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APPROPRIATE TECHNOLOGY FOR HEAVY INDUSTRIES

CHOICE AND ADAPTATION OF ALTERNATIVE TECHNOLOGY FOR THE IRON AND STEEL INDUSTRY

Background Paper

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CHOICE AND ADAPTATION OF ALTERNATIVE TECHNOLOGY FOR THE IRON AND STEEL INDUSTRY

by the

UNIDO secretariat

I. Introduction

Technological process routes and technological alternatives in multiple fields of iron and steel production for diverse product-mix present a wide spectrum irrespective of whether a country is developing or developed. The judicious choice of technological processes itself is not easy adjudged on techno-economic rationale. The selection of alternative technology in the production metallurgy of iron and steel in the developing countries is complex and often dictated by business interests and motivations and its applications in the developing world is still more so. There are many inter-linked factors which are not wholly technological or even remotely so, that come into play in the choice of technology, selection of alternative technology and their applications for the iron and steel industry in the developing countries.

Let us refer pragmatically to a few cases to illustrate the complex issues involved, say technology and the market (domestic and/or export). Take the case of Afghanistan for example: The country has abundant resources of high grade iron ores - Hajigak iron ore, thousands of million tons, well prospected and proved and also ample reserves of high grade natural gas and these two major raw materials are the basic feed to produce high grade sponge iron, which in turn can be easily melted into steel. The gaseous direct reduction processes to make steel via the sponge route are well proved adjudged by requisite techno-economic yardsticks/criteria. But Afghanistan has no rail or road transport system to service and feed the high grade iron ore deposits lying in the mountains. Additionally, the internal iron and steel market is very small and the export market is nil. These two non-technical factors viz the lack of infrastructure facilities rail/road transport system and scanty domestic market will therefore govern the choice of technology/alternative technology which has to be based pragmatically on a small iron and steel scrap melting electric furnace shop coupled with a small steel rolling mill to produce steel rods, bars, light sections/angles etc. for the building industry say with an initial capacity of 25,000 - 50,000 tons/year to meet domestic market needs. The training of manpower, availability of infrastructure facilities and the market can then grow in unison and the country can then plan for adaptation of a different alternative technology to produce iron and steel.

Let us now take the case of Mutan high grade iron ore deposits, equally well prospected and proved in Bolivia which also has abundant natural gas resources. What technological route should Bolivia follow and what alternatives present themselves; could be the Afghanistan model but possibly more in the field of mining the high grade iron ore for export to Argentina which needs this raw material for its expanding iron and steel industry and later for sponge production in Argentina and a mutual reciprocal trade can be established considering that Bolivian domestic steel market is very small. In fact, such joint projects between Bolivia and Argentina are on the active planning stages at the present time.

Let us now take Malaysia, with excellent forests of rubber wood and also having high grade iron ores and natural gas. However, considering the limited domestic steel market, the optimum choice of (alternative) technology is based on charcoal small iron blast furnace and conventional LD oxygen steelmaking integrated into a small/medium steel plant; this model was selected by Malaysia and the Malayawata steel plant is producing iron and steel product-mix profitably by this route. The choice, therefore, of alternative technology and its adaptation are based not wholly on technological parameters but governed by non-technical factors and rightly so.

Let us take the case of Argentina and Brazil. Pari passu with integratedheavy iron and steel plants operations (million tons/year capacity and higher), the charcoal based iron and steel industry in the private sector in Brazil is producing high grade foundry iron and basic iron for steelmaking at the rate of well over 3.5 million tons/year and exporting the relatively purer high grade foundry iron at a high premium export price to earn rich dividends in foreign exchange and feed it back to install currently planned capacity of 9-10 million tons of charcoal based iron and steel industry by the year 1985.

Likewise, forest rich countries, like Nepal, Cameroon, Paraguay are considering these technological routes and models for establishing the iron and steel industry on an optimum scale.

The choice of alternative technology has therefore to be based on various parameters ranging from raw materials and natural resources to infra-structure facilities and market potential. This then presents the broad and complex spectrum, nevertheless well defined, from which the developing countries have to choose the alternative technology to produce steel and apply it judiciously on commercial scale. This pattern of course, will grow with rising steel output and the market and so will the pattern of alternative technology with changing and growing market potential to produce the one most important basic product for economic growth and industrial development viz the iron and steel.

