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EVALUATION OF INDUSTRIAL RESOURCES IN MATERIALS AND MANPOWER 1/

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INTRODUCTION

The refractory industry includes very important industrial branches, as all technological processes using high temperatures depend on refractory products, e.g. the iron and steel industry, the power industry, the nonferrous industry, ceramic industry, etc.

There is a constant demand for refractories, in accordance with the steady development of the whole industry, especially for refractories of a better quality with respect to the intensification of thermal processes in recent years. The refractory industry is always looking about for new types and new sources of raw materials, for new manufacturing methods producing refractories of more uniformity and with better physical properties, for special refractories produced that fit more the individual needs and demands of customers. Generally the development of refractory industry contributes to the progress in most important industries.

Therefore, thanks to the United Nations Industrial Development Organization the in-plant training workshop on the production of refractories is being prepared. According to the outline many papers concerning various problems of the production of refractories from the geology of raw materials to the application of products will be presented and discussed.

This paper has been prepared according to the item 9 of the outline and it deals with the evaluation of industrial resources in materials and manpower.

The problems connected with the evaluation of resources mentioned above may be quite different and practically rather depending on the local situation. Therefore, the content of the paper was concetrated to general problems of raw materials, of material deposits, of testing and research and of training of new staff.

First the material possibilities are discussed as regards the quality and chemical composition of refractory raw materials and their sources. The attention was paid to the common problems of material deposists and to its evaluation concerning the material stock and the mining.

The testing methods are needed not only for the evaluation of raw materials but for the controlling and checking of production as well. There is a close connection between the testing methods and the research in the sphere of raw materials and of the technology producing various refractory products.

Finally the new staff must be prepared to control the production as much as other employees and workers must know how to operate and manipulate various technological lines, equipment and installations. Some proposals for training and for improvement of basic knowledge of refractories, - being the more desirable and important, the more modern production is, - are mentioned.

I. MATERIAL POSSIBILITIES

The main precondition of refractory production may be represented by sufficient sources of raw materials. These sources must be always evaluated from two points of view:

/a/ Qualitative

/b/ Quantitative.

By the qualitative view the requirement is understood to have available the raw materials determined for the production in a high quality, i.e. they must fulfil all criteria given either by the standards or by the generally known regulations.

By the quantitative view the requirement is involved to dispose with these raw materials a sufficient extent in the neighbourhood of the plant as to guarantee fluent supplies of production.

Near the vast deposits the large capacity plants may be errected raw materials being available for a long time-until the capital investment returns. In case of the smaller deposit it is necessary to solve the situation from several view points especially then if it is desirable to construct relatively smaller capacity of the plant or if it is possible to take into account the delivery of raw materials even from a longer distance without impairing the effectiveness of the production.

Both views must be considered at the estimation of the construction possibility in the whole extent, because they mostly affect the reasons and advantages of the investment intention - the construction of a refractory plant.

A. Survey and General Discussion

For manufacture of refractory of required properties these preconditionsshould be fulfilled (7):

/a/ Right chemical mineralogical composition of the raw materials;

/b/ Optimum firing as its temperature, time and atmosphere are concerned;

The third precondition may be added to them:

/c/ Suitable grain size of raw materials and consolidation during molding.

From the above mentioned the most important is undoubtedly the first one. That is due to the fact that during the technological process suitable for refractories no change in chemical composition occurs, with the exception of re - moving H_2O and CO_2 as far as the raw materials contain them.

Said in other words the chemical composition of the products is the same as that of raw materials. As far as the changes took place then in that respect only that the chemical compoments formed new compounds /minerals/ depending on temperature which they were exposed to. Between the raw material and products the difference is only in the phase /mineralogical/ composition.

For this reason each refractory product requires the raw materials of a certain limited chemical composition, which will form the microstrucutre of the body with characteristic feature after firing.

It results from here that keeping the chemical composition must be predominant as it cannot be changed by firing. If the raw materials have not the right chemical composition no optimum firing brings the product of desirable quality.

B. Evaluation of Raw Materials

The evaluation of raw materials for manufacture of refractories is carried out by means of certain chemical, physical and technological tests most which are involved in various standards (ASTM, BSS, DIN, ČSN, a.o.) (1) (3) (4) (8).

As these products are required to be refractory, i.e. their P.C.E. is to lie above No. 20 cone, the starting raw materials must meet this condition as well (10).

Since each refractory comprises a typical oxide /or sometimes even two/ of its own, its refractoriness will be the higher, the higher quantity of this basic oxide it contains. That is due to the fact that various accessories decrease its fusion point.

As the cleaner the raw materials are, the more suitable they will be and the better they will fulfill the requirements imposed on the starting materials.

It follows from the above-mentioned fact that the chemical analysis is the simplest test for evaluation of raw materials. The content of main refractory oxides is determined here as much as the amount of other undesirable components decreasing the quality of raw materials.

From the chemical analysis even the refractorines may by estimated, e.g. in case of fireclay after Schuen (7)

$$R = \frac{360 + Al_2O_3 - RO}{0.228} \quad / \, ^oC \, /$$

where R is the fusion point / ^{o}C /

Al_2O_3 - the content of this oxide after firing /%/

RO - the content of two- and monovalent oxides after firing /%/.

In case of quartzite another equation according to Niewenburg can be used (7)

$$P.C.E. = 35 - 0.35\ p \qquad / \text{cone} /$$

where P.C.E is the pyrometric cone equivalent

p - content of all oxides except SiO_2 /%/.

In table 1 the main refractory raw materials and some of their important properties are summarized (8) (10).

To get the possibility for comparison of various raw materials the chemical analysis of those being used for production and being normally supplied are given in tables 2 to 5 (1) (2) (4) (5) (10) (11). These analyses may serve as a guide for evaluation of the unknown raw materials after determination of its chemical composition.

This evaluation, however, must be accomplished by further tests in case of introduction of the raw material into production. These tests would illustrate which pro - perties the raw materials during the technological process will have and, mainly, which technical properties the final products will show. Tests serving this purpose are given in a survey in the chapter II; the character of these tests is mainly technological and physico-chemical.

In the final complex evaluation of raw materials for their application it is necessary to carry out the given tests besides chemical analysis. So we get the information about the decisive properties under which conditions this raw materials may be used in the factory.

Some of these tests must be performed during the technological process as well to get the possibility of controlling its correct course.

