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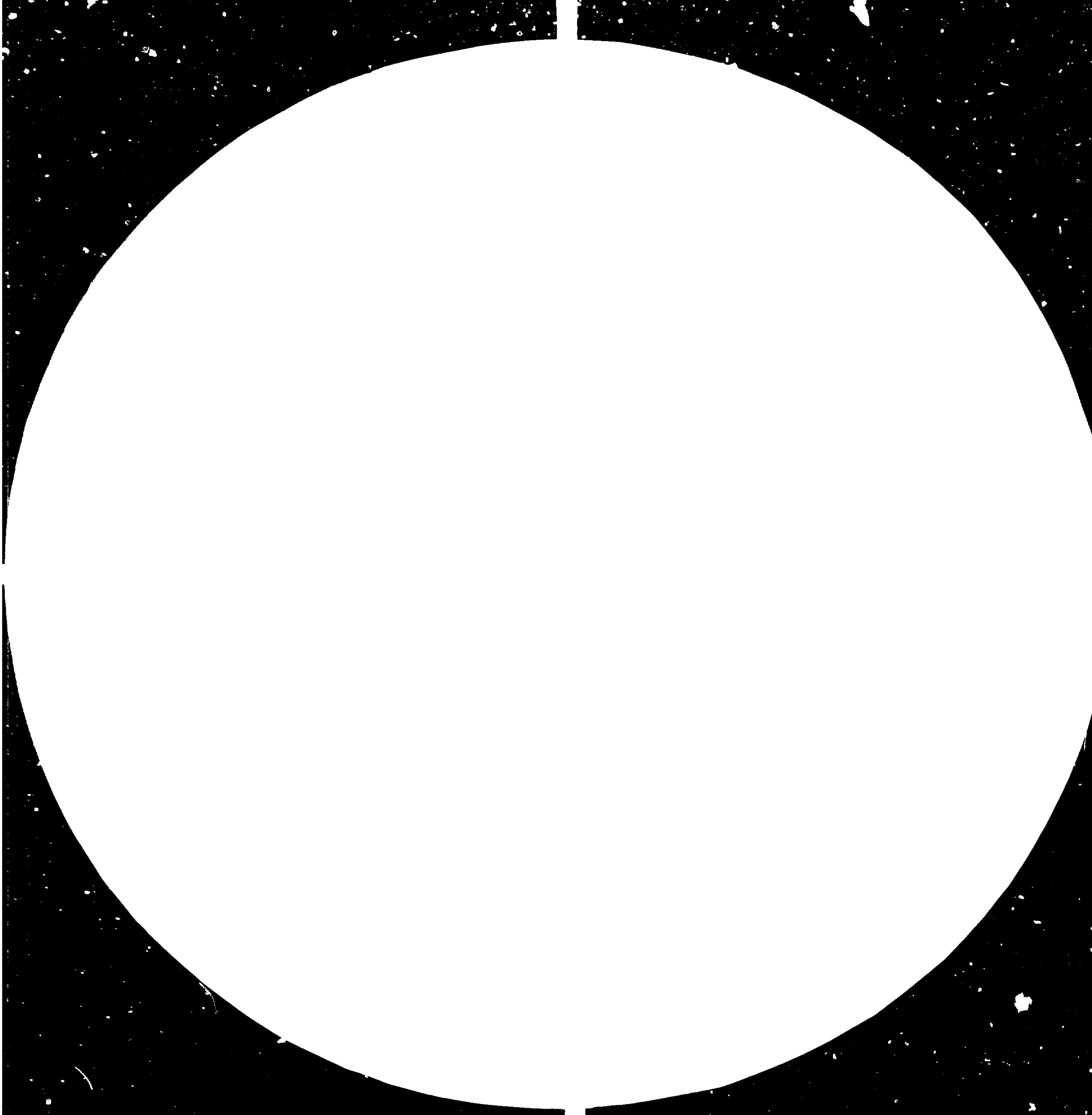

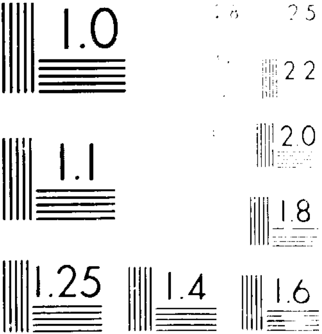
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GENERAL CONSIDERATION ON ENERGY CONSUMPTION IN SILICATE INDUSTRY

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CONTENTS

General considerations on energy consumption in silicate industry

I. General considerations on energy

Energy is the focus point of the contemporary world economy. The main principle at present is to preserve the energy sources and to cut its consumption in all fields of life to extend the existence of the present energy sources as long as possible.

The energy consumption in all countries is first of all affected by the development of industries requiring ever more energy despite the fact that the specific consumption per industrial unit tends to descend.

Research and development are providing new knowledge of energy conservation in all types of industry and it is urgent to apply and implement it most efficiently and expeditiously in the production plants. It applies considerably to silicate industries the share of which is quite large in the energy consumption.

Should we make considerations on energy conservation in silicate industry it would be useful to stem from the fundamental relations represented by the world energy situation, primary and secondary sources and energy management in various fields.

1. Energy in the World

Energy sources indispensable for the development of industries in every country have lately become the chief world problem both in industrial and political fields. The energy consumption in the world scale has kept increasing by 6 % yearly in average during the past 20 years and it still tends to grow. The world costs of energy are spiralling simultaneously and will evidently keep increasing in further development.

Both these factors - the increasing energy requirements by the developing industries and higher costs have ever more distinct impact on the national economies of countries and may also affect even the scheduled structure of their industries and even the existence proper of certain industrial branches. In some countries even nowadays some cases of limitation of production or shut down of some plants have appeared just due to energy shortage.

The influence of energy has also penetrated the strategy of world trade, it is significantly felt in the production and sales economy, the production of products consuming heavily energy is being intentionally reduced and their imports are supported as may be seen both in steel and building material industries. Whenever a product is to be put to production it is subjected to critical analysis mainly from the energy consumption point of view.

The contemporary world consumption of energy of all types expressed in terms of coal represents about 10 milliards tons of coal per year and would reach approximately 17 milliards in the year 2000. A more detailed analysis of the past and considerations on the future consumption are shown in fig. 1 (according to a UN publication).

