there has been a further reduction in solder-joined sections and the development of new circuit connectors due to advances made by LSI from the printed circuit board to silicon circuit board. As a result, there has been a proportionately large drop in the use of solder per unit equipment. On the other hand, the comparative increase in the use of solder with a high tin content combined with the rapid growth in the production of electronic equipment has tended to gradually increase the consumption of solder in the electronics industry.

3. Alloys

In the field of anti-friction alloys, sintered copper-lead alloy and aluminum-tin alloy have been replacing the tin base white metal used in the mass produced bearings of motors and automobile engines. And there has been a tendency to use other materials, such as resin bearings, for smaller sized bearings, too.

From the point of engine performance and corrosion resistance against poor quality oil, the use of tin base white metal for the larger sized bearings of internal combustion engines can be expected to continue.

As for copper alloy, bronze with its relatively higher content of tin is being replaced by nickel silver, high tensile brass, and ounce metal, all of which have lower tin contents, and by aluminum bronze which has no tin in it.

4. Tin Compounds for Chemical Industry Use

Although there are many kinds of tin compounds being used in the chemical industry, the use of organic tin compounds is a relatively recent development. A new market for this is expected to be developed in the near future.

Of the organic chemicals, the di-organo-tin compound is used in many ways. It gives vinyl chloride transparency and a stability towards heat and light. It has the nature of becoming a catalytic agent in the manufacture of polyurethane foam. Mixed with glass it provides electric conductivity. One of the tri-organo-tin compounds, because it has a sterilizing power, is being developed for applications which utilize that functional property. Of the many uses of tin, the field of tin compounds for chemical industry use holds the greatest prospects for development as a new market because of ongoing technological innovations.

D. INTERNATIONAL TRANSACTIONS

1. Trade Structure

Tin is traded internationally in two forms: tin concentrates and tin metal. As can be seen in Fig. D-1 the amount of transactions for tin concentrates has been steadily decreasing in recent years while that for tin metal has conversely been increasing. The amount of tin concentrates traded on the international market has steadily declined from 58,000 tonnes in 1968 to 27,100 tonnes in 1981. Compared with this, the amount of tin metal traded has grown from 164,700 tonnes in 1968 to 193,500 tonnes in 1980 and 178,400 tonnes in 1981.

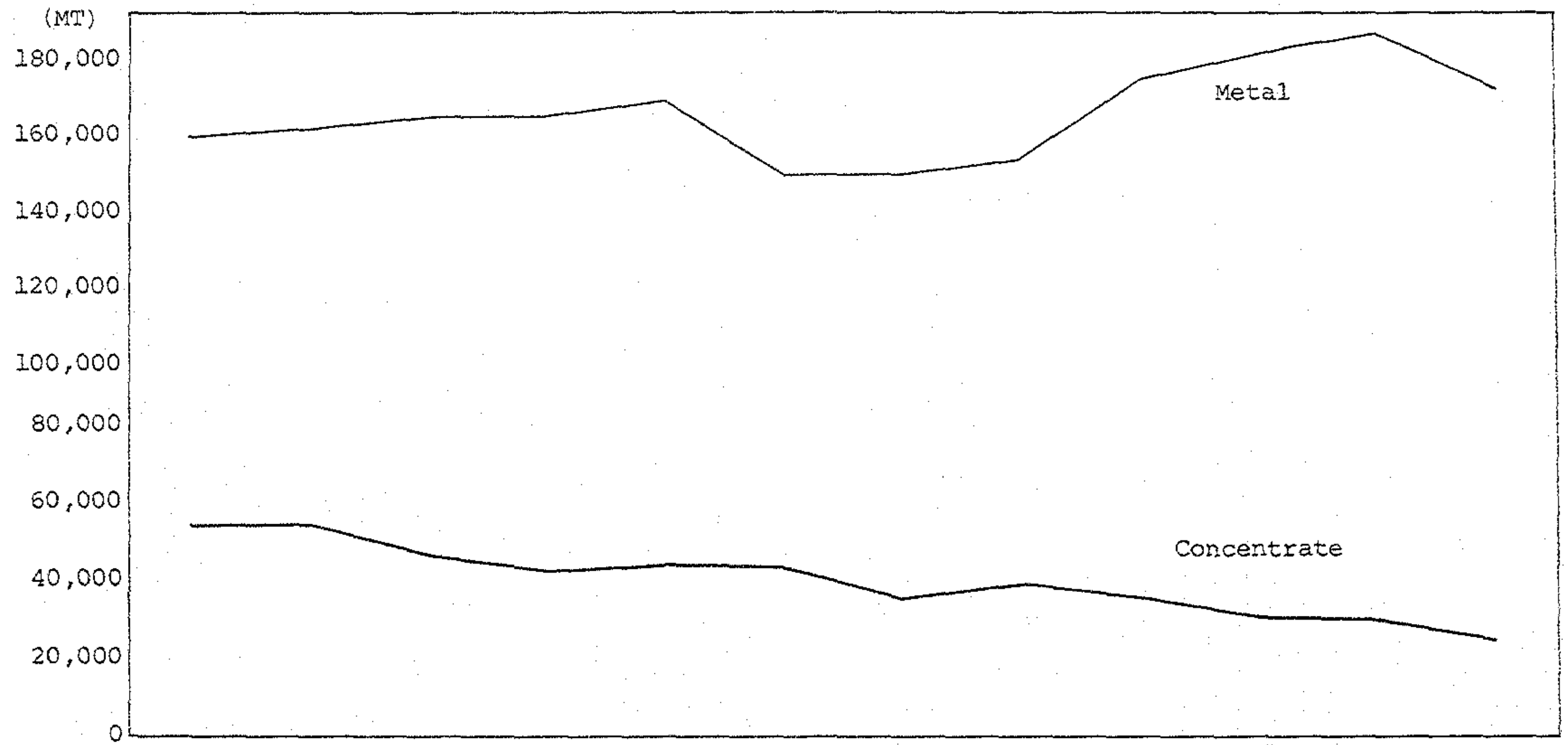
The reason for this lies in the fact that countries which produce tin concentrates have increased their smelting capabilities. Policies have been adopted to domestically smelt tin concentrates which then can be exported at a higher price. The smelting of tin, compared to that of other metals, is technologically more simple and requires less capital. Domestic smelter operations have been accelerated by the relative ease in raising the level of local processing of tin resources.

In 1982 the three main producing countries of Malaysia, Indonesia and Thailand enacted legislation which prohibited the export of domestically produced tin concentrates; it all must be smelted into tin metal to be exported. Bolivia has given impetus to strengthen its domestic smelting capacity and in the near future export of tin concentrates probably will come to an end. Of the major producing nations only Australia will likely continue exporting tin concentrates.

In the future, the trading of tin concentrates probably will be conducted on a small scale spot transaction type of basis by those countries with limited production capabilities. This will undoubtedly diminish the relative importance to the world market of tin metal produced and exported by the United Kingdom and the Netherlands who have been dependent upon imported tin concentrates. Table D-1 shows the amount of tin concentrates traded in 1981 and 1968.

As for international transactions of tin metal, major consuming nations such as the United States, Japan, the Federal Republic of Germany, and the USSR are naturally large importers with each of them importing from Malaysia, Indonesia, and Thailand. There has been a noticeable decline in domestic consumption in the United States which has resulted in the large drop in imports from Malaysia while Japanese and the Federal Republic of Germany imports from Thailand have been increasing. Bolivia is highly dependent upon the United States market. More recently, the increase in the USSR imports has been phenomenal while China, on the other hand, has expanded its export capability.

Fig. D-1 Tin-in-Concentrate and Tin Metal Export



	1968	1970	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981
—— Con.	57,800	58,300	50,200	45,800	47,900	46,800	38,300	42,300	38,800	33,500	32,700	27,100
—— Met.	164,700	167,000	170,300	170,800	174,900	154,200	154,500	158,300	180,400	187,800	193,500	178,400

Source: ITC, <u>Tin Statistics</u>, <u>Monthly Statistical Bulletin</u>

Table D-1 Trade of Tin-in-Concentrate

(1981) (MT)

Export / Import	Indonesia	Bolivia	Australia	Others		Total
Malaysia	422	-	8,190	Burma	536	10,718
				Peru	390	
					1,180	
UK (1980)	-	5,333	-	Argentina	1,212	8,228
				Peru	661	
					1,022	
Netherlands	-	303	-	Zaire	1,591	3,865
				Rwanda	1,170	
					801	

(1968) (MT)

Export / Import	Indonesia	Bolivia	Australia	Others		Total
Malaysia	12,673	-	587	Laos	542	13,889
					87	
UK	-	21,282	108	Argentina	841	23,809
				S. Africa	793	
					785	
Netherlands	-	1,067*	816*		5,338	7,221

Note : Import data excluding figures marked *.

Source: ITC, Tin Statistics, Monthly Statistical Bulletin

Table D-2 Trade of Tin Metal

(1981) (MT)

Export / Import	Malaysia	Indonesia	Thailand	Bolivia	Others	Total
USA	13,164	7,096	11,967	8,227	5,419	45,873
Japan	18,517	6,514	4,901	-	291	30,223
Germany, FR	1,884	4,580	6,230	848	2,382	15,924
USSR	9,908	530	-	478	Singapore 904 Germany, FR 662 UK 602 1,253	14,337

(1968) (MT)

Export / Import	Malaysia	Indonesia	Thailand	Bolivia	Others	Total
USA	41,988	356	12,523	39	3,672	58,278
Japan	18,338	700	1,004	-	531	20,573
Germany, FR	2,619	3,017	570	-	Netherlands 3,651 2,277	12,074
USSR	1,200				UK 5,200 700	7,100

Source: ITC, Tin Statistics, Monthly Statistical Bulletin

Table D-2 shows the amount of tin metal trade for the years 1981 and 1968.

As for future international tin transactions, there is an increasing tendency for it to be primarily composed of tin metal trade. It can be presumed that as long as the ITC control of the market is not weakened there probably will not be any great change. There are, however, factors which could alter the world market: increased exports by China and Brazil, who do not belong to the ITC and who are both rich in resources, and increased imports by the USSR which has probably reached the limits of its domestic production.

II. International Trade Practices

Tin metal is traded in ingot form and the most representative of this is so-called "the Straits tin metal of Malaysia" in 45 kg ingots. In addition to this there are 25 kg, 30 kg, 38 kg, and 50 kg ingots which vary according to country. There are two kinds of grades in the market: standard tin (99.75%) and high grade tin (above 99.85%), however at the London Metal Exchange (LME) only high grade tin has been traded since 1981. In addition to this an ingot more than 99% pure called "common tin" has been circulated.

Tin sellers in the international market are classified into the following three types.

(1) Mine operators

Mine operators either do the smelting by themselves or else entrust the smelting to another party and then market through their own sales channels. P.T. Timah of Indonesia is a good example of this type.

(2) Smelting operators

Smelting operators buy tin concentrates directly from the mines and then sell tin metal after they have smelted it. In order to protect themselves from price and exchange fluctuations, whenever they purchase tin concentrates they usually sell an equivalent amount of tin metal at the same time as a hedge. Datuk Keramat Smelting (DKS) of Malaysia is an example of this type.

(3) Trading firms

These trading operations purchase tin metal from smelters or from other trading firms, handling all the shipping, storage, insurance, and currency procedures by themselves.

Purchasers of ingots draw up contracts regarding all such matters as price, quantity, delivery dates and places, and methods of payment. Trading operations are divided into international and regional trading firms. Their primary function is to finalize the transaction by regulating the sales conditions of the producer and the purchase conditions of the consumer. Transportation, storage, insurance, and currency exchanges are included in the sales procedures which they perform on behalf of the consumer. The risk involved in trade transactions is minimized by hedging with the LME. There have been very few examples in recent years of consumers directly making purchases; mostly they deal through trading firms.

Both tin concentrate and tin metal are transacted by trading firms. The trading price for tin concentrate is determined by the following formula.

Tin concentrate price = P(T - U) - T/C

P : Market price
T : Ore grade
U : Unit deduction (Proportionate to the loss during smelting. For example, when the tin grade is 72%, a discount rate of 1.2% is established.)
T/C : Treatment charge

Transportation costs, insurance charges, storage fees, and the trading firm's commission are added to the tin concentrate price mentioned above. This becomes the smelter delivered price. Penalties are assessed according to the amount of impurities included.

III. The International Tin Council (ITC) and the International Tin Agreement (ITA)

Historically susceptible to demand imbalances and often an object of international speculation, tin, like other non-ferrous metals such as copper, lead, and zinc, has been a product of radical price fluctuations. This is a result of non-ferrous metals having the following characteristics:

(1) A unique aspect of underground resources industries is the limited flexibility of production.

(2) Resources are geographically unevenly distributed.

(3) The scale of international transactions is smaller compared to that of other commodities.

(4) High unit price relevant to the weight as well as extremely corrosive resistant and highly durable properties make them easy to store.

Tin, among all other non-ferrous metals, is particularly subject to the greatest price fluctuations.

As a result of the history of price and demand fluctuations for tin, international agreements came about for the purpose of price stabilization. The International Commodity Agreement established a structure to protect the interests of both producers and consumers.

In 1928 when speculators systematically tried to corner the market, prices rose sharply. As a result of the increased production, the market crashed in the following year, 1929, and the tin mine operators of the major producing countries were faced with the danger of collapse. Taking heed of this situation, and with the United Kingdom taking the lead, it together with Malaya, Bolivia, Indonesia, and Nigeria were joined by the First International Tin Agreement in 1931. Under this agreement the International Tin Commission was established. Production quotas were determined and the production was internationally reduced. As a result of this, over-production was eliminated, however, increased demand could not be met with supply and market prices rose sharply. In 1934 a buffer stockpile was established for the purpose of stabilizing the market. Later, Thailand, Congo, and Indochina were also included in the Agreement. Although the International Tin Commission had control over 96% of the world tin production, matters did not proceed smoothly because of entanglements regarding the interests of each country.

After World War II, the International Tin Study Group was established in 1946 at the urging of the United Kingdom and composed of the major tin producing and consuming countries. Through discussion at several times, the conception of International Agreement was proposed. In 1953 the market was plunged again and a draft of an agreement by the United Nations Social and Economic Council was adopted. On July 1, 1956 this was ratified by five producing countries (Malaysia, Bolivia, Indonesia, Thailand, and Nigeria) and ten consuming nations, thus implementing the First Agreement of the Second International Tin Agreement with a five-year term of validity. The International Tin Council (ITC) was established in accordance with this agreement. Smooth supply was provided by stabilizing tin prices through the formation of a buffer stockpile which controlled the exports of producing nations. Since then the following agreements have been concluded.

First Agreement :	July 1, 1956 - June 30, 1961
Second Agreement:	July 1, 1961 - June 30, 1966
Third Agreement :	July 1, 1966 - June 30, 1971
Fourth Agreement:	July 1, 1971 - June 30, 1976
Fifth Agreement :	July 1, 1976 - June 30, 1982
Sixth Agreement :	July 1, 1982 -

The following is a summary of the Sixth Agreement.

(1) Of the 50,000 MT stored in the buffer stockpile, 30,000 MT are provided by the compulsory contribution of producing and consuming nations while the remaining 20,000 MT are financed by the debts borrowed with warrant or government guarantees (In the Fifth Agreement, compulsory contributions by the producing countries was set at 20,000 MT and voluntary contributions by consuming countries was set at 20,000 MT for a total of 40,000 MT, however, supply became obligatory for consuming countries in the Sixth Agreement).

(2) The price range was raised M$0.04/kg, with the floor price set at M$27.32/kg and the ceiling price set at M$35.51/kg. Actually the floor price was set at M$29.15/kg and the ceiling price at M$37.89/kg by the ITC in October 1981 (This was the 23rd price range adjustment).

(3) Export regulations go into effect when the buffer stockpile exceeds 35,000 MT with at least 2/3 of the producing and consuming countries consenting or when it exceeds 40,000 MT with at least 1/2 of them consenting (Under the terms of Fifth Agreement, the ITC was able to determine the volume of exports from producing countries at any time).

Under this agreement the price range was divided into three zones: upper, middle, and lower. Cash and metal which make up the buffer stockpile are used to regulate prices. When in the upper zone, sales are made, while in the lower zone purchases are made. Basically the current price range would correspond to the following table.

Ceiling Price	M$37.89/kg	Must sell
Upper Zone	M$34.98/kg	May sell
Middle Zone		No operation
Lower Zone	M$32.06/kg	May buy
Floor Price	M$29.15/kg	Must buy

Since in the first half of 1982, prices have been close to the floor price, the ITC purchasing was started and the buffer stockpile seems to have reached 50,000 MT at the end of June 1982, which was the limit of stockpile set by the agreement then. On the other hand, production has been conducted under the ITA based production controls.

Table D-3 shows the operations of the ITC buffer stockpile from 1968 to 1981.

Fig. D-2 shows changes in the ITA floor price, ceiling price, and average Penang tin prices.

Currently there is a total of 24 countries signatory to the Sixth Agreement. Six of these are producing countries, Malaysia, Indonesia, Thailand, Australia, Nigeria, and Zaire, while the 18 consuming countries are made up of such countries as Federal Republic of Germany, France, the United Kingdom, Japan, and Canada. Until the Sixth

Agreement was established, opinions differed regarding the establishment of price ranges, management of the buffer stockpile, and export controls. The Fifth Agreement was extended for one year until the Sixth Agreement took effect with Bolivia as a producing country, and the United States and the USSR as consuming countries not participating. While it is unclear whether the ITC stability will be maintained, there are also elements of instability in the form of the effects on the market of the United States GSA stockpile release and questions of the ITC financial support of the buffer stockpile. It is significant that among mine products, it is only for tin that an international commodity agreement has been enacted and is functioning.

The voting rights of the major signatories of the Sixth Agreement are as follows:

Total Number of Ballots

Producing Nations		Consuming Nations	
Malaysia	(401)	Japan	(319)
Indonesia	(247)	Germany, Fed. Rep.	(146)
Thailand	(216)	France	(103)
Australia	(94)	UK	(90)
Nigeria	(22)	Canada	(50)
Zaire	(20)	Others	(292)
Total of 6 countries	(1,000)	Total of 18 countries	(1,000)

Currently, with the purpose of reinforcing the ITC, the producing nations, led by Malaysia, have taken steps to establish the Tin Producer's Association and a preparatory meeting was held in November 1982.

