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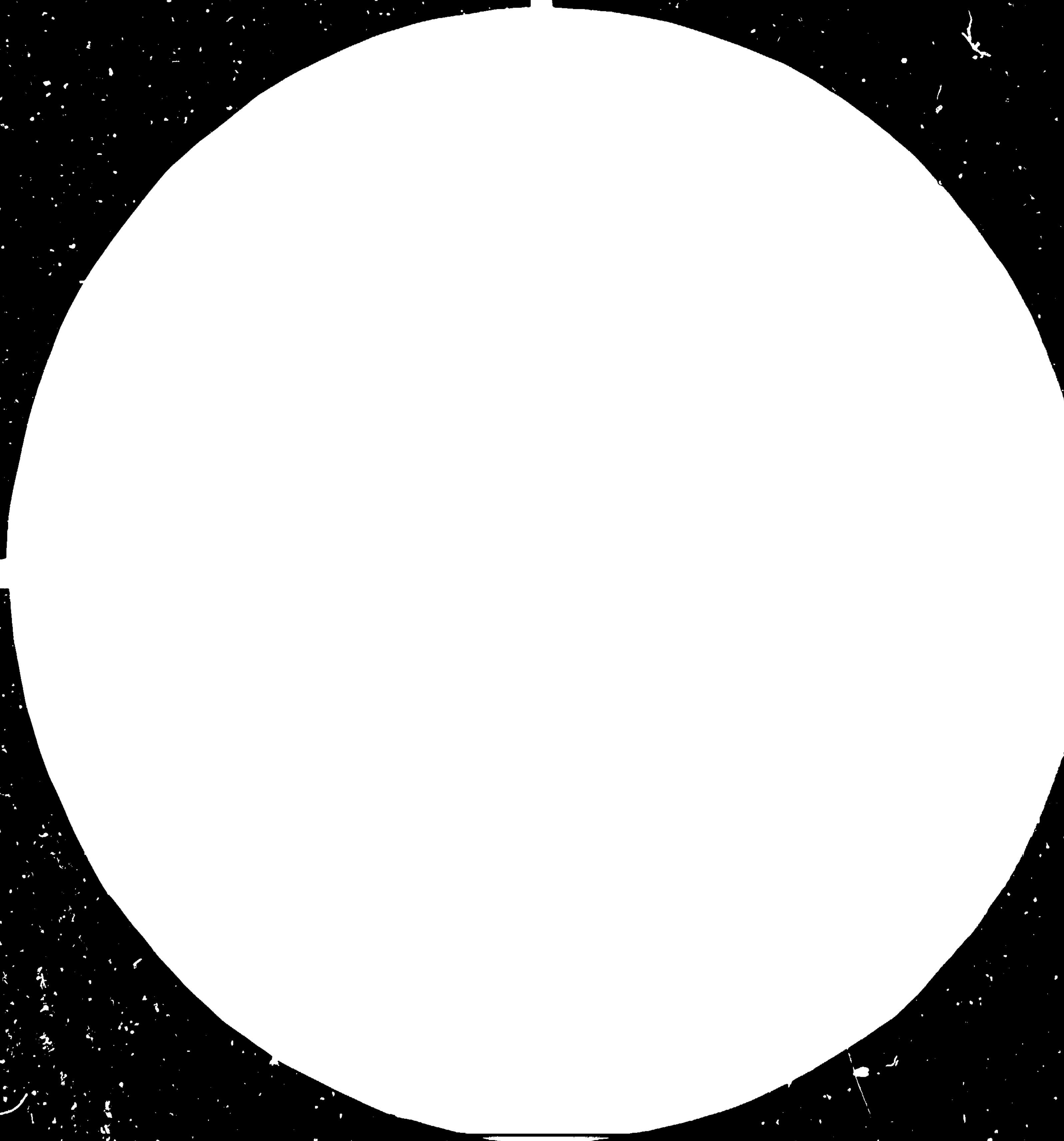

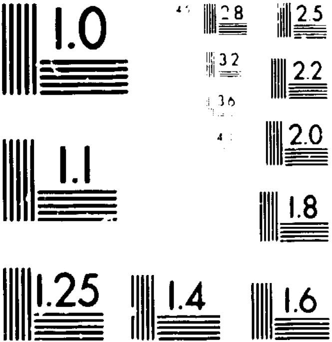

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THE PAST-, PRESENT-, FUTURE TREND OF ENERGY - SAVINGS IN THE NON-METALLIC MINERALS BASED INDUSTRY

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Annotation

In this paper the mutual relations between energy consumption and ceramics in two different fields are examined in an analytic form of to-day sources and prospective conception.

