OCCASION

This publication has been made available to the public on the occasion of the 50th anniversary of the United Nations Industrial Development Organisation.

DISCLAIMER

This document has been produced without formal United Nations editing. The designations employed and the presentation of the material in this document do not imply the expression of any opinion whatsoever on the part of the Secretariat of the United Nations Industrial Development Organization (UNIDO) concerning the legal status of any country, territory, city or area or of its authorities, or concerning the delimitation of its frontiers or boundaries, or its economic system or degree of development. Designations such as "developed", "industrialized" and "developing" are intended for statistical convenience and do not necessarily express a judgment about the stage reached by a particular country or area in the development process. Mention of firm names or commercial products does not constitute an endorsement by UNIDO.

FAIR USE POLICY

Any part of this publication may be quoted and referenced for educational and research purposes without additional permission from UNIDO. However, those who make use of quoting and referencing this publication are requested to follow the Fair Use Policy of giving due credit to UNIDO.

CONTACT

Please contact publications@unido.org for further information concerning UNIDO publications.

For more information about UNIDO, please visit us at www.unido.org

UNITED NATIONS INDUSTRIAL DEVELOPMENT ORGANIZATION
Vienna International Centre, P.O. Box 300, 1400 Vienna, Austria
Tel: (+43-1) 26026-0 · www.unido.org · unido@unido.org

D01423

United Nations Industrial Development Organization

Distr.
LIMITED

ID/WG.12/3
30 April 1968

ENGLISH ONLY

First Meeting of Expert Consulting Group
on the Copper Industry
Vienna, 20-24 November 1967

THE USE OF OXYGEN, HOT AIR AND OTHER IMPROVING AGENTS IN THE COPPER INDUSTRY 1/

by

K. I. Ushakov
USSR

1/ The views and opinions expressed in this paper are those of the author and do not necessarily reflect the views of the Secretariat of UNIDO.

id.68-048

We regret that some of the pages in the microfiche copy of this report may not be up to the proper legibility standards, even though the best possible copy was used for preparing the master fiche.

This paper was first presented at a meeting of experts consulting on the copper industry in Vienna at UNIDO headquarters, 20-24 November 1967.

SUMMARY

Preparing the charge for reverberatory smelting

At some Soviet plants, the charge is prepared for smelting by the wet method. Quartz and limestone are subject to a combined wet crushing, after which their pulp is added to the copper concentrate pulp in the required amount. The mixture is then filtered. The method ensures a variation of the silica content in the charge up to +/- 2 per cent abs, and of CaO up to +/- 1 per cent abs, and reduces the moisture content of the charge from 14 to 10 per cent.

Roasting of concentrates

At present, copper concentrates are roasted in a fluidized bed at two plants in the Union of Soviet Socialist Republics (Urals, Caucasus), at one plant in Bulgaria (Pirdop) and at one in the United States (Copperhill Tennessee Copper Company). Roasting in a fluidized bed, instead of multistage mechanical furnaces, practised at one of the Soviet plants, increased the specific capacity of the furnaces from 8 to 9 to 65 ton/m^2 per day and raised SO_2 content in the gases from 7.0 to 12.5 per cent. Semi-industrial tests have been conducted in the Union of Soviet Socialist Republics with a blast enriched with oxygen for roasting. When the oxygen content in the blast is increased from 21 to 35 per cent, the specific output of the furnace rises from 65 to 108 ton/m^2 per day and SO_2 in the gases grows from 12.5 to 18.7 per cent.

Reverberatory smelting

In recent years the output and thermal power of reverberatory furnaces in the Union of Soviet Socialist Republics have been considerably improved (up to 50 - 60 million kcal/hr). The total smelting rate of furnaces which process raw charge has reached 4 to 4.5 ton/m^2 per day and of those which handle roasted charge 7 to 8 ton/m^2 daily. The heating of the secondary blast to 200 to 350°C reduces fuel consumption by 7 to 10 per cent and increases the smelting rate by 15 to 20 per cent.

Industrial tests have been conducted with oxygen in a reverberatory furnace fuelled by natural gas. The oxygen in the blast was raised to 35 per cent. As a result, the total smelting rate has increased from 4.25 to 6.0 ton/m^2 daily, SO_2 in the exhaust gases rose from 1.5 - 2 to 6 - 7 per cent while the copper in the slag dropped from 0.46 to 0.39 per cent.