The quality of raw materials and their dressing are to be paid an extraordinary attention as it is the basis of successful manufacture or refractory products.

C. Evaluation of Material Deposits

The discovery of certain raw materials which, by their composition, fulfil the requirements of refractory industry will not do by itself.

It is always indispensable to estimate in what thickness and in what amount the raw materials appear as according to this the capacity of quarry and in this way the life-time of the material deposits will be determined.

The information about the extent of material deposit and about the quality of raw material in its different places is fixed by geological survey.

The detailed geological survey is essential with regard to the division of condition of deposition because the raw materials often change their deposition both in vertical and in horizontal direction. This situation is frequently influenced by different factors, e.g. by weathering, transport, erosion, etc. Sometimes the rapid changes of layers with different composition respectively the diminuation of thickness or pinching of layers occur (12).

The geological survey should be controlled according to the type of deposit being under prospecting and also according to what exact calculation of material deposit should be gained.

Typisation of Material Deposits

All material deposits may be divided according to different criteria e.g.:

Type I.: /a/ Large medium material deposits of simple form and of regular deposition of one kind of raw material;

/b/ Large and medium material deposits of simple form and regular deposition of several kinds of raw materials;

Type II.: Large material deposits of simple form and of irregular distribution of accessories /harmful substancies/ and of unworkable raw materials:,

Type III.: Large and medium material deposits of a com - plicated form;

Type IV.: Small material deposits with a regular deposition of layers.

The geological survey is always run by the type of material deposit. The specimens obtained from the test holes and test pit undergo the analysis characterizing suffi - ciently the suitability of the raw material for production. In the graphical illustrations of the profiles of the test holes the results of raw material analysis are indicated and the depth of the well is limited. The suitable analyses are especially for calculation of stock in the deposit denoted in the plot.

The Extent of Material Deposit

The calculated stock of raw materials is classified according to the extent of the geological survey, to the density of test holes and to the evaluation of technological tests.

These categories of stock in the material deposit are as follows:

/a/ Category A - mining stock. In its calculation just a small error is allowed. Therefore the geological survey must very detailed, the holes must be dense/ spaced 20 - 40 m/ out of which 5 to 10% dug and illustrated in the maps 1:500. On their basis the method of mining is elaborated. The technological tests of raw materials have been made on an operational scale.

/b/ Category B - industrial stock. In the calculation of this stock the error ± 25% is admitted. In this case the density of test holes is less frequent and the distance between the holes makes 80 to 160 m. from the holes 1 to 3 should be dug. The technological tests should be performed in the whole extent. The stock found out in this way serves the preparation design of refractory plants.

/c/ Category C_1 - prospective stock. The accuracy of stock calculation makes ± 65%. In this case the distance of tests holes is very long, approximately from 160 to 320 m according to the type of material deposit. The technological tests are of the informative character. The knowledge of this prospective stock serves the determination of perspective investment.

/d/ Category C_2 - informative stock. The calculation is carried out with a small exactness ± 100%. The test holes are unique only. The technological test need not be carried out. As a rule the informative stock completes the industrial /B and prospective /C_1/ stock in order to secure the possibility of futher extension of deposit.

From the classification of categories it follows that for the investment intention it is necessary to investigate the material deposits according to the categories A, B and C_1. When opening the construction of a plant the calculation of stock of the category A must be at disposal as according to them the opening and mining of the material deposit are to be prepared for the new plant. In the accordance with the character of the material deposists the geological survey for determination of mining stock /A/ must be carried out once a year at least.

The Description of Deposit

On the basic of the geological survey performed the technical report is elaborated containing:

/a/ Descriptive part including the chapters:

1. General description and data about the material deposit. This chapter contains the general features, the aims of the geological survey, the position of

deposit, the morphology of the area, the continuity to the transport, climatological conditions, the history of deposit, the energetic base, etc.

2. Geological characteristics of the neighbourning material deposit.
3. Geology of material deposit. All geological characteristics are included.
4. Hydrogeological characteristics of deposit.
5. Description of geological surveying works.
6. Technolgical evaluation of raw material.
   The results of laboratory and operational tests are discussed and the evaluation and classification are carried out.
7. Calculation of deposit stock. Fixed according to the method and extent of geological survey.
8. Mining and technical conditions of extracting.

/b/ Graphical part:

1. Mapping documents concerning the larger area including the deposit.
2. Geological maps and sections across the material deposit in the scale 1:1000 and 1:500.
3. Maps, sections and disposition of the material deposit needed for the calculation of raw material stock including the situation of all test holes and test pits.
4. Documentation of surveying works including all technological tests of gained specimens and description of all other works being used for evaluation of material deposit.

   The calculated raw material stock are denoted as
   - balance stock being verified and suitable for economic explotation,
   - non-balance stock, not being able to be used with regard to the small amount, small thickness, technological unsuitability, complexity of the mining conditions.

In the report of geological survey there is all the information and documentation on whose base the exploitation of the material deposit is guaranteed in case of suitability of present raw material.

D. Mining of Material Deposit

On the base of geological examination the mining plan containing all important procedures in discovering and mining the deposit, the methods of extraction, drainage and transport of raw material to the plant.

According to the time for which the mining plan is constructed we know:

(a) The long-term mining plan. This plan is elaborated according to the results of geological survey and it is usually includes the whole material deposit. It solves the main problems of mining, until the deposit is extracted. It contains the method of development, proceedings and methods of mining, drainage, transport and removal of waste material;
(b) Short-time mining plan is put down according to the type of the material deposit for one to two years. Here, the profiles of material layers are indicated, their technological properties, a detailed mining proceeding and transportation of raw materials. The plan determines the method and ratio of mixing of raw materials and providing of stock and its use if desirable. The safety regulations and the keeping of mining directions are paid a special attention.

Methods of mining and the choice of suitable mechanical equipments are decided by these features:

(a) The deposition of layers of raw materials - near the surface, across the slope, in the depth and the alternation of layers;
(b) The properties of raw materials - cohesion, hardness, humidity etc.;

(c) The extent of exploitation.

The mechanical mining of raw materials is preferable because it guarantees the needed amount, and the quality of raw materials and limits the use of manual work if desirable.

Recently a large number of various machines suitable for mining various materials is at disposal. The information about their output and utility can be offered in a detailed way by their producers.

