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THE USE OF OXYGEN IN STEEL PRODUCTION[1]

by

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[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.

SUMMARY

The paper presents a brief description of contemporary methods involving the use of top blowing for intensification of the steelmaking process in open-hearth, twin-bath, and electric-arc furnaces, as well as in LD converters. A reasonably detailed account is given of the methods themselves, the melting technology, and the results that can be achieved.

In addition to quoting performance figures for individual furnaces, the discussion of open-hearth steelmaking also contains general information on the effect of blast intensity on furnace output and on the consumption rate for oxygen and fuel. The paper examines the role of heavier furnace charges and faster charging rates in the attainment of better production efficiency. Particular attention is focused on the performance analysis of the twin-bath furnaces that have been installed, in place of open-hearths, at existing plants. Despite the acknowledged technical and economic soundness of this substitution, this approach through the modernization of the open-hearth shop is not at variance with the basic trend, which is one of primarily seeking the expansion of LD production.

The basic LD shop in the Soviet Union is the three-vessel shop. In the best Soviet shops, the yearly production per unit of total rated installed vessel capacity exceeds 10,000 tonnes. The paper contains data on the operation of three LD shops in 1971 and discusses ways of improving this steelmaking method.

In the section on electric steelmaking, information is presented on the use of oxygen in the production of very low-carbon, stainless, and electrical steels (with a C content of less than 0.03 per cent) and on the effectiveness of supplementarily heating the charge by means of fuel burners installed in the roof and charging aperture of the furnace. The resultant savings in electrical power amount to 34-43 percent of the energy required to heat the gas.

The paper's brief concluding section is devoted to a discussion of the most immediate outlook for the expansion of steelmaking in the USSR.

The use of oxygen has been one of the most effective means of increasing the productivity of steel mills and of improving their technical and economic performance. It would be no exaggeration to say that, by stimulating the development of new techniques and radically modifying older ones, this method has revolutionised the steelmaking process. The advances in the development of the oxygen-converter steelmaking method has marked the culmination of a definite stage during which the necessary data were gathered regarding the interaction of gaseous oxygen with the iron-carbon melt and the industrial methods were devised for the acquisition of large amounts of oxygen.

The Soviet Union addressed itself to the problems of an oxygen technology earlier than did other countries. Oxygen began to be used in the liquid-fuel open-hearth (OH) pig and scrap process in the USSR after 1945 as the result of experiments carried out as far back as the prewar period. The OH furnaces of one plant were completely converted to a system of oxygen injection into the flame and refining bath. The industrial use of oxygen in liquid-iron OH furnaces operating on the scrap-ore principle began in 1952.

The next period was marked by the rapid introduction of oxygen to steelmaking by the converter, OH, and electric-furnace methods and by an improvement in furnace performance. The achievements of individual plants in this area have been widely discussed in the technical literature and there is no need to dwell on them at this point. At the present time, 62 per cent of all OH steel in the Soviet Union is produced using oxygen at a specific rate of about 48 m^3 per tonne of steel.

Steel production by the oxygen-converter (LD) system reached 23.2 million tonnes by 1971, or more than 21 per cent of the total quantity of the steel produced in the country's iron and steel plants. Oxygen has likewise won wide acceptance at mills using electric furnaces, where it has contributed significantly towards simplifying the production of low-carbon (stainless, transformer, etc.) steels.

This report will deal with the modern state-of-the-art of a variety of steelmaking processes using oxygen, with attention also given to structural modifications of the associated equipment. In analysing the development trends reflected in different production processes, certain particular features which have affected the rate of re-equipping the Soviet iron and steel industry must by borne in mind. One of these special factors consists in the fact that when the technological restructuring of the metallurgical industry began on a worldwide basis, the Soviet Union had a very considerable steelmaking capacity concentrated in relatively new OH mills. Rather than build new converter-process plants, it was economically more advantageous and simpler to achieve increased output by shifting the OH furnaces to stepped-up operating conditions. The second particular factor had to do with the absence of reserve capacities, thereby excluding the possibility of substituting one method for another with no break in production. The over-all development policy for ferrous metallurgy in the USSR provided for a gradual shift in major emphasis to the more advanced oxygen-converter process, along with a larger share of steel produced in electric arc furnaces in the total production balance.

OPEN-HEARTH PROCESS

In recent decades the use of oxygen in OH steelmaking has been the key factor behind technical progress in this area. At mills operating with the scrap-ore process (which accounts for 85 per cent of OH steel), by far the greater part of the furnaces are equipped with devices to inject the oxygen into the furnace chamber and directly into the bath. Both these methods of process intensification are employed either separately or jointly, as local conditions may require.

