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# SEARCH AFTER APPROPRIATE QUALITY FOR INGOTS OF SECONDARY NON-FERROUS METALS AND ALLOYS DESTINED FOR CASTINGS 1/

by

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## SEARCH AFTER APPROPRIATE QUALITIES FOR INGOTS OF SECONDARY NON-FERROUS METALS AND ALLOYS DESTINED FOR CASTINGS

Addendum 1:

**Policies, Incentives and Programmes** 1/

by

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Developing countries are faced with many problems and have to adjust their efforts on each one, so that to obtain an optimal [illegible], [illegible] of metallurgy questions are rising.

[illegible] are not the most important, but they [illegible] more [illegible].

[illegible] should the developing countries follow in this field?

Some actions can be proposed without reference to a determined country. These actions of general concern are not very expensive; their impact is rather difficult to forecast, but they are necessary for any [illegible]. International bodies, such UNIDO, are well designated to do this preliminary work.

Other actions must be [illegible] with specific circumstances. These actions [illegible] expensive; their impact on economics [illegible] must be evaluated. Developed countries and international bodies [illegible] in the financial, technical, [illegible] fields.

1 - [illegible]

1,1 - [illegible] of the present situation

[illegible] about the present situation of the economy of [illegible] in developing countries.

[illegible] it is necessary to consider both ferrous and non ferrous [illegible], and both [illegible] and secondary metals. The report should [illegible] the impact of [illegible], as service, as linked import, etc.. [illegible] of metals are to be described, including the traditional ones.

It is hoped to have some words about recovery.

The report should describe the needs of metals and of metal articles, and especially what kind of needs can use secondary non ferrous metals.

Such a report can be done by a commission or, better, one expert.

1,2 - <u>Regulations about metals</u>

To save metals is always a necessity for countries faced with scarcity.

For instance we can see severe reductions of the liberty in use and trade of metals in China (circa 840) (1), in United States (circa 1950), etc.

It is desired to have a <u>report</u> collecting the means negative or positive used to refrain loss of metals by improper use, harmful export, etc.

The main topics seem to be :

- regulations of the uses of metals (it is necessary to consider also ferrous metals);
- regulations about the firms or persons authorized to handle metals (collecting of scraps, smelting, transformation, foundry, etc.);
- regulations and taxes on the import-export of virgin metals, articles of metals, scraps, etc.;
- Rewards for metal saving (but scarcity generates relative high prices for metals, and automatic rewards for recovery metals, without resort to ways and means).

Such a collect of regulations and rewards can be made by an expert or by experts in some countries. It would be good to have also an appreciation on the efficiency of the regulations.

1,3 - <u>Uses of non ferrous secondary metals</u>

1,31 - A <u>report</u> should study the possibility of use of recovered metals.

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(1) - Cf. Journal de voyage de ENNIN.

1,32 - In my opinion the secondary non-ferrous metals, recovered from discarded articles are specially interesting for foundry industry. If this origin of secondary alloys is important, it is necessary to have foundries using it.

The existence of an international group of foundry experts, would be fruitful. The group could give assistance to developing countries for building foundry plants.

A first work could be the definition of foundry types (nature of castings, tonnage), with data about equipment, power, labour, etc.

International bodies, for instance UNESCO, or UNIDO, could help people of developing countries to learn foundry technics, pattern making technics, etc. in the schools of the industrial countries.

To establish a list of recommanded books and selected documents about technics of foundry (and smelting) is worth of attention : this work could be undertaken by international bodies (UNIDO, International Committee of Foundry Technical Associations, etc.).

1,33 - For copper, an evaluation must be made of the tonnage required as cryptogamic, now and in the futur.

1,4 - Recovery

A report should be made about the traffic of old metals and the recovery.

A report should be made about the technical and economical structure of smelting plants (depending of tonnage, quality required, etc.).

Such reports could come from the present meeting, eventually through a smaller group of experts.

2 - ACTIONS OF SPECIFIC CONCERN

2,1 - Regulations about metals

From the general report (see 1,2), each country has to choose a system of regulations to preserve its metals. Of course the choice depends on the general policy of the country, and on the circumstances.

An important and simple disposition is the publication of national standards concerning non ferrous alloys (virgin or secondary). International documents (I.L) and some national specifications give a good basis.

2,2 - Foundry development

2,21 - Foundry makes few waste and reuses it completely. Moreover alone foundry can use secondary alloys of medium quality. Foundry is the most metal saving technic for the transformation of metals.

The economical advantages of castings should be widely explained to technical staff, draughtsmen, etc. in the mechanical industry. A teaching action on the use and properties of castings should be beneficial.

2,22 - Building foundry plants can be decided by each country with the technical assistance of the experts group (see 1,3). Often the economical development is based on agriculture, agricultural industry, transports. Hence foundries must be suited for small series and for single casting (repairing for instance) more than for big series.

Technical visits of existing foundry plants could be organised with the help of international bodies. Also each country has to select the proper number of persons for the staff of the plant, and eventually to send them learning technics in industrial countries.

2,3 - ~~2,23~~ - Building smelting plants can be decided by each country after considering the supply of scrape, the capacity of customers (foundries, etc.), and all economical data. The reports and the experts group (1,4) should be very useful. In many cases the tonnage of secondary alloys will not be very large. Hence the recovery will be done economically in the foundries. Besides similar training and teaching are required for recovery technic and for foundry technic.

Technical visits could be organised with the help of international bodies.

# 1 - INTRODUCTION

## 1,1 - ECONOMICAL AND JURIDICAL CIRCUMSTANCES

In France, the difference of price between cuprous scraps and ingot alloys is relatively low ; therefore the practice is to sort the scraps in order that their melting give compositions acceptable for the foundryman. In the United States, the difference of price between cuprous scraps and ingot alloys is stronger : scraps are generally treated to obtain pure copper (thermal quality) to which alloying elements are added. The economical data induce the technology. On the contrary physico-chemical laws give not many constraints to technology.

Thinking to the developing countries the metallurgist is perplexed. Developing countries are very far from being similar in the economic field. On the other side former analogous circumstances must be found, for instance periods of scarcity (1939-1945, 1950). In such cases recovery of metals generally took a great importance. But those former situations are bad models : technology has made great progress, the profit of which can be taken immediately.