The optimum organization of mining is run in accordance with these principles:

(a) The supply of raw material must be sufficient, fluent, and independent of atmospheric conditions and of the season;
(b) The mining must be carried out so that the raw materials from different layers may be mixed correctly from the technological point of view so that the raw material may enter the production process quite homogeneously;
(c) The mining must enable the dressing and benefication of raw materials if needed.

The keeping of these priciples helps a good operation of the manufacture and also the production of high quality products.

E. Dressing and Benefication of Raw Materials

Sometimes the raw material is not utilizable for the manufacture without a preceeding dressing and benefication in order to remove undesirable impurities. In another is suitable for use after proper benefication only (12).

Due to the lack of high quality of raw materials the benefication is indispensable to broaden the raw material basis for refractory industry.

The dressing lies mainly in crushing, milling and sieving of raw material. The benefication comprises the application of special dressing methods in which most impurities and accessories are separated. In this way the raw material gains the technological properties as required, or they are even improved to be utilizable for super-duty or special products.

The methods of benefication are subdivided according to the medium of performance (12):

(a) Dry methods:

1. Screen sizing.
2. Air sizing.
3. Magnetic separation.
4. Electrostatic separation.
5. Optical separation.
6. Classifier separation.
7. Pneumatic concentration.

(b) Wet methods:

1. Classification with water.
2. Washing.
3. Scrubbing.
4. Gravity concentration.
5. Sink-float separation.
6. Film sizing.
7. Flotation.

The method of benefication is chosen according to the kind and amount to the character and degree of degradation of raw materials. The dry methods of benefication are preferred to the wet methods since the costs with regard to the necessity of dewatering are lower. On the other hand, the wet methods of benefication are usually more intensive. Therefore the choice of methods depends on ecconomic evaluation of this process.

Many of the refractory, raw material are dressed, especially those serving the production of high quality or special refractories, e.g. kaolin, magnesite, sillimanite, cyanite, zircon-silicate, etc.

F. Mutual Location of Plant and Material Deposits

Considering the location of a new plant with respect to the situation of material deposits practically two possibilities are in question:

(a) To locate the plant close to the material deposit;

(b) To situate the plant outside the material deposit and to transport the material into the plant.

The answer how to decide can not be produced universally. Many other factors play an important role here. Therefore it is essential to elaborate a technical-economical analysis where all these factors would be estimated and discussed. The main factors of them are:

(a) Power supply;
(b) Water supply;
(c) Transport to and out of the plant;
(d) Manpower, accomodation;
(e) Building costs and conditions;
(f) Possibilities of enlargement of the plant;
(g) Costs of production of different alternatives, etc.

Only after an economic estimation of different alternatives the site of the construction may be chosen.

We must point out that in the case of refractory products the necessity of construction near the material deposits does not usually play such an important role. In some cases it is not even possible.

With regard to a limited occurrence of some raw materials and to high prices of products made of them, they are transported often at long distances. E.g. kyanite is imported to Europe from Manchuria, bauxite from India, South America, Africa, quartzit from Africa, magnesite from Brasil etc. Therefore the prices of products of raw materials must be decisive for solving of this problem. E.g. in the USA the magnesite costs US$ 100 per ton, the fireclays from US$ 15 - 30 per ton.

G. Selection of Technological Production Methods

The selection of technological methods is a most important part of design of the new plant or its modernisation, as the technical and economical effect of production depends on the level of technology.

These principles are valid for the selection of technology:

(a) The method of production must correspond to the most modern method known till now respectively to a method even improved by the recent knowledge;
(b) The most effective machinery with the long lifetime and small consumption of manpower and energy;
(c) Highly mechanized or automatically controlled production lines;
(d) The possibility of using computers for the control and checking of production.

The production lines are then differentiated in accordance with the sort of products they are determined for. These factors are decisive here: the size of product, the kind and method of dressing, the kind of moulding, drying and firing (5) (10) (11) .

The preparation of raw materials is usually arranged so that the raw materials should be automatically rated and mixed with a prescribed amount of water according to a programme.

The moulding methods consist of soft-mud, stiff-mud, dry-press and casting. The dry-press method with the content of 4 - 10% of water is preferred. In this case the products are moulded by presses with a relatively high specific pressure.

Only by a high pressure the damp powder can be consolidated into a homogeneous mass.

The bricks produced by dry pressing are very uniform in size, with strong corners and edges and little tendency to warp. They have good spalling resistance and generally good resistance to load.

In order to make a uniform brick, it is essential that the mix be uniform, that the same weight of the material be always charged into the dies each stroke, and that it be evenly in the die box. For non-plastic mixes a small amount of organic binder such as dextrin is used.

The brick discharged from the dry press can usually be set on the tunnel kiln cars with little or no drying. The dry process is used very extensively for the moulding of basic and special refractories (practically 100%) and mostly for the fireclay refractories (approx. 80%).

The drying of moulded body is not necessary when dry press method is used. On the other hand, continous tunnel drier is preferred.

The firing process is one of the most important steps in the manufacture of refractories, since fired body changes its properties due to the reactions at high temperatures and becomes much stronger with high durability (6).

Of the different kilns the tunnel ones are preferred. Although they have some disadvantages (high capital outlay, considerable space, high upkeep on the car tops, problems with the uniformity of temperature across the section, the low flexibility to the production, etc.), their advantages prevail so that these kilns are the most utilized in the refractory industry.

The most important advantages of tunnel kilns are:

(a) Their excellent suitability to a continous production process, which minimize handling;
(b) Good possibility of firing and cooling according to any desired schedule, which enables the body to be burned properly in the shortest time;

(c) The setting and drawing of the kiln are simple and regular;

(d) The uniform temperature makes the upkeep of the refractory of the kiln itself very easy;

(e) The possibility of rapid firing owing to the relatively small cross section of the charge and to the quick penetration of heat to the center of the charge;

(f) Good economy of fuel when the kiln properly operated in comparsion with the periodic kiln.

Different types of tunnel of various capacity (direct-fired or muffle types, various placing of burners, different lenght of preheating, burning and cooling zones etc.), are used succesfully to fire all kinds of refractories.

The very important improvement in the setting and drawing of the kilns is the use of automatic setting and drawing machines. The application of these equipment enables handling to be minimized and contributes to the continuity of process.

In recent years a great attention has been paid to the packing of the refractory bricks for the delivery to the customers. Proper packing prevents damaging the corners and edges of the refractory bricks, which is important from their laying into refractory construction. Various methods of packing are used e.g. steel bands, shrink plastic foils etc.

