THE TECHNOLOGICAL LEVEL
OF THE SOVIET IRON AND STEEL INDUSTRY

With some comparison to Japanese Steel Industry

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Synopsis

The technological level of the Soviet steel industry is analyzed on the basis of the recent operation data of each section of the industry as they appeared in the Soviet technical journals and also by comparing them with those of the Japanese steel industry. The performance of the Soviet steel industry is uneven. Although the blast furnace technology showed the highest level in the world standard, the Soviet Union falls 10 to 20 years behind Japan in both the modernization of the steel making process and the rolling section. In spite of the difficult condition, Soviet metallurgists succeeded in developing some specially pioneered technologies such as a plasma-arc furnace, multi-layer steel clads, large diameter multi-layer steel pipe and so on. Considering these facts and intensive work in the field of basic metallurgical science by Soviet scientists, the Soviet steel industry is estimated to be the world's best "laboratory" of the steel industry. To transform the best "laboratory" to the best "factory" is the task for Soviet metallurgists.

Introduction

The iron and steel industry is a typical big process industry and at the

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same time an intelligence intensive industry which has experienced considerable technological progress in the past few decades. Therefore, its technological level is one of the most important indicators evaluating the over-all technological level of the developed industrial countries.

Among the major countries producing iron and steel, the Soviet Union and Japan are two distinct countries in which the extensive efforts for rapid growth of production and technological progress have been done during the last two decades.

In contrast to major western industrial countries (except Japan) which suffered from considerable decrease in the production of steel due to the prolonged deep economic crisis during the 1970s, the Soviet Union maintains the production of crude steel at over 100 million tonnes per year since 1967 and has kept first place in the world in terms of the volume of steel production since 1974. Rapid expansion of production and growing needs for steel production are the characteristics of the Soviet steel industry. However, in the Soviet Union during the past four years since 1979, the planned output target has not been achieved and a certain trend of deadlock of the technological progress has been observed.

Although the Soviet steel industry has played an honourable role in promoting technological improvement in each branch of the steel industry since World War II, and is a pioneer of some modern technologies; the growth of the production has been attained mainly through intensifying traditional technologies. This shows the sharp contrast to the Japanese steel industry in which tremendous efforts for entire technological modernization have been concentrated since the end of 1960s.

Some of these features have already been analyzed by Julian Cooper[1] and some Japanese analysts[2-4]. However, [1] relies on the data only until the early 1970s and [2-4] only show the limited subjects. Therefore, it is worthwhile to analyze the technological level of the Soviet steel industry on the basis of the very recent data of each branch of it.

The purpose of this paper is to describe the recent features of the Soviet steel industry by comparing the technical data on performances of the concrete facilities that have appeared in the Soviet technical journals during the past 5-6 years with those in Japan.
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I. Outline

As mentioned above, the Soviet Union has maintained the steel production at over 100 million tonnes per year since it recorded 100.2 million tonnes of total crude steel in 1967, and keeps the top position of the production of both pig iron and crude steel in the world (Table 1). The production of crude steel of the 1st half period of 1983 was 76.2 million tonnes and they will recover 150 million tonnes per year after a four year depression of the production since 1979[7].

The apparent steel consumption per head of population has kept them in

| Year | USSR   | Japan  | USA     | FRG     |
|------|--------|--------|---------|---------|
| 1940 | 14902  | 5572   | 42619   | 13995   |
|      | 18317  | 6856   | 60766   | 19141   |
| 1960 | 46757  | 11896  | 61072   | 25739   |
|      | 65294  | 22138  | 90067   | 34110   |
| 1965 | 66184  | 27502  | 80611   | 26990   |
|      | 91021  | 41161  | 119266  | 36821   |
| 1970 | 85993  | 68047  | 83294   | 33627   |
|      | 115889 | 93322  | 119310  | 45041   |
| 1975 | 102968 | 86877  | 72506   | 30074   |
|      | 141344 | 102313 | 105818  | 40415   |
| 1976 | 105374 | 86576  | 78808   | 31849   |
|      | 144825 | 107399 | 116122  | 42415   |
| 1977 | 107368 | 85886  | 73780   | 28965   |
|      | 146678 | 102405 | 113702  | 38985   |
| 1978 | 110702 | 78589  | 79542   | 30148   |
|      | 151453 | 102105 | 124315  | 41253   |
| 1979 | 108998 | 83825  | 78929   | 35167.  |
|      | 149099 | 111748 | 123689  | 46040   |
| 1980 | 107283 | 87041  | 62344   | 33873   |
|      | 147941 | 111395 | 101457  | 43838   |
| 1981 | 107766 | 80048  | 66639   | 31876   |
|      | 148445 | 101676 | 109615  | 41610   |
| 1982 | 106723 | 77658  | n.a.    | n.a.    |
|      | 147165 | 99548  | 67656   |         |
Table 2  Apparent steel consumption per head of population, (kg/head), [6]

| Year | USSR | Japan | USA | FRG | UK | Poland |
|------|------|-------|-----|-----|----|--------|
| 1975 | 554  | 580   | 547 | 489 | 374| 524    |
| 1976 | 566  | 534   | 604 | 594 | 378| 533    |
| 1977 | 560  | 512   | 618 | 538 | 357| 540    |
| 1978 | 586  | 535   | 672 | 525 | 359| 561    |
| 1979 | 576  | 637   | 640 | 602 | 368| 545    |
| 1980 | 565  | 629   | 508 | 549 | 247| 542    |

There are some arguments on the causes of the recent depression of the Soviet steel industry[2, 3]. One is the shortage of capital investments. Table 3 shows the amount of capital investments in the steel industry and some other related industries in the Soviet Union in the last 20 years. According to these figures, the steel industry received 3210 million roubles in 1979 (7.1% of the total investments in the industry in 1979), which is rather small for such a big process industry like the steel industry. It is interesting to show capital investments in the steel industry of Japan during the past ten years (Table 4). Although it is difficult to compare directly these two countries which are in different socio-economic systems from each other, it is seen from Table 4 that, in Japan, very big efforts have been made to develop the modernization of the steel industry during the 1970s and it would be a main reason for the present situation of the super-high technological level of the Japanese steel industry.

The total capital investments of the steel industry during the 9th and 10th five year plan (FYP) period was about 30 billion roubles, in which the following are included; 8 blast furnaces (BFes), 11 oxygen converters, 9 big electric arc furnaces, 36 rolling mills, 26 pipe-and tube mills, 20 coke ovens, 32 pelletizing and sintering facilities and 100 automation systems1 [10].

Increase of output in each branch of the steel industry owing to capital

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1. The percentage of automation in the steel industry 49% in 1975 increased up to 61% in 1980[10].
Table 3  Capital investments of the state and cooperative companies and organizations (except collective firms) of the industrial branch, from 1960 to 1979 (comparable prices in million roubles) [8]

|                          | 1960    | 1965    | 1970    | 1975    | 1979    |
|--------------------------|---------|---------|---------|---------|---------|
|                          | Absolute| %       | Absolute| %       | Absolute| %       | Absolute| %       |
| Industry, total          | 14289   | 100.0   | 20266   | 100.0   | 27957   | 100.0   | 38932   | 100.0   | 45360   | 100.0   |
| Iron and steel           | 1219    | 8.5     | 1779    | 8.5     | 2021    | 7.2     | 2805    | 7.2     | 3210    | 7.1     |
| Electric power           | 1486    | 10.4    | 2456    | 12.1    | 3021    | 10.8    | 3649    | 9.4     | 3940    | 8.7     |
| Coal industry            | 999     | 7.0     | 1389    | 6.9     | 1502    | 5.4     | 1710    | 4.4     | 2020    | 4.5     |
| Oil industry             | 1725    | 12.1    | 2044    | 10.1    | 2491    | 8.9     | 3802    | 9.8     | 5860    | 12.9    |
| Gas industry             | 852     | 6.0     | 2157    | 10.6    | 2400    | 8.6     | 3791    | 9.7     | 4500    | 9.4     |
| Chemical and petrochemical | 1756   | 12.3    | 3106    | 15.3    | 5958    | 21.3    | 9408    | 24.2    | 11100   | 24.5    |
| Industry of construction materials | 2004 | 14.0    | 1011    | 5.0     | 1671    | 6.0     | 1859    | 4.8     | 1920    | 4.2     |
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Table 4  Capital investments in the steel industry in Japan (billion yen) [9]

| Year | Steel industry | All industries | Percentage of steel industry |
|------|----------------|----------------|-----------------------------|
| 1972 | 651.6          | 4281.4         | 15.2                        |
| 1973 | 592.8          | 5409.6         | 11.0                        |
| 1974 | 892.2          | 6408.2         | 13.9                        |
| 1975 | 1147.4         | 5998.5         | 19.1                        |
| 1976 | 1264.6         | 6241.4         | 20.3                        |
| 1977 | 684.1          | 6725.2         | 10.2                        |
| 1978 | 580.5          | 7389.9         | 7.9                         |
| 1979 | 618.3          | 8035.7         | 7.7                         |
| 1980 | 606.8          | 9787.7         | 6.2                         |
| 1981 | 802.5          | 10598.8        | 7.6                         |
| 1982 | 1092.4         | 11811.8        | 9.2                         |

