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# RECENT ACHIEVEMENTS IN THE IRON AND STEEL INDUSTRY OF THE SOVIET UNION AND THE AVAILABILITY TO DEVELOPING COUNTRIES OF SOVIET EXPERIENCE IN METALLURGY[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 introduction to the paper gives concise information on the development of the Soviet iron and steel industry, mainly in the postwar period. A table shows the rise in production of the major types of metallurgical output from 1950 to 1972. Data are given about the distribution of iron, steel, and rolled products output at the plants of the industry.

Technical progress in the extraction of iron ore and its preparation for blast-furnace smelting is illustrated by the following figures : in 1972, 208 million tonnes of commercial-grade iron ore were mined, including more than 80 per cent by the opencast method; the earth-moving capability of the newest excavation systems is as much as 5,000 m³/h. Because of the low iron content in the ore mined (36.8 per cent), some 80 per cent of it was concentrated, resulting in the production of 127 million tonnes of concentrate with an average iron content of 62.2 per cent. The concentration technology for lean ores is being continuously improved, whilst at the same time obsolete equipment is being modernized or replaced. Great attention is directed at the preparation of the burden for blast-furnace processing. The entire production of agglomerates for blast-furnace use is fluxed. New pelletizing plants are scheduled to go into operation.

In 1972, the Soviet Union produced some 80 million tonnes of coke and mined 170 million tonnes of coking coal. The paper discusses the present state of coke-chemical production and the methods whereby it may be further expanded and improved.

Technical advances in blast-furnace steel-making have been reflected in an increase in effective furnace volume to 3,000 m³ (a 5,000 m³ furnace is in the construction stage), in the raising of the blast temperature to 1,200°C, and in the use of natural gas and oxygen. At the present time, natural gas is used in the production of 85 per cent of all iron and oxygen in the production of more than 60 per cent. The best blast furnaces operate with an effective volume utilization factor of 40 per cent and a coke rate of about 450 kg/tonne.

Steel-making patterns have shifted in recent years towards a larger relative percentage of basic oxygen (LD) production. The major technical trends here include the following : processing units of greater capacity and improved design; the use of oxygen and high calorific-value fuel for process intensification; better steel casting techniques, primarily through the use of continuous casting plants; the introduction of electro-slag, arc, and induction heating in the manufacture of high-quality steels; and the use of synthetic slags for out-of-furnace processing of metal. The report cites data describing the performance of individual LD and open-hearth shops, as well as the working characteristics of twin-bath (tandem) steel-melting furnaces.

The section on rolled products offers a brief technical survey of the status of this sector, along with a discussion of problems relating to quality improvement and diversification of the product line, and the fitting out of production shops with the latest equipment and machinery. The paper concludes with the presentation of some data on developments in the field of tube, sheet (with metallic and non-metallic coatings), and iron-component production.

Prior to the Great October Socialist Revolution, Russia lagged considerably behind the leading capitalist countries in industrial development. In 1913 its share of world production of iron and steel amounted to only a little more than 5 per cent. At that time, the output of these metals stood at 4.2 million and 4.3 million tonnes, respectively.

With the triumph of the socialist revolution in our country, the foundation was laid for the rapid development of the entire national economy, including the iron and steel industry.

During the period of the five-year plans preceding the Second World War, Soviet ferrous metallurgy became a highly developed industry with a technology approaching that of the iron and steel industries of the most advanced capitalist countries, and in some instances surpassing them.

The war of 1941-1945 inflicted enormous damage on the economy of the Soviet Union. It was only in 1948 that the country re-attained the prewar level of steel and rolled stock output, and only in 1949 the levels of iron smelting, ore extraction and coke production.

Subsequent years witnessed a rapid expansion of Soviet ferrous metallurgy, which by 1967 was able to pass the 100 million-tonne mark in steel production per year, and in 1971 became the world's leading producer.

The growth rates for the major categories of iron and steel production can be seen in table 1.

## Table 1

## Basic indicators of the expansion of Soviet ferrous metallurgy in the postwar period

| **Basic production categories** | Production, millions of tonnes per year | | | | | | |
|---|---|---|---|---|---|---|---|
| | 1950 | 1955 | 1960 | 1965 | 1970 | 1971 | 1972 |
| **Iron** | 19.2 | 33.3 | 46.7 | 66.2 | 85.9 | 89.3 | 92.3 |
| **Steel** | 27.3 | 45.3 | 65.3 | 91.0 | 115.9 | 120.6 | 126.0 |
| **Rolled stock, total:** | 20.9 | 35.3 | 51.0 | 70.9 | 92.5 | 95.9 | 99.4 |
| **incl. finished rolled stock** | 18.0 | 30.6 | 43.7 | 61.6 | 80.6 | 84.1 | 87.4 |
| **Steel tubes** | 2.0 | 3.5 | 5.8 | 9.0 | 12.4 | 13.4 | 13.8 |
| **Iron ore** | 39.7 | 71.9 | 105.9 | 153.4 | 195.5 | 203.0 | 208.0 |
| **Coke** | 27.7 | 43.6 | 56.2 | 67.5 | 75.4 | 78.3 | 79.7 |

This expanded scale of production was accompanied by a significant improvement in quality, resulting from a consistent policy of equipment modernization and plant redesign, the establishment of new, technologically more advanced plants, technical improvements at all stages of processing and the introduction of new processes.

## Level of technological development in the Soviet iron and steel industry today

At the present time, the bulk of metal output - iron, steel and rolled stock - is produced at large metalworks having an annual output of more than one million tonnes (see table 2).

Table 2

### Percentage breakdown of total output of plants coming under the Ministry of Ferrous Metallurgy of the USSR in 1971, by size of plant

| Plants producing | Iron | Steel | Rolled stock |
|---|---|---|---|
| Up to 500,000 tonnes/year | 2.6 | 6.7 | 8.2 |
| 501,000 - 1 million | 3.7 | 4.3 | 8.3 |
| More than 1 million | 93.7 | 89.0 | 83.5 |
| | 100.0 | 100.0 | 100.0 |

## 1. Extraction and preparation of iron ore for blast-furnace melting

With its enormous natural supplies of iron ore, the USSR leads the world in the extraction of this resource. As a result, it is able to satisfy the requirements of its own iron and steel industry fully and to export a considerable quantity as well.