II. TESTING AND RESEARCH

Each production of refractories must be checked during the technological process when the products of designated properties should be obtained. Various laboratory testing methods serve testing materials and products (3)(4)(7)(8)(9)(12).

The laboratory tests have three main objectives:

(a) To determine the nature and/or the properties of raw materials or the raw materials mixture;

(b) To determine the properties of products;

(c) To determine the character and/or effect of the equipment or process in question.

The tests of the raw materials or products have to determine either inherent properties, e.g. identity, specific gravity, chemical composition etc. or accidental and ephemeral properties such as size, density, porosity, surface character etc.

The testing methods may be various. They may be divided:

(a) According to the complexity and claims at the laboratory equipment:

- Simple tests, (simple equipment needed);
- Complex tests (some apparatus needed);

(b) According to the principle:

- Chemical methods;
- Physical-chemical methods;
- Technical methods;
- Special methods (especially with regard to the application of refractory).

The selection of testing methods was aimed at simple tests, which however sufficiently characterize the properties or the behaviour of materials.

It should be stressed that a complete description of a raw material or product is only possible in a well equipped laboratory, where chemical, physico-chemical and technological methods of investigation may be combined. It is interesting to note that there is a remarkable shift from chemical to physico-chemical methods. For practical purposes of production, technological tests will be preferred.

Examinations and tests themselves should be carried out according to the standards. The standards of the American Society of Testing and Materials are listed in Table 6. It is possible to use the standards of other countries when they are approved.

These standards are not only explicit, but they enable to the producer to compare his results with those of other laboratories.

At present most of the main and decisive tests of raw materials and refractories are standardized. In other cases, if possible, corresponding standards or nonstandardized methods of testing of ceramic materials should be used. With respect to the extent of this paper the main methods may be only shortly discussed.

A. Chemical Methods

The chemical analysis is of great importance for the complete characteristics of materials. The full chemical analysis reveals all the elements in a sample and the proportion of each as expressed usually in terms of various oxides such as silica, alumine, titanium dioxide, ferric oxide, etc. But such an analysis does not indicate the forms in which the various elements are combined.

According to the character of sample a certain method of chemical analysis should be selected as shown in the table 6.

In recent years there have been attempts to reduce the tedium of the full silicate analysis and to shorten the time involved. Such methods utilize volumometric and colorimetric analysis for many components or some physical methods as light or X-ray spectrography.

It should be pointed out that mineralogic composition - sometimes quite important - can be calculated approximately from the complete chemical analysis.

B. Physico - chemical Methods

Spectrography

This method is based on the fact that at very high temperatures, such as those attained in an electric arc, the movement of electrons in their orbits is disturbed and charecteristic radiation emitted. The lines of a characteristic wavelength may be calibrated and determined. The method is rapid and is of a special value in the identification and estimation of elements present in small amounts.

X-Ray Spectrometry

X-ray fluorescence spectrometry is now widely accepted as a highly versatile and potentially accurate method of elemental analysis. The sample is irradiated by an X-ray beam and the characteristic fluorescence radiation is analysed in special crystal to gain the line of certain element, the intensity of which is proportional to the amount of the element in the sample. The special equipment - X-ray spectrometer - either in the simple form as sequence spectrometer or as a X-ray quantometer for simultaneous determination of more elements (e.g. 7 or more) is necessary.

Flame photometry

The content of calcium, potassium and sodium in a sample can be rapidly and accurately assessed in flame photometer. A photocell measures the intensity of radiation of a sample solution injected into a suitable flame. Comparing the in - tensity with standard samples tested under the same condi - tion the amount of the element can be determined.

X-ray Diffractonetry

X-ray analysis is very often used for the determination of mineralogical composition of various materials. In this case, the diffraction pattern is obtained, in which the po-sition of the lines may be measured, and the present mineral identified. Each mineral is characterized by its X-ray pattern and in this way it can be determined in a mixture of various minerals. The diffractometry is carried out in a variety of ways depending on the type of the specimen, the nature of X-ray radiation used and the diffractometer employed. The use of diffractometer makes it practical to ascertain whether a ceramic material is mainly cristalline or largely amorphous, to identify most cristalline minerals and to estimate the proportion of one or more minerals in the sample.

Differential Thermal Analysis (DTA)

This method is used frequently in the ceramic industry to identify minerals, to estimate the content of some mi-nerals in composite mixture and to assess the principal re-actions and the temperatures at which they occur in ceramic bodies on firing and on cooling. The principle of the ther-mal analysis is the simultaneous measuring of temperature in an inert standard during heating or cooling. If at certain temperatures physico-chemical reactions take place, a tem-perature difference appears, recorded as an exothermic or endothermic effect. This difference of temperature is plotted against the temperature of the system and so the thermogram is obtained. This thermogram is typical for every mineral so that it can be identified and its amount can be estimated.

Thermogravimetric Analysis (GTA)

As an alternative to the thermal analysis, which lies on the heat effects, the change in the weight when a reaction takes place may be measured. Weight loss measurements are more limited and applicable only to those reactions which involve evolution of a gaseous component. The loss of weight is expressed as w/o and plotted in the relation to the temperature. The heating of the sample can either be done periodically or continually. The curves are typical for some minerals and in this way then can be identified.

Dilatometry

Dilatometry is used for the determination of reversible and ireversible changes of the sample due to the reactions which occur on firing and cooling. The sample in the form of a rod is heated up in a furnace and the length of the rod is measured at different temperatures. The recording of the changes in the length and of the temperature can be reached by various methods, automatically or by hand. By plotting these length changes against the temperature the typical curve is obtained. This curve renders information on the temperatures at which the material should be fired and the schedule of burning and cooling. The region of quick length changes can be determined as well which has a great importance for the rate of heating or cooling.

Microscopy

The observation of external form of minerals by eye or under magnification is very important and simple method of identification. The use of microscope is more convenient especially at ceramic materials, which can be examined either in transmitted or reflected light. In the former, the sections of minerals should be prepared and studied either under ordinary or under polarized light. In this way, the necessary characteristics of minerals may be obtained and their fre - quency and size indentified.

Infra-red Spectrometry

This modern method makes use of radiation of a much longer wave than that of visible light. The infrared spectrum of a mineral is made up of a series of absorption bands of characteristic frequencies. The reason is in the fact that the molecular grouping within a crystal have characteristic vibrations with frequencies corresponding to the infra-red radiation. The infra-red radiation is then absorbed. For certain groupings absorb the radiation of certain frequency, the mineral composed of these groupings can be identified. It is possible to identify various minerals in a complex mixture. The quantitative determination of minerals have been elaborated as well, but the results are not yet satisfactory.

