OCCASION

This publication has been made available to the public on the occasion of the 50th anniversary of the United Nations Industrial Development Organisation.

DISCLAIMER

This document has been produced without formal United Nations editing. The designations employed and the presentation of the material in this document do not imply the expression of any opinion whatsoever on the part of the Secretariat of the United Nations Industrial Development Organization (UNIDO) concerning the legal status of any country, territory, city or area or of its authorities, or concerning the delimitation of its frontiers or boundaries, or its economic system or degree of development. Designations such as "developed", "industrialized" and "developing" are intended for statistical convenience and do not necessarily express a judgment about the stage reached by a particular country or area in the development process. Mention of firm names or commercial products does not constitute an endorsement by UNIDO.

FAIR USE POLICY

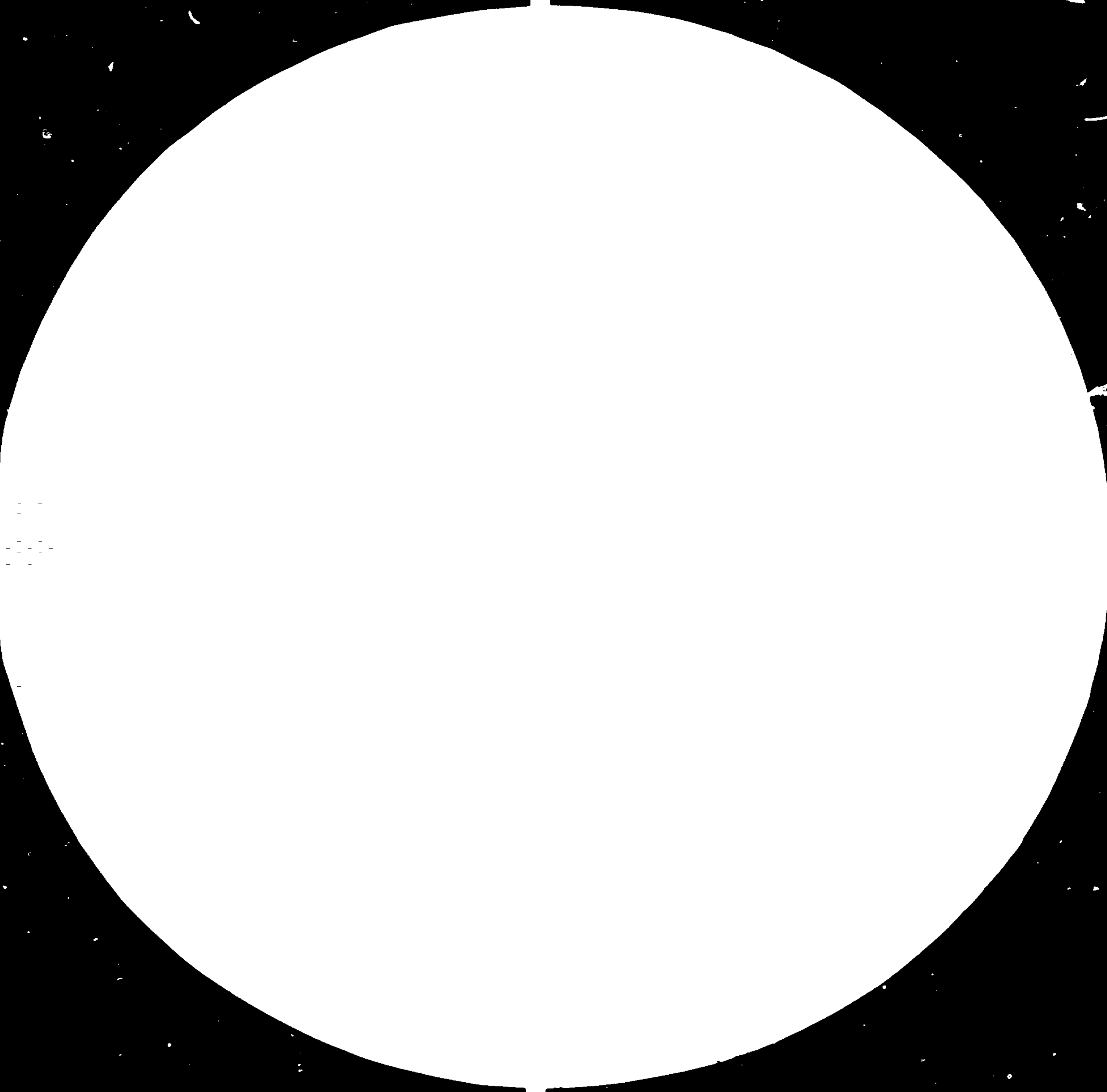
Any part of this publication may be quoted and referenced for educational and research purposes without additional permission from UNIDO. However, those who make use of quoting and referencing this publication are requested to follow the Fair Use Policy of giving due credit to UNIDO.