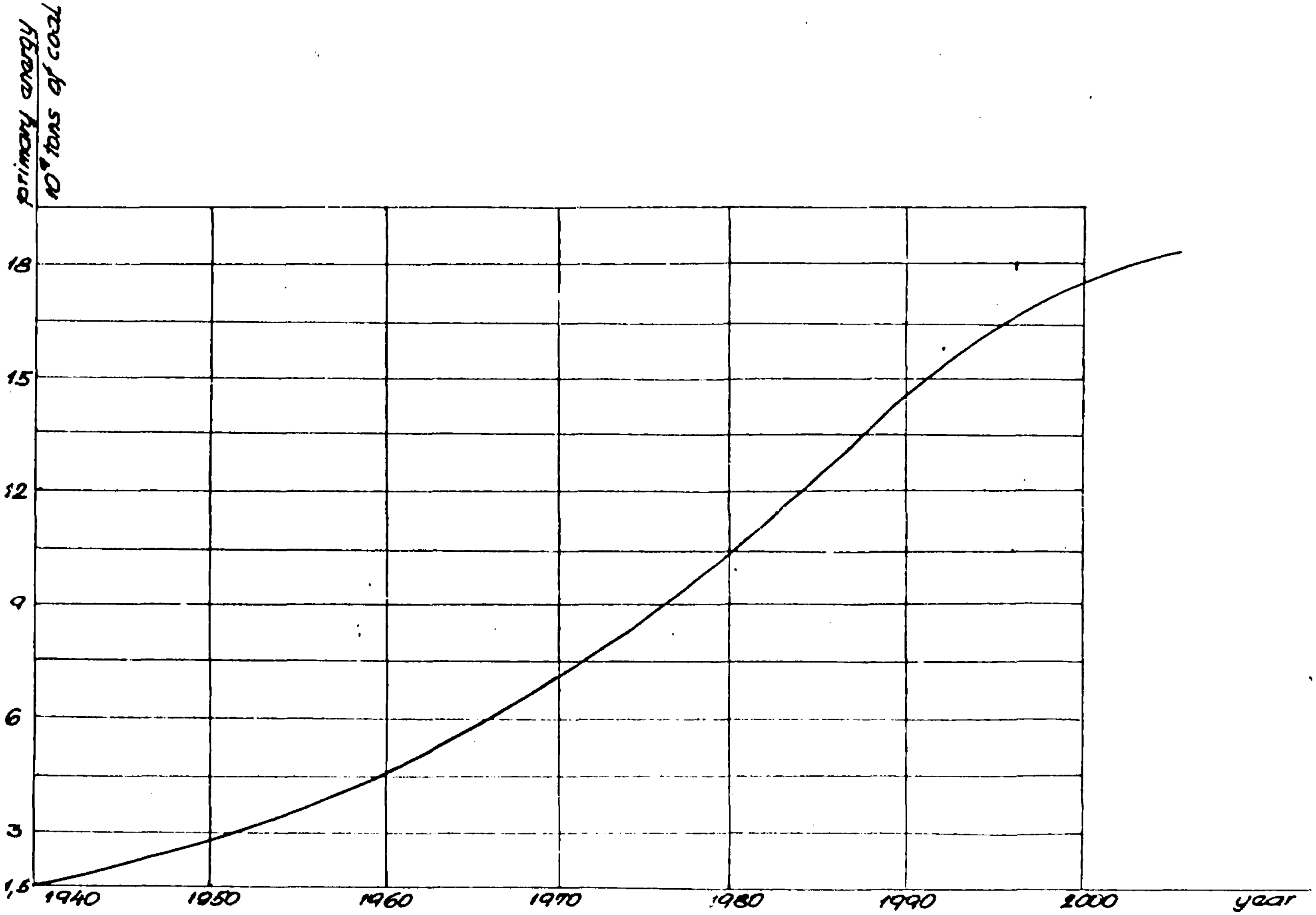


fig. 1 Development in world energy consumption and prognosis til the year 2000

The world economy has utilized cheap energy sources so far and their role in further world development has been considerably underestimated. The present situation already calls up the need to get energy practically at any cost to keep running the existing national economy in some countries.

It may be expected that the energy balance in the world will remain unchanged, the era up to the year 2000 will bring about a discrepancy of about 5 % due to the reduced exploitation of crude oil and natural gas. That will have to be made good for by an increased mining of coal and further development and utilization of new energy sources - nuclear, solar, geothermal and the like.

New, improved ways of energy transformation and utilization will call for vast research and heavy investments. It will take quite a lot of time and not every country will be able to contribute any more significantly in this respect to preserve the present sources.

On the other hand, however, everyone everywhere, without any difference, can take share in preserving the present energy sources by raducing its consumption. This applies to all spheres of life but first of all to industries being the sphere of the highest energy consumption.

2. Primary and secondary energy

Energy sources, their transformations and consumptions may be specified into two circles - primary and secondary ones being differentiated in their nature and management level and still being interlinked to each other (fig. 2).

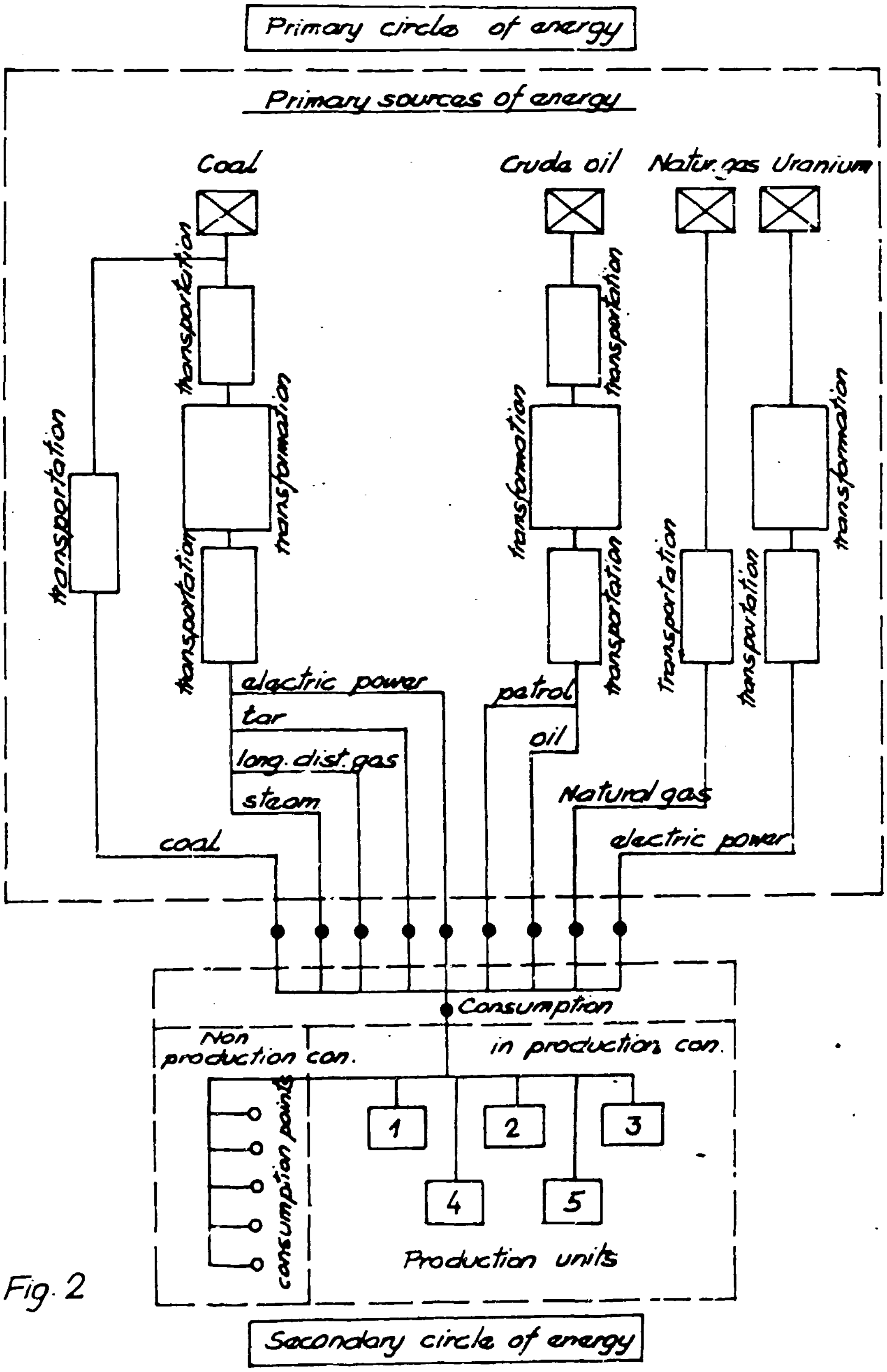

Primary circle of energy
Primary sources of energy
Coal
Crude oil
Natur. gas
Uranium
transportation
transformation
transportation
transportation
transformation
transportation
transportation
transportation
transformation
electric power
tar
long. dist. gas
steam
coal
petrol
oil
Natural gas
electric power
Consumption
Non production con.
in production con.
consumption points
1
2
3
4
5
Production units
Secondary circle of energy

Fig. 2

Primary energy circle

It covers first of all so called primary energy sources represented by energy contained in all natural sources proper and evaluated uniformly in terms of thermal energy obtained by releasing their units without any losses. Energy is specified by the calorific value of coal in the mines, crude oil and natural gas in the deposits etc. Primary energy converted into a common unit thus represents all natural energy sources in a state before they are transformed to another form or before they are transported to a distant consumer.