Smelting in shaft furnaces

Since 1960 oxygen enriched blast has been successfully used for smelting sintered copper concentrates at one of the Soviet plants. With 27.3 per cent oxygen in the blast, coke consumption dropped from 7.89 to 5.93 per cent, total smelting rate increased from 101 to 115 ton/m^2 daily, blast intensity rate decreased from 85.5 to 61.8 nm^3/m^2 min and temperature of the exhaust gases dropped from 590 to 320°C.

Some grades of sulphide ores rich in copper, sulphur and noble metals can be processed most effectively by the Orkll method. A low degree of reduction and a low direct (without catalysis extraction of sulphur in the elementary form) are the principle shortcomings of this method which can be eliminated by a blast enriched with oxygen. In the Soviet Union, this method will be introduced in the industry in the nearest future.

Flash smelting

Flash smelting on hot air blast is employed industrially at Harjavalta (Finland) Asio (Japan) and Baja-Mare (Romania). The air is heated to 500°C. If there is not enough heat to melt the charge, 1 to 2 per cent liquid fuel of the charge weight is burnt to melt down the charge. Smelting on technical oxygen is practised at the Copper-Cliff plant (Canada) and will be introduced in the Union of Soviet Socialist Republics in the nearest future. Flash smelting offers the following advantages: (a) fuel consumption for the smelting process is considerably reduced and is completely disponsed with in the case of oxygen smelting; (b) high degree of desulphuration; (c) high specific capacity (up to 12 ton/m^2 per day); and (d) full utilisation of sulphur. At the same time, flash melting is more complicated technically than smelting in a reverberatory furnace because the charge has to be dried thoroughly and the slags depleted additionally.

Converting the copper matte

At some plants, Copper-Cliff (Canada), Hitaty (Japan) and in the Soviet Union the blast is enriched with 25 to 32.5 per cent oxygen in matte conversion. The rate of the process has been found nearly proportional to the concentration of oxygen in the blast. The maximum temperature of the melt is maintained in the converter with the aid of cold additions in the form of cold matte and granulated copper concentrate.

Economic aspects of using oxygen and hot blast in the copper industry

The economic expediency of using oxygen depends on a number of conditions, primarily on the relationship between the costs of electric energy and fuel. Besides the purely technological advantages, the use of oxygen will facilitate the solution of the problem of reducing the discharge of sulphur dioxide into the atmosphere. Still more effective is the use of hot blast to reduce fuel consumption in smelting, especially when heating is done by the heat of exhaust gases and slags.

Contents

Tables

Introduction

1. Higher rates of copper output at the present-day level of development require more intensive metallurgical processes since a mere increase in the size and number of units becomes increasingly ineffective. This can be attributed to the fact that the benefits obtained hardly pay for the expenditures involved in the erection of equipment. Much labour can be saved and its productivity promoted by intensifying metallurgical processes. In the recent years much has been done to develop new intensive processes and improve the old ones by using oxygen and hot air.

2. Today, about 90 per cent of all copper in the world is obtained by smelting its concentrates in reverberatory furnaces and converting copper matte afterwards. In certain cases before smelting, it is good practice to subject concentrates low in copper (15 to 18 per cent) and high in sulphur (35 to 40 per cent) to dead roasting, usually in multi-stage mechanical furnaces. At the same time, copper smelting in shaft furnaces did not lose all its importance. One of the new trends is flash smelting of copper concentrates, a process in which the heat necessary to melt down the charge is generated by oxidation of sulphides contained in the concentrates.

I. PREPARING THE CHARGE FOR REVERBERATORY SMELTING

3. In the last few years much attention in the copper industry of the Union of Soviet Socialist Republics was given to preparing the charge before reverberatory smelting. The wet method of charge preparation is employed at three copper-smelting plants. This method presupposes a combined wet crushing of quartz and limestone used as fluxes. Copper concentrate pulp is delivered to the stockyard of a copper-smelting plant. Quartz and limestone pulp is then added in the required amount to the concentrate, after which the mixture is filtered and dried. Some difficulties in introducing the process were caused by the attempt to crush the quartz and limestone separately, which drastically impaired the filtering process because the limestone was broken too finely. These difficulties were removed when quartz and limestone were disintegrated together.

