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NEW PROCESS OF DIRECT METAL RECOVERY FROM DROSSES IN THE ALUMINUM CASTHOUSE

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SUMMARY

Traditional methods of aluminum recovery from drosses mean : transportation outside the casthouse, high energy consumption and pollution problems by fumes and dumping of oxides and salt. The newly developed process permits extraction of liquid metal by simple compression of drosses. The recovery rate is better than any other known process, while cost is much lower. Industrial tests have established that aluminum extraction by compression can be carried out on drosses of all major alloys, and is compatible with standard remelt or alloying procedure of each casthouse or foundry. Further the metal can be recycled immediately in the same furnace.

INTRODUCTION

The reactivity of aluminum, especially with oxygen, causes melt losses by formation of drosses in all casthouses and foundries.
The amount of drosses produced is very different dependent on the type of operation. Minimal for the simple holding of liquid aluminum in primary smelters to large quantities in remelting of scrap. However in all cases, considerable quantities of non oxidized aluminum are entrained in the dross, giving costly melt losses. Therefore foundry engineers have developed many processes permitting the partial recovery of aluminum out of drosses.

Most of these processes involved following stages :
- Cooling of drosses
- Transportation to dross treatment plant
- Crushing, screening and elimination by dumping of the fine fraction.
- Remelting of grains, sometimes in molten salt bath, and again dumping of residues.

The well known disadvantages are :
pollution by fumes, dust, dumping of salt residues, high energy consumption, labor and maintenance expenses, unpleasant work conditions, and generally poor recovery rates.

Several engineers of the Pechiney Group began working on an other idea in the late seventies :

The extraction of liquid metal directly by compression of the hot drosses, just after skimming of the furnace. In this case all the above listed problems disappear. Concerning the metal recovery rate, even better results could be expected because the burning of metal before and during cooling is avoided. Many experiments were perfomed using pilot equipment :
- Trials on small scale in the research laboratory of Voreppe.
- Compression of 30 kg (66 lb) and later 150 Kg (330 lb) dross charges in different reduction and fabricating plants.

During those years a lot of difficulties had to be surmounted but the metal recovery results met expectations, surpassing by far the recovery rates of conventional processes.

A prototype industrial compression equipment has been started up in early 1985 at the Neuf-Brisach fabricating plant. The dross production is over 5000 m. t./year and the batch dross charge about one ton. A second industrial press with a similar capacity is under erection at another plant of our Group.

Several other projects are being studied by Pechiney Aluminum Engineering under the trade mark COMPAL. The corresponding number 2559 786 patent was registered in France on August 23rd 1985. (Inventors : J. Julliard, L. Tirilly, P. Vigier) Extensions to other industrialized countries have been applied for.

DESCRIPTION OF THE COMPRESSION EQUIPMENT

Main characteristics of the Neuf-Brisach equipment are :
- Compression takes place in a cylindrical container, volume 750 liters (26 cu. ft.) corresponding to one metric ton of dross.
- Compression force : 600 m.t., power 100 KW
- Peripheral equipment : Tilter to fill the dross containers, automatic charger, cleaning station.

Before operation, the cylindrical dross container has to be preheated by a gas burner. After draining the hot drosses are fed into the dross container which is transferred under the press by the charger. The hydraulic press squeezes the aluminum out of the drosses. The liquid metal flows into the bottom and is collected in an ingot mold. After compression the container is raised to release the dross cake which remains on the bottom plate. The bottom plate with the dross cake is conveyed to the cleaning station where the dross cake is discharged by tilting. The bottom and dross container are reassembled.

The total time is 15 to 20 minutes per unitary load (including transfer times). The main compression cyclus is explained on the skeleton diagram below. (See figure 1).

