminium and its lower specific weight amply make up for this disadvantage.

For the most part of applications high purity aluminium (99.7%) is used, but where better mechanical properties are required, Al Si0.5 Mg0.5 alloys are used.
The most important types of cables are as follows.

(*) Manufacturer: Maschinenfabrik Steinheim und Kunze (W. Germany).

C.1.7.1. Non Insulated Power Electric Cables for Overhead Lines

They usually consist of aluminium wire plaited around a core, made of plaited galvanized steel wire, which improves the mechanical strength of the aggregate. No special problems have to be faced in recovering aluminium from this material; processing consists in cable shearing followed by disintegration of cable pieces and magnetic separation of the steel core.
The equipment used for these operations are equal to those used for unsorted aluminium scrap (see C.1.3). It is also possible to treat these cables in sweating furnaces (see C.1.4) with a lower cost of equipment.
In some case, aluminium wire can be unwound from steel wire core, so that the two component parts of cables can be recovered separately, and their upgrading can be improved.

C.1.7.2. Insulated Cables

For low, middle, or highest voltage electric power distribution, as well as for telecommunications, cables of a widest range of types are finding ever increasing applications.
Three basic types are to be considered:

Middle and High Voltage Power Cables

The conductors consist usually of metal ropes made of a number of plaited wires, the ropes being in turn insulated with special paper ribbon wrapping. The insulation is then completed by impregnation with mixtures of mineral oils and resins.

Then the conductor system is protected with a lead or aluminium sheath, which may be furtherly reinforced by steel strips or wires, and in turn protected by wrapping around it thermoplastic material or bituminized fabric.

For special ultra-high voltage cables, an insulating fluid oil filling is used.

Telecommunication Cables

They consist of one-strand conductors, sizing 0.4 to 1.6 mm in diameter, insulated from each other with paper or plastics; these conductors are assembled together in large numbers, up to some thousand circuits, according to cable capacity.

The conductors are protected outside by lead sheath, sometimes with an outer sheath made of plastics with steel strip or wire reinforcement.

Cables with Rubber or Plastics Insulation

Such cables have a widest range of applications, covering the whole low and middle voltage field of electrotechnics, inclusive of lines for domestic installations.

One-wire conductors may be used, or more frequently groups of plaited thin wires, affording a better cable flexibility.

The use of aluminium is restricted to conductor cross-sections not smaller than 5 mm^2.

The problem common to all these manufactured goods is the separation - as complete as possible - of non metallics consisting of oil, paper, plastics, fabrics, tarred jute, and metallics other than aluminium, viz. lead and steel armour.
A preliminary treatment commonly used for large size cables with external bituminized wrapping and steel-reinforced lead sheath, consists in the stripping of this external part.
The machinery used for this purpose is described with more details in Section B.2. concerning the Lead Recovery (second part of this Report) to which reference is made here.
The subsequent dressing stages for making the inner conductors free consist in incineration or, alternatively, in a mechanical treatment (43).

C.1.1.2.1. Incineration

This method is yet widely applied, owing to lower equipment costs and to its relative operating simplicity. It is yet the only possible solution to recovery problems, for special cables, like the oil impregnated types and where lead sheaths cannot be readily removed.
For a more complete description of the correspondent equipment, see the above referred section.
As the product thus obtained is often oxidized and sometimes partially molten, it is mainly utilized by secondary smelters.

C.1.7.2.2. Mechanical Treatments

By these methods the problems -mainly ecological ones - related to the use of incinerators can be avoided. However, they are less flexible and are not suited to all types of cables; another disadvantage is the high plant capacity, so that owing to the high investment costs, a sufficient supply is required to be guaranteed of adequately selected raw material.
Such plants are mainly used for recovering copper from insulated cables, owing to higher value of this metal and the relatevely low amount of aluminium old cables available, due to the long service life of these articles (see table IV).
A detailed description of this matter is done in the Report titled "A Survey of the Technology of Copper Recycling" recently presented by Société Générale des Minerais as a part of the general study dealing with recycling and recovery of non ferrous metals, in which also our report is to be included.
The same equipment is used also for treating aluminium insulated cables with only minor changes in operation procedures: however for this recovery less details are known from the technical literature.
Therefore only the peculiar features of the most important processes will be outlined here.

C.1.7.2.2.1. Pneumatic Separation on Fluidized Bed (44) (**)

Baled or coiled cables are first treated in a knife-granulator which cuts them into small, free-flowing pieces,

(**) Manufacturer: Triple/S Dynamics Inc. (USA) effecting simultaneously a preliminary separation of in sulation. After the primary granulation, a magnetic se parator removes the tramp ferrous metal to reduce conta mination and knife wear of secondary granulator: this one reduces the wire size sufficiently to separate a major part of insulation from the metal particles. The mixture of chopped wire, insulation and some unstripped wire passes to the separating section.

First a high speed vibrating screen sizes the mixture into coarse and fine fractions, and screens out the fine metal that might otherwise be lost in the tailings. These two sized fractions then feed separately two bins with bottom feeders: following each feeder a special fluidized bed separator using only air and mechanical vibration divides into four fractions: clean metal , middlings, unstripped wire and plastic. Middling are directly recirculated to the screen for further sizing, unstripped wire is sent to a tertiary granulator and from that to the same screen.

After separation the clean metal is conveyed to bins while the plastics tailings are pneumatically conveyed to a storage tank for later use as a landfill. Plant exhaust air is cleaned for recirculation in a baghouse air filter.

The productivity of this plant ranges between 500 and 2500 kg/h, according to size of cables: with well selec ted materials it is also possible to produce reusable PVC of good quality.

C.1.¶.2.2.2. Pneumatic Separation on Fluidized Bed with addition of a Heavy Medium

Similar installations based also on a final classification of the metal-insulators mixture previously mechanically separated are built by Dryflo (*).
This process differs from the previous one mainly in its final stage: to the metal-insulation mixture obtained by disintegrating cables, a drv medium of suitable density is added before separation, which - by the action of air blown through the porous bottom of the table - generates an intermediate density fluid bed, thus making easier the separation of metal from insulators. This additive is then recovered by screening and recycled. The hourly capacity of these plants ranges from 0.13 to 1.3 tons of cables, metal content recovery rising up to 99%, in the form of high purity metal granules.
This method cannot be applied to cables fitted with bituminous or oil-impregnated insulator or with lead sheath; the preliminary removal of such coatings is mandatory.

C.1.¶.2.2.3. Other Processes

According to the Alpine Lurgi process (45) cables, previously cut into pieces shorter than 50 cm, are treated in a rotating knife mill: then a magnetic sorting for iron and a pneumatic separation are made in order to remove a first portion of insulation. After a finishing treat

---

(*) Dryflo Separators Ltd (UK)

ment in a second set of mills a metallic granulate is obtained together with a lighter product. The latter is subjected to a further pneumatic classification to remove another part of insulation, while heavier pro-duct is treated in electrostatic separators for recovering a middle sized metallic fraction.
99,5% of the metal content is claimed to be recovered with operating costs lower than those of combustion treatment.

The granulated aluminium obtained by the above mentioned treatments is usually pure and free from heterogeneous parts: therefore it can get better prices, and is often utilized by foundries and semis manufacturers for correction of their melting charges.
Another possible alternative for unselected cables consists in shredding of a mixture of them with other aluminium scraps, as described in section C.1.3.1.

C.1.8. Treatment of Thin Aluminium Foils (39)-(40)

The treatment of these materials is a not negligible share of the business of some secondary smelters; therefore a brief description will be given here, for sake of completeness, though this matter is only partially within the scopes of our work as the main uses of these articles are to be found in the food industry.
Anyhow, it is to be noticed that the application is gaining ground in the building industry, of thin aluminium foils adhesive bonded to PVC, or of complex lamina

tes for external applications, consisting of two outer Al Mg alloy layers 0.5 mm thick, bonded to an inner polyethylene sheet 2 to 7 mm thick (34).
Owing to the long service life of building materials, these products are not yet being supplied in appreciable amounts to refiners.
The main portion of recycled thin aluminium foil-base products consists presently of factory rejects of package manufacturers supplying the food industry, as well as of cans for beverages and aerosols.
For these materials, a preliminary treatment is usually required before melting, consisting of a shredding in hammer mills; this treatment may be followed by pneumatic classification or screening, in order to separate the lighter fractions.
Clean thin foils are more frequently transformed outside the smelters in aluminium powder by grinding.

The material is then press-baled in order to reduce its volume and make the subsequent melting easier; for the last operation, salt bath rotary furnaces are preferred, when treating materials yet containing not negligible amounts of heterogeneous components. (see C.2.1.).
The average melting yields for the different sorts of scraps are as follows:

a) Swarves of white natural strip - bottoms, minipak containers, caps 93-94%

b) Swarves of white thin strip - packages for sweets, cigarettes, drugs 90-91%

c) Swarves of printed strip - caps, small boxes 89-90%

d) Swarves of coloured, printed or lacquered strip - for cheese, chocolate, etc.; covers for yoghurt, margarine, etc. 76-86%

e) Mixed old scrap - beverage containers of Al Mg Mn or Al Mg alloys. 70-85%

The treatment of aluminium-paper or aluminium-plastics composites containing frequently less than 30% of metal is a special problem. The direct melting under slag cover of such materials cannot be accomplished in practice, owing to the large consumption of salt, so that this method is usually uneconomical.

Some pyrometallurgical or hydrometallurgical pretreatment methods have been proposed, namely:

- Pyrometallurgical methods involve the carbonization of the organic components, by treating the material with defective air, then by grinding and screening in order to separate aluminium from the carbonaceous matter.
- Hydrometallurgical methods involve the steeping of the raw material and its treatment in "hollander" type machines for recovering pulp and paper.
  Alternatively, the treatment has been proposed with a sodium aluminate solution for dissolving aluminium, that after filtration of the organic components is subjected to Bayer process for recovering it in the form of alumina.

However, these methods have not yet reached the commercial application.

C.2) Melting of Scraps

The aluminium-base materials, after being pre-treated by one of the methods described in the previous section C.1, are melted in special furnaces, some of them peculiar of this metallurgical branch. The most typical ones are:

- Salt bath rotary furnaces
- Reverberatory furnaces
- Outer-hearth reverberatory furnaces
- Electric induction furnaces

In table V a comparison between performances of above-mentioned furnaces is reported.

C.2.1. Salt Bath Rotary Furnaces (see figure 5 a)

Their main advantage is great versatility; they are also suitable for refining, mixing, or holding.
Each furnace consists of a metallic cylindrical casing, fitted with rolling rings and ring gear for drive, which is accomplished by an electric, variable speed motor, through a reduction gear and a pinion. Drum ends are shaped as a truncated cone; at one end an oil or gas burner is mounted, at the other end there is the exhaust gas outlet: length/diameter ratio ranges from 1/1 to 3/1. Charging of scrap is made at one end by means of special channel feeders; tapping is made through a hole positioned at the drum center, whereas slags are discharged at drum ends.
The interior of drum casing has a refractory brick lining or a rammed lining; sometimes the cross-section of lining is polygonal, in order to improve the mixing action of the charge caused by rotation.
The upper part of the cylindrical wall of the furnace is heated directly by burner flame, through gaseous convection and radiation; in further rotation this part of the wall is covered by the molten charge and transfers heat to it by liquid convection.
By this way large amounts of heat energy can be supplied to the charge, without any overheating of the refractory lining; capacity can reach up to 7 tph in units which may contain totally 20 tons of aluminium.
Though the use of heat recuperating devices is not technically advisable, the thermal efficiency of such furnaces is reasonable: it ranges from 20 to 35%.
Heat consumption amounts to 0,8-1,5 10^6 Cal per ton,

according to quality of charge.
Rotary furnaces can melt all sorts of scraps, except for large sized ones, but they are particularly suitable for melting the finest and most oxidizable ones: the swift rabbling causes them to be quickly submerged under the salt flux, acting as a protecting cover.
The flux consists usually of sodium chloride (m.p.800°C) which is the most economical alkaline salt available, but in some cases binary sodium chloride-potassium chloride mixes have to used, which melt at lower temperatures (650° to 700°C), or even ternary fluoride-bearing mixes. The advantages of such mixtures consist in the possibility of operating at lower temperatures, thus reducing considerably the volatilization of alkaline chlorides.
This problem will be discussed in more detail, in section C5 involved by the control of such emissions.
The action of salt flux is not restricted to coating of metallic surfaces, as it causes too - by a surface tension effect - the separation of molten metal from oxide particles and the heterogeneous matters. The buildup of these impurities causes a gradual thickening of the flux, which must be periodically removed and replaced; consumption of flux depends upon the state of charge pre-dressing, and may range from 2% to 15% and upwards, for extremely dirty scraps.
The disposal problems of exhausted fluxes will be dealt with in section C5.

C.2.2. Reverberatory Furnaces

Their content may reach up to 80 tons of metal, and hourly capacity up to 8 tons; they consist of a rectangular, or sometimes round chamber, lined of clay-type

refractory, with collecting pool for the molten metal. They are oil or gas fired, by means of burners mounted in the walls; charging is made through side doors, by means of special, mechanically handled charging boxes, or - in the round chamber furnaces - from above by means of movable bottom canisters, after removing of the roof.
The molten metal is tapped periodically from a bottom hole, or transferred by means of a pump mounted in an external pool.
These furnaces are well suited to melt sufficiently thick scraps, loose or baled, provided that their content of heterogeneous matter is not too high; then, good melting yields (more than 95%) can be reached, fuel consumption being reduced to 1.2×10^6 Cal / ton; productivity can be improved even by 50%, without reducing the melting yield, when using oxygen-enriched air: its consumption is 220 m^3 per ton of product (2.5) (42).

C.2.3. Reverberatory furnaces with outer hearth (see figure 5b)

In its wider section it is similar to the usual reverberatory furnace, as it consists of a combustion chamber with oil or gas burners; the bottom of the main hearth which contain the molten metal extends outwards, forming one or two smaller hearths, open upwards (11). The communication between them and the inner main hearth consists of ports, through which the molten metal, heated in the inner hearth, flows in the outer hearth by natural convection or by a circulation pump, and gives the heat required to melt the scrap.
Operations in the outer hearth can be made with or without protective flux, according to fineness and oxi

dation degree of the raw material; frequently the charge is pressed or briquetted before immersion.
In the inner hearth, no flux cover is used on aluminium melt, so that any contamination of combustion gas is minimized; anyhow, metal oxidation is not severe, as no turbolence in the melt surface does occur.
In these furnaces, at tapping completion, about 30% of the melt is left in the hearth, in order to make further operations easier.
Maximum contents and capacities of units are respectively 80 tons of aluminium and 8 tph. The most improved units have heat recuperating devices, so that thermal yield rises up to 35%, and heat consumption is reduced down to 0.7×10^{6} kcal per ton of melted scrap. These units are also equipped with devices for the automatic control of bath temperature and of depression in combustion chamber, as well as for the analysis of combustion gases.

C.2.4. Induction-Heated Crucible Furnace (figure 6 a)

This furnace consists fundamentally of a crucible made of rammed refractory mass; around the crucible there is a low-impedance copper coil with internal water cooling; the coil is connected to the electric system trough an autotransformer with step switches (17).
In order to compensate the large phase displacement caused by secondary inductive load, the insertion of condensator batteries is required.
In order to provide a satisfactory power transfer from coil to crucible charge, the crucible must be sufficiently large in size: for the 50 Hz commercial frequency, minimum diameter is to be 400 mm.

./.

Moreover, minimum scrap size to be melted must be about 100 mm; when smaller scrap is introduced, a sufficient amount of metal is to be left in the crucible, in which the new charge added can be embedded; charging is made continuously by means of metering feeders.

The main advantage of the commercial frequency induction furnace is the vigorous stirring of the bath, caused by eddy currents; that gives the means to incorporate quickly the added solid scraps into the molten metal, by removing of their oxidized surface films, whereas the addition of salt fluxes is not required. Therefore, this furnace is particularly suited for melting scraps having a large specific surface area, especially machining swarves and scraps, previously treated according to the methods described in section (C1.5) Metal content and melting capacity of usual units reach up to 25 tons and 10 tph respectively. (15)

Power consumption is in the order of 500 kWh per ton of melted aluminium; this corresponds to an energy yield ranging 65 to 70%. If conversion yield at power station are also taken into account, global operative energy consumption is in the order of 1.2×10^6 kcal/t, a value comparable with the level of the other furnaces described previously.

C.3) Refining

The operating stage subsequent to melting includes the purification of the molten aluminium alloys from non metallic solid inclusions, dissolved gases, and alloying elements in amounts exceeding specification levels. The following operations are most frequently accomplished:

1) Removal of aluminium oxide
2) Removal of hydrogen
3) Removal of magnesium

C.3.1. Removal of Aluminium Oxide

This impurity originates both from oxide contained in scraps, and from the effect of a too long-lasting melting operation without protective fluxes. The presence of excessive amounts of oxide impairs castability and mechanical properties of the alloys, especially their machinability. On the other hand, the spontaneous separation of such inclusions is difficult, as their specific weight (2.8 - 2.9) is very close to that of molten metal.
Oxide removal is frequently done by means of salt fluxes consisting of sodium chloride, pure or mixed with potassium chloride, sometimes with small additions of fluorides. Their action is mainly physical, i.e. they carry away towards the melt surface alumina particles, which are more readily wetted by salt mix than by the molten metal.
Desoxidation is accomplished in the ladle or more efficiently in a rotary kiln.
Aluminium oxide can also be removed by filtering the alloy before tapping, through fiberglass or special ceramic filters (36).
Such treatment is more frequently associated with hydrogen removal by means of various gaseous mixtures as described in the subsequent paragraph.

C.3.2. Degassing

This operation is aimed to remove hydrogen, which is absorbed by alloys during melting, owing to contact with charge moisture and combustion gases: the solubility of hydrogen in molten aluminium ranges 1.2 to 2.2 cm^3 per 100 grams of metal, at 800° and 900°C respectively. Amounts above 0.2 cm^3/100 g already affect negatively castability and mechanical properties of aluminium castings, and must be reduced by suitable methods.

Actually, neglecting other methods without any practical application, like vacuum degassing and controlled cooling, two alternatives may be chosen:

- Degassing with inert gas (nitrogen or argon)
- Degassing with chlorine-bearing gas mixtures

An advantage of the former method is the absence of formation of volatile aluminium chloride and hydrochloric acid, so that no exhaust gas purification is required, but the process is rather slow, as its operating principle is the carryover of hydrogen by another gas; inert gas consumption is in the order of 0.7 m^3 per ton of alloy .

Degassing with chlorine-bearing mixtures is quicker and more efficient: chlorine reacts with aluminium, and volatile aluminium chloride is formed, which partially reacts with hydrogen dissolved into metal in the atomic state:

$$AlCl_3 + 3\,H \longrightarrow Al + 3\,HCl$$

The exhaust gases contain therefore hydrochloric acid and the unreacted excess aluminium chloride, so that they must be purified. In the presence of magnesium, its chloride is formed preferentially, which is less volatile (m.p. 713°C) but refining effects are similar.

In this process, the use of chlorine mixed with nitrogen, argon or carbon monoxide is preferred, instead of pure chlorine (19), as reaction control is improved, and reagent excess and its consequent polluting effects are reduced.
Chlorine treatment is made by means of various devices, namely:

- Gas mixtures are blown into melting furnace or ladle through special ceramic or graphite tubes. In ladle treatment solid hexachloroethane (C_2Cl_6) may also be used, which is dipped down to bottom by means of a bell, and in decomposing causes an intensive stirring.

- Special converters can be used, consisting of a rotating refractory lined drum, which has a row of blowholes along a mantle generatrix line. Gas is blown after holes are submerged under melt surface (2.6) . Chlorine consumption values are reported, ranging 0.2 to 0.5 kg per ton of treated metal, in order to reduce hydrogen level under 0.2 cm^3/100 g.

In the treatments described above, besides degassing of the melt the removal of suspended oxide is obtained simultaneously, owing to the flotation effect of gas bubbles rising to bath surface.
Some processes, applicable for large production, combine degassing with filtration of oxide by means of special devices mounted outside the melting furnace.
In Alcoa process (20) the alloy is caused to descend through two filtering layers fitted in series, consisting each of a supporting mass of alumina beads, and

above it of a 15-25 cm thick layer of tabular alumina flakes, ranging 3 to 6 mesh size. (Fig. 6 b)
The alumina beads supporting mass is in the same time active in diffusing a mix, consisting of argon and 5-6% chlorine, which is caused to pass upwards through the filtering layers, in countercurrent with the molten metal. Perfectly clean and gas free castings can thus be obtained, chlorine and argon consumption being 0.02-0.26 m^3 and 0.26-2.6 m^3 respectively per ton of melted alloy, according to hydrogen and impurity content of raw material. No purification of gases coming out from degassing device is required.
In an another similar process (21) the metal is caused to pass - before casting - through a molten layer of salt flux, consisting of a mixture of sodium and potassium chlorides, then through an alumina beads layer, with a cover of the same flux, whereas nitrogen is bubbled in countercurrent with molten metal by means of a special diffusing device mounted below the bead layer: gas consumption is in the order of 0.9 m^3 per ton of treated alloy.

C.3.3. Removal of Magnesium (22, 23)

Aluminium secondary smelters tend mainly to produce AlSiCu type casting alloys, and their specified magnesium levels are rather low (max 0.3%). On the other hand, a portion of the scraps received consists of articles in which high magnesium wrought alloys were used. Therefore, the average magnesium content of charges obtained by treating non selected scrap may be higher than specified tolerances of the most part of casting alloys. Though magnesium removal by vacuum distillation is also technical-

./.

ly feasible, purification processes with chlorine or salt flux are preferred, owing to higher productivity and lower cost of the equipment required.

In a molten aluminium-magnesium alloy, chlorine reacts selectively with magnesium, and the correspondent, relatively scarcely volatile chloride $MgCl_2$ (m.p. 713°C) is obtained, up to equilibrium concentration in the order of 0.0002% of Mg.

Actually, there are limitations in selectivity, owing to kinetic factors, and chlorine begins to react with aluminium in correspondence to higher magnesium concentrations: aluminium chloride-$AlCl_3$-is formed, which is in the volatilized state at the process temperature, and is highly polluting (see section C.5). Therefore, attempts are made to reduce to a minimum the excess of chlorine above the stoichiometric amount required to form magnesium chloride (3 kg per Kg of Mg approx.). In the conventional processes, operating in the 700° to 900°C range by blowing the gas by means of tubes into the alloy bath in a ladle or in a reverberatory furnace hearth, this result cannot easily be reached, owing to insufficient dispersion of gas bubbles and to short contact time between chlorine and melt; consumption are observed, rising up to 3 times the stoichiometric value, in the lower range of Mg conc.

An improvement set up by Alcoa (24) consists in circulating the molten metal by means of pumps through a reaction chamber, divided into a number of sections, outside the melting furnace: chlorine is introduced by means of a special rotating device, which disperses it in very fine bubbles.

By this way, conversion yield rises almost to stoichiometric value, and noxious $AlCl_3$ emission is reduced; besides, exploiting the by-product magnesium chloride is made easier.

In another similar process (25) a thick salt flux layer is used, covering the alloy melt in chloridizing chamber, in order to absorb aluminium chloride excess and transfer it in the metal-salt interface, to complete exchange reaction with magnesium.

Special pumps are used to circulate molten metal outside the melting furnace; figure 7a shows schematically a typical equipment for this process.

Chlorine gas use and related storage and handling problems can be also avoided, by treating Al-Mg alloys in a rotary kiln with aluminium fluoride-bearing fluxes, e.g. mixtures consisting of sodium chloride, potassium chloride and cryolite.

Magnesium content can be quickly reduced down to 0.2% by the following exchange reaction:

$$3Mg + 2Na_3AlF_6 \longrightarrow 3MgF_2 + 2Al + 6NaF$$

However, the cost of the reagent used in this process is positively higher than cost of chlorine gas; stoichiometric consumption of cryolite amounts approximately to 3 kg per Kg.Mg.

