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MANPOWER AND TRAINING REQUIREMENTS IN INDUSTRY: A METHODOLOGY WITH AN APPLICATION TO THE IRON AND STEEL SECTOR

Sectoral Working Paper Series

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SECTORAL WORKING PAPERS

In the course of the work on major sectoral studies carried out by the UNIDO Division for Industrial Studies, several working papers are produced by the secretariat and by outside experts. Selected papers that are believed to be of interest to a wider audience are presented in the Sectoral Working Papers series. These papers are more exploratory and tentative than the sectoral studies. They are therefore subject to revision and modification before being incorporated into the sectoral studies.

This paper was prepared by UNIDO consultants, Professor V.A. Romenets, Dr. N.I. Perlov and Dr. L.V. Kovalenko (the Union of Soviet Socialist Republics). The views expressed do not necessarily reflect the views of the UNIDO secretariat.

Preface

This study presents a methodology for determining manpower and training requirements in various routes of iron and steel production and for designing specific curricula for training courses.

It is hoped that this methodology will provide a practical tool to be used by decision makers and plant managers in developing countries as well as by others dealing with manpower training questions. The methods, as outlined in the study, are at present being tested in a particular application in the field in co-ordination with UNIDO's Division for Industrial Operation.

The application of the methodology can also be extended to other sectors and is not limited to the iron and steel sector alone.

The study has been prepared by Professor V.A. Romenets, Dr. N.I. Perlov and Dr. L.V. Kovalenko of the Union of Soviet Socialist Republics as consultants to UNIDO.

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Introduction

It has been predicted, both in the study [1] prepared in 1981 and in a paper presented by the UNIDO secretariat in 1982 to the Third Consultation on the Iron and Steel Industry [2] that the output of ferrous metals in developing countries will almost double during the 1980s. The training of high-skilled personnel is the main problem to be solved to ensure such rates of development for the iron and steel industry in developing countries and to meet the demand for personnel required for the normal operation of iron and steel works.

Developing countries must therefore identify their manpower needs, develop appropriate methods for vocational training and allocate the necessary resources and technical assistance.

To meet the personnel training requirements of developing countries in the iron and steel industry, UNIDO has recommended the following measures: development of national vocational training programmes; use of existing training capabilities of developed countries for vocational training of developing country personnel; relocation of human resources from developed to developing countries to provide technical assistance in the implementation of projects and promote the rapid growth of ferrous metal output [3].

The iron and steel industry forms the basis of the development and national independence of developing countries. Special criteria had to be drawn up to determine the most effective means of promoting the iron and steel industry in accordance with the specific conditions of each developing country. Based on those criteria, developing countries should be able to make the necessary technological choices, establish scales of production in the iron and steel industry and determine potential demand for labour and energy resources and capital investments. With this aim in view, an index of technological complexity for capital goods has been established as a result of work done by UNIDO and its consultants [4, 5, 6, 7, 8]. The concept of technological complexity is a basic aspect of methods of determining manpower requirements of developing countries.

An index of technological complexity for iron and steel products, based on the labour (man-hours) and energy expenditures required for the technological processes adopted, and the capital expenditures required for producing metallurgical equipment and construction of iron and steel works, has been developed in [6].

This study is designed to facilitate the task of establishing and promoting the development of the iron and steel industry of developing countries by helping to determine personnel requirements and to solve training problems.

In order to attain this objective, a method was developed for determining the personnel requirements of iron and steel works with different levels of output and production processes. It provides a basis for determining complex labour expenditures in man-hours per unit of metal products manufactured by the iron and steel industry. The calculation of complex labour expenditures at iron and steel works involves the use of square matrices incorporating direct expenditures on raw materials, semiproducts and energy for intermediate and final products multiplied by direct labour expenditures. The mathematical apparatus has been applied and computer software developed for the determination of complex labour expenditures and personnel required for iron and steel works producing different kinds of steel products. Personnel requirements have been determined for an iron and steel works as a whole and for separate production processes using different types of steel. The required numbers of engineers and technicians, clerical staff and workers, from the highly skilled to the unskilled, have been specified.

Based on the experience of the iron and steel industry in the Union of Soviet Socialist Republics, the qualifications required for the exercise of the main professions in iron and steel works are methodically formulated.

The study summarizes the experience of the Soviet Union in specialist metallurgical training for personnel with different levels of education. It describes the method of designing metallurgical training programmes for the iron and steel industry, the type of curricula required, its theoretical and practical aspects and the time alloted to the subject matter covered. It proposes a scientific method of drawing up curricula based on qualification requirements and the concept of subject significance, which has been successfully used in the Soviet Union for training specialists and workers in different industrial fields. Subject significance is determined by an analysis of its internal and external components.

The external component of the significance reflects the evaluation of the role of a given subject for vocational activity after training is completed. It makes it possible to take into account the needs of production and technological progress of different branches of the economy of a country when designing the curricula. The external component of the subject significance is complemented by its internal component, which reflects the significance of the given training course for studying all other training courses included in the curriculum. The internal component is determined by establishing the logical relationships between the given training course and the other courses of the curriculum. Square matrices are used to make quantitative assessments of the ultimate significance of the training courses and to provide an overall picture of the logical relationships between training courses in a given speciality curriculum. The matrices also make it possible to determine the relevance of a training course in other fields of study, which is very important for the establishment of cycles of general education and engineering in accordance with vocational demands.

In the study a mathematical method involving computer programming is elaborated for the quantitative assessment of the volume of subjects in a speciality curriculum and the determination of logic sequence of presenting the training materials. Examples are given of programmes for training engineers in iron and steel metallurgy. The approach to training is based on demand for personnel in the iron and steel works of developing countries and on determining the size of the population of students and trainees in educational institutions.

Attention is drawn to the use of automatic training systems in the process of personnel training. They suppose the availability in educational institutions of powerful computer terminals. The methods and advantages of applying the automatic training systems, including the combination with traditional forms of studies, are indicated. In developing countries with limited programmes of specialist training it is advisable to apply the automatic training courses in single subjects with the use of individual computers which do not require establishing networks from terminals or special premises and servicing by highly skilled personnel. An effective approach would be to develop automatic training courses for technicians and high-skilled workers, including training in the control of processes and units. This would make it possible to order the courses on magnetic tape from specialized firms.

The study considers different methods of training the workers, engineers and technicians required to develop the iron and steel industry of developing countries, depending on the condition of their educational systems. For this purpose it is advisable to establish vocational and technical schools with a training period of initially 3 to 4 years on the basis of an incomplete secondary schooling, reducing it to 1 to 2 years as the number of persons with a complete secondary schooling increases. In this case the training of teachers and instructors for vocational and technical schools should be provided in special industrial and pedagogic faculties of higher educational institutions.

The training of middle-grade specialists (technicians) should be carried out in specialized secondary technical educational institutions, which may admit persons with incomplete secondary education. The period of training in these institutions is 3 to 4 years, with its possible decrease to two years for persons having complete secondary general education.

The training of engineers for the iron and steel industry of developing countries may be initially effected by sending graduates of secondary schools to study at higher educational establishments of developed countries. At present it is also possible to send personnel for training in developing countries which have already developed personnel training centres. In addition, the training of engineers could be organized by establishing metallurgical faculties in the available universities. To help meet its great demand for engineers in establishing a multi-branch economy, a developing country could organize technical institutions with a comprehensive five-year period of trianing. If it has advanced university education a country can organize specialized technical institutions with a two-year period of training in industrial branches for university graduates having practical experience of working.

This study discusses different methods of training personnel of various skill levels for the iron and steel industry of developing countries. It encourages the sectorial form of personnel training through the use of international funds for the establishment of educational institutions. The experience of the Soviet Union in training engineers, technicains and skilled workers for metallurgical industries on the basis of bilateral intergovernmental agreements is generalized. In so doing, the participation of the Soviet Union in designing and constructing the iron and steel works is accompanied, as a rule, by obligations on the training of national metallurgical personnel.

The obligations mentioned above are carried out in the following three basic directions: establishing higher and secondary specialized educational institutions and vocational and technical training centres in developing countries; mass training of skilled workers in the course of implementation of industrial projects as well as establishing training centres at the site of completed industrial projects; training in educational institutions of the Soviet Union.

The training strategy is developed for different skill levels depending on the stages of preparation and construction of iron and steel works of developing countries, and taking into account the possibility of changing a speciality programme as the demand for engineers and technicians is met and new technological problems appear.

The methodological basis of determining demand for personnel of various qualifications, establishing personnel training programmes based on the required qualifications for specialities and professions, designing curricula according to scientific methods and meeting the demand of developing countries in national personnel can be used for different branches of national economies, despite the fact that they were specifically developed for the iron and steel industry.

By this means the implementation of the study makes it possible, with appropriate starting information about the condition and development of a branch of the national economy, to determine the demand for personnel with different qualifications in that branch of the eocnomy. In so doing one can define optimum methods of training workers and specialists according to the needs of particular branches of the national economy and elaborate curricula and programmes of training to meet those needs. It is also possible to establish appropriate ways and means of meeting the personnel demand of economic sectors of developing countries at different stages of development, with due regard for international co-operation, and to rationalize the process of training specialists.

I. DETERMINATION OF LABOUR EXPENDITURES AND THEIR USE FOR THE ESTIMATION OF MANPOWER REQUIREMENTS

This study was prepared by a group of experts of the Union of Soviet Socialist Republics on the basis of the methodology developed by them in their study "Technological complexity of iron and steel industry products" [6] and their further developments of the methodology.

In the course of this work we have chosen characteristics defining expenditures of various resources in the iron and steel industries of developing countries depending on the chosen metallurgical process. The following processes are meant here:

(a) Classical iron production in blast furnaces from prepared iron ore with the use of coke and BOF steelmaking;

(b) Production of pre-reduced materials by cokeless direct-reduction processes (or using 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.

All these processes provide for continuous casting of steel and production of various types of rolled products.

The three most essential indices for the iron and steel industry have been chosen, reflecting complex inputs of labour and energy resources as well as complex capital expenditures. The first one reflects the labour expenditures or of direct labour (man-hours) required for the functioning of the iron and steel works to be developed; the second - energy expenditures of process routes; the third - capital or cost expenditures for producing metallurgical equipment and construction of iron and steel works. All these indices characterize from different points of view the technological complexity of producing the chosen types of metal products.

For the purposes of this study it has been necessary to use complex labour expenditures for various types of intermediate and final products with different production processes. With that end in view we have considered the relationships arising within the limits of the adopted production processes.

The technological complexity of producing metal products, from the standpoint of labour expenditures, is increased as the final stages of the process are approached. The complexity indices of the previous stages are accumulated at the subsequent stages of the process. In the most general way it may be illustrated by an example of a "through" calculation of the labour expenditures for the production of heavy-section steel products according to the following process: blast-furnace ironmaking and BOF steelmaking with continuous casting of heavy-section steel products.

This process starts from iron ore mining and production of iron ore concentrate. The labour expenditures at this stage is 1.1 man-hours per tonne.

If the next stage is pelletizing then to the expenditures of this stage must be added the expenditures of the foregoing (0.5 man-hours per tonne) stage multiplied by specific requirements of the first-stage products for the second-stage products (1.082 tonnes per tonne). In this case, the labour expenditures, taking into account the foregoing stage, will amount to 1.68 man-hours per tonne. At the next stage (ironmaking) the labour expenditures (0.769 man-hours per tonne) are added to the expenditures on metal burden preparation multiplied by 1.7 (2.86 man-hours per tonne) and expenditures on cokemaking (to avoid double calculation without taking into account expenditures for mining and benefication of coal) multiplied by the coke rate for ironmaking (0.255 man-hours per tonne).

Then the expenditures in ironmaking will amount to 3.844 man-hours per tonne, taking into account the foregoing stages. In that way the through calculation of labour expenditures up to the final product (heavy-section rolled products) is performed. The calculation is presented in table 1.

This through calculation, though it is simple and illustrative, has an important drawback - it is incomplete. According to tentative calculations, it does not cover about 20 per cent of all labour expenditures. Thus, the calculation does not take into account labour 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 expenditures for the production of these materials. It is quite clear that such a considerable gap in expenditures cannot but have a negative effect on its integral values defining the technological complexity of the products made as a result of the process under study.

Table 1. Through calculation of labour expenditures for production of heavy-section rolled products

Stages of process routes	Labour expenditures per stage (man-hours per tonne)	Specific expenditures of products of foregoing stage in ensuing stage (tonnes per tonne)	Labour expenditures taking into account foregoing stage (man-hours per tonne)
Iron ore mining and iron ore concentrate production	1.1	-	-
Pelletizing	0.5	1.082	1.63
Cokemaking	0.581	-	-
Ironmaking	0.769	1.7 (pellets) 0.44 (coke)	3.884
BOF steelmaking	1.6	0.849	4.89
Production of heavy-section rolled products	2.7	1.06	7.88

It is essential to take into account the whole diversity of inter-product relations within process routes, to express these relations through coefficients of consumption of these products (steel for rolled products, iron for steel, coke for iron), and to determine the expenditures on raw materials, energy etc. and the labour intensity of these products.

For this purpose it is expedient to obtain indices which would define the whole set of natural expenditures on raw materials, materials, energy, semi-finished and intermediate products for production of intermediate and final products, to obtain among these indices the constituents of energy intensity (expenditures on fuel and electricity), and on the basis of natural values of the indices and specific values of labour expenditures to find the labour intensity of products within a process route.

As calculations demonstrated, it is necessary to solve jointly 75 equations, for which about 6,000 specific values of direct expenditures are used, to determine only natural expenditures on raw materials, materials, energy. semi-finished and intermediate products for intermediate and final products within the process routes under study. It is impossible to solve such a problem without using a computer. In this connection, a methodology for receiving natural values of expenditures for the metallurgical processes under study through the use of theoretical principles and software of interproduct balances (input-output balances) has been developed.

Basic initial data for realizing this method are the data on intermediate and final products, outputs made in the metallurgical routes investigated, the expenditures on raw materials, materials, energy, semi-finished and intermediate products for each type of product. Direct expenditures are determined through dividing the initial data by the corresponding outputs of each type of product. The expenditures characterize the expenditures on raw materials, materials, energy, semi-finished products etc. per tonne of intermediate and final products (sinter, pellets, coke, iron, steel, rolled products of different kinds etc.). Direct expenditures by themselves, however, do not give a clear picture of the expenditures as a whole for a process route. For this purpose it is necessary to take into account indirect expenditures as well, that is, the expenditures recalculated with regard to the coefficient of consumption for combined types of intermediate products.

Thus, BOF steelmaking requires a considerable consumption of iron (direct expenditures), and this, in its turn, results in a considerable consumption of fuel and energy for the production of iron, coke, blast-furnace blast, oxygen etc. (indirect expenditures). EAF steelmaking involves a high consumption of electric power (direct expenditures) resulting in increased consumption of fuel for electric power generation at iron and steel works (indirect expenditures) and increased consumption of electric power obtained from the outside.

It is therefore necessary to use, equally with the direct expenditures (for example, cokemaking and ironmaking), much more complicated expenditures allowing to express total expenditures of raw materials, materials, energy and semi-finished and intermediate products for intermediate and final products within the process route as whole. They take into account both direct expenditures on resources per product unit in the main (principal) production and indirect expenditures on these resources in other technological processes and related industries. These expenditures include not only those made at the last routine stage of production, but also at the foregoing stages and routes of production in all the allied branches of industry. They have been named complex expenditures.

The economic sense of the complex expenditures, as applied to the problem to be solved, consists in the subsequent adding of direct and indirect expenditures on raw materials, energy and semi-finished products for the manufacture of concrete types of products within planned process routes. In the most general way it is illustrated by the example of a through calculation presented in table 1.

Computation of the indirect expenditures is broken up into a number of consecutive operations. The indirect expenditures of each operation are normally designated by proper number (order).

The starting position for computing the direct and complex expenditures is the formation of a square statistical table. This table represents a distribution of materials, fuel, energy and semi-finished and intermediate products for production of both intermediate and final products of the iron and steel industry. Table 2 gives a mathematical model of the table mentioned.

The initial stage of forming this table consists in separating single elements which give the names to rows and columns. Each row of this table forms an independent balance of distribution of materials, fuel, energy, intermediate products etc. Even the simple combining of many material balances in one model (table) facilitates the analysis of quantitative internal relations in the production of various metallurgical products.

The set of horizontal rows forms vertical columns which reflect expenditures of the same materials, fuel, power, semi finished products etc. for the production of the distributed products. Thus, two apparently combined tables are formed in rows - the table of distribution of raw materials, materials, fuel, energy and semi-finished and 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 number of columns is equal to the number of rows, that is, the initial statistical table, being in principle a matrix, has a size n x n (square matrix). The above peculiarities represent important advantages of this table in comparison with the system of separate particular balances.

In table 2 the algebraic symbol for consumption of resources X has at the bottom two figures, the first figure designation of the row, the second that of the column. If these two figures are equal it means that resources are consumed for their own production, for example, consumption of electric power for generation of electric power.

The initial statistical table used for determining complex expenditures on raw materials, materials, electricity and semi-finished and intermediate products for production of intermediate and final products by appropriate process routes from ore up to rolled products is fairly large (75 x 75). This made it possible to have a rather detailed picture of expenditures on the resources in the investigated process routes of iron and steel production.

The mathematical base making it possible to obtain coefficients of direct and complex expenditures on the basis of the initial statistical table is presented in annex I.

The matrix of direct expenditures has been prepared by dividing the total expenditures on raw materials, materials, energy and semi-finished products by the outputs. Inversion of the matrix of direct expenditures with the help of a computer made it possible to obtain about 4,000 complex expenditures on raw materials, materials, energy and semi-finished products in terms of intermediate and final products.

Table 2. Mathematical model of the initial statistical table for computing direct and complex expenditures for process routes of iron and steel production

Type of resources or products	Consumption					
	1	2	3	...	n	Total
1	X_{11}	X_{12}	X_{13}	...	X_{1n}	X_1
2	X_{21}	X_{22}	X_{23}	...	X_{2n}	X_2
3	X_{31}	X_{32}	X_{33}	...	X_{3n}	X_3
4	X_{41}	X_{42}	X_{43}	...	X_{4n}	X_4
.	.	.	.	...	.	.
.	.	.	.	...	.	.
.	.	.	.	...	.	.
n	Xn_1	Xn_2	Xn_3	...	Xnn	Xn_j
Vector-row	X_1	X_2	X_3	...	Xn	

These complex expenditures were computed for all three routes investigated and for the combined variation of EAF steelmaking using 25 per cent of sponge iron and 75 per cent of scrap. The values of all these expenditures are given in the tables in subsequent sections of this study when complex labour expenditures are determined. To compute the complex labour expenditures on production of the investigated types of metal products according to the stipulated process route, the complex expenditures on raw materials, materials, energy and semi-finished products are multiplied by direct labour expenditures required for their production.

The use of complex labour expenditures makes it possible to determine labour requirements for establishing iron and steel works in developing countries.

For computing the complex labour expenditures for production of the evaluated metal products on the basis of the data provided by the USSR institutes which designed iron and steel works for developing countries and of the practice established in the USSR, the experts have taken the following values of direct labour expenditures in man-hours per tonne (thou.cu.m., Gigacal or thou.kWh): blast-furnace gas - 0.0206, coke-oven gas - 0.009, natural gas - 0.055, coke - 0581, coke breeze - 0.48, own electric energy - 0.2, outside electric energy - 1.555, scrap - 0.70, thermal energy - 0.136, oxygen - 0.232, blast-furnace blast - 0.198, iron ore - 1.1, sinter - 0.565, pellets - 0.5, prereduced pellets - 2.0, 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 are to be corrected according to actual conditions in developing countries.

In the course of the computer computations the complex labour expenditures were determined for intermediate and final products within the investigated process routes. This makes it possible to determine in more detail the technological complexity of a product, taking into account implementetion of certain process stages.

Table 3 presents the complex labour expenditures for BOF steelmaking and EAF steelmaking on the basis of scrap and sponge iron (pre-reduced pellets).

The data show that EAF steel made from scrap is the least labour-intensive (5.5 man-hours per tonne), and hence the least complicated from the standpoint of direct labour expenditures, complex labour expenditures for BOF steel are 20 per cent higher (6.6 man-hours per tonne) and that for EAF steel made from a charge containing 25 per cent sponge iron and 75 per cent scrap are 25 per cent higher. The use of EAF steelmaking is typical for mini-works.

All the complex labour expenditures for steelmaking were computed on the assumption that the steel is cast continuously. Should steel be cast into ingots using blooming and slabbing mills, additional complex labour expenditures will arise as compared with similar expenditures when using billets.

In tables 5 to 11 of the work "Technological complexity of iron and steel industry products" [6], the results of the determination of complex labour expenditures for the production of heavy, medium and light sections, plates, sheets, cold-rolled sheets and section structural steel using four different process routes were presented. These expenditures, however, should be increased in order to take into account complex labour expenditures for repair, services, transport facilities and general works. In addition, it is necessary to aggregate labour expenditures for separate energy expenditures and to correct some of the values in relation to the data on the practice of designing iron and steel works for developing countries.

For this purpose all data obtained as a result of the computation were compared with the complex labour expenditures estimated to proceed from the annual output of one million tonnes of rolled products using data prepared by USSR designing institutes which designed works for various countries, including India, Nigeria, Pakistan and Turkey. Complex labour expenditures for repair services, transport facilities and general works services were computed on the basis of these materials. Complex labour expenditures included similar expenditures on cokemaking by-products and refractory masses, concretes and powders. Tables 4 to 7 show values of the determined complex labour expenditures for different process routes.

The data presented in these tables show that the most labour-intensive and complicated from the standpoint of direct labour expenditures are cold-rolled sheets and section structural alloyed steel.

The process route for EAF steelmaking based on scrap has the smallest values of complex labour expenditures. The process route for EAF steelmaking based on sponge iron has values of complex labour expenditures almost 40 per cent higher. This is confirmed by published data [9].