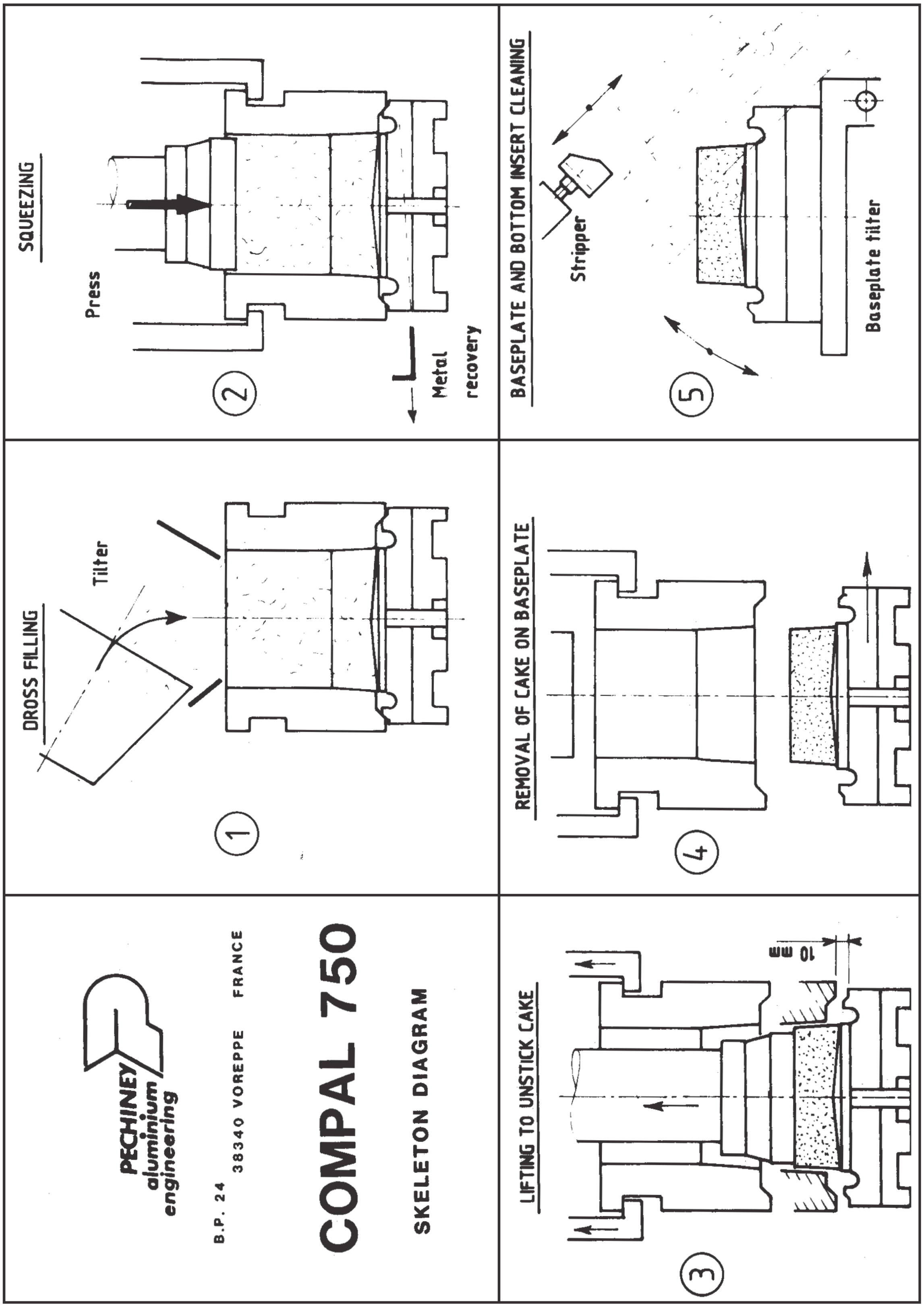

Figure 1 : Dross compression skeleton diagram

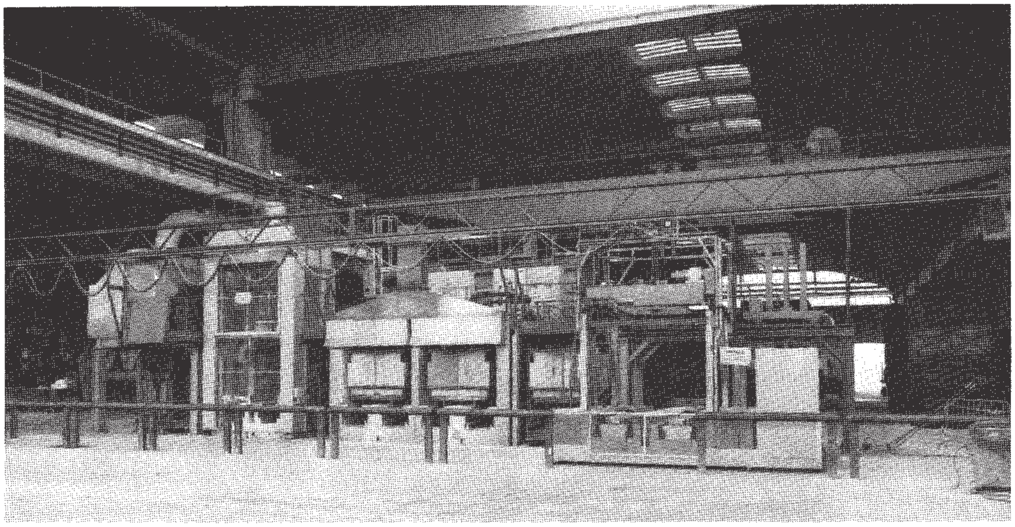

Figure 2 : General view of the Neuf-Brisach equipment.