The metals recovery is a process that inserts itself in a society customer of metals. It must therefore take various forms with the different societies. During a long time that activity have been exercised in Europe on a semi-industrial scale : for example workshops were set up in works recovered also ... new works particularly suitable to that function are erected. That is not an example, good or bad to follow : it is the consequence of the present economical state.

Therefore, that account will have the aim to display modern solutions; but solutions not so technologically fair will be also given, they would be used in other situations.

The pre-eminence of the economic in that subject induces to think that the juridical look, from which nothing will be said here, might have more importance than technology : the laws of the recovery industry, of the use of metals, customs regime (particularly concerning scraps) are worth of a very careful examination.

## 1,2 - [illegible]

A great deal of the recovery is made by direct exchanges between the large works transforming metals and those refining them. This ideal case is out of our account.

We will more particularly consider the case of scraps and wastes of very various origins which are treated to obtain good ingots. The unavoidable scattering of the chemical composition, for the principal elements as well as for the impurities, makes these ingots difficult to use for wrought-products. So foundries are natural customers for these ingots of recovery.

The scatter of chemical compositions are nevertheless limited in castings : ingots must give an alloy which can be normally poured (sufficient castability and other casting properties) and having satisfactory properties in service (machinability, tightness, mechanical properties, corrosion resistance, etc.).

That's the reason while we take the place of the foundryman, i.e. of the customer, to treat of that subject.

## 2 - ALUMINIUM CASTING ALLOYS

### 2,1 - FOUNDRIES NEEDS

#### 2,11 - The four classes

It is convenient to sort out the aluminium casting alloys in four great classes.

- The alloys for general purposes : they are employed in general mechanics. They compete with the other metals : gray irons, brass, bronzes. They are the most employed amongst aluminium casting alloys.

- Corrosion resisting alloys : they are relatively new and are necessary for shipbuilding, chemical industry, building, ornamentation.

- Heat resisting alloys : they are principally used for internal combustion engines : pistons, cylinder head. These limited uses consummate nevertheless very large quantities of alloys.

- Alloys for particular uses : for instance, antifriction alloys, high stress alloys.

We will survey the requirements of each of them.

#### 2,12 - Alloys for general purposes

2,121 - The required qualities are machinability for the final product, and casting properties for foundry operations.

Generally, the higher is the hardness, the better is the machinability. Wherefore when the alloying elements are more plentiful. However iron and silicium must be excluded. Non-metallic inclusions hinder machinability.

The casting properties are essentially hot crack tendency, castability and shrinkage tendency.

The nearer from an eutectic obtained by sufficiant contents of copper and silicium, is the alloy composition, the better are generally the two first properties.

The highly alloyed alloys are preferred for these three reasons, and those alloys are produced the most easily by the recovery. It will be therefore the favorite field of the refining.

2,122 - <u>Iron</u> is an usual and noxious impurity. Machinability and deformation capacity are reduced by that element. The iron content is increased by the foundries operations. Controls have discovered that, on an average, in the french foundries of quality, the iron content increase was of 0,05 % but could sometimes reach 0,15 %. Iron is more dangerous in thick walled castings cast in sand moulds; it is more allowable in pieces cast by gravity in metallic moulds and still more in pieces cast by pressure die casting.

The maximum contents are generally fixed, in castings, respectivaly : 0,8 - 1 - 1,3 %. The three corresponding boundaries for ingots will be :

0,7 %
0,9 %
1,2 %

by order of decreasing quality.

The recovery technology will eliminate as much as possible iron from scraps.

2,123 - <u>Copper</u> is good. The contents are 1,0 % to 5 % in the employed alloys. Naturally the variation must be reduced : ± 1,5 % is allowable for castings of mean quality.

2,124 - <u>Silicon</u> hinders machinability but is good for castability. The recovery gives usually an alloy with a too low content : silicon must be added, a tolerance of ± 1,5 % on the mean content is frequently imposed. Taking in account the analysis difficulties when the silicon content is above 6 %, such a tolerance is in our opinion a little low.

2,125 - Magnesium increases elastic limit and hardness. On the other hand, it decreases elongation, and, according to some opinions difficult to prove, could spoil casting properties. Foundry operations never increase this element content, on the contrary.

In some industrial countries, magnesium content resulting from the charges (sorted to avoid Al-Mg alloys and magnesium alloys) are accepted : ingot with magnesium content 0,15 are obtained. That "natural" content could increase during the next years if the use of Al-Cu-Mg alloys with magnesium content higher as in the past is confirmed.

In other countries magnesium cancels out by special treatments in refining works. In such cases the highest magnesium content is 0,15 % and the "normal" content about 0,05 %.

In one case (Mg $<$ 0,4 %) as in the another (Mg $<$ 0,15 %) it is essential the magnesium content is about the same in all the deliveries in order to not disturb the adjustements in the foundry (feeder head, etc.) or during tooling.

2,126 - Other elements - Zinc was never proved hindering, even with contents till 3 %.

Manganese, nickel, lead, tin, chrome, are "naturally" at allowable contents. They do not need attention, unless exceptional circumstances.

2,127 - The following ISO compositions (1) are given as typical : for castings (draft ISO R164 - R208) :

Al-Si5 Cu1

Al-Si5 Cu3

Al-Si12 U

Al-Si8 Cu3 Fe (pressure die casting).

## 2,13 - Corrosion resisting alloys

Any phase included in aluminium and clearly more noble as it is a danger for the corrosion resistance : it is especially the case of copper, nickel and zinc.

### 2,131 - Cu, Ni, Zn

These elements (x) must be maintained at contents as low as possible; for castings and also for wrought products the higher contents generally agreed upon for each of those elements are :

0,05 % - 0,10 % - or 0,15 %

following the alloy quality.

If the foundryman is not mistaken the additional pollution during the founding operation is limited : the compositions boundaries may be the same for ingots and for castings.

The other electropositifs elements, usually rare : lead, tin, need also attention.

### 2,132 - The usually present elements are magnesium and silicium.

Their contents must be fixed to avoid too large variations of the casting properties : the range is ± 1 % to 2 %. Iron must be limited as in the alloys for general employment.

