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IMPROVEMENT OF PYROMETALLURGICAL PROCESSES FOR COPPER RECOVERY BY THE APPLICATION OF OXYGEN

by

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Theses

of the report "Improvement of pyrometallurgical processes for copper recovery by the application of oxygen"

Oxygen application is currently the most efficient and very promising trend in the intensification of pyrometallurgical processes of copper recovery.

Some smelters still apply and even develop the process of treating copper concentrates in blast furnaces.

For example at one of the soviet smelters using this process the blast is enriched with oxygen (see Table I).

Table I

The influence of the oxygen enrichment on the efficiency of the blast furnace smelting process.

Items	Oxygen content in the blast %			
	20.9	23.7	25.2	27.3
Specific rate of smelting (daily rate of smelting per square unit of the hearth surface t/m^2/ /day)	101	107	115	115
Coke consumption (% of the charge weight)	7.89	6.94	6.13	5.93
Blast air consumption (nm^3/m^2/min)	85.5	77.0	75.2	61.8

Bulk oxygen consumption ($nm^3/m^2/min$)	-	2.7	4.1	5.1
Mercury pressure of blowing (mm)	153	126	124	113
Exhaust gas temperature °C	590	460	375	320
Exhaust gas volume nm^3/h	30700	30400	29300	29300

- -

The economic advantage is gained due to the production growth (60%), reduction of coke consumption (33%) and other factors (7%). This example demonstrates that blast smelting, if still practised, for this or that reason, can be intensificated by oxygen enrichment.

Oxygen flash smelting

During the last 20 years an essentially new method of metals recovery has being developped in the world pyrometallurgy.

The method consists of smelting finely ground and pulverised material, that is carrying out all necessary physical--chemical reactions(roasting and smelting) while keeping the charge in a pulverized state.

Inco was the first to try the oxygen flash smelting method on commercial scale at Copper Cliff (Canada) in 1952.

The success of this experiment in 1953 made it possible for the company to build a larger plant including a furnace with the hearth surface of 109 m^2 and the capacity of approximately 1300 t of charge per day.

The charge of the furnace used for the experiment consisted of (%): Cu 31.5; Ni 1.7; Fe 30.7; S 33.3; and SiO_2 1.9.

Feeding the charge is done through the opening in an end wall, while through the other end wall the copper content of the slag is minimised by burning of pyrrhotite.

Bulk oxygen consumption is approximately 140 m^3 per tone of charge. Exhaust gases contain near 75% sulphur dioxide utilised for the production of liquid SO_2 and sulphuric acid.

According to the opinion of the company, the process is feasible due to the possibility of substituting the imported coal by the local energy and of producing liquid SO_2 which makes it unnecessary to import sulphur.

The complex of the like type including an oxygen plant, a furnace with auxiliaries and a sulphuric acid plant was commissioned in the USSR in 1968.

Advantages of the oxygen flash smelting in comparison with the most popular reverberatory smelting are the following:

1) integration of two processes (roasting and smelting) in one unit
2) increase of the specific smelting rate (daily rate of smelting per square unit of the hearth surface): up to 12 against 4-6 t/m^2
3) elimination of fuel
4) higher grade of matte: 50-60% Cu instead of 30-40% (from roasted concentrates) and 20% (from wet concentrates).

The disadvantages are the necessity of thorough drying of charge, of oxygen plant construction and of treating the slag for copper recovery.

Reverberatory smelting

Oxygen enrichment of the blast is an important innovation in the practice of reverberatory smelting.

It is applied on commercial scale at three plants: Almalick (USSR), Copper Cliff (Canada) and intermittently at Balhash (USSR) where enrichment of the blast to 29% of oxygen increased specific smelting rate by 20% and cut down the fuel consumption per tone of copper by 18%.

At Copper Cliff (Canada) oxygen enrichment has been used since 1963-65 for reverberatory smelting of copper-nickel floatation concentrate.

Oxygen content in the blast was estimated at 25%. Saving in fuel constituted approximately 18%. Furnace capacity by metals yield increased by 30% (taking into consideration changes in fuel consumption).

At the Almalick smelter for a long time oxygen has been applied in reverberatory furnaces heated by natural gas. The enrichment of the blast was tried here to 40% of oxygen.

Experience gained during the long time of practising this method shows that the optimum is feeding 5000 m^3/h of oxygen (27% O_2 in the blast). The specific smelting rate equals in this case 5,6 t/m^2; percent of copper in slags - near 0,5; percent of SO_2 in the waste gas (in the moment of leaving the furnace) is near 4.

In comparison with the conventional air-blast practice the capacity of the furnace (by metal yield) increased by 25% while fuel consumption reduced by 25-30%.

Oxygen content in the blast of more than 30% leads to rapid deterioration of the first sections' lining.

Usage of the oxygen enrichment of the blast during reverberatory smelting is economically quite feasible.

Converter smelting of copper and copper-nickel concentrates

According to publications 7 plants or more use converter smelting of copper concentrates.