Table 5  Increase of output per year owing to capital investments in each branch of the iron and steel industry from 1971 to 1980 [5]

| Branch                  | 1971-75 | 1976 | 1977 | 1978 | 1979 | 1980 |
|-------------------------|---------|------|------|------|------|------|
| Coal (10^6 tonnes/year) | 22.5    | 12.5 | 17.4 | 26.0 | 19.4 | 15.0 |
| Iron one (")            | 26.3    | 46.4 | 8.3  | 19.8 | 31.3 | 28.2 |
| Pig iron (")            | 2.6     | 2.3  | 0.6  | 2.2  | 0.4  | 0.1  |
| Steel (")               | 2.2     | 1.2  | 6.0  | 2.9  | 1.5  | 2.7  |
| Rolled products (")     | 2.4     | 4.0  | 1.5  | 1.1  | 0.3  | 0.4  |
| Steel pipe (10^3 tonnes/year) | 477    | 340  | 708  | 433  | 3.3  | 377  |

Investments mentioned above is shown in Table 5. According to these figures, capital investments for BF slowed down except for the giant BF with useful volume of 5580m^3 at the Cherepovets Works, and those for oxygen converters and electric arc furnaces increased. The deceleration observed in the rolling section (Table 5) is probably due to the existense of a large number of aged rolling shops as shown later.

II. Technological Level

In the following sections, the technological level of the Soviet steel industry will be analyzed by comparing the performance of the main facilities in
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each section of the industry with that of Japan.

1. Iron Making: Level of the BF Technology

(1) Outline

To evaluate the iron-making technology, it is needed to analyze the technologies of ore-dressing, pretreatments of ores, coke-making, refractories, and so on. Here we will analyze the BF performance which is the most important one in this part.

In the Soviet Union, the technology of BF has kept a relatively high level in the world since the 1930s. After World War II, many progressive technologies have been launched by Soviet metallurgists and many of the present iron-making technologies acknowledge Soviet-origin inventions. The BFs with a useful volume of 2000m³ at the Novolipetsk Works and the Krivoj-Rog Works constructed in 1962 are the pioneers of the present giant furnaces in the world steel industry. The increase in the pressure of top gas of the furnace which is necessary to operate such big furnaces also has been developed by Soviet metallurgists.

At the end of 1978, BFs in the Soviet Union totaled 138 and 24 of them are the giant furnaces with a useful volume over 2000m³ [11]. The No.9 BF of the Krivoj-Rog Works, having a useful volume of 5026m³, is the 3rd biggest furnace in the world and the would-be biggest 5580m³ furnace is now under construction at the Cherepovets Works.

In addition to the above high-pressure operation, technologies such as natural gas injection for reducing consumption of coke, tal injection, oxygen injection, pulverized coal injection and etc have either initially or mainly been developed by the Soviet Union and diffused in the world. Among them, the natural gas injection method is the purely original technology of the Soviet Union which has a large amount of natural gas deposits. It is now widely adopted in the Soviet Union in combination with the oxygen gas injection method (in 1980, this method was adopted by 86.8% of the BFs (96.3% in volume)) [12]. The inventors of the technology, Prof. Nekrasov and his group were awarded the Lenin prize in 1960.

BF top pressure recovery turbines for reducing energy costs, and the coke dry quenching method were also developed by Soviet metallurgists and were
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Table 6 Average coke rate of major producing countries (kg/tonne of pig iron)

| Country          | 1970 | 1975 | 1979 | 1980 | 1981 |
|------------------|------|------|------|------|------|
| USSR [16]        | 544  | 521  | 513  | 512  | n.a. |
| Japan [6]        | 478  | 443  | 424  | 450  | 476  |
| USA [6]          | 658  | 611  | 575  | 569  | 550  |
| FRG [6]          | 559  | 497  | 497  | 515  | 550  |
| UK [6]           | 625  | 608  | 578  | 588  | 577  |
| Poland [16]      | 703  | 625  | 589  | 596  | n.a. |
| Czechoslovakia [16] | 613  | 537  | 510  | 519  | n.a. |

introduced by several Japanese big steel companies 2.

The Soviet steel industry is proud of the top level BF performance as mentioned above, while on the other hand, very small furnaces such as with a useful volume of 292m³ [14], 600m³ [15] are still under operation. Coexistence of the top level technology and the old one is the characteristic feature of the Soviet industry, not only in the iron making process but also in all other branches of the industry as is shown later.

The blast furnace is the typical much energy-consuming facility. The amount of consumption of coke which is its main energy source and indispensable raw materials, is one of the main indicators evaluating the technological level of BFes. The Soviet Union holds the 2nd position in the low coke rate next to Japan (Table 6).

Another parameter indicating the technological level is the productivity ratio of the furnace (average daily output per furnace volume). Those of the Soviet Union and Japan are shown in Table 7.

Productivity ratio of Soviet giant BFes is around 2 (Table 9, 10), but the mean value is lower than that of Japan. The recent decreasing trend in the

2. In addition to the above two licences, Japanese companies introduced 10 licences, patents or equipments from the Soviet Union including the walking-bar type C.C. machine, electro slag remelting (ESR) method from 1970 to 1981. While from Japan to the Soviet Union only two were exported during the same period [13]. The technology of the Japanese steel industry which is nowadays in the highest level in the world is based on a number of foreign licences and patents introduced during the 1960s to 70s. Only from 1977, the number of exporting licences or patents from Japan began to surpass that of importing ones.
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Table 7  Average productivity ratio of BF (tonnes/m³/day)

|        | 1970 | 1975 | 1976 | 1977 | 1978 | 1979 | 1980 | 1981 | 1982 |
|--------|------|------|------|------|------|------|------|------|------|
| USSR [17] | 1.675 | 1.760 | 1.776 | 1.782 | 1.821 | 1.776 | 1.751 | 1.75 | 1.74 |
| Japan [13, 18] | 1.95 | 1.87 | 1.90 | 1.83 | 1.80 | 1.93 | 1.94 | 1.78 | 1.74 |

Table 8  Average slag rate of BF in the USSR (kg/tonne of pig iron) [16]

|        | 1970 | 1975 | 1979 | 1980 |
|--------|------|------|------|------|
|        | 483  | 448  | 467  | 476  |

Table 9  Operation indices of the No. 9 BF of the Krivoj-Rog Works with a useful volume of 5028 m³, (A) [19], and those of the corresponding giant BF No. 6 of the Chiba works of Kawasaki Steel Corp., Japan, with a useful volume of 4500 m³, (B) [20]

|                     | (A)              | (B)              |
|---------------------|------------------|------------------|
| Productivity (tonnes/day) as above (million tonnes/year) | 11200 4 | 10310 n.a. |
| Productivity ratio (tonnes/m³/day) | 2.22 | 2.29 |
| Consumption per tonne of pig iron | | |
| coke (dry) kg | 372 | 381.0 |
| natural gas m³ | 141 | oil kg 37.4 |
| oxygen in blast m³ | 152 | |
| blast volume m³ | 811 | Nm³/min 6894 |
| sintered ore kg | 1115 | n.a. sinter 93.5% |
| pellet kg | 750 | n.a. pellet 3.2% |
| Output per tonne pig iron | | |
| slag kg | 391 | 330 |
| top gas (dry) m³ | 1440 | n.a. |
| Blast temperature °C | n.a. | 1312 |

productivity ratio is probably due to the lowering of the quality of iron ore. This is also seen in the change in the average slag rate in the last ten years (iron content in a charge of BF can be measured approximately by the slag rate), Table 8.