Complex labour expenditures were computed by the experts on the basis of an annual output of one million tonnes of rolled products. The expenditures are decreased with smaller outputs and increased with bigger ones. Thus,

Table 3. Determination of complex labour expenditures for production of BOF steel and EAF steel on the basis of scrap, sponge iron and 25 per cent sponge iron and 75 per cent scrap
(Man-hours per tonne)

Description of expenditures (tonnes, unless otherwise specified)	Specific labour expenditures	Complex expenditures for raw materials, energy and semi-finished products				Complex labour expenditures			
			EAF steel on the basis of				EAF steel on the basis of		
		BOF steel	Scrap	Sponge iron	25 per cent sponge iron and 75 per cent scrap	BOF steel	Scrap	Sponge iron	25 per cent sponge iron and 75 per cent scrap
<u>Fuel</u> (coal equivalent)		0.8697	0.2611	0.6467	0.3199	0.2675	0.0406	0.0272	0.0375
Natural gas (thousands of m^3)	0.055	0.205	0.071	0.479	0.183	0.0113	0.0039	0.0263	0.0101
Coke	0.581	0.379	0.0381	-	0.029	0.220	0.0221	-	0.017
Own electricity (thousands of kWh)	0.200	0.073	0.1445	0.1428	0.0139	0.014	0.0289	0.0286	0.003
Outside electricity (thousands of kWh)	1.555	0.532	0.887	1.555	1.0895	0.827	1.379	2.418	1.694
Scrap	0.700	0.300	0.9735	-	0.795	0.210	0.6815	-	0.557
Thermal energy (Gigacal)	0.136	0.250	0.033	0.196	0.075	0.034	0.0045	0.0267	0.010
Oxygen (thousands of m^3)	0.332	0.180	0.0313	0.026	0.032	0.058	0.0101	0.0084	0.010
Blast-furnace blast (thousands of effective m^3)	0.198	1.584	0.139	-	0.095	0.314	0.0275	-	0.019
Compressed air (standard m^3)	-	0.0437	0.049	0.048	0.054	-	-	-	-
Iron ore	1.100	1.493	0.104	1.460	0.460	1.460	0.1144	1.606	0.506

continued

Table 3 (continued)

Description of expenditures (tonnes, unless otherwise specified)	Specific labour expenditures	Complex expenditures for raw materials, energy and semi-finished products				Complex labour expenditures			
			EAF steel on the basis of				EAF steel on the basis of		
		BOF steel	Scrap	Sponge iron	25 per cent sponge iron and 75 per cent scrap	BOF steel	Scrap	Sponge iron	25 per cent sponge iron and 75 per cent scrap
Sinter	0.565	0.892	0.753	-	0.054	0.504	0.0425	-	0.031
Pellets	0.500	0.561	0.0271	1.300	0.359	0.281	0.0135	0.650	0.1785
Sponge iron	2.000	-	-	1.000	0.250	-	-	2.000	0.750
Iron	0.769	0.8495	0.0588	-	0.0511	0.653	0.0453	-	0.039
Refractories		0.0185	0.0622	0.0622	0.058	0.049	0.1853	0.1853	0.181
Fireclay brick	2.050	0.0102	0.0301	0.0301	0.028	0.021	0.075	0.0617	0.057
Silica brick	2.450	-	0.0006	0.0006	-	-	0.0015	0.0015	-
Magnesia refractories	4.800	0.0023	0.0105	0.0105	0.020	0.011	0.0504	0.0504	0.096
Fire dolomite refractories	2.800	0.006	0.021	0.021	0.010	0.017	0.0588	0.0588	0.028
Lime	1.050	0.100	0.110	0.110	0.115	0.105	0.116	0.116	0.121
Electric ferro-alloys	3.500	0.015	0.036	0.036	0.036	0.053	0.126	0.126	0.126
BOF steel	1.600	1.000	-	-	-	1.600	-	-	-
EAF steel	2.700	-	1.000	1.000	1.000	-	2.700	2.700	2.700
Total						6.609	5.515	9.879	6.9724

Table 4. Complex labour expenditures for the process route involving BOF steelmaking (Man-hours per tonne)

Denomination of production process	Production Heavy-section rolled products	Medium-section rolled products	Light-section rolled products	Plates	Sheets	Cold-rolled sheets	Section structural alloyed steel
1. Coke and by-product process	0.760	0.750	0.760	0.800	0.79	0.834	0.806
2. Production of sinter and pellets	0.830	0.820	0.830	0.870	0.860	0.810	0.876
3. Blast-furnace ironmaking	0.692	0.682	0.692	0.728	0.714	0.758	0.732
4. BOF steelmaking	1.700	1.670	1.700	1.780	1.756	1.858	1.792
5. Rolling	2.000	2.000	1.950	3.900	2.100	8.200	8.000
6. Scrap preparation	0.222	0.218	0.222	0.234	0.230	0.244	0.234
7. Production of refractories	0.100	0.100	0.100	0.110	0.106	0.114	0.110
8. Production of lime	0.110	0.110	0.110	0.116	0.114	0.122	0.118
9. Repair services	2.150	2.040	2.046	2.422	2.150	2.900	2.810
10. Energy facilities	1.660	1.640	1.650	1.780	1.700	1.840	1.720
11. Transport facilities	1.200	1.120	1.140	1.470	1.180	2.000	1.930
12. General works services	1.600	1.490	1.500	1.930	1.570	2.660	2.570
Total	13.620	12.640	12.700	16.140	13.270	22.440	21.700

according to Astier [9], when the annual output of steel is decreased from 1 million tonnes to 0.5 million tonnes using scrap, labour expenditures increase almost by 7 per cent, with an annual output reduction to 0.2 million tonnes the labour expenditures are doubled. By using pre-reduced pellets (sponge iron) and reducing the annual output of steel from 1 to 0.5 million tonnes, the increase in labour expenditures exceeds 12.5 per cent. According to data of the same author, an increase in the output of steel from 1 to 2 million tonnes per year results in a decrease of more than 30 per cent in labour expenditures for the process route with blast furnaces and basic oxygen furnaces, while an increase in steel output from 1 to 4 million tonnes per year reduces labour expenditures by more than a half.

For determining the industrial and production personnel requirements for newly established iron and steel works in developing countries, the final values of complex labour expenditures (the total and separate production processes, inclusive of repair services, energy and transport facilities and general works services) presented in tables 4 to 7 were multiplied by the given output of final products (as already mentioned, the experts took it to be equal to one million tonnes per year) and the value obtained was divided by the annual working time of one person (about 2,000 man-hours). The experience gained by the Soviet Union in constituting the manning lists for iron and steel works projects in developing countries was then used to determine the percentage of engineers and technicians, as well as of the percentage of clerical staff and workers, and the occupational structure required for different process routes as a whole and for single production processes. The indicated structure is tentative and can be corrected according to local conditions and to an adopted variation of an iron and steel works in a developing country. The required occupational structure was determined in the same manner, with subdivisions into highly skilled, skilled, semi-skilled and unskilled workers for the whole process route and single production processes.

Tables 8 to 11 show the values obtained for industrial and production personnel requirements for different process routes. Values for the required industrial and production personnel for the BOF steelmaking process route correspond to similar values for the same process route designed in the USSR for developing countries. For the production of 1 million tonnes per year of rolled products, the personnel requirements in the design of iron and steel works in India are as follows: 380 for the coke and by-product process (plant in Vizakhapatnam); 691 (plant in Burmpur); 976 (plant in Bhilai). These figures may be compared with the 477 required for iron and steel works in Karachi, Pakistan, and the 442 in the design of the iron and steel integrated plant in Ajaokuta, Nigeria. The personnel required for sintering vary from 284 to 423 and in table 8 include industrial and production personnel for pelletizing. The personnel requirements for the production of one million tonnes per year of rolled products in the above-mentioned iron and steel works are as follows: 327 to 517 for blast-furnace ironmaking; 727 to 822 people for BOF steelmaking; 944 to 1,593 for rolling; 108 to 113 for scrap preparation; 97 to 269 for refractories; and 832 to 1,248 for energy facilities. The figures for repairs, transport facilities and general works for the process routes as a whole are similar to those given above. The values presented in tables 9 to 11 were obtained by computing on the basis of the complex labour expenditures indicated in tables 5 to 7. They reflect the values for process routes in EAF steelmaking based on different charge materials. Such routes are typical for mini-works.

The advantage of the process route in EAF steelmaking based on scrap as compared with the process route in BOF steelmaking is the absence of the coke and by-product process and smaller industrial and production personnel

Table 5. Complex labour expenditures for the process route involving EAF steelmaking on the basis of scrap
(Man-hours per tonne)

Denomination of production process	Production						
	Heavy-section rolled products	Medium-section rolled products	Light-section rolled products	Plates	Sheets	Cold-rolled sheets	Section structural alloyed steel
1. Scrap preparation	0.722	0.710	0.722	0.760	0.748	0.790	0.764
2. EAF steelmaking	2.862	2.820	2.862	3.008	2.964	3.134	3.024
3. Rolling	2.600	2.000	1.950	3.900	2.100	8.200	8.000
4. Production of refractories	0.392	0.360	0.392	0.384	0.378	0.400	0.386
5. Production of lime	0.122	0.120	0.122	0.128	0.126	0.128	0.128
6. Repair services	1.486	1.396	1.404	1.794	1.472	2.606	2.412
7. Energy facilities	1.700	1.674	1.694	1.722	1.752	2.058	1.788
8. Transport facilities	0.900	0.830	0.830	1.074	0.866	1.584	1.498
9. General works services	1.200	1.100	1.100	1.424	1.156	2.100	2.000
Total	11.984	11.010	11.076	14.244	11.562	21.000	20.000

Table 6. Complex labour expenditures for the process route involving EAF steelmaking on the basis of sponge iron (Man-hours per tonne)

Denomination of production process	Production						
	Heavy-section rolled products	Medium-section rolled products	Light-section rolled products	Plates	Sheets	Cold-rolled sheets	Section structural alloyed steel
1. Production of pellets	0.690	0.680	0.690	0.724	0.714	0.754	0.728
2. Production of prereduced pellets	2.120	2.088	2.120	2.228	2.196	2.322	2.24
3. EAF steelmaking	2.862	2.820	2.862	3.000	2.964	3.134	3.024
4. Rolling	2.600	2.000	1.950	3.900	2.100	8.200	8.000
5. Production of refractories	0.378	0.360	0.366	0.384	0.378	0.400	0.386
6. Production of lime	0.122	0.120	0.122	0.128	0.126	0.128	0.130
7. Repair services	1.982	1.870	1.888	2.210	2.108	3.010	2.916
8. Energy facilities	2.780	2.714	2.776	3.058	2.840	3.030	2.930
9. Transport facilities	1.386	1.302	1.316	1.592	1.372	2.078	2.020
10. General works services	1.850	1.740	1.760	2.120	1.830	2.770	2.686
Total	16.770	15.684	14.895	19.344	16.528	25.826	25.060

Table 7. Complex labour expenditures for the process route involving EAF steelmaking on the basis of 25 per cent sponge iron and 75 per cent scrap
(Man-hours per tonne)

Denomination of production process	Production Heavy-section rolled products	Medium-section rolled products	Light-section rolled products	Plates	Sheets	Cold-rolled sheets	Section structural alloyed steel
1. Scrap preparation	0.590	0.590	0.590	0.620	0.610	0.646	0.624
2. Production of sinter and pellets	0.222	0.220	0.222	0.234	0.222	0.240	0.234
3. Production of prereduced pellets	0.530	0.522	0.530	0.556	0.548	0.560	0.560
4. EAF steelmaking	2.862	2.820	2.862	3.008	2.964	3.134	3.024
5. Rolling	2.600	2.000	1.950	3.900	2.100	8.200	8.000
6. Production of refractories	0.382	0.380	0.382	0.404	0.398	0.420	0.406
7. Production of lime	0.128	0.126	0.128	0.134	0.132	0.140	0.136
8. Repair services	1.520	1.402	1.444	1.966	1.530	2.498	2.526
9. Energy facilities	2.000	1.972	2.000	2.070	2.050	2.200	2.124
10. Transport facilities	1.032	0.944	0.930	1.232	1.008	1.694	1.654
11. General works services	1.376	1.278	1.286	1.632	1.342	2.258	2.206
Total	13.242	12.252	12.324	15.756	12.904	21.890	21.494

Table 8. Industrial and production personnel requirements for the process route involving BOF steelmaking

Denomination of production process	Production (1 million tonnes)													
	Heavy-section rolled products		Medium-section rolled products		Light-section rolled products		Plates		Sheets		Cold-rolled sheets		Section structural alloyed steel	
	Men	Percentage of total	Men	Percentage of total	Men	Percentage of total	Men	Percentage of total	Men	Percentage of total	Men	Percentage of total	Men	Percentage of total
1. Coke and by-product process	380	5.7	375	5.9	380	6.0	400	4.9	395	6.0	417	3.7	403	3.7
2. Production of sinter and pellets	415	6.1	410	6.4	415	6.5	435	5.4	430	6.5	455	4.1	438	4.0
3. Blast-furnace ironmaking	346	5.1	341	5.4	346	5.5	346	4.5	357	5.4	379	3.4	366	3.4
4. BOF steelmaking	850	12.5	835	13.2	850	13.4	890	11.0	878	13.2	929	8.3	896	8.4
5. Rolling	1 300	19.0	1 000	15.8	975	15.4	1 950	23.8	1 050	15.8	4 100	36.5	4 000	36.9
6. Scrap preparation	111	1.6	109	1.7	111	1.7	117	1.4	115	1.7	122	1.1	117	1.1
7. Production of refractories	50	0.7	50	0.8	50	0.8	55	0.7	53	0.8	57	0.5	55	0.5
8. Production of lime	55	0.8	55	0.9	55	0.9	58	0.8	57	0.9	61	0.5	59	0.5
9. Repair services	1 075	15.7	1 020	16.1	1 023	16.1	1 211	14.8	1 075	16.2	1 450	12.9	1 405	12.9
10. Energy facilities	830	12.3	820	13.0	825	13.0	890	10.9	850	12.8	920	8.2	860	7.9
11. Transport facilities	600	8.8	560	8.9	570	8.9	735	9.0	590	8.9	1 000	8.9	965	8.9
12. General works services	800	11.7	745	11.9	750	11.8	965	11.8	785	11.8	1 330	11.9	1 285	11.8
Total	6 810	100.0	6 320	100.0	6 350	100.0	8 170	100.0	6 635	100.0	11 220	100.0	10 850	100.0

Table 9. Industrial and production personnel requirements for the process route involving EAF steelmaking

Denomination of production process	Production (1 million tonnes)													
	Heavy-section rolled products		Medium-section rolled products		Light-section rolled products		Plates		Sheets		Cold-rolled sheets		Section structural alloyed steel	
	Men	Percentage of total	Men	Percentage of total	Men	Percentage of total	Men	Percentage of total	Men	Percentage of total	Men	Percentage of total	Men	Percentage of total
1. Scrap preparation	361	6.1	355	6.4	361	6.5	380	5.4	374	6.5	395	3.8	382	3.8
2. EAF steelmaking	1 431	23.9	1 410	25.6	1 431	25.8	1 504	21.1	1 482	25.6	1 567	14.9	1 512	15.1
3. Rolling	1 300	21.7	1 000	18.2	975	17.6	1 950	27.4	1 050	18.2	4 100	39.1	4 000	40.0
4. Production of refractories	196	3.3	180	3.3	196	3.6	192	2.7	189	3.3	200	1.9	193	1.9
5. Production of lime	61	1.0	60	1.1	61	1.1	64	0.9	63	1.1	64	0.6	64	0.7
6. Repair services	743	12.4	698	12.7	702	12.7	897	12.6	736	12.7	1 303	12.4	1 206	12.1
7. Energy facilities	850	14.2	837	15.2	847	15.3	886	12.4	876	15.1	1 029	9.8	894	8.9
8. Transport facilities	450	7.4	415	7.5	415	7.5	537	7.5	433	7.5	792	7.5	749	7.5
9. General works services	600	10.0	550	10.0	550	9.9	712	10.0	578	10.0	1 050	10.0	1 000	10.0
Total	5 992	100.0	5 505	100.0	5 536	100.0	7 122	100.0	5 781	100.0	10 500	100.0	10 000	100.0

Table 10. Industrial and production personnel requirements for the process route involving EAF steelmaking on the basis of sponge iron

Denomination of production process	Production (1 million tonnes)													
	Heavy-section rolled products		Medium-section rolled products		Light-section rolled products		Plates		Sheets		Cold-rolled sheets		Section structural alloyed steel	
	Men	Percentage of total	Men	Percentage of total	Men	Percentage of total	Men	Percentage of total	Men	Percentage of total	Men	Percentage of total	Men	Percentage of total
1. Production of pellets	345	4.1	340	4.3	345	4.4	362	3.7	357	4.3	377	2.9	364	2.9
2. Production of sponge iron	1 060	12.6	1 044	13.3	1 060	13.4	1 114	11.5	1 098	13.3	1 161	9.0	1 120	8.9
3. EAF steelmaking	1 431	17.1	1 405	17.9	1 431	18.1	1 500	15.5	1 432	17.3	1 567	12.1	1 512	12.1
4. Rolling	1 300	[illegible]	000	12.8	975	12.3	1 950	20.2	1 050	12.7	4 100	31.8	4 000	31.9
5. Production of refractories	189	[illegible]	180	2.3	183	2.3	192	2.0	189	2.3	200	1.5	193	1.5
6. Production of lime	61	0.7	60	0.8	61	0.8	64	0.7	63	0.8	64	0.5	65	0.5
7. Repair services	991	11.8	935	11.9	944	11.9	1 105	11.4	1 054	12.8	1 505	11.7	1 458	11.6
8. Energy facilities	1 390	16.6	1 357	17.3	1 388	17.5	1 529	15.8	1 420	17.2	1 515	11.7	1 465	11.7
9. Transport facilities	693	8.3	651	8.3	658	8.3	796	8.2	686	8.3	1 039	8.0	1 010	8.1
10. General works facilities	925	11.0	870	11.1	880	11.1	1 060	11.0	915	11.1	1 385	10.7	1 343	10.7
Total	6 385	100.0	7 842	100.0	7 925	100.0	9 672	100.0	8 264	100.0	12 913	100.0	12 530	100.0

Table 11. Industrial and production personnel requirements for the process route involving EAF steelmaking on the basis of 25 per cent sponge iron and 75 per cent scrap

Denomination of production process	Production (1 million tonnes)													
	Heavy-section rolled products		Medium-section rolled products		Light-section rolled products		Plates		Sheets		Cold-rolled sheets		Section structural alloyed steel	
	Men	Percentage of total	Men	Percentage of total	Men	Percentage of total	Men	Percentage of total	Men	Percentage of total	Men	Percentage of total	Men	Percentage of total
1. Scrap preparation	295	4.5	295	4.8	295	4.8	310	3.9	305	4.7	323	2.9	312	2.9
2. Production of sinter and pellets	111	1.7	110	1.8	111	1.8	117	1.5	111	1.7	120	1.1	117	1.1
3. Production of sponge iron	265	4.0	261	4.8	265	4.3	278	3.5	274	4.1	280	2.5	280	2.6
4. EAF steelmaking	1 431	21.6	1 409	23.0	1 431	23.2	1 504	19.1	1 482	23.0	1 567	14.3	1 512	14.1
5. Rolling	1 300	19.6	1 000	16.4	975	15.8	1 950	24.8	1 050	16.3	4 100	37.3	4 000	37.2
6. Production of refractories	191	2.9	190	3.1	191	3.1	202	2.6	199	3.1	210	1.9	203	1.9
7. Production of lime	64	0.9	63	1.0	64	1.0	67	0.8	66	1.0	70	0.6	68	0.6
8. Repair services	760	11.5	701	11.4	722	11.7	983	12.5	765	11.9	1 249	11.4	1 263	11.8
9. Energy facilities	1 000	15.1	986	16.1	1 000	16.2	1 035	3.1	1 025	15.9	1 100	10.0	1 062	9.9
10. Transport facilities	516	7.8	472	7.7	475	7.7	616	7.8	504	7.8	847	7.7	827	7.7
11. General works facilities	688	10.4	639	10.4	643	10.4	816	10.4	671	10.4	1 129	10.3	1 103	10.2
Total	6 627	100.0	6 126	100.0	6 172	100.0	7 878	100.0	6 452	100.0	10 995	100.0	10 747	100.0

requirements (8 per cent less). The biggest industrial and production personnel requirements are characteristic of the process route of EAF steelmaking based on sponge iron. In this process route almost 25 per cent of the total industrial and production personnel are required for pelletizing.

In preparing the qualification list of personnel required for iron and steel works of developing countries it is useful to consider particular products in detail and to indicate differences for other products. It is also advisable for developing countries to consider this qualification list for the production of light-section rolled products.

II. QUALIFICATION LIST OF PERSONNEL REQUIRED FOR IRON AND STEEL INDUSTRIES OF DEVELOPING COUNTRIES

The following qualification description are used in manning lists of single plants and production processes of iron and steel works in developing countries:

Managers (plant and department managers, heads of services, managers and their deputies);

Engineers and technicians (section and shift supervisors, general foremen and foremen, controllers, steelmakers, rollermen);

Clerical staff (office superintendents, typists, bookkeepers etc.).

The workers are subdivided into:

Highly skilled workers (operators of hot stoves, evaporative cooling plants, iron casting machines; steelmaker helpers, chargemen, casters, heaters etc.);

Skilled workers (furnace attendants, operators of cranes, excavators bulldozers and bins; fitters and riggers, greasers, electricians, recordkeepers, conveyer and furnace operators, welders etc.);

Semi-skilled workers (operators of duct collectors, conveyor attendants, workers for preparation of raw materials, tar, lime, troughs, tuyeres etc.);

Unskilled workers (messengers, handymen etc.).

These workers are classed into workers having secondary vocational education, those having general secondary education and those without secondary education but able to read and write.

This system was applied by the M.N. Dastur firm for manning lists of plants and services in Vizakhapatnam, India.

The results of computations of the occupational structure required to meet the need for industrial and production personnel for production of light-section rolled products for the process route involving BOF steelmaking are presented in table 12. The data contained in the table show that the share of engineers and technicians in the total number of employees is 12.4 per cent (790 people), including 4.1 per cent of engineers (260) and 8.3 per cent of technicians (530). This is considered to be a good ratio for iron and steel works in developing countries. For an iron and steel works of this route it is necessary to have 34 specialists on coking industry by-products

Table 12. Occupational structure of industrial and production personnel requirements for the process route involving BOF steelmaking in the production of 1 million tonnes per year of light-section rolled products
(Numerator: number of people; denominator: percentage of total)

Denomination of production process	Total needs for personnel	Engineers and technicians	Engineers	Technicians	Mechanics	Electricians	Clerical staff	Workers
1. Coke and by-product process	380	48/12.6	16/4.2	32/8.4	10/2.5	4/1.1	8/2.0	324/85.4
2. Production of sinter and pellets	415	32/7.7	11/2.5	21/5.2	6/1.4	5/1.1	9/2.1	374/90.2
3. Blast-furnace ironmaking	346	35/10.0	12/3.4	23/6.6	3/0.8	3/0.8	5/1.4	306/88.6
4. BOF steelmaking	850	60/7.0	20/2.3	40/4.7	5/0.6	5/0.6	10/1.2	780/91.8
5. Rolling	975	90/9.3	30/3.1	60/6.2	10/1.0	7/0.7	18/1.9	867/88.8
6. Scrap preparation	111	8/7.0	3/2.0	5/5.0	8/7.0	-	3/3.0	100/90.0
7. Production of refractories	50	4/7.0	1/3.0	3/4.0	1/0.6	1/0.5	1/2.4	45/90.6
8. Production of lime	55	4/7.0	1/3.0	3/4.0	1/0.6	1/0.5	1/2.4	50/90.6
9. Repair services	1 023	72/7.1	24/2.4	48/4.7	72/7.1	-	20/2.0	931/90.9
10. Energy facilities	925	165/20.0	55/6.3	110/12.7	-	58/7.0	16/2.0	644/78.0
11. Transport facilities	570	69/12.2	23/4.1	46/8.1	69/12.2	-	36/6.4	465/81.2
12. General plant services	750	203/27.0	68/9.0	135/18.0	75/10.0	60/8.0	172/23.0	375/50.0
Total	6 350	790/12.4	260/4.1	530/8.3	260/4.1	144/2.3	299/4.7	5 261/82.9

with higher or secondary education, 260 specialist mechanics, 4 specialists in refractories and 144 specialist electricians. For an enterprise with an output of 1 million tonnes per year of rolled products it is necessary to have 299 men of clerical staff and 5,261 workers.

Tables 13, 14 and 15 show occupational structures required for process routes involving EAF steelmaking based on scrap (75 per cent) and sponge iron (25 per cent).