The first one is the field of the Ceramic, Building Materials and the feasibility of energy savings which can be obtained in their production. The other fields are the refractories and refractory insulating materials for the lining of thermal equipment and the wide range possibilities of heat preservation through the development and use of new types of light weight materials with high insulation properties and their influence in the designs of kilns, furnaces and other thermal equipment.

The present possibilities are examined and the future trend considered in view of achieving optimal results and thereby make a vast contribution in energy-savings, a present world's priority

From the modern aesthetic and artistic point of view, the ceramic materials such as wall-, floor, facade tile, contribute to the social and cultural environment in which the people live. The use of these products have found and find an ever broader and more significant applicability. Besides, the non-metallic mineral based ceramics industry finds, however, many other effective utilities in other important products such as:

- refractories for the heat treating industry in many various types and qualities;
- insulating materials for heat insulation in nearly every energy based industry for example, steel-, oil-refinery, food industries.

The complexity in these kind of industries and their used technologies have a common denomenator, energy, as an important part of the used production processes. Energy, in the form of gaseous, solid, liquid, fuels and electric power, site by site, as a major cost component of the production. It is, therefore, understandable that long before a confrontation in energy-crisises were at state, their industries have used a major part of their research and development in energy saving devices, equipment, machinery and heat treating processes.

It is a wellknown established principle that by cutting production cost the energy consumption was one of the major predominant issues for cost reduction. It is therefore, not a sheer accidental approach when the ceramics and energy are sited closely together and a great attention is paid nowadays to the main scope aiming to a common objective - to save energy.

<u>Solution indentified to solve the energy problem</u>

First of all it is the field of energy consumption used to operate the ceramic machinery, which mentioned before, as a whole is aiming to cut down the specific energy consumption in the production of individual types of products. It is here, where the economy of the producers is focussed and closely connected at a vast research of optimalization of heat transfer into the production of heat transferred into the ceramic products.

In this context a development of ever new, more effective and more economically operated heating devices, such as driers, kilns and furnaces for high temperatures in the ceramic industry are stimulated along with the research and development of new kinds of raw materials to compose ceramic products which are fired at ever lower firing cycle. A firing cycle is a system related to temperature and time. It will be easy to understand that either through cutting time and/or energy, sizable savings in energy are obtained.

Another direction which has for a long time been a priority to energy savings is the combined energy consumption in the use of refractory materials used for, for instance, a large variety of kiln or furnace linings for the different industrial branches. Ill-applied refractories will result in a wasteful escape of energy from the kiln or furnace due to good or bad type of quality of the insulating peoperties of the refractories used.

A very important energy saving can be found by the research and development of refractory products used as supporting materials for the production of ceramics such as setters, plates, footings saggers etc. with better heat-absorption qualities and less mass to use less energy to acquire the temperature needed for the production of ceramics. The contemporary development in this field aims to highly insulating, light-weight materials and better quality of insulation that can resist to high temperature.

In this respect, therefore, new ceramic materials are of paramount importance to enable to reduce energy losses in many different applications of furnaces, kilns and other thermal equipment employed in a large part of industry.

We will, however, come back to the field of energy consumption where energy-uses can be reduced, namely in the composition of ceramic materials composed out of different non-metallic minerals, such as clay, kaolin, felspar, silica, pegmatites etc. etc.

The question arises how one can reduce the energy consumption. We have to go back to the time that for firing different types of kilns, originally designed for the production process were constructed prevailingly for low quality fuels, mainly peat, different types of coal, brown-gas, waste-heat from bad insulation furnace or kiln walls was used for drying materials along the sides of the furnace or kiln where the intensity of lost heat was the highest.

The characteristic feature of these kilns either round, chamber or tunnel types was their robust structure and the materials used to build them were mostly of compact refractory bricks and red-brick massenory The considerable weight of these kilns with a low effective utilization of the supplied energy for firing were, and, sometimes stil are, the cause of high consumption of energy for heating and at the same time time consuming thermal cycles and resulting with a low productivity rate for such kilns.