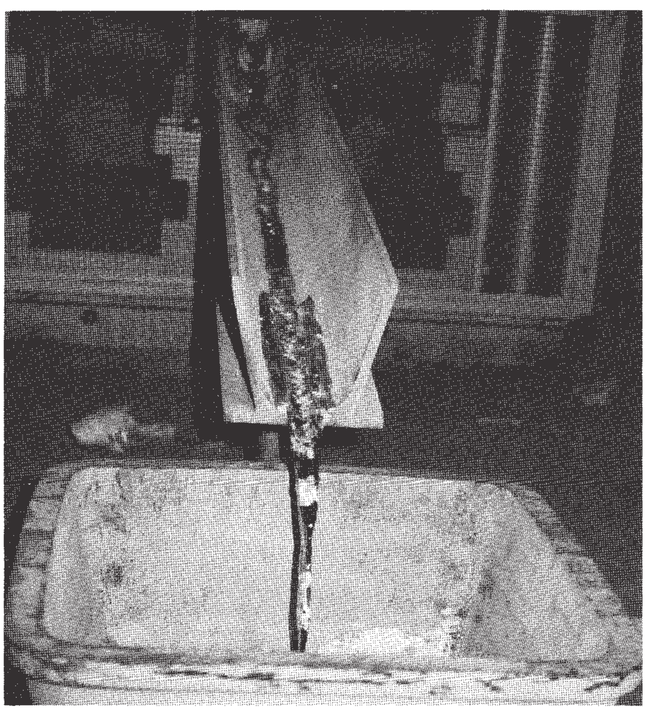

Figure 3 : Liquid metal flow

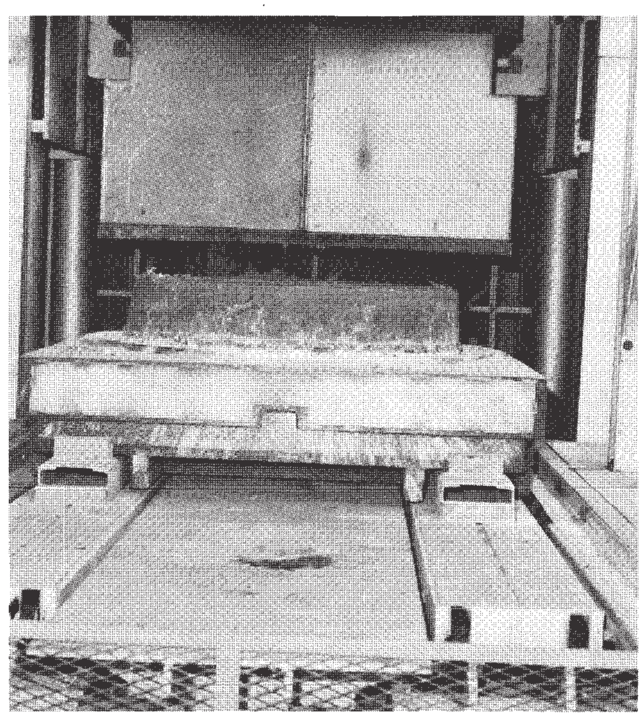

Figure 4 : release of dross cake

METAL RECOVERY RESULTS

The given figures are results obtained with the pilot equipment (150 kg unit load) and the new equipment in Neuf-Brisach (1 m.t. unit load). They are not labor results but based on industrial practice in normally producing casthouses.

Dross composition

For the understanding of the recovery rate, it is essential to know the metal percentage contained in the drosses.

To measure this percentage, the following method was used :
- A sample of 3 to 4 pounds is taken with a sample spear in several drawings when the drosses fall over the furnace sill during the drossing operation.
- The sample is cooled quickly by spreading on a thick aluminum plate.
- The sample is remelted after by mixing with molten salt to prevent oxidation (Na Cl - K Cl). After accumulation of the metal in the bottom of the salt bath, the salt containing the oxides and the metal are cast separately.
- The solidified salt is carefully ground to release all the contained small metal balls.

The total weight of extracted aluminum, related to the initial weight of the dross sample, gives the percentage of contained metal.

The representativeness of the sampling was also tested : In several cases the total amount of drosses from the furnace was remelted under excess addition of salt. The recovery rate obtained by this method was equal to the one obtained by the above descripted samples.

The experiments involved most usual aluminum alloys and were performed in scrap remelting foundries as well as primary casthouses.

The typical values found are :
70-80 % when the furnace is loaded whith liquid primary aluminum (alloying furnace).
70-90 % when the furnace is loaded with scrap.