The gained experience gives the possibility of making the following preliminary assumptions:

1) converter smelting of concentrates is done with the help of enrichment of the blast air;
2) the content of oxygen in the blast is 25-35%;
3) almost a half of all concentrates going for smelting is smelted in converters;
4) converters can be used for smelting pelletised and dried concentrates as well as wet concentrates after vacuum filtration;
5) there is no increase in lining deterioration compared to the conventional practice of matte air blowing. In comparison with the conventional practice SO_2 content in the waste gas increases up to 5.5-8%;
6) as a rule only the concentrates of very specific characteristics are treated in converters. These are: copper

concentrates of 73% Cu produced by the floatation separation of copper-nickel matte; high grade sulfide-siliceous and sulfide concentrates with copper content of more than 30%;

7) when considering the possibility of application of the converter smelting of concentrates one should think of specific conditions. Thus at one smelter (Falconbridge) this practice was found economically infeasible;

8) with the help of oxygen enrichment it is possible to smelt in converters not only concentrates but also reverts and blister from other sources;

9) bulk oxygen consumption equals approximatelly 90 m^3 per tone of concentrate charged into a converter (Kennecott);

10) at one smelter (Hitachi) it became necessary to introduce an additional route : floatation of converter slag for copper recovery.

It should be noted that during the conventional reverberatory smelting waste minerals contained in concentrates leave in the waste slag having copper content 0.5-0.6%, while in converter they are separated in the slag containing 2-5% Cu, the recovery of which makes the additional treatment necessary.

There is no base for conclusion that application of oxygen for converter smelting of concentrates is always economically feasible. The idea of such practice should be considered in every case individually taking into consideration the specific conditions.

It should also be noted that though oxygen application is connected with certain special safety precautions, these precautions are rather simple and easily learnt by personnel.

Oxygen application in pyrometallurgical processes makes it possible to increase unit production capacity through promotion of reactions involved, to increase heat of these reactions thus making savings in fuel and to reduce exhaust gases volume with simultaneous increase of the content of some useful ingrediente in them.

Oxygen application not only improved the existing processes but also lead to the development of some new ones, for example oxygen flash autogenous smelting.

Innovations in oxygen production make it possible to produce it by the cost equal approximately to the price of one kilowatt-hour. With future increase of the efficiency of oxygen production and of the capacity of air separation units, oxygen will be produced at correspondingly lower average unit cost.

Oxygen application is a progressive and rather promising trend of the intensification of pyrometallurgical copper recovery processes.

Processes with oxygen application should therefore attract in the first place the attention of the developing countries due to the possibility of promoting industry with greater economical gains.

Blast furnace smelting

Near 80% of the world copper is produced in reverberatory furnaces, although some quantities are still produced by blast furnace smelting.

Smelting in blast furnaces has a definite advantage in comparison with reverberatory smelting: due to the countercurrent movement of charge and gas ,the latter is not so hot when leaving the blast furnace (100-300°C) than it is in the uptake of the reverberatory one.This means lower fuel consumption during smelting (2-12% instead of 14-22% in flame furnaces) and,because of the lower temperature of the exhaust gas, gives the possibility of abandoning huge and uncomfortable waste-heat boilers.Saving in fuel during blast furnace smelting takes place also due to the partial utilization of the thermal capacity of charge (oxidation of iron sulphide) which is not possible in reverberatory practice.

But the wide development of the floatation process introducing extremely fine concentrates, not adapted to blast furnaces without some preliminary sintering, promoted the development of reverberatory smelting.

None the less, some smelters preserve and even develop the process of blast furnace smelting.

For example at one smelter in the USSR it has been improved by oxygen enrichment of the blast without any change in the design of the furnaces.

Operating results of smelting the sinter of copper concentrates in blast furnaces are given in the Table 1.

When the content of oxygen in the blast was increased by 1.3 times blast air consumption reduced by 1.4 times, specific smelting rate increased by 15% and fuel consumption became lower by 25%.Factor of the importance is also the decrease of the exhaust gas temperature from 590 to 320°C which improved the operating regime of the furnase mouth (life of hood and ducts was prolonged, working conditions improved etc.).

Table I

The influence of the oxygen enrichment on the efficiency of the blast furnace smelting process.

Items	oxygen content in the blast, %			
	20.9	23.7	25.2	27.3
Specific rate of smelting (daily rate of smelting per square unit of the hearth surface, t/m^2/day)	101	107	115	115
coke consumption (% of the charge weight)	7.89	6.94	6.13	5.93
blast air consumption (nm^3/m^2/min)	85.5	77.0	75.2	61.8
bulk oxygen consumption (nm^3/m^2/min)	-	2.7	4.1	5.1
mercury pressure of blowing (mm)	153	126	124	113
exhaust gas temperature °C	590	460	375	380
exhaust gas volume nm^3/h	30700	30400	29300	29300

Oxygen enrichment almost did not change the absolute volume of oxygen in the blast due to the corresponding reduction of the blast consumption. But its portion in the blast increased from zero to 5.1 nm^3/m^2/min.

Besides the improvement of the operating results given in Table I, oxygen application made the operation more smooth and steady, decreased skull formation in the crucible and in the upper part of the furnace, reduced time losses during shut downs and improved the environmrntal conditions.

Thus the economic gain is constituted by the following factors:

savings due to the increase of production (60%), due to the reduction of coke consumption (33%) and other savings (7%).

This example shows that the process of blast furnace smelting (where it is still preserved for this or that reason)can be improved by oxygen enrichment of the blast.

Special attention should be given to the so-called copper--sulphur smelting(method orkla), used for the recovery of elemental sulphur as an important co-product of copper.

Some ores rich in copper, sulphur, precious and rare metals (e.g. germaniun) can be more feasibly treated by this method than by the conventional benefication-reverberatory smelting route, due to the higher precious and rare metals recovery and the possibility of extracting a large amount of sulphur in its elemental form.