### 2,133 - Typicals alloys are for example :

- Al-Si5 (Cu $\leqslant$ 0,10, Ni $\leqslant$ 0,15 ...);
- Al-Si5 Mg (Cu $\leqslant$ 0,15, Ni $\leqslant$ 0,15 ...);
- Al-Si12 (Cu $\leqslant$ 0,10, Ni $\leqslant$ 0,15);
- Al-Si12 Fe ~~(moulage sous pression);~~ (pressure die casting);
- Al-Mg3 (Cu $\leqslant$ 0,10, Ni $\leqslant$ 0,05);
- Al-Mg5 Si1 (Cu $\leqslant$ 0,10, Ni $\leqslant$ 0,05).

The two last alloys are particularly difficult to prepare economically from scraps. In all cases they are very sensitive to sodium traces : no sodium salt must be come in touch with the melt.

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(x) - Fears about Zn are not proved so firmly as for Cu and Ni.

2,14 - Heat resisting alloys

Pieces for motors are concerned. A good reliability of the alloy properties are required, in foundry as well as in mechanic. Moreover pieces cast by gravity in metallic molds are often concerned.

A good deformation resistance at the service temperature is required for the alloy. That corresponds to a high hardness at the room temperature, which is obtained by sufficient contents in copper, nickel, magnesium, iron. A coefficient of thermal expansion nearly similar to this of cast iron ($12\ 10^{-6}$) is also wanted : it can be obtained only by large additions of silicon, the low coefficient of thermal dilatation ($8\ 10^{-6}$ /° C) of which balances that of aluminium ($23\ 10^{-6}$ /° C).

There are a large number of formulas and names of heat resisting alloys. However a simplification is possible by presenting three categories, which are the principal ones nowadays.

2,141 - The parents alloys of the Y alloy : Al-Cu4 Ni2 Mg2 (ISO). These are very accurate composition alloys: the limited iron content, and very low lead and tin ones, make these alloys difficult to obtain from recovered materials.

2,142 - Alloys alike to Lo-Ex ones :

These alloys contain 9 to 13 % silicon, copper, nickel, magnesium. The iron content is limited at 0,75 % in the pieces, consequently 0,70 % in ingots. These alloys may be easily obtained from recovered materials.

2,143 - High silicon alloys

They have a silicon content above 16 % and various additions (copper, magnesium, for example). The iron content is limited at 0,65 % in ingots.

These very particular alloys may be made from scraps and pure silicon.

The melting temperatures must be very high (800-850° C) and a phosphorus addition (for example by a low percentage cupro-phosphorus) has to be made when the refining operation is made.

2,15 - Alloys for particular uses

Generally these alloys are not made from scraps. It is for example the case of very high stress alloys which require consequently heat treatment. It is also the case of antifriction alloys, or of alloys for electrical uses.

However let us recall, out of our subject, the alloys used for desoxidation in steel making by the iron and steel industry : they allow to use materials particularly soiled with iron (percentage of aluminium 85 to 98 %).

2,16 - Non metallic impurities

This problem concerns all classes of alloys.

2,161 - Alumina and oxides

We know that the formed alumina cannot be reduced; consequently it has chances to go with the metal. Now alumina has many noxious affects.

It forms thin skins, which are solutions of continuity and which reduce deeply mechanical strength.

Alumina seems to unite with hydrogen : the result is easily gassed melts, but the degassing is uneasy.

For that reason, the recovery must avoid the most possible the making of alumina, and clear the melt of this impurity bound by a flux.

2,162 - Gas

Hydrogen is the only gas to fear, just as : water, organic products, moisture or crystal constitution water, etc., which can bring it.

In fact it seems unlikely that hydrogen trapped in ingots (at the molecular state) may hinder the foundryman. But the ingots gassing is an indication of recovery made carelessness, and for that reason may make the foundryman anxious : the gassing, obvious and not very dangerous, resulting often from the reaction of water on aluminium is coming with alumina not very obvious but dangerous.

2,163 - In this chapter we refer to sodium and calcium. Though they are metals, in the alloys we mention they play the part of gas. These elements may be introduced in the melt by salts reduced by aluminium. Then they tend to volatilize.

These elements are noxious, as we have said it, in the Al-Mg alloys.

They have a great influence on the alloys having a Silicon content of more than 8 % : they make that the form and place of the shrinkage pipes is changed. The ingots appearance (smooth or hammered surface) depends also on the presence of these elements. The foundryman need to receive such alloys with little variation in sodium and calcium content. That requires operation conditions to be constant when refining (salty raw materials, time, temperatures, etc.).

2,164 - Melted aluminium reacts slowly on silica to form corundum. So refractories too silicious or ill-maintained may abrade producing hard spots, washed away in the metal that are a disaster at the time of machining (2).

## 2,2 - CONSEQUENCES FOR THE TECHNOLOGY (3, 4, 5, 6, 7, 8, 9)

The aluminium oxidation is easy and non reversing : the alumina formed has no value. Therefore no chemical treatment will allow to separate aluminium from the other metals. Consequently, the sorting of materials has a great importance and happens at different stages of the process.

### 2,21 - Storage

The stocking yard must be large and divided. The deliveries homogeneity must be respected Let us note that the scraps sorting must begin in fact in the workshops that produce them (by machining for examples): it is there that the mixing which lowers the metallic materials value may be avoided.

### 2,22 - Preparation

#### 2,221 - Hand sorting

It applies itself particularly to discarded articles : each one is observed and classified by a sortingworker. He uses simple means that it is desirable to compare periodically with more accurate methods. He extracts information from the form, process, references marked on the pieces. His usual tools are file, hammer, magnet, electrical breast drill (drill of diameter 15 mm). Simple chemical tests (drop test) are sometimes used, just as electrochemical potential measures.

Chemical analysis allows entire identification. It is used for big pieces or for a sufficient number of similar pieces. In the case of a large delivery of small scraps, a part is taken, with all the care needed for a good sampling. It is melted and analysed.

2,222 - Scraps preparation (turnings, etc.)

Briquetting is out of date for aluminium. Generally large turnings are at once crushed, then cleaned of oil and grease that are always on them. Sometimes a centrifugal process is used. It seems that the more worthy method is burning in a rotary furnace, provided that temperature and air intake are carefully regulated in order to avoid aluminium oxidation and to decrease the amount of fumes.

Turnings are then cleaned ofdust. It is not interesting to use very fine screens : the screening time would increase very quickly and the fine particles are difficult to recovery. A screen of 35 mesh is recommanded. Air separator can also be used.