A variant for EAF steelmaking based on scrap requires the smallest number of specialists (697 people), and in this case there is no need for specialists on coking industry by-products. A smaller number of specialist mechanics and electricians is needed.

The maximum number of specialists is required for an alternative involving EAF steelmaking based on sponge iron and requiring 1,046 people. For implementation of this alternative, as demonstrated by the computations of the experts, it is necessary to have a bigger number of specialist mechanics (274), electricians (202) and heat engineers and technicians (181). A larger number of energy engineers and technicians is required as compared with EAF steelmaking based on scrap (their share is increased in this case from 15.3 per cent up to 16.6 per cent), though the percentage of specialist electro-metallurgists is reduced (from 25.8 per cent to 18.1 per cent) as well as that of rolling specialists (from 17.6 per cent to 12.3 per cent).

The maximum number of clerical staff (353) is required for an alternative with EAF steelmaking based on sponge iron, and the smallest number of clerical staff (237) is required for EAF steelmaking based on scrap.

The highest percentage of workers in the occupational structure for industrial and production personnel is characteristic for the process route involving EAF steelmaking based on scrap (83.1 per cent) and the lowest percentage (82.3 per cent) for the process route involving EAF steelmaking based on sponge iron.

Tables 16 to 19 show the results of computations of the occupational structure of personnel for the production of light-section rolled products by process routes being investigated by the experts. According to this structure, the share of highly-skilled and skilled personnel is about three fourths of the total labour requirements. The share of semi-skilled personnel constitutes from 7.1 per cent for the process route involving EAF steelmaking based on scrap to 8.5 per cent for the process route involving BOF steelmaking. The lowest percentage of unskilled workers (16.8 per cent) is for the process route with BOF steelmaking, and the highest percentage (17.8 per cent) is for the process route involving EAF steelmaking based on sponge iron.

From the standpoint of general characteristics of workers of the iron and steel industry, the Soviet Union job evaluation system has great potential, characterized by a unified six-category wage-scale according to which the qualifications of a worker or the complexity of the work performed by him are established [10].

Annex II gives the characteristics of workers of iron and steel works comprising the whole process route with indication of working grades corresponding to their qualification.

Table 13. Occupational structure of industrial and production personnel requirements for the process route involving EAF steelmaking on the basis of scrap for the production of 1 million tonnes per year of light-section rolled products
(Numerator: number of people; denominator: percentage of total)

Denomination of production process	Total needs for personnel	Engineers and technicians	Engineers	Technicians	Mechanics	Electricians	Clerical staff	Workers
1. Scrap preparation	361	26/7.0	8/2.5	18/4.5	26/7.0	-	11/3.0	324/90.0
2. EAF steelmaking	1 431	143/10.0	47/3.3	96/6.7	14/1.0	14/1.0	17/1.2	1 271/88.8
3. Rolling	975	90/9.3	30/3.1	60/6.2	10/1.0	7/0.7	18/1.9	867/88.8
4. Production of refractories	196	14/7.0	5/2.5	9/4.5	1/0.6	1/0.5	5/2.4	177/90.6
5. Production of lime	61	4/7	1/2.5	3/4.5	1/0.6	1/0.5	2/2.4	55/9.4
6. Repair services	702	50/7.1	11/2.4	33/4.7	50/7.1	-	14/2.0	638/90.9
7. Energy facilities	847	170/20.0	56/6.7	114/13.3	-	60/7.0	17/2.0	660/78.0
8. Transport facilities	415	51/12.2	17/4.1	34/8.1	51/12.2	-	27/6.4	337/81.4
9. General works services	550	149/27.0	50/9.0	99/18	55/10.0	44/8.0	126/23.0	275/50.0
Total	5 538	697/12.6	231/4.2	466/8.4	208/3.7	127/2.3	237/4.3	4 604/83.1

Table 14. Occupational structure of industrial and production personnel requirements for the process route involving EAF steelmaking on the basis of sponge iron for the production of 1 million tonnes per year of light-section rolled products
(Numerator: number of people; denominator: percentage of total)

Denomination of production process	Total needs for personnel	Engineers and technicians	Engineers	Technicians	Mechanics	Electricians	Clerical staff	Workers
1. Production of pellets	345	27/7.7	9/2.5	18/5.2	5/1.4	4/1.1	7/2.1	311/90.2
2. Production of prereduced pellets	1 060	106/10.0	36/3.3	70/6.7	8/0.8	8/0.8	15/1.4	939/88.6
3. EAF steelmaking	1 431	143/10.0	47/3.3	96/6.7	14/1.0	14/1.0	17/1.2	1 371/88.8
4. Rolling	975	90/9.3	30/3.1	60/6.2	10/1.0	7/0.7	18/1.9	867/88.8
5. Production of refractories	183	13/7.0	5/2.5	8/4.5	1/0.6	1/0.5	4/2.4	166/90.6
6. Production of lime	61	4/7.0	1/2.5	3/4.5	1/0.6	1/0.5	2/2.4	55/9.4
7. Repair services	944	67/7.1	23/2.4	45/4.7	67/7.1	-	18/2.0	859/90.9
8. Energy facilities	1 388	278/20.0	88/6.7	190/13.3	-	97/7.0	28/2.0	1 082/78.0
9. Transport facilities	658	80/12.2	27/4.1	53/8.1	80/12.2	-	42/6.4	536/81.4
10. General works services	880	238/27.0	79/9.0	159/18.0	88/10.0	70/8.0	202/23.0	440/50.0
Total	7 925	1 046/13.2	345/4.4	701/8.8	274/3.5	202/2.5	353/4.5	6 526/82.3

Table 15. Occupational structure of industrial and production personnel requirements for the process route involving EAF steelmaking on the basis of 25 per cent sponge iron and 75 per cent scrap for the production of 1 million tonnes per year of light-section rolled products
(Numerator: number of people; denominator: percentage of total)

Denomination of production process	Total needs for personnel	Engineers and technicians	Engineers	Technicians	Mechanics	Electricians	Clerical staff	Workers
1. Scrap preparation	295	21/7.0	7/2.5	14/4.5	21/7.0	-	6/3.0	268/90.0
2. Production of sinter pellets	111	9/7.7	3/2.5	6/5.2	2/1.4	1/1.1	2/2.1	100/90.2
3. Production of preroduced pellets	265	27/10.0	9/3.3	18/6.7	2/0.8	2/0.8	4/1.4	234/88.6
4. EAF steelmaking	1 431	143/10.0	47/3.3	96/6.7	14/1.0	14/1.0	17/1.2	1 271/88.8
5. Rolling	975	90/9.3	30/3.1	60/6.2	10/1.0	7/0.7	18/1.9	867/88.8
6. Production of refractories	191	13/7.0	5/2.5	8/4.5	1/0.6	1/0.5	5/2.4	173/90.6
7. Production of lime	64	5/7.0	2/2.5	3/4.5	1/0.6	1/0.5	2/2.4	57/9.4
8. Repair services	722	51/7.1	17/2.4	34/4.7	51/7.1	-	14/2.0	657/90.9
9. Energy facilities	1 000	200/20.0	67/6.7	133/13.3	-	70/7.0	20/2.0	780/78.0
10. Transport facilities	475	58/12.2	19/4.1	39/8.1	58/12.2	-	30/6.4	387/81.4
11. General works services	643	174/27.0	58/9.0	116/18.0	64/10.0	51/8.0	148/23.0	321/50.0
Total	6 172	791/12.8	264/4.3	527/8.5	224/3.5	147/2.4	266/4.3	5 115/82.9

Table 16. Occupational structure of the requirements for working personnel for the process route involving BOF steelmaking for the production of 1 million tonnes per year of light-section rolled products
(Numerator: number of people; denominator: percentage of total)

Description of production	Requirements for workers	Highly skilled	Skilled	Semi-skilled	Un-skilled
1. Coke and by-product process	324	48 14.9	174 53.7	46 14.1	56 17.3
2. Production of sinter and pellets	374	45 11.9	166 44.4	82 22.0	81 21.7
3. Blast-furnace ironmaking	306	31 10.0	186 60.8	38 12.6	51 16.6
4. BOF steelmaking	780	160 20.5	440 56.4	65 8.4	115 14.7
5. Rolling	867	133 15.3	537 62.0	84 9.7	113 13.0
6. Scrap preparation	100	6 5.8	72 71.9	6 5.8	16 16.5
7. Production of refractories	45	5 11.4	24 52.4	1 1.2	15 35.0
8. Production of lime	50	6 11.4	26 52.4	1 1.2	17 35.0
9. Repair services	931	76 8.2	705 75.7	10 1.1	140 15.0
10. Power facilities	644	113 17.6	308 47.7	82 12.8	141 21.9
11. Transport facilities	465	93 20.0	256 55.0	23 5.0	93 20.0
12. General works services	375	94 25.0	225 50.0	8 2.0	48 13.0
Total	5 261	810 15.4	3 119 59.3	446 8.5	886 16.8

Table 17. Occupational structure of the requirements for working personnel for the process route involving EAF steelmaking on the basis of scrap for the production of 1 million tonnes per year of light-section rolled products (Numerator: number of people; denominator: percentage of total)

Description of production	Requirements for workers	Highly skilled	Skilled	Semi-skilled	Unskilled
1. Scrap preparation	324	19 5.8	233 71.9	19 5.8	53 16.5
2. EAF steelmaking	1 271	261 20.5	716 56.4	107 8.4	187 14.7
3. Rolling	867	133 15.3	538 62.0	84 9.7	112 13.0
4. Production of refractories	177	20 11.4	93 52.4	2 1.2	62 35.0
5. Production of lime	55	6 11.4	29 52.4	1 1.2	19 35.0
6. Repair services	638	52 8.2	483 75.7	7 1.1	96 15.0
7. Power facilities	660	116 17.6	315 47.7	84 12.8	145 21.9
8. Transport facilities	337	67 20.0	186 55.0	17 5.0	67 20.0
9. General works services	275	69 25.0	164 60.0	6 2.0	36 13.0
Total	4 604	743 16.1	2 757 59.9	327 7.1	777 16.9

Table 18. Occupational structure of the requirements for working personnel for the process route involving EAF steelmaking on the basis of sponge iron for the production of 1 million tonnes per year of light-section rolled products
(Numerator: number of people; denominator: percentage of total)

Description of production	Requirements for workers	Highly skilled	Skilled	Semi-skilled	Un-skilled
1. Production of pellets	311	37 11.9	138 44.4	68 22.0	68 21.7
2. Production of pre-reduced pellets (sponge iron)	939	141 15.0	516 55.0	94 10.4	188 20.0
3. EAF melting	1 271	261 20.5	716 56.4	107 7.4	187 14.7
4. Rolling	867	133 15.3	538 62.0	84 9.7	112 13.0
5. Production of refractories	166	19 11.4	87 52.4	2 1.2	58 35.0
6. Production of lime	55	6 11.4	29 52.4	1 1.2	19 35.0
7. Repair services	859	70 8.2	650 75.7	10 1.1	129 15.0
8. Power facilities	1 082	190 17.6	516 47.7	138 12.8	238 21.9
9. Transport facilities	536	107 20.0	295 55.0	27 5.0	107 20.0
10. General works services	440	110 25.0	264 60.0	9 2.0	57 13.0
Total	6 526	1 074 16.5	3 749 57.4	540 8.3	1 163 17.8

Table 19. Occupational structure of the requirements for working personnel for the process route involving EAF steelmaking on the basis of 25 per cent sponge iron and 75 per cent scrap for the production of 1 million tonnes per year of light-section rolled products (Numerator: number of people; denominator: percentage of total)

Description of production	Requirements for workers	Highly skilled	Skilled	Semi-skilled	Un-skilled
1. Scrap preparation	268	16 5.8	192 71.9	16 5.8	44 16.5
2. Production of sinter and pellets	100	12 11.9	44 44.4	22 22.0	22 21.7
3. Production of pre-reduced pellets	234	35 15.0	129 55.0	23 10.0	47 20.0
4. EAF melting	1 271	260 20.5	717 56.4	107 8.4	187 14.7
5. Rolling	867	133 15.3	537 62.0	84 9.7	113 13.0
6. Production of refractories	173	20 11.4	91 52.4	2 1.2	60 35.0
7. Production of lime	57	6 11.4	30 52.4	1 1.2	20 35.0
8. Repair services	657	54 8.2	497 75.7	7 1.1	99 15.0
9. Power facilities	780	137 17.6	372 47.7	100 12.8	171 21.9
10. Transport facilities	387	77 20.0	213 55.0	20 5.5	77 20.0
11. General works services	321	80 25.0	193 60.0	6 2.0	42 13.0
Total	5 115	830 16.2	3 015 58.9	388 7.6	882 17.3

III. METHODOLOGY OF DESIGNING PROGRAMMES OF MANPOWER TRAINING FOR IRON AND STEEL INDUSTRY

Due to the complexity of the iron and steel production, a large number of different specialists at varying levels of higher and secondary technical education are needed as well as workers of various trades.

The actual output of the iron and steel production imposes specific organizational requirements and ratios of executors of different categories participating in the work.

The principal document defining the requirements for the training of engineers, technicians and workers is the qualification characteristics (profile) of a speciality or trade.

The qualification characteristic includes the following provisions: designation of a specialist or a worker; general requirements for a specialist or a worker; and necessary knowledge and skills of a specialist or a worker.

In the Soviet Union the training of personnel with a higher education in the field of iron and steel industry is carried out in the following specialities: iron and steel metallurgy; heat engineering and automation of metallurgical furnaces; foundry of ferrous and non-ferrous metals and alloys; physical and chemical study of metallurgical processes; physics of metals; physical metallurgy equipment and practice of heat treatment of metals; plastic working of metals; metallurgy and techniques of welding; economics and organization of the iron and steel industry; collection and utilization of dust and gas; and powder metallurgy and sprayed-on coats.

The period of training in all specialities is 4 years and 10 months. The training is carried out on the basis of a ten-year secondary general education. A graduate is a qualified engineer-metallurgist in a particular speciality.

The training of personnel with secondary specialized technical education is carried out in the following specialities: blast-furnace ironmaking; steelmaking; electrometallurgy of steel and ferroalloys; dust collection and cleaning of process and ventilation gases; foundry of ferrous metals; foundry of non ferrous metals and alloys; secondary metal production process; physical metallurgy and heat-treatment of metals; rolling; wire, sizing and wire rope production; forging and stamping; ore sintering; powder metallurgy and hard alloy production; treatment of cermet products.

The period of training in all specialities comprises two levels.

Level I. The period of training is 3 years and 10 months. The training is carried out on the basis of 8 years of secondary general education.

Level II. The period of training is 2 years and 8 months. The training is carried out on the basis of 10 years of secondary general education.

A graduate is a qualified technician-metallurgist or technologist in a particular speciality.

The period of training in all working trades comprises three levels [11].

Level I. The period of training is 1 year. The training is carried out on the basis of a ten-year secondary general education. Upon graduating from the training institution a person is given category 3-6.

Level II. The period of training is 2 years. The training is carried out on the basis of 8 years of a ten-year secondary general education. A person is given category 3-5 upon graduating from the training institution.

Level III. The period of training is 3 years. The training is carried out on the basis of 8 years of a ten-year secondary general education. Upon graduating from the training institution a person is given category 3-6 and receives a document entitling him to enter a higher educational institution.

The specialities and trades from the given list should be chosen according to the needs of the iron and steel industry of the country. The less the output of the iron and steel production of the country, the smaller should be the list of specialists and trades which are required for it due to the widening of the profile through combining specialities.

Annex III gives two qualification characteristics in specialities of metallurgical production.

The curriculum of each type of training includes a list and the scope of the subject to be studied, which in the aggregate define the profile of training in the given speciality or trade [12]. The list of subjects is established on the basis of the required qualification characteristics and existing experience in training.

In the curriculum of each type of training the subjects are grouped into certain cycles establishing the objective of the cycle in the training process. The volume of obligatory lecture-hall studies under a cycle or on a single subject is divided into theoretical and practical forms of training, in-plant training and training practicals.

The theoretic training comprises lectures in higher educational institutions and lessons at secondary specialized training establishments and vocational and technical schools. The practical training comprises laboratory work, practical exercises, seminars, course projects and on-the-job training. The length of training between examinations is established by terms (semesters).

The standard curricula for training specialists with higher and specialized secondary technical education and workers in ferrous metallurgy trades are presented below.

Cycles of the curriculum of an engineer-metallurgist
(Period of training: 4 years 10 months;
length of studies: 10 terms)

	Total hours	Theoretical training	Practical training
1. General education cycle (1st, 2nd, 3rd, 4th terms)	350	-	350
2. Social cycle (1st, 2nd, 3rd, 4th, 5th, 6th, 7th, 8th, 9th terms)	430	220	210
3. General science cycle (1st, 2nd, 3rd terms)	730	340	390
4. Chemical cycle (1st, 2nd, 3rd, 4th terms)	300	130	170
5. General engineering cycle (1st, 2nd, 3rd, 4th, 5th terms)	400	200	200
6. General metallurgic cycle (3rd, 4th, 5th, 6th, 7th, 8th, 9th terms)	1 200	800	400
7. Organization and economics cycle (7th, 8th, 9th terms)	200	150	50
8. Specialization cycle (6th, 7th, 8th, 9th terms)	500	280	220
Total:	[illegible]10	2 120	1 990

Practical work

1. Study visits, 2nd term, 4 weeks.
2. Technological practice, 6th terms, 7 weeks.
3. Specialization practice, 8th term, 7 weeks.
4. Pre-diploma practice, 10th term, 6 weeks.

Total: 24 weeks

Cycles of the curriculum of a technician-metallurgist

(Period of training: 3 years 10 months;
length of studies: 8 terms)

	Total hours	Theoretical training	Practical training
1. General education cycle (1st, 2nd, 3rd, 4th, 5th, 6th terms)	1 200	1 160	40
2. Socio-economic cycle (1st, 2nd, 3rd, 4th, 5th, 6th, 8th terms)	360	360	-
3. General engineering cycle (1st, 2nd, 3rd, 4th terms)	450	270	180
4. General specialization cycle (1st, 2nd, 3rd, 4th, 5th, 6th, 8th terms)	800	530	270
5. Specialization cycle (4th, 5th, 6th, 8th terms)	950	760	190
Total:	3 760	3 080	680

Practical work

1. Practical training:

- in fitter-mechanic skills according to specialization, 2nd term, 4 weeks;
- study tours to plants of iron and steel enterprises, 4th term, 1 week;
- in-plant training in trade, acquaintance and mastering of equipment, 4th term, 3 weeks;
- in mastering working skills, 7th term, 10 weeks.

2. Technological practice, 7th term, 16 weeks.

3. Pre-diploma practice, 8th term, 6 weeks.

Total: 40 weeks

Cycles of the curriculum of a technician-metallurgist

(Period of training: 2 years 8 months;
length of studies: 6 terms)

	Total hours	Theoretical training	Practical training
1. General education cycle (1st, 2nd, 3rd, 4th, 6th terms)	240	240	-
2. Socio-economic cycle (1st, 2nd, 3rd, 4th, 6th terms)	160	160	-
3. General engineering cycle (1st, 2nd terms)	440	260	180
4. General specialization cycle (1st, 2nd, 3rd, 4th, 6th terms)	610	410	200
5. Specialization cycle (2nd, 3rd, 4th, 6th terms)	810	620	190
Total:	2 260	1 690	570

Practical work

1. Practical training:

- in fitter-mechanic skills according to specialization, 2nd term, 4 weeks;
- study tours to plants of iron and steel enterprises, 3rd term, 1 week;
- in-plant training in trade, acquaintance and mastering of equipment, 3rd term, 3 weeks;
- in mastering working skills, 5th term, 11 weeks.

2. Technological practice, 5th term, 14 weeks.

3. Pre-diploma, 6th term, 6 weeks.

Total: 38 weeks.

Cycles of the curriculum for training a worker in trades of metallurgical production

(Period of training: 1 year; duration of training: 2 terms)

	Total hours	Theoretical training	Practical training
1. General education cycle (1st, 2nd terms)	150	150	-
2. Vocational and technical cycle (1st, 2nd terms)	1 510	440	1 070
Total:	1 660	590	1 070

Cycles of the curriculum for training a worker in trades of metallurgical production

(Period of training: 2 years; duration of training: 4 terms)

	Total hours	Theoretical training	Practical training
1. General education cycle (1st, 2nd, 3rd terms)	340	340	-
2. Vocational and technical cycle (1st, 2nd, 3rd, 4th terms)	2 670	610	2 060
Total:	3 010	950	2 060

Cycles of the curriculum for training a worker in trades of metallurgical production

(Period of training: 3 years; duration of training: 6 terms)

	Total hours	Theoretical training	Practical training
1. General education cycle (1st, 2nd, 3rd, 4th, 5th terms)	1 830	1 830	-
2. Vocational and technical cycle (1st, 2nd, 3rd, 4th, 5th, 6th terms)	2 530	650	1 880
Total:	4 360	2 480	1 880

It is evident from the data presented on different curricula that the training time alloted for practical training increases as one passes from the curricula for training engineers to the curricula for training technicians and further to the curricula for training workers. Here it should be noted that training in the form of lessons in secondary specialized technical schools and vocational and technical schools, which comes under theoretical training in the curricula, actually comprises both theoretical study and practical training. Therefore, half of the training time for the theoretical training and all training time for the physical training in the curricula of secondary specialized technical educational establishments and schools should come under practical training in addition to the time allotted for practical training in the curricula.

The training programme is the basis of a subject. It formulates the objective of the training course in accordance with the qualification characteristics. The objective of the course is stated so that the knowledge and skills which are to be acquired by students are indicated, and it is not limited to a simple enumeration of subjects included in the course. The goal of the course is specified according to the knowledge, skills and practical experience to be acquired. The content of the training programme is given in its logical sequence; the topics and lectures are singled out to ensure the logical co-ordination of the knowledge acquired during the whole period of training. A method of representing logical relations between programmes are given in matrices (tables) of logical relations. Matrices are the basis for formulation of objectives of the studies with regard to subject requirements, as well as for excluding material which is not used in teaching and in the activities of graduates.

The training programme contains a list of laboratory works, topics of practical training, homework and course projects which ensure the acquisition of concrete skills and practical experience.

Some examples of the practical skills to be acquired by students are given in annex IV.

The programme of a subject involves various fields of study and its approximate scope is established according to the qualification characteristics of the speciality. The quality of training specialists is determined to a large extent by the optimality of curricula and their conformity with the requirements of scientific and technological progress.

Traditionally, curricula are prepared on the basis of previous experience, without detailed accounting of the logical relationships of subjects and a clear idea of the significance of single courses for a specialist of a given profile.

The Moscow Institute of Steel and Alloys elaborated in 1968 a method of scientifically substantiated preparation of curricula [16-21].

The elaborated method makes it possible objectively to evaluate the significance of each training course to have a well-grounded approach to the distribution of the teaching hours between the training courses.

The scientifically substantiated preparation of a curriculum is based on the qualification characteristics (profile) of a speciality and evaluation of experts. The techniques comprise evaluation of significance of each training course. The significance consists of two components: the external one which reflects quantitatively the significance of the given course for the work of a young specialist and a worker; and the internal one, which reflects the quantitative significance of the training course for studying other training courses stipulated by the curriculum. The internal significance is determined by establishing the quantity and closeness of logical relationships between the given training courses and all other courses for the speciality according to the contents of the training programmes. The quantitative computation of the significance is based on the use of matrices.