The delivery of the oxygen to the flame for the purpose of boosting the heat action of the furnace is accomplished in different ways in differently fired furnaces. When liquid fuel and high-calorific-value gas is used, the oxygen is fed to burners, while in the case of furnaces having three-channel ports heated by a gas mixture, oxygen lances are installed along the sides of a water-cooled jacket; this is also the practice with furnaces fired by natural gas, a portion of which undergoes thermal decomposition in the vertical flue (so-called self-carburation). In certain instances, furnaces are equipped with roof rather than end burners, or else nozzles located in the furnace roof are used to inject the oxygen into the chamber.

The introduction of oxygen to the flame has a pronounced effect on the thermal operation and productivity rate of OH furnaces. With the combustion air enriched by oxygen, the amount of flue gas is reduced and the temperature of the flame is increased, while at the same time the thermal and aerodynamic characteristics of the gas flow within the furnace chamber are also modified. The fixed oxygen jets contribute to stability and good bath coverage on the part of the flame, while the marked difference in the flow rate of the oxygen and the basic gas-air stream promotes a better mixing of the gases in the furnace. As a result of these changes, convective and radiant heat exchange between flame and bath is improved and the oxidizing processes in the bath are stimulated. Ultimately there is an improvement in the furnace's fuel utilization and an over-all increase in the thermal efficiency of the active chamber.

With the blast only slightly enriched by oxygen (23-25 per cent) and with this oxygen injected during all cycles of the heat other than the fettling and final refinement stage, furnace efficiency increases by 15-20 per cent and general fuel consumption decreases by 10-15 per cent. More intense oxygen injection into the flame results in considerably higher furnace productivity (by 50 per cent and more); however, the implementation of this method under actual plant conditions entails great organizational difficulties along with the need to use well-prepared scrap. Oxygen injection into the flame becomes inefficient at low furnace charging rates (less than 100 tonnes/hour for furnaces with up to 200 tonnes capacity).

Experience indicates that, in terms of the effect on furnace productivity and fuel consumption, oxygen blowing of the bath is at least twice as efficient as flame enrichment. Moreover, this disparity in effectiveness grows larger as the blowing rate increases. The explanation for the wider use of what is, technologically speaking, the less advantageous method of melt intensification lies in the fact that this technique makes it possible, at mills with limited through-put in certain sections plus a wide range of steels to be produced, to maintain a rather high level of production, to schedule the heats, and to minimize the consequences of furnace "ageing".

As the so-called "bottlenecks" are eliminated, the percentage of oxygen used for the direct oxidation of the bath is increased.

In those cases in which the oxygen is used with both the flame and the bath, high-enrichment blowing occurs only during the initial periods of the heat - up to the addition of the hot metal. Oxygen injection into the flame is normally discontinued when blowing begins.

The use of oxygen to achieve more intense heat conditions in the furnace constitutes a basic operating procedure at Soviet steel works. As this method has undergone industrial development and improvement, the necessary equipment has been designed to provide failure-free operation during the entire furnace cycle.

At the present time, the major emphasis in research aimed at intensifying the OH process has shifted to direct oxidation of the bath by blowing oxygen through the liquid metal. The oxygen is introduced into the bath through water-cooled lances located in the roof of the furnace. Two or three such lances are employed for high oxygen flow-rates.

There is great structural variety in the lances used at the mills - in the number and diameter of the nozzles, their angles of inclination with respect to the axis and cylindrical surface of the lance, and also with respect to the location of the nozzle outlet sections. Soviet author's certificates (patents) have been issued for a number of original lance designs.

The reduction in heat duration with oxygen blow-through is achieved not only during those periods when this blowing occurs, but also during the preceding periods when the furnace is charged and initially warmed through. The reason for this is to be found in the fact that in oxygen-blown heats there is a substantial reduction in ore and lime consumption, while a lower-than-usual required level may be adopted for the heating of the charge prior to the addition of the pig.

Of no less and indeed even greater importance, in the achievement of high shop productivity, is the organization of the initial cycles in blown melts as opposed to those which do not use blowing or oxygen.

The blowing rates adopted at Soviet steel works do not normally exceed 6-8 cubic meters per tonne per hour, although at certain 250-tonne furnaces, including some with two baths, a specific rate of 15-20 $m^3/t/h$ is encountered. The maximum blowing intensity for heavy-load furnaces is no more than 10 $m^3/t/h$.

Some idea of the effectiveness of these forced operating conditions can be gained on the basis of the following data referring to the performance of individual furnaces in 1971.

Parameter	Rated furnace capacity, tonnes		
	240	600	900
Actual weight of melt, tonnes	241	634	913
Yearly output of steel, thousands of tonnes	604	631	728
Standard fuel consumption kg/tonne	39	39	84
Oxygen consumption, m^3/tonne	40	55	42
Idle time, percentage of calendar time;	14.8	9.5	9.4
including cold periods	8.4	4.9	6.4
Main roof life, no. of heats	196*	254	230

* To intermediate partial repair of the roof.