In 1972 the USSR mined 208 million tonnes of commercial-grade iron ore, including more than 80 per cent by the most advanced opencast methods.

The opencast iron and manganese mines of the Soviet Union were the first anywhere to employ powerful continuous-action earth-moving systems consisting of self-propelled bucket-wheel excavators, trunk conveyers and cantilever stackers. Systems of this kind have a capacity of as much as 5,000 $m^3/h$.

The average iron content in commercial-grade ore in 1971 was about 59 per cent. Because of the low iron content in the ore mined (36.8 per cent), about 80 per cent of it was concentrated; in this way, 127 million tonnes of iron ore concentrate with an average iron content of 62.2 per cent were obtained.

The beneficiation technology for low-grade ores is being constantly improved, specifically through the development of multi-stage concentration systems, the introduction of pebble and no-disc grinding at mining and beneficiation combines, the modernisation of one-stage and two-stage systems, and the replacement of obsolete and inefficient machinery.

The best-quality iron ore concentrates are produced at the mining and beneficiation combines of the Krivoy Rog Coal Basin. In 1971 the iron content in these concentrates amounted to 65.2 per cent. The country's total production for that year stood at 47.7 million tonnes of concentrate with an iron content of 65 per cent or more.

The total 1971 extraction of iron to concentrate form remained at the 1970 level and amounted to 75.9 per cent, despite the lower iron content in the ores mined. The principal trends in the further improvement of ore beneficiation involve thorough recovery of minerals from the tailings left over from the concentration process, greater extraction of magnetic iron, and a reduction in ore processing losses.

The Soviet Union is an important producer and exporter of commercial-grade manganese ores, production of which reached 7.3 million tonnes in 1971.

The five-year plan for the development of the USSR economy (1971-1975) calls for considerable further expansion in the supply of iron ore to the ferrous metallurgy industry. There is to be more extensive use of conveyer transport systems and heavy-duty motor vehicles in the opencast mines, and new types of beneficiation equipment are to be designed.

Keen attention has recently been focused on problems pertaining to the preparation of the burden for blast-furnace use. A significant percentage of the iron-ore raw material for blast-furnace use is agglomerated and reaches the furnace in the form of sinter or pellets.

The entire blast-furnace agglomerate is fluxed; its basicity in 1972 was 1.2.

The Soviet Union leads the world in agglomerate production. Approximately one third of the world output of agglomerate is produced in the USSR (138 million tonnes in 1970 and 140.6 million tonnes in 1971).

According to present plans, the main increase in production capacity will come from the construction of pelletizing plants. In 1971, 13.4 million tonnes of self-fluxed pellets were produced with a fluxing index of 0.8. Work is in progress to improve the production technology of metallized raw material intended for use in electric arc furnaces.

## 2. Coke-chemical production

The Soviet Union leads the world in coke production.

In 1972 approximately 80 million tonnes of coke were produced and some 170 million tonnes of coking coal were mined.

The Soviet Union is a major exporter of coke, coking coal and chemical coking products.

As of 1 January 1971 the country's effective coking furnace capacity consisted of 173 dinas-brick batteries and 12 fire-brick batteries.

Since 1958, coking batteries with large furnaces - 30 cubic metres and above - have been built. A project for the construction of 41.6-m$^3$ furnaces with coking chambers measuring 7 metres in height is in the course of implementation.

Virtually all hard coal intended for coking is enriched at large coal-concentration mills operating with advanced beneficiation methods: heavy media, hydro-cyclone devices and flotation.

The USSR leads the world in the technique and volume of coal flotation. Through the use of advanced technology, it has been possible to increase concentrate production (78 per cent concentrate yield) and to make extensive use of low-caking and gas coal.

At many plants, the burdens consist of 30-35 per cent gas coal.

Before the coal is used for coking, it is prepared by a number of advanced methods such as fluidised-bed grinding of the coal in an air-rated medium and preliminary heating before it is loaded into the coking furnaces. The beneficial effects of these methods are reflected in production of high-quality blast-furnace coke from burdens rich in weakly caking coals and in increased coking furnace productivity.

The technological processes of unloading,storing, transporting, concentrating and preparing the coal for coking have been completely mechanised.

Labour-intensive furnace-maintenance operations at the coking batteries have been largely mechanised and automated, and the smokeless method is in use when charging the coking chambers with coal burdens.

Efficient dry-quenching equipment is performing satisfactorily at a number of the newest plants, and this has made it possible to utilize the heat of the hot coke and to improve its quality.

The quality of the blast-furnace coke is up to international standards, so that maximum intensification of the blast-furnace process itself becomes feasible even with relatively low coke rates.

Chemical coking products are recovered and reprocessed using continuous processes and efficient equipment.

The range of these chemical coking products, which number 260 different substances, is up to modern standards.

Future plans look to further expansion and technical improvement in the area of coke-chemical production along the following lines: better preparation of coal for coking and the construction of even larger coke-oven batteries with fully automated chambers of 50-60 $m^3$ capacity. The building of an industrial plant for formed coke, a further increase in the size of the equipment used in the chemical processes, and the introduction of anti-pollution recycled water systems are additional measures which are contemplated.

## 3. Blast-furnace production

The main technical advances in the area of blast-furnace production have been an increase in effective furnace volume and an improvement in furnace design. During the period of Soviet rule, standard designs have been prepared and furnaces built with capacities ranging from 930 to 3,200 $m^3$ (one with a capacity of 5,000 $m^3$ is now under construction). In 1971 the average furnace capacity rose to 1,135 $m^3$.