These percentages corresponding to normal industrial practice are probably higher than expected, but it must be considered that they are measured immediately after drossing the furnace, before draining and before any loss of metal by oxidation during cooling. The following example can be given for the distribution when the drosses are processed after cooling :
- 75 % Al contained after drossing
- 72 % left after draining of 10 % of initial weigt
- 45 to 60 % metal contained after cooling (The value of 60 % means that a very efficient cooling process is used).
- 30 to 50 % metal can be extracted from the cooled drosses, depending on the dross treatment process.

This example shows that a lot of metal can be lost during the initial cooling of the drosses, and explains why we can expect higher recovery rates from hot dross processing.

Metal recovery rate by compression

In the tests the metal recovered by simple draining and by compression was weighed separately. Draining of drosses is a usual procedure and completely independent from the compression in a second stage. However, as the metal content of drosses was measured by samples taken during skimming, it was necessary to determine the weight of drained metal. We had thus all data necessary to calculate the metal content of drosses after draining.

Md = Metal recovered by draining
Mc = Metal recovered by compression
C = Weight of dross cake, after compression
D_o = Initial weight of drosses
D = Weight of drosses after draining
m_o = Initial metal content of drosses (before draining)
m = Metal content after draining.
r : recovery rate by compression

We can write following formulas :
Weight of drosses after draining : $D = D_o - Md$
Metal content after draining :

$$m = \frac{m_o D_o - Md}{D_o - Md} = \frac{m_o D_o - Md}{D}$$

Compression recovery rate :

$$r = \frac{Mc}{D}$$

Of course the important result is the compression recovery rate r. This result must be considered in relation to the metal content after draining m.

Tests were perfomed in different types of casthouses :
- A primary casthouse working on liquid metal from the potlines.
- Shops remelting scrap.