These figures attest to the very substantial possibilities for improving OH furnace output by blowing oxygen through the bath at stepped-up hourly flow rates. In an approximation, which naturally makes no allowance for the specific operating conditions of individual plants, furnace productivity P (tonnes/hour) can be found for a melt weight G (tonnes) and specific blowing intensity I (m^3/tonnes/hour) by using formulae corresponding to a normal (1) and high (2) level of shop organization:

$$P_1 = (2.5 + 0.125\ I)\ \sqrt{G}, \qquad (1)$$

$$P_2 = (2.5 + 0.188\ I)\ \sqrt{G}. \qquad (2)$$

Formulae (1) and (2) were derived from a generalization of experience in the operation of OH furnaces with charges of 250 to 900 tonnes.

For the consumption of a standard fuel g (kg/tonnes) one may approximately take:

$$g = 100 - 5.1\ I + 0.08\ I^2; \qquad (3)$$

for the oxygen expended in the blowing K (m^3/tonne):

$$K = 1.6\ I; \qquad (4)$$

and for the total oxygen consumption K_{Σ} (m^3/tonne):

$$K_{\Sigma} = 40 + 1.375\ I - 0.03\ I^2. \qquad (5)$$

A factor greatly affecting furnace productivity is the charge loading rate, taking into account the hot metal. In furnaces at different plants a two-fold increase in this parameter is also matched by an approximately similar increase in productivity.

The use of oxygen for bath refining fundamentally alters the traditional OH steelmaking technology in that it affects the kinetics of the transformations and modifies the material and thermal balance of the melt. The fundamental change consists in the fact that a process whose rate was basically determined by the diffusion kinetics of the oxygen's penetration of the metal has been replaced by one in which the delivery rate of this reagent is controllable over a wide range. Moreover, the thermal effect of direct oxidation has lead to a reduction in the bath's requirement for outside heat. On the technological level the change has primarily concerned the per-heat consumption of oxidizers and slag-forming materials, as noted above.

Oxygen blowing of the bath results in increased metal losses both in the slag and with the flue gases. Also observed is a faster rate of deterioration in the refractories of the roof due to the effect on them of the ferric oxides. A number of measures have been adopted for increased roof stability, such as alterations in roof design and attachment, the introduction of rules for thermal conditions and the use of the oxygen, techniques developed at certain works for the aerodynamic protection of the roof, and the like. To prevent the rapid fouling of the checkers by furnace dust, the dimensions of the regenerator chamber cells are increased, the slag chambers are cleaned during the run of the furnace, and the checkers themselves are de-skulled.

Furnace operation at normal (6–8 m^3/tonne/hour) and high oxygen flow rates for blowing has become a standard procedure at Soviet iron and steel works and may now be regarded as a thoroughly routine and tested intrinsic element of everyday practice.

Because of the great amount of time and labour required to repair the lower structure of OH furnaces, and in the interests of better adapting furnace design to high-rate blowing operations, considerable attention has been directed in recent years to the development of new systems of heat regeneration by some non-traditional means. What are involved here are the kind of twin-bath furnaces that were placed in operational service in the Soviet Union in 1965.

In 1972, the USSR had in operation at its iron and steel facilities four fixed twin-bath furnaces with a bath capacity of 250 tonnes each. The 1971 performance figures for three of them (the fourth was made operational only in 1972) are given in the following table.

Parameters	Furnaces A	B	C
Yearly output of steel, thousands of tonnes	1,132	1,134	1,078*
Mean real weight of melt, tonnes	283	289	287
Standard fuel consumption kg/tonne	21	13	13
Oxygen consumption, m^3/tonne	80	65	61
Expenditure of refractories for repair, kg/tonne	5.2	3.9	4.7
Lining life, no. of heats	575	771	702
Maximum life	652	923	926
Consumption of metal charge allowing for 50 per cent oxidant iron, kg/tonne	1,130	1,129	1,129
Idle time, percentage of calendar time:	9.4	8.9	7.4
including cold periods	6.4	7.0	5.6

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* Became operational on 8 January 1971

With respect to productivity rates, twin-bath furnaces have yet to achieve their limiting capabilities, as evidenced by the steel production figures for individual months. Recently, a blowing intensity of 7,000 - 8,000 m^3 per hour has been adopted, which is in line with established furnace operating conditions in the shop; however, design modifications of the equipment and improvements in working procedures will result in higher blowing rates.