II. Objectives

The objectives, therefore, of arriving at indigenous steel production (irrespective of the pragmatically selected alternative technological route(s) are to provide steel and feed the light and heavy engineering industries dependent upon steel as the basic raw material and thereby promote the economic development and industrial growth of the developing countries. The infra-structure facilities' growth of trained manpower and related auxiliaries, self-sufficiency in technical skills, team work and management, domestic production of equipment spares and machinery, capital goods and design engineering, establishment of technical consultancy services and applied research and development supporting network and the experience so gained are thus the main objectives which the iron and steel industry promotes and aims at in the overall economic and industrial growth of a developing country.

These objectives are equally important for relatively small developing countries or others currently at low and intermediate levels of industrial development, in order to self-reliance and self-sufficiency.

III. Review of Alternative technologies

The spectrum of available technologies for iron and steel production is wide and is well depicted in the attached Table No. I. Some major technological alternatives/options open to developing countries are given below:

Major options and technological alternative in terms of annual steel capacity

	Approximate Minimum Economic Size (tons/year)	Comments
Bar mill (re-rolling mill)	10,000	Depends on local or imported steel billets supplies
Bar mill with scrap-based electric furnace	25,000	Wholly dependent on scrap, the availability of which must be ensured; needs reasonably priced electric power
Bar mill with electric pig iron furnace and LD oxygen steel making	50,000	Needs very low-cost electric power
Bar mill with electric arc furnace and direct reduction (sponge production)- gasous/ solid reductant DR processes	20[illegible],000	Precludes dependence on scrap market, but depends on low-cost energy source to reduce iron ore and melt reduced material
Bar and flat products with blast furnace and LD oxygen steel making	500,000	Demands good quality coking coal and high investments

TABLE I

Technological alternatives

Type		Material —— Process —— Product	Application	Capacity of works (1000t/y)	Number of employees (persons)	Period of construct. (years)	Capital investment (million $)
				very	rough	esti	mates
I	a1	Billet —— Bar/Section mill —— Bars, light sections	Countries with very low steel consumption and without any significant raw materials. Material supplying countries often supply finance and technology.	30 (10/100)	200	2	5
	a2	Cold coil/sheet — Coating line —— Galvanised sheets, tin plates					
	a3	Hot coil —— Tube/pipe machine —— Tubes, pipes					
	b1	Hot coil —— Cold rolling mill — Coating line —— Flats	There are very few countries using those types today, but may become very important for regional and sub-regional co-operation in connexion with types IV, b1, b3	500 (100/ 1,000)	1,200	2-3	75
	b2	Bloom —— Billet/Bar/Section mill —— Non-flats					
	b3	Slab —— Hot rolling mill — Cold rolling mill — Coating line — Flats					
II		Scrap / Sponge iron / Cold pig — EF — [Ingot / CC] —— Rolling mill —— Mainly non-flats	Most common in developing countries. Availability of scrap at reasonable prices is most important. World wide spread of DR pellets may greatly contribute to the development of this type.	100 (20/400)	800	2	25
III	a	Charcoal / Ore — Charcoal BF —— Foundry pig iron	Highly recommended for those countries which have forest resources and are going to initiate steel industries.	10 (5/40)	50	2	1
	b	Charcoal / Ore — Charcoal BF —— LD —— [Ingot / CC] —— Rolling mill —— Mainly non-flats	Countr. with forest resources may become self-sufficient in steel utilising this type with relatively low investment	200 (150/ 400)	2,000	2-3	100
	c	Non-coking coal / Ore — Electric reduct. furnace — LD — [Ingot / CC] —— Rolling mill —— Non-flats and flats	Countries with abundant electricity with low cost but good coking coal may advantageously employ this type	200 (150/ 1,000)	2,000	2-3	100
IV	a1	Coke / Ore — BF —— LD —— [Ingot / CC] —— Rolling mill —— Non-flats and flats	Applicable for countries with large market and relatively high level of industrialisation	1,000 (300/ 10,000)	6,000	5-6	800
	a2	Gas (or coal) / High grade ore — DR —— EF —— [Ingot / CC] —— Rolling mill —— Non-flats [illegible] flats	Gas rich countries are most advantageous. Flexibility in scale of works is also advantageous for developing countries	500 (150/ 1,500)	3,000	3-4	250
	b1	Coke / Ore — BF —— LD —— CC —— Slabs, Blooms, Billets	Ore rich countries may have this type with long range export agreements of semis.	2,000 (2,000/ 10,000)	4,000	5-6	1,200
	b2	Gas (or coal) / High grade ore — DR —— DR pellets	Gas rich countries may contribute the development of type II in many developing countries by stable supply of pellets	1,000 (1,000/ 5,000)	1,500	3-4	150
	b3	Gas (or coal) / High grade ore — DR —— EF —— CC —— Slabs, Blooms, Billets	[illegible] countries may have this type with long range export agreements of semis	1,000 (1,000/ 3,000)	2,500	4-5	400