In the Soviet Union about 100 middle class BFes with a useful volume
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Table 10  Operation indices of the No. 6 BF with a useful volume of 3200 m³ of the Novolipetsk Works [21]

|                                | 1980   | 1981   | 1982 (Jan.–April) |
|--------------------------------|--------|--------|-------------------|
| Productivity (10⁸ tonnes/year) | 2563.9 | 2591.9 | 874.9             |
| Productivity ratio (t/m³/day)  | 2.21   | 2.25   | 2.28              |
| Coke rate (kg/t. of pig iron) | 435    | 426    | 423               |
| Slag rate (as above)           | 437    | 458    | 491               |
| Iron content in a charge (%)   | 55.38  | 53.8   | 54.47             |
| Natural gas (m³/t. of pig iron)| 126    | 130    | 131               |
| Oxygen (as above)              | 131    | 140    | 137               |
| Blast pressure (MPa)           | 0.377  | 0.395  | 0.406             |
| Blast temperature (°C)         | 1211   | 1223   | 1233              |
| Top gas pressure (MPa)         | 0.202  | 0.216  | 0.223             |
| Impurities in pig iron (%)     |        |        |                   |
| Si                             | 0.76   | 0.68   | 0.65              |
| Mn                             | 0.77   | 0.65   | 0.72              |
| S                              | 0.024  | 0.022  | 0.019             |
| Self cost of pig iron (roubles/tonne) | 63.38 | 63.0 | 74.7 |

Table 11  Operation indices of the No. 3 BF with a useful volume of 3223 m³ of the Fukuyama works of Nippon Kokan K.K., Japan

|                                | Oilless operation [22] | Normal operation [23] |
|--------------------------------|------------------------|-----------------------|
| Productivity (tonnes/day)      | 7636                   | 7436                  |
| Productivity ratio (t/m³/day)  | 2.37                   | 2.30                  |
| Blast temperature (°C)         | 1353                   | 1316                  |
| Oxygen enrichment (%)          | 0                      | 0.76                  |
| Coke rate (kg/t. of pig iron)  | 354                    | 365.2                 |
| Tar (kg/t. of pig iron)        | 42.1                   | Oil 63.0              |
| Slag rate (as above)           | 274                    | 317                   |
| Sinter (%)                     | 96.6                   | 79.9                  |
| Miscellaneous (%)              | 3.4                    | Pellet 4.5            |
| Impurities in pig iron (%)     |                        |                       |
| Si                             | 0.27                   | 0.35                  |
| S                              | 0.045                  | 0.033                 |
| Mn                             | 0.43                   | 0.54                  |
| P                              | 0.098                  | 0.114                 |
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1000 to 1800m³ (the mean useful volume of all BFes is 1298m³) are working now. The coke rate of those BFes is usually 500 to 600 and the mean blast temperature is 1071°C[24]. The lower blast temperature suggests that the quality of refractories is lower than that in Japan.

(2) Operation results of some typical BFes of the Soviet Union and Japan

Next we show some operation indices of typical BFes. Table 9 shows the technical data of the No.9 BF of the Krivoj-Rog Works with a useful volume of 5028m³ and of the No.6 BF of the Chiba works of Kawasaki Steel Corp. (Japan) with a useful volume of 4500m³. The productivity ratio 2.22 and 2.29 of the Krivoj-Rog Works and the Chiba works, respectively is the highest level in the world. The total fuel rate in both cases is almost the same and quite low for such a big furnace.

Table 10 and 11 show the operation indices of the No.6 BF of the Novolipetsk Works with a useful volume of 3200m³ and the corresponding BF No.3 of the Fukuyama works of Nippon Kokan K.K. Japan.

In the case of the 2000m³ class BFes in the Novolipetsk Works, the Cherepovets Works, the Magnitogorsk Combine and the West-Siberian Works; the coke rate lies between 420 and 470 and the productivity 4100 and 4800 tonnes per day, blast temperature 1100 and 1200°C[24].

By comparing these results in both countries, it is concluded that the performance of the giant BFes of the Soviet Union is of sufficiently high level in the world standard, although the blast temperature is about 100°C lower and the total fuel rate is slightly higher than those of Japan’s best furnaces.

In every case shown above, high quality and pretreated (sintered, pelleted) ores are used and henceforce the operation of the furnace is stable. However, in contrast to the Japanese steel industry in which all furnaces are operated by using all-imported, selected, high-grade ores, the condition of Soviet iron ore resources is rich in variety. For example, the No.4 BF with a useful volume of 3200m³ of the Karaganda Combine shows very low operation results, (Table 12). In this combine phosphorus-rich low grade iron ore of the Lisakov ore deposit is used. In other European countries, they have also a large amount of high-phosphorus iron ore deposits and are faced with a problem of utillization of such ore. Therefore the Karaganda Combine is a surely a pioneer factory in view of the effective utillization of domestic re-
Table 12  Operation indices of the No. 4 BF with a useful volume of 3200 m$^3$
of the Karaganda Combine [25]

|                      | 1977 | 1978 | 1979 |
|----------------------|------|------|------|
| Productivity (tonnes/day) | 4389 | 4690 | 4840 |
| Iron content in a charge (%) | 46.0 | 46.6 | 47.4 |
| Nontreated iron ore (%)   | 11.6 | 10.1 |  9.9 |
| Oxygen (%)               | 24.2 | 25.3 | 25.3 |
| Top gas pressure (MPa)   | 0.191|  0.2 |  0.2 |
| Slag rate (kg/t. of pig iron) | 637 |  642 |  630 |
| Coke rate (as above)     | 617  |  595 |  594 |
| Tar (as above)           | 49   |  55  |  51  |
| Impurities in pig iron (%) |  |      |      |
| Si                    | 0.88 | 0.86 | 0.87 |
| Mn                    | 0.83 | 0.78 | 0.87 |
| S                     | 0.031| 0.030| 0.028|
| P                     | 0.814| 0.867| 0.908|
| Blast temperature (°C)  |      | max. 1043 |      |
| Blast pressure (MPa)    |      | max. 0.338 |      |

sources. However, to solve this problem more effectively, further technological effort is required for dephosphorization by pretreatment of hot metal. In Japan, low phosphorus content in hot metal 0.1% was obtained already in 1975[26]. Although the main reason of decreasing phosphorus content is the import of low phosphorus iron ore. A lot of effort has been concentrated on the dephosphorization of hot metal, in Japan. For example, in the Kimitsu works of Nippon Steel Corp., dephosphorization is carried out in the torpedo ladle and 0.1 to 0.16% P in the starting hot metal is reduced to 0.01%[26].