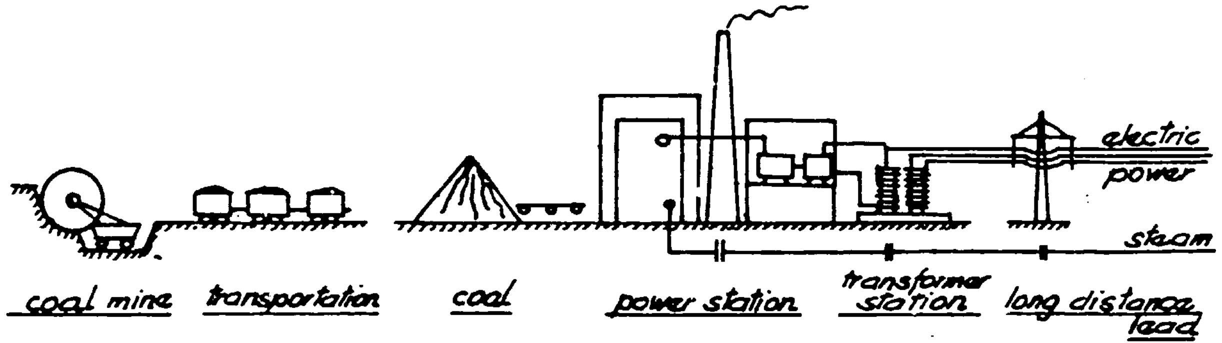
The industry nowadays needs an energy in the form of direct use in the individual appliances; i.e. electric current, industrial gases, oils, fuel oil, petrol and partly coal and wood, too.

According to the occurence of the primary sources and their types their transformation and transportation to the consumers are to be ensured. For instance coal from the coal basin is to be transformed into electric power in the thermal power stations, into long distance gas in gas producers. Crude oil is transformed in petrochemical industries into petrol and fuel oils. Hence, other types of energy are formed through the transformation processes and these other types of energy can be distributed to the individual consumers. (fig. 3)

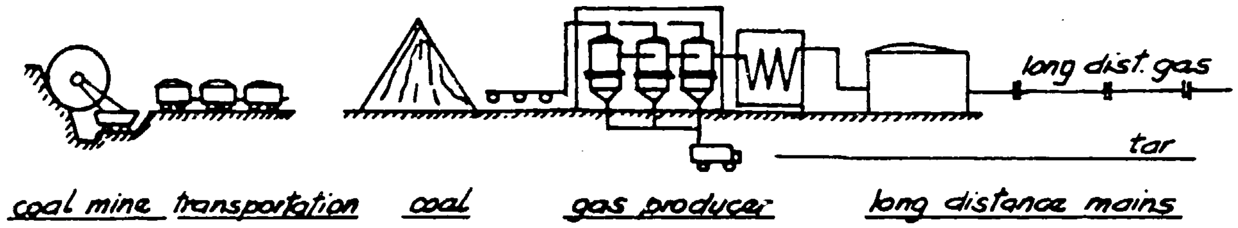
However, energy losses incur during the transformation and transportation the primary energy being thus succesively reduced that depends on how complicated is the transformation and how difficult is the transportation.

The primary circle ends at the outlet from the network and the secondary one starts at the inlet to the consumer thus the energy supplied has a lower value than that of the primary circle i.e. by all the losses incurred during the transformation and transportation. For instance when coal is transformed into long distance gas and transported about 70 % of primary energy of the coal gets lost and only 30 % of it can be utilized for consumption in the secondary circle.

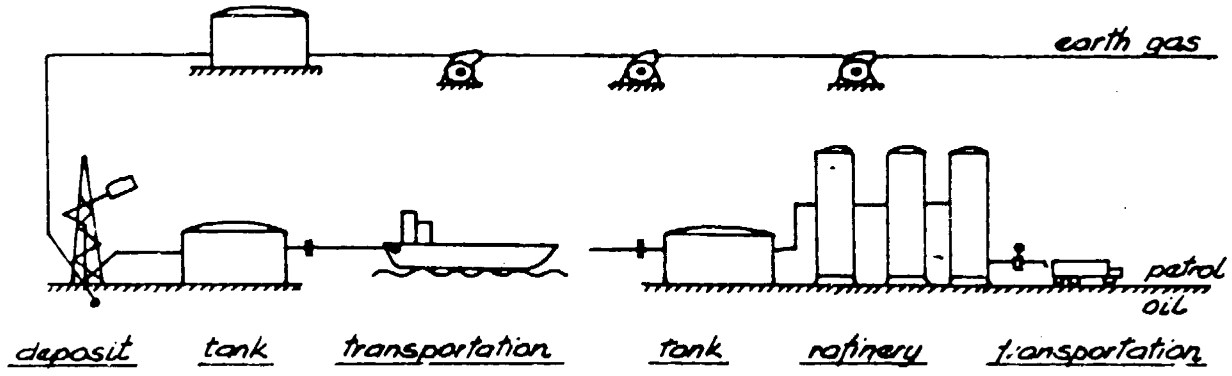
Energy transformation



① coal - electric power - steam



② coal - long distance gas - tar



③ natural gas
crude oil - petrol - oil

Fig. 3

Secondary energy circle

The secondary energy circle starts by its inlet into the sphere of consumption in a production unit. The energy input is identical with the outlet from the primary circle and the amount of energy taken is determined by the number of its units registered by meters.

The major part of the input secondary energy , after having been distributed over the plant, is consumed directly by the individual consuming equipment (e.g. gas and oil in kilns, electric power for the drive of machinery and the like). Here, too, are cases of transformation, e.g. coal from mines is transported by railway to the plant and producer gas is generated from it in a gas producer, similarly steam for technological purposes or heating is generated in a boiler house. Energy losses incur in the secondary circle as well such as due to the efficiency of kilns, driers, machinery idling, distribution of media etc.

Both circles - the primary and secondary ones - have a common point at which the amount of supplied energy and its cost per unit are defined.

The circles are independent within the scope of energy management and planning; the primary one is controlled either by central authorities, ministry or individual monopols and concerns, the secondary one then is infuenced and controlled by consumers.

The most important task of national economy authorities is a controlled exploitation of own energy sources, procurement of missing sources, their economical transformation into the industrial forms of energy in compliance with the needs and nature of the industry as well as the research and materialization of new energy sources. Any changes in the overall energy balance have a direct impact on the run of the entire industry.

Similar task within the secondary circuit is a maximum saving in energy consumption and a systematic reduction of energy losses in the production processes of any sort.

It ensues from the mutual interlinkage of the two circles that e.g. reducing the energy consumption in the secondary circle gives a distinct preference to the strategy of primary circle control whereas any increase in the consumption may only result in energy disproportions.

3. Energy management

The question of energy sources, their consumption and optimation under given conditions are not any longer a matter of mere local needs, interests and efforts. The energy problems have grown so much significant that their solution requires a central control nowadays both of primary and secondary circles.

It has been said here that everybody is not able to contribute to get new energy sources by a demanding research and prompt materialization but everyone can ~~to~~ contribute nowadays immediately to reduce the contemporary consumptions. Thereby the significance of energy management increases in the scope of the secondary circle consumption to solve the immediate situation as a whole.

The total energy supplied into the secondary circle in a pruduction plant may be divided into two parts:

- energy for non-production purposes (heating, lighting, maintenance, transport, administration)
- energy for all the consuming machinery & equipment in the production line.

The non-production energy depends on the size of the plant, nature of the production and the way how it is organized and represents a minor part of the total consumption. It amounts e.g. to about 14 % in the ceramic industry.

The production part of the consumption is represented first of all by large thermal units (kilns, driers) as well as power driven motors of all the production equipment.

The organization of energy consumption control in the secondary circle may be based first of all on perfect data on the existing production process and on the energy consumptions.

Hence, it is indispensable to work out - precise registration of the production run (outputs, assortment etc.) and any changes thereof during the year

- detail data on energy consumption as measured and registered during the year.

These data may then be evaluated into the following factors of energy demand:

- total yearly consumption of energy
- proportion of non-productive consumption
- proportion of productive consumption
- energy consumption specified per product

in relation to a yearly amount of production and the assortment of the existing original production.