Table D-3 ITC Buffer Stock Operations

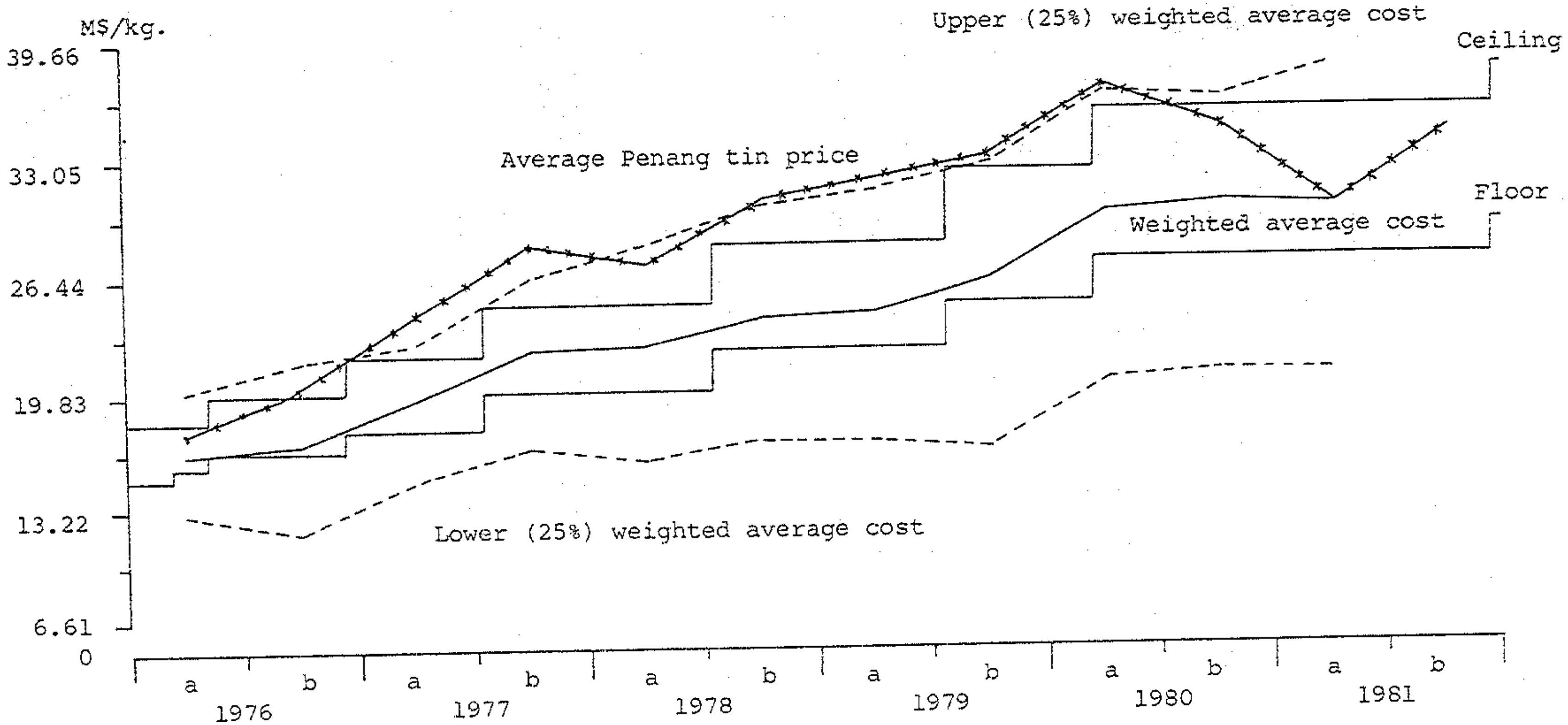
(MT)

	1968	1969	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981
Net purchases	6,640			5,405	5,842			19,929			-			3,865
Net sales		6,807	3,432			11,478	859		19,265	806	-			2,875
Tin held	11,471	4,664	1,232	6,637	12,479	1,001	142	20,071	806	-	-	-	-	2,490*

* Includes the balance of a contribution of 1,500 tonnes from the GSA stockpile.

Source: ITC, <u>Tin Statistics</u>, <u>Monthly Statistical Bulletin</u>

Fig. D-2 Tin Production Costs, Tin Price, ITA Price Range
(Including royalties, export duty and tributes)
(1976 - 1981)



Note : a: January to June
b: July to December

Source: ITC Data

E. PRICES

I. International Prices

International prices for tin are determined primarily by three markets: the Penang, the London Metal Exchange (LME) in London, and the Commodity Exchange (COMEX) in New York. For a long time the LME had the largest volume of transactions and as such set the international price for tin. However, due to difficulties in the United Kingdom economy and instability of the pound from the 1970s, the Penang spot trading market in Malaysia, the world's largest producer of tin, today actually determines the international price of tin. Basically the Penang market is a spot transaction exchange different from other markets. The LME and the New York market are used for trading futures and as fixed transaction markets they have the characteristic of being market hedges. Prices are quoted on the LME in Sterling pounds/MT, in M$/kg in Penang, and in US¢/lb on the COMEX in New York. The price of tin, depending on the ITC market intervention, differs from that of non-ferrous metals such as copper, in that price increases are relatively proportionate to and follow in the wake of production cost increases.

Table E-1 gives the LME prices and Table E-2 gives Penang prices. When the LME and Penang prices are adjusted for shipping and other costs, they are practically the same. Since 1972 the ITC has officially used the Penang prices for its controlling prices officially.

In 1973 the price averaged M$686/pikul when there was a sudden increase in the prices with all non-ferrous metals. Even release of almost all of the entire the ITC buffer stockpile was unable to contain the price rises. The 1974 average price was finally settled at M$1,137/pikul. In 1976 there was another increase in prices and release of stock was again begun, however, because the stockpile was exhausted in 1977, prices continued to rise over the stable price range. Prices continued to rise in 1980 until they reached an average of M$2,160/pikul. Then the supply increased more than the demand, prices once again stabilized. Tin price was pegged at the floor price, M$29.15/kg (= M$1,764/pikul), in October 1982.

II. The London Metal Exchange (LME) and the Penang Market

Copper, lead, zinc, silver, aluminum, and nickel are traded along with tin on the LME. Futures are traded as well as spot transactions while hedging and speculation give transactions color. High grade tin

Table E-1 Standard Tin Prices of LME Cash

(Ƀ/ MT)

Year	Highest	Lowest	Average	Ratio
1968	1,433.0	1,267.6	1,302.4	100.0
1969	1,621.5	1,326.7	1,428.4	109.7
1970	1,612.1	1,409.9	1,535.3	115.6
1971	1,497.5	1,398.0	1,437.4	110.4
1972	1,606.5	1,401.5	1,505.9	115.6
1973	3,182.5	1,593.0	1,960.4	150.5
1974	4,195.0	2,642.5	3,493.6	268.2
1975	3,415.0	2,959.0	3,090.8	237.3
1976	5,252.5	3,052.5	4,254.6	326.7
1977	7,335.0	5,130.0	6,181.2	474.6
1978	8,055.0	5,722.5	6,706.2	514.9
1979	8,125.0	6,335.0	7,275.9	558.7
1980	8,450.0	6,132.5	7,222.2	554.5
1981	8,555.0	5,682.5	7,085.0	544.0

Source: ITC, Tin Statistics, Monthly Statistical Bulletin

Table E-2 Standard Tin Prices of Penang

(M$/pikul)

Year	Highest	Lowest	Average	Ratio
1968	639.00	546.75	565.54	100.0
1969	710.13	578.25	626.10	110.7
1970	716.75	619.88	664.77	117.5
1971	659.88	617.00	631.70	111.7
1972	655.50	605.00	626.80	110.8
1973	1,026.00	615.50	686.28	121.3
1974	1,380.00	820.00	1,136.63	201.0
1975	1,050.00	910.00	963.79	170.4
1976	1,320.00	957.00	1,146.56	202.7
1977	1,895.00	1,314.38	1,588.03	280.8
1978	2,085.00	1,476.00	1,743.19	305.2
1979	2,171.00	1,750.00	1,960.65	346.9
1980	2,471.00	1,881.00	2,160.12	382.0
1981	1,986.16	1,727.91	1,955.92	345.9

Source: ITC, Tin Statistics, Monthly Statistical Bulletin

(more than 99.85%) is traded in 5-tonne units at FOB warehouses assigned by the LME. There are two rings each for the morning and afternoon sessions, each ring being five minutes long, during which time transactions are conducted by the representatives of about thirty companies. The closing prices are posted after the morning session and after the afternoon session. The closing price for the morning session is listed as the "Settlement Price." Simultaneously, the prices for futures are determined.

The Penang Exchange is not an exchange with sellers and buyers dealing with one another directly. Future transactions are not conducted; there are only spot transactions. In regards to the amount of marketable tin metal brought to the two largest smelters of Malaysia, Malaysia Smelting (MSC) and Datuk Keramat Smelting (DKS), on a certain day bids from buyers around the world are listed up until 10 o'clock the following morning. Basically, tin which is brought in is disposed of beginning with orders with the highest price. When there are a number of companies that have the lowest bid, the amount is proportionately divided and contracted. At 10:30 the same day the lowest price is announced as the quotation. The price is set for high grade tin (more than 99.85%). How the two large smelters determine the price is a complete secret.

Because the Penang Exchange only trades in spot transactions, there is a plan to list tin on the Kuala Lumpur Commodity Exchange (KLCE) which also has the function of future transactions like the LME and the COMEX. Palm oil futures are already being traded at the KLCE, however, there is no definite agreement among producing nations, such as Indonesia and Thailand, for the plan to list tin.

F. SUPPLY AND DEMAND PROJECTION

I. Prospects for Demand

1. Recent Demand Trends

Since 1973, the world consumption of tin has been declining steadily. For the period between 1970 and 1980 the average annual rate of decline was 0.4%. Although the demands in developing countries and that in the planned economy countries have been maintaining a rising tone of 1.7% and 1.6% average annual rate respectively, the demand in industrialized countries has remained at about 60% of the world consumption with a continuous average annual decline of 1.5%.

As a result of the supply and demand adjustments according to the International Tin Agreement, tin has been the only metal which has consistently increased its real market value over the past 30 years inspite of periodic fluctuations. For that reason the price difference between it and other metals has steadily widened. In regards to demand, its price competitiveness has become weakened and substitutions are making advances in all areas.

For the 40% of demand held by tinplate, the advances of substitution have been most severe. In the market of food and beverage containers where 90% of the tinplate consumed is used, there is a broad range of substitution, with aluminum, electrolytic chrome coated steel (a kind of TFS), and plastics.

The demand for solder, which accounts for 25% of tin consumption, is dependent upon the production of electrical machines, electronic equipment, and automobiles which make up the mainstay of the end-user market. However, there has been a slump in consumption as a result of stagnation in production of production goods and consumer durable goods along with reduction in unit consumption per product and progress of substitution with other materials.

Consumption for alloys depends heavily on the demands of the automobile, shipping, and machinery industries; however, there is a notable decline in consumption, same as for solder, because of a slump in production, reduction in unit consumption, and substitution.

There is a steady increase in demand in the new market for application in chemical products; yet, because this market accounts for a mere 10% of total consumption it cannot cover the decrease in consumption in other fields.

The impact of substitution has been most remarkable for industrialized countries while insignificant on the developing countries in which production of tinplate is still growing. Furthermore, it has not yet come to surface vividly in the strongly conservative planned economy countries. But it is clear that it is only a matter of time before substitution will be disseminated in these countries, too.

Changes in the demand pattern due to substitution are the largest factor substitutes most at work on the recent tin consumption trends, and in addition, cyclic factors of the world economy also exercise a major impact. Especially the declining consumption since 1980 due to the simultaneous recession around the world has been quite significant.

2. Currently Available Demand Projections

2.1 ITC Demand Projections

The result of demand projections conducted by the ITC office of administration was announced at the Fifth World Conference on Tin held in Malaysia in October 1981.

Based on the records of consumption up to 1980, short term projections for the world demand in 1985 were carried out. Regarding consumption of the two most important items, tinplate and solder, the study made projections based on field interviews with the producers of tin products, consumers, related associations, and government agencies of major consuming countries (The United States, EC members, Japan, Spain, and ASEAN countries), and built up the total demand from the estimates for individual country. Projections for the consumption of chemical products and alloys other than tinplate and solder were based on the published information and data for each country.

It is assumed that the world economy will bottom out in 1982 and enter a gradual expansionary phase between 1983 and 1985. In the field of tinning, the drop in tin consumption since 1976 was expected to stop and level off in 1981. Consumption of solder, which had been sluggish, was expected to improve slightly and the consumption in chemical products was expected to continue rising at a rapid pace. Based on these views, the study concluded that the world consumption would recover the 190,000 tonnes level of the 1970s, as indicated in the following table, by 1985.

Table F-1 World Consumption of Primary Tin Metal

(1,000 MT)

	1976	1980	1981	1982	1983	1984	1985
EC	51.6	44.9	43.0	44.0	45.0	46.0	46.0
USA	51.8	46.0	47.0	49.0	49.0	49.0	50.0
Japan	34.7	30.9	30.0	32.0	33.0	34.0	34.0
Others	55.7	53.7	53.0	55.0	58.0	59.0	60.0
World	193.8	175.5	173.0	180.0	185.0	188.0	190.0

Notes: 1) Excluding the USSR, China and the German Democratic Republic.
2) Actual performance in 1976, 1980; forecast for 1981-1985.

2.2 Projection by a Leading Research Institution in the United States

This research institution conducts continuous market research on major mineral products. Prospects for the tin market until 1990 were developed in July 1982 based on actual performance until 1981 and trends during the first half of 1982.

In the demand projections of this study, the annual growth rates for consumption until 1990 were estimated for six groups of the United States, Japan, France, the Federal Republic of Germany, the United Kingdom, and other countries with respect to four categories of end use, tinplate, solder, alloy, and others using 1981 as a base year.

Since 1973, the structural factor of, the drop in consumption due to substitution in the tinplate industry has had an increasingly strong effect upon the demand for tin rather than the effect of business cycle. The key to long term demand projection for tin therefore hinges upon how to forecast the ongoing structural changes. At the present, increase in consumption of tinplate in the developing countries is one major factor contributing to the growth in demand; even here, substitution with aluminum and TFS is anticipated to make progress in the longer range.

In conclusion, world demand,[1] as indicated in the following table, is not expected to recover the 1973 peak level of 214,200 tonnes, and is estimated to be 184,880 tonnes for 1985 and 201,170 tonnes for 1990.

1) Excluding the USSR, China, and the German Democratic Republic.

(MT)

	1973	1980	1985	1990
USA	59,080	44,340	43,830	46,840
Japan	38,680	30,880	34,480	36,840
France	11,700	10,050	8,650	8,930
Germany, Fed. Rep.	15,850	14,270	13,120	14,700
UK	16,600	6,450	11,070	12,910
Others	72,300	68,710	71,740	80,960
World Total	214,200	174,700	184,880	201,170

2.3 Projections by the World Bank

Demand projections for tin were announced in an investigative report entitled "The Outlook for Primary Commodities", published in January 1983.

The world is divided into three economic blocs: industrialized countries, developing countries, and the planned economy countries. Based on the average rate of increase for the periods 1961-1980 and 1970-1980 for the major consuming countries of each economic bloc, projections are made for the average rate of increase for the periods 1980-1985, 1985-1990, and 1990-1995. Based on the amount of consumption actually recorded in 1980, the demands are projected for 1985, 1990, and 1995.

Major factors considered in demand projections are the continued advances in substitution by aluminum and TFS for tinplate, which currently accounts for 40% of the total consumption, and the continued decline of tin consumption in industrialized countries. Contrary to this, growing demands for tinplate are anticipated for both the developing countries and the planned economy countries because of the growing domestic production of tinplate accompanying the improvements in the standards of living.

On the other hand, the increase in tin consumption in the field of alloys is anticipated to be only slight. And although the current share of consumption for chemical products is below 10% of the total, a sharp increase is expected because of the lack of any substitute.

As for overall consumption, a decline is expected to continue in the industrialized countries while an increase greater than in the 1970s is anticipated for the developing and planned economy countries. The average annual growth rates for the world demand from 1980 to 1995 is expected to increase to 0.8% from the -0.4% rate of the 1970s.

Table F-2 Tin Consumption by Economic Regions

(1,000 MT)

	Actual		Projected			Growth Rate (%)		
	1975	1980	1985	1990	1995	1980/1985	1985/1990	1990/1995
Industrialized	132	133	130	123	117	-0.4	-1.1	-1.0
Centrally Planned	37	36	40	47	53	2.3	3.3	2.4
Developing	42	41	49	55	65	3.5	2.3	3.4
World	211	210	219	225	235	0.9	0.5	0.9

Note: China is included in Developing Countries Group.

2.4 Projections by the U.S. Bureau of Mines

The U.S. Bureau of Mines projected and published in 1980 the demand for the year 2000 by modifying the regression equations derived by the analyses of historical data up to 1978 of mainly the United States in considering factors conducive to changes.

Consumption of primary tin metal is predicted to grow at an average annual rate of 0.9% from 1978 to 2000 and reach 280,100 tonnes in 1990 and 306,000 tonnes in the year 2000.

2.5 Projections by the Australian Mineral Economic Corporation

Consumption for the year 2000 is projected based on the actual amount of consumption up to 1978 of a total of 44 countries comprised of 15 industrialized countries, 22 developing countries, and 7 planned economy countries.

From the correlation equation of per capita GDP and the per capita tin consumption, projections are made based on the projected growth in population and GDP. World tin consumption in the year 2000 is estimated at 407,100 tonnes in the pessimistic case and at 488,900 tonnes in the optimistic case.

Of the above five projections currently available, the U.S. Bureau of Mines' projection and Australian Mineral Economic Corporation's projection are based on actual performance up to 1978. For that reason the progress of substitution for tin was underestimated while the anticipated growth in demand by developing countries and the planned economy countries was overestimated. And as the influence of the world recession since 1980 was not seriously considered, these two projections are considered too optimistic.

Studies by the ITC, a leading US research institution, and the World Bank are quite similar in that each study was conducted recently, and their approaches are to build up the projected demand by major consuming countries and by major end-use after obtaining a firm grip on the effects of substitution in each segment.

Furthermore, projections by these three institutions are highly reliable in their skill and approaches for demand build-up since all of them are conducting their surveys on tin consumption on a continuous basis. However, only the World Bank projects consumption for the whole world while the ITC and the US research institution do not cover the USSR, China, German Democratic Republic in their target areas of study.

The following summarizes the projections by the above three institutions.

(MT)

	1973	1980	1985	1990	1995
ITC*	214,200	174,700	190,000	-	-
US Research Institution*	214,200	174,700	184,880	201,170	-
World Bank**	250,000 (214,200)	210,000 (174,700)	219,000 (179,000)	225,000 (178,000)	235,000 (182,00)

* World Tin Consumption excluding the USSR, China, and German Democratic Republic.

** World Tin Consumption. Figures in parentheses indicate consumption excluding the USSR, China, and German Democratic Republic.

Regarding projections for tin demand, although these studies were conducted by the most world-wided experienced three groups at about the same time, their results vary considerably, which shows how difficult it is to come up with projections for tin consumption at this point in time.

3. Insight into Demand Projections

At the moment, the greatest difficulties in projecting future demands lie in predicting the cyclical factor of the recovery in the world economy in the short run, and in grasping a clear and how to grasp picture of the structural factor of the progress in substitution in the medium and longer range.

In this report, reappraisal and modification of demand projections were carried out based on the original and independent information and data on the World Bank projections, which are one of the above mentioned demand projections which has a high degree of reliability.

The World Bank projections overestimates the progress of substitution in industrialized countries and also the growth rate of consumption in the planned economy countries. Furthermore, China was included in the group of developing countries. These points were revised and the growth rates for consumption were estimated for the three groups of industrialized countries, developing countries, and the planned economy countries. Demand projections for the years 1985, 1990, and 2000 were made on the basis of actual data for 1980. Resulting projections of 228,000 tonnes in 1985, 226,000 tonnes in 1990, and 247,000 tonnes in 2000, are shown in Table F-3.

Table F-3 Revised Demand Projections

(1,000 MT)

	1975	1980	Projected Annual Growth Rate 1980/1985 (%)	1985	Projected Annual Growth Rate 1985/1990 (%)	1990	Projected Annual Growth Rate 1990/2000 (%)	2000
Industrialized countries	132	133	-0.4	130	-0.7	125	-0.5	118
Developing countries	28	28	3.5	33	3.5	39	3.4	55
Planned economy countries	51	49	2.4	55	2.3	62	2.2	74
World total	210	210		228		226		247
(Free world total)		(161)		(163)		(164)		(172)

II. Prospects for Supply

1. Current Condition and Outlook for Production

In spite of the drop in consumption during the period of 1970-1980, the world production of tin concentrates increased although slightly at an annual rate of 0.2%. Tin concentrates are primarily obtained by such methods as gravel pumps, suction boats, and dredges, which are orientated to sedimentary type of placer deposits. Because they differ from the mining and production of other metals it is not easy to ascertain production capacity. Especially in the major producing countries of Malaysia, Thailand, and Indonesia, medium and small size mining operations using gravel pump and suction boat methods comprise their major portion of capacities. There is a high degree of flexibility in production. The producers of these countries have created a marginal supply capability by working when insufficient demand causes prices to rise and by stopping production when prices fall.