2. Steel Making Process

(1) Stagnation of steel production by oxygen converter in the Soviet Union

In the Soviet Union, 88 million tonnes of steel (59.1% of total output in 1981) were still produced by open hearth furnaces (OHF). Production of steel by oxygen converters (OC) was only 44 million tonnes (29.5%), and by electric arc furnaces (EAF) was 16.2 million tonnes (10.9%), in 1981.
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Table 13 The proportion of steel output by type of process of major countries [6]

|       | USSR | Japan | USA | FRG | UK |
|-------|------|-------|-----|-----|----|
| 1972  |      |       |     |     |    |
| OHF   | 68.7 | 2.0   | 26.2| 19.0| 37.0|
| OC    | 20.5 | 79.4  | 56.0| 64.6| 42.6|
| EAF   | 9.8  | 18.6  | 17.8| 10.2| 19.4|
| others| 1.0  |       |     | 6.2 | 1.0 |
| 1975  |      |       |     |     |    |
| OHF   | 64.7 | 1.1   | 19.0| 16.7| 22.1|
| OC    | 24.6 | 82.5  | 61.6| 69.3| 50.1|
| EAF   | 9.9  | 16.4  | 19.4| 12.5| 27.7|
| others| 0.8  |       |     | 1.5 | 0.1 |
| 1978  |      |       |     |     |    |
| OHF   | 61.3 |       | 15.6| 11.0| 8.7 |
| OC    | 28.1 | 78.1  | 60.9| 74.6| 55.8|
| EAF   | 10.0 | 21.9  | 23.5| 14.4| 35.4|
| others| 0.7  |       |     | 0.1 |     |
| 1981  |      |       |     |     |    |
| OHF   | 59.1 |       | 11.1| 3.9 |     |
| OC    | 29.5 | 75.2  | 60.6| 80.2| 68.5|
| EAF   | 10.9 | 24.8  | 28.3| 15.8| 31.5|
| others| 0.5  |       |     |     |     |

Table 14 Number of OCs in major producing countries, numbers in parenthesis show the productivity per year (x 10^4 tonnes) [6]

|       | Furnace capacity (tonnes) |
|-------|---------------------------|
|       | <100          | 100 to 200     | >200          | total         |
| USSR  | 7 (323)       | 21 (2370)      | 17 (3050)     | 45 (5734)     |
| Japan | 24 (1439)     | 33 (4269)      | 33 (6885)     | 90 (12593)    |
| USA   | 4 (142)       | 21 (1179)      | 53 (6482)     | 78 (7803)     |
| FRG   | 6 (330)       | 15 (1568)      | 16 (3126)     | 37 (5024)     |
| UK    | 2 (120)       | 6 (700)        | 8 (1200)      | 16 (2020)     |

Current FYP foresees that the above ratio will be 52.3% by OHF, 33.7% by OC, 13.4% by EAF and 0.6% by others, in 1985. The above planned proportion corresponds to that of Japan in 1962, and of the USA in 1967.

Table 13 shows the proportion of steel output by type of process in the major steel producing countries. Table 14 shows the number of OCs in each country at the end of 1981.

For further development of steel production in the Soviet Union, immedi-
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Table 15  Relative consumption of scrap in each steel making process  
(kg/tonne of steel) [28]

|       | 1960 | 1965 | 1970 | 1975 | 1980 |
|-------|------|------|------|------|------|
| OHF   | 489  | 474  | 489  | 502  | 515  |
| OC    | –    | 38   | 192  | 242  | 257  |
| EAF   | 964  | 951  | 936  | 944  | 940  |

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ate replacement of the OHF by the OC or partially by the EAF is clearly needed.

Nevertheless, there are still arguments on the comparative merits of the OHF and the OC[27]. Some confusions are observed in the arguments about the way of the replacement of the OHF by the OC. Open discussion on the above subject organized by the Minichermet (the Ministry of Ferrous Industry of the USSR) in 1979 reveals the real problem of the Soviet steel industry [27]. There are two groups confronting each other. The progressive line of some people insists on the quick replacement of the amortized OHFes by the OCs by the end of this century at latest. While the conservative group insists on keeping OHFes much longer. The reasons of the insistence of the conservatives are the deficits in the production of pig iron, increasing amount of scrap, insufficient number of skilled personnel, shortage of investments funds, incompletion of the plan of steel production during the replacement time, and so on. Reconstruction of giant OHFes to the Soviet original twinbath open hearth furnace, which will be explained later, is the solution of the conservatives. The above controversy still continues and the progressive line is getting larger influence[28, 29].

(2) Structure of scrap resources

In the Soviet Union, a large amount of scrap is produced and its output increases every year. This is a major reason for keeping steel making by the OHF. The progressive group proposes the development of steel making processes using an unusually large amount of scrap by an OC.

Recently a proportion of scrap in a charge in an OC is over 25%, (Table 15). In the case of the newest top-and-bottom blown OCs planned to be introduced to the Dzerzhinsk Works and the West-Siberian Works; the percen-
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Table 16 Structure of resources of scrap in the Soviet Union (%) [30]

| Origin                  | 1970  | 1975  | 1979  | 1980  |
|-------------------------|-------|-------|-------|-------|
| Steel industry          | 46.7  | 45.3  | 44.5  | 44.4  |
|                         | 293*  | 283*  | 282*  | 281*  |
| Metal cutting           | 20.7  | 21.5  | 21.5  | 21.6  |
| Amortized scrap         | 30.1  | 30.9  | 31.7  | 31.7  |
| Slag recovery           | 2.5   | 2.3   | 2.3   | 2.3   |
| Total commercial scrap  | 58.1  | 50.3  | 51.1  | 51.7  |

*Steel industry origin scrap (kg/tonne of steel)

Table 17 Domestic resources of scrap in Japan [31]

| Production of steel (million tonnes) | 1978 | 1985 (plan) |
|-------------------------------------|------|-------------|
|                                     | 105.1| 120 to 125  |
| Scrap resources                     |      |             |
| Steel industry                      | $10^6$ tonnes | % | $10^6$ tonnes | % |
| Commercial metal working            | 15.4 | 40.9        | 12.6 | 29.2 |
| Commercial amortized scrap          | 21.1 | 56.1        | 30.6 | 70.8 |
|                                     | 8.4  | 22.3        | 10.1 | 23.4 |
|                                     | 12.7 | 33.8        | 20.5 | 47.4 |
| Stock                               | 1.1  | 2.9         | 0    | 0    |
| Total                               | 37.6 | 100         | 43.2 | 100  |

Percentage of scrap in a charge is expected to be 30 to 45% [29].

Table 16 shows the structure of scrap resources in the Soviet Union. By comparing this with that of Japan (Table 17), it is seen that a proportion of scrap produced inside steel works is larger than that of Japan. This is due to the delay in diffusion of the continuous casting process (C.C.) and the low yield of output in each section of steel works, especially in the rolling section as shown later. In this sense, insistence of keeping the OHF based on increasing scrap production commits a double mistake.

Recent trends of decreasing scrap output inside the steel industry in Japan is completely linked up with the increasing proportion of continuous casting steel. The amount of scrap yielded inside the steel industry was 191 kg per tonne of steel where a proportion of C.C. steel was 5.8% in 1970. In 1981,
the former decreased to 112kg per tonne of steel and the latter increased to 90.0% [31].

(3) Estimation of expenditure of construction of oxygen converters in the Soviet Union

Another reason of the delay of the replacement of the OHF by the OC is the deficit in capital investments. Let us now estimate total costs of such a replacement in the Soviet Union on the basis of the data cited in [27]. According to [27], the cost of the reconstruction of a middle scale OHF shop to a bottom-blown OC (150 tonnes capacity) shop is about 100 to 110 million roubles, and that of the construction of new OCs of 200 tonnes capacity is about 200 million roubles. To change the structure of steel making processes to that of the USA in 1981, the proportion of total steel output by the OHF must be reduced to 11.1% and 73 million tonnes out of 88 million tonnes of total crude steel by the OHF in 1981 must be produced by the OC. For this purpose, about 18 shops with 3 middle class OCs respectively with 160 tonnes capacity corresponding to the No.1 converter shop of the Novolipetsk Works with productivity 4 million tonnes per year [32], are needed. The minimum expenditure for the reconstruction is estimated to be 1.8 billion roubles and 4 billion roubles for the construction of new converter shops 3. These figures correspond to 60% and 125%, respectively, of total capital investments in the steel industry in 1979, (Table 3). This is apparently a good enough reason for the conservatives to insist on keeping the OHF. However, it is quite clear that further development of steel production in the Soviet Union is almost impossible without strong effort for the replacement of all OHFes by the end of this century as insisted by one of the reporters in [27].

