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METHODS OF MELTING NON-FERROUS METAL SCRAP AND POSSIBILITIES OF THEIR APPLICATION IN DEVELOPING COUNTRIES 1/

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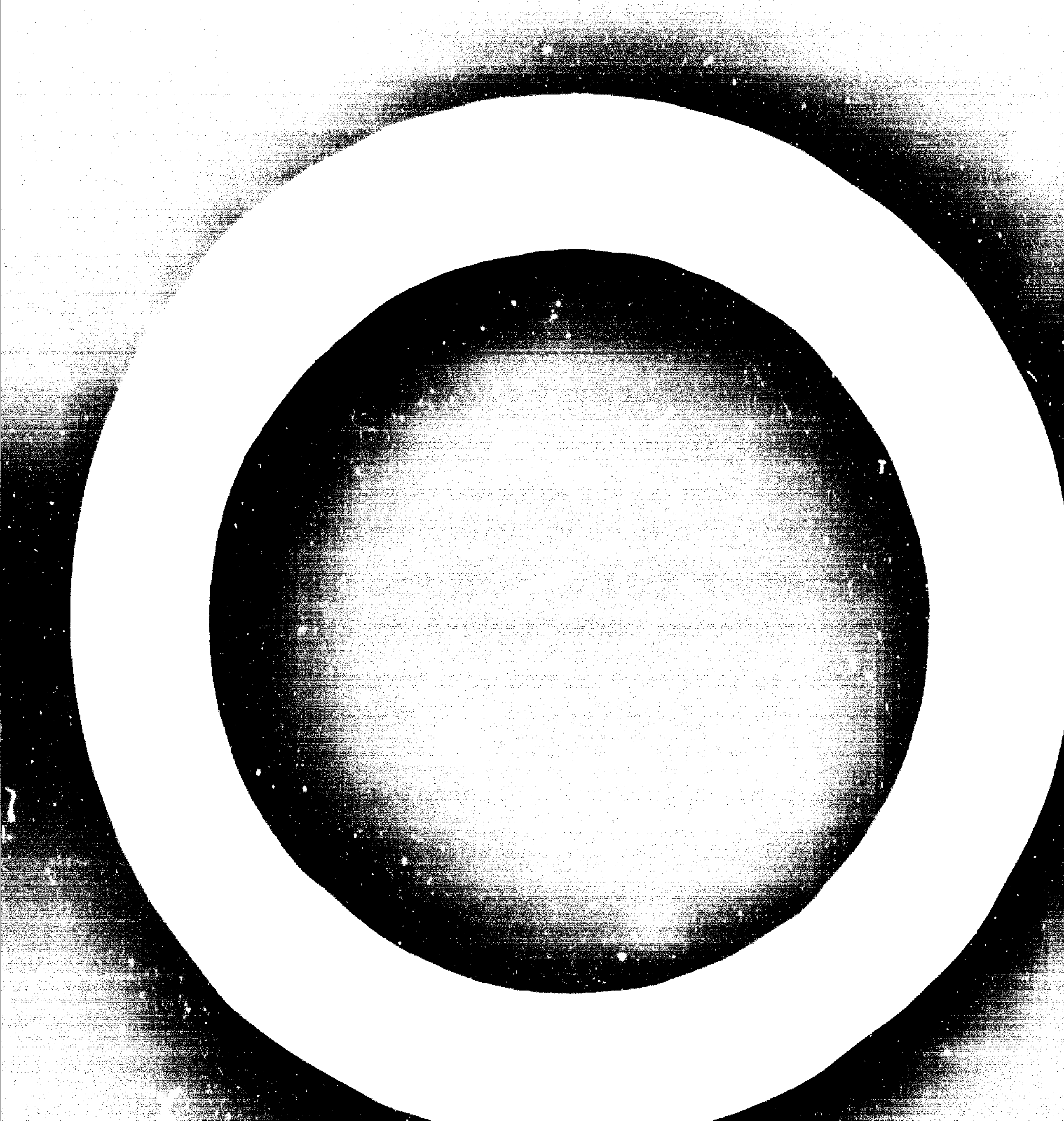

INTRODUCTION

The fact that many countries of Asia, Africa and Latin America have embarked on the road to independent development created the necessary conditions for rapid growth of industry in these countries. Particularly fast was the growth of production of non-ferrous metals.

Increment of Production of Non-ferrous metals in developing countries

(in per cent)

Metal	Average annual increment of production for 1956-1967		Share of developing countries in world production	
	world	developing countries	1955	1967
Aluminium	7.5	x)	0.3	4.6
Refined copper	2.75	6.0	22.7	32.8
Lead	1.5	1.1	23.3	22.4
Zinc	2.7	5.0	6.7	8.8
Tin	0.2	3.7	45.5	68.8

x) For 12 years production of aluminium in developing countries has increased more than 30 times.

The above data reveal that average rates of increment of non-ferrous metal production in developing countries considerably exceed the increment in the world production of these metals.

The rapid growth of national economy in the developing countries was accompanied by continuous growth of non-ferrous metal consumption in these countries.

Thus, the domestic consumption of non-ferrous metals in developing countries for 1956-1967 has increased in the following way:

aluminium	- 7.3 times
copper	- almost 2 times
lead	- 2.6 times
zinc	- 2.9 times

Assuming the average annual rates of increment of non-ferrous metals consumption in developing countries at the level of 1956-1967, the absolute consumption of non-ferrous metals by these countries by 1975-1980 shall increase up to the following values:

Prospective growth of non-ferrous metal consumption in developing countries

Metals	Actual consumption in 1967, thou tons	Average annual increment of consumption for 1956-1967, %	Prospective consumption, thou tons	
			1975	1980
Aluminium	314	18.0	1180	2700
Copper	180	5.7	280	365
Lead	243	8.3	460	680
Zinc	307	9.4	630	980

It should be noted, that actual consumption of non-ferrous metals by developing countries is somewhat higher, since the above mentioned data do not cover non-ferrous metals included in imported equipment (automobile pistons, radiators, bearings, cable products, etc).

