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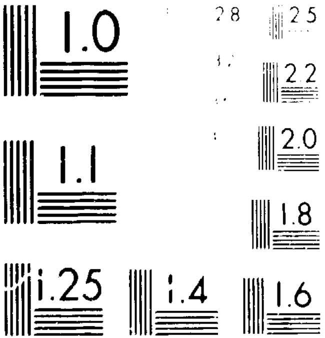
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12612

"TECHNOLOGICAL COMPLEXITY OF IRON AND STEEL INDUSTRY PRODUCTS"

Contribution
to the world 1990 iron and steel scenarios

(Prepared by the Group of Soviet Experts)

Moscow, May 1982

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"TECHNOLOGICAL COMPLEXITY OF IRON AND STEEL INDUSTRY PRODUCTS"

Intoduction

The UNIDO Secretariat assigned to carry on the research of technological complexity of iron and steel industry products to the group of the USSR experts. This technological complexity is essential to define the strategy of development and progress of the iron and steel industry of developing countries. The mentioned research is the further continuation of the study "Technology in the service of development" finished by the Sectoral studies branch of the UNIDO Division for industrial studies in November 1980. In this study the analysis has been conducted for technological complexity of developing machines and equipment coming under the heading "Capital goods production." This study has been conducted with regard to the problems put in the forefront by developing countries and was aimed at measuring the technological complexity of machines and methods of production in terms of different indices (somewhat hypothetical). The Index of technological complexity is the integral quantity of production complexity involved in a given product, as shown with the use of expert evaluations by 80 factors grouped into six technological levels. The greater the technological complexity of a product, the higher the Index of complexity and vice-versa.

The determination of the Index of technological complexity was based on evaluating the distinctive features of the following process stages : pre-design product concept - laboratory - manufacture of parts - assembly. All these stages were quantitavely evaluated in terms of 80 factors grouped into 6 technological levels of complexity. The sum of all the values of these factors represented the Index of complexity of the product. 480 theoretically possible combinations have been obtained with the maximum amounts of factors and technological levels of complexity (in practice this was reduced to 366 possible combinations). This made it possible to structure the system in such a way that it covered the majority of the technological stages required from the time of pre-design product concept to final operations of assembly.

The 80 factors which form the Index of complexity are divided into three main groups :

A - 39 production factors constituting the actual production process.

B - 23 factors associated with third-party semi-finished products and technical services ("production infrastructure").

C - 18 factors making allowance for the use of basic completing components and units.

In turn A and B are broken down into groupings which it is necessary to show in detail:

A_1 - 9 overall factors constituting the actual production process including weight of products, hours of know-how per US$ 1000 of finished products, laboratories, direct production hours per ton of finished products, manufacturing diversity in respect of number of types and models, manufacturing runs, product assembly, minimum recommended or possible product sizes.

A_2 - 30 factors associated with the use of production equipment including different equipment for gas cutting bending, rolling, drawing etc, machine tools, special production equipment down to the equipment for quality control of the final product.

B_1 - 8 factors associated with semi-finished products (conventional processes of casting iron, steel and non-ferrous metals, foundling and forging of main materials, more sophisticated processes of foundling and forging).

B_2 - 15 factors pertaining to third-party technical services including different operations of stress relief, heat treatments, metallic surface deposits and surface protection, manufacture and maintenance of metall-cutting tools, rough and very rough machining, cold pressing.

C - 18 factors making allowance for the use of basic completing components and units.

80 factors are dissimilar in importance and in order to reflect the differences between them, and consequently define their contribution to the total index of technological complexity , the authors of the mentioned study adopted four different performances exhibited by exponential characteristic reflecting geometrical ratios.

There are the following performances adopted by the authors : $\tau_0 = 2^{0.25}$, $\tau_1 = 2^{0.5}$, $\tau_2 = 2^{0.75}$, $\tau_3 = 2$. Their solution gave respectively $\tau_0 = 1.19$; $\tau_1 = 1.41$; $\tau_2 = 1.68$ and $\tau_3 = 2.0$

Consequently the complexity levels gained the following valnes according to the performances :

Complexity level / Performances	1	2	3	4	5	6
τ_0	1.00	1.19	1.41	1.68	2.00	2.38
τ_1	1.00	1.41	2.00	2.83	4.00	5.66
τ_2	1.00	1.68	2.83	4.76	8.00	13.45
τ_3	1.00	2.00	4.0	8.00	16.00	32.00

The authors adopted the following performances :

Weight of products - τ_2,

Hours of know-how - τ_3,

Direct production hours per ton of finished product $-\tau_3$.

Oxyacetylene cutting $-\tau_0$,

Conventional processes of iron casting $-\tau_1$,

Forging $-\tau_2$ etc.

For servicing of this system, a system of information on technological complexity has been constructed for 318 groups of products (machine tool equipment, machines, electric motors and other electric equipment, transport equipment, measurement and monitoring instruments office equipment, typewriters, calculators, computers etc). With 80 factors and 6 complexity levels the possiblity exists of bringing up the system to a recording capacity of 152640 data. The accomplished analysis shows that in practice when decreasing the number of product groups there is a possibility to mobilize effectively about 35000 data. The magnitude of this figure has justified the processing of the information by computer.

This analysis has led to distinguish some kind of "laws" and, among other things, the fact that capital goods are characterized by the considerable heterogeneity of their technological contents and, consequently, by their complexity. The technological complexity of machines entering into this group grows in the following order : simple metal products < electrical machines measurement and monitoring instruments < non-electrical machines < transport equipment.

Considered from a functional and technical point of view, the machines have the following order of mean complexity: semi-finished products < parts and components < autonomous finished products < integrated finished products and sub-systems.

According to the final demand in machines from the sectors of industry for which they are intended, the order of complexity of specific capital goods is as follows : agricultural machinery < agro-food industries < chemicals and petrochemicals industries < building and building materials industries < engineering construction < extraction of minerals < agro-industries, tobacco, leather, textiles < heavy metallurgy, iron and steel, forging, foundry < road transport equipment < rail transport equipment < air transport equipment.

The specific capital goods for these essential demand sectors have the following minimum, mean and maximum values of the index of complexity :

	Values of the index of complexity		
	Minimum	Mean	Maximum
1) Agricultural machinery	56.67	64.88	73.20
2) Agro-food industries	80.95	95.80	110.80
3) Chemicals and petrochemicals industries	76.46	100.16	123.98
4) Building and building materials industries	84.86	107.35	129.99
5) Engineering construction	86.13	113.95	141.92
6) Extraction of minerals	92.01	130.32	168.79
7) Agro-industries, tobacco, alcohol, leather, textiles	106.29	132.13	158.15
8) Heavy metallurgy, iron and steel, forging, foundry machinery	107.64	137.49	167.46
9) Road transport equipment	128.72	162.67	196.78
10) Rail transport equipment	167.74	197.65	227.70
11) Air transport equipment	389.59	460.97	532.41

The analysis of technological complexity of capital goods conducted by the UNIDO specialists makes it possible , from their opinion, to developing countries to master the most important strategic option for developing their industries, evaluate the levels of complexity of producing planned products and the period of time required for the assimilation of these levels, choose appropriate forms of integration c the national industry, develop the program of carrying out planned problems and adapt their educational and personnel training system with this in mind. The mentioned specialists concluded that the majority of the developing countries which at the present time have a weak production basis for production of capital goods could aim at level 3 of complexity of products. At this level, they have the possibility to produce independently only 40% of the required equipment.

For the less developed countries, it seems that the production of agricultural machinery and certain simple semi-finished products constitutes a preferable way of entry into the capital goods industry. /1,2,3/.

Attaining one or another value of the index of complexity of capital goods production in the developing countries are dependent upon the degree of the iron and steel industry development in many respects All the factors used by the UNIDO specialists and the complexity level are largely determined by the availability and quality characteristics of metal products. This deals to a largest extent with 8 factors associated with semi-finished products (B_1), 15 factors pertaining to third-party technical services (B_2) and 18 factors making allowance for the use of basic completing components and units.

Gaining the economical independence by the developing countries presupposes the development of their industrial base which would permit to change fundamentally the technical level of all the branches of the national economy.

Industrialization is the imperative condition for developing the economy. The iron and steel industry provides the base for developing other branches of the industry and not only producing capital goods. Some developing countries have attained a notable advance in the development of the iron and steel industry. India, Brazil, Mexico, Algeria and other developing countries have own large iron and steel enterprises and provide a substantial proportion of domestic demands by inherent production. In Iran, Libya, Indonesia the iron and steel enterprises have been constructed only in the last few years. Many developing countries have not yet had even small enterprises and only begin to constuct them using for this purpose financial and technical assistance of industrially developed countries.

The Soviet Union has rendered and is rendering technical assistance to developing countries with setting-up and development of the iron and steel industry. India, Iran, Algeria, Turkey and other developing countries have created and are developing their national iron and steel industries with the USSR's assistance. A distinguishing characteristic of the economic and technical cooperation of the USSR with developing countries is the fact that the Soviet Union renders assistance in creating and enhancing the public sectors of their economies.

This is important for speeding up of the rates of economic development and strengthening of the economic state of these countries.

The USSR's economic cooperation with developing countries in creating their own base for the iron and steel industry and exploitation of their natural resources is built on a long-term, stable, mutually advantageous and equitable basis, on the conditions of respect of national sovereignty and legitimate rights of cooperating nations.

The iron and steel works built with the USSR's assistance are full property of the states on the territory of which they are located.

Credits for purpose of developing the metallurgical industry given by the Soviet Union to developing countries are long-term and have favourable conditions. The credit of the Soviet Union, as developing countries know well, has a low level of annual percentage of compensation, a long term of its use, payment. The agreements have no special conditions. The sum of a submitted credit is guaranteed.

The Soviet assistance to foreign countries in creating their iron and steel industries is rendered with regard to making the most use of local resources and technical opportunities for manufacturing the equipment, steel structures and supply with building materials. This form of cooperation encourages drawing in of the country's indigenous resources, provides for a stable employment of the population, ensures accumulation of production experience in the construction of modern plants in respective countries, forms indigenous skilled personnel of builders, erectors, operating staff.

At the precent time there is a production of iron, steel and rolled products in 15 developing countries. Besides, 10 developing countries are producing steel and rolled products, that is they have small enterprises for reprocessing scrap in small electric arc furnaces or mini-mills built in the last few years. There is a group of countries manufacturing rolled products from imported billets. By the beginning of eighties about one-third of the developing countries, and particularly the most underdeveloped countries of Africa, South-East Asia, Oceania and some countries of Latin America, have no iron and steel enterprises.

There are over 500 enterprises producing ferrous metals in developing countries and among them 25 integrated iron and steel works of annual output of more than 1 mln ton of steel, with 20 of them have been built after the second world war.

The share of Latin America accounts for about 50%, Asia - about 47 %, Africa - 3% of the total steel output in the developing countries.

The creation of domestic iron and steel industry base or development of available capacities for production of ferrous metals are associated with necessity of taking into account a number of conditions, such as :

1) Transportation to sale markets and to raw materials suppliers;

2) Market condition , including demand structure, expected shortage of single kinds of ferrous metals, future prices of iron and steel industry products, expected in perspective resources of metallurgical scrap and its prices;

3) Sources of raw materials and fuel, including iron ore resources, knowledge of reserves, their qualitative and quantitative characteristics and geographical distribution, conditions of iron ores mining and their preparation for smelting, resources of process fuel, the availability or possibility of creating own mining establishments and evaluation of required for their creation capital investments and material resources;

4) Energy resources, including total water resources, power and power-generating resources, geographical distribution of resources and their main characteristics;

5) The potentialities of financing, including credits, prices, capital investments, availability of currency;

6) Employment and training of personnel, including concentration of labour force, actual and future possible labour force skills, its principal features, tendency and attitude to training, labour cost and associated with it policy of keeping the discipline and rising the qualification;

7) Social and economical measures, including labour resources, availability of houses and installations for social purposes, presence of trading establishments, markets and institutions for rest and entertainments, availability of transportation and communication means, availability and costs of civil services, existing policy regarding social planning and methods of financing social and economical measures, responsibility and participation of governmental organizations.

Taking into account indicated conditions associated with the availability of raw materials, labour force, finance, infrastructure etc determines the selection of the optimum for a particular country type of metallurgical enterprises.

The favourable conditions are created for development of integrated iron and steel works when required for the iron and steel industry mineral resources are available. Large blast furnaces (with volume above 2000 m^3) are constructed in the developing countries. But many small obsolete unproductive blast furnaces still work in these countries. The basic oxygen steel accounts for about 50% in the total steel output of developing countries.

In the developing countries nearly two-thirds of steel is made in basic oxygen furnaces of 60-100 t capacities at the integrated iron and steel works. About 25% of steel is made in electric arc furnaces (about 14 mln ton). The charge for these furnaces is sponge iron, production of which amounts over 6 mln ton in developing countries, and scrap (about 8 mln ton). This is associated with construction of a considerable number of mini-mills having, as a rule, up to 500000 ton annual capacity. These works use scrap or sponge iron as raw materials, steel is made in high-output electric arc furnaces. The distinguishing feature of the mini-mills is production of a limited range of rolled products which are mainly used in the domestic market. These works mainly produce long products.

The continuous casting of steel is finding ever increasing use in the developing countries. At the present time over one-third of steel made in these countries is continuously cast. All the constructing in greenfields steel works compose continuous casting plants. Some developing countries give a little way to industrially developed countries in this respect. To illustrate, Argentine continuously cast about one half of steel, Mexico - 30%, Brazil - 27.6%. Electric arc-furnace steelmaking grows with ever increasing rates in developing countries. In the developing countries the technical level of rolling-mill practice increases. Despite the fact that the main products of the metallurgical works of developing countries are long products , the developing branches of these countries industry are faced with the demand in flats which are produced at the integrated iron and steel works.

Starting from the above mentioned as the base, the purpose of present work is to determine the technological complexity of producing the most representative types of metal products required for production of capital goods in the developing countries.

1. INDICES CHARACTERIZING TECHNOLOGICAL COMPLEXITY OF METAL PRODUCTS

The investigation being carried out by UNIDO concerning the evaluation of strategy of capital goods production in developing countries is closely connected with the strategy of the iron and steel industry development in these countries. Metal products made by the iron and steel industry provide manufacturing of capital goods with semiproducts which comprise one of the factors for evaluating production complexity of these goods.

At the same time metal products are the base for the development of other branches of engineering, construction and transport in developing countries. Thus, the evaluation of iron and steel development strategy must result from economy requirements existing in developing countries while the character of its development must be determined by technological complexity of metal products necessary for economics.

Theoretically, technological complexity of metal products can be expressed through its costs, when increased costs lead to a higher complexity level of metal products, because the complexity accumulates large amounts of labour expenditures. This means that the establishment of more complex metal products in developing countries requires also higher socially necessitated expenditures. To conceive the amount of these expenditures, their direction and possibility of their realization depending on economic conditions of developing countries it is necessary to analyze the factors which determine the degree of metal products complexity. Factors comprising the complexity of metal products can be classified in the following ways :

1. Complexity of chemical composition of steel for metal products manufacturing. In order to obtain necessary chemical composition certain ferroalloys and alloying elements should be used.
2. Complexity of metal products configurations which are determined by their shape sizes and provided by different rolling facilities.
3. Metal products quality level which is provided by ladle steel refining, heat treatment and finishing of metal products.

Concerning the first point, apart from complexity changes in chemical composition, the complexity will also change for a definite chemical composition of a certain steel grade depending on the metallurgical route of steel production. The following routes are meant here :

a. classical route: iron production in blast furnaces from prepared iron ore and BOF steel making ;
b. production of prereduced materials by cokeless direct-reduction processes (or the use of imported sponge iron) and their smelting in electric arc furnaces to produce steel;
c. scrap remelting in electric arc furnaces for the production of required steel grades.

In all these routes steel is continuously cast. The technological diagrams are given in Fig. 1,2 and 3.

The possibility of the realization in a developing country of some or another diagram of metallurgical route is dependent on availability of necessary natural resources (iron ore of certain composition, coking coal, natural gas) and on the available scrap resources.

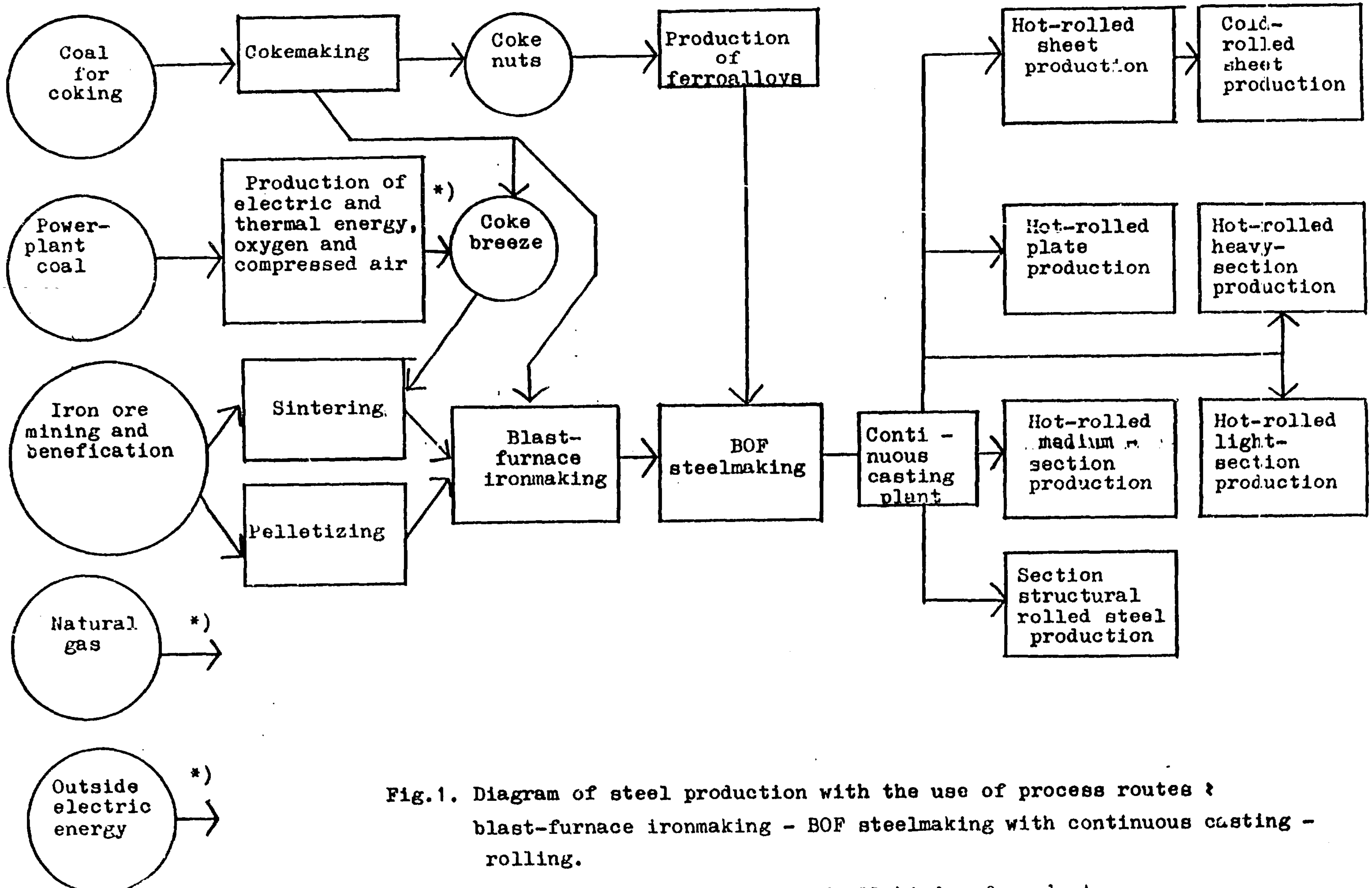


Fig.1. Diagram of steel production with the use of process routes : blast-furnace ironmaking - BOF steelmaking with continuous casting - rolling.

*) Natural gas, electric and thermal energy are used in production of all kinds of products.

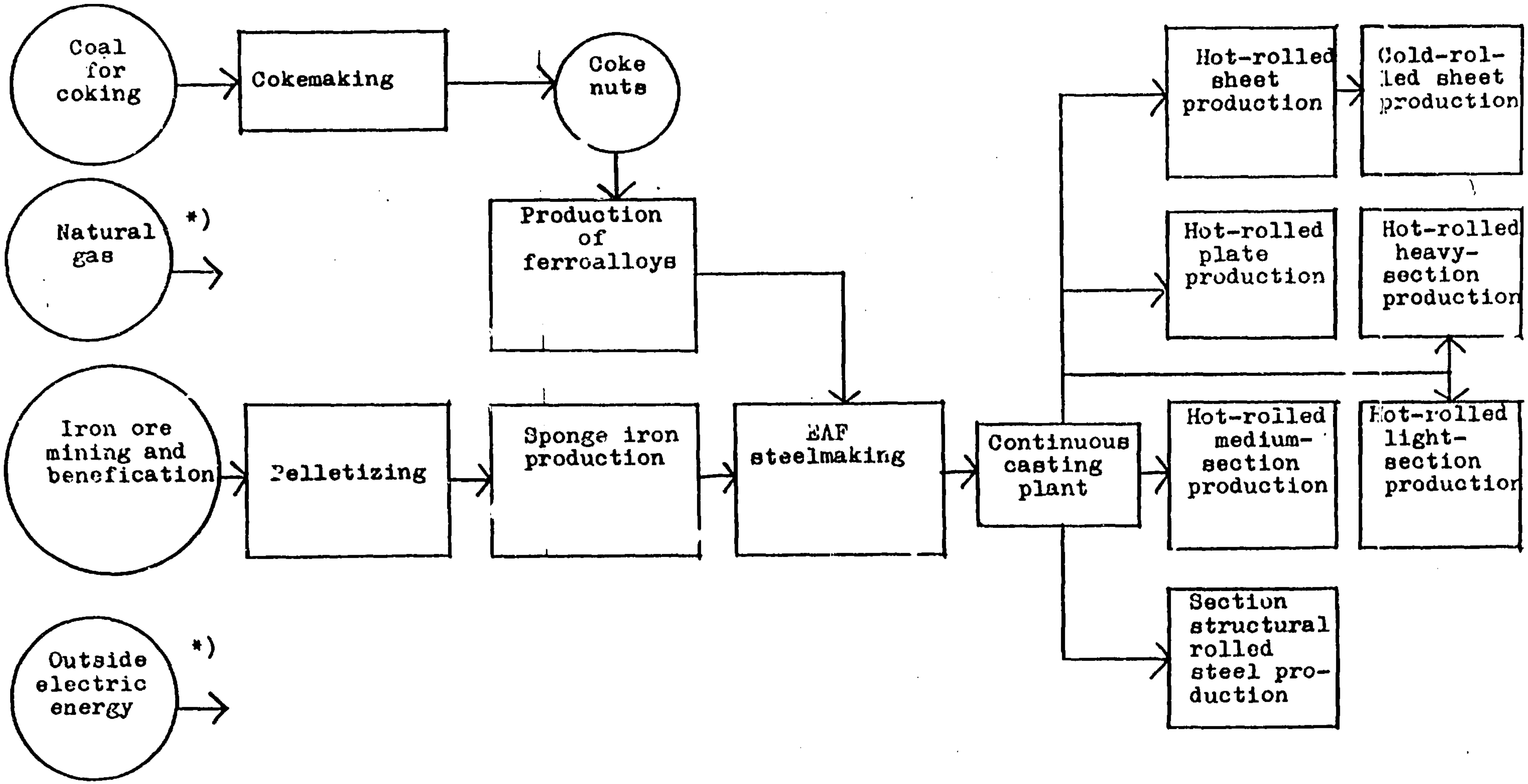


Fig.2. Diagram of steel production with the use of process route : sponge iron production - EAF steelmaking with continuous casting - rolling.