Keeping in mind this unique characteristic of tin mining, a look at current practical production capacities would produce a world total of 248,000 tonnes. This figure, when broken down by country would be as follows: Malaysia 65,000 tonnes, Indonesia 36,000 tonnes, Thailand 34,000 tonnes, Bolivia 26,000 tonnes, Australia 12,000 tonnes, the USSR 16,000 tonnes, China 25,000 tonnes, and other countries 34,000 tonnes. Although the U.S. Bureau of Mines placed the world production capacity of concentrate at the end of 1979 at 283,000 tonnes, this seems slightly excessive as an effective production capacity.

In any case, existing production capacity of all mines greatly exceeds the current production volume, resulting in a considerably low operating rate.

In regards to current production capacity, it is highly likely that the production capacity in countries such as Malaysia, Bolivia, Zaire, and Zambia will decrease because of lower grade of ore, depletion of reserves, and inadequate replacement investment, while in Indonesia and Thailand there is ample room to increase the production capacity of mining operations which employ dredging operations of sea bed deposits. In addition, there is also quite a large potential for increased production in Australia, China, and Brazil. In the medium and longer range, production can be stepped up readily to the extent of around 29,000 tonnes a year.

On the other hand, world smelting capacity now greatly exceeds production capacity of concentrate. World smelting capacity now reached 414,000 tonnes annually, due in large part to expansion of investment in domestic smelting capacities of such major concentrate producing countries as Malaysia, Indonesia, Thailand, and Bolivia during the 1970s.

2. Current Condition and Outlook for Stockpiles and Buffer Stock

When assessing the supply availability of tin, careful consideration must be given to changes in the GSA stockpile release of the United States, which reached as high as 203,700 tonnes as of the end of 1978 and movements in the ITC buffer stock operations.

Release of GSA stockpiles of tin, which was once stopped in 1978, was again resumed from July 1980 by the decision on a new stock reduction program based on the new law enacted in January 1980, and 25 tonnes were placed on the market in 1980, 5,920 tonnes in 1981, and 5,000 tonnes in 1982. 7,500 tonnes are expected to be released in 1983, another 7,500 tonnes in 1984, and 4,500 tonnes in 1985.

Because the world market prices fell below the floor price of the stable price range established by ITC in the first half of 1982, the ITC buffer stock began purchasing in order to support the price. It is believed that the full 50,000 tonne purchasing limit established at the Sixth Agreement has already been bought up by June, 1982. The number of countries participating in the Sixth Tin Agreement which became effective in July, 1982, was less than that of those which participated in the Fifth Agreement. The purchasing limit for the buffer stock was therefore reduced from 50,000 tonnes to 39,000 tonnes. At the end of June, the stock exceeded 50,000 tonnes. This figure is to be brought down to 39,000 tonnes by selling on the market when the price comes back up. This means that if the market recovers, another 11,000 tonnes can be expected to come into the market before the end of 1985.

In addition to the GSA stockpile and the ITC buffer stock, there are also the LME stocks, distributors, inventories, and producers' stocks. It is estimated that there was a surplus supply of commercial stock, including the ITC buffer stock, in excess of 42,000 tonnes at the end of 1981 and 70,000 tonnes at the end of 1982 resulting from the excessive supply in 1982. Viewed from the fact that normal commercial stock ranges between 30,000 tonnes and 35,000 tonnes, this is a considerably excessive stock.

3. Prospect of Demand and Supply Balance

Anticipated effective production capacity of tin concentrate compared to the projected demands for 1985, 1990, and 2000 is as follows:

(1,000 MT)

	1980	1985	1990	2000
Metal demand	210	228	226	247
Tin concentrate production capacity (metal content)	248	252	260	290

There will be a surplus tin concentrate production capacity over metal demand through the year 2000 even if the smelting yield is taken into account.

Moreover, on the supply side, when the GSA release due to stockpile reduction policy and the high level of ITC buffer stockpile will continue to be major factors affecting the balance of tin supply, the supply surplus situation can be expected to persist both for a short term and a medium and longer term.

As the smelting capacity at the end of 1980 exceeded 414,000 tonnes, a surplus condition is certain to prevail even if obsolete facilities in custom smelters in Europe are to be scrapped.

G. COMMENTS ON POSSIBILITY OF EXPORTS FROM CARAJAS

Tin is one of a few products that have been controlled by a long-term international commodity agreement designed to regulate supply and demand of the world market. It is a unique international commodity in that when the controls by the agreement are effectively operating, increases in the real market price are consistently maintained.

Supply and demand operations in the world market based on an international agreement are significant in regards to the production stability. However, the downward rigidity of prices is becoming increasingly pronounced. The prices of rival materials, such as other metals and plastics, are becoming increasingly competitive. As a result, substitution in the consumer market are accelerated and this is having the effect of inviting a remarkable sluggishness in demand. Furthermore, we must not overlook the fact that as a result of price control by market operations, marginal producers with high production costs are being protected from completion.

The market regulating capability of the Sixth International Tin Agreement is attenuating for a number of reasons. It is being weakened because the United States, which is a leading consuming country, and Bolivia, a major producing country, did not participate and because no definite means have been found to stop the shrinking market caused by the progress in substitution. Nevertheless, future market controls are expected to continue because of the firm cooperation of the three main producer countries of Malaysia, Indonesia, and Thailand. Tin reserves in Carajas are expected to have an acceptable quality and scale, therefore, tin exports from Carajas is promising.

APPENDIX

Appendix Table 1 Some Common Tin Minerals

(from Sainsbury and Reed, 1973 and Jones 1969)

Name	Composition	Occurrence
Native tin	Sn	Very rare
Cassiterite	SnO_2	Main commercial minerals
Herzenbergite	SnS	Rare
Thoreaulith	$SnTa_2O_7$	Occasionally common
Ottemannite	Sn_2S_3	Rare
Stannite	Cu_2FeSnS_4	Common
Mawsonite	$Cu_{44.5}Fe_{12.5}Sn_{10.4}S_{33}$	Rare
Teallite	$PbSnS_2$	Rare (1)
Hochschildite	$PbSnO_3 \cdot nH_2O$	Occasionally common
Franckeite	$Pb_5Sn_3Sb_2S_{14}$	Rare
Cylindrite	$Pb_3Sn_4Sb_2S_{14}$	Rare (1)
Stokesite	$CaSn(Si_3O_9) \cdot 2H_2O$	Very rare
Nordenskioldine	$CaSn(BO_3)_2$	Very rare
Malayaite	$CaSnSiO_5$	Rare
Canfieldite	Ag_8SnS_6	Rare
Nigerite	Complex Sn silicate	Rare
Arandisite	Complex Sn silicate	Rare
Hulsite	Tin borate	Rare
Paigeite	Tin borate	Rare

(1) occasionally found in smelter concentrates

(compiled from Taylor, 1979)

Province	Country	Age	Predominant type of deposit	General Environment
Provinces of Major Economic Significance:				
Bolivia		Tertiary and Upper Triassic	Primary	Post orogenic; volcanic
Nigeria		Jurassic	Alluvial	Fracture; volcanic
Southeast Asia		Upper Carboniferous, Tertiary	Alluvial	Post orogenic; intrusive
Provinces of Intermediate to Major Economic Significance:				
Yukutia	USSR	Upper Jurassic; Lower Cretaceous	Alluvial and primary	Post orogenic; intrusive; volcanic
S. Maritimes	USSR	Upper Cretaceous; Lower Tertiary	Primary	Post orogenic; volcanic
Chukotka	USSR	Middle Jurassic; Lower Tertiary	Alluvian and primary	Post orogenic; volcanic
Transbaikal	USSR	Upper Jurassic; Lower Cretaceous	Primary	Post orogenic; intrusive; volcanic
Province of Intermediate Economic Significance:				
Brazil		Precambrian	Alluvial	Fracture; volcanic (?)
Cornwall	UK	Upper and Lower Carboniferous; Permian	Primary	Post orogenic; intrusive
Erzebirge	East Germany & Czechoslovakia	Lower Carboniferous	Primary	Post orogenic; intrusive
Central Africa		Precambrian	Alluvial and primary	Cratonic (uncertain)
NW Tasmania	Australia	Middle-Upper Devonian	Alluvial	Post orogenic; intrusive
Herberton-Mt. Garnet, Qld	Australia	Upper Permian	Alluvial and primary	Post orogenic; intrusive; volcanic

Appendix Table 2 (cont'd)

Province	Country	Age	Predominant type of deposit	General Environment
NE Tasmania	Australia	Intermediate	Primary	Post orogenic; intrusive
New England, NSW	Australia (1)	Upper Permian	Alluvial	Mostly intrusive
East Kazakstan	USSR	Permian	Primary (?)	Post orogenic; intrusive; volcanic
<u>Provinces of Minor Economic Significance</u>:				
Seward Peninsula Alaska	US	Upper Cretaceous-Lower Tertiary	Primary	Post orogenic; intrusive
New Brunswick	Canada	Lower Carboniferous	Primary	Post orogenic; intrusive; volcanic
Mexico		Tertiary	Primary and alluvial	Post orogenic; mostly volcanic
W. Iberia		Carboniferous; Permian	Primary	Post orogenic; intrusive
France	Massif Central, Brittany	Carboniferous-Permian	Primary	Post orogenic; intrusive
Nigeria		Precambrian	Primary	Cratonic (uncertain)
South Africa		Precambrian	Primary	Part of Bushveld complex
Southern Rhodesia-Zambia		Precambrian	Primary	Cratonic (uncertain)
SW Africa (2)		Jurassic; Cretaceous; Precambrian	Primary	Fracture; volcanic; cratonic (uncertain)
Swaziland		Precambrian	Primary	Cratonic (uncertain)
Japan		Upper Cretaceous; Tertiary	Primary	Post orogenic; volcanic
Cooktown, Qld	Australia	Permian	Alluvial	Post orogenic; intrusive

Province	Country	Age	Prodominant type of deposit	General Environment
Albury-Ardlethan NSW	Australia	Upper Devonian	Alluvial and primary	Post orogenic ; intrusive
Kangaroo Hills, Qld	Australia	Carboniferous; Permian	Primary	Post orogenic ; intrusive; volcanic (?)
Greenbushes, WA	Australia	Precambrian	Alluvial	Cratonic (uncertain)
Pilbara, WA	Australia	Precambrian	Alluvial	Cratonic (uncertain)
Northern Terr.	Australia	Precambrian	Primary	Post orogenic (?) ; intrusive (?)
Broken Hill, NSW	Australia	Precambrian	Primary	Cratonic (uncertain)
Malay Kningan	USSR	Upper Cretaceous; Lower Tertiary	Primary	Post orogenic ; mostly intrusive
Miao Chang-Komsomol'sk	USSR	Upper Cretaceous	Primary	Post orogenic ; intrusive
Central Asia	USSR	Upper Carboniferous (?) Permian (?)	Primary	Post orogenic ; intrusive
E. Sayan	USSR	Precambrian	Primary	Cratonic (uncertain)
Ladoga-Karelia	USSR	Precambrian	Primary	Cratonic (uncertain)
Rondonia	Brazil	Precambrian	Primary	Cratonic (uncertain)

Appendix Fig. 1 Tin Mining Areas of the World

from ITC, 1979

Operation type & country	1971	1972	1973	1974	1975	1976	1977	1978
Underground (%tin)								
Australia	0.79	0.79	1.18	1.09	0.99	1.04	1.01	1.02
Bolivia	0.79	0.80	0.67	0.83	0.81	0.76	0.74	0.69
United Kingdom	—	—	—	0.88	0.88	1.00	0.82	1.06
Malaysia	0.87	0.94	0.90	—	—	0.70	0.70	0.55
Onshore dredges (kg/m³)								
Australia	—	—	—	—	—	—	0.22	0.31
Bolivia	—	—	—	—	1.01	0.55	0.48	0.40
Indonesia (1)	—	—	—	—	—	—	0.14	0.16
Malaysia (2)	0.19	0.18	0.17	—	—	—	0.16	0.15
Thailand (1)	—	0.14	0.13	0.11	0.13	0.15	0.17	0.13
Offshore dredges (kg/m³)								
Indonesia (1)	—	—	—	—	—	—	0.38	0.48
Thailand (1)	—	0.47	0.46	0.34	0.39	0.27	0.33	0.30
Gravel pumps (kg/m³)								
Indonesia (1)	—	—	—	—	—	—	0.30	0.27
Malaysia (2)	0.30	0.32	0.30	—	—	—	0.18	0.18
Thailand (1)	—	0.42	0.32	0.31	0.36	0.32	0.29	0.34
Zaire	—	—	—	—	—	0.65	0.45	0.40
Open-cut (kg/m³)								
Indonesia (1)	—	—	—	—	—	—	0.05	0.04
Malaysia (2)	1.39	1.00	0.83	—	—	—	0.49	0.88
Zaire								
Mechanized	—	—	—	—	—	1.29	0.67	0.90
Non-Mechanized	—	—	—	—	—	0.87	0.44	0.71

(1) Average grade of total material mined (overburden or waste and ore)
(2) Average grade of ore mined

Appendix Fig. 3 Simplified Dredge Flowsheet

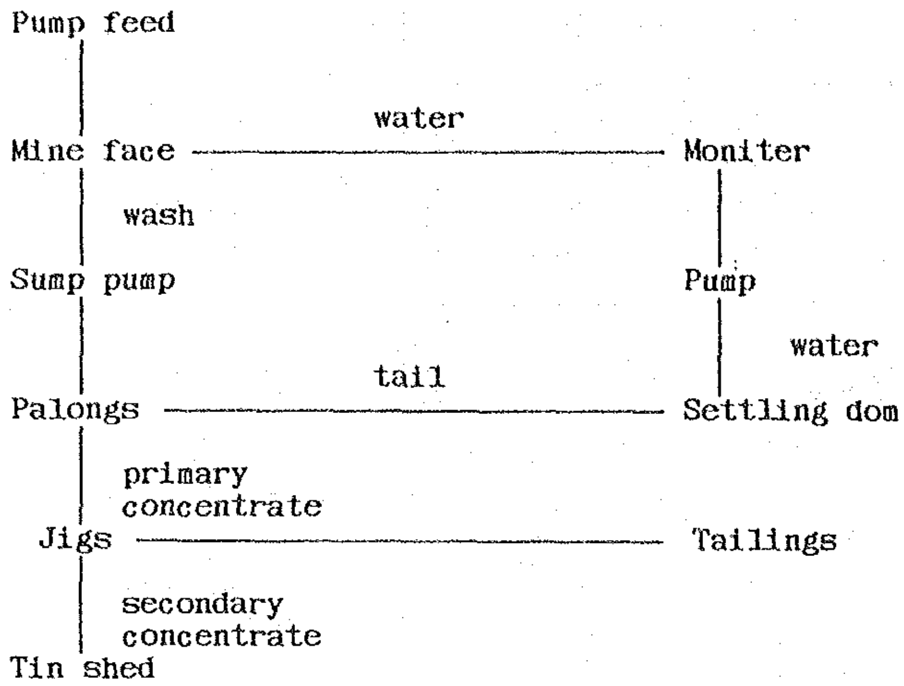
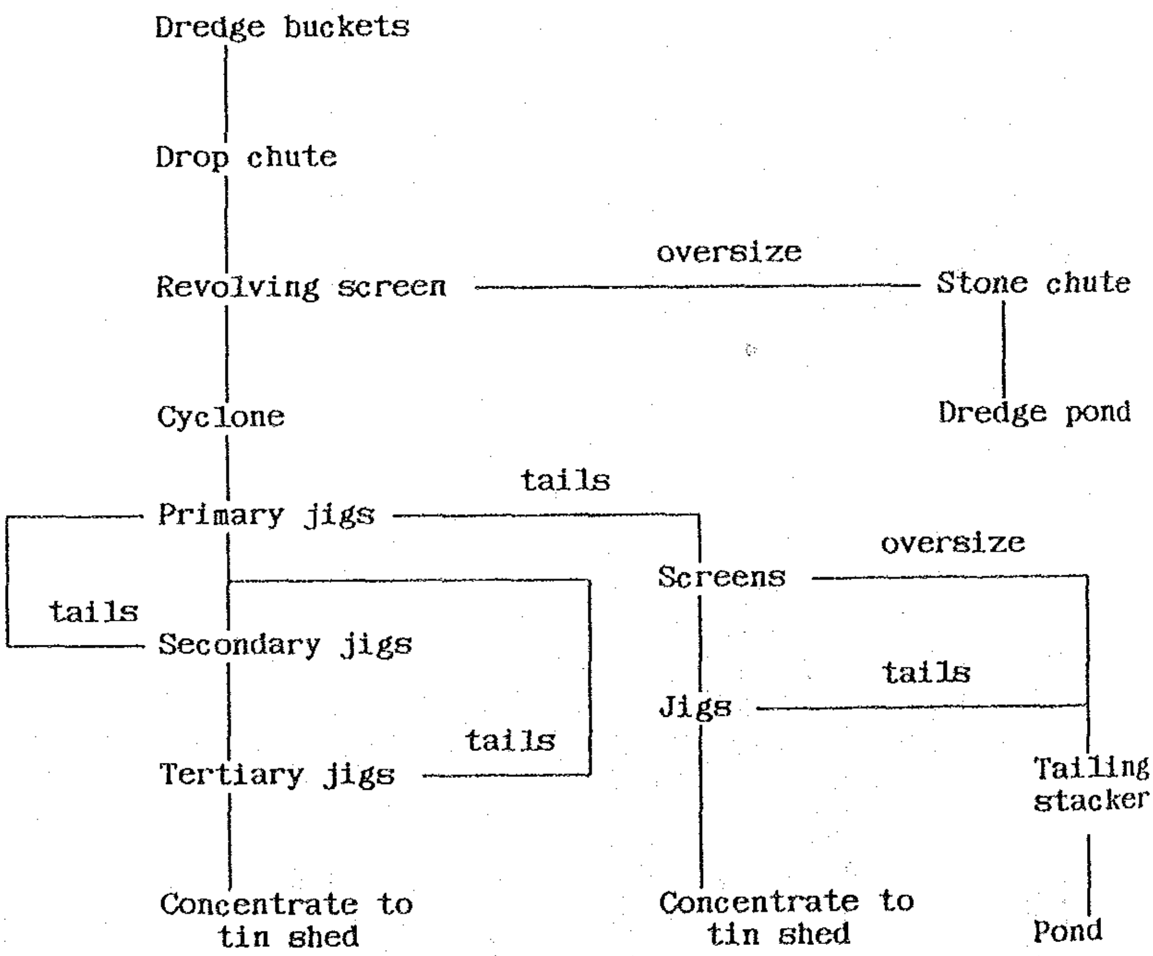
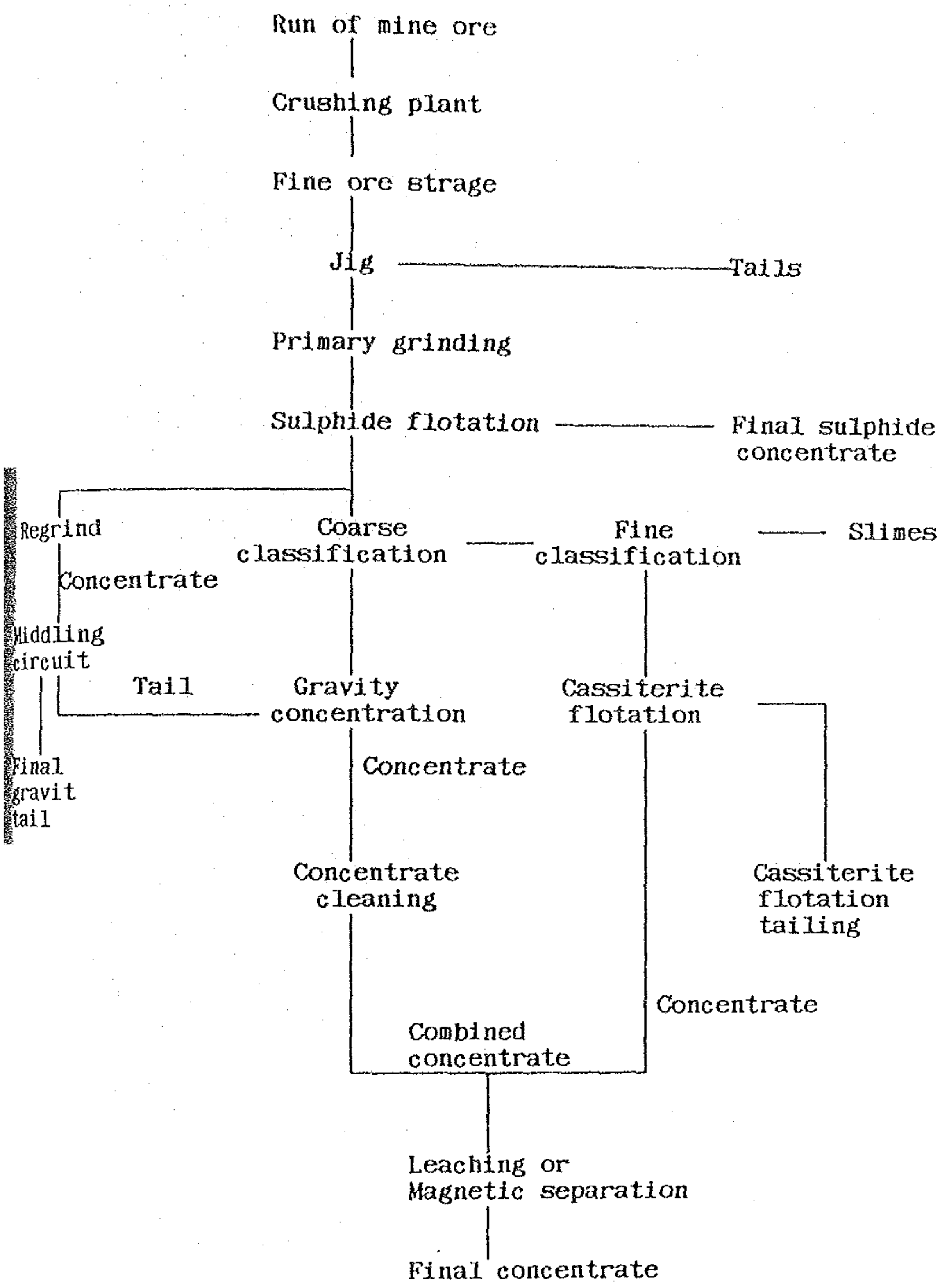