4. The method of wet charge preparation: (a) improved the quality of charge and ensured a variation of SiO_2 content in the charge up to ± 2 per cent abs., and of CaO up to ± 1 per cent abs.; (b) reduced the total moisture content of the charge after filtering from 14 - 15 per cent to 10 - 11 per cent; (c) increased the capacity of filters by 30 to 40 per cent; (d) provided for comprehensive automatisation of the charge preparation process.

Roasting of concentrates

5. Copper concentrates were roasted before smelting at old plants in multistage mechanical furnaces which had a rather low output. The roasting operation was intensified by conducting the process in a fluidized bed which was initially employed for zinc concentrates. The comparative indices of these two methods of roasting copper concentrates for one of the plants are illustrated in table 1.

Table 1

Roasting copper concentrates

	Multistage furnaces	Fluidised bed
Daily total output, ton/m^2	8 - 9	65.0
Content of O_2 in gases, per cent	7.0	12.5

6. At the present time, copper concentrates are roasted in a fluidised bed at two plants in the Union of Soviet Socialist Republics (Urals, Caucasus), at one plant in Bulgaria (Pirdop) and at one in the United States (Copperhill Tennessee Copper Company). A higher concentration of SO_2 in the roasting gases permits part of the converter gases low in SO_2 (2-3% SO_2) to be used for the production of sulphuric acid because the mixture of these gases contains 7 - 7.5% SO_2, the most suitable amount for the operation of contact apparatus. Semi-industrial experiments have been already conducted and tests on an industrial scale are anticipated in the near future for enriching blast with oxygen in roasting copper concentrates in a fluidized bed. Preliminary calculations indicate that a further increase in the capacity of furnaces and content of SO_2 in gases can be expected (table 2).

Table 2

Capacity increase of furnace

Oxygen content in the blast, %	Daily total output of furnace, ton/m^2	SO_2 content in gases, %
21	65	12.5
25	77	13.6
30	92	16.2
35	108	18.7

7. Enrichment of the blast with oxygen may raise the roasting temperature beyond all reasonable limits. This can be prevented by the extraction of surplus heat with

the aid of heat exchangers installed in the furnace or by adding some more water with the concentrate. When roasting is conducted in a fluidized bed, a considerable amount of concentrate is carried away from the furnace and precipitates in cyclones and electric filters. Roasted concentrate has a finer structure than that obtained in multistage furnaces. For this reason, much of the concentrate was carried away by the gases when it was loaded into the reverberatory furnace by the usual method, through the opening in the roof. Today the charge is loaded through the walls of the reverberatory furnace directly onto the bath, which has reduced the loss of the charge twofold.

Reverberatory smelting

8. The smelting of copper concentrates (raw and roasted) in reverberatory furnaces is the most widespread method for producing copper matte. Modern reverberatory furnaces with a hearth area of 200 to 250 m^2 are heated by coal dust, liquid and gaseous fuels. The specific consumption of fuel runs usually into 18 to 22 per cent of the charge weight. Most of the furnaces can handle 500 to 600 tons of charge daily, the specific smelting rate varying within 2.5 to 3 ton/m^2 per day for raw charge and 4 to 5 ton/m^2 for hot roasted charge.

9. The output and thermal power of reverberatory furnaces have been considerably improved in the Union of Soviet Socialist Republics (up to 50-60 million kcal/hr) by increasing the amount of fuel burnt in unit time. The specific smelting rate of furnaces which process raw charge has reached 4 to 4.5 ton/m^2 per day and of those which handle roasted charge 7 to 8 ton/m^2 daily. Only 20 to 25 per cent of heat generated by burnt fuel is used in reverberatory furnaces to smelt the charge. About 50 per cent of heat is carried away by exhaust gases having a temperature of 1200-1250°. As a rule, waste heat boilers which transform the heat of the exhaust gases into high-pressure steam suitable for the generation of electric energy are installed behind the reverberatory furnaces.

10. Some heat produced by the gases can also be employed to heat up the blast with the aid of recuperators mounted behind the waste heat boilers. The experience of heating up the blast to 200 to 350° gained in a number of countries shows that when the secondary air of the reverberatory furnaces is heated up, the specific consumption of fuel drops by 7 to 10 per cent and the specific smelting rate increases by 15 to 20 per cent. The heat of the exhaust gases can be thus utilized most economically and the thermal efficiency of the furnaces considerably improved.

