2.1.5 Work environment and energy conservation

A large quantity of gas that is generated from the electric furnace can be utilized effectively as fuel by capturing it and not permitting it to burn at the surface of the furnace. To accomplish this purpose, the furnaces were not only made larger in capacity but were made into the closed type. Table B-17 summarizes the ratio of the closed type to all electric furnaces for ferro-alloy in Japan. As shown in Table B-17, 100% of the electric furnaces for high-carbon ferro-manganese production are of the closed type.

2.2 Silico-Manganese

The production standards for silico-manganese have been improved in terms of raw materials, production facilities, environmental conditions and operating conditions just as for high-carbon ferro-manganese.

For reference, factors in the silico-manganese standards different from those of high-carbon ferro-manganese are shown in Table B-18.

2.3 Medium- and Low-Carbon Ferro-Manganese

The conventional electric furnace for producing medium- and low-carbon ferro-manganese is the stationary type of furnace, in which silico-manganese is used as the raw material and manganese ore is reduced by silicon. As it is operated in batches, the raw materials are completely molten down which is probably what is different from producing either high-carbon ferro-manganese or silico-manganese.

In the case of batch operation, heat radiation from the surface of the furnace is large. A technique of leaving the raw material ore unmolten at the surface of the furnace was thus established to prevent heat loss, but since then the furnace type began to be changed into the tilting type of furnace as a result of technological progress and because of the latter's relative ease in furnace body maintenance.

Established only quite recently is the outside-furnace smelting process which uses a shaking converter and other equipment. It attempts at making a drastic saving in power consumption by using molten silico-manganese as raw material.

Table B-17 Ratio of Closed Type to Total Operating Furnaces (1980)

Type of alloy		Electric Furnace (No. of sets) Closed	Open	Total	% Closed	Electric Furnace capacity (kVA) Closed	Open	Total	% Closed	Remark
Mn Type	FeMnM	8	0	8		251,900	-	251,900	100	
	SiMn	11	8	19		327,300	71,650	398,950	32	
	FeMnM.L	3	9	12		12,000	32,600	44,600	27	
	Subtotal	22	17	39	(56)	591,200	104,250	695,450	85	
Cr Type	FeCrH	5	9	14		131,000	157,000	288,000	55	
	SiCr	0	3	3		-	24,900	24,900	-	
	FeCrL	1	2	3		6,000	14,500	20,500	29	
	Subtotal	6	14	20	(30)	137,000	196,400	333,400	41	
Si Type	FeSi, MSi	3	28	31		120,000	562,900	632,900	17.6	
	CaSi	0	2	2		-	12,500	12,500	-	2 FeSi closed furnaces 50% Si
	Subtotal	3	30	33	(9)	120,000	575,400	695,400	17.2	
Total		31	61	92	(34)	848,200	876,050	1,724,250	49.2	

Notes:
FeMnH: High-Carbon Ferro-manganese
FeMnM: Medium-Carbon Ferro-manganese
FeMnL: Low-Carbon
SiMn: Silico-Manganese
FeC_2H: High-Carbon Ferro-chrome
Si-Cr: Silico-Chrome
CaSi: Calucium Silicon

Source: The Study Team

Table B-18 Comparison of Silico-Manganese Production Facilities and Operating Standards

			Around 1965 (small furnace)	1982 (large furnace)
Facilities	1)	Electric furnace	Small, open type	Large, closed type
			below 15,000 kVA.	around 30,000 kVA.
			No closed-type furnace.	82% closed type furnace.
Operating performance	1)	Unit power consumption	4,200-4,000 kWh/MT	3,700-3,400 kWh/MT
	2)	Mn yield	80%	85%
	3)	Slag ratio	1.4	1.0-1.2
	4)	Slag B.R. (Basic ratio)	Acidic	Acidic

Source: The Study Team

3. Future Production Technology for Ferro-Alloys

Basically, there are two different approaches to develop the technology for producing ferro-alloys.

One is which leads to innovations in production technology to meet the requirements of iron and steel producers who are the consumers of ferro-alloys, and the other is the approach that results from pursuing reductions in ferro-alloy production costs.

The key point in cost reduction is probably that of reducing power consumption, or in other words, energy saving as far as the current electric furnace system is concerned.

As an example of technological innovation along this line, there is the R&D on smelting reduction method which has been launched in Japan. South Africa has a plan to start producing ferro-chrome with plasma-arc furnace in 1983. The use of this plasma-arc furnace method is believed to reduce the unit power consumption by 20%. Depending on its success, the same production method may be applied to manganese as well.

Outstanding technological innovations such as these are of course important but we must not overlook also the improvements that might be made in production technology by the betterment of existing techniques and facilities.

Technological innovations that are being sought from the standpoint of the consumers extend to such matters like quality and shape of ferro manganese. We will take this subject up in Section C, "Consumption".

C. CONSUMPTION

I. World and By-Country Consumption Trends of Manganese

1. World and By-Country Consumption Trends of Manganese Ore

Consumption of manganese ore by the major countries of the world was at a level of 18 million tonnes in 1965. In 1979, it had increased to the level of 24 million tonnes. The average annual rate of growth during the period was 1.9%.

When consumption is reviewed by country, we see that the USSR has consumed the most, followed by the United States, Japan and France. We also see that the combined share of the top ten countries has remained almost constant at around 90% during 1965-1979.

However, a review of the consumption shares by country reveals that the share of the United States, Japan and South Africa have undergone big changes. Especially the consumption share of the United States dropped sharply from 20% in 1965 to as low as 5% in 1979. The reasons for this were that in addition to the fact that there was no growth of crude steel production, in the United States, its ore consumption also decreased due to the deteriorating cost competitiveness of its domestically produced ferro-manganese.

Japan's consumption share rose from 7% in 1965 to 12% in 1979 because of the growth of its domestic crude steel production which grew at a high average annual rate of 5.8% and also because the necessary ferro-manganese for it was domestically produced.

South Africa's consumption share also rose from 4% to 8% during 1965-1979. This was because the domestic crude steel production grew at a rapid pace of 6.8% per annum and because the country was able to export a lot of ferro-manganese (see Table D-6).

Table C-1 shows the trends of consumption volume and Table C-2 the trends of consumption pattern by country.

2. World and By-Country Consumption Trends of Ferro-Manganese

The worldwide ferro-manganese consumption during the late 1960s was three million tonnes. In 1974 consumption doubled and reached a record high of six million tonnes. Today, it has fallen to a level of five and a half million tonnes due to the cutback in crude steel.

Fig. C-1 compares the trajectory of ferro-manganese consumption with that of crude steel production.

Table C-1 Apparent Consumption of Manganese Ore by Country, 1965 to 1980

(1,000 MT)

Country/Region	1965	1966	1967	1968	1969	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980
South Africa	827	476	671	683	731	897	737	923	512	1,267	2,140	1,710	1,719	1,917	1,582	2,396
Australia	46	247	293	350	249	102	347	397	399	401	423	443	576	542	509	761
India	863	896	1,079	1,027	840	910	1,168	1,360	1,282	470	784	1,024	1,386	1,042	1,127	---
Brazil	328	499	816	821	1,150	450	875	1,227	832	302	598	623	956	1,023	1,072	---
USA	3,792	2,710	2,146	2,109	2,082	2,151	1,961	2,121	1,946	1,711	1,654	1,452	1,233	1,162	1,245	971
Japan	1,367	1,461	1,849	2,065	2,326	2,854	3,521	3,165	3,534	3,745	3,565	3,520	2,906	2,159	2,889	2,983
France	854	840	690	890	1,117	1,095	1,117	1,123	1,432	1,428	1,158	1,014	923	958	1,227	1,245
Norway	510	489	534	650	627	545	736	721	715	1,033	1,073	982	591	803	815	808
Germany, FR	636	617	354	582	319	403	459	476	716	828	733	610	453	672	717	750
Spain	86	143	135	184	142	200	174	260	331	384	437	410	433	370	487	---
UK	503	371	412	482	438	521	429	361	588	388	253	499	328	261	543	---
Italy	107	91	153	170	161	184	291	272	282	309	316	356	269	284	422	408
Free World Countries Total	9,919	8,840	9,132	10,013	10,182	10,312	11,815	12,406	12,569	12,266	13,134	12,643	11,773	11,193	12,635	---
USSR	6,804	6,488	5,925	5,414	5,788	5,811	6,300	6,541	6,993	7,045	7,065	7,294	7,239	7,871	8,927	8,995
China	1,000	1,000	700	900	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,100	1,100	1,270	1,500	1,600
Poland	347	397	354	352	394	389	401	505	525	556	556	538	698	651	518	490
Czechoslovakia	334	287	306	---	313	202	313	388	441	475	456	448	324	373	423	397
German DR	225	195	201	131	198	179	198	200	163	168	185	199	204	183	182	135
Centrally Planned Economies Total	8,710	8,367	7,486	6,797	7,693	7,581	8,212	8,634	9,122	9,244	9,262	9,579	9,565	10,348	11,550	11,617
Total	18,629	17,207	16,618	16,810	17,875	17,893	20,027	21,040	21,691	21,510	22,396	22,222	21,338	21,541	24,185	---

Notes : 1) The above are calculated according to:
Consumption = Production + Import − Export
2) --- Data unavailable

Table C-2 Apparent Consumption Share of Manganese Ore by Country, 1965 to 1979

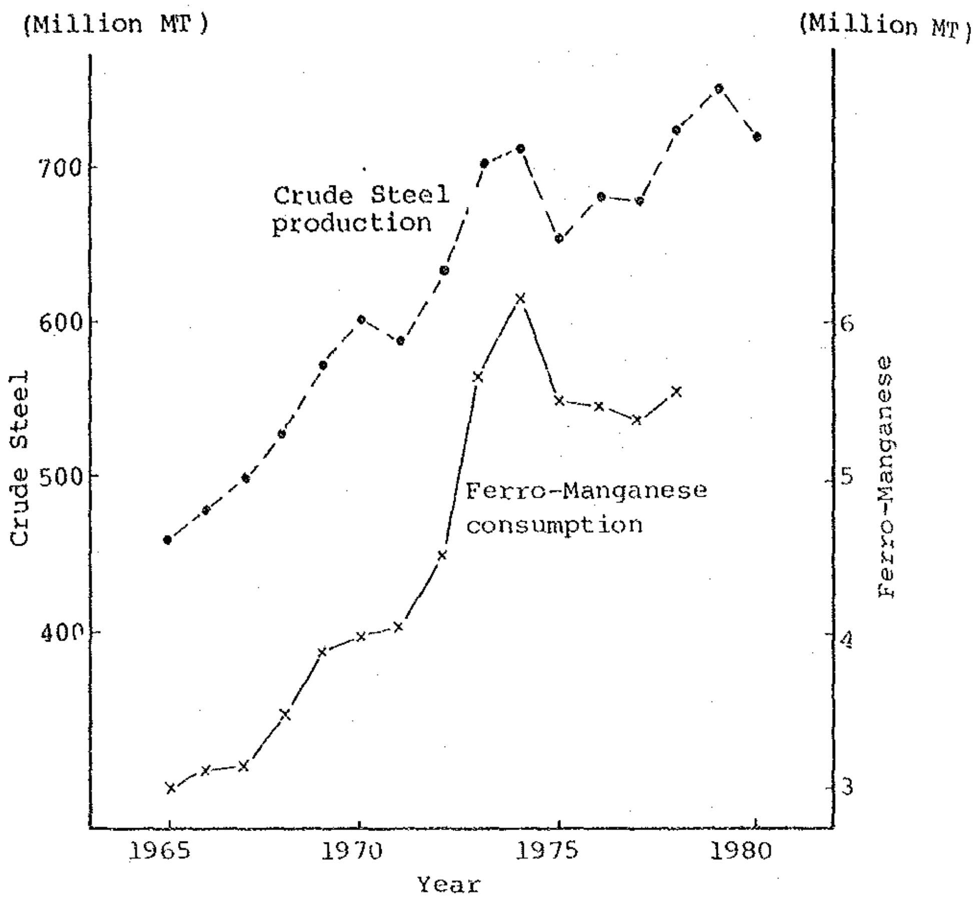
(%)

Country/Region	1965	1966	1967	1968	1969	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979
South Africa	4.4	2.8	4.0	4.1	4.1	5.0	3.7	4.4	2.1	5.9	9.6	7.7	8.0	8.9	6.6
Australia	0.3	1.4	1.8	2.1	1.4	0.6	1.7	1.9	6.1	1.9	1.9	2.0	2.7	2.5	2.1
India	4.6	5.2	6.5	6.0	4.7	5.1	5.8	6.5	5.3	2.2	3.5	4.6	6.5	4.8	4.7
Brazil	1.8	2.9	4.9	4.9	6.4	2.5	4.4	5.8	3.6	1.4	2.7	2.8	4.5	4.8	4.4
USA	20.4	15.8	12.9	12.5	11.6	12.0	9.8	10.1	8.8	8.0	7.4	6.6	5.8	5.4	5.1
Japan	7.3	8.5	11.1	12.3	13.0	16.0	17.6	15.0	16.1	17.4	15.9	15.8	13.6	10.0	11.9
France	4.6	4.9	4.2	5.3	6.2	6.1	5.6	5.3	6.2	6.6	5.2	4.6	4.3	4.5	5.1
Norway	2.7	2.8	3.2	3.9	3.5	3.0	3.7	3.4	3.1	4.8	4.8	4.4	2.8	3.7	3.4
Germany, FR	3.4	3.6	2.1	3.5	1.8	2.3	2.3	2.3	3.1	3.8	3.3	2.7	2.1	3.1	3.0
Spain	0.5	0.8	0.8	1.1	0.8	1.1	0.8	1.2	1.3	1.8	1.9	1.9	2.0	1.7	2.0
UK	2.7	2.2	2.5	2.9	2.5	2.9	2.1	1.7	2.4	1.8	1.1	2.3	1.5	1.2	2.2
Italy	0.5	0.5	1.0	1.0	0.9	1.0	1.4	1.3	1.1	1.4	1.4	1.7	1.3	1.3	1.7
Free World Countries	53.2	51.4	55.0	59.6	56.9	57.6	59.0	58.9	59.2	57.0	58.7	57.1	55.1	51.9	52.2
USSR	36.5	37.7	35.7	32.2	32.4	32.5	31.5	31.1	31.8	32.8	31.5	32.8	34.0	36.5	37.0
China	5.4	5.8	4.2	5.4	5.6	5.6	5.0	4.8	4.2	4.6	4.5	5.0	5.2	5.9	6.2
Poland	1.9	2.3	2.1	2.1	2.2	2.2	2.0	2.4	2.2	2.6	2.5	2.4	3.3	3.0	2.1
Czechoslavakia	1.8	1.7	1.8	-	1.8	1.1	1.6	1.8	2.0	2.2	2.0	2.0	1.5	1.8	1.7
German DR	1.2	1.1	1.2	0.7	1.1	1.0	1.0	1.0	0.6	0.8	0.8	0.7	0.9	0.9	0.8
Centrally Planned Economies Total	46.8	48.6	45.0	40.4	43.1	42.4	41.0	41.1	40.8	43.0	41.3	42.9	44.9	48.1	47.8
Total	100	100	100	100	100	100	100	100	100	10	100	100	100	100	100
Total of top 10 countries	91.1	90.0	88.8	90.1	89.3	90.1	89.4	88.7	84.3	87.5	88.4	87.0	86.8	87.6	87.4

Notes : Top 10 countries are: South Africa, India, Brazil, USA, Japan, France, Norway, Germany, Fed. Rep., USSR and China
- Not applicable

Source : Table C-1

Fig. C-1 Trends of Ferro-Manganese Consumption and Crude Steel Production



A review of consumption by country shows that contries that produce a large quantity of crude steel, like the USSR, the United States, Japan and Federal Republic of Germany also consume a large quantity of ferro-manganese.

Tables C-3 and C-4 show the consumption volumes and consumption shares of the USSR and free world countries. They show that there has not been much change since 1973.

Table C-3 Trends of Ferro-Manganese Consumption Volume

(1,000 MT)

	1973	1974	1975	1976	1977	1978	1979	1980
Canada	109.4	117.9	113.7	94.1	110.0	114.6	---	---
USA	960.1	1,310.1	1,060.6	1,096.6	1,063.3	1,138.9	---	---
Brazil	90.2	92.9	97.0	106.7	121.4	135.9	---	---
Austria	17.0	26.3	22.3	21.2	20.3	20.4	---	---
Belgium	133.8	146.8	75.6	99.1	76.2	87.5	---	---
France	262.7	253.4	188.9	202.1	194.2	208.5	---	---
Finland	12.2	11.4	11.5	10.5	12.7	16.0	---	---
Germany, Fed. Rep.	472.6	424.5	423.2	426.8	383.1	422.9	---	---
Italy	233.3	279.6	241.4	274.5	289.5	277.9	---	---
Luxemburg	57.6	60.5	46.5	46.9	45.7	51.7	---	---
Netherlands	30.6	31.9	26.1	23.6	19.8	21.1	---	---
Spain	150.6	134.0	167.3	152.7	168.8	150.9	---	---
Sweden	93.9	107.9	62.2	43.5	24.2	37.4	---	---
UK	289.7	254.6	222.4	236.2	215.7	200.2	197.7	---
South Africa	34.2	36.4	40.5	43.5	45.7	49.0	---	---
Japan	944.1	920.3	822.6	716.7	694.4	806.4	882.6	846.3
Australia	70.8	83.4	58.2	71.8	72.6	61.0	---	---
USSR *	724.0	819.8	832.7	815.0	820.0	855.0	872.0	---
World Total	5,670	6,140	5,470	5,420	5,380	5,640	---	---

* Consumption derived by: Production (Table B-5)-Export (Table D-6)
Note : --- Data unavailable

Source: Tables C-12 thru C-14

Table C-4 Trends of Ferro-Manganese Consumption Share by Country

(%)

	1973	1974	1975	1976	1977	1978
Canada	1.9	1.9	2.1	1.7	2.0	2.0
USA	16.9	21.3	19.4	20.2	19.8	20.2
Brazil	1.6	1.5	1.8	2.0	2.3	2.4
Austria	0.3	0.4	0.4	0.4	0.4	0.4
Belgium	2.4	2.4	1.4	1.8	1.4	1.6
France	4.6	4.1	3.5	3.7	3.6	3.7
Finland	0.2	0.2	0.2	0.2	0.2	0.3
Germany, Fed. Rep.	8.3	6.9	7.7	7.9	7.1	7.5
Italy	4.1	4.6	4.4	5.1	5.4	4.9
Luxemburg	1.0	1.0	0.9	0.9	0.8	0.9
Netherlands	0.5	0.5	0.5	0.4	0.4	0.4
Spain	2.7	2.2	3.1	2.8	3.1	2.6
Sweden	1.7	1.8	1.1	0.8	0.4	0.7
UK	5.1	4.1	4.1	4.4	4.0	3.5
South Africa	0.6	0.6	0.7	0.8	0.8	0.9
Japan	16.7	15.0	15.0	13.2	12.9	14.3
Australia	1.3	1.4	1.1	1.3	1.3	1.1
USSR	12.7	13.4	15.2	15.0	15.2	15.2
Combined Share in World Total	82.6	83.3	82.6	82.6	81.1	82.6

Source : Tables C-3

II. Manganese Consumption Trends by End-Use and by Type

1. Manganese Ore Consumption Trends by End-Use

Typical cases of manganese ore consumption by end-use of Japan and the United States are shown in Tables C-5 through C-8.

The following summarizes these specifically for 1980:

(1,000 MT)

- Japan 2,758
  - Iron and steel: 2,609 (94.6%)
    - for ferro-manganese: 1,586 (57.5)
    - for pig iron: 1,023 (37.1)
  - Other than iron and steel: 149 (5.4%)
- USA 971
  - Iron and steel: 779 (80.3%)
    - for ferro-manganese: 660 (68.0%)
    - for pig iron: 119 (12.3%)
  - Other than iron and steel: 192 (19.7%)

From the above, we conclude that:

1) Japan's ore consumption for ferro-manganese production is twice as much as the United States.

2) Ore consumption for pig iron use in the United States is one-tenth that of Japan.

3) Manganese ore consumption by sector other than iron and steel of the United States is more or less on the same level as Japan.

The conceivable reasons are:

1) The soaring energy cost since the 1973 oil crisis and growing expenditures for environmental protection led to a decline in the cost competitiveness of the American ferro-manganese industry and increased its imports of ferro-manganese; and

2) When adding manganese to steel, the choice of whether to use ore or ferro-manganese rests with each country's differing economic appraisal which stems from the difference in pig iron making and steel making technologies of the two countries.

Table C-5 Consumption of Manganese ore by End-use in Japan, 1968 to 1980

(1,000 MT)

	1968	1969	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980
Iron and Steel [1]													
Ferro-manganese production	1,095	1,169	1,445	1,737	1,756	1,808	1,939	1,941	1,792	1,535	1,336	1,625	1,586
Addition blast furnaces	755	999	1,163	1,191	1,160	1,428	1,445	1,401	1,264	1,109	992	1,031	1,023
Subtotal	1,850	2,168	2,608	2,928	2,916	3,236	3,384	3,342	3,056	2,644	2,328	2,656	2,609
Other than iron and steel [2]													
Electrolytic manganese dioxide production	101	116	132	143	126	134	151	114	90	85	93	99	100
Electrolytic metallic manganese production	22	24	35	48	42	31	29	21	21	21	19	15	16
Dry cells, medicine, etc.	38	44	51	50	47	51	47	35	40	41	37	33	33
Subtotal	161	184	218	241	215	216	227	170	151	147	149	147	149
Total	2,011	2,352	2,826	3,169	3,131	3,452	3,611	3,512	3,207	2,791	2,477	2,803	2,758

Sources: 1) Research and Statistics Department, Minister's Secretariat, Ministry of International Trade and Industry, Government of Japan, Yearbook of Iron and Steel Statistics
2) The Study Team

Table C-6 Consumption Share of Manganese Ore by End-use in Japan, 1968 to 1980

(%)

	1968	1969	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980
Iron and Steel:													
Ferro-manganese production	54.5	49.7	51.1	54.8	56.1	52.4	53.7	55.3	55.9	55.0	53.9	58.0	57.5
Pig iron and steel	37.5	42.5	41.2	37.6	37.0	41.4	40.0	39.9	39.4	39.7	40.0	36.8	37.1
Subtotal	92.0	92.2	92.3	92.4	93.1	93.7	93.7	95.2	95.3	94.7	94.0	94.8	94.6
Other than iron and steel:													
Electrolytic manganese dioxide production	5.0	4.9	4.7	4.5	4.0	3.9	4.2	3.2	2.8	3.0	3.8	3.5	3.6
Electrolytic metallic manganese production	1.1	1.0	1.2	1.5	1.3	0.9	0.8	0.6	0.7	0.8	0.8	0.5	0.6
Dry cells, medicine, etc.	1.9	1.9	1.8	1.6	1.6	1.5	1.3	1.0	1.2	1.5	1.4	1.2	1.2
Subtotal	8.0	7.8	7.7	7.6	6.9	6.3	6.3	4.8	4.7	5.3	6.0	5.2	5.4
Total	100	100	100	100	100	100	100	100	100	100	100	100	100

Source : Table C-5

Table C-7 Consumption share of manganese ore by end-use in USA, 1968 to 1980
(35% Mn and over)

(1,000 MT)

	1968	1969	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980
Metallurgical:													
Manganese alloys and metal	1,846	1,821	910	1,672	1,752	1,532	1,289	1,310	1,146	841	755	829	660
Pig iron and steel	106	143	98	170	192	216	202	160	130	182	199	209	119
Subtotal	1,952	1,964	2,008	1,842	1,944	1,748	1,491	1,470	1,276	1,023	954	1,038	779
Non-metallurgical	157	118	143	119	177	198	220	184	176	210	208	207	192
Total	2,109	2,082	2,151	1,961	2,121	1,946	1,711	1,654	1,452	1,233	1,162	1,245	971

Source: The U.S. Bureau of Mines, Mineral Yearbook

Table C-8 Consumption Share of Manganese Ore by End-Use in USA, 1968 to 1980

(%)

	1968	1969	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980
Metallurgical:													
Manganese alloys and metal	87.5	87.5	88.8	85.3	82.6	78.7	75.3	79.2	78.9	68.2	65.0	66.6	68.0
Pig iron and steel	5.0	6.9	4.6	8.7	9.1	11.1	11.8	9.7	8.9	14.8	17.1	16.8	12.3
Subtotal	92.5	94.4	93.4	94.0	91.7	89.8	87.1	88.7	87.8	83.0	82.1	83.4	80.3
Non-metallurgical	7.5	5.6	6.6	6.0	8.3	10.2	12.9	11.3	12.2	17.0	17.9	16.6	19.7
Total	100	100	100	100	100	100	100	100	100	100	100	100	100

Source: Table C-7

For reference, the volume of ore consumed as input to blast furnace and unit ore consumption per tonne of pig iron in Japan, the United States and several other countries are shown in Tables C-9 and C-10.