The replacement of OH furnaces by the twin-bath type has the effect of freeing considerable floor space in the shop, which can then be used for the installation of additional equipment - slag-melting furnaces, electric furnaces for alloying, and the like. This will facilitate the production in twin-bath shops of a wider range of steels, including low-alloyed and alloyed types, and will contribute to improved steel quality.

With the twin-bath furnace, charges of varying scrap content can be processed by supplying additional heat to compensate for any insufficiency (with a high metal scrap content). In point of fact, the furnaces at the plants cited above operate with a 65-68 per cent consumption of liquid iron, the thermal balance in this case being achieved by a slight addition of heat by means of burners installed in the furnace roof, or even with no additional consumption at all.

A typical low-fuel-consumption heat (furnace A) is characterized by the following parameters. The cold charge receives 110-130 tonnes of scrap and 10-15 tonnes of lime; iron ore is employed only during the hot running of the melt during the refining period. The liquid iron is poured in some 15-20 minutes before tapping from the adjacent bath. Plate dampers are used to vary the direction of the gases, and the blow-through of the bath, into which the first ladle of iron has been poured, commences. The blowing rate during this cycle is 5,000 m^3 of oxygen per hour. The thermal load during the hot metal charging drops to 4-6 kilocalories per hour, with fuel delivery to the working chamber of the furnace discontinued at the end of charging. Fuel is not added to the furnace during the melt and the oxygen flow rate into the bath is increased to 7,000-8,000 m^3 per hour, at which level it is maintained until half the refinement period has elapsed. When the carbon in the metal has been caught at about 0.1 per cent blowing ceases. Fuel is fed into the furnace during refinement, at up to 10 million Kcal per hour depending on the heating of the metal. While the furnace is being primed, the thermal load amounts to some 5 million Kcal per hour, standing at 30 and 20 million Kcal per hour during the brief periods of cold charging and heating, respectively.

Technologically speaking, the twin-bath steelmaking process differs only slightly from the OH process with high-rate oxygen blowing of the bath. On the other hand, a higher ferric oxide content has been noted in the slag during the heat and prior to the killing of the steel (the difference, when converted to ferrous oxide, may be as much as 10 per cent). When producing the more important grades of steel, a bath "boil-over" technique is employed towards the end of the heat by adding pig iron and ferromanganese, thereby more effectively flushing the steel clean of gases and non-metallic inclusions.

Assuming the usual sulphur and phosphorus content in the iron used, the desulphurization and dephosphorization processes take place in twin-bath furnaces with an acceptable degree of thoroughness and do not constitute a limiting factor in the production of steel having a low content of these admixtures (for example, very deep-drawing steel).

Rimmed and balanced steels for the manufacture of sheet structural shapes are the primary types produced at twin-bath shops. At certain shops the percentage of killed carbon and low-alloy steels accounts for only 5 to 35 per cent of the entire production, for the reason that there are sufficient OH furnaces at the shops to meet orders for this metal. Although in principle there are no problems in producing a wider range of steels with the twin-bath furnace system, this does entail a lowering of the rate of productivity.

The quality of twin-bath metal is on a par with OH metal. There is no difference in the oxygen content in the metal either during the heat, in teeming, in the ingots, or in the finished rolled steel. If technical oxygen with a purity rating of 95-96 per cent is used for the blowing, about a 0.001 per cent increase in nitrogen content is observed. The production of low-nitrogen steel requires the use of 99.5 per cent pure oxygen or better.

No substantial quality differences have been found in the actual use of OH and twin-bath rolled steel.

The ingot yield at twin-bath shops is approximately 1.5 per cent lower than at OH facilities operating with soft blowing (6-[illegible] m^3/tonne/hour), but is close to the yield achieved at OH furnaces working under forced intensification conditions.

By properly timing the work of twin-bath shops to turn out frequent but small heats of metal, a more uniform loading of steelmaking and rolling mill equipment is possible, with an attendant series of additional advantages (increased handling capacity for the casting bay, less iron loss in ingot heating for rolling, better soaking pit productivity and lower fuel consumption in the pits, etc.).

In the very near future, new and improved twin-bath furnaces are scheduled to be installed at Soviet iron and steel plants. Although this policy of replacing obsolete equipment with more modern units will continue to remain in force, it does not represent a departure from the major trend, which is one of emphasizing the development of production by the converter process. At all newly constructed steel works plans call for the installation of converter shops, which, once they have been placed in service, are to provide the basic production growth factor. On the other hand, the building of twin-bath furnaces at existing OH shops constitutes one of the measures aimed at modernizing shops currently in operation whose retention is deemed necessary for a long time to come.

The performance indicators of the twin-bath furnaces operating in the USSR attest to the high level of engineering involved and to the thorough development of the associated process. Nevertheless, experience shows that these indicators can be significantly improved.

