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United Nations Industrial Development Organization

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10 May 1974

ORIGINAL: ENGLISH

In-Plant Training Workshop on
the Production of Refractories

Pilsen, Czechoslovakia

11 - 28 June 1974

ECONOMIC AND TECHNICAL CHARACTERISTICS OF REFRACTORIES FACTORIES 1/

O. Maksi*

* Interprojekt Kosice, Czechoslovakia

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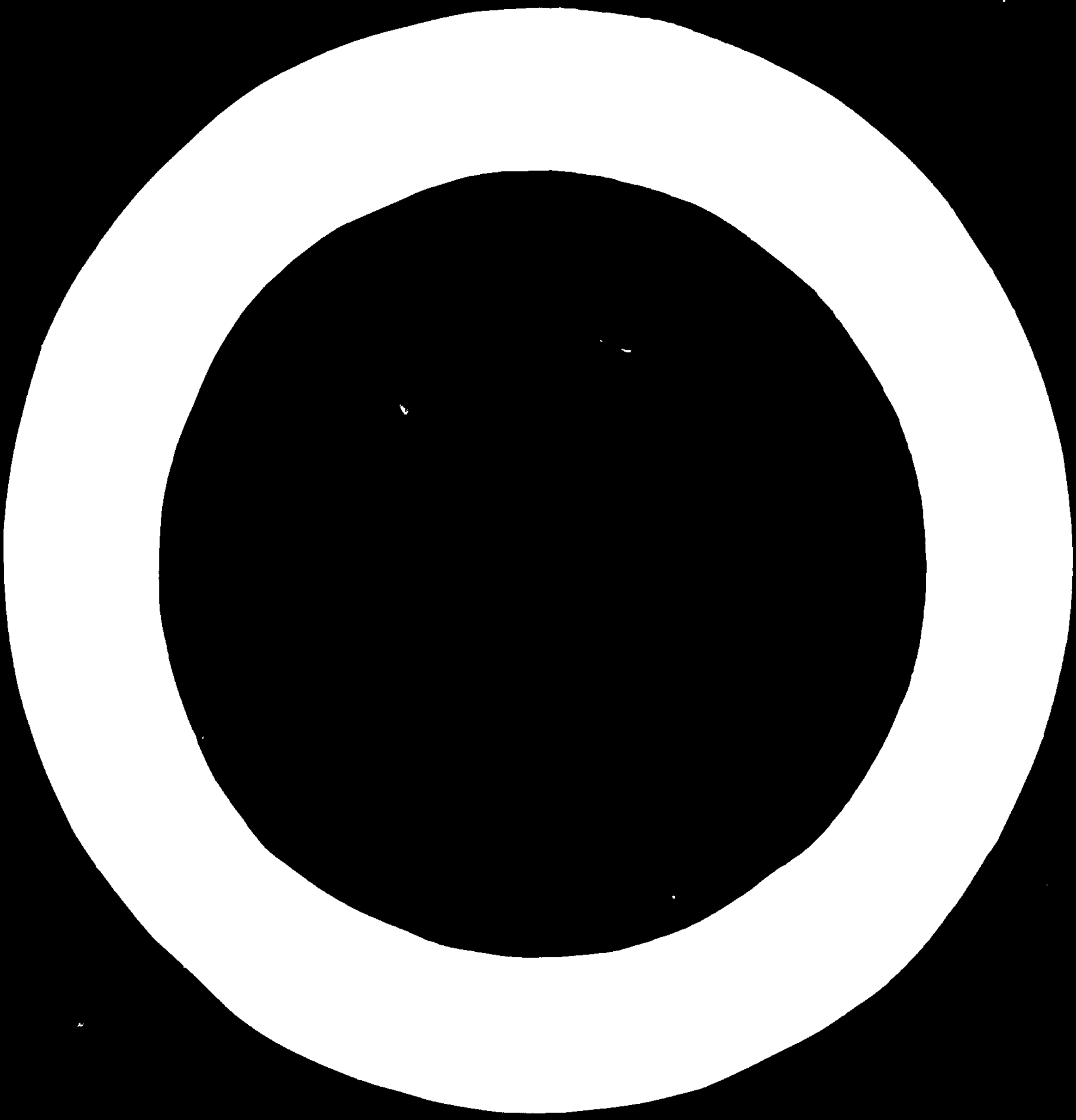

The purpose of this paper is to give a comprehensive view of the refractories industry, notably in its relation to its main consumers, the ferrous metallurgy and steel works. The development of steel production is dealt with at length to elucidate the conclusions concerning the quantitative output of the individual types of refractory materials, in dependence on the kinds of forging processes.

A greater amount of technical data is presented to illustrate the influence of economic factors. Economics always reflect technological processes at a certain level of the applied technologies and the organization of production factors. This paper attempts to elaborate this idea. Only a detailed knowledge of the technological processes can serve as an adequate basis for a prognosis in economics.

The questions of prices and investment costs are elaborated to such an extent as to provide impulses for a general economic evaluation of the necessary investment costs and at the same time to also give an idea of the profitability of the reproduction of manufacture.

We have attempted to summarize the experiences from the manufacture of refractories in Czechoslovakia and provide a contribution to their further development or application in economic and technical considerations and solutions.

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Curso práctico de capacitación en el trabajo sobre fabricación de productos refractarios

Pilsen (Checoslovaquia)

11 - 28 junio 1974

CARACTERISTICAS ECONOMICAS Y TECNICAS DE LAS FABRICAS DE PRODUCTOS REFRACTARIOS 1/

por

O. Maksi *

RESUMEN

El objetivo de la memoria que aquí se resume es dar una visión panorámica general de la industria de los productos refractarios, y especialmente de su relación con las principales industrias usuarias de sus productos, es decir, la metalúrgia férrea y la siderurgia. Se estudia extensamente el desarrollo de la producción siderúrgica con el fin de explicar las conclusiones relativas al volumen de producción de cada uno de los distintos tipos de materiales refractarios, en relación con los distintos tipos de procesos de forja.

Se presentan muchísimos datos técnicos para dar idea de la influencia de los factores económicos. La economía es siempre un reflejo de los procesos tecnológicos, cuando las tecnologías aplicadas y la organización de los factores de producción alcanzan cierto nivel. La memoria trata de desarrollar esa idea. En economía, sólo se pueden hacer pronósticos si se conocen detalladamente los procesos tecnológicos.

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* Interprojekt, Kosice (Checoslovaquia).