Method of producing briquettes of special mechanical strength recently developped and introduced in the USSR makes it possible to adapt to blast furnaces fine grades of ores and concentrates. Operating results of copper-sulphur smelting can be profoundly improved by oxygen enrichment . Oxygen in this case will oxidate the additional amount of iron sulphide in the tuyere zone, while the elemental sulphur recovered by the dissociation of pyrite (chalcopyrite) and sulphur reduced from SO_2 will not undergo any oxidation. This fenomena will enable to increase the extraction of elemental sulphur by 10%, to increase furnace concentrating capacity and to produce matte of higher grade at higher speed of smelting.

Oxygen flash smelting

During the last 20 years the essentially new method of metals recovery has being developed in the world pyrometallurgy: smelting of finely ground and pulverized material.

The essence of this method is to carry out all necessary physical-chemical reactions (roasting and smelting) while keeping the charge in a pulverized state. Fine and dry feed is catched in a special kind of nozzle by the blast air stream and introduced into the flame zone of the furnace where the feed is pulverized and reacts with oxygen of the blast.

The following examples of the flash smelting of concentrates are known in the practice of nonferrous metallurgy:

1) smelting of copper and copper-nickel concentrates using the preheated blast- plants in Harjavalta (Finland), Baia-Mare (Rumania), Ashio and others in Japan.

2) of copper concentrates with the application of oxygen - Copper Cliff (Canada) and Almalick (USSR).

The Outokumpy Oy company (Finland) has worked out and introduced on semi-commercial scale the process of flash smelting of lead concentrates.

Let us examine some details of flash smelting with oxygen enrichment.

To attain the temperature necessary for charge melting and separation and discharge of matte and slag (1200-1400°C) it is important to introduce more heat, that is to change the heat balance of the process. This is done by preheating blast up to 500-600°C. At Harjavalta the consumption of the additional fuel for this preheating equals 1% of the charge weight. If to displace the air by the oxygen blast, the volume of leaving gases will be sharply reduced due to the absence of nitrogen. This makes it possible to attain the necessary temperature without any additional heat and the process can be conducted autogeneously without any fuel consumption and blast preheating.

Thus flash smelting process can be made autogeneous with corresponding savings in fuel due to the utilisation of the heat potential of charge, which cannot be practically achieved in reverberatory practice.

INCO was the first company to introduce this process on commercial scale at Copper Cliff (Canada) in 1952 using the flame-type furnace with the hearth surface of 62 m^2 and capacity of 500-600 t of charge per day.

The success of this experiment in 1953 made it possible for the company to build a larger plant including a furnace with hearth surface of 109 m^2 and the approximate capacity 1300 t of charge per day.

The feed of the furnace used for the experiment consisted of %: Cu 31.5 ; Ni 1.7; Fe 30.7; S 33.3; and SiO_2 1.9.

The furnace is adapted for feeding from the both end walls and for gas emmission in the middle part of the aggregate. The charge undergoes treatment at one end of the furnace while through the other end wall slag is deprived partially of its copper content by burning of the pyrrhotite concentrate analysing (%) Ni 1.0; Fe 57.0; S 35.0; SiO_2 2.0.

The charge is introduced into the furnaces through two burners of special design and pyrrhotite through one burner. Outer dimensions of the furnace are: length 20.3 m; width 7.3 m; height of the end walls 5.2 m. Height of the roof from end walls to the uptake is approximately 1 m. Lining is of chrome-magnesite and partially backed up with water-colled jackets. Temperature in the uptake is near 1260°C.

Matte tapping through the side wall at the temperature of near 1180°C contains approximately 45% Cu and Ni. Slag is skimmed through the same end wall which serves for pyrite feeding and has the temperature of 1230°C.

Bulk oxygen containing more than 95% O_2 is fed by the separate oxygen plant at the pressure of 1.2 atm. Oxygen consumption is 140 m^2 per tone of charge.

Exhaust gases containing 75% SO_2 are cooled and cleaned of of dust in a special system and utilised then for the production of liquid SO_2 and sulphuric acid.

According to the opinion of the company the process is feasible due to the possibility of substituting the imported coal by the local energy and of producing liquid SO_2 which makes it unnecessary to import sulphur.

This saved for the company in 1954 some 60000 t of coal and gave the possibility of producing 70000 t of liquid SO_2 equivalent to 35000 of elemental sulphur. Furnace for the oxygen flash smelting substituted two reverberatory furnaces of 306 m^2 each used previously for treating copper concentrates.

Similar equipment for oxygen flash smelting including an oxygen plant, furnace with auxiliaries and a sulphur acid plant was commissioned in the USSR in 1967. The technology of the process is still developing.

Charge before smelting is dried in vertical tube driers for leaving moisture of less than 1%.

Surface of the molten metal bath in the furnace is 120 m^2 (20x6 m); side walls on the distance of 300 mm in direction from the bath to the roof are backed up by water-cooled jackets of special design.

Dust carry over is 6-10% of the charge weight.

Unlike the Copper Cliff furnace where dusty gases are cooled in a special chamber from 1260 to 650°C, at Almalick the descent of the gas temperature takes place in the waste heat boiler operating with steam pressure of 40 atm.