PRODUCTION BY THE CONVERTER METHOD

The first experiments involving the oxygen blowing of liquid iron were conducted in the USSR in 19[illegible]. The first oxygen converter was activated in 194[illegible], followed in 1956 by the starting of an oxygen-converter shop with three [illegible]-tonne vessels, and in 19[illegible] with three [illegible]-tonne vessels. There are presently in operation twenty-four 100-tonne to 1[illegible]-tonne and two 250-tonne converters.

The three-converter shop is the basic oxygen-converter (LD) shop type in the USSR. At the present time, in the best shops the specific rate of productivity (the shop's yearly production per unit of its total rated capacity) is more than 10,000 tonnes per nominal tonne of capacity per year; in a shop operating three 100-tonne converters this corresponds to a yearly output of 3.0-3.2 million tonnes. The following table reflects the performance indicators for two converter shops in 1971 and refined design data for a new 250-tonne converter shop.

Parameters	Plant		
	Novolipetsk*	West Siberian	Karaganda (per plan)**
Number of converters	3	3	3
Rated converter capacity, tonnes	100	100	250
Design capability of shop, thousands of tonnes per year	2200	2200	6000
Real output in 1971	3045	2894	
Real weight of melt, tonnes	142	124	
Mean duration of melt, min	45.0	42.4	45
Nominal running versus calendar time, per cent	64.1	65.2	66.7
Per cent of idle time versus nominal time	4.4	3.6	
Oxygen consumption, m^3/tonne	66.4	59.3	65
Consumption of metal charge per tonne of steel, kg:	1150	1131	1140
including iron	859	849	800
including scrap	277	268	327
Lining life, heats	485	709	600
Refractory consumption rate for lining, kg/tonne	3.8	1.6	3.0

* Material consumption figures are cited for 1 tonne of continuously cast slabs.

** Design data are cited for the Karaganda Plant since construction of the plant had not yet been completed in 1971 and the installed capacity was being broken in during this period.

In certain of the converter shops the blowing rate has at the present time been increased to 3.5–4.0 m^3/tonne/hour, resulting in a substantial reduction of the blowing time and, consequently, in greater steel output.

In the new 250-tonne converter shop of the Karaganda Steel Plant a blowing rate of 4–5 m^3/tonne/hour is possible with no after-burning of the gas. Plans call for all new shops to be designed in the future using gas-extraction systems having no after-burning.

Increasing the weight of the charge has also proven to be another effective technique for higher converter productivity. In point of fact, all converters having a capacity of 100 tonnes and more are operating with larger-than-nominal charges.

In their level of technology and operating procedures, as well as in terms of the use of converter capacity, the shops of the Soviet Union are not much different from the majority of similar facilities abroad – the blowing, slag-formation, reduction, and steel-casting methods are the same. Of vital importance to the achievement of improved converter-shop performance are the measures, in use and planned, for enhancing raw-material quality, standardizing the burden, and reducing converter idle time. A paramount concern is the need to ensure that the iron is of constant composition and that the level of harmful inclusions in it is low.

The range of steels produced in the converter shops of the Soviet Union is being constantly expanded. Along with rimmed, balanced, and killed steel of various composition and purpose, these shops are also turning out low-alloy and alloy steel (about 10 per cent). LD steel is employed in shipbuilding, in the construction industry, and for the manufacture of tanks, large-diameter gas pipelines, and many other items required by different branches of the national economy. There is, at the present time, a programme under way to broaden the range of oxygen-converter steel further, primarily by expanding it to include a number of stainless, electric, and other steel types for high-stress applications.

In recent years, as a result of research and development efforts to upgrade the quality of tar-dolomite refractory materials and improve melt procedures, there has been a significant increase in converter lining strength.

Factual data on the [illegible] lives achieved at the two plants is contained in the table presented above. It is important to bear in mind that, at several plants, when the converter charge was increased over the nominal value, this was accompanied by a considerable reduction in lining thickness (at the Novolipetsk Plant, for example), resulting in some strength loss. The greatest endurance was achieved at the West Siberian Plant - 850 heats. One of the tasks of the immediate future will be to raise this figure to 1,000 heats.

In 1971 the consumption of metal charge per tonne of oxygen-converter steel averaged 1,132 kg, although, depending on production conditions at the individual works, a wide variance can be found in mean plant figures - from 1,124 to 1,154 kg/tonne for converters with a charge of 100 tonnes and over. For all shops the specific oxygen consumption averaged close to 59 m^3/tonne.

Automation is destined to play a vital role in enhancing the efficiency of the oxygen-converter process. With the converter melt under static control, the number of heats which will fall within the assigned range for carbon and temperature can be increased to 65-70 per cent. By employing dynamic control, this figure can be raised to 85-90 per cent. Today in the Soviet Union a number of research and planning organizations are working on the development and improvement of dynamic systems and the design of the appropriate sensing units. In the 1971-1975 period computerized automation will inevitably become one of the more important trends in the progress of converter production technology.