Fig. 3 Simplified Dredge Flowsheet



Appendix Fig. 4 Simplified Flowsheet for Lode Ores
(based on Ottley, 1979)

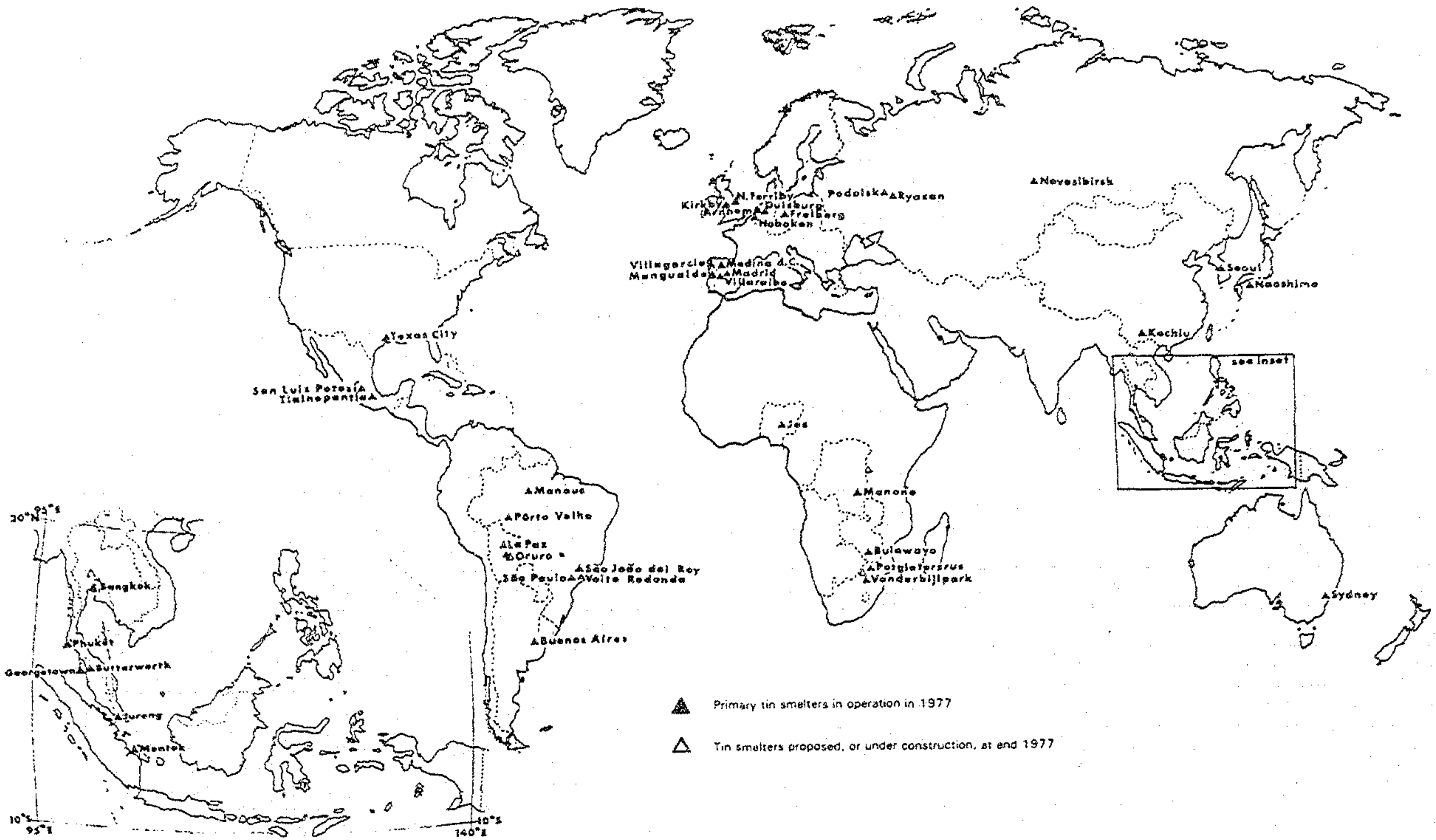


Appendix Table 4 World Primary Tin Smelters (1)

Country	Company	Location	Brand	Capacity
Nigeria	Makeri Smelting Co.Ltd.	Jos	Makeri (H.G.)	13,300 tonnes
Rwanda	Société Minière du Rwanda, SOMIRWA	Kigali		2,000 〃
South Africa	Zaaiplaats Tin Mining Co.Ltd.	Potgietersrus	ZTM	1,400 〃
	South African Iron & Steel Industrial Corp.Ltd.	Vanderbijlpark	ISCOR s use only	1,000 〃
	Rooiberg Tin Co.Ltd.		Rooiberg (H.G.)	2,500 〃
Zaire	Zairétain	Manono	Geomines (S)	7,000 〃
Zimbabwe	Kamativi Smelting & Refining Co.Ltd	Bulawayo	Jupiter (H.G.)	1,300 〃
Argentina	Estansa S.A.	Palpalá		2,000 〃
Bolivia	Empresa Nacional de Fundiciones, ENAF	Vinto	A1-A2-A3-A4-A5	30,000 〃
	Funestano	Oruro		5,000 〃
	Hormet S.A.	La Paz		500 〃
Brazil	Cia. Estanifera do Brasil, CESBRA	Volta Redonda	Cesbra (H.G.)	7,000 〃
	Cia. Industrial Amazonense	Manaus	CIA	4,800 〃
	Mamoré Mineracao e Metalurgia	Saõ Paulo	Mamore (H.G.)	2,400 〃
	Best Metáis e Soldas S.A.	Saõ Paulo	Best (H.G.)	1,200 〃
	Cia. Industrial Fluminense	Saõ João del Rei	Trevo (H.G.)	2,400 〃
	Bera do Brasil S.A.	Santo Amaro	Bera (H.G.)	200 〃
	Parecís - Alianca	Porto Velho		400 〃
Mexico	Metales Potosí	San Luis Potosí	MP (A) (B) (C)	6,000 〃
	Estano Electro S.A.	Tlalnepantla	Z (A)	1,300 〃
	Fundidora de Estãno	San Luis Potosí		1,200 〃
U.S.A.	Gulf Chemical & Metallurgical Corp.	Texas City	GCMC (H.G.) (A)	20,000 〃
China. P.R.	State Tin Enterprise	Ko-Chiu-Yunnan		

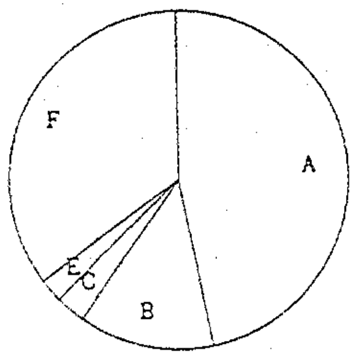
Country	Company	Location	Brand	Capacity
Indonesia	Peltim - Indonesian State Tin Corp. Smelting Unit	Mentok - Bangka	Bangka - Mentok	38,000 tonnes
Japan	Mitsubishi Metal Corp.	Naoshima	Tree Diamonds	3,600 〃
Korea, Ref.	Pyro Metal Industry Co.Ltd.	Seoul		1,200 〃
Malaysia	Datuk Keramat Smelting Sdn. Bhd.	Penang	E.S.Coy (H.G.-A)	60,000 〃
	Malaysia Smelting Corporation Sdn.Bhd.	Penang	S.R. (H.G.)	60,000 〃
Singapore	Kimetal Pte.Ltd.	Jurong		5,000 〃
Thailand	Thailand Smelting & Refining Co.Ltd.	Phuket	*Thaisarco (H.G.)*	38,000 〃
	Thai Pioneer Enterprise	Phathum Thani	Lotus (H.G.)	3,600 〃
	Thai Present Smelter Co.	Phuket	Thaipasco	3,600 〃
	Sutin Saja Wongse	Bangkok		650 〃
	Liang Ngiab Co.Ltd.	Bangkok		380 〃
German D.R.	Huttenkombinat Albert Funk	Freiberg	F	2,200 〃
Germany, F.R.	"Berzelius" Metallhutten GmbH.	Duisburg	Rose (H.G.)	3,600 〃
Netherlands	Hollandsche Metallurgische Industrie Billiton	Arnhem	Billiton (H.G.)	7,000 〃
Portugal	Neostano, Nova Empresa Estanifera de Mangualde, SARL	Mangualde	*Embel (S) (A)*	800 〃
Spain	Metalúrgical del Noroeste S.A., MENSA	Villagarcía	Concha A (H.G.)	7,000 〃
	Minero Metalúrgical del Estano S.A.	Madrid	Mesae 99.9 (H.G.)	1,000 〃
	Ferroaleaciones Espanolas S.A.	Medina	Reina Isabel B	1,200 〃
United Kingdom	Capper Pass & Son Ltd.	North Ferriby	Pass River	15,000 〃
U.S.S.R.	State Tin Enterprises	Novosibirsk	X X X (H.G.)	
Australia	Associated Tin Smelters Pty.Ltd.	Alexandria	ATS (H.G.) etc.	15,000 〃
	Greenbushes Tin N.L.	Greenbushes		1,500 〃

Appendix Fig. 5 Primary Tin Smelters of the World



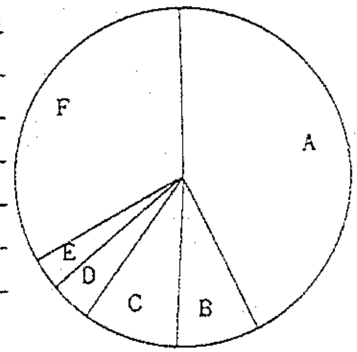
Appendix Fig. 6 Primary Tin Metal Production of the World

1 9 6 8



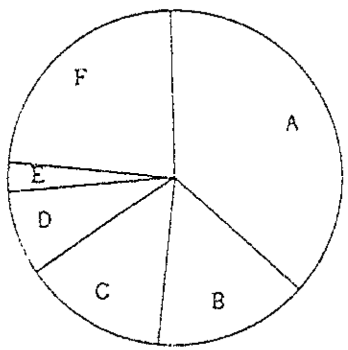
Total	187,800	tonnes
A—Mala.	89,600	(47%)
B—Thai.	24,826	(13%)
C—Indo.	4,630	(3%)
D—Boli.	60	(%)
E—Aust.	3,751	(2%)
F—Othe.	64,933	(35%)

1 9 7 5



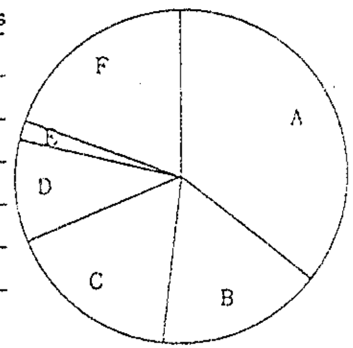
Total	193,144	tonnes
A—Mala.	83,070	(43%)
B—Thai.	16,630	(8%)
C—Indo.	17,826	(9%)
D—Boli.	7,552	(4%)
E—Aust.	5,243	(3%)
F—Othe.	62,823	(33%)

1 9 7 8



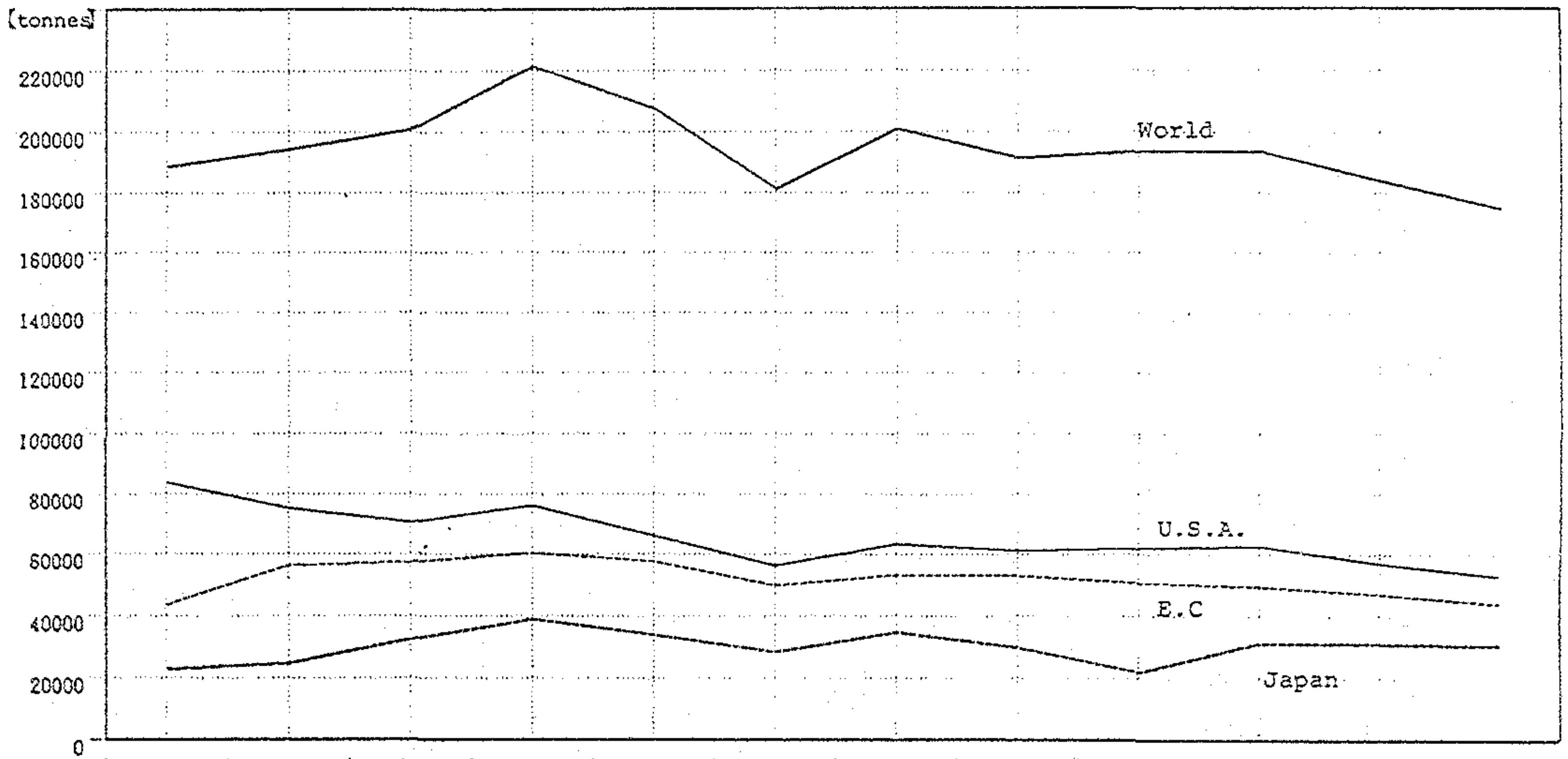
Total	191,400	tonnes
A—Mala.	71,953	(37%)
B—Thai.	28,945	(15%)
C—Indo.	25,830	(14%)
D—Boli.	16,181	(8%)
E—Aust.	5,129	(3%)
F—Othe.	43,362	(23%)

1 9 8 1



Total	195,300	tonnes
A—Mala.	70,326	(36%)
B—Thai.	32,636	(16%)
C—Indo.	32,519	(17%)
D—Boli.	19,937	(10%)
E—Aust.	4,205	(2%)
F—Othe.	35,677	(19%)

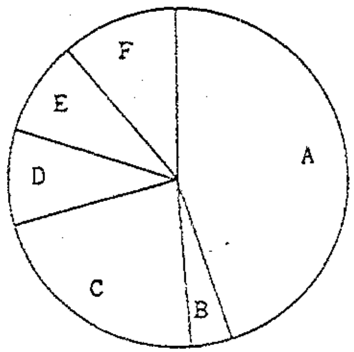
Appendix Fig. 7 Tin Metal Consumption of the World



	1968	1970	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981
—— Wor.	188,500	194,300	200,800	221,300	207,300	181,000	200,600	191,300	193,600	193,700	184,000	174,900
—— USA.	83,400	75,000	70,100	75,800	65,800	55,800	62,900	60,700	61,500	62,500	56,400	52,500
--- Jap.	22,700	24,700	32,300	38,700	33,800	28,100	34,700	29,700	21,800	31,200	30,900	30,500
--- EC	42,800	55,800	56,800	59,800	57,200	49,200	52,600	52,500	50,200	49,100	46,500	43,600