Cooled to 500-550°C and partially dedusted gas goes to the system of dry dust collecting which consists of a baghouse,cyclones and electric precipitators leaving which with dust content of only 0.1 g/m^3 it is conducted to the sulphuric acid plant for treatment together with converter gases (at Copper Cliff the system of wet scrubbing is applied which consists of a scrubber, ventury tubes, a cyclone and a wet electric precipitator). Concentrates treated in the furnace have the content of 15-20% Cu, 36-45% S, 2-5 SiO_2.

The skill of managing the process is still developing at Almalick. Current operating data of the autogeneous smelting are as follows:

- temperature of slags when leaving the furnace 1200-1350°C with maximum 1400°C;
- specific smelting rate: 7-8 t/m^2 (the higher rate has not been tried yet);
- specific oxygen consumption 180-200 nm^3 per tone of charge;
- Cu content in matte - 40-60%;
- content of SO_2 in gases from the uptake: up to 70%. Rate of desulphurisation is up to 80%;
- cleaning of slag by pyrite before skimming is not still introduced.

This information shows that oxygen flash smelting has the following advantages in comparison with the most popular reverberatory practice;

- integration of two processes (roasting and smelting) in one unit;
- higher specific smelting rate (daily rate of smelting per square unit of the hearth surface): up to 12 t/ m^2 instead of 4-6;
- fuel elimination;

- higher grade of matte: 50-60% Cu instead of 30-40% (from roasted concentrates) and 20% (from wet concentrates);
- readily controlled and high rate of desulphurization - up to 80%;
- possibility of producing liquid SO_2 or cheap H_2SO_4 from the waste gas;
- higher recovery of sulphur (by 25-30%) for reverberatory gases are not utilized for this purpose ;
- small amount of exhaust gas (by 5-7 times);
- nearly absolute automatic control of the furnace work.

It was estimated for a plant in the USSR that capital costs of the introduction at this plant of the oxygen flash smelting process would be by 17 mln roubles less than the capital costs for reverberatory smelting. Annual savings in operating costs would be 3.4 mln roubles.

Disadvantages of the process are the necessity of thorough drying of charge, oxygen plant erection, and cleaning of slag in the furnace itself or by some other method.

Compared to the process of flash smelting with the preheated blast, oxygen smelting has higher specific rate of production (almost twofold) and gives higher percent of sulphur dioxide in gases (75% compared to 12%) which makes it possible to produce liquid SO_2 and cheater sulphuric acid by diluting the strong gas with poor converter and other S containing gases.

This justifies the expenses for building an oxygen plant. Since reverberatory furnaces used in non-ferrous metallurgy have hearth surfaces of more than 300m^2, it would not be difficult for the art to master oxygen flash smelting furnaces of the same size, which having the specific rate of charge smelting 12 t/m^2/day would make it possible to smelt at the plant some 4000 t of charge per day.

This is rather important for large enterprises.

Reverberatory smelting

As mentioned already reverberatory smelting is the most popular process throughout the world for treating copper concentrates. Due to this and until the possible substitution of it by oxygen flash smelting , the improvement of this process retains high importance. One of the significant innovations in this practice is oxygen enrichment of the blast. It is known that on commercial basis it is now applied by three plants: Balhash (USSR), where it is used intermittently, Almalick (USSR) and Copper Cliff (Canada). At the Balhash smelter pulverized coal was used for heating the furnace the charge of which contained 12-22% Cu and 23% S.

The results are given in Table 2.

Table 2

Basic operating results of reverberatory smelting with and without oxygen enrichment of the blast.

items	without oxygen enrichment	with oxygen enrichment to %	
		25	29
specific rate of smelting (t/m^2/day)	3.2	3.8	3.9
specific fuel consumption kg/t of charge	186	161	153
specific air consumption m^3/t of charge	1390	930	910
specific bulk oxygen consumption nm^3/t of charge	-	56	108
recovery of copper into the matte %	97.9	97.9	97.8
volume of gases nm^3/t of charge	1760	1270	1080
Dust %	1.4	0.8	0.8
SO_2 in gases %	1.5	2.0	2.5
thermal efficiency of the furnace %	32.7	37.8	42.6

Enrichment to 29% of oxygen in the blast increased the specific rate of smelting by 20% and reduced specific fuel consumption by 18% with the same % of copper recovery into the matte and length of service of the roof lining.

From higher temperatures created by an oxygen flash, the roof was protected to a certain extent by an air curtain.

Cu content in slags increased as a result of oxygen application from 0.31 to 0.40% while dust carry over reduced slightly.

Despite only limited application of oxygen the plant saved during the first year of such practice some 160000 roubles.

At Copper Cliff (Canada) application of oxygen in reverberatory furnaces was introduced in 1963-1965 for smelting copper--nickel concentrate.

Total oxygen consumption equals some 300 t/day (for 7 furnaces having the hearth surface of 306 m^2 and the production capacity 1360 t/day each) or some 1300 m^3/hour per furnace. Furnaces are heated by gas and by pulverised coal through two different types of burners.

Oxygen is introduced through special lances from under the flash.

Experiments have been made at one of the commercial furnaces of reducing fuel consumption to the minimum (by introducing established amounts of oxygen) and of increasing the production capacity (introducing oxygen without any reduction of the absolute amount of the fuel). The results are given in Table 3.

Oxygen content in the blast during the experiments estimated at approximately 25% which made it possible to save some 18%

of fuel. As to the production capacity (by metals yield) it increased (taking into consideration changes in fuel consumption) by 30%.