*) Natural gas and electric[illegible]y are used in production of all kinds of products.

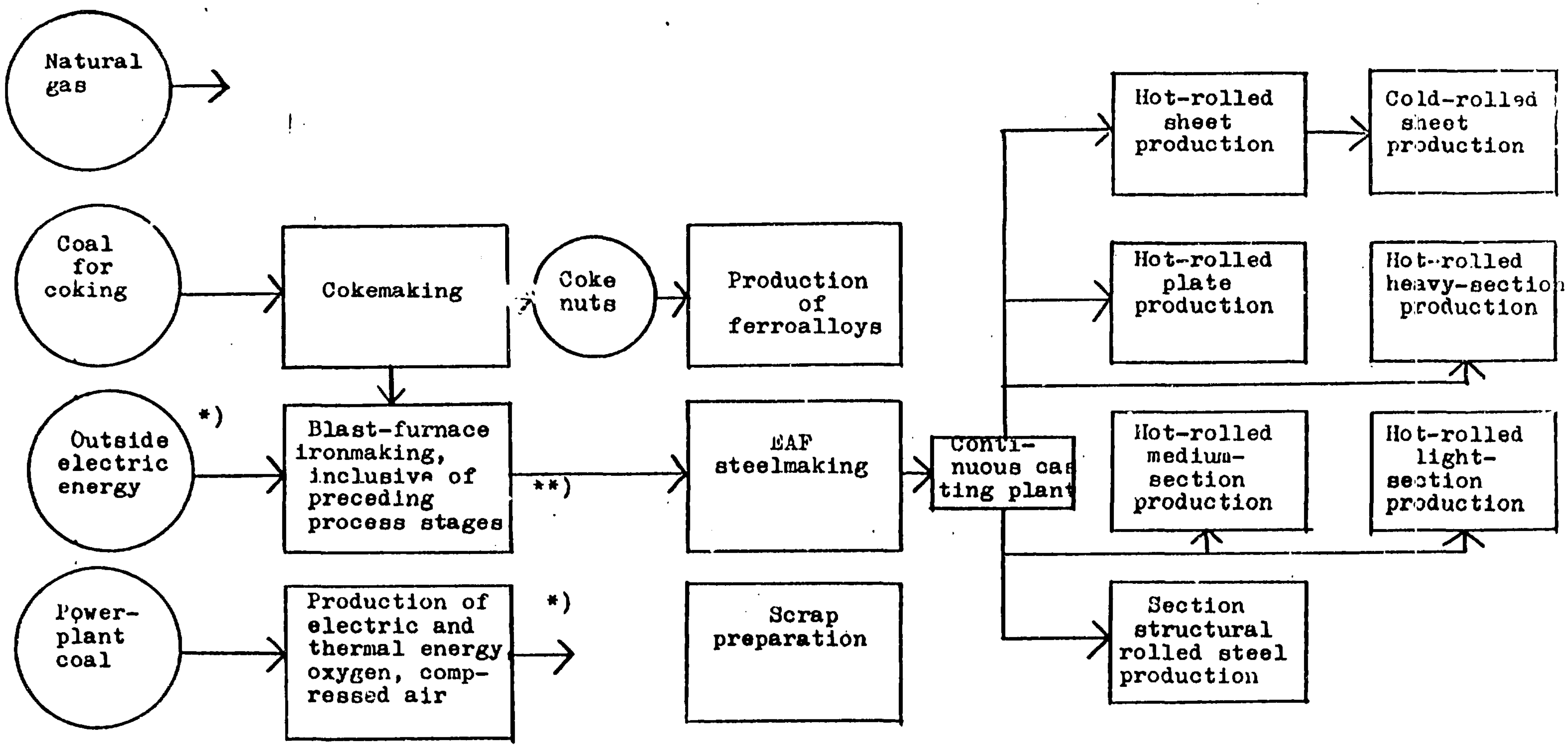


Fig.3. Diagram of steel production with the use of process route : Scrap preparation - EAF steelmaking with continuous casting - rolling

*) Natural gas, electric and thermal energy are used in production of all kinds of products.

**) Carbonaceous waste can be used instead of iron.

At the same time of some importance are the possibility to involve investment of various level and for various schemes of use of foreign currency for import as well as availability of labour resources, of necessary skill in the country, taking into account various levels of direct labour expenditures for every diagram of metallurgical routes of steel making.

Therefore the complexity of steel making for metal products is evaluated equally with the complexity of their chemical compositions as well as with diagram of the metallurgical route which include various stages and are characterized by various features of the equipment and technology.

It should be stressed that the necessary chemical composition of steel in developing countries can be ensured depending on the availability of natural resources and stages of their economical progress due to the development of own ferroalloy production and due to imported ferroalloys and alloying elements. It is natural that more complex chemical composition will be connected with certain expenditures for the development of ferro-alloy industry or currency for import of ferro-alloys.

For determining the complexity of metallurgical routes it should be taken into consideration that the route size depending on its stages may be different because of the natural resources of the country and possibilities of imports. For example, in the classical route "blast-furnace - basic oxygen-furnace" the number of stages may be reduced through imported pellets, while the route with steelmaking in electric arc furnaces with the use of prereduced raw materials - through the elimination of the domestic production of prereduced raw materials and their import from other countries. The route with scrap smelting in electric arc furnaces may also be connected with the import of raw materials when a country has small metal fund and poor scrap formation cannot ensure the appropriate output of steel resources and there is a demand in imported scrap.

Therefore every route from the point of view of its technological complexity is characterized not only by the number of operating stages demanding various expenditures of resources for their performance, but additionally by expenditures of currency for import of raw materials which are necessary for the realization of a metallurgical route. Otherwise "short" routes with the import of raw materials may take undue precedence from the point of view of their technological complexity although they actually are connected with the necessity of economical development of the country in the direction of accumulating currency reserves for the functioning of metallurgical routes. But for the developing countries where the utilization of natural resources allows to accumulate and spend currency reserves the development of iron and steel industry in accordance with the routes of imported raw materials will make it possible to create domestic steelmaking in the shortest time and with the lowest expenditures of resources in the country.

The formation of the technological complexity of metal products according to the second direction is evaluated on the basis of the preset complexity of the range of shape sizes which will be in demand in accordance with the country development. Steel produced according to different metallurgical routes may be used for the production of the same types of metal products possessing various technological complexity.

The possibility of producing metal products possessing various technological complexity of shape sizes depends on the equipment used for continuous casting and rolling. This is characterized by various labour expenditures for the realization of the technological process, its energy and capital expenditures for shop construction. The production of billets on continuous casting plants in combination with electric arc furnaces of various capacities and with high power transformers allows to construct required plants for the production of metal products practically without restrictions according to minimum capacities and economical values of metal production. All this promotes the possibilities of the organization in the developing countries of the production of metal products having various complexity ranges according to the section size form.

The range of rolled products which are spent for the production of capital goods in the developing countries, applicably to the new branches of industry, is distributed in the following way ; per cent (the numerator denotes sections, the denominator - sheets and plates) ; the sum of these two types of rolled products does not give 100 per cent because of the use of other types of rolled products, wire and rolled products from alloyed steel) : agricultural machinery - $\frac{40 - 60}{50 - 30}$, food industry - $\frac{30 - 35}{60 - 55}$, chemical and petrochemical industry - $\frac{25 - 45}{45 - 35}$, civil engineering and building materials industry - $\frac{55 - 61}{40 - 30}$, railroad building - $\frac{27 - 30}{68 - 65}$, and so on. Thus, for developing countries of some interest is the technological complexity of sections, sheets and plates. Hence in present work the following types of rolled products have been chosen for the evaluation of technological production complexity : heavy sections, medium and light sections, hot rolled sheets and plates, cold rolled sheets, section structural alloyed steel, that is a rather wide range of rolled product types has been used by the Soviet experts.

In the USSR the following rolled products are included in the above mentioned types :

Heavy sections made from steel of ordinary grades :

round, diameter 32 - 250 mm ;

square, dimensions 30 - 120 mm ;

strip, width 60 - 200 mm ;

unequal angles 70 x 45 mm ;

equal angles 50 x 50 mm and more.

Die-rolled steel rods - for reinforced concrete constructions from carbon and low carbon steels No.32 and more.

All shape special sections ;

Medium sections made from steel of ordinary grades :

round, diameter 20 - 30 mm,

square, 20 - 30 mm,

strip, width 50 - 60 mm;

equal angles 36 x 36 x 4 mm

40 x 40 x 4 mm

45 x 45 x (4-5) mm;

unequal angles 45 x 25 - 63 x 40 mm ;

Die-rolled steel rods for reinforced concrete constructions from carbon and low carbon steels, No 20-28.

Light sections made from steel of ordinary grades :

round, diameter upto 20 mm (including) ;

square, dimensions from 10 to 19 mm ;

strip, width from 12 to 45 mm ;

unequal angles upto 32 x 20 mm ;

equal angles upto 32 x 32 mm ;

shape sections.

Die - rolled steel rods for reinforced concrete constructions from carbon and low carbon steels, No.10, 12, 14, 16, 18.

Plates made from steel of ordinary grades :steel plates having 4 mm and more in thickness, as well as checkered wide steel strips of general purpose, steel for boilers, furnaces and for shipbuilding, three-layer steel.

Hot rolled sheets made from steel of ordinary grades :

steel sheets, thickness 1 - 1.8 mm.

Cold rolled sheets made from structural carbon steel ;

cold rolled sheets, thickness upto 3 mm.

Section structural alloyed steel

All sections made from alloyed steel.

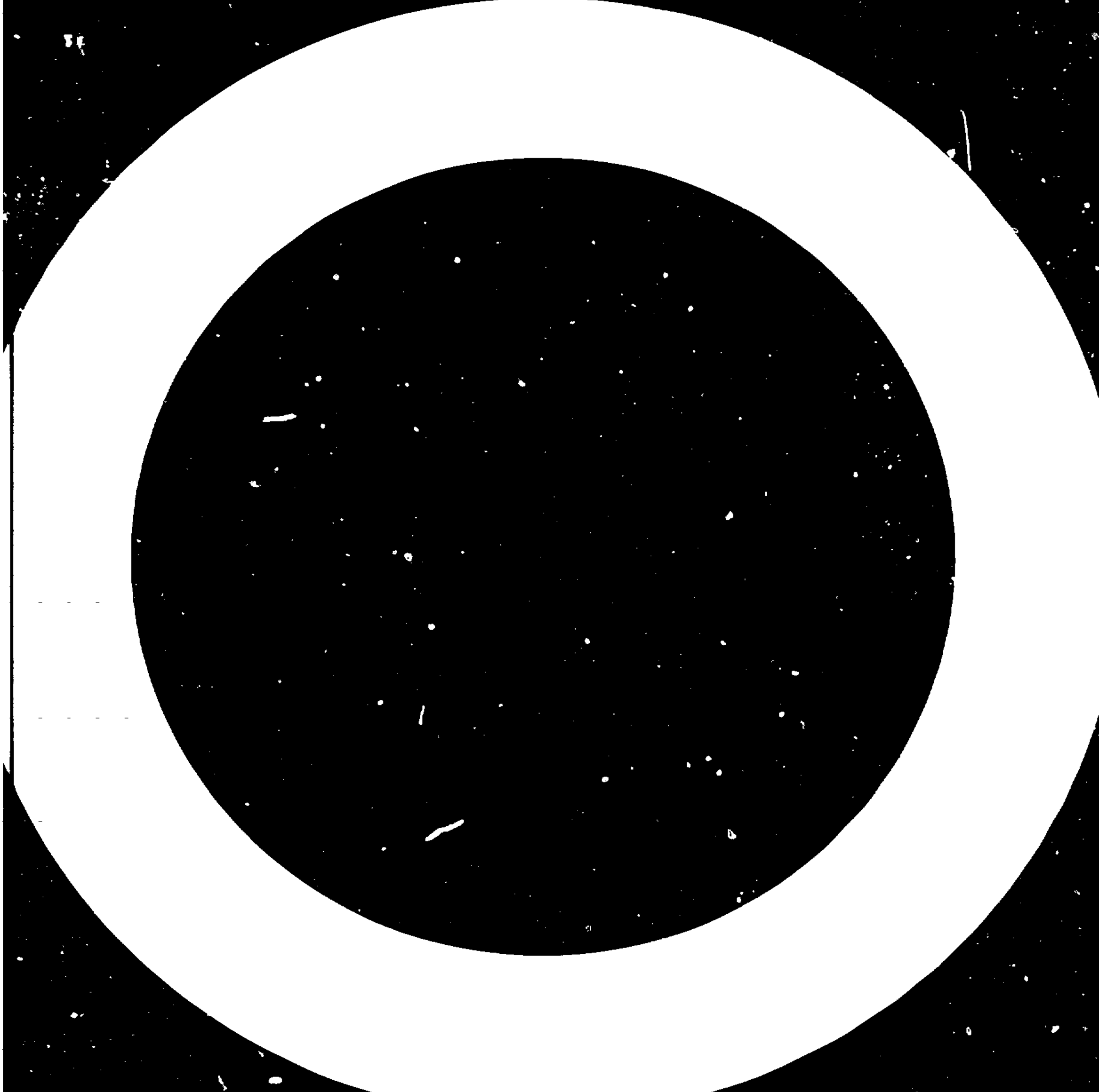
"Through" character of the metal products complexity evaluation including the evaluation of metallurgical process complexity and the complexity of metal products forming will allow developing countries to solve reasonably problems connected with the orientation in the development of iron and steel industry in conformity with demands of the economic structure of the country.

Diagrams of the process routes described above which include rolling operations, provide conditions for achieving a definite level of metal products quality sufficient for their usage in a wide range of applications. Some types of mechanical engineering products and some usage of metal in transport and construction demands increased reliability, long service life, which can be provided only by higher quality of metal products. The most urgent goal is in decreasing metal content of the products both in designing conditions and in lowering consumption of metal products. The latter goal is especially pressing under labour of different qualities with unequal complexity and tension with prime average labour used for producing metal products including the development of equipment required for this purpose. The difficulties in determining the complete value of metal products also present here.

Therefore the question arises what indices are required to use which as a whole could replace the costs expressed in the socially necessitated labour expenditures while evaluating the complexity degree of metal products.

While choosing these indices it is essential to take into account the fact that they must first of all characterize the expenses of all resources for iron and steel industry on different diagrams of technological routes and not for its current functioning. Therefore on the basis of the index of costs three indices have been formed expressing complex labour and energy expenditures as well as complex capital expenditures which are the most important characteristics of the iron and steel industry to be developed. The first one reflects the labour expenditures or direct labour (men/hours) required for the functioning of the routes to be developed. The second one is energy expenditures for technological routes. The third one is capital expenditures or cost expenditures for producing metallurgical equipment and construction of iron and steel works under various routes.

All these indices characterize from different points of view the technological complexity of producing the chosen types of metal products. When developing non-integrated metallurgical routes the import requirements should be taken into consideration in addition to the received indices, The import serves for meeting a lack of semi-products due to absence of the corresponding technological operations.



It is also essential to note that there is a possibility to form, if needed, on the basis of the indicated technological complexity one integral cost index. However, this is out of the scope of the present investigation.

2. A Method of Quantitative Determination of Indices of Technological Complexity for Producing Metal Products

In the preceding chapter the necessity of using the indices of technological complexity for producing metal products which express labour, energy and capital intensities for intermediate and finished products, have been substantiated.

For this purpose it is essential to consider mutual relations arising within the boundaries of adopted technological routes of production, to take account of their structure and to determine appropriate inside proportions etc.

The technological complexity of producing metal products increases as the final stages of the technological route are approached. It can be imagined that accumulation of the value of the indices of complexity of foregoing stages occurs in ensuing stages of this route. As the most general version this can be explained using the example of "through" calculation of labour expenditures, energy expenditures with the use of fuel expenditures in coal equivalent and capital expenditures for production of heavy-section steel products on the following technological route :

– blast-furnace ironmaking - BOF steelmaking with continuous casting of steel - production of heavy-section steel products.

This route starts with iron ore mining and production of iron ore concentrate . When achieving this stage, the labour expenditures account for 1.1 man·hour/t, fuel consumption in coal equivalent - 0.023 t/t, capital expenditures - 45 $/t.

Should the next stage is the pelletizing then to the expenditures on this stage (0.5 man.hour/t, 0.039 t of fuel in coal equivalent and 20 $/t, respectively) must be added the expenditures of the foregoing stage multiplied by specific expenditures of the first stage products for the second stage products (1.082 t/t). In this case the expenditures with regard to the foregoing stage account for 1.68 man·hour/t, 0.064 t of fuel in coal equivalent and 68.7 $/t. At the next stage (ironmaking) to the expenditures on this stage (0.769 man·hour/t, 0.68 t of fuel in coal equivalent and 32 $/t) is added the expenditures of the foregoing stage of metal burden preparation multiplied by 1.7 (2.86 man·hour/t, 0.109 t of fuel in coal equivalent and 116.8 $/t) and expenditures of the cokemaking (without taking into account the energy expenditures in coal mining and benefication to ensure against double counting) multiplied by coke rate for ironmaking (0.255 man·hour/t, 0.05 t of fuel in coal equivalent and 44 $/t).

Then the expenditures in ironmaking with due regard for foregoing stages account for 3.844 man·hour/t, 0.849 t of fuel in coal equivalent and 192.8 $/t. The "through" calculation of labour expenditures, expenditures of fuel in coal equivalent and capital expenditures up to final products (heavy-section rolled products) is realized in the same manner. This calculation is depicted in table 1.

The mentioned "through" calculation, even though its simplicity and obviousness, features extremely appreciable disadvantage - incompleteness. According to tentative calculations it does not cover about 20% of all the labour expenditures, expenditures of fuel in coal equivalent and capital expenditures. In this case performing that calculation does not take account of above mentioned expenditures for production of energy products (oxygen, compressed air and blast-furnace blast) consumed in the production of intermediate and final products, refractories, ferroalloys etc as well as the expenditures for production of these materials. It is quite understandable that so substantial unaccount of the expenditures can't help but affect adversely their integral values characterizing the tecnological complexity of products made by investigated process routes.

Proper allowance must be made for the whole vatiety of interproduct relations within the boundaries of technological routes, to express these relations in terms of consumption coefficients of these products to each other (steel for rolled products, iron for steel, coke for iron), to determine the expenditures of raw materials, materials, energy etc for these products, labour intensity, energy intensity and capital intensity of these products.

Table 1

"Through" calculation of labour expenditures, expenditures of fuel in coal equivalent and capital expenditures for production of heavy-section rolled products.

Stages of technological route	Labour expendtures, man-h/t			Expenditures of fuel in coal equivalent, t/t			Capital expenditures, $/t		
	In the stage	Specific expenditures of products of foregoing stage in ensuing stage, t/t	In the stage with regard to foregoing stage	In the stage	Specific expenditures of products of foregoing stage in ensuing stage, t/t	In the stage with regard to foregoing stage	In the stage	Specific expenditures of products of foregoing stage in ensuing stage, t/t	In the stage with regard to foregoing stage
1	2	3	4	5	6	7	8	9	10
Iron ore mining and production of iron ore concentrate	I.I	-	-	0.023	-	-	45	-	-
Pelletizing	0.5	I.082	I.68	0.039	I.082	0.064	20	I.082	68.7
Cokemaking	0.58I	-	-	0.II4	-	-	I00	-	-
Ironmaking	0.769	I.7 (pellets) 0.44 (coke)	3.884	0.69	I.7	0.849	32	I.7	I92.8
BOF steelmaking with continuous casting	I.6	0.849	4.89	0.0I3	0.849	0.734	60	0.849	223.7
Production of heavy-section rolled products	2.7	I.06	7.88	0.895	I.06	0.863	82	I.06	3I9.I

For this purpose, it is expedient to get the indices which should characterize the whole combination of natural expenditures of raw materials, materials, energy, semifinished products, intermediate products for the intermediate and final products, to obtain among these indices the components of energy intensity (expenditures of fuel and electric energy) and on the basis of natural values of the indices ana specific values of labour and capital expenditures - labour intensity and capital intensity of products within the boundaries of a technological route.