One means of improving performance may be to increase scrap consumption at individual converter shops. In 1971 this figure was close to 240-280 kg/tonne for most large converters.

For the new shops to be constructed, plans call for scrap charging by means of boxes of sufficient capacity to permit a one- or two-step operation.

For several years the Soviet Union has assisted a large number of countries in the planning, construction, and running-in of iron and steel mills incorporating converter shops.

With the assistance of Soviet specialists and according to blueprints provided by Soviet planning organizations, converter shops have been or are being built in Algeria, Bulgaria, India, Poland, Finland, Egypt, Iran, Turkey, and the Democratic People's Republic of Korea, and similar projects are in the design stage for other countries.

ELECTRIC STEELMAKING

The use of oxygen for the decarbonization of metal and the intensification of the charge melting process in the production of alloy steels in electric arc furnaces began in the Soviet Union in the late 1940's. At the present time, as much as 90 per cent of the electric steel is produced in this manner, while in certain cases decarbonization by oxygen blowing constitutes the fundamental production technology element permitting the acquisition of a prescribed steel composition. Oxygen is primarily used in electric steelmaking practice in the production of ingot steel.

Oxygen consumption in the shops averages some 23 m^3/tonne. The oxygen is delivered through the charging door by means of fireclay-lined tubing or through a water-cooled nozzle in the roof. The optimal oxygen pressure is 8-10 atmospheres.

The oxygen is first fed to the scrap at the end of the heat in order to melt the charge at the furnace banks. The metal is normally blown even before the complete melting of the charge, this being justified when producing steel with a fresh charge and when remelting medium-alloy steel croppings. Early blowing of high-alloy steels is not economically justified since the additional costs for the alloy-forming elements, caused by their increased loss in burning, are not compensated by any decrease in the duration of the melt.

The use of oxygen results in a 10-15 per cent increase in furnace productivity and a decrease by about the same order of magnitude in the consumption of electric energy.

In low-carbon stainless and electric steelmaking, by introducing gaseous oxygen into the bath the temperature of the metal can be rapidly raised, thereby creating the necessary conditions for selective carbon oxidation.

The use of carbon provides the technological basis for the production of electric steel with a carbon content of less than 0.03 per cent in electric arc furnaces. What is important in this connexion is the fact that, thanks to the shallowness of the bath, the oxygen delivery rate in the below-0.05-per-cent carbon concentration range can be lowered with no perceptible decrease in the rate of decarbonization. In the converter process, because of the depth of the bath, intensive mixing requires that a high blowing rate be maintained throughout the entire decarbonization process, and the production of low-carbon metal is accompanied by a considerable loss of iron on ignition and overheating of the melt, leading to accelerated lining deterioration and problems in the deoxidation of the metal.

The process of the deep decarbonization of the unalloyed melt in a 100-tonne electric furnace is characterized by the following parameters:

Duration of the blow	16 - 22 minutes
Oxygen consumption	950 - 1400 normal m^3
Final carbon content	0.012 - 0.020 per cent

By combining a rational set of blowing conditions and deoxidation technology, it is possible to produce Armco-type electric steel with a carbon content of no more than 0.02 per cent and possessing the required magnetic and engineering properties.

Together with the use of oxygen to decarbonize type 18-8 chrome-nickel steel, which has a chrome content of 14-18 per cent before blowing and 0.06-0.08 per cent carbon in the finished metal, the oxygen blowing of iron-nickel melts in electric arc furnaces ensures a lowering of the carbon concentration in the metal to 0.005 per cent, thereby opening the way to further technological advances in the production of high-alloy steels of especially low carbon content.

Such high-alloy very-low-carbon steels are usually considered to include stainless steels with a carbon content of less than 0.03 per cent. Steels of this type offer corrosion resistance without the need for titanium-stabilization of the metal.

The development of the chemical industry and of specialized branches of science and engineering has brought with it an ever-increasing need for stainless steels of particularly low carbon content. This need cannot always be met through production in large induction furnaces because of the lack of charge components which are pure with respect to carbon and other elements and because of the increased consumption of electric power (by a factor of 2.5) in comparison with arc furnace production.

The task of ensuring a carbon content of less than 0.03 per cent in the production of stainless steel in electric arc furnaces constitutes a difficult metallurgical problem.

Several trends can be discerned at the present time in the development and establishment of an optimal technology for the production of these steels.

Of the familiar methods, the simplest, most reliable, and most economical, in our view, is refining in arc furnaces with a capacity of up to 50 tonnes using carbon-pure ferro-alloys, metals, and special alloys.