C.4) Tapping and Casting

Some refining operations previously described, as well as the final adjusting of alloy composition by adding master alloys or pure aluminium, and ingot casting are usually accomplished in furnaces other than those used for melting scrap.

Such operations require actually long holding times, and on the other hand their energetic requirements a-

re lower, as alloys are fed already in the molten state. For these operations reverberatory, rotary and liquid ring type induction furnaces are frequently used.
Ingot casting is made by conventional methods, using straight line or wheel type casting machines: the metal is fed by natural gravity or alternatively by means of centrifugal or electromagnetic induction pumps. For large supplies and distances up to 400-500 km, the direct shipment of hot metal is becoming commonplace, using special trucks equipped with one or two ladles, which are thermally insulated so that temperature decreases only by some tens of degrees during transfer.

C.5) Ecological Problems (2.7)

On one hand, aluminium recycling gives a contribution to reduce environmental degradation caused in an appreciable amount by uncontrolled dumping of scraps and metallic rejects: on the other hand, it originates additional pollution owing to the peculiar features of some operations involved in it.

According to a detailed analysis (26) dealing with a 20,000 tpy secondary aluminium smelter, equipped with 3 rotary furnaces, 1 hearth furnace, and 1 sweating furnace, provisions for pollution control may require an increase in investment costs amounting up to 73%, and an increase of operating costs of 4.30 £ per ton.

According to another more recent estimate dealing with British secondary smelters (48), average increase of operating costs, caused by the said control, ranges 2 to 4 £ per ton.
Pollution affects atmosphere, land and streams, and will be briefly examined according to the above classification.

C.5.1. Gaseous Emissions

They consist mainly of combustion gases, which include also more or less large amounts of chlorine, HCl, SO_2, $AlCl_3$, volatilized organic substances, various fumes and dust.

C.5.1.1. Polluting Sources ·

C.5.1.1.1. Incineration of Cable Sheaths (see C.1.7)

Such operation is permitted only when units are used, equipped with after-burners; for HCl bearing gases, originating from polyvinyl chloride-base insulating sheaths, washing devices are also required after the afterburner.

C.5.1.1.2. Treatment of Turnings (see C.1.5.)

Oily residues included in such materials originate fumes and tar compounds; an afterburner must therefore be installed to control such emissions.

5.1.1.3. Scrap Shredding (see C.1.3.)

In the shredding mills the separation of lighter fraction is accomplished by air classification; outlet air treated in cyclones then is subjected to final dust removal by washing or in bag filters.

C.5.1.1.4. Reverberatory Furnaces and Induction Furnaces (see C.2.2. -2.3 -2.4)

The emission of fumes and dusts of these furnaces, usually operating without salt fluxes, is not so large, so that they do not require special purification equipments.

C.5.1.1.5. Sweating Furnaces (see C.1.4.)

Suspended solids content of fumes may range 100 to 300 mg/m^3, so these furnaces are operated above the limits of the present tolerance levels during some periods of the melting cycle.

./.

C.5.1.1.6. Rotary Furnaces (see C.2.1.)

Such furnaces usually operate in the 800°-900°C range, with salt fluxes: the volatility of these alkali chloride-base fluxes is yet high in this temperature range, and solids contents up to 5-6000mg/m^3 may be reached, so that gas purification is mandatory.

C.5.1.1.7. Chlorine Treatment (see C.3.2. - C.3.3.)

More or less considerable amounts of $AlCl_3$, chlorine and hydrochloric acid are developed. Aluminium trichloride, which volatilizes above 180°C, is to be found in the gaseous state, and decomposes in air according to the following reaction:

$$2AlCl_3 + 3H_2O \longrightarrow Al_2O_3 + 6HCl$$

So, highly persistent acid fogs are formed. Recent improvements achieved in minimizing chlorine consumption effectively reduce such pollution.

C.5.1.2. Gases Purification

C.5.1.2.1. Wet treatment

Different sorts of equipment are used for this end, tending to achieve maximum contacting between gas flow and washing fluid, usually water or aqueous alkaline solution in the case of fumes removal from gases derivated from combustion of PVC-sheathed cables.
A method widely applied owing to its simplicity and to the absence of moving parts is the Venturi scrubber. Some operative data are reported here of such a plant used to purify exhaust gases of a salt-bath rotary furnace:

Gas flow rate : 7500 Nm^3/h

Inlet temperature : 400 - 500°C

Suspended solids : 500 - 1000 mg/Nm^3

Purification yield : 95 - 96%

Washing solution flow rate : 45 m^3/h

Power requirement (fan and pumps) : 25 kW

The gases getting out from the scrubber pass into a wet cyclone for settling the suspended drops of washing solution. The latter is recycled continuously, after separation of solids by thickening, and by-passing of a portion which is sent to purification plant of effluent water (see C.5.3).

The disadvantages of the wet purification method consist in the intensive cooling and humidification of gases, with consequent magnified corrosion effects in the equipment downwards the purification plant.

C.5.1.2.2. Bag Filters

They are commonly used in all industrial branches and are also widely used in secondary aluminium metallurgy. Some operative data are reported here of such a plant treating gases coming from salt bath melting furnaces (27):

Gas flow rate: 110,000 Nm^3/h at 140°C

Filtering surface area: 3,300 m^2 (polyesther synthetic fabric)

Power requirement for fan: 150 HP

When using these filters, it is necessary to avoid any temperature decrease below certain limits, to prevent clogging of filter fabrics owing to moisture absorbed by salts: an auxiliary burner is then required to keep the plant at a suitable temperature level when the furnace is not operating.

./.

The firm "Metal Alloys" has developed a special process, involving the pre-coating of filter fabrics by means of chemically active powder, so that an efficient control can be made of high chlorine and fluorine-bearing gaseous emissions.

This method found application on a commercial scale, though correspondent investment and operating costs are considerably higher than those of conventional methods. For a 40,000 tpy secondary aluminium smelter, investment costs of fume collecting equipment have been estimated to account for 5 to 6% of total investment costs; correspondent operating costs are estimated to range 6 to 9 French Frs. per ton, energy costs accounting for 60-67% of total. (*)

C.5.1.2.3. Electrostatic Gas Cleaning

This method gives the means to achieve high purification yields (above 98%), with a relatevely low energy consumption ; it can be used in the 120° to 150°C temperature range, applying continuous current voltages of some ten kV to electrodes consisting of indented wires (negative) mounted in front of corrugated plates (positive), dust settling on the latter ones.

In this equipment too, the settling of hygroscopic salts on the electrodes, owing to excessive cooling of the gas entering into the plant must be avoided. This system is less frequently used owing to various operating difficulties.

(*) From a conference of Mr.Herbulod held at the 1975 Vienna meeting of O.E.A.

C.5.2. Solid Residues

These materials consist mainly of salty slags discharged from melting and refining furnaces: they contain sodium chloride(sometimes also potassium chloride)plus minor amounts of fluorides, magnesium chloride, aluminium oxide (10-40%) and metallic aluminium (1-10%).
Their storing in uncontrolled dumps is finding increasing restrictions owing to pollution of surface and ground waters by soluble alkaline salts.
These solids can be regenerated by disintegrating with an excess of water in rotating drums, thus recovering metallics; this treatment is followed by clarification of the brine in thickeners, which separate aluminium oxide slimes, and by final evaporation of the clarified brine, to crystallize the alkaline salts (28).
This operative principle has been applied in Europe in two plants, respectively owned by International Alloys Ltd. (UK), and by Refonda (Switzerland) (20,000 tpy).
A new 58,000 tpy plant is being set up by Newell Dunford Engineering Ltd., based on know how acquired in the British plant. The new concern should be economically active, taking into account recoveries of aluminium metal and salts and of alternative costs of alkaline slags waste disposal. Treatment cost of 1 ton of alkaline slags by these methods ranges 70 to 110 Sfr.
The problem of utilization of Al_2O_3- base residue, containing 3 to 5% alkaline salts is yet open: the weight of this material, with 20-30% water and 60-70% aluminium oxide, is about ½ of the original slag.
Owing to the high investment and operating costs of these plants, the choice is possibly preferred of melting furnaces, which can be operated without using such fluxes, like reverberatory or induction furnaces; however, in order to achieve high melting yields a thorough

preparation of the raw material is required, which must be as free as possible from any sort of heterogeneous matters.

C.5.3. Liquid Effluents

A peculiar feature of the secondary aluminium industry is the emission of high chloride-ions bearing solutions during scrubbing purification of gas emissions from salt bath rotary furnaces. cable incineration furnaces, and refining treatment using chlorine.
Chloride concentration cannot be allowed to rise above limits specified by law.
In Italy the maximum content allowed is 1200 ppm chlorides and 6 p.p.m. fluoride ions in effluent discharged into streams and lakes: similar values have been proposed by E.E.C. (1500 ppm chlorides and 15 p.p.m fluorides).
So, a suitable portion of the scrubbing solutions is to be diverted, neutralized, purified from heavy metals and clarified by conventional techniques before discharge outside the plant.

D) ALTERNATIVE TECHNOLOGIES

In section C the methods have been examined in detail, which are most commonly applied in aluminium recycling. A brief description is thought to be useful, of other methods which have not been entered until now in the commercial stage, but are potentially suitable for the future development of this industrial branch; for further details, reference is made to cited literature.

D.1) Scrap Sorting

D.1.1. Separation by eddy current (29,49,53,54)

This method, which is actively tested for recovering aluminium from urban solid wastes, might anyhow find applications also outside this field.

D.1.2. Separation by Magnetic Fluids (31, 35, 50)

The use of colloidal magnetite suspensions in high gradient magnetic fields gives the means to achieve separations similar to those obtained by heavy media, but in a wider density range: the diffusion of such methods - experimented for sorting non ferrous metals from urban wastes - is hindered by the high prices of the magnetic medium.

D.1.3. Cryogenic Crushing (32,45, 51,52)

The fundamental principle of this method is the fact that aluminium and copper alloys retain their ductility even at low temperatures (below -65°C) whereas ferrous materials, zinc alloys, rubber, and the mo

part of plastics are subject to embrittlement.
Heavy medium separation can be thus replaced by a simple screening after cryogenic crushing. This method has yet found industrial application in dismantling junked motor cars (Inchscrap process) (32): its spreading is hindered by the high consumption of liquid nitrogen which can reach 300 lt per ton of scrap (45).

D.2) Refining of Aluminium Alloys

D.2.1. Removal of Zn, Mg (Pb, Bi, Sb) by Distillation (4.3)

Low frequency, liquid metal ring induction furnaces are used, containing up to 3 tons of alloys, equipped with two condensing chambers mounted aside, made of Sicromal and heated electrically from outside (see fig. 7 b).
In distilling 30-35% Mg aluminium alloys, magnesium content could be reduced down to 0,1-0,2%: this metal was recovered in the molten state in the condenser, by operating in the 700-900°C range, under a 0,1-0,2 mm Hg vacuum, power consumption being 2 kWh/Kg Al.
By the same equipment zinc and other volatile metals (Pb, Bi, Sb, ...) which are present in minor amounts can be removed by distillation.
Vacuum arc furnaces can also be used, which are constructively simpler than the furnaces referred above (2.8).

D.2.2. Refining by Segregation

When aluminium alloys having some particular compositions are to be treated, a partial separation of one

or more components by fractional solidification can be made, when they form high melting point intermetallic compounds. Such compounds are then separated from melt by filtration or sedimentation.
Special attention has been devoted to the following operations (2.9):

- Partial removal of Fe (Mn, Ti) from Al-Mg alloys
- Partial removal of Si from Al-Mg alloys
- Partial removal of Fe and Mn from Al-Si alloys

D.2.3. Refining by Electrolysis (4.2)

Refining is carried on by operating at 800°C in 15,000-40,000 A cells, current flowing through a horizontal layer (anode) of Al-Cu (25-50% Cu) alloy set on the cell bottom, and a cathodic upper layer of high purity aluminium (plus 99.99%), floating on an intermediate density salt bath. A typical composition of the latter is: NaF 19%, CaF_2 17%, BaF_2 19%, AlF_3 45%.
The main operating data are reported here, regarding refining treatments carried on with commercial (99.3-99.5%) aluminium, and referred to 100 kg of refined product:

Power consumption 2,485 kWh
Primary aluminium used 100.5 kg
Copper 0.3 kg
Graphite consumption 1.1 kg

The treatment may be applied also to refine aluminium alloys, which are previously made free of magnesium and zinc. Consumption data shall be of course higher than for primary aluminium, owing to the higher

./.

buildup of impurities in the anodic layer; at any rate content of (Fe + Si + Mn) can reach 10%.
Power consumption is higher than that required for producing primary aluminium; therefore, this method might possibly not find commercial applications in secondary smelting, though it has been widely tested in industrial practice, unless substantial improvement are not achieved.

D.2.4. Refining by Means of Aluminium Subhalogenides (2.10)

This method has been widely experimented, then left aside, owing to a number of difficulties, related mainly to design and to corrosion resistance of construction materials for chloridizing reactors (38).
The process consists mainly in the formation of aluminium monochloride by causing aluminium trichloride to react with an excess of molten aluminium metal:

$$2Al + AlCl_3 \longrightarrow 3AlCl \qquad (1200°C)$$

Then a dismutation of monochloride at lower temperatures is achieved, giving aluminium metal and trichloride, which is recycled in the process:

$$3AlCl \longrightarrow AlCl_3 + 2Al \qquad (700°-800°C)$$

Refining by this way is very good for copper and iron, fair for manganese and silicon; zinc and magnesium interfere, and must be separated previously.
Energy consumption is in the order of 4-5 kWh per kg of aluminium: from this point of view, the process is intermediate between methods already practiced in secondary aluminium metallurgy, and direct production

./.

of primary metal. A similar process has been recently proposed involving the formation of aluminium monofluoride -AlF- by reaction between an aluminium alloy with MgF_2 at 1450-1700°C (33).

D.2.5. Refining by Means of Various Metals (Mercury, Lead, Zinc)

The methods (4.4) use these metals, which in the molten state and at higher temperatures are capable to dissolve aluminium, separating it totally or partially from other elements; from the molten alloy aluminium segregates then in the subsequent cooling, more or less polluted by the metal used to process it, so that it must be then refined by a special purification treatment.

Complexity of proposed processes, high energy consumption rates, ecological and industrial hygiene motives cause these methods to look hardly promising, as for practical applications.

D.2.6. Refining by Means of Magnesium (4.3)

This process, similar to those described in the paragraph (D.2.5) has already been experimented on an industrial scale: adding magnesium in high percentages (more than 37%), then cooling the alloy thus formed causes a total insolubilization of iron, manganese, chromium, and titanium, in the form of intermetallic compounds with aluminium, as well as of silicon in the form of Mg-Si compound. After filtering the solid residues, magnesium is separated from aluminium by vacuum distillation in the equipment described in Section D.2.1.; the complete removal of zinc, cadmium bismuth, lead, and antimony is thus obtained simultaneously.

However, the method cannot be used to remove copper,

./

nickel and tin from aluminium.
Similarly to subhalogenide method, this process is intermediate, owimg to the relatively high energy consumption - in the order of 2 kWh/kg of aluminium - between refining methods practiced in the secondary metallurgy and production of primary metal from alumina.

D.3) Direct Production of Semis from New Scrap

This method has been tested on a pilot plant scale (47) by utilizing new scrap of various compositions: Al 99.5, AlMg, AlSiMg, AlCuMgMn, AlCuMgSi, AlZnMgCu. The raw material, previously chopped in rotating blade machines and reduced down to a 15 mm size, is subjected to a softening annealing; subsequently it is pre-pressed into billet and extruded to produce rectangular shapes, by method similar to those used for the correspondent primary alloys. Semis thus obtained show a slight decay in mechanical properties, which are anyhow kept within acceptable limits.
Machines have also been developed, according to the same principle, but operating continuously (55) and capable to treat scrap consisting of soft aluminium alloys.
The operating principle of one of these machines, shown schematically in figure 8 a, uses two gripping surfaces moving in a straight line. These gripping surfaces are hardened steel blocks on a continuous chain.
The two fixed sides of the extrusion chamber are formed by two sides, or fork extension of the die.

./.

The gripper blocks moving above and below the chamber force the solid feedstock between the die forks.
The stock is made narrower than the opening between the die fork legs and upset to fill the chamber, extruding through the die opening.
Stock is fed in solid or powder form.

CONCLUSIVE REMARKS

In the previous chapters a detailed review has been made of the different methods, more or less generally applied in the secondary aluminium industry: we may reasonably draw the conclusion, that for the most part of the technological problems that refiners have at present to face to, technologies are available for resolving them in a fairly satisfactory way .

Some of the most important problems may be mentioned here: the increasing complexity of scraps to be converted into secondary alloys; the call for reduction of energy consumption and of labor requirement; the control of pollution related to some operative methods used in secondary aluminium metallurgy.
We may list briefly some methods, which have yet reached a remarkable technological level, as they are highly mechanized, and their productivities and yields are acceptable.
In the field of sorting and dressing of recycled raw materials:

- Shearing, baling, and briquetting processes
- Shredding treatments followed by pneumatic and magnetic classification
- Shredding treatments followed by heavy medium separation
- Mechanical dressing of aluminium-bearing cables
- Treatment of drosses
- Treatment of turnings
- Melting in outer hearth furnaces, rotary furnaces, induction furnaces

- Regeneration of salt fluxes
- Control of chlorine emissions in the treatments for degassing and magnesium removal
- Treatment by means of filters or scrubbers of flue dusts originating from melting and refining operations.

As for the above processes, further improvements are to be expected, related to natural evolution due to their industrial practice; such advances might require more or less intensive applied research work, but performed mainly on short term basis by equipment manufacturers and secondary smelters.

Entirely new approaches might however be tried for some of the processes above mentioned: for instance the results of conventional shredding applied to unsorted scraps or cables could be improved by the cryogenic grinding, or the heavy medium treatment could find a competitor in magnetic fluid or in eddy current separation.

Likewise, new types of furnaces could be developed with higher yields and melting rates or a lower energy consumption.

It is apparent that companies having a research organization are interested to developing by their own forces any project looking promising to give adequate return of expenditures, and to afford to improve its own technical condition against competitors.

However, the results thus obtained are kept as confidential , except for those intended to be patented both for commercial exploitation or for "defensive" purposes.

The treatment of some sorts of scraps and rejects, containing aluminium and nonferrous metals in general, in low concentration and in a not readily separable form, originates more difficult technological problems, requiring costly research programs uncertain in their issue and not easily amenable to exploitation in a short term.

A particularly important instance is the treatment of solid urban wastes, by means of non-destructive techniques and by recovering different components, non-ferrous metals included.
Another interesting field for research is the recovery of aluminium,and possibly of other components, from composite materials mainly consisting of thin foils bonded on paper or plastics.
In order to solve the above problems intensive research work is made for adapting conventional techniques as well as for developing new methods, like separation by means of eddy currents, utilization of magnetic fluids, cryogenic grinding.
In this field,State research concerns and University departments are active, besides private companies, reporting the results of their work in technical literature in a sufficiently comprehensive and timely manner.

A large development of methods for partially or totally refining aluminium from alloying elements or impurities was until now hindered by the intrinsic properties of this metal which - different from copper, lead and zinc - cause it to be hardly suited to such treatments. Actually, they are mainly restricted to removal of hydrogen and magnesium. Other known processes did not find extensive applications, owing to the high investment costs and energy consumption levels required (electrolytic refining in molten salts, vacuum distillation), or because of different yet not well resolved technical problems (purification with subhalogenides).

An intensification of research work in this field might bring forth further improvements in the technical and economical features of such processes, so that they possibly become more interesting for secondary smelters, mainly within a middle or long therm evolutional trend outlook of the secondary industry, peculiarly showing a decreasing availability of selected new scrap and an increasing supply of old scrap.

Another field in which interesting development might possibly take place consists in direct converting of some sorts of selected scrap into rolled or extruded products, avoiding the intermediate stage of melting and casting into plates or bars: this method has proved to be feasible, but the limits of applicability to the different aluminium alloys and the performances of the products thus obtained are not yet well known.

Some research subjects are then yet left, dealing with a better utilization of some byproducts of secondary smelters sold to other industrial branches: the correspondent programs require a comprehensive acquaintance of such branches from both commercial and technological points of view, but they are interesting for all refiners, in order to provide for a better profitableness of the whole operative cycle, so that these programs are suitable for a cooperative financing.

Some of the materials under question are:

- Aluminium oxides obtained from processing of drosses
- Aluminium oxide-base slimes originating from the hydro metallurgical treatment of salt fluxes
- The mixed heavy metals fraction (sink) obtained from the heavy medium separation, and consisting of a mixture of stainless steel, zinc and copper alloys.

T A B L E I

Typical Properties and Applications of the main Aluminium base Wrought-Alloys (7)

Italian Specification	Chemical Composition Cu (%)	Si (%)	Mg (%)	Mn (%)	Zn (%)	State	Mechanical Properties Tensile Strength (Kg/mmq)	Elongation (%)	Brinell Hardness	Applications
1) P-AM 1,2 3568	-	-	-	1,2	-	R-E H	10 21	35 5	30 35	Parts with improved strength and good drawing properties
2) P-AG 3,5 UNI 3575	- -	-	3,5	0,3	-	R-E H	22 30	25 6	65 90	Moderately stressed parts (Naval-building)
3) P-AG 5 UNI 3576	-	-	5	0,3	-	R-E H	29 38	25 10	75 105	More severely stressed parts
4) P-AS 0,4 UNI 3569	-	0,4	0,65	-	-	TA	22	15	70	Building Industry(door and window frames)
5) P-AS 1 G UNI 3571	-	1,0	0,7	0,65	-	TA	32	12	95	Mechanically stressed and corrosion resistant structural parts
6) P-AC4GM UNI 3579	4	-	0,5	0,5	-	TN	40	16	110	Highly stressed structural parts (aeronautics)
7) P-AC4,5GM UNI 3583	4,5	-	1,5	0,5	-	TN	45	12	120	As above
8) P-AZ5,8GC UNI 3735 (X)	1,5	-	2,5	0,35 +Cr+Ti	5,8	TA	55	7	150	Highly stressed structural parts Rolled products
9) P-AZ 7,8GC UNI 3737 (X)	1,5	-	2,5	0,35 +Cr+Ti	7,8	TA	65	6	170	As above Extruded products

E = extruded H = strain hardened TN = quenched and naturally aged TA = artificially aged

(X) = These alloys are sometimes plated with pure aluminium or with Al-Zn Alloy.