As indicated by calculations of the experts, it is necessary to solve 75 simultaneous equations for determination only natural expenditures of raw materials, materials, energy, semiproducts and intermediate products for the intermediate and final products within the boundaries of the investigated technological routes. About 6000 specific values of expenditures (direct expenditures) are used for solving these equations. Working such a problem is impossible without use of computers. As a consequence, the experts have developed the method of obtaining the natural expenditures for the investigated metallurgical routes with the use of theoretical principles and software of interproduct balances (input - output balances).

Basic initial data for realizing this method are the data on outputs of intermediate and final products made in the invesigated metallurgical routes, the expenditures of raw materials, materials, energy, semiproducts and intermediate products for each kind of products. Based on these data, the direct expenditures are determined through dividing the initial data by the corresponding outputs of each kind of products. The direct expenditures characterize the expenditures of raw materials, materials, energy, semiproducts etc per 1 t of intermediate and final products (sinter, pellets, coke, iron, steel, rolled products of different kinds etc). At the same time, the direct expenditures by themselves do not give an indication of the expenditures in the technological route as a whole. To do this requires to transform a portion of these expenditures into indirect ones, that is to say, recounted with due regard for coefficients of consumption for conjugated kinds of the intermediate products.

Thus, BOF steelmaking requires considerable consumption of iron (direct expenditures) and this in turn involves considerable consumption of fuel and energy going for production of iron, coke, blast-furnace blast, oxygen etc (indirect expenditures). EAF steelmaking requires the most substantial consumption of electric energy (direct expenditures) involving increased consumption of fuel for generation of electric energy at iron and steel enterprises (indirect expenditures) and increased consumption of electric energy obtained from outside.

In such a manner, along with direct expenditures determined by the level of technological progress and elementary proportions between technologically interrelated stages of production (for instance cokemaking and ironmaking) it is essential to have much more sophisticated interroute and interindustry proportions making it possible to express correctly total expenditures of raw materials, materials, energy, semiproducts and intermediate products for intermediate and final products within the boundaries of the whole national economy. Theytake into account not only direct expenditures of specific resources per unit of products in a given stage of production but also indirect expenditures of these resources in other stages of a technogical route and industries conjugated with a given stage of industry via the whole combination of inerroute proportions and interindustry relations. The total expenditures take account of expenditures of a given kind performed not only at the last routine stage of production but at the foregoing stages and routes of production in all the allied branches of industry. These expenditures make allowance thereby for the whole production vertical in making a given product considered as an intermediate or final product.

In addition to the total expenditures there is a possibility to use complex expenditures which are analogous by their nature to the total expenditures but form in the scope of more limited interrelationships (only in the boundaries of a predetermined complex of making products). This completely conforms to the problem worked by the experts.

The economic sense of the complex expenditures, as applied to the problem worked by the experts, consists in consecutive superposition of direct and indirect expenditures of raw materials, materials, energy, semiproducts for production of particular kinds of products in the boundaries of planned technological routes of production. In the most generl view this is illustrated by the example of the "through" calculation of expenditures of fuel in coal equivalent in table 1.

Computation of the indirect expenditures is subdivided into a number of consecutive iterations. The indirect expenditures of ever iterations are generally designated by a proper number (order).

Should the expenditures of raw materials, materials, energy, semiproducts for production of steel going into making rolled products be computed;then this gives in result the indirect expenditures of the first order. The expenditures of the same resources for ironmaking in turn form the idirect expenditures of the second order and the analogous expenditures for production of sinter - the indirect expenditures of the third order etc.

The starting position for computing the direct and complex expenditures is the formation of a square statistical table representing the combination of distribution of materials, fuel, energy, semiproducts, intermediate products for production both intermediate and final products of the iron and steel industry. The mathematical of the mentioned table is given in table 2.

Table 2

The mathematical model of the initial statistical table for computing direct and complex expenditures for technological routes of iron and steel production.

Type of resources or products	Consumption					
	I	2	3	...	П	Total
I	X_{II}	X_{I2}	X_{I3}	...	$X_{I\Pi}$	$\sum_{j=I}^{\Pi} X_{Ij}$
2	X_{2I}	X_{22}	X_{23}	...	$X_{2\Pi}$	$\sum_{j=I}^{\Pi} X_{2j}$
3	X_{3I}	X_{32}	X_{33}	...	$X_{3\Pi}$	$\sum_{j=I}^{\Pi} X_{3j}$
4	X_{4I}	X_{42}	X_{43}	...	$X_{4\Pi}$	$\sum_{j=I}^{\Pi} X_{4j}$
.	.	.	.		.	.
.	.	.	.		.	.
.	.	.	.		.	.
П	$X_{\Pi I}$	$X_{\Pi 2}$	$X_{\Pi 3}$	...	$X_{\Pi\Pi}$	$\sum_{j=I}^{\Pi} X_{\Pi}$
Vector-row	X_I	X_2	X_3	...	X_{Π}	

The initial stage of forming this table consists in separating single elements defining designations of its rows and columns. Every row of this table forms a separate balance of distribution of one or another types of materials, fuel, energy, intermediate products etc. Even simple combination of many material balances in one model (table) facilitates the analysis of quantitative internal material relations in the process of production of various metallurgical products.

The combination of horizontal rows of distribution forms vertical columns expressing the expenditures of the same materials, fuel, energy, semiproducts etc for production of distributed products. In this way as if two combined tables form: in rows - the table of distribution of raw materials, materials, fuel, energy, semiproducts, intermediate products for production of intermediate and final products, and in columns - the table of expenditures of the same types of resources for production of each specific type of products.
The quantity of columns is equal to the quantity of rows, that is to say, the initial statistical table being essentially a matrix has n x n dimension (a square matrix). The above mentioned distinctive features are important benefits of the indicated initial table by comparison with a system of separated individual balances.

The algebraic symbol of consumption of specific resources X has in the table two numbers at the bottom - the first one is determined by the numerical designation of the row, and the second - the column. When those two numbers are the same the consumption of one or another type of resources for its own production (for example, the consumption of electric energy for production of electric energy) takes plac

The initial statistical table used by the experts for determining complex expenditures of raw materials, energy, semiproducts, intermediate products for production of intermediate and final products by appropriate technological routes from ore up to rolled products features rather considerable dimensions (75 x 75). It made it possible to obtain a comprehensive pattern of the expenditures of the mentioned resources in investigated technological routes of iron and steel production. The table comprised fuel in coal equivalent X_1 and 13 its constituents X_2 - X_{14}. Among them power-plant coal X_2, fuel oil X_3, natural gas X_8, coke X_{10} etc. Electric energy is subdivided into own electric energy X_{16} and outside electric energy X_{17}. Thermal energy X_{19} included thermal energy produced by a heat and power plant X_{20} and an industrial boiler plant X_{21}, its total amount was taken excluding thermal energy produced by waste-heat plants as it can be conditionally adopted that fuel and electric energy don't consume for this need. Scrap X_{18} and iron ore X_{27} were adopted as raw materials. Semiproducts and intermediate products were presented by sinter X_{29}, pellets X_{30}, prereduced pellets or sponge iron X_{31}, pig iron X_{33}, BOF steel X_{40} and EAF steel X_{41}. Rolled products were depicted by their wide range with allocation of heavy section products X_{58}, medium section products X_{59} and light section products X_{60}, section structural rolled alloyed steel X_{65} as well as plates X_{66}, sheets X_{67} and cold-rolled sheets X_{68}.

In general terms the initial statistical table can be expressed by the combination of equations which can be mathematically written as :

$$X_i = \sum_{j=1}^{n} X_{ij} + Y_i \quad (i=1,2, \dots , n), \qquad (1)$$

where : X_i - total consumption of i-resource in iron and steel industry;

X_{ij} - consumption of j-resource for production of j-product;

Y_i - commercial output or outside distribution of i-resource.

One of the equations described in general terms by the formula (1), viz. the equation of fuel in investigated technological routes, for example has the following form:

$$\begin{aligned} X_1 = {} & X_{1.10} + X_{1.11} + X_{1.16} + X_{1.20} + X_{1.21} + X_{1.25} + X_{1.26} + \\ & + X_{1.27} + X_{1.28} + X_{1.29} + X_{1.30} + X_{1.31} + X_{1.33} + X_{1.40} + \\ & + X_{1.41} + X_{1.43} + X_{1.44} + X_{1.45} + X_{1.46} + X_{1.47} + X_{1.48} + \\ & + X_{1.49} + X_{1.56} + X_{1.58} + X_{1.59} + X_{1.60} + X_{1.65} + X_{1.66} + \\ & + X_{1.67} + X_{1.68} \end{aligned}$$

In this equation the second number at X denotes consumption of fuel in coal equivalent for producing : coke (10), coke breeze (11), electric energy by a heat and power plant of iron and steel works (16), thermal energy by a heat and power plant (20), thermal energy by an industrial boiler plant (21), blast-furnace blast (25), compressed air (26), iron ore (27), manganese ore (28), sinter (29), pellets (30), prereduced pellets or sponge iron (31), pig iron (33), BOF steel (40), EAF steel (41), fireclay brick (43), silica brick (44), magnesia refractories (45), magnesite powder (46), fired dolomite (47), lime (48), electric ferroalloys (49), continuously cast billet (56), heavy sections (58), medium sections (59), light sections (60), section structural rolled alloyed steel (65), plates (66), sheets (67), cold-rolled sheets (68).

In the formula (1) the component $\sum_{j=1}^{n} X_{ij}$ being the total production consumption can be transformed as

$$X_{ij} = a_{ij} \cdot X_j \qquad (2)$$

where: a_{ij} – direct expenditures of i-material for making j-product

In this case the formula (1) takes the following form :

$$X_i = \sum_{j=1}^{n} a_{ij} X_j + Y_i \qquad (i=1,2, \ldots , n) \qquad (3)$$

Based on the formula (2) direct expenditures can be obtained by dividing consumption of i-resource arising from production j-product by the output of j-product

$$a_{ij} = X_{ij} : X_j \qquad (4)$$

This rather simple formula was the basis of determining direct expenditures from the initial statistical table. For this purpose, the statistical table (square matrix) was divided by a vector-row representing the outputs of iron and steel products (j-products). As a result, the matrix A of direct expenditures was obtained.

$$A = \left\| \begin{matrix} a_{1.1} & a_{1.2} & a_{1.3} & a_{1.4} & \ldots\ldots & a_{1.n} \\ a_{2.1} & a_{2.2} & a_{2.3} & a_{2.4} & \ldots\ldots & a_{2.n} \\ a_{3.1} & a_{3.2} & a_{3.3} & a_{3.4} & \ldots\ldots & a_{3.n} \\ a_{4.1} & a_{4.2} & a_{4.3} & a_{4.4} & \ldots\ldots & a_{4.n} \\ \cdot & & & & & \\ \cdot & & & & & \\ \cdot & & & & & \\ a_{n.1} & a_{n.2} & a_{n.3} & a_{n.4} & \ldots\ldots & a_{n.n} \end{matrix} \right\| \qquad (5)$$

On the basis of determined direct expenditures,the complex expenditures were computed as they were mathematically related to direct expenditures :

$$C_{ij} = a_{ij} + a_{ij}^{(1)} + a_{ij}^{(2)} + a_{ij}^{(2)} + a_{ij}^{(3)} + \ldots + a_{ij}^{(m)} + . \qquad (6)$$

Thus, the complex expenditures of i-products per unit of j-products (in our case this can be rolled products, steel, iron etc) is,according to the boundaries of the complex, the sum of appropriate direct expenditures and indirect expenditures of i-products in all the foregoing production stages stemming from production of the same unit of j-products.

The indirect expenditures in turn are expressed in terms of direct expenditures through the following formulae :

$$a_{ij}^{(m)} = \sum_{k=1}^{n} a_{ik} a_{kj}^{(m-1)} \qquad \text{for the columns}$$

$$a_{ij}^{(m)} = \sum_{k=1}^{n} a_{ik}^{(m-1)} a_{kj} \qquad \text{for the rows} \qquad (7)$$

By this means the formala (6) as a whole can be written as

$$C = A + A^{(1)} + \ldots + A^{(m)} + \ldots ,$$

where the matrix of indirect expenditures of the first order is the second power of the matrix of direct expenditures :

$$A^{(1)} = AA = A^2$$

Resources or products	I ...	8..	I7.	27 ...	29	30	3I ...	33...	40	4I...	56...	58	59	60...	65	66
1.Fuel in coal equivalent, t	–	–	–	0,023	0,065	0,039	0,49	0,69	0,0I27	0,029	0.022	0.086	0.076	0.058	0.044	0.09
8.Natural gas, t m³	–	–	–	0.0I7	0.003	0.033	0.4I9	0.I27	0.08	0.022	0.0I5	0.034	0.03I	0.028	0.0I9	0.03[illegible]
17.Outside electric energy t kW.h	–	–	–	0.078	0.039I	0.0685	0.395	0.0I5	0.03I	0.6II	0.0I2	0.064	0.048	0.07	0.07	0.07[illegible]
27.Iron ore with benefication, t	–	–	–	–	0.98	I.08	I.3	–	–	–	–	–	–	–	–	–
29.Sinter, t	–	–	–	–	–	–	–	I.05	–	–	–	–	–	–	–	–
30.Pellets, t	–	–	–	–	–	–	I.3	0.66	–	–	–	–	–	–	–	–
31.Sponge iron, t	–	–	–	–	–	–	–	–	–	0.25	–	–	–	–	–	–
33.Pig iron, t	–	–	–	–	–	–	–	–	0.849	0.05	–	–	–	–	–	–
40. BOF steel, t	–	–	–	–	–	–	–	–	–	–	(I.05)x)	–	–	–	–	–
41.EAF steel on 75% scrap and 25% sponge iron, t	–	–	–	–	–	–	–	–	–	–	(I.05)x)	–	–	–	–	–
56.Cont.cast billet, t	–	–	–	–	–	–	–	–	–	–	–	I.06	I.044	I.06	I.I2	I.II
58.Heavy sections, t	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
59.Medium sections, t	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
60.Light sections, t	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
65.Section struct. steel, t	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
66.Plates, t	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–

x) Shown conditionally as direct labour and capital expenditures take account of continuous casting of steel.

To determine the complex labour, energy and capital expenditures defining the technological complexity of producing the investigated types of metal products with the use of determined technological routes, the obtained complex expenditures of raw materials, materials, energy and semiproducts are multiplied by direct labour or capital expenditures which are essential for their production (when d etermining complex labour and capital expenditures). These expenditures are directly used for determining the total complex expenditures for intermediate and final products.

3. Evaluation of Complex Labour Expenditures for Obtaining the 1st Process Complexity Index for Investigated Types of Metal Products

The use of complex labour expenditures enables to evaluate the requirements in labour resources needed for constructing metallurgical plants in developing countries. The following values for direct labour expenditures, man.hour/t (thou, m^3, Gcal or thou. kWh) have been taken by experts for calculating complex labour expenditures for producing the investigated types of metal products on the basis of Soviet research and design institutes : blast-furnace gas - 0.0206, coke-oven gas - 0.009, natural gas - 0.055, coke - 0.581, coke breeze - 0.48, own electric energy - 0.2, outside electric energy - 1.555, scrap - 0.70, thermal energy - 0.136, oxygen - 0.322, blast-furnace blast - 0.198, iron ore - 1.1, sinter - 0.565, pellets - 0.5, pre-reduced pellets - 2.0, pig iron - 0.769, fireclay brick - 2.05, silica brick - 2.45, magnesia refractories - 4.8, burnt dolomite - 2.8, lime - 1.5, electric-furnace ferroalloys - 3.5. These expenditures can be corrected depending on the actual conditions of the developing countries. Among above stated direct labour expenditures higher expenditures for blast-furnace gas in comparison with coke-oven gas draw attention. This is related to the labour intensive operation that is being carried out in cleaning the blast-furnace gas from dust. In comparison with outside electric energy supplied from external sources own electric power being generated in thermal-and-power plant is considerably less labour intensive. This can be explained by the fact that due to the considerable combination degree of energy products generation (blast-furnace blast, compressed air, thermal energy and electric energy) direct labour expenditures for electric energy generation is lowered.

Complex labour expenditures for intermediate and final products in the ranges of investigated process routes have been obtained during calculations on EC - 1033 computer. This enables to perform more detailed evaluation of process complexity of any product taking into account carrying over certain process stages.

Prior to the evaluation of complex labour expenditures for individual types of metal products it is advisable to consider the value of these indices for earlier process stages - pig iron and sponge iron production and steel-making by various method which represent the basic metallurgical stages of investigated process routes for making metal products. In addition to the labour expenditures needed for pure metallurgical production stages it is necessary to take into account the labour expenditures for associated nonmetallurgical stages for the production and transportation of natural gas and coking coal and electric power generation in allied industries.

It is advisable at the beginning to consider the calculation of complex labour expenditures values for the production of conversion pig iron and sponge iron (produced by Midrex process). These values are shown in Table 3.

The data of this table (5.006 and 5.145) show that complex labour expenditures for both products are identical (the expenditures for sponge iron are only by 3% lower than that for pig iron) even when taking into account the labour expenditure in the gas industry and electric power generation. If the latter cases are not taken into account then the complex labour expenditures for 1 t of sponge iron will be lower by 2% than that for 1 t of pig iron.

Table 3

Determination of complex labour expenditures (man.hour/t) for production of iron and sponge iron

Expenditures	Unit of measurement	Direct labour expenditures man.hour / unit of measurement	Complex expenditures of raw materials, energy, semiproducts per 1 t: Pig iron	Sponge iron	Complex labour expenditures, man.hour/t: Pig iron	Sponge iron
Fuel	t of coal equival.	-	0.9677	0.5654	0.305	0.026
Incl. natural gas	Thou m^3	0.055	0.2I28	0.458	0.0II	0.025
coke	t	0.58I	0.44	-	0.0I8	-
Own electric energy	Th kWh	0.2	0.07II	0.0278	0.0I4	0.005
Outside electric energy	"	I.555	0.394	0.535	0.6I3	0.832
Thermal energy	Gcal	0.I36	0.277	0.I94	0.038	0.026
Oxygen	Thou.m^3	0.322	0.I36	-	0.044	-
Blast-furnace blast	Th.tr m^3	0.I98	I.87	-	0.370	-
Compressed air	Th.st.m^3	-	0.022	-	-	-
Scrap	t	0.7	0.008	-	0.005	-
Iron ore	t	I.I	I.758	I.46	I.934	I.606
Sinter	t	0.565	I.05	-	0.593	-
Sponge iron	t	2.0	-	I.0	-	2.0
Pellets	t	0.5	0.659	I.3	0.330	0.65
Pig iron	t	0.769	I.0	-	0.769	-
Total					5.006	5.I45

Complex labour expenditures for the production of BOF steel and electric-furnace steel on the basis of using scrap and sponge iron (that is to say steel made by all of the three investigated metallurgical routes) and electric furnace steel made from a charge containing 25% sponge iron and 75% scrap (Table 4).

The summarized data show that less labour intensive and hence less complicated regarding direct labour expenditures is EAF steel made from scrap (5.5 man.hour/t). Complex labour expenditures for BOF steel (6.6 man.hour/t) is by 20% more than above stated value while that for electric furnace steel made from a charge containing 25% sponge iron and 75% scrap it is more by 25%. The considerable complex labour expenditures for electric-furnace steel made from sponge iron (9.38 man.hour/t) can be decreased by 1.3 man.hour/t as compared with the similar expenditures for scrap based on electric-furnace steel if only the labour expenditure strictly in the metallurgical route are taken into account without the expenditure for allied industries (gas industry and electric power generation).

All above stated complex labour expenditures for steelmaking have been calculated on the basis that the steel is to be cast by noncontinuous method. In casting steel into ingots and using blooming and slabbing mills additional complex labour expenditures will be bound as compared to similar expenditures when using billets - 1.5 man.hour/t.

Consideration of the obtained values for complex labour expenditures of steels being made by the various methods that can be carried out at newly built metallurgical plants of developing countries simplifies the understanding of values for complex labour expenditures of the rolled products being made from these steels.

Table 4

Determination of complex labour expenditures (man.hour/t) for production of BOF steel and EAF steel on the base of scrap, sponge iron, 25% of sponge iron and 75% of scrap

Expenditures	Unit of measurement	Direct labour expenditures man.hour / Unit of measurement	Complex expenditures of raw materials, energy and semiproducts: Per 1 t of BOF steel	Per 1 t of EAF steel on the base of: Scrap	Sponge iron	25% of sponge iron and 75% of scrap	Complex labour expenditures: Per 1 t of BOF steel	Per 1 t of EAF steel on the base: Scrap	Sponge iron	25% of sponge iron and 75% of scrap
1	2	3	4	5	6	7	8	9	10	11
Fuel	t of coal equival.		0,8697	0.26II	0.6467	0.3I99	0.2675	0.0406	0.0272	0.0375
Incl. natural gas	Thou.m^3	0.055	0.205	0.07I	0.479	0.I83	0.0II3	0.0039	0.0263	0.0I0I
coke	t	0.58I	0.379	0.038I	-	0.029	0.220	0.022I	-	0.0I7
Own electric energy	Th.kWh	0.2	0.073	0.I445	0.I428	0.0I39	0.0I4	0.0289	0.0286	0.003
Outside electric energy	"	I.555	0.532	0.887	I.555	I.0895	0.827	I.379	2.4I8	I.694
Scrap	t	0.7	0.3	0.9735	-	0.795	0.2I	0.68I5	-	0.557
Thermal energy	Gcal	0.I36	0.25	0.033	0.I96	0.075	0.034	0.0045	0.0267	0.0I0
Oxygen	Thou.m^3	0.332	0.I8	0.03I3	0.026	0.032	0.058	0.0I0I	0.0084	0.0I0
Blast-furnace blast	Th.tr.m^3	0.I98	I.584	0.I39	-	0.095	0.3I4	0.0275	-	0.0I9
Compressed air	Th.st.m^3	0.0437	0.049	0.048	0.054	-	-	-	-	-
Iron ore	t	I.I	I.493	0,I04	I.46	0.46	I.64	0.II44	I.606	0.506
Sinter	t	0.565	0.892	0.0753	-	0.054	0.504	0.0425	-	0.03I

I	2	3	4	5
Pellets	t	0.5	0.56I	0.027I
Sponge iron	t	2.0	–	–
Iron	t	0.769	0.8495	0.0588
Refractories	t		0.0I85	0.0622
Incl. fireclay brick	t	2.05	0.0I02	0.030I
silica brick	t	2.45	–	0.0006
magnesia refractories	t	4.8	0.0023	0.0I05
fired dolomite refractories	t	2.8	0.006	0.02I
Lime	t	I.05	0.I	0.II
Electric ferroalloys	t	3.5	0.0I5	0.036
BOF steel	t	I.6	I	–
EAF steel	t	2.7	–	I
Total				

6	7	8	9	10	11
I.3	0.359	0.28I	0.0I35	0.65	0.I785
I.0	0.25	–	–	2.0	0.75
–	0.05II	0.653	0.0453	–	0.039
0.0622	0.058	0.049	0.I853	0.I853	0.I8I
0.030I	0.028	0.02I	0.075	0.06I7	0.057
0.0006	–	–	0.00I5	0.00I5	–
0.0I05	0.02	0.0II	0.0504	0.0504	0.096
0.02I	0.0I	0.0I7	0.0588	0.0588	0.028
0.II	0.II5	0.I05	0.II6	0.II6	0.I2I
0.036	0.036	0.053	0.I26	0.I26	0.I26
–	–	I.6	–	–	–
I	I	–	2.7	2.7	2.7
		6.609	5.5I5	9.879	6.964

Complex labour expenditures in the production of heavy, medium and light sections, plates, sheets, cold-rolled sheets and structural section steel are determined in Tables 5 - 11.