According to the world practice, the ratio of scrap formation and consumption of non-ferrous metals (including those contained in alloys) is as follows, in per cent:

aluminium	- from 18 to 35
copper	- from 30 to 50
lead	- from 20 to 50
zinc	- from 20 to 35

If the above ratios, even approaching the lower limits, are assumed for developing countries, the approximate raw material resources of secondary non-ferrous metals in 1975-1980 shall be as follows:

Approximate resources of non-ferrous metal scrap in developing countries in 1975-1980

Metal x)	Scrap formation in % of consumption	Approximate resources of scrap in thou tons	
		1975	1980
Aluminium	20	240	540
Copper	30	84	110
Lead	30	140	200
Zinc	20	126	195

x) Including those contained in alloys

The above data are indicative of continuous growth in scrap sources in developing countries and of creation therein of sufficient raw material base for establishment of their own secondary non-ferrous metallurgy.

However consumption of non-ferrous metals and consequently amounts of scrap, are so different in different countries, that the problem of establishment of their own secondary non-ferrous metallurgy should be solved seperately for each particular country both from the point of view of capacity of the enterprises and from the point of view of time of construction of the proposed plants.

Before turning to the major subject of this Report, it is worth to dwell on the high economic efficiency of secondary non-ferrous metallurgy.

As a result of relatively low material, power,transport and labour expenditures, the cost price per 1 ton of secondary non-ferrous metals (not accounting for the cost of primary and secondary raw materials, since the prices for the raw materials are subjected to significant fluctuations according to the market condition) makes up only 15-25% of the cost of similar primary non-ferrous metals.

Specific capital investments required for construction of enterprises of secondary non-ferrous metallurgy are nearly 10 times less than those required for construction of enterprises of primary non-ferrous metallurgy.

That is why in order to meet ever growing requirements of developing countries in non-ferrous metals, creation of secondary non-ferrous metallurgy in these countries is no less important problem than development of production of primary non-ferrous metals.

Basic Principles of Processing of Non-Ferrous metal scrap

1. High quality of secondary non-ferrous metals, minimum losses of metal at melting, capacity of melting units and other technical and economic data depend mainly on quality of preliminary preparation of the charge.

Unsatisfactory preparation of scrap, its mixing and contamination inevitably involves the deterioration of technical and economic data at processing of these most valuable secondary raw materials.

Thus, for example, while melting non-ferrous metal clips which have not been preliminary degreased, the oxidation loss of metal increases by 2-3%, and alloys after melting will contain high content of gases and iron admistures.

Sometimes, due to mixing of chips of various alloys, efficient processing of these becomes impossible. For example, it is practically impossible to separate the mixed chips of tin and aluminium bronzes and such chips can be processed only to blister copper with considerable losses of such valuable components as tin, aluminium, lead, zinc, the cost of which often exceeds that of copper obtained.

Therefore, at designing enterprises of the secondary non-ferrous metallurgy in developing countries, particular attention should be paid to the stock yards and raw materials storages, the areas of which should allow for separate storing of various metal and alloy, scrap.

2. The main principle predetermining the most effective utilization of non-ferrous metal scrap is to ensure the most complete and complex extraction of all valuable components contained in scrap. This can be achieved only provided the scrap is processed into metals and alloys similar or close in composition to initial materials. For example, scrap of tin bronze should be processed into tin bronze, scrap of aluminium bronze - into aluminium bronze, scrap of accumulator lead - into antimonial lead, etc.

METHODS OF MELTING SCRAP AND WASTES OF NON-FERROUS METALS

1. Melting of aluminium scrap and wastes

When remelting aluminium scrap the following specific features of aluminium should be taken into account: high affinity to oxygen; quick formation of solid oxide skin which prevents metal from further oxidizing; high heat capacity and latent heat of fusion; reactions of aluminium with carbon and nitrogen at high temperatures accompanied by formation of carbides and nitrides deteriorating mechanical properties of aluminium alloys; impossibility of reduction of aluminium oxide by means of carbon monoxide.

Due to high affinity of aluminium to oxygen, the reduction smelting as well as oxidizing refining of its alloys in secondary aluminium metallurgy are impracticable.

At present a great number of aluminium alloys of various compositions is being produced (in the USSR, for example, over 100). Therefore sorting of aluminium scrap must be performed with a special care. Scrap should be sorted according to alloys to be produced at this particular plant

Calculation of the charge in the secondary non-ferrous metallurgy is a very important and complicated operation. Therefore calculation of the charge at large plants in the USSR and some other countries is performed by means of quantometers and electronic computers.

Within several minutes this complex can give an answer as to the most advisable utilization of the scrap components in melting of high-quality and expensive grades of alloys and with minimum consumption of alloying metals.

The following three groups of aluminium alloys are usually produced from aluminium scrap:

wrought alloys (for treatment under pressure), containing copper, manganese, magnesium and zinc as the main alloying component;

casting alloys - (for shaped casting), containing mainly silicon, copper, magnesium, manganese, zinc, nickel and some other alloying additions;

Deoxidizers - (for deoxidizing of steels and smelting ferroalloys) which allow for the highest content of admixtures of iron, magnesium, silicon and manganese.

When determining particular grades of alloys, special attention should be paid to the national economy requirements of developing countries, as well as to availability in these countries of such industries as machine industry, automobile industry, steel making, etc which are the major consumers of aluminium alloys.

The charge for production of secondary aluminium alloys usually consists of sorted scrap and alloying metals: copper, silicon, magnesium, manganese, zinc, nickel, etc, as well as primary aluminium or pure aluminium scrap to diminish the impurities content of the alloys.

To protect aluminium against oxidation, melting of aluminium scrap should be carried out as a rule under fluxes, consisting of a mixture of various salts. The most usable salts for fluxes preparation are the following:

Salt	Formula	Specific weight		Melting point °C
		hard	melted	
Calcium chloride	$CaCl_2$	2.15	2.06	744
Magnesium chloride	$MgCl_2$	2.18	2.08	715
Manganous chloride	$MnCl_2$	2.98	-	650
Potassium chloride	KCl	1.99	1.53	772
Sodium chloride	$NaCl$	2.17	1.55	805
Zinc chloride	$ZnCl_2$	2.91	-	365
Sodium fluoride	NaF	2.77	1.95	980
Cryolite	Na_3AlF_6	2.95	2.09	995
Carnallite	$MgCl_2KCl$	-	1.5	487

Fluxes of the following composition are widely used in the secondary aluminium metallurgy of the Soviet Union (in per cent):

	Covering flux	Refining flux
Sodium chloride	50	53
Potassium chloride	50	37
Cryolite	-	10

The selection of fluxes for developing countries should be based on availability of natural salts and on their cost in these countries.

For secondary aluminium melting, usage is made of various melting furnaces which can be divided into several groups according to the type of power used (flame and electric furnaces), type of working space (crucible ,bath furnaces), method of metal tapping (stationary, rotary furnaces).