(4) Continuous casting

Continuous casting (C.C.) technology is one of the indispensable conditions to the contemporary steel making processes both for raising the produc-

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3. In Japan, the cost for the construction of a converter shop with 3 converters, 300 tonnes capacity is estimated to be about 60 billion yen [33]. This figure is almost the same as in the USSR, when the exchange rate of one rouble is estimated to be 300 yen. Total costs of the introduction of C.C. installations to the above mentioned shop is estimated to be about 16 to 18 billion yen [33].
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Table 18  Output of steel by C.C. and its proportion to total crude steel (1000 tonnes/%) [6]

| Year | USSR | Japan | USA | FRG | UK  |
|------|------|-------|-----|-----|-----|
| 1975 | 7729 | 31814 | 9652| 9813| 1704|
|      | 5.47 | 31.1  | 9.12| 24.3| 8.48|
| 1976 | 11729| 37629 | 12246| 12014| 2165|
|      | 8.10 | 35.0  | 10.5| 28.3| 9.72|
| 1977 | 12200| 41807 | 14268| 13272| 2554|
|      | 8.32 | 40.8  | 12.5| 34.0| 12.5|
| 1978 | 14400| 47159 | 18903| 15670| 3149|
|      | 9.51 | 46.2  | 15.2| 38.0| 15.5|
| 1979 | 15300| 58116 | 20904| 17948| 3627|
|      | 10.3 | 52.0  | 16.9| 39.0| 17.0|
| 1980 | 15900| 66271 | 20611| 20162| 3059|
|      | 10.7 | 59.5  | 20.3| 46.0| 27.1|
| 1981 | 18100| 71843 | 23003| 22319| 4958|
|      | 12.2 | 70.7  | 21.0| 53.6| 32.2|

Table 19  Number of C.C. installations in the Soviet Union [34]

| Year | Type of machine | Vertical | V. with bending | Curve | Total | Semi-C.C. | Sum total |
|------|-----------------|----------|-----------------|-------|-------|-----------|----------|
| 1960 |                 | 2        |                 |       |       | 1         | 3        |
| 1965 |                 | 6        |                 |       |       | 1         | 7        |
| 1970 |                 | 14       | 1               | 2     | 18*   | 8         | 26       |
| 1975 |                 | 16       | 3               | 3     | 22**  | 7         | 29       |
| 1980 |                 | 16       | 3               | 3     | 34**  | 12        | 46       |

*Including a conveyer type C.C. machine in the Omutninsk Works.
**Including two horizontal type machines in the test plant Turachermet.

Activity and yield of good products, and for reducing energy consumption. In the Soviet Union under the leadership by I. P. Bardin, much effort has been made to develop the practical application of this system since World War II. A Japanese company, Kobe Steel Works, introduced the equipments and licence of the Soviet original walking-bar type C.C. installations. These type machines are widely used in the world. This pioneer country of the C.C. technology, however, was caught up with by the USA in 1972 in the proportion of production of C.C. steel. It was only 12.2% even in 1981, (Table 18). The numbers of C.C. installations in the Soviet Union are shown in Table 19.
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Table 20 Operation indices of the 350 tonnes oxygen converter of the West-Siberian Works (1978) [36]

| Number of heats 233 | Impurities in pig iron (%) |
|---------------------|-----------------------------|
|                     | Mn  0.45                    |
|                     | Si  0.70                    |
|                     | P   0.24                    |
|                     | S   0.033                   |
|                     | Impurities in steel (%)     |
|                     | C   0.12                    |
|                     | Mn  0.15                    |
|                     | P   0.015                   |
|                     | S   0.022                   |
| Consumption kg (%)  | oxygen m³/t. of steel 51.5  |
| hot metal           | 267.4 (74.7)                |
| scrap               | 90.7 (25.3)                 |
| lime                | 24.4 (6.8)                  |
| fluorite            | 0.83 (0.23)                 |
| sinter              | 0.22 (0.06)                 |
| ferromanganese      | 2.51 (0.7)                  |
| Operation cycle     | 39.5 min.                   |
| charging            | 3.5                         |
| melting pig iron    | 1.52                        |
| refining            | 15.8                        |
| Yield of molten steel: 92.08% |
| Yield of good ingot: 91.08% |

Table 21 Operation indices of the oxygen converter shop of the Novolipetsk Works and the West-Siberian Works (1980) [32]

|                  | Q   | M   | q   | T   | Number of heats |
|------------------|-----|-----|-----|-----|-----------------|
| Novolipetsk      |     |     |     |     |                 |
| No. 1 shop       | 3 × 160 | 4.0 | 166.5 | 42.9 | 913             |
| No. 2 shop       | 2 × 300 | 4.5 | 328.2 | 41.4 | 607             |
| West-Siberian    |     |     |     |     |                 |
| No. 1 shop       | 3 × 130* | 3.1 | 146.1 | 41.8 | 870***          |
| No. 2 shop       | 2 × 300** | 4.0 | 322.8 | 43.7 | 590             |

Q: capacity of furnace, tonnes. M: productivity, million tonnes/year. q: productivity, tonne per cycle. T: operation cycle, min.
*now 160 tonnes. **now 350 tonnes. ***The maximum number of heats 2500 was recorded and the period of continuous operation reached 108 days [36].

In 1981, Japan had 169 machines, the USA 99 and the FRG 45 machines [35].

Rapid diffusion of the C.C. process is also a key problem for the development of the Soviet steel industry. Under the 11th FYP, the new C.C. installations for alloyed steel will be introduced to the Donetsk Works and the Oskol' Electrometallurgical Works. Small-scale horizontal type C.C. installations linked to the OHF will be introduced to the Karaganda Combine, the Uzbek Works, the Petrovsk-Zabaikal' Works, the Slishk Works and the
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Table 22  Operation indices of OCs of the Ohgishima works of Nippon Kokan K.K., Japan (2 x 250 tonnes capacity*) [37]. March—May, 1977

| Productivity 746395 tonnes/3 months |
|-------------------------------------|
| Number of charge                     |
| ingot                               | 1449 |
| C.C.                                | 1369 |
| total                               | 2818 |
| Consumption                         |
| hot metal (%)                       | 93   |
| burnt lime (kg/t. of steel)         | 69.6 |
| dolomite and burnt dolomite (as above)| 26.5 |
| iron ore (as above)                 | 44.1 |
| mill scale (as above)               | 10.5 |
| fluorite (as above)                 | 0.4  |
| oxygen (Nm³/t. of steel)            | 47.2 |
| Yield of good ingot:                | 92.6%|
| Yield of molten metal:              | 95.4%|
| Number of heats                     |
| No. 1 converter:                    | 922  |
| No. 2 converter:                    | 884  |
| Operation cycle (min):              | 35.3 |
| Blowing time (min):                 | 17.4 |

*Now 3 converters of 250 tonnes capacity are working.

Omutminsk Works[29]. However, the delay of the introduction of the horizontal type machine which was planned to be completed in 1984 is suggested [29]. It cannot be denied that the Soviet Union has a long way to go before the full diffusion of the C.C. technology.

(5) Technological level of each steel making process

(a) Oxygen converter

The technological level of the OC performance itself is by no means low in the Soviet Union. Table 20 and 21 show the operation indices of typical OCs in the Soviet Union. Corresponding ones for OCs in Japan are shown in Table 22 to 24.