Table I is self explanatory but the following points are worthy of attention:

- There is a wide variety of processes, equipment and scale of operations to choose from.

- Small semi-integrated (steelmaking plus rolling) plants can be operated on the basis of scrap at scales as low as 20,000 t/yr.

- Pig iron can be produced at scales as low as 5,000 t/yr for foundries.

- Small integrated plants based on the charcoal BF can be very successfully operated at scales as low as 100,000 t/yr. Production of sponge for sale is also an interesting option for certain developing countries.

- In certain cases production is carried out only to the semi-product stage (slab, floom, billet) which is then shipped for processing elsewhere in the country or exported. Certain developing countries seem to have good possibilities in this connexion.

It should be noted that for some of the process route options outlined in Table 1, certain developing countries are in a position to assist other developing countries better than developed countries would be able to do. This is particularly true for certain direct reduction processes and for charcoal based iron and steel production.

The iron and steel plants now in successful operation in developed countries and developing countries, for production of plain carbon steels, cover a wide spectrum in regard to scale and processes used. A diversity of raw materials and products (and by-products) are processed or produced, in a variety of equipment, at levels, reaching over 10 Mt/yr or as low as 20,000 t/yr.

The spectrum of possibilities in use covers, for example:

- Iron ores: low grade oolitic ores with iron as low as 26-28% and high phosphorus; hematites with over 60% iron; taconites and itabirites needing ore dressing; etc.

- Iron containing materials for reduction to iron: screened ores; sinter; pellets.

- High iron content materials for steel making; scrap; pre-reduced ores; sponge iron; pig iron (liquid or solid).

- Reductants; coke; non-coking coals; charcoal; hydrocarbones (liquid or gaseous); hydrogen (for special iron powder production).

- Reduction furnaces; coke B.F.; charcoal B.F., electric reduction furnace; rotary kilns of various types; vertical retorts of various types; fluidized bed units.

- Steel making furnaces; oxygen converter; open hearth; electric arc furnace; induction furnace; Thomas and Bessemer converters; special type furnaces.

- Ingot casting conventional top and bottom-poured ingot molds; continuous casting (various types).

- Rolling: a wide variety of equipment is available to roll all types of plate, sheet, sections, bars, rod and tube products. They vary widely in size, degree of automation, principle of operation, output, etc.

The selection of process and equipment best fitted to local conditions (such as raw materials availability, reductants, energy, market situation, infrastructure, related industries, economic situation, etc.) is of vital importance for the success of newly installed steelworks. Table I indicates various alternative routes which are actual use today. It also indicates the normal ranges for capacity, number of employees, required construction period and cost. These figures change quite widely depending on local conditions and should be treated as only a rough indication of the scope of applicability of the various process routes.