1. Flame Reverberatory Furnaces

Reverberatory furnaces are most widely used for melting non-ferrous metals and, in particular, secondary aluminium. These furnaces are highly efficient, simple in design and in maintenance and do not need often repairs.

The main disadvantage of reverberatory furnaces is a contact of furnace gases with the surface of molten aluminium therein which causes oxidizing of aluminium and its saturation with gases.

Reverberatory furnaces of various capacities are used (according to the bath size) and vary from 7 to 50 tones.

There are furnaces of up to 80-ton capacity in the USA. Output of the furnace depends upon the hearth area.

In recent years in the USA and countries of Western Europe there have been constructed several round reverberatory furnaces with removable roofs of up to 40-ton capacity.

Rapid charging , easy cleaning of the furnace from the skull and high output, are the operating advantages of the furnaces.

Reverberatory furnaces can be fired with solid, liquid and gaseous fuel. The most effective fuel, however, when melting secondary aluminium in reverberatory furnaces, is natural or producer gas.

With a view to increase the furnace output, reduce metal losses and decrease fuel consumption, in some countries and in the USSR researches are being carried out on using of oxygen blast for melting of secondary aluminium. However, the use of oxygen for this purpose can be recommended for the large scale production only.

Up-to-date reverberatory furnaces are equipped with the instruments ensuring automatic control of temperature and pressure in the working chamber of the furnace and of the gas and air ratio, as well as with instrumentation for measuring and recording temperature and pressure at the various sections of the furnace and flues, temperature of the flue gases, CO content in these gases, gas and air consumption , etc.

The most labour-consuming and difficult operation in the process of melting is charging the furnace.

Therefore this operation should be mechanized to the maximum extent. With a small volume of production, the use of the following devices might be sufficient: inclined table, charging shovel moving on a monorail, chutes with pushers, etc.

For charging the furnaces of over 7-ton capacity it is advisable to use the mould charging machines allowing for mechanization, of not only the charging process, but such labour-consuming processes as mixing of metal, slagging off, mixing in of chips into the bath, clearing of furnace from the iron , slag, etc.

Method of metal pouring into ingot moulds should be selected according to the scale of production. With a small scale of production, molten aluminium can be poured into the ingot moulds installed on the car running along the narrow gauge railway.

At the large scale of production, use is made of belt--type casting machines, 6-8 m long. Casting of metal into the ingot moulds by means of these machines can be done either directly from the furnace tap hole or by means of a ladle.

Stamping of pigs on belt casting machines is performed automatically, and at the end of the machine the pigs are piled also automatically by means of special equipment.

Reverberatory furnaces are designed for melting all types of aluminium scrap and do not require very through preliminary separation of ferrous metal parts from the scrap, since they designed so as to allow for elimination of ferrous metals from the furnaces directly in the process of melting.

In the Soviet Union the two-chamber reverberatory furnaces of 15-30 ton capacity find extensive application . The first chamber is designed for melting of aluminium scrap, the second chamber serves as a receiver. On completion of melting liquid aluminium is poured over into the second chamber, wherein simple of metal is taken for express analysis, alloy is corrected and the metal is cast into ingot moulds.

The two-chamber furnace has the following advantages over the one-chamber one:

1. Cutting down the time for which aluminium remains in contact with ferrous metal parts, results in reducing the iron content in the melt.

2. The furnace output increases by 20-25%, the number of personnel being the same.

3. Casting the metal into ingot moulds directly from the second chamber (receiver) reduces losses of metal, eliminates any necessity in using teeming ladles and heating devices and reduces the amount of work to be performed by overhead cranes.

At present , electromagnetic mixing of liquid metal in the reverberatory furnace is being used at one of the secondary aluminium plant in the USSR.

The basic technical and economic data at secondary aluminium melting in two-chamber reverberatory furnaces are as follows:

Metal yield	90-93%
Furnace output	3.5-4 ton/m^2 of furnace hearth per day
Conventional fuel consumption	150-200 kg/ton
Consumption of fluxes	up to 300 kg/ton

2. Furnaces with inclined hearth

One of the most labour-consuming operations on preparation of aluminium scrap for melting is the separation of ferrous metal parts. Due to this, the furnaces with inclined hearth have been applied in some of the countries. The operating principle of these furnaces is based on the difference in temperature of aluminium fusion (660°C) and that of iron (1580°C). Scrap with iron parts is being charged into the melting chamber of the furnace. During fusion of the scrap, aluminium runs off the inclined hearth into the metal receiver, while lumps of iron are being retained on ceramic grate. After fusion of aluminium, iron is removed and a new batch of scrap is being charged into the furnace. Shaft-type fusion furnaces are sometimes used to facilitate scrap charging.

The general disadvantages of the furnaces with inclined hearth are high losses of aluminium (up to 20%), low efficiency and high specific fuel consumption.

3. Furneces with external bath

In the USA extensive use for aluminium scrap melting (chips in particular) has been made of furnaces with open external bath, or as they are called otherwise open bath furnaces. The design of this furnace is similar to that of ordinary reverberatory furnace with an external chamber attached to it. Both chambers (closed and open) are interconnected by means of two channels with drop gates. Only first (closed) chamber is fired.

The massive scrap charge is fed into the closed chamber wherein it is being fused under covering fluxes. After molten aluminium has partially filled both chambers, the further charging of chips is performed into the open chamber only.

The open chamber is not being fired and the charge is being melted therein at the expense of forced circulation of liquid metal between both chambers.

The main advantage of the furnace with external bath is low oxidation loss of metal, since in the closed chamber the metal is all the time under flux and the metal level is not disturbed, and in the open chamber the metal does not contact the furnace gases. While melting chips in such furnaces, aluminium loss is 4-5%, that at scrap melting being about 2%. The disadvantage of these furnaces is comparatively high heat loss in the open chamber.

4. Rotary drum-type furnaces

The rotary drum-type furnaces have been used extensively in the countries of Western Europe for melting of non-ferrous metal scrap. This furnace comprises a steel drum with refractory lining, rising by its two rims on four rollers. On rotating the furnace executes complete revolution. The charging door and the tap-hole, are located on one side wall of the furnace the burner (in the center) and water cooled flue - on the other side wall.

From the point of view of heat-engineering the rotary drum furnace has big advantages over the stationary furnace, since the heat is transferred to metal not only at the expense of flame radiation but directly from the heated wall as well.