Magnetic separation is a very important and cheap operation. 80 to 98 % of the iron is taken away. The two irums separators are to be preferred. A belt conveyor 0,6 m wide treats about 750 kg of aluminium by hour

2,223 - Discarded articles preparation

These used materials are cleaner as turnings, but they are very dissimilar. After the hand sorting the big pieces go directly in the melting furnace. The other one, that is the most, go in a hammer crusher which separates joinings and gives regular pieces which go through magnetic separator.

It is possible to simplify handsorting by sorting automatically these pieces, for instance by specific gravity : dipping in liquors the specific gravity of which is regulated between 2,4 and 3,2. That method is not convenient for little scraps.

2,224 - Dross preparation

Dross comes from works making melted aluminium. It contains 20 to 50 % of aluminium. Of course dross formed on the alloys are not mixed with those coming from pure aluminium.

The metal is contained in more or less small balls. The various brittleness of oxides and metals may be utilized to make a sorting.

For example, a crushing by mortar-mill, with screening, enriches the material. It goes then in the ball-mill (diameter 50 mm), is screened and dusted.

2,225 - Particular cases

As soon as an important delivery offers particular features, it is better to look for the most economical means to treat it : to take away the aluminium of cables armoured with steel, carbonizing organic paints on aluminium papers, etc.

2,23 - Melting

Prepared scraps and discarded articles must be stocked before melting in maintening the separation in homogeneous piles. The chemical composition, verified or supposed, of each pile allows to prepare furnace charge that must give an alloy alike of the desired composition.

2,231 - Reverberatory furnace

It concerns open-well reverberatory furnace of 30-40 t

The loading is easy; it may be mechanized . The consumption of salt flux is lower as in rotary furnaces (salt addition in the open well alone); the cycle is slow; the chemical composition evolution may by easily followed, and eventual corrections made.

2,232 - Rotary furnaces

These furnaces are classical in Europe. Let us take the example of a 10 t furnace. It is a cylinder with horizontal axis and a lining of refractory bricks rich in alumina; a salt flux composed of 90 % sylvinite (KCl + NaCl) and 10 % spath fluor ($CaF_2$) is loaded. The amount of flux is 20 to 25 % of the weight of the metal. The flux is melted and heated to 750° C. It shields the scraps against the air and the burning gas, decreasing the melting loss. Moreover the flux is a detergent for alumina and allows the metal drops coalescence.

The scraps are then progressively loaded and vigorously stirred. If the flux becomes too thick it is fluidised by ..F additions.

As indication, a 10 t rotary furnace, with a holding furnace for the pouring and a pouring line may produce 40 t/day. Three shifts of seven men are then needed to load the furnace, survey the melting, pouring and ingots casing. For one worker at the melting, two workers are needed for the sorting (in the case of a hand sorting relatively carefull).

2,233 - Induction electric furnaces

Coreless induction furnaces, working at the netfrequence, of 3 to 5 t, are used (800-1 200 kVA). They cause a very little melting loss. They allows to make easily particular compositions.

2,234 - Crucible furnaces

For the recovery in little quantity the crucible furnace is convenient (low melting loss) : tilting furnaces (the most classical) or tilting and rotary furnaces around sloped axis.

2,235 - Sloped hearth furnaces

These furnaces are only used in the particular case of recovery of compound pieces (for example skeleton of plane). They allow with very limited means (no crushing) to make a sorting by liquation between white metals, light alloys, copper alloys, scrap iron. This sorting is relatively summary and gives an unclearly defined alloy. It may be however, in certains circumstances, an interesting process (see 6).

2,24 - Refining

The iron having been taken away during the preparation, it remains to decrease the magnesium content, and to take away gases and alumina. Moreover the composition must be ajusted.

2,241 - Magnesium elimination

Chlorine is used, but the temperature must be plainly lower as 1 000° C to avoid the formation of Cl Al. Generally, 750° C is chosen. It has been proposed to inject the gas by alignments along a generating line of a rotary furnace (10, 11).

A nitrogen flow is must first injected, then chlorine; a nitrogen flow is finally injected to drain chlorine from the lime. 50 kg of chlorine are needed to extract 10 kg of magnesium. A neutralization of the gasses is necessary before to throw up them in the atmosphere. Magnesium can also be taken away by fluorine fluxes (5).

2,242 - Alumina elimination

Alumina decants very slowly. In the works of virgin alumina, the molten metal is let to remain 24 hours to purify. It is hoped that an alike effect occurs in the large reverberatory furnaces.

In the rotary furnaces, that is the fluxes which agglomerate (or dissolve) alumina.

2,243 - Elimination of hydrogen, sodium, etc.

Hydrogen and sodium tend to escape from the melt during the melting. It is necessary to watch to reintroduce no hydrogen by water (stream) reacting upon the metal.

Particularly, hydrocarbides burning gasses are always rich in water. A flux layer separating them of the metal is necessary.

Treatments by gas bubbling (chlorine or nitrogen) quicken these impurities elimination.

2,244 - Additions

Copper is added under the form of good copper discarded articles (wire for example).

**Silicon** is added under the form of pure silicon, in pieces of a nut size. Silicon dust, generally very oxidised, efficiency of which is very bad, is not used.

**Phosphorus** (case of the high silicon alloys) is added through a low rate (5 for example) cupro-phosphorus, carefully dipped in melted aluminium.

**Titanium**, refining the grain, is sometimes added through $TiF_4$ or potassium fluotitanate.

2,25 - Pouring

Many kinds of devices are used, with ~~by~~ hand or automatically. An usual device is the ingot molds chain, stationary or movable. ~~The pouring comprises~~ There is a device allowing to stop the pouring when the ingot mold is full. The stripping comprises devices of cooling and extraction of ingots (striking). The chain which works in very hard conditions must be extremely strong.

The chain moves forward for example at the speed of 2 m/mn, corresponding to the pouring of 100 kg/mn of aluminium alloy.

Another device is the monorail with electric drive upon which are hanging frames sustaining for example nine ingot molds (7). The monorail makes the frames to go to the stripping place (cooling, extracting of ingots, mold coating) then before the furnace which is ready for pouring.

The ingots form can allow to obtain various sizes of ingots

The as cast ingot molds are in grey iron, hematite quality, their carbon equivalent being 4,2-4,3 % and they are relatively pures (better thermal shock resistance).