A large range of alloys were tested including :
- Pure aluminum (1000 series)
- Al_Mg alloys (5000 series)
- Al_Mn alloys (3000 series)
- High silicon casting alloys (7 to 13 % Si)

Under normal operating conditions the result was :

$$37{,}5\ \% \leqslant r \leqslant 61{,}2\ \%$$

The mean value is : r = 50 %

Discussion of the results

The recovery rate r was analysed as a function of the percentage of metal contained in the drosses after draining : m

We set : $r = K \cdot m$

The variable K is the real efficiency, or performance rating, of the metal recovery process. K was determined for the different tested alloys, as a function of the variable m. Figure 5 - shows K as function of the metal contained in drained drosses.

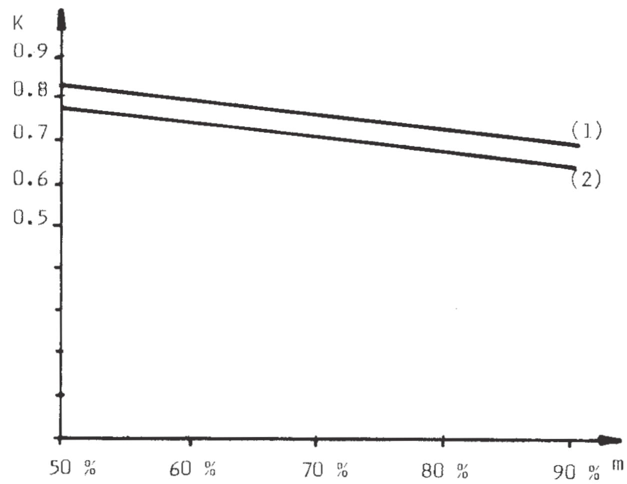

Figure 5 : Compression efficiency

The curve (1) represents high silicon casting alloys (7 to 13 % Si) and the curve (2) pure aluminum (1000 series) and other usual alloys for rolling or extrusion products (3000, 5000 and 6000 series).

These curves indisputably prove that the compression process can be used with similar efficiency on normal drosses (m > 65 %) and also when the metal content is very low (about 50 %). Surprisingly the process even seems more efficient when the metal content is lower : It is a fact drosses with as low as 40 % metal have been processed succesfully.

It appears also that high silicon alloys are more favorable than, for instance, pure aluminum. This is easy to explain by the difference in solidification temperature (liquidus value).

Pure aluminum : 660°C or 1220° F

High Si alloy : 575-600°C or 1067-1112° F.

It can be observed that most current alloys can be found between these two extreme values.

COMPARATIVE EVALUATION OF THE PROCESS

We shall examine what dross treatment by compression means pratically and compare the general flow sheet in different cases.

Conventional processes

What we call conventional dross treatment is :
- Cooling of drosses
- Crushing and screening to obtain a higher aluminum content on grains (optional)
- Remelting the coarse fraction directly, and the medium fraction under molten salt.
- The fine fraction and dust have to be dumped.

These stages can be combined in different manners, depending on nature of drosses and local economic conditions. The metal recovery rate can vary from 30 % to 50 % for the same drosses. The highest recovery rate will be obtained without crushing or screening, by directly remelting the drosses under salt bath in a rotary furnace, but of course the treatment cost will be correspondingly high. On the contrary, the remelt of only enriched size fractions obtained by crushing and sieving is cheaper, but metal will be lost in the dumped fine fractions. We shall compare the compression process to two conventional processes, chosen because they are considered as most competitive until now.
- Direct remelt process (direct remelting of drosses in salt bath without crushing or screening).
- Crushing process (supposed combined to a very efficient cooler and optimum settings of the equipment)

We suppose that drosses can be drained in every case with the same rate. Therefore draining will not be taken into account in the following paragraphs, and the considered production of drosses will be the production of drained drosses.

The figures of the flow sheets are set for the example of a plant producing 3000 m.t./year drosses.