11. Enrichment of the blast with oxygen is yet another method for increasing the capacity of reverberatory furnaces. In this field only experiments on an industrial scale are being carried out so far. The industrial experiments conducted at one of the Soviet plants, which utilizes coal dust as fuel, have shown that when the concentration of oxygen in the blast is increased by 1 per cent (within the range from 21 to 29 per cent) the furnace has a 2.74 per cent greater capacity and some 2.2 per cent less fuel is used. With 29 per cent oxygen in the blast, the exhaust gases contained about 2.5 per cent of SO_2. It has been calculated that the saving in fuel effected at this plant pays for nearly all the expenditures involved in producing oxygen. At another plant, experiments are underway on using the oxygen from a furnace fuelled by natural gas. The content of oxygen in the blast was raised to 35 per cent. The comparative indices of smelting on air and oxygen enriched blast (35 per cent) are shown in table 3

Table 3

Comparative indices of smelting on air and oxygen enriched blast

	Air flow rate, normal m^3/hr	Oxygen flow rate, normal m^3/hr	Daily specific smelting rate, ton/m^2	SO_2 content in exhaust gases,%	Copper content in slag, %
Air blast	30,000	-	4 25	1.5 - 2	0 46
Oxygen enriched blast	38,000	8,900	6.0	6 - 7	0 39

12. The flame temperature was found to increase noticeably (from 1450-1480° to 1580-1600°) while the temperature of the gases in the uptake underwent practically no changes. The use of oxygen made it possible to decrease the fuel consumption by 30 per cent, reduce the amount of exhaust gases by 40 per cent and increase the specific smelting rate by 30 per cent. Similar results were provided by the tests on using oxygen in reverberatory smelting of nickel concentrates conducted at the Copper-Cliff Works (Canada). With a blast of 72 to 80 tons of oxygen per day, the output increased by 36 per cent and fuel consumption dropped by 31 per cent.

13. A higher concentration of SO_2 in exhaust gases gives us grounds to consider the problem of their utilization for the production of sulphuric acid, which is especially important for preventing contamination of the air. Greater capacity of reverberatory furnaces and therefore higher output of matte required a new method of tapping. Instead of opening the shot hole by burning it through with oxygen manually, matte is now let out by means of a bottom gate system.

II. SMELTING IN SHAFT FURNACES

14. Some plants in the Union of Soviet Socialist Republics employ both the semi-pyrite smelting of copper ores and sintered copper concentrates and the shaft smelting of sulphide copper ores with a simultaneous production of elementary sulphur (Orkll method). Since 1960, oxygen enriched blast has been successfully used for smelting sintered copper concentrates in water jacket furnaces. The technological indices of the process are represented in table 4.

Table 4

Technological indices at smelting in shaft furnaces

	Content of oxygen in the blast, %			
	20.9	23.7	25.2	27.3
Consumption of coke in % of charge weight	7.89	6.94	6.13	5.93
Blast intensity rate, normal $m^3/m^2/min$	85.5	77	75.2	61.8
Blast pressure, mm Hg	153	126	124	113
Daily specific smelting rate, ton/m^2	101	107	115	115
Temperature of exhaust gases, °C	590	460	375	320
Amount of exhaust gases, normal m^3/hour	30,700	30,400	29,300	29,300

15. Besides better technical indices, oxygen enriched blast provides for a more stable and uniform working of furnaces, reduces the formation of sculls in the tuyere zone and the furnace top. The outage of the furnaces has been cut down, servicing made much easier and the sanitary conditions of labour appreciably improved. The economical effect from the use of oxygen is derived from: (a) saving obtained by increasing commodity output - 60 per cent; (b) saving from lower fuel consumption - 33 per cent; and (c) other items - 7 per cent.

16. Technical and economic calculations show that some grades of copper sulphide ores rich in copper, sulphur, noble metals and rare elements can be processed most effectively by shaft smelting with the use of the Orkll method. The method ensures a higher degree of extraction of noble metals and rare elements as compared with the enrichment-concentrate smelting process in reverberatory furnaces while the bulk of sulphur is extracted in the elementary form. However, the efficiency of the method is impaired by a low degree of reduction, a low direct (without catalysis) extraction of sulphur in the elementary form and the absence of an efficient and cheap procedure for granulating ore fines.

