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CONVERTER STEELMAKING IN THE USSR[1]

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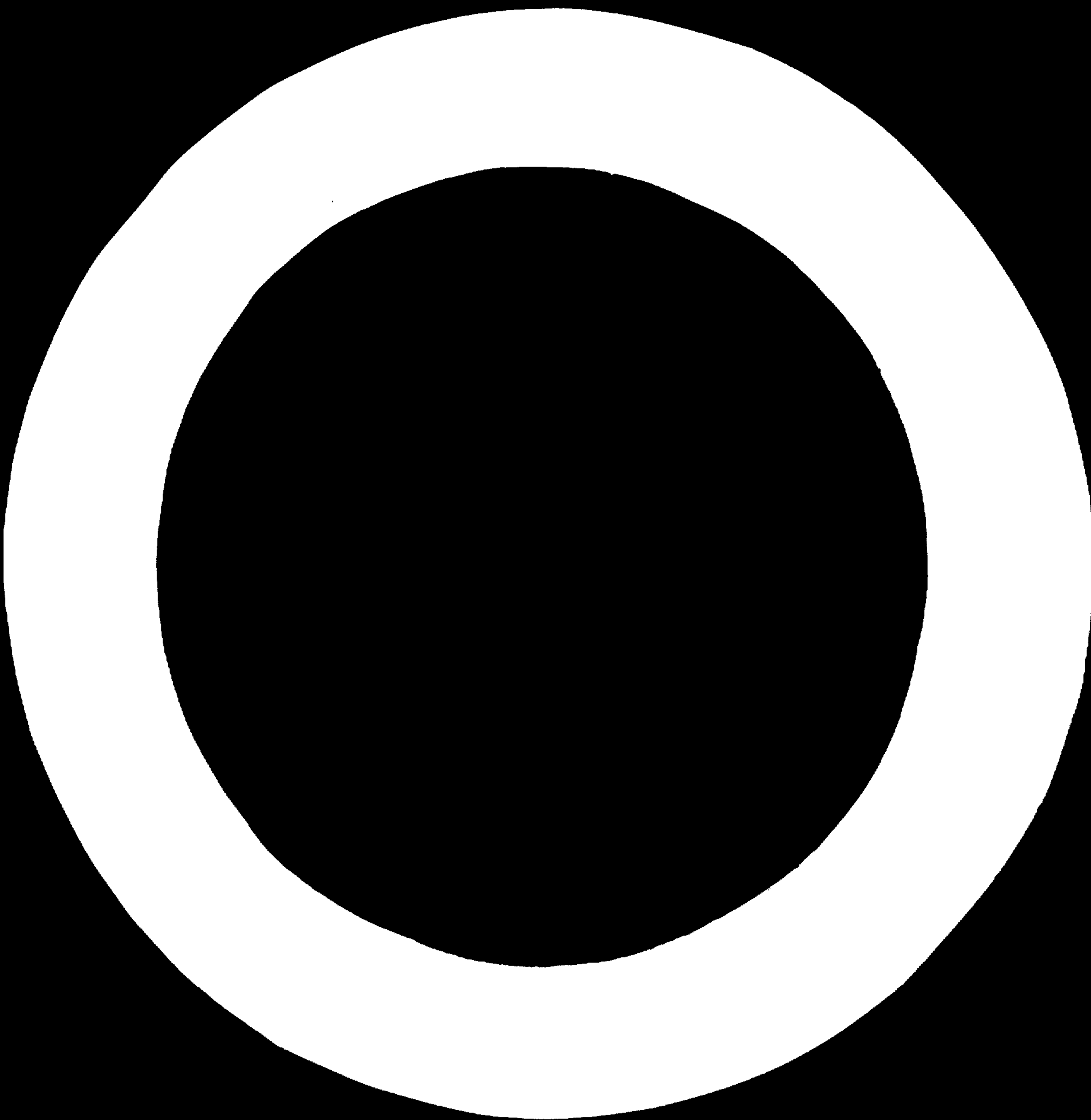

Converter steelmaking in the USSR

The economic and technical advantages of the oxygen-converter process for steel production - lower capital costs, high labour productivity, possibility of complete automation, wider range of raw materials that can be used - are so great that this process has developed at a rate unprecedented in the history of metallurgy.

The process has also been developed on a considerable scale in the Soviet Union. At present oxygen-converter steel is produced at ten shops in units of up to 300 tonnes capacity.

In 1970 converter steel accounted for 17.2 per cent of total steel output, and by 1975 production will increase by 100-150 per cent and account for about 30 per cent of the country's total steel output. It is noteworthy that in recent years technological progress in steel production, and particularly in the converter process, has been marked by an increase in furnace capacity.