Table 12 shows the summarised values of complex labour expenditures for all investigated process routes.

Comparison of these data shows that the most labour intensive and the more complex regarding living labour expenditures types of products are cold-rolled sheets and alloyed structural section steel. The very high value for complex labour expenditures in the production of EAF steel with the use of sponge iron can be lowered by making calculations only within the limits of the metallurgical route without taking into account the labour expenditures in the production of gas and generation of electric power in power systems (2-3 man.hour/h), and also by importing the sponge iron (saving of 5-6 man.hour/t) or by replacing it by scrap. The last action can be made only in the case of hard currency availability in one or another developing country.

Table 5

Determination of complex labour expenditures (man.hour/t) for production of heavy-section rolled products

Expenditures	Unit of measurement	Direct labour expenditures, man.hour / Unit of measurement	Complex expenditures of raw materials, energy and semiproducts per 1 t when using				Complex labour expenditures, when using			
			BOF steel	EAF steel on the base of			BOF steel	EAF steel on the base of		
				Scrap	Sponge iron	25% of sponge iron and 75% of scrap		Scrap	Sponge iron	25% of sponge iron and 75% of scrap
1	2	3	4	5	6	7	8	9	10	11
Fuel	t of coal equival.		I.027	0.3244	0.7227	0.408I	0.2866	0.0468	0.033I	0.0372
Incl. natural gas	Thou.m^3	0.055	0.2363	0.0943	0.527	0.2I30	0.0I30	0.005	0.0290	0.0II7
coke	t	0.58I	0.40I7	0.040	–	0.03I	0.233	0.023	–	0.0I8
Own electric energy	Th.kWh	0.2	0.09I4	0.I67I	0.I654	0.0287	0.0I83	0.033	0.033	0.0057
Outside electric energy	"	I.555	0.6324	I.009	I.7I68	I.2234	0.9834	I.5690	2.6696	I.9024
Scrap	t	0.7	0.3I8	I.032	–	0.843	0.2226	0.7224	–	0.590I
Thermal energy	Gcal	0.I36	0.305	0.075	0.2478	0.II95	0.04I5	0.0I02	0.0337	0.0I63
Oxygen	Thou.m^3	0.322	0.I958	0.0382	0.0326	0.0389	0.063	0.0I23	0.0I05	0.0I25
Blast-furnace blast	Th.tr.m^3	0.I98	I.679	0.I473	–	0.I007	0.332	0.0292	–	0.0I99
Iron ore	t	I.I	I.5826	0.II28	I.5476	0.4876	I.7409	0.I24	I.7024	0.5364
Sinter	t	0.565	0.9455	0.080	–	0.0572	0.5342	0.0452	–	0.0323

I	2	3	4	5
Pellets	t	0.5	0.5946	0.0287
Sponge iron	t	2.0	–	–
Iron	t	0.769	0.9005	0.0623
Refractories	t		0.0I96	0.0659
Incl. fireclay brick	t	2.05	0.0I08	0.03I9
silica brick	t	2.45	–	0.0006
magnesia refractories	t	4.8	0.0024	0.0III
fired dolomite refractor.	t	2.8	0.0064	0.0223
Lime	t	I.05	0.I06	0.II7
Electric ferroalloys	t	3.5	0.0I59	0.038
BOF steel	t	I.6	I.06	–
EAF steel	t	2.7	–	I.06
Heavy-section rolled products	t	2.6	I	I
Total				

6	7	8	9	10	11
I.38	0.38I	0.2973	0.0I44	0.69	0.I905
I.06	0.265	–	–	2.I2	0.530
–	0.0542	0.692	0.0479	–	0.04I6
0.0659	0.06I3	0.05I5	0.I958	0.I826	0.I9I3
0.03I9	0.0297	0.022I	0.0654	0.0654	0.0608
0.0006	–	–	0.00I5	0.00I5	–
0.0III	0.02I	0.0II5	0.0533	0.0533	0.I008
0.0223	0.0I06	0.0I79	0.0624	0.0624	0.0297
0.II66	0.I2I9	0.III3	0.I229	0.I224	0.I280
0.0382	0.038	0.0556	0.I33	0.I337	0.I33
–	–	I,696	–	–	–
I.06	I.06	–	2.862	2.862	2.862
I	I	2.6	2.6	2.6	2.6
		9.73	8.56	I3.I9	9.833

Table 6

Determination of complex labour expenditures (man.hour/t) for production of medium-section rolled products

Expenditures	Unit of measurement	Direct labour expenditures, man.hour / Unit of measurement	Complex expenditures of raw materials, energy and semiproducts, when using				Complex labour expenditures, when using			
			BOF steel	EAF steel on the base of			BOF steel	EAF steel on the base of		
				Scrap	Sponge iron	25% of sponge iron and 75% of scrap		Scrap	Sponge iron	25% of sponge iron and 75% of scr
1	2	3	4	5	6	7	8	9	10	11
Fuel	t of coal equiv.		I.0I4I	0.298I	0.72I	0.4462	0.2835	0.0474	0.0333	0.0382
Incl. natural gas	Thou.m^3	0.055	0.252	0.II2I	0.538I	0.229I	0.0I39	0.0062	0.0296	0.0I26
coke	t	0.58I	0.3957	0.0398	–	0.0303	0.2299	0.023I	–	0.0I76
Own electric energy	Th.kWh	0.2	0.0922	0.I355	0.0I67	0.0305	0.0I84	0.027I	0.0033	0.006I
Outside electric energy	"	I.555	0.6269	0.9975	I.6949	I.2089	0.9748	I.55II	2.6356	I.8798
Scrap	t	0.7	0.3I32	I.0I6	–	0.8300	0.2I92	0.7II2	–	0.58I0
Thermal energy	Gcal	0.I36	0.292	0.0654	0.2356	0.I093	0.0397	0.0089	0.0320	0.0I49
Oxygen	Thou.m^3	0.322	0.I939	0.0387	0.033I	0.0394	0.0624	0.0I25	0.0I07	0.0I27
Blast-furnace blast	Th.tr.m^3	0.I98	I.6537	0.I45	–	0.0992	0.3274	0.0287	–	0.0I96
Iron ore	t	I.I	I.5587	0.IIII	I.5242	0.4802	I.7I46	0.I222	I.6766	0.5282
Sinter	t	0.565	0.93I2	0.0786	–	0.0564	0.526I	0.0444	–	0.03I9

1	2	3	4	5	6	7	8	9	10	11
Pellets	t	0.5	0.5857	0.0283	I.357	0.375	0.2929	0.0I42	0.679	0.I88
Sponge iron	t	2.0	–	–	I.044	0.26I	–	–	2.088	0.522
Iron	t	0.769	0.8869	0.06I4	–	0.0533	0.6820	0.0472	–	0.040
Refractories	t		0.0I93	0.0648	0.0649	0.065	0.0503	0.I795	0.I80	0.I29
Incl. fireclay brick	t	2.05	0.0I06	0.03I4	0.03I4	0.0292	0.02I7	0.0644	0.0644	0.059
silica brick	t	2.45	–	0.0006	0.0006	–	–	0.00I5	0.00I5	–
magnesia refractories	t	4.8	0.0024	0.0I09	0.0II0	0.0209	0.0II5	0.0523	0.0528	0.I00
fired dolomite refractor.	t	2.8	0.0063	0.02I9	0.02I9	0.0I04	0.0I76	0.06I3	0.06I3	0.029
Lime	t	I.05	0.I044	0.II48	0.II48	0.II96	0.I096	0.I205	0.I205	Q.I25
Electric ferroalloys	t	3.5	0.0I5	0.0376	0.0376	0.0376	0.0525	0.I3I6	0.I3I6	0.I3I
BOF steel	t	I.6	I.044	–	–	–	I.6704	–	–	–
EAF steel	t	2.7	–	I.044	I.044	I.044	–	2.8I88	2.8I88	2.8I8
Medium-section rolled prod.	t	2.0	I,0	I,0	I.0	I.0	2.0	2.0	2.0	2.0
Total							9.024	7.865	I2.40	9.I28

Table 7

Determination of complex labour expenditures (man.hour/t) for production of light-section rolled products

Expenditures	Unit of measurement	Direct labour expenditures, man.hour / Unit of measurement	Complex expenditures of raw materials, energy and semiproducts, when using				Complex labour expenditures, when using			
			BOF steel t	EAF steel on the base of			BOF steel	EAF steel on the base of		
				Scrap	Sponge iron	25% of sponge iron and 75% of scrap		Scrap	Sponge iron	25% of sponge iron and 75% of scrap
1	2	3	4	5	6	7	8	9	10	11
Fuel	t of coal equival.		I.004I	0.30I7	0.7II7	0.423	0.2862	0.0462	0.0327	0.0529
Incl. natural gas	Thou.m^3	0.055	0.259	0.I073	0.540	0.226	0.0I5	0.0062	0.0297	0.0I24
coke	t	0.58I	0.40I7	0.40	–	0.03I	0.233	0.023	–	0.0I8
Own electric energy	Th,kWh	0.2	0.0927	0.I685	0.I667	0.030	0.0I85	0.0337	0.0333	0.006
Outside electric energy	"	I.555	0.6299	I.0062	I.7I43	I.2209	0.9795	I.5646	2.6657	I.8985
Scrap	t	0.7	0.3I8	I.032	–	0.843	0.2226	0.7224	–	0.590I
Thermal energy	Gcal	0.I36	0.289	0.0590	0.23I8	0.I035	0.0393	0.008	0.03I5	0.0I4I
Oxygen	Thou.m^3	0.322	0.I958	0.0382	0.0326	0.0389	0.063	0.0I23	0.0I05	0.0I25
Blast-furnace blast	Th.tr.m^3	0.I98	I.679	0.I473	–	0.I007	0.322	0.0292	–	0.0I99
Iron ore	t	I.I	I.5826	0.II28	I.5476	0.4876	I.7409	0.I24	I.7024	0.5364
Sinter	t	0.565	0.9455	0.080	–	0.0572	0.5342	0.0452	–	0.0323
Pellets	t	0.5	0.5946	0.0287	I.38	0.38I	0.2973	0.0I44	0.69	0.I905

1	2	3	4	5	6	7	8	9	10	11
Sponge iron	t	2.0	–	–	I.06	0.265	–	–	2.I2	0.530
Iron	t	0.769	0.9005	0.0623	–	0.0542	0.692	0.0479	–	0.04I6
Refractories			0.0I96	0.07I3	0.0669	0.06I3	0.05I4	0.I958	0.I826	0.I9I3
Incl. fireclay brick	t	2.05	0.0I08	0.03I9	0.03I9	0.0297	0.022I	0.0654	0.0654	0.0608
silica brick	t	2.45	–	0.006	0.0006	–	–	0.0I47	0.00I5	–
magnesia refractories	t	4.8	0.0024	0.0III	0.0III	0.02I	0.0II5	0.0533	0.0533	0.I008
fired dolomite refractor.	t	2.8	0.0064	0.0223	0.0223	0.0I06	0.0I79	0.0624	0.0624	0.0297
Lime	t	I.05	0.I06	0.II7	0.II66	0.I2I9	0.III3	0.I229	0.I224	0.I280
Electric ferroalloys	t	3.5	0.0I59	0.038	0.0382	0.038	0.0556	0.I33	0.I337	0.I33
BOF steel	t	I.6	I.06	–	–	–	I.696	–	–	–
EAF steel	t	2.7	–	I.06	I.06	I.06	–	2.862	2.862	2.862
Light-section rolled products	t	I.95	I	I	I	I	I.95	I.95	I.95	I.95
Total							9.070	7.9I2	I2.537	9.I90

Table 8

Determination of complex labour expenditures (man.hour/t) for production of hot-rolled plates

Expenditures	Unit of measurement	Direct labour expenditures, man.hour / Unit of measurement	Complex expenditures of raw materials, energy and semiproducts, when using				Complex labour expenditures, when using			
			BOF steel	EAF steel on the base of			BOF steel	EAF steel on the base of		
				Scrap	Sponge iron	25% of sponge iron and 75% of scrap		Scrap	Sponge iron	25% of sponge iron and 75% of scrap
1	2	3	4	5	6	7	8	9	10	11
Fuel	t of coal equiv.		I.I254	0.32I5	0.75I6	0.4477	0.3026	0.0507	0.I702	0.I5I
Incl. natural gas	Thou.m^3	0.055	0.2654	0.III6	0.5706	0.I2I	0.0I46	0.0064	0.03I4	0.I3I
coke	t	0.58I	0.4222	0.0424	–	0.0323	0.2453	0.0246	–	0.0I88
Own electric energy	Th.kWh	0.2	0.0980	0.I777	0.I758	0.0322	0.0I96	0.0355	0.0352	0.0064
Outside electric energy	"	I.555	0.650I	0.69I	I.8032	I.2847	I.0II	I.662	2.8040	I.9977
Scrap	t	0.7	0.3342	I.0845	–	0.8856	0.2339	0.7592	–	0.6I99
Thermal energy	Gcal	0.I36	0.3305	0.0888	0.2703	0.I356	0.0449	0.0I2I	0.0368	0.0I84
Oxygen	Thou.m^3	0.322	0.2055	0.0399	0.0340	0.0406	0.0662	0.0I28	0.0I09	0.0I3I
Blast-furnace blast	Th.tr.m^3	0.I98	I.7646	0.I548	–	0.I058	0.3494	0.0307	–	0.0209
Iron ore	t	I.I	I.6632	0.II85	I.6264	0.5I24	I.8295	0.I304	I.7890	0.5636
Sinter	t	0.565	0.9937	0.0839	–	0.060I	0.56I4	0.0474	–	0.0340
Pellets	t	0.5	0.6250	0.0302	I.448	0.3909	0.3I25	0.0I5I	0.724	0.I999
Sponge iron	t	2.0	–	–	I.I44	0.2785	–	–	2.228	0.5570

I	2	3	4
Iron	t	0.765	0.9463
Refractories	t		0.0207
Incl. fireclay brick	t	2.05	0.0II4
silica brick	t	2.45	–
magnesia refractories	t	4.8	0.0026
fired dolomite refractor.	t	2.8	0.0067
Lime	t	I.05	0.III4
Electric ferroalloys	t	3.5	0.0I67
BOF steel	t	I.6	I.II4
EAF steel	t	2.7	–
Hot-rolled plates	t	3.9	I
Total			

5	6	7	8	9	10	11
0.0655	–	0.0569	0.7277	0.0504	–	0.0438
0.0693	0.0693	0.0646	0.0546	0.I92I	0.I92I	0.202
0.0335	0.0335	0.03I2	0.0234	0.0687	0.0687	0.0640
0.0007	0.0007	–	–	0.00I7	0.00I7	–
0.0II7	0.0II7	0.0223	0.0I24	0.0562	0.0562	0.I070
0.0234	0.0234	0.0III	0.0I88	0.0655	0.0655	0.03I0
0.I225	0.I225	0.I28I	0.II70	0.I286	0.I236	0.I345
0.040I	0.040I	0.040I	0.0585	0.I404	0.I404	0.I404
–	–	–	I.7824	–	–	–
I.II4	I.II4	I.II4	–	3.0078	3.0078	3.0078
I	I	I	3.9	3.9	3.9	3.9
			II.672	I0.I75	I5.I67	II.655

Table 9

Determination of complex labour expenditures (man.hour/t) for production of hot-rolled sheets

Expenditures	Unit of measurement	Direct labour expenditures, man.hour / Unit of measurement	Complex expenditures of raw materials, energy and semiproducts, when using: BOF steel	EAF steel on the base of: Scrap	Sponge iron	25% of sponge iron and 75% of scrap	Complex labour expenditures, when using: BOF steel	EAF steel on the base of: Scrap	Sponge iron	25% of sponge iron and 75% of scrap
1	2	3	4	5	6	7	8	9	10	11
Fuel	t of coal equiv.		I.0667	0.3087	0.7323	0.4326	0.2979	0.0495	0.0347	0.05I4
Incl. natural gas	Thou.m^3	0.055	0.258I	0.II09	0.5589	0.2339	0.0I42	0.006I	0.0307	0.0I29
coke	t	0.58I	0.4I6	0.04I8	–	0.03I8	0.24I7	0.0248	–	0.0I85
Own electric energy	Th.kWh	0.2	0.0955	0.I74I	0.I722	0.0307	0.0I9I	0.0348	0.0344	0.006
Outside electric energy	"	I.555	0,6496	I.0394	I.7729	I.26I8	I.0I0I	I.6I63	2.7569	I.962I
Scrap	t	0.7	0.3294	I.0689	–	0.8729	0.2306	0.748	–	0.6II0
Thermal energy	Gcal	0.I36	0.3I65	0.0782	0.2572	0.I243	0.0430	0.0I06	0.0350	0.0I7
Oxygen	Thou.m^3	0.322	0.2026	0.0344	0.0335	0.040I	0.0652	0.0II0	0.0I08	0.0I29
Blast-furnace blast	Th.tr.m^3	0.I98	I.7392	0.I526	–	0.I043	0.3444	0.0302	–	0.0207
Iron ore	t	I.I	I.6393	0.II68	I.603I	0.505I	I.8032	0.I285	I.7634	I.5556
Sinter		0.565	0.9794	0.0827	–	0.0593	0.5534	0.0467	–	0.0335
Pellets	t	0.5	0.6I60	0.0298	I.427	0.394	I2.320	0.596	28.54	7.88
Sponge iron	t	2.0	–	–	I.098	0.2745	–	–	2.I96	0.549

I	2	3	4
Iron	t	0.769	0.9328
Refractories	t		0.0203
Incl. fireclay brick	t	2.05	0.0II2
silica brick	t	2.45	–
magnesia refractories	t	4.8	0.0025
fired dolomite refract.	t	2.8	0.0066
Lime	t	I.05	0.I098
Electric ferroalloys	t	3.5	0.0I65
BOF steel	t	I.6	I.098
EAF steel	t	2.7	–
Hot-rolled sheets	t	2.I	I
Total			

5	6	7	8	9	10	11
0.0646	–	0.056I	0.7I73	0.0497	–	0.043I
0.068I	0.068I	0.0637	0.0534	0.I388	0.I888	0.I993
0.0330	0.0330	0.0307	0.0229	0.0667	0.0667	0.0629
0.0006	0.0006	–	–	0.00I5	0.00I5	–
0.0II5	0.0II5	0.0220	0.0I2	0.0552	0.0552	0.I056
0.0230	0.0230	0.0II0	0.0I85	0.0644	0.0644	0.0308
0.I207	0.I207	0.I263	0.II53	0.I267	0.I267	0.I326
0.0395	0.0395	0.0395	0.0577	0.I383	0.I383	0.I383
–	–	–	I.757	–	–	–
I.098	I.098	I.098	–	2.9646	2.9646	2.9646
I	I	I	2.I	2.I	2.I	2.I
			9.476	8.259	I3.064	9.594

Table 10

Determination of complex labour expenditures (man.hour/t) for production of cold-rolled sheets

Expenditures	Unit of measurement	Direct labour expenditurs, man.hour / Unit of measurement	Complex expenditures of raw materials, energy and semiproducts, when using				Complex labour expenditures, when using			
			BOF steel	EAF steel on the base of			BOF steel	EAF steel on the base of		
				Scrap	Sponge iron	25% of sponge iron and 75% of scrap		Scrap	Sponge iron	25% of sponge iron and 75% of scrap
I	2	3	4	5	6	7	8	9	I0	II
Fuel	t of coal equiv.		I.I453	0.3548	0.7203	0.490I	0.3II78	0.23I6	0.0335	0.0447
Incl. natural gas	Thou.m^3	0.055	0.2530	0.0974	0.57II	0.2275	0.0I39	0.0054	0.03I4	0.0I25
coke	t	0.58I	0.4400	0.0277	–	0.0337	0.2556	0.0I6I	–	0.0I96
Own electric energy	Th.kWh	0.2	0.I03I	0.I860	0.I84I	0.0344	0.0206	0.0372	0.0368	0.0069
Outside electric energy	"	I.555	0.6969	I.I087	I.8843	I.3438	I.0837	I.7240	2.930	2.0896
Scrap	t	0.7	0.3483	I.I302	–	0.9230	0.2438	0.79II	–	0.646I
Thermal energy	Gcal	0.I36	0.3963	0.I443	0.I308	0.I93I	0.0539	0.0I96	0.0I78	0.0263
Oxygen	Thou.m^3	0.322	0.2I60	0.0433	0.0372	0.0442	0.0696	0.0I39	0.0I20	0.0I42
Blast-furnace blast	Th.tr.m^3	0.I98	I.8390	0.I6I4	–	0.II03	0.364I	0.0320	–	0.02I8
Iron ore	t	I.I	I.7334	0.I235	I.695I	0.534I	I.9067	0.I358	I.8646	0.5875
Sinter	t	0.565	I.0356	0.0874	–	0.0627	0.585	0.0494	–	0.0354
Pellets	t	0.5	0.65I3	0.03I5	I.5093	0.4I65	0.3256	0.0I57	0.7546	0.2083