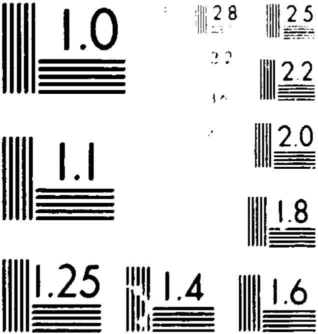
CONTACT

Please contact publications@unido.org for further information concerning UNIDO publications.

For more information about UNIDO, please visit us at www.unido.org

UNITED NATIONS INDUSTRIAL DEVELOPMENT ORGANIZATION
Vienna International Centre, P.O. Box 300, 1400 Vienna, Austria
Tel: (+43-1) 26026-0 · www.unido.org · unido@unido.org





MICROCOPY RESOLUTION TEST CHART

[illegible]

11451

UNIDO-Czechoslovakia joint Programme
for International Co-operation in the Field of Ceramics,
Building Materials and Non-metallic Minerals Based Industries
Pilsen, Czechoslovakia

Distr.
LIMITED

JP/21/79
December 1979

ORIGINAL: English

In-plant Training Workshop
on the Exploitation and Beneficiation
of Non-metallic Minerals

Pilsen, Czechoslovakia

8 - 26 April 1980

NON-METALLIC RAW MATERIALS - SOURCE OF ENERGY CONSERVATION

By: Z.A. Engelthaler
M. Grotte
J. Krejsa [+]
L. Kuna [++]

[+] Ceramic and Glass Raw Materials Works, Sedlec, Czechoslovakia

[++] Research Institute for Ceramics, Refractories and Raw Materials, Horní Bříza, Czechoslovakia

Content:

I. INTRODUCTION

In view of energy requirements and energy consumption factor the silicate industries stand in the foreground of all the industrial activities. Due to the well known circumstances having arisen in this decade just in this industrial branch it is the problem of energy to which attention is rather strongly attracted. Since silicate industries in every industrial system represent one of the fundamental production lines the endeavour towards the solution of energy problems is far from being isolated and, apart from the attention it receives within national economies, it becomes a point towards which the international co-operation is focussed particularly in this decade.

The tenth World Conference on Energy held in Istanbul in 1977 has indicated the main trends in this field and envisaged the most probable developments. Though they all are very generally defined formulations in pointing out the respective fields which might result in a positive contribution to the solution of energy problems in the years to come it is advisable to take them as a reliable guideline for true pursuit and enforcement of energy savings. It only may enable a systematic approach towards these questions in the various types of production of silicates. Hence, it is indispensable to spare no pains both in the existing production capacities and in those being under construction, to adjudge the problems of energy from several viewpoints since these problems will decisively influence the prosperity of the production along with the requirements for excellent quality and utility properties of products made of non-metallic raw materials in the future.

The viewpoints can be classified as follows:
- to get the energy sources rid of the dependence on importing expensive fuels,
- to extend the utilization of secondary energy sources in local conditions,
- to utilize the existing energy sources to the highest possible degree of effectivity,
- the industrial development should tend towards using such technologies and materials to avoid extreme requirements for the most rare energies
- to increase absolute savings in energy consumption
- to accentuate social interest in effective exploitation of energy sources

It is quite obvious that the above general scheme can well serve as a basis for a series of concrete steps applicable straight forward according to local conditions and local economic interest.

II. PRESENT SITUATION IN THE PROCESSING OF SELECTED NON-METALLIC RAW MATERIALS

a) The first steps leading towards energy conservation in cement industry were made by replacing the former "wet" process furnaces with up-to-date high-capacity ones of low energy requirements. It was a fundamental change in the technological process. It resulted, apart from absolute energy savings, in the solution of capacity problems. It is just the "dry" process which enables to manufacture daily in the order of thousands of tons of cement.