The first converters in the Soviet Union had a charge of 25 tonnes, but units are now operating successfully with a charge of 130-300 tonnes. The main type of oxygen-converter shop in the USSR until recently had three units with a capacity of 100-130 tonnes each.

The average operating conditions in such shops are as follows:

Weight of charge - 130-160 tonnes
Oxygen consumption - 280-550 m^3 per minute
Blow pressure - 2.2-4.5 m^3 per minute
Blow duration - 14-25 minutes
Proportion of usable output - 88-90.5 per cent
Scrap consumption - 26-32 per cent (of weight of iron)

The first experiments with blowing oxygen through iron from above in the Soviet Union were carried out in 1936 by N.I. Mozgovoy, in a unit with a capacity of 1 tonne. Considerable research was done to develop this process from 1946 onwards under the direction of Academician I.P. Bardin, with the participation of N.I. Mozgovoy, the founder of this process in the USSR, which showed that top blowing of pure oxygen was promising and indeed preferable.

However, because of the lack of cheap oxygen, and for other reasons, the first industrial application of the process did not take place until 1955, and the first oxygen-converter plant was brought into operation in the USSR in 1956.

A great deal of research has now been done in the Soviet Union on the development and refinement of the oxygen-converter process. Since the raw materials used for steel manufacture in the USSR are very varied, the process has been developed for different kinds of iron: open-hearth, vanadium, low and high-manganese, chrome and high-phosphorus. One of the 100-130 tonne unit shops uses a duplex process, processing vanadium iron and extracting the vanadium in the slag.

The most widely developed process has been converter processing of ordinary open-hearth iron. The efficiency of the oxygen-converter process at high rates of operation is ensured by careful organization of production and the use of high-speed equipment and high-quality raw materials. In the Soviet Union the iron used is subject to uniform quality standards - regardless of the furnace capacity. Great importance is attached to the constancy of the iron's chemical composition.

Variations in the iron's silica content cause marked changes in the basicity of the slag; in many cases they hinder the extraction of phosphorus and sulphur, lead to the production of metal which is too hot or too cold and reduce the life of the lining.

Variations in the iron's manganese content also lead to an irregular temperature and slag regime. Excessive variations in the sulphur content of the iron (0.3-0.6 per cent) make it difficult to get steel with a low sulphur content and are one of the reasons for afterblows, which lower the quality of the metal, reduce the life of the lining and lengthen the smelting period.

By reducing variations in the iron's silica, manganese and sulphur content to within acceptable limits it is possible to standardize the smelting process to a considerable extent, to improve the quality of output and to increase lining resistance and converter productivity.

In order to reduce the iron's sulphur content, it is very important to remove the slag from the surface of the iron ladles regularly, to pour the slag from the mixer not less than once a shift and to maintain the level of iron in the mixer at not less than 50 per cent of capacity.

A very important question, which is not given enough attention, is the temperature of the iron. Iron is produced from the blast furnaces at a temperature of about 1,480°C and poured into the converters at 1,300°C, a drop in temperature of 180°C. Experience has shown that by raising the temperature of the iron and taking a number of other steps, scrap consumption can be raised to 350 kg per tonne. A fundamental improvement in this connexion would be a changeover to the use of mixer-type ladles. With fewer pourings and a shorter period during which the iron remains in the ladles, 4 per cent more scrap can be used with mixer-type ladles than with a mixer.

A factor which has a great influence on the converter process and lining life is the quality of the lime used, and in evaluating its quality a very important element is its reactivity, which is determined by the time it takes to achieve maximum temperature in hydration of the lime.

Lime produced in revolving furnaces has a higher calcium oxide content, a higher reactivity, and a more satisfactory fractional composition than lime produced in shaft furnaces. Lightly calcined lime is obtained by calcination of fine limestone for a relatively short period at 900-1,100°C and heavily calcined lime by prolonged calcination of limestone at a temperature of more than 1,200°C. Highly calcined lime is dense and large-grained, while lightly calcined lime is loose and small grained.

The total surface area of internal pores in lightly calcined lime is approximately fourteen times greater than in heavily calcined lime and the infiltration of liquid slag through the pores of such lime is therefore easier and it dissolves quicker. This is particularly important in order to obtain as basic a slag as possible during the initial period of smelting. Other factors which are just as important for rapid solution of the lime in the slag are its fractional composition and the absence of dust.

It is essential that all revolving furnaces should supply all converter shops with lightly calcined lime with a fractional distillation of 10-30 mm, dust-free and highly reactive.