1	2	3	4	5
Sponge iron	t	2.0	–	0.0683
Iron	t	0.769	0.9863	–
Refractories	t		0.0215	0.0722
Incl. fireclay brick	t	2.05	0.0118	0.0349
silica brick	t	2.45	–	0.0007
magnesia refractories	t	4.8	0.0027	0.0122
fired dolomite refract.	t	2.8	0.0070	0.0244
Lime	t	1.05	0.1161	0.1277
Electric ferroalloys	t	3.5	0.0174	0.0418
BOF steel	t	1.6	1.161	–
EAF steel	t	2.7	–	1.161
Hot-rolled sheets	t	2.1	1.05	1.05
Cold-rolled sheets	t	6.0	1	1
Total				

6	7	8	9	10	11
I.I6I	0.2903	–	0.I366	2.322	0.5606
–	0.0593	0.7584	–	–	0.0456
0.0722	0.0673	0.0568	0.I998	0.I998	0.2I03
0.0349	0.0325	0.0242	0.07I5	0.07I5	0.0666
0.0007	–	–	0.00I4	0.00I4	–
0.0I22	0.0232	0.0I30	0.0586	0.0586	0.III3
0.0244	0.0II6	0.0I96	0.0683	0.0683	0.0324
0.I277	0.I335	0.I2I9	0.I278	0.I278	0.I402
0.04I8	0.04I8	0.0609	0.I46	0.I46	0.I46
–	–	I.8576	–	–	–
I.I6I	I.I6I	–	3.I347	3.I347	3.I347
I.05	I.05	2.205	2.205	2.205	2.205
I	I	6.0	6.0	6.0	6.0
		I6.025	I5.00	I9.785	I6.I24

Table 11

Determination of complex labour expenditures (man.hour/t) for production of section structural alloyed steel

Expenditures	Unit of measurement	Direct labour expenditures, man.hour / Unit of measurement	Complex expenditures of raw materials energy and semiproducts, when using: BOF steel	EAF steel on the base of: Scrap	EAF steel on the base of: Sponge iron	EAF steel on the base of: 25% of sponge iron and 75% of scrap	Complex labour expenditures, when using: BOF steel	EAF steel on the base of: Scrap	EAF steel on the base of: Sponge iron	EAF steel on the base of: 25% of sponge iron and 75% of scrap
1	2	3	4	5	6	7	8	9	10	11
Fuel	t of coal equiv.		I.II73	0.358	0.7099	0.488	0.3004	0.0482	0.0333	0.0556
Incl. natural gas	Thou.m³	0.055	0.2486	0.0985	0.5555	0.224	0.0I37	0.0054	0.0306	0.0I23
coke	t	0.58I	0.4244	0.0427	–	0.0324	0.2466	0.0248	–	0.0I88
Own electric energy	Th.kWh	0.2	0.09576	0.I758	0.I739	0.0296	0.0I92	0.0352	0.0348	0.0059
Outside electric energy	"	I.555	0.6638	I.06I4	I.8096	I.2882	I.0322	I.6505	2.8I39	2.0032
Scrap	t	0.7	0.336	I.0903	–	0.890	0.2352	0.7623	–	0.623
Thermal energy	Gcal	0.I36	0.07I3	0.0940	0.2765	0.084	0.0097	0.0I28	0.0376	0.0II4
Oxygen	Thou.m³	0.322	0.25I6	0.040	0.034I	0.0858	0.08I0	0.0I29	0.0I09	0.0276
Blast-furnace blast	Th.tr.m³	0.I98	I.7740	0.I557	–	0.I064	0.35I3	0.0308	–	0.02II
Iron ore	t	I.I	I.672	0.II9I	I.6352	0.5I5	I.8392	0.I3I0	I.7987	0.5665
Sinter	t	0.565	0.999	0.0843	–	0.0604	0.5644	0.0476	–	0.034I
Pellets	t	0.5	0.6283	0.0304	I.456	0.402	0.3I42	0.0I52	0.728	0.20I

1	2	3	4	5
Sponge iron	t	2.0	–	–
Iron	t	0.769	0.95I4	0.0659
Refractories	t		0.0207	0.0696
Incl. fireclay brick	t	2.05	0.0II4	0.0337
silica brick	t	2.45	–	0.0007
magnesia refractories	t	4.8	0.0026	0.0II8
fired dolomite refractor.	t	2.8	0.0067	0.0234
Lime	t	I.05	0.II2	0.I232
Electric ferroalloys	t	3.5	0.0I68	0.0403
BOF steel	t	I.6	I.I2	–
EAF steel	t	2.7	–	I.I2
Section structural alloyed steel	t	8	I	I
Total				

6	7	8	9	10	11
I.I2	0.28	–	–	2.24	0.56
–	0.0572	0.73I6	0.0507	–	0.0440
0.0696	0.065	0.0547	0.I929	0.I929	0.2033
0.0337	0.03I4	0.0234	0.069I	0.069I	0.0644
0.0007	–	–	0.00I7	0.00I7	–
0.0II8	0.0224	0.0I25	0.0566	0.0566	0.I075
0.0234	0.0II2	0.0I88	0.0655	0.0655	0.03I4
0.I232	0.I288	0.II76	0.I294	0.I294	0.I352
0.0403	0.0403	0.0588	0.I4II	0.I4II	0.I4II
–	–	I.792	–	–	–
I.I2	I.I2	–	3.024	3.024	3.024
I	I	8	8	8	8
		I5.502	I4.286	I9.I85	I5.76

Table 12

Total complex labour expenditures (man.hour/t)

Type of metal products	Complex labour expenditures in the use of :			
	BOF steel	EAF steel on the base of :		
		scrap	sponge iron	25% sponge iron and 75% scrap
Heavy sections	9.33	8.56	13.19	9.833
Medium sections	9.024	7.865	12.40	9.128
Light sections	9.070	7.912	12.537	9.190
Plates	11.672	10.175	15.167	11.655
Sheets	9.476	8.259	13.064	9.594
Cold-rolled sheets	16.025	15.00	19.785	16.124
Section structural alloyed steel	15.502	14.286	19.185	15.66

Total complex labour expenditures can be also decreased by importing pellets which enables to do without the ore mining and preparation stage and also pellets production and reduce complex expenditures by 2-2.5 man.hour/t. It is also possible to import refractory materials and ferroalloys (saving of 0.25 man.hour/t).

To determine the requirement in industrial and production personnel for newly built iron and steel works the total complex labour expenditures for the production of the required range of rolled products are multiplied by the given production capacities and the result is divided by the annual time fund of a worker. According to the data of the experts total number of industrial and production personnel of a plant producing 1 million ton of rolled products ranges between 5,000 - 10,000 men depending on the adopted metallurgical route. In the whole metallurgical cycle, according to experts data, it is necessary to have 6% specialists with higher education and 12% technicians with secondary special education from the total number of industrial production personnel. For individual industries these figures amount to 8 and 14% in the production of section structural alloyed steel, 6.5 and 15.5% in ore mining and benefication, 4 and 15% in refractories production, 7 and 14% in ferroalloys production, 16 and 15% in thermal and power facilities, 5 and 105 in maintenance services and 11 and 18% in the coke and by-products industry.

According to the experience of Latin America's metallurgical companies the share of production workers should amount to 60% from the whole number of workers, while workers involved in the repair and maintenance of equipment amount to about 40%. The share of skilled workers among production workers should amount to 50%, while for workers involved in equipment repair and mainenance amount to about 60% [5].

The efficient utilization of equipment and machines in the iron and steel industry depends on the qualification and training of attending personnel. Workers attending metallurgical units should know in details the machines and equipment which are served by them, and also the specifics of the actual production processes and their relation to other processes involved in the metallurgical route.

The form of training workers, engineers and technicians required for ensuring the development of iron and steel industry in a developing country is determined by the conditions of education system dominating in the country. Without sufficiently developed training of pupils with incomplete secondary or secondary education it is possible to start training of skilled workers on the basis of primary education (6 forms). For this purpose it is expedient to establish vocational and technical schools with 3-4 years of educational period during which the pupils will finish incomplete secondary school. With increasing number of pupils with incomplete secondary education the period of education for the vocational and technical schools could be reduced for this category to 1-2 years. It is important to envisage training of teachers for vocational and technical schools in higher educational establishments of a country by organizing special industrial and pedagogical departments for this purpose.

At the first stage of economic development of the country workers of required skills can be trained in the training centres for workers of the developed countries with the help of which the iron and steel industry is being developed. The above centres are also established by the United Nations Development Organisation.

The Soviet Union renders cooperation to the developing countries in the field of training indigenous personnel of builders and metallurgists for the iron and steel industry, plants installed in those countries with the USSR's technical assistance. Beginning from 1965 six month instruction courses (seminar) have been held under the auspices of UNIDO in the city of Zaporozhie organized by the Government of the Ukrainian Soviet Socialist Republic.

The training of specialists of mean qualification - technicians including teachers of vocational and technical schools should be carried out in the medium technical educational establishments with education period of 3-4 years where pupils graduated from incomplete secondary schools. The educational plan of technicians' training for the iron and steel industry should cover general educational, general technical and professionally metallurgical cycles. With the development in the country of secondary education the graduates from secondary schools can be admitted to the technical schools with the reduced educational period covering 1-2 years.

The training of engineers for the iron and steel industry of developing countries can be conducted in a number of forms. Initially, it is centralized direction of the graduates of secondary schools for studying in higher educational establishments of developing countries for receiving concrete speciality. Simultaneously, it is essential to organise in the country the training of engineers for the iron and steel industry in the national higher educational establishments. If university education is available in the country then in this case for training engineers - metallurgists the graduates of universities can be used for training them during 2 years in the established specialised technical higher educational institutes on special metallurgical disciplines at the level of Magister of Technology.

In case the university education is developed in the country it could be possible to organize in the universities metallurgical departments with 5-year educational period. Depending on industrial development scale of the country and with great requirements in engineers it is possible to organize many-profiled technical institutes with 5-year educational period included metallurgical departments.

These are general approaches to the organisation of training of workers, technicians and engineers for developing iron and steel industry the content of which could be the subject of independent study.

4. Determination of complex energy expenditures for receiving second index of technological complexity of investigated types of metal products

The usage of complex energy expenditures allows to determine the requirements in fuels and electric energy per 1 tonne of intermediate and finished metal products and define the energy intensity of the products.

The complex energy expenditures intermediate and finished products for the investigated technological cycles were obtained during the calculations. This allows to define with more details the distinguishing features of producing the metal products under investigation.

The complex energy expenditures for intermediate and finished products of the technological cycles under investigation is received by using complex values of single kinds of fuel and energy expenditures per 1 tonne of product calculated as a result of direct inversion of matrix of direct expenditures mentioned in Chaper 2. The complex fuel expenditures were calculated as a whole including 14 kinds of fuel as well as expenditures of own and outside electric energy, thermal energy including thermal energy produced by thermal electric plants, industrial boiler-houses and waste-heat plants, expenditures of oxygen, furnace blast and compressed air.

For determining the technological complexity of iron and steel industry products it is necessary to use integral characteristic summerising complex expenditures of primary fuel and electric energy obtained outside for producing different types of metal products. For this purpose the blast-furnace gas expenditures are deduced from the complex expenditure of fuel in coal equivalent in order to avoid double account and to the obtained result is added the complex expenditures of outside electric energy and multiplied by the specific consumption of fuel required for its production (350 kg of fuel in coal equivalent /1,000 kWh). This characteristic is the complex energy expenditures. The consumption (energy intensity) of other energies - for which primary fuel and electric energy are used - oxygen, blast-furnace blast, compressed air, thermal energy, is taken into consideration by using the expenditures of primary fuel and electric energy for these products in analogy to the expenditures for the remaining types of intermediate and finished products.

Before determining the complex energy expenditures for various types of rolled products it is expedient to consider these characteristics for the previous technological stages - iron or sponge iron production and steel production by various methods which comprise the basis of the investigated technological routes for producing metal products.

The characteristics calculated per 1 tonne of iron and sponge iron are given in Table 13.

The data indicated in this table show that energy intensity of sponge iron is almost 25% below this characteristic for iron despite the fact that higher consumption of natural gas and electric energy in production of sponge iron.

Table 13

Determination of complex energy expenditures for the production of pig iron and sponge iron

Expenditures	Unit of measurement	Pig iron	Sponge iron
Fuel	t of coal equiv.	0.967	0.565
including coke	thou. t	0.44	-
natural gas	thou. m^3	0.2128	0.458
blast furnace gas	t of coal equiv.	0.135	-
Electric energy	thou. kW.h	0.465	0.562
including outside el. energy	- " -	0.394	0.535
Oxygen	thou. m^3	0.136	-
Blast furnace blast	thou. tr. m^3	1.87	-
Energy intensity	t of coal equiv.	0.97	0.75

In Table 14 the complex energy expenditures are determined for the production of BOF-steel and EAF-steel made on the base of scrap and sponge iron and also on the base of the charge containing 25% sponge iron and 75% scrap.

The data in the Table illustrate high complex fuel expenditures required for the production of BOF-steel because of high pig iron consumption for its production (850 kg/t). From the point of view of energy-intensity they are considerably lower in the case of EAF-steel melted on the base of scrap and they are the highest when EAF-steel is melted on the base of sponge iron.

If we do not take into account the fuel expenditures for the generation of electric energy in electric-energy complexes not included in the complex of the steel works then energy-intensity of the EAF-steel made on the base of sponge iron within the works will be reduced nearly by 35%.

Table 14

Determination of complex energy expenditures for the production of BOF-steel and EAF-steel

Expenditures	Unit of measurement	BOF-steel	EAF steel on the base of		
			scrap	sponge iron	25% sponge iron and 75% scrap
Fuel	t of coal equiv	0.87	0.26I	0.647	0.32
including coke	thou. t	0.379	0.038	-	0.029
natural gas	thou. m^3	0.205	0.07I	0.479	0.I83
Blast-furnace gas	t of coal equiv	0.I2	0.03	-	0.027
Electric energy	thou. kW .h	0.605	I.033	I.698	I.I04
including outside electric energy	"	0.532	0.887	I.555	I.09
Oxygen	thou, m^3	0.I8	0.03I	0.026	0.032
Blast-furnace blast	thou, tr, m^3	I.584	0.I39	-	0.095
Energy-intensity	t of coal eqiv.	0.936	0.54I	I.I9I	0.68

Complex energy expenditures required for the production of investigated steel types are determined on the assumption that all the steels are continuously cast. In case of ingot production and with the use of blooming and slabbing mills the complex energy expenditures will increase by 15-17%.

In Table 15 complex energy expenditures for the production of heavy sections are given.

These results show that the energy-intensity of heavy sections can vary from its minimum values (0.626 t of coal equiv.) in case of EAF steel on the base of scrap to maximum values (1.357 to coal equiv.) when making this steel on the base of sponge iron. At the same time from the point of view of fuel consumption for the production of heavy sections the use of EAF-steel made from sponge iron is by 30% lower than that of BOF-steel. These trends also can be observed in the case of the production of medium and light sections. (Tables 16 and 17).

Table 15

Determination of complex energy expenditures for the production of heavy sections and its energy-intensity

Expenditures	Unit of measure-ment	When using			
		BOF-steel	EAF-steel on the base of		
			scrap	sponge iron	25% sponge iron and 75% scrap
Fuel	t of coal equiv.	1.027	0.324	0.723	0.408
including coke	t	0.402	0.04*	-	0.031
natural gas	thou. m^3	0.236	0.094	0.527	0.213
Blast-furnace gas	t of coal equiv.	0.143	0.051	0.025	0.041
Electric energy	thou. kW.h	0.724	1.168	1.882	1.51
incl.outside el.energy	-"-	0.632	1.009	1.717	1.223
Oxygen	thou. m^3	0.196	0.038	0.033	0.039
Blast-furnace blast	thou.tr. m^3	1.678	0.147	-	0.1
Energy-intensity	t of coal equiv.	1.105	0.626	1.357	0.795

Table 16

Determination of complex expenditures for the production of medium sections

Expenditures	Unit of measurement	When using			
		BOF-steel	EAF-steel on the base of		
			scrap	sponge iron	25% sponge iron and 75% scrap
Fuel	t of coal equiv.	1.014	0.298	0.721	0.446
including coke	t	0.396	0.04	-	0.03
natural gas	thou, m^3	0.252	0.112	0.538	0.229
Blast-furnace gas	t of coal equiv.	0.139	0.048	0.023	0.046
Electric energy	thou,kW.h	0.72	0.013	1.71	1.23
including outside energy	— " —	0.627	0.998	1.695	1.209
Oxygen	thou. m^3	0.1939	0.0387	0.0331	0.0394
Blast-furnace blast	thou.tr. m^3	1.654	0.145	-	0.0992
Energy-intensity	t of coal equiv.	1.094	0.599	1.291	0.823

Lower energy intensity of medium sections in comparison with heavy sections is expl ined by a lower consumption of continuously cast billets for a given type of rolled produc s (1.044 versus 1.06 for heavy sections).

In Table 18 complex energy expenditures for the production of steel plates are given, and in Table 19 similar indices for steel sheets are shown.

A considerable power-intensive of steel plates is explained by an increased steel consumption for this kind of rolled products (1.116 t/t instead of 1.06 for light steel sections).

Table 17

Determination of complex energy expenditures for the production of light sections

Expenditures	Unit of measurement	When using			
		BOF - steel	EAF steel on the base of		
			scrap	sponge iron	25% sponge iron and 75% scrap
Fuel	t of coal equiv.	1.004	0.302	0.711	0.423
including coke	t	0.402	0.04	-	0.03
natural gas	thou. m^3	0.259	0.107	0.540	0.226
Blast-furnace gas	t of coal equiv.	0.137	0.045	0.019	0.041
Electric energy	thou. kW.h	0.72	1.175	1.88	1.31
incl. outside energy	— " —	0.63	1.006	1.71	1.22
Oxygen	thou. m^3	0.196	0.038	0.033	0.039
Energy-intensity	t of coal equiv.	1.088	0.609	1.291	0.809

Table 18

Determination of complex energy expenditures for the production of steel plates

Expenditures	Unit of measurement	When using			
		BOF-steel	EAF steel on the base of		
			scrap	sponge iron	25% spong iron and 75% scrap
Fuel	t of coal equiv.	1.1254	0.3215	0.7516	0.4477
including coke	t	0.422	0.042	-	0.032
natural gas	thou. m^3	0.265	0.112	0.571	0.210
Blast-furnace gas	t of coal equiv.	0.151	0.054	0.027	0.051
Electric energy	thou.kW .h	0.75	1.24	1.98	1.32
inc.outside energy	— " —	0.65	1.07	1.803	1.041
Blast-furnace blast	thou. m^3	1.765	0.155	-	0.106
Energy-intensity	t of coal equiv.	1.201	0.623	1.356	0.848

Table 19

Determination of complex energy expenditures for the production of steel sheets

Expenditures	Unit of measurement	When using BOF-steel	EAF steel on the base of scrap	sponge iron	25% sp. iron and 75% scrap
Fuel	t of coal equiv.	1.0667	0.3087	0.7323	0.4326
inc. coke	t	0.416	0.0418	-	0.0318
natural gas	thou. m^3	0.258	0.111	0.559	0.234
Blast-furnace gas	t of coal equiv.	0.176	0.052	0.025	0.049
Electric energy	thou. kW .h	0.746	1.21	1.94	1.29
incl.outside energy	— " —	0.650	1.04	1.77	1.26
Oxygen	thou. m^3	0.203	0.034	0.033	0.04
Blast-furnace blast	thou.tr.m^3	1.7392	0.153	-	0.104
Energy-intensity	t of coal equiv.	1.119	0.621	1.327	0.825

The energy intensity of steel sheets is lower than that of steel plates which is connected with a lower steel consumption (1.098 instead of 1.116 t/t).

The highest values of energy intensity characterize cold-rolled sheet and structural steel sections (Tables 20 and 21).

For cold-rolled sheets it can be explained with energy expenditures for an additional intermediate stage - sheet rolling.

Table 20

Determination of complex energy expenditures for the production of cold-rolled sheets

Expenditures	Units of measurements	When using			
		BOF-steel	EAF steel on the base of		
			scrap	sponge iron	25% sponge iron and 75% scrap
Fuel	t of coal equiv.	1.1453	0.3548	0.7163	0.4901
inc. coke	t	0.44	0.028	-	0.034
natural gas	thou. m^3	0.253	0.097	0.571	0.277
Blast-furnace gas	t of coal equiv.	0.143	0.042	0.018	0.039
Electric energy	thou. kW . h	0.80	1.29	2.207	1.38
incl. outside energy	— " —	0.70	1.109	1.884	1.34
Oxygen	thou. m^3	0.216	0.043	0.037	0.044
Blast-furnace blast	thou.tr.m^3	0.839	0.161	-	0.110
Energy-intensity	t of coal equiv.	1.247	0.701	1.407	0.920

Table 21

Determination of complex energy expenditures for the production of section structural alloyed steel

Expenditures	Units of measurements	When using			
		BOF - steel	EAF steel on the base of		
			scrap	sponge iron	25% sp. iron and 75% scrap
Fuel	t of coal equiv.	1.117	0.358	0.71	0.488
incl. coke	t	0.424	0.042	-	0.032
natural gas	thou. m^3	0.249	0.0985	0.556	0.224
blast-furnace gas	t of coal equiv.	0.141	0.04	0.017	0.04
electric energy	thou.kW .h	0.76	1.23	1.98	1.31
incl.outside energy	— " —	0.66	1.06	1.81	1.29
oxygen	thou. m^3	0.252	0.04	0.034	0.086
blast-furnace blast	thou.tr.m^3	1.774	0.156	-	0.106
energy-intensity	t of coal equiv.	1.207	0.683	1.327	0.900

Medium-alloyed steel grades were taken as section structural alloyed steel. The total values of energy intensity in all technological routes which have been investigated are given in Table 22.