Table 3

The experimental results reached at Copper Cliff (Canada)

items t per day	reduction of fuel consumption		increase in production capacity	
	enriched blast	convention-al blast	enriched blast	conventional blast
coal consumption	157.8	194.1	193.2	186.9
oxygen consumption	82.5	-	72.6	-
matte + slag yield	1397	1270	1724	1240

According to preliminary data, consumption of refractories did not increase.

The hottest zone of the flash shifted approximately 3 m in the direction of the slag surface.

Temperature under roof somewhat increased, particularly at a distance of 10 m from burners in the direction of the slag end of the furnace.

Oxygen blast is applied also by the Almalick plant where the furnaces are heated by natural gas. Here the enrichment of the blast up to 40% of oxygen has been experimented. Oxygen was introduced into the blast air and through special lances from under the flash. Comparative results are given in Table 4.

Charge of the reverberatory furnace contained 80% concentrates, 8% reverts, 5% limestone and 7% quartz (the latter was added during experiments). Specific smelting rate during the experiments with the conventional air blast was 3.62 t/m^2/day.

Table 4

Experimental results of reverberatory smelting with conventional air and oxygen blasts as the Almalick smelter.

items	conventional air blast	oxygen content in blast %							
		25		30		35		40	
		A	B	A	B	A	B	A	B
specific rate of smelting %	100	119.5	122	144.4	155.8	157	164	184.4	
specific consumption of fuel kg/t	264	220	215	185	169	168	160	144	
Cu content in slag %	0.49	0.43	0.47	0.46	0.41	0.44	0.45	0.46	
SO_2 content in the exhaust gas %	3.37	6.2	6.2	6.0	6.0	7.2	7.2	7.2	
Dust carry over into the stack %	0.95	0.48	0.47	0.35	0.32	0.37	0.35	0.41	

Remarks: I. With 40% of oxygen, heat load was preserved at $59 \cdot 10^6$ kilocal/hour; under other regimes - $67.2 \cdot 10^6$ kilocal/hour.

II. A - oxygen is introduced into tuyers.

B - oxygen is introduced into the air duct.

The result of the experiments was the recommendation to introduce at the plant 30% oxygen enrichment of the blast. Operating data of this regime compared to the conventional blast practice are given in Table 5.

Table 5

Comparative operating results of reverberatory smelting under the conventional and recommended regimes at the Almalick smelter.

type of blast	air consumption m^3/hour	oxygen consumption m^3/hour	specific smelting rate t/m^2/day	SO_2 content in gases %	Cu content in slag %
Air	80000	-	3.6	3.3	0.49
Enriched to 30% of oxygen	49200	6700	5.6	6.0-7.0	0.44

Further practice shew that the optimum variant was introducing oxygen into the furnace in amount of 5000 m^3/hour (27% of oxygen in the blast), which gave the specific rate of smelting 5.6 t/M^2, copper content in slag near 0.5% and SO_2 percent in gases from the uptake near 4.0%.

This practice made it possible to increase the production capacity by 25% and to reduce fuel consumption by 25-30% compared to the conventional air blast practice. Under the condition of 30% of oxygen in the blast lining deterioration of the first two sections of the roof becomes more intense.

In general oxygen enrichment of the blast during reverberatory smelting is economically quite feasible.

Converter smelting of copper and copper-nickel concentrates

During the last few years new practice of smelting concentrates directly in converters has being developped in the world non-ferrous metallurgy.

The method includes enrichment of the converter blast by oxygen. Concentrates in some cases are previously pelletized.

For example at the Hitachi smelter (Japan) this method has been used since 1956 for smelting pelletized copper concentrates containing 17% Cu; 32.7% S; 3.4% Zn.

Preliminary studies shew that concentrates taken for converter smelting should contain near 28% Fe and 28-30% S. Concentrates with low S content cannot be treated.

5 converters working at the Hitachi smelter have each the dimensions of 2.8x5 m and the capacity of 30 t. 70% of concentrates coming to the plant are smelted in converters and 30% in blast furnaces.

Operation starts with pouring blast furnace matte into converters, after which blowing begins with blast containing 35% oxygen. Then pellets are charged into converters and smelted there during three hours. The temperature of feed during smelting is 1200-1300°C.

Gases from blast furnace, converters and furnaces for roasting pyrite concentrates are mixed in the mixing chamber to the established average content pf 6-7% SO_2 in them. The mixture of gases passes through a scrubber and wet electric precipitators and is fed to the contact apparatus for producing H_2SO_4 with the help of vanadous catalyst. Slimes rich in selenium, tellurium and bismuth are transferred from washing tower and wet electric precipitators to hydrometallurgical plant.

Converter slag contains 4.7% Cu; 40-50% Fe; 15-20% SiO_2.

Partial recovery of useful compounds from the slag was accomplished in the past by electrosmelting with a reducer. But as this method turned to be very expensive, it was substituted by a floatation route. The floatation concentrate contains Cu - 20-25%; Fe - 40-50%; SiO_2 -7%.

Copper recovery from slags by this method is 90-95%. Slag after decopperisation contains 0.3-0.5% Cu and 52-55% Fe. Copper carried by slag is estimated to be 21% of Cu in concentrates.

Converter smelting of concentrates is used also at the Hibi smelter in Japan.

But much more popular in that country becomes the process of smelting concentrates in pulverised condition. This process has been introduced at the Kosaka and Saganoseki smelters together having annual capacity of 120000 t (by 1971, estimated) and is planned to be applied at the Niihama smelter (currently erected) with the production capacity 110000 t annually.