At the end of 1972, 132 blast furnaces were in operation at the plants of the Ministry of Ferrous Metallurgy, including 18 with an effective capacity of 2,000 $m^3$ and above, four of which had a capacity of 2,700 $m^3$ and one a capacity of 3,000 $m^3$. More than 96 per cent of the iron produced was smelted at 109 furnaces operating with high top pressure.

Blast furnaces of 2,000 $m^3$ capacity and above are designed to operate with a blast temperature of 1,200°C and high top pressure, supplementary fuel injection and oxygen enrichment of the blast. At the present time, 106 furnaces are running on natural gas, accounting for 85 per cent of all the iron produced.

Blast-furnace [illegible] introduced in 1957 at the Petrovski Plant. By 1971, [illegible] per cent of all iron was smelted by this method.

In 1971, six furnaces were operating with mazut (fuel oil) injected into the blast-furnace tuyeres, and two with coal dust.

By feeding natural gas into the furnace hearth, the coke rate can be substantially lowered. This technique is considerably more effective if accompanied by the use of oxygen for air blast enrichment.

It has been established that furnace productivity increases by approximately 2.5 per cent for each additional percentage point of oxygen in the blast. In 1971, 77 blast furnaces were operating with oxygen, accounting for 60.1 per cent of the overall iron production.

Modern blast furnaces are highly mechanized systems. The furnaces are enclosed in a seamless welded housing and have air-cooled hearths and stave-cooled shafts; some furnaces operate partly with evaporative cooling systems, which are extremely economical on water.

The make-up, batching, and charging of the burden and the operation of the hot-blast stoves are fully automated. Automatic control of skips and bell-and-hopper apparatus has been introduced, and top-gas pressure is maintained automatically. A number of works use computers.

Hearth maintenance and iron and slag tapping operations have been largely mechanised.

Some indicators of the evolution of blast-furnace performance over recent years are cited in the following table.

## Table [illegible]

## Variation of principal blast-furnace performance indicators in the USSR

| Indicators | 1965 | 1970 | 1971 |
|---|---|---|---|
| Iron production per furnace, thousands of tonnes per year | 513 | 646 | 662 |
| Coke rate, kg/t | 633 | 575 | 567 |
| Natural gas consumption, $m^3/t$ | 64 | 68 | 72 |
| Oxygen consumption, $m^3/t$ | 19 | 40 | 45 |
| Furnace volume utilization factor, $m^3/t$ | 0.661 | 0.596 | 0.592 |
| Blast temperature, °C | 987 | 1036 | 1041 |
| Top-gas pressure, gauge atmospheres | 1.08 | 1.24 | 1.21 |

**Performance data for the blast-furnace shop of the Cherepovets Metalworks, at which furnaces of various sizes are in operation, are given in table 4.**

## Table 4

## Blast-furnace performance indicators for the Cherepovets Metalworks, 1971

| Indicators | Furnaces | | | | Shop average |
|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | |
| Furnace volume, $m^3$ | 1007 | 1033 | 2000 | 2700 | 1685 |
| Furnace volume utilization factor, $m^3/t$ | 0.534 | 0.454 | 0.447 | 0.502 | 0.481 |
| Coke rate, kg/t | 561 | 464 | 450 | 458 | 471 |
| Blast temperature, °C | 1033 | 1026 | 1133 | 1145 | |
| Top-gas pressure, gauge atmospheres | 1.69 | 1.71 | 1.67 | 1.68 | |

## 4. Steelmaking and ferro-alloy production

The present state of the art in steelmaking has been described in the paper "The Use of Oxygen in Steel Production", submitted by the Soviet delegation, and for that reason we shall limit ourselves in this paper to a few additional remarks.

Technical advances in steelmaking are being made primarily along the following lines: increasing the capacity and improving the design of steelmaking units; intensifying the melt process through the use of oxygen; extensive use of high-caloric fuel; improvements in the technology of steel casting, principally at continuous casting plants; the use of electro-slag arc, and induction-vacuum melting in the production of premium-quality steels and alloys; the introduction of out-of-furnace vacuum treatment; and the use of synthetic slags.

In recent years there have been profound changes in the pattern of steelmaking, some idea of which is conveyed by the data in the following table.

### Table 5

### Changes in the pattern of steelmaking since 1965

| Steels | Production, millions of tonnes | | | Share in total production, % | | |
|---|---|---|---|---|---|---|
| | 1965 | 1970 | 1971 | 1965 | 1970 | 1971 |
| Open-hearth | 76.4 | 84.1 | 84.8 | 84.0 | 72.6 | 70.3 |
| LD | 4.0 | 19.9 | 23.2 | 4.4 | 17.2 | 19.3 |
| Electric | 8.6 | 10.7 | 11.5 | 9.4 | 9.2 | 9.5 |
| Bessemer | 2.0 | 1.2 | 1.1 | 2.2 | 1.0 | 0.9 |
| Total: | 91.0 | 115.9 | 120.6 | 100.0 | 100.0 | 100.0 |

During the period in question, production increases were achieved mainly through higher output of LD steel. By the beginning of 197[illegible] the Soviet Union had in operation 35 LD converters, of which 2[illegible] had a capacity of 100 tonnes or more including three in the 250-300-tonne range.

The basic type of LD shop is a three-vessel one. In the best of these shops the "specific productivity" (the shop's annual output per unit of total rated installed capacity) is more than 10,000 tonnes per tonne per year (see table 6).