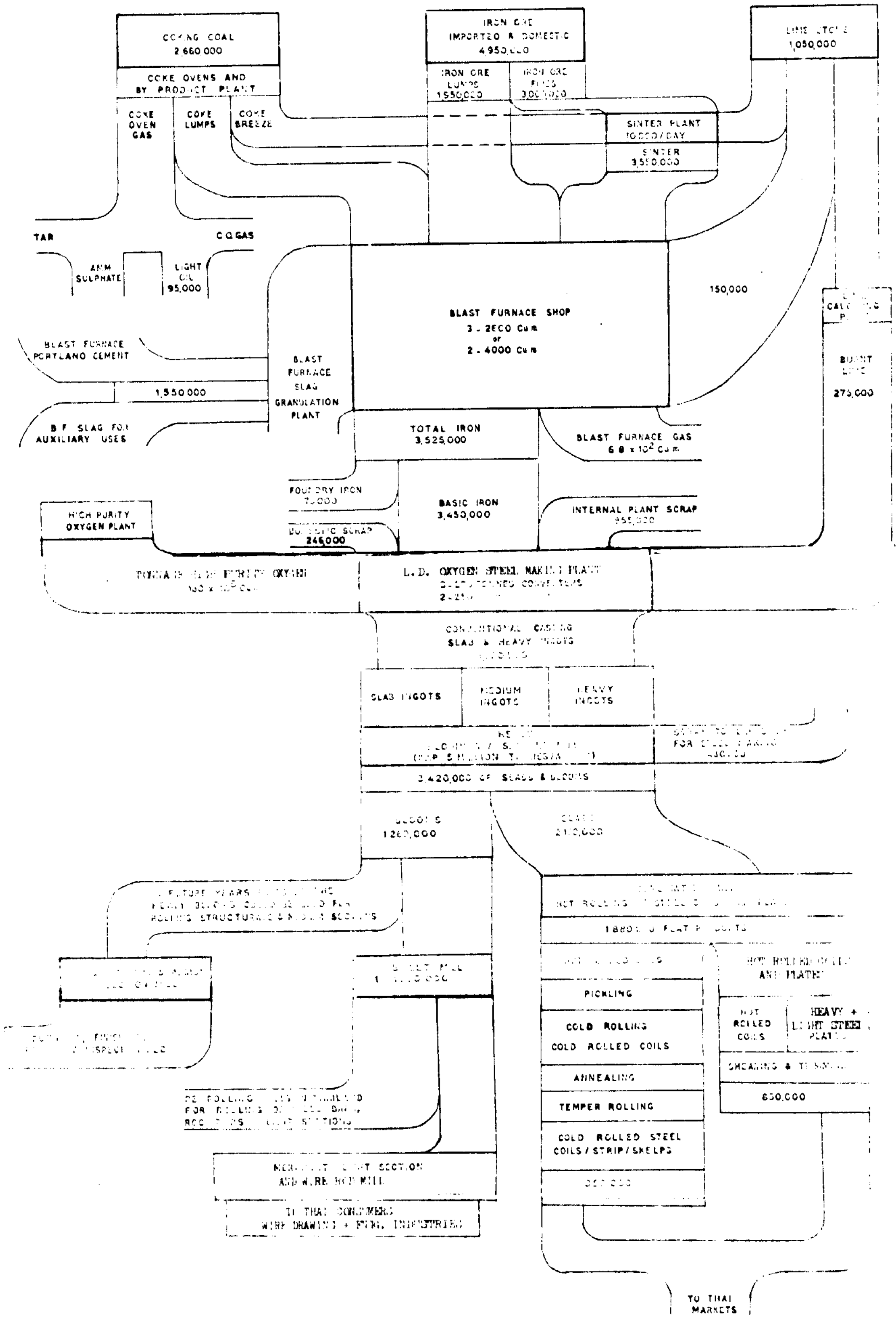
Since there is at present unused steel capacity in the industrialized world considering that many of their plants are operating at 60% rated capacity, the rate of return on capital invested has been low and which largely precludes new or expanding steel capacity in the developing countries based on exports. Because of economies of scale and quality of product when considering export markets, one needs the most modern technology to compete with the existing excess capacity of the heavily industrialized countries and the marketing structure of large steel companies. As a result of these difficulties, as well as the fact that so called dumping of excess steel production from the developed countries on the world markets may have occured, it is extremely risky to plan on export market to keep the plant at 100% capacity and thereby hope to break even. Because of such severe competition and the difficulties in the start-up years in meeting the principal and interest payments, excess capacity should be no larger than that needed to meet expected demand during start-up years. Furthermore, market projections in terms of demand and price can easily fluctuate by 10 to 20% on the world market and careful consideration should be paid to the consequences of lower demand or prices.