Studies conducted by the I. P. Bardin Central Scientific Research Institute of Ferrous Metallurgy jointly with one of the iron and steel works regarding the production of chrome-nickel-manganese steel of type 000Kh20N16AG6 in a 40-tonne electric arc furnace using a particularly low-carbon (to 0.02 per cent C) chrome-manganese alloy demonstrated the possibility and attractive future potential of producing this steel with a carbon content below 0.03 per cent.

At the same time it was established that by using high-quality graphitized electrodes the carbon content in the metal during the alloying of the bath is raised by only 0.01-0.015 per cent.

Work is presently being carried out in the direction of expanding the range of stainless steels, whose production by this method is exceptionally efficient.

In recent years, much attention has been directed in many countries to the problem of increasing the power of the transformers for electric furnaces. On a 140-tonne furnace a transformer power increase from 35-40 to 80 thousand kWA makes it possible to raise furnace productivity by 60-70 per cent; this means an increase in annual productivity to 400,000 tonnes. Specialists in a number of countries have voiced the opinion that specific transformer output should be 500 kWA and above for every tonne of furnace capacity, which is more than twice the power of the transformers normally used for furnaces of 100-200 tonnes capacity. It is to be noted, however, that the installation of ultra-high-power transformers is translated into especially high productivity rates only in the production of the conventional OH steel types.

Although it has shortened considerably the solid charge melting period, the use of oxygen for scrap handling in electric steelmaking has somewhat increased metal loss through burning.

In the absence of high-power transformers, the use of gas-oxygen burners is to be recommended for the intensification of the charge melting period in electric arc furnaces.

By reducing the duration of the charge melt, which accounts for a significant portion of the heat, not only is the productivity rate of the furnace increased, but the consumption of electric power is also cut back. One means of accelerating the charge melting rate is to additionally heat the charge in the electric arc furnace through the combustion of liquid or gaseous fuel. As compared with other methods, the combined use of heating and melting offers the following advantages: less capital investment than required to increase transformer output, no need for additional floor space for scrap preheating stands prior to furnace loading, and practically none of the released dust that accompanies the oxygen cutting of the charge.

Recent work in the Soviet Union has been aimed at the selection of suitable gas-oxygen burner designs and installation sites in the electric furnace, research into the technological and thermal features of steelmaking in heavy-load electric furnaces with fuel-burning devices, the determination of technical and economic performance indicators of the process, and the development of production technology involving the supplementary heating of the charge. Particular attention, in the analysis of the special features of the heat, has been focused on changes in the composition of the furnace atmosphere, ignition loss in the iron, the effect of the process on metal quality, and problems of improved burner operating efficiency.

As a result of these studies it has been established that the most rational location for the fuel-burning devices is in the charging door and roof of the furnace. For installation in the charging door, powerful three-nozzle movable burners have been developed which provide internal mixing with no water cooling and with a low noise level. For roof installation it is advisable to employ industrially developed and tested internal-mixing multi-nozzle water-cooled burners with elongated mixing chamber, using them in place of the oxygen lances.

The efficiency of the charge pre-heating process, determined as the ratio of the saving in electric power to the heat of the gas, is 0.44-0.63.

For 100-tonne furnaces with a 25-MVA transformer for two-slag steelmaking the use of such movable and roof burners with a gas flow rate of 3.6-9.3 m^3/tonne makes it possible to reduce melt time and electric consumption, in comparison with the process of intensification by oxygen alone, by 1.5-5.1 per cent and 2.6-9 per cent, respectively. Operation with an oxygen and gas flow ratio of V_o/V_g = 2.3-2.4 leads to even better performance figures.

CONCLUSIONS

The directives of the Twenty-Fourth Congress of the Communist Party of the Soviet Union call for an increase in steel production in 1975 to 142-150 million tonnes. The fulfilment of this task requires the improved exploitation of existing facilities, the further intensification of production procedures, the remodelling of a number of equipment systems so as to increase their productivity, and the construction of a large number of new systems with high unit output. By far the greater part of the steel production increases planned are to be accomplished through improved labour productivity.

During the current five-year period new shops will be placed in operation with converters of up to 400 tonnes capacity and with electric arc furnaces of 100 and 200 tonnes capacity. By increasing transformer output it will be possible to boost steel production in the existing shops or to reduce the number of electric furnaces in those being activated for the first time.