Good prospects are offered by the use of dolomitized lime. Dolomitised lime has a manganese oxide content of up to 8-10 per cent; it helps to increase converter lining resistance and leads to a considerable saving of fluorite spar. The use of manganese limestones is equally promising. These limestones contain up to 9-10 per cent manganese and they can be very effective in the treatment of low-manganese iron.

In all converter shops, in order to avoid destroying the lining, fine slag is loaded first, and then coarser slag. The hot metal is poured on to the slag.

In converter shops the addition of loose materials is spaced out during the blow. The charge usually includes part of the lime and all the necessary quantity of fluorite spar. Some shops include in the charge from 30-40 to 60 per cent of the required quantity of lime and 200-400 kg of fluorite spar. The degree to which the addition of lime is staggered is different at different plants.

Experience has shown that it is not advisable to add the lime in large doses, because if this is done, when blowing begins pieces of lime get coasted with slag, making it much more viscous, and as a result the lime forms separate lumps which remain more or less undissolved until the end of the blow.

Limestone is added in small doses after ten to twelve minutes, but not later than three minutes before the end of the blow. The addition of iron ore is also spaced out over the duration of the blow: 60 per cent of the required quantity is included in the charge and the remainder is mostly fed in after six to seven minutes. At some shops the addition of iron ore is spread over a longer period.

During the period of intensive decarbonization, part of the iron is regenerated from the slag, which increases its viscosity. In order to prevent this, some shops add a small quantity of fluorite spar after fifteen to twenty minutes, amounting to about 20 per cent of the total.

When the convertor is operated without combustion of the fumes, in order to ensure safety of operation the addition of loose materials coincides with the time when the "skirt" is raised and the automatic control system starts to operate. The most widely used quenching medium is steel scrap. Some shops using units with a capacity of 35-55 tonnes use ore and ore nodules for quenching purposes.

The quantity of scrap used is 32 per cent of the weight of the iron or 24 per cent of the weight of the charge when the iron has a silica content of 0.7-0.8 per cent. Special research is now being carried out on ways of increasing the proportion of scrap in converter steel production.

Among the most important factors influencing the process of slag formation during the converter blow are the following: the chemical composition of the iron and charge, the quantity and quality of lime and fluorite spar, the order in which the charge materials and particularly the loose materials, are charged, the blow pressure, the lance design and its position during the blow, etc. Optimum regulation of these factors should ensure an efficient slag regime, ensuring a high degree of freedom from phosphorus and sulphur impurities, protecting the smelted steel from excessive absorption of gas (oxygen, nitrogen, hydrogen) and reducing the damage done by the slag to the converter lining.

An increase in the basicity and fluidity of the slag at an early stage in the blow makes it possible to considerably improve the desulphurisation of the metal at this stage. The sulphur distribution ratio, of course, declines as the degree of oxidation of the metal increases. Furthermore, in iron and metal with a very high carbon content (3-4 per cent), there is almost no oxygen. It is therefore in particular at the beginning of the smelt that the introduction of basic and fluid slag makes it possible to achieve a high sulphur distribution ratio. At the same time the lining life also increases considerably.

In order to assist slag formation, when scrap is introduced as the quenching medium, during the initial period iron ore nodules with a low silica content are introduced, in the amount of 2-3 per cent of the weight of the iron. The higher iron oxide content of the slag and a certain rise in the initial temperature of the smelt, due to the lower proportion of scrap, help to speed up the formation of slag.

Research has been done in the USSR on the use of specially prepared limestone-ore briquettes. Good results have been achieved, with a marked increase in the basicity of the initial and final slag compared with the usual kind.

In all converter shops blowing is now done through three or four-hole lances, the inclination of the holes to the vertical being from 8 to 15 degrees and the critical section of the holes within the limits 29.7-36.1 mm.

At one converter works, lances with holes at an angle of 20 degrees have been tried out in industrial conditions.

According to the information provided by the works, the use of these lances has reduced dust formation by 20 to 25 per cent, raised the output of usable metal by 0.6 per cent and increased lining life to some extent.

The blowing cycle must ensure not only oxidation of the additions to the required composition but also formation of slag of the right acidity and basicity.

At one works two blowing methods have been tried out: in the first the lance was kept at a distance of 1,300 mm from the level of the melt bath throughout the smelting process and in the second the lance was kept at a distance of 2,000 mm for a period of four to six minutes, after which it was lowered to 1,300 mm and kept there until the end of the blow.