A refractory coating is protecting the ingot molds; for example :

- Water .................. 10 l;
- Chalk .................. 2,5 kg;
- Sodium silicate ........ 0,5 l.

During the pouring or after, the ingots must be marked (alloy grade and mark of the pouring). It is a costly but absolutely necessary operation. It can be done by hand (paint, with or without plate, etc.); or automatically (striking the mark on the ingot on the pouring chain, marking at the time of the ingots casing).

The ingot casing piles must be easy to move and arrange.

These ingots are stocked weather sheltered.

The ingot form itself requires study, but the chosen solutions are very various.

It is needed to think to :

- the strength of the ingot molds;
- the stripping;
- the stacking;
- the casing;
- the carriage (paletts);
- the loading in the foundry furnace.

## 2,3 - QUALITY INSPECTION

### 2,31 - The homogeneity of the batches

The liquid state allows an excellent homogeneization of the alloy, whichever furnace capacity.

For example in a reverberatory furnace of 35 t containing a secondary alloy, the following evalution was noted (12) :

| | beginning of pouring | middle of pouring | end of pouring |
|---|---|---|---|
| - Iron .......... | 0,52 | 0,52 | 0,54 |
| - Silicon ....... | 9,19 | 9,73 | 9,40 |
| - Magnesium ..... | 0,087 | 0,085 | 0,083 |
| - Copper ........ | 3,71 | 3,79 | 3,75 |

One must not let lose that homogeneity.

The marking of ingots by pouring is a measure which go in that way. It is necessary that all the ingots of one delivery to a foundry come from the same pouring.

2,32 - Chemical composition

Spectrographic determination (direct reading) allows easy control during the remelting and analysis adjustment. It is the choice method. The work is done on permanent mold cast specimen. The figure 4 shows a gray iron mold giving satisfaction. Spectrographs work by comparison with standard specimens. The results accuracy depends on the standard specimen set. It is necessary to watch to use specimens alike the tested alloys (to avoid synthetic alloys purer as the secondary alloys) and poured in alike conditions (influence of the phase fineness on the spectrographic answer).

Spectrographic control on ingots must be avoided because the scatter is larger, as shown by the following table

| Element | Content | Standard deviation on ingot | Standard deviation on disk | Maximum deviation for 2 sparks (disk) |
|---|---|---|---|---|
| Iron | 0,5 | 0,03 | 0,01 | 0,03 |
| Silicon | 9 | 0,4 | 0,3 | 0,9 |
| Copper | 3,5 | 0,15 | 0,1 | 0,3 |
| Zinc | 0,3 | 0,01 | 0,02 | 0,05 |

A current practice is to use the disk and to make 3 sparks discharges : if the difference between the values are no more than the maximum indicated in the last column of the table, the average value is adopted; if the difference is more than this maximum, others sparks discharges are made. Of course, this table is valuable only for the indicated alloy grade; it was drawn up from 76 deliveries to a foundry (12).

From the standard deviation signification, it may be seen that the scatter due to the analysis is important, concerning silicon.

Simples spectrometers have a fixed photoelectric cell used as reference and a movable cell which is placed successively in front of each ray (for example Cameca apparatus).

More powerful spectrometers have a cell for each element determined in a choosen composition range. There are so a number of channel doing the determinations at the same time (for example ARL apparatus).

All these direct reading spectrographs must be placed in a ~~climatised room.~~ air-conditioned room.

The specimens and results transmission must be fast (pneumatic tubes for example).

2,33 - Other controls

The other controls have very less importance.

The gas content may be estimated by the solidification of a 80 g specimen under pression of 60 tor. The observation of the solidifying surface (bubbles), the specimen growth, allows to know if a melt is gased (13).

Machining and polishing of a specimen allows to detect hard spots by the surface examination.

Mechanical properties may be controlled for the best grades, by permanent mold casting of tensile test bars (the die temperature must be accurately fixed).

The other controls are not worthy of commendation. It is the case of the fluidity the measure of which asks very great care and gives not much interessant results. It is the case of the alumina content the determination of which is not satisfying, in our mind, even with the method of oxygen neutronic activation. (14).

The micrographic inspection, if made by a competent man, may be useful (refining of silicon and high-silicon alloys, hard spots).

## 3 - COPPER-BASE FOUNDRY-ALLOYS

### 3,1 - REQUIREMENTS FROM FOUNDRIES

#### 3,11 - Coppers

Foundries use copper ingots and mix them with other metallic materials.

There are also some special castings made of copper on account of its electrical conductivity.

One method is to refine all the scraps into thermal copper. This solution is good, just in countries where the scraps are cheap. We just mention it.

Another method is to sort the scraps : pure copper (fire-box, wire-rope, wire, sheet, etc.) or deoxidized copper (sheet, rotating band of shell, bullets) and to treat them.

The common impurities which are prone to reduce conductivity are :

- zinc;
- tin;
- phosphorus;
- oxides.

Generally speaking the elimination of tin is not considered. On the other hand the oxidising melting reduces appreciably the zinc and phosphorus contents. At the same time some copper is oxidized; the copper oxide must be reduced. The usual process, with phosphorus, is forbidden.

The introduction of magnesium gives good results (50 % Cu-Mg alloy is better than pure magnesium). The quantity of magnesium added to the melt depends on the proportion of copper oxide. The first adding may be 0,05 % of the weight of copper scrap; if the deoxidation is not sufficient later addings ~~of 0,05 % of the weight of copper scrap; if the deoxidation is not sufficient later addings~~ of 0,01 % are made.

Finally the copper will be 99 % or 99,5 %.

### 3,12 - Bronzes

The bronzes with 14 % tin, or more, form a narrow market, which is unfavourable to the smelting industry.

The bronzes with 9-13 % tin are high quality alloys. The tin content must be accurate, on the account of the price of this element. This bronzes must be reasonably free of lead (maximum : 0,8-1,0 %); not easily eliminated by smelting; hence lead and leaded bronzes must be sorted out. In some specifications the zinc content is very low (e.g. maximum 0,5 %). Nevertheless, the elimination of zinc is expensive; now zinc contributes to the deoxidization in the foundry; thus in many specifications the zinc range is large (e.g. 0-2 %).