When a system of energy management is being implemented to cut the consumption the following main steps are to be taken:

within the range of non-productive consumption:

the energy consumption is to be examined, first of all the usage during certain periods, to minimize it as a whole and to adapt the existing organization accordingly. Such energy savings will not be singnificant in view of its small share of the total consumption.

within the range of productive consumption:

there are more complicated conditions for the energy management and the system as shown in figure 4 should be followed: (fig. 4)

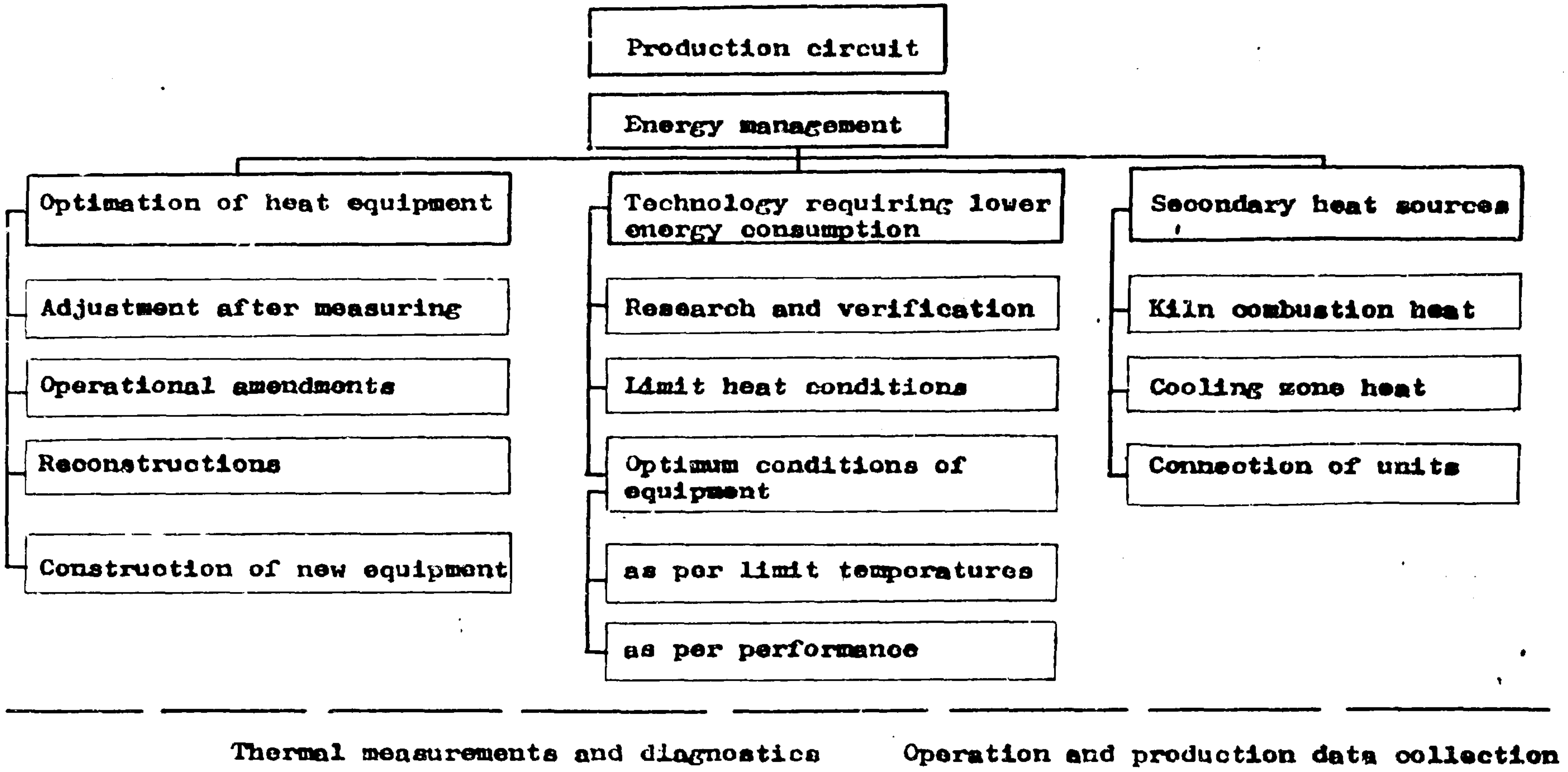

Production circuit
Energy management
Optimation of heat equipment
Adjustment after measuring
Operational amendments
Reconstructions
Construction of new equipment
Technology requiring lower energy consumption
Research and verification
Limit heat conditions
Optimum conditions of equipment
as per limit temperatures
as per performance
Secondary heat sources
Kiln combustion heat
Cooling zone heat
Connection of units
Thermal measurements and diagnostics
Operation and production data collection

fig. 4

Optimation of thermal equipment

It applies to an already well established production technology and can only be implemented on the basis of a detail energy measurement, elaboration of heat balance and analysis of heat losses. The measurement results will enable to improve run and cut the energy consumption to an optimum condition in the form of various adaptations and betterments:

- the equipment run may be "tuned up" during the measurement by more control (adjustment of burners, kiln draughts etc.)
- by the form of minor adaptations on the equipment further energy consumption may be reduced
- some parts of kilns and driers may be reconstructed on the basis of the measurements and of the new experiences from the construction of kilns; it may improve the quality of the equipment and the cource of the thermal process substantially
- a complete innovation or replacement of obsolete equipment for a new one may often prove to be the best solution.

New technology with a reduced energy demand

The thermal processes of heating, firing, heat treatment and drying and their time curves may be specified by an appropriate technological process according to which the thermal transformations of the structure and material or product properties are controlled.

The properties of initial materials and raw materials are so much untransformable in a series of industrial branches e.g. in chemistry, metallurgy and others that the energy demands of such a production cannot be changed any significantly by possible changing the composition of a charge.

In the silicate industry and mainly in the ceramic and glass industries there exist certain possibilities in the application of new compositions of bodies at which energy savings can be achieved in the form of reducing the maximum processing temperatures by combining two thermal processes into one, reducing the period of exposure to heat or by changing the dressing process of raw materials proper.

The way of controlling the energy savings in such a case must stem up from a research and verification of a product made of new materials. Limit curves have to be specified to show, in a time interval, extreme attainable thermal stress while maintaining the quality of a product. Further step then should contain an optimation of the limit processing to suit the conditions of the equipment under which the energy consumption could be minimized. This optimation should also be elaborated to match the most suitable output of a given equipment.

Utilization of secondary heat sources

A series of kilns being in use nowadays have been built in times when the opinions on the utilization of waste heat from the exhausted combustion products, coaling water etc. were affected adversely both by cheap and easily available energy and by higher investment costs and more complicated operation. Hence, till recently, the waste heat was not made use of except for recuperators at some kilns.

Many types of the present equipment first of all in the silicate industry, however, has quite considerable possibilities to obtain this wasted energy and utilize it e.g. for heating of buildings, technological heating etc. In such a way various water heaters, air heaters, heat pumps and heat exchangers can be made use of in many a case.

It is also useful to explove the possibility of combining the energy equipment e.g. to utilize the waste heat from a firing kiln for the preceding drying of products.

The main task of the energy consumption control system in this sphere is also to judge carefully all the possibilities of utilization of the waste heat in the entire production system and to materialize them in maximum extent.

The control of energy consumption therefore has, in the secondary energy circle, several main activities. By carrying them out in detail and by their mutual interlinkage an optimum condition with minimized energy consumption can be accomplished subsequently in a given production process. Diagnostics of the thermal equipment and of all machinery as well as detail collecting of production data necessary for the final evaluation are the indispensable accompanying activities.

4. Energy in silicate industry

Silicate industry is one of the industrial branches being extraordinarily demanding in energy consumption. The main reason are the huge amounts of bodies being processed on one hand and mainly the high energy consumption in melting, firing, heat treatment and drying processes on the other hand in the production technology. This can be documented e.g. by the cost of energy in the ceramic industry which represents about 50 % of the total cost of the products.

The main consumers are

- in the ceramic industry: kilns for the firing of refractory products, stoneware and tiling materials
- in the glass industry: glass melting furnaces
- in the cement industry: rotary kilns for the firing of clinker and all the driving units in the production line.

Each of these branches of the silicate industry has its own peculiarities in technology and in the production equipment. Possibilities of implementing new body compositions, new non-traditional raw materials or their new ways of dressing should also be differentiated.

Therefore, it is of utmost importance to judge in detail and evaluate the energy consumptions individually.

Hence, the energy management system is of extraordinary importance in the silicate industry and its implementation is one of the indispensable points nowadays.

II. Ceramic industry

Ceramic industry has its significant position within the world economy. It produces a large variety of ceramic tiling materials both for interior and exterior use in houses, public and industrial buildings. Stoneware products are used in the building industry and brick goods are still widely applied in the construction of buildings. Utility and artistic ceramics made of china and stoneware form also a traditional branch in the ceramic industry.