Table 6

**Performance indicators for the LD shops of the Novolipets (A) and West Siberian (B) metal works, 1970-1972**

| **Indicators** | Shop A<br>3 x 100 t | | | Shop B<br>3 x 100 t | | |
|---|---|---|---|---|---|---|
| | 1970 | 1971 | 1972 | 1970 | 1971 | 1972 |
| **Design capacity, thousands of tonnes per year** | 2200 | | | 2200 | | |
| **Actual weight of heat, t** | 121 | 142 | 143 | 122 | 124 | 132 |
| **Production, thousands of tonnes per year** | 2637 | 3045 | 3224 | 2393 | 2894 | 3214 |
| **Consumption per tonne of steel:** | | | | | | |
| iron | 866* | 859* | 649* | 854 | 849 | 851 |
| scrap | 276* | 277* | 285* | 269 | 268 | 262 |
| **Lining life, number of heats** | 515 | 485 | 513 | 548 | 709 | 748 |

*** For shop A the consumption figures are per tonne of slabs produced in continuous casting plants.**

A major factor contributing to increased LD shop productivity has been the increase in the weight of the charge, which in some cases has been 50 per cent greater than the design weight. By upgrading the quality of tar-dolomite refractories and improving the melt technology, it has been possible to achieve substantially longer vessel lining life (see table 7).

Table [illegible]

Improvement in lining life for 100-130-tonne vessels from 1967 to 1972

| Lining life, number of melts | Year | | | | | |
|---|---|---|---|---|---|---|
| | 1967 | 1968 | 1969 | 1970 | 1971 | 1972 |
| **Average** | 179 | 259 | 346 | 467 | 479 | 467 |
| **Maximum** | 300 | 546 | 646 | 764 | 850 | 829 |

A significant increase in LD steel production has been achieved by stepping up the blast intensity to 3.5–4.0 $m^3/t$. It is planned that at all the LD shops now under construction, or scheduled for construction, oxygen blast intensity will be 5–7 $m^3/t$. The new shops will operate with the system of incomplete gas combustion.

With respect to level of technological development, operating methods and utilization of vessel capacity, Soviet LD steel plants are not much different from their counterparts abroad: the same methods of blowing, slag formation, and steel killing and casting are in use.

Of great importance to improved LD shop performance are the measures taken to upgrade the quality of raw materials, standardise the burden and reduce converter down-time.

The range of steels produced in oxygen converter shops has been continuously expanding. Along with rimmed, balanced and killed carbon steels of various composition and purpose, LD shops also turn out approximately 10.4 per cent of low-alloy and alloy steel. Work is under way to extend the range of output to include a number of stainless, electric and other steel grades meeting particularly high requirements.

The industry has profited greatly from the work done by research institutes and metallurgical plants on the conversion of special irons – vanadium, phosphorus and manganese. This research has been incorporated into the technology which is now, or soon will be, in use at Soviet works.

Whether or not LD production [illegible] depends to a large measure on the quantity of scrap used. At the present time, the average rate of scrap consumption in the order of large (100-t and over) oxygen converters is close to 260 kg/t, and in some instances it may be as high as 281 kg/t. During the period 1965-1972, average scrap consumption in Soviet LD shops rose from 38 to 206 kg/t.

One possible means of increasing LD productivity is by reducing the time between blasts, much of which is taken up by scrap loading. To speed up this operation, the new shops are to have high-capacity ladles, with which scrap loading can be completed in one or two operations.

Further improvements in LD steelmaking will require more extensive use of high-speed monitoring and control devices, and great attention is therefore being given to the development of new systems for dynamic control of the melt and flexible control of the production process as a whole. The use of computer-assisted automation systems provides a means of optimising the blowing, and of reducing its duration, in addition to establishing the necessary conditions for improved steel quality.

At the present time, the Soviet Union's basic steelmaking capacity is concentrated in open-hearth plants. The reason for this lies in the fact that at the time when the LD process came into general industrial use, the iron and steel works of the Soviet Union already had in service a large number of technically up-to-date open-hearth furnaces operating with a high degree of technical and economic efficiency.

At the beginning of 1973, 350 open-hearth furnaces were in operation at iron and steel works, distributed according to capacity as shown in the following table.

Table 8

Distribution of open-hearth furnaces in operation at iron and steel works by capacity

| Indicators | Furnace capacity, tonnes | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | 50 | 51-100 | 101-150 | 151-200 | 201-300 | 301-400 | 401-600 | 601 and over |
| Number of furnaces | 35 | 56 | 49 | 44 | 48 | 7 | 86 | 25 |
| Percentage of total number | 10.0 | 16.0 | 14.0 | 12.6 | 13.7 | 2.0 | 24.6 | 7.1 |
| Percentage of total steel production | 2.4 | 6.2 | 10.4 | [illegible] | 15.0 | 12.1 | 38.2 | 7.0 |

The largest furna[illegible] ) [illegible] of 900 tonnes.

Over a number of years, open-hearth furnace productivity has been raised by increasing the weight of the charge, converting the furnaces to tandem operation (with partial reconstruction of the furnace's upper and lower parts during major overhaul), and improving the design and melt technology. A particularly important innovation in open-hearth production was the use of oxygen to speed up both refinement and intensify thermal conditions during furnace operation (see table 9). The application of oxygen was accompanied by the conversion of the furnaces to all-basic linings, which meant that the oxygen could be used to better effect.

### Table 9

### Performance indicators for the open-hearth furnaces of the Kuznets Metallurgical Combine (C), the Orsko-Khalilov Metallurgical Combine (D) and the Zaporozhstal Steelworks (E), 1971

| Indicators | No oxygen used |  |  | Oxygen in use |  |  |
|---|---|---|---|---|---|---|
|  | Plant C |  | Plant D |  | Plant E |  |
| Nominal furnace capacity, t | 210 | 425 | 185 | 400 | 200 | 430-500 |
| Actual weight of the melt, t | 209-211 | 425-429 | 215 | 431-463 | 241-248 | 482-490 |
| Annual output of steel, thousands of tonnes per furnace | 201-208 | 302-320 | 236 | 344-388 | 314-484 | 382-452 |
| Downtime, percentage of calendar time: | 7.9-8.9 | 5.2-7.5 | 7.4 | 6.7-9.1 | 8.4-11.2 | 7.4-11.8 |
| incl. cold down-time | 3.6-4.8 | 1.3-4.6 | 5.9 | 5.5-7.1 | 2.8-8.9 | 5.2-9.4 |

When analysing the data of table 9, it is important to bear in mind that plants C and D produce a more extensive range of grades than does plant E.