It is necessary to note, however, that these furnaces, enabling to produce as much as 5 000 tons of clinker per day, work with almost identical thermal efficiency as furnaces of medium capacity (i.e. from 600 to 1200 tons of clinker within 24 hours). This is an example how a fundamental change in technology can help to achieve absolute savings in energy on the one hand and new paths towards further effectivity on the other hand. It has led to start using giant furnaces and, consequently, a technical problems connected with furnace and heat exchanger sizes had to be solved since in both cases there are certain limits beyond which any further expansion in sizes cannot be afforded without negative consequences e.g. in the life of equipment.

In this respect the application of the so called pre-calcination method, apart from other technical impacts, helps very favourably in solving the point of calorific efficiency in relation to the quality of fuel or to the possibility of utilization of waste heat from the clinker cooling system. When a combination of such a process is summed up it results not only in creating better conditions for the utilization of thermal energy sources but it also reflects more favourably in investment and operation costs. They are influenced particularly by that fact that extreme furnace sizes can be avoided and they can be thus operated more easily and with more flexibility. Needless to say the furnace refractory lining life has better prospects. From energy point of view, however, the most important factor is a successful cut-down of the specific heat consumption to 760 to 780 kcal/kg level at the production capacity of 2 000 to 8 000 tons per day.

Further development is oriented towards the application of such types of fuel which would allow another reduction in specific heat consumption down to as much as 700 kcal per kilogramme of clinker. Thereby the level of about 60% thermal efficiency of fuel will be achieved. Such a limit is quite reasonable and to reach it it does not depend on fundamental technological changes any longer but rather on how perfectly and reliably the entire production cycle will be kept within the optimal limits of the technological and economical operation.

Consequently, it is quite apparent that the resulting thermal cum economical regime of clinker production is, to a considerable extent, dominated by the perfectness of technological process both at the input and dressing of raw materials and by the "upkeeping" of the entire production process within the limiting conditions of a stable balance. This objective, however, should be reached through a progressive implementation of automation both in the control of the production line operation and in the control of the complete production process.

Apart from the firing units in cement industry the desintegrating and milling processes constitute another principal energy consumers. In recent years a considerable progress has been made in this process, as well. There have been developed such milling machines which enable to increase the milling capacity significantly and to reduce the specific energy consumption at the same time. The problems of milling capacity are mostly solved by more perfect design of milling machines and by applying the latest milling technologies. The question how to reduce the specific energy consumption is solved by the application of such physical-chemical method that can have a favourable impact on the milling process intensity. The main attention in the research has been paid to the study of tensile and compression strengths,

toughness, porosity, distribution of particles and pores and the tendency towards aggregation and aglomeration. There are true, positive results already at hand which can be successfully implemented even in the already existing production processes whereby their better application can be accomplished.
The main role here, however, plays an application of suitably chosen reagents which act on the surface of the material to be milled. From the energy consumption point of view an energy saving expressed in terms of specific energy consumption in the milling process can be reliably expected to amount as much as 20% when compared with the usual state.

b) The theoretical heat consumption in the <u>burning of 1 kg of lime (CaO)</u> amounts to about 760 kcal while the burning takes place at the temperatures ranging from 950°C up to 1250°C. Any significant reduction in the energy consumption under the present conditions in the production may hardly be achieved. Mostly all the possibilities in reducing the energy consumption have been exhausted mainly due to the fact that input conditions have been optimized already for every type of the existing production equipment (a consistent size of lime lumps at the inlet) and the optimal conditions of stabilization of the production regime have been profoundly elaborated. It has been proved through experience that when rotary kilns have been used in the lime production requiring the reduction of the grain size at the inlet it did not allow to cut down the energy consumption below the limit of 1200 or 1300 kcal per kg in the production capacity of about 500 to 800 tons per day. It is necessary to point out that these results were achieved at the cost of considerably higher investment costs so that this is a way which cannot be considered as promising in the years to come. From the energy cum economical point of view the shaft kilns may be expected to be the most promising ones to meet the future requirements. Out of the numerous types of kilns the most interesting ones are those based on the "regenerative co-current flow" principle in which either oil or gas are used as fuel. These types of kilns are designed with two or three shafts the capacity ranging from 100 to 250 tons per day in each shaft showing the heat consumption of 900 to 1 000 kcal per kilogramme of burned lime. It is apparent that this value of specific consumption approaches very favourably the theoretical specific consumption. The present circumstance under which more suitable and effective production equipment failed to be developed so far can in no case depreciate the value of some progressive production processes such as e.g. the new process developed by the Research Institute for Building Materials at Brno.