Direct remelt process

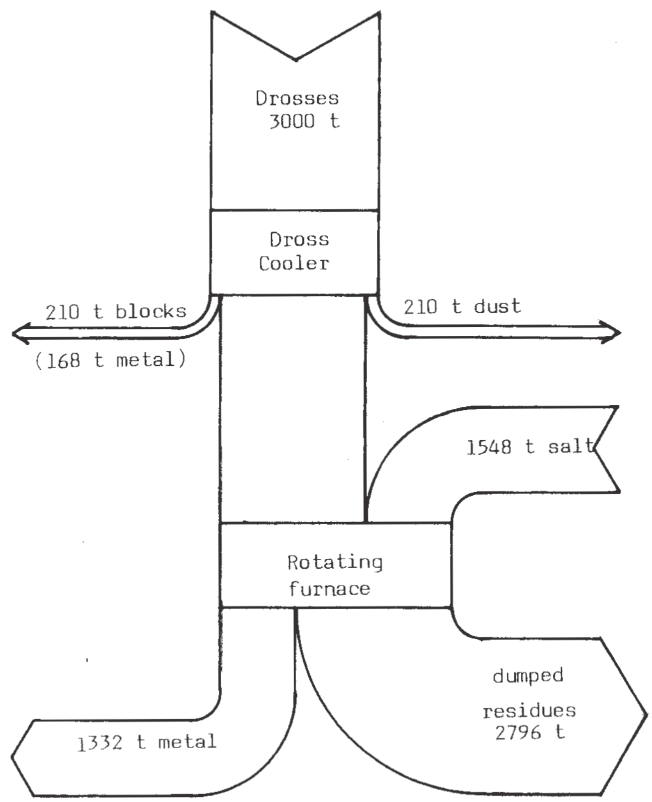

Figure 6 : Direct remelt process flow-sheet.

When a rotating dross cooler is used, the drosses will split up in following fractions :
1) 210 m.t. metallic blocks over 3 inches (7%). They can be remelted directly in casthouse furnaces with a recovery rate of 80 %.
2) 2580 m.t cooled drosses (86 %). When the cooling process is very well conducted, the metal contents can be as much as 60 %. Such drosses can be remelted directly in a rotating furnace with addition of 60 % melting salt, the recovery rate being about 51,6 %. That means that 1548 m.t. salt will be used for the recovery of 1332 m.t. of metal.
3) 210 m.t. of dust from the air filter which has to be connected to the cooler (7 %). This dust usually contains less than 20 % aluminum, which cannot be extracted. In some reduction plants dust is recycled in the potlines, otherwise it has to be dumped.

Crushing process

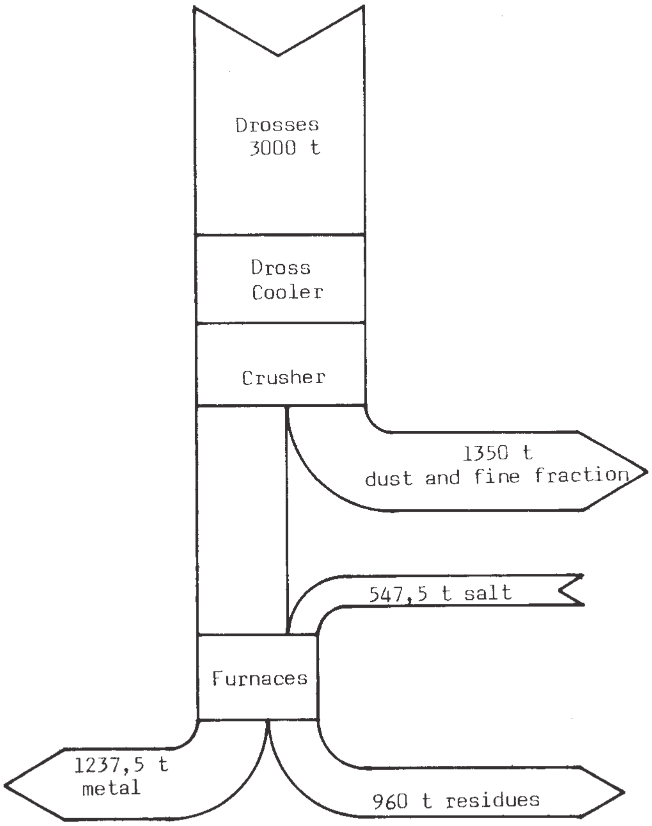

Figure 7 : Crushing process flow-sheet

When the process is well conducted the corresponding flow-sheet will give :
1) 750 m.t.(25 %) coarse grains over 1/8 inch. They can be remelted with some difficulties in a specialized furnace with addition of 25 % salt. The recovery rate will be 75 %.
2) 900 m.t. small grains over 0.01 inch (30 %). They need recycling in a rotating furnace with addition of 40 % salt, the recovery rate being about 75 %.
3) 1350 m.t. (45 %) dust and fine grains with less than 30 % aluminum contained have to be dumped.