Mindful of the economic advantages to be gained from a more thorough utilization of its existing production capacity, in recent times the Soviet Union has been devoting great attention to the development of new units which would be compatible in size with the open-hearth shops already in operation, but would be superior to them in terms of productivity and certain other criteria. One such system is the twin-bath furnace in which heat is regenerated in a non-traditional manner - through the use of the exhaust gas to heat the scrap in the adjacent bath (the tandem process).

The substitution of twin-bath for open-hearth furnaces results in a two-fold increase in productivity in a single unit, a five-fold decrease in fuel consumption, a two-fold to three-fold reduction in the amount of refractory material required for repairs, and in a more uniform tapping of the melt over a twenty-four-hour period, this being an important factor in achieving more efficient equipment utilisation in the steelmaking shop and during subsequent processing. Because twin-bath furnaces do not need regenerators, off-blast repair periods can be shortened and the man-hour requirement for each period considerably reduced.

At the present time, there are six twin-bath furnaces, with a bath capacity of 250-285 tonnes each, in operation at Soviet iron and steel works. Certain of their performance indicators for 1972 are listed in the following table.

## Table 10

## Twin-bath furnace performance indicators for 1972

| Indicators | Furnaces | | |
|---|---|---|---|
| | 1 | 2 | 3 |
| Annual steel output, thousands of tonnes | 1058 | 1127 | 1174 |
| Average weight of melt, tonnes | 277 | 281 | 284 |
| Down-time, percentage of calendar time: | 11.6 | 8.0 | 9.9 |
| including cold down-time | 8.9 | 6.2 | 6.7 |

That these figures should not be regarded as limits is indicated by the way they have moved over the years at one of the furnaces in question (table 11).

### Table 11

### Variation in the performance indicators of twin-bath furnace No. 1

| Indicators | Years<br>1966 | <br>1968 | <br>1970 | <br>1971 |
|---|---|---|---|---|
| Annual steel output, thousands of tonnes | 498 | 830 | 1149 | 1174 |
| Furnace roof life, number of heats | 284 | 397 | 764 | 771 |
| Refractory consumption for repair, kg/t | | | 4.95 | 3.9 |
| Standard fuel consumption, kg/t | 40.9 | 14.5 | 9.5 | 12.8 |
| Oxygen consumption, $m^3/t$ | 64 | 84 | 63 | 65.3 |
| Charge consumption, kg/t | 1158 | 1162 | 1133 | 1130 |
| Down-time, per cent | 12.9 | 11.3 | 7.1 | 8.9 |

Hot-metal consumption in twin-bath furnaces amounts to 65-68 per cent. Burners installed in the roof or ends of the furnace may be used to supply additional heat as a means of compensating for any insufficiency that might arise because of an increase in the amount of scrap to be processed.

Twin-bath furnaces are now being used for the production primarily of rimmed, balanced and killed carbon steels, and also, in smaller amounts, of various grades of low-alloy steel.

The conversion of open-hearth furnaces to the twin-bath design is a measure dictated by short-term considerations; the basic policy in long-range planning is to build up LD and electric steelmaking capacity, with a gradual cut-back, over the longer term, of steel production at the open-hearth shops now in operation.

A characteristic feature of the expansion of electric steelmaking is the trend towards larger units and larger steelworks in general.

[illegible] technological features. These furnaces are equipped with electromagnetic stirring devices, roof-mounted water-cooled oxygen lances, exhaust gas scrubbers, and up-to-date monitoring and control devices.

At the larger electric arc furnaces the power is regulated automatically, while certain plants have introduced programme-controlled systems for the automatic supervision of the steelmaking process.

At the newly built shops with large electric furnaces, heavy and labour-intensive operations have been successfully mechanized. The charging of the furnaces and the feeding in of bulk materials and ferro-alloys are examples of processes that have been almost totally mechanized.

As of 1 January 1972, 212 electric furnaces, including 18 of the induction type, were in operation at the iron and steel works of the Ministry of Ferrous Metallurgy. At 99 of these furnaces the steel produced is cast into ingots or in continuous casting plants; at the rest, it is used for castings.

In 1971 the Soviet Union produced a total of 11,48[illegible],000 tonnes of electric steel, including 5,593,000 tonnes in ingot form.

At the present time, Soviet iron and steel works are operating 16 electric furnaces ranging in capacity from 35 to 50 tonnes, 12 with a rated capacity of 100 tonnes, and 2 with a rated capacity of 200 tonnes.

Some 80 per cent of electric steel is produced with the use of oxygen. The oxygen consumption rate in the production of carbon and low-alloy steels is 23-26 m$^3$/t. By blowing the metal with oxygen and powdered materials the oxidation and reduction periods of the melt are shortened and more efficient use of the power transformers is possible.

The use of oxygen in the production of stainless steel has made it possible to work with burdens containing more than 70 per cent of high-alloy scrap, and to produce stainless steels with a carbon content of up to 0.03 per cent in 40-tonne arc furnaces, and unalloyed steels with a carbon content of up to 0.02 per cent in 100-tonne arc furnaces. Oxygen can be used to equally good effect in the production of other steel types as well. The result is a 10-15 per cent decrease in the time of the melt and a 15-20 per cent reduction in electric power consumption.

One operating method which has won wide acceptance involves combining process of oxidizing a number of additions with the melting of the scrap. This is accomplished by introducing iron ore concentrates and lime into burden to form an oxidizing slag; in this way, the phosphorus content of the metal can be reduced to 0.015 per cent by the time it melts, and the duration of the subsequent oxidation period can also be cut back to 15-30 Because of the low phosphorus content, as soon as the metal has reached the necessary temperature, the bath can be given a short oxygen flow to bring the carbon content quickly down to the required level.