At Copper Cliff in Canada near 60% of copper is produced by oxygen flash smelting and 40% by treating rich concentrates in converters with the blast enriched by oxygen. Concentrates used for converter smelting contain 73% Cu and are produced as a pulp by floatation separation of the copper-nickel matte. The pulp coming from the separation section of the plant is transferred to the storage tank at the upper mark of the converter aisle building from where it is fed to a vacuum filter. Cake containing 8% moisture is transferred to an intermediate storage bin from where it is transported by feeders and belt conveyers to a converter.

Smelting is produced in three converters with the blast containing up to 30% of oxygen. Each converter has a separate line of auxiliaries including vacuum filter. Charging of concentrate is produced by the compressed air through a Garr Gun along with simultaneous charging of quartz flux crushed to 25-30 mm.

Gases cleaned by electroprecipitation are emitted to the atmosphere through the stack.

At the Kennecott smelter, Utah (USA) smelting of wet concentrates in converters with oxygen enrichment of the blast was introduced after full-scale experiments for studying the efficiency of the process. One of the nine smelter converters was equipped by a Garr Gun, a bin with storage capacity of 40.8 t, a belt feeder and necessary control devices.

The route of the experiments was as follows:
Empty converter having dimensions of 3.96x9.14 was charged at first with 36.3x54.4 t of molten matte containing 36.8% Cu; 32.2% Fe; 26.1% S which was blown then with 425-510 m^3/min of blast till reaching the temperature of 1120°C inside the converter. After this a portion of wet concentrates (containing

moisture 8.5-12.5%; Cu - 29%; Fe - 24.8%; S - 31.5%; SiO_2 - 9%; Al_2O_3 - 1.4%; CaO - 0.5%) mixed with fluxes (Fe - 5.8%; SiO_2 - 69.8%; CaO - 2.7%; Al_2O_3 - 3.8%) was added through the Garr Gun into the converter with the rate of 1-2 t/min. Air was blown into the Garr Gun with the rate of 74 m^3/min. Oxygen content in the converter blast varied in the range of 23-36% (with the preference of 28-30%).

After the addition of 31.8-40.8 t of concentrate the feeding stopped and mouth of the Garr Gun was closed by a clay plug.

Blowing continued till slag was ready for tapping, after which the whole operation repeated beginning with charging the matte.

Due to the necessity of treating cold reverts the addition of concentrates was made usually during the first stage of blowing and more rarely during the second.
Sometimes cement copper was also added when blowing for blister or for white metal.

Alltogether 44 experimental cycles were conducted with the following results:

flux consumption - 13% of concentrate (by dry weight)

concentrate consumption - 56.0% of matte (by weight)

time of operation - 630-650 min

SO_2 content in gases - 6.5-9.5% (4-4.5% when air blowing for matte)

Average Cu content in slags during a compaign 3.21% (4.8% when air blowing for matte).

A tone of oxygen introduced into the blast air gives the possibility of treating 6.1-9.6 t of wet concentrate. Thus it is possible to treat in 9 converters some 907 t of concentrate per day.

Duration of operation (during which 36.3-145 t of wet concentrates were treated) increased by 3%. Average weight of the product of smelting increased by 8% (from 60 to 68-72 t in case of blister produced). Dust carry over increased from 1.74 to 2.38% with the reduction, though, of copper content in the dust.

Life of chrome-magnesia castable refractory did not practically reduced.

At the smelter of the "Falconbridge Nickel Mines" company in Canada experiments were conducted for studying technical and economical feasibility of oxygen enrichment of the converter blast during smelting copper-nickel concentrates.

Blowing was conducted in a converter with dimensions 7.2x3.9 m. Concentrate contained Ni 7.2%; Cu 6.8%; moisture 8%. Oxygen content was variable.

It was found out that for achieving autogeneous reaction, oxygen content in the blast was to be 50%.

Dust carryover was less than 5% of the concentrate weight.

Application of this process gave the possibility of eliminating sintering, of using the blast furnace for converter slag smelting, of producing rich-in SO_2 gases and of better air pollution control.

It was found though that the oxygen consumption per tone of concentrate was rather high and that the application of it would be costly for small enterprises.

In the USSR converter smelting of copper concentrates is applied successfully at the Balhash smelter.

The method includes pelletizing of copper concentrates with high silica content and smelting the pellets in converters using the blast enriched by oxygen.

Pelletised concentrate containing (%) Cu - 32.5-35.1; Fe - 4.5-6.1; SiO_2 - 28.3-3.15; S - I2.I-13.2; Pb - 1.55 is charged by the vibrating feeder through a trough and a doser to the converter mouth during only the first stage of blowing. The blast is enriched by oxygen to 25-27%. Converter has the dimensions of 3.96-9.14 and the capacity of 75 t.

Pelletised concentrate and fluxes are charged after pouring into the convertes of the established portion of matte (concentrate 88% of the not matte)/

The experiments gave the following results:

1) Concentrate is consumed in amount of 40% of the matte. 70% of copper were charged into the converter with the matte and 24% with the pelletised concentrate.
2) compared to the conventional blast SO_2 content in gases of the first stage of blowing increased from 4.3 to 5.5-6.1%; Cu content in siags reduced by 0.2%; dust carry over during the first stage of blowing increased by 14.9%.
3) copper distribution when smelting concentrate: 90.24% into blister; 5.63% into revert slags and dust, 4.13% - not detected due to the absence of weight analysis.