Refractory and insulation materials have become quite indispensable for the linings of boilers, kilns, furnaces etc. in metallurgy, chemical industry, engineering and energy industries. Electric insulators of all sorts have found their application in the power distribution system. Winning and dressing of raw materials for all types of ceramic products should not be omitted, either. The amounts of these products manufactured in the world are quite considerable and require large quantities of energy. The present world production of tiling materials e.g. represents about 300 mil. m^2 and, when converted into the primary sources, it consumes energy of about 6 mil. tons of coal.

Thermal processes - drying and firing are the principal stages of all the types of ceramics to which all the ceramic products are subjected to attain the required properties and final appearance. They are much time consuming to secure the structural changes in the bodies.

Any ceramic plant, when judged from the energy point of view, represents a secondary circle of energy, i.e. a circle of consumptions in which they are classified into the following principal groups (fig. 5)

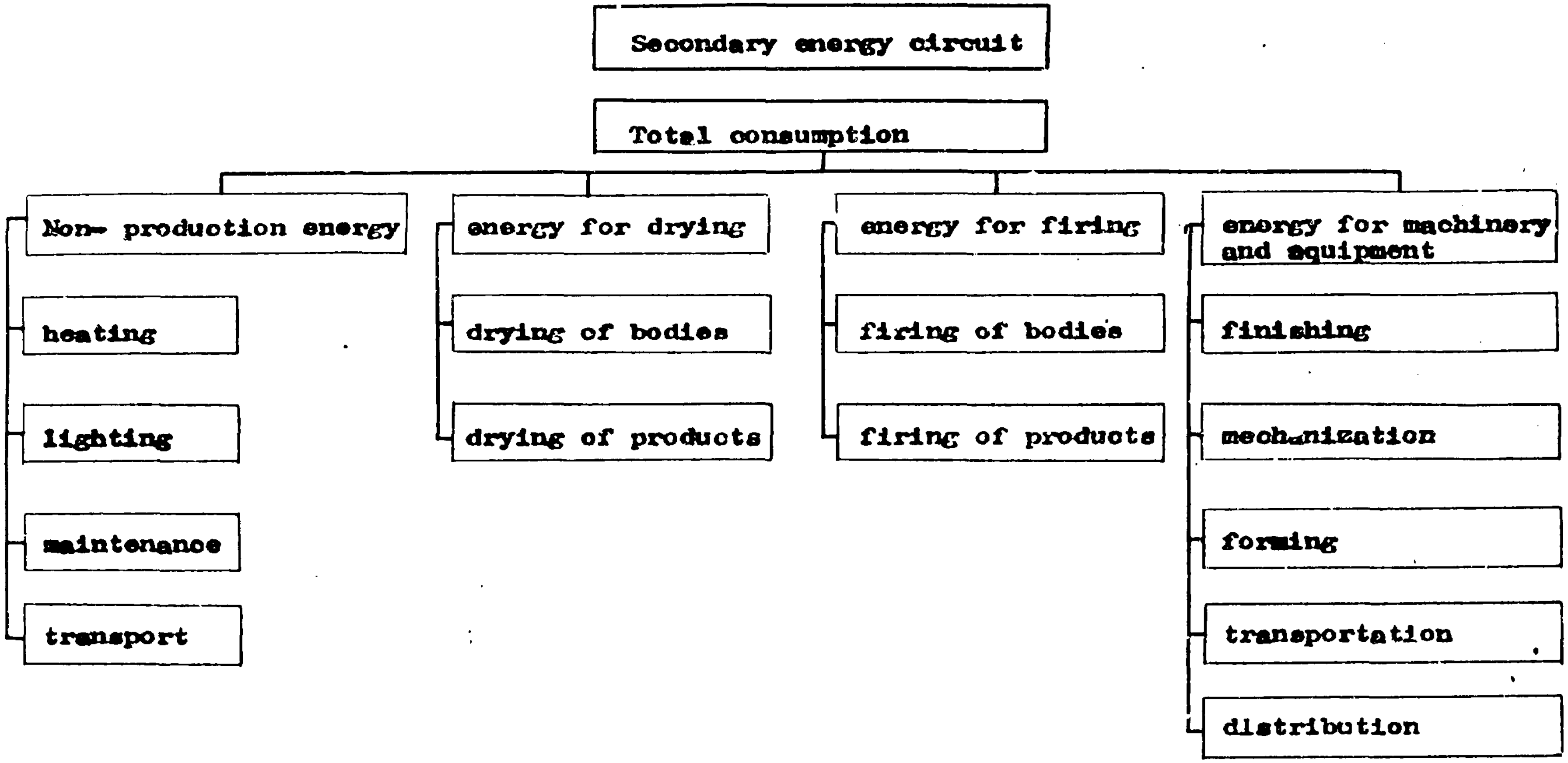

Secondary energy circuit
Total consumption
Non- production energy
heating
lighting
maintenance
transport
energy for drying
drying of bodies
drying of products
energy for firing
firing of bodies
firing of products
energy for machinery and equipment
finishing
mechanization
forming
transportation
distribution

fig. 5

Energy demands in ceramics within the range of technological equipment are given first of all by the degree of up-to-dateness of equipment, mechanization and automation of processes, technological condition of the equipment and skill of the operators. The present condition of production plants differs quite a lot starting from out-dated plants with less perfect technology and lower productivity up to the latest automated newly constructed, factories. Thereby also the different specific energy demands are the result. Despite that there exist possibilities under all the production conditions for reducing the existing energy consumption while the effect achieved will be relatively higher in the less perfect manufacturing plants than in the latest ones.

Ceramic technology and energy savings

Let us look now into the technical feasibility of reducing the energy consumption owing to the technological changes at the following ceramic products:

- tiling materials
- stoneware
- refractories
- brickware
- sanitary, utility and artistic ceramics
- porcelain

While trying to judge and determine the trends we cannot do without showing some characteristics and properties of raw materials.

Tiling materials

cover wall tiles, floor tiles and mozaics and their production process consists chiefly in the preparation of bodies, pressing, drying, bisque firing and glost firing.

Porous wall tiles

were originally based on kaolinitic-aluminum semi-silica body having been fired at 1230° - 1280° C temperature and following zircon glaze based on potassium feldspars was fired at 1080° -

- 1120° C.

New types of lime-siliceous body have resulted from a succesful research to cut the firing temperature down to 1050° - - 1080° C and glaze made on the basis of sodium-calcareous feldspars at 960° - 1040° C.

The original time required for the firing was thus reduced to a half. This change in the body composition has resulted in reducing the energy consumption by 8 - 12 % in average.

Semi-dense glazed floor tiles

This type of tiling ware based on raw and dressed kaolin and clays shows that it is useful from the energy point of view, to implement so called melting effect, i.e. by adding about 30 % of phonolite which enables to reduce the original firing temperature of 1200° - 1250° C down to 1100° C whereby about 10 - 15 % energy saving.

In this case, however, so called one-fire firing process in a conveyor line is of a considerable significance when both bisque and glost firing take place simutaneously as against the original technology i.e. a separate glost firing process is eliminated. While applying finaly ground fluxes at the same time about 50 % energy can be saved by this method.

Stoneware

generally covers stoneware for sewerage and agricultural purposes, salt glazed tiles, insulators, chemical stoneware and fine stoneware, i.e. the sanitary and utility ones.

Stoneware production uses suitable medium and low sintering clays supplemented with grog (silica sand, shale aggregates). Firing temperature of these bodies can be reduced by adding fine fluxes (marlstone, phonolite, tuffs, perlite, dolomite etc). It may be expected that by changing the raw materials in stoneware the firing temperature can be cut down by 150° - 170° C, i.e. about 8 - 12 % energy can be saved.

That may be illustrated e.g. by experiments in the manufacture of stoneware pipes at which the addition of 32 % of marlstone resulted in reducing the firing temperature from the original conventional one of 1250° C to 1160° C and an addition of 31 %

of phonolite reduced it even to 1080° C.

Refractories

represent a wide range of dense and light-weight materials for linings, i.e. fireclay, corundum, silica and magnesite products each of them requiring a certain quality of raw materials corresponding with the manufacturing technology.

For example the quality of a fireclay made of a refractory clay and grog is decided first of all by the content of Al_2O_3 and SiO_2 as well as by the production method, i.e. in a plastic way or by pressing them from a semi-dry mixture. The quality may be specified as High Duty, Medium Duty and Low Duty. Any substitution of raw materials of lower sintering temperature results in deteriorating the properties of the products and is, consequently, useless.