Table 22

Total values of energy intensity of metal products, t of coal equivalent/t

Metal product type	Energy intensity of metal products when using			
	BOF-steel	EAF steel on the base of		
		scrap	sponge iron	25% sponge iron and 75% scrap
Heavy sections	1.105	0.626	1.357	0.735
Medium sections	1.094	0.599	1.291	0.823
Light sections	1.088	0.609	1.291	0.809
Steel plates	1.201	0.623	1.356	0.848
Steel sheets	1.119	0.621	1.327	0.825
Hot-rolled sheets	1.247	0.701	1.407	0.920
Structural alloyed steel sections	1.207	0.683	1.327	0.900

The comparison of these values shows that the most energy- intensive and complex from the point of view of energy expenditures are steel plates, cold-rolled sheets and section structural alloyed steel. The energy intensity of metal products used for the production of steel with the use of sponge iron can be reduced due to imported sponge iron (the energy intensity can be reduced by more than 40%). It should be stressed that high values of electric complex energy expenditures for the indicated types of metal products when using EAF steel on the base of sponge iron which are 700 kW.h higher than that of scrap. This can be explained by the necessity of additional electric energy consumption required for the beneficiation of ore with medium Fe content and for remelting sponge iron containing gangue.

5. Determination of complex capital expenditures for obtaining third process complexity index of investigated types of metal products

For calculating complex capital expenditures in producing the investigated types of metal products the following direct capital expenditures $/t (thou. m^3, G cal or thou. kW.h) has been assumed :

power-plant coal - 12, fuel oil - 80, blast-furnace gas - 3, coke-oven gas - 15, natural gas - 90, coke - 100, coke nuts - 80, coke breeze - 60, own electric energy - 30, outside energy - 25, scrap - 28, thermal energy - 4.0, oxygen - 80.0, blast-furnace blast - 2,0, compressed air - 1.5, iron ore - 45.0, sinter - 25.0, pellets - 20.0, pre-reduced pellets (sponge iron) - 120.0, pig iron - 32,0, BOF steel (including continuous casting) - 80, fireclay brick - 120, silica brick - 150, magnesia brick - 360, dolomite refractories - 200, burnt lime - 35, electric-furnace ferroalloys - 260, heavy sections - 82, medium sections - 100 (220 with thermal treatment), light sections - 85 (140 with heat treatment), plates - 110 (230 with heat treatment), sheets - 50, cold-rolled sheets - 200 and section structural steel - 190.

Mentioned unit capital expenditures have been taken on the basis of foreign practice and the practice of design institutes in the Soviet Union to some degree are approximate. These costs require correction when calculations are made for specific conditions of this or other developing country.

Capital expenditures for the production of pig iron and sponge iron are shown in Table 23. Resulting calculation data show that capital expenditures for producing sponge iron are lower than that for producing pig iron by 9 %.

Complex capital costs for the production of BOF-steel and EAF-steel on the base of scrap, sponge iron and 25% sponge iron and 75% scrap are calculated in Table 24.

Total data of this Table show that the lowest value of complex capital costs are those for producing EAF steel from scrap and the highest values are those for EAF-steel made from sponge iron. The last value is by 20% higher than that for BOF-steel. All complex capital costs values shown in Table 24 have been calculated on the basis that steel is cast in continuous casting plants.

In casting steel into ingots and using blooming and slabbing mills for billets reduction additional capital costs, amounting to 25% of shown in Table 24 values are required.

On the base of the estimated values of complex capital expenditures for the production of various steel types which can be made in new works in developing countries the following complex capital expenditures were obtained for different types of rolled products (Tables 23 - 31).

Table 23

Determination of complex capital expenditures ($/t) for production of pig iron and sponge iron (prereduced pellets)

Expenditures	Unit of measurement	Direct capital expenditures, $/Unit of measurement	Complex expenditures of raw materials, energy and semiproducts		Complex capital expenditures	
			Per 1 t of pig iron	Per 1 t of sponge iron	Per 1 t of pig iron	Per 1 t of sponge iron
Fuel	t of coal equival.		0.9674	0.5654	72.0	42.2
Incl. natural gas	Thou.m^3	90	0.2128	0.458	19.2	41.2
coke	t	100	0.44	-	44.0	-
Own electric energy	Th.kWh	30	0.0711	0.0278	2.1	0.8
Outside electric energy	"	25	0.394	0.535	9.9	13.4
Thermal energy	Gcal	4.0	0.277	0.194	1.1	0.8
Oxygen	Thou.m^3	80.0	0.136	-	10.9	-
Blast-furnace blast	Th.tr.m^3	2.0	1.87	-	3.7	-
Compressed air	Th.st.m^3	1.5	0.022	-	0.03	-
Scrap	t	28.0	0.008	-	0.2	-
Iron ore	t	45.0	1.758	1.46	79.1	65.7
Sinter	t	25.0	1.05	-	26.3	-
Pellets	t	20.0	0.659	1.3	13.2	26.0
Sponge iron	t	80.0	-	1.0	-	80.0
Pig iron	t	32.0	1.0	-	32.0	-
Total					250.5	228.9

Table 24

Determination of complex capital expenditures ($/t) for production of BOF steel and EAF steel on the base of scrap, sponge iron, 25% of sponge iron and 75% of scrap

Expenditures	Unit of measurement	Direct capital expenditures, $/Unit of measurement	Complex expenditures of raw materials, energy and semiproducts				Complex capital expenditures			
			Per 1 t of BOF steel	Per 1 t of EAF steel on the base of			Per 1 t of BOF steel	Per 1 t of EAF steel on the base of		
				Scrap	Sponge iron	25% of sponge iron and 75% of scrap		Scrap	Sponge iron	25% of sponge iron and 75% of scrap
1	2	3	4	5	6	7	8	9	10	11
Fuel	t of coal equiv.		0.8697	0.26II	0.6467	0.3I99	64,5	I3.277	44.33	22.0
Incl. natural gas	Thou.m^3	90	0.205	0.07I	0.479	0.I83	I8.45	6,39	43.II	I6.5
coke	t	I00	0.379	0.038I	–	0.029	37.9	3.8I	–	2.9
Own electric energy	Th.kWh	30	0.073	0.I445	0.I428	0.0I39	2.I9	4.335	4.284	0.42
Outside electric energy	"	25	0.532	0.887	I.555	I.0895	I3.3	22.I75	38.875	27.23
Scrap	t	28	0.3	0.9735	–	0.795	8.4	27.258	–	22.3
Thermal energy	Gcal	4,0	0.25	0.033	0.I96	0.075	I.0	0.I32	0.784	0.3
Oxygen	Thou.m^3	60	0.I8	0.03I3	0.026	0.032	I4.4	2.504	2.08	2.56
Blast-furnace blast	Th.tr.m^3	2,0	I.584	0.I39	–	0.095	3.I7	0.278	–	0.I9
Compressed air	Th.st.m^3	I.5	0.0437	0.049	0.048	0.054	0.07	0.0735	0.072	0.08
Iron ore	t	45	I.493	0.I04	I.46	0.46	67.I8	4.68	65.7	20.7
Sinter	t	25	0.892	0.0753	–	0.054	22.3	I.8825	–	I.35

1	2	3	4
Pellets	t	20	0.561.
Sponge iron	t	80	-
Iron	t	32	0.8495
Fireclay brick	t	120	0.0102
Silica brick	t	150	-
Magnesia refractories	t	360	0.0023
Fired dolomite refractories	t	200	0.006
Refractories, total	t		0.0185
Lime	t	35	0.1
Electric ferroalloys	t	260	0.015
BOF steel	t	60	1
EAF steel		80	-
Total			

5	6	7	8	9	10	II
0.027I	.I.3	0.359	II.22	0.542	26	7.I8
–	I.0	0.25	–	–	80	30.0
0.0588	–	0.05II	27.I8	I.88I6	–	I.64
0.030I	0.030I	0.028	I.22	3.6I2	3.6I2	3.36
0.0006	0.0006	–	–	0.09	0.09	–
0.0I05	0.0I05	0.02	0.83	3.78	3.78	7.2
0.02I	0.02I	0.0I	I.2	4.20	4.20	2.0
0.0622	0.0622	0.058	3.25	II.68	II.68	I2.56
0.II	0.II	0.II5	3.5	3.85	3.85	4.025
0.036	0.036	0.036	3.9	9.66	9.36	9.36
–	–	–	60	–	–	–
I	I	I	–	80	80	80
			305.56	I83.90	367.02	24I.90

Table 25

Determination of complex capital expenditures ($/t) for production of heavy-section rolled products

Expenditures	Unit of measurement	Direct capital expenditures $/Unit of measurement	Complex expenditures of raw materials, energy and semiproducts, when using				Complex capital expenditures, when using			
			BOF steel	EAF steel on the base of			BOF steel	EAF steel on the base of		
				Scrap	Sponge iron	25% of sponge iron and 75% of scrap		Scrap	Sponge iron	25% of sponge iron and 75% of scrap
1	2	3	4	5	6	7	8	9	10	11
Fuel	t of coal equiv.		I.027	0.3244	0.7227	0.408I	70.736	I9.I44	52.I29	26.266
Incl. natural gas	Thou.m^3	90	0.2363	0.0943	0.527	0.2I30	2I.267	8.487	47.43	I9.I7
coke	t	I00	0.40I7	0.040	–	0.03I	40.I7	4.0	–	3.I
Own electric energy	Th.kWh	30	0.09I4	0.I67I	0.I654	0.0287	2.742	5.0I3	4.962	0.86I
Outside electric energy	"	25	0.6324	I.009	I.7I68	I.2234	I5.8I0	25.225	42.92	30.585
Scrap	t	28	0.3I8	I.032	–	0.843	8.904	28.I96	–	23.60
Thermal energy	Gcal	4.0	0.305	0.075	0.2478	0.II95	I.220	0.300	0.99I2	0.478
Oxygen	Thou.m^3	80.0	0.I958	0.0382	0.0326	0.0389	I5.664	3.056	2.608	3.II2
Blast-furnace blast	Th.tr.m^3	2.0	I.679	0.I473	–	0.I007	3.358	0.2946	–	0.20I
Compressed air	Th.st.m^3	I.5	0.0623	0.0679	0.0669	0.0732	0.0935	0.I0I9	0.I003	0.I09
Iron ore	t	45.0	I.5826	0.II28	I.5476	0.4876	7I.2I7	5.076	69.64	2I.94
Sinter	t	25.0	0.9455	0.080	–	0.0572	23.638	2.0	–	I.430
Pellets	t	20.0	0.5946	0.0287	I.38	0.38I	II.892	0.574	27.6	7.620
Sponge iron	t	80.0	–	–	I.06	0.265	–	–	84.8	2I.2

1	2	3	4
Iron	t	32	0.9005
Fireclay brick	t	I20	0.0I08
Refractories, total	t		0.0I96
Silica brick	t	I50	-
Magnesia refractories	t	330	0.0024
Fired dolomite refractories	t	200	0.0064
Lime	t	35	0.I06
Electric ferroalloys	t	260	0.0I59
EAF steel	t	80	-
BOF steel	t	60	I.06
Heavy-section rolled products	t	82	I

Total

5	6	7	8	9	10	11
0.0623	-	0.0542	28.8I6	I.9936	-	I.7344
0.03I9	0.03I9	0.0297	I.2960	3.828	3.828	3.564
0.0659	0.0659	0.06I3	3.44	I3.I84	8.389	I3.24
0.0006	0.0006	-	-	0.09	0.09	-
0.0III	0.0III	0.02I	0.864	3.996	0.0III	7.56
0.0223	0.0223	0.0I06	I.28	4.460	4.460	2.I2
0.II7	0.II66	0.I2I9	3.7I0	4.095	4.08I	4.2665
0.038	0.0382	0.038	4.I34	9.880	9.932	9.880
I.06	I.06	I.06	-	84.8	84.8	84.8
-	-	-	63.6	-	-	-
I	I	I	82	82	82	82
			4I0.98	284.82	474.95	333.33

Table 26

Determination of complex capital expenditures ($/t) for production of medium-section rolled products

Expenditures	Unit of measurement	Direct capital expenditures $/Unit of measurement	Complex expenditures of raw materials, energy and semiproducts, when using				Complex capital expenditures, when using			
			BOF steel	EAF steel on the base of			BOF steel	EAF steel on the base of		
				Scrap	Sponge iron	25% of sponge iron and 75% of scrap		Scrap	Sponge iron	25% of sponge iron and 75% of scrap
1	2	3	4	5	6	7	8	9	10	11
Fuel	t of coal equiv.		I.0I4I	0.298I	0.721	0.4462	72.997	I8.I648	52.0369	22.532
Incl. natural gas	Thou.m^3	90	0.252	0.II2I	0.538I	0.229I	22.68	I0.089	48.429	20.6I9
coke	t	I00	0.3957	0.0398	–	0.0303	39.57	3.98	–	3.03
Own electric energy	Th.kWh	30	0.0922	0.I355	0.0I67	0.0305	2.766	4.065	0.50I	0.9I50
Outside electric energy	"	25	0.6269	0.9975	I.6949	I.2089	I5.6725	24.9375	42.3725	30.2225
Scrap	t	28	0.3I32	I.0I6	–	0.8300	8.7696	28.448	–	23.24
Thermal energy	Gcal	4.0	0.2[illegible]2	0.0654	0.2356	0.I093	I.I68	0.26I6	0.9424	0.4372
Oxygen	Thou.m^3	80.0	0.I939	0.0387	0.033I	0.0394	I5.5I2	3.096	2.648	3.I52
Blast-furnace blast	Th.tr.m^3	2.0	I.6537	0.I45	–	0.0992	3.3074	0.290	–	0.I984
Compressed air	Th.st.m^3	I.5	0.0886	0.0942	0.093I	0.0994	0.I329	0.I4I3	0.I396	0.I49I
Iron ore	t	45.0	I.5587	0.IIII	I.5242	0.4802	70.I4I5	4.9995	68.589	2I.609
Sinter	t	25.0	0.93I2	0.0786	–	0.0564	23.28	I.965	–	I.4I0
Pellets	t	20	0.5857	0.0283	I.357	0.375	II.7I4	0.566	27.I4	7.5

Sponge iron	t	30	–	–
Iron	t	32	0.8869	0.06I4
Refractories	t		0.0I93	0.0648
Incl. fireclay brick	t	I20	0.0I06	0.03I4
silica brick	t	I50	–	0.0006
magnesia refractories	t	300	0.0024	0.0I09
fired dolomite refractories	t	200	0.0063	0.02I9
Lime	t	35	0.I044	0.II48
Electric ferroalloys	t	260	0.0I5	0.0376
BOF steel	t	60	I.044	–
EAF steel	t	80	–	I.044
Medium-section rolled products	t	I00	I	I
Total				

I.044	0.26I	-	-	83.52	20.68
-	0.0533	28.38	I.9648	-	I.7056
0.0649	0.065	3.396	I2.I44	I2.086	I3.I08
0.03I4	0.0292	I.272	3.7680	3.768	3.504
0.0006	-	-	0.072	0.0006	-
0.0II0	0.0209	0.8640	3.924	3.960	7.524
0.02I9	0.0I04	I.260	4.380	4.380	2.080
0.II48	0.II96	3.6540	4.0I80	4.0I80	4.I860
0.0376	0.0376	3.900	3.776	9.7760	9.7760
-	-	62.64	-	-	-
I.044	I.044	-	83.52	83.52	83.52
I	I	I00	I00	I00	I00
		427.43	298.36	487.3I	373.54

Table 27

Determination of complex capital expenditures ($/t) for production of light-section rolled products

Expenditures	Unit of measurement	Direct capital expenditures $/Unit of measurement	Complex expenditures of raw materials, energy and semiproducts, when using				Complex capital expenditures, when using			
			BOF steel	EAF steel on the base of			BOF steel	EAF steel on the base of		
				Scrap	Sponge iron	25% of sponge iron and 75% of scrap		Scrap	Sponge iron	25% of sponge iron and 75% of scrap
I	2	3	4	5	6	7	8	9	I0	II
Fuel	t of coal equiv.		I.004I	0.30I7	0.7III7	0.423	70.2I3	I8.597I	5I.48	27.879
Incl. natural gas	Thou m^3	90	0.259	0.I073	0.540	0.226	23.6	9.657	48.60	20.34
coke	t	I00	0.40I7	0.40	–	0.03I	40.I7	4.0	–	3.I
Own electric energy	Th.kWh	30	0.0927	0.I685	0.I667	0.030	2.78I	5.055	5.60I	0.9
Outside electric energy	"	25	0.6299	I.0062	I.7I43	I.2209	I5.475	25.I550	42.8575	30.5225
Scrap	t	28	0.3I8	I.032	–	0.843	8.904	28.896	–	23.60
Thermal energy	Gcal	4.0	0.289	0.0590	0.23I8	0.I035	I.I56	0.236	0.0927	0.4I4
Oxygen	Thou.m^3	80	0.I958	0.0382	0.0326	0.0389	I5.664	3.056	2.608	3.II2
Blast-furnace blast	Th.tr.m^3	2.0	I.679	0.I473	–	0.I007	3.358	0.2946	–	0.20I4
Compressed air	Th.st.m^3	I.5	0.0893	0.0949	0.0939	0.I002	0.I340	0.I425	0.I409	0.I503
Iron ore	t	45	I.5826	0.II28	I.5476	0.4876	7I.2I7	5.076	69.64	2I.94
Sinter	t	25	0.9455	0.080	–	0.0572	23.638	2.0	–	I.430
Pellets	t	20	0.5946	0.0287	I.38	0.38I	II.892	0.574	27.60	7.620

I	2	3	4	5
Sponge iron	t	80	–	–
Iron	t	32	0.9005	0.0623
Fireclay brick	t	I20	0.0I08	0.03I9
Silica brick	t	I50	–	0.006
Magnesia refractories	t	360	0.0024	0.0III
Fired dolomite refractories	t	200	0.0064	0.0223
Refractories, total	t		0.0I96	0.07I3
Lime	t	35	0.I06	0.II7
Electric ferroalloys	t	260	0.0I59	0.038
BOF steel	t	60	I.06	–
EAF steel	t	80	–	I.06
Light-section rolled products	t	85	I	I
Total				

6	7	8	9	10	11
I.06	0.265	-	-	84.8	2I.2
-	0.0542	28.8I6	I.9936	-	3.564
0.03I9	0.0297	I.2960	3.828	3.828	3,564
0.0006	-	-	0.9	0.009	-
0.0III	0.02I	0.864	3.996	0.0III	7.56
0.0223	0.0I06	I.28	4.460	4.460	2.I2
0.0659	0.06I3	3.44	I3.I84	8.389	I3.24
0.II66	0.I2I9	3.7I0	4.095	4.08I	4.2665
0.0382	0.038	4.I34	9.880	9.932	9.880
-	-	63.6	-	-	-
I.06	I.06	-	84.8	84.8	84.8
I	I	85	85	85	85
		4I6,6	30I.2	484.3	353

Table 28

Determination of complex capital expenditures ($/t) for production of hot-rolled plates

Expenditures	Unit of measurement	Direct capital expenditures, $/unit of measurement	Complex expenditures of raw materials, energy and semiproducts, when using: BOF steel	EAF steel on the base of: Scrap	Sponge iron	25% of sponge iron and 75% of scrap	Complex capital expenditures, when using: BOF steel	EAF steel on the base of: Scrap	Sponge iron	25% of sponge iron and 75% of scrap
1	2	3	4	5	6	7	8	9	10	11
Fuel	t of coal equiv.		I.I254	0.32I5	0.75I6	0.4477	77.4329	I9.I026	53.9[illegible]	29.0573
Incl. natural gas	Thou.m^3	90	0.2654	0.II6I	0.5706	0.2I	23.886	I0.449	5I.354	I8.9
coke	t	I00	0.4222	0.0424	–	0.0323	42.22	4.24	–	3.23
Own electric energy	Th.kWh	30	0.0980	0.I777	0.I758	0.0322	2.94	5.33I0	5.274	0.966
Outside electric energy	"	25	0.650I	I.069I	I.8032	I.2847	I6.3	25.73	45.08	32.II75
Scrap	t	28	0.3342	I.0845	–	0.8856	9.3576	30.366	–	24.7966
Thermal energy	Gcal	4.0	0.3305	0.0888	0.2703	0.I356	I.3220	0.3552	I.08I2	0.5224
Oxygen	Thou.m^3	80	0.2055	0.0399	0.0340	0.0406	I6.440	3.I920	2.720	3.2480
Blast-furnace blast	Th.tr.m^3	2.0	I.7646	0.I548	–	0.I058	3.5292	0.3096	–	0.2II6
Compressed air	Th.st.m^3	I.5	0.0487	0.0976	0.0965	0.I032	0.073I	0.I464	0.I448	0.I548
Iron ore	t	45	I.6632	0.II85	I.6264	0.5I24	74.844	5.3325	73.I88	23.058
Sinter	t	25	0.9937	0.0839	–	0.060I	24.8425	2.0975	–	I.5025
Pellets	t	20	0.6250	0.0302	I.448	0.3999	I2.50	0.6040	28.96	7.998
Sponge iron	t	80	–	–	I.II4	0.2785	–	–	89.I2	22.28

I	2	3	4	5
Iron	t	32	0.9463	0.0655
Fireclay brick	t	I20	0.0II4	0.0335
Silica brick	t	I50	–	0.0007
Magnesia refractories	t	360	0.0026	0.0II7
Fired dolomite refr.	t	200	0.0067	0.0234
Refractories, total	t		0.0207	0.0693
Lime	t	35	0.III4	0.I225
Electric ferroalloys	t	260	0.0I67	0.040I
BOF steel	t	60	I.II4	–
EAF steel	t	80	–	I.II4
Hot-rolled plates	t	II0	I	I
Total				