Table C-9 Selected Countries: Additions of Manganese Ore to Blast Furnaces, 1973 to 1980

(1,000 MT)

	1973	1974	1975	1976	1977	1978	1979	1980
Japan	1,440	1,470	1,440	1,310	1,130	952	1,058	1,107
USA	283	293	208	210	252	298	286	178
Germany, FR	200	249	162	207	190	208	---	---
Italy	167	133	141	135	171	189	---	---
UK	108	100	104	138	158	90	---	---
France	80	90	70	70	75	80	---	---
Australia	50	58	71	94	102	96	---	---
South Africa	49	66	78	96	101	100	---	---

Note : --- Data unavailable
Source: Roskill Information Service Ltd., The Economics of Manganese

Table C-10 Addition of Manganese Ore to Blast Furnace per ton of Pig Iron in Selected Countries, 1973 to 1980

(kg Mn Ore)

	1973	1974	1975	1976	1977	1978	1979	1980
Japan	16.0	16.3	16.6	15.1	13.2	12.1	12.6	12.7
USA	3.1	3.4	2.9	2.7	3.4	3.7	3.6	2.9
Germany, FR	1.4	6.2	5.4	6.5	6.6	6.9	---	---
Italy	16.5	11.3	12.4	11.5	14.9	16.6	---	---
UK	6.3	7.1	8.6	10.0	12.7	7.8	---	---
France	3.9	4.0	3.9	3.7	4.1	4.3	---	---
Australia	6.5	8.0	9.3	12.7	15.1	13.1	---	---
South Africa	11.3	14.3	15.1	16.6	17.3	16.9	---	---

Note : --- Data unavailable
Source: Table C-9
Japan Federation of Iron and Steel Industry, Overseas Iron and Steel Statistics

2. Ferro-Manganese Consumption Trends by Type

On the whole, high-carbon ferro-manganese commands the highest percentage ratio[1)] of ferro-manganese consumption by type in the major countries of the free world, accounting for 74% of the total, followed by 16% of silico-manganese and 10% of medium- and low-carbon ferro-manganese.

The difference in consumption however is large among countries. Japan, Brazil and Spain for instance consume high ratios of silico-manganese - almost as much as high-carbon ferro-manganese.

This is probably because the price of silico-manganese is cheaper relative to the cost of using a combination of ferrosilicon and high-carbon ferro-manganese, because silico-manganese which uses high-, medium- and low-carbon ferro-manganese slag as the raw material is produced in parallel with ferro-manganese which is produced by the electric furnaces in these countries.

The reason for the high percentage ratio of high-carbon ferro-manganese in the United States, Federal Republic of Germany, France and the United Kingdom is probably because these countries mainly use the blast furnace manufacturing method which can only produce high-carbon ferro-manganese.

Percentage ratio of ferro-manganese consumption by type is shown in Table C-11 and trends of its consumption by type and by country in Tables C-12 through C-14.

3. Ferro-Manganese Consumption Trends by End-Use

All of ferro-manganese is used for iron and steel which can be classifed into carbon steel, special steel, and cast irons and steel.

In Tables C-15 and C-16, we have taken the United States as an example to show the trends in ferro-manganese consumption volume and consumption share in these three segments. When we compare the early 1970s with the latter half of the 1970s, we see a relatively significant difference. The carbon steel segment, in terms of consumption share, decreased its share in both high carbon ferro-manganese and silico-manganese whereas it increased its share in medium- and low-carbon ferro-manganese. In terms of its share in total ferro-manganese, it declined from 78% to 74%.

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1) Spiegeleisen had been used much in the open hearth furnace steel making process in the past, but it is seldom used now because of the decline in the use of the open hearth furnace in steel making. Statistics prove the use of only a modicum of spiegeleisen yet in the United States and elsewhere, its percentage share in total ferro-manganese consumption being less than 1%.

Special steel increased its consumption share in both high-carbon ferro-manganese and silico-manganese and raised its share in total ferro-manganese from 15% to 21%.

Cast irons and steel increased its share in silico-manganese but lost its share in medium- and low-carbon ferro-manganese. In terms of the ratio to total ferro-manganese, it rose in share from 2.5% to 4%.

These changes are presumably attributable to the upgrading of carbon steel and quantitative expansion of both special steel and cast irons and steel.

4. Historical Trends in Unit Consumption of Net Manganese Content in Ferro-Manganese per tonne of Crude Steel

Table C-17 shows the trends in consumption level of ferro-manganese in terms of the unit consumption of net manganese in ferro-manganese per tonne of crude steel.

The consumption level of the free world as a whole remains constant in the range of 6.2 to 6.6 kg, but the disparity among countries is large.

Table C-11 Percentage of Ferro-Manganese Consumption by Type in Major Countries

(%)

	High-Carbon	Medium- and Low-Carbon	Silico-Manganese
Japan	49.1	9.3	41.6
USA	77.1	9.7	12.2
Brazil	53.7	11.7	34.6
France	73.6	20.4	6.4
Germany, FR	73.1	5.4	21.4
Spain	49.7	3.3	47.0
UK	82.0	8.5	9.5
World Average	73.7	10.3	16.0

Soruce: Tables C-12 thru C-14

Table C-12 Trends of High-Carbon Ferro-Manganese Consumption

(1,000 MT)

		1965	66	67	68	69	70	71	72	73	74	75	76	77	78	79	80
Canada	a)	---	---	---	---	---	---	---	---	80	89	86	73	77	86	---	---
USA		---	---	---	---	f) 658	f) 620	---	---	a) 671	a) 1,029	a) 813	a) 821	a) 810	a) 887	---	---
Brazil	a)	---	---	---	---	---	---	---	---	57	60	63	64	71	73	---	---
Austria	a)	---	---	---	---	---	---	---	---	13	20	18	17	16	16	---	---
Belgium	a)	---	---	---	---	---	---	---	---	109	124	63	85	62	70	---	---
France	a)	---	---	---	---	---	---	---	---	222	215	159	170	165	173	---	---
Finland	a)	---	---	---	---	---	---	---	---	3	2	2	2	2	3	---	---
Germany, FR	a)	---	---	---	---	---	---	---	---	375	415	325	326	289	290	---	---
Italy	a)	---	---	---	---	---	---	---	---	175	200	185	210	202	194	---	---
Luxemburg	a)	---	---	---	---	---	---	---	---	56	59	45	45	44	49	---	---
Netherlands	a)	---	---	---	---	---	---	---	---	29	30	24	22	19	20	---	---
Spain	a)	---	---	---	---	---	---	---	---	88	74	91	80	84	75	---	---
Sweden	a)	---	---	---	---	---	---	---	---	59	66	42	37	19	29	---	---
UK	b)	---	---	---	---	---	---	---	---	236	204	181	192	177	164	---	--
South Africa	a)	---	---	---	---	---	---	---	---	32	33	37	37	36	38	---	---
Japan	c)	166	202	252	281	349	359	379	406	467	432	367	371	359	396	422	416
Australia	a)	---	---	---	---	---	---	---	---	48	44	42	49	57	58	---	---
Subtotal		d) 1,930	1,930	1,920	2,110	2,320	2,320	2,300	2,380	e) 3,900	4,420	3,890	3,950	3,900	4,160	d) 3,240	---
Silico-manganese		d) 800	870	910	1,000	1,150	1,180	1,280	1,450	e) 1,200	1,120	1,050	900	900	900	1,120	---
Medium-, low-carbon Ferro-manganese Mn		d) 270	310	330	370	400	440	460	540	e) 570	600	540	570	580	580	d) 580	---
Ferro-manganese Total		d) 3,000	3,110	3,160	3,480	3,870	3,940	4,040	4,370	e) 5,670	6,140	5,470	5,420	5,380	5,640	4,940	---

a) Roskill Report (1982)
b) Metal Bulletin Handbook
c) Japan Ferro-Alloy Association
d) Estimated from b) and c)
e) Estimated from a), b) and c)
f) The U.S. Bureau of Mines

--- Data unavailable

Table C-13 Trends of Silico-Manganese Consumption

(1,000 MT)

		1965	66	67	68	69	70	71	72	73	74	75	76	77	78	79	80
Canada	a)	---	---	---	---	---	---	---	---	20	19	19	15	16	22	---	---
USA		---	---	---	---	f) 97	f) 83	---	---	f) 165	a) 161	a) 146	a) 140	a) 134	a) 140	f) 156	f) 141
Brazil	a)	---	---	---	---	---	---	---	---	22	20	23	30	37	47	---	---
Austria	a)	---	---	---	---	---	---	---	---	4	6	4	4	4	4	---	---
Belgium	a)	---	---	---	---	---	---	---	---	24	22	8	11	11	14	---	---
France	a)	---	---	---	---	---	---	---	---	17	16	15	14	12	14	---	---
Finland	a)	---	---	---	---	---	---	---	---	9	9	9	8	10	12	---	---
Germany, FR	a)	---	---	---	---	---	---	---	---	53	58	57	52	52	85	---	---
Italy	a)	---	---	---	---	---	---	---	---	43	60	37	39	45	56	---	---
Luxemburg	a)	---	---	---	---	---	---	---	---	0	0	0	0	0	0	---	---
Netherlands	a)	---	---	---	---	---	---	---	---	0	0	0	0	0	0	---	---
Spain	a)	---	---	---	---	---	---	---	---	53	56	69	71	76	71	---	---
Sweden	a)	---	---	---	---					24	19	13	4	3	5	---	---
UK	b)	24	27	24	27	29	28	26	21	24	20	18	19	19	19	22	---
South Africa	a)	---	---	---	---	---	---	---	---	3	3	3	6	9	10	---	---
Japan	c)	114	140	174	192	241	273	287	329	387	400	375	254	256	335	356	337
Australia	a)	---	---	---	---	---	---	---	---	18	31	13	19	9	3	---	---
Subtotal		d) 800	870	910	1,000	1,150	1,180	1,280	1,450	e) 1,200	1,120	1,050	900	900	900	1,120	---
High-carbon Ferro-Manganese		d) 1,930	1,930	1,920	2,110	2,320	2,320	2,300	2,380	3,900	4,420	3,890	3,950	3,900	4,160	3,240	---
Medium-, Low-Carbon Ferro-manganese		d) 270	310	330	370	400	440	460	540	e) 570	600	540	570	580	580	d) 580	---
Ferro-manganese Total		d) 3,000	3,110	3,160	3,480	3,870	3,940	4,040	4,370	e) 5,670	6,140	5,470	5,420	5,380	5,640	4,940	---

a) Roskill Report (1982) b) Metal Bulletin Handbook c) Japan Ferro-Alloy Association
d) Estimated from b) and c) e) Estimated from a), b) and c) f) The U.S. Bureau of Mines

Table C-14 Trends of Medium- and Low-Carbon Ferro-Manganese Consumption

(1,000 MT)

		1965	66	67	68	69	70	71	72	73	74	75	76	77	78	79	80
Canada	a)	---	---	---	---	---	---	---	---	9.4	9.9	8.7	6.1	7.0	6.6	---	---
USA		---	---	---	---	f) 93 e)	f) 92 e)	---	---	a) 124.1	a) 120.1	a) 101.6	a) 105.7	a) 102.3	a) 111.9	---	---
Brazil	a)	---	---	---	---	---	---	---	---	11.2	12.9	11.0	12.7	134	15.9	---	---
Austria	a)	---	---	---	---	---	---	---	---	0	0.3	0.3	0.2	0.3	0.4	---	---
Belgium	a)	---	---	---	---	---	---	---	---	0.8	0.8	4.6	3.1	3.2	3.5	---	--
France	a)	---	---	---	---	---	---	---	---	23.7	22.4	14.9	18.1	17.2	21.5	---	---
Finland	a)	---	---	---	---	---	---	---	---	0.2	0.4	0.5	0.5	0.7	1.0	---	---
Germany, FR	a)	---	---	---	---	---	---	---	---	44.6	51.1	41.2	48.8	42.1	47.9	---	---
Italy	a)	---	---	---	---	---	---	---	---	15.3	19.6	19.4	25.5	42.5	27.9	---	---
Luxemburg	a)	---	---	---	---	---	---	---	---	1.0	1.5	1.5	1.9	1.7	2.7	---	---
Netherlands	a)	---	---	---	---	---	---	---	---	1.6	1.9	2.1	1.6	0.8	1.1	---	---
Spain	a)	---	---	---	---	---	---	---	---	9.6	4.0	7.3	1.7	8.8	4.9	---	---
Sweden	a)	---	---	---	---	---	---			10.9	22.9	7.2	2.5	2.2	3.4	---	---
UK	b)	20.5	19.4	13.8	22.6	25.0	26.8	24.4	29.9	29.7	30.6	23.4	25.2	19.7	17.2	18.7	---
South Africa	a)	---	---	---	---	---	---	---	---	0.2	0.4	0.5	0.5	0.7	1.0	---	---
Japan	c)	19.9	28.1	32.2	42.0	51.0	62.5	64.6	73.8	90.1	88.3	80.6	91.7	79.4	75.4	84.6	96.3
Australia	a)	---	---	---	---	---	---	---	---	4.8	8.4	3.2	3.8	6.6	---	---	---
Subtotal		d) 270	310	330	370	400	440	460	540	e) 570	600	540	570	580	580	d) 580	---
High-carbon Ferro-Manganese		d) 1,930	1,930	1,920	2,110	2,320	2,320	2,300	2,380	e) 3,900	4,420	3,890	3,950	3,900	4,160	d) 3,240	---
Silico-Manganese		d) 800	870	900	1,000	1,150	1,180	1,280	1,450	e) 1,200	1,120	1,050	900	900	900	1,120	---
Ferro-manganese Manganese Alloy Total		d) 3,000	3,110	3,160	3,480	3,870	3,940	4,040	4,370	e) 5,670	6,140	5,470	5,420	5,380	5,640	4,940	---

a) Roskill Report (1982)
b) Metal Bulletin Handbook
c) Japan Ferro-Alloy Association
d) Estimated from b) and c)
e) Estimated from a), b) and c)
f) The U.S. Bureau of Mines

--- Data unavailable

Table C-15 Ferro-Manganese Consumption by End-Use in USA

(1,000 MT)

Steel type	1969	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980
Carbon steel												
High-carbon Ferro-manganese	528.0	508.0	---	---	---	---	528.8	544.6	522.2	586.4	571.6	452.2
Silico-manganese	61.3	52.6	---	---	---	---	88.3	67.7	67.3	75.4	75.2	74.4
Medium-, Low-carbon Ferro-manganese	67.1	65.3	---	---	---	---	82.3	96.0	93.7	107.1	107.6	85.0
Spiegeleisen	2.1	1.8	---	---	---	---	7.4	3.4	5.3	3.6	0.4	0.3
Subtotal	658.5	627.7	---	---	---	---	706.8	711.7	688.5	772.5	754.8	611.9
Special steel												
High-carbon Ferro-manganese	81.1	78.8	---	---	---	---	131.6	120.8	132.0	137.3	151.3	126.2
Silico-manganese	25.1	21.1	---	---	---	---	39.3	37.7	38.7	41.8	46.2	40.7
Medium-, Low-carbon Ferro-manganese	21.8	23.2	---	---	---	---	32.4	29.1	27.0	27.7	28.8	23.4
Spiegeleisen	0.4	---	---	---	---	---	0.5	0.3	0.1	---	---	---
Subtotal	128.4	123.1	---	---	---	---	203.8	187.9	197.8	206.8	226.3	190.3
Cast irons & steel												
High-carbon Ferro-manganese	13.2	10.1	---	---	---	---	51.8	17.4	18.3	21.9	33.6	13.7
Silico-manganese	5.0	5.4	---	---	---	---	14.3	15.9	15.8	16.6	16.1	12.9
Medium-, Low-carbon Ferro-manganese	2.6	2.4	---	---	---	---	5.4	1.6	2.0	1.6	0.8	0.5
Spiegeleisen	1.5	1.2	---	---	---	---	0.5	4.1	0.8	---	---	---
Subtotal	22.0	19.1	---	---	---	---	72.0	39.0	36.9	40.1	50.5	27.1
Miscellaneous												
High-carbon Ferro-manganese	35.9	23.1	---	---	---	---	0.7	0.7	0.5	0.5	0.7	0.6
Silico-manganese	5.2	3.8	---	---	---	---	3.8	4.3	4.5	3.9	4.8	1.7
Medium-, Low-carbon Ferro-manganese	1.5	1.3	---	---	---	---	0.9	1.0	1.0	1.1	1.1	0.6
Spiegeleisen	---	---	---	---	---	---	---	---	---	---	---	---
Subtotal	42.6	28.2	---	---	---	---	5.4	6.0	6.0	5.5	6.6	2.9
Total	851.8	798.1	---	---	---	---	988.0	944.6	929.2	1,024.9	1,038.2	832.2

Note : --- Data unavailable
Source: The U.S. Bureau of Mines, Mineral Industries Surveys

Table C-16 Share of Ferro-Manganese Consumption by End-Use in USA

(%)

	1969	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980
Carbon steel												
High-carbon Ferro-manganese	80.2	81.9	---	---	---	---	74.1	79.7	77.6	78.5	75.4	76.3
Silico-manganese	63.5	63.4	---	---	---	---	60.6	53.9	53.3	54.7	52.8	57.3
Medium-carbon	72.2	70.8	---	---	---	---	68.0	75.1	75.8	77.9	77.8	77.6
Ferro-manganese Spiegeleisen	52.5	54.5	---	---	---	---	57.3	43.6	85.6	100.0	100.0	100.0
Subtotal	77.3	78.6	---	---	---	---	71.5	75.3	74.1	75.4	72.7	73.5
Special steel												
High-carbon Ferro-manganese	12.3	12.7	---	---	---	---	18.5	17.7	19.6	18.4	20.0	21.3
Silico-manganese	26.0	25.5	---	---	---	---	27.0	30.0	30.0	30.6	32.5	31.4
Medium-, Low-carbon Ferro-manganese	23.4	25.2	---	---	---	---	26.8	22.8	21.8	20.1	20.8	21.4
Spiegeleisen	10.0	36.4	---	---	---	---	3.9	3.8	1.6	---	---	---
Subtotal	15.1	15.4	---	---	---	---	20.6	19.9	21.3	20.2	21.8	22.9
Cast irons & steel												
High-carbon Ferro-manganese	2.0	1.6	---	---	---	---	7.3	2.5	2.7	3.0	4.5	2.3
Silico-manganese	5.2	6.5	---	---	---	---	9.8	12.7	12.5	12.1	11.3	10.0
Medium-, Low-carbon Ferro-manganese	2.8	2.6	---	---	---	-	4.5	1.3	1.6	1.2	0.6	0.5
Spiegeleisen	37.5	9.0	---	---	---	---	38.8	52.6	12.9	---	---	---
Subtotal	2.6	2.4	---	---	---	---	7.3	4.1	4.0	3.9	4.9	3.3
Miscellaneous												
High-carbon Ferro-manganese	5.5	3.8	---	---	---	---	0.1	0.1	0.1	0.1	0.1	0.1
Silico-manganese	5.3	4.6	---	---	---	---	2.6	3.4	3.6	2.8	3.4	1.3
Medium-, Low-carbon Ferro-manganese	1.6	1.4	---	---	---	---	0.7	0.8	0.8	0.8	0.8	0.5
Spiegeleisen	---	---	---	---	---	---	---	---	---	---	---	---
Subtotal	5.0	3.6	---	---	---	---	0.6	0.7	0.6	0.5	0.6	0.3
Total	100.0	100.0	---	---	---	---	100.0	100.0	100.0	100.0	100.0	100.0

Note : --- Data unavailable
Source: Table C-15

Table C-17 Steel Industry Unit Consumption of Manganese as Ferro-Alloys

(kg.Mn/MT crude steel)

Country*	1973	1974	1975	1976	1977	1978
Japan	5.61	5.64	5.68	5.54	5.46	5.54
USA	6.60	6.89	6.94	6.38	6.29	6.28
Canada	5.64	5.98	6.13	5.10	5.28	5.78
Belgium	6.51	6.87	4.69	6.15	4.96	5.15
Germany, Fed. Rep.	6.39	6.63	7.01	6.66	6.49	6.65
France	6.71	6.41	6.04	6.14	5.95	6.18
Italy	7.50	7.87	7.43	7.85	7.86	7.59
Luxemburg	7.48	7.16	7.59	7.21	7.36	7.08
Netherlands	3.93	3.95	4.08	3.48	3.17	2.94
UK	7.17	7.29	7.83	7.25	7.32	6.88
Austria	2.75	3.70	3.75	3.13	3.72	3.25
Finland	4.99	4.60	5.00	4.42	4.16	4.40
Norway	5.98	6.30	6.46	6.42	8.17	7.22
Spain	8.72	8.08	10.30	9.74	10.15	9.15
Sweden **	14.64	14.13	9.73	7.93	5.66	7.90
South Africa	4.73	4.89	4.49	4.56	4.67	4.51
Australia**	6.63	8.12	12.66	6.96	9.78	8.69
Brazil	8.09	7.90	7.54	7.40	6.96	7.11
Latin America***	6.12	7.32	9.63	8.82	8.72	N.A.
Average	6.26	6.46	6.61	6.23	6.19	6.19

* Selected countries only
** Apparant consumption; production + imports - exports
*** Latin America except Brazil

Source: IISI, Manganese and the Iron and Steel Industry, 1980, p. 35

Note : We are using the above data in projecting supply and demand as we believe them to be fairly accurate as a result of having compared them against following data obtained from another source for Japan and the United Kingdom and having found them to be alike in value and tendency.

(kg Mn/MT Crude steel)

	1973	1974	1975	1976	1977	1978
Japan (1)	5.46	5.58	5.58	5.28	5.41	5.32
UK (2)	7.10	7.57	7.94	7.10	7.31	7.11

Sources: 1) Japan Ferro-Alloy Association
2) Metal Bulletin Handbook

The unit consumption of net manganese content is small in Australia, the Netherlands, Finland and South Africa, but large in Sweden, Brazil, Latin America (except Brazil) and Australia.

The major reasons for the difference among countries are said to be attributable to:

1) differences in the amount of manganese ore that the countries add to blast furnace during the pig iron making process.

2) differences in yield[1] of manganese due to different methods that the countries use in the steel making process.

3) differences in manganese consumption volume resulting from the differences in ratios of special steel production volume to total crude steel production volume.

4) differences in manganese consumption volume resulting from the differences in ratios of production volume of continuous cast billet to total production volume of crude steel.

III. Innovations in Application Technology of Manganese

1. Technological Innovations in Manganese Ore Consumption

There does not seem to be any new technological innovation in the use of manganese ore that is worth mentioning.

We have already stated that more than 90% of manganese ore is consumed in the iron and steel sector and only 7 to 8% in the non-ferrous sector. It is our assumption that technological innovations in steel making, which we will discuss in the next section, will reduce ore consumption for ferro-manganese production and that ore used as input to blast furnace will remain level in the iron and steel sector.

2. Technological Innovations in Ferro-Manganese Consumption

To talk about the future prospect of ferro-manganese consumption is tantamount to discussing the progress in the pig iron and steel making technology.

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1) Yield of manganese by type of steel making process:
   (1) Open hearth furnace steel making : about 60%
   (2) Pure oxygen converter furnace method : about 90%
   (3) Electric furnace method : about 95%

We might rightly say that as a general tendency the unit ferro-manganese consumption tends to decrease with the progress of the pig iron and steel making technology.[1] The following examples show the relationship between the latest pig iron and steel making technology and ferro-manganese consumption trends.

- Preliminary treatment of molten pig iron: The technology to desulfurize pig iron with carbide or soda ash during heat retaining of pig iron or in the ladle has been developed. This has lessened the need for desulfurization treatment inside the steel-making furnace and as a result reduced the unit managanese consumption.

- Improvement in converter operating technique: The adoption of the computerized control in the converter furnace operating technique has improved temperature control and the passing rate of component tests. The development of complex blowing (LD-OB, Q-BOP)[2] has made blowing out possible and raised the manganese content and, as a consequence, made the use of manganese ore possible in the converter furnace also. It is being said that these technological improvements will probably reduce the unit ferro-manganese consumption per tonne of crude steel by as much as 1 kg.

- Improvement in electric furnace steel making technology: The electric furnace is being made increasingly larger, and in order to prevent unevenness of molten metal and assure uniform quality, the guided agitator device has been adopted. This improvement is also believed to lead to ferro-alloy saving.[3]

  Feeding methods were studied in terms of reaction kinetics, and as a result the injection process was developed as a method for feeding ferro-alloy. This method has changed the form of ferro-alloy from lump to powder. This technology is popular in Japan only for effective utilization of undersize ferro-manganese which naturally occurs in the sizing process, but if the technology should be diffused on a full scale, it will become necessary to improve the sizing technology for ferro-alloy.