As a result of furnace rotation, metal is being mixed all the time, which also contributes to the heat transfer. Thus, the thermal efficiency of the rotary furnace is considerably higher than that of the stationary one. The furnace can be fired with liquid and gaseous fuel and coal dust.

From the technological point of view the rotary furnace has some merits as well. The furnace is heated-up very rapidly and while on hot idle period fuel consumption is low; the charge fed into the furnace is immediately covered by liquid metal and flux owing to which metal loss is insignificant. In a rotary furnace one can melt various kinds of aluminium scrap, including chips, clippings and skimmings and drosses.

Sampling of melting products can be done in any zone of the bath with no interruption of the process. The furnace allows for gas bubbling through the metal bath.

When melting aluminium chips metal recovery may be as great as 96%.

Recently, short-drum furnaces witha diameter nearly equal to the length of the furnace have found wide application. The design of these furnaces allows for heating of metal within a very short period of time.

A short-drum furnace was constructed according to Kolmeier's design (Berlin). The gas duct and burners in this furnace are located on one end wall with the result that the flame traces out a horseshoe trajectory in working chamber, which considerably increases the thermal efficiency of the furnace. The charging door and tap hole are located on the opposite end wall.

Designs of burners, flues, charging and transporting devices, metal and slag ladles, air preheaters, waste-heat boilers and dust catching arrangements depend upon local conditions, raw materials characteristics and type of fuel.

According to the nature and lump-siwe of the charge, the charging takes from 1 to 5 minutes per 1 ton of charge. Melting of the charge takes 1-2 hours (provided melting conditions are not too difficult). Sligging off and metal tapping require not more than 10-20 minutes.

The furnace output depends upon the character of the charge, type of fuel and furnace sizes. Usually, the length and diameter of the furnace are equal and vary within a range of 2.5 to 4 m, the efficient volume varrying within 1 to 5 m^3 respectively.

The furnace is universal and may be used for melting aluminium, copper, lead and tin scrap.

One of the British plants employs rotary furnaces fired with fuel oil, having 3 m diameter and about 5 m length. Capacity of the furnace is 10 ton, actual charging - 6 to 7 tons. Sodium chloride with addition of fluorspar or cryolite is used as flux. Flux consumption makes up from 150 to 300 kg per ton of metal. Metal recovery is about 95% when melting chips and about 90% when melting foil. Aluminium content of waste slag is from 3 to 5%.

Steel parts should be very thoroughly separated from the scrap before melting since their removal from the furnace in the process of melting in practically impossible. This comprises the main disadvantage of the drum-type furnace.

5. Induction crucible furnaces

Induction crucible furnaces of 1 to 10-ton capacity are finding ever increasing use for melting of aluminium chips, foil, clippings and other scrap, as well as small-size scrap free of iron parts.

At the plants of the Soviet Union there are employed induction crucible furnaces of normal frequency, with a crucible capacity 6 tons. Installed capacity of the furnace is 1300 kW, the input - 950 kW.

Principal technical end economic characteristics of the furnace are as given below:

Metal recovery	- 93-97%
Average duration of melt	- 3 hours
Daily capacity of the furnace with 80% content of chips in the charge	- 30-35 tons

Average power consumption per 1 ton of melted metal	- 600 kWhr
Crucible life	- over 1000 melts
Number of furnace attandants	- 2 workers

At the Szekesfehervar Plant, Hungary, the induction crucible furnaces of 1-ton capacity, 200 kW, are used for melting of briquetted aluminium chips.

The average metal loss makes up 6.8%.

At the Home Sound Aluminium Plqnt, Pa., USA the crucible furnaces of 3.2-ton capacity, 700 kW (60 cps) are employed for melting of chips and clippings of aluminium alloys, the metal recovery being up to 98%. Furnace output is about 1400 kg/hr. Metal melted in the furnace is of high quality, free of any traces of liquation and with minimum content of gases and non-metallic inclusions.

As compared to the flame furnaces, induction crucible furnaces have the following advantages:

- increase in metal recovery by 2-4%;
- improvement of quality of molten metal both in uniform composition and in density;
- considerable improvement in sanitary conditions of work for the personnel;
- insignificant pollution of the environment with flue furnace gases.

Necessity of thorough preliminary separation of ferrous metals from the aluminium scrap, reducing of scrap to small sizes and relatively high specific power consumption should be considered as drawbacks of the crucible furnaces.

6. Induction channel furnace

Specific power consumption in the channel furnaces is almost by 20% less than that in crucible furnaces.

However, due to high content of oxides in aluminium scrap the channels of induction furnaces tend to clogged. Therefore, the channel induction furnaces are used mainly for producing primary aluminium base alloys and for melting exclusively pure scrap.

Some of secondary aluminium plants employ, melting aluminium scrap in furnaces of various types. For instance in the USSR, the large-size scrap with unseparated iron parts is melted in large two-chamber reverberatory furnaces, while for melting pure and small-size scrap free of iron parts in induction crucible furnaces are used.

At the plants of the GDR and in some other countries, they melt scrap with unseparated iron parts in shaft furnaces with inclined hearthes and pure scrap - in short-drum rotary furnaces.

From the shaft and rotary furnaces the liquid aluminium is being transferred into 3-ton induction channel furnaces, wherein correction of alloy composition and refining of alloy for the purpose of eliminating gases and non-metallic inclusion takes place.

7. Refining of secondary aluminium alloys

To obtain high-quality aluminium alloys it is necessary to remove harmful impurities comprising metals, non-metallic inclusions and gases.

At present the following methods of refining aluminium alloys are known:

(a) liquation with subsequent filtering;

(b) barbotage of chlorine or nitrogen through liquid a alloy;

(c) treatment with active fluxes;

(d) mercury method;

(e) distilling off aluminium as aluminium subchlorides;

(f) magnesium method for iron removal from the alloy;

(g) distillation of zinc and partially magnesium under vacuum;

(h) the three-layer method of electrolysis.

Many of the above mentioned methods have not been used on industrial scale. Therefore this Report deals only with those ethods which are most practicable and may be recommended for application in the developing countries.

Excess magnesium can be removed by treating molten aluminium with fluorine salts, in particular, with cryoline. This method is widely used at all secondary aluminium plants in the USSR. Cryolite consumption makes up about 10 kg per 1 kg of magnesium removed. By using this method, magnesium content in the alloy may be reduced to 0.1%.