Soviet iron and steel works have mastered the technology of steel production using brief oxidation periods. A number of carbon steel grades are produced without running off the oxidizing slag.

At the present time, induction and electric arc furnaces with capacities up to 5 tonnes are mainly producing precision and virtually non-deformable refractory steels; furnaces of up to 30 tonnes - free-cutting steel; furnaces of 40-60 tonnes - very-low-carbon, stainless, and structural high-strength steel; furnaces of 40-100 tonnes - stainless, structural and ball-bearing steel.

An effective means of improving the quality and intensifying the process of steel production is to treat the steel outside the furnace. The use of synthetic slags of varying composition is the most widespread method.

High-productivity slag-melting furnaces and kilns for the production of the aluminous semi-product have been developed along with other necessary equipment.

As the result of the synthetic slag treatment the sulphur content in the finished steel is reduced to a half or a quarter (to 0.001-0.006 per cent in the structural steel produced in 100-tonne furnaces), and the level of non-metallic inclusions is also reduced by the same factor. When tested on transverse samples (at room temperature and lower), the impact strength of structural alloy steels is 1.2-2 times higher; the plasticity of the steel at hot-processing temperatures increases by 30-40 per cent. There is a significant reduction in the vulnerability of the steel to crystallisation cracking when welded, resulting in greater opportunities for the use of high-efficiency submerged-arc welding.

Another effective means of improving steel quality is by blowing the metal in the ladle with some inert gas (argon, nitrogen, etc.). Special equipment for use with this method has been developed and a technology for the production of refractory lances has been devised.

Argon blowing has made it possible to set up production of particularly low-carbon, corrosion-resistant, economic alloy steels in open arc furnaces. Approximately one million tonnes of various steel grades were produced with argon at Soviet iron and steel works in 1972.

Steelmaking shops are making use of out-of-furnace vacuum degassing, the process being carried out in the ladle, when pouring from one ladle to another, and in a batch degassing unit.

Special methods of high-quality steel and alloy production have been developed along with techniques of melting in vacuum-arc and induction furnaces and electroslag processing.

The electroslag method, first developed and introduced in the USSR, which permits the production of high-quality metal at relatively low cost, is particularly wide-spread. Not only have individual processing units been built, but specialized electroslag shops have been brought in operation. The weight of the ingots which can be produced by this method has risen considerably (up to 40 tonnes).

The Soviet Union has a higher output of <u>ferro-alloys</u> than any other country. It produces a wide range of reducing and alloying agents, including rare and rare-earth metals. The widely encountered ferro-alloys - ferro-silicon, ferro-manganese, silico-manganese, silico-chromium, silico-calcium, high-carbon ferro-chromium - are melted in powerful closed electric furnaces manufactured according to designs developed by Soviet research and development organizations. Silico-manganese, for example, is melted in electric arc furnaces of 63 MVA transformer power and 53,000-56,000 kW effective power.

Closed electric furnaces rated from 16.5 to 27 MVA have been installed for the other alloys mentioned above and are performing well.

[illegible] produced in less powerful electric furnaces.

Many of the new [illegible] alumino-thermal (silico-thermic [illegible]) process which gave good results for the extraction of [illegible] of the alloys, particularly when the metal [illegible] furnaces. This process has been very successfully [illegible] of ferro-niobium.

The Soviet Union has developed and implemented an original process for obtaining carbon-free ferro-chromium, with a carbon content of 0.03 per cent and below, through the use of liquid silico-chromium to reduce chromium and iron from an ore-lime melt in the ladle (reactor), the metal being cast into a bottom plate or slag pot beneath a slag layer. The reduction takes place in a single stage and no intermediate products are formed. By increasing the temperature during the reduction stage, the carbon content can be reduced to 0.004-0.010 per cent, which is important when producing stainless steel.

In addition to carbon-free ferro-chromium, complex low-carbon alloys containing other alloying elements besides chromium (manganese, niobium, etc.) are also produced.

Considerable progress has recently been made in the area of steel casting, both conventional and continuous.

Soviet iron and steel works are making increasing use of the continuous casting method. At the beginning of 1971 the USSR had in operation 35 continuous casting plants, with from one to eight strands, their total capacity being 5.7 million tonnes. This equipment is used with killed and rimmed, carbon and alloy steels to cast blooms of numerous shapes and sizes: squares with sides measuring from 55 to 350 mm, rectangles 55-315 x 300-2000 mm and rounds of 100-522 mm in diameter.

At Novolipets the world's first major steelworks at which the entire steel output from the LD and electric steelmaking shops is cast in continuous casting plants is performing satisfactorily. None of the new steelworks are to be built with blooming or slabbing mills, but are to be equipped for continuous casting operations.

To improve the quality of the cast bloom, elongated nozzles are used, with the stream directed to beneath the level of the metal in the mould and with the metal surface sprinkled with slag-forming mixtures. A method whereby many melts can be continuously cast, with no disruption of the strand, is in wide use.

Continuous casting plants are equipped with automatic systems to maintain a constant level of the metal in the moulds, ensure the best possible cutting of the strand into properly sized blooms, and control the cooling cycle.

Among the methods aimed at improving the conventional casting of steel ingots, one of the most significant is high-speed casting. At a number of steel-works, strands 60-80 mm in diameter are being used in place of the usual 30-40-mm-diameter strands. In some instances, casting rates of 33 tonnes per minute have been achieved with low-carbon rimmed steel using strands 110 mm in diameter.

Many steelworks use the method of casting under a layer of slag, this being a highly effective means of improving ingot quality. Very often the metal surface is filled in with heat-insulation agents of various composition produced from inexpensive and readily available materials: ash from thermoelectric plants, expanded perlite, and vermiculite with amorphous graphite additives.

Inserts of exothermic mixtures are used to heat the side surfaces of the riser.

## 5. Rolled production

Among the trends observed in the production of rolled stock one finds improved quality and expanded range of production, the use of high-efficiency mills and finishing equipment in the rolling shops, the introduction of more advanced heating furnaces, greater diversification in the heat and mechanical-heat treatment of the bloom, and finally the application of automatic systems to monitor the operation of the mills and the quality of the finished product.