This process is based on the application of "fluidiset bed gas exchanger" principle and is used in the production of very fine final product. When compared with the energy consumption data of the aforesaid most effective processes applied so far, however, it is not commensurable. Nevertheless, the prospective development clearly tends towards kilns of high thermal efficiency, automized production processes showing the specific energy consumption range from 900 to 950 kcal per kilogramme of burned lime.

c) The highest consumption of energy in the brick manufacture can be found at the drying and firing production sections. The total specific heat consumption mostly ranges from 400 to 800 kcal per kilogramme of manufactured products while this consumption is divided more or less between the firing and drying sections. Therefore the rationalization in this branch is aimed primarily towards these two main operations. As far as the drying process in concerned such an endeavour results in the implementation of continuous drying units which can be automized more easily and, hence, they enable better standard control of the drying process increasing thus the efficiency of the thermal energy supplied to it. To achieve the specific heat consumption ranging from 860 to 900 kcal per kilogramme of water in a continuous drier is a common requirement which can be met. There is yet another advantage at the same time in the drying cycle the period of which has been substantially cut down to 1 up to 6 hrs when compared with the former of the order of 30 to 70 hrs. Even though the numerical data mentioned above represent more or less the extreme limits they are proving the feasibility of such a technological solution which may result both in energy savings and in an overall more effective economy in the production. It is a matter of course that it is not simple to solve the problems of the drying process in the brick manufacture because of all the possible types of products. The full effect of the continuous drier in any case can only be achieved when the entire capacity of the drier is engaged and operated at a uniform drying rate.

When tunnel kilns are used in the brick manufacture they represent the most progressive technology of firing nowadays. The optimal economy in the tunnel kiln operation in all aspects can only be achieved provided that the preceding drying process has been stable enough and the chemical and mineralogical composition of the material to be fired is constant, too. It is quite obvious here again that a standardization of the entire production process in its all stages is not only a prerequisite for potential increase in the productivity expressed in terms of a nominal unit of the production capacity and in relation to the criterions of high demands for the utility value of the final product but for the energy effectivity of the whole production process, too.

d) Quite similar conditions can be traced in the ceramics industries particularly in the production of wall tiles and floor tiles and other products to be used in the final building industry. Nevertheless, the sphere of potential and feasible changes in this branch gets a little broader. Such changes may have a favourable impact on the overall energy consumption and economical balance in the final stages of the production process. It is also necessary, however, to solve the question of body standardization apart from the problems concerning the mechanical and technical parts of the drying and firing units. Choice of suitable raw materials is vital for the product as well as for its surface finish. It also is necessary to choose a nontraditional technology for the body preparation before moulding. It may be quite expected in the near future that these questions will be solved in the production that both size and weight of the products proper will be changed. It may be closely followed by gradual implementation of such technology which will use multicomponent body allowing to successfully reduce the thickness of products while their standard strength will be maintained or even increased. This trend namely is complementary with the tendency towards optimal utilization of tunnel kiln. Without the solution of these problems our efforts to reduce the energy requirements would hardly get over the limits set by the optimation of rated parameters of a kiln or furnace and by the optimation of waste heat utilization connected with the discharge of kiln gases. These two ways leading towards the betterment of the thermal efficiency can be immediately followed by a suitable insulation of kilns or by utilizing the discharged kiln gases in the preceding drying section. Implementation of single layer quick firing process and production of one-fire tiling materials are the way very good results can be achieved in energy conservation and increased productivity at reasonable costs.

e) As far as the objective of energy requirements is followed similar principles and ways are applicable in further development in fine ceramics and sanitary ware industries. In this branch, however, there are substantially higher demands for the properties of bodies as well as glazes and, it goes without saying, there are other demands for the moulding technology as far as the quality is concerned. It is indispensable to strictly adhere to the optimal production regime in the existing production capacities in drying and firing units since these two production sections are unambiguously decisive for the effectiveness of energy supplies. Moreover, particularly the firing units are decisive for the degree of quality achieved at its final stage. Therefore a particular accent is given to the requirements for a continuous control of the production regime or even its automation and regulation of any production fluctuation in this branch of industry and its existing production equipment.

The future trend of development in this branch may indicate a deviation from the traditional wet moulding process that will have an indisputable impact on the energy balance in the production proper and will necessitate a corresponding adaptations at the producers of raw materials. The fine ceramics industry will show a tendency to decline from its traditional own production of bodies and will increase its requirements for direct supply of ready made bodies or at least "semibodies" which can be applied according to the concrete requirements of the moulding processes without any special modifications.