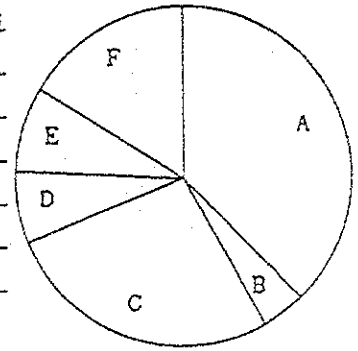
Appendix Fig. 8 Tin Metal Consumption of the World by Use

1968



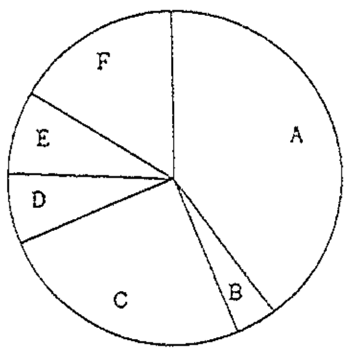
Total	145,200	tonnes
A—Plat	65,400	(45%)
B—Tinn	6,500	(4%)
C—Sold	32,600	(22%)
D—Bron	12,600	(9%)
E—Whit	12,400	(9%)
F—Othe	15,700	(11%)

1973



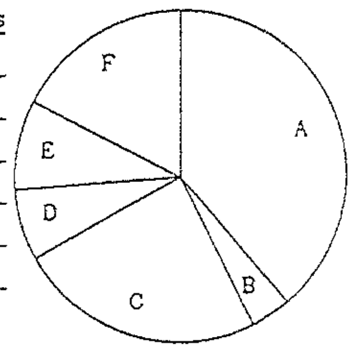
Total	169,300	tonnes
A—Plat	65,000	(38%)
B—Tinn	7,000	(4%)
C—Sold	45,100	(27%)
D—Bron	12,700	(7%)
E—Whit	13,300	(8%)
F—Othe	26,200	(16%)

1976



Total	149,700	tonnes
A—Plat	61,000	(40%)
B—Tinn	6,200	(4%)
C—Sold	37,000	(25%)
D—Bron	9,700	(7%)
E—Whit	11,900	(8%)
F—Othe	23,900	(16%)

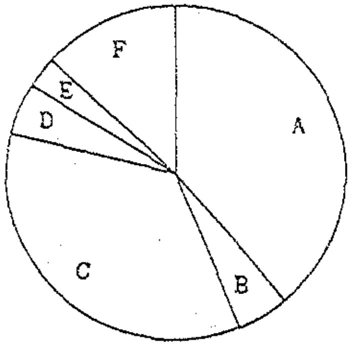
1978



Total	140,400	tonnes
A—Plat	55,200	(39%)
B—Tinn	5,900	(4%)
C—Sold	33,700	(24%)
D—Bron	10,000	(7%)
E—Whit	12,700	(9%)
F—Othe	22,900	(17%)

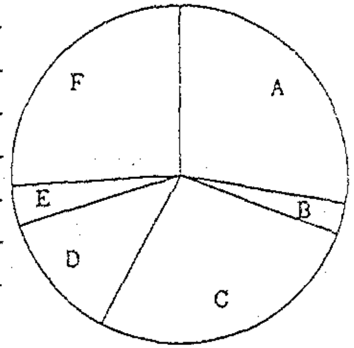
Appendix Fig. 9 Tin Metal Consumption by Use (1981)

Japan



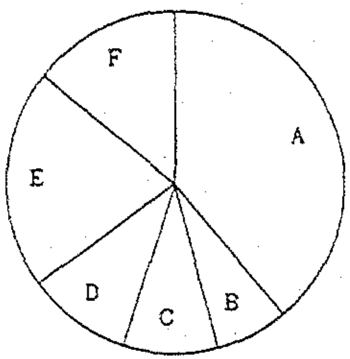
Total	30,879	tonnes
A–Plat	12,226	(39%)
B–Tinn	1,396	(5%)
C–Sold	10,878	(35%)
D–Bron	1,521	(5%)
E–Whit	855	(3%)
F–Othe	4,003	(13%)

U.S.A.



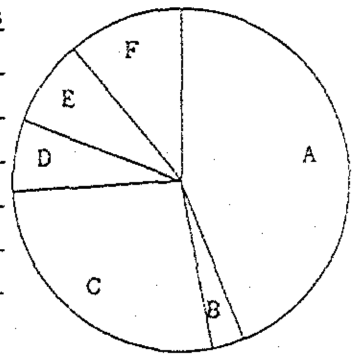
Total	46,624	tonnes
A–Plat	13,207	(28%)
B–Tinn	1,556	(3%)
C–Sold	12,393	(27%)
D–Bron	5,831	(12%)
E–Whit	1,666	(4%)
F–Othe	11,966	(26%)

United King.



Total	10,929	tonnes
A–Plat	4,274	(39%)
B–Tinn	795	(7%)
C–Sold	993	(9%)
D–Bron	1,122	(10%)
E–Whit	2,310	(21%)
F–Othe	1,435	(14%)

France



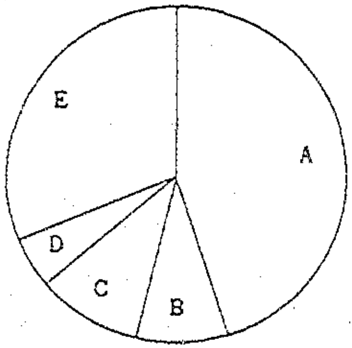
Total	9,024	tonnes
A–Plat	4,026	(44%)
B–Tinn	225	(3%)
C–Sold	2,459	(27%)
D–Bron	618	(7%)
E–Whit	704	(8%)
F–Othe	992	(11%)

tonnes

Coutry	1968	1969	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981
South Africa	680	950	700	780	910	1,080	1,175	1,400	1,380	1,355	1,340	1,510	1,600	1,490
Brazil	921	949	936	1,045	1,029	1,016	905	1,044	1,303	1,785	1,928	2,140	2,354	1,692
Canada	2,408	2,175	2,445	2,515	2,504	2,819	2,975	2,286	2,434	2,736	2,360	2,268	2,462	1,815
Mexico	900	950	900	800	840	875	990	1,000	900	900	1,200	1,070	880	1,200
U.S.A.	29,302	27,318	25,530	24,049	21,408	21,608	22,686	18,869	20,766	18,539	17,280	17,929	16,347	13,207
India	1,184	1,431	1,628	1,140	962	708	720	798	1,200	1,000	1,200	1,120	1,400	1,400
Japan	10,672	12,232	10,592	13,728	13,845	15,612	15,688	11,890	14,574	12,988	12,265	12,408	11,997	10,760
Korea, Rep.	—	—	—	115	115	176	246	220	320	300	560	800	860	960
Philipines	391	343	800	498	375	525	860	900	900	900	900	293	450	450
Taiwan	—	—	—	—	—	—	—	50	108	108	360	640	510	450
Belguim	1,311	1,388	1,444	1,485	1,540	1,392	1,806	1,637	1,550	1,724	1,403	1,510	1,466	1,320
Czechoslova.	538	550	540	400	470	438	526	469	504	540	585	625	600	535
France	4,514	5,493	5,555	5,550	5,540	5,408	6,207	4,497	4,866	5,279	4,969	4,581	4,886	3,944
Germany, F.R.	3,820	4,800	4,785	4,952	4,692	5,076	6,285	4,862	5,326	5,114	4,947	4,255	4,329	3,663
Italy	1,946	2,008	2,250	2,277	2,460	2,662	3,065	2,606	2,042	2,414	2,337	2,400	2,500	2,000
Netherlands	2,652	3,413	3,567	3,415	2,941	2,985	2,905	2,305	2,606	2,629	2,730	2,818	2,808	2,685
Norway	237	216	216	300	372	324	433	432	444	415	410	394	359	347
Poland	1,290	1,280	1,200	931	966	980	965	960	920	870	900	890	870	515
Spain	1,326	1,645	1,776	1,130	1,283	1,579	1,555	1,740	1,560	2,300	2,560	1,820	2,340	2,485
United King.	8,783	8,787	7,960	7,977	7,119	8,018	6,997	5,679	6,403	6,372	6,024	5,872	3,155	4,274
U.S.S.R.	4,000	4,000	3,500	3,610	3,620	3,920	4,230	4,200	4,200	4,200	4,200	4,200	4,200	4,200
Australia	2,077	2,429	2,505	2,617	1,923	2,281	2,475	1,848	2,315	2,415	2,251	2,049	1,693	1,631
World	79,500	83,100	80,000	80,900	76,900	81,700	86,500	72,100	79,800	78,600	76,300	75,200	71,700	64,400

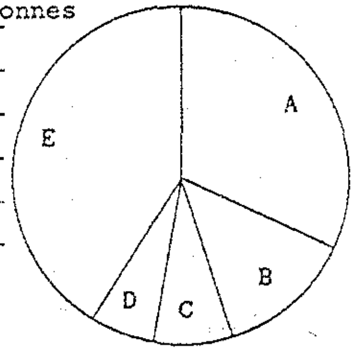
Appendix Fig. 10 Tin Plate Production of the World

1 9 6 8



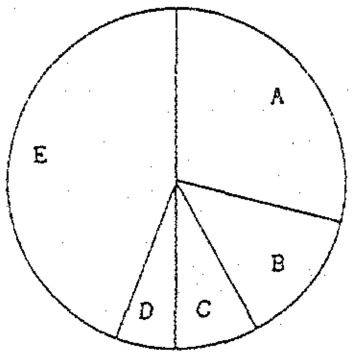
Total	12,187 ,000 tonnes	
A—USA	5,523	(45%)
B—Jap.	1,108	(9%)
C—UK	1,248	(10%)
D—Ger.	614	(5%)
E—Othe	3,694	(31%)

1 9 7 5



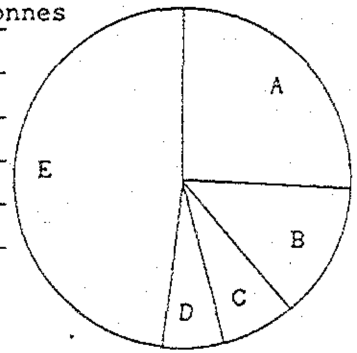
Total	12,243 ,000 tonnes	
A—USA	4,018	(32%)
B—Jap.	1,559	(13%)
C—UK	981	(8%)
D—Ger.	752	(6%)
E—Othe	4,933	(41%)

1 9 7 8



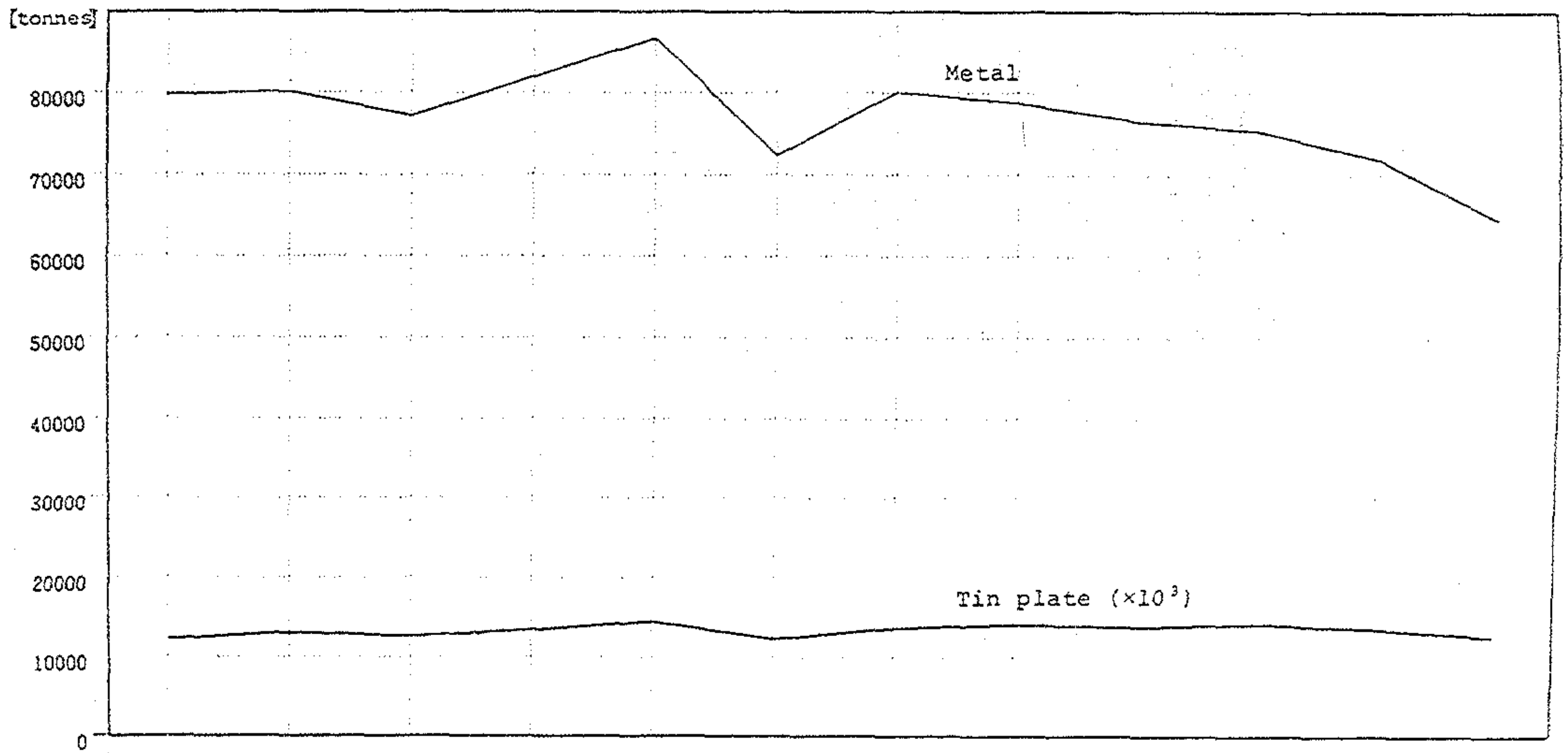
Total	13,787 ,000 tonnes	
A—USA	4,023	(29%)
B—Jap.	1,810	(13%)
C—UK	1,126	(8%)
D—Ger.	813	(6%)
E—Othe	6,015	(44%)

1 9 8 1



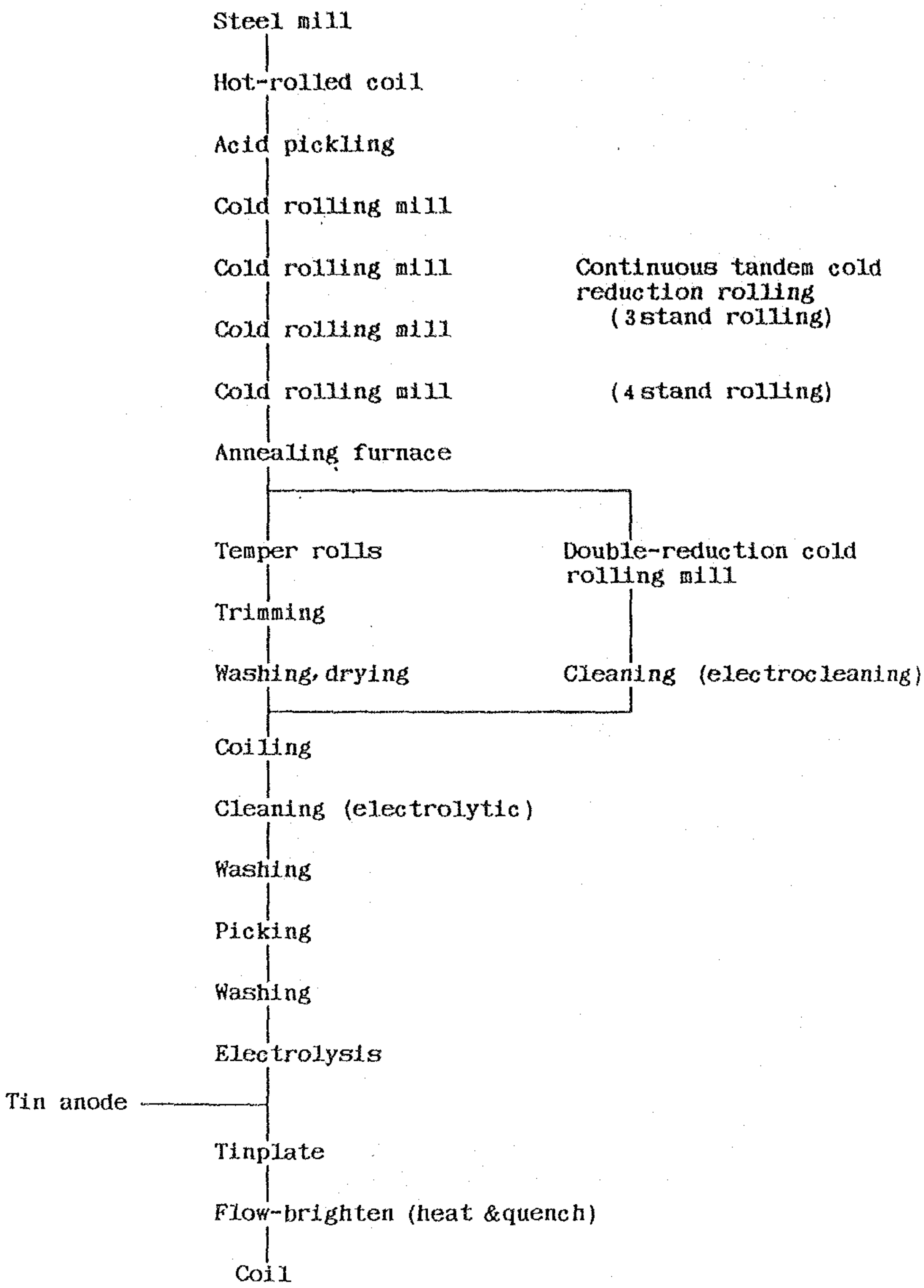
Total	12,587 ,000 tonnes	
A—USA	3,274	(26%)
B—Jap.	1,666	(13%)
C—UK	876	(7%)
D—Ger.	843	(6%)
E—Othe	5,928	(48%)

Appendix Fig. 11 Production and Tin Metal Use of Tinplate



	1968	1970	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	
— Pla.	12,187	12,967	12,577	13,400	14,398	12,243	13,557	14,081	13,787	14,243	13,618	12,587	(x10³)
— Met.	79,500	80,000	76,900	81,700	86,500	72,100	79,800	78,600	76,300	75,200	71,700	64,400	

Appendix Fig. 12 A Modern Tinplate Line



Appendix Table 6 Nominal Composition and Typical Applications of Commonly Used Solders

(from ITRI Pub. 540)

Nominal composition (%)			Typical used
Tin	Lead	Other	
100	—	—	Special non-toxic can soldering
63 60	37 40	— —	Electronic assemblies ; printed circuit boards; sheet metal work; light engineerings; soldering of copper, brass and zinc
50 40	50 60	— —	General & light engineering; capillary fittings; can soldering; sheet metal work
30	70	—	Plumbers' solder; cable jointing; auto radiators
20	80	—	Auto radiators
50 40 30	Rem Rem Rem	2.8 Sb 1.7 Sb 1.7 Sb	General engineering; dip soldering; auto radiators
95 96.5	— —	5.0 Sb 3.5 Ag	Elevated temperature applications
5	Rem	1.5 Ag	Low and high temperature applications
62	Rem	2.0 Ag	Soldering silver-containing substrates
50	Rem	18.0 Cd	Low melting point solder

Note : Rem = remainder ; Sb = antimony ; Ag = silver ; Cd = cadmium

Appendix Table 7 Nominal Composition, Typicla Mechanical Properties, and Uses of Some Tin Alloys

(from Avner, 1974)