New types of kilns and furnaces development were stimulatedd with the main objectives to:

(i) reduce the cost in the production of used energy by:

a) Increase the capacities;
b) Better product quality;
c) Quick changes for loading and inloading of kilns and furnaces;
d) Diversification of the to be fired products

(ii) Hand in hand with the above to require better quality of energy electic power, natural gas, pipeline supply, mineral oil.

It becomes apparent that in the present it becomes indispensable to cut the present specific energy consumption which, under the contemporary critical energy situation in the world has grown into a need of fist priority.

New designs of kiln and furnace types vary considerably form the conventional ones mainly in the field of ceramic firing process.

The so-called terminal kiln as a contingeous kiln of the type in which ware passes through a stationary firing zone was the centre of kiln. In the most common type of kiln the ware is placed on the refratory-lined deck of a car, a contineous series of loaded cars being slowly puched through a long straight tunnel. The tunnel kiln, so far make: place for a single story kiln, multiple story, roller kiln, rotary-hearth kilns or bee-hive kilns, double firing process of bisque firing and glaze (glost) firing of ceramic products in two cycles is replaced by a one fire process.

Traditional pre-fire drying processes give way to dust spray driers (spray dryers) and to roller driers in the production process.

The present position of development has ensued from a detail research of heat transfer methods and it goes without saying that it will keep its pace hence forward.

Basically, the properties of ceramic products are predetermined first by a choice of initial raw materials and mixtures, secondly by significantly suitable thermal firing processes during which thermo-chemical reactions take place, whereby the composed material structure changes into the final state, processing the required proportion and characteristics.

The thermal process must meet the technological requirements as far as the time and thermal course in the structural and phase changes in the material composition is concerned. It must follow the basic properties as it is established during its development and research work on a laboratory scale and adopted for its production process.

It is sololy the laboratory testing of the thermal process for the firing of a ceramic compositive material which will determine its sequential alternatives, so called "limited curves for heating and cooling", at the final research phase.

The curves show the conditions under which the respective changes in the basic compositive material formula will take place, in order that the expected product reaches its final properties.

The fastest heating and/or cooling processes are established with a minimal thermal energy consumption per firing cycle may be expected from the duration point of view. The proper firing process in the production kiln cannot be determined in accordance with the knowledge of the limited curves. The limit thermal process may incorporate many factors which will cause fail-production and losses. Certain factors will have to be adhered before a certain firing cycle can be adopted. Simply said a way for proper heating or firing over the available kiln type cannot be determined by mere laboratory determination of firing conditions.

Another feature of research and development takes its turn by simulating the thermal process in kilns. It is simulating the heat transfer from the heat sources into ceramic compositive product under pre-conditioned principles.

While the space in which the products are situated is stable, the simulated method of development and research should examine and verify the optional dimension of the space, the manner in which the to-be-fired materials are place therein, size and shape of the kiln furniture under which the determined thermal firing schedule can be obtained by means of verified both thermal inputs and flow of combustion products.

The exigency of the simulating method of development of the thermal firing process in the kiln has been evolved by efforts to minimize the consumption of energy as well as by the requirements for the firing process to be uniformly spread over the entire cross-section of the internal kiln dimensions so that the kiln charge of ceramic products results in an equal quality of the products leaving the kiln.

A uniform firing process in the kiln can be achieved solely by changing the characteristics of heat transfer used by flames by radiation and by heat conduction for firing utilizing convection of hot combustion products for maximal conduction in the heating zone of the kiln. The simulating method of research for a given kiln volume results then in the way how the to-be-fired materials are placed, the direction of flow of combustion product, size and place as well as setting of the burners.

From the simulating research method the to-day types and designs of kilns and furnaces have been derived. The main part of the kiln, namely the heating system is equipped with new type of burners or suitably situated heating resistor elements for electric resistance kilns and furnaces.

Based upon the fore-mentioned trends of development new types of kilns and furnaces have been invented. The specific heat consumption in them has been decreased to considerable lower values than those of classic types of kilns and furnaces due to the ever growing concern of lowering the production costs since the last 50 years. Such types of kilns used for ceramics are; e.g.:

- Improved types of tunnel kilns
- Electric resistance channel kilns
- Roller-type conveyor kilns
- Wire cassiers operated electric resistance kilns
- Rotary hearth kilns
- Pin-belt conveyor kilns

These new types of kilns, inventions during the period after the second World War are designed to reduce the energy consumption and to produce ceramic products at higher speed and lower temperatures, thus better time-temperature ratios with the main objective to reduce production cost and faster turn-over of production.