TABLE II

A) Typical properties and Applications of the main primary Aluminium base casting alloys (7)

Italian Specification	Chemical Composition Cu (%)	Si (%)	Mg (%)	Mn (%)	Others (%)	State	Mechanical Properties Tensile strength (Kg/mmq)	Elongation (%)	Brinell Hardness	Applications
G-AC10 NSG UNI 3042	10	1	0,25	--	Ni1,5 TiO,15	Gc-TA	39	0,5	150	High temperature applications
G-AC3 FGN UNI 3046	3	0,7	0,6	--	NiO,6 TiO,15 Fe1,5	Gs-TA Gc-TA	33 37	1,5 2	130 140	High temperature applications or highly stressed parts
G-AS13 UNI 4514	-	13	--	--	--	Gs Gc Gp	18 20 24	5 6 2	55 60 80	General purposes and especially thin walled castings
G-AS21-CNK	1,6	21	0,6	0,7	Co 0,8	Gs-TS	20	0,5	100	High temperature applications with low thermal expansion
G-AS12 MG UNI 3049	--	12	0,3	0,5	--	Gs-TA Gc-TA	25 27	2 2,5	90 95	Mechanically stressed thin Walled castings
G-AS10 CGN UNI 3050	2,2	10	1,4	--	Ni 1	Gc-TA	28	0,5	110	High temperature applications
G-AS9 Mg UNI 3051	--	9	0,35	0,5	--	Gs-TA Gc-TA Gp	24 27 22	3 4 3	85 90 80	As for No 5 alloy but for more general uses
G-As8,5 C UNI 3601	3,5	8,5	--	-	(FeO,8)	Gp	25	1,5	95	General purpose
G AS2 MG UNI 3055	--	2	0,65	0,7	--	Gs-TA Gc-TA	25 27	1,5 2	90 95	General,purpose, decorative and corrosion resistant parts
G AG7 UNI 3057	--	-	7	0,4	--	Gs Gc Gp	20 28 22	4 7 2	75 80 65	Highly stressed corrosion resistant parts (naval applications)
G AG 5 UNI 3058	-	-	5	0,4	-	Gs Gc	18 22	5 9	60 70	As No 10 Alloy but more general uses
G AG 3 UNI 3059	-	-	3	0,3	-	Gs Gc	14 16	6 10	45 50	Moderately stressed corrosion resistant parts
G AN2,5 M2,5	-	-	-	2,5	Ni2,5 TiO,15	Gc Gp	20 22	12 5	55 55	For cooking stoves
G AZ 5 F UNI 3602	-	-	-	0,6	Zn 5 TiO,2 Fe 1,0	Gc-TcN	32	.12	95	For applications requiring good mechanical properties without any heat treatment

Gs = Sand cast Gc = gravity die cast Gp = pressure die cast TcN = hardened by chill casting and naturally aged TA = quenched and artificially aged TS = quenched and stabilized

B) Typical composition of the main secondary Aluminium base casting Alloys

Al-Si 12 Cu Fe Cu max 1%; Mg max 0,3%; Si 11,0-13,5%; Fe max 1,3%; Mn max 0,5%; Ni max 0,3%;
Al-Si 8 Cu 3 Fe Cu 2,5-4,0%; Mg max 0,3%; Si 7,5-10,0%; Fe max 1,3%; Mn max 0,5%; Ni max 0,5%;

Zn max 0,5%; Pb max 0,2%; Ti max 0,2%
Zn max 1,2%; Pb max 0,2%; Ti max 0,15%

T A B L E III

Despatches of Aluminium and.its alloys in terms of end uses in some EEC Countries (1)

	France	Federal Germany	Italy	United Kingdom
Transportation	154,0 (24,4)	174,8 (16,2)	145,3 (26,1)	143,7 (24,3)
Mechanical engineering	36,9 (5,9)	78,8 (7,3)	42,7 (7,7)	41,6 (7,0)
Electrical engineering	78,7 (12,5)	74,4 (6,9)	33,6 (6,0)	78,2 (13,2)
Building	53,3 (8,5)	144,9 (13,4)	115,5 (20,8)	62,0 (10,5
Chemical, food agricultural equipment	11,7 (1,9)	18,9 (1,7)	10,4 (1,9)	7,6 (1,9)
Packaging	50,7 (8,0)	91,4 (8,4)	54 (9,7)	54 (9,1)
Domestic & office appliances	32,2 (5,1)	71,8 (6,6)	69,2 (12,4)	49,0 (8,3)
Aluminium powder	2,7 (0,4)	5,0 (0,5)	3,5 (0,6)	10,9 (1,9)
Metallurgical Industries	83,9 (13,3)	150,9 (15,0)	35,9 (6,5)	93,2 (15,8)
Directexports	125,8 (20,0)	270,3 (25,0)	45,9 (8,3)	51,1 (8,6)
Total	629,9 (100)	1081,2 (100)	556,0 (100)	591,3 (100)
Production of secondary aluminium	127	324	209	206

(1) from OECD Statistics for 1974

TABLE IV

Mean useful life of manufactured goods (years) and estimated percentage of scraps recycled (a)

	Tangen	OEA	Chapman	ITE	Reicher	Percentage recycled
Electrical cables	50	=	40	40	40	90
Industrial equipment	20	10-20	20-40	15	15	25
Equipment for electricity supply	50	10-30	40	=	30	90
Equipment for electricity consomers	10	4-12	10	=	10	15
Building material	30	10-30	40	=	30	15
Transportation	10	10	10	10	10	40
Packaging	1	1	2	=	1	7
Others	10	=	10-20	=	10	7

(a) (from : Metall 31 Heft 5 pag. 476)

Other estimate for recovery rate from various industrial sectors (b)

Electrical engineering	60-70%
Building	40-70%
Transport	30-50%
General Engineering	30-50%
Domestic equipment	5-20%
Packaging	3-5%

(b) From OEA report 75-76

T A B L E V

Comparison between various furnaces (X)

	Reverberatory furnace	Reverberatory furnace with outerhearth	Rotary furnace	Low frequency induction furnace	Sweating furnace
Fuel	Gas or oil	Gas or oil	Gas or oil	Electrical Energy	Gas or oil
Max. Capacity	80 T	80 T	20 T	25 T	=
Max. melting rate	8 T/h	8 T/h	7 T/h	10 T/h	5 T/h
Thermal efficiency (%)	20-30 (without recuperators) 23-33 (with recuperators)	20-35	20-35	65-70	15-20
Melting residue	Normal	low	low	low	high
Temperature control	good	good	good	very good	=
Aptitude for making alloys of fixed composition	non suitable	suitable	suitable	suitable	=
Aptitude for changing composition of alloys	non suitable	non suitable	suitable	suitable	=
Maintenance cost	low	high	low	high	low
Cost of equipment	low	low	low	high	low
Advantages	high melting rate	high melting rate; ease of charging; homogeneous melting	high melting rate; homogeneous melting	No athmospheric pollution; ease of charging; ease of relining	=
Drawbacks	not suitable for melting fine scraps		Works under a saline flux	Start with big size scraps; low metal capacity	only suitable for sweating

(X) from K.Schneider "Die Verhüttung von Aluminiumschrott" p.139

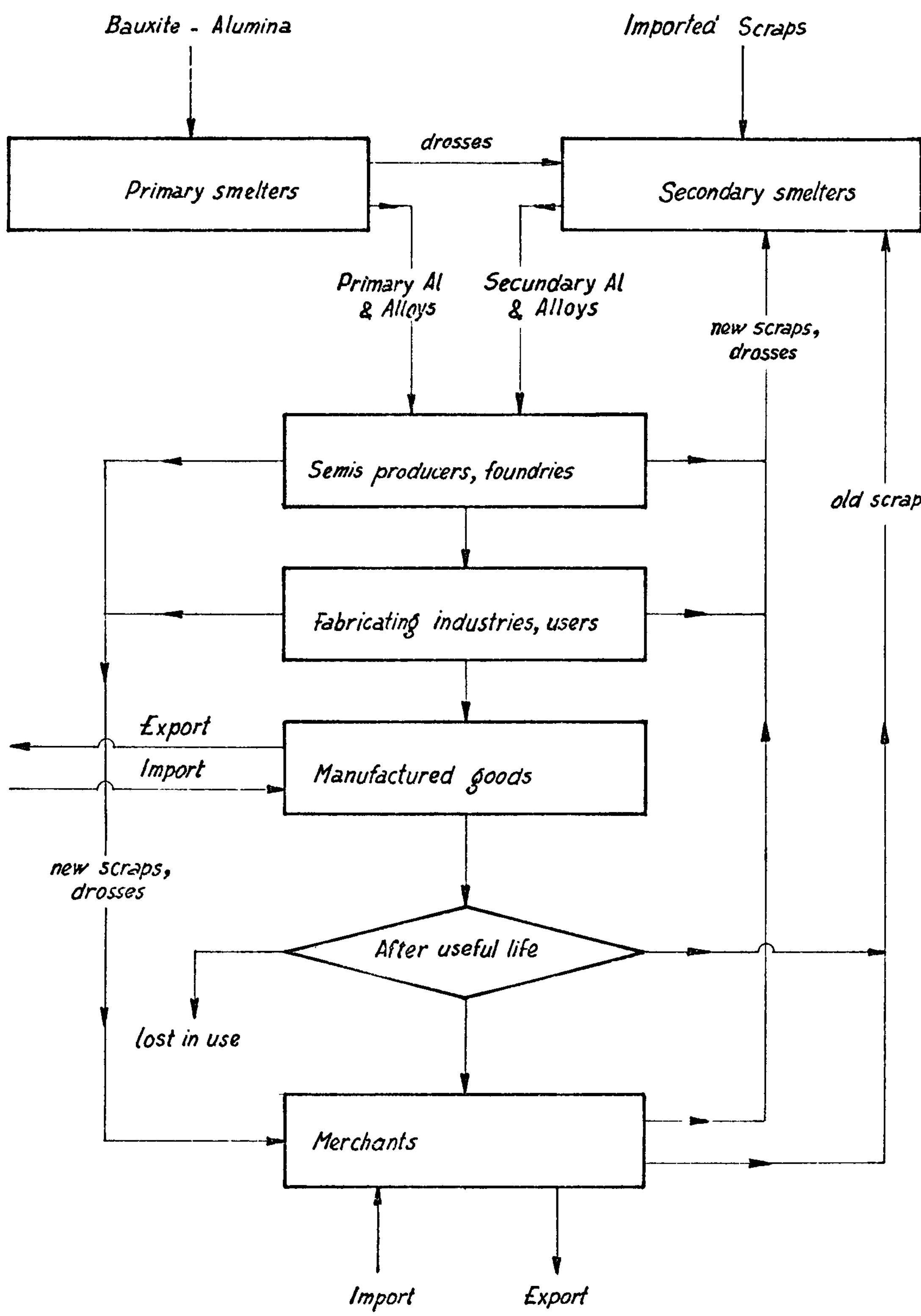


FIG. 1 — ALUMINUM BASE SCRAPS FLOW SHEET

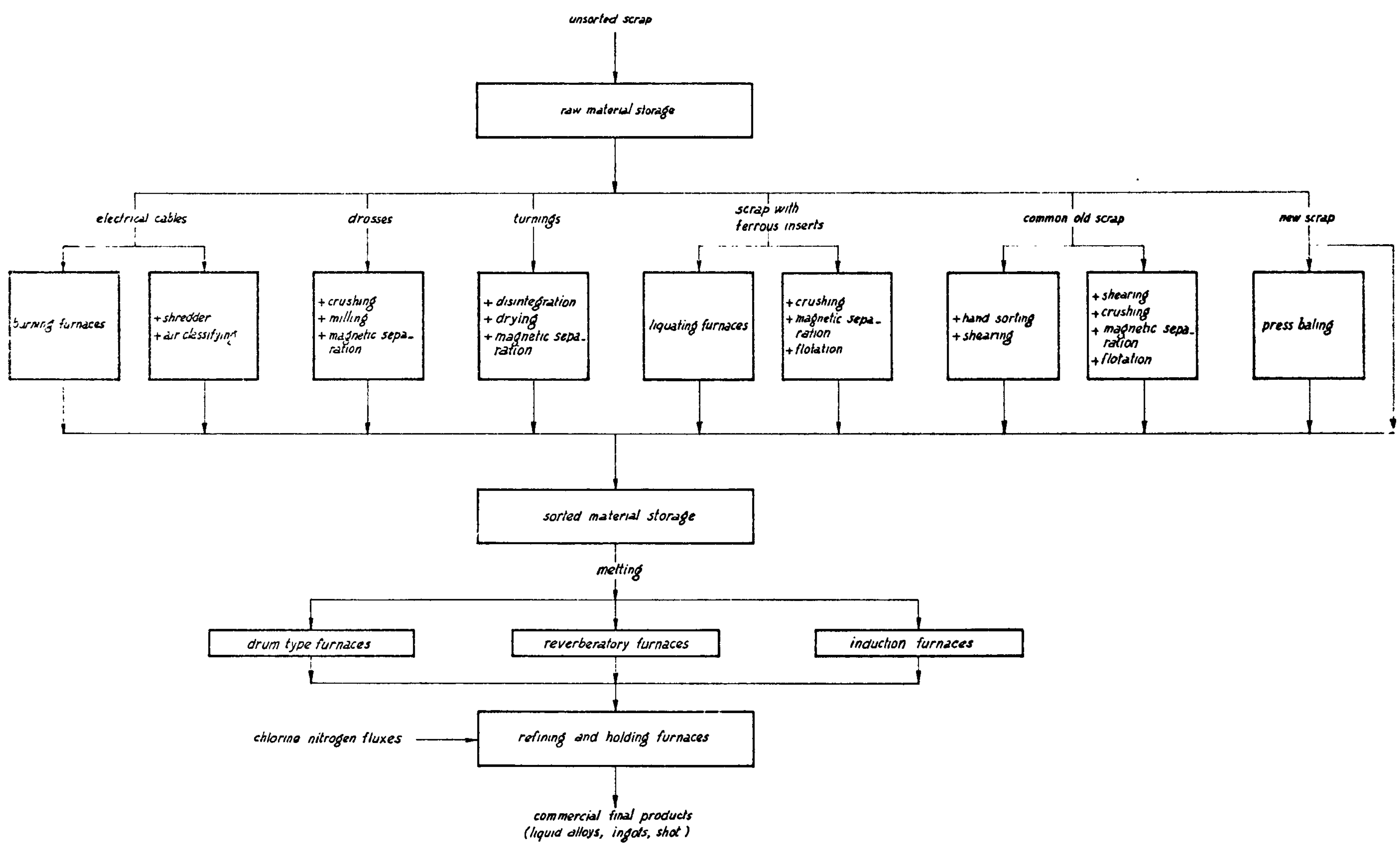


FIGURE 2 — FLOWSHEET OF A SECONDARY ALUMINIUM SMELTER

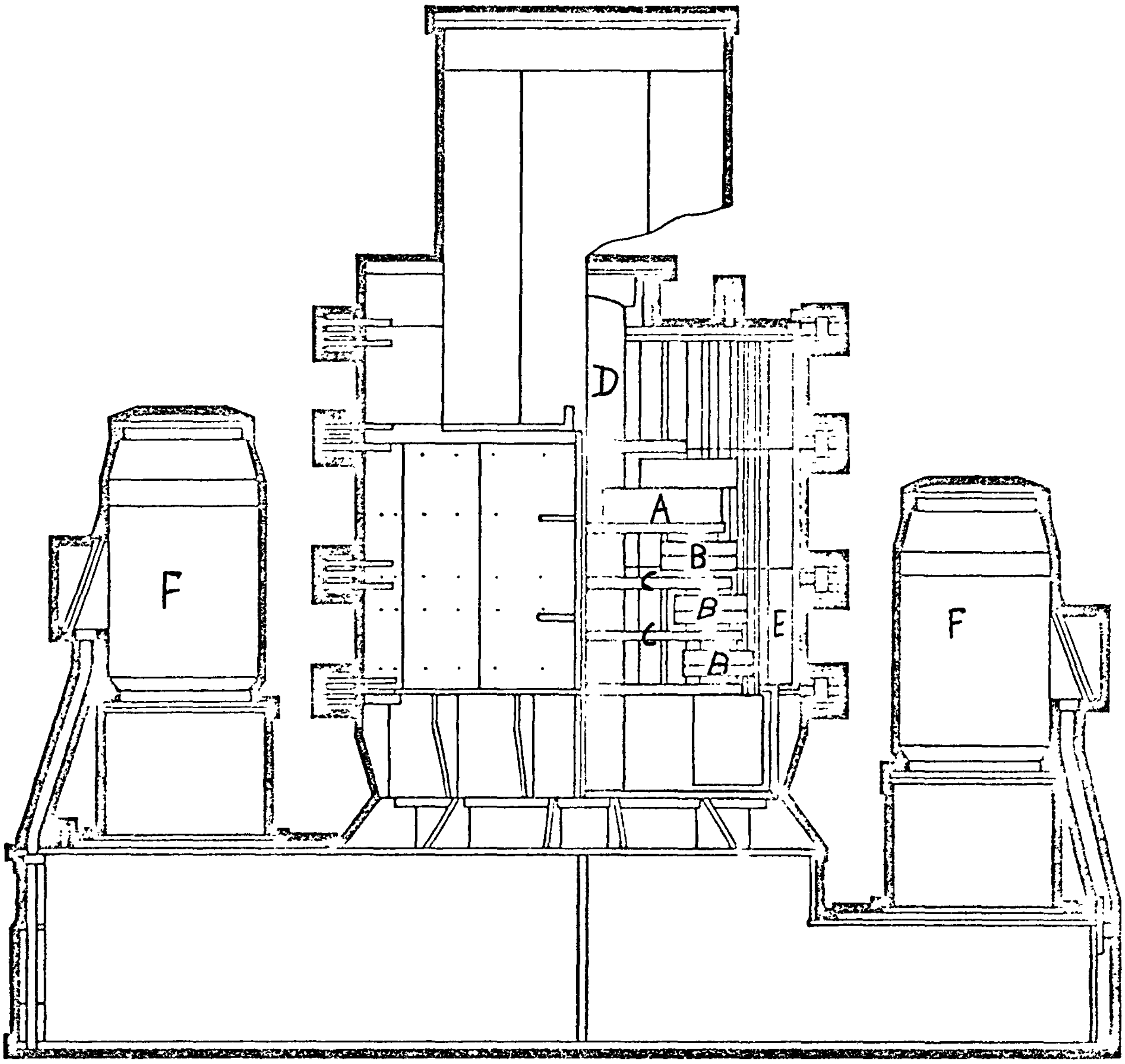


Fig. 3 - Schematic section of Henschel Vertical shaft shredder

A = breaker B = toothed rings

C = supporting disks D = vertical shaft

E = breaking plate F = electric motors

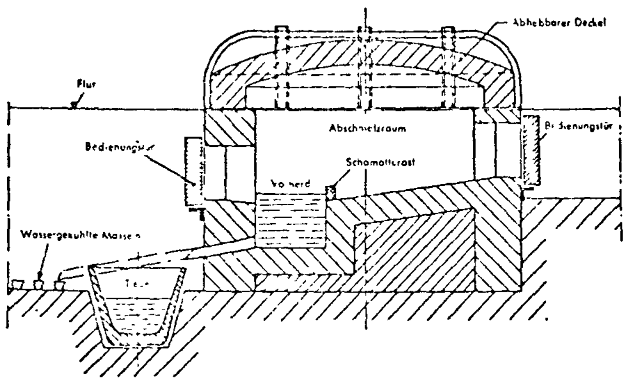


Fig. 4a : Sweating furnace: chamber type
Abhebbarer Deckel = removable cover;
Flur = floor; Bedienungstür = Service door;
Abschmelzraum = fusion chamber; Schamotterost = refractory grate; Vorherd = Settler;
Tiegel = crucible
(from K.Schneider p.124)

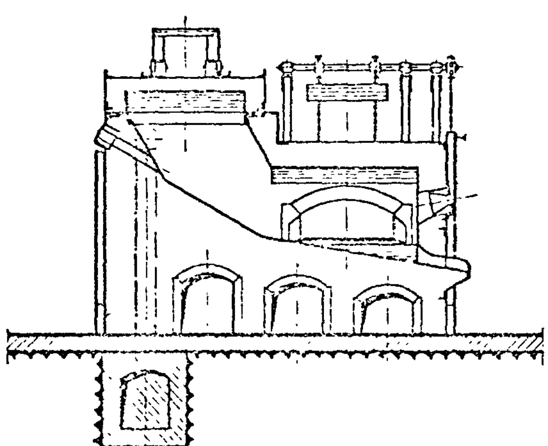


Fig. 4b : Sweating furnace : shaft type
(from K.Schneider p.124)

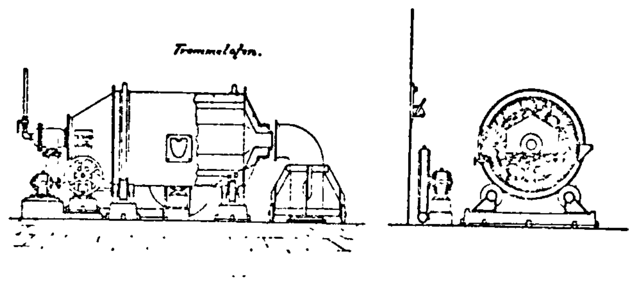


Fig. 5a : Rotary furnace
(from K.Schneider p.120)

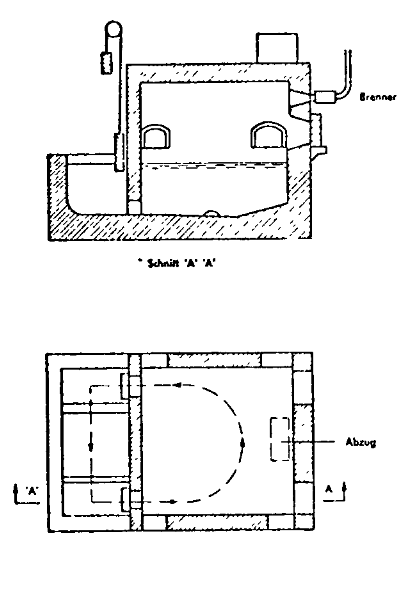


Fig. 5b : Reverberatory furnace with external well
Brenner = burner; Abzug = fumes outlet
(from K.Schneider p.115)

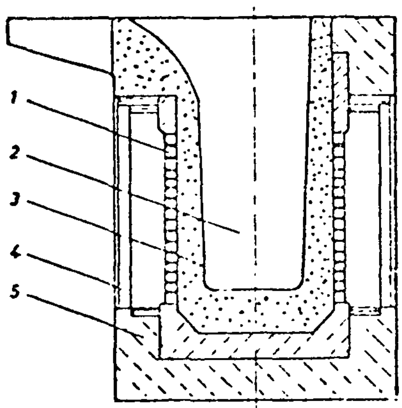


Fig. 6 a: Induction heated crucible
1 = primary coil; 2 = melting charge;
3 = refractory lining; 4 = support;
5 = heat insulation
(from Erzmetall H.G. 1970 p.278)

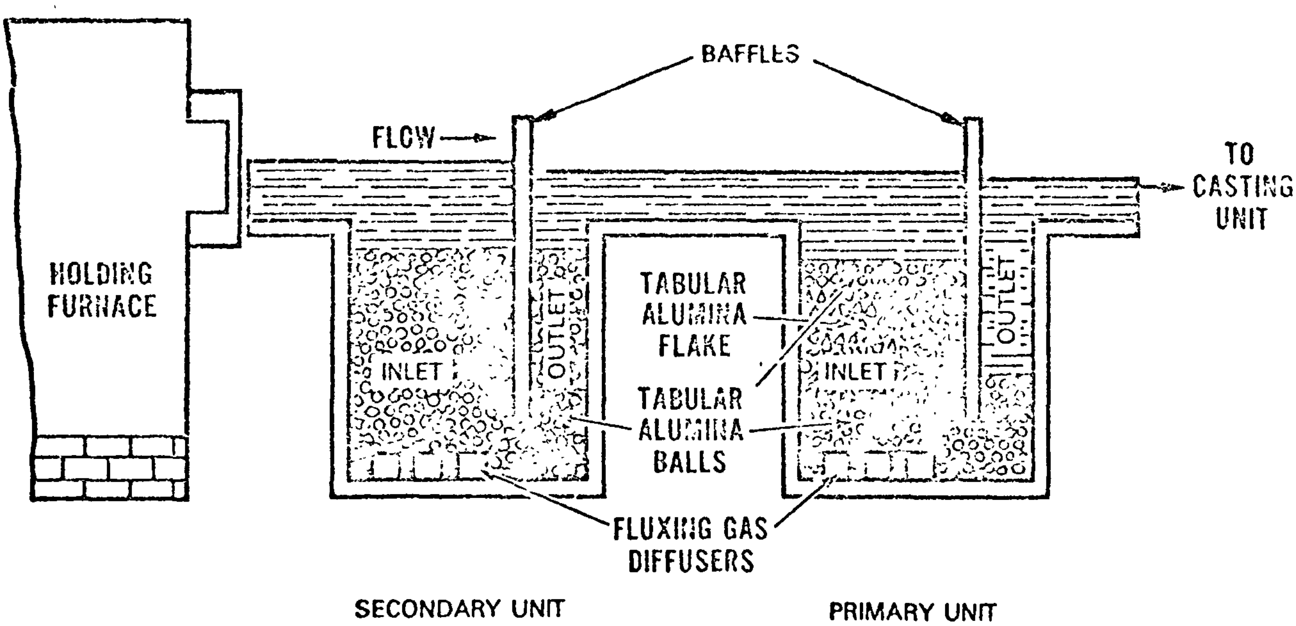


Fig. 6 b : Alcoa process
(from Journal of Metals, February 1974 p.25)