The harmful elements are the same for all bronzes : silicon, aluminium, sulfur. These elements reduce the quality of castings, specially the tightness. The specifications are generally :

- Si ......... $<$ 0,02 %
- Al ......... $<$ 0,01 % or 0,02 %
- S ......... $<$ 0,05 % or 0,10 %.

Phosphorus is kept at a low level (e.g. maximum 0,05 %); the foundryman has free scope to add it or not.

In the leaded bronzes (80-10-10, etc.), the silicon, aluminium and sulphur contents are specified as above. A high zinc content is allowed.

In all bronzes the iron content is restricted. Maximum for ingots is :

- 0,15 % for low zinc alloys;
- 0,25 % for less pure alloys.

On the other hand, nickel is allowed : it counts as copper until 2 %.

For all bronzes a correct chemical composition is not enough to secure good ingots. Gas included can make troubles for the foundryman.

3,13 - Brass

There is a very important recovery of brass from stamping and machining. This is out of our subject.

Brasses for foundries have not the same importance. Composition of brass for sand castings is :

- Cu ..... 63-67 %
- Pb ..... max. 1 %
- Sn ..... max. 1 % or 1,5 %
- Fe ..... max. 0,5 %
- Al ..... max. 0,05 %
- S ..... max. 0,05 %
- Si ..... max. 0,05 %.

Brass for permanent mold castings contains more zinc; there is also a deliberate content of aluminium in order to moderate zinc volatilization :

- Cu ..... 59-64 %;
- Pb ..... max. 2 %
- Sn ..... max. 0,8 %
- Al ..... max. 0,8 %.

It is worth noting that iron can create hard spots harmful for polishing and machining.

3,14 - Cupro-aluminium

Cupro-aluminiums are more and more popular. The risk to pollute the other copper alloys compels to sort out very carefully cupro-aluminium scrap.

The compositions of the cupro-aluminiums are not the same for sand or for permanent mold castings. For permanent mold castings we prefer to start with virgin metals.

On the contrary, there is a market for secondary ingots intended for sand castings. This ingots may contain iron, nickel and manganese. On the other hand zinc and tin must be avoided : sum of this impurities must remain below 0,8 %.

The aluminium content must be controlled in a narrow range : ± 1 % or better. The presence of aluminium gives to these alloys some physico-chemical characters of aluminium. Thus the oxidation-reduction process is unserviceable. The occurence of alumina is troublesome. Hydrogen is the only soluble gas; it is the indication of a careless smelting.

## 3,2 - CONSEQUENCES FOR TECHNOLOGY (3, 4, 15, 16, 17)

Copper is easily reduced or oxidized (15). Hence more oxidable elements can be removed by chemical means. This principle is good for coppers and for bronzes. A severe sorting is not necessary.

It is not the same for brasses or for cupro-aluminiums : Zn or Al are lost by oxidizing. The sorting of these alloys must be very careful, since there is no adjustment by chemical treatment.

### 3,21 - Stocking

See aluminium section (2,21).

### 3,22 - Preparation

#### 3,221 - Manual sorting

It is the main method for discarded articles. The sorter uses his knowledge of industrial parts and makes simple tests (See aluminium section). One may [illegible] the Brinell test, which allows to class bronzes according to [illegible] content :

| Brinell Hardness | Tin % |
|---|---|
| below 80 | below 8 |
| 80-95 | 8-12 |
| 95-115 | 12-14 |
| above 115 | above 14 |

Fast analysis is useful (for instance drop test, measure of the electrochemical potential or better spectrography). Aluminium deserves special attention : the bulk of its content goes out easily, but minor traces are troublesome. Hence it is necessary to pick out aluminium-base alloys, cupro-aluminiums and manganese bronzes (aluminium containing brasses).

3,222 - Automatic sorting

The usual task is to separate white metal and copper base alloys.

Shaking and screening allow a rough separation of small chips of white metal from larger turnings or drillings of red metal. Shaking is more efficient if the mixture is heated at a temperature between the melting point of white metal and the copper alloys one.

A good device is the furnace with rotating screen (16).

The cylindrical screen is made of heat and wear-resisting steel wire (25 meshes) : it rests on a perforated cylinder (diameter of the holes : 5 mm).

The diameter of the cylinder is about 0,80 m. It is better when the section is hexagonal. Longitudinal and internal ribs improve the shaking. The cylinder stands at an angle of 10° to the horizontal. The speed ranges between 10-15 R.P.M.. The temperature must be uniform, about 400-450° C.

3,223 - Drying

Various ways are possible : centrifugation, hot water with cleaning products, etc.. Frequently the stoving is prefered (kiln-type drier).

3,224 - Magnetic separation

The magnetic sorting is cheap and very useful. It is employed with dry scrap, eventuelly after crushing.

3,225 - Briquetting

Briquetting is rather frequent for copper scrap. This operation requires a good press (7,5 $t/cm^2$), so as that the density be 75 % of the compact alloy one.

Briquetting reduces the melting losses; nevertheless this advantage is questionned and briquetting is not in use everywhere.

3,23 - Smelting and refining

3,231 - Coppers

We just mention the water-jacket.

Frequently smelting is done in semi-rotating furnaces with oil heating; the capacity reaches 15 t and still more. Lining is made of alumina-rich bricks (70 % alumina) and with stands 500 operations. These furnaces have a large opening on the top : thus large parts can be loaded.

The melting is done with oxidizing atmosphere, in order to eliminate impurities : Al, Zn, Si, Fe, Mn, Pb, Sn. After the oxidizing melting and a careful clearing, the reducing is done by stirring with a perch.

3,232 - Bronzes

The refining of bronzes is specially important. The principle is the same as for coppers : oxidizing and reducing. The furnaces are of the rotary-type (15 t), as in 3,231.

The smelting is made with or without slag.

The refining with slag gives generally better alloys. The slag is used for several melts; its fluidity is kept up with addings of spath fluor.

A good scorification of the oxides is obtained with the following mixture :

- Borax ...... 15 %
- $CO_3Ca$ ...... 25
- $CO_3Na_2$ ..... 35
- $SiO_2$ ....... 25

Some prefer bottle glass (green glass), which is inexpensive; but there is no chemical effect on to the melt.

The layer of the slag is 5-10 cm thick over the surface of the melt, thus 400 kg in a 5 t furnace. The oxidation is activated by bubbling air.