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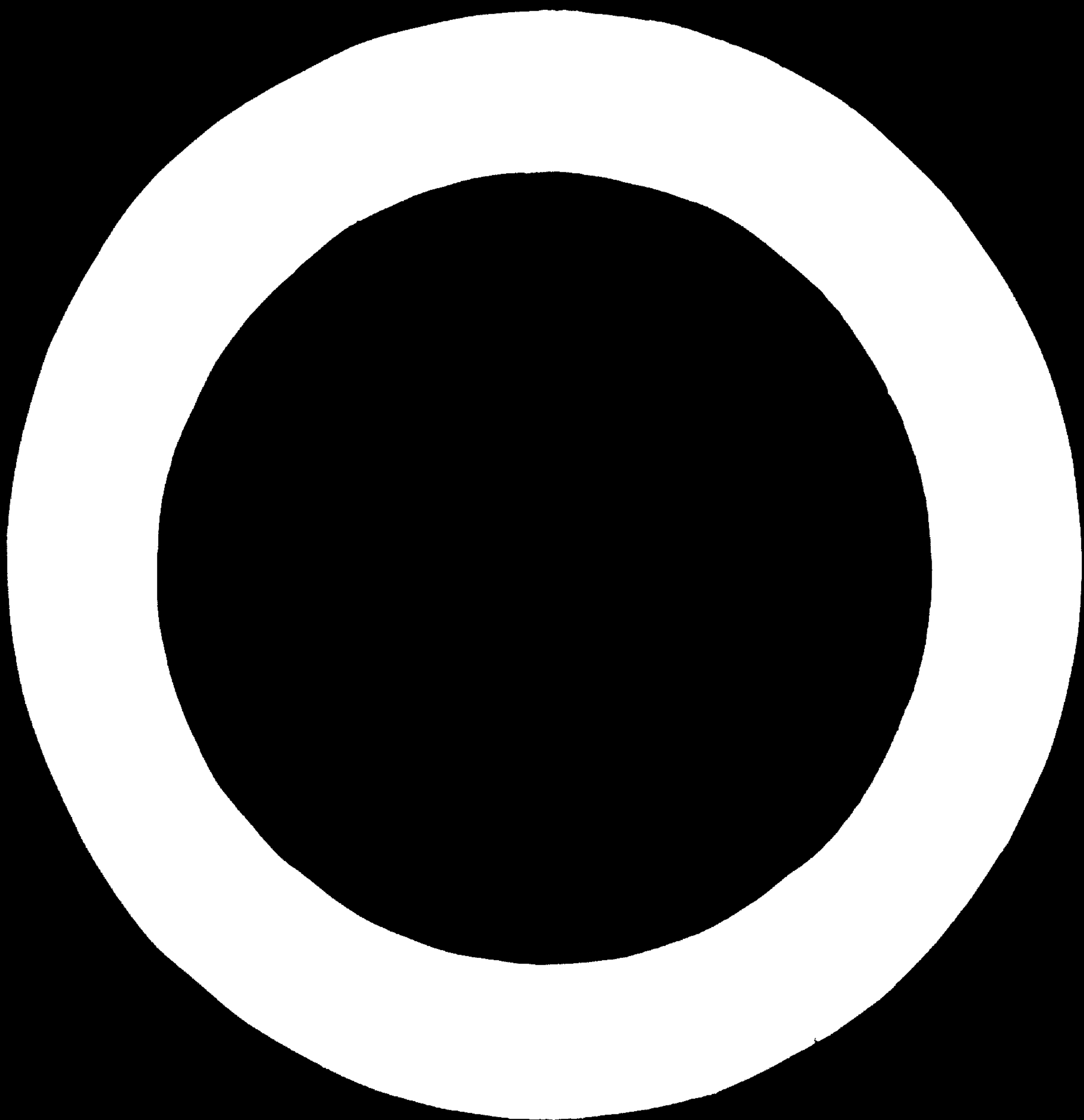
Las cuestiones de precios y de costos de inversión se tratan con el grado de detalle necesario para incitar a llevar a cabo una evaluación económica general de las inversiones necesarias y, al mismo tiempo, dar idea de la rentabilidad del proceso de manufactura.

Hemos intentado resumir las experiencias adquiridas en Checoslovaquia en la fabricación de materiales refractarios y contribuir a su mayor desarrollo o aplicación aportando consideraciones y soluciones sobre sus aspectos económicos y técnicos



C O N T E N T S

Page

The refractories industry represents in the national economy of a country a branch which from the point of view of industrial reproduction is linked with the raw material resources, and from the point of view of consumption with the other industrial branches. Viewed from these aspects, the refractories industry has the character of industrial consumption. Direct consumption does not occur at all or only to a slight degree.

Taking this situation into consideration, the manufacturer must investigate the needs of his own country, and those of the neighbouring states, should he decide to export his products. This investigation must be focused on all branches of the national economy, primarily to the metallurgical industry and its perspectives. Ferrous metallurgy is the largest consumer of refractories.

A thorough familiarity with the raw material basis is essential for a decision as to the quality-types of refractories to be manufactured. It is true that in the production of fireclay refractories no factory can do without corrective raw materials, when higher-quality refractories are to be manufactured. Therefore it is necessary to investigate also the possibilities of co-operation or the resources and costs of obtaining these corrective raw materials. In taking a decisionone has to weigh what is primary in the given branch, whether the raw material base upon which the manufacture could be built, or the consumption which necessitates the manufacture of refractories.

In rational, economic thinking we cannot ascribe priority to any of these elements, as industrial production can arise only there and then when both /raw material deposits and an outlet for refractories/ are in harmony. Consequently.

there must exist a situation in which there is a growing demand for refractories on the market. This is the case when the industrial potential is developing or the industrial consumption in existing plants becomes intensified. A situation may arise when there appear on the market products w ich have a higher utility value and permit the increase of productivity of labour in the field of industrial consumption. In such a case, products of an inferior utility value are being eliminated. These conditions apply also to the refractories industry.

Raw material deposits are a prerequisite for the establishment of refractories factories. Their occurrence, quality and other natural conditions are decisive for the answer whether the given raw material resources can be brought into harmony with the development of industrial consumption.

The harmony between resources and consumption develops in the field of manufacture. The latter is characterised by the proportional representation of natural resources, labour and capital in all its forms, in the production of refractories. The profitableness of the manufacturing process is no mere secondary matter. One has to take into consideration the social conditions of production in the respective country and on the requirements that should be balanced from the point of view of social or individual notions.

These are the main ideas we wish to elaborate upon in this lecture so as to make possible their practical application.

I. BASIC TECHNICAL AND ECONOMIC CRITERIA FOR THE ESTABLISHMENT OF FACTORIES FOR THE PRODUCTION OF REFRACTORIES

We shall divide refractories into three basic types :

- fireclay
- silica
- magnesite

Each of these has its characteristic properties. From the point of view of technical applicability, fireclay can be used up to temperatures of 1390°C, its refined types to 1650°C . Silica can be used for temperatures up to 1700°C, while magnesite up to 1800 - 2000°C.

These thermal characteristics point also to the difference in the basic raw materials for the manufacture of the individual types of refractories.

For fireclay, use is made of refractory clays and raw materials with a higher alumina content. Here, the bearer of refractoriness is alumina /Al_2O_3/.

In the manufacture of silica, quartzite with a high silica content is used. It should be above 95%. In these refractories the carrier is silica /SiO_2/.

For magnesite refractories use is made of raw magnesite. Its most common form is magnesium carbonate /$MgCO_3$/ In heat it decomposes into MgO + CO_2, while the latter escapes as gas into the atmosphere and its portion in raw magnesite is about 49 - 50.5%. Since MgO /its melting point is 2800°C / is the carrier of refractoriness, the main interest is concentrated on its maximum content in the final product.

A. The raw material base for the fireclay industry

Refractory clays are fairly abundant, they form the upper part of the earth crust. Of interest are those kinds of refractory clays which occur in large quantities, have an Al_2O_3 content above 3% and a low stripping ratio. For optimum economic mining conditions this ratio should be up to 2 cu.m./ton of substance. Purity is a further important factor. This means that refractory clays in a natural state should not contain admixtures of stone and organic matter. Their removal necessitates further technological treatment, which makes its further applicability disadvantageous from the economic point of view. This leads to increased costs, which in turn reduce its competitiveness.

From the point of view of the natural conditions, transport distance from

a/ the processing plant

b/ the perspective customer

has become an important economic factor.

Here we have in mind those costs which come between the mining costs and the price of the raw material. The longer the transportation distance, the lower the profitableness of mining, and should the optimal transportation distance be exceeded, the deposit becomes unattractive for exploitation.

B. Raw material for silica refractories

Its occurrence in dispersed form is fairly abundant. Concentrated deposits are rarer. For industrial use a silica concentration of not less than 95-96% is desirable. The other conditions are the same as in refractory clays. It should be noted that the mining of these refractory clays is rather difficult because of their hardness and toughness. Commercial considerations, focused on export, are of no interest since these raw materials fetch very low prices on the world market. Consequently, they are suitable only for the manufacture of final products at the place of their occurrence, and only in the form of silica bricks can they be considered for export to foreign markets.