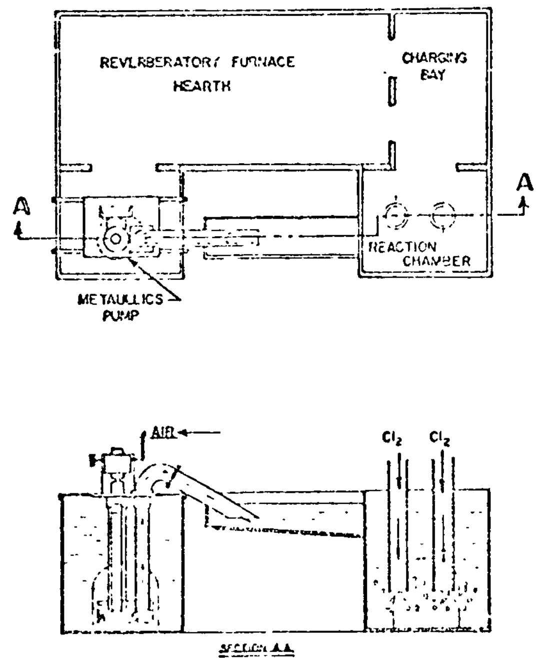


Fig. 7 a : Magnesium Removal by Chlorine
(from Light metal Age Dec. 74 p.15)

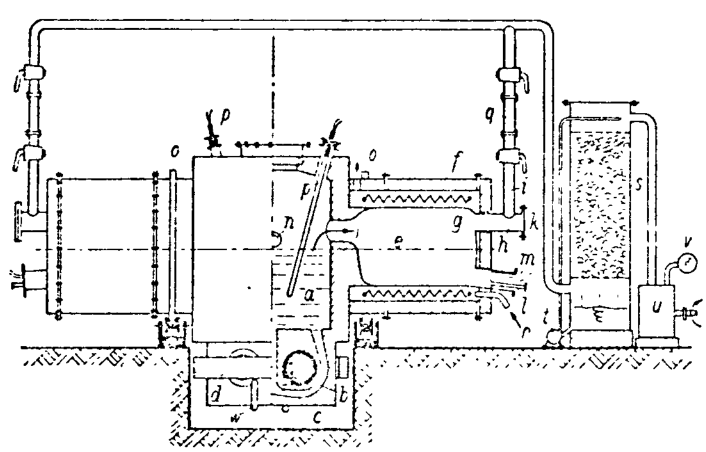


Fig. 7 b: Apparatus for distilling Magnesium and Zinc under vacuum

a = melted alloy; b = induction ring
c = primary coil; d = transformer core
e = condensator; f,g = electric heated muffle
h,i,q = vacuum line; o = rotation ring
p = thermocouple; S = oil filter;
u = vacuum pump
(from Ullmann 3 Band p.357)

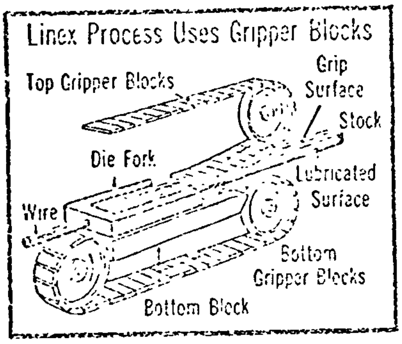


Fig. 8A Apparatus for direct extrusion of scraps
(from Iron Age, December 20, 1976, p.34)

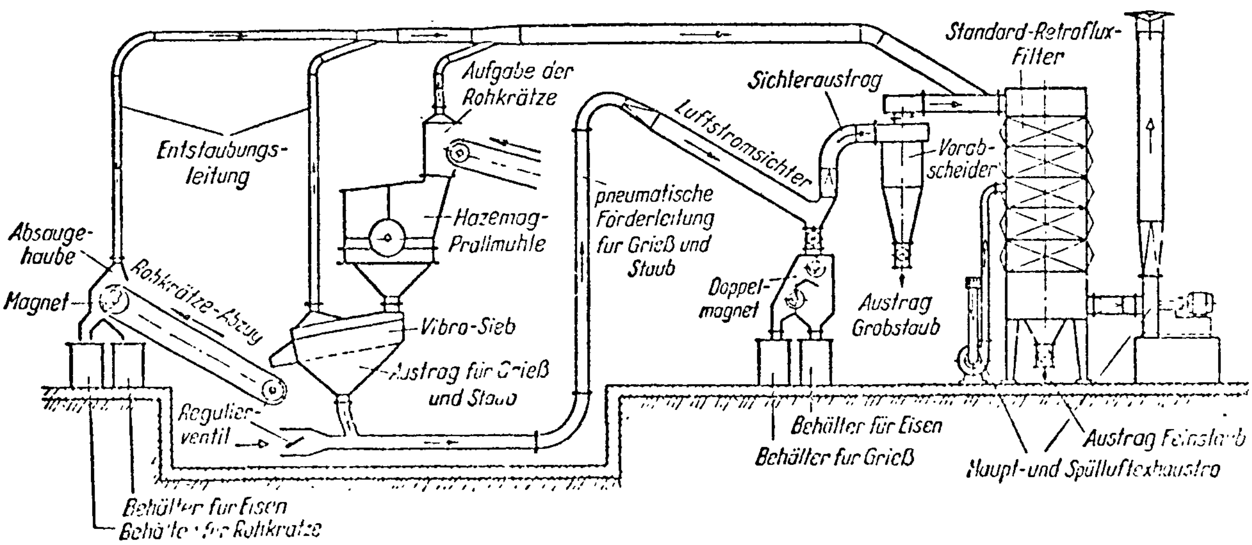


Fig. 8 b Refonda mechanical dross treatment

Absauge haube = Suction hood; Behälter für Eisen, Rohkratze, Griess = container for iron, aluminium granules and powder; Prallmühle = hammer mill; Vibro-Sieb = vibratory sieve; Austrag = discharge; Luftstromsichter = air separator; Pneumatische forderleitung = pneumatic conveyor line

(from Metall Oktober 1961 p. 1015)

REFERENCES

1.1) Taschenbuch der Metallhandels I, 13

1.2) Ibid. VII, 81

2.1) K. Schneider "Die Verhüttung von Aluminiumschrott"
3 Auflage p. 286

2.2) Ibid. p. 51-55

2.3) Ibid. p. 143-145

2.4) Ibid. p. 70-75

2.5) Ibid. p. 141

2.6) Ibid. p. 165-167

2.7) Ibid. p. 274-284

2.8) Ibid. p. 199-200

2.9) Ibid. p. 179-191

2.10) Ibid. p. 210-215

2.11) Ibid. p. 34

3.1) O E A report 1973-1974

3.2) O E A report 1974-1975

3.3) O E A report 1975-1976

3.4) O E A report 1976-1977

4.1) Ullmanns Encyclopädie der technischen Chemie
3 Band p. 411-418

4.2) Ibid. p. 355-357

4.3) Ibid. p. 357-358

4.4) Ibid. p. 353-355

5) Kirk - Othmer "Encyclopedia of Chemical Technology"
Vol. I, p. 605-609

6) BIPE - Charter - ITE ."Analyse technico-economique de la recuperation et du recyclage des metaux non ferreux dans la Communauté europeenne"

7) Enciclopedia della Scienza e della Tecnica (EST) Vol. I p. 419-420 Ed. Mondadori

8) D. Barthel et al. "Aufbereitung von Aluminiumschrott mit einer Shredderanlage" Metall Dezember 1976 Heft 2 p. 1208-1210

9) D. Hausler "Schrottaufberatungsanlage in neuer Technologie" Metall Februar 1976 p. 115-117

10) "Mill speeds aluminium to a new life" Iron Aye 207 (16) 1971 p. 81

11) R. Seurin "Traitment des déchets d'aluminium dans une grosse unitè de production" ATB Métallurgie 13 (3), 1973; p. 96-104

12) J. Dumontet "Due aspetti dell'industria dell'alluminio secondario" - Alluminio n. 1, 1970; p. 9-16

13) Anon. "Shredding developments" Metal Bulletin Monthly - May 1975; p. 35-41

14) Anon. "Spotlight on shredded metals" Metal Bulletin Monthly - April 1976; p. 23-25

15) M. Spross "Beitrag Zum Einschmelzen von Aluminiumfrässpänen in Netzfrequenz - Induktions - Tiegelofen" Erzmetall 1970; H.6; p. 278-280

16) A. Businger "Neues Verfahren für die Aufarbeitung Von Aluminium Krätzen" Metall Oktober 1961 p. 1014-1015

17) D. Hartmann, H. Rohn "Der Netzfrequenz Induktions - Tiegelofen zum Schmelzen von Nichteisen - Schwerme tall-Legierungen " Z. Metallkde 1957 Heft 3 p.85-90

18) J. Reichert "Abschätzung der Recycling - Potentiale von Kupfer und Aluminium" Metall Mai 1977 p.475-477

19) J. Adamo, C.L. Brooks "Trigas fluxing" Journal of Metals August 1972 p. 21-24

20) C. Blayden, J. Brondyke "Alcoa 469 Process" Journal of Metals - February 1974 p.25-28

21) V. Brant et al. "Fumeless in live degassing and clea ring of liquid Aluminium" Journal of Metals March 1971 p.48-53

22) C. Mangalick "Demagging in the secondary aluminium industry" - Journal of Metals June 1975 p. 6-10

23) C. Mangalick "Now pollution can be eliminated from Aluminium demagging" Light Metal Age December 1974 p. 14-15

24) "Alcoa fumless demagging unit" Report n. 1 Alcoa te- chnology marketing Division - June 1972

25) U.S. Patent n. 3650730 marketed by Aluminium Processes Inc., Cleveland Ohio

26) Anon. "Rifusione di rottami ricoperti e problemi re lativi agli effluenti" L'alluminio 1973 p.583-585

27) Anon. "Dust collection System proves good Investment for an Aluminium smelter" Light Metal Age August 1973 p.17-18

28) Anon. "Il recupero delle scorie nella fonderia di Al luminio" Alluminio 1976 p.116-117

29) H. Alter et al. "Pilot studies processing MSW and recovery of aluminium using an eddy current separa tor" Proceedings of the fifth Mineral Waste Utiliza tion Symposium - April 1976

30) H. Coyle jr. et al. "A technical and economical ana lysis of processes for the recovery of metals in the non ferrous portion of automobile shredder refuse" Procedings of the fifth Mineral Waste Utilization Symposium - April 1976

31) W. Reimers et al. "Cell design to separate nonferrous Metals in incinerator Residue with Magnetic Fluids" Mat. Science and Eng. 15 (1974) p. 129-135

32) P. Pearce "Cryogenic scrap fragmentation" Metall Bulletin Monthly October 1975 p. 51-53

33) S. Layne et al. "Aluminium extraction from impure sources by vapour transport with magnesium fluoride" Proceedings of the fourth Mineral Waste utilization Sumposium May 1974

34) F. Frewer "Aluminium/Kuntstoff - Verbundwerkstoffe für optimale Lösungen" Metall Dezember 1976 p.1119-1203

35) J. Mungovan "Cash from trash schemes tap new natio-nal resource" Modern Metals June 1974 p.61-67

36) C. Mangalick "Operation of a rigid porous media fil ter for liquid Aluminium" Light Metal Aye February 1973 p. 5-8

37) A.I. Nussbaum "Remeltshop System for aluminium mill scrap recycling" Light Metal Age April 1975 p.10-15

38) J. Dahlmann "Kritische Übersicht über mögliche Substitutionverfahren der Aluminium - Schmelzflusselektrolyse" Erzmetall 1976 H.3 p.125-129

39) P.L. Fracchia "Il recupero dei residui dell'alluminio impiegato nell'imballaggio" L'Alluminio - Settembre 1976 p. 470-473

40) L. Fagnani; R. Rigatti; G. Martinelli "Perchè e come recuperare l'alluminio dagli imballaggi" La Metallurgia Italiana n.5 1977 p. 218-225

41) A.W. Maynard, M.S. Caldwell "Identification and sorting of Non ferrous scrap Metals" Proc. 3° Mineral Waste Utilization Symposium 1972

42) Anon. "Melt furnaces pass rated output with added oxygen-fired burners" Modern Metals February 1972 p.69-70

43) D. Hughes "Die Rückgewinnung von Kupfer und Aluminium aus Kabelabfällen" Metall Februar 1973 p.172-174

44) Anon. "Triple/S Wire recovery" Metall Bulletin Monthly September 1976 p. 57-59

45) A. Melin "Physikalische Aufbereitungsverfahren für sekundäre Rohstoffe" Erzmetall 1972 H 6 p.290-295

46) R. Rakovski "Aluminium scrap: worth more if it's handled right" Modern Metals March 1971 p.65-74

47) L. Mori, M. Conserva, S. Veronelli "Produzione di estrusi di leghe di alluminio da materiale di recupero" Alluminio n.11, 1976 p. 553-560

48) Anon. "UK non ferrous pollution control costs" Metal Bulletin Monthly September 1977 p. 65-69

49) B. Morey et al. "Resource Recovery from refuse" Proceedings of the fifth Mineral Waste utilization Symposium April 1976

50) W. Reimers et al. "Density separations of non ferrous scrap metals with magnetic fluids" Proceedings of the fifth Mineral Waste utilization Symposium April 1976

51) R. Braton, A. Koutsky "Cryogenic recycling" Proceedings of the fourth Mineral Waste Utilization Sumposium May 1974

52) H. Bilbrey jr. "Use of Cryogenic in scrap processing" Proceeding of the fourth Mineral Waste Utilization Symposium May 1974

53) J. Sommer Jr. et al. "An electromagnetic system for dry recovery of nonferrous Metals from shredded municipal solid Waste" Proceedings of the fourth Mineral Waste Utilization Symposium May 1974

54) A. Campbell "Electromagnetic Separation of Aluminium and nonferrous metals" - Proceedings of the fourth Mineral Waste Utilization Symposium May 1974

55) Anon. "Continuous extruding reclaims soft scraps" Iron Age December 20, 1976, p. 34

Appendix A

EUROPEAN CLASSIFICATION FOR NON-FERROUS METAL SCRAP (E U R O)

(Prepared in collaboration with the consumers of non-ferrous Scrap metal in Europe and various national and international Associations included in which are the Organisation of European Aluminium-Smelters (OEA), the International Wrought Copper Council and the Fédération Internationale des Associations de Négociants en Acier, Tubes et Métaux [FIANATM].)

Definitions

Furnace Chargeable:	Material of maximum dimensions 100 × 50 × 40 cm, weights of more than 200 kg only according to special agreement.
Crucible Chargeable:	Material of maximum dimensions 35 × 25 × 15 cm, weight max. 50 kg.
Small Pieces:	Material less than 10 × 10 × 0,2 mm.
„Fines":	Material through 20 mesh sieve (0,84 mm aperture).
Foreign Substances:	Material, whether metallic or nonmetallic, which does not fall within the specification.
Coated Material:	Material with any kind of coating including paint, varnish, print, plastics, anodic oxide and other metals however applied, including Cr, Ni, Sn, Pb, Al etc. Includes also material with adhering metal: e. g. solder.
Plastics:	Unless otherwise agreed the scrap has to be generally free of plastics.
Compacted Material:	Unless otherwise agreed the scrap shall not be delivered in hydraulically compressed bales or briquettes.

VIII. ALUMINIUM

EURO VIII/1 "actor"

New Pure Aluminium Wire and Cable Scrap

New uncoated unalloyed aluminium wire and cable scrap, not burnt or corroded.

Free from hair wire, wire screen, and from iron and all other foreign substances.

Tolerance: Max. 1 % oil, grease and dust.

EURO VIII/2 "adept"

Old Pure Aluminium Wire and Cable Scrap

Old uncoated wire and cable scrap of unalloyed aluminium, burnt or not burnt.

Free from hair wire, wire screen and from iron and all other foreign substances.

Tolerance: Max. 3 % oil, grease and free oxide.

EURO VIII/3 "adult"

Old Aluminium Alloy, Wire and Cable Scrap

Old uncoated wire and cable scrap of one or more aluminium alloys, not burnt or corroded.

Free from hair wire, wire screen and from iron and all other foreign substances.

Tolerance: Max. 3 % oil, grease and free oxide.

EURO VIII/4 "agate"

New Pure Aluminium Scrap

New scrap of unalloyed aluminium of 99 % min. purity. Minimum thickness 0,2 mm. A delivery may contain a stated percentage of small pieces by previous arrangement between the parties. Free from coated material, castings and all other foreign substances.

Practically free from oil, grease and dust.

EURO VIII/5 "agent"

New Scrap of One Aluminium Alloy

New scrap of one specified aluminium alloy only. Minimum thickness 0,2 mm. A delivery may contain a stated percentage of small pieces by previous arrangement between the parties.

Free from coated material, castings and all other foreign substances.

Practically free from oil, grease and dust.

EURO VIII/6 "alder"

New Low-Copper Aluminium Alloy Scrap

New scrap of two or more aluminium alloys none of which shall contain more than 0,2 % Cu and 0,1 % each zinc, lead, tin, antimony and bismuth. Minimum thickness 0,2 mm. A delivery may contain a stated percentage of small pieces by previous arrangement between the parties.

Free from coated material, castings and all other foreign substances.

Practically free from oil, grease and dust.

EURO VIII/7 "amble"

New Low-Zinc Aluminium Alloy Scrap

New scrap of two or more aluminium alloys none of which shall contain more than 0,25 % zinc and 0,1 % each lead, tin, antimony and bismuth. Minimum thickness 0,2 mm. A delivery may contain a stated percentage of small pieces by previous arrangement between the parties.

Free from coated material, castings and all other foreign substances.

Practically free from oil, grease and dust.

EURO VIII/8 "amour"

New Mixed Aluminium Alloy Scrap

New scrap of two or more aluminium alloys which are not covered by EURO VIII/6 and 7. Minimum thickness 0,2 mm. A delivery may contain a stated percentage of small pieces by previous arrangement between the parties.

Free from coated material, castings and all other foreign substances.

Practically free from oil, grease and dust.

EURO VIII/9 "anger"

Old Rolled Aluminium Scrap — First Quality

Old household utensils and other rolled scrap of unalloyed aluminium or aluminium-manganese alloys. Minimum thickness 0,2 mm.

Free from cans, from pieces which will pass through an aperture of 5 cm diameter, coated material, castings, toothpaste tubes, bottle caps, milk bottle caps, and from all foreign metallic substances.

Tolerance: Max. 2 % calcareous and other non-metallic substances.

EURO VIII/10 "anvil"

Old Rolled Aluminium Scrap — Second Quality

Old household utensils and other rolled scrap of unalloyed aluminium or aluminium-manganese alloys. Max. 10 % clean, open cans free from adhering residual contents. Minimum thickness 0,2 mm. May contain a max. of 3 % of material which will pass through an aperture of 5 cm diameter.

Free from coated material, castings, tooth paste tubes, bottle caps, milk bottle caps, and from all foreign metallic substances.

Tolerance: Max. 2 % calcareous and other non-metallic substances.

EURO VIII/11 "arbor"

Old Rolled Aluminium Scrap — Third Quality

Old household utensils and other rolled scrap of unalloyed or alloyed aluminium, excluding copper- and zinc-containing alloys. Minimum thickness 0,2 mm. May contain a max. of 10 % of material which will pass through an aperture of 5 cm diameter and/or open cans with adhering residual contents, tooth paste tubes and bottle caps.

Tolerance: Max. 5 % calcareous and other non-metallic substances.

EURO VIII/12 "arras"

New Pure Aluminium Foil Scrap

New uncoated foil scrap of unalloyed aluminium.

Free from paper and other foreign substances.

EURO VIII/13 "aspen"

Old Aluminium Alloy Scrap

Old scrap of one or more aluminium alloys, none of which may contain more than 0,25 % zinc. Max. 10 % clean, open cans free from adhering residual contents. Minimum thickness 0,2 mm. May contain a max. of 3 % of material which will pass through an aperture of 5 cm diameter.

Free from castings, tooth paste tubes, bottle caps, caps of milk bottles and other foreign metallic substances.

Tolerance: Max. 2 % oil, grease and other foreign, non-metallic substances.

EURO VIII/14 "atlas"

Aluminium Pistons

Whole or broken aluminium alloy pistons. May contain a maximum of 10 % of material which will pass through an aperture of 5 cm diameter.

Free from free iron and other foreign substances.

Tolerance: 2 % oil, grease and dust.

EURO VIII/15 "attic"

Mixed Aluminium Castings

Whole or broken aluminium alloy castings of all kinds, excluding boot lasts, hat blocks and moulding boxes. May contain a maximum of 5 % of material which will pass through an aperture of 5 cm diameter.

Free from crusher scrap, free iron and other foreign substances.

Tolerance: 2 % oil, grease and dust.

EURO VIII/16 "audit"

Mixed Irony Aluminium Castings

Whole or broken aluminium alloy castings of all kinds, excluding boot lasts, hat blocks and moulding boxes. May contain a maximum of 5 % of material which will pass through an aperture of 5 cm diameter.

Free from crusher scrap and other non-metallic foreign substances.

Tolerance:
Max. 2 % oil, grease and dust,
Max. 2 % metallic foreign substances.

EURO VIII/17 "aural"

Segregated Aluminium Borings, Millings and Turnings

Aluminium borings, millings and turnings of one specified alloy only, not oxidised.

Free from grindings and from free magnesium, non-magnetic steel and other free metals.

Tolerance: Max. 3 % „Fines".

Subject to direct deduction for fines in excess of 3 %, and for free iron, moisture, oil and other non-metallic foreign matter to a total of 12 %, and to a deduction of 1½ % for each 1 % in excess of 12 %. Above 20 % does not conform to EURO VIII/17.

EURO VIII/18 "azure"

Mixed Aluminium Borings, Millings and Turnings

Borings, millings and turnings of two or more aluminium alloys, none of which may contain more than 2 % zinc, 0,2 % lead, and 0,1 % each tin, antimony and bismuth; not oxidised.

Free from grindings and from free magnesium, non-magnetic steel and other free metals.

Tolerance: Max. 3 % „Fines".

Subject to direct deduction for fines in excess of 3 %, and for free iron, moisture, oil and other non-metallic foreign matter to a total of 12 %, and to a deduction of 1½ % for each 1 % in excess of 12 %. Above 20 % does not conform to EURO VIII/18.

Ingots, coloured aluminium foil with paper, grindings, drosses, residues, irony aluminium, aircraft scrap and other scrap not included in the above specifications should be sold on analysis or by special arrangement.

Al 4

Appendix B

Standard Classification for Non-Ferrous Scrap Metals
CIRCULAR NF-66
(National Association of Secondary Material Industries, Inc.)

Apple 1 — Delivery

a. Delivery of more or less on the specified quantity up to 1¼ per cent is permissible.

b. If the term "about" is used, it is understood that 5 per cent more or less of the quantity may be delivered.

c. Should the seller fail to make deliveries as specified in the contract the purchaser has the option of cancelling all of the uncompleted deliveries or holding the seller for whatever damages the purchaser may sustain through failure to deliver and if unable to agree on the amount of damages, an Arbitration Committee of the National Association of Secondary Material Industries, Inc. may be appointed for this purpose, to determine the amount of such damages.

d. In the event that buyer should claim the goods, delivered on a contract, are not up to the proper standard, and the seller claims that they are a proper delivery, the dispute may be referred to an Arbitration Committee of the National Association of Secondary Material Industries, Inc. to be appointed for that purpose.

e. A carload, unless otherwise designated, shall consist of the weight governing the minimum carload weight at the lowest carload rate of freight in the territory in which the seller is located. If destination of material requires a greater carload minimum weight, buyer must so specify.

f. A ton shall be understood to be 2,000 pounds unless otherwise specified. On material purchased for export shipment a ton shall be specified as either a Gross Ton of 2240 lbs., or a Metric Ton of 2204,6 lbs.

g. If, through embargo, a delivery cannot be made at the time specified, the contract shall remain valid, and shall be completed immediately on the lifting of the embargo, and terms of said contract shall not be changed. When shipments for export for which space has been engaged have been delivered or tendered to a steamship for forwarding and through inadequacy of cargo space the steamship cannot accept the shipment, or where steamer is delayed in sailing beyond its scheduled time, shipment on the next steamer from the port of shipment shall be deemed a compliance with the contract as to time of shipment.

h. In case of a difference in weight and the seller is not willing to accept buyer's weights, a sworn public weigher shall be employed and the party most in error must pay the costs of handling and reweighing.

i. When material is such that it can be sorted by hand, consignees cannot reject the entire shipment if the percentage of rejection does not exceed 10 per cent. The disposition of the rejected material should then be arranged by negotiations; no replacement of the rejected material to be made.