The refining without slag brings about progressive oxidation, by air, of Fe, Zn, Si, Mn, Al.

Some of the oxides produced stick on the lining : after some heats the furnace is washed with a flux ($CO_3Na_2$ + $SiO_2$); the metallic silicates are reduced by adding of pulverulent coal and thus metals recovered.

The final reduction is done by cupro-phosphorus. Sulfur is brought by combustion gas. The fuel oils with low sulfur content are preferable. Sulfur can be removed by treatment with $CO_3Na_2$ or by adding of magnesium. The latter process gives also MgO, which does not decant easily and reduces the fluidity.

The typical operation in a rotary furnace (5 t) is :

- Melting .................. 3 h;
- Air injection ............ 20 mn;
- Deoxidizing (P) ........... 15 mn;
- Tapping ................... 45 mn.

In some plants the treatment of the melt by chlorine or by the mixture $Cl_2N_2$ is possbile (18).

It is payful to keep a close eye on the refining operation. If the oxidizing stage is too hard, valuable elements are wasted (Sn, Zn, Pb). If the oxidizing stage is not sufficient, a certain amount of iron, aluminium, gasses are retained in the metal, with serious troubles for the foundryman.

3,233 - Brass

The small batches of turnings, drillings, etc. go usually to the smelter, which brings them together and remelts. The ingots thus produced are sold for sand or permanent mold casting. The smelting process is simple : there is no gas to fear. Generally the brass scrap is melted in crucible-furnace (low melting losses); the alloy is just cleaned with ClNa at the end of the melting.

3,234 - Cupro-aluminiums

Cupro-aluminiums are remelted under a slag (cryolith or $F_2Ca$). For the alloys which contain mangan, $Cl_2Mn$ is sometimes used : $Cl_2Mn$ degasses strongly, but brings a little mangan into the alloy.

There is no elimination of impurity : the previous sorting must be very careful.

## 3,3 - QUALITY INSPECTION

### 3,31 - Homogeneity of the batches

Specially with bronzes, it is worth to take advantage of the homogeneity of each melt. The chemical composition does not define completely a batch of bronze ingots. Then it is necessary, that the foundryman receives separate batches, each collecting ingots from a single melt of a single charge.

The homogeneity of a good melt is remarkable. Here is a typical example (12 t rotary-furnace) :

| | Beginning of melting | Middle of melting | End of melting |
|---|---|---|---|
| - Cu | 84,04 % | 84,05 % | 84,12 % |
| - Sn | 5,03 | 5,03 | 5,04 |
| - Pb | 4,74 | 5,03 | 4,96 |
| - Zn | 5,13 | 4,89 | 4,83 |
| - Fe | 0,335 | 0,315 | 0,290 |
| - Ni | 0,445 | 0,450 | 0,450 |
| - S | 0,070 | 0,073 | 0,075 |
| - P | 0,052 | 0,036 | 0,026 |
| - Sb | 0,17 | 0,17 | 0,185 |

Alone the phosphorus content changes strongly.

There are other examples in (20).

The chemical analysis allows to test easily if two ingots are from the same melt : the percentages of the impurities are like finger-print of the alloy. For instance, the spectro-analysis should not give differences larger than the following values for two ingots from the same melt :

| | difference max. |
|---|---|
| - Ni | 0,02 % |
| - Sb | 0,03 |
| - Sn (< 1,5) | 0,16 |
| - Fe | 0,02 |

3,32 - Chemical composition

The choice instrument is the direct reading spectrograph. It gives the percentages of 8 or 9 elements in few minutes. The rapidity of the test allows one more analysis when there is a composition adjustment.

There are some data on the accuracy of spectrographic analysis in (20).

It is worth noting that spectrophotometry gives the analysis of some elements in 15 mn (19).

3,33 - Test of degassing

The solidification under reduced pressure is useful for coppers, bronzes and cupro-aluminiums. If the metal is gassy, there is enough time to cure it before pouring. A good practice is to pick up 150 g of liquid metal and to put it under reduced pressure (60 Tor).

3,34 - Test of melting under borax (21)

The quality of the ingots can be tested by the melting under borax. A bulky specimen (2 $cm^3$) is weighted, then set into a porcelain crucible placed in an electric furnace and filled with fused borax. Pure tin is added, in a weighted amount, so to bring the copper content to 65 %. The crucible is holded at a temperature a little below 900° C. The weight loss measured on the metallic button gives the percentage of substances which are collected by the borax. A loss of 0,5 % is generally regarded as acceptable.

3,35 - Other tests

The ingot surface is alway inspeced. The lack of spitting is required.

The fracture test is common, but its interpretation is difficult. A slice of the ingot is broken along its axis. The surface must be free from light yellow spots, from blows and from slag inclusions.

The mechanical properties are rarely tested; yet it would be very interesting.

The fluidity test is not recommandable.

The microscopical examination is of some aid for the study of hard spots.

4 - OTHER ALLOYS

The foundry industry is not very much concerned by the other base-metals. For instance the zinc alloys used in pressure diecasting are necessarily virgin alloys, with the greatest purity; the remelting for its return is merely allowed.

The recovery of magnesium is common in foundry (risers, sprues, etc.). It is worth noting the simple cleaning device proposed by (22).

Few lines about white metals are in 3,22. It will be highly profitable to read the review of the methods used in South Africa 30 years ago (23) : it refers a very good practice in the case of the alloys for railways.

## 5 - ECONOMICAL ADVANTAGES OF CASTINGS

It is necessary to recover metals, specially those which are bought with foreign currency.

Before thinking to recover, it is good to avoid wastes. The varied means of working metals do not produce waste metals in the same proportion. Stamping, at this point of view, is an expensive methode. Machining also. Cuttings, turnings, borings, etc., even recovered in the best way, cause metal loss. The slogan "chip is the enemy", which had its day in France, is, perhaps, valid in other countries : a chip involves a time loss, a mechanical energy loss and a metal loss.

In comparison, foundry is one of the more metal saving methods : it gives castings machining of which is small, or parts to use as cast. Foundry makes few waste, and reuses it completely. Moreover alone foundry can make use of some secondary alloys, the purity of which is not sufficient for the other working methods.

In return, drawing cast parts require more technical knowledge than drawing parts assembled with bolts, rivets, or weldings. May be there is here a programme about technical teaching, with important economical consequences : to teach people who draws parts how to get a better use of foundry.