C/ Raw materials for magnesite refractories

While the preceding two kinds of raw materials occur fairly abundantly, magnesite raw materials are rarer. This applies particularly to those deposits in which the MgO content in raw state is close to 50%. Raw magnesite in its natural form cannot be industrially processed. For technological application it must be rid of its carbon dioxide content. By heat treatment it is transformed into a sintered form. Only this form of magnesite has an interesting utility value, on which economic considerations can be based. For firing magnesite, use can be made of rotary or shaft kilns.

The magnesite raw material should not have a high portion of CaO, SiO_2 and R_2O_3. The lower the portion of these admixtures, the higher the utility value of the raw material. Raw materials with a lower than 40% content of MgO have little technological value. They can be utilised only for inferior quality refractories, which, however, cannot bear the transport costs or face the competition.

The method of mining magnesite raw materials depends on the geological conditions. Open-cast mining is recommended in places with a loose overburden and a ratio of up to

3 cu.m. of stripping to 1 cu.m. of magnesite.Where this ratio is surpassed,underground mining becomes preferable.

In magnesite raw materials the form of degradation during mining is of a great importance.In most cases, at least washing is necessary. Before washing,raw magnesite must be dressed granulometrically. A more expensive method is dressing in heavy suspensions or floating.

In recent years,many industrially advanced countries have engaged in obtaining magnesite from seawater,by a synthetic method.In this way they wish to replace natural magnesite.The advantage of this method consists in the fact that the magnesite sinter thus obtained can attain a purity of up to 99.5% of MgO.The disadvantage lies in the high production costs and heavy capital investments. Therefore natural magnesites, insofar as they are sufficiently pure, prove to be more advantageous even if the part of human labour in the manufacture of refractories is considerably higher.

Owing to the fact that during the processing of raw magnesite into sinter 50% of its weight portion escapes into the atmosphere,it is preferable to treat the raw material on the spot or in the close vicinity of the mine. This place should have good communication with the processing plant or the consumer,or favourably situated for export shipments.

II. REFRACTORIES AND THEIR APPLICATION

One can state as a principle that wherever the operating temperature of an open flame continually exceeds 800°C, use must be made of one of the basic types of refractories. Obviously, for lower operating temperatures, inferior-quality refractories will suffice. One type is used for tiled stoves, and a totally different for arc furnaces. Apart from this basic consideration one must also bear in mind other criteria, such as the technological process, insulating properties, dielectrical constants, etc. In the acid open-hearth process for special silicon steel use should be made of a silica lining with an SiO_2 content above 95%, whereas for standard and alloy steel, in which the presence of SiO_2 is undesirable, the furnace lining should be basic, that is from magnesite shapes. Fireclay refractories are used for glass furnaces, but the roofs are from silica the chemical properties of which are akin to those of the glass batch.

In principle, one can determine the application of refractories from the point of view of the temperature ranges stated in Chapter I. and of the industrial equipment requiring refractory linings as follows :

1/ Steam and gas producers - fireclay

2/ Industrial furnaces e.g. boilers, combustion chambers, locomotives, tunnel and chamber furnaces in the ceramic industry, heating flues of smoke gases, chimneys, etc., where temperatures do not exceed 1400°C - fireclay refractories are applicable.

3/ In metallurgy

a/ Blast furnaces - fireclay

b/ Cowper stoves - fireclay, silica

c/ Open-hearth furnaces: all zones exposed to heat stress or corrosion by acids are lined with magnesite /90%/, parts exposed to lower stress under heat and the contact linings are made from fireclay refractories.

d/ Oxygen converters are lined with magnesite, dolomite, tar-dolomite, or their modifications; the contact lining is from fireclay.

e/ Electric furnaces - magnesite , the roofs , predominantly from silica or fireclay with a high content of alumina

f/ Pig iron mixers - magnesite, fireclay

g/ Foundry ladles - fireclay .

4/ Foundries and enginieering

In addition to linings listed under 3, the following types of refractories are used :

a/ Cupola furnaces - fireclay

b/ Reverberatory furnaces- magnesite and fireclay

c/ Electric induction furnaces - magnesite and fireclay

5/ Cement works

Magnesite is used in the sintering zone of rotary and shaft furnaces, in which temperatures exceed 1400°C , fireclay refractories are applied in the other zones.

6/ Glass works

In regenerative pot and tank furnaces the roofs and the burners are from silica /also magnesite and fireclay with high alumina content/, the rest from fireclay.

7/ Gas - and Coke works

The linings of producers and recuperators -from fireclay; in coke ovens the linings are predominantly from silica, the contact walls from fireclay.

8/ The Chemical industry

Where the lining is exposed to aggressive influences, magnesite or fireclay refractories are applied.

9/ Non-ferrous metallurgy

- in the copper industry
- in the lead and antimony industry
- in the aluminium industry
- in the nickel and tin industry

use is made of linings from magnesite combined with fireclay, in shaft and rotary furnaces,converters,reverberatory and drum furnaces,mixers and refining furnaces.

10/ In the consumer industry

in the production of electric heat-storage stoves, magnesite or fireclay refractories are used.

In the foregoing survey of the applicability of refractories we have in mind shaped products,i.e. bricks. Table 1 gives a survey of the consumption of refractories by the individual branches of industry in Czechoslovakia during 1972.

Refractories are available also in the form of loose ramming materials,coatings,mortar ,and refractory concrete.

Mortars represent about 2% of the production of moulded refractories. Ramming materials,which include also refractory concrete in dry or plastic form, represent in fireclay refractories about 20-30% of the output of bricks, and in magnesite together with gunning materials as much as 120 % of moulded bricks.

In the following chapters we shall discuss mainly the economic aspects of the manufacture of moulded bricks, and only in cases requiring special attention shall we deal with the production of refractory materials,notably with regard to magnesite refractories in which the ratio between moulded and unmoulded products is of a decisive importance.

TABLE 1 - Domestic consumption by individual branches of industry in Czechoslovakia /in 1972 /

Industrial branch	Fireclay %	Silica %	Magnesite Bricks %	Magnesite Grain %
1/Metallurgy	63.62	72.33	90.01	99.80
2/Engineering	2.19	3.22	1.06	-
3/Non-ferrous metals	0.75	-	0.10	-
4/Fuel and Power	0.56	-	-	-
5/Chemical industry	1.17	5.20	0.54	-
6/Cement and Lime	5.81	-	6.04	0.06
7/Investment plants	6.29	-	-	-
8/ Glass works	7.19	10.23	0.08	-
9/ Ceramics industry	3.40	6.20	1.97	-
10/ Small consumers	9.02	2.82	0.20	0.14
Total	100.00	100.00	100.000	100.00

The analysis of the structure of consumption given in Table 1, illustrates also the basic outlets for the individual types of refractories in various industrial branches.This structure may be different in individual countries,depending on the proportional representation of the respective branches.One can however definitely state that the predominant use of refractories concentrates on metallurgy. Other branches play no negligible role, as can be seen in the case of fireclay,and to a lesser degree of silica refractories. One should note the building materials and ceramics industries / items 6-9 in Table I /,in which the consumption of fireclay amounts to 22.7 %,and together with metallurgy to 86.3 %,which represents the decisive part of the output of this kind of refractories.

In silica refractories the predominant part of consumption is concentrated in metallurgy and the glass works /32.5%/, if we add to this the ceramics industry,then the consumption of this group attains 88.8 % ,which is again the decisive part of industrial consumption.

Mention should be made also of the production and consumption of dolomite or dead-burnt lime as refractory materials,used for lining acid converters /LD/.Their application is modified by the admixture of tar to prevent their high hygroscopicity.Their share of the consumption in oxygen converters is not negligible,since in some countries which do not dispose of more suitable raw materials they are used up to 70-90 % for the ramming or lining of oxygen converters.Extremely pure magnesite bricks are applied to the most exposed zones.