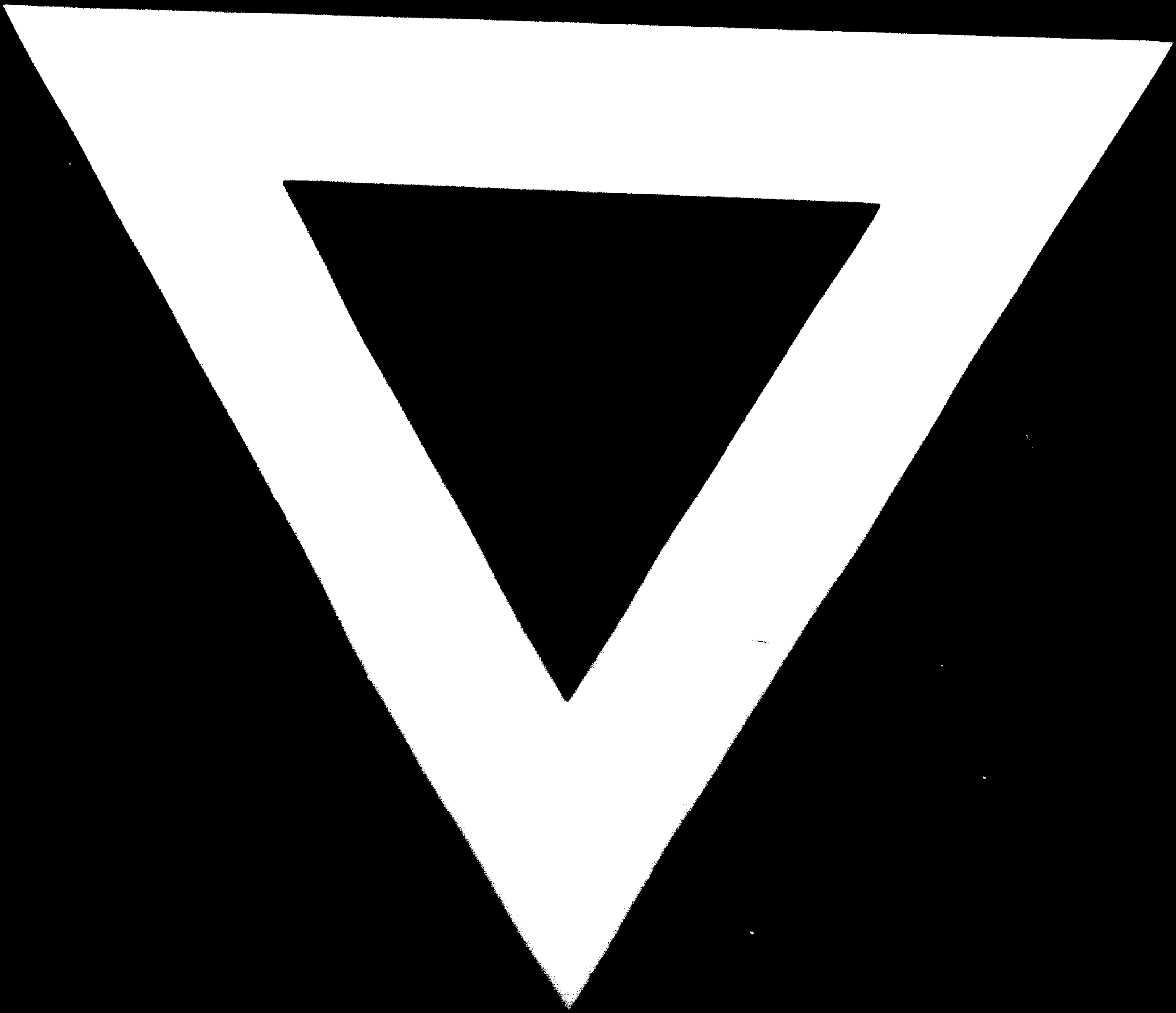
During this same five-year period fundamental changes will take place in the steelmaking sector. There will be a significant increase in the share of LD and electric steel in the over-all volume of steel produced. Plans call for a sharp intensification of oxygen converter operation by increasing the per-minute oxygen flow rate from 2.0-2.5 to 4-6 m^3/tonne capacity.

At the OH shops as much as 80 per cent of the steel produced will be processed with the use of oxygen. For greater efficiency in the delivery of the oxygen to the bath and flame, improved charging devices will be used and the bulk weight of the scrap increased through better preparation.

Improved technical and economic performance at already operating electric furnaces will be achieved, specifically through a more extensive use of oxygen for metal blowing and charge heating by means of gas-oxygen burners.

The key task of Soviet iron and steel making in the 1971-1975 period is the radical upgrading of the quality of metal production through the introduction of advanced production techniques and the expansion of the range of rolled products to achieve a substantial improvement in the effectiveness with which this product is employed in the national economy.

The fulfilment of these plans in the technical restructuring of the Soviet iron and steel industry will greatly enhance the technical and economic performance of this branch and will lay the foundation for its even more impressive acceleration in the foreseeable future.



8. 8. 74