Out of the significant technological changes the spray drying process is worth mentioning which has already found a vast applicability in a series of ceramic plants.

From the energy point of view the implementation of spray drying process is especially valuable in the body preparation stage for it positively changes the energy consumption in the preparation of such a body.

The spray drying process alone is known for its very positive influence it has on the granulometric composition of the "elementary particles" in the body and, to some extent, irreversibly because a product made in the traditional wet process from raw material having been spray-dried shows by about 10 to 15% lower energy consumption in the bisque drying process.

In case of a complex technological change, i.e. by implementing a moulding process by pressing from the spray-dried body it will indisputably lead towards high savings in specific heat during the firing process.

It is a matter of course that there are also ways to influence the body composition i.e. by optimizing its mineralogical composition (according to the criterions on the body behaviour during the moulding and firing processes) and its chemical composition (in view of influencing the height of firing temperature either by the choice of raw materials or by the addition of suitable unorganic chemicals).

f) Problems in energy requirements in the glass industry are aiming at common objectives as are those of the aforesaid branches but the particular steps towards their solution would require special attention and fall beyond the scope of this discussion. In this field the present attention is paid to the production of such types of glass requiring less time for their melting, such as crystal glass, packing glass and sheet glass and to new types of glass melting furnaces. In the foregoing notes the contemporary trend in energy conservation has been shown briefly on several examples in the main branches of the silicate industries. It is quite natural that the more or less general aspects in which the main energy problems have been discussed are not the most suitable ones in all cases for deducing cencrete applications a particular producer may wait for and which are strongly neee[illegible] his production process. Nevertheless, it is [illegible] to keep such prospective trends always in mind because they may positively influence the decision-making process in all considerations on future developments.

It is felt that every producer should keep to the following sequence in dealing with the energy conservation problems:

1. To assess the existing conditions and to make immediate corrections without requiring unproportional capital

investments.

2. Timely corrections in projects of new production plants being under preparation and, if necessary, even corrections in production plants already under construction as far as it can be afforded from the investment requirements evaluation point of view.

3. More profound evaluation of perspective intentions from the point of view of the latest knowledge both in technology and in the prospective developments in energy sources.
It is a matter of course that maximum attention should be paid to the utilization of all the local conditions and sources available that may have positive impact on the energy balance.

Another viewpoint that may serve the purpose of a reliable orientation in the problem is to estimate the points where the remedial steps are to be taken. In principle, there are three alternatives:

1. Focusing to the entire energy system in the production plant.

2. Focusing to measures to be taken in the production technology while the energy system remains more or less intact.

3. Complex solution which may comprise both, i.e. measures in the production as well as steps into the energy system.

It is obvious that the last approach is most attractive but it is necessary to note that in such a case the innovation process is of such an extent that there is a risk that the amount on investments spent might be reflected unfavourably after rather a long time. It may be so particularly when there are not available detail data and experience immediately after the implementation required for the elimination of breakdowns after the commissioning in the whole existing production system.

Therefore, it is recommendable to choose measures in that sequence as mentioned above. Experience in the long run may show that mere realization of measures in the energy system alone in a particular production plant will fetch so good results that the costs spent could be highly recovered within the latest time. These measures taken are usually rather simple requiring relatively minor arrangements, easily understandable and easily implementable within the existing regime. Concrete simulated procedure is shown hereinafter. It is a matter of course that all the steps actually taken towards the energy savings cannot be expected to be applicable successfully in all branches. Nevertheless, such measures are recommended for consideration since they may give immediate positive results whereas any changes in the technology will require a medium up to long time perspective from the point of view of time and the investment costs involved represent incomparably higher demands.

III. POSSIBILITIES OF REDUCING THE ENERGY CONSUMPTION IN TECHNOLOGICAL PROCESSES

Non-metallic raw materials may very well be utilized in reducing the energy demands in such cases where the body is not composed of single components, i.e. when it is blended of several sorts of raw material. The role and knowledge of a technologist in such a case become important to choose such a technology which corresponds to the raw material availability of a particular country on one hand and which is most advantageous from the energy consumption point of view on the other hand. For this purpose there are several practical examples presented here to show the concrete possibility of choice of proper optimal technology.

a) Brick manufacture is usually based on a single-component production technology. In some cases the basic plastic raw material may be corrected by another type of a raw material. This production depends prevailingly on the type of raw material which is decisive for the main technological principles of the entire production process from the plastic blend.