For zinc elimination and partial removal of magnesium, the Soviet plants are widely employing vacuum distillation. Alloy to be refined is being poured into the electric induction furnace of 3 or 6-ton capacity. Distilling of zinc and partially of magnesium takes place at a temperature of 800--900°C in vacuum of 0.1-0.5 mm m.c. The vapours settle in condensators. The distillation process takes from 2 to 6 hours according to initial content of zinc. Zinc can be removed practically completely by this method. Average electric power consumption is about 200 kWhr per 1 ton of refined alloy.

To eliminate non metallic impurities included in aluminium alloys and dissolved hydrogen, wide use is made of bubbling chlorine (sometimes mixed with nitrogen), carbon monoxide and dioxide through the melt. Chloridizing may be carried out either in reverberatory or crucible furnaces or special converters.

Certain plants make use of hexachloro-ethane, as degassing agent charging it into the bath in the form of tablets.

The "Air Liquide", France, has improved the method of bubbling chemically active or inert gases, in particular nitrogen, through the molten alloy.

This improved method called the "Gasal" method, is based on maximum dispersion of gas bubbles rising in the metal bath by feeding it to the melt through porous plugs, thus considerably reducing sizes of bubbles and increasing their number hundreds of times. As a result, the rate of hydrogen diffusion into the inert gas bubbles increases many times. Nitrogen consumption makes up from 1.5 to 2m^3 per 1 ton of alloy. The use of this method ensures almost complete degasing of alloys and reduction of their aluminium oxide content by almost 10 times.

At the plants of the USA and the USSR, wide use is made of filtering aluminium alloys, through glass cloth. Removing thus suspended non-metallic inclusions in the alloys.

Due to use of fluxes containing chlorine and fluorine salts for melting of secondary aluminium, the furnace flue gases should be subjected to cleaning in scrubbers, cyclones and Venturi pipes.

II. Melting Copper and Copper Alloys Scrap

The share of copper and its alloys in the general scrap accumulation makes up [illegible] %. The proportion of secondary copper[x)] relative to the world consumption of this metal is the highest and in some years is as high as 42%.

Copper and copper alloys scrap is remelted into corought alloys, casting alloys and secondary blister copper.

To produce corought alloys use is made exclusively of very pure scrap which serves as a full-value substitute of primary non-ferrous metals. From the economic point of view this is the most advisable application of the secondary copper-bearing materials.

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x) including copper in secondary alloys.

According to the world practice, the major part of the secondary copper-bearing materials (over 60%) is being reprocessed at the specialized plants of the secondary non-ferrous metallurgy into casting alloys, mainly, into various grades of bronze and brass. This utilization of scrap and wastes is also reasonable, since by this process the most valuable components are extracted into secondary alloys.

Processing secondary copper-bearing materials into pure copper involves large losses of valuable components contained in scrap. Therefore only the most contaminated, oxidized and poor scrap (rubbish, slags, drosses, mixed chips, bimetallic scrap , etc.) are advisable to be subjected to processing into copper.

The use of pure scrap by the rolling mills instead of primary metals for producing wrought alloys does not present much difficulties and therefore is not covered in this Report.

Charge for the production of secondary copper-base casting alloys consists of different kinds of scrap and alloying materials such as primary metals or scrap of pure metals (but not alloys).

For example, charge for production of tin bronze (containing tin, zinc and lead) comprises scrap of tin bronze, scrap of soldered and tinned copper and brass and primary tin (in case its content in secondary materials is not sufficient). The charge for manufacture of aluminium bronze comprises scrap of aluminium bronze and copper scrap, that for production of leaded brasses-leaded brass scrap and pure lead scrap, charge for production of silicon brass scrap of silicon brass and crystalline silicon, etc.

Metallurgical treatment of secondary copper-bearing materials for production of casting alloys is being performed both in flame and electric induction furnaces.

The following flame furnaces have found the most wide application: reverberatory, short-drum and shaft (of water jacket type) furnaces. The latter are used mostly for reduction smelting of oxidized scrap.

With a small scale of production of secondary bronzes and brasses use may be made of crucible hearthes with a 100-300 kg capacity crucibles. These hearthes may be single--crucible and multi-crucible, stationary and rotating, fired with solid fuel, fuel oil or gas.

The output of a 100-kg crucible hearth fired with fuel oil is 90-100 kg/hr, average fuel consumption being about 25% of the melted metal weight.

Reverberatory furnaces, as the most efficient, simple in maintenance and convenient for charging of scrap of various sizes, have found wide application for melting of secondary bronze and brass. Capacity of bronze melting furnaces varies between 5 to 30 tons, and that for brass manufacture- from 4 to 10 tons. Furnaces may be fired with gas or fuel oil. The use of solid fuel sharply reduces efficiency of the furnaces.

Daily output of the furnace depends upon capacity of the same, characteristic of the charge and kind of the fuel used.

The melting process comprises the following operations:

(a) charging;

(b) metal melting;

(c) fluxing and slagging off;

(d) casting.

Bronze and brass are melted at a bath temperature of 1000-1200°C, the duration of melting in small-size furnaces being 3-4 hours. For the purpose of intensifying the process, the melting is carried out with a sump of molten metal.

The most widely used fluxes have the following composition, in per cent:

1. Soda ash - fluorspar 50:50
2. Soda ash - fluorspar - quartz sand 20:40:40
3. Soda ash - fluorspar - granulated slag 15:15:70
4. Soda ash - fluorspar - borax 60:33:7.

For charging and casting metal into pigs use is made of mould charging machines and belt casting machines in the same manner as for melting secondary aluminium in reverberatory furnaces. The furnaces are fitted with necessary automation and controls and instruments.

The basic technical and economic performance characteristics of gas fired reverberatory furnaces are as follows:

	Bronze manufacture	Brass manufacture
Metal recovery, % into:		
Commercial products	91-94	89-92
Slag	3-2	3-2
Splashes and skimmings	2-1	2-2
Oxidation losses and unaccounted losses	4-3	6-4
Yield from 1 m^2 of furnace hearth, ton/day	12-14	15-20
Reference fuel consumption per ton of metal	110-140	120-130
Consumption of fluxes, kg/ton	12-15	15-17
Electric power consumption, kWhr/ton	9-9.5	9.8-10

2/ Drum-type rotary furnaces

The drum-type rotary furnaces are widely used in the countries of Western Europe for melting copper and copper alloys scrap. The design and knowhow of the process have been already described in the section dealing with the secondary aluminium metallurgy. It is worth noting however, that drum-type furnaces may be used for reduction smelting of oxidized copper-bearing scrap. Average recovery of metal at melting of secondary brass is 90-94%.