Hence, there is no possibility to reduce energy consumption by technological changes in the manufacture of fired refractory shapes. However, it is possible to replace this type of lining materials by manufacturing unshaped masses, i.e. fireclay concretes, plastic ramming masses, various slinging and gunning masses which, owing to their properties, can replace the fired refractory shapes. Their share in the total world production of refractories increases steadily and has reached about 35 % of the total production nowadays. These masses have quite considerable effect in the energy consumption because by eliminating the final firing process about 750 - 1350 kcal per kg of manufactured mass may be obtained in the ceramic production.

Brickware

This type of goods covers chiefly all types of bricks, various shaped bricks and roof tiles characterized by 10 - 20 % water absorption and 100 - 150 kp/cm^2 compression strength. The basis of the body is formed by suitable clays containing 60 - 80 % of SiO_2, 5 - 20 % Al_2O_3 and grog (sand, cinder, ashes and coal).

The demand for energy in the manufacture of the brickware is relatively low, about 150 - 20 kcal/kg for drying and 400 - 700 kcal/kg for firing. Possibility of energy conservation is little too, mainly in the stage of drying where using of minimum water for mixing is desirable and, furthermore, waste heat from the adjacent kilns can be used for drying purposes.

Sanitary, utility and artistic ceramics

This group of ceramic products covers wash bowls, dishes, bath tubs, utensils and artistic subjects.

Two different technological processes are known. So called double fired ceramics consists of 35 % clay, 20 % kaolin and 45 % fired grog, body being fired at 1100° C and glaze at 1280° C. To the contrary, however, one-fire ceramics (Vitreous China) contains feldspar and silica instead of a part of grog and its single firing process takes place at 1280° C temperature.

Therefore, from the energy conservation point of view it is vital to implement or re-build the production technology of these ceramics into the one-fire method which is more advantageous even in view of rather simple manufacturing equipment.

Porcelain

Porcelain products are well known for their perfect white and glassy dense body. The basic raw materials consist of kaolin, feldspar and silica. According to its properties porcelain is classified into the following types:

soft -	feldspar contents	28 % -	firing temperature	1320-1380° C
hard -	" "	22 % -	" "	1380-1460° C
electrical-	" "	35 % -	" "	1300° C

The production technology of porcelain is quite demanding and based on raw material properties and on experiences gained in long-year manufacture.

While considering porcelain manufacture in view of making it more effective within the scope of energy required for its firing the three following possibilities may be applied in principle:

- to substitute part of feldspar with nepheline- syenite in the manufacture of hard porcelain whereby the firing temperature can be reduced by 60° C

- to change the production towards soft porcelain (about 5 - 8 % saving)
- to explore prospectively the possibility of firing the porcelain in an one-fire process.

Conclusions from the ceramics technology

From the individual hints how to reduce the energy consumption in the manufacture of ceramic ware it may be concluded that there are not favourable conditions at some types (refractories, bricks and porcelain).

The other types then may be covered under the following principles:

- to reduce the firing temperatures by implementing raw materials with lower vitrification temperatures (floor tiles, stoneware)
- to reduce the firing temperatures by fundamental changes in the body and glaze compositions (wall tiles)
- to replace the double-fire production process applied so far by an one-fire method common for both body and glaze (floor tiles, sanitary ware, artistic and utility ceramics).

Thermal processes and equipment

The heaviest energy consumption points in the ceramics are the drying and firing processes while energy requirements for mechanical and forming operations, transportation machinery and equipment are comparatively low. It may be clearly seen from the following proportions of 100 % energy for these products:

	Energy	
	for thermal processes	for machinery and equipment
wall tiles	87 %	13 %
floor tiles	78 %	22 %
fireclay	92 %	8 %
sewerage stoneware	90 %	10 %

Hence, the thermal equipment in which the thermal processes take place should be paid an extraordinary attention in view of energy management.

Drying

Drying is indispensable in ceramics. Dry raw materials are transformed into a plastic form by means of mixing water to make them ready for forming by pressing or extruding into the required shapes. The formed products are to be dried to remove mixing water from them; the products shrink and get stiffened at the same time. The drying process velocity must not exceed specified limits to avoid crazing and cracking.

The quantity of mixing water differs at the ceramic products from 7 - 30 % depending on the type of the respective product. While considering that about 640 kcal/kg are necessary to evaporate 1 kg of water then about heat ranging from 45 - 190 kcal would be theoretically required for 1 kg of a ceramic body. However, about 120 - 320 kcal/kg are required in fact first of all to keep to a specified time schedule of the drying process.

Although the energy required for the drying represents mere 10 - 20 % of energy required for the firing process it is necessary to develop efforts in this respect, too, to achieve energy savings though they may not be so distinct.

The fundamental steps towards them are:

- to use technologically minimum amount of mixing water
- to restrict plastic forming and apply more pressing of a semidry mixtures
- to utilize waste heat from the kilns for drying
- to modernize driers to implement a controlled circulation of air

Firing

The ceramic products receive their required properties and appearance by firing. Complicated physical-chemical processes take place in the body during the firing due to which the body changes its physical, chemical and mechanical properties. These phenomenas are intricate requiring a detail research. For practical use it results in limit curves of heating, maximum temperature and cooling under which the particular product can be successfully fired or glazed within the shortest possible time.

Heat required for the endothermic reactions in the body only is not very high; it ranges within 167 - 222 kcal/kg of plastic component of the particular body. Heat needed to reach 1000 - 1400° C amounts to 240 - 340 kcal/kg. Theoretically, about 300 to 450 kcal only could be thus required for the firing of 1 kg of ceramic products. In fact, however, 5 to 10 times more energy is consumed because the thermal process taking place in the kilns is of low efficiency and the major part of the energy supplied is consumed to cover losses.

The practical values of the energy consumed in firing the main types of ceramic products in terms of kcal/kg of products are as follows:

product	firing temperature °C	energy consumption kcal/kg
wall tiles		
bisque firing	1040 - 1070	750 - 1100
glost firing	1040 - 1060	700 - 1250
one-fire firing	1040 - 1060	850 - 1000
floor tiles		
semidense bisque firing	1100	800 - 1200
glost firing	1050	600 - 900
one-fire firing	1100	800 - 1200
one-fire mozaics	1180	1700 - 1900

product	firing temperature °C	energy consumption kcal/kg
brickware		
firing of bricks	960	400 - 700
fireclay		
standard bricks	1350 - 1450	650 - 1200
stoneware		
firing of pipes	1280	600 - 900
firing of floor tiles	1090	900 - 1200
elelctric porcelain		
insulators	1300 - 1400	2500 - 4000
sanitary ware		
firing of sanitary ware	1250	2800 - 3000

The consumption of energy first of all depends on the type of fuel used, degree of modernization and operation of a kiln. Kilns heated with producer gas applied in similar thermal process show higher consumption of energy than kilns heated with long-distance gas or natural gas or with liquid fuels. This is effected by the possibility of intensification of heat transfer in case of good quality gases and liquid fuels to the material being heated mainly by the faster flow of combustion products through the whole cross section of kilns. All fuel-heated kilns show a disadvantage in the necessity to draw the hot combustion products out by a chimney that constitutes a considerable heat loss.

Such a loss is practically non-existant in electric resistance kilns in which all the other types of losses are lower, too. Consequently, the consumption of energy in these kilns is substantially lower than that in the fuel ones. It is to be kept in mind, however, that the cost of electric power energy is higher than that of gaseous or liquid ones.

Any detail analysis of the rationalization trends for various types of kilns in ceramics would go too far beyond the framework of these theme. Nevertheless, the following principles may be set forth for the kilns proper:

- to intensify the thermal processes in compliance with already verified limit conditions
- to utilize good quality gases and liquid fuels in fuel fired kilns
- to cut down the chimney draught losses by utilizing the waste heat of the combustion products for production and technological purposes
- to minimize heat losses through linings by using light-weight highly insulating insulation building materials
- to minimize similarly the losses by accumulation
- to automatize heating systems with a feedback measuring

When we sum up now all the possibilities mentioned in the scope of technology, thermal processes and kilns aiming at the rationalization in energy conservation in the ceramic industry we may arrive then at the following conclusions:

- it is indispensable to focus further research in the ceramics to the technology and raw materials and let them get subjected without fail to the requirement of minimum energy consumption.
- to optimize the thermal processes in accordance with the limit firing temperatures and apply them strictly in the kilns
- to modernize subsequently the ceramic kilns with the objective to reduce all sorts of heat losses to minimum.