Apart from the intensification of heat transfer at the above mentioned kiln developments, the weight and sizes have been minimized which came about through intensified approach of developments for better insulating refractories, with the lower weight.

The kiln furniture, such as plates, setters, saggers bricks, peers, etc. was redesigned and produced with lower weight refractories, have made a considerable contribution to the energy savings programmes in the industry.

The development of lighter and better temperature resistance kiln furniture for a better and more systematic placement of ceramic products in the firing space of the kiln resulted in a higher production of ceramic ware for energy unit. It is easy to understand that the demand for energy consumption was and is the common denominator for "saving of energy" whereby we cannot produce brick or ceramics as a fudge, hard on the outside but soft inside with other words keeping the characteristics and quality specifications the same.

The intensive modernization of kilns and furnaces, aimed at a systematic reduction of energy consumption in the ceramic industry in the developed countries has resulted in reducing the total energy consumption to produce for instance 1 square meter of ceramic tile by 30 (thirty) to 35 (thirty-five) % percent in the recent 10 (ten years).

It is hereby understood that the programme for savings of energy are influenced by the overall extent of using more modern production processes and equipment with different energy requirements. When for instance electic energy is applied as source for heat consumption the energy consumption can be reduced as far as 75% (seventy

Influenced by the price difference between electric energy and fuel the following example is worthwile to mention. In Czechoslovakia (CSSR) through a modernization of the original ceramic industry, a 30% savings of energy use was achieved for the production of ceramic floor tile and a 29% saving for the production of wall-tile.
This renumerable achievement was the result of an intense research and development for new types of firing kilns and process equipment as well as a more uniform quality of raw materials.

The present trend in the manufacture of ever more perfected kilns and furnaces as well as driers will go on with the energy crisis, as we experience to-day. It may be expected that in the preparation of raw materials a switch-over to hover firing of particles to reduce the heat transfer and firing cycles in the ceramic industry would be cut whereby a reasonable expectation can be achieved in improving kiln-designs and in particular applied lower temperatures and heat losses.

In the céramic industry, it may be expected that in the preparation of raw materials, a switch-over to hover firing of particles to reduce the heat transfer and firing cycles in the ceramic industry can be obtained and achieved with reasonable expectation improved kiln design with, in particular, lower temperature application and reduction of heat losses.

In the following table the average firing-temperatures of double fired wall tiles during the last 30 years is expressed whereby one can observe the downwards trend in firing temperatures.

	Bisque firing temperature	Glaze firing temperature
After Warld War II	1280–1300	1180
Beginning 60's	1120–1200	1080–1120
At present	1040–1060	960–1020
Prospects by the year 2000	lower than 1000	900–960

In the future trend of development in the CSSR there have already been considrable results verified in new types of raw materials compositions and surface coverage in the form of glazes for wall-tile whereby the bisque and glaze (glost) fire can be combined in a one-fire method at much lower temperatures and short firing cycles.

Very good results in semi-production processes were obtained in the production of floor-tile and the achievements with single firing process on temperatures of 1050°C and firing cycles reduced to 60 minutes and even lower.

The achievements have enabled the industry to create new types of kilns with considerable smaller sizes than before and let to a significant reduction of energy consumption, irrespectible of any cost price savings up to 45% of applied energy. The average reduction of double firing cycles expressed by time (unit of hours) can be expressed for the last 30 years in the following table:

Average reduction in firing cycle expressed in hours for double fired wall tile

	Bisque firing in hours	Glaze (glost) fire in hours
After World War II	60-120	24-48
At the beginning of 60's	24-48	3-24
At present	1-24	95-24
Prospects by the year 2000	0-5	lower than 0.5

Along this projected trend, research and development of new types of ceramic raw materials for ceramics will go forward and with the new properties, they will facilitate further reductions in thermal processing, thus energy savings.

Let us have a look and pay attention to another relation of special types based on non-metallic minerals, i.e. refractories and ceramic insulating materials used as linings for all types of heat producing and heat using equipment in the industry.

The significance of this field dominates rather unambiguously from the energy point of view which will find its consequences in qualitative changes of the lining materials for kilns, furnaces and other heating devices of the entire industry beyond the ceramic industry, i.e. other large consumer of energy.