III - The DEVELOPMENT OF THE BASIC CONSUMPTION BRANCHES OF REFRACTORY MATERIALS

In the preceding chapter we have shown that ferrous metallurgy is the main consumer of refractorias in all industrially advanced countrias.Its development influences the growth of the other branches of the national economy,beginning with engineering and chemistry and ending with the development of the services and the consumer industry,If the individual branches of the national economy are to develop with the aid of the construction of industrial planta,priority should be given to the development of the power,engineering and building industries. Power and construction materials are the prerequisites for the development of the remaining branches of industry.

A/ The development of ferrous metallurgy

Our century is characterised by the striking growth of ferrous metallurgy. A comparison of data on the world's steel output from 1870 to 1970 will give us the following picture/+/:

Year	mil.tons	Year	mil.tons
1870	11		
1880	14	1930	99
1890	25	1940	126
1900	37	1950	190
1910	58	1960	341
1920	65	1970	592

/+/ Cordes W., Hamburg - Stahl und Eisen , No.14/1971

In 1960 the per capita steel production in the world was 136 kg, in 1970 it was already 151 kg, but in some countries it rose more steeply, e.g. in Sweden to 678 kg., in Czechoslovakia 662 kg, and in Japan 620 kg.

Taking into consideration the trend in steel consumption we may assume -according to certain author and sources /Prof. Manuelli, Italy, in the US Steel Bulletin ,1970, in the Czech magazine Hutnické listy No.10/70/and notably according to the works of Prof.A.S. Burasov * /, the following per capita, specific steel consumption in the world :

Y e a r	1970	1980	1990	2000
Per capita, specific steel consumption in kg.	151	196	250	321

On the basis of the number of inhabitants we calculate the probable steel production in the world till 1990, as shown in Graph I.

As the trend of the specific consumption of refractories for the individual metallurgical processes is varied, we examine the development of these processes from the point of view of their share in world steel production. The data thus gained are important, as converter /LD/ show a considerably lower consumption of refractories when compared with open-hearth processes. For comparison, we quote examples from two large steelworks in Czechoslovakia, in 1970:

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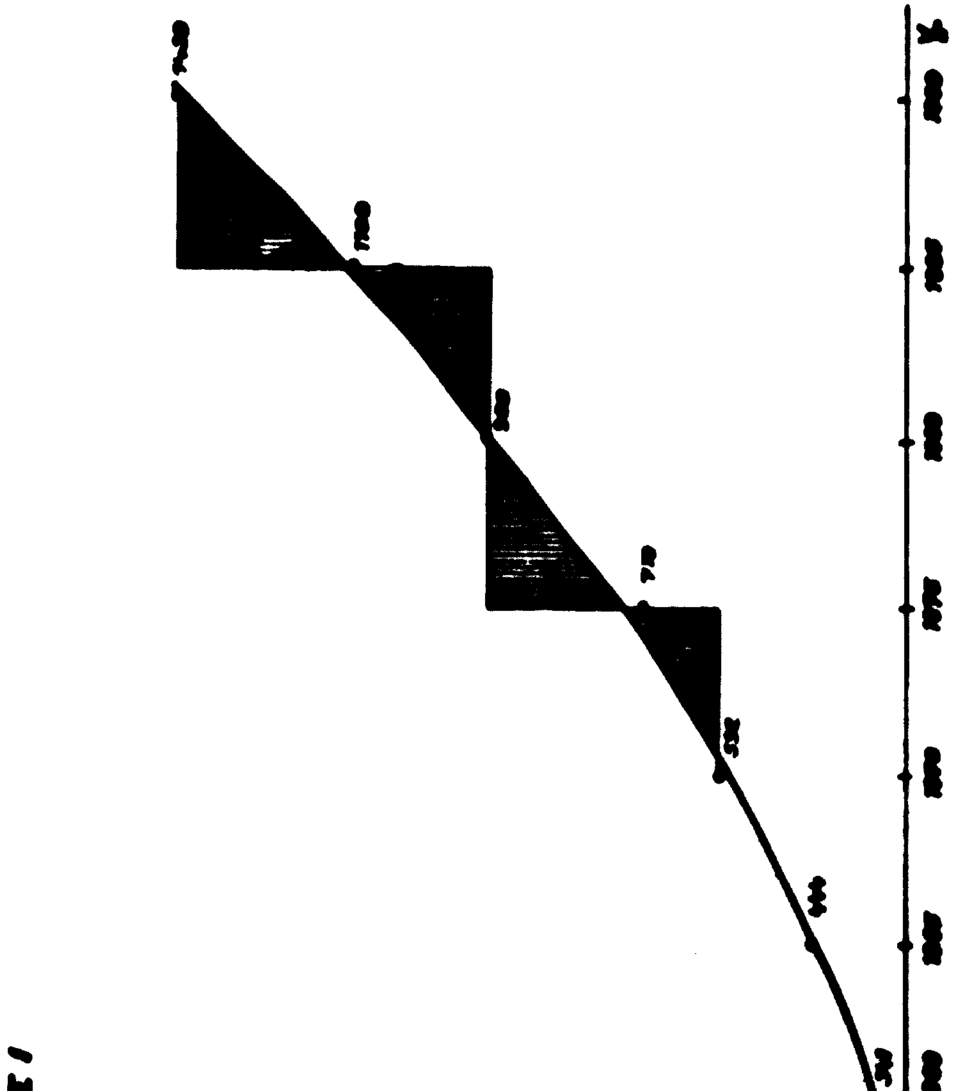
* Biulleten inostrannoj komerčeskoj informacii, No.2/71 Moskva

FIGURE I



Probable World Steel Production

T y p e		Open-hearth ++ furnaces	LD ++ converters
Magnesite bricks	kg/t.	14.28	1.96
Magnesite loose materials	"	1.29	6.3
Fireclay bricks and materials	"	12.26	11.6
Silica bricks and mortar	"	0.1	0.0

++ These data do not include the consumption in blast furnaces, coking plants, rolling mills and related branches.

These practical experiences show that the consumption of refractories in LD oxygen converters is rapidly decreasing. This is due to the fact that the steel melting process in oxygen converters lasts 29-53 minutes,while in open-hearth furnaces it takes 4 - 6 hours,depending on the capacity of the furnace unit.

Considering the trend of steel production in oxygen converters one would assume that the existing production capacities of refractories could suffice for a long period ahead.But this is not so.On the one hand,there is a steady growth in absolute steel production / see Graph I /. and on the other, one must consider the role of metal scrap in the technology of steel production.Scrap is more abundant in industrially advanced countries. Its share in the production of new steel amounts in certain countries up to 30 - 40 %. This is due to the rapid innovation of the existing industriel potential and to the introduction of new products or the liquidation of technically and economically outdated factories.

As oxygen converters permit to process only about 22% of the cold metal charge /scrap and alloys/,it is desirable to develop such processes that make possible a higher utilisation of the cold metal charge and at the same ensure also the production of higher-quality steel.These demands are met by the steel production process in electric furnaces which can work with 95% of the cold metal charge/scrap/.