Upon request of the shipper, rejections shall be returnable to the seller on domestic shipments within 10 days and on foreign shipments within 30 days from the time notice of rejection is received by them and provided government regulations permit such return. Seller to pay $ 0.01 per lb. on material rejected to cover cost of sorting and packing and seller to be responsible for freight both ways.

j. Packages

Shall be good strong packages suitable for shipment and each package shall be plainly marked with separate shipping marks and numbers and with the gross and tare weights so that the packages may reach their destination and their weights can be easily checked.

metallic and free from corrosion or oxidation. Should be poured in molds or in small mounds weighing not over 75 pounds each. Zinc shall be a minimum of 85 %.

Any other grades of zinc-bearing materials not mentioned are subject to special arrangement.

Table 61 — **New Pure Aluminum Clippings**
Shall consist of new, clean, unalloyed sheet clippings and/or aluminum sheet cuttings, free from oil and grease, foil and any other foreign substances and from punchings less than 1/2" in size.

Taboo 62 — **Mixed Low Copper Aluminum Clippings and Solids**
Shall consist of new, clean, uncoated and unpainted low copper aluminum scrap of two or more alloys and to be free of foil, hair wire, wire screen, dirt, and other foreign substances. Grease and oil not to total more than 1 %. Also free from punchings less than 1/2" in size. New can stock subject to arrangement between buyer and seller.

Tabor 63 — **Mixed Old Alloy Sheet Aluminum**
Shall consist of clean old alloy sheet aluminum of two or more alloys and to be free of 70 S series, foil, Venetian blinds, castings, hair wire, screen wire, food or beverage containers, pie plates, dirt, and other foreign substances. Oil and grease not to total more than 1 %. Up to 10 % painted sidings and awnings permitted.

Taint 64 — **Scrap Sheet and Sheet Utensil Aluminum**
Shall consist of clean, unpainted old 2 S or 3 S aluminum sheet and sheet utensils, free from hub caps, radiator shells, airplane sheet, foil, food or beverage containers, pie plates, oil cans and bottle caps, dirt, and other foreign substances. Oil and grease not to total more than 1 %.

Talon 65 — **New Pure Aluminum Wire and Cable**
Shall consist of new, clean, unalloyed aluminum wire or cable free from hair wire, wire screen, iron, insulation and any other foreign substance.

Taste 66 **Old Pure Aluminum Wire and Cable**
Shall consist of old, unalloyed aluminum wire or cable containing not over 1 % free oxide or dirt and free from hair wire, wire screen, iron, insulation and any other foreign substance.

Tarry 67 — **Aluminium Pistons**
(a) Clean Aluminum Pistons
Shall consist of clean aluminum pistons to be free from struts, bushings, shafts, iron rings and any other foreign materials. Oil and grease not to exceed 2 %.

(b) Aluminum Pistons with Struts
Shall consist of clean whole aluminum pistons with struts to be free from bushings, shafts, iron rings and any other foreign materials. Oil and grease not to exceed 2 %.

(c) Irony Aluminum Pistons
Should be sold on recovery basis, or by special arrangements with purchaser.

Teens 68 — Segregated Aluminum Borings and Turnings
Shall consist of clean, uncorroded aluminum borings and turnings of one specified alloy only and subject to deductions for fines in excess of 3 % through a 20 mesh screen and dirt, free iron, oil, moisture and all other foreign materials. Material containing iron in excess of 10 % and/or free magnesium or stainless steel or containing highly flammable cutting compounds will not constitute good delivery.

Telic 69 — Mixed Aluminum Borings and Turnings
Shall consist of clean, uncorroded aluminum borings and turnings of two or more alloys and subject to deductions for fines in excess of 3 % through a 20 mesh screen and dirt, free iron, oil, moisture and all other foreign materials. Material containing iron in excess of 10 % and/or free magnesium or stainless steel or containing highly flammable cutting componds will not constitute good delivery. To avoid dispute should be sold on basis of definite maximum zinc, tin and magnesium content.

Tense 70 — Mixed Aluminum Castings
Shall consist of all clean aluminum castings which may contain auto and airplane castings but no ingots, and to be free of iron, dirt, brass, babbit, and any other foreign materials. Oil and grease not to total more than 2 %.

Tepid 71 — Wrecked Airplane Sheet Aluminum
Should be sold on recovery basis or by special arrangements with purchaser.

Terse 72 — New Aluminum Foil
Shall consist of clean, new, pure, uncoated, unalloyed aluminum foil, free from anodized foil, radar foil and chaff, paper, plastics, or any other foreign materials. Hydraulically briquetted material by arrangement only.

Testy 73 — Old Aluminum Foil
Shall consist of clean, old, pure, uncoated, unalloyed aluminum foil, free from anodized foil, radar foil and chaff, paper, plastics, or any other foreign materials. Hydraulically briquetted material by arrangement only.

Thigh 74 — Aluminum Grindings
Should be sold on recovery basis or by special arrangements with purchaser.

Thirl 75 — Aluminum Drosses, Spatters, Spillings, Skimmings and Sweepings

Should be sold on recovery basis or by special arrangements with purchaser.

Throb 76 — Sweated Aluminum

Shall consist of aluminum scrap which has been sweated or melted into a form or shape such as an ingot, pig or slab for convenience in shipping; to be free from corrosion, drosses or any foreign materials. Should be sold subject to sample or analysis.

Tooth 77 — Segregated New Aluminum Alloy Clippings and Solids

Shall consist of new, clean, uncoated and unpainted aluminum scrap of one specified aluminum alloy only and to be free of foil, hair wire, wire screen, dirt, and other foreign substances. Oil and grease not to total more than 1 %. Also free from punchings less than 1/2" in size. New can stock subject to arrangement between buyer and seller.

Tough 78 — Mixed New Aluminum Alloy Clippings and Solids

Shall consist of new, clean, uncoated and unpainted aluminum scrap of two or more alloys free of 70 S series and to be free of foil, hair wire, wire screen, dirt, and other foreign substances. Oil and grease not to total more than 1 %. Also free from punchings less than 1/2" in size.

Tread 79 — Segregated New Aluminum Castings, Forgings and Extrusions

Shall consist of new, clean, uncoated aluminum castings, forgings, and extrusions of one specified alloy only and to be free from sawings, stainless steel, zinc, iron, dirt, oil, grease and other foreign substances.

Trump 80 — Aluminum Auto Castings

Shall consist of all clean automobile aluminum castings of sufficient size to be readily identified and to be free from iron, dirt, brass, babbitt bushings, brass bushings, and any other foreign materials. Oil and grease not to total more than 2 %.

Twist 81 — Aluminum Airplane Castings

Shall consist of clean aluminum castings from airplanes and to be free from iron, dirt, brass, babbitt bushings, brass bushings, and any other foreign materials. Oil and grease not to total more than 2 %.

Items not covered specifically in aluminum scrap specifications should be discussed and sold by special arrangements between buyer and seller.

Aroma 82 — New Nickel Scrap

Shall consist of new clippings, plate, skeleton and all other rolled shapes.
Nickel plus Cobalt minimum — 99 %
Cobalt maximum — 0,25 %
Copper maximum — 0,50 %
This grade shall be free of all castings

Part B

LEAD

(by M. CIVERA)

CONTENTS

SURVEY OF TECHNOLOGIES APPLIED FOR RECYCLING LEAD FROM BATTERIES, CABLES, AND CHEMICAL PRODUCTS

Introduction

In order to outline properly the problems of lead recycling, the uses of this metal will be summarized briefly:

1) Uses as lining material in many chemical and non-chemical plants, owing to its advantage to provide a protective surface against many corroding agents.
2) Uses in sanitary and hydraulic systems, owing to its scarce polluting power.
3) Uses as an absorbent of sound energy and of X-rays.
4) Uses for the fabrication of electric storage batteries, the main item among uses of lead.
5) Uses for producing a number of alloys.
6) Uses for the production of oxides and salts.

Except for item 6), which shows hard problems to be faced for recovery, lead used in other fields of application is potentially recoverable.

In a recent study (1) the fact has been emphasized, that the uses of lead not clearly dispersive account in the EEC to about 67% of total lead consumption: this is the maximum level that recovery should attain, by improving collection and smelting techniques.
In Table I the share of secondary lead is given, in total production of some countries of Western World.
Lead can be readily remelted without any special problems, so that it can be recovered directly from home scrap; recycling is made essentially from new scrap, and mainly from articles returned as waste at the end of their period of use, i.e. old scrap.

Old scraps life is for the most part short (batteries), but some have a considerably longer average life (cables). According to data of a Nato study (4), lead articles last 5 years on the average.
The scope of this report is to make a survey of technologies applied for recycling lead from batteries, cables, and some chemical products (paints, enamels, plastics).

Lead Scrap Trade

For the convenience of trade business, lead scraps are divided into a number of classes; Bureau International de Récuperation specifies 6 classes, three of them dealing with scrap battery trade, specifications ranging from clean plates to complete batteries.
The National Association of Secondary Industries Inc. in its Standard Classification specifies 8 classes, 4 of them dealing with battery trade, another dealing with cables.

The above specifications are listed in Enclose A B. Prescriptions are given in them, so that batteries are to be sold after being made free from acid, what thing is not always accomplished, as it will be put into evidence in this report (17).

A) RECYCLING OF BATTERIES

As shown in Table IA, 33% of lead consumption in the European Community (or at least in the four countries under question) is devoted to production of storage batteries.

They can be divided into three groups:

1) Starter batteries.

2) Driving batteries.

3) Stationary batteries.

The first item accounts for 85% of the total, and as they service life is short - about 36 months - they are the main source of lead scrap (6).
According to estimates, 90% of the lead content of these batteries is recovered (6).

Lead is used in batteries in the form of metal as well as in the form of active mass (oxide + dioxide + sulfate).

The batteries consist of a casing, usually made of hard rubber less frequently of polypropylene, glass, wood or metal; of separators generally made of PVC, paper, rubber or fiberglass; of grids and

connecting bridges made of a suitable lead-antimony alloy; of the above mentioned active mass; of the liquid filling, i.e. diluted sulfuric acid.
Table II shows the percent composition of starting batteries (6).

The recycling of driving batteries is a chapter quite apart, owing to the high silver content of the plates of some of them, and to other features, such as metal casings and tubular plates (12).
The non-metallic components of batteries originate considerable problems for recycling processes: casings in burning generate fumes with a high percentage of unburnt matter, they are difficult to be crushed, lastly caution is required in laying them to waste, as they are always contaminated by lead; separators made of PVC are decomposed at higher temperatures with emission of large amounts of hydrochloric acid; sulfuric acid originates risks for manual handling and corrodes all mechanical equipment.

The choice of retreatment techniques is related to battery composition and to the aim to overcome preferentially some of the problems reported above; these techniques may be divided into:

1) Direct methods which can retreat batteries in the as-received condition;
2) semi-direct methods which treat batteries after the only removal of casing;
3) Indirect methods, in which batteries are shredded or crushed, and the different lead-bearing components are separated from other components and from each other in a mechanical dressing stage, so that l ad-bearing components

can be smelted separately, whereas non-metallics can then be disposed of as waste or resold.

A-1 DIRECT METHODS

A-1-1 Blast Furnaces Methods (14) (15)(fig. I)

Batteries are treated in the "as-received" state in the blast furnace, after partial removal of the acid.

Advantages:

1) Any mechanical or manual shredding is avoided, except sometimes for making some openings in battery casings, to remove acid (14).
2) Any dumping is eliminated of casings and of non-reusable parts of the batteries, which always contain some ecologically noxious lead.
3) Casings and separators are utilized as an energy source in the process.
4) The only solid waste to be disposed of is slag.
5) Maintenance costs of blast furnaces are lower than those of rotary furnaces and productivity is higher.

Disadvantages:

1) Battery components made of organic matter are subjected to a partial distillation in the blast furnace, so that the emission takes place of fumes, with a high content of unburnt matter
2) The sulfur content of batteries (average 6.5%) is to be fixed chemically in the form of lead-rich mattes, arising heavy problems for their sale or re-processing.

3) Owing to the thermal decomposition of polyvinyl chloride, chloride-bearing fumes are generated.

Whole batteries or shredded batteries are yet charged occasionally in conventional blast furnaces, together with usual sinter charge, especially in smelters located in remote places, treating locally available scrap batteries; however, specially equipped blast furnaces have been developed - in a number of years - for treating such a raw material (13).
The features of these furnaces will be described here.
They consist in blast furnace, similar in size to those used in primary lead metallurgy; preheated (about 500°C) blast is used, sometimes enriched with oxygen,, in order to cause a temperature rise in the tuyere level, and to reduce exhaust gas volume. After-burning devices are used too, consisting in large chambers, where organic matter is destroyed by means of a supplementary burner.
Subsequently the gases are cooled down to 120°C by adding the air taken externally from furnace bottom thus improving environmental hygiene; gases are then filtered in a baghouse. Bergsoe Co. uses ITK filters, which have no moving parts. (14) (15) (16)
A typical analysis of gases discharged in the exterior is reported here:

Chlorine:	traces .
Sulfur	200 ppm .
Dust	5 - 10 mg/Nm^3.
Lead	7 - 8 mg/Nm^3 .

Data are given here on a charge composition, as an example: 50% whole batteries, 50% scrap of batteries (the possibility is claimed of operating with 100% of whole batteries);

then coal (5%) is added, as well as recycled slags, drosses fumes and additives.
Operations are carried on by keeping gas flow rate at a low level, in order to reduce dust carryover.
A thorough slag control is necessary in order to transfer into slag the alumina content of hard rubber casing, and to fix sulfur; lime and iron scraps are added according to analysis data.
Smelting products are:

1) Low-antimony (2-3%) antimonial lead.
2) Mattes containing 25% sulfur and 8-10% lead, corresponding to 3.2 - 4% of the total lead content of batteries (17). 90% of the total sulfur content of batteries is to be found in blast furnace mattes and slags.
3) Low-lead slags (less than 1% Pb) which are disposed of to waste as non-reusable.
4) Chlorine-bearing dusts, in amounts corresponding to 2 - 4% of furnace feed. These dusts collected in baghouses are treated by flash agglomeration which causes their sintering and makes their recycling possible without any hindrance to furnace gas flow. Any rise in chlorine content is prevented by treating a portion of these dusts (Chlorine content is 20%) by a chemical method, e.g. in a rotary furnace, with sodium carbonate and a carbonaceous reducing agent, obtaining metal lead and a sodium chloride rich slag, which is laid to waste (18).

Usual daily plant capacity is 80 to 100 tons of lead, in blast furnaces having a 6 m^2 cross-section area at tuyere level (Bergsoe Co.) (16).
Some presently plants are listed here: Murph Metals, Dal-

las (USA); Chloride, Manchester (U.K.); Arbez, Compiègne (France); Varta, Krautscheid (W.Germany); Bergsoe, Glostrup (Denmark) Lands-Kroma (Sweden).
Only a part of the above mentioned plant make use of the equipment partaining to this process in its final evolution, a few work with more simple procedure.

A-1-2 B) Rotary Furnace Methods

In the Oliforno method used by Oerlikon Co., whole batteries, after removal of acid, are treated in a rotary Kiln; the lead-slag mixture thus obtained is granulated in water and subjected to further treatments (12) in a rotary furnace.
In order to achieve an efficient burning of casings, an excess of air is required, which involves a heavy carryover of lead-bearing dust. Sulfur content of flue gases is 0.1 - 0.2% and purification is required, by absorption of sulfur compounds in an aqueous lime suspension (12).
Oerlikon Co. processes annually 15,000 tons of scrap batteries (12).

A-1-3 Future Trends of Blast Furnace Direct Processes

A further diffusion of blast furnace processing might be favoured by ecological protection legal regulations, which make difficult the laying to waste of casing scrap, produced by other battery processing methods, but might be hindered by a larger diffusion of polypropylene casings, as they can be resold after recovery, which advantage cannot obviously be achieved in the blast furnace process.

A-2 Semi-Direct Processes

By these methods batteries are usually treated, after removal of casings, but not of separators.
Short rotary furnaces ("kurztrommelofen" KTO) or electrical furnaces are used. Their advantage is the versatility of plants, which are also suited for small production capacities.

Disadvantages:

1) The problem of casing waste disposal is not eliminated.
2) The chloride-bearing dust production rate is high, owing to the presence of separators, mainly made of PVC.
3) Costly additions of ferrous metal scrap are required to fix sulfur, and high-lead mattes are produced, hardly saleable or re-treatable.
4) A cumbersome and costly preliminary partial shredding is required, whatever be the method used, either manual dismantling, or guillotine top cutting and casing emptying.

The electric furnace is mainly used in the countries of Eastern Europe, whereas in the West the short rotary furnace (KTO) is preferred; a brief description of the latter is given here. (7)
It consists of a cylindrical body with two conical parts at both ends. Usual dimensions are: lenght 3 to 5 m; diameter 2 to 3 m; its axis is horizontal and the furnace can rotate at slow speed, less than 1 rpm (figure II).
The interior refractory lining is usually basic, or made of high aluminous material (mullite).
For firing fuel oil or natural gas is used, operating temperature ranges 900° to 1000°C. A typical charging feed is given here: battery scrap 65%, recycled products (mattes

+ fumes) 20%, carbonaceous reducing agent 3%, soda and broken glass 3%, ferrous sheet scrap 9% (7).

Each charge lasts 4 to 8 hours. The purpose of soda additions is to reduce the formation of mattes.

The production of dust is considerable, amounting to 9-10% of total feed; the plant must consequently be equipped with suitable systems for dry or wet dust collection.

In dry collection methods, a portion of dust is to be treated separately to keep chlorine content under a certain level.

Raw material requirement for ton of lead produced.

Natural gas = 250 m^3 sodash = 25 kg.

Daily production 800-1000 kg of lead for m^3 of short rotary furnace.

Plant of this kind are numerous: some of them are cited here: B.S.B. Braubach (Federal Germany); Magneti Marelli, Romano Lombardo (Italy).

A common feature of all direct or semi-direct plants is the production of low-antimony lead (about 3%), as antimony--free lead coming from the active mass (oxide + dioxide + sulfate) is smelted together with grid lead.

The secondary alloy thus produced requires therefore a correction, at least until 6% antimony grid alloys are used.

Factories interested in production of batteries generally take up the whole production of antimonial lead after a suitable upgrading.

A lot of factories work with installations, somewhat simplified, for thermally refining of recovered lead in order to produce soft lead and an oxidised concentrate containing 15-25% Sb: this is recycled into melting furnaces with other battery scraps for producing directly an antimonial alloy suitable for batteries.

A-3 Indirect Methods (fig. III)

As pointed out previously, before remelting scraps are dressed by a special sorting process, which separates non--lead-bearing materials (casings and separators) from lead-bearing materials, which in turn are then separated from each other.

Advantages:

1) When lead-bearing materials are smelted separately, better lead recoveries are obtained, and products consist of high-antimony alloys directly reusable, and lead metal almost free of antimony; the disadvantages are thus avoided of the direct method.
2) The atmospheric pollution is greatly reduced, which originates from remelting, owing to the absence of casings and separators from the smelting charge, and reduction of sulfur content.

A disadvantage is the problem of the disposal of casings and separators. This disadvantage tends to be reduce down by the use of polypropylene casings.

Battery dressing, i.e. crushing and sorting, is to be made by mechanical methods, as manual dressing is no more feasible owing to economical and social motives.
According to evualuations of experts (19), a team of 25 workers would be required permanently, for dressing 30,000 tons of batteries per year.

Methods applied are:

1) Dry methods
2) Wet methods

A-3-1 B.B.U. Dry Method (6) (fig. IV)

By this method "packets" are treated, consisting of plates + active mass + separators, separated only from casings: consequently preliminary casing removal has to be provided for generally by using guillotine-type shears or mechanical saw.

The plant consists of a drying system, an air classifying and screening section, and a crushing and screening section.
In the first stage the raw material is fed into rotary kiln drier, heated in equicurrent. During drying the most part of active paste looses itself from grids, whereas PVC separators are hardly crushed, as they soften owing to heating.

Subsequently the material is conveyed to a screening and air classifying machine, where separators and some paste are removed by draught, collected in a cyclone and subsequently separated from each other by screening.
Separators can then be shipped to waste
In the latter stage the fraction not taken up for by suctio consisting of grids with some paste adhering to it, are fed into hammer mill, where paste yet adhering to grids get loose, and is removed in a zigzag classifier.
Grids can be stored in a bin. Fines coming from the zigzag classifier are jointed to fines previously separated by air draught, moistened, and stored in a bin.

Products:

1) Grid metal, containing 4 to 6% antimony.
2) Fines containing 78% lead and 1 to 1.5% antimony.
3) Separators containing 0.5% lead.

Hourly capacity is about 3 tons of "packets".
The main example of this method is the plant operated by B.B.U. at Arnoldstein,Austria.
Like semi direct method,this one seem to be suited for small and middle capacity plants.

A-3-2 Tonolli Wet Method (19) (fig. V)

This method requires the preliminary dry crushing of the batteries, which is followed by a sink-and-float separation.

The originary method described here is not suited for treating batteries with polypropylene casings.

Battery acid is removed, if required,by a squeezing process which cracks the casings; then batteries are fed in a drying drum fired in countercurrent, where material is dried and acid is neutralized by sulfatation of lead oxides; crushing takes also place in the rotary drum, in which special dragging devices are mounted.
Exhaust gases and fumes are collected and purified in electrofilters.
Crushed batteries are then fed to a screen, having two sections respectively with 10 X 10 mm and 200 X 200 mm holes. Active paste falls through holes in the first section, whereas grids, connecting bridges, casing pieces, and separators pass through the holes of the second section.
Then uncrushed batteries, usually fitted with polypropylene casings, are discharged at sieve end.
Active paste is sent to smelting, the coarse fraction sizing above 10 mm is treated by gravimetric sorting in a sink-and-float plant; heavy medium is prepared by using

active paste of batteries.

From this plant a sink is obtained, consisting of metal, and a float, consisting of crushed casings and separators. Both fractions are throughly washed and conveyed respectively. to remelting (metal), and to waste (hard rubber). Washing effluents are reused after thickening; thickening pulps are filtered on Dorr filter, dried and joined to the minus 10 mm fraction (active paste).

Products:

1) Dry active paste with 68% lead and 5 to 6% moisture (corresponding to 43% of total plant feed)
2) Metallic parts with 1% moisture (28% of total feed)
3) Hard rubber and plastics with less than 1% lead (20 to 23% of total feed)

As recent technology trend (17) show that in Europe 15 to 20% of batteries shipped to recycling have polypropylene casings, and this percentage rises to 30 - 35% in the U.S., the plant has been modified to suit it to treat such materials: a strong mill has been mounted before the drying drum, which can crush polypropylene casings; moreover, a special classifier separates hard rubber from plastics in a final stage of the process by gravimetric method. Polypropylene plastics can be resold advantageously.

A-3-2-1 Labour and raw materials requirements (for a 25 tph plant):

1) two or three workers per shift
2) 100 kW installed power
3) 40 to 60 m^3/h of natural gas (maximum in the winter season).

Floor space required for this plant is about 600 m^2. Minimum hourly capacity required for economical operation is 20 tph.