Electron Microscopy

The source of radiation in a electron microscope is an electron beam which provides a means of higher magnification than the visible light used. The magnified image may be viewed directly on the fluorescent screen. The sample must be prepared in a very thin shape and the crystals must be very fine as well e.g. under 2 µm. New modification of an electron microscope s.c. scanning microscope enables three dimensional view on the sample examined which is more convenient, especially for ceramics, and the results are then more precise.

C. Technological Methods

There are many technological methods for examination of raw materials and products which are applicable for all kinds of refractory. On the other hand, technological tests exist appropriate only for certain refractories.

Space does not permit a detailed description of technological methods and the reader who desires this information should refer to other volumes dealing more particularly with this subject, respectively to the standards for a certain test elaborated.

Some standards of technological tests are given in table 6. The most important of them are recapitulated:

(1) Raw materials tests:
- (a) Appearance of sample;
- (b) Moisture content;
- (c) Absorptive capacity;
- (d) Plasticity and workability;
- (e) Particle size determination-dry sieve method and wet method;
- (f) Sedimentation analysis;
- (g) Drying shrinkage;
- (h) Green strength;
- (i) Sensitivy of drying.

(2) Fired samples or products:
- (a) Preparation of test pieces for firing at different temperatures;
- (b) Firing of test pieces and firing schedule;
- (c) Appearance of test pieces after firing;
- (d) Firing shrinkage;
- (e) Water absorption;
- (f) Porosity apparent and true;
- (g) Specific gravity;
- (h) Bulk density;
- (i) Temperature of sintering;
- (j) Compressive strenght;
- (k) Modulus of rupture;
- (l) Modulus of elasticity;
- (m) Hardness;
- (n) Refractoriness (P.C.E);
- (o) Load bearing capacity at high temperatures;
- (p) Spalling;
- (r) Expansion and shrinkage after reheating a.o.;

According to the character of technology it is shown that the frequency of technological tests must not be the same. Some of these tests are carried out every day or in a shorter time, others after a longer period provided the technology does not change.

It is necessary to elaborate the schedule of a technological tests for the control and checking of the production.

D. Special Methods

With regard to the application of refractory materials in various branches it is necessary to get full information about their behaviour under different conditions. Therefore many special tests of refractories under special conditions were elaborated as well as other tests with special respect to the thermal properties.

Some of these methods are used for the determination of:

(a) Coefficient of thermal expansion;
(b) Specific heat;
(c) Thermal conductivity;
(d) Electric conductivity;
(e) Abrasivity;
(f) Corrosion to molten glass;
(g) Heat losses trought furnace wall;
(h) Desintegration in an atmosphere of carbon dioxide;
(i) Desintegration by alkali a.o.

These tests enable to evaluate various refractories with respect to the special condition during their use. Sometimes the results of laboratory tests and of durability as the most decisive criterion disagree. This may be caused by different conditions in the practice which destroy refractory materials very quickly or by wrong application of refractory in the construction.

It must be noted that the creation of conditions in the laboratory of exactly the same character as in the practice is sometimes rather complicated. And in addition to this fact the time factor is hard to compensate even when the refractory materials should serve for many years.

In this paper, it was not possible to treat all methods of testing in detail. If continually testing the raw materials of the same deposit, the worker will gain not only the necessary laboratory skill but great experience, so that according to the appearance and only a few tests he can at once evaluate the raw material and the product as well.

It is advisable to prepare the samples from different places of deposit or from different deposits too and to use them as the standards. These samples can be attached to a board and described so that the specimens can be compared with these standards and the evaluation may be made even mor easily and quickly.

Finally, it should be pointed out that it is recommendable to send the raw materials and products periodically to special laboratories or research institutes for a detailed examination to make sure of the correctness of our results.

E. Development of Research

The aim of research is to obtain knowledge about the properties of material, about the influence of technology on these properties and vice versa about new products and new technologies, etc.

Research is usually divided into two categories:

(a) Basic research, which is dealing with theoretical problems discovering laws and principles, with creation of hypotheses and theorems;

(b) Applied research, which starts from the basic research and makes use of this knowledge in the area of materials and technology.

While the basic research is reserved practically for various institutes, it is usually of advantage to establish the laboratory of applied research even at larger plants, i.e. at the plants producing refractories.

This applied research can mostly influence further development of technology and quality of production on the basis of the studies of different partial problems e.g.:

(a) Influence of quality of raw materials on the quality of products;
(b) Influence of raw material dressing on the improvement ot technology;
(c) Relation between technology and the properties of products
(d) Preparation of new kinds of products;
(e) Influence of items on technological process;
(f) Alternation of raw materials in the working mixtures;
(g) Relation between firing and properties of the product;
(h) Reduction of costs and saving of energy, etc.

It would be possible to present many further problems, but from the above mentioned short survey the tasks and the importance of research can be imagined.

Therefore it is necessary to take into account in the design of a new plant the construction of a laboratory where the tests of raw materials and products are performed. It is recommendable to construct it in such a way that the applied research may be carried out to an extent wanted. Later on the extension of research can be accomplished here as well. The design of the laboratory should be prepared so as to enable its extension, in accordance with the needs of research.

III. DEVELOPMENT OF TRAINING

The manufacture of refractory is performed on modern equipment that are set in very mechanized respectively automated production lines. Manual work is limited as much as possible in order to eliminate the subjective factors and the influence on the quality of products as little as possible. In spite of it many workers are needed for attendance.

Therefore great care must be paid to the training of workers so that they may perform the work reliably and accurately and know how to do the work and why they should keep the regulation exactly. They must learn the interrelation between the work itself and the quality of products.

The training of workers will pass according to the kind of work to be performed by them. As we may divide all the workers into several categories, their training will be arranged according to their category.

All employees may be divided into these categories:

/A/ Manual workers categories:

(a) Manual workers for simple and auxiliary operations;
(b) Manual workers operating machines, e.g. crushers, mills, presses, mixers atc.;
(c) Workers operating and controlling large equipmenty e.g. driers, kilns, automatic sections of the production lines, or supervising the other workers as mentioned under a) and b).