The scope of training courses is corrected and the initial contents of training programmes are specified according to the resulting significance (external and internal).

Formerly, preparation of a curriculum started from establishing general science and general engineering subjects without taking into account the objective of studying them in relation to the profile of a specialist to be trained [16, 17].

The drawing-up of curricula according to the techniques under consideration starts from establishing, on the basis of the qualification characteristics of a speciality, a list of special subjects and a list of general engineering subjects necessary for studying the special subjects. The list of general science subjects is prepared with regard to these lists.

The preliminary scope of each training course is determined in accordance with the qualification characteristics and the available training and methodical experience. Formerly the work on preparation of curricula ended at this point and training programmes were drawn up according to the established scopes of the courses.

With the new method it is just a starting-point for drawing up a curriculum which, in this case, is only a basis for further optimization.

Training programmes prepared in conformity with the qualification characteristics and the established scopes are combined in a collection of training programmes for the given speciality. The programmes of training courses are divided into a certain number of sections (themes), the scope of each section being fixed, and each section (theme) is subdivided into lectures. Such collections of training programmes are used for evaluating the significance of each subject for the given specialization, which is determined in the following way. Collections of programmes for a speciality together with a special table of demand are sent to appropriate enterprises and organizations where there are experienced specialists who act as evaluating experts.

The experts give a quantitative evaluation of sections of training programmes and prepare written comments on their structure and contents. These comments are used for defining and specifying the list of problems to be solved by specialists in their practical activity and the scope of theoretical knowledge and practical skills necessary for them to perform their duties. A curriculum should be based on expert evaluation if it is to be organically connected with and to meet the requirements of science and production and the rate of their growth.

Thus, the needs of science, technology and production in expert evaluations are considered as external factors in relation to the teaching process. The expert evaluations of the training programmes determine the external significance of subjects.

Simultaneously with the expert evaluations, teachers and professors establish logical relationships of sections of programmes of different subjects on the basis of a collection of programmes.

Relationships of all material to be studied are fixed in the form of matrices of logical relationships of sections of subjects. Further, the number of logical relationships between the subjects is determined and used as a basis for establishing the internal significance of a subject in relation to the teaching process [18].

A logical relationship is understood as an interconnection of the content of a certain problem with the content of other problems of other sections in other courses, which is necessary for explaining newly introduced concepts, definitions or material. In making such a table a lecturer does not add any work but systematizes the knowledge under his teaching course in respect of its logical relationships with basic courses.

Tables of logical relationships of all subjects are attached to each other according to the order of studying them in the horizontal direction and a square table is formed which is called a summary matrix of a speciality.

The table presents in horizontal lines and vertical columns the same subjects of the curriculum according to the order of study, and the crossings of vertical columns and horizontal lines reflect the logical relationships on the matrix field.

Logical relationships of sections within a subject and with sections of other subjects of the curriculum of the specialization are established [12, 19].

Figure I gives an example of a matrix. This matrix is drawn up for relationships of the lecture programmes of two sections (themes) No. 1 and No. 2 of the teaching programme for the subject, physical chemistry, which is given in Annex IV.

In filling the matrix numbers of sections, an indication is given of where and which material is used. If the material of lecture "K" is used in lecture "M", a unity is put in the square at the crossing of line "K" and column "M". Other squares are not filled in and the total sum of unities is given.

Quantitative computations for establishing new rated scopes of sections and subjects as a whole and computations of the optimum arrangement of sections and subjects within the period of training are carried out on the basis of matrices of relationships and tabulated results of expert evaluations of programmes.

When this work is carried out a close relationship is established between the curriculum and the training programmes in specialization.

Availability of the quantitative expert evaluations of sections and their parts makes it possible to elaborate programmes on an hourly basis and not summary programmes as has previously been the case. Such programmes ensure both the logic of the material to be studied and its conformity with the expert evaluation for each section.

Let us consider some matters pertaining to the quantitative evaluation of parameters of the curriculum.

Speciality No 1	Speciality No 2		Number of section where material is used Number of lecture where material is used									
Number of section from which material is used	Number of lecture from which material is used		1	2	3	4	5	6	7	8	9	10
		1							1	1	1	1
		2							1	1	1	1
		3							1	1	1	1
		4							1	1		1
		5							1	1	1	1
		6							1	1	1	1
		7										
		8										
		9										
		10										

Total sum of unities: 23

Figure I. Matrix of logic relationships of sections; speciality - iron and steel metallurgy

Every teacher and professor establishes and fixes in matrices logical relationships of lectures of his subject with each other as well as relationships with the lectures of other subjects of the curriculum. In so doing the relationships are established only with those lectures on which the study of the given lecture is based. Therefore, the matrix of logical relationships of sections is filled in only by separate columns and not by lines.

Consideration of matrices (figure I) by columns reflects individual views of teachers and professors about logical relationships of the subjects taught by them.

If we are to consider an arbitrary line (lecture) of a matrix, the unities put on it at the crossing with respective columns will show numbers of columns (lectures) where the material of this particular lecture line is used. And here it is not an opinion of a teacher or professor delivering a lecture, he may even not know where the material of this lecture is to be used.

It is a collective opinion of his colleagues on the significance of this lecture during the whole period of specialist training, stated by lecturers of other courses in using it as a basic lecture. Such an approach to evaluation of the use of the course excludes subjectivism and reflects the actual state of affairs.

Relationships of the given lecture for using its content in other lectures are called direct relationships (by lines). Relationships of the lecture for using the content of basic lectures are called inverse relationships (by columns).

Each teacher and professor, in establishing logical relationships, does that very thing without detailed knowledge of which a qualified exposition of a subject is impossible. Nevertheless, experience shows that in some cases uncertainties and disputes may arise during establishment of such logical relationships. These relationships should therefore be carefully analysed.

As a result of the drawing-up of a matrix of logical relationships of sections of subjects information is obtained on logical relationships which could not have been known before. If formerly we knew on what the study of each section was based, that is, from which sections information was taken in the form of logical relationships, and for this purpose it was necessary to look at the vertical column of the given section, now in the matrix it is possible to see in which other sections of subjects each section is used. To determine this it suffices to look through a whole horizontal line. It is evident that the analysis of the number of logical relationships of sections of subjects in the matrix makes it possible to judge the degree of correlation of the training process as a whole and to elaborate concrete measures for improving the unity of the training process, including the preparation of specialist training programmes.

Matrices also enable one to analyse the use of lectures on each subject in the training process and its different sections. On this basis it is possible to determine the usefulness of delivering a particular lecture and the scope of each section and of all the subjects.

Knowledge of the use of the content of a section, taken from matrices, makes it possible precisely to formulate objectives of lectures, to select the material properly and to measure the scope of exposition of some problems from the programme of a subject [12].

The matrix of logical relationships of lecture courses on the iron and steel metallurgy (figure II) is described below.

Numbers of lines and columns are referred to subjects. Thirty subjects are to be studied for specialization.

1. Introduction to the speciality. 2. Inorganic chemistry. 3. Engineering graphics. 4. Higher mathematics. 5. Theoretical mechanics. 6. Programming and computers. 7. Physics. 8. Strength of materials. 9. Analytical chemistry. 10. Physical chemistry. 11. Theory of metallurgical processes. 12. Machine parts and materials-handling machines. 13. Metallurgical heat engineering. 14. Electrical engineering and electrical equipment. 15. Physical metallurgy. 16. Plastic metal working. 17. Industrial electronics. 18. Preparation of ores for smelting and ironmaking. 19. Steelmaking and production of ferroalloys. 20. Fundamentals of iron and steel enterprises design. 21. Economics of iron and steel metallurgy. 22. Environmental protection and rational use of natural resources. 23. Application of computers and electronic control systems. 24. Organization and planning of enterprises. 25. Labour protection. 26. Fundamentals of law. 27. Production engineering. 28. New processes of steelmaking and metallurgy of quality steels. 29. Equipment and designing of steelmaking plants and units. 30. Automation of steelmaking processes.

There are numbers in matrix squares which express the number of logical relationships between two interconnected subjects. These values represent sums from matrices of logical relationships of sections (figure I) into which subjects are divided.

Significant elements of the matrix are situated above the main diagonal. Such a matrix is well arranged and makes it possible to determine the order of subjects in accordance with logical relationships.

Methods of determining the quantitative evaluations of curricula on the basis of matrices are given in annex V.

Quantitative computations using formulas 10-30 in annex V provide a basis for drawing up curricula in which the scopes of subjects and their sections are determined by quantitative evaluations according to logical relationships and the knowledge required for work in the given specialization.

The scientifically substantiated preparation of a specialist curriculum and elaboration of training programmes on a scientific basis are carried out according to a certain programme comprising several stages.

A list of special, vocational and technical subjects, of general metallurgical and engineering subjects and of general science subjects and the chemical cycle are determined on the basis of the existing curriculum for a speciality or trade in accordance with the qualification characteristics [20, 21].

Distribution of the total time alloted for training according to the subjects of the curriculum is carried out on the basis of the available experience of teaching them.

The approximate distribution of teaching hours between subjects is specified later on the basis of qualitative and quantitative analyses.

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
											2					7									5				
						4		55	31	54		8				21	10	129			10			8					
							13				5										1								
				165	31	532	19		389	41	18	31	105		27	66	195	76				8	15	14		7	25	47	47
					5		7				20						2												
																8	1	1					3						
							12	12	41	55	21	8	57		21	60	11	53			3			9			15	15	
											17				21		13							4				19	
																	1	23						8			5		
										39		8		75			173	184									78		16
																	106	121									121		
															16			3						4				10	
																	46	119	58		1			12			92	27	4
																46	3	22						7				25	
															29		11	28											
																				17									
																		16	73	14	9	2	11	7					
																			85	44		2	9	6		3	59	63	24
																				9				9				78	
																					7		15	9	2	13		79	
																								4				10	
																							12	5		12			16
																								7	2	13			
																									1	9		68	

Figure II. Matrix of logic relationships of lecture courses on iron and steel metallurgy with specialization in metallurgy of steel

Elaboration of special, general science and general engineering subjects is carried out and necessary corrections of the existing training programmes are made in relation to the established scopes of the subjects and to the required knowledge and skills included in the qualification characteristics. The existing training programmes of subjects should be considered as the initial data for the elaboration and drawing-up of training programmes.

When new specialities and trades appear, the data on programmes for allied specialities and working trades are used in conformity with the requirements of the qualification characteristics.

A logically completed content of a section of the training programme which is to be presented in up to 10 lectures is drawn up as a section (theme). The programme of lectures within a section has an ordinal numbering (1, 2, 3 ... 10) according to the number of lectures in the section.

Then a collection of training programmes for a speciality is made up. The collection contains subjects of the specialization curriculum divided into sections. Each section within one speciality has a system of ordinal numbers (1, 2 ...), where n is the number of sections in specialization subjects.

There are logical relationships between the subjects of the specialization curriculum. The logic of the material to be studied is fixed in the form of matrices of logical relationships of sections (figure I) based on the collection of training programmes for a speciality. Logical relationships are established among sections of a subject and with sections of other subjects in other specialization curricula.

Matrices of logical relationships of sections of the given training course are established with sections of other courses the material of which is necessary for the training course.

A list of material required for studying sections of a subject but not available in the initial programmes is established on the basis of the collection of training programmes for a speciality (stage 4). Needs for additional material are dealt with as required.

A survey is then carried out among specialists as to the evaluation of all training programmes for a speciality. The following are required for carrying out the survey. A collection of training programmes; a questionnaire for specialists.

The range of organizations with specialists working in this field is established. A certain number of collections of training programmes for a speciality and questionnaires are sent to these organizations. A questionnaire contains an instruction on how to fill it out and a return address to which the filled-in questionnaires should be sent.

Computations to determine the scope of sections and subjects and the optimum arrangement of subjects within the training period (by terms) are carried out on the basis of matrices of logical relationships.

Basic indices of the specialization curriculum are then established and training programmes corrected.

A new curriculum and new training programmes are prepared and corrected on the basis of the following: the qualification characteristics of a speciality or a working trade; results of the quantitative analysis of the curriculum and written evaluations of specialists; a collection of training programmes; and requests for subjects.

The results of the quantitative analysis are used in correcting the curriculum (scopes of courses and arrangement by terms) and the training programmes, including those for courses which are unchanged in scope. Requests for subjects and specialist evaluations are used for correcting training programmes.

The volumes of practical types of studies are changed and established in conformity with quantitative evaluations of the theoretical parts of subjects in proportions existing for these subjects and with the qualification characteristics of a speciality or a working trade.

Quantitative computations of basic parameters of the specialization curriculum are carried out by means of electronic computers.

The following three programmes are used in the work [20]: input and check of initial information; determination of cutouts of the directed graph; and quantitative characteristics of curricula (annex VIII).

Programmes are written in programming languages IISI-I, OC, EC.

The curriculum for preparing an engineer in iron and steel metallurgy, with a specialization in the metallurgy of steel, is the result of computing according to the above techniques using the matrix shown in figure II.

Subjects are presented by cycles and terms are given in brackets.

CURRICULUM

Iron and steel metallurgy; specialization: "Metallurgy of steel"

	Total hours	Theory	Practicals
1	2	3	4
<u>General education cycle</u>			
1. Foreign language (1st, 2nd, 3rd, 4th terms)	210	-	210
2. Physical training (1st, 2nd, 3rd, 4th terms)	140	-	140
Total:	250		350
<u>Social science cycle</u>	430	220	210
<u>General science cycle</u>			
3. Higher mathematics (1st, 2nd, 3rd terms)	374	170	204
4. Physics (1st, 2nd, 3rd terms)	272	136	136
5. Programming of computers and calculus methods	85	34	51
Total:	731	340	391

		Total hours	Theory	Practicals
	1	2	3	4
	Chemical cycle			
6.	Inorganic chemistry (1st, 2nd terms)	153	68	85
7.	Physical chemistry (3rd, 4th terms)	153	68	85
	Total:	306	136	170
	General engineering cycle			
8.	Engineering graphics (1st, 2nd terms)	102	17	85
9.	Theoretical mechanics (2nd term)	68	34	34
10.	Applied mechanics (3rd term)	85	51	34
11.	Electrical engineering, electronics, electrical equipment (4th, 5th, 8th terms)	146	96	50
	Total:	401	198	203
	General metallurgical cycle			
12.	Introduction to speciality (1st term)	34	34	-
13.	Crystallography, mineralogy, petrography and radiography (3rd, 4th terms)	51	34	17
14.	Metallurgical heat engineering and heat power engineering (4th, 5th terms)	131	98	43
15.	Experiment designing (4th, 5th terms)	98	49	49
16.	Iron and steel metallurgy (4th, 5th, 6th terms)	200	150	50
17.	Physical metallurgy and heat treatment (5th, 6th terms)	149	99	50
18.	Theory of metallurgical processes (5th term)	80	48	32

	Total hours	Theory	Practicals
1	2	3	4
19. Foundry (5th term)	48	32	16
20. Plastic metal working (6th term)	68	51	17
21. Theory of systems and its application (6th term)	85	51	34
22. Up-to-date methods of analysis and quality control of raw materials and production products (7th term)	56	28	28
23. Control and automation of iron-and-steel furnaces (7th term)	70	42	28
24. Industrial hygiene and environmental control (9th term)	60	34	26
25. Corrosion and metal rust protection (9th term)	48	36	12
26. Equipment and designing of iron and steel plants (9th term)	48	36	12
Total:	1 226	822	404
<u>Organization and economics cycle</u>			
27. Economics of the iron and steel industry (7th term)	70	56	14
28. Organization, planning and management of enterprises (8th term)	90	60	30
29. Law. Personnel management (9th term)	48	36	12
Total:	208	152	56
<u>Specialization cycle</u>			
30. Fundamentals of theory of steelmaking processes (6th term)	102	68	34

		Total hours	Theory	Practicals
	1	2	3	4
31.	Steelmaking practice (6th, 7th terms)	132	90	42
32.	New processes and ladle treatment of steel (9th term)	60	48	12
33.	Steel casting and crystallization (8th term)	60	30	30
34.	Designs and designing of units (8th term)	60	45	15
35.	Course training research (8th term)	90	-	90
	Total:	504	281	223
	Grand total:	4 156	2 149	2 007

The curriculum for training a technician in the speciality of steelmaking is prepared on the basis of the qualification characteristics.

CURRICULUM

Steelmaking
(Period of training: 3 years 10 months, on
the basis of 8 years of a 10-year secondary school)

		Total hours	Theory	Practicals
	1	2	3	4
	General education cycle			
1.	Literature (1st, 2nd, 3rd, 4th terms)	210	210	-
2.	Mathematics (1st, 2nd, 3rd terms)	388	388	-
3.	Physics (1st, 2nd terms)	210	178	32
4.	Biology (3rd, 4th terms)	70	60	10
5.	Foreign language (1st, 2nd, 3rd terms)	106	106	-

	Total hours	Theory	Practicals
1	2	3	4
6. Physical training (1st, 2nd, 3rd, 4th, 5th, 6th, 8th terms)	218	218	-
Total:	1 202	1 160	42
Socio-economic cycle			
7. History (1st, 2nd, 3rd, 4th terms)	193	193	-
8. Social science (5th, 6th terms)	80	80	-
9. Law (8th term)	40	40	-
10. Economic geography of foreign countries (2nd term)	51	51	-
Total:	364	364	-
General engineering cycle			
11. Drawing (1st, 2nd terms)	140	-	140
12. Fundamentals of technical mechanics (3rd, 4th terms)	140	132	8
13. General electrical engineering and fundamentals of electronics (3rd, 4th terms)	174	140	34
Total:	454	272	182
General speciality cycle			
14. General chemistry (1st, 2nd terms)	176	106	70
15. Chemical and physico-chemical methods of analyses (4th, 5th, 6th terms)	144	46	98
16. Fundamentals of physical chemistry (3rd term)	108	84	24
17. Iron-and-steel furnaces (3rd, 4th terms)	140	100	40

	Total hours	Theory	Practicals
1	2	3	4
18. Iron and steel metallurgy (5th term)	72	64	8
19. Fundamentals of physical metallurgy (4th, 5th terms)	122	92	30
20. Fundamentals of standardization and quality control of products (8th term)	40	40	-
Total:	802	532	270
<u>Specialization cycle</u>			
21. Steelmaking (4th, 5th, 6th, 8th terms)	304	214	90
22. Operation of mechanical and transferring equipment of steelmaking plants (5th, 6th terms)	152	135	16
23. Operation of electrical equipment of steelmaking plants (5th term)	72	62	10
24. Instrumentation, automatic control facilities of production processes, computers and microprocessor facilities (5th, 6th, 8th terms)	120	100	20
25. Economics, planning, organization and management of production (5th, 6th, 8th terms)	160	124	36
26. Industrial hygiene (6th term)	66	58	8
27. Narrow specialization subjects (8th term)	80	70	10
Total:	954	764	190
Grand total:	3 776	3 092	684

CURRICULUM

Steelmaking
(Period of training: 2 years 10 months, on the basis of a 10-year secondary school)

		Total hours	Theory	Practicals
	1	2	3	4
	General education cycle			
1.	Mathematics (1st term)	108	108	-
2.	Physical training (1st, 2nd, 3rd, 4th, 6th terms)	132	132	
	Total:	240	240	
	Socio-economic cycle			
3.	Political economy (1st, 2nd, 3rd, 4th terms)	126	126	-
4.	Law (6th term)	40	40	-
	Total:	166	166	
	General engineering cycle			
5.	Drawing (1st, 2nd, terms)	140	-	140
6.	Fundamentals of technical mechanics (1st, 2nd terms)	140	132	8
7.	General electrical engineering and fundamentals of electronics (1st and 2nd terms)	159	125	34
	Total:	439	257	182
	General speciality cycle			
8.	Chemical and physico-chemical methods of analyses (2nd, 3rd, 4th terms)	138	40	98
9.	Fundamentals of physical chemistry (1st term)	108	84	24
10.	Iron-and-steel furnaces (1st, 2nd terms)	140	100	40
11.	Iron and steel metallurgy (2nd term)	68	60	8

	Total hours	Theory	Practicals
1	2	3	4
12. Fundamentals of physical metallurgy (1st, 2nd terms)	121	91	30
13. Fundamentals of standardization and quality control of products (6th term)	40	40	-
Total:	615	415	200
Specialization cycle			
14. Steelmaking (2nd, 3rd, 4th, 6th terms)	299	209	90
15. Operation of mechanical and transferring equipment of steelmaking plants (3rd, 4th terms)	147	131	16
16. Operation of electrical equipment of steelmaking plants (3rd term)	70	60	10
17. Instrumentation, automatic control facilities of production processes, computers and microprocessor facilities (3rd, 4th, 6th terms)	124	104	20
18. Organization, economics, planning and management of production (3rd, 4th, 6th terms)	150	114	36
19. Industrial hygiene (4th term)	56	48	8
20. Narrow specialization subjects (6th term)	70	60	10
Total:	816	626	190
Grand total:	2 276	1 704	572

The curriculum for training a worker as a "steelmaker helper of wide range" is prepared on the qualification characteristic and is given in two types.

CURRICULUM

For training a worker as a steelmaker helper of wide range
(Period of training: 3 years, on the basis of 8 years
of a 10-year secondary school)

		Total hours	Theory	Practicals
	1	2	3	4
	General education cycle			
1.	Russian language and literature (1st, 2nd, 3rd, 4th, 5th terms)	228	228	-
2.	Mathematics (1st, 2nd, 3rd, 4th, 5th terms)	325	325	-
3.	History (1st, 2nd, 3rd, 4th terms)	251	251	-
4.	Social science (5th term)	68	68	-
5.	Geography (5th term)	51	51	-
6.	Biology (5th term)	68	68	-
7.	Physics and astronomy (1st, 2nd, 3rd, 4th terms)	318	318	-
8.	Chemistry (1st, 2nd, 3rd terms)	194	194	-
9.	Foreign language (1st, 2nd, 3rd terms)	114	114	-
10.	Fundamentals of aesthetics (1st, 2nd terms)	40	40	-
11.	Physical training (1st, 2nd, 3rd, 4th, 5th terms)	173	173	-
	Total:	1 830	1 830	
	Vocational and technical cycle			
12.	Industrial training (1st, 2nd, 3rd, 4th, 5th, 6th terms)	1 878	-	1 878
13.	Special technology (2nd, 3rd, 4th, 5th terms)	222	222	-
14.	Fundamentals of iron and steel production (1st, 2nd, 3rd terms)	80	80	-

	Total hours	Theory	Practicals
1	2	3	4
15. Fundamentals of heat engineering (3rd term)			
16. Safety engineering and technical supervision (3rd, 4th, 5th terms)	55	55	-
17. Instrumentation automatic devices (4th, 5th terms)	76	76	-
18. Electrical engineering (2nd, 3rd terms)	80	80	-
19. Technical drawing (1st, 2nd terms)	57	57	-
20. Fundamentals of economics of labour and production (5th term)	34	34	-
Total:	2 533	655	1 878
Grand total:	4 363	2 485	1 878

CURRICULUM

For training a worker as a steelmaker helper of wide range
(Period of training· 1 year on the basis of a 10-year secondary school)

	Total hours	Theory	Practicals
1	2	3	4
General education cycle			
1. Political economy (1st, 2nd terms)	69	69	-
2. Fundamentals of law (1st, 2nd terms)	25	25	-
3. Physical training (1st, 2nd terms)	54	54	-
Total	148	148	
Vocational and technical cycle			
4. Industrial training (1st, 2nd terms)	1 070	-	1 070

	Total hours	Theory	Practicals
1	2	3	4
5. Special technology (1st, 2nd terms)	233	233	-
6. Reading of drawings (1st term)	34	34	-
7. Instrumentation and automatic devices (1st, 2nd terms)	71	71	-
8. Electrical engineering and fundamentals of electronics	68	69	-
9. Safety engineering and technical supervision (2nd term)	34	34	-
Total:	1 510	440	1 070
Grand total:	1 658	588	1 070

The above materials show that quantitative methods may be fruitfully used for planning a training process.