The fineness of grinding of the raw material usually fluctuates at the maximum grain size from 1 mm to 3 mm. It is due to the following influences of the raw material:

Table No. 1

Brick Manufacture - Influences of Inclusions
and Grain Size of the Raw Materials

maximum grain size	
$x_o = 3$ mm	kaolinitic clays with finely disperged sands and other impurities
$x_o = 1$ mm	shales, clays with calcareous inclusions and rough impurities

The firing temperature level is given by the process of vitrification of the raw material, i.e. by reducing its porosity and by achieving the standard mechanical properties of the fired test pieces along with the increasing firing temperature. The optimal firing temperature of raw materials is to be decided either by a progressive firing of the test pieces within the range from 900°C to 1 100°C or by the firing of the raw material in a gradient kiln. When porosity ranges within 10 to 25% and the compression strength is 150 kp per sq.cm. to 250 kp per sq. cm. at an ambient temperature it is usually a sufficient criterion to determine the optimal firing temperature.

Such a raw material the mineralogical analysis of which indicates a high fraction of kaolinite, minimum content of illite and montmorillonite, at which no cracks occur during the drying process, when there are no undesirable inclusions of carbonates and which does not need too fine grinding and has suitable physical properties at a minimum possible firing temperature,it is very advantageous for the manufacture of brick ware.

b) Manufacture of glazed wall tiles is a typical production process in which the body is blended from a series of raw materials. In this case then a technologist has to choose from a number of possibilities the most suitable one, i.e. which will result in a high quality final product at a minimum demand on the technology.

Table No. 2 shows the selected types of compositions of wall tile body classified according to their energy demands. The kaolinitic type in which the kaolinite mineral content reaches 80 per cent of total represents a classical European type of wall tiles being still made by some manufacturers because it enables to make bisque of rather high whiteness, low consumption of glazes but their firing process requires relatively high temperatures. The majority of the manufacturers, however, have already abandoned this technology because the sizes of the fired bisques are not accurate enough while the costs of raw materials are high (when quartz content is low washed kaolin and ball clays with low silica content are required). To the contrary, however, calcium-siliceous body enables to achieve good accuracy in sizes while a reasonable white colour of the body can still be obtained and high fraction of raw kaolin can be processed along with calcium minerals at very low bisque and glost firing temperatures.

Table No. 2

Selected Types of Wall Tile Body Composition

	Type of Wall Tile Body					
	kaolinitic	semi-kaolinitic	silica -feldspar	talc	combined	calcium -siliceous
	1	2	3	4	5	6
Rational % composition						
kaolinite	80	25	55	50	50	48
quartz	15	27	35	14	40	37
feldspar	5	8	10	3	3	-
chalk (lime-stone)	-	-	-	3	7	15
talc	-	-	-	30	-	-
Grog %						
total	60	60	50	55	55	55
fired grog	46	30	10	10	10	10
Firing temperature						
bisque	1280	1250	1230	1180	1150	1050
glaze	1120	1080	1080	1050	1040	960
Main components	Normal and silica clays, binding clays, kaolins, fired grog, returnable bisque rejects	Normal and silica clays, binding clays, kaolins, silica kaolins, pegmatitic clays, fired grog, returnable bisque rejects	Normal and silica clays, binding clays, marls, kaolins, silica sand, quartz, feldspar, pegmatite, returnable bisque rejects	Normal and silica clays, binding clays, marls, kaolins, silica sand, quartz, talc, dolomite, marble, feldspar, returnable bisque rejects	Normal and silica clays, binding clays, marls, kaolins, silica sand, quartz, feldspar, pegmatite, chalk, marble, dolomite, returnable bisque rejects	Normal and silica clays, binding clays, marl, kaolins, silica sand quartz, chalk, marble, dolomite, limestone, wollastonite, returnable bisque rejects
Bisque water absorption capacity %	16-22	16-22	16-20	15-22	15-20	14-16
Tensile cum bending strength kg/sq.cm.	100-150	150-200	150-200	200	180-230	200-250

Table No. 3

Glazes Composition Dependent on Firing Temperature

1. Lead Glazes: temperature 960°C, i.e. 07a PCE

Na_2O	0,03 - 0,07				
K_2O	0,07 - 0,00	Al_2O_3	0,20 - 0,25	SiO_2	2,50 - 2,75
CaO	0,25 - 0,00				
PbO	0,65 - 0,93				

temperature 1060°C, i.e. 02a PCE

Na_2O	0,08 - 0,15				
K_2O	0,22 - 0,15	Al_2O_3	0,14 - 0,24	SiO_2	1,64 - 2,70
CaO	0,18 - 0,30				
PbO	0,52 - 0,40				

temperature 1160°C, i.e. 4a PCE

Na_2O	0,25 - 0,05				
K_2O	0,20 - 0,30	Al_2O_3	0,25 - 0,35	SiO_2	3,00
CaO	0,35 - 0,25				
PbO	0,20 - 0,40				