- Outside furnace smelting: Spectacular progress has been made in this technique, leading to the development of R-H process,[4] D-H

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1) Refer to Table C-17
2) LD-OB: Top and bottom blown converter
   Q-BOP: Improved bottom blown converter
3) Objects extend to all of ferro-alloys such as ferro-manganese, ferro-chromium and ferro-silicon.
4) R-H process: This process, used at the integrated steel mill, uses blast furnace molten pig iron as a basis. Dephosphatizing and decarbonizing are done during the converter process and vacuum decarbonation and finish smelting in R-H degassing tank. In other words, it is an integrated process of blast furnace - LD converter - outside furnace smelting.

process,[1] VOD process,[2] AOD[3] process and numerous other techniques. The objectives of these outside furnace smelting methods are quite diverse, ranging from decarbonation to deoxidation, desulfurization, degassing, component adjustment, etc. Of these, the improvement in decarbonation technique has resulted a shift from the use of medium- and low-carbon ferro-manganese with less carbon to high-carbon ferro-manganese.

- Continuous casting process: By the popularization of the continuous casting process, the yield of ingot will rise, and even if the production volume of the final products is the same, the production volume of crude steel will be held down and reduce the consumption of ferro-alloy (not only ferro-manganese).

Factors that might increase ferro-manganese consumption are the develepment of new kinds of steel and new applications. For example, the oil pipeline used in oil development projects requires the use of ultra-low carbon ferro-manganese (high manganese, low silicon and low phosphorus), and for this a new type of weather-resisting, anti-corrosive steel has been developed. Ultra-low carbon ferro-manganese is also used in making sheet material for the automobile. Also, as material for earth-moving equipment for land development, high manganese abrasion resisting steel has yet to be developed which will no doubt lead to the development of high quality ferro-manganese with the least of unnecessary impurities.

IV. Import and Stockpile Policies in Major Consuming Countries

1. Import Policies

There is no country among the manganese importing countries that adopts any sort of special import policy.

The tariff rates in the United States, who imports a lot of ferro-manganese, are 1.6% on high-carbon ferro-manganese, 3.9% on silico-manganese and 1.4% on medium- and low-carbon ferro-manganese.

The EC countries levy import duty of 11.2% on high carbon ferro-manganese and 3.8% on silico-manganese which, compared to the United States, are high being intended to protect the high-carbon ferro-manganese producers within the region.

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1) D-H Process: Same as R-H process in principle, only D-H process uses one molten steel suction pipe where as R-H process uses two.
2) VOD Process: A method of decarbonizing in vacuum.
3) AOD process: A method of decarbonizing and desulfurizing in Ar, N_2 or atmospheric furnace gas under atmospheric pressure.

Japan's import duty is 9.6% on high-carbon ferro-manganese and 3.8% on silico-manganese.

2. Stockpile Policies

Every major country has some sort of stockpiling scheme on manganese.

The reason may be attributed to the world's extremely uneven distribution of manganese, as we have already seen. The United States in particular has no manganese resources at all.

Countries with a manganese stockpile now are the United States, Sweden, Federal Republic of Germany and others.

Countries that make stockpiling a means of national security are the United States and Sweden, while countries that place their objective on economic security are countries like Federal Republic of Germany (conceptual plan only).

France also adopts a stockpile policy but manganese is excluded.

2.1 The United States

The American stockpile policy calls for stockpiling of manganese in accordance with the Law[1] on "Strategic Critical Materials Stock Policy" and the target quantity of stock is three years' supply which is deemed necessary for national security.

The latest information on targets and actual volumes stocked are shown in Table C-18.

It is noteworthy that the United States has achieved its target volumes on manganese and ferro-manganese and that in the case of electric manganese, it is maintaining its stock at a level of 14 thousand tonnes despite the fact that it has abolished the system of setting any target volume since May 1980.

The objective of stockpiling is not only to have an appropriate quantity on stock but to be able to utilize it as a means of market adjustment.[2]

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1) This Law was enacted in 1939 and amended in 1946.

2) The United States released manganese ore to the market when the price soared in 1964 and increased the quantity of stockpile when the market collapsed in 1960.

Table C-18 Target and Achieved Manganese Stockpile in USA

(1,000 MT)

		Manganese ore		Ferro-manganese						Electric manganese	
				High-carbon		Medium-, low-carbon		Silico-manganese			
		T.	A.	T.	A.	T.	A.	T.	A.	T.	A.
1973	4		7276		1176		50		24		21.5
1973	6.30	750		200		10.5		15.9		4.75	
1974	12.31		4438		600		29		24		14.3
1976	3.31		3931		600		29		24		14.2
	10.1	2052		439	---	99	---	81	---	15	
1978	3.31		2607		600		29		24		14.1
1979	3.31		3592		600		29		24		14.1
1980	5.1	2700	---	439	---	——	---	——	---	——	---
1981	4.30		2630		600		29		24		14.1

T.: Target A.: Achieved

Note : --- Data unavailable
—— Not applicable

Source: Metal Bulletin Handbook

2.2 Sweden

In Sweden, stockpiling is carried out under national guidance. The Department of Commerce and the Economic Defence Agency directly buy from or release to the market as well as keep custody of the stock at facilities owned by the Agency. The target stockpile is said to be one month's supply.

2.3 The Federal Republic of Germany

Federal Republic of Germany has not yet started stockpiling but a plan is in progress between the Government and about 100 private enterprises to establish the stockpile Association as a private organization to initiate and operate a stockpiling project.

2.4 France

France has been stockpiling since 1975 for the purpose of national security, but manganese is not included in the plan.

2.5 Japan

Stockpiling in Japan is carried out by the private sector for five kinds of metals including nickel and chromium, but manganese is not covered as an object of stockpiling at present.

D. INTERNATIONAL TRADE

I. Trends of International Trade in Manganese Ore and Ferro-Manganese

1. Changes in Trade Volumes of Manganese Ore

The worldwide manganese ore exports[1)] rose from 6.88 million tonnes in 1965 to a peak of 12.29 million tonnes in 1974, then dropped to 10.3 million tonnes by 1979. The average annual growth rate between 1965 and 1979 was 2.6%.

A review of export volumes by country shows South Africa to be the largest exporter, followed by Gabon, the USSR, Brazil, Australia and then India. The seven countries collectively account for more than 80%, sometimes over 90%, of the world total exports.

Of these major exporting countries, the growth of South Africa has been remarkable, recording a 7.0% a year growth from 0.92 million tonnes in 1965 to 3.3 million tonnes by 1980. The country's share in the export market rose from 13% to 35% during the same period and its ratio of exports to production has hovered around 70%. The USSR, the largest producer of manganese ore in the world, consumes most of its production internally so that its ratio of exports to production is low, fluctuating between 13% and 18%. Although its share of the export market has declined from 16% to 13% it still continues to rank high among the exporters.

The worldwide manganese ore imports[1)], on the other hand, rose from 8.47 million tonnes in 1965 to a peak of 11.12 million tonnes in 1974 but fell to 8.06 million tonnes in 1980. The average annual growth rate between 1965 and 1980 computed by taking the average of each of these two years and the year preceding and following each (3 years each) was 0.6%.

When imports are reviewed by country, Japan is the largest importer, followed by the United States, France, Norway, Federal Republic of Germany, Poland and the United Kingdom, - collectively accounting for 80 to 90% of the world total imports.

Of these major importing countries, the growth of imports of Japan is remarkable, having grown from 1.07 million tonnes in 1965 to 2.9 million tonnes in 1980 at an average rate of 5.8% a year and its share of the import market from 13% to 36%.

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1) The difference in worldwide ore exports and imports seems attributable to errors and omissions of data in the Metal Bulletin Handbook and the Roskil Report to which we have referred for data on manganese. We have had to use these as data source as no other was available.

By contrast, the United States sustains a declining trend, having reduced its imports from 3.5 million tonnes in 1965 to 0.63 million tonnes in 1980, or to less than one-fifth of its 1965 level. The country's share in the import market has also declined from 41% to 8% during the same period.

Its ferro-manganese imports, on the other hand, which we will discuss in the next section, are yearly rising and when reviewed in terms of the combined manganese content, the volume is commensurate to the requirements of its iron and steel and other sectors.

The above situation is illustrated in Fig. D-1. Also, trends of manganese ore exports are shown in Table D-1, trends of shares in export markets of manganese ore in Table D-2, trends of export ratios of manganese ore in Table D-3, trends of manganese ore imports in Table D-4, and trends of shares in import markets of manganese ore in Table D-5.

2. Flow of World Trade in Manganese Ore

The flow of world trade in manganese ore is illustrated in Fig. D-2 with primary emphasis on major exporting countries.

A review from importing side:

Japan imports mostly from South Africa. With those imported from Australia and India which are nearer, they account for 78% of total imports.

France imports mostly from Gabon and South Africa which collectively account for 90% of its total imports. In the case of Gabon, its nearness and equity relations are probably the reasons for the large imports from that country.

Norway mainly imports from South Africa, Gabon and Brazil, with the three accounting for 84% of its total imports.

Federal Republic of Germany's imports from South Africa accounts for a particularly large share of 60%. When combined with imports from Australia and Brazil, the three account for 88% of its total imports.

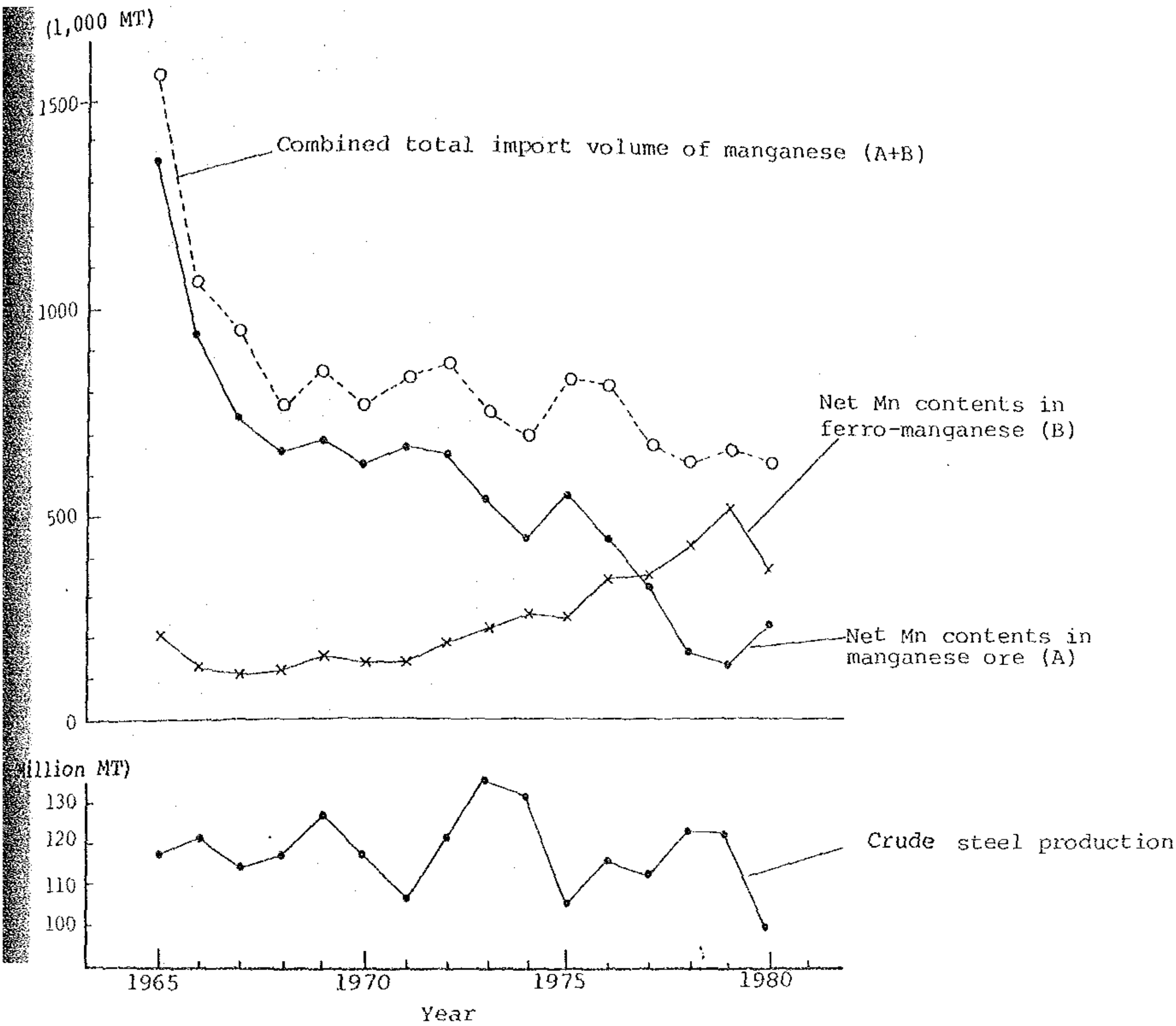
The United States mainly imports from Brazil, South Africa, Australia and Gabon, and the combined share of imports from these countries is 96%.

The United Kingdom primarily imports from South Africa and Brazil with a combined share of 88% of total imports.

When reviewed from the exporting side:

South Africa exports the largest volume to Japan.

Fig. D-1 Trend in Manganese Import Volume in USA



Note : Mn content — Manganese Ore : 38.5%
Ferro-manganese: 73.0%

Source: Tables D-4, D-9, and B-5

Table D-1 Exports of Manganese Ore by Country 1965 to 1980

(1,000 MT)

Country/Region	1965	1966	1967	1968	1969	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980
South Africa	918	1,506	1,449	1,744	1,911	2,125	2,681	2,450	3,677	3,493	3,641	3,742	3,329	2,400	3,600	3,300
Gabon	1,149	1,181	1,226	1,248	1,548	724	1,750	2,162	776	2,078	1,968	1,754	1,450	1,142	1,685	1,500
Australia	56	70	276	400	640	649	704	768	---	1,203	1,132	1,711	811	1,301	1,157	1,200
Brazil	1,068	956	542	1,124	861	1,588	---	1,175	788	1,493	1,558	1,073	560	894	1,187	---
India	641	700	458	565	472	546	382	282	211	1,034	793	714	554	577	628	---
Ghana	574	599	452	446	329	403	---	475	290	281	373	355	282	228	232	150
Morocco	321	305	214	170	132	116	91	118	151	165	110	104	131	140	139	---
Zaire	---	---	---	---	243	440	---	---	---	199	115	306	192	---	---	---
Others	1,057	835	653	451	59	164	74	154	191	744	644	580	664	644	331	228
Free World Total	5,783	6,152	5,270	6,148	6,195	6,755	5,682	7,584	6,084	10,690	10,334	10,339	7,973	7,326	8,959	6,378
USSR	1,020	1,218	1,250	1,150	1,197	1,200	1,422	1,278	1,278	1,482	1,411	1,342	1,352	1,186	1,317	1,255
Others	80	49	60	67	48	28	49	37	21	121	80	42	54	45	46	---
Centrally Planned Economies Total	1,100	1,267	1,310	1,217	1,245	1,228	1,471	1,315	1,299	1,603	1,491	1,384	1,406	1,231	1,363	1,255
World Total	6,884	7,419	6,580	7,365	7,440	7,983	7,153	8,899	7,383	12,293	11,825	11,723	9,379	8,557	10,322	7,633

Note : --- Data unavailable

Source: 1965 to 1973: Metal Bulletin Handbook
1974 to 1980: Roskill Information Service Ltd., The Economics of Manganese, 1982

Table D-2 Changes in Share of World's Manganese Ore Exports by Major Countries

(%)

	1965	66	67	68	69	70	71	72	73	74	75	76	77	78	79	80
South Africa	13.3	20.3	22.0	23.7	25.7	26.6	---	27.5	---	28.4	30.8	31.9	35.5	28.0	34.9	---
Gabon	16.7	15.9	18.6	16.9	20.6	9.1	---	24.3	---	16.9	16.6	15.0	15.5	13.3	16.3	---
Australia	0.8	0.9	4.2	5.4	8.6	8.1	---	8.6	---	9.8	9.6	14.6	8.6	15.2	11.2	---
Brazil	15.5	12.9	8.2	15.3	11.6	19.9	---	13.2	---	12.1	13.2	9.2	6.0	10.4	11.5	---
India	9.3	9.4	7.0	7.7	6.3	6.8	---	3.1	---	8.4	6.7	6.1	5.9	6.7	6.1	---
USSR	14.8	16.4	19.0	15.6	16.0	15.0	---	14.4	---	12.1	11.9	11.4	14.4	13.9	12.8	---
Subtotal	70.4	75.8	79.0	84.6	89.0	85.5	---	91.1	---	87.7	88.8	88.2	85.9	87.5	92.8	---

Note : --- Data unavailable
Source: Table B-1

Table D-3 Export Ratio of Manganese Ore in Major Countries

(Export/Production; Volume %)

	1965	66	67	68	69	70	71	72	73	74	75	76	77	78	79	80
South Africa	51.7	76.0	68.3	71.9	72.3	70.3	78.4	72.6	87.8	73.4	63.0	68.6	65.9	55.6	69.5	57.9
Gabon	90.0	92.8	106.9	99.5	111.2	49.8	93.8	111.6	40.3	100.4	87.7	79.1	78.3	68.8	73.3	70.0
Australia	54.9	22.1	48.5	53.3	71.2	86.4	67.0	65.9	---	78.8	72.3	79.4	58.5	104.2	69.4	61.2
Brazil	76.5	65.7	40.0	57.8	42.8	77.9	---	48.9	48.6	83.2	72.3	63.3	36.9	46.6	52.5	---
India	42.6	43.9	29.8	35.5	36.0	37.5	24.6	17.2	14.1	68.8	50.3	41.0	28.6	35.6	35.8	---
USSR	13.0	15.8	17.4	17.5	17.1	17.1	18.4	16.3	15.5	17.4	16.6	15.5	15.7	13.1	12.9	---

Note : --- Data unavailable
Source: Tables B-2 and D-1

Table D-4 Imports of Manganese Ore by Country 1965 to 1980

(1,000 MT)

Country/Region	1965	1966	1967	1968	1969	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980
Japan	1,065	1,140	1,507	1,753	2,025	2,584	3,243	2,904	3,345	4,042	3,832	3,378	2,780	2,055	2,801	2,905
France	854	840	690	890	1,117	1,095	1,117	1,123	1,432	1,428	1,158	1,014	923	958	1,227	1,245
Norway	510	489	534	650	627	545	736	721	715	1,033	1,073	982	591	803	815	808
Germany, Fed. Rep.	636	617	354	582	319	403	459	476	716	828	733	610	453	672	717	488
USA	3,497	2,406	1,873	1,656	1,761	1,574	1,736	1,674	1,353	1,111	1,428	1,195	844	477	453	633
Spain	86	143	135	184	142	200	174	260	331	384	437	410	433	370	487	125
UK	503	371	412	482	438	521	429	361	588	388	253	499	328	261	543	127
Italy	107	91	153	170	161	184	291	272	282	309	316	356	269	284	422	408
Belgium-Lux	309	259	286	307	463	350	463	357	424	400	313	329	206	252	432	299
Free World Total	7,567	6,356	5,944	6,674	7,053	7,456	8,468	8,148	9,186	9,923	9,543	8,773	6,827	6,182	7,897	7,036
Czechoslovakia	334	287	306	---	313	202	313	388	441	475	456	448	324	373	423	397
Poland	347	397	354	352	394	389	401	505	525	556	556	538	698	651	518	490
German Dem. Rep..	225	195	201	131	198	179	198	200	163	168	185	199	204	183	182	135
Centrally Planned Economies Total	906	879	861	483	905	770	912	1,093	1,129	1,199	1,197	1,185	1,226	1,207	1,123	1,022
World Total	8,473	7,235	6,805	7,157	7,958	8,226	9,741	9,241	10,315	11,122	10,740	9,958	8,053	7,389	9,027	8,058

Note : --- Data unavailable

Source: 1965 to 1973: Metal Bulletin Handbook
1974 to 1980: Roskill Information Service Ltd., The Economics of Manganese, 1982

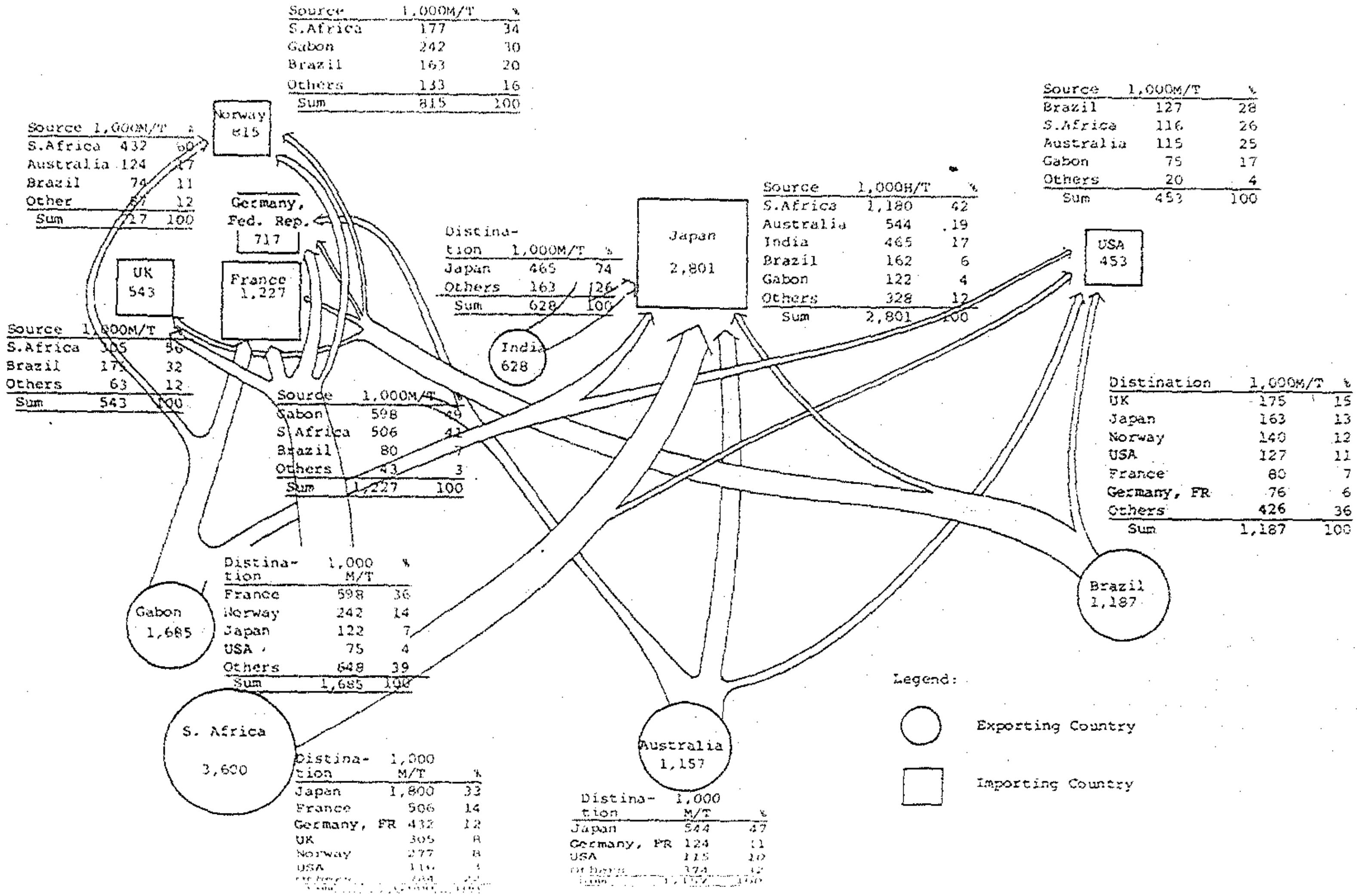
Table D-5 Imports of Share of Manganese Ore by Country 1965 to 1980

(%)

Country/Region	1965	1966	1967	1968	1969	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980
Japan	12.6	15.8	22.1	24.5	25.5	31.4	33.4	31.4	32.4	36.3	35.7	33.9	34.5	27.9	31.1	36.1
France	10.1	11.6	10.1	12.4	14.0	13.3	11.7	12.2	13.9	12.8	10.8	10.1	11.5	12.8	13.6	15.5
Norway	6.0	6.8	7.8	9.1	7.9	6.6	7.8	7.8	6.9	9.3	10.0	9.9	7.3	10.9	9.0	10.0
Germany, Fed. Rep.	7.5	8.5	5.2	8.1	4.0	5.0	4.8	5.2	6.9	7.4	6.8	6.2	5.6	9.2	7.9	6.1
USA	41.3	33.2	27.5	23.1	22.1	19.1	17.9	18.1	13.1	10.0	13.3	12.0	10.5	6.6	5.0	7.9
Spain	1.0	2.0	2.0	2.6	1.8	2.4	1.9	2.8	3.2	3.5	4.1	4.1	5.4	5.0	5.4	1.5
UK	5.9	5.1	6.1	6.7	5.5	6.3	4.6	3.9	5.7	3.5	2.4	5.0	4.1	3.6	6.0	1.5
Italy	1.3	1.2	2.3	2.4	2.0	2.2	3.2	2.9	2.7	2.8	2.9	3.6	3.3	3.9	4.7	5.1
Belgium-Lux	3.6	3.6	4.2	4.3	5.8	4.3	4.9	3.9	4.1	3.6	2.9	3.3	2.6	3.5	4.8	3.7
Free World Total	89.3	87.8	87.3	93.2	88.6	90.6	90.2	88.2	88.9	89.2	88.9	88.1	84.8	83.4	87.5	87.4
Czechoslovakia	3.9	4.0	4.5	---	3.9	2.5	3.3	4.2	4.3	4.3	4.2	4.4	4.0	5.0	4.7	4.9
Poland	4.1	5.5	5.2	4.9	5.0	4.7	4.3	5.5	5.1	5.0	5.2	5.4	8.7	8.9	5.7	6.1
German Dem. Rep.	2.7	2.7	3.0	1.9	2.5	2.2	2.2	2.1	1.7	1.5	1.7	2.1	2.5	2.7	2.1	1.6
Centrally Planned Economies Total	10.7	12.2	12.7	6.8	11.4	9.4	9.8	11.8	11.1	10.8	11.1	11.9	15.2	16.6	12.5	12.6
World Total	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100

Note : --- Data unavailable
Source: Table D-4

Fig. D-2 Flows Diagram of World Trade in Manganese Ore



It also exports to most of the major importers of the free world including France, Federal Republic of Germany, the United Kingdom, Norway and the United States.