Comparing the above operation results of the West-Siberian Works and the Novolipetsks Works with those of Japan, one can see that the operation cycle, oxygen consumption, number of heats and so on are nearly the same as the mean values of Japan, (Table 24). These are relatively high values under the
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Table 23 Operation indices of the bottom-blown OCs of the Chiba 3rd steel making shop of Kawasaki Steel Corp., Japan [38]
2 x 230 tonnes capacity. June—August, 1978.

|                        | 692190 tonnes/3 months | max. 1016, min. 911 |
|------------------------|-------------------------|----------------------|
| Production             |                         |                      |
| Number of heats        |                         |                      |
| Consumption            |                         |                      |
| hot metal ratio (%)    | 97.3                    |                      |
| burnt lime (kg/t. of steel) | 36.0          |                      |
| dolomite (as above)    | 6.3                     |                      |
| mill scale (as above)  | 2.7                     |                      |
| iron ore (as above)    | 57.0                    |                      |
| fluorite (as above)    | 0.5                     |                      |
| oxygen (Nm³/t. of steel) | 43.3                |                      |
| Yield of good ingot (%)| 95.3                    |                      |
| Yield of molten steel (%)| 96.3                  |                      |
| Operation cycle blowing (min) | 14.8               |                      |

Table 24 Average operation results of OC in Japan [39]

|                        | 1977 | 1978 | 1979 | 1980 | 1981 |
|------------------------|------|------|------|------|------|
| Productivity (tonnes/hr)| 236.1| 250.3| 267.1| 279.8| 282.0|
| Operation cycle (min)   | 40   | 40   | 39   | 39   | 39   |
| Consumption             |      |      |      |      |      |
| pig iron (%)            | 91.8 | 89.8 | 88.9 | 91.8 | 92.6 |
| liquid metal (%)        | 91.0 | 88.0 | 87.1 | 90.9 | 91.5 |
| oxygen (Nm³/t. of steel)| 50.3 | 50.9 | 50.9 | 50.9 | 51.4 |
| Output                  |      |      |      |      |      |
| killed steel (%)        | 55.2 | 59.3 | 61.7 | 68.9 | 79.5 |
| C.C. steel (%)          | 35.2 | 40.3 | 46.1 | 55.5 | 69.7 |
| Vacuum treatment (%)    | 11.2 | 13.8 | 16.2 | 24.2 | 34.5 |

operation condition using 25% scrap in a charge. However, the yield of good ingot in the Soviet Union is generally lower than that of Japan. For instance, at the West-Siberian Works, it is 4% less than that of the Chiba works of Kawasaki Steel Corp., (Table 23).

The difference in yield 4% is very large in such a shop with a productivity of 4 million tonnes per year. If the yield of good ingot at the converter shops
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Table 25  Operation indices of twin-bath furnaces of the Magnitogorsk Combine [40]

| Furnace number | 35  | 29  | 30  | 31  | 32  |
|----------------|-----|-----|-----|-----|-----|
| Productivity (tonnes/year) | 1613508 | 1141028 | 982805 | 1143160 | 1094643 |
| Productivity (tonnes/day) | 4731 | 3266 | 3115 | 3726 | 3229 |
| Output (tonnes/cycle) | 282.4 | 285.5 | 280.7 | 281.4 | 285.4 |
| Operation cycle (h-min) | 2-48 | 4-08 | 4-15 | 4-00 | 4-02 |
| Productivity (tonnes/hr) | 100 | 69 | 66 | 70 | 70 |
| Consumption |     |     |     |     |     |
| fuel (kg/t. of steel) | 12.8 | 18.6 | 23.2 | 19.5 | 20.7 |
| oxygen (m³/t. of steel) | 73.2 | 78.3 | 74.1 | 71.9 | 75.0 |

in the West-Siberian Works rises 91% to 95%, total output of good ingot per year of the shops increases from 7.1 to 7.4 million tonnes.

If the average yield rises from, for example, 90% to 94%, output of crude steel by the OC 44 million tonnes increases up to 46 million tonnes which corresponds to increasing 1.33% of total output of crude steel in 1981.

(b) Open hearth furnace

Although the technology of the OHF already is dead now in Japan, it is impossible to neglect to evaluate this technology in the Soviet Union.

(b-1) Twin-bath furnace

In the Soviet Union, gigantic OHFes with 600 to 900 tonnes capacity have been constructed since 1960s. Even though the output per operation cycle is very large, the efficiency of heat, and the productivity of such a furnace is generally low. To improve these faults, unique technological reconstruction of the furnace has been done in the Soviet Union. The hearth is divided into two parts keeping the original furnace structure and while smelting in the one bath, scrap in another bath is preheated and thus smelting is carried out without a break. By this way, the operation cycle and fuel cost decrease and productivity increases. By 1976, 11 installations of this type were introduced.
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[4]. Above mentioned debate[29] suggests that the reconstruction of OHFes into this type of furnace would be a major modernization programme for the Soviet OHFes in future.

Table 25 shows the operation indices of the twin-bath furnaces of the Magnitogorsk Combine. According to [40], the No.35 twin-bath furnace of the combine is the best twin-bath furnace in the Soviet Union. However, it is clear that its productivity 100 tonnes per hour is lower than that of the standard OC with 250 tonnes capacity, or of the smaller OC with 160 tonnes capacity at the Novolipetsk Works or the West-Siberian Works.

The average metal loss (waste plus loss) of the twin-bath furnace is 147.5kg per tonne of steel (yield 85.2%) in 1980, 145.5 (85.5) in 1981, 146.1 (85.4) in 1982[41].

(b-2) Traditional OHF

Operation results of the traditional OHFes are as follows: productivity; 57.4 tonnes per hour (609 tonnes per cycle), operation cycle; 10.6 hrs, in the case of the 600 tonnes capacity furnace of the Komunarsk Works[42], and in the case of the 350 tonnes capacity furnace of the Amurstal', productivity; 27.3 tonnes per hour, operation cycle; 12.15 hrs[43].

When considering the low productivity shown above, and unavoidable and undesirable environmental pollution effects by using a large amount of oxygen (see Table 25) in the open system, the lack of economy in the OHF process is now quite clear.

(c) Electric arc furnace

Usually, EAF is used to produce special steels, alloy steels and other ordinary steel for light and medium sections.

As an example of the best EAF in the Soviet Union, operation indices of the 100 tonnes capacity furnace of the Cherepovets Works are shown in Table 26. By comparing these with the average operation results of EAFes of Japan (Table 27), it is seen that the productivity per hour is about 14% lower, the yield of good ingots 2 to 2.5% lower, and consumption of electric power is 5% larger in the case of the Cherepovetsk Works, than those in Japan. Yield of good ingots depends on the kind of steels produced by the furnace and considering that a larger amount of alloy steel is produced in Japan, the actual difference might still be bigger.
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Table 26 Operation indices of the EAF of 100 tonnes capacity of the Cherepovets Works [44]

|                          | 1971     | 1972     | 1975     | 1978     | 1979     |
|--------------------------|----------|----------|----------|----------|----------|
| Operation cycle (h-min)  | 5–19     | 4–36     | 4–16     | 4–20     | 4–21     |
| Consumption              |          |          |          |          |          |
| electric power (MJ/t. of steel) | 2275.2  | 1877.0   | 1754.6   | 1739.9   | 1754.4   |
| as above (KWh/t. of steel) | 632      | 520      | 487      | 483      | 487      |
| charge (tonnes/t. of steel) | 1.1546   | 1.1447   | 1.1384   | 1.1316   | 1.1331   |
| Yield (%)                | 86.6     | 87.4     | 87.8     | 88.4     | 88.3     |
| Number of heats          |          |          |          |          |          |
| wall                     | 129      | 159      | 191      | 189      | 186      |
| arch                     | 70       | 100      | 113      | 98       | 101      |
| Productivity (tonnes/hr)*| 18.8     | 21.7     | 23.4     | 21.4     | 21.3     |

*Based on the assumption that the output per cycle is 100 tonnes.

Table 27 Average operation results of EAFes of Japan [39]

|                          | 1977 | 1978 | 1979 | 1980 | 1981 |
|--------------------------|------|------|------|------|------|
| Productivity (tonnes/hr) | 18.6 | 21.5 | 24.5 | 25.3 | 26.2 |
| Consumption              |      |      |      |      |      |
| electric power (KWh/t. of steel) | 509   | 496  | 483  | 475  | 466  |
| oxygen (Nm³/t. of steel)  | 20.0 | 19.3 | 22.5 | 24.9 | 24.2 |
| Pig iron in a charge (%) | 2.8  | 2.8  | 3.2  | 3.4  | 4.9  |
| Yield of good ingot      | 89.7 | 89.8 | 90.0 | 90.1 | 90.3 |
| Percentage of C.C.        | 56.0 | 52.6 | 58.8 | 61.2 | 63.5 |
| Percentage of alloyed steel | 34.9 | 30.2 | 30.2 | 30.0 | 29.7 |

Although the cost of electric power in the Soviet Union (4.95 roubles per Giga Joule (GJ) in the Cherepovets region) is much lower than in Japan, a sheer 5% reduction of electric power use would economize 1.42 million GJ (= 7 million roubles) per year on the basis of the production by the EAF in 1981.
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Table 28  Production of steel made by the ladle refining processes in the Soviet Union, (1000 tonnes) [45]

|        | 1970  | 1975  | 1976  | 1977  | 1978  | 1979  | 1980  |
|--------|-------|-------|-------|-------|-------|-------|-------|
| Vacuum treated | 142.0 | 344.9 | 503.4 | 609.8 | 585.5 | 596.8 | 602.2 |
| Synthetic slag treatment | 810.3 | 1697.7 | 2114.5 | 2447.6 | 2252.0 | 2638.6 | 2214.1 |
| Inert gas treatment | 38.1 | 974.3 | 5012.3 | 8984.1 | 12724.6 | 14145.4 | 13966.0 |

(d) Special Refining

For making quality steels, alloy steels and special steels, such special refining methods of molten steels are now widely adopted in the world as vacuum degassing methods (DH, RH etc.), argon degassing methods, (LF, VAD etc.), vacuum oxygen decarburisation (VOD) method, argon oxygen decarburisation (AOD) method. These ladle refining processes are rather young technology in the Soviet Union and have not been diffused widely.