6	7	8	9	10	11
–	0.0569	30.28I6	2.096	–	I.8208
0.0335	0.03I2	I.3680	4.020	4.020	3.744
0.0007	–	–	0.0840	0.0840	–
0.0II7	0.0223	0.9360	4.2I2	4.2I2	8.028
0.0234	0.0III	I.340	4.680	4,680	2.220
0.0693	0.0646	3.644	I2.996	I2.996	I3.992
0.I225	0.I28I	3.899	4.2875	4.2875	4.4835
0.040I	0.040I	4.3420	I0.426	I0.426	I0.426
–	–	66.84	–	–	–
I.II4	I.II4	–	89.I2	89.I2	89.I2
I	I	II0	II0	II0	II0
		462,2	334,5	526,38	375,78

Table 29

Determination of complex capital expenditures ($/t) for production of hot-rolled sheets

Expenditures	Unit of measurement	Direct capital expenditures, $/Unit of measurement	Complex expenditures of raw materials energy and semiproducts, when using				Complex capital expenditures, when using			
			BOF steel	EAF steel on the base of			BOF steel	EAF steel on the base of		
				Scrap	Sponge iron	25% of sponge iron and 75% of scrap		Scrap	Sponge iron	25% of sponge iron and 75% of scrap
1	2	3	4	5	6	7	8	9	10	11
Fuel	t of coal equiv.		I.0667	0.3087	0.7323	0.4326	76.62I7	I8.66I8	52.7685	37.3694
Incl. natural gas	Thou.m^3	90	0.258I	0.II09	0.5589	0.2339	23.229	9.98I0	50.30I	2I.05I
coke	t	I00	0.4I6	0.04I8	–	0.03I8	4I.6I	4.I8	–	3.I8
Own electric energy	Th.kWh	30	0.0955	0.I74I	0.I722	0.0307	2.8650	5.2230	5.I660	0.92I0
Outside electric energy	"	25	0.6496	I.0394	I.7729	I.26I8	I6.240	25.9850	44.3225	3I.55
Scrap	t	28	0.3294	I.0689	–	0.8729	9.2232	29.929	–	24.44I2
Thermal energy	Gcal	4.0	0.3I65	0.0782	0.2572	0.I243	I.2660	0.3I28	I.0288	0.4972
Oxygen	Thou.m^3	80.0	0.2026	0.0344	0.0335	0.040I	I6.208	2.7520	2.680	3.208
Blast-furnace blast	Th.tr.m^3	2.0	I.7392	0.I526	–	0.I043	3.4784	0.3052	–	0.2086
Compressed air	Th.st.m^3	I.5	0.09I0	0.0538	0.0957	0.I023	0.I365	0.0807	0.I435	0.I535
Iron ore	t	45	I.6393	0.II68	I.603I	0.505I	73.7685	5.256	72.I395	22.7295
Sinter	t	25	0.9794	0.0827	–	0.0593	24.485	2.0675	–	I.4825
Pellets	t	20	0.6I60	0.0298	I.427	0.394	I2.320	0.596	28.54	7.88
Sponge iron	t	80	–	–	I.098	0.2745	–	–	2.I96	0.549

I	2	3	4	5
Iron	t	32	0.9328	0.0646
Refractories	t		0.0203	0.068I
Incl. fireclay brick	t	I20	0.0II2	0.0330
silica brick	t	I50	–	0.0006
magnesia refractories	t	360	0.0025	0.0II5
fired dolomite refractories	t	200	0.0066	0.0230
Lime	t	35	0.I098	0.I207
Electric ferroalloys	t	260	0.0I65	0.0395
BOF steel	t	60	I.098	–
EAF steel	t	80	–	I.098
Hot-rolled sheets	t	50	I	I
Total				

6	7	8	9	10	11
–	0.056I	29.850	2.067	–	I.7952
0.068I	0.0637	3.564	I2.79	I2.79	I3.804
0.0330	0.0307	I.3440	3.960	3.960	3.6840
0.0006	–	–	0.09	0.09	–
0.0II5	0.0220	0.9	4.I4	4.I4	7.92
0.0230	0.0II0	I.32	4.60	4.60	2.2
0.I207	0.I263	3.843	4.2245	4.2245	4.4205
0.0395	0.0395	4.290	I0.27	I0.27	I0.27
–	–	65.88	–	–	–
I.098	I.098	–	87.84	87.84	87.84
I	I	50	50	50	50
		394.039	2[illegible].287	459.75	320.53I

Table 30

Determination of complex capital expenditures ($/t) for production of cold-rolled sheets

Expenditures	Unit of measurement	Direct capital expenditures, $/Unit of measurement	Complex expenditures of raw materials, energy and semiproducts, when using				Complex capital expenditures, when using			
			BOF steel	EAF steel on the base of: Scrap	Sponge iron	25% of sponge iron and 75% of scrap	BOF steel	EAF steel on the base of: Scrap	Sponge iron	25% of sponge iron and 75% of scrap
I	2	3	4	5	6	7	8	9	10	II
Fuel	t of coal equival.		I.I453	0.3548	0.7203	0.490I	76.6I92	38.6557	53.093	33.3707
Incl. natural gas	Thou.m^3	90	0.2530	0.0974	0.57II	0.2275	22.770	8.766	5I.399	20.475
coke	t	I00	0.4400	0.0277	–	0.0337	44.0	2.77	–	3.37
Own electric energy	Th.kWh	30	0.I03I	0.I860	0.I84I	0.0344	3.093	5.58	5.523	I.032
Outside electric energy	"	25	0.6969	I.I087	I.8843	I.3438	I7.4225	27.7I75	47.I075	33.5950
Scrap	t	28	0.3483	I.I302	–	0.9230	9.7524	3I.6456	–	25.844
Thermal energy	Gcal	4.0	0.3963	0.I443	0.I308	0.I93I	I.5852	0.5772	0.5232	0.7724
Oxygen	Thou.m^3	80.0	0.2I60	0.0433	0.0372	0.0442	I7.28	3.4640	2.976	3.536
Blast-furnace blast	Th.tr.m^3	2.0	I.8390	0.I6I4	–	0.II03	3.678	0.3228	–	0.2206
Compressed air	Th.st.m^3	I.5	0.1007	0.I069	0.I057	0.II27	0.I5II	0.I604	0.I586	0.I69I
Iron ore	t	45	I.7334	0.I235	I.695I	0.534I	78.0030	5.5575	76.2795	24.0345
Sinter	t	25	I.0356	0.0874	–	0.0627	25.89	2.I85	–	I.5675
Pellets	t	20	0.65I3	0.03I5	I.5093	0.4I65	I3.026	0.630	30.I86	8.33

1	2	3	4	
Sponge iron	t	80	–	
Iron	t	32	0.9663	
Refractories	t		0.0215	
Incl. fireclay brick	t	120	0.0118	
silica brick	t	150	–	
magnesia refractor.	t	360	0.0027	
fired dolomite refr.	t	200	0.0070	
Lime	t	35	0.1161	
Electric ferroalloys	t	260	0.0174	
BOF steel	t	60	1.161	
EAF steel	t	80	–	
Hot-rolled sheets	t	50	1.05	
Cold-rolled sheets	t	190	1	
Total				

5	6	7	8	9	I0	II
0.0683	I.I6I	0.2903	-	5.464	92.88	23.224
-	-	0.0593	3I.56I6	-	-	I.8976
0.0722	0.0722	0.0673	3.788	I3.544	I3.544	I4.572
0.0349	0.0349	0.0325	I.4I60	4.I880	4.I88	3.90
0.0007	0.0007	-	-	0.084	0.084	-
0.0I22	0.0I22	0.0232	0.972	4.392	4.392	8.352
0.0244	0.0244	0.0II6	I.400	4.88	4.88	2.32
0.I277	0.I277	0.I335	4.0635	4.4695	4.4695	4.6725
0.04I8	0.04I8	0.04I8	4,524	I0.868	I0.868	I0.868
-	-	-	69.660	-	-	-
I.I6I	I.I6I	I.I6I	-	92.88	92.88	92.88
I.05	I.05	I.05	52.50	52.50	52.50	52.50
I	I	I	I90	I90	I90	I90
			602.598	486.22I	672.988	523.086

Table 31

Determination of complex capital expenditures ($/t) for production of section structural alloyed steel

Expenditures	Unit of measurement	Direct capital expenditures, $/Unit of measurement	Complex expenditures of raw materials, energy and semiproducts, when using				Complex capital expenditures, when using			
			BOF steel	EAF steel on the base of: Scrap	Sponge iron	25% of sponge iron and 75% of scrap	BOF steel	EAF steel on the base of: Scrap	Sponge iron	25% of sponge iron and 75% of scrap
1	2	3	4	5	6	7	8	9	10	11
Fuel	t of coal equival.		I.II73	0.358	0.7099	0.488	72.759	I7.I87	5I.976	26.6426
Incl. natural gas	Thou.m^3	90	0.2486	0.0985	0.5555	0.2240	22.374	8.865	49.995	20.I60
coke	t	I00	0.4244	0.0427	-	0.0324	42.44	4.27	-	3.24
Own electric energy	Th.kWh	30	0.09576	0.I758	0.I739	0.0296	2.8728	5.274	5.2I7	0.888
Outside electric energy	"	25	0.6638	I.06I4	I.8096	I.2882	I6.595	26.535	45.24	32.20
Scrap	t	28	0.336	I.0903	-	0.890	9.408	30.528	-	24.92
Thermal energy	Gcal	4.0	0.07I3	0.0940	0.2765	0.084	0.2852	0.376	I.I06	0.336
Oxygen	Thou.m^3	80.0	0.25I6	0.040	0.034I	0.0858	20.I28	3.20	2.728	6.864
Blast-furnace blast	Th.tr.m^3	2.0	I.7740	0.I557	-	0.I064	3.548	0.3II4	-	0.2I28
Compressed air	Th.st.m^3	I.5	0.0649	0.0709	0.0698	0.0765	0.0974	0.I064	0.I047	0.II48
Iron ore	t	45	I.672	0.II9I	I.6352	0.5I5	75.420	5.3595	73.584	23.I75
Sinter	t	25	0.999	0.0843	-	0.0604	24.975	2.I075	-	I.5I0

I	2	3	4	5
Pellets	t	20	0.6283	0.0304
Sponge iron	t	80	–	–
Iron	t	32	0.95I4	0.659
Refractories	t		0.0207	0.0696
Incl. fireclay brick	t	I20	0.0II4	0.0337
silica brick	t	I50	–	0.0007
magnesia refractories	t	360	0.0026	0.0II8
fired dolomite refractor.	t	200	0.0067	0.0234
Lime	t	35	0.II2	0.I232
Electric ferròalloys	t	260	0.0I68	0.0403
BOF steel	t	60	I.I2	–
EAF steel	t	80	–	I.I2
Section structural alloyed steel	t	I90	I	I
Total				

6	7	8	9	10	11
I.456	0.402	I2.566	0.608	29.I2	8.04
I.I2	0.28	–	–	89.6	22.4
–	0.0572	30.4448	2.I088	–	I.8304
0.0696	0.065	3.644	I3.077	I3.077	I4.072
0.0337	0.03I4	I.3680	4.044	4.044	3.768
0.0007	–	–	0.I05	0.I05	–
0.0II8	0.0224	0.936	4.248	4.248	8.064
0.0234	0.0II2	I.340	4.68	4.68	2.24
0.I232	0.I288	3.92	4.3I2	4.3I2	4.508
0.0403	0.0403	4.368	I0.478	I0.478	I0.478
–	–	67.2	–	–	–
I.I2	I.I2	–	89.6	89.6	89.6
I	I	I90	I90	I90	I90
		533.05	40I.I68	606.048	457.79

On the basis of the total data of Tables 25-31 a following overall Table of complex capital expenditures for the production of investigated metal products can be made.

Table 32

Total complex expenditures for the production of investigated metal products ($/t)

Type of metal products	Complex capital expenditures when using			
	BCF steel	EAF-steel on the base of		
		scrap	sponge iron	25% sponge iron and 75% scrap
Heavy steel sections	411.0	284.8	475.0	333.3
Medium steel sections	427.4	298.4	487.3	373.5
Light steel sections	416.6	301.2	484.7	353.0
Steel plates	582.2	454.5	646.4	495.8
Steel sheets	394	258.3	459.8	320.5
Cold-rolled sheets	602.6	486.2	673.0	523.1
Structural alloyed section steel	533	401.2	606.0	457.8

The values of complex expenditures indicated in the Table allow to conclude that the plates, cold-rolled sheets and section structural alloyed steel are of highest capital-intensity. This can be explained by a high steel consumption for the production of these types of metal products (1.114, 1.161 and 1.12 correspondingly) which leads to additional considerable complex capital expenditures. A considerable ferro-alloy consumption has a great influence on complex capital expenditures for the production of section structural alloyed steel. Depending on the metallurgical route the complex capital expenditures are 40 $/t higher in case of EAF-steel on the base of sponge iron.

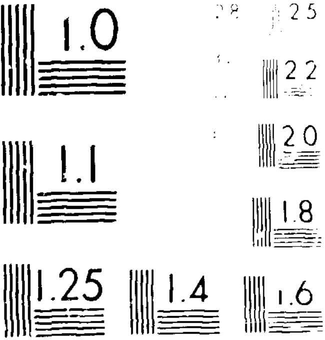
There is a possibility to reduce the total capital intensity by half if to import sponge iron, but in this case it is necessary to search for currency reserves.

6. Influence of metal quality on technological complexity of products in iron and steel and consuming industries.

The metal products quality improvement as a rule has an influence on increasing three discussed values of technological complexity indices of these products, but at the same time allows to reduce considerable indices of technological complexity in the production of capital goods and in other industries consuming metal products.

The problem of metal quality improvement is of the greatest importance for any country, including developing countries because the use factor of metal products in different industries consuming the metal varies within great limits and equals on average to 0.8. From the rest quantity of metals nearly 15% is intended for the insurance of safety factor which is necessary because of heterogeneity of steel. Taking account of steel consumption factor for the production of rolled products only some more than a half of the total volume of produced steel is used in the form of finished products.

83.09.01


1.0
2.8
2.5
2.2
2.0
1.1
1.8
1.25
1.4
1.6

When evaluating the efficiency of metal quality improvement measures in any definite case it is necessary to determine the relationship between the metal performance changes and its service features (for example, between increase of pure and uniformity of the metal and increase of its strength and safety, between increase of metal strength characteristics and reduction of its products mass and increase their service life, between change of geometrical form of rolled products and reduction of metal working volume and so on).

The metal products of improved quality are equivalent from the point of view of their consuming characteristics to a greater volume of products featuring ordinary quality. Besides, the economy value depends on the process or utilization stage where the effect of improved quality is realized. This is connected with the fact that the value of the embodied labour in the metal mass unit is increased in the course of its development from the initial stage of production to the final stage of consumption.

If the effect from the improved quality is realized in the process of metal-working and utilization of the metal product then the economy of the direct labour, energy and capital investments in iron and steel industry as a whole is insured due to relative decrease of metal production, and in metal-working and machinery - due to reduced volume of worked metal and due to reduced number of produced machines and equipment.

In this connection along with redistribution of these resources within the industry one should take into consideration possibilities of searching additional resources due to the economy which would be received by industries consuming metal and metal products of improved quality.

Metal products quality is characterized by a number of properties and therefore has no unique measuring instrument. In practice the most important metal property which is considered to be most significant for a given purpose is distinguished as the main one. The comparative assessment of metal quality can be performed therefore on the basis of this main property (for example, according to the strength) provided that all other properties are within the permissible (for the given purpose) limits.

For steels of ordinary grades, carbon and low-carbon, as well as structural and alloyed steels used for the production of the investigated metal products, the main quality characteristics are yield point and ultimate strength at static test (or fatigue limit) and auxiliary ductility (elongation or impact strength).

In the Soviet Union today when assessing the quality of ferrous metals as a rule orientation is made on the characteristics stipulated by the standards. The standards for ferrous metals strictly normalize the chemical composition of the metal, its mechanical properties (yield point, ultimate strength, elongation or compression, sometimes impact strength, bending test and others), as for quality metal norms for hardness, macrostructure, thermal treatment etc. are also established. At the same time there are more than 100 various increased requirements for the metal quality which can be united in 10 groups (Table33). All these requirements characterize the technological complexity of metal products and products of industries-consumers as well as in iron and steel industry and lead to the growth of complexity indices values.

It is very important to determine the stage of production where an improved quality effect is realized. This is connected with the fact that complex labour, energy and capital expenditures are being increased from the initial stage of its production to the final stage. For example, if improved steel quality results in decreased volume of wastes in metallurgical processes, then the

Table 32

Classification of additional technical requirements for the quality of ferrous metals and the nature of effect manifistation in their use

Additional requirements (in comparision with standard requirements)	Additional expenditures in the production of a higher quality metal				The effect of metal quality improvement
	Metallic charge cost increase	Production process cost increase	Technology change	Losses	
1	2	3	4	5	6
	Additional requirements for chemical composition				
Lowering in the limits for sulphur and phosphorus impurities content	Selection of pure metallic charge (with utmost limitation of the use of pigs in the charge)	Increase of heat time (Formation of Special slag or slag removal)	Smelting in electric furnace instead of open-hearth furnace	—	Ensuring high reliability of products due to good metal homogeneity. Improvement of weldability and cold resistance
Lowering the content of residual chrome, nickel, copper and others	Selection of metallic charge that contains less ammount of these elements	—	—	—	Improving steel workability during patenting and cold stamping
Lowering or narrowing the carbon content limits	—	Precise carrying out and control of the production process	Complication of the production process, more frequent sampling	Possible due to separation of the metal that does not meet the strict specifications	Lowering the limits of mechanical properties variations after heat treatment

1	2	3	4	5	6
Increasing the content of alloying elements	Additional consumption of ferro-alloys and alloying elements	—	—	—	Improvement of strength ductility, durability an metal saving during use
Additional check analysis of chemical composition of final rolled products	—	Direct expenditures for the check analysis	—	Possible due to separation of the metal that does not meet the strict specification	Ensuring high metal homogeneity and reliabili ty
		Additional requirements for mechanical properties			
Additional strength and ductility tests	—	Expenditure for preparation and testing of specimens	—	—	Ensuring metal homogeneity and high reliabil ty
Boosting the standards on strength and ductile properties	—	Narrowing the content limits of carbon and others	—	Possible during ordinary operations due to sorting out heats not meeting the strict standards	Improvement of the strength and ductility, metal saving during use
Increasing the size of control work	—	Expenditures for the preparation and test of additional specimens	—	Due to metal sorting out in increasing the size of test work	Ensuring high reliabili ty of the metal

1	2	3	4	5	6
		Additional requirements for purity and homogeneity			
racture test for de-ermining fibrousness f structure	Ensuring high quality raw materials	Improvement of the production process, high qualified personnel	—	Due to metal sorting out	Ensuring high reliability due to the decrease in brittleness
tandardization of mac-ostructure according o numerical reference talons	Selection of ingot of strictly definite mass and shape	Precise conditions of melting and casting (specification of temperature and speed)	—	Due to metal sorting out	Ensuring metal high reliability
on metallic inclusions standardization	Ensuring high quality raw materials	Right process technology, strictly defined ingot mass, obligatory observation of temperature and slag conditions	In case of very strict requirements it is necessary to change the process technology right up to the use of slag and vacuum remelting	—	Improvement of surface quality of worked parts (polishability) and lowering costs of processing at the users premises
air crack standardi-ation during tests on pecimens (by gradual urning, magnetic me-hods or others)	—	Specimens control	—	Due to sorting out of the metal that does not meet specified standards for specimens	Ensuring high reliabilit of superduty steel and improving the surface quality of worked parts (polishability)
tandardization of de-ects detected by the ser on ready parts hair cracks)	—	—	—	At the expense of payments for sorting out parts above agreed norms	ditto

1	2	3	4	5	6
Ultrasonic inspection	—	Inspection at the metallurgical plant and at users premesis	—	At the expense of payments for sorting out the metal at the metallurgical works	Improvement of the reliability of highduty steel before making parts from it
Determination of the gases content	—	Expenditure for additional tests	—	—	Improving the reliability of steel treated in vacuum, etc.
Increasing the size of work in macrostructure examination	—	Expenditure for specimens number increase, for their preparation and test	—	Possible due to macrostructure rejection	Ensuring high reliability of the steel
Additional requirements for microstructure and decarburization depth					
Microstructure standardization; pearlite shape	—	Technology improvement, adequate heat freatment	—	Due to sorting out of the metal that does not meet the strict standards	Improvement of properties uniformity and wo ability of the steel
Carbide network	—	Observation of cooling-temperature schedule; more correct finishining tempereture	—	Due to sorting out of the metal not meeting specification (for more round sections)	Improving steel toughne and ensuring higher re liability
Steel grain	Deoxidation control, usually with aluminium	Precise carrying out of the production process	—	Due to sorting out of the metal, not meeting strict standards	Improvement of proper ties uniformity of th steel and decreasing distortion of parts d ring quenching

1	2	3	4	5	6
α - phase	Higher nickel content and lower chrome content should be used	—	—	Due to sorting out of the metal, not meeting strict standards	Increasing steel ductity in hot working and suring non-magnetic pr perties of it
Boosting microstructure standards	—	Improving technology with adequate heat treatment	—	ditto	Ensuring higher reliab lity
Depth of decarburization layer	—	Precise observation of the production process, additional control	Expenditures for technological process complexity in heightening the requirements	Due to sorting out of the metal, not meeting strict standards	The possibility of ap plying cheaper treatment and reduction ir wastes at users premi ses owing to less all wances
		Additional requirements for physical properties			
Hardness penetration guaranty	—	Carefull development of the process, narrowing the limits of carbon content	—	Due to sorting out of the metal, not meeting strict standards	Increase in the durat lity of products of c sumer enterprises
Hardenability guaranty	—	Strictly defined chemical composition	—	Due to sorting out of the metal in certain cases	Increase in the durat lity of products of c sumer enterprises
Standardization of the tendency to intercrystalline corrosion	—	—	—	Due to metal sorting out	Ensuring steel resist ce to intercrystallir corrosion
Standardization of the tendency to graphitization	Narrowing the limits of residual chrome content	Observation of soaking time during annealing by decreasing the charge	—	—	Ensuring high reliabi lity of the steel