Gabon exports the largest volume to France and also to Norway, Japan, the Unitsd States, etc.

Brazil's export destinations are more diverse, including the United Kingdom, Japan, Norway, the United States, France and Federal Republic of Germany.

Australia exports the largest volume to Japan. Its other export destinations, which include Federal Republic of Germany and United States, are not many.

India exports mostly to Japan.

3. Changes in Trade Volumes of Ferro-Manganese

Here, we will review high-carbon ferro-manganese which is the most produced as well as the most consumed of all ferro-manganese. Exports of the world's major countries grew from 0.71 million tonnes in 1965 to a peak of 1.37 million tonnes in 1974 and slightly fell thereafter to 1.24 million tonnes in 1978. The average annual growth rate during the period was 4.9%.

When export volumes are reviewed by country, France ranks at the top, seconded by South Africa. These two, with Norway and USSR, collectively account for 70 to 80% of total exports by major countries.

France, the leading exporter, increased its exports from 210 thousand tonnes in 1965 to 290 thousand tonnes in 1980 at an average annual rate of 3.7%, and its export share has remained almost same level, ranging between 25% and 30%.

South Africa increased its exports from 170 thousand tonnes in 1965 to 370 thousand tonnes in 1978 at an average annual rate of 6.4% and increased its and export share from 23% to 26%.

Norway expanded its exports from 100 thousand tonnes in 1965 to 250 thousand tonnes in 1980 at an average annual rate of 7.0%, and increased its share of exports from 14% to the 20% mark.

These top three countries' ratios of export to production are very high, with France having raised its export ratio from about 60% to roughly 70% and South Africa[1] and Norway maintaining export ratios of about 82% and 87% respectively on average.

1) In computing the average export ratio, South Africa's export ratios in 1969 and 1970 were excluded as they were considered abnormal in the light of its domestic supply and demand balance.

Imports of the world's major countries, on the other hand, increased from 400 thousand tonnes in 1965 to 840 thousand tonnes in 1980 at an average annual rate of 5.0%.

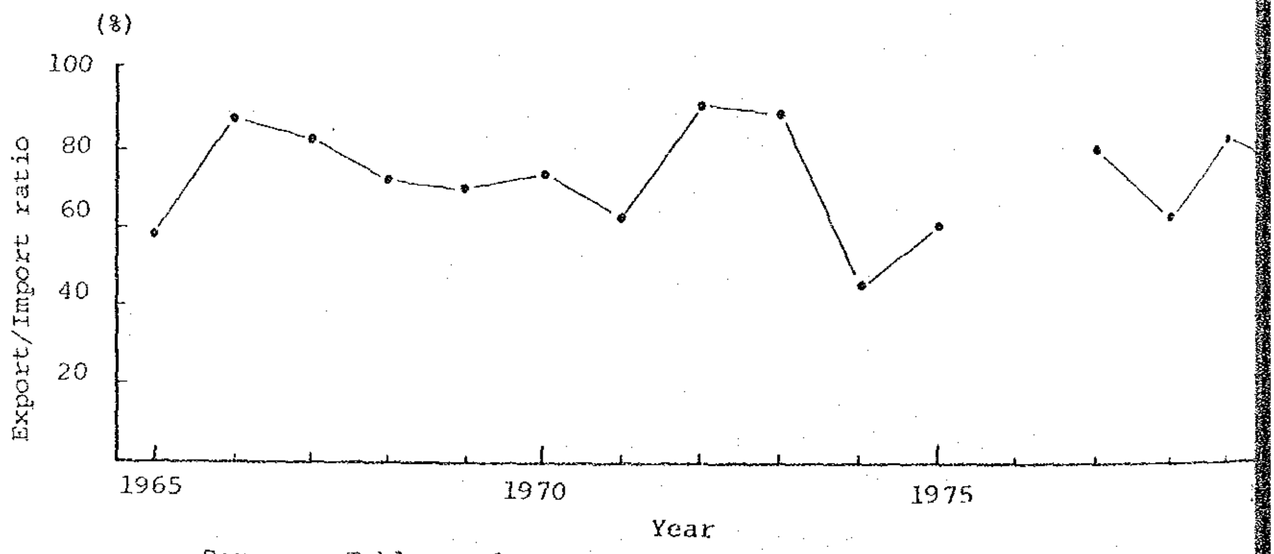
When import volumes are reviewed by country, the United States is seen to be the largest importer, followed by Federal Republic of Germany, Italy, and Belgium. These four countries collectively account for 80% - to almost 90% during the latter half of the 1970s - of the world's total imports by major countries.

The increase in imports of the United States was particularly large, having grown from 180 thousand tonnes in 1965 to 470 thousand tonnes by 1980 at an average annual rate of 9.5% with an associated increase in its import market share from 44% to 57%.

The rates of increase in imports of Federal Republic of Germany and Italy were modest at 2.7% and 1.6% a year respectively. In terms of import market share, Federal Republic of Germany's share fell from 16% to 13% and that of Italy from 18% to 11%.

Belgium's trade volume is not large but it exports around 70% of that it imports every year as shown in Fig. D-3, and functions as the Western Europe's distribution center.

Fig. D-3 Movements in Belgium's Ratio of Ferro-Manganese Exports to Imports (Exports/Imports)



Source: Tables D-6, D-9, D-11 and D-13

We have omitted giving any close review of the world trade in silico-manganese because the volumes traded are small. We have instead provided pertinent information in the form of tables as follows:

Table D-6 Trends in High-Carbon Ferro-Manganese Exports by Major Countries

(1,000 MT)

	1965	1966	1967	1968	1969	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980
Belgium	41.6	60.3	63.5	58.8	62.7	66.1	52.8	51.6	54.1	50.9	38.2	66.6	44.5	38.7	42.2	40.4
France	205.7	182.0	157.3	194.7	213.3	289.5	221.8	281.9	352.7	376.5	245.6	236.0	241.7	268.8	304.6	288.0
Germany, FR		86.5	32.6	64.3	32.6	28.4	29.2	24.8	41.4	68.5	33.9	37.8	62.8	44.0	85.7	28.2
Italy	0.1	8.9	7.9	10.7	6.7	5.4	5.8	8.7	5.4	5.9	2.7	2.2	2.1	10.3	6.2	1.2
Norway	101.8	114.3	120.5	143.8	188.1	155.1	187.5	210.5	225.3	309.4	256.6	327.2	244.0	266.7	293.9	245.5
Sweden	3.1	2.3	0.3	1.0	20.7	8.4	13.1	13.8	11.8	2.4	1.0	2.1	0.2	0.2	0.3	0.3
UK	13.7	22.1	17.8	22.0	4.8	4.6	0.3	0.2	0.2	1.1	1.2	0.6	0.6	2.0	7.0	1.0
South Africa	173.7	172.9	140.9	143.9	279.9	235.3	187.5	---	276.0	347.0	276.0	330.0	265.0	372.0	---	---
India	87.6	56.4	10.0	29.3	55.6	115.4	84.9	17.3	75.1	20.4	14.1	14.1	25.1	28.4	85.9	29.9
Japan	15.3	15.0	4.8	7.2	11.3	8.4	19.3	50.5	26.4	54.3	130.6	121.9	48.6	37.1	92.9	40.3
USSR	67.3	87.4	87.0	97.2	107.5	118.5	124.8	129.7	135.0	129.2	125.3	125.0	125.0	125.0	125.0	125.0
Brazil	---	---	---	---	---	---	---	---	---	5.0	10.0	11.0	34.0	40.0	50.0	50.0
Total	709.9	808.1	642.6	772.9	983.9	1,035.1	927.0	789.0	1,203.4	1,370.6	1,135.2	1,274.5	1,093.6	1,253.2	1,093.7	849.8
Top 4 countries	548.5	556.6	505.6	579.6	788.8	798.4	721.6	622.1	989.0	1,162.1	903.5	1,018.2	875.2	1,052.5	723.5	658.5

Notes : 1) Some data include medium- and low-carbon ferro-manganese, and partially spiegeleisen and silico - manganese.

2) Top 4 countries are France, Norway, South Africa, and USSR.

3) --- Data unavailable

Sources : Metal Bulletin Handbook
Roskill Information Services Ltd., The Economics of Manganese, 1982

Table D-7 Changes in the Share of High-Carbon Ferro-Manganese Exports by Major Countries

(%)

	1965	1966	1967	1968	1969	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980
Belgium	5.9	7.6	10.0	7.6	6.5	6.5	5.8	6.5	4.5	3.7	3.5	5.2	4.2	3.0	3.9	4.9
France	29.0	22.6	24.4	25.2	21.7	28.0	23.9	35.8	29.3	27.5	21.6	18.5	22.1	23.0	27.9	33.9
Germany, FR	---	10.7	5.1	8.3	3.3	2.8	3.1	3.1	3.4	5.0	3.0	3.0	5.7	3.5	7.8	3.3
Italy	0	0.2	1.2	1.4	0.7	0.5	0.6	1.1	0.4	0.4	0.2	0.2	0.2	0.8	0.6	0.1
Norway	14.3	14.3	18.8	18.6	19.1	15.0	20.2	26.7	18.7	22.6	22.6	25.6	22.3	21.3	26.9	28.9
Sweden	0.4	0.4	0.0	0.1	2.1	0.8	1.4	1.8	1.0	0.2	0.1	0.2	0	0	0	0
UK	1.9	2.7	2.8	2.8	0.5	0.4	0	0	0	0	0.1	0	0	0.2	0.5	0.1
South Africa	24.5	21.5	21.9	18.6	28.4	22.7	20.2	---	22.9	25.3	24.3	25.9	24.3	29.7	---	---
India	12.3	7.1	1.6	3.8	5.7	11.1	9.2	2.2	6.2	1.5	1.2	1.1	2.3	2.3	7.9	3.5
Japan	2.2	2.0	0.7	0.9	1.1	0.8	2.1	6.4	2.3	4.0	11.5	9.6	4.4	3.0	8.5	4.7
USSR	9.5	10.9	13.5	12.7	10.9	11.4	13.5	16.4	11.3	9.5	11.0	9.8	11.4	10.0	11.4	14.7
Brazil	---	---	---	---	---	---	---	---	---	0.3	0.9	0.9	3.1	3.2	4.6	5.9
Total	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
Top 4 countries	77.3	69.4	78.6	75.1	80.1	77.1	77.8	78.9	82.2	84.9	79.5	79.8	80.1	84.0	66.2	77.5

Notes : 1) Top 4 countries are France, Norway, South Africa, and USSR.

2) --- Data unavailable

Source : Table D-6

Table D-8 Changes in Export Ratio of High-Carbon Ferro-Manganese by Major Countries

(Export/Production, volume %)

	1965	1966	1967	1968	1969	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980
South Africa	92.4	93.0	80.1	83.7	147.3	112.0	72.4	---	85.7	95.7	64.8	94.3	66.3	77.5	---	---
France	62.9	60.4	60.1	60.0	46.6	60.0	49.8	62.6	64.8	71.9	58.5	64.7	67.5	74.1	68.1	66.7
Norway	85.8	79.2	90.5	86.3	90.0	75.5	81.5	82.2	80.2	92.1	75.7	87.2	99.9	96.5	87.0	77.8
India	59.6	41.7	7.4	20.4	36.2	66.8	52.6	10.8	53.2	14.0	10.0	8.1	15.0	12.9	45.5	---
USSR	7.5	9.8	9.7	10.4	12.2	12.4	14.8	14.6	15.7	13.6	13.1	(13.3)	(13.2)	(12.8)	(12.5)	---

Notes: 1) Figures in parentheses for USSR were estimated assuming export volume of 125 thousand tonnes per year

2) Statistical data for South Africa indicate export volumes in excess of production in 1969/70, which reason has not been elcidated within the scope of available data.

3) --- Data unavailable

Table D-9 Trends in High-Carbon Ferro-Manganese Imports by Major Countries

(1,000 MT)

	1965	1966	1967	1968	1969	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980
Canada	31.3	44.5	14.5	25.3	22.2	17.9	19.6	17.1	24.0	17.0	126.3	25.1	29.4	26.8	83.6	26.7
USA	179.7	176.5	147.6	150.2	212.7	205.4	177.5	249.2	275.6	327.6	324.0	415.1	416.2	523.8	637.7	474.4
Belgium	67.2	67.0	72.3	72.9	81.9	82.6	81.3	51.6	54.1	110.6	67.4	88.4	63.7	63.6	70.8	64.0
Germany, FR	---	79.5	67.6	102.9	129.9	145.2	114.3	148.5	153.4	142.7	127.0	143.9	132.7	123.1	114.3	108.2
Italy	74.6	77.9	86.9	87.4	111.9	111.0	117.4	88.1	120.6	153.4	124.8	116.8	90.3	108.7	108.7	96.1
Sweden	15.5	22.5	21.1	30.7	26.4	31.2	33.5	28.7	52.2	44.3	44.3	44.9	21.7	33.1	36.8	28.0
UK	26.4	23.9	23.1	26.9	30.3	29.2	20.4	28.5	29.5	20.5	23.9	25.8	22.5	48.0	27.2	16.6
Japan	0	0	9.4	2.4	24.6	47.9	2.2	0.2	22.1	16.2	1.9	1.9	5.8	17.0	18.8	2.7
Australia	9.8	11.0	9.5	14.1	17.7	15.6	15.6	17.5	20.1	13.6	12.6	14.6	14.7	17.0	22.2	18.9
Total	404.5	502.8	452.0	512.8	657.6	686.0	581.8	629.4	751.6	845.8	852.2	876.2	797.0	961.1	1,120.1	835.6
Top 4 countries	321.5	400.9	374.4	413.4	536.4	544.2	490.5	537.4	603.7	734.3	643.2	764.2	702.9	819.2	931.5	742.7

Notes : 1) Top 4 countries are USA, Germany, Fed, Rep., Italy, and Belgium.
2) --- Data unavailable

Source: Metal Bulletin Handbook

Table D-10 Changes in Share of High-Carbon Ferro-Manganese Imports by Major Countries

(%)

	1965	1966	1967	1968	1969	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980
Canada	7.8	9.0	3.2	4.9	3.4	2.6	3.4	2.7	3.2	2.0	14.8	2.9	3.8	2.9	7.4	3.2
USA	44.4	35.1	32.6	29.2	32.3	29.9	30.5	39.6	36.7	38.7	38.0	47.4	52.2	57.1	57.0	56.8
Belgium	16.6	13.0	16.0	14.2	12.5	12.0	14.0	8.2	7.2	13.2	7.9	10.1	8.0	6.9	6.3	7.0
Germany, FR	---	15.8	15.0	20.1	19.8	21.2	19.6	23.6	20.4	16.9	14.9	16.4	16.6	13.4	10.2	12.9
Italy	18.5	15.5	19.2	17.0	17.0	16.2	20.2	14.0	16.0	18.1	14.6	13.3	11.3	9.9	9.7	11.5
Sweden	3.8	4.5	4.7	6.0	4.0	4.5	5.8	4.6	6.9	5.2	5.2	5.1	2.7	3.6	3.3	3.4
UK	6.5	4.8	5.1	5.3	4.6	4.3	3.5	4.5	3.9	2.4	2.8	2.9	2.8	2.4	2.4	2.0
Japan	0	0	2.1	0.5	3.7	7.0	0.3	0	2.9	1.9	0.3	0.3	0.7	1.9	1.7	0.3
Australia	2.4	2.3	2.1	2.8	2.7	2.3	2.7	2.8	2.8	1.6	1.5	1.6	1.9	1.9	2.0	2.3
Total	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
Top 4 countries	79.5	79.4	82.8	80.5	81.5	79.3	84.3	85.4	80.3	86.9	75.4	87.2	88.1	87.3	83.2	88.8

Notes : 1) Top 4 countries are USA, Germany, Fed. Rep., Italy, and Belgium.
2) --- Data unavailable

Source: Table D-9

Table D-11 Trends in Silico-Manganese Exports by Major Countries

(1,000 MT)

	1965	1966	1967	1968	1969	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980
Belgium	2.1	3.0	2.0	2.1	3.3	3.0	4.1	5.3	10.2	9.1	8.1	---	15.2	24.5	35.5	28.2
France	3.8	4.4	6.7	6.1	8.7	8.5	5.0	4.3	7.0	8.3	5.4	11.8	9.3	10.8	11.5	9.4
Germany, FR	---	0.1	0.1	0.1	0.1	0.1	0.1	0.2	1.0	1.2	0.6	2.1	2.2	0.7	3.6	5.6
Norway	118.8	108.5	113.3	131.9	143.5	127.3	130.8	145.6	162.8	189.7	126.3	153.0	117.5	162.5	171.9	164.0
Spain	---	---	---	---	---	---	---	10.8	15.3	23.3	13.4	16.0	5.4	28.8	40.6	44.0
Brazil*	---	---	---	---	---	---	---	---	---	3.0	4.0	4.0	5.0	34.0	43.0	36.0
Japan	0.7	0.6	0.3	1.3	1.3	1.2	4.6	7.0	1.4	36.0	8.9	9.9	3.1	0.3	2.4	0.4
USSR	0.5	1.1	0.4	---	---	---	---	---	---	---	---	---	---	---	---	---
Yugoslavia	2.1	9.1	13.4	16.7	15.1	14.4	13.0	11.3	8.4	10.4	10.3	20.0	20.6	20.6	---	---
Total	127.9	126.8	136.2	158.2	172.0	154.5	157.6	184.5	206.1	281.0	177.0	216.8	178.3	282.2	308.5	287.6

Note : --- Data unavailable

Sources: Metal Bulletin Handbook
* Roskill Information Services, Ltd., The Economics of Manganese, 1982

Table D-12 Changes in Share of Silico-Manganese Exports by Major Countries

(%)

	1965	1966	1967	1968	1969	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980
Belgium	1.6	2.4	1.5	1.3	1.9	1.9	2.6	2.9	4.9	3.2	4.6	---	8.5	8.7	11.5	9.8
France	3.0	3.5	4.9	3.9	5.1	5.5	3.2	2.3	3.4	3.0	3.1	5.4	5.2	3.8	3.7	3.3
Germany, FR	---	0	0	0	0	0.1	0	0	0.5	0.4	0.2	1.0	1.2	0.2	1.2	1.9
Norway	93.0	85.6	83.2	83.4	83.4	82.4	83.0	79.0	79.0	67.5	71.4	70.6	66.0	57.6	55.7	57.0
Spain	---	---	---	---	---	---	---	5.9	7.4	8.3	7.6	7.4	3.0	10.2	13.2	15.3
Brazil	---	---	---	---	---	---	---	---	---	1.1	2.3	1.8	2.8	12.0	13.9	12.5
Japan	0.5	0.5	0.3	0.8	0.8	0.8	3.0	3.8	0.7	12.8	5.0	4.6	1.7	0.1	0.8	0.2
USSR	0.3	0.9	0.3	---	---	---	---	---	---	---	---	---	---	---	---	---
Yugoslavia	1.6	7.1	9.8	10.6	8.8	9.3	8.2	6.1	4.1	3.7	5.8	9.2	11.6	7.4	---	---
Total	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100

Note : --- Data unavailable

Source: Table D-11

Table D-13 Trends in Silico-Manganese Imports by Major Countries

(1,000 MT)

	1965	1966	1967	1968	1969	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980
Canada	---	1.8	4.2	1.3	4.6	1.1	1.8	16.6	10.8	0.5	6.3	13.3	5.3	17.5	24.1	23.0
USA	105.2	11.9	21.4	16.5	19.4	8.7	21.0	23.5	27.3	44.9	35.7	57.9	56.8	62.1	62.5	48.5
Belgium	7.6	4.7	6.0	10.3	11.8	10.1	9.5	10.5	17.5	18.1	9.1	9.1	10.6	18.9	22.3	22.6
France	---	---	---	---	---	---	---	---	---	---	---	---	4.3	12.8	29.5	33.7
Germany, FR	---	40.2	37.5	61.6	67.7	73.5	61.8	58.7	74.8	73.4	70.3	70.7	68.6	101.2	115.6	129.9
Italy	6.0	6.9	12.2	15.9	21.6	18.2	18.5	19.7	23.2	30.7	17.2	19.9	24.9	28.6	30.8	32.0
Sweden	8.8	8.7	7.8	12.0	10.4	9.0	8.9	12.6	22.2	17.3	14.5	---	5.4	7.8	9.2	10.3
UK	32.7	28.1	24.4	26.5	30.7	28.6	24.4	21.1	22.0	20.4	20.4	21.3	22.2	22.1	25.5	24.7
Total	160.3	102.4	113.5	144.1	166.2	149.2	145.9	162.7	197.8	205.3	173.5	192.2	198.1	271.0	319.5	324.7

Note : --- Data unavailable

Source: Metal Bulletin Handbook

Table D-14 Changes in Share of Silico-Manganese Imports by Major Countries

(%)

	1965	1966	1967	1968	1969	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980
Canada	---	1.9	3.7	0.9	2.8	0.7	1.2	10.2	5.5	0.2	3.6	6.9	2.7	6.5	7.5	7.1
USA	65.6	11.6	18.9	11.5	11.7	5.8	14.4	14.4	13.8	21.9	20.6	30.1	28.7	22.9	19.6	15.0
Belgium	4.8	4.6	5.3	7.1	7.0	6.8	6.5	6.5	8.9	8.8	5.2	4.7	5.4	7.0	7.0	6.9
France	---	---	---	---	---	---	---	---	---	---	---	---	2.2	4.7	9.2	10.4
Germany, FR	---	39.3	33.0	42.8	40.7	49.3	42.4	36.1	37.8	35.8	40.5	36.8	34.6	37.3	36.2	40.0
Italy	3.7	6.7	10.7	11.0	13.0	12.2	12.7	12.1	11.7	15.0	9.9	10.4	12.5	10.6	9.6	9.8
Sweden	5.5	8.5	6.9	8.3	6.3	6.0	6.1	7.7	11.2	8.4	8.4	---	2.7	2.9	2.9	3.2
UK	20.4	27.4	21.5	18.4	18.5	19.2	16.7	13.0	11.1	9.9	11.8	11.1	11.2	8.1	8.0	7.6
Total	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100

Note : --- Data unavailable

4. Flow of World Trade in Ferro-Manganese

Fig. D-4 illustrates the flow of world trade primarily in high-carbon ferro-manganese which is the most produced and consumed of all ferro-manganese.

When reviewed from the importing side:

The United States imports mostly from South Africa which, when combined with imports from France, accounts for 74% of its total imports. The United States also imports from many other sources including Norway, Belgium, Canada and India.

Federal Republic of Germany imports mainly from Norway and France which jointly account for 68% of its total imports. Other sources of import are South Africa, Brazil, Belgium, etc.

Italy imports mainly from South Africa and France which jointly account for 84% of its total imports. Italy also imports from Federal Republic of Germany,[1)] Belgium and other sources.

When reviewed from the exporting side:

Of South Africa's total exports, the United States accounts for the highest share of 64%. South Africa also exports to Italy, the United Kingdom, Canada and other distinations.

Of France's total exports, the United States accounts for the highest share of 52%. France also exports to Italy, Federal Republic of Germany, Belgium and others.

Norway does not give priority to any particular destination but exports to diverse destinations including Federal Republic of Germany, the United States and many other consuming countries.