These conclusions do confirm that the implementation of energy management for energy conservation in the ceramic industry is fully justified owing to the technological as well as organizational complicacy.

III. Glass industry

The glass industry has experienced progressively quite a vivid development mainly at the end of 19th and at the outbreak of the 20th centuries when glass has become subsequently goods of widely popular use. The last development stage has been featured mainly by electrification, broader assortment and automation of the production.

As this branch being highly demanding in view of energy it takes a significant share in the exploitation of world fuel deposits. The contemporary situation in energy does not create any favourable conditions for its further development but, to the contrary, it is vital to solve the energy problem in glass industry very seriously.

The today's glass production can be divided into various branches in view of their percentage shares by the following values

packing glass	75 %
mirror and cast glass	10 %
glass panes	8 %
glass for technical purposes	7 %

Hence, the production of packing glass prevails considerably and it is therefore useful to focus the rationalization efforts to this branch though the majority of the solutions may be applied to the other branches, as well.

Raw materials and their preparation

Raw materials are first of all the factor influencing the glass quality. Their range changes in accordance with the research development in technology and in the melting process.

The raw material composition of a glass batch and the glass manufactured of it may show the following example:

batch raw materials	
sand	59.5 %
sodium unhydrate	20 %
sodium sulphate	0.3 %
borax	1.8 %
feldspar	8,9 %
dolomite	9.5 %

chemical composition of glass	
SiO_2	72.5 %
Na_2O	14.6 %
B_2O_3	0.7 %
Al_2O_3	2.0 %
CaO	5.9 %
MgO	4.2 %
Fe_2O_3	0.04 %

and loss by ignition of the batch (moisture and volatile components): 9.8 %

Sand - makes the major part; it is dressed by washing, sieving and by magnetic separation, if need be, the grain size being about 0.5 mm and melting temperature about 1800° C.

Sodium unhydrate - acts as a flux decreasing thus the melting point of the batch

Sodium sulphate - acts as a solving agent in the melt to solve the slag remainders

Borax - in a small quantity makes the glass plaining of better quality

Feldspar - with its addition of Al_2O_3 makes the devitrification slower

Dolomite - acts as stabilizer for making the glas insoluble in liquids.

Already the preparation proper of these raw materials for the melting phase makes the reduction in energy demand feasible in two ways:

- by utilizing waste glass cullets

It has been proved by research that by utilizing cullets for the production of glass the moisture of a glass batch gets reduced the melting point decreased and the amount of combustion products get reduced, too. Professional sources put the energy savings to 0.3 % of fuel per every 1 % of cullets added.

- by agglomeration and preheating of the batch

Both the methods are under research, now. As against a batch in bulk the fine grains are agglomerated by rolling or pressing into pellets, briquets, granules and the like. Then they are gradually dried and preheated to move than 540° C. The agglomeration methods has already been practically verified and the following were the results as against those of the batch in bulk:

melting time has been shortened by 24 - 28 %
melting temperature has been reduced by 100 - 200° C
and about 6 % energy saved.

Preheating, too, results in further possibility of reducing the melting time and improving other parameters.

The above listed possibilities show that maximum use should be made of waste glass cullets and the agglomeration and preheating processes should become a standard method of the batch preparation in today's preparation departments in glass works.

Melting of glass and melting furnaces

The glass melting process is considerably demanding in view of energy consumption and requires about 70 % of all energy supplied to the plant.

Glass melting temperature has been reduced by the use of fluxes to about 1500° C (melting temperature of SiO_2 is 1010° C). The melt in the tank is heated from the top, glass passes the zone of maximum temperature that results in a perfect glass plaining and homogenization. The glass then is cooled to 1100° C in the working space and is ready for further processing.

The melting equipment proper may be classified according to the type of operation and capacity into:

- periodic tanks
- daily tanks
- continuous tanks for high capacity

according to fuels into:

- fuel types (gas, liquid fuels)

- electric (electric current in the melt)
- combined types

Gas equipment with regeneration

The tank properis divided by a partition into melting and wörking space, walls, roof and the tank are built of a heavy masonry lining in which a cooling system is built in the walls.

Due to the high temperature the heating system is based on the preheating of air or,even of gas, in regeneration chambers by means of combustion products being exhausted. The air or even the gas are preheated in a couple of chambers by the heat accumulated in the grid of the chambers, mixed in a burner and burned. The combustion products lead away than heat up the grid of the other two chambers. After some time of this operation the flow direction is turned back by means of reversion. The efficiency of the regenerators is about 90 % and the air can be preheated above 900° C.

Recuperators are similar equipment to the regeneration chambers. The heat of the combustion products in the former ones is tranferred to the air or gas in parallâl ducts.

The thermal efficiency of the gas regeneration equipment is about 33 % while the ration of the individual losses is as follows:

23 % by combustion products
41 % by losses through the masonry
6 % by the foundation of the equipment

and 30 % is the heat proper being utilized.

Electric melting

The method of electric heating of the glass works tank furnaces has not yet been fully verified practically. It has been evoked by the shortage of fuel oils and natural gas and also by prospective availibility of electricity from nuclear power stations.

The design of this system has several variants of arrangement of molybdenum electrodes which are used prevailingly. A higher quality of refractories for lining is required. On the other hand a series of pertaining equipment units can be omitted (regeneration chambers or recuperators, air and gas distribution systems). The operation can be almost fully automated and the input can be kept at a constant value between the electrodes.

Practical verification covers both sole electric heating and combined with gas heating. In such a case the electric heating proper is direct and additional heating is provided by gas and vice versa, when there is a gas heating and the additional one is by electric power. These combinations seem to be really advantageous because gas provides a faster starting into operation on one hand while the additional electric heating is positively valuable in the stage of a steady run owing to its easy controllability.

The electric resistance heating system needs less thermal input than in the fuel heated furnaces. Thereby even its specific heat consumption is reduced (approx. 700 kcal/kg) as against the regeneration furnaces (950 kcal/kg).

Possibility of energy conservation during melting

When we summarize all the ideas hinted so far for the glass melting process and melting furnaces the following main rationalization trends can be derived:

- to reduce the glass melting point by the research in new raw material compositions
- to use maximum amount of waste glass cullets in the preparation of batches by that as much as 15 % of total energy can be saved
- to implement the agglomeration process of fine fractions and their subsequent preheating that may result in 8 % energy savings
- to increase the efficiency of the regenerators and recuperators by more perfect designs and by utilizing refractories of high density in the grids
- to reduce heat losses through the linings at roofs by introducing light-weight high-quality fireclays and to reduce the necessity of their cooling

- to install furnaces of higher outputs in which the specific consumption of heat is lower
- to introduce fuel systems in which high quality gases, liquid fuels and combination with electric heating can be applied
- to make the equipment operation automatic to achieve an optimum condition in view of energy consumption
- to make use of chimney heat as a secondary source for the heating of water (approx. 95° C) or for steam generation (about 0.48 t of saturated steam can be obtained per ton of glass).

Cooling of glass

Glass must be cooled suddenly during the forming process to pass the temperature of 1000° C quickly so as the formation of crystalline phase be avoided. On the other hand the quick cooling results in the creation of internal stress in the glass that could cause cracking later.

Stress relieving in a product having been pressed is performed by slow reducing the temperature from the initial one (400 - 550° C) to the final one (50° C).

For this purpose belt-type tunnel kilns are used in which the initial thermal input in the inlet zone is adapted to the inlet temperature and is gradually reduced in the other zones of the kiln and replaced by cooling air.

The heat consumption in these kilns is rather insignificant; e.g. in a kiln of 47 tons of glass /24 hrs. output it amounts to about 50 kcal/kg whereas in case of smaller kilns the consumption reaches 100 - 120 kcal/kg. Hence, it represents about 10 % of the heat consumed in the melting process.

Conclusions

The glass industry being another branch of the silicate industry is a heavy consumer of energy both for the large number of products of all shapes and due to the high energy demands of the production process. Like in the ceramics the firing process is the centre of energy consumption it is the melting process in the glass industry.