3. Shaft furnaces and reprocessing of scrap into copper

The shaft furnaces pay for themselves only provided secondary copper-bearing materials are coming in big lots, ensuring continuous operation of the furnaces.

The shaft furnace is used mainly for reprocessing of very contaminated and oxidized scrap. Before refining the black copper is subjected to blowing in the converter. The main disadvantage of the shaft furnace melting is the necessity of preliminary sintering or briquetting of bulk and s small-size scrap which increases the cost of production.

Among the advantages of the shaft furnaces are uniform composition of: metal obtained , high out-put, low metal content of slags and comparatively low operating expenses.

As an example of processing secondary copper-bearing materials into copper, we are enclosing herewith the flowsheet of reprocessing this materials at the Mansfield Plant, German Democratic Republic. This plant treats both ore and secondary materials. Melting of copper from scrap makes up about 56% of the total production of this metal.

In the USSR, there is a specialized copper smelter, treating exclusively secondary copper-bearing materials.The plant is equipped with shaft furnaces, converters, anode furnaces and electrolytic baths. Inspite of high contamination of initial materials, the plant produces catode copper of high purity with a copper content of up to 99.99%.

Secondary copper-bearing materials contain, as a rule, a certain amount of tin, load and zinc. Formerly these metals were partially lost with dump slag and partially were recovered from furnace gases as oxides. It has been established, that the maximum amount of tin is concentrated in converter and anode furnace slags. Formerly these slags were returned to water jacket conversion for complete removal of the tin.

At present, converter and anode furnace slags are withdrawn and smelted in a special furnace into blister bronze.

Composition of the blister bronze: 5-8% tin; 3-5% lead; 0.4-1.5% zinc; about 2% nickel; up to 0.5% iron, rest copper.

Production of blister bronze has increased tin extraction, simplified the process and considerably improved technical and economic characteristics of the plant.

4. Electrical induction furnaces

In the USSR and other countries, induction channel furnaces are used for production of secondary bronzes and brasses. These furnaces may treat all kinds of secondary copper-bearing materials expt for highly oxidized scrap.

In efficiency, the induction furnaces are second to big size reverberatory furnaces, but their other technical and economic data are much better. The use of induction furnaces for melting secondary brass and bronze contributes to improving quality of these alloys; ensures minimum metal losses;

furnaces are easy in operation and maintenance; melting process may be fully automatic, amount of generated furnace gases is insignificant.

The basic technical and economic characteristics of induction channel furnaces used in the USSR for melting of secondary brasses are as follows:

Description	Furnace capacity, kg 50-600	4000
Electric power consumption, kWhr	340	320
Recovery, %	92-96	92-97
Duration of melt, min	40-45	100-120
Furnace output, ton/day	8-10	45-60

5. Refining of secondary bronze and brass

Refining of secondary tin bronze and brasses to remove harmful impurities, mainly iron and aluminium, is carried out by a way of blowing air through molten metal or by means of refining fluxes.

Blowing of bronzes and brasses with air may reduce iron and aluminium content to 0.2 and 0.01% respectively.

Mixtures of various materials are used as refining fluxes. The most widely used components of fluxes are soda ash, sodium nitrate, cryolite, borax and quartz sand.

For the purpose of cleaning furnace gases escaped during melting of bronze and brasses and the recovery of their of zinc, lead and tin oxides content, flues of the melting units and exhaust hoods of the furnaces should be connected to dust catching arrangements (dust chambers, cyclones, scrubbers, electrostatic precipitators, bag filters). The maximum degree of cleaning can be obtained by using bag filters, with extraction of zinc oxide being as high as 99%.

III. Melting of Lead and Lead Alloys Scrap

Secondary lead-bearing materials comprise:

(a) pure lead scrap(acid-resistant lining of chemical apparatus, etc.)

(b) low-alloy lead alloy scrap (mainly cable sheathing);

(c) antimonial lead scrap (lead accumulators, pump bodies, flanges, etc.);

(d) lead-tin alloys scrap (mainly babbit scrap and drosses);

(e) by-products formed during melting of lead scrap (dust, slags, drosses skimming).

Pure lead and non-oxidized lead alloy scrap may be remelted in steel or cast iron kettles, fired with coke, fuel oil or gas or electrically heated. With a view of prolongation the life of Kettles, melting must be carried out at a temperature not exceeding 650-700°C. To prevent air pollution by lead fume the Kettles should be equipped with exhaust hoods.

Molten lead is poured over into the second Kettle wherein the sampling is done for express analysis. Alloy is corrected and cast into moulds.

The largest proportion in the secondary lead sources accounts for the lead accumulators scrap, consisting of grids with antimony content from 2 to 8% and of active mass (packing) of pure lead oxides. In the used up accumulators, the packing is sulphurized; its sulphur content makes up to 1%.

Smelting of accumulator scrap and other types of lead scrap may be carried out in shaft, reverberatory short-drum and electric furnaces.

The shaft furnace output is determined by its section in the tuyere area which varies within 0.8 to 3 m^2. The charge may consist of accumulator scrap only or with addition of sintered fine lead-bearing materials and return products (skimmings, dust). Coke serves as a technological fuel. Coke consumption is 10-15% of the charge weight. The components of flux are: iron ore, limestone, quartz sand, fluorspar. To reduce lead losses as sulfides, steel or iron chips are added into the charge.

The temperature of flue gases must not exceed 300-400°C. Periodically tapped slag is subjected to granulation and flue furnace gases - to cleaning.

Shaft furnace smelting ensures metal (lead and antimony) recovery as high as 85-92%. Antimonial lead produced by the shaft furnace may be used according to its composition as commercial product or as intermediate alloy for production of babbits or solders.

When smelting lead scrap in a reverberatory furnace, the general recovery of metal with account for reprocessing of return products (slag, skimmings and dust) is as high as 95%. The best reducing agent is coke or coal fines. Lime and quartz sand are used as fluxes. Fuel oil consumption makes up about 100 kg/ton of charge. The output of the furnace is determined by the hearth area. When melting accumulator scrap it achieves 25 ton/m^2 per day.