When low-cost scrap is available, of course, the lowest investment is found in a non-integrated steel facility. In such so-called backward integration, domestic and/or imported scrap is melted in the electric furnaces to roll steel rods and bar products. Over a period of years, such an operation could be integrated with direct-reduction facilities based upon local or imported ore. Thus, an initial capacity of 50,000 tons a year of steel bar products, for example, could be met by an electric furnace and as the demand for steel grew to say 200,000 tons a year, a direct reduction sponge facility could be installed. Alternatively, if low-cost hydro-electric power should be available, an electric smelting iron plant could be considered. In the same light, one could import coils and produce flat products, welded steel structurals, galvanized sheet, tin plate, and the like.

For sufficiently large capacities (i.e., over 500,000 tons a year of steel), the blast furnace can be considered, based upon local iron ore and most likely imported coking coal since the amount of coking coal in the world at large is rather limited. However, such reliance on imported coking coal might be undesirable - and even risky - even though the economics of the future might dictate the selection of a charcoal blast furnace or direct reduction units in which non-coking coal, or gaseous or liquid fuels can be used for sponge production and steel making.

In the case of integrated iron and steel plant, the attached Flow-Chart is typical of the alternative technology which is currently under study by Thailand and is in full scale application in India at the leading Indian integrated steel plants.

into tonnes



INTEGRATED IRON AND STEEL INDUSTRY IN THAILAND BASED ON IMPORTED RAW MATERIALS (IRON ORES + COAL) SUPPLEMENTED BY LOCAL IRON ORES AND FLUXING MATERIALS

Fig. 1 SCHEMATIC QUANTITATIVE FLOW SHEET FOR THE INTEGRATED IRON AND STEEL WORKS AT A COASTAL LOCATION WITH AN ANNUAL CAPACITY OF FINISHED STEEL PRODUCTION BY 1985-87 OF 2.9 MILLION TONNES (CORRESPONDING TO 3.9 MILLION TONNES OF CRUDE STEEL BASED ON AN OVERALL YIELD RATIO, 75% FINISHED TO CRUDE STEEL) COMPRISING 1.7 MILLION TONNES OF FLAT STEEL PRODUCTS AND 1.2 MILLION TONNES OF NON-FLAT STEEL PRODUCTS, THE LATER WILL BE SUPPLEMENTED BY [illegible] MILLION TONNES ANNUAL CAPACITY OF NON-FLAT STEEL PRODUCTS CURRENTLY EXISTING TO GIVE A TOTAL [illegible] TONNES OF NON-FLAT STEEL PRODUCTS BY 1985 88 FORECASTS ARE REALISTICALLY BASED ON ACTUAL CONSUMPTION FIGURES DURING THE LAST DECADE

Role of International Co-operation

International co-operation in the field of iron and steel industry can be followed inter alia as follows:

(a) Technical co-operation between developing countries;

(b) Technical assistance/co-operation amongst developed and developing countries;

(c) Technical assistance promoted by UN Agencies and other international organizations;

(d) Bilateral and multilateral technical assistance/co-operation amongst different countries;

Various examples can be furnished in respect of the above.

A typical latest example of multilateral co-operation is the fabrication of heavy steel plant equipment/machinery at the Heavy Engineering Corporation, Ranchi in India to Soviet designs for supply by Soviet Union to the Eskandria integrated steel plant in Turkey under bilateral Soviet-Turkey aid programme.

Other possibilities of bi-lateral, multi-lateral and regional and international co-operation are outlined herewith in the case of Arab countries and can be equally well applied in the case of other developing countries on a regional basis.

a) Study of steel demand Studies of the sectoral steel demand on a national and regional market basis can provide estimates of steel demand by product, based on the steel consumer industries.