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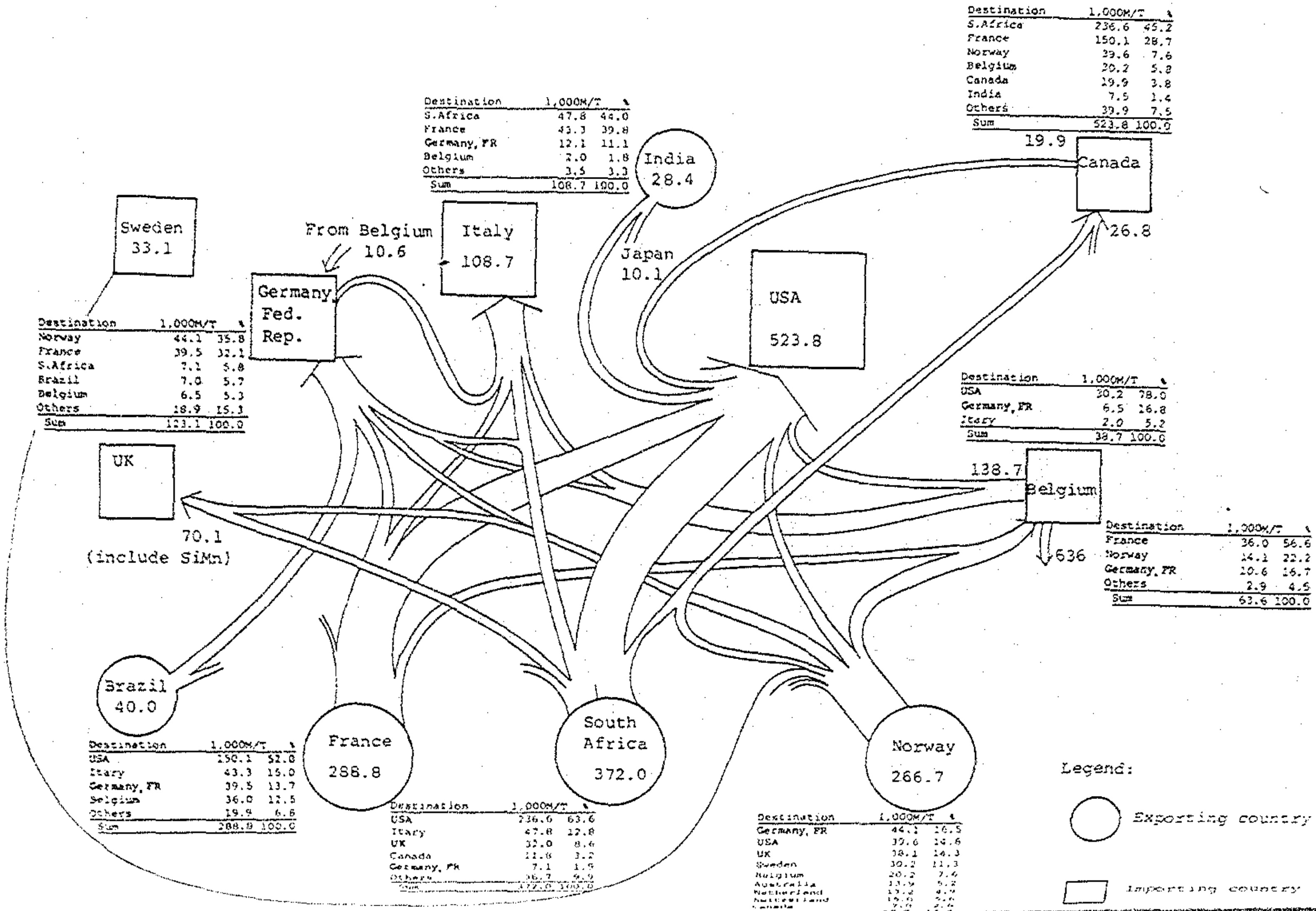
1) Federal Republic of Germany is also a ferro-manganese importer, and what it exports are presumably special products (that with low carbon, low silicon and low impurities).

Fig. D-4 Flow Diagram of World Trade in High-Carbon Ferro-Manganese (1978)



Destination	1,000M/T	%
S.Africa	236.6	45.2
France	150.1	28.7
Norway	39.6	7.6
Belgium	20.2	5.8
Canada	19.9	3.8
India	7.5	1.4
Others	39.9	7.5
Sum	523.8	100.0

Destination	1,000M/T	%
S.Africa	47.8	44.0
France	43.3	39.8
Germany, FR	12.1	11.1
Belgium	2.0	1.8
Others	3.5	3.3
Sum	108.7	100.0

Destination	1,000M/T	%
Norway	44.1	35.8
France	39.5	32.1
S.Africa	7.1	5.8
Brazil	7.0	5.7
Belgium	6.5	5.3
Others	18.9	15.3
Sum	123.1	100.0

Destination	1,000M/T	%
USA	30.2	78.0
Germany, FR	6.5	16.8
Italy	2.0	5.2
Sum	38.7	100.0

Destination	1,000M/T	%
France	36.0	56.6
Norway	14.1	22.2
Germany, FR	10.6	16.7
Others	2.9	4.5
Sum	63.6	100.0

Destination	1,000M/T	%
USA	150.1	52.0
Italy	43.3	15.0
Germany, FR	39.5	13.7
Belgium	36.0	12.5
Others	19.9	6.6
Sum	288.8	100.0

Destination	1,000M/T	%
USA	236.6	63.6
Italy	47.8	12.8
UK	32.0	8.6
Canada	11.8	3.2
Germany, FR	7.1	1.9
Others	36.7	9.9
Sum	372.0	100.0

Destination	1,000M/T	%
Germany, FR	44.1	16.5
USA	39.6	14.6
UK	38.1	14.3
Sweden	30.2	11.3
Belgium	20.2	7.6
Australia	13.9	5.2
Netherland	13.2	4.9
[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]

II. International Transaction Modes

Manganese ore and ferro-manganese are internationally transacted in the same way that usual commodities are transacted but are characterized by the following:

1. The size of manganese ore may range from what may be as large as the size of a human head to what may be as small as 0.5 inch or so. Also no definite mineral composition is specified.

   The size of ferro-manganese is mostly in the range of 10 to 50 mm or 10 to 100 mm, and packing style is normally bulk handling.

2. Normally, they are transacted mostly through trading companies who occasionally adopt the sole agency system. Sometimes there are exceptions, however, where the involvement of trading companies are excluded in dealing with state-run enterprises.

3. Generally, the most normal way of concluding a contract is to agree on the quantity and price by year or by quarter.

   France concludes long-term contracts for definite quantities but makes separate agreements on price.

   Also, a good many spot contracts seem to be concluded but we have not been able to grasp the actual situation.

4. In the case of ore, next year's price is determined by the end of the current year usually according to the following steps.

   First, price negotiation is carried out between one of the major mining companies and one of the major ferro-manganese producers. When an agreement is reached on price, the rest of the mining companies and ferro-manganese producers follow their example and determine their prices along the same line among themselves.

   The price is determined on a CIF basis which means that the ferro-manganese producers in every country buy ore at approximatley the same price.

   The actual market price of ferro-manganese in every country is determined on a cost plus formula. In other words, the ore price is determined in the world market to which power costs, labor costs and others are added according to the standard rates prevailing in each country. In international transactions, the price cannot exceed the market price in the consuming country and if the price of the exporting country based on a cost plus formula underruns this, the actual selling price is determined by both sides meeting half way.

There is no free market price like at London Metal Exchange or producers' price established by a dominant producer.

III. Changes in International Price and Contributing Factors

1. Changes in International Price of Manganese Ore and Contributing Factors

As the price of manganese ore varies greatly depending on grade, impurities contained, and form, it is difficult to make an accurate comparison of the various brands.

Here, we will examine the CIF prices on ores of a similar grade in the Japanese, American and Eurpean markets.

Price movements in these three markets are shown in Table D-15 and Fig. D-5.

The price movements show that the prices in Japan, the United States and Europe are generally on the same level and follow the same trajectory. As for the rate of increase in price, the price almost doubled between 1965 and 1980, but when modified by the change in the exchange rate of US$/SDR (1.302), it is an increase of about 1.7 times.

When we trace the price movements, we see that the price jumped temporarily in 1957 due to a supply shortage. However, by the start-up of the Moanda Mine in Gabon in 1962 and B.H.P.'s Groote Eylandt Mine in Australia in 1966, the market turned into an excess supply and depressed the price to the level of $0.50 to $0.60 per 10 kg. of metric tonne unit Mn content.

Then since 1973, the price began to soar due to the sharp rise in freight in the aftermath of the first oil crisis in 1973 in addition to the fact that supply and demand became tight with the oil crisis having coincided with the peak in worldwide production of crude steel while resource nationalism began to mount among the manganese ore producing countries.

As a consequence, the 1976 price tripled the 1972 level to $1.40 - $1.60.

Since then, the demand for ore decreased because of a cutback in crude steel production by the major steel producing countries of the free world so that the price began to fall from around 1977. But the second oil crisis in 1978 and signs of a pickup in crude steel production pushed the price up again, although not by any large margin, until it reached the record high in 1981. The price since has been levelling off or perhaps slightly softening.

Table D-15 Movements in Manganese Ore Price

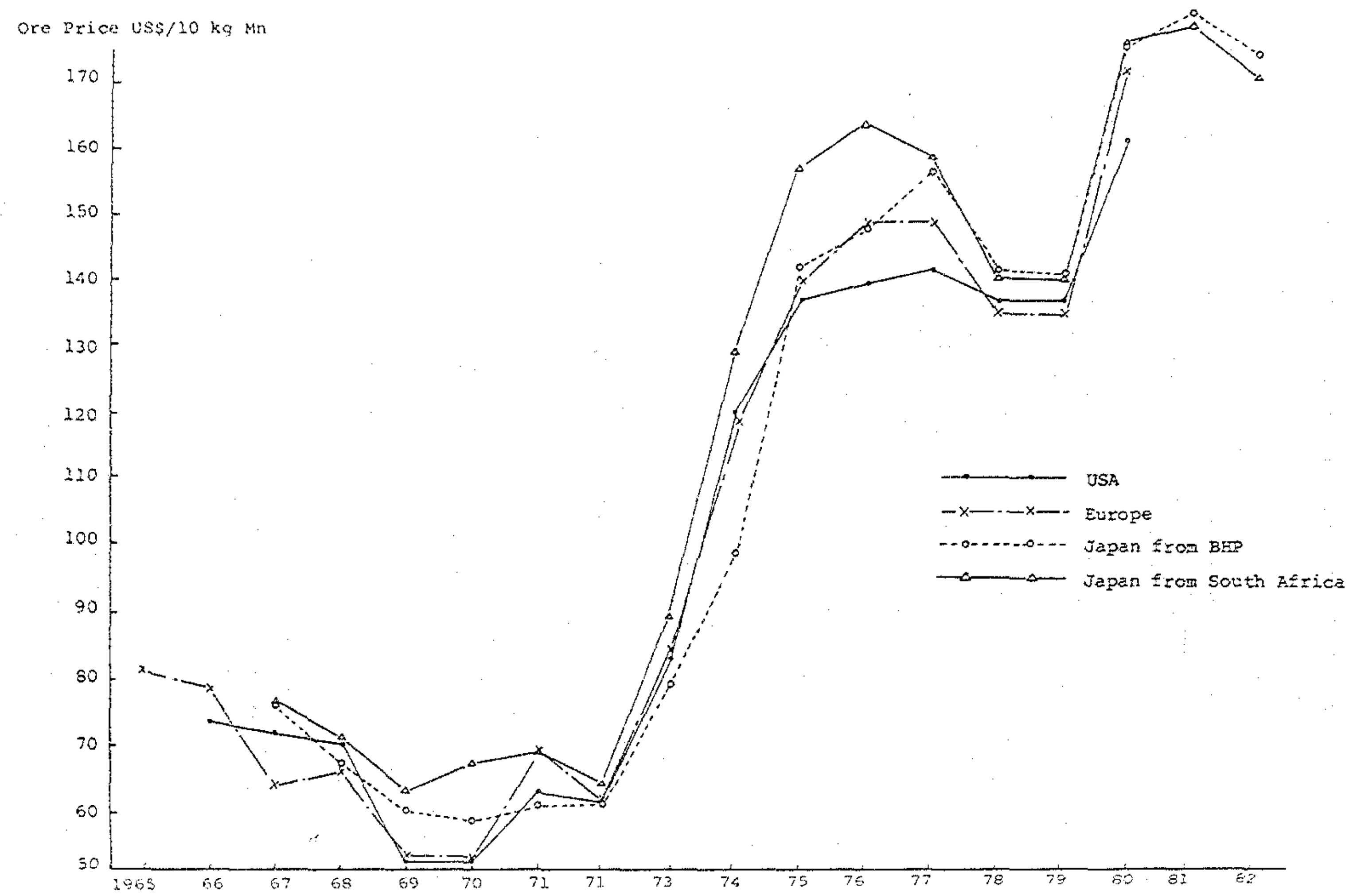
(US¢)

Nation	USA	Europe	Japan	
Quality	Min. 48% Mn low impurity	46-48% Mn max. 0.1% P	Australia 48% Mn Fe below 4%	S. Africa 48% Mn Fe above 10%
1965	---	82	79	84
1966	73	78	76	79
1967	72	64	76	76
1968	70	66	66	71
1969	52	53	60	63
1970	52	53	58	67
1971	63	69	61	69
1972	62	62	62	64
1973	83	89	79	90
1974	120	118	98	129
1975	132	140	142	157
1976	139	148	153	163
1977	142	148	156	158
1978	132	135	142	140
1979	132	135	141	140
1980	161	172	175	175
1981	---	---	180	179
1982	---	---	169	166

Notes : 1) --- Data unavailable
2) Ore Price: US¢, metric tonne unit Mn content, CIF

Source: USA, Europe - Metal Bulletin Handbook
Japan - Estimates by the Study Team

Fig. D-5 Movements in Manganese Ore Price



2. Changes in International Price of Ferro-Manganese and Contributing Factors

In Table D-16, we have shown the movements of the market prices of major countries on high-carbon ferro-manganese to represent all of ferro-manganese products, both in local currency and in US$ equivalent. Fig. D-6 shows the price movements in terms of US$ equivalent.

Table D-16 Movements in High-Carbon Ferro-Manganese Prices

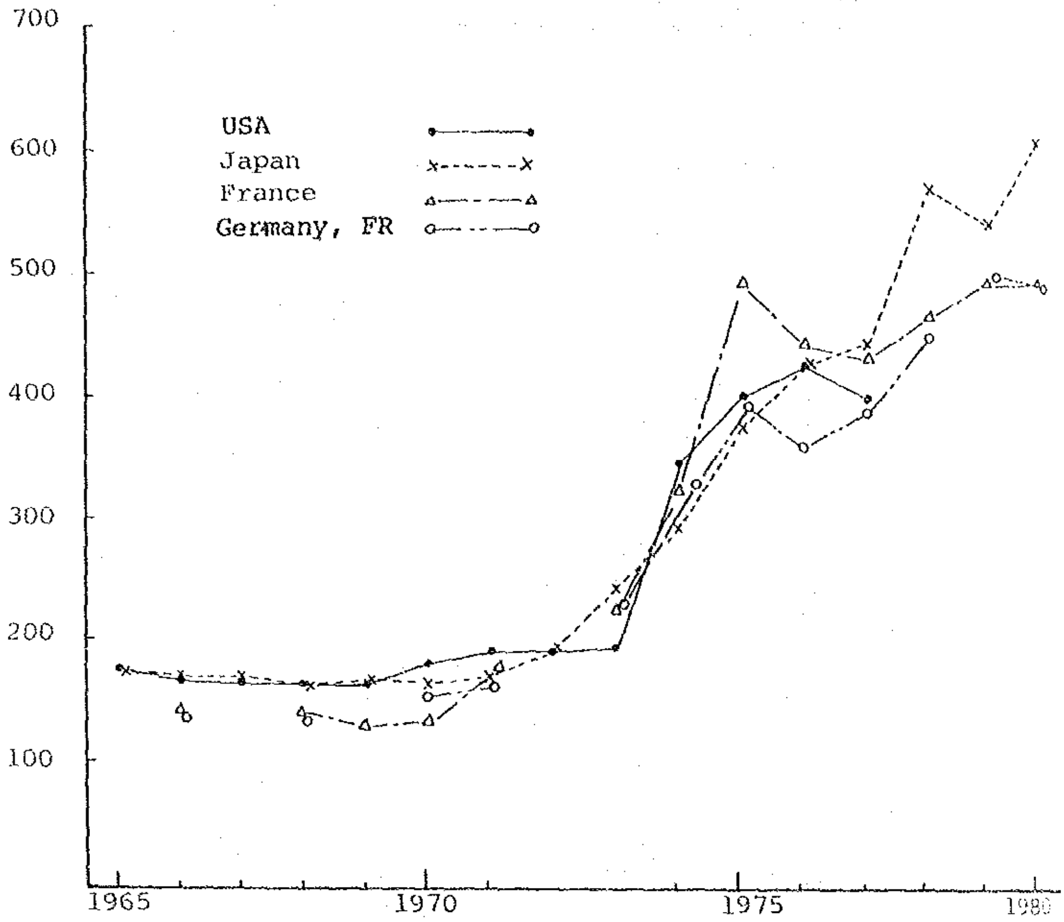
(Price per MT)

Year	USA	Japan		France		Germany, FR	
	US$	¥	US$	F.Fr	US$	D.Mark	US$
1965	175.3	63,000	174.2	---	---	---	---
1966	167.5	62,000	171.1	708.0	144.1	565	141.3
1967	166.1	62,000	171.1	---		---	
1968	164.5	60,000	166.4	708.0	142.9	536	134.3
1969	164.5	59,000	164.6	690.0	132.7	---	
1970	181.3	59,000	164.7	750.0	135.7	558	153.0
1971	190.0	59,000	169.5	990.0	179.7	565	162.3
1972	190.0	59,000	194.6	---		---	
1973	195.0	66,000	243.3	995.0	223.4	630	235.7
1974	345.0	85,000	291.6	1,544.0	321.0	843	325.8
1975	400.0	97,000	326.8	2,115.0	493.4	1,090	443.0
1976	425.0	112,000	377.7	2,115.0	442.5	900	357.4
1977	400.0	120,000	446.9	2,115.0	430.5	900	387.6
1978		120,000	570.2	2,115.0	468.7	900	448.1
1979	437.0	120,000	547.6	2,115.0	497.1	900	491.0
1980		139,000	613.0	2,115.0	500.5	900	495.1
Rate of rise in prices %							
1979/1966	260.9	217.7	358.3	298.7	347.3	159.3	350.4

Notes : 1) Domestic prices in each country were converted into US$ by the exchange rate (per Foreign Economic Statistical Yearbook of the Bank of Japan) then current.
2) Domestic prices: Domestic producer's price for Japan, and actual market for USA, France, and Germany, Fed. Rep.
3) Size: Sizes 10 - 15 m/m for Japan and lumpy size for USA, France and Germany, Fed. Rep.
--- Data unavailable

Source: Metal Bulletin Handbook and the Study Team

Fig. D-6 Movements in High-Carbon Ferro-Manganese Prices (converted into US$/MT)



A review of these show that the price of high-carbon ferro-manganese began to rise sharply from around 1974 as in the case of the price of ore. A comparison of the prices in 1966 and 1979 reveals that the prices in local currency rose 1.6 times in Federal Republic of Germany, doubled in Japan, rose 2.6 times in the United States and trebled in France, all of which translates into a rise of 3.5 times in U.S. dollar equivalent.

The comparative stability of the prices in local currency of each country bespeaks the declining value of the U.S. dollar during the period.

A review of the movements in price of each country in U.S. dollar equivalent show that prices in 1966 were not much different among them, having ranged between $141 - $171 per MT and that despite a sharp increase triggered by the oil crisis in 1973, they followed approximately the same pattern of movement until 1976 or so.

Ever since, the price in the United States has remained level; in France and the Federal Republic of Germany it is rising slowly (although in terms of each local currency it remains the same); but in Japan, it is soaring at a fast rate. The price gap in terms of U.S. dollar equivalent is also widening. As of 1979, the U.S. price was $437/MT against the Japanese price of $548/MT which means a difference of $110.[1)]

The reason for the higher price in Japan in terms of U.S. dollar equivalent is partly due to the appreciation of the yen exchange rate, but the main reason is the high pace of cost increases due to the high cost of power.

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1) As pricing basis in Japan differs from those of the United States, France and the Federal Republic of Germany (refer to footnotes 2) and 3) of Table D-16), accurate comparisons are difficult to make.

E. SUPPLY AND DEMAND PROJECTION

I. Demand Projection

1. Past Trends and Recent Situations

As stated already, the demand for manganese is supported by the iron and steel industry which consumes 100% of ferro-manganese and more than 90% of manganese ore, and this pattern is unlikely to change for the foreseeable future.

The largest demand in the past was 24.2 million tonnes for manganese ore (in 1979 when crude steel production reached a record high) and 6.14 million tonnes for ferro-manganese (in 1974 when crude steel production recorded its fourth highest in history at 790 million tonnes, but since then the demand for both seems to have fallen due to a cutback in steel production.1)

The free world countries and the planned economy countries each have their own independent channels for supply and demand and hardly any transaction takes place between the two.

2. Projections by Various Institutions

Table E-1 presents the published results of projection made by various institutions. What can be said for all of them is that none of them necessarily clarifies the assumptions and methods employed in projections and the projection was made only on manganese ore and not on ferro-manganese. Also none of the projected demands for manganese ore matches the existing situation as being excessive in the light of the prevailing circumstances.

I.I.S.I. overestimates the prospective growth of crude steel production and hence, the projected demand for manganese ore which is made to slide with crude steel production is also too large.

The U.S. Bureau of Mines makes separate forecasts for the United States and the rest of the world, and the World Bank makes a detailed forecast by estimating the projected growth rates for each region for each intervening period. However, their forecast results, both being expressed in terms of manganese content, are deemed too abstract and the forecast values also too large.

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1) Data on the demands for manganese after 1980 were unobtainable. The demand for 5.64 million tonnes in 1978 is the latest available data on ferro-manganese.

Table E-1 Demand Projections on Manganese Ore by Various Institutions (1,000 MT)

Projecting Institutions	Announced year	Base year			1985	1990	1995	2000	Remark
			Grw., % P.a.	(1,000 MT)					ex: Assumption of Crude Steel production: 1985 year 911 Mil.ton; 1990 year 1,081 Mil.ton; 2000 year 1,524 Mil.ton
ISII (1)	1980, Mar.	1975	3.0		29,000	33,000	--	45,000	
			3.5		30,000	36,000	--	50,000	
			4.0		32,000	38,000	--	57,000	
			Grw., % P.a.	(1,000 MT)		(Mn content)			Figures for year 2,000 in the left-hand side table are mean values between upper and lower limits shown in the righthand side box.
U.S. (2) Bureau of Mines	1980	1978 (1,000 MT)	1.4	USA	--	1,780	--	2,000	
			2.9	Others	--	13,800	--	17,600	
		9,582	2.7	World	--	15,600	--	19,600	
				(1,000 MT)		(Mn Content)			Projected growth rates are as shown in the righthand side box.
World (3) Bank	1982, July	1980		Oceania	1,250	1,450	1,800	--	
				USSR	3,100	3,300	3,800	--	
				Asia	1,070	1,190	1,310	--	
				Africa	4,290	4,800	5,460	--	
				America	1,205	1,460	1,700	--	
				World	11,300	12,650	14,500		
				(1,000 MT)					
Roskill (4)	1982, May		73 - 81 trend lino (Grw., P.a. 0.92%)		26,000	27,000	--	30,000	
			Roskill (" 2.5 %)		27,000	31,000	--	41,000	
			Amax (" 3.21%)		31,000	35,000	--	47,000	
			Publised forcasts 1977/80 (Grw., P.a. 4.21%)		34,000	40,000	--	57,000	

U.S. Bureau of Mines, year 2000:

	Low	High
USA	1,790	2,380
Others	15,600	21,800
World	17,400	24,200

World Bank, Up to year 2000:

Growth, % P.a.	80/85	85/90	90/95
Oceania	3.8	3.0	4.4
USSR	1.3	1.3	2.9
Asia	1.4	2.1	1.9
Africa	2.4	2.3	2.6
America	4.8	4.1	2.6
World	2.4	2.3	2.8

Note : --- Data unavailable

Sources:
1) A.K. Davaies et al., Manganese and the Iron and Steel Industry, Committee on Raw Materials, IISI
2) Gilbelt L. Dehuff and Thomas S. Jones, "Manganese", Mineral Facts and Problems, The U.S. Bureau of Mines
3) World Bank, Price Prospects for Major Primary Commodities Volume IV: Metals and Minerals, July 1982
4) Roskill Information Services Ltd., The Economics of Manganese, 1982

The Roskill Report introduces the forecast results of other institutions as well as its own, but every one of them seem slightly too large at this time.