Research has shown that with the first method a slag basicity (CaO/SiO_2) of 1.5 is obtained after twelve to fourteen minutes; with the second it is obtained after four minutes and after twelve to fourteen minutes it reaches 2.8-3.2. The dephosphorization and desulphurization processes also go considerably better with the second method.

Thus, on the basis of research results and practical experience it can be said that it is more efficient for the position of the lance during the blow to be variable rather than fixed.

Converter productivity is increased both by raising their capacity and also by increasing the blow pressure and reducing the time lost on auxiliary operations.

In recent years research has been done with units of varying capacity on raising the blow pressure.

At various works, in shops using converters with a capacity of 100-130 tonnes, the oxygen supply has been raised from 240-260 cubic metres per minute to 450-550 cubic metres per minute (from 2.2 to 4.5 cubic metres per tonne per minute). As a result the duration of the blow has been reduced from twenty-four to between twelve and fifteen minutes. At the same time work has been done on ways of reducing the time wasted on auxiliary operations.

On the basis of the results of this research, the following practical conclusions have been drawn: in the case of converters with a capacity of up to 200 tonnes an appreciable increase in output can be achieved merely by raising the pressure to 5 cubic metres per tonne per minute. Raising the pressure further does not have much effect, if the time spent on auxiliary operations remains the same (twenty-two minutes or more). This also applies to units with a capacity of 300-400 tonnes.

Any increase in the pressure beyond 5 cubic metres per tonne per minute must undoubtedly be accompanied by a reduction in the auxiliary time.

An increase in the blow pressure to 10 cubic metres per tonne per minute could be recommended only in the case of converters with a capacity of 300-400 tonnes and provided that auxiliary time was kept to a minimum. All in all, to raise the blow pressure to 10 cubic metres per tonne per minute would require very careful preparation from the design and economic standpoints, because it might entail a completely new type of converter shop.

On an experimental basis with a trial converter of 10 tonnes capacity blow pressures of 7, 9, 11 and 13 cubic metres per tonne per minute were adopted and the blow period was reduced to 3.7-4.2 minutes.

At these pressures there are difficulties with the process of slag formation. The slag formers have to be specially prepared, melted and fed to the converter in liquid forms. Among the units that can be used for melting slag are cyclones.

When the blow period is reduced to four to five minutes, the use of large-sized, untreated scrap can take too long to melt; hence the need for preliminary heating of the scrap.

Difficulties are already arising at works where experiments with raising the blow pressure have been started because none of the oxygen-supplying apparatus (valves, etc.) or the control or measuring instruments are designed for high oxygen throughput and pressure.

The specifications of the oxygen equipment will therefore also have to be changed. The production of oxygen hoses for pressures of up to 20-25 atmospheres and with a corresponding throughput capacity will have to be organised.

The converter process can be intensified by standardizing the basic materials and using high-speed computers. Reducing the smelting period will raise converter shop productivity and lining life, make it possible to increase the amount of scrap used and the output of usable metal and improve the basic indicators of the converter process.

Since the oxygen-converter process was introduced, its indicators have improved from year to year. This is particularly noticeable with regard to the output of usable metal and lining life. In recent years the output of steel has risen to 88-90.5 per cent. The use of multi-hole lances has played a considerable part in this connexion. This alone has raised the output of usable steel by 0.8-1.0 per cent.

The lances used at all shops in the Soviet Union are as a rule three and four-hole ones with a hole angle of between 8 and 20 degrees.

Research has shown that the use of lances with a hole angle of 20 degrees reduces dust formation, and hence the loss of iron in dust.

The angle of inclination of the holes influences the rate of slag formation and the amount of iron carried away in the fumes. The hole angle should be related to the diameter of the converter, the position of the lance and other parameters and should in every case be related to the volume and design of the converter. For a given angle of inclination, the indicators are the same whether three-hole or four-hole lances are used.

Raising the number of holes further, especially for high-capacity converters, leads to better slag formation and greater contact between the lime and the slag. Research is being done along these lines with converters of varying capacity. Studies are made of the effect on the process of staggered blowing, the use of lances with from five to thirteen holes and different angles of inclination, the use of two lances, etc. These trials are conducted at various blow pressures.

Apart from increasing the number of converters, their capacity and the blow pressure, oxygen-converter production is also being developed by improving the quality of the process. In the early stages of the process's development the range of output was limited to standard types of steel, but now it has been considerably expandod.