/B/ The staff:

(d) Foremen and chiefs of departments;
(e) Managing staff.

The top category staff e) is assumed to obtain the qualification needed at the technical college or university, local or foreign. They should have sufficiently long practice in production of refractories. This qualification entitles them to train other workers except special profession not included in their studies.

The workers of the categories d), c) and b) can reach the qualification in a different way. The principle holds true that the higher level the staff have, the better the qualification of other workers of lower categories is increased.

The category d) occupies an important position in the control of production as they directly run the proper technological process, they intervene in its operation, they give the orders to workers and check their activities. They must master this general knowledge:

(a) Technology of production;
(b) Machinery;
(c) Human relation;
(d) Economic and safety regulations;
(e) Testing and quality control.

Besides this more general knowledge, a special knowledge is required respecting the section which they supervise, e.g. raw material dressing, moulding, burning, etc.

This training can be reached:

(a) In a technical college;
(b) During a training in a foreign factory;
(c) Long-term course organized by the plant.

Is this training course the main subjects should be those already mentioned above. The experience in Czechoslovakia shows that such course usually lasts two years and may be realized at work. The extent of lectures covers about 600 hours within 2 years. These courses are especially intended for those employees of the plant that proved themselves to be skilled in lower categories and having abilities of vocational growth.

Category c) has also a relevant position as it is operating the most important equipments or supervises a group of machines operated by other workers of categories b) or a). They may reach their qualification by training

(a) In their factory;
(b) In a factory abroad;
(c) At a technical school.

Since this training is organized by the plant itself the extent of lessons covers 100 to 300 hours including practical training on the working site under supervision of specialists. Here they get acquainted with:

(a) Technology of production and machinery in general;
(b) In a detailed way with the production section of their future job;

(c) With the operation of machines, their service and conditions of right production;
(d) Quality of products;
(e) Safety regulation.

It is recommendable to finish the training of categories d), c) and b) according to the circumstance by an examination with the certificate of proficiency and to combine the succesful finishing of the course with a reward.

The training of categories b) and a) is due to the character of the job occupied different. If the workers performing simple functions are in question, a simple training-sometimes even during one or two days-will do.

The category b) operating certain equipments, as e.g. presses, mills, mixers, etc. must obtain a training. This training with the character of equipment may last from 2 to 10 days including a practice at the machine under direct supervision.

The safety regulations training must be performed with all these workers. [illegible] warning against danger are recommended to be situated directly at each machine. Is is also useful to situate there the information what to do in case of defects.

Illustrative hints and information can very quickly and simply instruct all workers about all they must kown.

Finally the fact can be pointed out that the instruction and training of workers should be paid the greatest attention. Especially in the beginning it is most suitable to send them abroad to similar plants to obtain the first training and necessary knowledge. There is another way possible to invite the foreign experts to come and instruct the workers at all machines and about the complex technology.

Well-trained employees are indispendable for succesful operation of the plant. This results from the fact that not even automatic plants, although this is not the case, cannot do without skilled labour. And just efficient equipment, considerable mechanization, complicated machines need a good quality operation as otherwise the defects occur here decreasing the volume of production and quality of products as well which causes essential losses and minimize the effectivity of production.

IV. CONCLUSION

This paper deals with some problems connected with the production of refractories being a subject for an in-plant training workshop in this branch.

The material possibilities for the production of various refractories, the properties of raw materials used and their dressing have been discussed.

The procedures for evaluation of raw materials deposits, the extent of geological survey for the estimation of deposits, the calculation of stock by various categories suitable for mining and processing have been analysed.

The relation between the distance of the suitable material deposits and the dislocation have been described. General problems of raw materials mining and the elaboration of the plan of mining procedures were mentioned. The main methods of benefication of raw materials have been indicated.

Briefly the selection of suitable and profitable items and the last technological production methods have been dealt with.

The importance of testing and research and the use of various testing methods were in the center of interest. The modern physico-chemical methods are shortly presented, chemical and technological tests are summarized.

With regard to the need of trained workers for the production, the possibilities of training and instruction about the basic knowledge of refractories according to the character of the work being performed were given.

Table 1. Refractory Raw Materials

Refractory	Main raw materials	Approximate formula	Fusion point °C	Density	Hardness	Occurence
Fireclay bricks	Fireclay	$Al_2O_3.2SiO_2.2H_2O$	1750	2,5	2	Widespread
	Flintclay	$Al_2O_3.2SiO_2.2H_2O$	1750	2,5	2	Widespread
	Kaolin	$Al_2O_3.2SiO_2.2H_2O$	1770	2,5	2	Many deposits
High-alumina bricks	Bauxite (mixture of gibbsite and kaolin)	$Al_2O_3.nSiO_2.mH_2O$	2050	2.5-2.6	2	Scattered deposits
	Diaspore	$AlO(OH)$	2050	3.4-3.6	5	Small deposits
	Gibbsite	$Al(OH)_3$	2050	2.4		Scattered deposits
	Sillimanite	$Al_2O_3.SiO_2$	1800	3.2	6-7	Small deposits
	Andalusite	$Al_2O_3.SiO_2$	1800	3.1-3.2	7	Small deposits
	Cyanite	$Al_2O_3.SiO_2$	1800	3.5-3.6	4-7	A few deposits
Silica	Quartzite (Ganister)	SiO_2	1713	2.65	7	A few large deposits
	Limestone	$CaCO_3$	2570	2.4-2.8	3	Common
Magnesite	Magnesite	$MgCO_3$	2800	2,96	4	Numerous deposits
Chromite	Chrome ore	$(Fe,Cr)_2O_3$	2085	4.3-4.6	5-6	A few deposits

Table 2. Analyses of Typical Kaolins and Refractory Clays

	Kaolinit pure	Zettlitz kaolin	Georgia kaolin	English kaolin	Kemmlitz kaolin	Flint-clay Pennsylvania	Plastic clay Ohio	Fire-clay England	Plastic clay Czechoslovakia	Shale Czechoslovakia
SiO_2	46.6	46.2	45.8	48.3	56.0	44.5	58.1	50.5	48.0	48.0
Al_2O_3	39.5	39.2	38.5	37.6	30.0	37.1	24.1	32.0	33.0	36.0
TiO_2	-	0.2	1.4	0.4	0.5	1.4	1.4	1.7	1.1	0.8
Fe_2O_3	-	0.6	0.7	0.5	0.8	1.2	1.8	2.3	1.6	0.5
CaO	-	0.1	-	0.1	0.1	0.6	0.8	0.5	0.9	0.2
MgO	-	0.1	-	-	0.1	0.2	1.0	0.5	0.1	0.1
K_2O	-	0.2	-	1.1	0.6	0.6	1.8	0.7	1.0	0.3
Na_2O	-		-			0.1	0.4	0.2	0.1	0.1
Loss of ignition	13.9	13.4	13.6	12.0	11.4	14.3	10.6	11.6	14.2	14.0