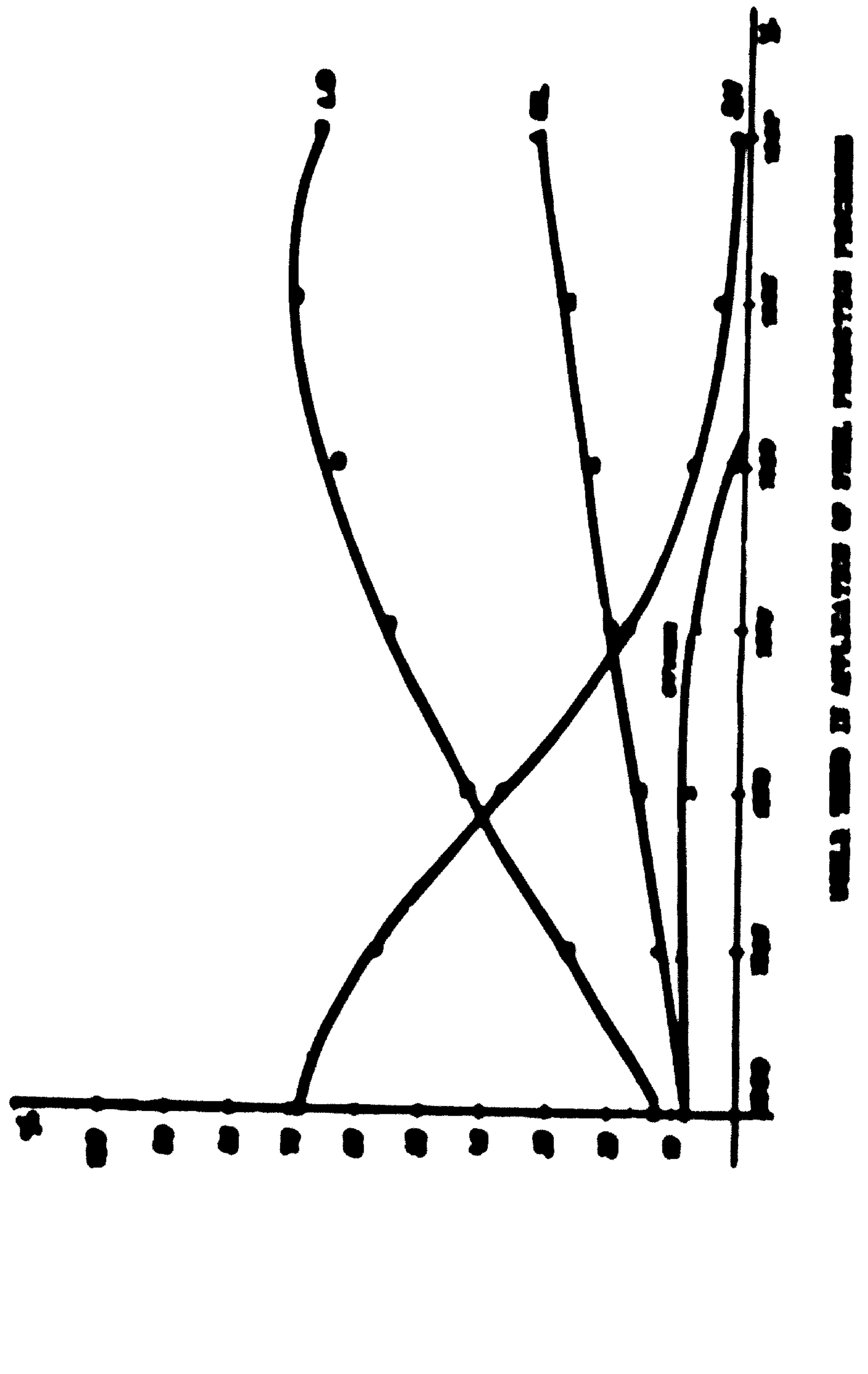
Considering these conditions we confront our assumptions with the data published by leading experts and institutes and plot graph II which shows that in oxygen converters the point of inflection appears around 1980,and the transition point between 1985-1990. This does not mean that steel production in oxygen converters will decrease, but only its share in the total production will diminish, which reflects a structural change in steel production in different vessels /furnaces /. This information is very important from the point of view of the development of the consumption of refractories ,since their specific consumption in electric furnaces is substantially higher than in LD converters.

Let us quote an example from an electric steelworks in Czechoslovakia in 1970:

T y p e	Electric furnaces kg/t. of steel
1/ Magnesite bricks	7.5
2/ Magnesite loose materials	24.0
3/ Fireclay bricks and materials	16.2
4/ Silica refractories	1.4

Even in the case of oxygen converters,constructional changes point to blowing oxygen from below,thereby exposing to corrosion ,to a larger extent,contact refractories, which results in their increased consumption.

Furthermore, the present discontinuous process will gradually give way to continuous ones,which will result in energy



cost- savings so that the share of the consumption of refractories will not play such a decisive role in the production costs of steelworks.

For better orientation we list below the specific consumption of refractories in metallurgical-engineering steel production in Czechoslovakia in 1971 :

T y p e	kg/t. of steel
Fireclay and morter	30.55
Silica	1.64
Magnesite /bricks /	12.40
Magnesite loose materials	14.60

B/ <u>The development of cement production and of other ceramic branches</u>

Cement is becoming more and more important all over the world,both for road construction and the building of houses and industrial plants. By the end of this century,the present world population will have doubled.This determines the manufacture of all types of goods,whether capital or for consumption.

The present development of production follows,with slight deviations, so closely the curve of steel production that we can state that Graph I. is valid also for cement production with the difference that around 1980 it will exceed it and show an increased pace by 2-3 %.

The present specific consumption of refractories in relation to cement output in Czechoslovakia in 1971 is as follows:

Refractory material	Cement kg/t.
Magnesite	1.15
Fireclay /incl. insulating materials and mortars/	2.23

As the determination of the consumption, notably of fireclay in the other branches of the national economy, is very difficult, and would be beyond the frame of this lecture, let us assume that these branches of industry utilise about 25-31 % of the domestic consumption.

IV - CHARACTERISTIC OF PRODUCTION COSTS AND TECHNICAL-ECONOMIC INDEXES

A/ Production costs

When examining the production process in the broader social-production relations we must necessarily arrive at the conclusion that for society only such a production is desirable which fulfils two basic criteria, namely it is

1/ **effective** - in the sense that by its utility values the production satisfies social, individual or industrial requirements,

2/ **economical** - in the sense that the production funds spent on reproduction prove profitable.

In this consideration we leave out those requirements of the state which are measured by other criteria.

Production costs are closely linked with prices both for the purchased raw materials and services and the market prices of finished products. The difference between market prices and production costs represents profit/gross profit/, and its ratio to the production funds indicates the profitability of the latter, i.e. the amount of interest they yield.

in the production process.This rate must be higher than the average rate of capital interest in the given country.

The development of production costs in every industrial country reflects :

1/ the level /size and adequacy / of production funds
2/ the degree and level of the organisation of the production process.

This applies in general also to the refractories industry. Under the term "level of production funds" we understand production means and working capital,especially their influence on the structure of manufacturing costs,the demands for their procuring and maintenance,yield of interest and profitability. A high organic structure,i.e. the ratio of technological means of production to constructional, results in increased efficiency of production.
The production means represent the sums spent on capital investments in mining or processing plants.Working capital is spent on all kinds of supplies required for ensuring the process of production /reproduction/.Only a mutual interrelation - symbiosis - of these two make possible the social production process. We speak of the level of investment funds because investment media themselves have their technological and constructional character. Their mutual relation indicates the share of investments in production costs.They represent depreciation.The amount of depreciation depends on the physical durability of the technological equipment and the life of the buildings and plants.

The ratio between investment costs and average annual depreciation indicates the economic life of investments. They show in what time the investments return irrespective of the profit.

The size of the second part of production funds i.e. the working funds is determined by the degree and the level of organisation. If the production is organised so that it is not necessary to create large reserves of raw materials or to keep large supplies of spare parts or supplies of finished products, then less working capital is needed, which means lower financial costs /interests/.

The level of organisation points, among others, also to what extent there exist in the production control points which prevent the entry of inferior-quality raw materials into the production process, thus eliminat waste at the earliest stage. The observation of these principles results in the attainment of a good reputation which is a prerequisite of success in manufacture. The level of organisation reflects, how instructions reach down to the working place, how the control of the instructions is organised, how the records are kept, etc. These seemingly unimportant matters become reflected in the production costs.

The structure of production costs depends on the technological degree of the production. Mining costs have a structure that differs from those of the production of finished goods /bricks/.