4) the amount of copper-containing products treated during the operation of smelting increased by 29% while the length of the operation increased by 9%.

5) rhenium distribution improved by 94% Re in fumes.

6) utilisation of S content of raw material also shew the improvement.

7) grade of blister became lower with Pb content increase by 16% (from 0.171 to 0.196%), As - by 33% (from 0.024 to 0.032%), Fe - almost twofold (from 0.0066 to 0.0113%).

8) addition of pelletised concentrate while enriching the blast to 25-27% of oxygen does not reduce life of the tuyere zone of the converter.

a) Saving due to the converter smelting of 75000 t of granulated concentrate were 300000 roubles of which 63000 roubles due to the production of rhenium, 147000 due to the reduction of copper losses and 90000 due to the lower operating costs.

At the Hayden smelter (Arizona, USA) one converter is blowing copper concentrate with the enriched blast to produce matte which is then transferred to another converter for finishing to blister copper.

At the Chino plant (New Mexico, USA) one converter is fed copper concentrates for the production of blister copper. No details concerning the processes at Hayden and Chino are available but copper content in the molten matte poured into converters being 40-60%Cu.

Converter treatment of concentrates and cement copper is known to be planned by the Garfield smelter (USA), experiments having been conducted at Anaconda (USA) and W.Germany.

No less than 7 plants in the world do treat copper concentrates in converters. Available publications data are given in Table 6.

At the Copper Cliff smelter only peculiar types of concentrates are treated in converters, these concentrates being in fact cold white metal produced by the floatation separation of the copper-nickel matte and containing more than 70% Cu.

At the Balhash smelter too the converter is fed with the specific type of concentrate, mixture of cold rich matte (more than 50% Cu) and guarts flux.

The following preliminary conclusions concerning the world practice of the converter treatment of sulphide copper concentrates can be made on the basis of the available publications:

1) Converter smelting of concentrates suggests enrichment of the blast by oxygen.
2) Oxygen content in the blast is in the range of 25-35%.
3) Almost a half of all concentrates going for smelting is smelted in converters.
4) Converters can be used for smelting pelletized and dried concentrates as well as wet concentrates after vacuum filtration.
5) There is no increase in lining deterioration compared to the conventional practice of matte air blowing. In comparison with the conventional practice SO_2 content in the waste gas increases up to 5.5-8%.

6) As a rule only the concentrates of very specific character are treated in converters: concentrates with 73% copper content produced by the floatation separation of copper-nickel matte; high grade sulfide-siliceous and sulfide concentrates with copper content of more than 30%.

7) When considering the possibility of application of the converter smelting of concentrates one should think of specific conditions. Thus at one smelter (Falconbridge) this practice was found economically unfeasible.

8) With the help of oxygen enrichment it is possible to smelt in converters not only concentrates but also reverts and blister from other sources.

9) Bulk oxygen consumption equals approximately 90 m^3 per tone of concentrate fed into a converter (Kennecott).

10) At one smelter (Hitachi) it became necessary to introduce additional treatment:
floatation of converter slag for copper recovery.

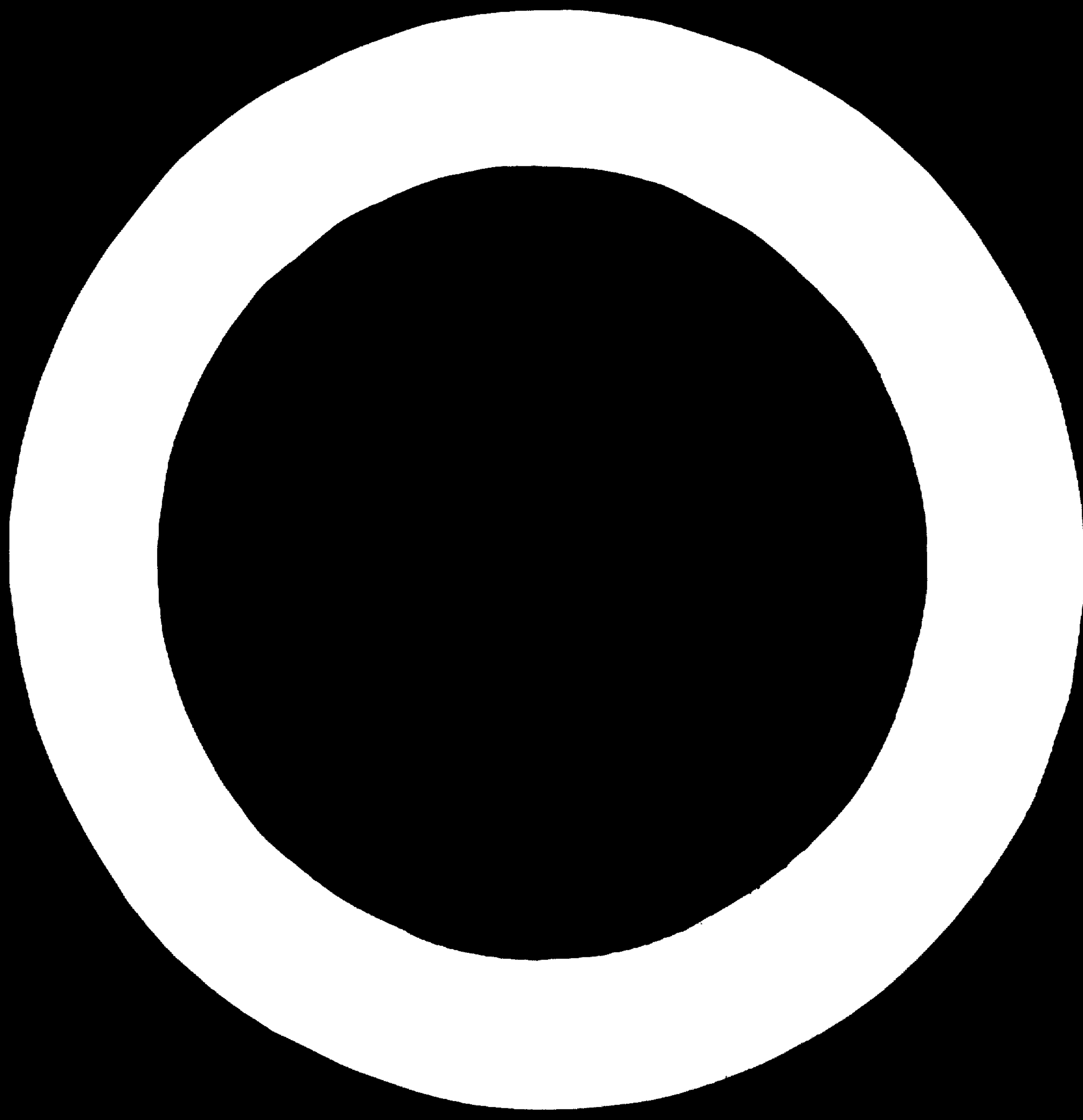
Calculations based on the above data made for a smelter in the USSR show that for converter smelting of concentrates having the content (%) Cu - 18.0; S - 34.1; Fe - 34.5; SiO_2 - 6.9; bulk oxygen consumption (30% O_2 in the blast) should be 160 m^3 per tone of concentrate.

