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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

Table 1 Output of pig iron and crude steel of major industrial countries [5, 6], pig iron/steel, $\times 10^3$ tonnes/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	

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Table 2 Apparent steel consumption per head of population, (kg/head), [6]

	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

the 2nd or 3rd position in the last several years of the major industrial countries (Table 2).

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

1. The percentage of automation in the steel industry 49% in 1975 increased up to 61% in 1980[10].

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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	%	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			611	3.0	1031	3.7	1777	4.6	2020	4.5
Chemical and petrochemical	852	6.0	2157	10.6	2400	8.6	3791	9.7	4500	9.4
Machinery and metal cutting	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]

	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]

	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 5580m³ 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 existence 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 BFes 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, BFes 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 BFes (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)

	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 companies².

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)	11200	10310
as above (million tonnes/year)	4	n.a.
Productivity ratio (tonnes/m ³ /day)	2.22	2.29
Consumption per tonne of pig iron		
coke (dry) kg	372	381.0
natural gas m ³	141	oil kg 37.4
oxygen in blast m ³	152	
blast volume m ³	811	Nm ³ /min 6894
sintered ore kg	1115	} n.a. sinter 93.5%
pellet kg	750	
Output per tonne pig iron		
slag kg	391	330
top gas (dry) m ³	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 (10 ³ tonnes/year)	2563.9	2591.9	874.9
Productivity ratio (t/m ³ /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 (m ³ /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/m ³ /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, pelletized) 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 utilization of such ore. Therefore the Karaganda Combine is a surely a pioneer factory in view of the effective utilization of domestic re-

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Table 12 Operation indices of the No. 4 BF with a useful volume of 3200 m³ 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. The

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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 ($\times 10^4$ 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

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 OHFs by the OCs by the end of this century at latest. While the conservative group insists on keeping OHFs 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, incompleteness of the plan of steel production during the replacement time, and so on. Reconstruction of giant OHFs 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	46.7 293*	45.3 283	44.5 282	44.4 281
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]

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

tage 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 191kg per tonne of steel where a proportion of C.C. steel was 5.8% in 1970. In 1981,

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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 shops³. 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 OHFs 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-

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]

	USSR	Japan	USA	FRG	UK
1975	<u>7729</u> 5.47	<u>31814</u> 31.1	<u>9652</u> 9.12	<u>9813</u> 24.3	<u>1704</u> 8.48
1976	<u>11729</u> 8.10	<u>37629</u> 35.0	<u>12246</u> 10.5	<u>12014</u> 28.3	<u>2165</u> 9.72
1977	<u>12200</u> 8.32	<u>41807</u> 40.8	<u>14268</u> 12.5	<u>13272</u> 34.0	<u>2554</u> 12.5
1978	<u>14400</u> 9.51	<u>47159</u> 46.2	<u>18903</u> 15.2	<u>15670</u> 38.0	<u>3149</u> 15.5
1979	<u>15300</u> 10.3	<u>58116</u> 52.0	<u>20904</u> 16.9	<u>17948</u> 39.0	<u>3627</u> 17.0
1980	<u>15900</u> 10.7	<u>66271</u> 59.5	<u>20611</u> 20.3	<u>20162</u> 46.0	<u>3059</u> 27.1
1981	<u>18100</u> 12.2	<u>71843</u> 70.7	<u>23003</u> 21.0	<u>22319</u> 53.6	<u>4958</u> 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	—	—	2	1	3
1965	6	—	—	6	1	7
1970	14	1	2	18*	8	26
1975	16	3	3	22**	7	29
1980	16	3	13	34**	12	46

*Including a conveyer type C.C. machine in the Omutninsk Works.

**Including two horizontal type machines in the test plant Turachermet.

tivity 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 (%)	
Consumption kg (%) 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) oxygen m ³ /t. of steel 51.5		Mn	0.45
		Si	0.70
		P	0.24
		S	0.033
		Impurities in steel (%)	
		C	0.12
		Mn	0.15
Operation cycle 39.5 min. charging 3.5 melting pig iron 1.52 refining 15.8		P	0.015
		S	0.022
		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 Slinsk Works and the

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Table 22 Operation indices of OCs of the Ohgishima works of Nippon Kokan K.K., Japan (2 × 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 (Nm ³ /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.

Omutninsk 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 Novolipetsk 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 × 230 tonnes capacity. June–August, 1978.

Production	692190 tonnes/3 months	
Number of heats	max. 1016, min. 911	
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 (Nm ³ /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 (Nm ³ /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 (m ³ /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 Cherepovets 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 (Nm ³ /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 slag⁴ 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

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]

	Rolling velocity m/sec	reduction %
Stand 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]

	Rolling velocity m/sec	Reduction %
Stand 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

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Table 33 Drawing velocity of the standard Soviet wire mills No. 250 and 150 [53]

Year	Number of stands	Velocity m/sec
No. 250 1966	29	16 to 40
1971	37	17.4–39.9
1977	25	12–25
1966	37	35–40
1970	37	44, 47
No. 150 new project	23 stands, two units	18–60

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 Urengoi-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]

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

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

	Shops, factories				Works			
	1971	1975	1979	1980	1971	1975	1979	1980
All industries	44248	66229	83471	91022	4984	5383	6200	6479
Steel industry	1305	1694	2095	2344	60	60	53	57

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.

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

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- 2 × Minsk 6000: the Novo-Krivoj-Rog Ore-dressing Combine, in 1980.
- 2 × Minsk 6000: the West-Siberian 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 Nidjnetagil' 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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