A-3-3 Wet Processes - Stolberger Process (11) (6) fig. VI

This process includes five stages:

1) Crushing of casings and removal of acid.
2) Milling of batteries in a ball mill.
3) Sieve separation of the different components.
4) Further wet separation of fine fractions.
5 Gravimetric separation of metal from plastics and organic matter

The process flowsheet may be summarized as follows: batteries in the as-received state are fed into a single roll mill where casings are crushed by struts protruding from the roll, whereas acid flows away. Then the crushed material is neutralize with lime, and is fed into a hammer mill, where the battery components are furtherly desintegrated, then they are sieved on a screen with 80 mm wide openings.

Undersize is furtherly trated in a washing classifier, and fine fractions (-5 mm) are fed to a spiral classifier, where a separation of coarse and finest products is accomplished. This coarse fraction-called "middlings"- is fed to stock. The finest fraction is collected - after thickening on a rotating filter and fed to stock.

The -80 + 5 mm fraction is dressed by gravimetric separation by a sink-and-float process, so that plastics are separated from metallics. Heavy medium may consist of magnetite or even of battery paste.

The products are then thoroughly washed, and magnetite is recovered by magnetic separation.

The use of magnetite for preparing the heavy medium contributes to reduce the lead contamination of casing scrap to be disposed of as waste.

In another version, this process is suited for recovering separately separators scrap and casings scrap (6).
Typical process products (example):

- Grid metal:	92.5% Pb, 5 to 6% Sb	(26% of total feed)
- Middlings:	74.8% Pb (14.8% metallic lead), 1.5% Sb, 0.3% Cl, 15% S, 11 to 18% water	(36% of total feed)
- Fines:	65.5% Pb (3% metallic lead), 0.7% Sb, 15% S, 0.4% Cl, 20 to 23% water	(16% of total feed)
- Scrapped: casings and separators	less than 0.1% Pb	(22% of total feed)

A-3-3-1 Labour requirements and other requirements per ton of dressed batteries (11):

- Labor : 0.75 hours
- energy : 5.70 kWh
- Fuel : 0.50 kg
- Lime : 4.42 kg
- Magnetite : 1.2 kg
- Water : 10.4 m^3

Data are relative to a 20,000 tpy plant operating on one shift

A-4 Remelting of Separated Products

For remelting separated raw products recovered from batteries, all metallurgical methods are obviously suitable. However, local factors strongly affect their selection. Grids do not originate tough problems. Active paste may be regarded as a gangueless lead ore, suited for re-smelting in a reverberatory furnace by the roasting reaction method.
Actually, B.B.U. retreats active mass in its special rotary hearth furnace (figure VII). This furnace puddles the charge by rotating, and causes the active mass to melt, with the only addition of lignite, no high value reducing agent being required.
By the same method grid scrap together with guillotined battery heads are remelted, which provide for a portion of the energy requirements of the process. (8)(9)(10)(12)
In a number of plants, Tonolli remelts grids in a rotary furnace, whereas active paste is treated in a reverberatory furnace. The drosses of the latter plant are then treated in blast furnace. Stolberger retreats active mass together with ore sinter in the blast furnace, whereas grids are remelted separately; alternatively active paste are desulfurated with ammonia (6).
Some other secondary smelters treat both raw products separately in short rotary furnace (KTO) using a number of different special artifices. E.g., the S.M.M. Penarroya foundry at Villefranche-sur-Saone, France, operating according to a simplified separation method, pelletizes active mass before remelting in KTO furnace equipped with after-burning system (6). During separation of battery components, the most part of sulfur content of batteries is

removed, except for that combined in the active mass. Some of the said sulfur is removed in the form of sulfur dioxide during smelting, so that maximum lead loss in the sulfur-bearing mattes is estimated not to rise above 1% of usual battery lead content, instead of the correspondent 3 to 4% loss in the direct methods (17).

A-4-1 New Developments in the Treatment of Separated Products

Grid metal does not originate great problems, as it can be recycled into battery manufacturing, after simple decoppering and antimony-content adjusting operations.

On the contrary, ecological problems originate from active mass treating, owing to emissions of sulfurous gases and chlorine-bearing products; therefore radical changes in methods are proposed in a number of patents.
Some of them choose pyrometallurgical methods, proposing the use of induction furnaces for reducing gas emissions (20 some other tend to replace pyrometallurgy with hydrometallurgy, but pollution is thus transferred in part to liquid effluents. Some advanced patents, among the many ones dealing with this matter, propose the direct electrochemical reduction on suitable supports,(21) but the most part of them propose the leaching with different reagents. According to the simplest methods, active mass is subjected to a chemical treatment, being converted into lead carbonate, which is then treated by a pyrometallurgical method.
Sodium carbonate (22) or ammonium carbonate (23) are used to remove chemically fixed sulfur and chlorine, but potential chlorine-leasing materials (e.g. separators scrap) are

thus left in the active mass.

Some methods involve paste dissolution, and therefore the removal of all impurities. Dissolution is accomplished by an aqueous solution of amines, and subsequent stripping with carbon dioxide, similar to methods already proposed in primary metallurgy (24).(fig. VIII)

By suitably accomplishing precipitation and thermal dissociation, high quality oxides might possibly be recovered from recycled materials (6).

Another "hybrid" method (combining pyrometallurgical and hydrometallurgical methods) involves the treatment of active paste with calcium hydroxide, so that lead sulfate is converted into lead oxide, simultaneously producing calcium sulfate. The product is then reduced with carbonaceous material under a sodium chloride + potassium chloride flux, which dissolves calcium sulfate, whereas hydrochloric vapours originating from PVC separators are presumably absorbed by excess lime.

Sodium and potassium chlorides are then recovered and recycled (25) (fig. IX)

A-5 DEVELOPMENT OF CALCIUM BEARING ALLOYS AND THEIR INFLUENCE ON THE RECYCLING OF SCRAP BATTERIES (26)

The development and applicative work is underway, of batteries equipped with grids made of lead-calcium (0.06 to 0.09% Ca) or less frequently of lead-calcium-tin (0.5 to 1.0% of tin).

The main advantages of these alloys are:

- High corrosion resistance.
- High electrical conductivity.
- Low cost of alloying elements.
- Good mechanical properties.

Their main disadvantage consists in poor adhesion of active mass to the grids.

Since long Pb-Ca alloy batteries are used for stationary communication standby service, for uninterruptable power supply, for emergency lighting, owing to the low maintenance costs they require.

Their most wide application is as stationary telephone standby batteries.

Pb-Ca and Pb-Ca-Sn batteries have been recently developed for application as starting batteries. Their advantages are:

- Extension of average battery life with an obvious reduction of costs related to battery turnover.
- Reduction of battery fabrication costs, owing to the lower cost of alloying elements.
- Improvement of the properties of the batteries, owing -among the other factors - to reduction of positive grid corrosion.

The influence of such batteries recycling may be outlined as follows:

Case 1) calcium batteries are only a portion of batteries available on the scrap market, and are shipped to dismantling mixed together with lead-antimony batteries.

Such a situation is to be foreseen for Europe, where lead-antimony batteries are thought to be continuing to predominate. The remelting of some amounts of lead-calcium does not originate any technological problem, as calcium is available in small amounts and is readily oxidized passing into slags (12).
However, the recycling of these batteries worsens the problem of the dilution of antimonial alloys, which is yet to be faced to in the direct or semi-direct methods: that causes a depreciation of scraps.

Case 2) More complex problems are to be faced when recovered metal is intended to be used for producing new lead-calcium batteries.

Lead-calcium alloys manufacturing requires high-purity and low-bismuth lead as raw material, though the really acceptable impurity levels are yet subject to objections and discussions (12). Generally, small and middle-size recycling plants use pyrometallurgical refining methods - often simplified - which cannot control bismuth content: such refining is therefore more conveniently used in electrolytical refining plants, which can produce 99.99% lead.
On the contrary, in recycling lead-antimony batteries bismuth content tends to increase, but within certain limits that does not give rise to problems (12), as average bismuth content of scraps is 0.01%.

A-6 INFLUENCE OF THE DEVELOPMENT OF LOW ANTIMONY ALLOYS ON THE RECYCLING OF SCRAP BATTERIES (27) (28) (29)

A complex development work is presently underway, for lowering antimony grid content from the conventional 6-7% level to a 2,5% - 4% level.

If antimony is reduced below a 5% level, a heavy decrease of mechanical strength is observed, owing to an increased trend to grain coarsening, to formation of solidification cracks and of other casting defects. Such inconveniences can be corrected by adding other elements acting as grain refining agents, such as copper and sulfur in small amounts (400-550 ppm and 160-120 ppm respectively), selenium, tellurium, as well as arsenic in higher amounts. Alloys are also proposed, including antimony, arsenic, selenium, and silver.

The advantages of these alloys are:

1) Savings in antimony consumption.
2) Longer battery life.
3) Lower amount of battery self-discharge.

The development of such batteries shall affect positively recycling, as for the period of some years the amount of antimony required for alloying additions will be reduced, though some problems are to be envisaged for refining in secondary smelters, owing to some alloying elements (12).

A-7 DEVELOPMENTS IN BATTERY FABRICATION AND THEIR EFFECTS ON SCRAP BATTERY RECYCLING

The metallurgical effects have been previously discussed of the use of lead-calcium and of low-antimony alloys. Changes in composition of non metallic parts of batteries may affect in yet higher amount recycling processes, in comparison with changes in alloy composition.

The use of polypropylene casings has two mutually discordant effects. Owing to their elasticity, polypropylene casings are difficult to crush, and hinder some indirect wet treating methods; the strong bonds keeping together plastics with metallic bridges and terminals cause fragments of plastics to remain bonded to lead parts, thus hindering sink-and-float separation. On the other hand, when the above problems are overcome, the secondary smelters using indirect processes can - provided that they are suitable equipped for separating hard rubber from polypropylene - recover and sale the latter material, which is priced 75 to 80 U.S. $ per ton (17).

The development of maintenance free sealed batteries, with fibreglass separators for fixing the electrolyte, does also hinder wet processing, owing to possible clogging of screens and hindrances to sink-and-float separation, caused by fibreglass material (12).

On the other hand, polypropylene casings affect favorably dismantling with mechanical saws, as plastics do not contain filling materials which might wear the mechanical tools.

The problem of casing scrap stocking and disposal might be reduced; for one hand, owing to the recovery of polypropylene casings; on the other hand, owing to the energy shortage problems, as possibilities are to envisaged of using hard rubber scrap as an auxiliary fuel in thermoelectric power plants or other plants equipped with combustion gas purification devices.

It is apparent that direct (blast furnace) processes are less sensitive with regard to composition and fabrication characteristics of scrap batteries, and therefore can look less apprehensively to any changes of these factors, but in the same time they do not afford "side benefits", like profits coming from the sale of polypropylene.

Within the limits of the development trends outlook, it is to be noticed that remarkable advantages might be obtained, if battery manufacturers would keep in mind recycling problems, e.g. by avoiding the use of polyvinyl chloride separators, as the generation of chlorine gas during remelting gives rise to disadvantages, that are larger than the advantages obtained in using such separators.

A-8 Location of Plants

The blast furnace direct method, as well as indirect wet methods, can be operated economically only when a certain capacity level is exceeded; that involves the transportation of remarkable tonnages of scrap batteries, and trasportation may be costly and cumbersome, especially with batteries yet containing acid, which might possibly cause damages to transporting vehicles. Therefore, such plants are located - as a rule - near to areas where junked batteries are largely available, i.e. densely populated areas, thus generating ecological problems.

A proposal has been put forth (12), i.e. to split battery dismantling operations into small decentralized units, using the indirect dry method, suited for small capacity plants. The moistless lead-bearing materials can be transported safely to refiners; in particular, active paste can be used by smelters recovering lead from ore, as it can be included into the charge for producing ore sinter, thus avoiding any ecological problems due to sulfur content.

A-9 Future Outlook

Ecological problems are liable to worsen, as environment protection regulations become sharper, and many small and middle-size plants are liable not to be in the future capable to meet their requirements.

On the contrary, large plants, using direct blast furnace methods or indirect methods, may reasonably provide for meeting law regulations. For pyrometallurgical processes, transferring all polluting matters into the gaseous effluents, care must be taken for keeping really sulfur dioxide and chlorine-bearing flue dusts levels within the limits prescribed.

For indirect methods, attempts must be made to reduce battery waste amounts, by recovering and re-selling plastics, and using in some way - as an auxiliary fuel or something else - hard rubber scraps.
An economic comparison between the different methods is very hard, even when the disadvantage is considered of direct method, i.e. the remarkable lead losses in the mattes. Leading factors in the choice of a process are, besides lead yields, local conditions, such as scrap batteries availability, the relative amount of batteries with plastics casing, and mainly the environment protection regulations.

B) RECYCLING OF LEAD FROM CABLES

Lead consumption for cable manufacturing amounts to 15% of total lead consumption in the four EEC countries considered in table 1A.
Except for Italy, such item shows a decreasing trend, owing to competition by other materials. Table IV evidences such a trend both in EEC and in the world as a whole.
As average life of cables is very long, namely 20 to 30 years, the amount of recycling shall continue to increase for a long period of time, notwithstanding the decrease in lead cable sheat production.

B-1 Types of lead-sheathed cables (30) (fig.10)

Lead-sheathed cables may be divided into four classes:

- Communication cables.
- Power installation cables.
- High frequency cables
- Lead-sheathed cables used for domestic systems.

Communication cables consist of a conductor or of a number of conductors, made of copper or aluminium, wrapped in paper, so that voids are left within the outer mantle or sheath, made of lead.

Power installation cables may too have an insulation consisting of paper, impregnated with a mineral oil-resin composition, and may consist of a number of single cables joined together, each of them may be in turn lead-sheathed. In some case, such cables are oil-filled.
Power cables have more frequently an insulation made of rubber or plastics of different compositions.

High frequency cables are exclusively insulated with plastics non containing polar groups (polystyrene or polytene).

Lead sheaths may be left bare or may be protected by: polyvinyl or rubber sheaths, bituminized fabrics, ferrous strip or wire or plate armour, in turn protected with bituminized fabrics.

B-1-1 Lead Alloys Used for Cable Sheaths

Raw commercial 99.85% lead was used until World War II, providing that cable locations were well away from vibration sources; subsequently purer lead produced by refineries proved to be unsuitable for resisting to vibrations, even in the mere transporting, so that alloyed lead had to be used.
In Table VI some of these alloys are listed. From the few data shown there, it is apparent that lead recycling may prove to be sometimes a cumbersome operation.

B-2 METHODS FOR RECYCLING LEAD FROM CABLES

The commercial value of sheath lead is generally lower than that of the conductor metal, especially when the latter is made or copper; consequently, lead recovery methods are conditioned by a good recovery of conductors.
The methods may be classed as follows:

B-2-1 Incineration Methods (fig. XI)

When burning the insulating materials of cables, lead is caused to melt and is collected on the bottom of the combustion chamber, whereas the copper or aluminium conductor is made thus free and can be recovered.

Combustion in air of these materials is no more tolerated by the regulations of all countries, though it is yet made stealthily by single smelters; industrial operation is performed in refractory lined chambers, operating temperature being not somewhat above 400°C, air flux being controlled in order to avoid the oxidation of the conductor metal.

Lead is collected on the inclined bottom, or on the bottom equipped with a grid, of the combustion chamber.

Fumes are treated by afterburning, i.e. they are heated up to 800 - 900°C with an auxiliary burner, so that unburnt residues originating from plastics combustion are eliminated. When operating properly, fuel additions in afterburning can be avoided, as unburnt gases originated from insulating materials are sufficient to reach the required temperature, if air is added to support combustion.

It is apparent that, when burning cables with polyvinyl chloride or rubber insulation, the removal is required of sulfur dioxide, hydrochloric acid, and of the dangerous chlorine-bearing flue dusts, by washing flue gases with alkaline solutions. Therefore this method is costly and is applied only for cables, that owing to small diameter - less than 1.5 cm - or to their conditions of maintenance or to their length, are not suited for being treated by mechanical methods.

Moreover, conductor metals may be contaminated by lead in the above treatment.
Batch operation is usual for combustion chambers, and charging and discharging operation may be performed with fork lift trucks.

B-2-2 Semi-Mechanical Dressing - Cable Stripping Machines (fig. XII)

By this method cables are cut along their axis and are open up, so that exterior layers are left free and are separated.
Strips are thus obtained of lead, of armour, and of coating material. Obviously, interior conductors yet partially covered by insulation are also recovered.
The machine used for this purpose consists of two grooved wheels mounted vertically, their spacing being controlled suitably.
These wheels grip the cable and push it against a cutting blade, which "disembowels" it.
The following conditions are required for applying this method:

1) Cables of sufficiently large diameter, at least 1,5 cm.
2) Sufficiently long cables, wound by collectors on reels.
3) Cables in good conditions.

A disadvantage of this method is the excessive labour required, as each cable is an individual problem ;

actually, wheels spacing is to be adjusted, cables are to be fed manually, and also manual separation of the different cut cable coatings is required. Some machines have automatic wheels spacing adjustment, according to cable diameter, but they have not found wide applications.

Advantages of the method are: 1) lead and other values are recovered separately, so that they may be utilized in the best manner; 2) conductor metal does not be subjected to oxidizing or contamination.

Operating speed varies with cable diameter, but tipically it averages 30 meters of cable per minute.

B-2-3 Mechanical Processing - Cable Desintegrating

Cable are desintegrated by various crushing method, and the different component parts are separated by a number of processes. These methods are described in chapter 2.1.3.1. of the parallel report " A Survey of Technology of Copper Recycling", to which reference is made (prepared by Société Générale des Minerais)
These methods are not presently suited for dressing lead sheathed cables, as well as armoured, tarred, and greased cables. Feasibility studies are underway for applying some processes to the dressing of lead sheated cables. If these efforts are successful, it will be possible to separate lead from other metals, both with gravimetric methods or by liquation (preferential melting; sweating).

B3 Developments and Outlook

Owing to difficulties involved in direct cable burning in air, and to costs of flue gas purification in incineration with afterburning and subsequent sulfur dioxide and chloride compounds collecting devices, considerable development work is made on this matter, but almost totally within company plant limits. A new proposal (32), related to the cable desintegration method described previously, involves cryogenic crushing, in order to lower energy consumption for cutting and cutting blade wear. According to another proposal (33), cables are immersed into a bath heated slightly above the melting point of lead, so that this metal is separated by melting from the other components.

C) Chemical Uses

Under this item application are considered, in which lead is used in the following forms:

1) oxides and salts, except for those used for forming active paste in storage batteries.
2) anti-knock products ,
3) other products .

As shown in Table IA lead consumption for such items in EEC (or at least in the four referred countries) amounted to 23% of total in 1975.
The recycling of metal present in the above listed products can be studied only, when the "destiny" is traced of the articles or composites in which these products have been used. In this survey, an attempt shall be made to evaluate the recoverability of lead from:

1) paints and enamels
2) plastics

C-1 Paints and Enamels

Lead is used in paints in the form of pigment.
A substantial portion of pigments is used in enamels.
In Table V data are given about consumption for pigments and compounds in the last years in some countries of EEC. Obviously, paints and enamels are used to coat articles, which may be made of metals (mainly cast iron or steel) or non metallic material.
Metallic articles are recycled as old scrap to feed stelworks, and lead bound to them is to be found in the so-called steel-work fumes, containing 50-70% Fe,

5-20% Zn 4-7% Pb.

Considerable advances have been made in studies on the treatment of these fumes, and the commercial phase is beginning, owing too to the urge of ecological law regulations.

As 7 to 10 kg of steelwork fumes per ton of ingot steel are produced by the electric furnace method, a yearly production of 60,000 tons of fumes in Italy and 82,000 in U. K. may be estimated, lead content being about 4,000 and 3,200 tons respectively.(34)

When comparing the above data with those of table (V), it is apparent the any recovery by this way does not reach above 10%, even if all lead content of fumes is supposed to originate from pigment oxides, and not from any small lead objects left in scrap, or from lead-bearing steel scrap.

Though we are well aware of the great inaccuracy of the above data, as scarcely homogeneous values are compared- present production of pigments and scrap painted a number of years ago - possibilities of recovery from paints look at once modest, as metallic materials are repainted many times before being scrapped, and obviously a large portion of painting gets eventually lost before scraps reach the steelwork.

However, the methods, for retreating these fumes, in a rotary kiln or in an-other sort of furnace (35) cause lead to be collected in a metal value (Zn + Pb) rich concentrate, which may be treated conveniently in lead and zinc smelters, and is particularly suited for Imperial Smelting blast furnace.

The same considerations might be made about enameled ferrous articles.
Non metallic articles coated with paints or enamels are to be found eventually in part in solid urban wastes, which shall be dealt with when considering plastics.

C 2 Plastics

In the working up of some plastics special lead compounds are added as stabilizers, as well as colouring pigments.
In the production of polyvinyl chloride lead additions may reach up to some unit per cent.
Lead is added to vinyls in the form of different compounds, such as tribasic phosphate, basic carbonate, sulfosilicate, dibasic orthosilicate, dibasic phosphite etc.
Lead recovery is obviously related to the recovery of lead-bearing materials.
These materials are collected separately, or are dumped into urban solid waste, which in turn may be re-treated
The plastics content of solid urban wastes is 2 to 3% and 10% of these plastics - i.e. 0.2 to 0.3% of total amount - consists of polyvinyl chloride, which is often stabilized by lead compounds. (36)
Some uses of plastics scraps, which do not involve the destruction of plastics , have no other effect, but a yet more certain eventual dispersion of their lead content.
The recycling might be of interest for this report, of plastics for the production of similar materials, or uses which involve the destruction of matrix, like the production of carbon black or the incineration together with urban solid wastes. The latter material is thought to contain 0.04% lead (in Italy) (37), total-

ling 4,800 tons per year (of course in Italy); a portion of this total - which cannot be readily estimated - comes from plastics, paints and enamels.
Similar data, 8000 tons per year have been estimated by another approach (34) in the United Kingdom.
Though some precaution is required for transferring such data to thc whole Community, they evidence the limitation of such a recovery which, being uneconomical in itself, might only be accomplished, within a general recovery system, under the support of suitable governmental actions.

E) SUMMARY AND CONCLUDING REMARKS

E-1 Mechanical Dressing of Batteries

From the review of the processes described in this report, the fact is to be pointed out, that different battery treating methods are being opposed each to other, viz. pyrometallurgical blast furnace processes and indirect wet processes; both methods require an adequate capacity level, to ensure profitability, and that involves the cumbersome transportation of whole undismantled batteries.

In paragraph (A-8) the proposal has been referred of decentralizing battery dressing in small units operating by the BBU dry method, and then shipping to refineries the products thus obtained, dry, neutralized, and consequently easy to handle.

But BBU method requires a preliminary partial dismantling of batteries by semi-mechanical methods, like guillotining or mechanical sawing. An interesting development might consist in wholly mechanical processes, capable of being applied economically to limited amounts of raw material, always providing for the transportation to refiners of the separate products thus obtained.

E-2 Dressing of Cables

The recovery of cable sheaths by the stripping methods involves heavy labour costs, whereas incineration methods involve heavy ecological problems.

On the other hand, desintegration methods do not look suitable for treating lead sheathed cables or anyhow

armoured or oil-filled cables (see paragraph B-2-3) A future development might possibly consist in adapting some of the existing methods for treating lead sheathed cables by modifying the desintegration process, and complementing it with the separation of lead from the other metals. In paragraph (B-3) the possibility has been pointed out of a cryogenic grinding in which lead is subject to embrittlement.
Of course, the economical factors are prevailing on all other ones.

E-3 Reduction of Environmental Pollution in Lead Recycling

The recycling of scrapped lead in its more sophisticated forms, like batteries and cables, give rise to a number of pollution problems, mainly air pollution, owing to the emission of sulfur dioxide and of chloridized fumes, but also water pollution, in view of the lowest lead levels in streams, tolerated by law regulations. The last referred factor might cause law infringement, when dumping materials, even slightly contaminated by lead compounds.
Under such conditions, future development might come off as follows:

A) Improvements in retreatment and recovery of sulfurized-chloridized fumes, to be accomplished possibly in one plant, jointly owned by many smelters, and operating e.g. by hydrometallurgical methods.
B) Replacing pyrometallurgical methods for treating battery active masses and other lead oxides and compounds, with other partially or totally hydrometallurgical methods, thus reducing air pollution

and possibly hindering also stream pollution.
A number of such processes are listed in paragraph (A-4-1).