More than 15 years of experience at the Moscow Institute of Steel and Alloys makes it possible to judge the efficiency of the scientifically substantiated method of drawing up curricula.

Here two basic concepts are taken into account [13]. On the one hand, the external concept takes into account demand of the public production and is reflected at the stage of planning by the qualification characteristics of a speciality or a trade and by expert evaluations of elaborated training programmes.

On the other hand, the internal concept takes into account the principles and the dynamics of the establishment of the training process and includes the following elements at the planning stage: a collection of speciality programmes for all subjects covering the whole period of training, interrelationships of subject sections in the form of a matrix of logical relationships; and specification of subject areas requiring additional consideration.

From this point of view the given approach may be regarded as a method allowing the elaboration of programmes of training in the speciality as a whole and not in single subjects.

In addition to the planning of training the above method is fruitful at the stage of training as well.

Availability of the qualification characteristics, collection of training programmes and matrices of logical relationships are very important for teachers and professors.

Presentation of the information to be studied in the form of matrices of logical relationships makes it possible for teachers and professors to look through the whole process of training in the speciality for a whole period of training using one methodical document-matrix. In doing so they receive a graphic logical exposition of the material for all training courses. A teacher will know all relationships of the sections of his subject, and teaching will become more comprehensive and better meet the needs of trainees from the viewpoint of their experience as well as the final objective of studying the subject.

By this method it is possible to elaborate curricula and training programmes for each level of education and training - for higher educational establishments, secondary specialized training establishments and vocational and technical schools. It is possible to make matrices of logical relationships taking into account continuity of education in the system - vocational schools, secondary specialized training establishments and higher educational establishments.

Matrices of logical relationships make possible a scientifically substantiated approach to elaboration of automatic training systems (ATS).

Planning and training are therefore carried out on the same methodological basis. A traditional form of establishing a training process according to curricula includes: delivering lectures, practical work and seminars, homework, checks, laboratory work, course project and literature on the training course.

IV. ESTABLISHING THE TRAINING PROCESS AND THE USE OF AUTOMATIC TRAINING SYSTEMS

After determining the contents of training and elaborating curricula and programmes of study, the next stage is to establish the training process. In many developing countries the task-oriented training of specialists for iron and steel works to be constructed is the function of industry management bodies Here it is necessary to understand the peculiarities of establishing the training process, which includes determining the number of terms in the academic year, the duration of training, the number and time of tests and examinations, the schedule of industrial practice at iron and steel works, the number and time of preparation of course projects, hours of study per week (lectures, seminars, practical and laboratory work), the time for independent studying of textbooks by students and preparation of homework and projects, system for providing students with textbooks, and the number of the teaching staff and auxiliary personnel.

The initial information for elaboration of a training process is the scale of preparation of specialists in particular fields, since it determines the required number of students and educational institutions. In developing countries the need for specialists for the iron and steel industry may be determined on a national scale on the basis of manning lists of engineers and technicians of existing iron and steel works. At the stage of forecasting development of the iron and steel industry it is posible to use the method of direct and complex expenditures elaborated in this study for assessing the needs. In determining the need for specialists it is necessary to take into account the actual replacement of their posts at existing enterprises and an increase in the number of posts with the planned development of the iron and steel industry as well as possible natural loss of specialists. As a result of this, the need for specialists for a particular year is established. The minimum planned period for determining the need for specialists should correspond to the period of training specialists and with five-year studies in higher educational institutions it is equal to five years. The established needs for specialists is the basis for estimating the number of specialists to graduate from educational institutions. In establishing the training process, however, it is necessary to take into account the number of students admitted to the first course and not the number of graduating specialists. The number of graduating specialists may be less than the number of the first-year students because of possible dismissal of some students during the period of training due to the state of their health, change of speciality, marital state or financial position and failure to master the training programme. The total number of students dismissed annually (percentage from the total number of students in a higher educational institution) depends on many factors, including the system of education in the country, the level of requirements when admitting to higher educational institutions and their regulations. If, for example, this percentage averages five per cent per year (taking into account the rehabilitation and re-admission of some dismissed students), this means that for a five-year period of training 25 per cent of all students admitted to the first course will be dismissed. Therefore, the admission-graduation ratio will be 0.75. The number of students admitted to the first course is determined as a quotient of the required number of graduating specialists divided by 0.75. The students admitted to the first course are distributed to academic groups with regard to the selected speciality. It is most advisable, from the pedagogical and economic viewpoint, to have 25 students in a group. Seminars and practical work are carried out for an academic group, while it is advisable to divide a group into two sub-groups for laboratory work. The number of terms in a academic year is established with regard to the traditions existing in the country and climatic conditions, and may vary from two to four. The maximum use of school hours is achieved with a two-term academic year. Tests are carried out and exams are to be passed for the subjects completed within a term. Examination is to take place after the end of a term and the time for it is to be specially assigned. The system of students' industrial practices at industrial enterprises is drawn up with regard to practical skills acquired by students in maintenance of units and equipment and preparation for their specialization. Experience shows that the required practical training of graduating specialists is achieved when the system comprises the following:

(a) Study tours for the whole process route of iron and steel enterprises;

(b) Production practice requiring an acquaintance with the production process and equipment of iron and steel plants according to the speciality;

(c) Specialization practice in iron and steel plants according to the selected narrow specialization;

(d) Pre-diploma practice in studying the material required for preparing the diploma project or work.

Duration of production practices is 1-2 months, and it is preferable to carry them out during the summer-autumn season after the end or before the beginning of an academic year. Study hours of students, including independent studying of the teaching material, are in the order of 50-60 hours per week. The ratio of compulsory studies of students according to the time table and independent study of the teaching material depend on the existing system of training, the use of computers and national traditions. When it is necessary to ensure the pre-determined number of graduating specialists dictated by needs of the national economy of a developing country the emphasis should be on compulsory studies under the guidance of a teacher or professor. The optimum time for the above studies is 28-36 hours per week, which makes it possible sufficiently to prepare the students for independent study of the teaching material. Independent work of students during a term is encouraged and suitably monitored. A special place in the stimulation of independent work of students belongs to practical and laboratory work, participation in which is binding for all students and requires regular preliminary study of their themes.

Provision of the trainees with textbooks on the subjects to be studied is an essential part of establishing the training process. The number of textbooks on a subject in a library is determined by the number of students studying at a particular time. A shortage of textbooks is made up by offset duplicating of lecture courses and teaching aids written by teachers and professors of an educational institution. Curricula for all specialities should therefore be analysed for each subject from the viewpoint of being provided with textbooks including teaching aids for performing laboratory and practical works.

The biggest difficulties in establishing the process of training in metallurgical specialities in new educational institutions arise in connection with establishing laboratories and elaboration of the contents of practical laboratory work. The projects for establishing of educational institutions should define the number of training laboratories and their specialization, including the specification of equipment, instruments and their arrangement in laboratories, as well as supplies of water, electricity and other requirements. The beginning of specialist training, as a rule, precedes establishment of the material and technical base of educational institutions Therefore, at the initial stage of establishing the training process the emphasis should be on the use of technical teaching means, especially projectors for educational films and slides. This makes up for a lack of laboratory experiments. It would be advisable to have a special section for technical teaching in an educational institution, which would provide a centralized supply of technical material for the whole training process. In equipping new higher educational institutions it is necessary first to establish a computer centre with terminals in laboratories. When there is no practical laboratory work at the initial stage of establishing an educational institution, this makes possible the use of mathematical models and simulation of processes and phenomena in computers, the study of which is provided for in the training programmes.

The use of computers in training specialists is not limited to drawing up curricula but finds expanding application in the process of specialist training. Computers are used as computing means in performing various training tasks allowing trainees to have some free time for acquiring creative knowledge and skills. Here particular emphasis is placed upon the fact that the transfer of calculating operations to computers should not exclude the mastering of basic stages in solving technical tasks by trainees. Computers are also used for simulation of various objects, production processes and physical phenomena. The use of simulation makes possible the study of the relationships of various factors determining the course of actual processes, without the need for expensive laboratory equipment and units. Simulation of the work of industrial units and production processes in combination with hardware components of management and control has made possible the development of trainers for specialist training. These trainers are used for teaching skills in operating units and controlling processes in the process of training before graduation from an educational institution.

During the 1970s automatic training systems were developed on the basis of electronic computers which are now used for training skilled workers, technicians and engineers.

ATS suppose availability of the following:

(a) Computers with collective access of terminals to them or a set of individual computers;

(b) Video terminals connected to a computer. If individual computers are used there is no need for a computer of collective use;

(c) A special software system which controls the training process at displays and has a special language for writing training courses;

(d) Proper training programmes in subjects of the curriculum;

(e) Training materials and aids required to enable instructors and trainees to work with a computer.

With the use of ATS the process of training takes place at a video terminal in the form of a dialogue between a trainee and a computer carried out in accordance with the programme of a training course. The control of the process of training in one or several subjects is ensured by system programmes of ATS. The ATS is a complex of dialogue, technical means, special software controlling the work of a computer during training, and training materials and aids which are interconnected on the basis of a computer.

Hence, ATS is referred to man-machine dialogue systems with a so-called interactive mode of operation when a computer reacts to external events put in from a terminal so quickly that it is possible to affect them. This is achieved through the use of a high-capacity computer ensuring reactivity of the system (response time) within 3 seconds. Recently there appeared in the field of ATS developments aimed at creating training conditions approximating to a dialogue between a trainee and an instructor-coach. A traditional training process supposes delivering lectures to trainees, practical work and seminars, performance of laboratory work, preparation of projects and homework, check-ups, tests and examinations. All these types of studies and checks are separated in time. By means of ATS they are combined in one training course which is studied by trainees, and the learning of which is checked by means of a dialogue with a computer through a video terminal (or through an individual computer). All training courses to be studied and all trainees are registered in the computer file before the beginning of training. In a general case the process of training starts from sending a message to the system by a trainee stating his code (his surname, group number etc.) and the name of the training course. When this is done a trainee begins to receive from a display screen certain portions of the teaching material for study. An ATS terminal may also include audio-visual aids (film and slide projectors, sound-recording and reproducing equipment, facilities for reproducing graphic information) improving efficiency of learning of the teaching material. As soon as the study of a certain portion of the material is completed, a trainee receives a check task on a display, and on the basis of its fulfilment it is determined whether a trainee has learned the material and the system gives an instruction about further work.

Developed ATS has a special video terminal for an instructor who monitors the training. With the help of this terminal it is possible to see what theme is being studied by each trainee and to render timely assistance in case of difficulty.

ATS may be used in combination with traditional forms of studies in different proportions. If teaching in the form of lectures is preserved, displays may function as a means of reproducing the information and as a feedback means for a teacher or professor. With ATS the delivering of lectures may be replaced by studying the teaching material in traditional textbooks according to the instructions given by the system to the display. The maximum effect is attained when ATS is used for practical work (problem-solving and skill-drilling), for computing and supplying reference information for the preparation of course and diploma work and projects, and for performing practical laboratory work. ATS may be used for business games with simulation of objects and processes, and trainers may be developed for drilling skills in monitoring production processes.

ATS has the following advantages contributing to improvement of the quality of training as compared with the traditional form of training:

(a) Individualization of trainees training and checking progress in learning;

(b) Adaptation of the training process to individual characteristics of trainees according to the level of their knowledge and rates of studying the teaching material;

(c) Relief of instructors from a number of laborious repetitive operations connected with presentation of teaching material and checking the work of trainees;

(d) Unification of training courses at the best level and possible improvement in the training process on the basis of analysis of statistical information accumulated in ATS concerning the training process.

When ATS is established the most laborious operation is the development of training courses. It comprises the following stages:

(a) Formulation of the objectives of the training course, preparation of its programme and determining its logical structure, where the relationships between the themes studied are established, and the algorithm of training;

(b) Selection of the teaching material and its distribution between themes;

(c) Writing the scenario of a course in one of the languages of training courses;

(d) Input of a training course into a computer and its adjustment;

(e) Experimental testing of a course on trainees and collecting information required for further improvement of the course;

(f) Introduction of a training course into the process of specialist training.

There are two parts in the process of programming training courses and establishing portions of the teaching material, namely information for a trainee (a portion of the material, check-up questions and tasks) and information for ATS. In the latter case, the following is included: time for studying a portion of the material, the name of a programme analysing the answer, standard answers, marks for answers, numbers of material portions for additional study in relation to the degree of correctness of an answer.

Development of training courses is carried out by the most highly qualified instructors and is very time consuming. An instructor needs from 60 to 100 hours of work for ensuring one hour of training by ATS. Either algorithmic languages of general designation or special author's languages may be used for describing training courses. The most widely used languages among the languages of the first group are APL, FORTRAN, BASIC, PASCAL. These languages permit the implementation of single training programmes but do not provide the author with a universal means for developing a course for ATS. The author's language permits the achievement of a bigger number of training objectives and ensures the analysis of the data on the results of training. The language of training courses as compared with universal algorithmic languages ensures a higher productivity of the programming and adjustment of courses owing to: problem orientation of language means; input media functionally more complete for broadening and correcting course programmes and checking language operators at the moment of input; and a possibility for effective checking of the course programme by the author under conditions of a trainee.

Nowadays the number of authors' languages exceeds 100. A considerable part of them are experimental, and the most widely used are PLATO-IV, COURSEWRITER, TUTOR and some others. In the USSR the basic language for writing a course is СИОК-ВУЗ, АОС-ВУЗ. An important requirement for authors' languages, is openness of the system, that is, a possibility of its operation with different types of terminals and computers of various configurations as well as availability of means for broadening the language itself. Concurrent with an author's language for training courses, system programmes are developed in ATS to ensure the following: monitoring and control of the training process; running a register on the study of the material of the course by each trainee; connection with a computer when solving problems; interpretation of the language of training courses in which an instructor programmes the scenario of a course; exchange with external devices of a computer; and adjustment for concrete configuration of a computer. A certain volume of an on-line storage should be given for storing ATS system programmes in each electronic computer. For storing programmes of training courses and ATS archives a computer should have a capacious external memory (magnetic disks). ATS stores information about each trainee, the course studied, the date and time of work, time required for answering the questions, texts of trainee's answers, his requests for help and the number of errors.

Studies with the use of ATS are carried out in special class-rooms equipped with video terminals connected to electronic computers or individual computers.

ATS may be implemented practically in all types of electronic computers, from high-capacity electronic computers and computer systems to micro computers, among them computers of IBM, CDC, mini-computers of DEC, PDP, micro computers of Wang, AI Electronic and other firms. In the USSR big electronic computers of the series EC, mini-computers of the series CM and micro-computers of the series Electronica are used for ATS. Here a two-level system may be used when the first level is based on a EC-computer where the major part of information data and software which require a high-capacity computer are accumulated. The second level is based on mini-computers of series CM and is designed for carrying out a dialogue with a trainee.

Big prospects for developing ATS are connected with the use of mini- and micro computers which have software convenient for ATS and permitting to perform the programming of training courses in authors' languages of a higher level within shorter periods. Here it is rather important that these computers are oriented to dialogue conditions of operation with time-sharing.

In developing countries at initial stages of economic development and a small scale of specialist training it is possible with the use of ATS to use mini- and micro-computers of an individual type which do not require establishing networks from terminals to a computer and using telegraph circuits. The use of ATS is most effective in training skilled workers and technicians in dealing with actual technical problems. The cost of these computers is much lower than that of bigger ones, and there is an opportunity to order and buy training courses on magnetic disks. Mini- and micro-computers require practically no preparation of premises for installation and no highly skilled personnel for maintenance if they are provided with a required set of spare parts.

The use of ATS based on big computers and a considerable number of trainees becomes advantageous in developing countries as the higher education system and the level of economic development improves. The use of electronic computers in training is regarded as an index of the up-to-date level of specialist training. Priority should be given to the use of electronic computers in the training process for computing and practical laboratory work. This is the first stage of introduction of ATS when a part of classroom studies and independent work of students are covered. The final stage is development of training courses.

V. EVALUATION OF VARIOUS METHODS OF PERSONNEL TRAINING FOR THE IRON AND STEEL INDUSTRY OF DEVELOPING COUNTRIES

The form of the training of workers, technicians and engineers required for ensuring development of the iron and steel industry in a developing country is determined by the condition of the educational system in a particular country. If a country does not have a sufficient number of trainees with complete secondary education and secondary general education, the training of skilled workers may be started on the basis of the primary education (6 years of schooling). For this purpose it is advisable to establish vocational and technical schools with a training period of 3-4 years. As the number of persons graduating from an incomplete secondary school is increased, the period of training in vocational and technical schools of this category may be reduced to one or two years. The training of teachers and instructors for vocational and technical schools should be provided for. For this purpose it would be advisable to establish special industrial and teaching faculties.

The training of middle grade specialists - technicians, including the training of trainers, teachers and instructors of vocational and technical schools, should be carried out in specialized secondary technical educational institutions which may admit persons with incomplete secondary education. The period of training in these institutions is 3 to 4 years. The curriculum for the training of technicians for the iron and steel industry should include subjects of general education, general engineering and vocational metallurgical cycles. As the system of secondary education develops, specialized secondary technical educational institutions may admit persons with complete secondary general education, and in this case the period of training is reduced to one or two years.

The training of engineers for the iron and steel industry of developing countries may be effected in several forms. Initially, graduates of secondary schools could be sent to study at higher educational establishments of developed countries. At the same time, it is necessary to organize the training of engineers for the iron and steel industry at higher educational institutions in developing countries. If there is a university in the country, graduates from the university may be trained for two years in a specially established technical higher educational institution in metallurgical subjects.

If there is a university in a country it is possible to establish a metallurgical faculty at this university with a five-year period of training. According to the level of industry development, multi-purpose technical institutes may be established with a five-year training period including metallurgical faculties.

Studies carried out by UNIDO suggest that the process of preparing a person for skilled work in industry, including the iron and steel industry, has four stages: general education; technical and vocational education (or technical and vocational studies within general education); basic practical training; and specialized branch training.

The purpose of general education is to develop the individual as a person able to participate fully in his society. A basic education during 8 to 10 years is regarded as a prerequisite for further education or training.

The purpose of technical and vocational education is to provide a technical and scientific base for a technical career, not necessarily in industry [22]. Duration of the vocational training of workers depends on the length of primary and secondary education, and the same is true for technicians and instructors of technical and vocational schools.

The lower the level of education in a country, the larger the programme of transfer of technical knowledge should be. In such cases, vocational training may be to a certain extent a continuation of school education. On the other hand, the higher the level of education, the larger the accumulated experience and the smaller the volume of transferred knowledge and required expenses.

General vocational training of managers, specialists, technicians, foremen and workers in developing countries is, as a rule, insufficient. It should be supplemented by specific sectorial training which is carried out most often within frameworks of sectorial programmes [23].

The purpose of basic practical training is to give the trainee knowledge and experience of the basic manual skills in use throughout industry, as well as initial experience with selected production processes. Such training is carried out at large industrial enterprises, at joint training centres with the co-operation of small enterprises, or at centres of the national personnel training system.

The purpose of the specialized branch training is to equip a new employee with the skill and knowledge needed to do a particular job in the enterprise, or to give him further training to improve his skill, or to retrain him for another job in the enterprise.

The prospects of further new technological innovations and resulting changes in the nature of work make continuous training inevitable. Some developing countries have already successfully introduced continuous training, sometimes for as much as five months every three years. Nevertheless, most developing countries have accepted less expensive repeated training.

It appears that more attention has to be paid to the training of trainers in developing countries, so as to increase and replace the staff initially trained by a foreign contractor. This requirement is included in contracts both for the supply of training services and for major development projects.

In industry there are three principal types of trainers: the company trainer, operating within a single enterprise or organization; the group trainer, responsible for co-ordinating company trainers in a number of units of a large enterprise or a whole industry; the training advisor or training development officer, employed by a national training organization as its link with industry.

In no way should the trainers be used as inspectors or enforcement officers. The trainers must previously have worked in industry themselves [22].

When iron and steel works are constructed both on a green field or near the existing works the training of skilled personnel for technology, operation and maintenance is very important and becomes an integral part of establishing or expanding iron and steel industries. When an iron and steel works is the first enterprise of this type in a country, it is hardly possible that there will be many local resources from which skilled and semi-skilled manpower may be taken. If such a new enterprise is a part of the expansion scheme, the situation may be simplified to a certain extent as the personnel for key posts may be selected or trained at an allied or affiliated plant. Though even in such cases some stages are required for forecasting necessary qualification requirements and planning personnel training to ensure normal comissioning of the works.

In those cases when an enterprise is constructed on a separate site and there are no working plants nearby, there may be some limitations in respect of qualification improvement. New enterprises have a number of peculiarities which distinguish them from the older ones. It is therefore impossible to rely on old enterprises for meeting all requirements for personnel training, since some additional training is required to cover new technologies.

In addition, it is hardly possible to do without additional training if the industry is to be provided with skilled and unskilled workers. For works in rural or scarcely populated areas, a usual source of manpower is workers without any previous training or production experience. Many of them are illiterate or half-literate, or have only the minimum compulsory education.

Insufficient qualification of local personnel in combination with a wish to use local personnel affect the depth and scope of training to be provided by the iron and steel industry and the rates of development of the industry.

There are a number of ways of meeting personnel requirements for operation of iron and steel works in developing countries. For the most part they are as follows:

(a) Direct recruiting of all workers of the required qualification in the country or abroad;

(b) Development and use of own resources of the iron and steel industry for providing complete training of personnel with all required qualifications;

(c) Use of national educational establishments for training personnel of the required qualifications;

(d) Use of available types of equipment and resources of the manufacturers or allied firms inside the country or abroad for the training of workers;

(e) Various combinations of the above;

(f) Joint training of personnel with other branches of industry having common training needs.

Programmes for industrial training of personnel for the iron and steel industry should, as a rule:

(a) Be easily adaptable to changes in technology;

(b) Ensure flexibility in selection of professions;

(c) Ensure conformity of the general personnel training and experience accumulated in more than one trade;

(d) Combine general education and practical training on the job, ensure introduction of standard teaching forms in personnel training;

(e) Take into account individual abilities of trainees and establish periods of training for workers of different qualifications and levels of knowledge;

(f) Ensure introduction of appropriate standards [23].

As a rule, when the iron and steel industry is established it is responsible for a considerable part of the training of its own personnel, which covers on-the-job training (including apprenticeship), further training to ensure an up-to-date level of knowledge, upgrading of qualifications, expansion of the scope of knowledge, training abroad and the use of consultants.

Plants use their own capabilities for personnel training, which include establishing training centres with courses of practical and theoretical training of skilled and semi-skilled workers at different levels.

Many such centres are concentrated on basic training with specialization on the job for completing the primary training of skilled workers. These basic training courses are normally carried out off the job, are, for a number of specialities, associated with the electrical engineering industry and have a theory course on the iron and steel production. During specialization the workers visit production plants and the centre, visits to the latter being gradually reduced in time. As a rule, newcomers receive the major part of their initial training in the centres, particularly those who are going to become members of the operating staff.