Alloys	Nominal composition (%)					Condition	Tensile strength (PSI)	Typical uses
	Sn	Sb	Cu	Pb	Ag			
Tin, pure	99.8 min	—	—	—	—	Cast	3,100	Electrotinning ; alloying
Hard tin	99.6	—	0.4	—	—	80% reduction	4,000	Collapsible tubes & foil
Antimonial tin solder	95	5	—	—	—	Cast	5,900	Solder for electrical equipment
Tin-silver solder	96.5	—	—	—	3.5	Sheet	4,600	Solder for electrical equipment
Soft solder	70 63	— —	— —	30 37	— —	Cast Cast	6,800 7,500	For joining and coating of metals
Tin babbit	91 89 84 65	4.5 7.5 8 15	4.5 3.5 8 2	— — — 18	— — — —	Chill-cast 〃 Die-cast 〃	9,300 11,200 10,000 7,800	Automotive applications (better corrosion and wear-resistance than lead-base bearing alloys)
White metal	92	8	—	—	—	Chill-cast	7,200	Engine bearings, castings for costume jewllery
Pewter	91	7	2	—	—	Annealed sheet	8,600	Utensils

Appendix Table 8 Estimated Uses of Tin Chemicals by Type in the Free World

(from Australian Tin Information Centre)

Compound	tonnes (approx)	Uses
Inorganic tin chemicals	6,000	
SnO_2 (stannic oxide)	3,000	Ceramic glazes, glass ; melting electrodes; stone polishing compounds
$SnCl_4$ (stannic chloride)	1,000	Organotin production (6,000 tonnes) which is not included in the total estimate of tin in inorganic chemicals ; glass treatment ; textiles and soap ; catalyst for tin plating
$SnSO_4$ (stannous sulphate and sodium and potassium stannates)	500	Tin plating
SnF_2 ; $Sn(BF_4)_2$; $Sn_2P_2O_7$ (stannous fluoride, fluoborate, and phrophosphate)	200	Plating and toothpaste
$SnCl_2$; SnO ; $Sn(C_8H_{15}O_2)_2$ (stannous chloride, oxide, and octoate)	1,000	Catalysts ; stabilizers ; textile and dyeing
Organic tin chemicals (1)	30,000	
Mono-and Di-organotins	21,000	PVC stabilizers (20,000 tonnes) ; homogenous catalysts (1,000)
Triorganotins (biocidal)	9,000	Agriculture fungicides (1,000 tonnes) ; other (8,000 tonnes)

(1) equivalent to 8,000 tonnes tin ; 5,600 tonnes of tin in mono- and di-organotins, and 2,400 tonnes of tin in triorganotins

Appendix Table 9 Tin Metal Trade 1968 (1)

(from ITC export data) tonnes

imp. \ exp.	Nigeria	Zaire	Bolivia	Brazil	U.S.A.	China	HongKong	India	Indonesia	Japan	Malaysia
Canada	—	—	—	—	763	—	—	—	—	—	3,361
U.S.A.	483	—	—	—	—	—	—	—	—	—	42,168
Hong kong	—	—	—	—	—	3	—	—	—	—	112
India	—	—	—	—	2,840	—	—	—	—	—	1,800
Japan	—	—	—	—	—	496	—	—	457	—	18,688
Korea	—	—	—	—	62	—	—	—	—	24	122
Belgium/Luxemb	—	—	—	—	—	—	—	-	—	—	224
Czechoslovakia	—	—	—	—	—	—	—	—	—	—	—
Denmark	—	—	—	—	—	310	—	—	—	—	—
France	—	—	—	—	—	1,265	—	—	—	—	655
Germany, F.R.	1,082	—	—	—	—	388	—	—	—	—	1,387
Hungary	381	—	—	—	—	—	—	—	—	—	—
Italy	—	—	—	—	—	—	—	—	—	—	4,862
Netherlands	925	—	—	—	—	775	—	—	—	—	5,781
Norway	—	—	—	—	—	143	—	—	—	—	—
Poland	—	—	—	—	—	65	—	—	—	—	701
Romania	—	—	—	—	—	720	—	—	—	—	—
Switzerland	—	—	—	—	—	10	—	—	—	—	—
United Kingdom	8,169	—	—	—	144	173	—	—	—	—	1,261
U.S.S.R	—	—	—	—	—	300	—	—	—	—	1,219
New Zealand	—	—	—	—	—	—	—	—	—	—	180
Other	421	—	—	—	759	138	—	—	3,510	—	5,022
TOTAL	11,461	1,800	60	—	4,568	—	—	—	3,967	—	87,363

imp. \ exp.	Singapo.	Taiwan	Thailand	Belg./Lux	Germany	Netherl.	Switzer.	Unit.Kin	Austrari.		
Canada	–	–	–	–	–	–	–	6	–		
U.S.A.	–	–	12,045	38	–	942	–	1,527	–		
Hong Kong	–	–	–	–	–	–	–	–	–		
India	–	–	–	–	–	–	–	7	–		
Japan	–	–	1,116	–	–	–	–	–	–		
Korea	–	–	–	–	–	–	–	–	–		
Belgium/Luxem.	–	–	–	–	–	–	–	–	–		
Czechoslovakia	–	–	–	–	–	–	–	7	–		
Denmark	–	–	–	–	–	81	–	41	–		
France	–	–	–	1,955	741	1,456	–	521	–		
Germany, F.R.	–	–	–	867	–	3,739	–	340	–		
Hungary	–	–	–	–	–	–	–	41	–		
Italy	–	–	–	169	–	452	–	–	–		
Netherlands	–	–	8,911	585	48	–	–	616	–		
Norway	–	–	–	–	–	10	–	182	–		
Poland	–	–	–	–	–	–	–	864	–		
Romania	–	–	–	–	–	–	–	548	–		
Switzerland	–	–	–	–	76	346	–	88	–		
United Kingdom	–	–	–	18	–	–	–	–	–		
U.S.S.R.	–	–	–	–	–	–	–	5,142	–		
New Zealand	–	–	–	–	–	–	–	–	97		
Other	–	–	1,945	714	318	2,097	–	758	141		
TOTAL	–	–	24,017	4,346	1,107	9,123	–	10,681	238		

Appendix Table 10 Tin Metal Trade 1981 (1)

(from ITC export data) tonnes

imp. \ exp.	Nigeria	Zaire	Bolivia	Brazil	U.S.A.	China	HongKong	India	Indonesia	Japan	Malaysia
Canada	–	–	–	–	2,626	–	–	–	–	–	50
U.S.A.	520	–	–	–	–	2,031	–	–	–	–	9,953
Hong kong	–	–	–	–	–	792	–	–	–	–	951
India	–	–	–	–	–	–	–	–	–	–	2,650
Japan	–	–	–	–	–	232	–	–	–	–	17,770
Korea	–	–	–	–	–	–	–	–	–	–	983
Belgium/Luxemb	–	179	–	–	–	17	–	–	–	–	168
Czechoslovakia	–	–	–	–	–	230	–	–	–	–	420
Denmark	–	–	–	–	–	20	–	–	–	–	–
France	–	–	–	–	–	298	–	–	–	–	–
Germany, F.R.	160	–	–	–	–	244	–	–	–	–	180
Hungary	–	–	–	–	–	60	–	–	–	–	–
Italy	–	–	–	–	–	–	–	–	–	–	456
Netherlands	–	–	–	–	1,351	244	–	–	–	–	24,146
Norway	–	–	–	–	–	–	–	–	–	–	–
Poland	–	–	–	–	–	–	–	–	–	–	–
Romania	–	–	–	–	–	61	–	–	–	–	–
Switzerland	–	–	–	–	–	1	–	–	–	–	–
United Kingdom	1,667	–	–	–	97	–	–	–	–	–	270
U.S.S.R	–	–	–	–	–	294	–	–	–	–	5,710
New Zealand	–	–	–	–	–	–	–	–	–	–	–
Other	–	–	–	–	2,006	150	–	–	–	–	2,736
TOTAL	2,347	179	–	–	6,080	4,684	–	–	–	–	66,443

imp. \ exp.	Singapo.	Taiwan	Thailand	Belg./Lux	Germany	Netherl.	Switzer.	Unit.Kin	Austrari.		
Canada	—	—	—	—	—	—	–	2	—		
U.S.A.	7,604	—	10,540	—	—	100	–	6	320		
Hong Kong	4	—	—	—	—	—	–	—	—		
India	—	—	—	—	—	—	–	—	—		
Japan	602	—	4,430	—	—	—	–	—	—		
Korea	537	—	—	—	—	—	—	—	—		
Belgium/Luxem.	—	—	—	—	81	335	–	—	—		
Czechoslovakia	—	—	—	—	–	—	—	50	—		
Denmark	—	—	—	—	64	12	38	—	—		
France	—	—	—	76	99	269	50	26	—		
Germany, F.R.	—	—	—	145	—	817	32	202	—		
Hungary	—	—	—	—	—	—	—	—	—		
Italy	—	—	—	8	—	—	31	1	—		
Netherlands	3,575	—	14,030	210	3,063	—	—	68	315		
Norway	—	—	—	—	—	—	–	126	—		
Poland	—	—	—	—	—	—	—	—	—		
Romania	—	—	—	—	—	—	–	—	—		
Switzerland	—	—	—	—	—	—	-	—	—		
United Kingdom	219	—	—	—	—	145	–	–	34		
U.S.S.R.	654	—	—	—	—	—	–	602	–		
New Zealand	25	—	—	—	—	—	–	–	145		
Other	2,117	—	1,220	342	285	403	7	265	245		
TOTAL	15,335	—	30,220	781	3,592	2,081	158	1,348	1,059		

Appendix Table 11 Tin Metal Trade 1968 (1)

(from ITC import data) tonnes

imp. \ exp.	Nigeria	Zaire	Bolivia	Brazil	U.S.A.	China	HongKong	India	Indonesia	Japan	Malaysia
Canada	25	—	—	—	939	—	—	—	—	—	3,080
U.S.A.	616	—	39	—	—	—	—	—	356	—	41,988
Hong kong	—	—	—	—	—	3	—	—	—	—	83
India	—	—	—	—	1,908	—	—	—	—	—	1,997
Japan	—	—	—	—	—	496	—	—	700	—	18,338
Korea	—	—	—	—	81	—	—	—	—	24	139
Belgium/Luxemb	—	1,812	—	—	—	—	—	—	—	—	81
Czechoslovakia	—	—	—	—	—	—	—	—	—	—	—
Denmark	—	—	—	—	—	310	—	—	—	—	46
France	427	46	—	—	—	1,265	—	—	1,021	—	1,136
Germany, F.R.	776	—	—	—	—	388	—	—	3,017	—	2,619
Hungary	—	—	—	—	—	—	—	—	—	—	—
Italy	—	—	—	—	—	—	—	—	434	—	4,439
Netherlands	163	—	—	—	—	775	—	—	—	—	229
Norway	—	—	—	—	—	143	—	—	—	—	—
Poland	280	—	—	—	—	65	—	—	—	—	549
Romania	—	—	—	—	—	720	—	—	—	—	—
Switzerland	—	—	—	—	—	10	—	—	51	—	183
United Kingdom	8,027	—	—	—	147	173	—	—	—	—	1,041
U.S.S.R	—	—	—	—	—	300	—	—	—	—	1,200
New Zealand	—	—	—	—	—	—	—	—	—	—	180

imp. \ exp.	Singapo.	Taiwan	Thailand	Belg./Lux	Germany	Netherl.	Switzer.	Unit.Kin	Austrari.	Other	TOTAL
Canada	—	—	320	—	—	—	—	6	—	—	4,370
U.S.A.	81	—	12,523	12	—	885	—	1,452	—	326	58,278
Hong Kong	—	—	—	—	—	—	—	11	—	25	139
India	21	—	—	—	—	—	—	7	—	2	3,935
Japan	—	—	1,004	—	—	—	—	—	15	20	20,573
Korea	3	—	—	—	—	—	—	—	—	35	282
Belgium/Luxem.	—	—	—	—	—	365	—	—	—	191	2,449
Czechoslovakia	—	—	—	—	—	100	4,364	109	—	—	4,573
Denmark	—	—	269	—	—	—	—	43	—	106	774
France	—	—	1,148	1,939	42	1,720	—	791	—	—	9,535
Germany, F.R.	—	—	510	803	—	3,651	—	228	—	82	12,074
Hungary	—	—	—	—	—	—	—	757	—	526	1,283
Italy	—	—	1,227	162	—	551	—	—	—	124	6,937
Netherlands	—	—	2,103	238	10	—	—	208	—	564	4,290
Norway	—	—	—	—	—	20	—	199	—	57	419
Poland	—	—	457	—	—	—	—	1,946	—	—	3,297
Romania	—	—	—	—	—	429	31	1,222	—	10	2,412
Switzerland	—	—	121	—	76	326	—	103	—	13	883
United Kingdom	—	—	—	20	—	15	—	—	15	129	9,567
U.S.S.R.	—	—	—	—	—	—	—	5,200	—	400	7,100
New Zealand	—	—	—	—	—	—	—	16	99	1	296

Appendix Table 12 Tin Metal Trade 1981 (1)

(from ITC import data) tonnes

imp. \ exp.	Nigeria	Zaire	Bolivia	Brazil	U.S.A.	China	HongKong	India	Indonesia	Japan	Malaysia
Canada	—	—	917	427	2.006	—	—	—	—	—	30
U.S.A.	—	—	8,277	1.129	—	2.031	50	1	7,096	—	13.164
Hong kong	—	—	—	—	·	792	—	—	—	65	62
India	—	—	—	—	—	—	—	—	—	—	1.180
Japan	—	—	—	—	—	232	—	—	6,514	—	18.517
Korea	—	—	·	—	—	—	—	—	—	—	—
Belgium/Luxemb	—	179	—	—	—	—	—	—	—	—	414
Czechoslovakia	—	—	—	—	—	—	—	—	—	—	—
Denmark	—	—		—	—	20	—	—	—	—	15
France	—	—	591	—	—	298	—	—	1.980	—	1.727
Germany.F.R.	160	—	848	—	—	244	—	—	4,580	—	1.884
Hungary	—	—		—	—	—	—	—	—	—	—
Italy	—	—	—	—	—	—	—	—	1,730	—	1,636
Netherlands	—	—	64	—	—	244	—	—	421	—	1.035
Norway	—	—		—	—	—	—	—	—	—	16
Poland	—	—	—	—	—	—	—	—	—	—	—
Romania	—	—	—	—	—	—	—	—	—	—	—
Switzerland	—	—		—	—	—	—	—	525	—	130
United Kingdom	1,667	—		—	—	—	—	—	965	—	210
U.S.S.R	—	—	478	95	141	294	—	—	530	—	9.908
New Zealand	—	—		—	—	—	—	—	—	—	18

imp. \ exp.	Singapo.	Taiwan	Thailand	Belg./Lux	Germany	Netherl.	Switzer.	Unit.Kin	Austrari.	Other	TOTAL
Canada	365					50		6		10	3.811
U.S.A.	656		11.967					46	553	903	45.873
Hong Kong	-		10							174	1.103
India	175				-	-				-	1.355
Japan	-		4.901			-				59	30.223
Korea	-					-				-	-
Belgium/Luxem.	-				106	903		21		927	2.550
Czechoslovakia	-										
Denmark	-		20					1		34	90
France	-		3.280	96	17	187		19	45	612	8.852
Germany.F.R.	-		6.230	162		819		309	79	609	15.924
Hungary	-					-				-	-
Italy	-		494							627	4.487
Netherlands	15		2.596	271	401			202	30	50	5.329
Norway	-				5	1		443		35	500
Poland	-									-	
Romania	-									-	-
Switzerland	-		150	1	59	15		29		31	926
United Kingdom	-					1.349			84	1.000	5.285
U.S.S.R.	904		210		662	295		602	60	158	14.337
New Zealand	-								149	13	180

[7] PIG IRON AND SEMI-FINISHED STEELS

[7] PIG IRON AND SEMI-FINISHED STEELS

CONTENTS

[7] PIG IRON AND SEMI-FINISHED STEELS

A. OUTLINE

I. Concept and Characteristics of Pig Iron and Semi-finished Steels

Before presenting the results of the study on pig iron and semi-finished steels of the Carajas project, it is necessary to deal with briefly the concept of pig iron, semi-finished steels and their characteristics. This Study includes also a study on various conditions which should be taken into account when Brazil will consider the feasibility of producing those products using domestic iron-making raw materials for export. In such case, if it must be assumed that constant trade of those products with purchasers outside of Brazil is feasible, it is imperative that the Brazilian products, as merchandise, satisfy the purchasers' various requirements as to quality, shape, size, specifications and price of the products. However, in order to ensure their international competitiveness, generally they need be produced on a large scale, and this makes it unavoidable to consider sale of a part of the production to unspecified and non-regular purchasers, which in turn causes a difficulty of finding purchasers who would be satisfied with the products each time.

The concept and characteristics of pig iron and semi-finished steel described here are only rudimental and introductory. In case that export of those products from Brazil is to be considered in the frame of a broad, world steel industry, it is necessary to study not only quantitative possibility but qualitative suitability of the products for export. At any rate various factors must be examined closely not only in their domestic sale but in their international trade.

1. Pig Iron

Pig iron is an intermediate product produced by reducing iron ore to iron. Major part of pig iron is used as raw material for steelmaking and a part is used for foundry. Chemical composition of pig iron varies according to grades or uses, but it consists of the element iron combined with other chemical elements; 1.7% to 4.6% carbon and small amount of Si, Mn, P, S, etc. and is hard and brittle.

A large part of pig iron produced in the world is produced in blast furnaces which use coke as main fuel. It is also produced, though in small amount, in charcoal blast furnaces using charcoal as fuel and in electric iron-making furnaces.

Pig iron produced in blast furnaces which use charcoal contains less detrimental impurities such as P and S than that produced in blast furnaces using coke and has better quality in use. However, it is difficult to produce in a large quantity as possible with blast furnaces based on coke and is generally more expensive and used for limited purposes. Electric furnace pig iron is produced by using electric power as energy source for melting. As raw materials, mainly sand iron is used when producing pig iron used for steelmaking, and mainly pyrite cinder, mill scale and iron scrap are used when producing it for foundries. As reducing agent, low grade coke or coke breege, and in rare cases, anthracite are used.

Pig iron tapped from a blast furnace is in molten form, but soon solidifies. Pig iron in molten form is called liquid iron or hot metal, and that in solid form cold pig. In making cold pig, usually pig-casting machines are used to divide liquid iron into small pigs weighing as little as 10 kg to 30 kg to facilitate handling.

Generally pig iron for sale is in this form of cold pig.

Types of pig iron are mainly classified as follows:

a. Steelmaking pig iron

This applies to pig iron used for steelmaking in B.O.F., electric furnaces and open hearth furnaces.

b. Foundry pig iron

This pig iron is used for iron casting and foundries and contains higher Si content than steelmaking pig iron. High Si pig iron is used for acid-resisting cast iron or foundries requiring specially high Si content. Foundry pig iron may also be used for steelmaking in some cases if its chemical composition is close to that of steelmaking pig iron.

c. Low phosphorus pig iron

In many cases, sand iron is used as raw material and this pig iron is produced in electric furnaces as in case of low copper pig iron. Since special care is taken in selecting raw materials, P content is exceptionally low (about 0.03%) and the pig iron is used in acid open hearth furnaces or electric furnaces to produce high quality steel. It is difficult to remove P and S in acid furnaces.

2. Steel Ingots (Reference)

Steel ingot is made by casting or teeming molten steel made in steelmaking furnaces into ingot molds. Though a part of molten steel is cast into molds to produce steel castings, a major part of molten steel is made into ingots. Weight of an ingot varies from 20-30 metric tonnes to as small as 150 kg. In particular, small ingots are slender as candles and called candle ingots. There are not much but constant demand for those small ingots for use in small section mills in developing countries.