<u>In mining</u>, which must be organised in accordance with the natural conditions, the raw material does not enter in the costs, only such materials as explosives, timbering, tc.

An important item is represented by geological preparatory work and overburden removal which are bracketed under "other costs ". A comparison of the trend of production costs of mining refractory clays, quartsite and magnesite is given in Table 2 which characterizes the structure of mining costs in selected plants in Czechoslovakia.

Table 3 shows the structure of the costs of dressing magnesite in heavy suspensions, and the production costs of magnesite sinter in rotary and shaft furnaces. In the case of heavy suspensions, only the structure of processing costs is given, and the expenses for material represent predominantly the costs of ferrosilicium /FeSi/. In the production of magnesite sinter one should note the large difference of raw material costs. This is due to the fact that rotary furnaces are charged with raw materials processed in heavy suspensions, that is that the raw material costs include also the costs of mining and processing, which is not the case of shaft furnaces where they reflect only the mining costs.

TABLE 2 Structure of raw material mining costs

Costs	Clays Open-cast mining	Quartzite Open-cast mining	Magnesite Underground mining	Magnesite Open-cast mining
A/ Primary costs	/9.50/	/42.70/	/17.20/	/11.22/
1/ Raw and other materials	2.51	10.68	6.17	4.11
2/ Technological fuel	-	-	-	0.60
3/ Wages	6.99	32.02	11.03	6.51
B/ Working costs	/77.78/	/48.75/	/79.95/	/81.94/
4/ Electric energy	3.04	1.94	4.69	8.84
5/ Depreciation	7.72	6.72	8.40	26.37
6/ Repair and maintenance	7.13	3.13	8.48	22.14
7/ Other expenses	20.39	15.60	23.82	2.82
8/ Set-up costs	39.30	21.36	34.56	21.77
C/ Joint costs	/12.73/	/8.55/	/2.85/	/6.84/
9/ Social costs	1.79	8.55	2.85	1.61
10/ Overhead expenses	1.55	-	-	5.23
11/ Transport costs	9.39	-	-	-
Total costs %	100.00	100.00	100.00	100.00

TABLE 3 Structure of the costs of dressing and firing raw magnesite

Cost Items	Dressing of the raw material in heavy suspensions	Magnesite sinter: Shaft furnaces	Magnesite sinter: Rotary furnaces
A/ Primary costs	/45.10/	/57.62/	/74.35/
1/ Raw and other materials	17.18 1/	39.95	66.07
2/ Technological fuel	-	14.85	6.06
3/ Direct wages	27.92	2.82	2.22
B/ Working costs	/47.95/	/24.61/	/11.46/
4/ Electric energy	5.36	5.18	3.47
5/ Depreciation	9.12	3.09	1.87
6/ Repair and maintenance	5.14	15.56	4.12
7/ Other expenses	28.33	0.78	2.00
8/ Set-up costs	-	-	-
C/ Joint costs	/6.95/	/17.77/	/14.19/
9/ Social costs	6.95	0.71	0.56
10/ Overhead expenses	- 2/	8.46	8.88
11/ Marketing costs	- 3/	8.60	4.75
Total costs %	100.00	100.00	100.00

1/ The data do not include the costs of the raw material entering the plant

2/ Overhead charges relating only to market production

3/ These include only the costs connected with the sale and transportation of finished products

TABLE 4 **Structure of the costs of refractory bricks**

Cost items	Silica	Fireclay		Magnesite		
		Standard	With high alumina content	Burnt 1/	CMB 2/	TM 3/
A/ Primary costs	/41.42/	/45.71/	/ 56.15/	/66.78/	/73.38/	/74.60/
1/ Raw and other materials	15.12	25.47	44.32	55.75	67.85	66.53
2/ Technological fuel	13.24	2.96	5.50	4.05	-	3.56
3/ Wages	13.06	17.28	6.33	6.98	5.53	4.51
B/ Working costs	/21.60/	/23.57/	/34.50/	/15.31/	/12.42/	/19.35/
4/ Electric energy	1.88	3.54	1.10	1.76	1.67	1.06
5/ Depreciation	4.41	2.15	9.46	6.37	5.05	6.59
6/ Repair and maintenance	14.52	16.87	18.11	4.04	3.21	8.60
7/ Other expenses	0.79	1.01	5.83	3.14	2.49	3.10
8/ Set-up costs	-	-	-	-		
C/ Joint costs	/36.98/	/30.72/	/9.35/	/17.91/	/14.20/	/6.05/
9/ Social costs	3.27	4.71	2.50	1.75	1.39	2.02
10/ Overhead expenses	17.83	18.56	4.43	12.42	9.85	2.99
11/ Transportation costs	15.88	7.45	2.42	3.74	2.96	1.04
Total costs %	100.00	100.00	100.00	100.00	100.00	100.00

1/ Data refer to burnt magnesite bricks

2/ Data refer to chemically-bonded metalclad bricks

3/ Data refer to tar-magnesite bricks

Table 4 shows the structure of the manufacture of silica and fireclay bricks in two quality groups, and of magnesite: burnt, chemically-bonded , and the production of tar-magnesite blocks. The highest raw material costs are in chemically bonded, metal-clad magnesite bricks. The metal casing is specially prepared and then simultaneously pressed with the magnesite mass.

Noteworthy are the transportation costs of silica bricks. The factory to which the data refer exported 35% of its output, consequently it had increased expenses for packing and transportation.

The data on fireclay bricks refer to two different factories. The factory producing high-alumina bricks /with an Al_2O_3 content of up to 65% / is one of the modern works with a high structure of production funds and modern organisation, while the other factory producing standard fireclay refractories dates from the first half of this century; consequently the percentage of depreciation is low.

All the data refer to the level of structure in 1972

<u>3/ Technical-economical indexes</u>

The structural pattern of production costs indicates the proportional representation of the individual types of costs in the total costs. It does not give, however, a sufficient idea about the size expressed in currency value. Therefore we supplement the analysis with technical-economic indexes which reflect consumption per unit of output or time. These values supplement and extend the idea about the organic structure of the basic funds, the consumption of energy of all kinds as well as that of human labour per output unit. They indicate how much live human labour is require for producing a unit in a certain technological degree.

Table 5 shows synthetic indexes for mining according to the kind of refractory raw material.

Table 6 gives indexes for magnesite sinter. Three types of furnaces have been selected.

Shaft furnaces are most advantageous from the point of view of overfiring, but least favourable as regards capacity, as the basic investment costs per 1 cu.m. are the highest. From the point of view of time efficiency they show the fewest breakdowns and yield therefore the greatest advantages from the point of view of repair costs.

Cement rotary furnaces

They make for mass production, but their coefficient of overfiring /raw material consumption/ is unfavourable; they produce a vast amount of dust and from the point of view of energy are less advantageous than shaft furnaces, on the other hand the basic investment costs /i.e. the costs per 1 ton output or 1 cu.m. capacity/ are lower than in shaft furnaces.

Rotary furnaces with lepol grate

Their advantage consists in their large capacity and only from the point of view of energy are they more favourable than the standard cement or shaft furnaces. The maintenance costs are higher. They are technically more complex and have a lower time efficiency than shaft furnaces. Owing to their large output and low consumption of energy they are used with advantage.

Table 7 shows the most complex process in the refractories industry from the points of view of organisation and technology, applied in the manufacture of fireclay,silica and magnesite bricks.

The set of technical-economic indexes and the structure of production costs provide a complete picture about the technical and organisational level of manufacture in the respective type of refractories.