In recent years, modern hot and cold rolling mills have been put into service, including powerful roughing mills (the 1300 blooming and 1150 slabbing mills); the 2000 and 1700 high-productivity wide-strip mills for hot rolling, the 2500 four-stand wide-strip cold-rolling mill, the 600 heavy-section mill; the 350 medium-section mill and the 250 light-section and wire mills.

Together with the introduction of these new rolling mills, many existing mills have been remodelled and obsolete ones dismantled. At 100 of the mills more stringent tolerances have been introduced, resulting in considerable savings of metal.

To keep pace with the demands of the national economy, the number of rolled shapes is being constantly increased. Plants are systematically mastering the production of new low-cost hot and cold rolled shapes similar in size and shape to finished machine and structural components.

Plans call for the production of wide-flange beams using radio-frequency welding and for the manufacture of irregular and bimetal shapes.

Some 85 per cent of sheet metal is produced by continuous and semi-continuous wide-strip hot-rolling mills. The USSR ranks first in Europe in the number and capacity of these mills. There are eleven wide-strip hot-rolling mills in operation at the country's iron and steel works.

The new mills differ from those previously built in their larger number of stands (12), the greater weight of their slabs (as much as 35 tonnes), their higher rolling rates (up to 21 m per second), and their wider range of thicknesses (1.2-16.0 mm).

Cold-rolled sheet production increased by 48 per cent during the five-year period from 1966 to 1970. Specialized cold-rolling shops are turning out automobile sheet, tinplate and electric steel.

At the country's largest continuous four-stand mill, the 2500, provision has been made to roll sheet steel measuring 0.6-2.5 mm in thickness and up to 2350 mm in width.

For better accuracy in sizing their cold-rolled sheet, a number of mills are equipped with thickness and tension control systems.

The production of bimetal [illegible] the rise. Steelworks are turning out corrosion-resistant anti-friction electrical engineering and other duplex steels (more than [illegible] grades).

In recent years the production of protectively coated tinplate and rolled sheet has entered a phase of considerable expansion. New shops and plants have been built and put into service for the production of various kinds of sheet steel coatings.

The fastest growth rates are observed in the production of tinned and galvanized sheet steel. Tinplate is produced in several varieties : electrolytic, hot-dipped, chomium-plated, and lacquered blackplate.

Chromized tinplate production has been initiated to provide containers for a large variety of canned goods, including the most corrosive kinds. A distinguishing feature in the production of this type of tinplate is the use of a single production unit for the successive operations of chromising and lacquering the sheet. In this way, tinplate delivered to the customer has been chromized and lacquered at the same time.

A process has been developed in the Soviet Union for the production of very thin tinplate (0.1-0.16 mm) by a double-rolling method; another process combines, in a single contiruous processing unit, the operations of annealing, dressing and coating the tin.

The USSR supplies tinplate to many other countries, including developing countries.

Galvanized sheet production has been set up on modern, high-capacity production lines. New lines are being built for the hot galvanization of flat steel which include preliminary non-oxidizing heating, rapid cooling in the master furnace and coating thickness control and are equipped with flattening-dressing stands and a unit for the recovery of iron-zinc alloy.

Galvanized sheet is produced for the automotive and other industries. Continuous hot-galvanization systems geared for the manufacture of non-porous, corrosion-resistant coatings are being built.

New technological processes are today being developed for the application of metal coatings to flat steel by the electron-beam evaporation and vacuum-deposition method for such metals as aluminium, titanium and others.

Also in the design phase is a process for applying aluminium, chromium, titanium and other coatings to steel in an electrostatic field using powder metallurgy techniques or an electrophoresis method followed by rolling and heat treatment.

The current year will see the beginning of the industrial production of flat steel with plastic (polyvinyl chloride) coatings.

As long ago as 1963 the Soviet Union became the world leader in the production of steel tubes. Our industry has mastered virtually all the advanced tube production methods used in the world today. The widest possible variety of tubes are produced for different applications, ranging from 0.3 to 1,420 mm in diameter and from 0.05 to 75 mm in wall thickness. The latest tube rolling and welding plants offer technical characteristics on a par with the best international models, in some instances even surpassing them.

Tube production has benefited in recent years from a wealth of innovative approaches to the production of welded and seamless hot-rolled and cold-deformed tube. Methods have been introduced for the production of high-strength large-diameter tubes with straight or spiral welds, for use in the construction of long-distance gas pipelines. A technology has been devised for the manufacture of high-strength piping for the petroleum industry with new kinds of threading and unions to ensure hermetically sealed fittings, as well as a boiler pipe technology to guarantee lasting strength. A warm-rolling tube method, first developed in the Soviet Union, has been made operational, whereby the productivity of cold-rolling mills producing stainless and other alloy steel tubes can be increased by 50-80 per cent.

The bulk (about 80 per cent) of all the iron ware and bright-drawn steel produced in our country is manufactured at ferrous metallurgy enterprises. The iron ware nomenclature includes more than 63,000 items.

Widely employed at sizing shops are systems for the induction annealing of rods by [illegible] and also continuous furnaces operating with a protective atmosphere.

A positive accomplishment of the hardware industry can be seen in the successful development and industrial application of a dry drawing process for steel wire under conditions of hydrodynamic friction. Another method that has been put into practice involves the brass plating of steel wire by electrolytic copper plating and galvanization followed by treatment based on thermo-diffusion.

The quality and variety of thin strip steel production has increased substantially in recent years. Large amounts of such strips are produced from precision alloys. The technique of manufacturing micron-gauge strips of as little as 1.5 microns in thickness has been mastered.