Short-drum rotary furnaces are widely used for smelting secondary lead materials, in particular for reduction smelting accumulator scrap, lead dust, drosses skimmings and all types of oxidized lead scrap. The drum furnace output depends upon its effective volume and characteristics of materials treated. For instance when smelting accumulator scrap together with lead drosses in short-drum furnaces of different capacity the output is as follows:

Effective volume of the furnace, m^3	Daily output, tons
1.0	15-20
2.2	35-50
5.1	55-70

General recovery of metal (lead and antimony) when melting lead scrap varies from 90. to 94%.

Comparatively small is the use of electric resistance furnaces for smelting lead scrap. In the USSR, the electric furnace is installed at one of the plants producing antimonial lead from accumulator scrap.

The furnace has a round cross section with a hearth rcea of m^2. Three electrodes are descended through the roof. Ventilators produce a slight underpressure. The charge comprises accumulator scrap, iron chips, limestone, quartz sand and fluorspar. Coke is used as a reducing agent. Installed capacity of the furnace is 2900 kVa. Specific power consumption is 330 kWhr/ton. General recovery of lead and antimony makes up about 90%.

In Bulgaria there have been carried out comparative balance melten of accumulator scrap containing 77.7% of lead and 2.83% of antimony.

Melts aere carried out:

(a) in a shaft furnace with a section in the tuyere area of 0.84 m^2 and shaft height of 2.5 m. The furnace operated with a coke consumption of 15-16% of the charge weight and air consumption of 2000-3500 nm^3/hr;

(b) in a short-drum furnace with a diameter of 3 m and 3.2m long.

The furnace operated with a fuel oil consumption of 100 l/ton and soda consumption of 5% of the charge weight;

(c) in an electric resistance furnace of 410 kVa and hearth area of 3 m^2.

The furnace operated with electrode consumption of 6.1-6.5 kg/ton of lead.

The balance melt data are as follows:

Furnace type	Output ton/day	Power consumption, kWhr/ton	Recovery	
			lead	antimony
Shaft-type	12	80	87-88	85-87
Drum-type	20	40	92-95	90-92
Electric	7	475	87	96
Reverberatory[x)] ($4m^2$ hearth)	8	no data	85	84

x) According to the banalce melts carried out in the USSR.

The metal produced contained in all cases, mobe than 96% of lead and from 2.5 to 3.4% of antimony.

Some of the plants in the USA, West Germany and other countries use separate melting of grids and packing of accumulator scrap. The oxide fraction is smelted in the shaft furnace producing pure lead, while metallic fraction is melted in Kettles producing antimonial lead suitable for accumulator grids manufacture.

Refining of secondary lead may be carried out by the same methods as those used for primary lead.

IV. Remelting of tin and tin alloys scrap

The majority of secondary tin-bearing materials is used directly as charge components for when melting bronzes, babbits, solders and typemetals, and only a small part of materials as tinplate scrap, cans, tin drosses, slag, lithopone cake and some other types is remelted to secondary tin.

Tin drosses, casting slag, skimmings and cakes are usually smelted in small reverberatory furnaces of up to 2.5-ton capacity. Anthracete is used as a reducing agent and limestone, quartz sand, soda and fluorspar - as fluxes. Smelting is carried out at a temperature of about 1200°C and lasts for about 8 hours. Metal is subjected to refining in steel Kettles to eliminate the impurities such as iron, copper and arsenic. Refining methods are the same as those used when producing primary tin.

Treating of tinplate scrap to recover tin is performed by various methods. Most widely used are the chlorine, chemical and electrolytic methods.

When using chlorine method, tinplate scrap is being degreased by means of a weak alkaline solution, dried and faggoted. Faggots are being treated in iron retorts with dry chlorine at a temperature of about 100°C. Tin tetrachloride is used in the textile or chemical industries or reduced to tin metal by means of zinc or aluminium . The other method consists in treating tin tetrachloride by lime milk to settle stannic hydroxide and subsequent smelting of the latter in a reverberatory furnace.

The chemical method comprises treating degreased scrap with a of sodium hydroxide solution, solving tin as sodium stannite. When treated with sulphuric acid solution, carbon dioxide or lime milk, tin is settled as hydroxide. The latter is reduced to tin metal by conventional methods.

Most widely used is the electrolytic method comprising tin dissolving in 10% sodium hydroxide solution with subsequent electrolytic settling of tin on the cathode.

Electrolysis may be carried out with soluble or insoluble anodes with obtaining of sponge or metallic tin. In the latter case 1.5 % metanitrobenzoate acid is added to the alkaline solution.

The basic technical and economic characteristics of the electrolytic tinplate theating are as follows:

Tin extraction	[illegible] %
Consumption of sodium hydroxide	[illegible] kg/ton
Consumption of metanitrobenzoate acid x)	[illegible] kg/ton

x) used to ensure settling tin metal on the cathode

Electric power consumption	[illegible] kWhr/ton
Current output	[illegible] %
Current density	[illegible] a/m²