TABLE 5 **Technical-economic indexes of mining**

Item	Unit	Refractory clays /open-cast mining	Quartzite Open-cast mining	Magnesite Open-cast mining	Magnesite Underground mining
1/ Mining - mechanized	%	100	96.43	100	100
- manual	%	-	3.57	-	-
productivity	ton/person shift	13.42	6.47	5.84	24.64
2/ Stripping	cu.m./ton	1.40	0.31	0.70	-
3/ Power consumption	kWh/ton	4.15	7.31	30.07	13.80
4/ Water consumption	l/ton	-	56.0	24.0	37
5/ Consumption of explosives	kg/ton	0.13	0.32	0.36	0.33

TABLE 6 Technical-economic indexes concerning the manufacture of dead-burnt magnesite

Item	Unit	Dead-burnt magnesite SF 1/	RFC 2/	RFL 3/
1/ Furnace capacity	cu.m.	64	218	522
2/ Output	t/hr.	1.89	5.40	11.60
3/ Specific output	kg/cu.m./hr.	29.5	24.77	22.22
4/ Fuel consumption 4/	kg/t	192	197	158
5/ Heat consumption		1.631	1.803	1.539
6/ Coefficient of overfiring	t/t	2.142	2.404	2.622
7/ Furnace utilization/related to time	%	90.30	80.54	71.24
8/ Consumption of electric energy	kWh/t	40.10	43.80	60.55
9/ Volume weight of the sinter	g./cu.cm.	3.10	3.29	3.01
10/ Labour/output ratio	hr./t	1.12	1.52	1.06
11/ Water consumption	cu.m./t	2.12	5.20	4.00
12/ Yield of dead-burnt magnesite	%	52.00	59.02	55.00

1/ Refers to automatic, vertical shaft furnace

2/ Refers to rotary furnaces, similar to those used in cement works

3/ Refers to rotary furnaces with Lepol grate

4/ Refers to heavy fuel oil

TABLE 7 Technical-economic indexes concerning the manufacture of refractory bricks.

Item		Unit	Fireclay	Silica	Magnesite
a/ Preparation plant					
1/ Output		t/hr./machine	1.48	2.80	2.65
2/ Labour/output ratio		hr./t	1.50	2.15	4.50
3/ Efficiency in the use of machines	1/	%	54.67	52.47	50.07
4/ Standard of consumption		t/t	1.032	1.100	1.094
b/ Pressing plant					
1/ Output		t/hr./machine	0.88	1.19	1.13
2/ Labour/output ratio		hr./t	2.56	3.46	3.06
3/ Efficiency in the use of machines	1/	%	30.82	30.01	30.94
4/ Consumption /production/		t/t	1.056	1.116	1.117

C/ Furnaces

1/	Production of burnt bricks	%	100	100	73.80
2/	Production of chemically-bonded bricks	%	-	-	26.20
3/	Utilisation/related to time	%	100	100	98.00
4/	Output per hour		1.06	3.43	3.00
5/	Furnace capacity		600	150 2/	477
6/	Specific output per furnace	kg/cu.m./hr.	2.67	11.45	8.0
7/	Heat consumption	Gcal/t	0.850	2.275	1.155
8/	Batch charge on the car /chamber/	t/car	5.50 2/	100 2/	6.00
9/	Consumption of electric energy	kWh/t	17.5	15.5	32
10/	Labour time related to output	hr./t	4.19	3.70	3.10
11/	Waste	%	5.15	6.54	10.76
12/	Total consumption of electric energy	kWh/t.	95.2	112.2	176
13/	Total time required for 1 ton of bricks	h/t	9.12	10.42	12.53

1/ Time efficiency is calculated on the basis of 8760 hours per year

2/ Capacity of 1 chamber

V. PRICES AND MARKETING

A/Prices

The prices depend on the social form of the state and on whether they develop within the state frontiers by a free formation based on production costs,or are regulated by the price- fixing organs of the state. The second form is more widely spread .Therefore,we cannot speak with sufficient authority of prices within national frontiers. Of greater importance are the prices that are formed on the decisive /world/markets.The prices of refractories are not quoted at stock exchanges.They develop in their own way. We incline to the opinion that there is no unified world price / there exist two world economic systems, the socialist and the capitalist /. We think that one should take for world prices those at which decisive manufacturers sell their products to decisive markets.The latter are those with an advanced economy ,but without the raw materials needed for the production of the commodity in question.A decisive manufacturer is one disposing of large raw material resources and obliged to realise the greater part of his output on the foreign markets of those countries which lack in raw materials. In European conditions,this applies to Sweden and the Federal Republic of Germany ,as far as refractreies are concerned. This statement is valid primarily as regards magnesite products,but to some extent also for fireclay and silica refractories.

One should bear in mind also the buying conditions and the exporter's charges /custom duties, transportation costs, commissions, rebates, etc./, as individual countries buy on different conditions. Advantageous prices are not always profitable ones.

The difference between production costs and selling price indicates the profit, and the latter's relation to the costs reflects the profitability of the production, how economically and effciently it is run.

For comparison we give here the prices of refractories on the decisive European markets.

1/Fireclay a/The Federal Republic of Germany buys on the condition" Free to the customer"

b/Sweden buys "Free factory "

FRGermany	Al_2O_3 content	Price DM / t.
Standard bricks	up to 42%	428.40
" "	48	471.60
Keys	42	482.40
"	48	525.60

SWEDEN	Al_2O_3	Skr /t.
Standard bricks	up to 42%	400
" "	65 -80	694-1200
Keys	42	563
"	65 -80	925-1625

/1 $ = 2.8 DM, 1 $ = 4.275 Skr /.

2/ **SILICA** /t export goes predominantly to Sweden which does not manufacture silica and has to rely on imports/

Shaped bricks: FRGermany /"free to cust."/ DM 400

Sweden /"Free Trelleborg"/ Skr 300-434

3/ **MAGNESITE**

Here we indicate the prices for FR Germany only, which with its production of about 35 million tons of steel is an important consumer that lacks its own resources of raw materials. The largest exporter is Austria whose prices can be considered as decisive for this commodity. They may differ in individual countries, but essentially they follow the prices of magnesite products on the West German market.

Type	Average price DM /t.
a/Magnesite bricks /shaped/	794.00
b/Magnesite/granulated/-brickmakers' grade	350.70
c/Magnesite/granulated/-steelmakers' grade	265.00

German customers buy on the condition "Free to the customer". Granulated materials are not subject to customs duties which for shaped bricks amount to an average of DM 44 per ton. Freight charges in the Federal Republic of Germany are on the average DM 15 per ton. In addition, one has to calculate with a 6% commission for the agent.

From the point of view of production costs and prices on foreign markets and of the development of production costs in Czechoslovakia we can observe a varying trend in profitability i.e. in the ratio between profit and total costs.

B/ Marketing

The quality of the refractories produced is decisive for their sale. Common types of fireclay refractories are not in great demand, as every country has certain raw material deposits on the basis of which it can develop their manufacture. The same applies also to silica. Magnesite occupies a position of its own, since the natural sources of pure magnesite are comparatively rare. Consumers are interested in high-quality refractories. In the case of fireclay refractories the demand is for products with an Al_2O_3 content above 48%, silica products should have a low specific density, within the range of 2.35 - 2.37 g/c.cm., while magnesite should have a high MgO content /above 96%/, low porosity and high softening point / 1750°C /.

Taking into consideration the above demands one can determine the range of the distance of export markets, assuming comparatively good transport routes, as follows :

Quality	Market distance
Standard	350 - 800 km
High	1000 -2200 km
Special	4000 -5000 km

We can consider as special quality the following types: melted magnesite, siliconcarbide, synthetic mullite, corrosion-resistant refractories, and materials with a high content of the basic mineral.

In some cases, transportation costs or the protective duties of the importing country may become decisive factors.

Bearing the above considerations in mind, any potential manufacturer must carefully weigh in the first instance the needs of his own country in relation to the situation of the raw material base and the conditions in the neighbouring countries which may serve as an outlet. Intercontinental trade is feasible only if the relations between production costs and prices are such as to ensure the yield of an adequate manufacturer's profit. Barter deals form a different category of business relations.