2. Lead-boron Glazes: temperature 960°C, i.e. 07a PCE

K_2O	0,25 - 0,20	Al_2O_3	0,25 - 0,30	SiO_2	2,10 - 3,00
CaO	0,50 - 0,40			B_2O_3	0,40 - 0,50
PbO	0,25 - 0,40				

temperature 1060°C, i.e. 02a PCE

Na_2O	0,10 - 0,22				
K_2O	0,15 - 0,17	Al_2O_3	0,15 - 0,30	SiO_2	2,30 - 3,20
CaO	0,50 - 0,27			B_2O_3	0,20 - 0,50
PbO	0,25 - 0,34				

temperature 1160°C, i.e. 4a PCE

Na_2O	0,25 - 0,25				
K_2O	0,25 - 0,20	Al_2O_3	0,27 - 0,40	SiO_2	2,60 - 3,50
CaO	0,35 - 0,55			B_2O_3	0,31 - 0,50
ZnO	0,15 - 0,00				

3. Boric, Lead Free Glazes:

temperature 960°C,i.e. 07a PCE

Na_2O	0,25 - 0,30				
K_2O	0,25 - 0,20	Al_2O_3	0,25 - 0,50	SiO_2	2,20 - 5,00
BaO	0,50 - 0,00			B_2O_3	0,50 - 1,00
CaO	0,00 - 0,50				

temperature 1060°C,i.e. 02a PCE

Na_2O	0,25 - 0,30				
K_2O	0,25 - 0,15	Al_2O_3	0,19 - 0,32	SiO_2	1,91 - 2,58
CaO	0,50 - 0,45			B_2O_3	0,45 - 0,80
ZnO	0,00 - 0,10				

temperature 1160°C,i.e. 4a PCE

Na_2O	0,25 - 0,10				
K_2O	0,25 - 0,10	Al_2O_3	0,40	SiO_2	3,20
CaO	0,20 - 0,50			B_2O_3	0,50
BaO	0,30 - 0,30				

4. Opaque Glazes:

temperature 960°C,i.e. 07a PCE

CaO	0,22				
PbO	0,78	Al_2O_3	0,29	SiO_2	2,60
				SnO_2	0,29

temperature 1060°C,i.e. 02a PCE

Na_2O	0,24				
K_2O	0,045	Al_2O_3	0,15	SiO_2	2,037
CaO	0,292			B_2O_3	0,703
ZnO	0,423			ZrO_2	0,337

temperature 1160°C,i.e. 4a PCE

Na_2O	0,08				
K_2O	0,18	Al_2O_3	0,630	SiO_2	4,56
CaO	0,74			B_2O_3	1,28
				ZrO_2	0,32

Wall tiles glazes can be classified into those to be fired at temperatures of 1060 to 1160°C and those which can be fired at low temperatures below 1060°C. The reduction of firing temperature of a glaze, down as much as to 960°C, however, is qualified, apart from suitable properties of a bisque, by an addition of strong fluxes such as lead compositions, alkaline oxides, etc.

Table No. 3 shows some examples of glaze composition in dependence on the temperature and classified into typical groups of glazes.

c) Ceramic glazes are another industrial branch where a suitable choice of raw materials may substantially influence the firing temperature.

Because of the fact that glaze, being a special type of glass covering a ceramic product of various porosity and thermal expansivity, it is vital to always maintain a correct relation between the properties of ceramic bisques and ceramic glazes.

Table No. 3 shows a series of concrete compositions of ceramic glazes for the firing temperatures of 960°C 1060°C and 1160°C in the glaze classification into:

The reduction of the fusion point of a glaze can be achieved by applying some of the following ways:

1) to replace a part or completely the content of K_2O by sodium oxide which appears to be a substantially more effective flux;

2) to replace a part or completely the content of CaO by sodium oxide or by compositions of lead or BaO;

3) to replace a part of the content of SiO_2 by boron compositions or to further reduce its content;

4) to reduce the Al_2O_3 content.

d) Fluxes represent a considerably large source of energy conservation for every technologist. When properly chosen and combined with the fundamental ceramic raw materials a remarkable reduction of bisque firing temperatures can be achieved in the production of building ceramics while the properties of the final products remain either same or reach even better ones.