In addition to the basic and initial training of newly employed workers, the major part of the centres provide further training for workers already engaged in production, operation and maintenance. There are courses for up-grading the qualification of workers, or re-training them for another job and acquainting them with new technical processes.

The enterprise centres for personnel training become a part of the whole system of advanced personnel training at enterprises. The staff accumulates experience both in carrying out the production processes and training workers of different qualifications. The equipment used in the process of training, training sections, laboratories and class-rooms equipped with video tape recorders, simulating devices, training appliances etc. facilitate the mastering of the material.

The major advantage of works training centres is a possibility to ensure close links between enrolment, training and use of personnel at the enterprise. The objectives of training may be formulated more definitely directly at the production level. The main difficulties arising in the work of enterprise training centres reside in a necessity to co-ordinate their work with institutions responsible for personnel training in the country and using it as well as to observe the existing standards. Serious problems arise even when such centres function as constituent parts of the national system of personnel training and recruiting, national legislation on this matter and issuing certificates for workers upon completion of training.

In enrolling trainees at enterprise training centres, the iron and steel industry should take into account their previous training. For apprentices and other categories of young workers, the bigger part of education has already been received within the framework of the national education system or the national personnel training system. Hence, it is desirable for enterprise training centres to have close links with the national training system. In this case, the iron and steel industry gains maximum advantages as a result of the functioning of such external training systems, since this makes it possible to shorten the period of training at the enterprise. Therefore it is important to ensure effective links with the national training systems and the iron and steel industry. Development of national institutions for personnel training allows for some reduction in the scope of similar activities in the iron and steel industry and centres, which are able to focus their attention on further training and the training of apprentices, particularly those from the operating staff and workers specialized in more sophisticated trades.

A number of measures may be taken to deepen links between the enterprise training centres and national training systems as well as to elaborate unified standards for the two systems:

The measures include:

(a) Establishment of joint consulting bodies, in which both systems are represented, for elaborating curricula, training programmes, standards and educational certificates;

(b) Exchange of teachers, instructors and professors;

(c) Joint use of training aids and applicances.

With training in public educational institutions specialists responsible for personnel training on the national scale try to take into account the wishes of managers of some enterprises as well as those of leaders of some sectors of industry as a whole It is therefore natural that establishment of the iron and steel industry exerts influence on curricula of the general education system and those of training centres. When such educational institutions are in the direct vicinity of iron and steel works, their curricula and programmes include subjects directly related to the activity of those enterprises. For example, metallurgy is a rather usual subject in secondary schools situated in the vicinity of iron and steel works, and the curricula of such schools provide for practice at these works as a part of the programme of vocational orientation and preparation for entering higher educational institutions. A number of vocational training centres are established as the iron and steel industry develops, special course are organized with partial off-the-job training or evening courses for elderly workers or candidates for promotion who do not have proper general education.

There are certain limitations for basic training and primary education which are provided by national educational institutions and training centres. In particular, they do not have appropriate metallurgical equipment which may be used for training purposes. Training in these centres should be supplemented by training on the job.

The national educational institutions and training centres connected with the iron and steel industry ensure upgrading of qualifications or supplementary training, acquaintance with modern trends, refresher courses and specialized training.

The main prerequisite for improving efficiency of training is the qualification of trainers who, in addition to good technical knowledge, should have up-to date pedagogical skills and teaching methods. When training centres are a part of a metallurgical complex, instructors ensure the training of supervisory workers who train the personnel working under them. These educational institutions contribute to elaboration of the national and international qualification standards. These standards are the basis of the wage system.

Suppliers and manufacturers of equipment play an important role in training skilled workers. First, they define the procedures of equipment operation and maintenance. Secondly, in conformity with contracts they are very often obliged to provide the training of skilled personnel to ensure the commissioning and operation of the equipment. The suppliers of equipment encounter a number of difficulties in establishing the iron and steel industry in developing countries. These include the absence of data on the available resources in skilled workers with the required levels of training for the commissioning of enterprises and long-term operation of equipment.

The manufacturers and suppliers of equipment for iron and steel works to be constructed on green fields have various approaches to the training of workers. These methods comprise: the group training of supervisory workers at special courses organized at enterprises, individual training abroad for local workers and the sending of specialists for training workers on the job. The training is also carried out during the manufacture and assembly of equipment.

In practice various combinations of these methods may be encountered. For example, basic and, sometimes, initial training of newcomers is carried out by the national vocational training courses. Higher technical and specialized educational institutions provide general education and vocational training in subjects related to iron and steel metallurgy. Upon completion of training, the trainees are employed as skilled workers and further trained in conformity with their specialization. By this method an effective combination of national and sectorial capabilities of personnel training is achieved. As a result, a balanced approach to training and the improvement of qualifications is obtained.

Personnel training should be distributed between the iron and steel industry and other sectors manufacturing equipment for this branch of industry and servicing sectors of the industry. Special training is required for electricians and mechanics who provide maintenance and repair of equipment and manufacture spare parts for it.

The iron and steel industry as many other branches of industry is orientated in the training of personnel to the national general education systems and vocational training institutions. Changes in the technology require that workers should have skills and special training different from those they had in the past.

A number of skilled workers and foremen are required for commissioning enterprises and the initial stage of their operation. The training to be performed before the commissioning should be intensive and carried out with regard to the requirements of certain operations. Hence training is carried out to develop an acquaintance with the equipment and its methods of operation.

Training at this stage is the most complicated in the cycle of personnel training for the iron and steel industry.

The personnel training measures required before commissioning an enterprise should be designed to achieve the following:

(a) Elaborate training programmes and establish personnel training courses;

(b) Establish training means at the most initial stages of construction and provide conditions for long-term training of personnel at the construction site;

(c) Elaborate training aids, reference books etc.;

(d) Select and train instructors and supervisory workers;

(e) Select and train probationers;

(f) Organize and check the system of instruction;

(g) Begin long-term training of personnel.

During commissioning and at the beginning operation many workers complete their training under production conditions which are difficult tc simulate and the workers are trained on-the-job.

VI. INTERNATIONAL CO-OPERATION IN NATIONAL PERSONNEL TRAINING FOR THE IRON AND STEEL INDUSTRY OF DEVELOPING COUNTRIES

The nature of the demand of developing countries for personnel training for the industry has essentially changed during the past decade. Initially training was given to individuals or small groups of probationers for ensuring successful operation of industrial enterprises. Currently, however, there is a demand for the training of complete teams providing production, repair and management, as well as for establishing technological and training centres for providing personnel for concrete branches of industry.

Personnel training within the framework of commercial agreements is carried out on a relatively large scale as compared with training within the framework of assistance. Currently there is a process of establishing a large world market for the training of industrial manpower, though it is far from being perfect because of the lack of information on capabilities of personnel training in particular countries and levels of training in concrete technological processes.

A number of developing countries have accumulated a considerable amount of industrial knowledge and skills which might be useful for other devoloping countries. For the transfer of this knowledge and skills it is necessary to have a special body responsible for accepting requests for training and controlling co-operation programmes among developing countries. It is suggested to establish for these aims a centre for foreign trainees from developing countries at the national level and centres for co-ordination of the training of industrial manpower among developing countries.

Agreements for technical assistance usually include the training of personnel and are of a long-term nature. In some cases, for more effective training it is advisable to approach an enterprise using equipment and not the enterprise manufacturing the equipment.

With regard to the training of managerial staff, the personnel of the supplier works for some limited period of time at key posts at a new enterprise and must prepare their local counterparts for the jobs.

The agreement should foresee the access of the customer's personnel to the manufacturing plant and main headquarters of the supplier-firm. As a result of this, the personnel of a new enterprise will have an opportunity to become acquainted with the operation of various types of equipment, to learn the sequence of technological operations, to become acquainted with the operational problems and ways of solving them. The supplier's personnel, in turn, will have an opportunity to become acquainted with the customer's personnel.

It would be advisable to have regional projects for personnel training. Practice shows that when an agreement is negotiated with a country concerning construction of an educational institution (university, college, special centre for personnel training etc.), the needs of the neighbouring countries are also taken into consideration. When the project is completed, very often with international financial assistance, after some time the use of the educational institution becomes an exclusive right of the country in which it is located.

During more than two decades students from developing countries (mostly Africa) were educated in other developing countries (for the major part Brazil, Egypt and India).

The following factors favour the efficiency of education and training:

(a) A thorough selection and good grounding (schooling) of trainees and instructors;

(b) The adaptation of a training programme to the requirements of the foreign trainee (the programme should provide him with knowledge which will be useful to him when he is back in his home country);

(c) Sufficient knowledge of the language of training before the beginning of the technical training;

(d) Good conditions of life of the trainee (including trips, accommodation, allowances to release him from problems not related to his studies);

(e) Control of the trainee's work, including regular sending of his reports to his employer in the home country;

(f) A mutually accepted qualification grade or a certificate of skill on the basis of a thorough comparison of the equivalence of certificates.

When the trainees are back home it is necessary to: discuss the programme of their training as a reference-point for others; to discuss how the trainees are going to use their training in practice; and to analyse their work after several months.

The training of national personnel - engineers and technicians and skilled workers is a prerequisite for establishing the iron and steel industry in developing countries. The scheme of training national personnel suggested below is based on the experience of the Soviet Union in rendering assistance to developing countries in this field.

At the initial stage, preceding the construction of an iron and steel enterprise, it is advisable for a developing country to prepare engineering and research staff in the field of metallurgy in the higher educational institutions of a country that is prepared to share its expertise in that field.

At the next stage, when a developing country starts the construction of a metallurgical works, it is advisable to establish a national technological institute for educating engineers with a five-year period of studies and enrolment of graduates of secondary schools. In relation to the scale of the country economy and branches of industry and agriculture developed in it, these may be multi-purpose technological institutes with faculties for different branches of industry, or special technological institutes with specialization in one of the branches of industry. Institutes of the first type were established in India under the Ministry of Higher Education when its economy began to diversify.

In developing countries where the scale of the economy is not so large and where at the beginning of development the emphasis is focused on the development of mining and metallurgical industry, a mining and metallurgical institute may be established for preparing the required engineering personnel. In Algeria, for example, a mining and metallurgical institute has been established near the constructed iron and steel complex with the assistance of the Soviet Union.

Establishment of a mining and metallurgical institute in a developing country is important not only for providing engineering personnel for the iron and steel industry, but also for the training of technicians. Thus, in the Algerian institute referred to above there was established a special department for training technicians in a four-year training programme, in addition to the engineering faculty with its five-year programme of studies. Lycee (secondary school) graduates with a degree are admited to the engineering faculty without examinations, while lycee graduates without a degree are admitted to the technician training faculty after an entrance examination. The level of schooling of the latter is lower than that of the first. Some of the engineers at such an institute may be specialized in the preparation of engineers and metallurgists for training technicians and skilled workers at vocational and technical educational institutions.

To more quickly meet the demand for metallurgical engineers, technicians and skilled workers, it is advisable to establish the institute under the Ministry of Industry. This makes it possible to establish the material and technical base of the institute within a shorter period and to meet the demand for specialists more purposefully. At the initial stage of development of the iron and steel industry the institute may prepare personnel in the following specialities: ore mining; mining electromechanics; metallurgy; plastic metalworking; physical metallurgy and heat treatment; manufactauring engineering; electric power supply and electrical equipment; and analytical chemistry.

As the demand for engineers and technicians is met and some technological problems arise in the industry, there may appear a necessity for more narrow specialization of personnel, for example, in iron and steel production (foundry), and in plastic metalworking (sheet, section and pipe rolling). Finally, when the initial goals of establishing the iron and steel industry and providing it with engineering and technical personnel are achieved, further training of engineering and technical personnel may be transferred to the Ministry responsible for education and scientific research. Here, with a relatively small scale of metallurgical production in the country, specialization in metallurgical occupations may be widened and a higher educational institution (university or polytechnical institute) established on the basis of the mining and metallurgical institute. Such an institution will meet the demand for engineers and technicians of a more diversified economy.

There is one more way of providing the iron and steel industry of a country with engineering personnel at the initial stage of economic development if university education is available in the country. In particular, the qualification of university graduates in the field of metallurgy may be upgraded by establishing a special metallurgical institute with a two-year period of studies. This method was used by Egypt during the construction of an integrated iron and steel complex. The university system of this country prepared specialists with a sufficient level of knowledge in fundamental sciences (mathematics, chemistry, physical chemistry, theory of metallurgical processes) at engineering faculties. Unfortunately the level of preparation of the graduates in the field of technology of metallurgical production did not meet the requirements of practical activities for its elaboration, improvement and process control. To make up the deficiency a metallurgical institute has been established under the Ministry of Industry with the assistance of the Soviet Union. The institute provides training in the following specialities: mining; metallurgy of ferrous and non-ferrous metals; plastic metalworking; heat engineering of metallurgical units; coke and by-product process; heat treatment of metals and alloys; and mechanical equipment of iron and steel works.

Students are sent to the institute on scholarships paid by firms where they work and to which they return, with a promotion, upon graduation. The curricula of the institute do not provide for studies of independent fundamental subjects and include specialized subjects in combination with basic metallurgical subjects (physical chemistry, physical metallurgy, theory of metallurgical processes, continuum mechanics etc.). For a diploma all students are required to do research work which is to be carried out, as a rule, at their firms and to be related to their needs. In some cases diploma work may be prepared in the laboratories of the institute according to requests of the firms.

The experience of training specialists for the iron and steel industry at the institute shows that it is useful to have graduates at two levels. At the first level, the degree of master of science is awarded. At the second, a certificate attesting the upgrading of engineering qualifications is issued. Specialists of the first level may be recommended for further studies at post-graduate courses and for work at scientific research departments of firms and scientific research centres.

Recently the training of personnel from developing countries on a multilateral basis has been promoted by various international organizations. For example, on the basis of an agreement between the International Labour Organisation (ILO) and UNIDO, ILO will carry out programmes in the field of personnel training and advanced training at all industrial enterprises irrespective of ownership. The agreement also refers to technicians and instructors. UNIDO is to ensure the specialized training of personnel directly at enterprises, acquainting them with equipment and production processes, specialized quality control, maintenance and repair. It will also be responsible for the training of graduate engineers.

The UNIDO six-month in-plant group training programme in English for engineers and technicians in the field of iron and steel industry carried out from 1965 at the metallurgical works "Zaporozhstal" in USSR is highly regarded. In the field of research work and implementation of joint projects for elaboration of technology, UNIDO investigates the technical, economic and engineering aspects and ILO the socio-economic aspect.

ILO has established a number of international centres of technical and vocational education. In particular, such a centre was established in Turin in 1965, and its activity is aimed at rendering assistance to developing countries in establishing national schemes and systems for personnel training and services. This centre implements its functions by organizing courses and seminars for personnel training, managing co-operation programmes, publishing teaching aids, organizing consultations and carrying out research. Training in the centre consists of courses for the following: directors of various enterprises and organizations, including supervisors of educational institutions, training officers and instructors engaged in management, technical and vocational training; trade union officials; officials of employers' organizations; trainers; and technicians from various branches of industry in developing countries.

The centre organizes seminars on behalf of other training organizations and agencies. It also organizes short-term courses and seminars in developing countries according to requests of Governments and governmental organizations facing specific and urgent problems in connection with personnel training.

ILO has a number of regional centres for personnel training. These are the Inter-American Research and Documentation Centre on Vocational Training, the Asian Regional Skill Development Programme, the Inter-African Centre for the Development of Vocational Training and the Inter-Regional Training Information System [24].

VII. SUMMARY OF CONCLUSIONS AND RECOMMENDATIONS

1. Wholesale training of highly skilled personnel is the main problem which is to be solved to ensure the planned rates of development for the iron and steel industry in developing countries. To solve this problem it is necessary to identify the needs for manpower, to develop appropriate methods for vocational training and to make allocations for this purpose.

2. For determining manpower needs it is suggested that complex labour expenditures should be used for various types of production and final products with different process routes. The method for computing these expenditures was presented originally in the study of the technological complexity of iron and steel industry products [6] and is further developed in this study.

3. The use of complex labour expenditures helps to determine the need for industrial and production personnel for the production of various iron and steel products, including engineers, technicians, mechanics, electricians, clerical staff, workers.

4. The occupational structure of the requirements for workers of various skill levels with different process routes for production of iron and steel products is determined.

5. General characteristics of the workers of the iron and steel industry are defined on the basis of the unified job evaluation and wage scale system as well as qualification characteristics of specialists, types of curricula and contents of programmes for single subjects.

6. There is suggested a method of scientifically substantiated preparation of curricula making it possible to evaluate the significance of each training course by means of matrices of logical relationships of subject matter, and the scope of each training course is determined in the curriculum for a speciality.

7. There is suggested a method of preparation of programmes for specialist training on the basis of experts' evaluations of elaborated training programmes and computations of basic parameters of a curriculum by means of computers. Schematic diagrams of algorithms for problem solving are presented, and a curriculum for one of the specialities is elaborated according to the suggested method.

8. A recommended method of organizing the training process and using automatic training systems is given.

9. An evaluation of different methods of personnel training for the iron and steel industry of developing countries is made.

10. A brief description of various forms of international co operation in the field of personnel training for the iron and steel industry of developing countries is given.

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Annex I

THE MATHEMATICAL METHOD OF OBTAINING COEFFICIENTS OF DIRECT AND COMPLEX EXPENDITURES

In general terms the initial statistical table may be expressed by a set of equations which may be written mathematically in the following way:

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

where:

X_i = Total consumption of i-type of resources in the iron and steel industry;

X_{ij} = Consumption of i-type of resources for production of j - product;

Y_i = Commercial output or distribution to other consumers of i - resource.

In the formula (1) element $\sum_{j=1}^{n} X_{ij}$ representing the total production consumption may be transformed as

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

where:

a_{ij} = Direct expenditures of i - material for the production of j - products.

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

$$X_i = \sum_{j=1}^{n} a_{ij} \cdot X_i \qquad (i = 1, 2, ...n) \qquad (3)$$

Proceeding from equation (2) the direct expenditures may be determined by dividing consumption of i - resources, appearing as a result of production of j - products, by the output of j - products.

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

This rather simple formula is used as a basis for determining the direct expenditures with the use of the initial statistical table. For this purpose the statistical table (square table) is divided by a vector-row X_j which represents the outputs of iron and steel products (J - products). This results in obtaining matrix A of direct expenditures.

$$A = \left\| \begin{matrix} a_{11} & a_{12} & a_{13} & a_{14} & .... & a_{1n} \\ a_{21} & a_{22} & a_{23} & a_{24} & .... & a_{2n} \\ a_{31} & a_{32} & a_{33} & a_{34} & .... & a_{3n} \\ a_{41} & a_{42} & a_{43} & a_{44} & .... & a_{4n} \\ \vdots & & & & & \\ a_{n_1} & a_{n_2} & a_{n_3} & a_{n_4} & .... & a_{nn} \end{matrix} \right\| \qquad (5)$$

The complex expenditures have been computed on the basis of the obtained direct expenditures as they are mathematically related to direct expenditures.

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

and hence the complex expenditures of i - products per unit of j - products (in our case it may be rolled products, steel, iron etc.), depending on the limits of the complex, is a sum of direct expenditures and indirect expenditures of i - products at all previous production stages stipulated by the production of the same unit of j - products.

The indirect expenditures, in turn, are expressed through the direct expenditures by means of the following formulae:

$$a_{ij}^{(m)} = \sum_{k=1}^{n} a_{ik} \cdot d_{kj}^{(m-1)} \quad \text{(for columns)} \qquad (7)$$

$$a_{ij}^{m} = \sum_{k=1}^{n} a_{ik}^{(m-1)} \quad a_{kj} \quad \text{(for rows)} \qquad (8)$$

Thus, as a whole equation (6) may be written as follows:

$$C = A + A^{(1)} + \dots + A^{(n)} + \dots ,$$

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

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

In the general case the matrix of coefficients of indirect expenditures of m-power is equal to (m+1) power of the matrix of direct expenditures.

In such a manner the matrix of coefficients of complex expenditures may be represented as a power series of matrices of coefficients of direct expenditures:

$$C = A + A^2 + A^3 + A^4 + \dots = \sum_{k=1}^{n} A^k$$

It is known from linear algebra that matrix $(E-A)^{-1}$ has a similar expansion into a power series

$$(E - A)^{-1} = E + A + A^2 + \dots + A_m + \dots$$

If $A_m \to 0$ at $m \to \infty$, from tnis it follows that

$$C = (E - A)^{-1} - E \qquad (9)$$

that is, for determining complex expenditures it is enough to find a matrix inverted to E - A and to deduct the unitary matrix from it.

Annex II

QUALIFICATION CHARACTERISTICS OF WORKERS IN METALLURGICAL PROFESSIONS

A ladle man may have a category ranging from 1 to 5. A ladle man of category 1 prepares hand ladles and spoons under the direction of a worker of a higher category and cleans ladels, coats damaged places, performs heating and painting of ladles, brings materials and tools and cleans the working place. He should know the following: the design of ladles, the procedure of their coating and drying; requirements for ladles designed for receiving liquid metal, tools used for cleaning, repairing and preparing of ladles; and the designation of all materials used for fritting and repair of ladles.

A ladle man of categories 3-5 prepares casting ladles for receiving heats, installs together with a steel caster new stoppers, checks the condition of ladle lining and the quality of stopper rod setting, prepares and delivers hot metal transfer ladles to blast furnaces, accompanies them during transportation of hot metal, takes part in its discharge, inspects the ladles after iron discharging, removes scums and ladle bears. He should know the process route of steelmaking and casting; the values of metal temperatures for casting; the effect of the quality of ladle preparation and casting speed on formation of non-metallic inclusions in ingots; and the design of hot-metal transfer ladles and the principle of operation of their undercarriage.

A ladle man of category 3 prepares casting ladles with capacities up to 15 tonnes and hot-metal transfer ladles and delivers them to blast furnaces.

A ladle man of cateogry 4 prepares castings of heat tundishes and casting ladles with capacities from 15 to 100 tonnes.

A ladle man of category 5 prepares casting ladles with capacities above 100 tonnes, casting ladles in BOF plants and continuous and semi-continuous casting plants.

An inspector of category 3 in the iron and steel industry checks sampling of hot metal, loading and unloading of metal from heating facilities according to sizes, grades of steel and heats, correctness of cutting, weighing of metal and final products, outside surface, marking and painting of metal and pipes, and registers the quality of products and executes necessary documents. He should know the process route, range of products, specifications for final products, procedure of sampling, design and the principle of operation of inspection instruments and tools.

An inspector of category 2 performs inspecting functions under the direction of an inspector of a higher category.

An inspector of category 4 in the iron and steel industry performs the flow control of validity of the production process and finishing of ferrous metals and pipes, and approves and controls metal quality by means of flaw detection. He should know physical and chemical properties of inspected semi-finished products, raw materials, fuel and finished products, the principle of control and measuring instruments installed at furnaces and units.

An inspector of category 5 in the iron and steel industry performs the flow control of validity of the production process and quality control of finished products at the most important sections of the process route, quality control of received raw materials, semi-finished products and fuel, guides the work of other inspectors at this section, and registers the quality of products. He should know the terms and conditions of delivery and the procedure of claim submission to suppliers, major disturbances in the process and their effect on the quality of products.