Comparison with the compression process

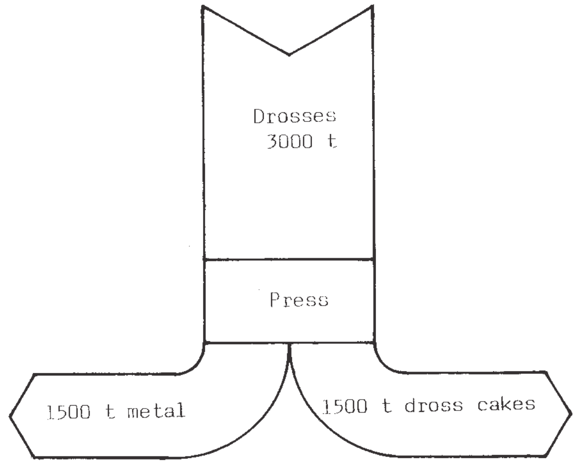

Figure 8 : Compression process flow-sheet.

By compressing the hot drosses we can directly extract 1500 t aluminum (50 %). The only residues produced by the COMPAL process are 1500 m.t. dross cakes.

The three flow-sheets let appear considerable differencies in the amounts of recovered metal, used salt and dumped residues (See table 1).

Table 1

in m.t.	Recovered metal	Used salt	Residues
Direct remelt	1 500	1 548	3 006
Crushing	1 237.5	547.5	2 310
Compression	1 500	----	1 500

The most polluting element in the reject is salt, because it is easily in solution and pollutes the ground water. Therefore in most countries environmental regulations prohibit the opening of new dumping places for salty residues, and existing dross treating plants are under strong pressure to reduce their salt rejects. The comparison between the direct remelt and crushing process shows that with conventional processes the metal recovery rate increases with the salt consumption.
On the contrary, by compression we can obtain a recovery rate as good as the most efficient conventional process, without using any salt.

The dross cakes contain usually 20 to 30 % aluminum, the rest being mainly oxides (Al2 O3,MgO...) which do not dissolute in water. Pollution by undegradable products contained in smelting salt is avoided (Na Cl, KCl, CaF2, Ca SO4...)
From the ecological point of view, we can thus conclude that treating drosses by compression brings a drastic improvement in nuisances caused by industrial residues.

ECONOMIC EVALUATION

The economics of a new process needs considering the situation and characteristics of each, cast shop :
dross production, metal percentage, initial dross treatment process when existing... No general answer can be given but we shall discuss two examples giving an idea of the cost benefits.

At the moment the equipment in service is used in a big rolling plant producing 5000 m.t/year drosses. We have the corresponding knowledge on operating cost and can extrapolate it down for 3000 m.t/year (This can be the dross production of a primary smelter producing 200 000 m.t. aluminum per year) These two situations will be taken as examples.

Compal operating cost

Labor : The equipment working automatically except for the loading of drosses and removal of cakes, one operator present around the clock is enough to run it.

Energy : the gas or fuel consumption to maintain two compression containers at the right temperature is supposed independent from production.

The other expenses are mainly container replacement cost and maintenance, supposed proportional to the amount of compressed drosses.
Summing up :

Labor		100,000
Gas consumption		25,000
Total fixed costs	$	125,000
Diverse expenses	$ /m.t.	2.00
Maintenance		12.00
Container replacement		36.00
Dumping of cakes		5.00
Total variable expenses	$ /m.t.	55.00

For 5000 m.t. drosses per year :
The annual operating cost is $ 400,000 for 2500 m.t. recovered metal (160 $ /recovered m.t.).
For 3000 m.t. drosses per year :
The annual operating cost is $ 290,000 for 1500 m.t. recovered metal (193 $ / recovered m.t.).