3. Assumptions for Demand Projection

The demands for both manganese and ferro-manganese fluctuate following changes in the iron and steel production volume. Accordingly, the demand for manganese ore and ferro-manganese can be projected by using the projected crude steel production as a basic parameter and also by taking into account the projected trends in unit consumption of manganese ore and ferro-manganese per tonne of crude steel.

3.1 Projected Crude Steel Production

We adopted IISI's data for crude steel production, but as the forecast is for only up to 1990, we used the projected figures presented in the chapter on pig iron and semi-finished steel of this Study (refer to Table E-2).

Table E-2 Projected Worldwide Consumption of Crude Steel

(million MT)

	1981	1982	1983	1985		1990		2000
World total	707	672	689	749	(1.32)	800	(1.18)	900
Free world countries	457	411	435	487	(1.44)	523	(1.38)	600
Planned economy countries	250	251	254	262	(1.12)	277	(0.80)	300

Note : Figures in parentheses are projected annual growth rates.

Sources: 1) IISI 16th Annual Meeting and Conference (October 1982)
2) The Chapter on Pig-Iron and Semi-finished Steel

3.2 Assumptions for Projecting Demands for Manganese Ore

As we have seen cases of the unit consumption per tonne of crude steel being used as a basic figure in estimating the demand for manganese ore instead of dividing the end-uses into iron and steel related applications and those for other than iron and steel applications like in the Roskill Report[1] and the World Bank forecast[2], we too have adopted the same approach in presenting the actual unit consumption in the free world countries and the planned economy countries as shown in Table E-3 and Fig. E-1.

From these results, we adopted the actual value obtained by the regression equation of 31.8 kg as the projected unit manganese ore consumption for forecasting demand by the free world countries. For the planned economy countries, on the other hand, we took into account the fact that the actual data rose in 1979 and 1980 and, as a result, deemed the projected unit consumption to converge into the 1980 value of 44.7 kg computed according to the regression equation.

3.3 Projection of Demands for Manganese Ore by Consuming Sector

3.3.1 Unit consumption rate of ferro-manganese

More than 90% of manganese ore is used in the iron and steel industry, and a little over half of it for producing ferro-manganese. To forecast the ore volume used for ferro-manganese, the demand may be forecast for each type of ferro-manganese, but as available data are scarce to permit analysis by type to make such an approach difficult, we have used as a basis the metric ton unit Mn content obtained by converting the net volume of manganese used in steel making into unit consumption of net Mn content per tonne of crude steel.

Here, we have used Table C-17 as a reference and also taken into account the anticipated reduction in unit ferro-manganese consumption due to the progress in steel making technology as well as the factors contributing to its increase because of the orientation toward better quality steel i.e. 6.2 kg/MT of crude steel for the free world countries.

As a figure for the planned economy countries, we have decided to use 4.3 kg/MT of crude steel in accordance with the Roskill Report.[3]

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1) Roskill Information Services Ltd., The Economics of Manganese, May 1982
2) World Bank, Price Prospects for Major Primary Commodities, Volume IV; Metals and Minerals, July 1982
3) Roskill Information Services, Ltd., The Economics of Manganese, 1982, p. 55

Table E-3 Changes in Unit Consumption of Manganese Ore

Year	Free World Countries			Planned Economy Countries		
	Crude steel prosuction (million MT)	Manganese ore consumption (1,000 MT)	Unit consumption (kg/tonne of steel)	Crude steel production (million MT)	Managanese ore consumption (1,000 MT)	Unit consumption (kg/tonne of steel)
1965	279.6	9,919	35.5	126.6	8,710	68.8
1966	286.9	8,840	30.8	136.4	8,367	61.3
67	299.7	9,132	30.5	137.2	7,486	54.5
68	317.3	10,013	31.6	144.8	6,797	46.9
69	351.1	10,182	29.0	152.1	7,693	50.6
70	358.7	10,312	28.7	162.4	7,581	46.7
1971	335.3	11,815	35.2	172.1	8,212	47.7
72	366.7	12,406	33.8	180.8	8,634	47.8
73	417.6	12,569	30.1	190.3	9,122	47.9
74	416.3	12,266	29.5	195.6	9,244	47.3
75	354.6	13,134	37.0	203.2	9,262	45.6
1976	380.6	12,643	33.2	202.2	9,579	47.3
77	368.9	11,773	31.9	210.1	9,565	45.5
78	385.1	11,193	29.1	224.8	10,348	46.0
79	404.6	12,635	31.2	224.6	11,550	51.4
80	371.8	---	---	226.2	11,617	51.4

Notes: --- Data unavailable

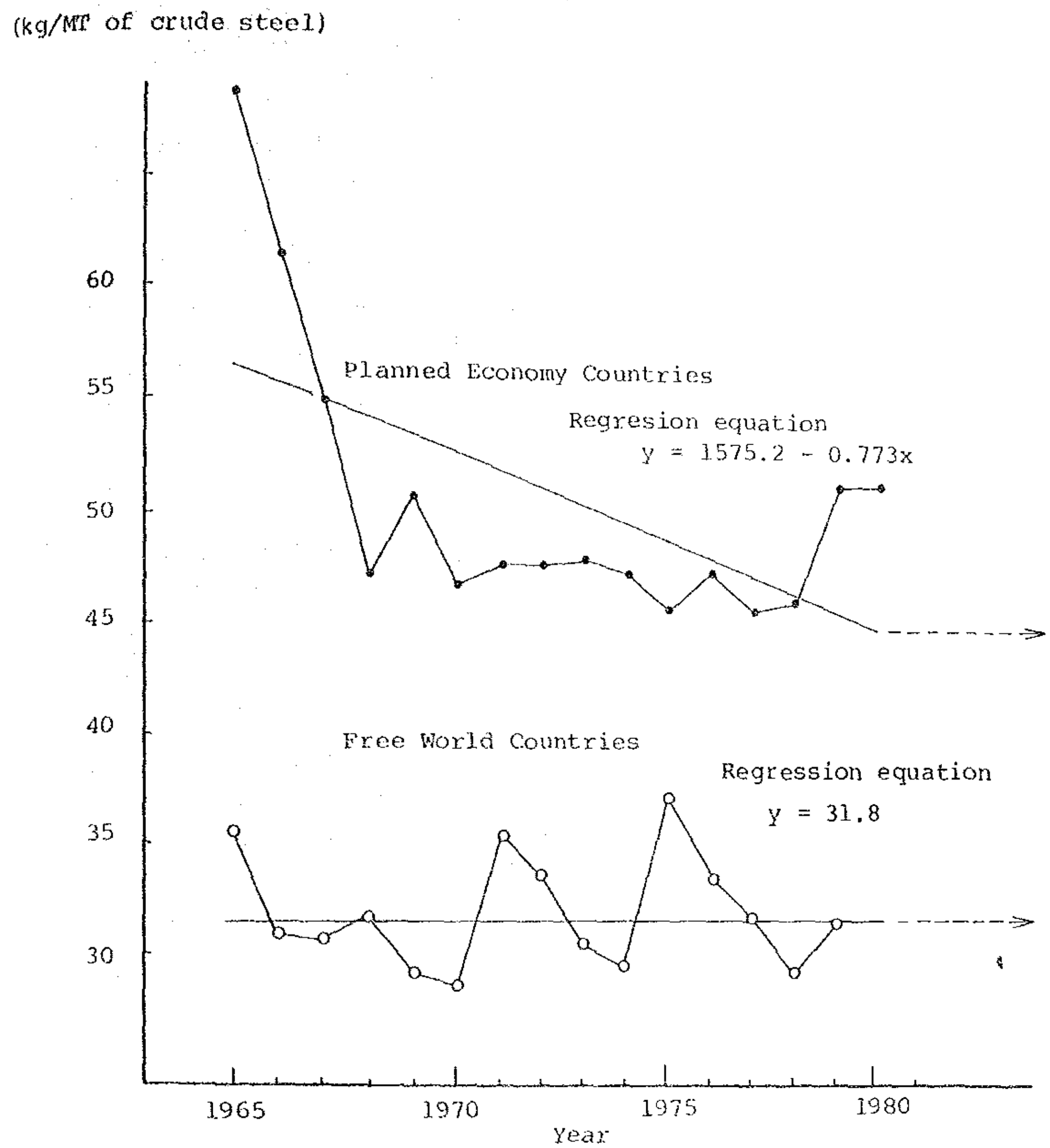
1) The free world countries were represented by Japan, USA, France, the Federal Republic of Germany, UK, Italy, Norway, Spain, Brazil, South Africa, India, and Australia.

2) The planned economy countries were represented by USSR, China, Poland, Czechoslovakia, and German Dem. Rep.

3) Overseas Iron and Steel Statistics by the Japan Iron and Steel Federation is refered.

4) Manganese ore consumption is based on Table C-1.

Fig. E-1 Changes in Unit Consumption of Managanese Ore and Projected Trend



3.3.2 Consumption share of the use in iron and steel

We have already dealt with the trends in manganese ore consumption by end-use in Section C, Subsection II, wherein we mentioned that the consumption share of the iron and steel sector is between 92 to 95% in Japan and between 90 to 94%[1] in the United States. As these consumption shares are considered unlikely to change for some time, we have decided to take 93% - a figure halfway between the two - for projection.

3.3.3 Consumption share of uses other than for iron and steel

The consumption share of the non-iron and steel industry use is therefore the remaining 7%.

The end-use applications can be further classified into chemicals, batteries, ceramics and others. By using the actual data of the United States as a reference, we have taken 3% as the consumption share for chemicals[2] and 1.5% for batteries [3], both being applicable only to the free world countries.

4. Demand Projection

Projected demands for ferro-manganese and manganese ore are presented in Tables E-4 and E-5 respectively. These projections were made on the basis of the projected crude steel consumption and assumptions detailed in the foregoing section. As for the projection for year 2000, we considered that the growth rate projected for the period after 1990 might have been too conservative reflecting the current economic environment, and also because we lacked sufficient technical data to discuss probable changes in consumption trends of ferro-manganese, we modified the mean growth rate between 1990 and 2000 by 0.5% upward and downward to assume both a high and low case.

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1) If we translate the imported ferro-manganese of Table C-9 into equivalent manganese ore for 1973 and thereafter when U.S. import of ferro-manganese began to increase, the consumption share for iron and steel after 1973 also ranges between 90.2 and 92.6%.

2) The U.S. consumption share between 1970 - 1980 is 2.8 to 5.4% according to the Manganese Ore Handbook and 2.8 to 5.4% between 1969 - 1979 according to USBM.

3) The U.S. consumption share between 1970 - 1980 is 1.1 to 2.1% according to the *Manganese Ore Handbook* and 1.2 to 1.6% according to USBM.

Table E-4 Projected Demand for Ferro-Manganese

(1,000 MT)

	1982	1983	1985	1990	2000		
					Low	Standard	High
Ferro-Manganese							
Free World	3,500	3,700	4,140	4,450	4,860	5,100	5,360
Centrally planned economies	1,480	1,500	1,550	1,630	1,680	1,770	1,850
Total	4,980	5,200	5,690	6,080	6,540	6,870	7,210
(Ore volume for producing ferro manganese)							
Free World	7,700	8,140	9,110	9,790	10,690	11,200	11,790
Centrally planned economies	3,250	3,300	3,410	3,590	3,700	3,890	4,070
Total	10.950	11,440	12,520	13,380	14,390	15,090	16,860

Notes: 1) Unit consumption rate of ferro-manganese

Free World

8.5 kg ferro-manganese/tonne of crude steel

(. Mn content 6.2 kg/tonne of crude steel
. Mn content in ferro-manganese is deemed at 73%.)

Centrally planned economies

5.9 kg ferro-manganese/tonne of crude steel

(. Mn content 4.3 kg/tonne of crude steel
. Mn content in ferro-manganese is deemed at 73%.)

2) Ore volume for producing ferro-manganese

Unit ore consumption for producing ferro-manganese is deemed at 2.2 tonnes/tonne of ferro-manganese.

Table E-5 Projected Demand for Manganese Ore

(1,000 MT)

		1982	1983	1985	1990	2000 Low	2000 Standard	2000 High
Total gross weight of ore								
	Free World Countries	13,070	13,833	15,487	16,631	18,150	19,080	20,040
	Planned Economy Countries	11,220	11,354	11,711	12,382	12,760	13,410	14,090
	World Total	24,290	25,189	27,198	29,013	30,910	32,490	34,130
(By End-Use)								
Free World Countries	Iron and Steel							
	Use in ferro-manganese	7,700	8,140	9,110	9,790	10,690	11,220	11,790
	Use in blast furnace	4,455	4,725	5,293	5,677	6,190	6,524	6,847
	Subtotal	12,155	12,865	14,403	15,467	16,880	17,744	18,637
	Other than Iron and Steel							
	Use in chemicals	392	415	465	499		572	
	Use in batteries	196	207	232	249		286	
	Other uses	328	346	387	416		478	
	Subtotal	916	968	1,084	1,164	1,270	1,336	1,403
	Total	13,070	13,833	15,487	16,631	18,150	19,080	20,040
Planned Economy Countries	Iron and Steel							
	Use in ferro-manganese	3,250	3,300	3,410	3,590	3,700	3,890	4,070
	Use in blast furnaces	7,185	7,259	7,481	7,925	8,167	8,581	9,034
	Subtotal	10,435	10,559	10,891	11,515	11,867	12,471	13,104
	Other than Iron and Steel	785	795	820	867	893	939	986
	Total	11,220	11,354	11,711	12,382	12,760	13,410	14,090

Notes:
1) Unit consumption of manganese ore: See Fig. E-1
Free world countries 31.8 kg/MT of Crude steel
Planned economy countries 44.7 kg/MT of Crude steel

2) Share in total consumption:
For both free world countries and planned economy countries:
Iron & Steel : 93%
Other than Iron & Steel: 7%

3) Share by non-iron & steel end-use in total consumption:
For free world countries only:
Use in chemicals: 3% Use in batteries: 1.5%

II. Supply and Demand Balance

1. Supply and Demand Balance of Manganese Ore

As hardly any trade is transacted between the free world countries and the planned economy countries, we have reviewed the balance between supply capacities and projected demand for each bloc separately as summarized in Table E-6 below.

Table E-6 Supply and Demand Balance of Manganese Ore

(1,000 MT)

	Supply capacity	Demand			Diffe-rence
		Low	Standard	High	
(Free World countries)					
1983	18,200		13,833		4,367
1985	18,200		15,487		2,713
1986	21,300		15,710		5,590
1990	21,300	(16,631)	16,631	(16,631)	4,669
2000		18,150	19,080	20,040	3150 - 1260
(Planned economy countries)					
1983	12,000		11,354		646
1985	12,000		11,711		299
1987	12,000		11,990		10
1900	12,000		12,382		382
2000	12,000	12,760	13,410	14,090	760 - 2090

Accordingly, if the development projects are carried out as planned in the free world countries, a surplus supply of 4.367 million tonnes will result in 1983. But the largest surplus would reach 5.59 million tonnes [1] immediately after such projects as Rio Doce's one million tonne in Brazil, Comilog's 1.6 million tonne in Gabon and B.H.P.'s 0.5 million tonne in Australia, all of which are planned for 1986 and later, have been implemented, and in the year 2000, there would still be an excessive supply of between 1.26 to 3.15 million tonnes.

However, if all of the development projects which are planned for 1986 and later are postponed, a supply shortfall will result in and after 1997[2] if we assume a standard case of demand growth and in and after 1995[3] if we assume a high case of demand growth.

In the planned economy countries, supply and demand would be brought to balance in 1987 if all goes as they are now and a shortage of 380 thousand tonnes would occur in 1990.

2. Supply and Demand Balance of Ferro-Manganese

When we review the relationship between supply capacity and projected demand, we see that both the free world countries and the planned economy countries have surplus supply capacities. Even in the year 2000, the excessive supply capacities are estimated to range between 2.1 to 2.6 million tonnes in the free world countries and between 0.63 to 0.80 million tonnes in the planned economy countries.

Even if the expansion projects slated for 1990 and later are foregone, there will still be a surplus capacities of 1.5 to 2.0 million tonnes in the free world countries and 0.18 to 0.35 million tonnes in the planned economy countries.

---

1) It was assumed that all of the projects will be implemented in 1986.

2&3) The demand for manganese ore in the free world countries (1,000 MT)

	Low case	Standard case	High case
1995	17,380	17,810	18,250
1996	17,530	18,060	18,600
1997	17,680	18,310	18,950

Table E-7 Supply and Demand Balance of Ferro-Manganese

(1,000 MT)

	Supply capacity	Projected demand			Diffe-rence
		Low	Standard	High	
(Free world countries)					
1983	6,811 Note)		3,700		3,111
1985	6,811		4,140		2,671
1990	7,461		4,450		3,011
2000	7,461	4,860	5,100	5,360	2,101 - 2,601
(Planned economy countries)					
1983	2,030		1,500		530
1985	2,030		1,550		480
1990	2,480		1,630		850
2000	2,480	1,680	1,770	1,850	630 - 800

Note: (Table B-8, Free world capacity 6,661 thousand MT) +
(Table B-10, 150 thousand MT capacity addition by South Africa)
= 6,811 thousand MT

F. COMMENTS ON POSSIBILITY OF EXPORT FROM CARAJAS

I. Manganese Ore

Projected supply and demand of manganese ore is as shown in Table E-6. A number of countries of the free world are planning to step up production which is resulting in a tendency of excessive supply. However, if these expansion programs are not carried out, then a supply shortage is certain to occur.

If the supply capacity in 1983 remains unchanged, the possible shortage for the year 2000 is estimated to be between 0.88 and 1.84 million tonnes for the free world countries as shown below, in which event, it will give Brazil and the other countries such as Gabon and Australia a chance to implement their production expansion projects.

Shortage in the Year 2000

(1,000 MT)

	Free world countries	Planned economy countries	World total
Low case		760	760
Standard case	880	1,410	2,290
High case	1,840	2,090	3,930

II. *Ferro-Manganese*

The relationship between supply capacity and projected demand for ferro-manganese is as shown in Table E-7 which shows excessive supply capacities in both the free world countries and the planned economy countries. The excess supply of the free world countries is expected to reach 3.11 million tonnes in 1983, and even if the currently known expansion projects which are presumed to be implemented in 1990 are not carried out, there would still be a surplus supply of 1.45 to 1.91 million tonnes in the year 2000.

For the planned economy countries, too, their 1983 supply capacity would still be sufficient to supply the projected demand in the year 2000.

Under the above described circumstances, facility expansions would not be required for some time. However, if we consider the phenomena of scrap and build due to aging of facilities[1)] and also energy issues and resource issues, there might be a chance for Brazil to expand its ferro-manganese industry.

If we are to consider the possibility of Brazil expanding its ferro-manganese industry, it would have to satisfy the following conditions:

a. Resources such as manganese ore must be inexpensive and a stable supply of them must be secured.

b. Stable supply of electricity as energy source must be secured.

c. Although only in the specified area, infrastructures adequate to operate a plant must be provided.

d. Market outlets must be secured (quality must be stable and the price cheap).

e. Quality of labor must be satisfactory.

f. Expansion of the industry must be in keeping with the national policy.

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1) As there are differences in the year constructed and model of each facility and also differences in circumstances of each country, it is difficult to estimate when each facility will become obsolete.

[5] COPPER AND COPPER CONCENTRATE

[5] COPPER AND COPPER CONCENTRATE

CONTENTS

[5] COPPER AND COPPER CONCENTRATES

A. OUTLINE OF THE EXTRACTION AND USE OF COPPER

I. Properties and Applications

Copper has the longest history of use among the metals, having been used by mankind since 4,000 to 3,000 B.C. Along with progress in human culture and technology, the applications for copper have expanded and the consumption has increased. It has now become the most important metal after iron and aluminum.

The metal has a range of useful properties such as:

a. High electrical and thermal conductivity
b. Toughness, superior forgeability and ductility, and good workability
c. High resistance to chemicals means that it is not corroded easily
d. Fine metallic luster
e. Ready combination with many other metals such as zinc and nickel to produce alloys

Furthermore, the worldwide distribution of copper ore and the relative ease with which it is smelted are crucial factors that have promoted the use of copper as a metallic material.

In ancient times, copper was used for utensils in daily life because of its mechanical strength and processability. Its beautiful luster, rarity and corrosion-resistance also resulted in its extension to uses such as for ritualistic implements and personal ornaments.

During the medieval period, the invention of gunpowder and artillery increased the demand for bronze, a strong copper-alloy used to make firearms.

Although the principal role of metals in the Industrial Revolution in the 18th century was taken by iron, copper, in the form of brass, also established an essential place among industrial materials and its production increased to provide metal parts of machines and devices for steam engines, ships, rolling stock and so on.

However, the greatest increase in the demand for copper was accounted for by the advent of the age of electric power and telecommunications in the 19th century. This was triggered by the invention of power generators, electric motors and communication equipments. The progress in electrification and the diffusion of telecommunications led to a rapid increase in the consumption of copper. This, in turn, promoted worldwide exploration for copper and modernization of the mining, milling, smelting and fabricating processes, resulting in the modernization of the copper industry at the beginning of the 20th century.

The present copper market falls into two groups of uses, i.e., electrical conductors and structural materials. The major use in the former group is for electrical wire and cables, and that in the latter group includes elongated copper and copper-alloy products.

The demand for copper for electrical conductors has been increasing along with worldwide economic growth, and it is expected to continue increasing. However, steel-reinforced aluminum conductors are replacing those made of copper in the field of high-voltage overhead transmission lines, and fiber-optics cables may take over copper in the field of telecommunication systems which still remains an area of high growth.

The use of copper as a structural material covers a wide range of applications from machinery to architecture, but in many sectors of these industries copper faces severe competition from newly-developed materials such as products made of stainless steel, aluminum and plastics, and is now suffering a loss in its position mainly because of its price. The consumption of copper as a structural material has thus recently declined.

The primary reason for the substitution of copper by other materials is that the price of copper has repeatedly fluctuated greatly over the past century, due to the imbalance in supply and demand caused by wars and speculative activities.

Although a proportion of electrical conductors made from copper has been or may be replaced with other materials, the superiority of copper in this market is very firm, and its proportion of the market for industrial materials is unlikely to change in the future. The relative position of elongated copper and copper-alloy products in the market for structural materials will be somewhat lower, but the absolute consumption is not expected to decrease.

II. Type of Ore and Ore Deposits

Copper ores can be divided into sulfide and oxide ores, and native copper. Sulfide ores account for 85% to 90% of worldwide copper mine production and oxide ores, 10% to 15%, but native copper supplies less than 1%. Many mines consist of oxide ores near the surface and sulfide ores in deeper strata. These ores generally contain sulfide and silicate minerals of other metals. The principal copper minerals are shown in Table A-1.

Table A-1 Principal Minerals from which Copper is Extracted

Mineral	Theoretical composition	Theoretical % Cu	Principal occurrence
Sulfides			
Chalcopyrite	$CuFeS_2$	34.6	General
Chalcocite	Cu_2S	79.9	General
Bornite	Cu_5FeS_4	63.3	General
Covellite	CuS	66.4	African Copper Belt
Oxides			
Malachite	$CuCO_3.Cu(OH)_2$	57.5	General
Azurite	$2CuCO_3.Cu(OH)_2$	55.3	General
Chrysocolla	$CuSiO_3.2H_2O$	36.2	General
Antlerite	$Cu_3SO_4(OH)_4$	53.7	Chuquicamata (with other sulphates)

Source: A. K. Bismas, <u>Extractive Metallurgy of Copper</u>

The types of copper deposits are as follows:

a. Massive ore deposits

In its broad definition, this type of deposit includes bedded deposits. The ore bodies of massive deposits are in the form of lumps with a relatively high copper content. Most of the deposits include a mixture of ores of other metals. Massive ore deposits exist in parts of eastern North America, parts of southern Africa, Australia and Japan.

b. Strata-bound deposits

These are bedded ore deposits consisting of compact, hard and massive ores which have a small amount of gangue minerals. These deposits occur in the so-called "African Copper Belt" in central Africa.

c. Porphyry deposits

These are large disseminated deposits associated with porphyry, the copper grade of which is generally as low as 0.3% to 2.0%. The distribution of porphyry deposits is horizontal rather than vertical so that large-scale open-pit mining is practicable. A typical porphyry deposit is located in the "Andes-Rocky Mountains Copper Belt" that runs from Chile to western Canada through Peru, Panama, Mexico and North America. A similar porphyry deposit occurs along the Circum-Pacific Volcanic Belt which covers a belt from the Philippines to Papua New Guinea.

The world mineable copper ore reserves with present technology total 493 million tonnes, and the foremost copper mines are in the following four areas:

a. Circum-Pacific Belt
b. Manitoba, Ontario and Quebec regions in eastern Canada
c. Zaire and Zambia at the center of the African Copper Belt in central and southern Africa
d. Kazakhstan and Dzhezkazgan regions in the southeastern USSR, and the Udokan region, a new mining area in Siberia.