## 6 - CONCLUSION

There is another way to save metal : to reduce stocks in the smelting plants and in the foundry plants. Standardization of alloys is a part of the way. We know that the common trend is proliferation of the kinds of alloys. Sometimes there is a good reason for that (new alloy); more often there are not any grounds. Frequent debates between producers and customers allow to agree upon simple and short lists of recommended alloys. ISO documents give a solid basis. But ISO is an international work : for one country there are generally too much alloys. It is to developing countries interest to pich up some of the alloys determined by ISO.

The chemical composition limits must be specified thinking of scrap supplying, of technical means of smelting works, and of the kind of castings to be made. It is also worth thinking of scatter or analysis. For bronzes and coppers, specification must not rest only on chemical composition. For all alloys it is indispensable to deliver homogenous batches from one melt of one charge. The great thing is to try to specify the quality at the adequate level, not too high, not too low.

Making and following specifications with a correct number of alloys, and with good limits on chemical compositions is probably a useful factor of the saving of metals.

## SUMMARY

### 1 - INTRODUCTION

1,1 - The economical and the juridical data are the great thing for the industry of recovery.

1,2 - The foundry industry can use alloys of relatively scattered compositions, and is naturally an important customer of secondary alloys.

### 2 - ALUMINIUM ALLOYS

2,1 - Foundry needs general purposes alloys, corrosion resisting alloys, heat resisting alloys, which can be supplied by smelting industry. Chemical stipulations are described for the common elements. The importance of some nonmetallic impurities is emphasized.

2,2 - Consequences for technology.

The aluminium oxidation is easy and non reversing : thus the sorting of materials has a great importance ; storage, hand and automatic sorting, preparations of scraps, discarded articles and dross.

Melting in reverberatory furnace, in rotary furnace, sloped hearth furnaces, etc.

Elimination of Mg, $Al_2O_3$, $H_2$, Na.

Pouring devices.

2,3 - Quality inspection.

Homogeneity of the batches, check of chemical composition.

## 3 - COPPER BASE ALLOYS

3,1 - Foundry uses "coppers", bronzes, a little brass, cupro-aluminiums for sand casting, from the smelting industry. Chemical stipulations are described for the common elements.

3,2 - Consequences for technology.
Copper is easily reduced or oxidized. Hence a severe sorting is not necessary for "coppers" and bronzes. On the contrary brasses and cupro-aluminiums must be sorted very carefully, because Zn and Al are lost by oxidizing.
Storage, manual and automatic sorting, preparation, briquetting.
Smelting of "coppers", bronzes, brasses, cupro-aluminiums.

3,3 - Quality inspection.
Homogeneity of the batches, check of chemical composition, melting under borax and other tests.

## 4 - OTHER ALLOYS

## 5 - FOUNDRY AS METAL SAVING INDUSTRY

The foundry industry is one of the more metal saving methods : few chips, possibility of using secondary alloys. In return the drawing of cast parts requires more technical knowledge than the drawing of assembled parts : to consider the utility of a programme about teaching of the good use of castings.

## 6 - CONCLUSION

A good standardization, setting the quality level at the right place, can reduce stocks and save metals.

## REFERENCES

(1) - Recommandations ISO :

Al : R.164 (juillet 1960); R.208 (juillet 1961;
Cu : Draft, ISO/TC26 - GT3; doc. n° 240 (août 1965).

(2) - DROUZY M.- Revue de Métallurgie, février 1967, p. 185-201.

(3) - SCHEUER E.- Metallurgical Reviews(LONDON), 1956, vol. 1, part 3, p. 339.

(4) - SCHEUER E. et alia.- Institute of Metals Informal Discussion. Metal Industry (London), 4 march - 1 april 1955.

(5) - SCHNEIDER K.- Die Verhüttung von aluminiumschroot. BERLIN 1950.

(6) - Anon.- Iron Age, march 23, 1961, p. 86.

(7) - L'industrie de l'aluminium de deuxième fusion aux Etats-Unis. O.E.C.E., Mission d'assistance technique n° 19 (1952).

(8) - F.H. SMITH.- "The recovery of aluminium from waste products". Society of Chemical Industry, 1956, LONDRES.

(9) - P. BARRAND et R. GADEAU.- L'Aluminium, tome I, p. 883-912, PARIS, 1964.

(10) - W. DAUTZENBERG.- Metall, avril 1960, p. 125-129.

(11) - K. KURSKI.- Hutnik, 1955, p. 409.

(12) - Rapport non encore publié du Centre technique des Industries de la Fonderie (Paris, 1969).

(13) - C. MASCRE et A. LEFEBVRE.- FONDERIE, n° 131, décembre 1956, p. 496. FONDERIE, n° 161, juin 1959, p. 272-273.

(14) - BERTOLDI S., CASA VOLONE F.- Aluminio, vol. XXX, n° 10, octobre 1961.

(15) - M. CIROU.- Fonderie, n° 76, mai 1952, p. 2927-2937.

(16) - THEWS E.R.- Metal Industry (LONDON), 21 décembre 1951, 11 janvier 1952.

(17) - R. LOISEAU.- Fonderie, n° 156, janvier 1959, p. 3-12.

(18) - J. MUMMER et W. BUCHEN.- GIESSEREI, 27 août 1959, p. 497.

(19) - NIGAUD L.- Congrès de l'Association technique de Fonderie française (1969).

(20) - ARNAUD D., KUHN V.- Fonderie, n° 248, octobre 1966. p. 383.

(21) - ARNAUD D.- Fonderie, n° 215, janvier 1964, p. 26.

(22) - KITTILSEN B.- Affinage des retours en fonderie sous pression de magnésium. 6ème Congrès international de la Fonderie sous pression (PARIS, 1969).

(23) - SIDEY A.B.- Proceedings of the Institute of British Foundrymen (1942-1943), 36, p. 277.

(24) - Le marché européen des déchets de métaux non ferreux. O.C.D.E., PARIS, 1961.

(25) - DUMONTET J.- Revue de l'Aluminium, janvier 1966, p. 71.

(26) - L'industrie des métaux non ferreux en 1964. O.C.D.E., PARIS 1965.

(27) - L'industrie des métaux non ferreux en 1967. O.C.D.E., PARIS 1968.

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