Table 3. Analyses of Raw Materials for High-alumina Bricks

Constituents	Sillimanite S. Africa	Sillimanite India	Cyanite India	Bauxite India	Bauxite Guayanna	Diaspore Missouri	Gibbsite Brasil	Bauxite Georgia	Burley Clay Missouri	Andalusite California
SiO_2	14.4	35.1	31.6	1.8	4.5	10.9	0.2	26.0	33.8	33.9
Al_2O_3	83.0	62.0	67.7	59.2	58.4	72.4	63.8	54.0	49.4	57.6
TiO_2	-	-	-	6.4	2.9	3.2	-	2.1	2.6	1.5
Fe_2O_3	0.5	1.0	0.4	2.3	3.2	1.1	0.5	1.0	1.8	1.6
CaO	0.4	0.2	0.1	0.5	0.4	0.1	-	-	-	1.3
MgO	0.2	0.1	0.1	0.1	0.1	-	-	-	-	0.8
K_2O	-	-	-	0.2	-	-	-	-	-	0.6
Na_2O	-	-	-		-	-	-	-	-	
Loss of ignition	1.5	1.6	0.1	29.5	30.5	12.3	35.5	16.9	12.4	2.7

Table 4. Analyses of Quartzites and Other Silicic Minerals

Constituent	Quartzite South Africa	Quartzite Pennsylvania	Quartzite Sweden	Quartzite Czechoslovakia	Quartzite Wales	Silica Pebbles England	Silcrete South Africa	Sand
SiO_2	94.2	97.5	98.3	96.6	96.7	99,86	97.0	99,70
Al_2O_3	0.3	0.9	0.8	1.2	1.0	0.06	0.5	0.13
TiO_2	1.7	-	0.2	0.2	0.3	0.03	1.4	0.06
Fe_2O_3	0.8	0.9	0.3	0.7	0.8	0.02	0.6	0.05
CaO	2.0	0.1	0.1	0.5	0.1	-	0.1	0.02
MgO	-	0.2	0.1	0.2	0.3	-	-	-
K_2O								
Na_2O	1.0	0.4	0.2	0.4	0.4	-	-	-
Loss of ignition	-	-	-	0.2	0.4	0.03	0.4	0.04

Table 5. Analyses of Raw Materials for Basic Refractories - Dead Burned Magnesites and Chrome Ores

Constituent	Sea water magnesite	Magnesite Czechoslovak.	Magnesite Austria	Magnesite China	Magnesite Greece	Magnesite India	Chrome ore Turkey	Chrome ore USSR	Chrome ore Cuba	Chrome ore Rhodesia
SiO_2	1.2	3.7	1.0	3.7	6.6	5.4	6.7	3.3	3.1	3.6
Al_2O_3	0.4	1.2	1.0	1.0	4.4	0.4	12.5	7.9	31.1	14.1
Fe_2O_3	1.0	5.3	6.9	1.5	0.4	0.7	12.9	15.1	13.7	15.0
Cr_2O_3	-	-	-	-	-	-	46.6	56.0	33.8	48.2
CaO	1.0	2.3	2.1	2.1	2.4	2.6	1.2	0.9	-	1.0
MgO	97.3	87.5	88.6	92.0	86.4	90.8	17.3	12.6	17.6	15.5
Loss of ignition	0.1	0.2	0.3	0.1	0.2	0.3	2.8	2.2	0.7	2.6

Table 6. Testing Methods of Refractory Rew Materials and Products

		ASTM
1.	Chemical Analysis of Fireclay and High-Alumina Refractories	
2.	Chemical Analysis of Silica Refractories	C 573-65
3.	Chemical Analysis of Magnesite and Dolomite Refractories	C 575-65
4.	Chemical Analysis of Chrome-Containing Refractories and Chrome Ore	C 574-65
5.	Sampling of Clay	C 572-65
6.	Free Moisture Content	C 322-56
7.	Plasticity of Clay after Rieke-Attenberg	C 324-56
8.	Sieve Analysis - Dry Method	
9.	Sieve Analysis - Wt Method	C 92-46
10.	Determination of Forming Water	C 325-56
11.	Drying Shrinkage	C 324-56
12.	Green Strength	C 326-56
13.	Pyrometric Cone Equivalent	C 67-57
14.	Firing Shrinkage	C 24-56
15.	Water Absorption	C 326-56
16.	Suction	C 20-46
17.	Apparent and True Porosities	C 67-66
18.	Apparent Specific Gravity and Bulk Density	C 20-46
19.	True Specific Gravity of Refractory Materials	C 40-46
20.	Cold Crushing Test and Modulus of Rupture	C 135-66
21.	Testing Refractory Bricks under Load at High Temperatures	C 133-55
22.	Panel Spalling Test for Refractory Bricks	C 16-68
23.	Panel Spalling Test for High Duty Fireclay Brick	C 38-68
24.	Panel Spalling Test for Super Duty Fireclay Brick	C 107-67
25.	Thermal Conductivity of Fireclay Refractories	C-122-67
26.	Thermal Spalling of Silica Bricks	C 202-68
27.	Bulk Density and Size of Refractory Bricks	C 439-61
28.	Modulus of Rupture of Refractory Materials at elevated Temperatures	C 134-61
		C 583-67

Table 6.