1	2	3	4	5	6
Magnetic properties--lowering the upper limit of coercive force in low-alloy electrical steel	—	—	—	Due to metal sorting out	Boosting the require electrical propertie
Increasing the lower limit of coercive force and residual induction in magnet steel	—	—	—	Due to metal sorting out	Boosting the require electrical propertie
		Additional requirements for manufacturing methods			
Melting of steel with ladle treatment with liquid synthetic slags	—	Lowering in the costs of the production process by reduction the time of electric melting	Direct expenditure for the use of synthetic slag, taking into account electric smelting speeding up	—	Improving metal reli bility due to loweri in sulphur content,d crease in hair crack and non-metallic inclusions
Steel melting with subsequent remelting	—	—	Direct expenditures for electroslag remelting and additional costs for hot working of the steel	Additional losses from melting losses and wastes	Boosting the reliabi ty of superduty stee owing to decrease of non-metallic inclusi ons, improvement of m rostructure and boos ting the mechanical properties
Steel melting with subsequent remelting in vacuum arc furnaces	—	—	Direct expenditures for the vacuum-arc remelting and additional costs for the hot working of steel	ditto	Boosting the reliabi ty of superduty stee owing to the decreas in non-metallic incl sions, improvement of macrostructure and mechanical propertie and lowering the con tent of gases

1	2	3	4	5	6
Steel melting in vacuum induction furnaces	Ensuring a high quality charge	—	Direct expenditures for vacuum induction remelting and additional costs for small ingots processing	Additional losses from melting losses and wastes	Boosting the reliabili of superduty steel by decreasing non-metalli inclusions and lowerin o: the content of gase
Steel melting with subsequent double remelting	—	—	Direct expenditures for the double remelting and additional costs for the hot working of the steel	ditto	Utmost boosting of the reliability of superdu ty steel due to the de crease in non-metallic inclusions, improvement of macrostructure and mechanical properties and lowering the conte of gases
Additional requirements for surface and appearance					
Improvement of surface finishing (grinding, polishing, etc.)	—	Direct expenditures for finishing	—	—	Costs reduction of met working at users and i provement of appearanc
Roughing, planing, brightening	—	Direct expenditures for roughing or planing	—	Losses due to wastes during roughing or planing	Decrease of wastes at users premises
Pickling	—	Direct expenditures, differentiated according to the type of rolled products and steel group	—	Losses from processing loss	Costs reduction of metal treatment at users premesis and improvement of surface qualit

1	2	3	4	5	6
		Heat treatment			
Normalization or annealing	—	—	Direct expenditures, differentiated according to rolled-products kind and type of treatment	Losses due to treatment loss	Equalization and boosting of mechanical properties, improving steel treatment
Heat hardening	—	Complication of the technology because of the quenching and subsequent tempering	Direct expenditures, differentiated according to kinds of rolled products and type of treatment (with special or rolling process heating)	ditto	Improving strength properties of the steel ar its saving
		Additional requirements for dimensions and accuracy			
Determination of standard or multiple length	—	—	—	Increase of wastes during cutting (above normal processing wastes)	Decrease in wastes during steel processing at users premises
Accuracy improvement, minimum curvature, buckles, camber	—	Costs increase due to more strict requirements for surface quality, reduction in rolls service life	—	Sorting up is possible in case of strict standards	Costs reduction in metal working at users premises

1	2	3	4	5	6
		Additional requirements for marking and packing			
ıdditional stamping ınd marking	—	Direct expenditures	—	—	Loss prevention at user. premises
ımprovement of contain- ·rs,packing,coating	—	Ditto	—	—	Improvement of steel pr· servation in handling a· storage

effect is summerized mainly from economy of expenditures in steel-making and rolling processes.

The utilization . in machine-building and construction of metals characterized by higher strength properties and more rational rolled metals ranges insures their reduced consumption, increased labour productivity and thus reduced manufacturing and construction costs. The utilization of machines manufactured from the metal of improved quality will reduce operating costs and will allow to minimize the machine stock, energy capacities and so on. Thus if the effect from the improved quality is realized in the process of metal working and operating of the metal products, then the summerized economy in labour, energy and capital expenditures is insured as a whole in iron and steel industry as a result of relatively reduced metal production, and in metal working and machine building due to reduced volume of metal being worked and reduced number of machines and equipment being produced.

The efficiency of the utilization of the improved quality metal is generally resulted in increased yield in iron and steel industry and in efficiency of the use of ferrous metals due to their decreased losses with wastes as well as in reduced volume of metal-intensive products, in increased safety and extended period of their life, in other improved operating characteristics of the machines and products.

The character and stages of the efficiency evidence have their specific features.

1. If the effect is realized in the process of metal-working and the operating properties of the products made from the metal of improved quality do not change, then the result will be in reduced metal consumption and volume of its working in metal working

industries. For example, the application of rolled sections of additional intermediate sizes, steel sheets in coils instead of sheets and so on allows to reduce metal losses due to wastes. In this connection the demand in metal and its working operations are reduced and hence required capital investments and current costs in metal working industries per unit of this product are also reduced.

2. The use of improved quality metals (low-alloy steels, thermally strengthened rolled products, enlightened beams and channels, formed sections and others) makes it possible to decrease the mass of 1 metre of reinforced steel rods, construction steel structures, pipelines, machines and others per unit productivity. In this case if decrease in weight of metal products does not affect their operational characteristics (e.g. while producing fixed steel structures) the effect will be expressed in decrease in the metal demand and lower volume of its processing [6].

Relative characteristics of metal products quality are the coefficients of metal saving. These coefficients show the quantity of conventional metal products intended for replacement to be saved with the use of 1 tonne of improved quality instead of metal products. With the help of these coefficients the effect of the contemplated upgrading of quality on the intended outputs and consumption of ferrous metals.

The total saving of metal as a result of the extension in the range of rolled products and enhancing quality of metal products is determined as the product of particular saving coefficient on the outstripped increment of the proper types of improved quality metal.

In the USSR the mean value of coefficients for every item of improved quality products is determined on the basis of the saving coefficients and share of increment of demand in these products of specific industry.

For every item the saving coefficient is determined as a weighted mean value according to formula :

$$\bar{K}_{э} = \sum_{1}^{i} K_{э1} \cdot q_1 + K_{э2} \cdot q_2 + \dots + K_{эi} q_i \qquad (9)$$

where $K_{э1}$; $K_{э2}$; $K_{эi}$ - coefficients of saving in various fields of the use of definite type of improved quality metal.

q_1 ; q_2 ; q_i - shares of increments of every field in the total volume of demand in the given type of metal.

The methods of coefficients calculation are differentiated depending on the trends of actual saving of metal :

1. Decreasing the weight of products ;
2. reduction in metal intensity of a product using high-quality metal.
3. reduction in quantity of metal wastes when machining the articles
4. increase in durability of articles as a result of
   - short-term use with service life less than one year ;
   - long-term use with service life more than one year.

Definition of metal saving in reducing the weight of an article on account of increase in strength properties of metal or use of more rational sections is based on the principle of equal strength replacement. For every concrete case the principles of equal strength are used in different ways : in some cases it it achieved by comparing metal consumption for an article, in others - per unit length of rolled product. In this case the coefficient of metal saving is determined according to formula :

$$K_{э} = \frac{Q_1}{Q_2} - 1 \qquad (10)$$

where Q_1 - weight of article made of metal of previous quality, t.

Q_2 - weight of article of improved quality, t.

The coefficients of saving as a result of using the metal of improved strength properties have substantial fluctuations due to different extent of use of properties depending on purpose and conditions of operation.

Hence, the actual saving of metal, as a rule, is less than the value obtained by the use of relationships between indices due to failure to coincide the calculated shape-sizes, e.g. section steel with the actually produced shape-sizes.

Besides, the actual value of metal saving is influenced by the character of load of structure elements (tension, pressure, bending, mixed deformation as well as relationship of strained, compressed, bended and other elements in various structures).

The calculated section area of tension elements (F) is determined, without regard to their length, as per load value (P) according to formula :

$$F = \frac{P}{R} \qquad (11)$$

where R - calculated resistance, kg /cm^2 .

When working for compression :

$$F = \frac{P}{U \cdot R} \qquad (12)$$

where U is coefficient of decrease in permissible stress for compressed rods.

This coefficient is taken according to predetermined standards depending on the bendability of elements.

In case the elements work for bending, the metal saving is determined as per calculated resistance (R) :

$$R = \frac{M}{W} \qquad (13)$$

where M is bending moment, kg/sm

W is moment of resistance to bending, sm^3.

In the tensiled elements of structures the metal saving, in comparison with the increase in yield limit, is less by 15-20%. In compressed and bended elements of structures the effect is decreased more. In compressed elements the effect is approximately by 50% less than in tensile elements and in bended elements by 25%.

On the average, the increase in metal saving is less than the increase in yield strength by 40-50%.

The evaluation of metal saving when using higher-strength reinforcing rod steel is based on equal strength of 1 m. of reinforced rods.

The quantity of reinforced rods of various grades (T) can be expressed by the given quantity of steel of any grade of conventionally equivalent strength which is determined by formula :

$$T_1 = K_{np} \times T \qquad (14)$$

where K_{np} - is coefficient of transformation.

This coefficient is equal to

$$K_{np} = \frac{R_a \times K_n \times K_M}{R_{a1} \cdot K_{n1} \cdot K_{M1}} \qquad (15)$$

where R_a - is calculated resistance, kg/sm^2

K_n - is coefficient of strength utilization.

K_M - is coefficient of metal utilization.

The saving of metal is determined as follows :

in tonnes $\quad Э_M = K_{np} - 1$

in per cent $\quad Э_M = \left(1 - \frac{K_{np}}{K_{np^1}}\right) \qquad (16)$

If the use of metal with higher level of properties allows to increase equipment efficiency, then coefficient of saving should be calculated according to formula :

$$K_Э = \frac{P_{M1} \cdot \alpha_Э - P_{M2}}{P_{M2}} = \frac{P_{M1} \cdot \alpha_Э}{P_{M2}} - 1 \qquad (17)$$

where P_{M1} - is consumption of metal of former quality per an article

P_{M2} - is consumption of metal of improved quality per an article.

$\alpha_э$ – is coefficient of equivalence showing the quantity of finished articles of former quality that is equivalent to the quantity of "finished articles" of new quality.

The coefficient of equivalence is calculated as follows :

$$\alpha_э = \frac{Q_н}{Q_c} \qquad (18)$$

where $Q_н$ – is annual output of a "finished article" produced with the use of improved quality metal.

Q_c – is annual output of a "finished article" produced from the metal of ordinary quality.

As a result of improvement of a range, shapes and sizes of products the quantity of wastes and savings in metal processing is decreased without changing the weight of products. The metal saving in this case is determined according to the difference between rates of consumption of imported metal of conventional quality in accordance with formula :

$$K_э = \frac{P_{м1} - P_{м2}}{P_{м2}} = \frac{P_{м1}}{P_{м2}} - 1 \qquad (19)$$

where $P_{м1}$ – is consumption of metal of conventional quality per article, t

$P_{м2}$ – is consumption of improved quality metal per article, t

The evaluation of metal saving as a result of the increase in durability of an article has its own specific features. As a rule, the increase in durability does not lead to the change of specific rates of metal consumption per article or any other measure unit. The increase in durability generally results in the decrease of consumption of metal intended for repair and maintenance purposes.

With the durability of a part or an article being less than one year the economy coefficient of saving is determined by the following formula :

$$K_э = \frac{T_2}{T_1} - 1 \qquad (20)$$

where K_3 – is a coefficient of saving, t/t ;

T'_2 – is a durability of an article when using improved quality metal, t/t ;

T_1 – is a durability of an article when using metal of former quality, months.

The peculiarity of evaluating metal saving with the increased durability of an article of long-term use with the durability of more than one year is that the achievement of this saving does not go in time with the use of improved quality metal.

The metal saving for every year can be determined as difference between :

a. metal production output needed in a particular year for changing articles if their durability does not change and

b. metal production output needed for the change of articles with higher durability that should be changed in a particular year.

The metal saving for every year is determined by equation :

$$Э = A_{T-t} - A_{T-t_1} \quad (21)$$

where A – is the output of improved quality metal ;

T – is the year for which metal saving is determined.

t – is durability of articles made of traditional metal ;

t_1 – is durability of articles made of higher quality metal ;

$T-t$; $T-t_1$ are indices of years for which output is taken.

For evaluating the influence of improvement of metal product quality on the indices of its technological complexity it is necessary to have the values of coefficients of metal saving.

It is expedient to dwell on some examples of quality improvement.

The use of rolled products of low-alloy steel insures considerable metal saving. Low-alloy steels are characterized by higher strength properties as a rule good weldability, ability for bending and forging, higher corrosion-resistance strength. It is expedient to use it for more loaded elements of structures.

In the USSR the most widely used grades of low-alloy steel with the yield point of 33 and 40 kg/mm^2 are 09Г2С, 14Г2, 10Г2С1, 15ХСНД, 10ХСНД and others. These steel grades are generally used for main base structures and elements of constructions and buildings instead of normal grade steel CT3 insure the metal saving of about 17% (0.21 t/t). The saving of steels with yield point of 45 to 75 kg/mm^2 can make up in comparison with steel CT , 35-40% for the main bearing structures of buildings and constructions.

The use of low-alloy steel rods for prefabricated and monolithic concrete structures gives saving of metal in comparison with steels of conventional quality by 0.275 t/t.

The use of low-alloy steels for hot-rolled sections for wagons makes up 0.126 t/t and for sheets - 0.18 - 0.22 t/t. The coefficient of saving on account of the use of these steels in the USSR accounts for 0.14 t/t in wagon building, 0.16.t/t in diesel locomotive building, 0,224 t/t in metallurgical engineering, 0.231 t/t in hoist-transport machine-building, 0.110 t/t in mining machine-building, 0.16 t/t in coal machine-building, 0.16 t/t 0.14 t/t in chemical and petrochemical machine-building, 0.16 t/t in construction and road machine-building, 0.20 t/t in automotive, tractor and agricultural industries, 0.16 t/t in ship-building, 0.18 t/t in energy machine-building, 0.1 t/t in other industries. The complex labour, energy and capital expenditures are increasing while changing steels of conventional quality for low-alloy steels less than 5%.

One more method of metal saving by consumers is thermal strengthening of rolled products that lies in intensive cooling of metal heated up to a hardening temperature. There are several methods of thermal strengthening: tempering for flat and long products, strengthening of reinforcing rods with the use of rolling heating etc.

Thermally strengthened rolled products are used for manufacture of building metal structures, rods for reinforced concrete and machine-building. The utilization of low-alloy and carbon thermally strengthened steel with yield point of 29-40 kg/mm^2 saves 0.126 t/t of metal.

When using low-alloy thermally strengthened long and flat rolled products in the welded span structures of bridges the economy for the substituting parts will comprise 0.28 t/t.

However, according to the figures calculated by experts, 60-120 dollars/t are required additionally in the complex capital expenditures of rolled products for carrying out thermal strengthening and other kinds of thermal treatment. But taking into account the obtained saving in the consuming industries and decrease in the total output of metal it fully proves its value.

The average metal saving from the use of thermally strengthened rolled products amounts to 0.175 t/t of flats for the construction steel structures, 0.28 t/t for transport machine-building, 0.25 t/t for automotive industry, 0.181 t/t for heavy and tractor machine-building and rods, 0.277 t/t for reinforcing steel and 0.207 t/t of long products for machine-building.

One of the most efficient ways of decreasing wastes is the usage of die-rolled sections made by helical rolling. The metal saving obtained from using these sections amounts on the average to 0.13 t/t including for heavy, energy and transport machine-building - 0.122 t/t, automative industry - 1.109 t/t, tractor and agricultural machine-building - 0.206 t/t, construction, road and community machine-building - 0.236 t/t, electrotechnical industry - 0.139 t/t.

The metal saving from using cold-rolled sheets instead of hot-rolled sheets comprises saving on account of more rigid tolerances (3-4%) and possibility of using thinner sheets in place of hot-rolled sheets (15-17%). Hence, the average saving is evaluated at 20%, and the coefficient of saving is 0.25 t/t. Thus, the great complex labour, energy and capital expenditures for the production of this type of iron and steel industry products is justified from the point of view of reducing total expenditures for the whole economy of developing countries.

The coefficient of metal saving due to wider use of hot-rolled sheets of 1.2 - 1.8mm and 2 mm thick in comparison with the use of sheets of wider range of thickness amounts to 0.25 t/t.

The use of coiled rolled products allows to reduce the consumption of metal on account of improvement of cutting out and related decrease in wastes.

In electrotechnical industry the use of coiled steel makes it possible to save 5 - 8% metal, and in automative industry - 5%. On the average the coefficient of metal saving from the wider use of steel in coils is 0.05%. When using this metal the labour intensity of cutting works decreases by 35-40%, and a great number of cutting-out equipment is released. The use of coiled rolled products creates also favourable conditions for introducing automatic forging.

The largest demand in coiled steel is observed in automative industry, agricultural, tractor and electrotechnical machine-building.

Conclusion

The conducted research allows to determine the technological complexity of the products of the iron and steel industry by 3 indices : complex labour, energy and capital expenditures required for this product which give the possibility to determine the strategy for setting up and progress of the iron and steel industry of developing countries, requirements in labour resources, various kinds of fuel and energy and capital investments. In the research attention is attached to the influence of level of product quality on the complexity of its production in the iron and steel industry and utilization in other industries of economy of developing countries. The distinguishing feature of the study is the determination of labour, energy and capital expenditures for the production of important types of metal products with due regard to the most characteristic technological routes in the modern iron and steel industry.

It has been found in the work that the simplest route for introduction is the process one with melting EAF steel on the base of scrap, but for this it is required to use sufficiently large quantity of scrap and that is difficult to carry out in the developing countries which have low volumes of the metal fund.

The import of scrap requires high expenditures in currency and this is not an effective solution of the problem of setting-up the iron and steel industry. Besides, the excessive import volumes could make the developing countries dependent economically on the developed countries and could not contribute to the achievement of their political independence. The use of at least 25% of sponge iron in electric furnace charge makes the position easier. All three indices of technological complexity of this process route have comparatively low values and can be carried out in the developing countries with considerable saving in labour, energy and capital expenditures in comparison with the classical route (blast-furnace - basic oxygen urnace) and the route based on the use of sponge iron for charge of electric arc furnaces. The realization of the later technological route leads to the highest values on the metal products under investigation. However, it should be mentioned that the calculations of experts are based on the tentative average values of direct labour, energy and capital expenditures. In practice, depending on the capacities of iron and steel works to be set up these values can be changed to one and the other side. The natural resources available in various developing countries also play a great role.

For instance, when considerable resources of rich iron ore and natural gas are available and their prices are relatively low the development of steel iron and steel industry on the basis of direct reduction process can score significant advantages.

The system of complex labour, energy and capital expenditures makes it possible to assess both totally and by stages the demand in manpower, to identify the requirement in the number of higher and secondary education specialists and the requirements in all kinds of fuel, energy and capital investments. Thus, for a works with a capacity of 1 mln t/year of steel sections operating with the use of the route "blast furnace - basic oxygen furnace" it will be necessary to have 5,000 workers, 300 engineers and 600 technicians, to consume 1.1 mln t of primary fuel in coal equivalent ; the construction of the works will demand 400-500 mln $.

In case with a works of the similar output producing cold-rolled sheets in accordance with the same technological route the above mentioned figures will be increased correspondingly up to 8,000 workers, 450 engineers, about 1,000 technicians, 1.25 mln t of primary fuel and 600 mln $.

When the technological route is based on the use of electric arc furnaces operating on the sponge iron the above figures will be increased by 25%.

The developing countries will benefit a great deal if they use the system proposed by the Soviet experts for the determination of complex expenditures for raw materials, energy and semi-finished products required for the production of intermediate and final products. This system allows to observe certain ratios when calculating the requirements of the indicated resources, to make calculations with the elimination of some technological stages and substitution of some kinds of fuel by others, to establish rational relationships between certain kinds of raw materials (pellets, sinter, pre-reduced pellets and so on.) Finally, this system allows to determine with the use of direct labour and capital expenditures proper ratios when calculating the requirements in these resources.

Taking into consideration concrete conditions of the developing countries the technological complexity of iron and steel industry products which is determined by three indices comprising complex labour, energy and capital expenditures can be varied within rather wide limits. The values of these indices obtained by the experts on the basis of average data are necessary for the orientation and approximate calculations, the final calculations must be performed with due corrections of initial data.

While making these calculations it is essential to know the technological complexity of the production methods used by metal product consumers including suppliers of equipment and machines for iron and steel industry. It is worthwhile to obtain hereafter the unified indices of technological complexity in all branches of the national economy. Total labour, energy and capital expenditures can be used as these indices. These expenditures are of the same nature as complex expenditures, but embrace a wider range of industries within the limits of the national economy.

The merit of these indices consists in their reality and high utilization significance.

The development of iron and steel industry is connected with a wide range of problems, concerning technique and production technologies, production organization and control, social problems and,finally, financing problems.

The priority of production costs and financing is of great importance for the developing countries.

The development of iron and steel industry in the developing countries today is going on due to various financing forms : state, private and complex. The most reliable and objectively sound form is the state centralized financing which contributes mainly to the independence of the country.

The participation of the state in financing corresponding programs on plan basis provides for the proper orientation in the development of the national economy, and particularly of iron and steel industry, in developing countries with due consideration of the national interests.

It should be noted that as a rule in the developing countries there is not production base for the construction of necessary equipment and for this reason they have to address industrial countries and to buy the equipment on credit. Under these conditions industrial countries must play their positive role either in one form or another.

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