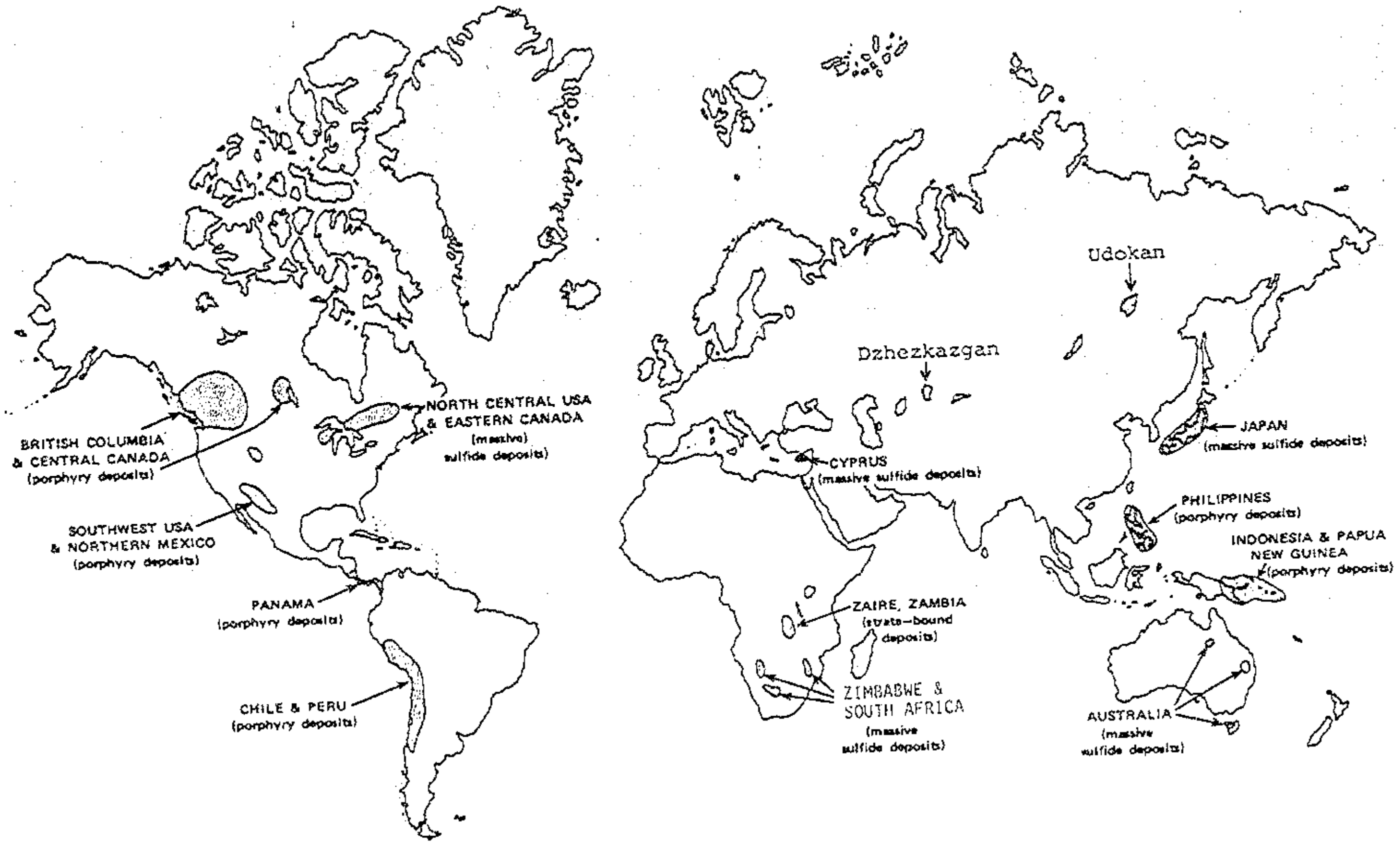
The characteristics of each area are as follows: (1) in the Circum-Pacific Belt, copper mines in Japan and Australia consist of massive sulfide deposits, while others have large porphyry deposits, and as a whole the Belt forms the nucleus of the worldwide copper ore reserve; (2) mines in eastern Canada are massive sulfide deposits coexisting with nickel or zinc; and (3) in Zambia and Zaire copper ores are strata-bound deposits containing cobalt and some other metals. (Refer to Fig. A-1).

III. Outline of Production Technologies

1. *Mining and Milling*

The methods for mining copper ores are roughly grouped into the following two types:

Fig. A-1 Principal Copper Deposits of the World



Source: R.F. Mikesell, <u>The World Copper Industry</u>

a. Open-pit mining
b. Underground mining

Open-pit mining is a method to directly stope copper ore bodies from the earth's surface by stripping off the surface soil. This method is therefore suitable for deposits where ore bodies are exposed at the surface or occur in wide, shallow and horizontal strata just below the surface.

Underground mining is a method of extracting copper ore through excavation of shafts and inclines, and is suitable for deposits where ore bodies lie deep underground or are distributed vertically. There are various underground mining methods, and typical ones are:

a. Cut and fill
b. Room and pillar
c. Block-caving
d. Sub-level caving
e. Shrinkage stoping

The choice of the most suitable method depends on factors such as the shape of the ore body and the strength of the host rock.

Crude ores from a mine are smashed with a crusher and then pulverized in a grinding mill. Through the flotation process, these pulverized pieces are stirred in a bath containing a diluted aqueous solution of a collector, during which particles containing copper adhere to air bubbles floating on the surface. These bubbles are gathered, dehydrated and dried, thus resulting in copper concentrates, the grade of which is generally 20% to 40%. Residual waste from the solution is dumped as tailings.

In contrast, because the flotation process is not effective for oxide ores, crude oxide ores are pulverized, followed by leaching with sulphuric acid to form dissolved copper sulphate from which impurities are then separated. The dissolved copper in solution is precipitated using scrap iron, forming cement copper (60% to 80% copper content). This cement copper is supplied as the raw material for smelting. The dissolved copper in solution can also be treated by another means, the hydrometallurgical process, explained later, through which copper is extracted electrolytically.

2. Smelting

The main process for copper smelting is pyrometallurgical smelting, and the hydrometallurgical process is applied to only low-grade ores and oxide ores for which the concentration process cannot be used economically.

The pyrometallurgical smelting of copper consists of three principal processes: smelting to produce matte, converting of the matte into blister copper, and electrolytic refining to purify the blister copper. A flow diagram of these three processes is shown in Fig. A-2.

2.1 Smelting

Smelting is a process through which the iron component in copper concentrates is oxidized and combined with silica, which is added as a flux, to form molten slags, while the copper component is thickened to form molten mattes. The main smelting methods refer to different types of furnace as follows:

a. Reverberatory furnace
b. Flash furnace
c. Electric furnace
d. Continuous smelting furnace

Continuous smelting method utilizes a furnace that continuously performs both the smelting and converting processes.

2.2 Converting

Through the converting process, the iron component in mattes is completely oxidized and removed in the form of slags, and the copper component is condensed to form blister copper. Because excessive reaction heat is generated during the converting process, coolants such as reverts including, for example, anode scraps and used copper scraps, are fed to the furnace.

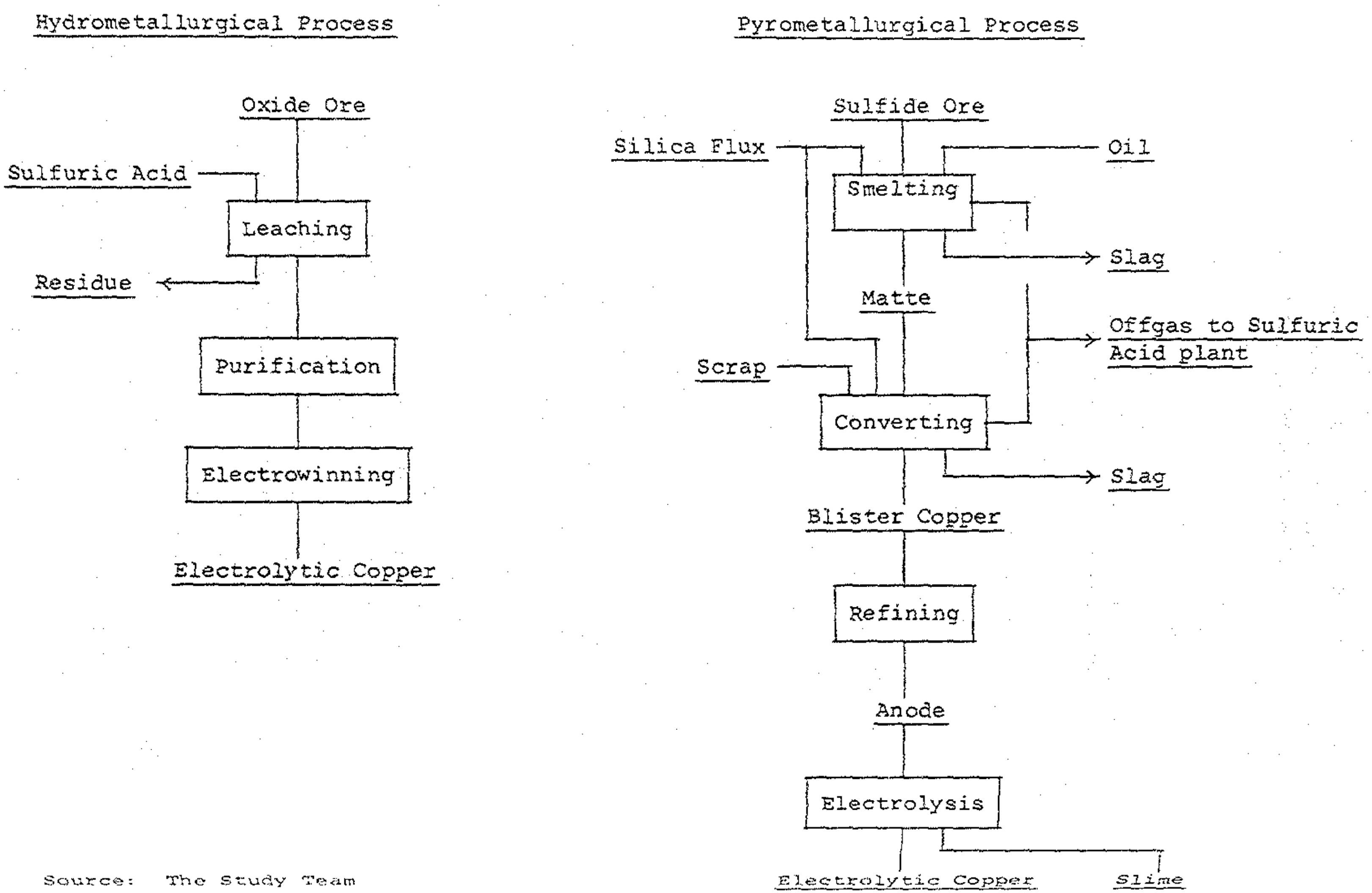
2.3 Electrolytic Refining

The molten blister copper (98.5% to 99% grade) is transferred to the refining furnace, where impurities are removed by oxidation and the copper component is deoxidized with reductants such as ammonia to upgrade it to about 99.5%, and the resulting product is cast into anodes. These anodes are purified electrolytically into 99.99% grade cathodes which are generally called refined copper.

The term of fire-refined copper refer a purified grade of copper of 99.8% to 99.9% without electrolytic refining, but this grade of copper is not suitable for use in electrical industries, and its production is less than 5% of the world total production of refined copper.

Some of the electrolytic copper, the final product in the

Fig. A-2 Copper Extracting Processes



Source: The Study Team

copper smelting process, is put on the market as it is. A proportion of the product is, depending on applications, melted again or purified as well to adjust the content of impurities such as oxygen to produce oxygen-free and tough-pitch coppers, as well as to produce deoxidized copper by a treatment with deoxidizers such as phosphorus, in a variety of product forms such as cake, billet, wire-rod and so on.

3. Copper Scrap

Copper scrap is one of raw materials for copper and is as important as copper concentrates and blister copper. Because the unit price of copper by weight is relatively high and the metal has good resistance to corrosion, abrasion and breakage, copper portions of offcuts coming from manufacturing processes for copper products and used finished products are recovered and reused as raw materials.

A flow diagram for copper scrap, which represents about 15% of the world production of refined copper, is illustrated in Fig. A-3. The amount of copper scrap recycled through any direct sources of scrap or through copper scrap collection and industrial reuse is more in industrialized countries where historically consumption is great, whereas it is less in developing countries. For instance, the percentage of the production of refined copper from scrap is about 40% in the Federal Republic of Germany, some 20% in the United States and around 10% in Japan.

Copper scrap is classified into new or old scrap according to its origin.

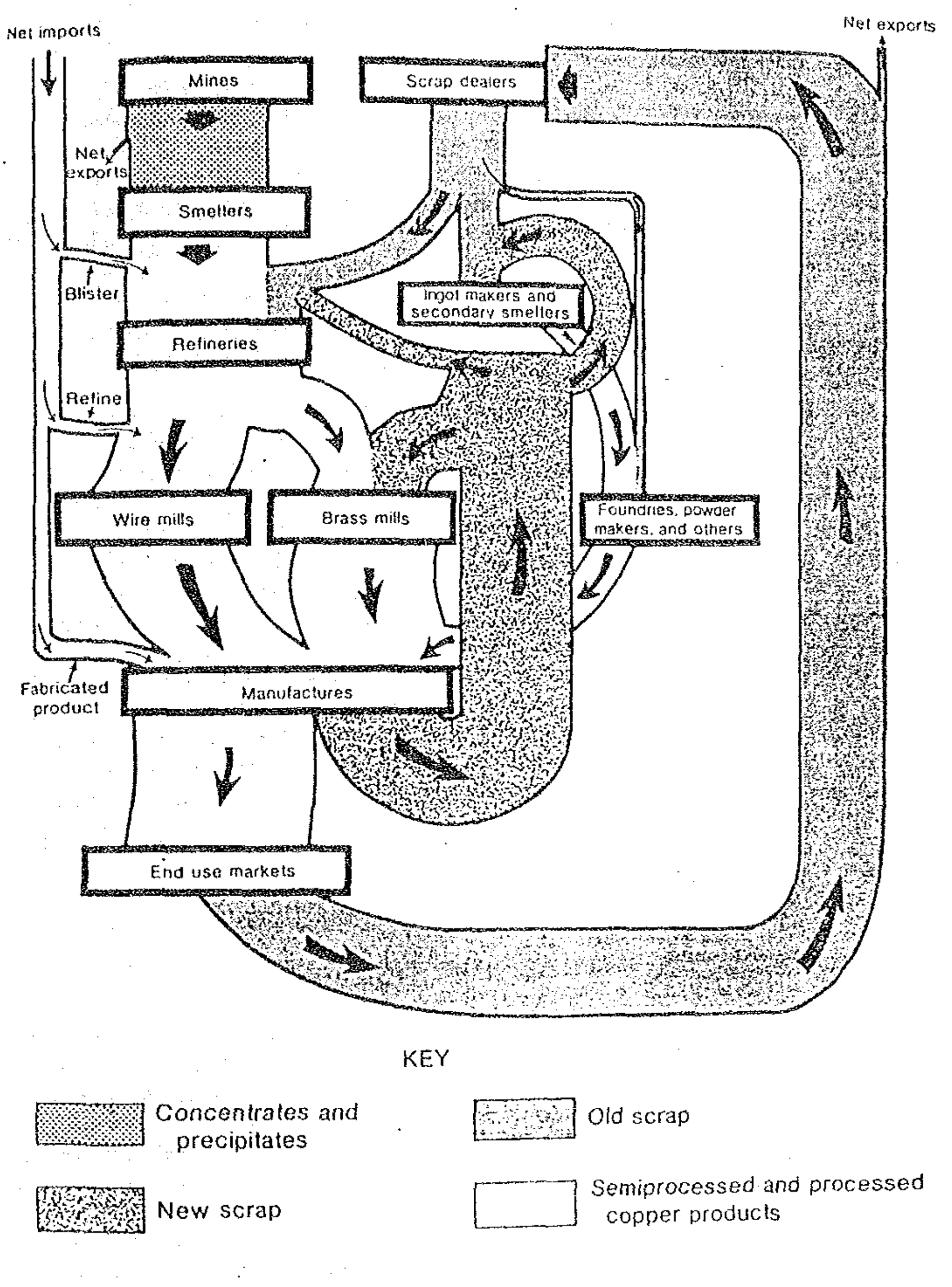
a. New scrap: This comes from various manufacturing processes in electrolytic refining plants and factories producing wrought copper products such as electrical wire cables and castings. Such scraps are usually high grade and quality.

b. Old scrap: This comes from finished copper products after they had been used by consumers and recovered by scrap metal dealers. The grade of such scrap is uncertain and much of it often contains various impurities, thus its quality is low.

Reclamation plants and processes for copper scrap vary depending on the origin and grade of the scrap. In general, new scrap is reused repeatedly in appropriate processes as return-scrap within the production plant. Old scrap is sorted according to grade and impurities; that of higher quality is fed into the anode furnace of an electrolytic refinery or thrown into the melting furnace of a plant producing elongated products, while the lowest grade scrap is returned to the converter furnace of a copper smelting plant or refined in the blast furnace of a secondary smelter which is designed especially for the reclamation of old copper scrap.

In industrialized countries, most copper scrap is ranked according to its origin and grade, and traded domestically and internationally through established distribution networks, the large amount of which has a considerable impact on refined copper markets. A rise in the price of copper will lead to an increase in the supply and recovery of copper scrap, resulting in suppressing the market; while a decline in the price will inhibit recovery and increase the stocks of scrap, which acts to support the bottom of the market. Accordingly, the trends in the supply and recovery of copper scrap are an essential factor that cannot be overlooked in estimating the refined copper supply and the market trends in advanced countries.

Fig. A-3 Copper Scrap Flow Diagram



Source: The U.S. Bureau of Mines (USBM), The U.S. Copper Industry, 1980

B. COPPER PRODUCTION

I. Worldwide Reserves of Copper

A reserve in an area means the amount of ore that has been confirmed as being economically mineable on the basis of the current metal price and established mining techniques. Therefore, any reserves vary over time, according to the technology, the price of metals, restrictive environmental controls and other legal regulations.

A research carried out by the U.S. Bureau of Mines indicates that the worldwide copper resources are an estimated 1.627 billion tonnes plus the 689 million tonnes contained in seabed manganese nodules.

The copper reserve which is economically mineable with present technology is 493 million tonnes, corresponding to 30% of the estimated land-based resources, which excludes seabed manganese nodules.

The world estimated reserves of 493 million tonnes in 1982 are listed by country in Table B-1. The principal reserves are the 97 million tonnes in Chile, which accounts for 20% of the world total and 22% of the free world reserves, 92 million tonnes in the United States (19% of the world total and 21% of the free world), 34 million tonnes in Zambia (7% and 8% in like manner), 32 million tonnes in each of Canada and Peru (6% and 7%), 30 million tonnes in Mexico (6% and 7%) and 24 million tonnes in Zaire (5% and 6%). The total reserves of these seven countries account for about 80% of the reserves in the free world, which indicates the uneven geographical distribution of copper reserves.

II. Trends in Production of Copper Concentrate

The worldwide production of copper concentrate was 5.067 million tonnes in 1965. The subsequent trends indicate that the production increased at an annual rate of 5% reaching 7.683 million tonnes in 1974, which dropped to 7.358 million tonnes in 1975, but recovered to a little under 8 million tonnes in 1977, and continued generally at the same level until 1980. (For copper concentrate production by country, refer to Appendix Table 2).

Although the world production recorded its highest level of 8.322 million tonnes in 1981, it has been expected to drop to a little over 8 million tonnes in 1982, because substantial production cuts have been initiated in the United States and Canada due to the sluggish

Table B-1 World Copper Reserves

(million tonnes of copper)

	Reserve	%	Resource	%
North America				
USA	92	19	472	22
Canada	32	6	173	8
Mexico	30	6	87	4
Subtotal	154	31	734	34
South America				
Chile	97	20	366	17
Peru	32	6	100	5
Others	10	2	83	4
Subtotal	139	28	549	26
Europe and the Near East	22	4	80	4
Africa				
Zaire	24	5	75	3
Zambia	34	7	131	6
Others	12	2	42	2
Subtotal	70	14	248	11
Asia	27	6	117	6
Oceania	23	5	100	5
Planned economy countries	60	12	292	14
World Total (land-based)	493	100	2,120	100
Seabed Nodules	0		689	

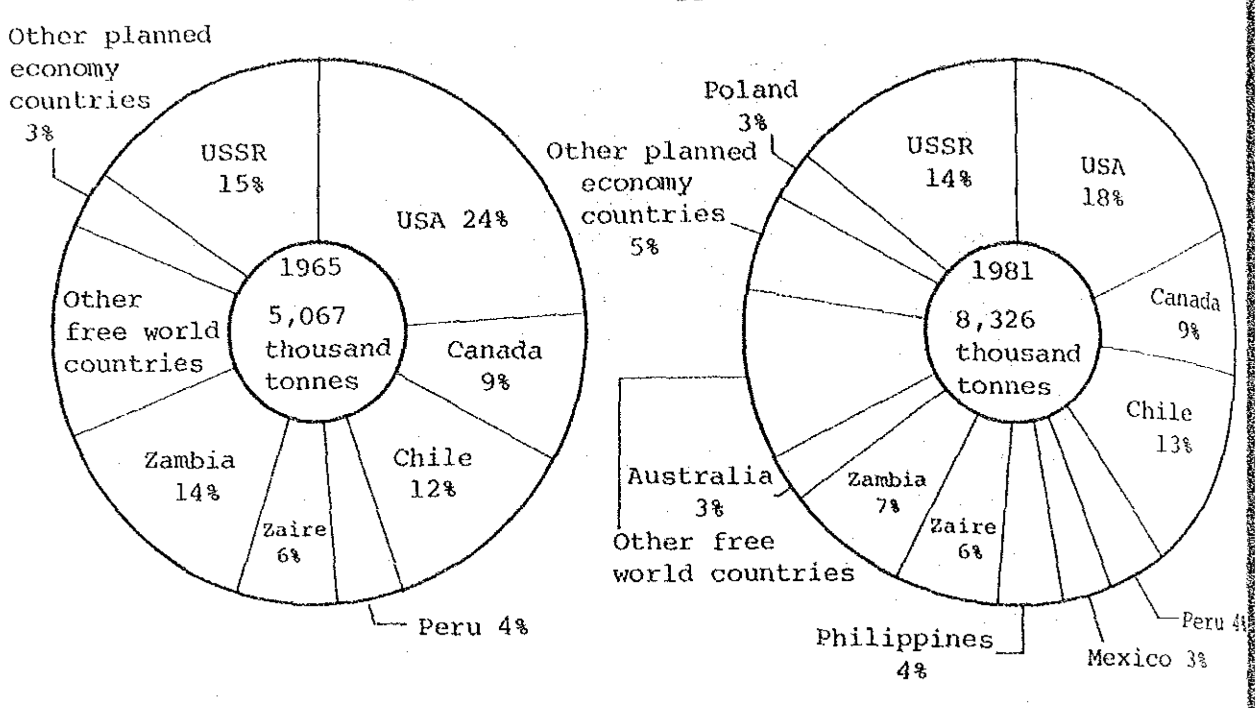
Source: The U.S. Bureau of Mines, The U.S. Copper Industy, 1981

metal prices, and the resulting decline in production seems to be 30% below the production in 1981.

The trends in copper concentrate production from 1965 through 1981 in major countries are shown in Fig. B-1.

The production in the United States was 1.226 million tonnes with a 24% share of the world production in 1965, which has increased to 1.538 million tonnes but the share has dropped to 18% of the world

Fig. B-1 World Copper Mine Production



(1,000 tonnes)

	1965		1970		1975		1981	
USA	1,226	24%	1,560	24%	1,282	17%	1,538	18%
Canada	461	9	610	10	734	10	718	9
Chile	585	12	686	11	828	11	1,081	13
Peru	180	4	212	3	189	3	328	4
Mexico	55	1	61	1	78	1	230	3
EC	3	-	4	-	16	-	7	-
Yugoslavia	63	1	98	2	115	2	111	1
Japan	107	2	120	2	85	1	52	1
Philippines	63	1	163	3	226	3	302	4
Zaire	289	6	387	6	495	7	505	6
Zambia	696	14	684	11	677	9	587	7
Australia	92	2	158	2	219	3	226	3
Papua New Guinea	-	-	-	-	173	2	165	2
Other free world countries	330	7	427	7	619	8	651	8
Free world total	4,150	82	5,170	81	5,736	78	6,494	78
USSR	750	15	925	15	1,100	15	1,140	14
Poland	15	-	83	1	230	3	308	3
Other planned economy countries	152	3	201	3	293	4	384	5
Planned economy countries total	917	18	1,209	19	1,623	22	1,832	22
World total	5,067	100	6,379	100	7,358	100	8,326	100

Sources: Metallgesellschaft, and World Bureau of Metal Statistics (WBMS) total in 1981. The production in other principal countries in 1981 was 1.140 million tonnes (14%) in the USSR, 1.081 million tonnes (13%) in Chile, 718,000 tonnes (9%) in Canada, 587,000 tonnes (7%) in Zambia, and 505,000 tonnes (6%) in Zaire. The total in nine countries, the above six plus Peru, Poland and the Philippines, accounted for about 80% of world production in 1981.