VI. INVESTMENT CONDITIONS

Before deciding on investments one should investigate the following basic issues:

a/raw material resources, their quality and the mining conditions

b/the market demands as regards quantity and quality

c/approximate needs of capital investments and the profitability of the enterprise

To prevent an economic failure one has to study these questions with regard to the objective conditions of the country in which the manufacture is to be established.

In the chapter we should like to touch upon two questions:

a/Prospective needs of refractories

b/Investment costs

A. Prospective needs of refractories

If any investor in the refractories industry is to have a basic security as regards consumption and the situation on the market, he must be familiar with most fundamental prerequisite, namely the prospective needs for his refractories, viewed from the broadest aspects.

In Graph I we have shown the trend in steel production in the world. The growth in output per decade is as follows:

1960 - 1970	251 million tons
1970 - 1980	303 " "
1980 - 1990	520 " "

In the preceding chapters we have indicated that the consumption of refractory materials varies according to the technological processes and shows sometimes a rapidly, sometimes a gradually decreasing tendency. This is due to the continuous improvement of their quality. Thus, for instance, in Czechoslovakia the specific consumption of magnesite bricks in open-hearth furnaces fell from 14.2 kg/t. of steel in 1965 to 13.3 kg/t. in 1970, and that of magnesite materials dropped in the same period from 20.5 kg/t. to 14.25 kg/t. of steel. The reduced consumption of fireclay bricks is compensated by an increase in the consumption of materials and refractory concrete. Silica shows a steadily decreasing trend and its prospective use will be in coking plants, electric furnace lids, and in glass furnaces.

Graph II. shows the trend of steel production according to the individual forging processes.

Taking into consideration the decreasing trend in the specific consumption of refractories in different forging processes * in relation to the absolute output at the end of the respective decades, we can estimate the approximate needs of the individual types of refractories, as follows:

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* Ing. A. Makši - Study of the long-term development of the magnesite industry up to the year 2000. Interprojekt Košice - ČSSR/ 1971.

		1970	1980	1990
1/Fireclay bricks	%	63	60	59
2/Fireclay materials	%	81	83	85
3/Silica bricks	%	54	52	50
4/Magnesite bricks	%	73	75	76
5/Magnesite materials /incl.burnt dolomite/	%	99	99	99.5

The results of the calculations are given in Table 8 which indicates also the probable yearly increase of production in the world. For orientation we give also data on the anticipated trend of the specific consumption per 1 ton of steel.As far as the latter is concerned we should like to point out that the consumption refers to the complete technological cycle of steel production, i.e.from blast furnaces,coking plants up to rolling and the respective soaking pits and annealing furnaces. Nevertheless,these data may differ from reality,partly owing to the trend in steel output / a slighter growth in the first years of the decade/ and the intensity in the growth of technical progress.This difference can be estimated to amount to ± 12%.

/For illustration we quote the following example :

Nigeria,if it increases her steel output by 1990 to 4 million tons a year, will require 1[illegible]1,000 t. of refractories yearly,according to our estimates. Her population should by then increase to 125 millions and the anticipated production of steel would be 32 kg per head. That is very little ! /.

B/ Investment costs

The question of investment costs is as important as the familiarity with the markets. Investments that cannot be obtained from the resources of the national income or the national budget must yield capital. Such resources burden the production costs not only with depreciation, but also with the interest rate. Therefore, the main efforts should be focused on places in which the profitability of the production funds would be the highest. These question have been dealt with in the chapter on production costs.

Here we wish to touch upon the specific investment costs, i.e. those that must be invested in one ton of output.

Table 8 - Anticipated absolute growth of refractories output in the world till 1980 and 1990 ,and annual increase

	Total output 1000t.	Increase per decade 1,000t.	Annual increase 1,000t.	Specific consumption kg/t.of steel
1.	2.	3.	4.	5.
A/Bricks				
1/Fireclay				
1970	19,730	--	--	21.00
1980	26,250	6520	652	16.50
1990	33,600	7350	735	13.20
2/Silica				
1970	1,430	--	--	1.30
1980	1,900	470	47	1.10
1990	2,500	600	60	0.9[illegible]
3/Magnesite				
1970	4,400	-	-	5.44
1980	4,620	220	22	3.85
1990	7,550	930	93	4.04
B/Materials,Mortars, Refractory concrete				
1/Fireclay and silica				
1970	7,090	-	-	9.70
1980	9,760	670	67	9.00
1990	13,360	3600	360	8.00
2/Magnesite and Dolomite				
1970	6,350	-	-	10.63
1980	7,800	530	53	8.67
1990	11,200	3320	332	7.80

As this lecture cannot deal with all the characteristics of investing and investment policy, reference will be made to the size of the specific investment costs according to individual comprehensive technological phases, according to the conditions as they developed in investment activities in Czechoslovakia.

The specific investment costs depend on the size of the erected capacities,on the technical equipment of the plants,on the proportional representation of constructional and technological investments,on the price of supplies ,and on the location of the works/ terrain/.

The specific investment costs for mines /SIC/ refer to an output of 60,000 t. per year,with full mechanisation of the mining,loading and removal.

	SIC $ / t.	Percentage of constructional investments
1/**Mining**		
-refractory clays	7.60	50.4
-quartzites	9.50	59.0
-magnesites		
a/open-cast/cap.500,000T/year	14.50	73.5
b/deep / " 1250,000 "	9.35	43.5
2/**Dressing**		
Magnesite raw materials /capacity: 1250,000 t/yr. charge/	3.80	49.6
3/**Thermal processing of raw mater.**		
Fireclay / 60,000 t/yr /	32.20	33.2
Magnesite		
a/Rotary furnaces/240,000 t/yr/	40.00	48.7
b/Shaft furnaces / 15,000 " /	47.60	32.8
4/**Brickworks**		
Fireclay /60,000 t/yr/	144.20	37.2
Silica /35,000 " /	123.00	57.8
Magnesite /80,000 " /	136.20	38.1

The percentage of constructional investments are given because their amount depends on the geographical location of the planned investment and on the altitude. The most advantageous conditions for investment are between 30° - 45° of latitude. In regions nearer to the equator one must reckon with increased costs of air-conditioning. High-lying regions have the disadvantage of higher consumption of energy and require insulated buildings for the winter period.

One can therefore state the principle that the percentage of technological investments may be considered as constant, while constructional requirements change with the latitude. Consequently, the data about specific investment costs regarding the latitudes 49 - 51° are valid only insofar the technological investments remain constant, while the level of technical equipment and the technological demands may to a certain extent influence their amount.

The percentage of constructional costs in open-cast mines includes also the investment costs of stripping, during the opening of the mine.

The data given in this chapter can help to determine the approximate investments needed for the construction of the planned capacities. Technological processes and peculiarties should, of course, be respected.

A more precise determination of the necessary investments and working capital, that is the production fund can be specified only in an investment study, which can be elaborated only by a qualified and experienced projecting organisation.

CONCLUSIONS

The purpose of the lecture was to give a comprehensive view of the reefrectories industry,noteblly in its relation to its main consumers, the ferrous metallurgy and steel works. The development of steel production is dealt with at length to elucidate the conclusions concerning the quantitative output of the individual types of refractory materiele,in dependence on the kinds of forging processes.

A greater amount of technical date is presented to illustrate the influence of economic factors. Economics always reflect technological processes at a certain level of the applied technice and the organisation of production factors . The lecture has attempted to elaborate this idea.Only a detailed knowledge of the technological processes can serve as an adequate basis for a prognosis in economics.

The questions of prices and investment costs are elaborated to such an extent as to provide impulses for a general economic evaluation of the necessary investment costs and at the same time also an idea of the profitability of the reproduction of manufacture.

We have attempted to summarise the experiences from the manufacture of refractories in Czechoslovakia and provide a contribution to their further development or application in economic and technical considerations and solutions.

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