As it may be seen from the aforesaid possibilities of rationalization the implementation of the enrgy management in the glass industry is fully justified. The conditions here appear to be slightly more favourable to achieve these goals and the organization less demanding than in the ceramics.

IV. Cement industry

Cement is one of the main building materials nowadays and is applied in various grades of quality for monolithic and prefabricated structures in countries all over the world. Its production is broadly extended because there are raw materials for its production available in almost every country.

All types of cement are hydraulic mixtures. The production process starts with a joint grinding of raw materials:

limestone, limestone clay, chalk, pyrite, ashes, bauxite, quortzite, sand, marl etc. Homogenized mixture is fired in kilns to sintering state - clinker. Clinker having so been produced is ground along with 3 % of gibsum to fine powder whereby Portland cement is made. Various types are made having different properties, such as compression strength, solidification speed, resistance to chemical effects etc.

The ASTM classification shows 5 fundamental sorts of Portland cement:

I - Standard for general purposes applied in concrete structures
II - with a low hydration heat
III - quick solidifying cement
IV - with a low hydration heat for heavy concrete structures
V - sulphate resisting cement

Basically, the cement quality is affected by the quality of raw materials, firing of clinker and its subsequent grinding.

The typical chemical composition of the Standard cement is as follows:

SiO_2	21.0 %
Al_2O_3	6.0 %
Fe_2O_3	2.7 %
CaO	63.2 %
MgO	3.0 %
K_2O	0.5 %
Na_2O	0.3 %
SO_3	1.8 %
loss by ignition	1.3 %

Besides the aforesaid fundamental sorts of cement other sort e.g. white cement, ferrous-portland cement, slag-portland cement, pozzuolana cement and aluminum cement are manufactured.

1. Production technology

From the technological point of view the cement production is divided into the following processes:

wet method - raw materials are ground along with water, the sludge is homogenized and dosed into a rotary kiln. The water content amounts to 33 - 40 %

semi-wet method - a part of water is removed from the sludge by filtration. The water content amounts to 14 - 18 %

dry method - disintegrated raw materials are dried, ground, and homogenized and dosed into the kiln. Such a mixture contains about 1 % of water.

semi-dry method - homogenized powder is wetted, granulated and dosed into the kiln. The water content is 10 - 15 %.

Wet process

From the technological point of view it is a universal process widely applied - about 40 % of the world's production of cement is based on it. Perfect homogenization is its advantage. It is suitable for softer, porous raw materials.

The firing of clinker takes place in a rotary kiln of cylindrical shape fitted in an incline of about 4° and runs at 1.1 r.p.m. The sludge proceeds slowly through a drying zone (40 - 100° C), preheating zone (100 - 550° C) clacining zone (550 - 1100° C) and, finally, through a sintering zone in which there is 1350 - 1450° C temperature. Cooling is done on grates or in drums and the cilnker is cooled by air to 80 - 150° C.

In case of short kilns (1 : 12) heavy heat losses occurred due to the discharge of hot combustion products (as much as 40 %). The efforts to improvement led to changing the ratio of kiln diameter to its length to 1 : 40 and inner heat exchangers and sludge concentrators were installed. The original specific heat consumption of 2100 - 2200 kcal/kg clinker has been thereby cut down to 1500 - 1600 kcal/kg after the adaptations. The new kilns with built-in concentrators are simpler and the specific heat consumption has dropped down to 1350 kcal/kg.

The wet process needs a relatively less electric power. The total energy consumption however is much higher than that of the dry process.

Semidry and semiwet processes

The raw materials for this method are to be fired either in long kilns or in short ones equipped with grate calciners of Lepol type in which the precalcination enables a very intensive firing.

The original one-flue kilns showed the specific heat consumption of 1050 - 1300 kcal/kg, later the double-flue kilns have reduced it to 740 - 780 kcal/kg.

Besides rotary kilns for these types of technology there are used "automatic shaft kilns" from which clinker is taken by means of a rotary grate. Raw materials are mixed with fine fuel (coke, anthracite, coal) in an amount of about 7 %. The contemporary outputs of these kilns start from 150 - 300 t per day and the specific heat consumption is 800 - 1050 kcal/kg. This technology is rather simple, has a low energy consumption and is suitable for the developing countries. The share of this technology in the world's cement production, however, tends to grow smaller.

Dry process

Homogenized dust is supplied to a dispersion cyclon-type heat exchanger in which it is partly precalcined by the combustion products coming from the rotary kiln. It enters then the short kiln in which the calcining process is gradually completed, then sintering takes place and the clinker is cooled down on the grate cooler.

Kilns for the dry process are designed for 300 - 500 tons per day output and the specific heat consumption is 720 - 960 kcal/kg of clinker. Lately, rotary kilns (1 : 33 to 1 : 38) have been designed for large outputs of about 3000 tons of clinker per day without inside or outside exchangers, combustion products pass through the entire kiln and are 700° C hot at the outlet and are to be cooled with water. The specific heat consumption is 950 - 1170 kcal/kg.

Energy consumption and possibility of savings

Average values of energy consumption in the cement production per kg, are:

thermal energy	800-2000 kcal/kg
electric power	85- 135 kWh/kg

When expressing the electric power in terms of thermal units (680 - 1160 kcal/kg) it may be revealed that the share of electric power in the cement production is substantially higher than in the other silicate industrial branches.

As in any other industrial branch the energy consumption depends on the specific conditions of each production unit, on the technical level of the industrial equipment and on the way it is operated.

Fuels used in the rotary kilns may be gaseous, liquid and solid. Coal is to be dried, ground and there must be dosing device installed; oil must be heated up to a temperature to reach a suitable viscosity. The difference in heat consumption of various fuels are not substantial, a certain advantage in this respect has fuel oil.

Possibilities in thermal energy saving

The following trends may be derived within the framework of the firing process aiming at the reduction in heat consumption:

- to use maximum reactive raw materials if possible
- to reduce the water content from 35 to 30 % in the wet process
- to utilize deflocculants to reduce the water content
- to install inside coolers
- to utilize combustion products in the outside exchangers
- to reduce combustion products in the cooler by using a recuperator
- to utilize the heat from the cooler for heating the primary combustion air
- to utilize the heat of the combustion products for the drying of raw materials
- to reduce heat losses through the lining by using new insulation materials
- to optimize the firing process and to provide it with automatic process control
- to apply nowadays only new designs of kilns for the dry or semi-dry processes.

Possibilities in electric power saving

A considerable part of electric power in the cement industry is consumed in the preparation of raw materials, i.e. for crushing and drying of raw materials, coal and clinker grinding proper consumes 60 - 75 % of the total electric power. Ball mills have exhausted all their possibilities and cylindrical mills are now in the focus having only a half of electric power consumption. The consumption proper e.g. in grinding of raw materials depends on their hardness; therefore it is advisable to make respective tests prior to deciding the grinding ~~xhx~~ method.

Among the possibilities of reducing the electric power consumption belong:

- by optimum composition of clinker, good firing and cooling processes during the grinding of clinker about 10 % savings may be achieved
- maximum savings can be achieved by correct operation of the grinding machinery, its inspection and maintenance. This way as much as 15 % energy can be saved
- grinding intensifiers - about 3 - 12 % of energy can be saved by wet grinding of raw materials.

Consequently, when the processes and equipment in the cement industry are looked closely at in view of energy conservation similar conslusions may be drawn as in the other branches of the silicate industry. Besides the fundamental trends aiming towards the improvement of economy there is a series of steps, though of minor importance, but when thoroughly observed the common goal - energy conservation - may surely be accomplished.

V. Conclusion

The data of the three main branches of the silicate industry show, first of all, the heavy energy demands they really have. Under the present conditions given by the world energy crisis and by the prognoses of exploiting the sources the silicate industry position is far from being favourable and yet will be sensitive to further development.

The main trends of activity have been specified towards the improvement in the consumption of technological, operational, innovation and conception nature. Materialization of the suggestions, their technical and organizational implementation are to be solved in all the complex aspects. That may only be successful when the energy management system is introduced in the secondary circle of energy being represented by each of these branches of the silicate industry.

This way only and mobilization of great numbers of research workers, technicians for thermal measurements, designers and industrial experts the present energy consumption could be significantly reduced. By achieving this objective better conditions will be created for national economies in energy of the primary energy circle whereby the solution of the worldwide situation will thus be assisted, too.

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