The general opinion on the quality of linings which requires a maximum durability and insulating capacity properties has been gradually uprooted from the conception of heavy in weight refractory blocks and red-brick masonry.

The development of light weight refractories for temperatures up to 1000 °C and other types based on perlite, vermiculite and refractory concrete materials has resulted into a gradual reduction of kiln or furnace linings in thickness and weight, simultaneously reducting heat losses to the ambient atmosphere.

It is necessary and indispensable to improve the insulating properties even more. This affects the insulating part made of heavy weight materials with a resistance up to 1500 °C.

Highly insulating fibre mats and boards for insulation layers or sandwich layers are used instead. A broad variety of these products has been recently supplemented with incorporation or supplementation of fibre-based products for temperature resistance of 1100 °C to 1600 °C. The present kilns and furnace linings, therefore, are completely different from the ones of 10 - 20 years ago. Their total thickness is reduced to a 1/4 of their original one and as much as 1/5 of their weight 30 years ago. It goes without saying that energy can be saved.

The difference of opinion on the real classical and the up-to-date kiln or furnace lining under similar conditions, i.e. similar inner and ambient temperatures and heat transfer losses to the ambient atmosphere is stated and shown in the chart below where it is indicated that a classical kiln or furnace lining of 62.5 cm total thickness, with a 50 cm layer of fire-clay refractories is in thermal terms equal to an up-to-date lining made of ceramic fibre-mat of 17.5 cm total thickness layer.

Apart from a distinct difference in total wall thickness of 62.5 cm and 12.5 cm, a similar distinction are the weight differences which for 1 square meter of kiln or furnace lining is 1080 kg for the classical type and 23 kg per square meter for the modern type.

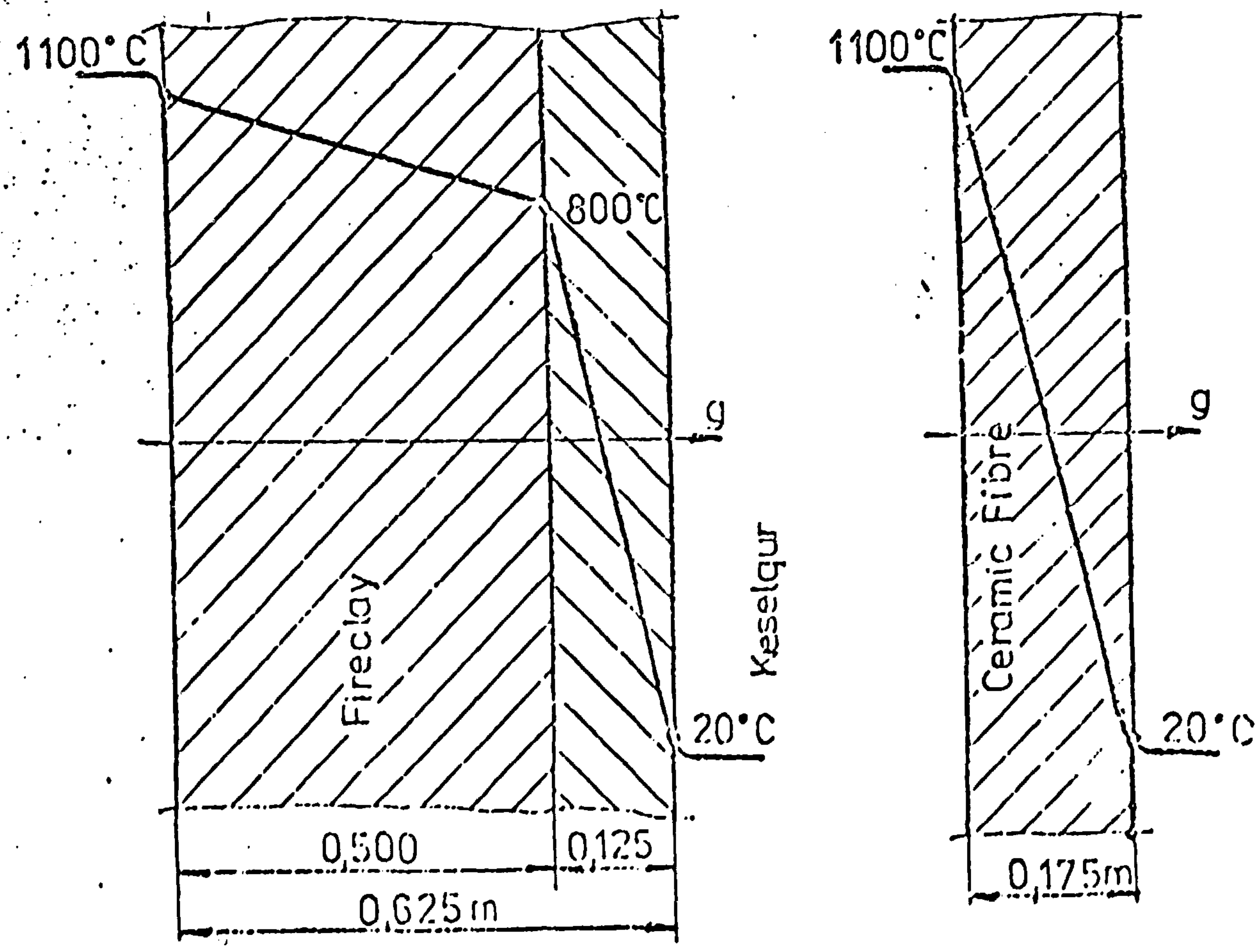
The difference of 1057 kgs for one square meter of kiln or furnace brickwork may indicate that the ceramic industrial development has taken the task to save energy very seriously during the past 30 years. It should, however, be mentioned that the developments in this area were found due to the increased costs for energy in this sector of industry. The cost of energy which one by now has recognized is the major item in the ceramic production cost and if cost reduction is to be persued in the direction of energy savings, the research and development has done a major part towards saving cost of applied energy in the different production processes.