Table 28 shows the output of steel by vacuum, synthetic slag and inert gas treatments in the Soviet Union.

In Japan, already in 1973, most of all output of stainless steel were treated by AOD or VOD method. In 1981, 34.5% of total crude steel (29 million tonnes) by OC were vacuum treated (Table 24). The rapid diffusion of the ladle refining method is one of the important projects of the 11th FYP. The vacuum degassing process in the ladle of 350 tonnes capacity is planned to introduce to the Azovstal', and a proportion of vacuum treated steel will be four times larger at the end of the 11th FYP period[29, 46].

In addition to the above ladle refining methods, highly refined steels are produced by the Soviet original well-known ESR (electro-slag remelting) method. In the 11th FYP, production of heavy plates, development of martensite-ferrite dualphase steel plates, by using ESR are now underway[46].

The big effort is concentrated now in major producing countries on the development of the plasma-arc furnace which is a promising future furnace for making high-nickel, chromium and other high alloyed steels. Recently, the Soviet Union constructed a pilot furnace of 30 tonnes capacity by joint

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4. This technology is a Soviet original method for desulphurizing molten steel.
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Table 29  Apparent yield of rolled products (%), calculated on the basis of the data in [6]

|       | USSR  | Japan | USA  | FRG  | UK    |
|-------|-------|-------|------|------|-------|
| 1975  | 71.0  | 84.4  | 68.5 | 81.6 | 78.7  |
| 1976  | 71.2  | 86.8  | 69.9 | 80.7 | 76.3  |
| 1977  | 70.9  | 88.0  | 72.7 | 84.8 | 80.7  |
| 1978  | 70.8  | 89.5  | 71.5 | 85.2 | 80.5  |
| 1979  | 70.5  | 90.9  | 73.8 | 83.6 | 79.7  |
| 1980  | 70.9  | 91.4  | 75.0 | 85.2 | 89.4  |
| 1981  | n.a.  | 91.7  | 72.0 | n.a. | n.a.  |

work with GDR[47].

3. Rolling Technology

Evaluation of rolling technology is very complex because of the diversity and variety of the processes and products. Here the data of the yield of rolling mills and the rolling velocity will be shown.

(1) Yield

The apparent yield of rolling (here, annual output of the hot rolling section per total crude steel is adopted) is known as one of the important macroscopic indicators evaluating the level of the rolling technology as a whole. Table 29 shows the apparent yield of rolling in the past five years in major countries.

According to these data, the level of rolling technology of the Soviet Union takes the lower position in major countries.

The high values of Japan is mainly due to very big production of C.C. steel, (Table 18). However, it must be noted that in Japan even in the blooming and slabbing processes, the yield of good product is over 95%[48]. On the contrary, in the Soviet Union, the proportion of C.C. steel is only 12% and the yield of good product in the above processes is much lower than that in Japanese factories as shown below.

Table 30 shows the change in the yield of good products at the blooming and slabbing sections of the Magnitogorsk Combine.
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Table 30 The yield of good products at the blooming and slabbing sections of the Magnitogorsk Combine [49, 50]

|                        | 1970 | 1975 | 1978 | 1980 |
|------------------------|------|------|------|------|
| Average yield of the combine (%) | 76.0 (in 1971) | 76.7 | 77.0 | n.a. |
| No. 1 slabbing shop     |      |      |      |      |
| mean weight of ingot (tonnes) | 18.9 | 18.6 | 18.7 | 19.1 |
| yield (%)               | 82   | 82   | 82   | 82   |
| break (%)               | 17.8 | 11.9 | 11.4 | 11.4 |
| defect (%)              | 0.14 | 0.064 | 0.033 | 0.040 |
| No. 2 blooming shop     |      |      |      |      |
| mean weight of ingot (tonnes) | 7.50 | 7.29 | 7.43 | 7.79 |
| yield (%)               | 84.4 | 84.0 | 84.4 | 84.0 |
| break (%)               | 9.7  | 8.9  | 8.7  | 8.8  |
| defect (%)              | 0.13 | 0.11 | 0.11 | 0.12 |

In Japan, recently, the yield of good product 96.8% at the slabbing of capped steel ingot was recorded at the Nagoya works of Nippon Steel Corp.[36]. This is near to the theoretically limited value. At the direct hot rolling mill of the Muroran works of Nippon Steel Corp., the yield 95% at the slabbing process was also recorded. The average yield of the slab-and-blooming mills in Japan, was 92%, in 1976 and 96% in 1981[48].

In the Soviet Union, as is the case with the steel making process, the yield of good products in every process is low and this leads to rising scrap inside the steel works. If the yield in the rolling section rises from 82% to 92% which is the Japanese average figure in 1976, by simple calculation based on the data in 1980, annual total output of hot-rolling sections would increase by 12.79 million tonnes (12%). This means that the planned target for increasing production of the 11th FYP can be achieved only by increasing yield of good products in the rolling section. For this purpose, however, an intensive effort is needed for diffusion of an automation system.

(2) Rolling velocity

One of the important factors for determining the productivity of a rolling mill shop is the velocity of the rolling mill. In recent years it is increasing very rapidly in the world steel industry.

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Table 31 Rolling velocity of the No. 1200 cold strip mill of the Magnitogorsk Combine [51]

| Stand | Rolling velocity m/sec | reduction % |
|-------|------------------------|-------------|
| 1     | 3.37 ± 0.16            | 28          |
| 2     | 5.32 ± 0.39            | 32          |
| 3     | 9.17 ± 0.57            | 36          |
| 4     | 11.4 ± 1.20            | 41          |
| 5     | 18.6 ± 0.70            | 38          |

The mean productivity in 1977 was 1.9 tonnes/hr.

Table 32 Rolling velocity of the corresponding rolling mill in Japan, in 1962 [52]

| Stand | Rolling velocity m/sec | Reduction % |
|-------|------------------------|-------------|
| 1     | 3.9                     | 37.3        |
| 2     | 6.2                     | 38          |
| 3     | 10.0                    | 37.2        |
| 4     | 14.7                    | 31.7        |
| 5     | 20.0                    | 27.5        |

The thickness of hot-coil is 2 mm.

(a) Hot strip mill

As an example of the hot strip mill in the Soviet Union, we here show the rolling velocity of the No. 2500 mill having 7 finishing stands of the Magnitogorsk combine [62]. The usual rolling velocities of each stand are; 180-250 m/min. for strip thickness 10 mm, 360-505 m/min. for 5.0 mm thick, 900-1250 m/min. for 2.0 mm thick. These values are almost the same as those of the Japanese standard mill [52].

(b) Cold strip mill

Table 31 shows the rolling velocity of the cold strip mill No. 1200 with five stands of the Magnitogorsk Combine [51]. By this mill, 12 to 15 tonnes of hot coil which is directly passed from the hot-rolling mill No. 1400 is cold rolled from 2.2mm thick to 0.25mm x 730 to 836mm width.