17. Soviet scientists have developed and introduced into practice the silicate process for the production of briquettes with a high mechanical and thermal strength. Tests conducted in industrial furnaces have clearly shown that a low reduction in smelting is the result of oxygen deficiency. The use of oxygen enriched blast in smelting copper ores by the Orkll method presents therefore a considerable interest. Experiments and theoretical calculations suggest that, in addition to higher output of the furnaces, it will be justifiable to expect, under definite conditions, a higher copper content in matte, and an increase in the extraction of copper from 82 to 91 per cent and of sulphur by 8 to 10 per cent.

III. FLASH SMELTING

18. Flash smelting consists essentially in burning pulverized sulphur copper concentrates. The process will be autogenous if the heat evolved in sulphide oxidation is enough to melt down the charge. When sulphur concentrates are burnt in the flow of cold air the developing temperature is too low to melt the charge. In order to obtain the required temperature (1250 to 1300°) the structure of the thermal balance of the process must be changed either by increasing the input of heat or by reducing its flow rate.

19. Heat input can be increased with a hot air blast, which is now used on an industrial scale at Harjavalta (Finland), Asio (Japan) and Baja-Mare (Romania) plants. When the blast is heated up to 500°, the developing temperature may be insufficient to melt down the charge. For this reason, some more additional liquid fuel (1 to 2 per cent of the charge weight) is burnt in the furnace at the Harjavalta plant. The volume of exhaust gases and the amount of heat they carry away can be reduced by oxygen blast. In this case, the volume of exhaust gases is reduced four- or fivefold, the amount of heat carried away decreases in proportion, while the developing temperature is high enough to melt down the charge. The smelting process is fully autogenous. This method is employed at Copper-Cliff (Canada) and will be introduced at one of the Soviet plants.

20. These two methods can be also combined by using the hot and oxygen enriched blast. Flash smelting offers the following advantages: (a) fuel consumption for the smelting process is considerably reduced and is completely dispensed with in the case of oxygen smelting; (b) the degree of desulphuration for the production of matte rich in copper is sufficiently high and easily adjustable; (c) high specific capacity of the furnace (up to 12 ton/m^2 per day); and (d) practically all the sulphur contained in the concentrates can be used to obtain sulphuric acid (with a hot blast) or liquified sulphur dioxide (with a technical oxygen).

21. At the same time, flash smelting is more complicated technically than smelting in a reverberatory furnace for the following reasons: flash smelting requires a thorough preliminary drying of the charge since wet charge cannot be blown in through the burners; slags from flash melting furnaces are more rich than slags obtained from reverberatory furnaces and contain 1 to 1.5 per cent copper without any additional treatment. Various methods are in common use for reducing copper content in slag. For example, at the Harjavalta plant, cooled slag is subjected to floatation concentration, producing a concentrate with 16 to 18 per cent of copper and tailings with 0.3 per cent of copper. The Copper-Cliff decreases the copper content in slag inside the furnace by blowing pyrite concentrate into the rear end of the furnace. The Asio plant does the same in an electric furnace and the Baja-Mare plant in a reverberatory furnace.

22. However, despite all its shortcomings, the advantages offered by flash smelting (primarily full utilization of sulphur) make it a most promising method for smelting copper sulphide concentrates. A series of experiments have been undertaken in the Soviet Union for flash smelting on oxygen blast in a semi-industrial furnace, 8 m^2 in area, which served as the basis for designing and building an industrial furnace at one of the copper-smelting plants. The summary data on the operating flash smelting furnaces are illustrated in table 5.