The trend to substitute hydrometallurgical methods for the pyrometallurgical ones is already to be osserved in the primary lead metallurgy, though in limited amount until now.
Attempts might be made - within the hydrometallurgy research work - to produce high value lead oxides or compounds directly from recycled material, avoiding the reduction to metal, by using special selective reagents or by purifying lead salt solutions.
The economic advantages of such an approach are apparent.

E-4 <u>Recovery of By-products</u>

In the indirect treatment of batteries, and in cable stripping a number of non-metallics are recovered, like rubber, hard rubber, polyvinylchloride, polypropylene, etc. An utilization of these materials, as is already the case for polypropylene, might improve the economics of the recycling processes.
The already proposed simple use of rubber and hard rubber as an auxiliary fuel in electric power station might eliminate any waste disposal problem. Other more rational approaches might afford direct economical advantages.

T A B L E I

Secondary lead production in percent of total lead production

	72	73	74	75	76
Italy	67,5 (A)	79,0 (A)	73,75 (A)	63,11 (B)(o)	
France			47,78 (A)		
United Kindom		65,39 (A)	59,20 (A)		
U S A				48,60 (C)(o)	49,30 (C)(

(A) see literature (2)

(B) see literature (5)

(C) see literature (3)

(o) only refined lead

Table IA- Lead Consumption in the EEC for 1975

Percentages	France	Federal Germany	United Kingdom	Italy	Ponderal mean values (%)
Semi-finished 1. products	15.6	15.9	20.8	26.9	19.82
Sheets and strips	5.8			4.4	
Pipes	3.0		17.2	9.2	
Others	2.8		0.7	0.8	
Shot	4.0		2.9	12.5	
2. Cables	16.3	14.5	12.5	18.0	15.10
3. Batteries	41.0	41.1	22.6	29.3	33.05
Plates and Grids	20.5		12.7		
Oxides and powder	20.5		9.9		
4. Alloys	5.5	1.6	8.9	2.6	4.70
Solder	3.1		4.1	1.6	
Antifriction	0.2				
Typography	1.8			0.6	
Others	0.4		4.8	0.4	
5. Chemicals	18.5	23.3	29.1	21.0	23.41
Oxides (1)	12.0		8.4	15.3	
Anti-knock	6.5		19.9	4.2	
Others			0.8	1.5	
6. Miscellaneous	3.1	3.6	6.1	2.2	
Surface protection powders etc.		1.1			
Castings		1.7			
Others		0.8			
Total consumption (thousands metric tons)	209.6	285.6	293.1	242	

(1) Oxides for batteries excluded

See literature reference (5)

Table II -

Percent Composition of a Battery, Before Removal of Acid		Percent Composition of a Battery, after Removal of Acid
Active mass	25.2%	34.0%
Acid	25.8%	- -
Lead Metal (grids, connectors)	27.2%	36.8%
Grips	1.4%	1.8%
Separators	3.4%	4.6%
Case	17.0%	22.8%

See literature (6) (Battery with hard rubber casing)

Table III - Plants for Treatment of Battery Scrap See literature (6) (34)

Smelting Method	Dressing Method	Smelting Furnace	Company and Plant Site
Direct		Blast Furnace	Murph Metals Dallas USA Chlorine, Manchester, UK; Arbez, Compiègne, France Varta, Krautscheid, West Germany; Bergsoe, Glostru Denmark; Lands Kroma, Sweden; Britannia lead Co, Gravesham UK.
Semi-direct		Short rotary kiln (KTO)	BSB, Braubach, W. Germany; Magneti Marelli, Romano Lombardo, Italy and other plants
Indirect	Dry	Rotary hearth furnace	BBU, Arnoldstein, Austria
Indirect	Wet	KTO and blast furnace	Stolberger, Stolberg, Oker, W. Germany & Newark USA and other plants abroad
Indirect	Wet	KTO	Penarroya, Villefranche-sur-Saône, France
Indirect	Wet	KTO & reverberatory	Tonolli, Paderno Dugnano & Marcianise, Italy; San Paulo Brasil, Toronto USA; and other plant abroad

Table IV - Lead Consumption for Cable Construction in Europe and abroad (thousands of metric tons)

year	1971	1972	1973	1974	1975
Italy	29.5	32.0	44.8	50.2	43.5
France	40.8	40.0	41.1	40.2	34.1
Federal Germany	74.1	67.4	54.6	52.0	41.5
UK	51.9	48.6	45.8	44.5	36.5
Japan	29.1	27.7	28.7	21.4	16.0 (1)
USA	48.0	41.7	39.0	39.4	19.5

(1) refined lead only

See literature reference (5)

Table V - Lead Consumption for Oxide and Salts, Exclusive of Oxides for Storage Batteries in Some EEC Countries (thousands of metric tons)

year	1971	1972	1973	1974	1975
Italy	35.6	36.5	40.2	47.5	37.1
France	28.5	32.0	34.5	32.3	25.2
UK - oxides	30.5	30.5	37.1	35.5	24.5
UK - carbonate	3.2	3.0	1.7	1.2	2.5

See literature reference (5)

	Tensile Strength in kg/mm²	Elongation in %	Bending fatigue strength in kg/mm²
Commercial Lead (99.85)[3]	1.34	50	0.28[1]
Lead with 0.06% Cu	1.62	40	0.42[1]
" " 1% Sn	1.7	40	0.50[2]
" " 2% Sn	2.11	45	0.56[1]
" " 3% Sn	2.2	35	0.55[2]
" " 0.6% Sb	2.0	30	0.70[2]
" " 0.06% Cu + 0.85% Sb	2.96	10	0.85[1]
" " 0.03% Ca	1.8	40	0.60[2]
" " 0.035% Ca + 0.6% Cu	2.82	30	0.99[1]
" " 0.05% Te	2.0	45.	0.70[2]
" " 0.07% Te	1.97	45	0.63[1]
" " 0.25% Cd + 0.5% Sb	2.96	15	0.85[1]
" " 0.25% Cd + 1.5% Sn	1.97	30	0.63[1]

[1] 10^7 Alternations of load
[2] $2 \cdot 10^7$ Alternations of load. 3.000 rotations/min
[3] ASTM Tab. 3.

Table n. VI see literature (30)

Composition and Properties of cable sheathing Alloys

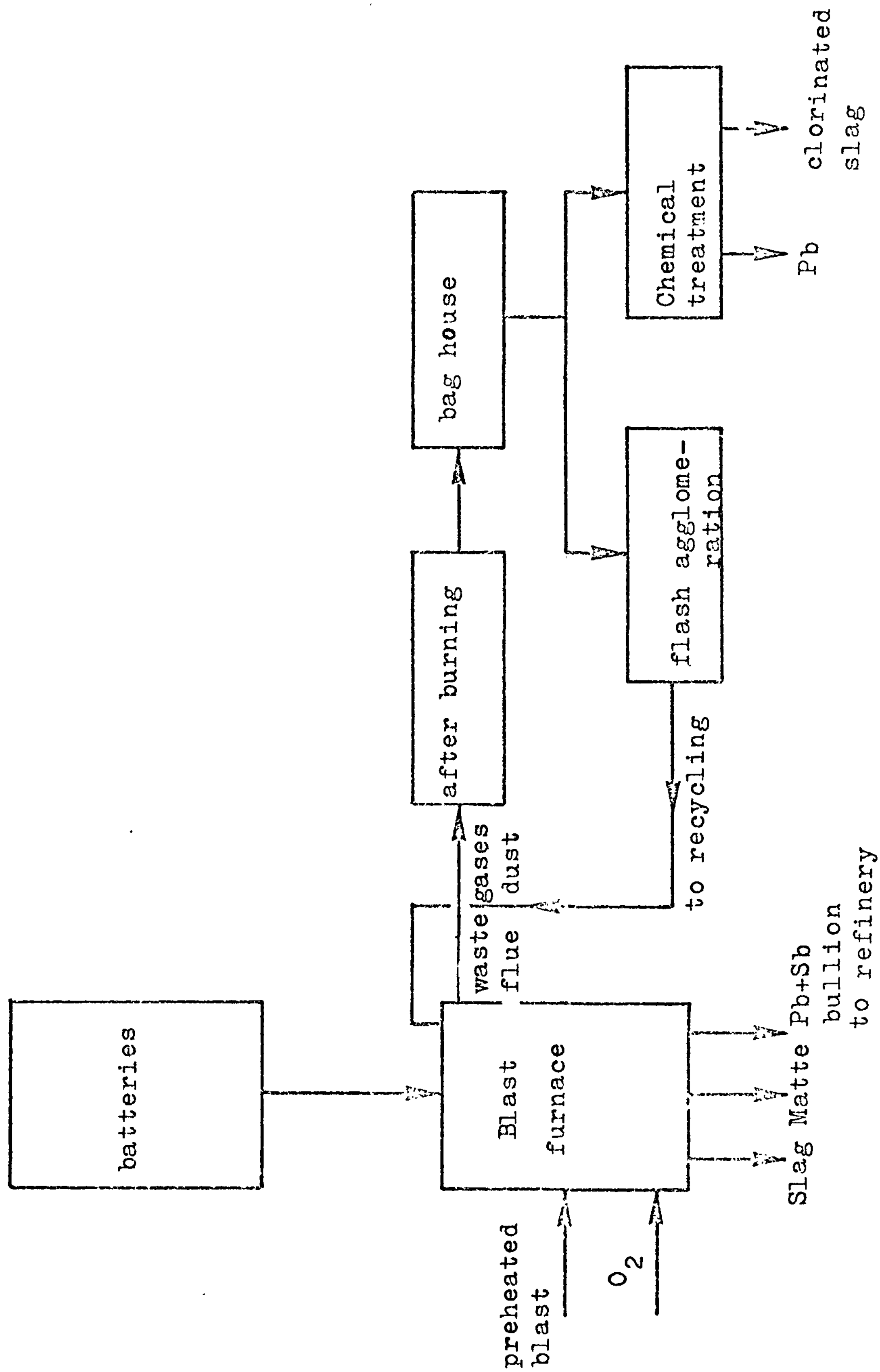


Fig. I Bergoes process See literature (14) (15)

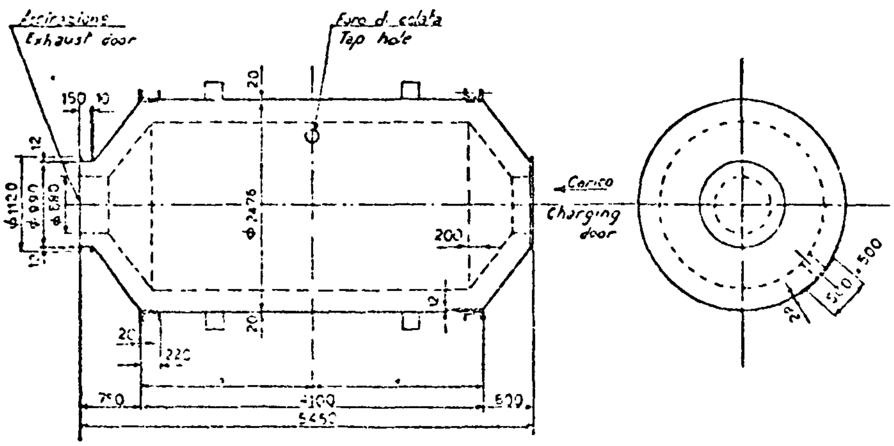


Fig. II Short Rotary Furnace See literature 7

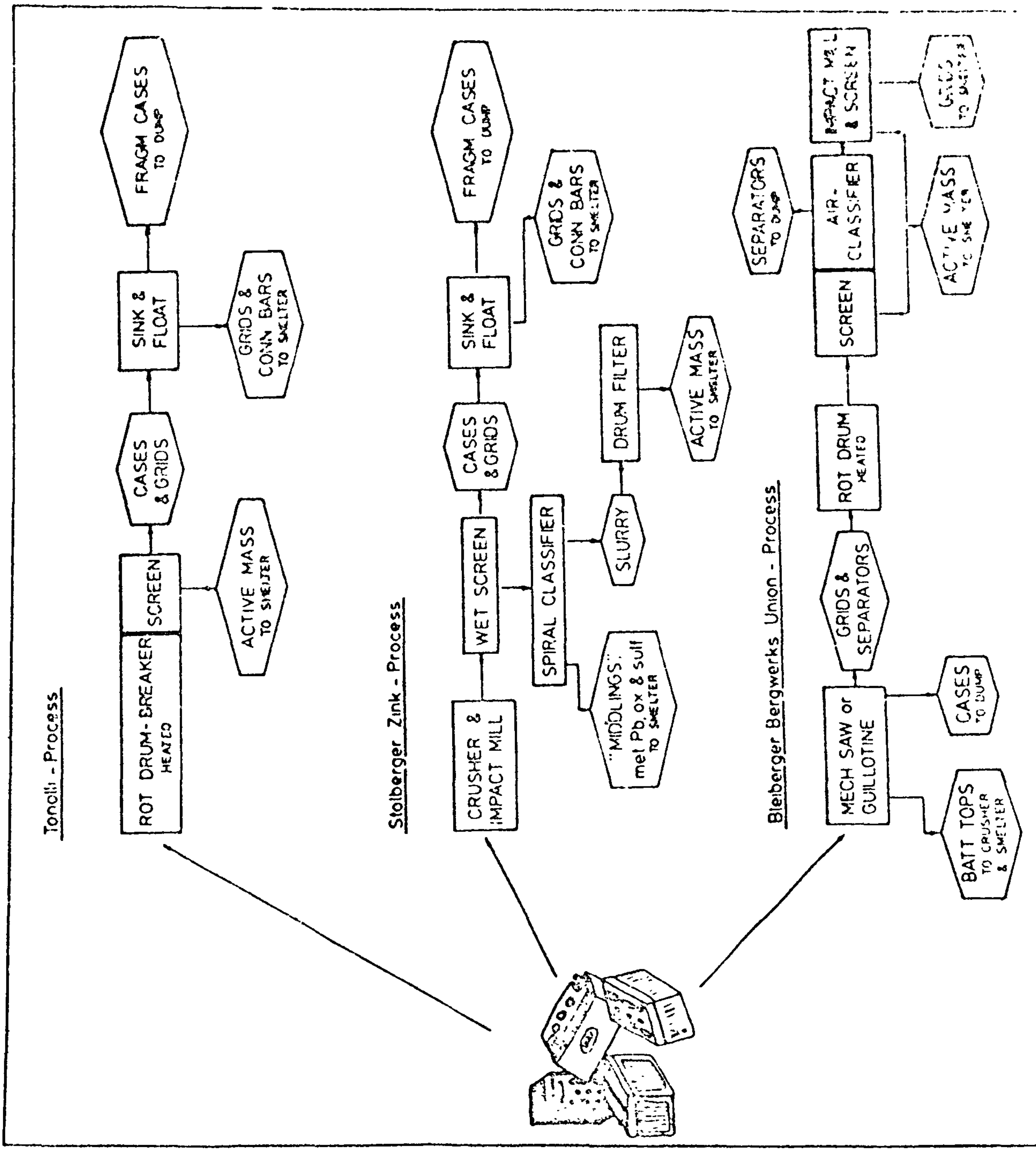


Fig. III- Flow diagrams of various indirect methods

See literature (12)

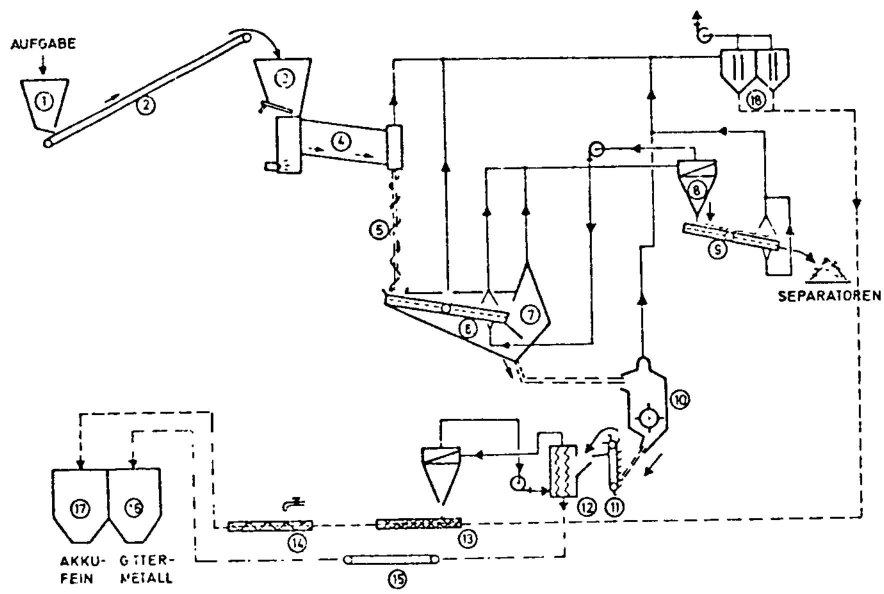


Abb 3 Schematische Darstellung des BBU-Verfahrens zur Aufbereitung von Akkuschrott [2]

1 Aufgabebunker
2 Forderband
3 Pufferbunker und Abzugsrinne
4 Trommeltrockner
5 Vibrationsrinne
6 Vibrationssieb
7 Absaugvorrichtung
8 Zyklon
9 Sieb-Schwingförderrinne
10 Prallhammerbrecher
11 Becherwerk
12 Zick-Zack-Sichter
13 Schwingrinne
14 Befeuchtungsstrecke
15 Muldenbandforderer
16 Endproduktbunker (Gittermetall)
17 Endproduktbunker (Akkufein)
18 Sackfilter

Fig. IV: schematic flowsheet of B.B.U. process for the preliminary dressing of scrapped storage batteries.
Aufgabe = feed (raw material)
akkufein = fines (paste)
gittermetall = grid metal
separatoren = separators

1 - feed bin
2 - belt conveyor
3 - surge bin and discharge chute
4 - drum drier
5 - vibrating chute
6 - vibrating sieve
7 - air draught device
8 - cyclone
9 - screen + shaking conveyor
10 - swing-sledge mill
11 - bucket conveyor
12 - zig-zag classifier
13 - shaking chute
14 - moistening screw conveyor
15 - ribbed belt conveyor
16 - final product bin (grids)
17 - final product bin (fines, paste)
18 - bag filters

See literature (6)

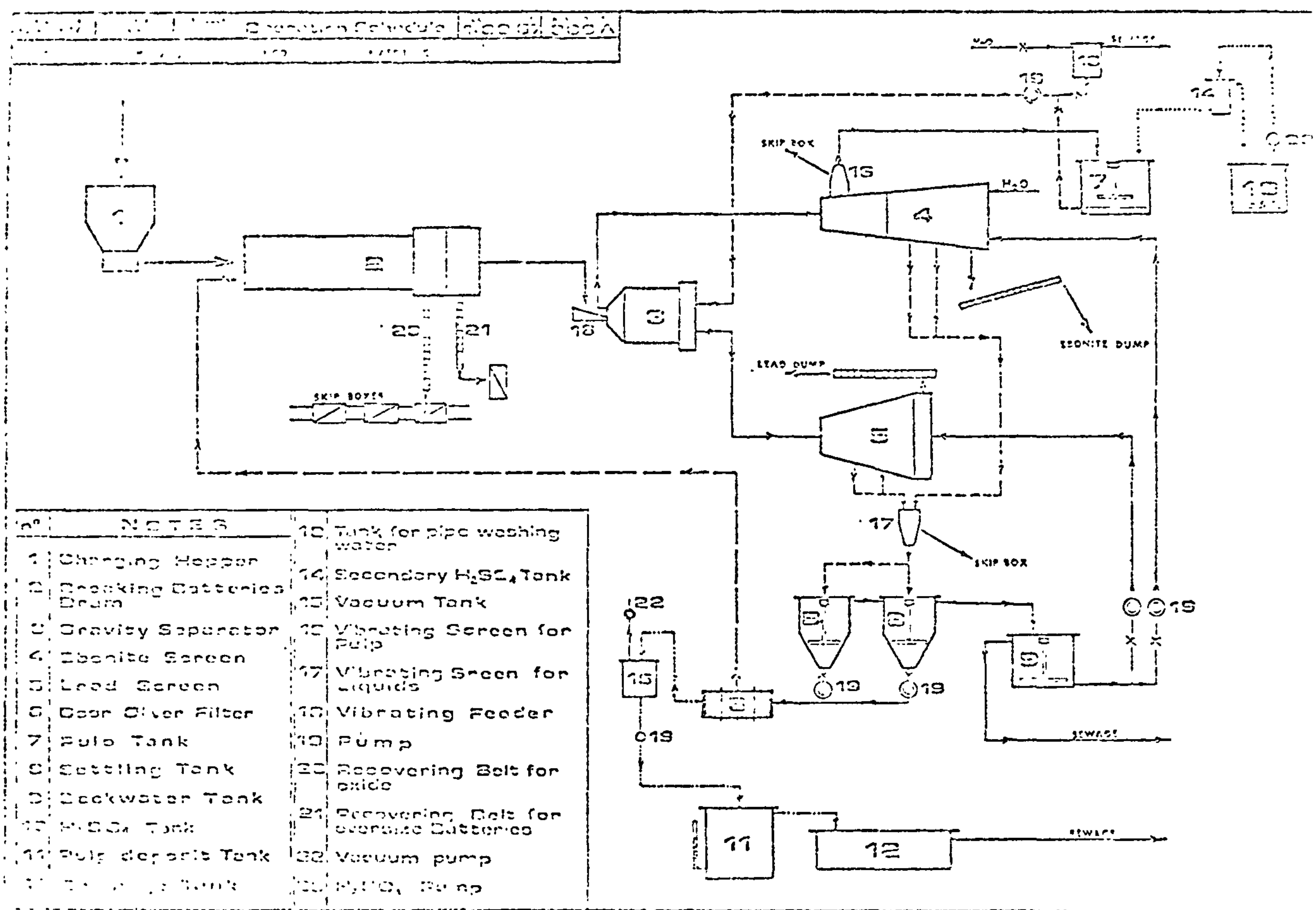


Fig. V Schematic flowsheet of Tonolli process

See literature 19

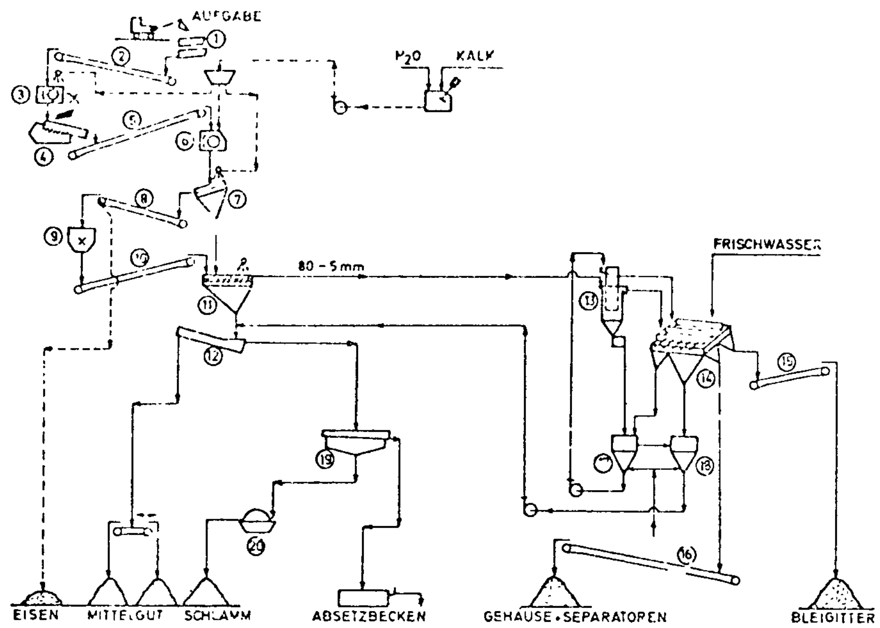


Abb 4. Vereinfachte schematische Darstellung des Stolberger Verfahrens zur Aufbereitung von Akkuschrott [3]