Operating cost of conventional processes

Conventional processes are more complex and the total recovery cost must be split up in sections. The amounts given are based on industrial experience under normal economical conditions.

- Cooling of drosses : 20 $/m.t. drosses.
This cost can be achieved with an efficient equipment working automatically. It includes mainly maintenance, and no labor.
- Crushing and screening : 20 $ /m.t. drosses, including mainly maintenance and labor.
- Recovery of metal by direct remelting of drosses in rotating furnace : The split up will be different, depending if this part of the process is performed at the producer plant or by a secondary smelter who has the advantage of processing a larger amount.
In this last case which is the more usual, transportation costs and the margin of the secondary smelter must be added.
Experience shows that we can retain the same total cost in both cases (processing by producer or secondary smelter) :
175$ /m.t. drosses (350 $ /m.t. recovered metal), when the cooled drosses are remelted diretly in a rotating furnace, with a metal recovery of 50 %.

When remelting grains with a higher recovery rate of 75 %, saving in salt, energy and labour can be made which allow a reduction to 150 $ /m.t. drosses. (200 $ /m.t. recovered metal). These costs include dumping of residues.
- The compression process permits recycling of the recovered metal directly into the same furnace. By contrast, with conventional processes, drosses from different alloys are mixed together and the composition of the recovered metal is variable : valuable alloying metals as Mg are burnt, impurities as Fe increase, and all other additions will be present together.
Recycling of this metal will be more complicated and we can count at least 20 $ /m.t. loss on alloying elements.
- Conventional processes imply a necessary delay between production of drosses and recycling of metal. If we admit an average time of 1 month before recycling corresponding financial charges are 12 $ /m.t. metal, taking the interest rate 12 % and the metal value at 1200 $ /m.t.
- Dumping cost is included in the processing cost given for remelt in salt bath. For dumping of residues containing no salt (compression cakes or dust) we take the cost at 10 $ /m.t.

Comparison of processing costs of conventional and compression processes

We have established the balance for each of the two conventional processes, compared to the compression process. The metal value is taken at 1200 $ /m.t.

The balance demonstrates clearly the reduction in processing cost for the compression process.
In the chosen examples the conventional processes bring additional expenses between $ 271,600 and $ 826,000 (See table 2 below).

We can thus state positively that for new plants, when a complete dross treatment plant is required, treatment by compression is the best solution. Even for the cases of plants with existing dross processing equipments, or using already a cooler, the compression process must be considered.
It appears that for plants producing large amounts of drosses, the substantial possible gains permit the pay-back of the compression investment in a short time

The equipment, such as it used in Neuf-Brisach, is very well adapted to a large plant producing more than 2000 m.t. drosses per year.

The process being now well known, we intend to design a smaller compression equipment offering the same advantages in smaller plants.

Table 2 : Comparative evaluation of operating costs in US $

	3000 m.t. drosses		5000 m.t. drosses	
Compression process	290 000		400 000	
	Direct remelt	Crushing	Direct remelt	Crushing
Metal recovery diminution	-	315,000	-	525,000
Cooling	60,000	60,000	100,000	100,000
Crushing	-	60,000	-	100,000
Dross or grain processing	451,500	247,500	752,500	412,500
Alloying element loss	30,000	24,750	50,000	41,250
Extra financial charges	18,000	14,850	30,000	24,750
Dumping of dust	2,100	13,500	3,500	22,500
Total	561,600	735,600	936,000	1 226,000
Balance in favor of compression process	- 271,600	- 445,600	- 536,000	- 826,000

CONCLUSION

Processing drosses by compression has been performed on industrial scale and offers many advantages :

- Environment protection by diminution of residues
- High metal recovery rate
- Better work conditions
- Low processing cost.

We have demonstrated that either in a reduction plant or in a fabricating plant drosses can be treated succesfully by compression.

The high profitability of this process suggests that it will be adapted to many shops in a near future.