Table 5

Summary data on operating flash smelting furnaces

	Harjavalta (Finland)	Copper-Cliff (Canada)	Asio (Japan)	Baja-Mare (Romania)	USSR – Semi-industrial plant	USSR – Industrial plant (project)
Blast	hot 500°	techn. oxygen	hot 500°	hot	techn. oxygen	techn.oxygen
Furnace area, m^2	76	150	42	-	8	120
Output, ton/charge per day	550	1360	200	-	20 - 120	1400
Concentration of SO_2 in gases, %	7 - 8	80	-	11 - 12	80 - 85	75
Method of decreasing copper content in slag	floatation	pyrite blast	electric smelting	reverberatory furnace	pyrite blast	pyrite blast
Copper content in slag, %	0.3	0.55	0.6-0.7	-	0.5-1.5	0.5
Copper content in matte, %	60	40 - 45	52	55 - 60	30 - 70	40 - 50

IV. CONVERTING THE COPPER MATTE

23. The use of oxygen enriched blast in copper matte conversion has been the object of research in the Union of Soviet Socialist Republics since 1949, at first in an experimental three-ton convertor and then in a forty-ton industrial convertor. Oxygen in the blast has been found to vary from 21 per cent to 45 per cent. The object of the research was to determine whether the operation of the converters can be intensified and the concentration of SO_2 in gases increased to facilitate their use in the production of sulphuric acid. It has been found that the conversion rate is almost proportional to the concentration of oxygen in the blast. Freezing of the converter tuyeres has been observed to diminish. Concentration of SO_2 in converter gases also increases in proportion to the content of oxygen in the blast. At the same time, the rising temperature intensified the wear of the refractories.

24. The use of a blast enriched with oxygen up to 24 to 25 per cent has proved quite feasible in practice. The temperature of the mass in the converter could be maintained at a constant level on condition that more cold additions were processed. Similar results were obtained at the Copper-Cliff (Canada) in converting copper-nickel matte. Formerly, the converters could not cope with all the rich returned materials in the foundry and some of them (up to 360 tons per day) had to be processed in a shaft furnace. An addition of oxygen to the blast enabled this surplus to be processed in converters. It has been shown that 2.6 tons of cold returned materials can be smelted in a converter per ton of blown-in oxygen.

25. It has also been found possible to smelt a concentrate (moisture content 7 per cent) and rich ore (moisture content 5.5 per cent) by blowing them into a converter when the blast contains 29 and 32.5 per cent oxygen. The converter output in terms of concentrate and ore exceeded 360 tons per day. The metallurgists at the Hitaty plant (Japan) have been smelting sulphide copper concentrate for a number of years in converters using an oxygen enriched blast, the converter gases being utilized for the production of sulphuric acid.

26. At one of the Soviet plants, copper matte is converted by a blast with up to 25 per cent oxygen. The converter is loaded with siliceous copper concentrate containing 34 per cent copper, 12.5 per cent sulphur and 40 per cent silica. The concentrate is granulated in advance and the granules are dried. The maximum amount of granulas smelted in a converter was 88 per cent of the hot matte weight. The consumption of quartz flux dropped by 20 per cent at the expense of the silica contained in the concentrate. The duration of the operation remained practically the same,

but the weight of copper melt increased by 27 to 29 per cent. Thus, an oxygen enriched blast can be effectively employed for conversion with an adequate supply of cheap oxygen and a surplus of copper-rich hard materials (returned products, rich ores and concentrates).

V. ECONOMIC ASPECTS OF USING OXYGEN AND HOT BLAST IN THE COPPER INDUSTRY

27. Experiments and practical experience show that oxygen intensifies metallurgical processes, increases efficiency of the equipment and saves fuel. The economic expediency of using oxygen depends on a number of conditions, primarily on the relationship between the costs of electric energy and fuel. Modern oxygen plants consume about 0.6 kWh to produce 1 m^3 of oxygen. Accounting for the other operational expenditures it can be assumed that the cost of 1 m^3 of oxygen is equal to the cost of 1 kWh of electric power. If the saving from reduced fuel consumption and other expenses is larger than the cost involved in producing oxygen, its use will be economically justified. Still more effective is the use of hot blast to reduce fuel consumption in smelting, especially when heating is done by the heat of exhaust gases and slags.

28. An oxygen plant is invaluable when the capacity of the enterprise has to be increased but there is no space for additional equipment. The third aspect of the problem consists in reducing the discharge of sulphur dioxide into the atmosphere. All the known methods employing gases with a low content of sulphur dioxide (ammonia, magnesia etc.) are not economical, involve a large capital outlay and are used therefore in the copper industry on a limited scale. Oxygen enriched blast increases the concentration of sulphur dioxide to an extent suitable for a direct production of sulphuric acid.

[redacted]

74.10.14