The types of steel that can now be produced include rimmed and killed steel, rail steel, armature steel, tube steel, deep-drawing steel, gas main steel and low-alloy steels covering the whole open-hearth range. Large-scale industrial research is being conducted to develop the technology for smelting electrical engineering steel. Stainless steel has been produced in an experimental semi-industrial unit. It is planned to improve the quality of steel by improving smelting, casting and deoxidization technology and by processing the metal in a vacuum and with synthetic slags. There is one shop processing a certain range of steel with synthetic slags of varying composition.

One of the main problems in the oxygen-converter process in its first years was the resistance of the lining. As late as 1966-1968 its life was no more than 200 smelts.

In recent years, as a result of research to improve the quality of tar-dolomite refractory materials and to improve smelting and converter lining technology, lining resistance has greatly increased and its life is now 500-750 smelts.

The question of increasing the specific volume of converters is one of great interest. The specific volume influences the evolution of the process, the indicators, the lining life, etc.

The first converters were built with a specific volume of 0.8-1.0 cubic metres per tonne. In future, with greater converter loads, the specific volume of 100-130 tonne converters will decline to 0.8-0.9 cubic metres per tonne. Some works, in order to increase productivity, have adopted the practice of over-loading converters, which further reduces this parameter.

The experience of shops using converters with varying specific volume leads to the conclusion that for high-capacity converters the specific volume, with a new lining, should be within the limits 0.8-0.85 cubic metres per tonne.

In setting-up a new shop the technological regime and the volume of capital expenditure are greatly influenced by the method of removing and cooling gases.

In Soviet industry three systems for removing gases are used:

(a) With complete combustion of CO to CO_2

(b) With partial combustion of CO to CO_2 (CO ≈ 42 per cent)

(c) Without combustion of CO.

The most economical method is removal of the gases without combustion, especially for high-capacity converters. The number of shops at which this system is used has therefore recently been increasing. A mill has been successfully established in the Soviet Union which operates with 300-tonne converters equipped for gas extraction without combustion.

The indicators for the oxygen-converter process and steel smelting as a whole depend to a considerable extent on the casting system used. The world's first large-scale oxygen-converter shop complex carrying out continuous-casting has been put into operation in the Soviet Union. The shop now operates according to a constant technological regime, with good technical and economic indicators and high productivity.

The experience of this shop and the results of research have shown that continuous-casting is advisable in oxygen-converter mills both for the sake of economic efficiency and of output quality. In new converter shops, therefore, continuous-casting will be the main process.

In improving the quality of output and the productivity of converters, automation has a substantial role to play.

In some converter shops in the USSR there is static smelting control by means of computers. With this method it is possible to automate the charge mix, the oxygen supply and the heat balance. Considerable research is at present being done in the USSR to develop a dynamic control system.

The rapid growth of converter production means that a wide range of research is necessary into such matters as expanding the range of steel produced, the choice of lance design, the selection of optimum blowing regimes with higher blowing pressures, the development of automation methods, methods of reducing dust formation and the loss of iron in fumes.

The main directions for the further development and improvement of the oxygen-converter process are: extending the range of types of steel produced, including high-alloy, alloy and electrical engineering steels, increasing converter productivity, raising blowing pressure and the proportion of scrap in the charge, increasing converter lining resistance, raising the output of usable steel and developing optimum blowing devices for high pressure blowing.

The further development of converter production in the USSR will be in the direction of the construction of large shops using units with a capacity of 300 tonnes and more. In the initial stages of the development of this process, shops were built with converters of up to 100-130 tonnes capacity, but in the near future it is planned to build and put into operation shops with units of up to 400 tonnes capacity. It should be noted here that the size of the charge is not only being increased in newly constructed converters but also in existing ones.

The capacity of existing converters in the USSR is being increased as follows:

Original charge, tonnes	Increased charge, tonnes
25.0	35.0
37.0	55.0
100.0	130 - 160

Practical experience and planning studies have shown the desirability of building shops with large units (300-400 tonnes).

The installation of converters with a lower capacity in individual cases is not, however, rules out, particularly when converters replace open-hearth furnaces but continue to use the existing crane and other equipment. From the technological standpoint, increasing the capacity of converters does not create any additional difficulties in the smelting process. High-tonnage converters can smelt the same range of steels as converters with a capacity of 100-130 tonnes.

As a result of the experience accumulated in the operation of oxygen-converters, there has been a reduction in the running-in period for new shops recently installed.

In shops using 100-tonne converters the highest annual average output of steel per converter has been 810,000 tonnes. Obviously, all shops using 100-130 tonne converters have considerable leeway for increasing their output. A considerable part of this unused capacity could be brought into play by such measures as increasing the blow pressure, reducing the length of the cycle, particularly the charging period, increasing the output of usable steel and lining life, carrying out further automation of the process, etc.

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