The above figures just corresponds to those of the Japanese steel industry in 1965, (Table 32). At present, rolling velocity is much higher in Japan. For example, at the cold strip mill shop of the Kimitsu works of Nippon Steel Corp., the average maximum velocity of rolling of the cold strip mill with 6
stands, (usually coil weight is about 60 tonnes) is 2500m/min (=41.7m/sec) [52].

(c) Wire mill

Table 33 shows the technical data of the wire mills No.250 and No.150 which are the standard mills in the Soviet Union[53].

At the wire mill shop of the Kakogawa works of Kobe Steel Works of Japan, the average drawing velocity is 60m/sec, diameter of wire 5.5 to 13mm, weight per unit of product about 2000kg, and productivity is 35000 tonnes per month[52]. When the new Soviet 150 mill will be in full operation, the Soviet Union will catch up with Japan.

(3) Pioneer technologies in the rolling sections

As shown above, in the Soviet Union the gap in the rolling technology is considerably high. However, in this section some specially pioneered technologies are developed by Soviet metallurgists like in other sections. They have already succeeded in developing and realizing the double-multi layer steel clads. Major industrial countries now put a tremendous effort in developing them and in Japan several big companies just began to produce them. At the end of the 10th FYP, the Soviet Union produced about 20 kinds of bimetal steel clads, and in the present FYP, direct process of making double-triple layer clads from molten steel by using ESR or other methods is now under developing[46].

Recently, double-layer seamless tube composed of stainless steel inside and weldable pearlite steel outside has been produced[54].
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In the Volzhsk Tube Works, the large diameter welded tube with 1420mm dia., maximum working pressure 7.5MPa and impact strength 5kg-m/cm² at -60°C, which is the strategic material for the construction of the Urengoj-Uzhgorod gas pipe lines, is produced. This technology combined with the heat treatment technology of tube is patented in the U.K., France, the FRG and the USA.[55].

III. Some Problems for Modernization of Facilities

Even though the Soviet Union has long kept and will keep first place in the world in the volume of production of pig iron and crude steel, the Soviet steel industry is well behind Japan, the FRG and the USA in the modernization of facilities and equipments in the last decade. Especially the tempo of diffusion of automation and computation is much slower than the other industrial countries.

In the Soviet steel industry, a portion of manual labour is still large like other heavy industry sections, and not a few factories keep manual labour over 40% (the percentage of the number of workers being engaged in manual labour) which is the mean value of the Soviet industry.

In 1982, the average share of manual labour in the works of the Soyuzmetallurgprom is 30.7%, only 0.9% lower than the preceding year[56].

Metallurgical works having relatively less manual labour are; the Novolipetsk Works: 24.2%, and the Karaganda Combine: 26%. The worst four works are; the Shchelkovsk Rolling Works: 48.8%, the Petrovsk-Zabaikal'sk Works: 43.9%, the Uzbek Works: 43.8% and the Kuznets Works” 40.6%[56].

One of the reasons for the difficulty of introducing automation to the steel industry in the Soviet Union is the existence of old factories in which introduction of the new system is very complex and essentially difficult. Especially, in the rolling section, introduction of the new system to the working old factories is almost impossible. Even in the Soviet Union there is an opinion that “the introduction of an automation system of management (ASU) in the rolling section is only effective in the case of the construction of a new automation plant.”[57].

The average age of each section is as follows: coke battery; 20.8 years, BF;
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Table 34 The numbers of mechanical conveyer systems and automation lines in all the industries and the steel industry in the Soviet Union [60]

|                  | 1971  | 1975  | 1979  | 1980  | 1971  | 1975  | 1979  | 1980  |
|------------------|-------|-------|-------|-------|-------|-------|-------|-------|
| Mechanical conveyers | 89481 | 114108| 136213| 145276| 10917 | 17072 | 24313 | 27397 |
| Automation lines   | 1798  | 2281  | 2869  | 3118  | 595   | 1067  | 1283  | 1439  |

|                  | 1971  | 1975  | 1979  | 1980  |
|------------------|-------|-------|-------|-------|
| All industries   |       |       |       |       |
| Steel industry   | 1305  | 1694  | 2095  | 2344  |

Table 35 The numbers of shops, factories and works having complex mechanical systems and automation systems in the Soviet Union [60]

|                  | 1971  | 1975  | 1979  | 1980  |
|------------------|-------|-------|-------|-------|
| Shops, factories | 44248 | 66229 | 83471 | 91022 |
| Works            | 4984  | 5383  | 6200  | 6479  |

The numbers of shops, factories and works having complex mechanical systems or automation systems are shown in Table 35.

Some examples of the introduction of the process computers in the last ten years are given as follows [44]:

30.4 years, OHF; 33.4 years, rolling mills; 32.8 years, EAF; 22.1 years [58].

Another reason for the delay of automation and computation is due to a lack in production of equipments for an automation system. Strong effort is now concentrated on the production of these materials. The number of automatic manipulators, industrial robots produced in the first half period of 1983 is 4300 which is 83% larger than the same period of the preceding year [7]. To analyze the above problem, we must look carefully at the future trend of the production of computers and equipments for automation.

The number of computers introduced in the steel industry by the end of the 10th FYP is 4.3 times larger than at the end of 9th FYP. A proportion of automation lines in the steel industry has been risen from 39% to 63% during the 10th FYP. It will be 71% at the end of the present FYP [59].

The total numbers of mechanical conveyer systems and automation lines of all industries and the steel industry are shown in Table 34. The numbers of shops, factories and works having complex mechanical systems or automation systems are shown in Table 35.
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2 × Minsk 6000: the Novo-Krivoj-Rog Ore-dressing Combine, in 1980.
2 × Minsk 6000: the West-Siberain Works, No.2 and No.3 BFes, in 1977.
8 × Minsk 6000: as above, OC, in 1974.
3 × Simens 330: as above, No.450 merchant mill.
4 × Minsk 6000: the Nidjetagil' Combine, No.1500 blooming mill, in 1977.
3 × Minsk 7000: as above, No.1300 wide-strip mill, in 1978.

In the 11th FYP, 39 process computers, 48 ASUPs (automation system of management by factory) and 600 industrial robots are planned to be introduced[59].

In the case of the Japanese steel industry, the total numbers of process computers are 866, and 63 of them are for BF, 74 for steel making process, 124 for blooming and slabbing, 387 for other rolling mills, 156 for others at the end of 1981[6].

For the Soviet Union to catch up with this Japanese level, far more efforts are obviously needed.

Concluding Remarks

As was pointed out in [1], and was clearly seen above, the performance of the Soviet steel industry is still uneven. In respect of the BF technology the Soviet Union showed a number of technical advantages. However, the Soviet Union falls 10 to 20 years behind Japan and other major producing countries in terms of diffusion of the OC, the C.C. process, automation systems, modernization of rolling processes, although the Soviet Union played a very significant role in developing some of technologies in these sections.

On the other hand, Soviet metallurgists have succeeded in the invention or development of the pioneer technologies, such as the production of multi-layer steel clads, large diameter (multilayer) tube for gas pipe lines, the plasma-arc furnace in the industrial scale, and so on. Soviet original BF technologies and related ones, C.C. technology, ESR have been widely used in the major industrial countries.

Speaking about the level of the basic metallurgical science, it must be noted here that the Soviet Union has played a leading role in this field. Theory of phase transformation in steels, theory of heat treatments of steels,
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developed by Soviet scientists take practically first place in metallurgical science in the world[61]. For example, the basic concept of thermomechanical treatments of steels, and also of strengthening steels by phase hardening (phase naklep) are developed mainly based on the ideas of Soviet scientists.

By considering such energetic works on pioneer technologies and metallurgical science as mentioned above, it is permissible to call the Soviet steel industry the most prominent and excellent "laboratory" of the world steel industry.

However, different from physics or chemistry, the technology of the steel industry must be estimated on the basis of the concrete results in the factory. The responsibility of Soviet metallurgists is very heavy when considering the fact that the Japanese steel industry which has never originated technology is now in the highest position in the world by concentrating its effort to develop imported know-how or licences into the practical industrial use and to diffuse them into the whole section of the industry.

To transform the Soviet steel industry from the world’s best “laboratory” to the world’s best “factory” is the urgent task for Soviet metallurgists.

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