The value of these studies on a national and regional basis is important in view of the diversity of the steel product-mix in the demand for steel in individual countries. Steel production in individual countries may be inhibited by the limited domestic markets, and, therefore, the possibilities of developing subregional markets and co-operation can help in counteracting the effects of the national market constraints.

b) Interchange and supply of raw materials It will be helpful to promote the interchange of raw materials (high grade iron ores/ pellets), directly reduced sponge iron, etc. on a mutually advantageous basis. For example, high grade pellets from the RIF Mines in North Morocco could be exported to sponge plants in other Arab countries; the resultant highly metallized sponge could be consumed locally for steel making and also exported to other Arab countries.

c) Interchange of metallurgical know-how, expertise and consultancy services A developing country within the Arab world which has attained a high standard of metallurgical expertise, technical know-how and consultancy services could assist another developing country lacking such specialization. This type of interchange can be promoted through governmental or private action.

d) Interchange of steel plant and equipment A developing country within the Arab world which has set up technical design and manufacturing facilities for the fabrication of iron and steel plant equipment and machinery can supply them to another developing country lacking corresponding design and manufacturing capabilities; such exchanges can be promoted through bi- and multilateral trade in raw materials, fuels, finished steel products or semis, on mutually beneficial terms.

e) Interchange of trained manpower and business management Some developing countries have achieved a high standard of business management and executives and have trained personnel for the iron and steel industry. They can assist other Arab developing countries in training plant managers and executives, steel plant operators, skilled workers, technicians and trouble shooters at various levels. Additionally, arrangements for sharing of short or long term expatriate staff and trained personnel can be mutually negotiated.

f) Interchange of capital investment, equity partnership and sharing of financial resources Developing countries relatively well endowed with capital resources including foreign exchange while lacking raw materials could assist other Arab countries through long-term loans, joint capital investment, equity participation and formation of joint consortia.

g) Interchange of trade and complementarity of production Developing countries in the Arab world can foster interchange of trade in finished steel products and semis (billets, blooms and ingots) so that complementarity of their efforts may lead to mutual gain. Plans for bilateral and multilateral iron and steel industry development can thereby be promoted.

h) Production of sponge iron using high grade iron ores/pellets and natural gas Several Arab countries have good resources of natural gas and also have good reserves of iron ores. These are favourable conditions for the production of metallised sponge based on proved gaseous DR processes (HYL, Midrex, etc.). It may be necessary to pelletise the iron ore fines to feed to the DR sponge plants and also to provide an added value product for export. A Master Plan can be prepared for the establishment of DR sponge plants in the Arab countries with a view to stepping up their steel production capacities.

i) Production of alloy, tool, special and stainless steels The ratio of alloy, tool, special and stainless steel output to that of mild and plain carbon steels is normally between 5 - 15%. In Arab countries there is little production of alloy, tool, special and stainless steels except in the ARE in a small way. At a later stage it may become helpful to plan the production of alloy steels on a regionally co-ordinated basis. UNIDO can promote the preparation of such a plan on request by the countries concerned under the respective Country Programmes for UN technical assistance.

j) The production of ferro-alloys and steel plant refractories There is very little production of ferro-alloys and steel plant refractories in Arab countries. Techno-economic feasibility studies can be of great value to the iron and steel industry to the Arab countries irrespective of the latter's establishment on a national or regional basis. These studies and plans for their actual production can be stepped up.

k) Iron and steel industry documentation and statistical data for Arab countries The importance of documentation and cataloguing of technical information pertaining to the iron and steel industry's technology is great; however, statistics concerning the iron and steel industry in Arab countries are not readily and fully available. A good start has been made by the Arab Iron and Steel Union and IDCAS. A centralized technical data bank for the Arab countries will be most useful to the latter.

l) Standardization of steel products It is never too early or late to study the standardization of multiple grades of plain carbon and mild steels as also of alloys, tool, special and stainless steels. Unified and mutually accepted standard specifications will greatly facilitate mutual co-operation and trade. The current practice is to apply standards and relevant specifications as formulated in developed countries (ASTM, BSS, etc). in Arab countries, a practice which assists with the broader international aspects of trade. At later stages more specifically Arab standards may need to be developed for steel products of particular interest to the Arab countries.

m) Manpower and training of steel industry personnel The training of personnel, skilled workers and technicians, foremen at operational levels and of business management executives and managers will be of great importance to Arab steel industries. Little appears to have been done in these fields except possibly in an ad-hoc manner in a few Arab countries. There is room for a review of the capacity, future potential and types of technical educational and training facilities available in Arab countries, with a view to stepping up co-operation amongst them.

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