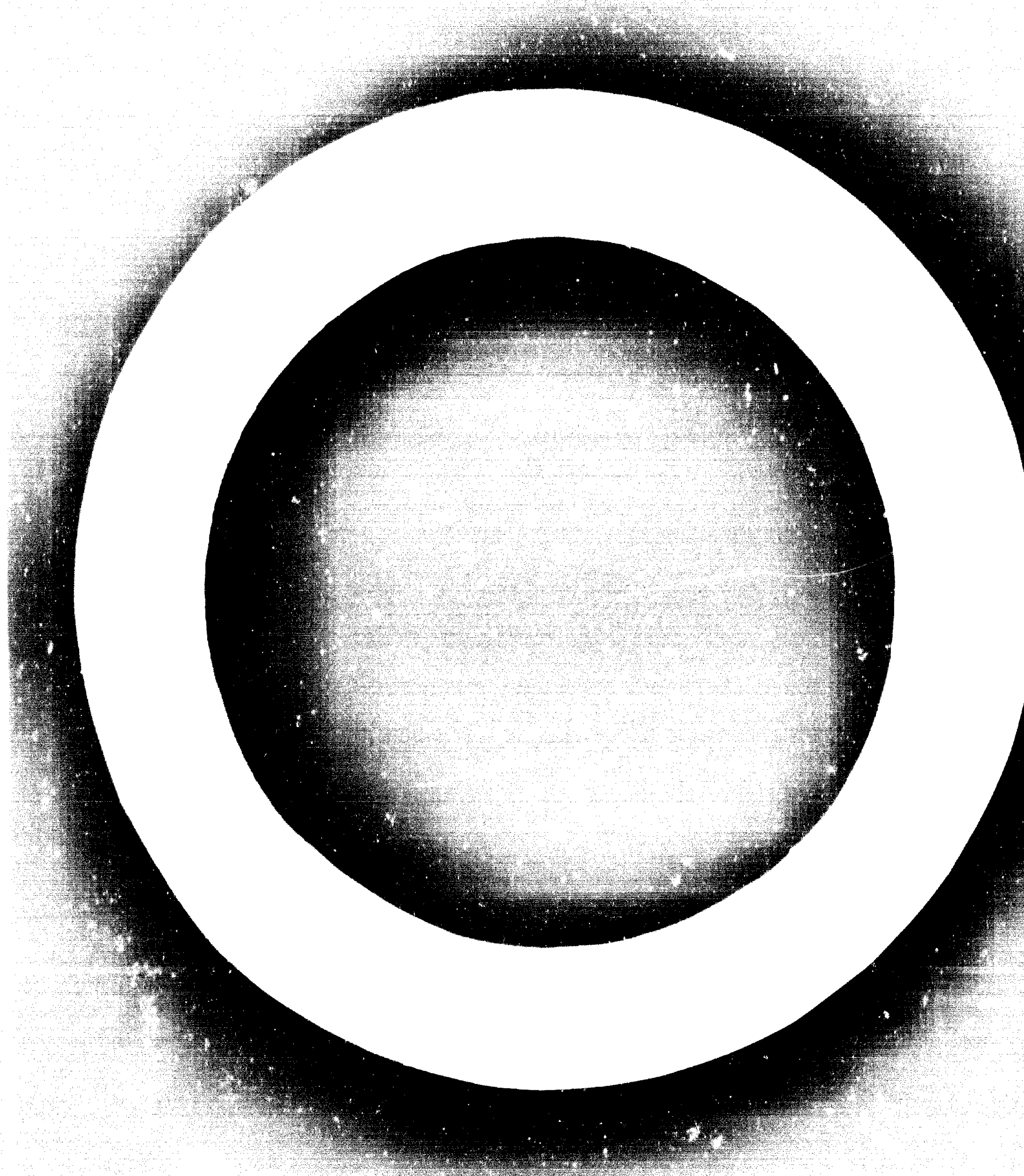
At present one of the plants in the USSR employs electrolytic detinning of tinplate scrap, containing 0.6-0.9% tin. There is a round bath installed outdoor (the process can be carried out at an outside temperature of down to -30°C). At a time the bath can be charged with [illegible] ton of tinplate. Charging is performed by means of a bucket crane. The bath is served by one worker. The cost price of recovered tin is by 20-30% lower than that of tin recovered in ordinary baths.

Cans are subjected to preliminary shredding and washing, with hot water and 2% solution of sodium hydroxide; shredding is performed by means of special machines.

V. Processing of zinc and zinc alloys scrap

Pure zinc scrap is usually used for addition into the zinc-bearing alloys, for instance brasses, while the zinc-aluminium alloys scrap is added to alloys subjected to die-casting.

Poor and oxidized zinc-bearing materials, such as zinc drosses and hard zinc are used after they have been dechlorized in the chemical industry for production of whitening or at primary sinc smelters.



CONCLUSIONS

Based on the foregoing, I shall venture upon the following general conclusions:

1. When selecting a flowsheet for reprocessing of non-ferrous scrap for developing countries, one should primarily proceed from the planned volumes of production and availability of power resources, auxiliary materials, labour and skilled personnel in the country under consideration.

2. In case of availability of primary non-ferrous metallurgical plants or plants for non-ferrous metal treatment in developing countries, with a view to speed the development and t to reduce the cost of construction, production of secondary non-ferrous metals may be set up at those plants.

3. In developing countries posessing relatively small scrap resources and with no metallurgical plants and rolling mills available, it is advisable to set up combined plants for production of various types of secondary non-ferrous metals.

4. In developing countries with large amounts of scrap formation, with the purpose to prevent possible mixing various types of non-ferrous metal scrap it is advisable to set up specialized plants for producing definite types of secondary non-ferrous metals.

As to the choice of methods of treating secondary non-ferrous metals and types of melting units, the recommendations are as follows:

Production of secondary aluminium

With the small volume of production use of crucible hearth furnaces is expedient.

With the volume of production being up to 2-3 thousand tons per year, it is expedient to use short-drum rotary furnaces.

With the annual production of up to 10 thousand tons, the aluminium chips and shavings prevailing in the materials, it is advisable to use short-drum furnaces together with induction crucible furnaces.

When having large volumes of production, two-chamber reverberatory and induction crucible furnaces are advisable to be installed.

Due to the fact that many of developing countries posses reserves of free labour, the application of furnaces for aluminium scrap fusing is not advisable, since this involves additional losses of metal and increase in fuel consumption.

These countries should set up preliminary mechanical separation of ferrous metal parts from aluminium scrap.

In all cases of melting aluminium scrap covering or refining fluxes should be used.

For refining aluminium alloys we would recommend the use of active fluxes, treating molten metal with chlorine or inert gases, filtration of metal through glass cloth and in case of large scale production, - the use of vacuum distillation furnaces.

Production of secondary copper-based alloys

With availability of cheap electric power, melting of secondary bronzes and brasses should be performed in induction channel furnaces and in case of shortage of electric power melting should be carried out in short-drum rotary furnaces.

Very oxidized, contaminated and poor materials should be subjected to reducing smelting in shaft furnaces.

To avoid repeated melting of bronze and brass pigs at machine industry plants and basing on the experience of the Soviet Union it is expedient to use continuous casting of ingots and bushings.

In order to prevent air pollution and for the purpose of recovering zinc, lead and tin oxides contained in furnace gases, flues and exhaust hoods of melting furnaces should be connected to gas cleaning plants.

Production of secondary lead-based alloys

When melting lead and lead alloys scrap including lead accumulators scrap, it is most advisable to use short-drum furnaces producing both commercial antimonial lead and semi-alloys for producing babbits and solders.

Taking into account toxicity of lead fume, all melting units should be thoroughly provided with exhaust hoods and the flue gases should be subjected to obligatory cleaning in the dust catching devices.

Types of auxiliary metallurgical equipment, degree of mechanization and automation of processes are determined according to the volumes of production and types of melting units.

Types of fuel and compositions of fluxes should be specified according to local conditions.

Methods of express analysis are recommended for quick assay of chemical analysis of molten metal due to extremely non-uniform composition of non-ferrous metal scrap.

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4 12