The crisis in the supply of energy for industrial purpose will further accelerate research and development in this section of industry.

A step in this area is the movement to improve the workmanship and technical applied media to minimize breakdowns, stoppages and necessary repairs of a kiln which is accompanied with heavy energy losses, due to cooling and reheating of the kiln, whereby the production of the kiln is practically zero.

Comparison of classical and up-to-date kiln and furnace linings

a) classical method b) up-to-date method



In the area of ceramic-blends of raw materials awaiting shaping into a definite form, normally called plaste body by the green state ramming, gunning and refractory concretes, represents an entire special group of refractories which all contribute to energy saving in their application of kiln and furnace-linings. Since they do not acquire any firing in auxiliary production units the application time is reduced considerably and the expected life of such a lining is 2 to 3 times longer than convential linings.

These bodies are intended to prevail for furnace linings in a metallurgical industry for firing temperatures up to 1600°C. Advanced development will be supplemented with new types, which have more increased insulating properties and decrease of weight. Hereby is thought of better use of refractory type fillers with high temperature insulating properties. The significance of refractory ramming bodies is growing very much and to-day the rate of these bodies represents approximately 30% of the total refractory production world-wide. The general future trend indicates, and particular with the energy problems to cope with, that the production of these types of refractories will continue to grow and will exceed 50% of the demand by the year 2000.

In the concept of technological processes for the production of fillers to be incorporated with organic polymers such as polyethilene, polypropylene, etc., another contribution is made to energy savings. Suitable refined and beneficiated kaolin and lime-stone, becoming very valuable non-metallic minerals, as natural resources for the substitution of 50-60% of deficient polymers produced by the petro chemical industry from crude oil.

By filling the polymers with selected and properly dressed non-metallic raw materials, one will not only save half of the used crude oil, but will at the same time increase the value of utilization and diversify the production into products used in the food industry, new types of paper with unique properties, replacements of automobile parts in the manufacture of automobiles and various other industrial uses.

Conclusion

..going mentioned considerations regarding the significance of energy producing industry, ceramics and non-metallic minerals are far from being fully exhaustive as in regard to the entire problem of energy saving. It indicates that the evolution in this field will go forward and will require, due to its complexity, further accelerated intensive activities of development and research. This action will bring about possible further improvements for energy savings for the energy using industry and the ceramic and non-metallic minerals based industries.

The UNIDO-CSSR Joint Porgramme for International Co-operation in the Field of Ceramics, Building Materials and Non-Metallic Based Industries has taken the demand of energy saving at heart and will contribute and support to further share the responsibility placed upon the entire world industry and has placed this important issue on the agenda for assisting the Developing and Least Developed Countries in their demand to save energy as the further increase of energy costs has placed their countries in a serious financial condition.

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