In the period from 1965 through 1981, the production of copper concentrate in Zambia fell from about 700,000 tonnes to about 600,000 tonnes. This represented a drop from 14% to 7% of the world total. In contrast, during the same period, the production increased from 15,000 tonnes to 308,000 tonnes in Poland, quadrupled to 305,000 tonnes in the Philippines, and rose to 230,000 tonnes in Mexico, while it leveled off in Chile, Canada and Peru. In addition to the nine top-ranking countries, Bougainville Mine in Papua New Guinea started its operation in 1972, with a subsequent annual production of 180,000 tonnes (2% of the world total).

III. Trends in Production of Refined Copper

The world production of refined copper was 6.176 million tonnes in 1965, which subsequently increased with an annual growth rate of about 4% to 8.909 million tonnes in 1974. However, the production decreased temporarily just after the first oil crisis and thereafter the annual rate of growth in the production continued at about 1%, resulting in a level of 9.655 million tonnes in 1981.

The reason why the production of refined copper is greater by some 15% than that of copper concentrate is that the former includes the portion produced from copper scrap. The annual growth rates for the production of copper concentrate and refined copper have continued, from 1965 through 1981, in parallel with each other, at roughly similar rates.

The trends in the production of refined copper in major countries since 1965 are as follows: The production in the United States was 1.942 million tonnes (31% of the world total) in 1965, 228,000 tonnes (4%) in the United Kingdom and 342,000 tonnnes (6%) in the Federal Republic of Germany; while that in 1981 was 1.984 million tonnes (21%) in the United States, 136,000 tonnes (1%) in the United Kingdom and 387,000 tonnes (4%) in the Federal Republic of Germany, showing a considerable fall in their shares of the world total.

On the other hand, large increments in production occurred in the following countries over the same period: From 37,000 (0.6% in 1965) to 327,000 tonnes (3% in 1981) in Poland, from 16,000 (0.3%) to 145,000 tonnes (2%) in South Africa, from 366,000 (6%) to 1.05 milion tonnes (11%) in Japan, and from 289,000 (5%) to 776,000 tonnes (8%) in Chile (for an outline of and trends in production by country, refer to Fig. B-2 and Appendix Table 3 respectively).

IV. Production Capacity

The world production capacity and actual production records for the mining, smelting and refining sectors in 1981 are as follows:

	Capacity (1,000 tonnes)	Actual production (1,000 tonnes)	Utilization rate (%)
Mines	9,580	8,326	87
Smelters	9,720	8,316	86
Refineries	10,880	9,655	89

The United States enjoys a position as the country with the largest production capacity from mining through the refining stage in the world, with around a 20% share of the world total in each sector. Production capacities by sector and country are summarized in Table B-2.

The major copper producing countries can be grouped as follows:

a. Self-sufficient countries — mining, concentrating, smelting, refining and consuming copper are consistently carried out within the country — the United States and the USSR.

b. Copper concentrate exporters — Papua New Guinea, the Philippines [1] and Mexico

c. Blister exporter — Zaire

d. Refined copper exporters — Zambia and Poland

e. Exporters of various forms of copper — Canada, Peru and Chile

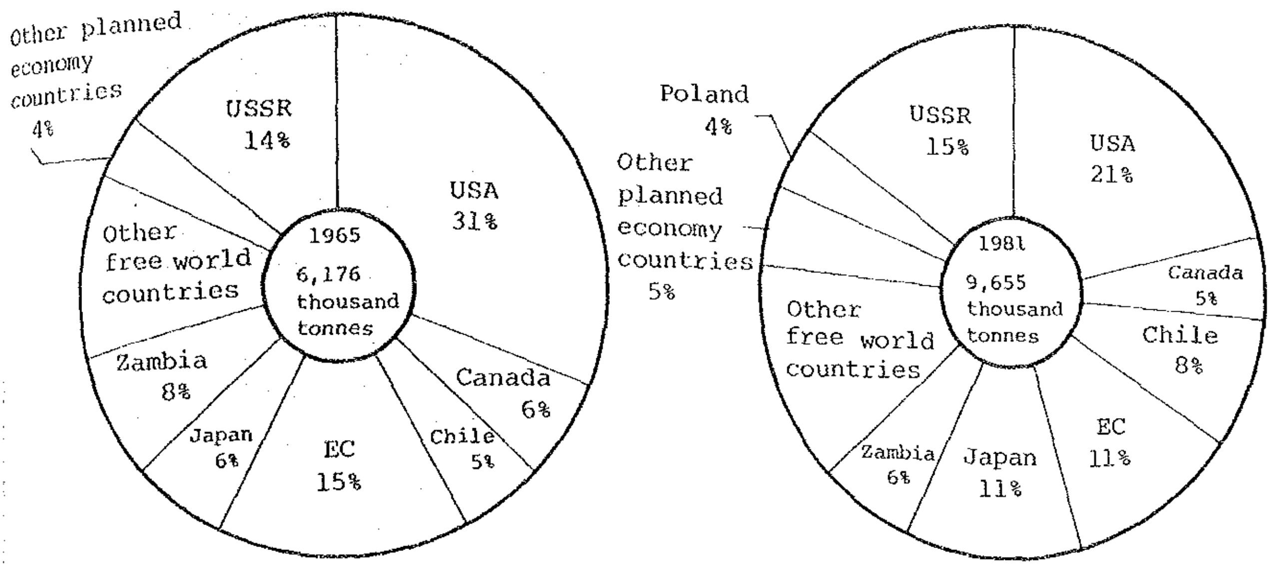
f. Copper concentrate importers — Japan and the Federal Republic of Germany

g. Blister importer — Belgium

The production capacity of copper concentrate in the United States, the largest producer in the world, has recently diminished.

1) A copper smelting plant is now under construction, to be completed in 1983.

Fig. B-2 World Refined Copper Production



(1,000 tonnes)

	1965		1970		1975		1981	
USA	1,942	31	2,035	27	1,610	19	1,984	21
Canada	394	6	493	7	529	6	477	5
Chile	289	5	465	6	535	6	776	8
Peru	41	1	54	1	70	1	209	2
Mexico	46	1	36	-	72	1	68	1
EC	924	15	997	13	967	12	1,022	11
Yugoslavia	56	1	89	1	138	2	133	1
Spain	59	1	83	1	130	2	152	2
Japan	366	6	705	9	819	10	1,050	11
South Korea	-	-	-	-	21	-	113	1
Zambia	522	8	581	8	629	7	564	6
Zaire	152	2	190	3	226	3	151	2
Australia	93	2	146	2	192	2	192	2
Other free world countries	172	3	286	4	352	4	456	5
Free world total	5,056	82	6,160	81	6,290	75	7,347	76
USSR	875	14	1,075	14	1,420	17	1,460	15
Poland	37	1	72	2	249	3	327	4
Other planned economy countries	208	3	257	3	437	5	521	5
Planned economy countries total	1,120	18	1,404	19	2,106	25	2,308	24
World total	6,176	100	7,564	100	8,396	100	9,655	100

Sources: Metallgesellschaft, and World Bureau of Metal Statistics (WBMS)

Table B-2 World Copper Production Capacity - 1981

(1,000 tonnes)

	Mines		Smelters		Refineries	
North America						
Canada	830	9%	640	7%	660	6%
USA	1,660	17	1,690	17	2,240	21
Others	280	3	140	1	120	1
Total	2,770	29	2,470	25	3,020	28
South America						
Chile	1,170	12	1,020	10	820	8
Peru	450	5	410	5	240	2
Others	180	2	-	-	-	-
Total	1,800	19	1,430	15	1,060	10
Europe						
W. Germany	2	-	350	4	450	4
Belgium	-	-	90	1	480	4
Others	318	3	380	4	590	5
Total	320	3	820	9	1,520	13
Africa						
Zaire	570	6	520	6	250	2
Zambia	730	8	620	6	740	7
Others	370	4	300	3	180	2
Total	1,670	18	1,440	15	1,170	11
Asia						
Philippines	400	4	-	-	-	-
Japan	60	1	1,200	12	1,240	12
Others	240	2	220	2	260	2
Total	700	7	1,420	14	1,500	14
Oceania	430	4	230	2	210	2
Planned economy countries						
USSR	1,200	12	1,220	12	1,560	14
Poland	350	4	350	4	400	4
Others	340	4	340	4	440	4
Total	1,890	20	1,910	20	2,400	22
World total	9,580		9,720		10,880	

Source: The Study Team

In 1978 the capacity was 1.81 million tonnes, which decreased to 1.66 million tonnes in 1981, due to successive mine closures stemming from the dull market for copper and its byproducts.

The annual production capacity exceeded 100,000 tonnes in the 1970s in Chile, Peru, the Philippines, Canada, Mexico, and in the USSR and Poland in centrally planned economies.

The total capacity of the eight top-ranking countries, the United States, the USSR, Chile, Canada, Zambia, Zaire, the Philipppines and Peru, accounted for 73% of the worldwide production capacity for copper concentrate at 9.58 million tonnes.

The production capacity of the smelter sector in the United States has also fallen off markedly over the past four years: the smelter production capacity of the United States was about 1.5 million tonnes, 25% of the world total of about 6 million tonnes in 1965, and it increased to 2.045 million tonnes with a reduced share of 22% in 1978, and the share diminished further to only 17% in 1981.

The production capacity of the smelter sector nearly doubled in the 1970s in Japan, Chile, Peru and Poland. The total smelting capacity of the eight top-ranking countries, the United States, the USSR, Japan, Chile, Canada, Zambia, Zaire and Peru, accounted for 75% of the world total capacity of 9.72 million tonnes in 1981.

Similarly, regarding the capacity of the refinery sector, the share of the United States was over 30% of the world total of about 7 million tonnes in 1965, but fell to some 20% in the 1970s. Refining facilities were expanded rapidly in the USSR, Japan and Zambia through the 1960s, and their respective shares were 14%, 12% and 7% in 1981. Chile's share in 1981 was 8%, which was similar to that in the 1970s.

Countries with a high production capacity in the smelter sector, after the United States, the USSR, Japan, Chile and Zambia, are Canada with 660,000 tonnes annual capacity and a 6% share of the world total in 1981, Belgium with 480,000 tonnes (around 4%), the Federal Republic of Germany with 450,000 tonnes (about 4%), and Poland with 400,000 tonnes (some 4%). The total capacity of these nine countries amounts to 8.59 million tonnes, 79% of the world total of 10.88 million tonnes of refinery capacity.

V. New Projects and Plans for Increases in Production

There are about sixty new copper-related projects and plans to expand production capacity in free world countries that are definite at present. The total amount of investment required by these projects exceeds 20 billion dollars. All projects other than those which are now under construction, have been deferred temporarily or indefinitely, due to a slackening of demand and lower prices caused by the prolonged worldwide recession, uncertainty in the long-term outlook, and anxiety over the international financial situation brought about by excessive foreign debts in developing countries.

The principal new projects and expansion plans due to be completed in 1983 or thereafter are listed in Table B-3.

Mine developments are now in progress at Tintaya in Peru and OK Tedi in Papua New Guinea. But concrete development programs for other big projects such as Valley Copper in Canada, Cerro Colorado in Panama and Disputada in Chile have been suspended until the long-term supply and demand situation has improved. This is because they are so large that they require an enormous investment of over one billion dollars.

In addition to the above, an integrated project is progressing at Sar Cheshmeh in Iran to annually produce 158,000 tonnes of refined copper from mining through to refining. Although 99% of the plant has been built, full-scale production had not yet started by 1982.

VI. Production Costs

1. Byproduct Credits and Production Costs

The costs of copper production vary widely depending on various conditions, but the following three are crucial factors.

a. Geological conditions —— copper grade of crude ores, grade of the byproducts, and mining methods and scale.

b. Geographical conditions —— the location of a mine, supplies of water and electric power, and infrastructure such as roads and port facilities.

c. Social and capital conditions —— labor costs, tax systems, the total construction costs, and ways of finances.

The costs for the mining sector are around 70% of the overall production costs of copper. The relative merits of a mine depend basically on the grade of ore and the scale of operation. The existence of byproducts such as gold, silver, molybdenum and cobalt in the ores, and their market prices also greatly influence the copper production costs.

Table B-3 Major Projects Expected in 1983 and Thereafter

Country	Project name	Production scale (copper, tonnes/year)	Expected start-up	Investment (million dollars)
(Mine)				
Canada	Goldstream*	18,000	1983	62
"	Valley Copper*	130,000	Within 3 years after the decision	1,000
USA	Chino	140,000	1983	350
Mexico	Cananea	140,000	1986	250
Chile	Andina	80,000	1985	45
"	Disputada	100,000	Temporarily postponed	1,200
"	Cerro Colorado*	55,000	Within 3 years after the decision	350
Peru	Tintaya*	55,000	1984	327
"	Cerro Verde	70,000	1985	288
Panama	Cerro Colorado*	235,000	Temporarily postponed	1,000
Portugal	Neves Corvo	50,000	1983	40
Oman	Sohar*	20,000	1983	200
Pakistan	Saindak*	30,000	1986	200
Turkey	Kure	25,000	1983	Unknown
Papua New Guinea	OK Tedi	100,000	1986	1,500
Australia	Olympic Dam*	150,000	1995	1,000
(Smelter/Refinery)				
Mexico	Empalme	180,000	1985	210
Yugoslavia	Krivelj	90,000	1985	366
Philippines	Pasar	130,000	1983	250

* These are new mine projects, while others are mainly capacity expansion projects.

Note : OK Tedi already started operation as a gold mine in 1981, and will turn into a copper mine as the mining operation gets down to deeper strata.

Source: Engineering and Mining Journal, International Directory of Mining, 1982

When the value of byproducts that is credited against the copper production costs is converted into the price per pound of copper, it corresponded to several cents (about 10% of the copper production costs) in the 1960s, but rose to over 30 cents (around 30% of the production costs) per pound of copper at many copper mines around the world in the 1980s, during which the value of credits such as gold and molybdenum soared. As a typical example of the considerable significance of byproducts, the itemized production costs at Dizon Mine of Benguet Consolidated in the Philippines are shown in Table B-4.

Table B-4 Production Costs and Byproduct Credits

Direct operating cost	125	cent per pound
Financial charges	47	"
Gross producing cost	172	"
Credit	112	"
Net producing cost	60	"

Note : The crude ore contains copper at 0.5% and gold at 0.96 gram per tonne of ore, and the annual production is 21,000 tonnes of copper and about 4 tonnes of gold.

Source: Benguet Consolidated, Quarterly Report, 1982

Trends in the estimated average of the world net production costs, which is the result of the subtraction of byproduct credits from the gross production costs, are shown in Table B-5. The worldwide average in 1981 was some 90 cents per pound.

Table B-5 Trends in Net Production Cost

Average in the 1950s	50 - 55	cent per pound
Latter half of the 1960s	60 - 65	"
Latter half of the 1970s	55 - 60	"
1981	About 90	"

Source: R. Perlman, Cost Trends and the Recession in the Copper Industry, 1982

The reason that the net production cost was temporarily lower in the latter half of the 1970s than in the same period of the 1960s was the increase in credits due to the rise in the prices of byproducts such as gold and molybdenum. In contrast, the net production cost rose in 1981 because less credits were derived due to a fall in the price of byproducts. Although it might be somewhat meaningless to estimate production costs by country because they vary from mine to mine, not from country to country, a somewhat artificial estimate indicates that one of the countries which has maintained the lowest production costs is Canada which has a relatively lot of copper mines producing zinc and nickel as co-products.

Chile has three large copper mines other than Chuquicamata Mine with ore grade of 2% and a crude ore treatment capacity of 72,000 tonnes per day, which is one of the world's largest mines. Crude ores from these mines are high in copper content despite of porphyry deposits and also contain molybdenum, and their transportation costs are relatively low. These mines have therefore made Chile one of the few copper producing countries that could make profits even in the second half of 1982 during which the market for copper and its byproducts were dull.

Other countries with low production costs are Papua New Guinea, which extracts ores of high gold content, and South Africa's Palabora Mine, where the crude ore treatment capacity is as large as 93,350 tonnes per day and where there are many byproducts including uranium. The detailed production costs of individual copper mines are company secrets and can be estimated only through published data such as annual reports. The range of net production costs of some major copper mines around the world are listed in Appendix Table 1.

2. Break-down of Costs by Process

Production costs from mining through to refining have been estimated to have roughly doubled through the 1970s alone because of a rise in the prices of fuels, machinery and equipments, and in labor and other costs, triggered by skyrocketing crude oil prices. As an example, a break-down of costs and comparisons of cost items at a large open-pit mine in the United States are summarized in Table B-6.

3. Cost of Financing

Copper production is a processing industry that requires enormous expenditure for production facilities. To construct the new necessary facilities for developing a mine, smelting and refining,

Table B-6 Comparison of Production Cost Components

	(%)	
	1972	1976
Mine	70	130
Labor	19	28
Energy	9	25
Consumable materials	13	24
Parts and supplies for maintenance	8	14
General and administration	21	39
Smelting	18	31
Refining	12	24
Total	100	185

Notes : 1) Taxes are included in General costs and administration.
2) Freight charges for copper concentrate to the smelting sector are included in smelting.
3) Transportation fees for blister copper and further processing are included in Refining.

Source: F.M. Lewis, Mining Engineering, 1978

the average capital cost estimated from plans of various projects requires 7,500 dollars per tonne of production capacity (in 1981 dollars). This figure indicates that the estimated cost of financing is over 40 cents per pound of copper with a depreciation term of 15 years and at 10% discount rate that is generally used for conversions of initial expenses, and that the break-even price of copper generally exceeds 110 cents per pound with an assumed direct operation cost of 70 cents per pound. An outline of the capital costs by operational sectors is given in Table B-7.

The long preparatory period and the large investment cost to develop a copper mine results in a very heavy burden of capital costs in the early stage of the construction work. The schedule of the capital outlays in a project for a mine provided with smelting and refining capacity is shown in Table B-8. In this project the annual production of refined copper is 100,000 tonnes, and the construction requires 750 million dollars and five years for completion.

Table B-7 Example of Capital Costs for a Copper Project (in 1981 and dollars per annual tonne of copper production)

Mine and mill	5,000
Pyrometallurgical smelter	1,800
Electrolytic refinery	700
Total	7,500

Source: The Study Team

Table B-8 Example of the Schedule of Capital Outlays for New Mine and Smelter Projects

(million 1981 dollars)

	Year 1	2	3	4	5	1-5
Mine	20	30	30	70	30	180
Concentrator	40	40	90	10	10	190
Smelter	10	50	60	50	10	180
Refinery	-	-	10	50	10	70
Road & port	10	20	20	-	-	50
Ancillary facilities	10	30	30	10	-	80
Total	90	170	240	190	60	750

Source: The Study Team

VII. Administrative Policies for the Copper Mining Industry

1. Government Controls

Because natural resources are consumable, not renewable, developing countries that are rich in such resources are strongly willing to utilize their natural resources at the highest possible efficiency by keeping such resources and principal industries under state control.

The movement towards national control triggered by the nationalization of a copper mine in Zaire in 1960, which had been owned by Union Miniere du Haut-Katanga S.A., a Belgian firm, spread to include the nationalization of copper mines in Chile and Zambia in 1969, and in Mexico and Peru in the 1970s.

Such nationalization, however, resulted in these mines one after another suffering from the withdrawal of foreign skilled technicians and difficulties in continuing operations due to factors such as insufficient funds. Since the second half of the 1970s, the governments of principal copper producing countries have continued to participate in the management of existing mines on the one hand, while they have actively promoted the introduction of foreign capital for new development projects on the other. The reasons for this are the uncertainty in sales due to the fluctuation in copper prices caused by market conditions, increasing maintenance costs, and the necessity of the introduction of advanced and specialized techniques.

The categories in which the state participates in the management and administration of major mines in copper producing countries fall roughly into the following groups.

a. State-led type —— Zambia, Zaire and Chile (with the exception of middle, small and newly-developed mines)

b. State-participating type —— Peru and Papua New Guinea

c. State-nonintervening type —— Canada, Australia and the Philippines

2. Tax Systems

The development of mines involves great risks, all the more because it not only requires a long period of time and enormous funds, but also because earnings are unstable. Consequently, some copper producing countries have adopted tax systems which alleviate the heavy financial costs in the early stages just after starting up the operation of a mine. A depletion allowance system has been adopted to reserve funds for the development of alternative mines when the present mines become depleted or exhausted.

Other countries, where they earn large amounts of foreign currency from copper resources, have put into effect certain preferential and promotional measures as follows.

a. Accelerated depreciation —— Because huge capital costs are required to develop copper mines, the depreciation for structures and facilities can be accelerated in the earlier stages. This system has been in force in such countries as the United States, Chile, the Philippines and Mexico.

b. Depletion allowances —— This type of scheme has been adopted in the United States, Canada and Japan, etc.

c. Tax exemption —— Newly developed and re-developed mines are exempt from income tax for some five years, and the system has been adopted in Zaire and the Philippines.

d. Special relief —— These measures come into force when the export price of copper has fallen below a certain level, at which time the government compensates to adjust for the difference in price. This system was employed by the Philippines, though the period during which it applied was short.

An outline of tax systems in the principal copper producing countries is given in Table B-9.

VIII. Technological Innovations in Production

Factors that have now made operations economically possible even with porphyry deposits where the copper grade of crude ores is as low as 0.5% are the progress in engineering, mining machinery and the enlargement of the ore treatment capacity resulting from technological innovations in the milling process.

1. Mining

a. Mining

Along with the fact that the scale of mining has become larger and larger, automation and rationalization have been promoted with the application of computers to increase efficiency in mining methods. For open-pit mining, efficient pit designs have been devised with improved safety. The principles of mass production adopted in open-pit mining have also been applied to underground mining as widely as possible. This has resulted in the promotion of large-scale block caving in many mines and the sub-level caving method, which divides blocks into further smaller ones for more efficient mining, has also been developed. Additionally, pillars have been improved by the use of standardized steel and artificial roofs have been applied to improve the safety and efficiency of underground mining operations.

Table B-9 *Comparison of Selected Tax Law Provisions*

Country	Corporate tax rate	Capital recovery	Exploration and development costs	Other deductions or credits
Chile	Chilean - 48.57% Foreign - 48.57% or 49.5% fixed	Accelerated system	Deducted over life of mine	Special tax relief for small mining companies
Peru	max. 55%	Straight line	Deductible	Up to 45% of taxable profits may be reinvested and capitalized free of tax.
Philippines	25 - 35%	Accelerated system	Deducted as cost depletion	5 year exemption for new and reactivated mines
Mexico	42% plus 8% profit sharing	Accelerated depreciation on machinery and equipment up to 33%		75% of import tax on machinery and equipment returned as credit
Zaire	50%	Straight-line adjusted for inflation	Pre-production costs capitalized and deducted over a period of 5 years	Certain tax exemptions provided for new companies and business improvements
Zambia	45%	Varies with age of mine	Deductible	Tax relief for "priority" and "exporting enterprises"

Source: The Study Team

b. Drilling

The drilling speed has become faster and faster, and the motive power has changed from electricity to hydraulic pressure resulting in the development of fully hydraulically-powered drills. In addition, automatic or remote-controlled equipment for continuous drilling, blasting and loading, such as in full-size tunneling, has also been developed.

In blasting, high-safety explosives such as ANFO and slurry explosives have also been developed and used.

c. Transportation

The conveying devices for transporting copper ores from the pits in large open-pit mines have become larger year by year, and conventional track freight cars in underground mines have been modified into trackless vehicles which provided with rubber tires, to achieve high-speed transportation of large volumes of material. Moreover, the system of television monitors with computers is advancing the automation and rationalization of ore transportation.

2. Milling

a. Crushing

The development of wear-resistant materials used in machines and parts which wear out, has improved the durability of crushers, grinding mills and slurry pumps, and also enabled larger machines to be constructed. In particular, the improvement of the rubber liners of grinding mills and the development of autogenous mills that smash ores by themselves without using iron balls and bars have made it possible to continuously operate such machines for longer periods than usual.

b. Concentration

Advances in the flotation process, which selects pulverized ore particles with a high content of copper by causing them to adhere to bubbles in flotation cells with some reagents, have permitted treatment of low-grade ores in large quantities. Due to developments in hot water flotation where the temperature of the flotation solution is kept high and the flotation is according to particle size, copper can be separated more precisely now from mixed ores containing lead and zinc. The advent of on-stream analyzers utilizing X-ray fluorescence has speeded up the continuous analysis of chemical components and particle sizes of ores, enhancing the effectiveness of recovery.