1 Aufgaberinne
2, 5, 8, 10, 15, 16 Muldengurtforderer
3 Einwalzenbrecher,
4 Resonanzforderer,
6 Prallmuhle,
7 Exzentrasieb,
9 Hammermuhle,
11 Resonanzsieb,
12 Spiralklassierer,
13 Hubradscheider,
14 Resonanzsieb,
17 Dicktrubespitze,
18 Dunntrubespitze,
19 Eindicker,
20 Vakuumtrommelfilter

Fig. VI: Schematic flowsheet of Stolberger process for dressing scrapped storage batteries (6)
aufgabe = feed of raw material
frischwasser = fresh water
eisen = ferrous material
mittelgur = middlings
schlamm = slimes
gehause+separatoren = casings + separators
bleigitter = lead grids

1 - feeding chute
2,5,8,10,15,16 - ribbed belt conveyors
3 - single roll crusher
4 - vibrating conveyor
6 - hammer mill
7 - excentric screen
9 - hammer mill
11 - vibrating screen
12 - spiral classifier
13 - lifting wheel classifier
14 - vibrating screen
17 - separating cyclone for high concentration pulp
18 - separating cyclone for low concentration pulp
19 - thickener
20 - vacuum drum filter

See literature (6)

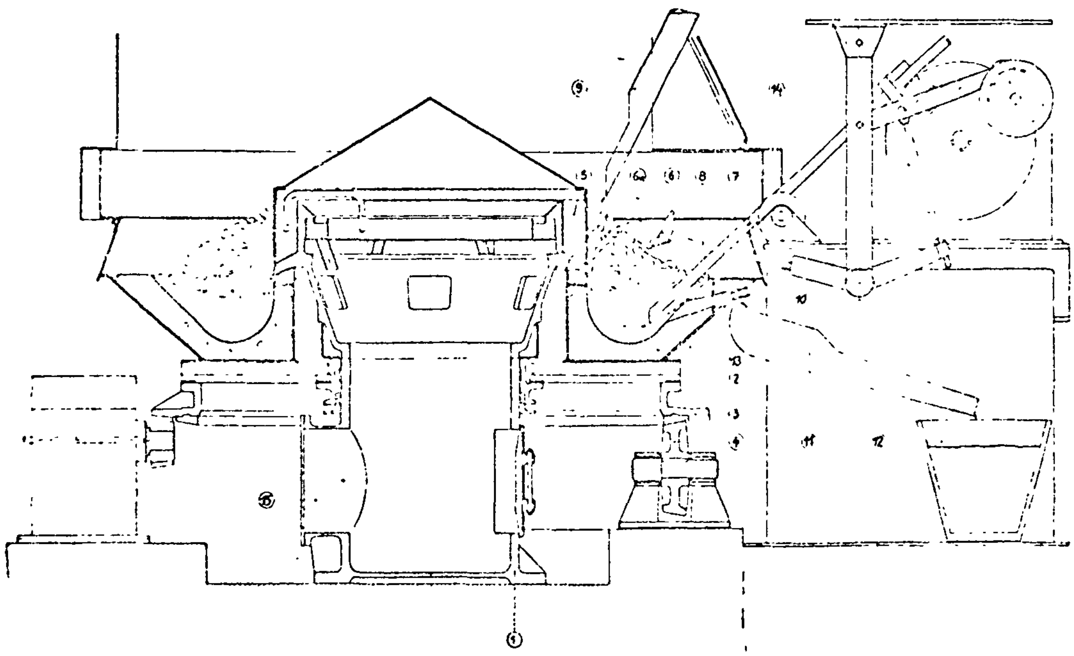


Fig. VII - Cross-section of the BBU-rotary hearth furnace
see literature (9)

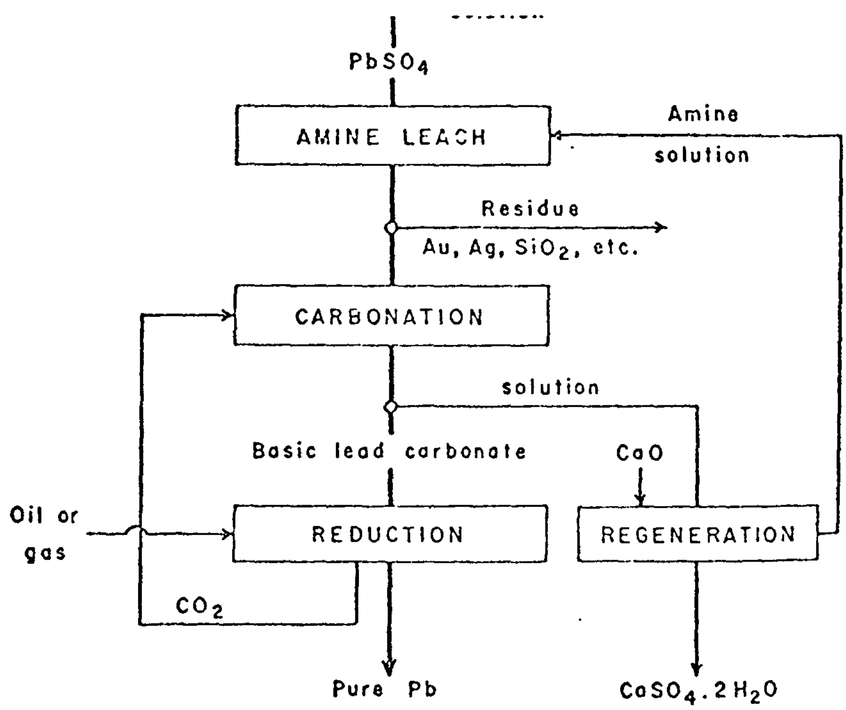


Fig. VIII- Production of lead from lead sulfate

See literature (24)

Component	Negative paste range, pct	Positive paste range, pct
Pb°	30.8-11.1	5.4- 2.1
$PbSO_4$[1]	85.2-40.1	86.5-13.7
PbO[2]	27.8- 2.2	-
PbO_2[2]	-	74.0- 6.6
Insoluble........	2.0- 1.0	3.0- 2.0
Total sulfate...	27.0-17.5	27.4- 2.0

Fig. IX - General composition of battery paste material

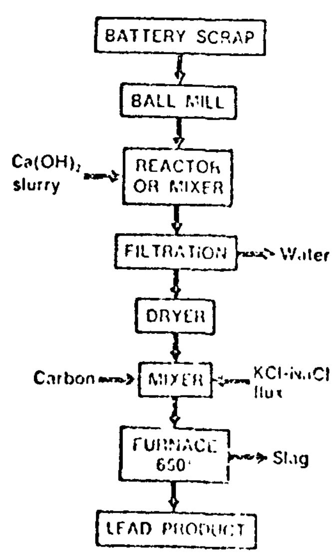


Fig. IX - (see literature 25)
Flow diagram of sulfur-dioxide-free process for recovering lead from battery scrap

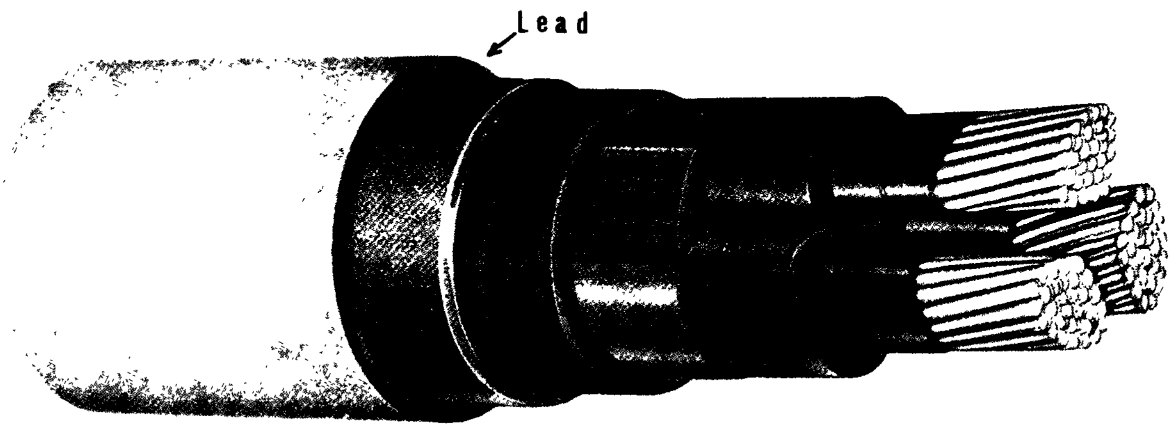


Fig. 10 – Lead sheated cable

The lead sheat is surrounded by plastic cover

The insulation consists of paper impregnated with

a mineral oil–resin composition

The conductors are made by copper plait

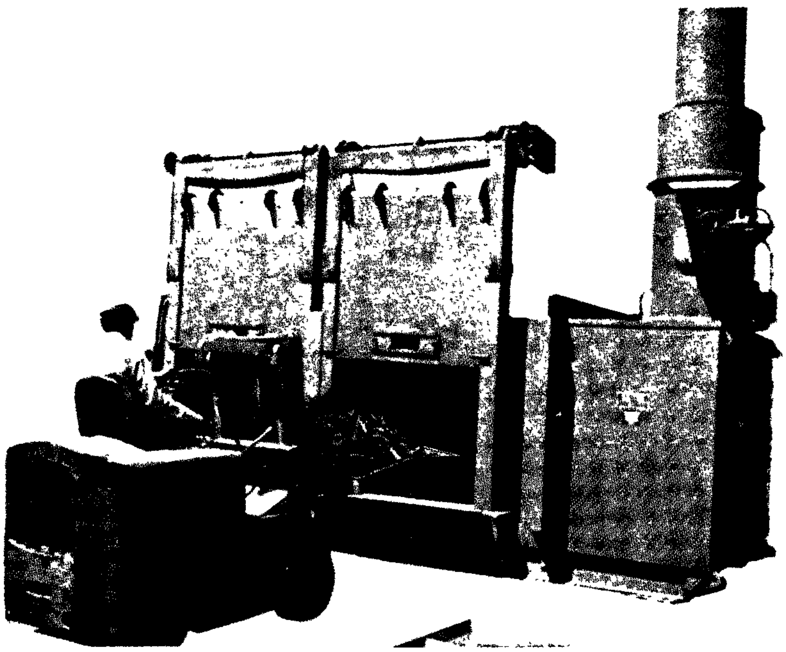


Fig. 11 - United's Wire Insulation Incinerator

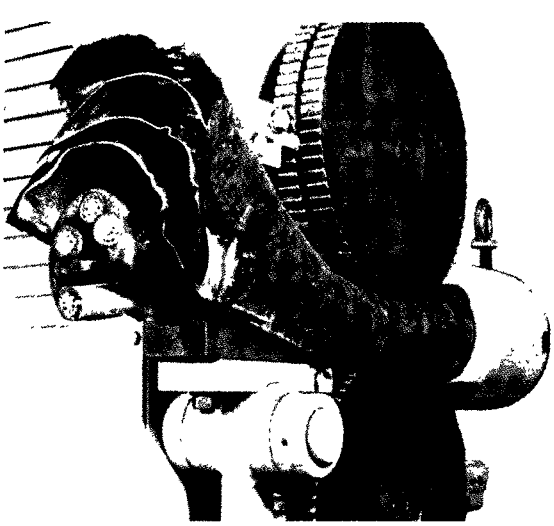


Fig. 12 - Cable stripping machines

Literature References

1) P.Martini (FIAT - Centro Ricerche): "Re-utilization of materials derived from industrial cycle" (report presented at a study meeting held by the Chamber of Commerce of Milano; 6 May 1977)

2) BIPE - Charter - ITE:"Technical-economical analysis or recovery and recycling of non-ferrous metals in EEC"

3) J.A.Wright: "Lead and zinc outlook 1976-1980" (paper presented at NARI 63rd Annual Convention, San Francisco, March 1976)

4) "Rational use of potentially scarce metals" (Report of a NATO Science Committee Study Group 1976)

5) Italminiere: "Non ferrous metals and ferroalloys - Statistics 1975" (29th edition)

6) A.Melin: "Present state of the smelting of storage battery scrap" (Metall, vol. 31, no. 2, pp.133-138, Feb. 1977)

7) P.Costa, A.Mambelli: "Production of battery grids based on the use of antimonial alloys obtained from scrapped batteries" (Fonderia Italiana, vol.19, no.11, pp.367-376; Nov. 1970)

8) H.Dlaska: "Smelting of lead ore and accumulator scrap by the BBU-round buddle process" (Erzmetall, vol. 28, no.1, pp. 6-12; Jan. 1975)

9) H.Dlaska: "Rotary hearth process for smelting lead ores and battery scrap of Bleiberger Bergwerks Union, Arnoldstein, Austria" (AIME World Symposium on mining and metallurgy of lead and zinc 1970; vol.2, pp.960-982)

10) G.Fuchs: "The melting of scrap accumulators in the lead smelting work of Binsferldhammer" (Erzmetall, vol.24, no. 11, pp. 519-523, Nov. 1971)

11) R.Fischer: "Treatment of lead battery scrap at Stolberger Zink AG" (AIME World Symposium on mining and metallurgy (pag.984-994)

12) H.Dlaska: " Treatment of scrap batteries - New problems and new approaches" (Lead 74 - Edited Proc. 5th International Conf.on Lead, Paris; pp. 53-57; disc. 103-104)

13) J.L.Harrison: "Application of oxygen to smelting and refining of lead" (Advances in Extractive Metallurgy and Refining; Symposium, London 4-6 Oct. 1971; pp.394-397)

14) "Bergsoe's SB furnace" (Metal Bulletin Mounthly, Oct. 1976; pp.59-61, 63)

15) "Scrap - Battery smelting" (Metal Bulletin Mounthly, Oct. 1976, pag. 65)

16) European Lead Development Committee (ELDC): "Preliminary Report on Meeting Held at Copenhagen on 2-3 Dec.1976"

17) P.Fracchia, :"Technical and economic remarks on modern processes of lead recovery from scrap batteries" (Lead & Zinc into the 80's; 6th International Lead Conf.London 1977)

18) Journal of Metals, vol.29, no.3; Mar.1977

19) E.Del Sorbo: "The Tonolli process for the treatment of scrap batteries" (B.C.I. Convention, May 1974)

20) German Patent, Offen. 2,600,384; 15 Jul.1976

21) Electric Power Storage Ltd.: Brit.Patent 1,368,423

22) Minerals Technology Corp.: U.S.Patent 3,689,253

23) RSR Corp.: U.S.Patent 3,883,348

24) A.Vizsolyi: "Aqueous oxidation of galena under pressure in ammonia solution" - (Unit Processes in Hydrometallurgy; Metallurgical Soc.Conf., vol.24, pag. 342)

25) D.A.Wilson: " A new sulfur-dioxide-free process for recovering lead from battery scrap" (Proc. 5th Mineral Waste Utilization Symposium, Chicage, 13-14 Apr. 1976)

26) M.V.Rose, J.A.Young: "Lead-calcium-tin-alloys - Properties and prospects" (Lead 74 - Edited Proc. 5th International Conf. on Lead, Paris; pp.37-52)

27) M.Borchers; S.C.Nijhawan, W.Scharfenberger: Development of low-antimony lead alloys for starting battery grids" (Metall, vol.28, no.9, pp.863-867; Sept.1974)

28) U.Heubner, A.Ueberschaer: "Castability of lead-antimony alloys for battery grids with particular reference to nucleation techniques" (Lead 74 - Edited Proc. 5th International Conf. on Lead, Paris; pp. 59-66)

29) U.Heubner,: "Low-antimony lead alloys for maintenance--free batteries" (Metall, vol.31, no.9, pp.962-968, Sept.1977)

30) W.Hofmann: "Lead and Lead Alloys" (Springer Verlag, Berlin, 1970)

31) "Britannia opens No. 2" (Metal Bulletin, no.6237, pag.22, Oct. 28, 1977)

32) N.R.Braton: "Cryogenic recycling" (Proc. 4th Mineral Waste Utilization Symposium, Chicago 7-8 May 1974)

33) Eisen-und Metall AG: German Patent 1,758,911; 3 Sept.1968

34) Warren Springs Laboratory (Dept.Industry U.K.): "Non-ferrous metal losses in the U.K." (Extract from WXL Report "The role of R & D in the promotion of industrial recovery) (pp. 29 & 36)

35) G.Kossek, H.Serbent: "Large scale test for the processing of by-products of metallurgical plants in the Waelz kiln of Berzelius Metallhütten GmbH" (paper; Colloquium at Berzelius Metallhütten GmbH, Duisburg, Oct.22, 1974)

36) University of Padova: "Environment and Resources" (1st Meeting on Chemical and Technological Problems of Pollution, Bressanone, 3-8 Sept.1973)

37) Italian Ministry of Industry and Commerce: "Recycling of materials from urban wastes and detecting the use of non return products" (Preliminary Report of the Study Group for Rational Utilization of Energy - Industry Branch - Subgroup B; 28 Dec.1974)

Appendix A

EUROPEAN CLASSIFICATION FOR NON-FERROUS METAL SCRAP (EURO)

(Prepared in collaboration with the consumers of non-ferrous Scrap metal in Europe and various national and international Associations included in which are the Organisation of European Aluminium-Smelters (OEA), the International Wrought Copper Council and the Fédération Internationale des Associations de Négociants en Acier, Tubes et Métaux [FIANATM].)

Definitions

Furnace Chargeable:	Material of maximum dimensions 100 × 50 × 40 cm, weights of more than 200 kg only according to special agreement.
Crucible Chargeable:	Material of maximum dimensions 35 × 25 × 15 cm, weight max. 50 kg.
Small Pieces:	Material less than 10 × 10 × 0,2 mm.
„Fines“:	Material through 20 mesh sieve (0,84 mm aperture).
Foreign Substances:	Material, whether metallic or nonmetallic, which does not fall within the specification.
Coated Material:	Material with any kind of coating including paint, varnish, print, plastics, anodic oxide and other metals however applied, including Cr, Ni, Sn, Pb, Al etc. Includes also material with adhering metal: e. g. solder.
Plastics:	Unless otherwise agreed the scrap has to be generally free of plastics.
Compacted Material:	Unless otherwise agreed the scrap shall not be delivered in hydraulically compressed bales or briquettes.

IV. LEAD

EURO IV/1 "panel" — **Soft Lead**

Clean soft lead scrap only in the form of sheet, tubes and cable strippings.

Free from radio-active material, and other foreign matter. The presence of runnings and remelted soft lead must be specified.

EURO IV/2 "party" — **Old Lead**

Old soft lead scrap of various types. Minimum lead content 96 %.

Free from radio-active material, Hard Lead, Lead covered cable, capsules, lead foil and foreign matter. The inclusion of runnings and remelted soft lead must be specified.

EURO IV/3 "pedal" — **Old Lead Alloy**

Clean old hard Lead Scrap.

Free from radio-active material, alloys of Zinc and battery plates.

EURO IV/4 "pewit" — **Battery Plates**

Clean broken battery plates complete with lugs and bridges. It is to be specified whether the lot is with or without separators.

Free from accumulator lead, free from mining lamps, bells and motors, Lead Residues, as well as other foreign matter.

Tolerance — Maximum 5 % moisture, any excess moisture to be deducted.

EURO IV/5 "pilot" — **Storage Plates**

Storage Plates.

Tolerance — Moisture content to be stipulated.

EURO IV/6 "poker" — **Complete Drained Batteries.**

Complete, old drained Batteries of Bakelite, but without stoppers.

Free from batteries from mining Lamps, bells and aircraft motors.

Tolerance — Maximum 5 % moisture, any excess moisture to be deducted.

Other lots such as typemetal, printers' plates, capsules, various residues and oxides to be the subject of special agreement.

Appendix B

Standard Classification for Non-Ferrous Scrap Metals
CIRCULAR NF-66
(National Association of Secondary Material Industries, Inc.)

Apple 1 — Delivery

a. Delivery of more or less on the specified quantity up to 1¼ per cent is permissible.

b. If the term "about" is used, it is understood that 5 per cent more or less of the quantity may be delivered.

c. Should the seller fail to make deliveries as specified in the contract the purchaser has the option of cancelling all of the uncompleted deliveries or holding the seller for whatever damages the purchaser may sustain through failure to deliver and if unable to agree on the amount of damages, an Arbitration Committee of the National Association of Secondary Material Industries, Inc. may be appointed for this purpose, to determine the amount of such damages.

d. In the event that buyer should claim the goods, delivered on a contract, are not up to the proper standard, and the seller claims that they are a proper delivery, the dispute may be referred to an Arbitration Committee of the National Association of Secondary Material Industries, Inc. to be appointed for that purpose.

e. A carload, unless otherwise designated, shall consist of the weight governing the minimum carload weight at the lowest carload rate of freight in the territory in which the seller is located. If destination of material requires a greater carload minimum weight, buyer must so specify.

f. A ton shall be understood to be 2,000 pounds unless otherwise specified. On material purchased for export shipment a ton shall be specified as either a Gross Ton of 2240 lbs., or a Metric Ton of 2204,6 lbs.

g. If, through embargo, a delivery cannot be made at the time specified, the contract shall remain valid, and shall be completed immediately on the lifting of the embargo, and terms of said contract shall not be changed. When shipments for export for which space has been engaged have been delivered or tendered to a steamship for forwarding a .d through inadequacy of cargo space the steamship cannot accept the shipment, or where steamer is delayed in sailing beyond its scheduled time, shipment on the next steamer from the port of shipment shall be deemed a compliance with the contract as to time of shipment.

h. In case of a difference in weight and the seller is not willing to accept buyer's weights, a sworn public weigher shall be employed and the party most in error must pay the costs of handling and reweighing.

i. When material is such that it can be sorted by hand, consignees cannot reject the entire shipment if the percentage of rejection does not exceed 10 per cent. The disposition of the rejected material should then be arranged by negotiations; no replacement of the rejected material to be made.

Upon request of the shipper, rejections shall be returnable to the seller on domestic shipments within 10 days and on foreign shipments within 30 days from the time notice of rejection is received by them and provided government regulations permit such return. Seller to pay $ 0.01 per lb. on material rejected to cover cost of sorting and packing and seller to be responsible for freight both ways.

j. Packages

Shall be good strong packages suitable for shipment and each package shall be plainly marked with separate shipping marks and numbers and with the gross and tare weights so that the packages may reach their destination and their weights can be easily checked.

Racks 40 — **Scrap Lead — Soft**
Shall consist of clean soft scrap lead, free of all foreign materials such as drosses, battery lead, lead covered cable, hard lead, collapsible tubes, foil, type metals, zinc, iron and brass fittings, dirty chemical lead. Free of radioactive materials.

Radio 41 — **Mixed Hard/Soft Scrap Lead**
Shall consist of clean lead solids, free of foreign materials, such as drosses, battery lead, lead covered cable, collapsible tubes, type metals, zinc, iron and brass fittings, dirty chemical lead. Free of radioactive materials.

Rails 42 — **Battery Plates**
If cells (plates, separators, and lugs) or battery plates, must be reasonably free of rubber. May be bought and sold by assay or as agreed between buyer and seller.

Rains 43 — **Drained Whole Batteries**
Batteries to be free of liquid and extraneous material content. Aircraft (aluminum or steel cased) and other special batteries subject to special agreement.

Rakes 44 — **Battery Lugs**
Shall be free from battery plates, rubber and foreign material. A minimum of 97 % metallic content is required.

Relay 48 — **Lead Covered Copper Cable**
Free of armored covered cable, and foreign material.

Rents 49 — **Lead Dross**
Should be clean and reasonably free of foreign matter, iron, dirt, harmful chemicals or other metals. Free or radioactive materials. Assay basis, or as agreed between buyer and seller. Other metals present such as antimony, tin, etc. to be accounted for as agreed between buyer and seller.

Ropes 50 — **Lead Weights**
May consist of lead balances with or without iron, as may be specified. Free of foreign materials.