The machine-building plants are turning out, in addition to mills, a wide range of auxiliary equipment, including planetary shears, continuous etching systems, longitudinal and transverse cutting rigs, rolled sheet trimming and grading apparatus, etc., etc. The USSR has developed a number of original technological processes and is manufacturing complete sets of equipment for the through hardening of rails of up to [illegible] m in length and for the rolling of machine-building components - pinions, car axles, wheels, ball bearings, grinding wheels, high-precision shapes, and the like.

Actual experience with Soviet-manufactured equipment has shown it to combine excellent reliability with high efficiency.

There has been a substantial increase in the last few years in the amount of rolled steel hardened by thermal and thermo-mechanical treatments. Eight hardening-press lines for the thermal hardening of plate steel are now in plant operation, and a unit for hardening moving sheets is nearly ready. Industrial plants for hardening reinforcement steel and rails using high-frequency electricity are also in operation. A technology has been developed to produce thermo-mechanically hardened rolled steel which yields plate 10-20 mm in thickness, circular shapes 10-15 cm in diameter and thin strips 0.1-1.0 mm in thickness.

## 6. The possibility of using Soviet technical experience in the developing countries

Following the triumph of the socialist revolution in Russia, our country was able, in a relatively short period of time, to develop an advanced economy, and to rise to second place in the world in industrial output and to first in the production of ferrous metals. In solving the many problems that confronted them at various stages of our national industrialization, Soviet metallurgists were forced to rely on their own ingenuity to create the various types of equipment for primary and secondary steel processing, to develop new process technologies, and to determine optimal alternative approaches to the planned development of industry.

Even as it expands its own economy, the Soviet Union has for a long time been lending assistance to a large number of developing countries engaged in establishing their own iron and steel industries. This assistance has not been limited to the construction of metallurgical plants, but has also included deliveries of various kinds of raw material and equipment, the sale of licenses and patents, and so on. The high technical level of Soviet metallurgy, described in general terms in this report, serves as a reliable guarantee of the quality of the supplies, designs and advanced technical processes exported, all of which have proved themselves under industrial conditions both at home and abroad. This creates a good basis for the further expansion of mutually advantageous relations between the Soviet Union and those countries which may be interested in availing themselves of its technical know-how in the area of metallurgy.

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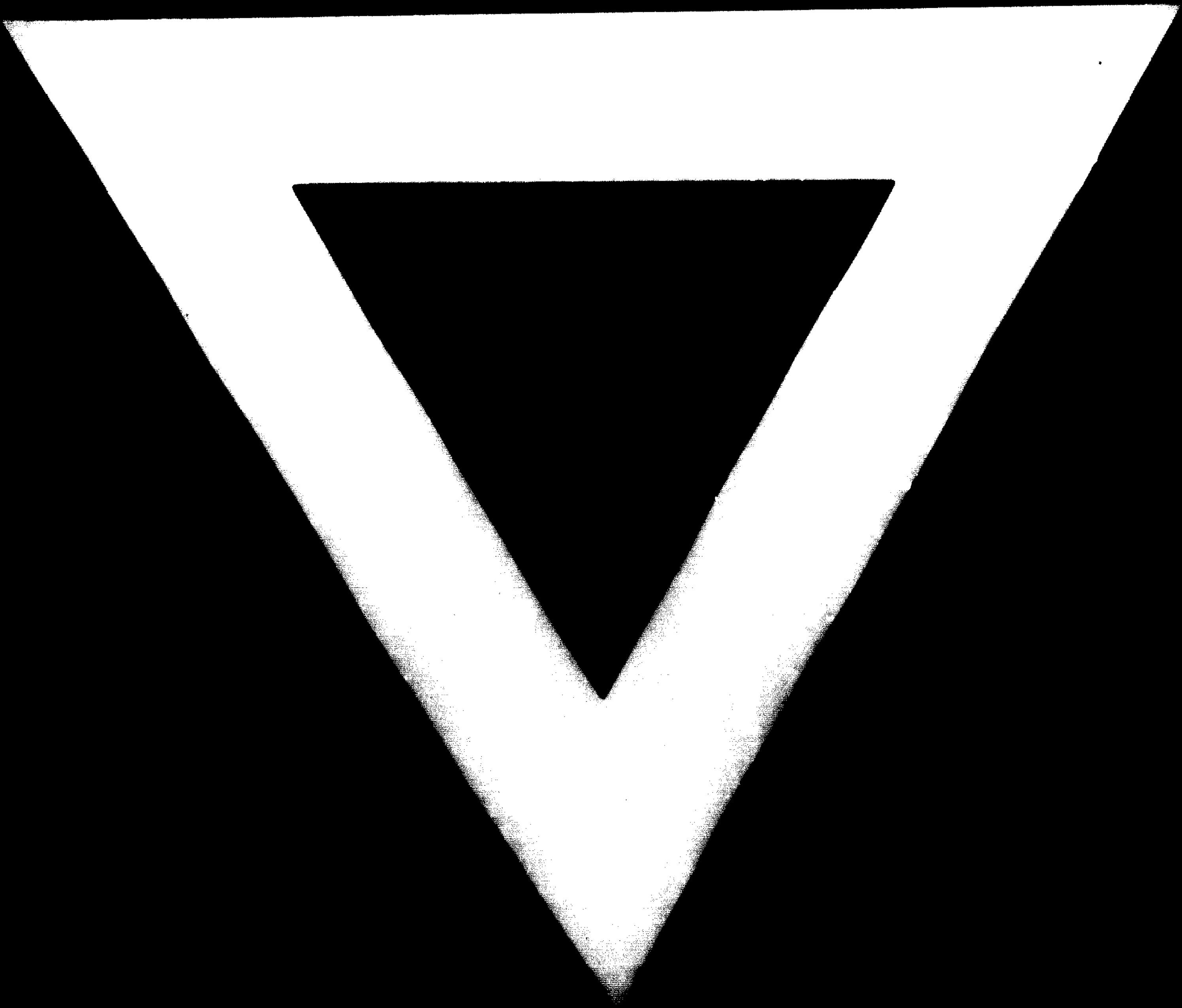

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