Ingots are classified according to chemical properties into rimmed steel, killed steel and semi-killed steel.

Rimmed steel is low carbon steel. During teeming and solidification, steel solidifies in a mold giving off gas and sparks, first outer skin forming along the wall of mold. This outer skin is called rim containing relatively few impurities and no blowholes, and right behind this rim there are zones containing blowholes, and the center of the ingot is not homogeneous in composition with segregation. Rimmed steel can be rolled to products with good surface quality and workability and used in making sheets and strips.

When molten steel is teemed with addition of strong deoxidizers such as aluminum, the steel does not emit gas during solidification and is made ingots relatively homogenous in chemical and physical properties. This steel is called killed steel and is carbon steel used for making boiler plate and tubes, high grade ship plate, wire rod for wire ropes and structural parts of machinery. Killed steel is low in yield and high in cost.

Semi-killed steel comes between rimmed steel and killed steel and is generally used for making plate and sections.

- Crude steel
  - Ingots
    - By ingot mold
      - For rolling
      - For forging
    - By continuous casting (C.C. slabs, blooms, billets)
  - Cast steel

When ingots are intended for sale, it is necessary to produce them according to the requirements of purchasers, and therefore it is not rare that sale of steel ingots to unspecified and non-regular purchasers from the beginning of operation encounters some difficulties.

3. Concept of Semi-finished Steels

Semi-finished steels are intermediate products called blooms, billets, slabs, etc. Steel ingots are heated and rolled on primary rolling mills such as blooming and/or slabbing mills or continuous billet rolling mills. The ingots are reduced in sectional area gradually and given fine structure to improve quality to be ready for processing to subsequent products. Semi-finished steels are also made by continuous casting process.

Table A-1 Kinds of Semi-finished Steels

Name	Dimension at section	Subsequent products
Blooms	Length of a side over 130 mm	Heavy rail, large sections, medium sections, pipes
Billets	Length of a side 130 mm or less	Medium sections, small sections, wire rods, strips, pipes
Slabs	Thickness over 45 mm	Heavy plate, medium plate, sheet, strips, wide strips
Sheet bar	Thickness 45 mm or less (excl. medium rolled sheet)	Medium plate, sheet, black plate
Intermediate sheet	Thickness 45mm or less, materials for sheet, produced on strip mill, etc. When used on sheet mill, rolled on finishing stands without passing roughing stands.	Sheet

Semi-finished steels are classified according to use and size, but there are cases where special treatment is made customarily according to special use or kind of rolling mills used as follows:

a. Semis for plate are always called slabs regardless of sectional configuration.

b. Independent of size, those produced by blooming mills are blooms, and those made by billet mills are billets.

c. There are also cases where semis consumed for making strips are all called slabs customarily depending on process and use.

Though there are special cases as above, as a rule semi-finished steels are classified according to shape and size. There are cases, however, where small steel mills cast small ingots or candle ingots and roll them directly into steel products without passing the semi-finished stages so as to save investment in blooming and billeting mills. In this case, main products are medium and small bars and sections, and wire rods.

The most important of semi-finished steels for sale in domestic and international markets are generally billets and slabs, and they occupy a dominant part of semis traded in world markets.

II. Iron-Making Processes and Their Characteristics

Pig iron is an intermediate product produced from iron ore consisting of iron oxide and gangue by reducing it to iron and removing unwanted elements by burning metallurgical coke or charcoal.

Chemical composition of pig iron varies according to uses, but it contains about 1 to 5% carbon and a small amount of silicon, manganese, phosphorus, sulphur, etc.

Manufacturing processes are classified according to heat sources into coke blast furnace process, charcoal blast furnace process, electric furnace process, etc.

1. Coke Blast Furnace Process (Blast furnace pig)

This pig iron is produced by using coke as heat source which is burned by hot blast in a blast furnace. This process is the most important process for making pig iron at present and the pig iron from this process occupies the dominant part of pig iron production.

What made the expansion of steel demand possible is the change of fuel used in pig iron production from charcoal to metallurgical coke, namely emergence of coke blast furnaces.

Compared to other processes, coke blast furnaces can be enlarged and the process can produce a large quantity of pig iron most efficiently (This is because coke has more physical strength under load than charcoal).

Through successive technological innovations, the blast furnaces today have high productivity, some furnaces being capable of producing 10,000 tonnes of pig iron a day. New technologies which contributed to the increase in productivity include intensified pretreatment of furnace burdens, use of self-fluxing sinters, high top pressure, high temperature blast (hot stoves) and production of coke with high strength. However, the blast furnace process requires various large facilities, which involve a vast amount of construction investment. Besides, the blast furnaces and ancillary facilities need constant maintenance in order to ensure their efficient operation.

2. Charcoal Blast Furnace Process (Charcoal pig)

Charcoal pig is produced in small blast furnaces, using charcoal as fuel. Charcoal has better reactivity but lower strength than coke, and this makes it difficult to have large furnaces, especially in their height. At present, their inner volume is 20 to 600 cubic meters with daily production of about 20 to 800 tonnes. Since large scale production as possible with coke blast furnaces cannot be expected, the production cost is high.

On the other hand, the furnaces of this process are small and so are ancillary facilities such as raw material charging devices and hot stoves, and their construction cost is low compared with that of coke blast furnaces. Production of charcoal furnaces has been 20,000-200,000 tonnes of pig iron annually, but through introduction of advanced facilities and technologies such as bell-less top, conveyor charging, high top pressure operation (1.5 kg/cm^2), high temp. blowing (1,100°C), etc., the charcoal blast furnaces built in recent years have annual capacity to produce 250,000-300,000 tonnes of pig iron.

In the meantime, production of charcoal may be endlessly repeated through plantation if an expanse of plantable land is available barring question of difficulty of land acquisition and environment conservation whereas coal for making coke is not reproducible.

Taking into consideration production scale, construction cost and manpower requirement, the charcoal furnace process enjoys some promising future for mini-mills with annual production of 200,000-300,000 tonnes of steel products through the route of charcoal furnace—steelmaking furnace—continuous casting—rolling.

3. Electric Iron-Making Furnace Process (Electric pig)

Electric pig is pig iron made in electric furnaces, and compared with the preceding coke blast furnace and charcoal blast furnace processes, this process is in a smaller production scale with 2,000 to 50,000 tonnes a year.

As this process uses electric furnaces and consumes a large electricity (1,000 kWh-3,000 kWh per tonne of pig iron), the site selection for a plant based on this process is very limited by availability of electric power. In other words, the site must be located in the area where electricity is available at low cost while metallurgical coke is in short supply or expensive. On the other hand, however, the process can utilize iron ore which is unsuitable for blast furnaces such as sand iron, titan bearing ore, low phosphorus iron, and this makes it easy to select the side in terms of raw materials supply. In particular, recently pretreatment technologies have been developed for various raw materials, and this electric furnace process has been adopted at such countries as Sweden, Norway and Yugoslavia, with a view of utilization of low grade iron ore. If power supply is favorable, construction cost of this process is considerably lower than that of blast furnace and charcoal furnace processes.

4. Direct Reduction Process

Direct reduction (DR) process is so called in a broad sense as against the process of blast furnace - B.O.F. route.

In DR process, iron ore is reduced to iron using coal, coke or natural gas as reducing agent, and so far several methods have been developed, with some already in commercial operation. There are two types of DR process; one to reduce iron ore in solid state and the other in melted state. The former is already in wide use in several countries whereas the latter is attracting interest recently as new DR process, and research and development are being made in earnest.

Reasons for much interest in DR process are: As compared with blast furnace - B.O.F. process, construction cost is low; various reductants such as coke, natural gas, coal, etc. can be used; low grade iron ore can be used; the process is flexible in operation (with respect to facilities and manpower). Recently the steel industry throughout the world is experiencing shortage of available fund and raw materials (especially good coking coal) and difficulty in recruiting able and skilled workers (due to outflow to other industries). Once blown-in, a blast furnace cannot be stopped operation for a long period (5 to 10 years) and requires a considerable burden, economic, technical and labor, for control and maintenance of the facilities involved.

Productivity of DR facilities is considerably lower than that of coke blast furnaces having daily production of 1,000 to 10,000 tonnes because DR facilities have production capacity of 100 to 1,200 tonnes a day and have limits in their expansion.

4.1 Direct Reduction Process (Solid reduction)

Most of the present DR processes are to reduce iron ore in solid form into reduced iron or sponge iron, and there are rotary-kiln process, shaft-furnace process and fluidized bed process. Those processes have been developed and put in operation already.

4.2 Smelt Reduction Process

In this process, iron ore is melted and reduced to iron, and compared with solid reduction process, it is possible to produce reduced iron similar to hot metal depending on kind and use of reducing agents.

There are rotary-kiln process, fine ore reduction process and electric iron-making process.

Considerable research and development works have been made on the rotary-kiln process and fine ore reduction process in Sweden, the United Kingdom, and the United States, but they are not yet commercialized. But there is a report that CIP process (Centrifuge ironmaking process) developed in the United Kingdom was test operated in the beginning of 1980s. Electric iron-making process is as described in the proceding section on pig iron production.

Many other processes are under research and development as new smelt reduction processes mainly in Sweden.

Among others, there are new processes based on electric furnaces using plasma or arc, some already in commercial operation. For example, through remarkable progress in plasma generating facilities and technology, it became possible that local concentration and high temperature of energy characteristic of plasma is utilized to promote melting and reducing reaction in a furnace. This process has been developed in Sweden, the United States and Canada and some already in operation.

Appendix: Characteristics of Blast Furnace, Electric Steelmaking and DR Process

	Blast Furnace	Charcoal Blast Furnace	Direct Reduction	Electric Steelmaking Furnace
1. Raw materials	Iron ore	Iron ore	Iron ore	Scrap
2. Main fuel	Metallurgical coke indispensable (coking coal)	Charcoal (Restricted in site selection)	Flexible (natural gas, coke, coal, etc.)	Electricity
3. Facilities				
Production scale	large/unit 1,000-10,000t/d	Small/unit 20-800t/d	Med.-small/ unit 100-2,000t/d	Med.-small/ unit 50-400t/ heat
Crude steel production/ year/plant	300,000 - 16,000,000t	5,000 - 700,000t	30,000 - 2,000,000t	5,000 - 2,400,000t
Aux. facilities	Many, both up & down stream	Fairly many, both up & down stream	Not many, both up & down stream	No facilities up stream
4. Operation				
Engineers & workers	Many	Not so many	Not so many	Not so many
Period	5-10 years continuous	3-7 years continuous	Stop & resumption flexible	Stop & resumption very flexible
5. Construction period	5-6 years	2-3 years	2-3 years	1-2 years
6. Capital investment	Large	Med.-small	Small	Small

Source: Japan Iron & Steel Federation

III. Patterns of Manufacture of Semi-finished Steels and Their Characteristics

Production and consumption of crude steel are universally adopted throughout the world as criterions or indices indicating the condition or trend of demand and supply of steel and of steel industry in each country as well as in the world.

Crude steel is produced in steelmaking furnaces such as B.O.F., electric arc furnaces, and open hearth furnaces and in the form of ingots for rolling or forging, continuously cast products or steel castings according to use and manufacturing processes employed. Crude steel production according to this classification in major countries is shown in Table A-2 together with percentage of each category.

Semi-finished steel products (semis) are in the form of bloom, billet, slab and sheet bar. A major part (more than 90%) of these semis are manufactured from ingots for rolling or are continuously cast (C.C.) products.

1. Semis by Blooming, Slabbing and Billeting

Molten steel from steelmaking furnaces is taken in ladles, from which it is teemed into ingot molds to make ingots. This process is called teeming.

Size and shape of ingots vary according to the uses intended (Weight varies from 100 kg to 60 tonnes). Ingots thus produced are charged into soaking pits for uniform heating to 1,100-1,300°C, and heated ingots are rolled on the primary rolling mills into semis with specified cross section and size. To produce semis from ingots involves the processes of teeming, reheating and rolling, which requires much investment and consumes much energy.

To skip such costly and energy-consuming route, therefore, so-called continuous casting (C.C.) process has gained popularity, which does not make ingots but make semis direct from molten steel by continuous (sequence) casting.

However, large-sized semis for extra heavy plate or large diameter round billets, very wide slabs and semis with special shape which are difficult to produce by C.C. have to be made from ingots through the conventional route.

Therefore, when a new steel plant is constructed or an expansion of an existing steel mill is made to produce semis, it would be advantageous to adopt the production pattern of steelmaking-c.c. route. In this case, however, its steel products may not include part of high carbon steel, highly alloyed steel, or forgings and castings. As seen in Table A-2, the percentage of ingots in the total steel production is declining while that of C.C. semis is increasing.

Table A-2 Crude Steel Production in Major Countries (by category)

Country	Year	Production (1,000 t/MT)				Percentage (%)		
		Ingots	c.c. Semis	Steel castings	Total	Ingots	c.c. Semis	Steel castings
USA	1977	99,261	14,268	171	113,700	87.3	12.5	0.2
	78	105,219	18,903	191	124,313	84.6	15.2	0.2
	79	102,588	20,904	195	123,687	82.9	16.9	0.2
	80	80,940	20,595	161	101,696	79.6	20.3	0.2
	81	85,622	23,003	157	108,782	78.7	21.1	0.1
UK	1977	17,382	2,554	475	20,411	85.2	12.5	2.3
	78	16,722	3,149	440	20,311	82.3	15.5	2.2
	79	17,442	3,627	396	21,465	81.3	16.9	1.8
	80	7,845	3,059	372	11,276	69.6	27.1	3.3
	81	10,306	4,958	308	15,572	66.2	31.8	2.0
Germany, FR	1977	25,201	13,272	512	38,935	64.7	34.0	1.3
	78	25,092	15,670	491	41,253	60.8	38.0	1.2
	79	27,548	17,948	544	46,040	59.8	39.0	1.2
	80	23,138	20,162	538	43,838	52.8	46.0	1.2
	81	18,777	22,319	514	41,610	45.1	53.6	1.2
France	1977	16,494	5,244	356	22,094	74.7	23.7	1.6
	78	16,208	6,286	347	22,841	71.0	27.5	1.5
	79	16,076	6,930	354	23,360	68.8	29.7	1.5
	80	13,240	9,561	375	23,176	57.1	41.3	1.6
	81	9,975	10,917	369	21,261	46.9	51.3	1.7
Italy	1977	14,106	8,986	242	23,334	60.5	38.5	1.0
	78	13,976	10,073	234	24,283	57.7	41.3	1.0
	79	12,780	11,243	227	24,250	52.7	46.4	0.9
	80	12,974	13,300	247	26,521	48.9	50.1	0.9
	81	11,988	12,578	211	24,777	48.4	50.8	0.9
Japan	1977	59,573	41,807	1,024	102,405	58.2	40.8	1.0
	78	53,898	47,159	1,048	102,105	52.8	46.2	1.0
	79	52,502	58,116	1,130	111,748	47.0	52.0	1.0
	80	43,900	66,271	1,224	111,395	39.4	59.5	1.1
	81	28,694	71,843	1,139	101,676	28.2	70.7	1.1
Total of 29 IISI member countries in Western World	1977	321,065	107,636	3,836	432,537	74.2	24.9	0.9
	78	319,959	128,275	3,979	452,213	70.7	28.4	0.9
	79	320,979	150,016	4,098	475,093	67.6	31.6	0.9
	80	270,178	170,744	4,210	445,132	60.7	38.4	0.9
	81	245,416	189,888	3,865	439,169	55.9	43.2	0.9

Source: IISI

2. Semis by Continuous Casting

Continuous casting facilities are such machine in which molten steel is poured into water-cooled copper molds having cross section of intended semis and cooled rapidly passing through the mold to solidify and the semis are withdrawn continuously from the machine; in other words, the machines make semis direct from molten steel. This does away with the conventional processes of teeming, heating and primary rolling, resulting in reduction of capital investment and labor cost, saving of energy consumption, improvement of production yield and better working environment. Recently, through progress in C.C. machines and technologies and remarkable innovation of ladle refining at up stream and of facilities and technologies in down stream rolling departments, it became possible to expand kinds of steel suitable for C.C. and shapes and sizes of C.C. semis as well as improve quality of C.C. semis. As a result, the percentage of C.C. semis in the total crude steel production is increasing year after year.

However it should be mentioned that primary rolling mills would have priority in producing high value-added special steels which tend to be produced in small lots of varied kinds (The C.C. process cannot be employed naturally for making large ingots for forging or steel castings).

Up to the first half of the 1970s, motivation for installation of C.C. machines in each country was mainly improvement in productivity (yield) and labor saving by elimination of certain processes as well as improvement of working environment. But from the latter half of the 1970s, emphasis was shifted to its effect on energy saving, and this further promoted installation of C.C. machines.

By scale of steel mills, large integrated steel mills install mainly C.C. machines for blooms or slabs in place of primary rolling mills whereas small electric furnace steel mills (including DR based mills) employ C.C. machines for billets more frequently to replace small blooming or billeting mills. In particular, DR based steel mills constructed in recent years more often than not install C.C. machines for billets. At integrated steel mills, further research and development are under way to enhance efficiency, productivity and quality of C.C. machines with a view of better meeting demands for diversified and high grade steel products.

To satisfy requirement for large semis, for example, there are C.C. machines producing slabs with width of 2,500 mm or more and blooms with thickness of 350 mm or more, and now large C.C. machines having annual capacity of one million tonnes a year have appeared.

Table A-3 shows existing and planned C.C. machines by product (slabs, blooms and billets) throughout the world.

Table A-3 C.C. Machines by Product in the World

	At end of		At end of 1981				Planned for 1981 & after			
	1970	1974	Slabs	Blooms	Bil-lets	Total	Slabs	Blooms	Bil-lets	Total
USA	48	64	25	29	50	104	5	10	3	18
USSR	42	50	28	23	3	54	-	3	1	4
Germany, FR	23	38	22	12	10	44	-	1	-	1
France	4	13	11	10	5	26	-	-	-	-
Italy	29	74	16	29	73	118	1	6	4	11
UK	11	23	12	4	8	24	1	1	1	3
Japan	40	111	39	33	75	147	2	7	4	13
Subtotal	197	373	153	140	224	517	9	28	13	50
Others	102	178	101	115	224	440	23	18	68	109
Total	299	551	254	255	448	957	32	46	81	159

Note : - sign indicates data which is not available.

Source: Japan Iron & Steel Federation

IV. Some Consideration on Iron Ore and Fuel as Raw Materials

Raw materials used for iron making in a blast furnace are divided largely into main raw materials and auxiliary raw materials. Main raw materials include iron ore, sinters and pellets made by calcining iron ore and prereduced iron, and coke as heat source. Auxiliary raw materials are limestone and dolomite for removing unnecessary elements.

As blast furnace fuels, there are, in addition to coke, heavy oil, natural gas, tar, etc. and oxygen used for enriching blast to promote combustion of coke around tuyers may be considered as a kind of fuel.

1. Iron Ore

For making 1 tonne of pig iron in a blast furnace, about 1.6 tonnes of iron ore is necessary though the figure differs somewhat depending on grades. Iron ore can be divided into lump ore and fine ore.

Iron ore directly charged into a blast furnace is crushed and screened to a proper size, removing fines, to enhance its reducibility in the furnace and ensure permeability of reducing gas. Fine ores, if charged into the furnace, interfere with the permeability to obtain good wind rate, which has adverse effect on production efficiency and fuel consumption.

In order to increase operation efficiency of a blast furnace, therefore, it is necessary to do sizing of iron ore before charging. However, there are some cases recently where limitation of available plant site for expansion of screening facilities and shortage of fund for necessary investment restrict expansion of sizing capacity.