29. Permeability of Refractories	C 577-68
30. Reheat Change of Refractory Brick	C 113-68
31. Refractory Brick at High Temperatures Under Long-Time Conditions	C 546-67
32. Static Corrosion of Refractories to Molten Glass	C 621-68
33. Disintegration of Refractories in an Atmosphere of Carbon Monoxide	C 288-62
34. Chemical Analysis of Carbon and Carbon-Ceramic Refractories	C 571-65
35. Disintegration of Carbon Refractories by Alkali	C 454-62
36. Reheat Change of Carbon Bricks and Shapes	C 436-67
37. Drying and Firing Shrinkage of Fireclay Plastic Refractories	C 179-67
38. Modulus of Rupture of Air Setting Plastic Re - fractories	C 491-66
39. Modulus of Rupture of Castable Refractories	C 268-68
40. Panel Spalling Test for Fireclay Plastic Re- fractories	C 180-67
41. Permanent Linear Change [illegible] of Castable Refractories	C [illegible]
42. Refractoriness of Air-Setting Refractory Mortar	C [illegible]-67
43. Thermal Conductivity of Castable Refractories	C 417-60
44. Thermal Conductivity of Plastic Refractories	C 438-61
45. Workability Index of Fireclay Plastic Refracto- ries	C 181-47
46. Bulk Density and Size of Insulating Fire Brick	C 437-61
47. Crushing Strength and Modulus of Rupture of Insulating Fire Brick at Room Temperature	C 93-67
48. Reheat Change of Insulating Fire Brick	C 210-68
49. Thermal Conductivity of Insulating Fire Brick	C 182-47
50. Hydration Resistance of Basic Refractories	C 456-68
51. Hydration of Magnesite or Periclase Grain	C 544-68
52. Hydration of Granular Dead-Burned Refractory Dolomite	C 492-66

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

Pilsen (Checoslovaquia)

11 - 28 junio 1974

EVALUACION DE LOS RECURSOS INDUSTRIALES EN LO RELATIVO A MATERIALES Y PERSONAL 1/

por

Vladimír [illegible] *

RESUMEN

La monografía que aquí se resume trata de algunos de los problemas relacionados con la producción de refractarios.

Se examinan las posibilidades que ofrecen diversos materiales para la fabricación de diversos productos refractarios, las propiedades que deben tener las materias primas utilizadas, y la preparación de éstas.

Se analizan los procedimientos aplicables para la evaluación de los yacimientos de materias primas, el alcance de los levantamientos geológicos que esa evaluación requiere, y los métodos utilizables para calcular las existencias de las diversas materias minerales aprovechables.

Se describe la relación entre las distancias a que están situados los yacimientos de materiales adecuados y su distribución. Se mencionan los problemas generales inherentes a la extracción de las materias primas y a la elaboración del plan de extracción. Se indican los principales métodos de beneficio de las materias primas.

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1/ Las opiniones que el autor expresa en este documento no reflejan necesariamente las de la Secretaría de la ONUDI. La presente versión española es traducción de un texto no revisado.

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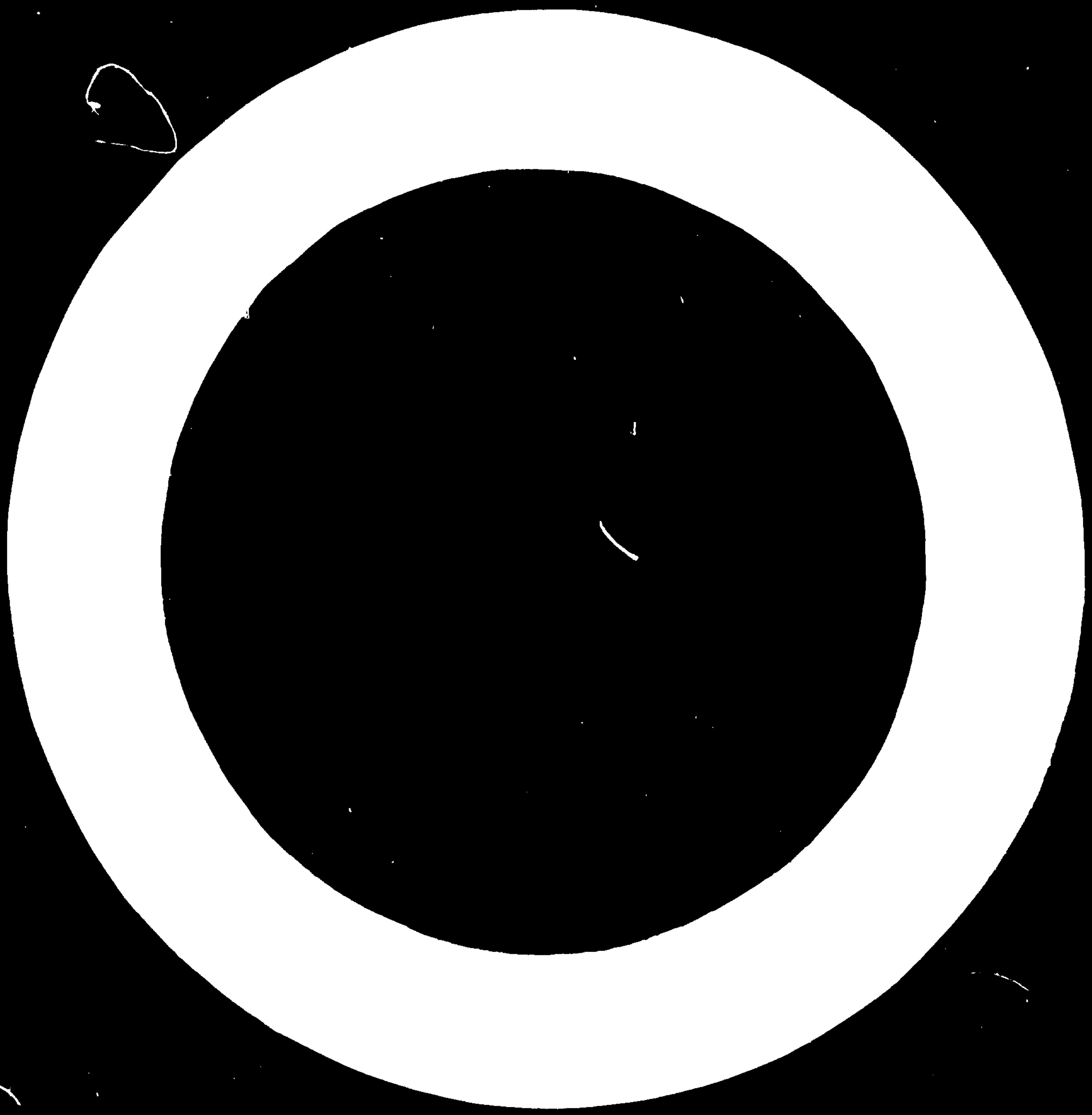

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[illegible] producción, se indica [illegible] productos refractarios, técnicos y prácticos, [illegible] trabajo [illegible].

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