An inspector of category 6 is responsible for quality control of finished products if there is no step-by-step checking.

Similarly, an operator of charging machines controls metal loading and unloading mechanisms of heating and heat-treating furnaces and has category 1 when he controls pushers or ejectors; category 2 when he is responsible for maintenance of floortype loading and unloading machines of heating furnaces; category 4 when he control a charging machine loading and unloading ingots at the thermal bay of ring and sectional furnaces; category 5 when he controls a charging machine loading, reloading and unloading ingots; category 6 when he controls a charging machine reloading ingots for wheels from continuous furnaces into batch-type furnaces and unloading ingots from chamber furnaces.

A crane operator in the iron and steel production sections controls load-lifting cranes of various designs equipped with different load-handling accessories and performing operations in blast-furnaces operates steelmaking and rolling mill plants. He has category 2 when he operates an overhead crane at the casting yard of blast-furnace plants, a jib crane or a telpher in metallurgical plants (irrespective of the load-lifting capacity of a crane), when he operates an overhead or gantry crane with a load-lifting capacity up to 10 tonnes for preparing taphole mass, lunkerite and other mixtures for steel casting, for removing cuttings and unfinished sections, and for lifting and transport of semi-finished products and finished products in the sections beyond the main process route; category 3 when load lifting capacity of a crane exceeds 10 tonnes; category 4 when he operates an overhead crane with a load-lifting capacity from 15 to 100 tonnes in furnace and casting bays of steelmaking plants; category 5 when the load-lifting capacity of a crane exceeds 100 tonnes.

An operator of a lining demolition machine operates the machine demolishing the lining of converters, steel ladles and hot-metal transfer ladles and has category 3 when he demolishes the lining of ladles and category 4 when he demolishes the lining of basic oxygen furnaces.

An operator for handling hot metal drives an electric car (ingot car) transporting and delivering hot metal in the process of production as well as a teeming ladle car and has category 2 when he drives a teeming ladle car with a load carrying capacity up to 50 tonnes in teeming steel into moulds, an electric car transporting ladles with metal to a continuous casting plant and delivering hot metal to rolling mills; category 3 when he drives a hot-metal ladle car delivering and pouring hot metal into basic oxygen furnaces, a teeming car with a load-lifting capacity above 50 tonnes, an ingot car transporting hot ingots from soaking pits to the receiving roll-table of blooming and slabing mills; category 4 when he drives a steel teeming ladle car delivering empty steel ladles to basic oxygen furnaces for receiving steel from the basic oxygen furnaces and transporting it to the casting bay; category 5 when he controls simultaneously a basic oxygen furnace and deoxidizers handling route during steel pouring into a ladle.

A metal heater participates in tilting and unloading of metal from heating facilities of rolling and pipe mills, controls the process of ingot and billet heating (category 3), performs the heating of metal, arbours and pipes in one or several heating furnaces (soaking pits), controls the supply of fuel and air as well as the amperage in electric arc furnaces, checks the condition of a bottom, brickwork and accessories of the attending furnaces (category 4); heats ingots in soaking pits of blooming and slabing mills or in batch-type car botton furnaces for plate mills, in continuous furnaces with three or more metal-heating zones for rail and structural steel, continuous and tandem heavy-section and medium-section mills, universal continuous sheet and plate mills; in continuous furnaces with two or three ingot and billet heating zones for cogging and billet mills; heats billets for continuous skelp, light-section and wire mills etc. (category 5); heats ingots in soaking pits of blooming and slabing mills or in batch-type car bottom furnaces for plate mills, in continuous furnaces with three or more heating zones of universal, continuous, sheet and plate mills, and checks the temperature and quality of metal heating, calorific value of used fuel, gas pressure and the temperature of waste gases (category 6).

A flame scarfer operator for scarfing metal defects marks out and removes metal surface defects from ingots, slabs, blooms and billets by means of flame-scarfing (category 3); with steels of quality grades (category 4), with high-alloy steel and alloys (category 5).

An operator of scalping machines removes metal surface defects from ingots, slabs, tubular and rolling billets of steels of all grades by means of complete or spiral scalping in machines of various types and designs (category 3); controls the process of metal scalping in coils with preliminary straightening and section sizing, operates decoiling and sizing facilities (category 4).

An operator of the control pulpit controls casting machines as well as machines delivering, transferring, tilting, straightening, cutting, scarfing, grading, removing and transporting cold and hot metal; works at simple control pulpit which does not control directly the rate of operation and output of machines with metal pushers and ejectors of metal from heating facilities and roll tables for metal loading and unloading (category 1); works at simple control pulpit controlling the rate of operation and the output of machines (cold saws, cold straightening machines, transfer tables, intermediate roller tables, coil conveyers, stamping machines, elevating and turnaround platforms etc.) (category 2); works at control pulpit of medium complexity controlling the rate of operation and output of machines, (roller-tables and transfer tables of cooling banks, pushers, inlet and outlet tables of roller-straightening machines, remote control systems of travelling cranes, coiling and uncoiling machines) (category 3); works at sophisticated control pulpits controlling the rate of operation and output of machines (flying shears of continuous mills, circular shears of uncoiling unit), works at control boards of single units and mechanisms of the automatic metal sizing line (category 4); works at control desks of units and mechanisms of the automatic metal sizing line (category 5).

A metal charger performs delivery and loading of metal into heating facilities of rolling mills, controls movement of ingots and billets in furnaces, metal tilting on inlet tables (category 2); loads metal into heating facilities of continuous section, wire and skelp mills as well as linear section mills with heating 20 and more grades of steel (category 3); supervises delivering and loading of metal into heating facilities of rolling mills, loading of metal into heating facilities of continuous section, wire and skilp mills (with heating 20 and more grades of steel) as well as universal mills with an output above 50 tonnes per hour (category 4).

A straightener of rolled products and pipes participates in straightening of strips and sheets in a straightening mill, rollers or machine (category 1); straightens hot splice bars under a press after piercing, participates in levelling by levelling machines and under presses of billets, rails, section and sheet metal as well as metal cast by continuous casting machines (category 2); performs the levelling of rails, channels, heavy-section and medium-section rolled products in a roller leveller and under stamping presses, in straightening plates when they are put into a straightener by hand, metal cast by continuous casting plants with diameters above 200 mm (category 3); straightens heavy thin-wall shaped sections of rolled products (category 4).

An operator of an EAF control pulpit switches on and off electricity supply of the furnace transformer, generator, reducer etc., controls the lifting and lowering of electrodes as well as the voltage and current amperage according to orders of a steelmaker, controls the furnace tilting when tapping a heat, registers the actual melting conditions and consumption of electricity in furnaces with capacities up to 10 tonnes (category 1) and in furnaces with capacities above 10 tonnes (category 2).

A hot metal cutter participates in delivering metal for shearing, turning and loading into shears (category 2); cuts hot pipes and billets in shears and by saws, controls shears and saws of different designs both from the control desk and directly near a metal shearing unit (category 3); trims front and rear ends of workpieces, sheet edges, cuts metal to length in shears, under presses and by saws, performs gas cutting of plates, alloy steels (category 4); cutting by press-shears with parallel shearing knives and a capacity above 800 tonnes, by flying and guillotine shears of continuous sheet and billet mills, cutting plates 4 mm thick and more by guillotine and circular shears as well as cutting heavy sections by press shears.

A sorter-discharger of metal performs the sorting of nonessential rolled products, weighing of single coils, sheets and sheet bars, groups them into piles by weight, makes or stamps the lable, glues or attaches it, registers the received and graded metal (category 1); performs sorting, storing and discharging of finished or semi-finished products according to heats, grades, sections, sizes and orders, checks the sizes of rolled sections and correctness of the marking, the grading of finished products with simultaneous conditioning and elimination of surface defects, weighing and packing of metal according to orders (category 2); grading of wide range of section rolled products and plates after two or more types of finishing, cold-rolled band in coils (category 3).

A heat specialist for rolled products and pipes performs heat treatment of ingots, slabs, forgings, rolled products in furnaces, prepares, tilts and loads metal, switches on and off vacuum pumps and furnace gates, operates instruments controlling the supply of electric energy, gas and air as well as handling mechanisms and mechanisms for unloading metal from furnaces (category 2); anneals sheet and coiled rolled products in bell furnaces with a charge weight of 30-60 tonnes, anneals plates, sheets and sheet iron in batch-type furnaces with a charge weight above 15 tonnes, sheets from high-grade steels, ingots and slabs of high-alloy steels (category 3); anneals sheets and coiled rolled products in bell furnaces with a charge weight above 60 tonnes as well as in vacuum and vacuum-hydrogen furnaces, strips of steel sheets in continuous furnaces, plates of wide range from alloy steel in batch type furnaces with a charge weight above 35 tonnes etc. (category 4); anneals strips of steel sheets in continuous tower-type furnaces as well as in plants with heat-resistant coating built in the continuous annealing line (category 5).

A burden man crushes iron, fluxes and scrap into pieces of the required size and removes non-metal admixtures, participates in the charging of moulds and feeding of charge to melting furnaces, cleans the area of the stockyard and its lean-to (category 1); performs the loading of charge, additive and fettling materials and oxidizers into moulds or boxes and delivers them by crane to a trolley, unloads scrap and loads it into moulds, weighs the charge, ferroalloys and alloying additions, cleans moulds, cars, railways of the stockyard and its lean-to from scrap and debris (category 2); performs the loading of charge in steelmaking plants producing alloy steels, the loading of charge with its simultaneous preparation in scrap preparation sections of steelmaking plants (category 3).

A slag man cleans casting and other bays of melting plants from slag, debris and metal ejections, opens the slaghole, opens and closes tapholes, discharges and removes slag from heating furnaces in rolling-mill plants, cleans and fettles the hearth of soaking pits (category 2); removes slag in BOF plants and steelmaking plants working on phosphoric iron, removes slag under the operating platform of steelmaking plants and liquid slag from soaking pits (category 3).

A bin operator of a blast-furnace plant is responsible for bins and under-bin premises, he breaks big pieces of ore and fluxes on bin grates, removes oversized scrap and entangled chips, pokes burden materials in bins, removes build-ups from bin walls, controls operation of bin gates, grizzly and the quality of coke screenings (category 2); performs the same in operating blast furnaces with capacities above 930 m^3 (category 3).

A gas-operator of a blast furnace participates in switching air-heaters from air to gas and from gas to air, in blowing out and starting up blast furnaces and has category 4 when he services a blast furnace with capacities from 1,700 to 2,000 m^3 and category 5 with capacities above 2,000 m^3; controls the process of heating of stoves of a blast furnace or a direct reduction furnace, switches stoves from gas to air and from air to gas, controls winches of the gas throttle and atmospheric discharge valves, blows a blast furnace out and starts it up, turns on and off gas of the gas supply system, controls the operating conditions of air blowers and the quality of gas cleaning and has category 5 when he services a blast furnace with a capacity up to 300 m^3 or a direct reduction unit (furnace), category 6 for blast furnaces with capacities from 300 to 930 m^3, category 7 for capacities from 930 to 2,000 m^3 and category 8 for capacities above 2,000 m^3.

A blast-furnace attendant (third) prepares iron and slag runners, cutting-off spades, participates in iron and slag tapping, in breaking and drying the casting pit, fettling damstones and a gun, in changing tuyeres and cooling equipment and has category 4 in servicing blast furnaces with capacities up to 930 m^3, category 5 for blast furnaces with capacities from 930 to 2,000 m^3 and category 6 with volumes above 2,000 m^3.

A blast-furnace attendant (second) dismantles and assembles the sheath of the slag notch, rams cinder runners and fettles slag troughs, controls slag stoppers during slag tapping, participates in preparation and replacement of slag instruments, in opening iron tapholes, iron tapping, preparation for fettling of the main iron runner, tuyeres and arches and has category 5 when he works at blast furnaces with volumes up to 930 m^3, category 6 at blast furnaces with volumes from 930 to 2,000 m^3 and category 7 for volumes above 2,000 m^3.

A blast-furnace attendant (first) works at the hearth of a blast furnace in accordance with the schedules of iron and slag tapping, dismantles and assembles the sheath of the slag notch and prepares the main runner for tapping iron and slag, charges guns with stopping mass, replaces cooling equipment, tuyeres and arches, operates a boring machine and a gun during opening and stopping-up of the iron taphole, controls the slag composition according to instrument readings as well as the heating of the hearth surface, water circulation, operation of tuyeres and cooling equipment and has category 6 when he works at blast furnaces with volumes up to 930 m^3, category 7 at blast furnaces with volumes from 930 to 2,000 m^3, category 8 with volumes above 2,000 m^3.

A trough operator of casting machines prepares the pouring spout, installs troughs and regulates the lifting and lowering of a ladle during iron casting (category 4).

An operator of a weight bridge collects, weighs, delivers and unloads into a skip burden materials and has category 3 when he works at a direct reduction furnace (plant), category 4 at blast furnaces with volumes up to 500 m^3, category 5 with volumes from 500 to 930 m^3, category 6 with volumes above 930 m^3.

An operator of a blast-furnace hoist operates lifting and burden charging mechanisms of the blast furnace (category 3) or a direct reduction plant (furnace) (category 2).

A burden delivery operator performs remote control of the burden feed to blast furnaces under direction of an operator of the highest qualifications, controls operation of mechanisms of the burden delivery electrical system (category 4); operates the automatic system for collecting, weighing and charging burden materials into the blast furnace, controls, according to indications of traffic lights and weighing instruments, operation of mechanisms of the automatic system of collecting, weighing and charging burden materials into the blast furnace (category 6).

A skip operation cleans the skip pit, removes and loads spilt raw materials into the skip, operates a lift of the small skip when automatic instruments, opening and closing mechanisms of coke and ore bins are switched off (category 2); when he works at blast furances with volumes above 930 m^3 (category 3); fills skips of incompletely mechanized blast furnaces with burden materials, regulates the sequence of burden materials supply to the fire grate and the charging of them into the furnance, and checks completeness of the blast furnace charging (category 4).

An iron tapping operator knocks out ingots stuck in moulds of casting machines, removes ingots from railways, participates in replacement of moulds, links, rollers, sprockets and in other repair works in casting machines (category 3).

An operator of the mould hydraulic cleaning and coating system cleans and varnishes the inner surface of moulds and ensures the supply of trains for moulds cleaning and coating (category 3).

A distributor operator (a BOF operator) operates the BOF tilting mechanism under guidance of an operator of a higher qualification, participates in repair operations and has category 3 when he works at basic oxygen furnaces with capacities up to 10 tonnes, category 4 when he works at basic oxygen furnaces with capacities from 10 to 250 tonnes, category 5 at basic oxygen furnaces with capacities above 250 tonnes; controls BOF steelmaking from the control panel, controls the drive during the rising up and turning down of the converter, the oxygen lance proportioning and feeding of flux materials into the BOF, slag flashing into the slag pan and metal tapping into a ladle, operates a pushing car and a charging machine and has category 5 when he works at basic oxygen furnaces with capacities up to 10 tonnes, category 6 when he works at basic oxygen furnaces with capacities from 10 to 100 tonnes, category 7 at basic oxygen furnaces with capacities from 100 to 250 tonnes and category 8 at basic oxygen furnaces with capacities above 250 tonnes.

An operator of a charging machine participates in charging into steel-making units, operates the lever switching on and off the mould-locking mechanism, participates in repair operations (category 3); charges materials into electric arc furnaces, participates in removal and installation of electrodes, moves them in electrode-holders and has category 5 when he works at electric arc furnaces.

A mixer operator participates in slag flushing, fettling of lip and mouth, cleaning of hot iron transfer ladles after pouring, accompanies a ladle with hot metal, operates the mixer tilting mechanism as well as the mechanism for lifting mixer pouring and discharging hole covers (category 2); flushes slag from the mixer, fettles the discharging trough and mixer mouth, cleans hot metal transfer ladles, delivers a slag ladle and refractories for fettling the mixer and has category 4 when he works at mixers with capacities from 600 to 2,500 tonnes and category 5 at mixers with capacities above 2,500 tonnes; averages iron in the mixer, receives and discharges iron from the mixer in accordance with the schedule of pouring hot metal into steelmaking units and has category 4, when he works at mixers with capacities from 600 to 2,500 tonnes, category 5, and above 2,500 tonnes, category 6.

A stopper assembler procures, stores and brings to the working place ladle sleeves, plugs, rods, refractory and other materials for assembling stoppers, prepares the mortar levels metal rods and cleans the working place (category 1); assembles pipes for oxygen injecting into steelmaking units, participates in stopper assembling for steel teeming ladles (category 2); participates in stopper assembling for steel teeming ladles with capacities above 100 tonnes (category 3); assembles and dries stoppers for casting ladles, checks the quality of stopper sleeves and plugs, controls stopper drying conditions (category 3); assembles stoppers for steel teeming ladles with capacities above 100 tonnes and for continuous and semi-continuous casting plants (category 4).

A gas cutter operator at the continuous plant operates mechanisms for gas-cutting of slabs and ingots to lengths or cuts them with hand operated gas cutters, prepares dummy bars for next casting (category 3); operates mechanisms for gas cutting of continuous casting into lengths or cuts billets by a hand-operated gas cutter, operates mechanisms gripping and lifting gas cutter cabins, moving gas cutters and adjusting the lengths of billets, controls the delivery of billets to roller conveyers, billet conditioning (category 4); performs the same functions at plants with capacities above 100,000 tonnes per year (category 5).

An operator of the continuous casting plant controls from the control pulpit mould reciprocating mechanisms, lifting-turning table, withdrawal-roll set, tundish car, installs moulds, seals clearances between dummy bars and moulds, controls casting speed (category 4); performs the same functions in casting high alloy steel (category 5); controls from the control pulpit stoppers of tundishes and casting ladles, withdrawal roll sets, moulds, lifting-turning tables, nozzle tilting mechanisms and mould electric gates, feeding mechanisms, mechanisms for moving, cutting, transferring and removing of metal, guides the work of operators of control pulpit during metal casting (category 5); performs the same functions at plants with summary capacities above 150,000 tonnes per year or during the casting of high alloy steel (category 6).

A BOF steelmaker helper (third) participates in iron pouring, introduction of additions and deoxidizers, tapping of steel and flushing of slag, knocking out and sealing of tuyeres, replacement of bottoms, takes samples and measures the temperature of metal, knocks down slag from BOF hoods after heat, cleans the working platform, participates in the repair of equipment and BOF brickwork, and has category 2 when he works at basic oxygen furnaces with capacities up to 5 tonnes, category 3 at BOFs with capacities from 5 to 10 tonnes, category 4 - at BOFs with capacities from 10 to 100 tonnes, category 5 at BOFs with capacities from 100 to 250 tonnes or above 20 tonnes in making alloy steels, and category 6 at BOFs with capacities above 250 tonnes.

A BOF steelmaker helper (second) participates in carrying-out BOF heats, BOF heating up, closing and opening of tap-holes, cleans the BOF mouth from scrap, performs maintenance of a lance injecting oxygen to the BOF, cleans and prepares troughs, operates the car during scrap charging into the BOF, as well as weighing proportioner and mechanisms of the flux handling channel, and has category 3 when he works at BOFs with capacities up to 5 tonnes, category 4 at BOFs with capacities from 5 to 10 tonnes, category 5 at BOFs with capacities from 10 to 100 tonnes, category 6 at BOFs with capacities from 100 to 250 tonnes or BOFs with capacities above 20 tonnes in making high alloy steels, and category 7 at BOFs with capacities above 250 tonnes.

A BOF first steelmaker helper makes steel in basic oxygen furnaces, performs the heating-up of the converter, pours hot metal, introduces additions and deoxidizers, taps steel and flushes slag, controls oxygen feed, determines readiness of the heat and has category 4 when he works at basic oxygen furnaces with capacities up to 5 tonnes, category 5 at BOFs with capacities from 5 to 10 tonnes, category 6 at BOFs with capacities from 10 to 100 tonnes, category 7 at BOFs with capacities from 100 to 250 tonnes or BOFs with capacities above 20 tonnes in making alloy steels, and category 8 at BOFs with capacities above 250 tonnes.

An EAF first steelmaker helper melts steel and alloys in electric arc furnaces of different types, adds anad installs electrodes, cleans the bottom from the slag and metal after heat tapping, fettles the furnace and frits the bottom, charges, controls the electric and thermal conditions of the furnace, taps the heat, he has category 5 when he works at furnaces with capacities up to 3 tonnes, category 6 at furnaces with capacities from 3 to 25 tonnes, and category 7 at furnaces with capacities above 25 tonnes.

A hot mill roller man rolls hot metal of various steel grades, shapes and sections in single groups of stands or mill single stands, controls the position of rolls and the rate of rolling, passes the feed into rolls and controls its exit from rolls, operates the screw-down mechanism of two-high non reversing-sheet mills, checks the temperature of metal and correctness of section of the rolled metal (category 4); operates continuous sheet-bar and billet mills, the front side of sheet-bar-and-billet mills, heavy-section and wire mills, finishing stands of medium section and light-section mills, continuous and semi-continuous sheet mills, the rear side of single-stand two-high reversing plate and universal mills, stands of two-high plate tandem mills, the front side of three-high universal mills (category 5); the finishing line of stands of continuous, semi-continuous and tandem section and skelp mills, the finishing stand group of train-type heavy section, medium section and light-section mills, roughing and finishing groups of stands of continuous and semi-continuous sheet mills, stands of three-high and four-high plate tandem mills (category 6); the finishing group of stands of train-type wire mills with 5 and more rolling strands (category 7).

An operator of a flame scarfing machine in the blooming (slabing) mill flow controls operation of gas torch cutting equipment, ventilation system, hydraulic scale breaking equipment and pumps, checks the quality of scarfing (category 5); installs the machine in the rolling line and scarfs hot metal, controls roller tables, gas torch blocks, pumping station and other mechanisms, controls the pressure of oxygen and fuel gas, watches metal-scarfing and operation of the hydraulic scale breaking system (category 6).

An operator of a hot rolling mill control board controls in the process of rolling the lifting platform, transfer tables and roller tables at medium section and light-section mills, watches metal passing into rollers, participates in roll changing, setting and repair of mills (category 3); at train-type billet and heavy-section mills, the lifting platform at univseral mills, controls the manipulator screw-down mechanism, working roller tables end shears and feed rolls at two-high stands of billet, section and sheet mills, controls operation of the finishing stand of the finishing train at heavy-section tandem mills and continuous and semi-continuous heavy section, medium-section, light-section and wire mills (category 4), operates manipulators and turn-over gears in the process of metal rolling, receiving and roll tables at roughers of heavy-section mills, two-high reversing-plate mills, plate tandem mill of all types and universal mills, controls the number of roll revolutions in relation to the temperature of metal, reductions and engine loads in the process of rolling (category 5); ensures the metal reduction schedule and controls in the rolling process the screw-down mechanism, main tables and engines of rolling-mill main drives, main engines at continuous and semi-continuous section, skelp and wire mills and operation of the finishing group of stands at continuous sheet mills etc. (category 6); controls the screw-down mechanism, main tables and engines of main drive of plate mills and two-high universal mills (category 7).

A hot-mill-rollerman assistant participates in metal rolling, turns feeds and is responsible for their proper passing over roll tables, participates in feeding metal to rolls, receives feeds, participates in disassembly and assembly of stands, changing and setting of rolls and lubrication of roll necks (category 3); performs the same in working at continuous billet, sheet and wheel rolling mills and at the finishers of wire, section and billet stands (category 4); performs the same in working at two-high non reversing mills in rolling high quality steels (category 5).