On the other hand, fines can be charged into a blast furnace after processed to sinters or pellets. In recent years, high quality, strong agglomerates have been produced through research and development of facilities and technologies for sintering and pelletizing fine ore; for example, self-fluxing sinters containing slag-forming flux is one. Blast furnaces can be operated more efficiently with sinters than lump ore.

With increase in use of fine ore, demand for lump ore relatively declined. Consequently, some efforts are being made on the part of ore suppliers to crush and screen ores at mines and shipping ports. It may be also necessary for the suppliers to push rationalization and modernization of mining technology at mines to improve quality and strengthen infrastructures such as railways and port facilities so as to maintain and improve their competitiveness in international markets. Table A-4 shows unit consumption of charged ore per tonne of pig iron produced by blast furnaces in the United States, the United Kingdom, the Federal Republic of Germany, France, Italy and Japan, in iron ore, sinters and pellets.

2. Fuels

Coke is indispensable for blast furnace process. In the furnace, coke acts as fuel and reductant and also plays an important role to provide passages for reducing gas and fused iron. Therefore, coke must have physical properties to keep its strength in the furnace as well as proper chemical quality.

In particular, enlargement of a blast furnace which contributes to furnace productivity in great measure depends on availability of coke with considerable strength and hardness because the bigger a blast furnace the more load coke is subjected to.

For producing coke having such properties, so-called coking coal is used. But because of limited availability of coking coal, technology of charging formed coal has been established to use ordinary steam coal and non-coking coal, and many research and

Table A-4 Unit Consumption of Charged Ore in Blast Furnaces in Major Countries

Country	Year	Consumption (kg/MT)				Percentage (%)				Lime-stone consump-tion (kg/MT)
		Ore	Sinter	Pellet	Total	Ore	Sinter	Pellet	Total	
USA	1970	418	517	670	1,605	26.0	32.2	41.8	100.0	154
	1975	296	441	869	1,606	18.4	27.5	54.1	100.0	234
	1980	104	406	1,053	1,563	6.7	26.0	67.3	100.0	182
	1981	83	373	1,099	1,555	5.3	24.0	70.7	100.0	167
UK	1970	466	1,173	—	1,639	28.4	71.6	—	100.0	73
	1975	468	1,139	—	1,607	29.1	70.9	—	100.0	78
	1980	456	1,133	...	1,589	28.7	71.3	...	100.0	17
	1981	567	1,027	...	1,594	35.6	64.4	...	100.0	8
Germany, FR	1970	482	1,036	91	1,609	30.0	64.4	5.6	100.0	36
	1975	209	1,202	102	1,513	13.8	79.4	6.8	100.0	24
	1980	226	1,071	278	1,575	14.3	68.0	17.7	100.0	26
	1981	*487	1,098	...	1,585	30.7	69.3	...	100.0	24
France	1970	684	1,422	14	2,120	32.3	67.1	0.6	100.0	10
	1975	193	1,702	31	1,926	10.0	88.4	1.6	100.0	9
	1980	149	1,593	59	1,801	8.3	88.5	3.2	100.0	7
	1981	*202	1,572	...	1,774	11.4	88.6	...	100.0	4
Italy	1970	157	1,095	282	1,534	10.2	71.4	18.4	100.0	...
	1975	131	1,263	176	1,570	8.3	80.4	11.3	100.0	...
	1980	*364	1,223	...	1,587	22.9	77.1	...	100.0	...
	1981	...	...	...	...	...	...	...	100.0	...
Japan	1970	371	991	208	1,570	23.6	63.1	13.3	100.0	25
	1975	271	1,159	185	1,615	16.8	71.8	11.4	100.0	9
	1980	180	1,244	195	1,619	11.0	76.8	12.0	100.0	2
	1981	200	1,244	172	1,616	12.4	77.0	10.6	100.0	2

Notes : 1) * Includes pellets
2) – sign indicates data which is not available.
... sign indicates data which is unreliable and excluded in this Study.

Source: ECE, Annual Bulletin of Steel Statistics for Europe and National Statistics on Iron & Steel development works have been made in various countries on technologies of formed coke to produce coke from ordinary coal, most actively in Japan.

Gas, ammonia, light oil and tar generated as by-products in coke making are recovered and used as energy sources in steel mills or as raw materials for chemical products.

Before the oil crisis, oil injection into a blast furnace was made in some countries. Because coking coal is rather limited in supply and expensive, heavy oil was injected at the rate of 20 to 80 kg/t of pig iron to lower coke ratio. But as a result of increase of oil prices in the 1973 oil crisis, oil injection decreased, and particularly after the second oil crisis, the oil injection has almost disappeared. Instead of the oil injection, use of coke has increased, or injection of far, natural gas or other fuel has been made in recent years.

V. Speciality of Pig Iron and Semi-finished Steels as Merchandise and General Consideration

The study concerning pig iron and semi-finished steels as a part of the Carajas Project is characterized by the fact that those two products do not comprise items generally traded as independent items in everyday iron and steel markets.

Usually, sale or export of iron and steel means trading of final iron and steel products or rolled steel products. Pig iron may become an object of trade, but semi-finished steels or semis may not. They are offered for sale when there is surplus because of non-alignment in capacities among production processes and purchased when there is demand for rolling them to finished products (e.g. billets for bar mills and slabs for plate) as observed in the backward integration. Their trade is therefore rather limited.

Steel industry is a typical capital-intensive industry, and its efficient and economical production is only possible with concurrent existence and growth of related industries in its supporting fields and availability of public utilities and other infrastructures. Consequently a vast amount of investment is required not only for construction of the industry but of related industries.

In the case of an integrated steel mill, iron and steel is produced most efficiently when each phase of production processes from receiving and treating raw materials, iron making, steel making, rolling to finishing is organically connected with each other in a good balanced condition. Recently the entire flow of production is computer-controlled on on-line system.

Throughout the world, there are only a very few instances of construction of iron and steel works specializing in production of pig iron or semis for sale, which can produce those products with competitiveness, mainly due to vast construction cost involved.

If pig iron or semis are to be sold singly, they have very low added-value and cannot be profitable generally unless they are produced in exceptionally favorable condition or traded under special selling condition such as firm commitments to buy them.

Attention should be paid also to future supply and demand situation of scrap as far as pig iron is concerned. Pig iron is always in competition with scrap as steelmaking materials, and generation of scrap and its price has a profound effect on consumption of pig iron in steelmaking.

At present, steelmaking facilities in the world steel industry consist mainly of basic oxygen furnaces (B.O.F.), where hot metal is principal charge and scrap can be used only to a certain limit. It should be kept in mind, however, that pig iron ratio in the charge fluctuates considerably depending on scrap price. Also depending on price of hot metal or pig iron, there are cases electric furnace steelmaking or mini-mills have relative advantages even after taking electric power cost into consideration.

Generally speaking, occurrence of scrap in a country is determined by steel consumption in the country about 20 years ago, but the period of such cycle has become shorter recently as durable goods are being intentionally made outdated sooner, and as a result occurrence of scrap in industrialized countries in particular has increased. Such trend may be seen as working to decrease demand for pig iron in future.

When the Study on this project is made by paying due consideration to those basic factors, it would be reasonable to study future trend of production of pig iron and semis and their specific patterns in the world in comparison with those products produced in Brazil under given conditions and aim at positioning Brazilian production of those two products in their world production.

For this purpose, this Study will first outline the present condition and future prospects of steel industry in industrialized countries, developing countries and centrally planned countries, all affected more or less by an extensive change in the world steel industry structure and then view the Brazilian production of pig iron and semis in the light of the changed pattern of world iron and steel production.

The analysis in the Study will be focused on the present condition and prospects of steel industry in major countries, among others in industrialized countries including the USSR and partly in comparison with direction of the industry in newly industrializing steel producing countries. In such sense, this Study will concern the object field in major steelmaking countries having bearing on Brazil and aim at positioning Brazil in the global steel industry structure in future.

B. PRESENT CONDITION OF WORLD STEEL INDUSTRY AND ITS STRUCTURE

I. Trend of World Production of Pig Iron and Crude Steel

1. Trend of World Pig Iron Production by Region and by Country

Change in world pig iron production by region and by country during 10 years from 1972, a year before the impact of the oil price increase effected by OPEC countries, to 1981 is as shown in Tables B-1 and B-2.

Analyzed by region, Western Europe and North America showed a remarkable decrease in production during the decade; pig iron production of the former region in 1981 was 95.0% of that in 1972 while that of the latter was 83.4%. On the other hand, the regions which showed a notable increase are Latin America, Africa/Middle East and Asia with 172.0%, 147.3% and 126.6%, respectively. Eastern Europe and the USSR showed 119.6% increase and Oceania also showed 112.2% increase, but the growth in the decade was slow. Growth of free world as a whole was only 101.7% and that of world total for the 10 years was a slightly higher than 9%. Among them notable are Latin American countries and some Asian countries (see Table B-1).

Analysed by country, decrease of nearly 20% of the United States and about 10% of EC and in contrast, increase of 123% of Brazil and about 36% of Mexico are outstanding. In Eastern Europe notable are 20% increase of the USSR and 81% increase of Romania. The growth in the two countries has slowed in recent years but contributed considerably to about 20% increase of the region.

As major iron ore producers, India showed an increase of 28% and Australia 12.2%.

Newly industrializing steel producing countries in Asia, the Republic of Korea expanded pig iron production during the decade 1,321 times and Taiwan 12.6 times, reflecting start-up of newly integrated steel mills based on blast furnace process.

Thus, weight of world pig iron production by region shifted as shown in Table B-1; Western Europe and North America decreased the regional shares while developing regions (in particular, Latin America and Asia) and Eastern Europe gained their shares.

Table B-1 Change in Weights of Regions in World Pig Iron Production

(1,000 MT)

	1972 (A)		1981 (B)		B/A
	Production	%	Production	%	
Western Europe	113,132	25.2	107,520	21.9	95.0
Eatern Europe	117,767	26.2	140,845	28.7	119.6
North America	91,583	20.3	76,382	15.6	83.4
Latin America	10,401	2.3	17,891	3.6	172.0
Africa/M. East	5,780	1.3	8,515	1.7	147.3
Asia	105,153	23.4	133,089	27.1	126.6
Oceania	6,006	1.3	4,740	1.0	112.2
World Total	449,822	100.0	490,982	100.0	109.2

Source: IISI

2. Trend of World Crude Steel Production by Region and by Country

During the 10 years from 1972 to 1981, world crude steel production increased from 630 million MT to 706.9 million MT, but the growth is about 1.06 times or 0.6% at average annual rate. This was caused by the fact that the impact of the oil price increase in 1973 on the world economy brought about a considerable decrease in steel demand in major countries in the world and that the demand has not recovered yet. The impact was most strongly felt by industrialized countries and non-oil-producing developing countries. During the 10 years to 1981, crude steel production decreased about 10% in EC, about 5% by Western Europe as a whole and about 7% in the United States. In the other hand, the production increased 75.3% in Latin America, 387.7% in Middle East, 28.5% in Asia and 20.8% in Eastern Europe. Increase in Eastern Europe can be attributed to the increase in the USSR while other countries in the region showed a slowing growth, and the increase in developing countries was helped greatly by increased production in oil producing countries and newly industrializing countries such as Brazil (about twice), the Republic of Korea (18.4 times), India (1.57 times), Taiwan (5.8 times) and Mexico (1.7 times), etc.

Outstanding in the increased production by region are 4.88 times of Middle East, 1.73 times of Africa, 1.75 times of Latin America and 1.29 times of Asia. The crude steel production in Western Europe and North America showed decrease of about 5% and 7%, respectively. World total increased 12.1%.

Table B-2 World Pig Iron Production

Country or Region	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1981/1972
	(Calendar year)											(1,000 MT)
BELGIUM	11,777	12,655	13,152	9,069	9,866	8,912	10,128	10,858	9,900	9,809		
DENMARK	204	76										
F R OF GERMANY (1)	31,793	36,581	39,901	28,049	31,629	28,784	29,939	35,181	33,873	31,876		100.3
FRANCE	18,552	19,760	21,986	17,494	18,659	17,884	18,100	19,415	19,159	17,273		93.1
GREECE												
IRELAND												
ITALY	9,634	10,271	11,761	11,411	11,630	11,411	11,340	11,327	12,149	12,259		
LUXEMBURG	4,671	5,091	5,468	3,889	3,759	3,568	3,721	3,801	3,569	2,858		
NETHERLANDS	4,289	4,707	4,804	3,970	4,267	3,922	4,613	4,814	4,330	4,600		
UNITED KINGDOM	15,358	16,884	13,941	11,935	13,873	12,266	11,465	10,898	6,264	9,470		
SUB-TOTAL	96,278	106,025	111,013	85,817	93,683	86,747	89,306	96,294	89,244	88,175		91.6
AUSTRIA	2,846	3,006	3,443	3,056	3,320	2,965	3,077	3,702	3,485	3,477		
FINLAND	1,184	1,412	1,381	1,368	1,329	1,764	1,858	2,038	2,019	1,976		
NORWAY	647	700	661	638	647	503	553	654	610	618		
PORTUGAL	377	347	282	327	344	421	422	432	349	410		
SPAIN	6,093	6,567	6,905	6,842	6,626	6,636	6,254	6,454	6,370	6,247		
SWEDEN	2,587	2,782	2,979	3,309	2,952	2,330	2,363	2,905	2,377	1,770		
SWITZERLAND (2)	36	26	35	35	25	27	25	30	30	35		
TURKEY	1,135	896	1,317	1,337	1,679	1,616	1,710	2,302	2,140	1,996		
YUGOSLAVIA	1,949	2,109	2,126	2,001	1,919	1,928	2,081	2,368	2,436	2,816		
WESTERN EUROPE	113,132	123,876	130,142	104,730	112,522	104,937	107,649	117,179	109,060	107,520		95.0
BULGARIA	1,562	1,610	1,528	1,509	1,552	1,614	1,493	1,451	1,539	1,514		
CZECHOSLOVAKIA	8,476	8,656	8,905	9,290	9,475	9,715	9,944	9,529	9,820	9,905		
GERMAN Dem. Rep.	2,147	2,197	2,280	2,456	2,528	2,628	2,560	2,586	2,448	2,423		
HUNGARY	2,074	2,115	2,290	2,219	2,221	2,320	2,330	2,385	2,214	2,212		
POLAND	7,291	7,601	7,654	7,604	7,912	9,517	111,109	10,966	11,378	8,870		
ROMANIA	4,890	5,713	6,081	6,602	7,416	7,781	8,155	8,879	9,102	8,857		
USSR	91,327	94,937	78,876	101,759	104,400	106,500	110,000	108,300	106,582	107,066		
EASTERN EUROPE	117,767	122,829	127,614	131,639	135,504	140,075	145,591	143,896	143,083	140,845		119.6
CANADA	8,722	9,740	9,582	9,311	10,033	9,661	10,338	10,906	10,893	9,744		111.7
UNITED STATES (1)	82,861	93,522	87,008	72,506	78,808	73,780	79,541	78,929	62,343	66,638		80.4
NORTH AMERICA	91,583	103,262	96,590	81,817	88,841	83,441	89,879	89,835	73,236	76,382		83.4
ARGENTINA	849	804	1,083	1,030	1,284	1,100	1,435	1,114	1,036	907		
BRAZIL	5,300	5,532	5,846	7,053	8,170	9,380	10,043	11,594	12,686	11,793		222.5
CHILE	487	458	516	418	403	433	539	612	647	592		
COLOMBIA	288	271	269	298	285	223	295	241	281	232		
MEXICO	2,778	2,885	3,207	2,048	2,531	2,999	3,509	3,486	3,639	3,770		
PERU	163	253	303	286	226	241	246	265	258	177		
VENEZUELA	536	533	546	546	421	352	413	509	497	420		
LATIN AMERICA	10,401	10,736	11,770	11,679	13,120	14,728	16,480	17,821	19,044	17,891		172.0

Table B-2 (cont'd.)

Country or Region	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1981/1972
	(Calendar year)											(1,000 MT)
EGYPT (3)	299	250	250	250	250	250	250	250	250	280		
TUNISIA (2)	143	158	145	145	103	136	132	140	140	150		
SOUTH AFRICA	4,899	4,886	4,663	5,213	5,845	5,807	5,895	7,021	7,218	7,365		
ZIMBABWE	427	432	441	553	861	654	690	650	786	700		
OTHERS (4)	12	10	12	12	15	20	20	20	20	20		
AFRICA/M.EAST	5,780	5,736	5,511	6,173	7,074	6,867	6,987	8,081	8,414	8,515		147.3
CHINA (5)	21,000	21,000	22,000	22,000	18,000	20,000	26,000	28,000	30,000	29,000		138.1
INDIA	7,402	7,341	7,406	8,437	9,776	9,803	9,269	8,767	8,509	9,474		128.0
JAPAN	74,005	90,007	90,437	86,877	86,576	85,886	78,589	83,825	87,041	80,049		108.2
KOREA, Dem. Rep. (5)	2,600	2,700	2,700	2,900	3,000	4,000	5,000	5,000	5,400	5,000		
KOREA, Rep. of	6	455	987	1,194	2,012	2,426	2,741	5,063	5,577	7,925		
TAIWAN(ROC)	128	150	111	117	105	623	1,417	1,760	1,724	1,611		
THAILAND (2)	12	15	17	14	18	20	27	30	30	30		
ASIA	105,153	121,668	123,658	121,539	119,487	122,758	123,043	132,445	138,281	133,089		253.3
AUSTRALIA	6,006	7,182	7,515	7,513	7,308	6,733	7,280	7,759	6,976	6,740		112.2
OCEANIA	6,006	7,182	7,515	7,513	7,308	6,733	7,280	7,759	6,976	6,740		112.2
WORLD TOTAL	449,822	495,282	502,800	465,090	483,856	479,539	496,909	517,016	498,094	490,982		109.2
SUMMARY BY REGION												
WESTERN EUROPE	113,152	123,870	130,142	104,730	112,522	104,937	107,649	117,179	109,060	107,520		95.0
EASTERN EUROPE	117,767	122,829	122,614	131,639	135,504	140,075	145,591	143,896	143,083	140,845		119.6
NORTH AMERICA	91,585	105,262	96,590	81,817	88,841	83,441	89,879	89,835	73,236	76,382		83.4
LATIN AMERICA	10,401	10,736	11,770	11,679	13,120	14,728	16,480	17,821	19,044	17,891		172.0
AFRICA/M.EAST	5,780	5,736	5,511	6,173	7,074	6,867	6,987	8,081	8,414	8,515		147.3
ASIA	105,155	121,668	123,658	121,539	119,487	122,758	123,043	132,445	138,281	133,089		126.6
OCEANIA	6,006	7,182	7,515	7,513	7,308	6,733	7,280	7,759	6,976	6,740		112.2
WORLD TOTAL	449,822	495,283	502,800	465,090	483,856	479,539	496,909	517,016	498,094	490,982		109.2
WESTERN WORLD TOTAL (6)	308,455	348,754	350,486	308,551	327,352	315,464	320,518	341,428	319,081	313,822		101.7

(1) INCLUDES BLAST-FURNACE FERRO ALLOYS OTHER THAN FERROMANGANESE AND SPIEGELEISEN
(2) 1979, 1980 AND 1981 : ESTIMATED
(3) FROM 1974 TO 1981 : ESTIMATED
(4) ESTIMATED SERIES
(5) FROM 1976 TO 1981 : ESTIMATED
(6) WESTERN WORLD MEANS THE WORLD EXCLUDING THE USSR AND EASTERN EUROPE, CUBA, CHINA AND THE DEMOCRATIC REPUBLIC OF KOREA
1981P : FOR 1981 -PRELIMINARY FIGURES

Source: IISI