Table 6

Basic operating data on converter concentrate smelting process at the plants of concern

Smelter	Raw material analysis %				converters		oxygen content in the blast %	concentrates smelted in converter as % of the total amount of concentrates	SO_2 in gases %	Duration of operation increase as compared to the conventional blowing (%)	Production increase (by copper) during the operation as compared to the conventional blowing (%)	Converter slag analysis %			Method of slag treatment
	moisture	Cu	S	Fe	number	dimensions, m						Cu	Fe	SiO_2	
Copper Cliff	8.0	73.0	-	-	3	4x10.67	30	55			50	3-9			Reverberatory smelting
Falconbridge[1]	8.0	6.8 +Ni 7.2	-		4	4x10.67	-	50							
Kennecott	10.0	29.0	31.5	24.8	9	4x9.14	28-30	30	6.5x9.5	3.0	8	3.21	46.6	25.7	Reverberatory smelting
Balhash	dry pellets	34.0	12.6	5.3	-	4x9.14	26	40	5.5	9.0	29	2.20	46.5	26.0	- " -
Hitachi	-"-	17.0	32.7		5	2.8x5	35	70	7-8			4.7	50.0	15-20	floatation
Nibi	dry				6	5x2.3 7.44x 3.35									
Hayden		20.0			3	4x9.15									
Chino															

1) After try the method was rejected



It should be noted that during the conventional reverberatory smelting waste minerals contained in concentrates leave in the waste slag having copper content 0.5-0.6%, while in converters they are separated in the slag containing 2-5% Cu, the recovery of which makes the additional treatment necessary.

When treating in converters rich concentrates with copper content near 35% and more, the amount of slags produced would not be large and their further treatment can be conducted in reverberatory furnaces (if these exist at the plant). But in case of low grade concentrates the amount of slags would be so large that reverberatory furnaces of the plant would not be able to smelt them and an additional route of treatment would be necessary (as in case of the Hitachi smelter).

It is useful to compare some operating results of oxygen application for smelting copper concentrates in converters and in reverberatory furnaces.

1) Oxygen consumption per tone of the additional concentrate treated in converters equals 160 m^3 and in reverberatory furnaces - 460 m^3.

2) In case of oxygen enrichment of the blast, converter gas contains more than 5% SO_2 which makes it adaptable to sulphuric acid production, while in the uptake of the reverberatory furnace gas contains up to 4% SO_2 and considering further dilution in ducts and a waste heat boiler this gas seems to be too poor.for economic production of H_2SO_4.

These facts show that oxygen application is more feasible in converters than in reverberatory furnaces.

But it cannot be generalised that oxygen application in converters is always feasible and the idea of such practice should be considered in every case individually.

Roast of concentrates

Semi-commercial experiments for roasting copper-zinc sulphide materials in a fluidised bed reacter using oxygen enrichment to 29.8% of the blast have been conducted in the USSR.

The experiments shew the proportional increase of the furnace production capacity and of SO_2 percent in gases with the increase of oxygen content in the blast.

It is planned to apply oxygen enriched blast in commercial furnaces of one of the smelters in 1970.

Conclusion

Application of oxygen in copper industry gives the possibility of making metallurgical processes as a rule more efficient and profitable.

The practice can be introduced either for the improvement of t the existing process without major requirement or through the reconstruction of the whole smelter.

Oxygen application makes it possible to reduce the volume of the waste gas with simultaneous increase of its SO_2 content thus stimulating the production of sulfuric acid and even liquid SO_2 and improving the control of air pollution in the vicinity of the plant.

It should also be noted that though oxygen application is connected with certain special safety precautions, these precautions are rather simple and easily learnt by personnel.

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