A press operator performs the work connected with pressing semi-finished products by presses, switches on and off feeders, controls their operation, controls and ensures uniform feed of the mass into the press, moulds small-size piece refractory articles weighting up to 1 kg, services the feeders of dry press process presses (category 2), briquetting, repressing air brick, presses silicon carbide rods, high alumina tubes and articles according to the dry press process at mechanical presses with a force up to 150 tonnes (category 3); presses articles at mechanical hydraulic presses with a force up to 1,000 tonnes and friction presses according to the dry press process presses silit rods, articles of high refractory oxides, light-weight articles, feeds articles at auger extruders (category 4); presses articles according to the semi-dry press process at hydraulic presses with a force of 1,000 tonnes and higher, presses spiders and screw thread stoppers, funnels, nozzles and particularly complicated refractory articles weighing above 14 kg according to the semi-dry press process (category 5).

A gas-torch operator, cutting scrap and waste, performs the marking-out and oxygen cutting of simple oversize scrap into predetermined lengths (category 2); of mixed scrap with separation of non-ferrous scrap and preservation or cutting-out of machine parts or units which may be used after repair (category 3); performs the same with gas cutting of ships for melting (category 4).

An inspector of scrap and ferrous and non-ferrous waste receives and distributes scrap, determines the content of admixtures, grade, group and class of the scrap (category 2); performs preventive and pyrotechnical inspection, removes explosion-hazard materials from the scrap and participates in their disposal (category 3); performs the same in processing above 100,000 tonnes of scrap in sections and plants (category 4).

A press operator, pressing metal waste, performs baling or briquetting of metal waste at baling or briquetting presses or iron-breaking machines with a force up to 400 tonnes (category 3); at baling or briquetting presses or iron breaking machines with a force from 400 to 800 tonnes (category 4); performs the same with a force above 800 tonnes (category 5).

A gas-collecting pipe operator controls spraying of the gas collector and stand-pipes, opens and closes gas bleeders of the gas collector, checks the pressure and temperature of gas in the gas collector as well as water consumption for tar washing-away spraying (category 4); performs the same at the hourly capacity of equipment above 40 tonnes of total coke or when working at non-coke ovens (category 5).

A door operator controls the opening and closing of doors of coking chambers, cleans them from tar and graphite, packs and fixes the doors (category 4), and when he attends the door cleaning mechanism (category 5).

A trap-door operator charges the chambers of ovens, opens and closes loading trap doors, cleans the covers and seats of the doors from graphite, ensures completeness and uniformity of coke chambers charging (category 5); when he attends trap-door extracting and installing mechanisms and with smokeless charging (category 6).

An operator of a coke-pushing machine discharges the coke from coking chambers, controls conveying mechanisms and door-removing devices, press rods, cross-bar screw unscrewing and driving rods, rods for levelling coal charge etc. (category 5); when he controls the cross-bar unscrewing mechanisms, door cleaning mechanisms and automatic equipment for charge levelling (category 6).

Annex III

QUALIFICATION CHARACTERISTICS OF ENGINEER-METALLURGISTS SPECIALIZED IN IRON AND STEEL MATALLURGY

Designation of the specialist

The specialist is prepared for production and technological administration and management, designing and research activities in the field of the iron and steel industry in conformity with his specialization.

The specialist is trained for the work at industrial enterprises and designing organizations at initial posts to be filled in by specialists with higher education.

General requirements for the specialist

The specialist should have a high level of vocational training, comprehensive learning and culture. The specialist should combine fundamental scientific grounding and practical training, know his speciality perfectly, continuously widen his knowledge, know how to use the principles of industrial engineering in practice, and master advanced methods of personnel management.

The specialist should know:

(a) Fundamentals of general theoretical subjects in the scope required for solving production, designing and research problems;

(b) General engineering subjects, including engineering graphics, general, inorganic and physical chemistry, theoretical and applied mechanics, heat engineering, electrical engineering, industrial electronics and subjects of the metallurgical cycle;

(c) Physical and chemical foundations of ore preparation processes, iron and steelmaking, production of ferroalloys; fundamentals of new metallurgical processes, pelletizing of iron-ore concentrates, direct reduction of iron, continuous steelmaking, vacuum and plasma-arc melting, electroslag remelting, ladle refining, continuous casting of steel etc.;

(d) Iron metallurgy. The theory of iron ore pelletizing, caking and hardening of sinter, hardening of pellets during roasting and specific features of the design of pelletizing equipment; regularities in burden and gas movements in blast-furnaces; principles of preparation of material and heat balances of blast-furnace ironmaking; specific features of up to date ironmaking practice and quality control indices; process of ferroalloys making in blast furnaces;

(e) Steel metallurgy. The theory of BOF and hearth steelmaking processes and prospects for their modification and intensification; continuous steelmaking processes; theory of steel ingot crystallization and up-to-date practice of steel casting; methods of steel quality control and checking; process of producing large and extra-heavy ingots;

(f) Electrometallurgy of steel and ferroalloys. The physical and chemical foundations and EAF practice of melting of steel and alloys; theory and practice of vacuum melting and ladle degassing, steelmaking in plasma-arc furnaces and production of fused ingots, vacuum, arc, electron beam, electroslag and plasma-arc remelting; carbothermic, silicothermic and aluminothermic processes of ferroalloy production and master-alloys smelting, theory of steel ingot crystallization and up-to-date practice of steel casting; production of alloy steel ingots;

(g) Specific features of the design, practice and equipment of sintering and blast-furnace ironmaking, BOF, open hearth and EAF processes; fundamentals of the mathematical description of metallurgical projects and production automatic control systems; mechanization and automation means of metallurgical processes; designing practice of metallurgical projects, basic principles and methods of design solutions;

(h) Economics of iron and steel industry and enterprises, fundamentals of organization, planning and management of production and quality control of products; industrial hygiene and environmental protection; fundamentals of law, patent branch and industrial engineering.

The specialist should be able to do the following:

(a) Control the production process; compute the optimum composition of the burden and obtain products with predetermined physical and chemical properties; use up-to-date methods of iron, steel and ferroalloys quality control; develop and master processes for making new grades of steel;

(b) Identify major materials and rocks visually and by chemical composition; describe a concrete metallurgical process by means of equations of basic chemical reactions; select methods of production of cast and worked articles from a given grade of steel and alloy;

(c) Simulate and optimize metallurgical processes, analyze conditions and modes of operation of furnaces and equipment; rationally use different parts of refractory linings of furnaces and mechanical and electrical units of equipment; design metallurgical units and plants; compute, design and operate vacuum systems;

(d) Measure physical values; carry out electrical engineering, thermodynamical and kinetic computations as well as computations of stationary and non-stationary heat-mass-transfer; design and stage physical and chemical experiments; use basic methods of analysis of metal, slag, and gas; work at plants for structural examination of materials;

(e) Use up-to-date computers;

(f) Take independent decisions; elaborate and register technical documents; organize socialist competition and advanced training of workers; contribute to the process of rationalization;

(g) Use rational methods of search and application of scientific information.

Annex IV

QUALIFICATION CHARACTERISTICS OF TECHNICIAN-METALLURGISTS SPECIALIZED IN STEELMAKING

Designation of the specialist

The technician-metallurgist is trained for the work at enterprises with steelmaking, in open-hearth and BOF plants, at works management departments, in laboratories and scientific research institutes as shift superintendents, bureau supervisors, senior foremen, foremen, senior technicians and technicians as well as workers whose duties require specialized secondary education.

General requirements for the specialist

The specialist should have deep and sound theoretical knowledge, practical experience and skills in the selected field of his specialization, and display diligence, initiative and creativity in his work.

The technician-metallurgist should know the following: structure and properties of metals and alloys; fundamentals of physical chemistry and theory of metallurgical processes; composition and properties of raw mateials and materials for steelmaking, designation of different grades of steel, carbon and alloy steelmaking processes; design and procedures of operation and maintenance of production, heat engineering, electrical, mechanical and transferring equipment of steelmaking plants; chemical and physico chemical methods of analysis, instruments for measuring, control and automation of production processes; principles of the design of manipulators with programmed control; microprocessor facilities and their use in the iron and steel industry, economics, planning, organization and management of the production; rates, wage scales and existing regulations for wages and salaries, requirements for industrial hygiene and environmental protection, safety engineering and fundamentals of fire protection in conformity with the safety engineering standards system; the system of quality control of products, fundamentals of labour legislation.

The technician-metallurgist should be able to do the following: organize the work of subordinate personnel, direct the work of the production sector entrusted to him; ensure fulfilment of the work quota in respect of quantity, quality and range of products; efficiently use equipment, observe the rules of technical operation of metallurgical units, economically and rationally use raw materials, take direct part in introduction of advanced technology, ndustrial engineering, automation and mechanization of production processes; execute technical documents defining the work of the sector and register fulfilment of the work quotas; ensure safety of work and check observance of regulations on industrial hygiene, safety and fire protection; and contribute o development of rationalization and invention.

The technician metallurgist should be trained in one of the following working trades and be certified for it:

1. Converter steelmaker helper - category 2.

2. Steel caster - category 2.

3. Ladle man - category 3.

Programme of study in physical chemistry

The objectives of and the practical skills to be acquired in the programme for the subject physical chemistry (13) for the engineering specialization iron and steel metallurgy are formulated in the following way.*

The objective of the course is to teach students experimental and theoretical methods of research on systems of equilibrium and kinetics of transformations; to determine the direction of spontaneous homogenous and heterogenous processes according to the conditions of the system; to teach the use of the methods of thermodynamics and kinetics for forecasting the behaviour of metallurgical systems.

Practical skills are acquired in making thermochemical calculations of chemical equilibrium, calculations of equilibrium in solutions including the activity of components and solutions of electrolytes, analyses of phase equilibrium on the basis of the diagram of condition and calculation of phase composition, in calculating thermodynamic functions of the surface, adsorption and surface tension, in calculating rates of processes, measuring thermal effects of chemical reactions, partial mole values, osmotic effects, transport numbers in solutions, equilibrium characteristics, cooling curves, adsorption and surface tension.

Below is given an abstract from the training programme of the subject physical chemistry*:

Theme 1. Laws of thermodynamics (12).

1. Introductory lecture. Subject of physical chemistry. Problems and methods of physical chemistry. Importance of physical chemistry for the iron and steel industry.

2. Thermodynamic system and thermodynamic parameters, function of state. First law of thermodynamics. Internal energy, enthalpy, work.

3. Thermodynamic analysis. Hess's law. Dependence of the thermal effect on the temperature. Standard heat of compounds formation.

4. Inverse and irreversible processes. Second law of thermodynamics. Entropy.

5. Statistic substantiation of the second law. Computation of entropy for some simple processes. Thermodynamic function: Gibbs energy and Helmholtz energy.

6. Dependence of functions G and F on state variables. Equation of maximum work. Third law of thermodynamics.

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*A figure in parentheses after the title of the subject indicates the number of lecture hours devoted to the subject.

Theme 2. Chemical equilibrium (8).

7. Phase equilibrium. Clausius-Calpeyron equation. Dependence of saturated steam pressure on the temperature.

8. Chemical equilibrium in a homogenous system. Law of mass action. Computation of reaction yield.

9. Isothermal line of chemical reaction. Dependence of equilibrium constant on the temperature.

10. Heterogenous chemical reactions. Dissociation pressure. Calculation of chemical equilibrium according to the standard values tables. Use of chemical thermodynamics for the purpose of production processes control.

Theme 9. Thermodynamics of irreversible processes (4).*

41. Basic provisions of thermodynamics of irreversible processes. Hypothesis of Thomson. Onsater relation.

42. Final lecture. Examples of application of methods of thermodynamics of irreversible processes for thermal diffusion of substances. Physical and chemical problems of modern metallurgy.

Formulation of objectives and acquired practical skills in the programme of the general technical subject electrical engineering, electronics, electric equipment (14) for an engineering speciality "Iron and steel metallurgy" is as follows.

The objective of the course is to teach students to select electric engineering and electronic devices for solving technical problems in researches, designing and operation of production equipment; to teach the methods of analysis and practice of measuring parameters of electric circuits.

Practical skills are acquired in:

- Measuring amperage, voltage, capacity and phase shift by means of instruments of the electomechanical group;
- Measuring the amplitude and time response of electric signals by an electronic oscillograph; investigation of characteristics of electric engineering devices;
- Ensuring the safety of work with electric engineering installations and instruments;
- Selecting according to a catalogue and assembling a connection circuit of electric motors and transformers;
- Selecting rational methods for measuring parameters of an electric circuit according to absolute values of the permissible error and frequency;

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*Enumeration of lectures within the same subject goes through all themes.

- Reading electronic circuits;

- Assembling and adjusting the simplest circuits of rectifiers and amplifiers;

- Trouble-shooting in and adjusting circuits with the help of electronic measuring instruments and an oscillograph.

- Formulation of objectives and acquired practical skills in the programme of the general metallurgical subject "Theory of metallurgical processes" (15) for an engineering speciality "Iron and steel metallurgy" is as follows.

The objective of the course is to teach students to analyse thermodynamic and kinetic laws of the most important physical and chemical phenomena forming the base of up-to-date processes of the iron and steel metallurgy.

Practical skills in:

- Calculating thermodynamic characteristics of simple and complex metallurgical systems and processes;

- Carrying out high-temperature experiments for studying the thermodynamics and kinetics of processes in metallurgical systems with the use of up-to-date equipment, mathematical processing of the results and modelling by computers.

Annex V

METHOD OF QUANTITATIVE EVALUATIONS OF CURRICULA

Let us introduce into consideration a matrix of logical relationships of sections of subjects of the speciality.

$$A = (a_{ij}) \qquad (1)$$

where element a_{ij} is the number of unities fron the matrix on figure I for two interconnected sections i and j.

If there are n sections in the speciality, the values of i and j vary within i, j = 1, n and, consequently, matrix A has n-lines and n-columns.

The degree of using each section by direct relationships in the training process on the speciality and the degree of using by each section of inverse relationships may be expressed quantitatively.

Calculate the total sum of elements in each line of matrix A and the total amount of elements in each column of matrix A.

These sums express the total number of direct and inverse lecture logical relationships of each section in the training process for the speciality.

Represent the summing process mathematically in the matrix representation (20).

Let us designate a vector-line with a size 1xn through X_0, each co-ordinate (position) of this vector is referred to one of the sections.

$$X_0 = (1, 1, \ldots\ldots, 1) \qquad (2)$$

Let us draw up two matrix expressions:

$$X_{\bar{1}}^T = A \cdot X_{\bar{1}}^T;\ X_{\bar{1}}^T = A \cdot X_o^T \qquad (3)$$

Here: A^T = Transposed matrix A

X_o^T = Transposed vector X_o^T

X_1^T = Vector-column each co-ordinate of which is equal to the sum of elements in a respective line of matrix A or to the number of direct lecture relationships of a respective section;

X_2^T = Vector-column each co-ordinate of which is equal to the sum of elements in a respective column of matrix A or to the number of inverse lecture relationships of this section.

The common characteristics, being invariant of the time position of the section in the training period, is the sum of its direct and inverse relationships.

The summary number of direct and inverse relationships of each section is determined from vector X_3.

$$X_3^T = (A + A^T) \cdot X_o^T \qquad (4)$$

The total number of summary logical relationships for a whole period of training in the speciality is equal to:

$$S = X_0 \, (A + A^T) \cdot X_0^T \qquad (5)$$

An average number of summary logical relationships per lecture on the speciality is:

$$\lambda av = \frac{S}{m} \qquad (6)$$

where m = the number of lectures on the speciality.

The internal significance of sections by direct relationships is designated by vector X_4:

$$X_4 = \frac{1}{\lambda av} \cdot X_1 \qquad (7)$$

The internal significance of sections by inverse relationships is designated by vector X_5:

$$X_5 = \frac{1}{\lambda av} \cdot X_2 \qquad (8)$$

The internal significance of each section by summary relationships, both direct and inverse ones, may be expressed by vector X_6:

$$X_6 = \frac{1}{\lambda av} \cdot X_3 \qquad (9)$$

Quantitative evaluation according to logical relationships in terms of one lecture of a section is specified by means of the following formulae:

Let us consider a diagonal matrix of initial scopes of sections:

$$T = (t_{ij}) \qquad (10)$$

Its elements $t_{ij} = 0$ at $i = j$ and $t_{ij} = t_i$ at $i = j$. Here t_i - scope of a section i which is equal to the number of lectures of this section. Availability of matrix T makes it possible to consider respective vectors and matrices which elements are rated per lecture of each section.

Let us call matrix $F = (f_{ij})$ of order n a matrix of coefficients of the direct use of sections.

$$F = A \cdot T^{-1} \qquad (11)$$

Matrix $Q = (q_{ij})$ of order n will be a matrix of coefficients of the inverse use of sections.

$$Q = A^T \cdot T^{-1} \qquad (12)$$

where A is from (1), T - from (10).

Matrix B of summary coefficients of sections will be an analog of matrix $A + A^T$:

$$B = F + C \qquad (13)$$

In a general case matrix B is asymmetric, that is

$$F \neq 0 \qquad (14)$$

Let us make up vector X_7

$$X_7 = X_6 \cdot T^{-1} \qquad (15)$$

The spread in evaluations for vector X_7 is the first approximation of the evaluation of the training process in the speciality as a single unified complex of the whole set of sections. A considerable spread in evaluations over co-ordinates of vector X_7 indicates nonuniformity of the use of logical relationships in sections.

Up to the present moment we have considered only the internal logic of the training process in the speciality at the level of sections.

The objective of training in the speciality, however, is correspondence of the training objectives with the needs of practical activity of specialists. Such an approach should reflect the external aspect of evaluation of the contents of sections in relation to the training process.

We may subject the content of sections on the speciality to experts' evaluation as to the conformity of this content with the practical activity of specialists with regard to the progress of science and technology.

As a result of this, the sections will receive evaluations or weights which we shall set by vector of external significance .

$$Y = (Y_1, Y_2, \ldots\ldots, Y_n) \qquad (16)$$

where Y_i = significance or weight of section i in the practical activity of specialists.

Finally, each section may be evaluated according to basic indices: its significance for the practical activity of a specialist and its significance inside the training process in the speciality. Therefore we shall determine the resulting significance of each section on the speciality taking into account its external and internal significances.

A respective mathematical formulation of the task for determining the resulting significance through vector Z will be:

$$Z = (Z_1, Z_2, \ldots\ldots, Z_n) \qquad (17)$$

where Z_i = the resulting significance of section i.

Let us make a matrix equation:

[illegible] $\cdot Z^T = F \cdot Z^T + Y^T$ (18)

where F is from (2), Y - from (7);

$F \cdot Z^T$ = vector of internal significance of sections for using their contents by other sections of the speciality. This vector determines internal significance of sections only by direct relationships.

[illegible] > 0 - coefficient of proportionality, common for all sections of the speciality.

If we could know β we should determine the vector of resulting significance Z from equation (18) with certain limitations at β.

In one case, however, we may determine vector Z definitely without knowing the value of β. If logical relationships have not been established between sections of the speciality, F = 0 and equation (18) is transformed into equation:

$$\beta \cdot Z = Y \qquad (19)$$

This is the case when the significance of sections is exactly proportionally with experts' evaluations.

Evaluations of sections according to the vector or external significance include not only evaluation of the contents of sections in general without taking into account information from other sections, but, indirectly, evaluation of the same sections information from which they are using.

Therefore, if A = 0 evaluation of a section according to the vector of external relationships Y (16) should be distributed between this section and sections to which references are made.

As a result we obtain:

$$Y^T = Z^T + Q \cdot Z^T \qquad (20)$$

where $Q \cdot Z^T$ is vector of significance of sections for using inverse relationships.

Equations (4) and (11) provide all data necessary for determining a single vector of the resulting significance of sections of speciality Z and coefficient β according to known matrix (I), vector Y (16) and matrix T (10).

Let us put vector Y from equation (20) to equation (18):

$$\beta \cdot Z^T = (E + F + Q) \cdot Z^T \qquad (21)$$

Otherwise, taking into account (22):

$$(\beta - I) \cdot Z^T = B \cdot Z^T \qquad (22)$$

We obtained a characteristic equation for proper vectors of non-negative matrix B.

It is known from matrix algebra that a non-negative matrix has a non-negative proper vector to which the maximum proper value corresponds.

Let us designate the maximum proper value of matrix B by $\lambda_{max.}$ The proper vector, corresponding to λ_{max} will be designated by X_{max}.

We obtain:

$$\lambda\, max. \cdot X^T_{max.} = B \cdot X^T_{max.} \qquad (23)$$

We receive from (22) and (23)

$$\beta = \lambda_{max.} + 1 \qquad (24)$$

Values β from (24) are used in solving equation (18).

Proper vector X_{max} from matrix B shows the significance of the through use of each section in the training process in the speciality, i.e. its use according to logic relationships through foregoing and ensuing sections.

The number of λ_{max} defines the degree of the through use of each section on the speciality according to direct and inverse relationships.

New scopes of sections are established in proportion to evaluations according to vector Z (18).

Evaluations of scopes of sections according to vector Z (18) take into account the logic of the training process in the speciality which is given by matrix A (1) and number β (24) expressing an average number of logical relationships of the through use of each lecture on the speciality according to direct and inverse relationships. The final objective of training in the speciality is taken into account, it is determined by vector Y (16).

Let us introduce three new vectors of scopes of sections, T_o,

$$T_o + (t_1, t_2, \ldots\ldots, t_n) \tag{25}$$

the vector of initial scopes of sections is received from matrix T (19).

$$Z_o = (Z_1, Z_2, \ldots\ldots, Z_n) \tag{26}$$

the vector of rated scopes of sections being in proportion to evaluations according to vector Z (18)

$$V_o = (V_1, V_2, \ldots\ldots, V_n) \tag{27}$$

vector of the finally established scopes of sections.

There are three logical possibilities for evaluating the range of permissible values of co-ordinates of vector V_o.

$$\begin{aligned} &1.\quad 0 \le V_i \le Z_i && \text{if } Z_i < t_i; \\ &2.\quad t_i \le V_i \le Z_i && \text{if } Z_i > t_i \\ &3.\quad V_i = Z_i = t_i && \end{aligned} \tag{28}$$

The total established scope of sections on the speciality V_{est}

$$V_{est} = n \sum_{i=1}^{n} V_i \tag{29}$$

A spare reserve of time for the speciality ΔV:

$$\Delta V = m - V_{est} \tag{30}$$

where m is the number of lectures on the speciality.

The duration of a lecture is equal to two academic hours.

The time reserve ΔV may be used for new lectures, sections or new training courses.

If the scope of a section is increased its programme may be expanded by new problems supplementing and strengthening the initial programme of this section.

If the scope of a section is reduced with the same programme the rate of studying is increased. If it is impossible to expose the programme of the section within the reduced time period the pgoramme may be reduced by excluding a part of its problems.

Quantitative computations with the use of formulae 25-39.

For the guidance of our publications programme in order to assist in our publication activities, we would appreciate your completing the questionnaire below and returning it to UNIDO, Division for Industrial Studies, D-2119, P.O. Box 300, A-1400 Vienna, Austria

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QUESTIONNAIRE

Manpower and training requirements in industry: A methodology with an application to the iron and steel sector

(please check appropriate box)

	yes	no
(1) Were the data contained in the study useful?	☐	☐
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