Feldspars are classical fluxes. There are three fundamental types of feldspars:

potassium feldspar - $K_2O \cdot Al_2O_3 \cdot 6\ SiO_2$ - orthoclase
sodium feldspar - $Na_2O \cdot Al_2O_3 \cdot 6\ SiO_2$ - albite
calcium feldspar - $CaO \cdot Al_2O_3 \cdot 2\ SiO_2$ - anorthite

Percentage content of individual components:

	orthoclase	albite	anorthite
SiO_2	64,7	68,8	43,3
Al_2O_3	18,4	19,4	36,6
K_2O	16,9	0	0
Na_2O	0	11,8	0
CaO	0	0	20,1
Total	100,0	100,0	100,0

Series of transition types of feldspar are found in nature, mainly in the following mixtures:

a) orthoclase and albite

b) anorthite and albite and orthoclase

Feldspars are an indispensable component in the production of sanitary ware and table ware and in the production of frits and glazes. The fusion temperature of feldspars being mostly higher than 1200°C a modern technology may yield from a number of other non-metallic raw materials with higher fluxing efficiency.

Among them the following ones may be mentioned:

calcareous marls
phonolites
tuffs and tuffites
perlites
nepheline, syenite
dolomite, limestone and magnesite
or ground glass as the case may be.

The application of fluxes in the ceramic technology is supported in several following examples.

e) Earthenware pipes production under a conventional conception of technology is based on the processing of kaolinite clays of low vitrification point and long deformation interval. Conventional firing temperatures of an earthenware body are ranging within the interval of 1250°C and 1280°C, when the glazing method by using salt can be safely applied. Transfer of earthenware tubes firing into tunnel kilns has required the use of earthen glazes but it enables to reduce the firing temperature at the same time as shown in table No. 4.

As it ensues from table No. 4 the firing temperature of earthenware products can be reduced rather significantly. In such a process the salt glazes should be abandoned and earthen ones applied instead. Though the NaCl salt vaporizes at 880°C temperature it must be increased to 1120°C for the decomposition by water steam that is the minimum theoretical temperature required for the salt glazing process. In the actual production process, however, higher temperatures are to be used ranging from 1160 to 1280°C because the glaze formation on the earthenware product also depends on the body composition, when the gaseous Na_2O reacts with a part of SiO_2 and Al_2O_3 from the body when a glaze of the following composition is to be produced:

Table No. 4

Reduction of Firing Temperatures in the Production of Earthenware Products

	Conventional blend	Blend with marl	Blend with phonolite
Body composition %			
Clay A	47,0	31,0	32,0
Clay B	47,0	31,0	31,0
Marl	-	32,0	
Phonolite	-	-	31,0
Fired rejections	6,0	6,0	6,0
Total percentage	100,0	100,0	100,0
Vitrification point °C	1230	1160	1080
Total shrinkage at the vitrification point, %	13,9	10,4	12,8

$1{,}0\ Na_2O \cdot 0{,}67\ Al_2O_3 \cdot 3{,}33\ SiO_2$

The minimum ratio of SiO_2 to Al_2O_3 in the body must be 3 or 4 : 1 . The higher is this ratio, the lower is the vitrification point of the glaze on the earthenware products.

To the contrary, however, when earthen glazes technology is applied the glazing by dipping is quite currently used. In this process a low vitrification point of the glaze can be achieved by adding non-conventional fluxes or glasses and frits.

f) Ceramic floor tiles either glazed or non-glazed represent another example how the firing temperatures can be reduced by using non-metallic raw materials with fluxing effects. The classical technology again is based on the processing of kaolinite raw materials, kaolins and low-vitrifying clays. When feldspar is added their vitrification point ranges from 1200°C to 1250°C. Fast development of firing kilns and, mainly, the implementation of single-layer firing process both enable a considerable reduction of firing temperatures both in case of unglazed and vitrified floor tiles and particularly at the glazed and semi-vitrified floor tiles.

Table No. 5 shows practical examples.

Table No. 5

Reducing the Firing Temperatures in the Production of Ceramic Floor Tiles

	Conventional blend	Blend with phonolite
Body composition,% Clay A	35,0	40,0
Raw kaolin	10,0	30,0
Washed kaolin	25,0	-
Phonolite	-	30,0
Feldspar	30,0	-
Total percentage	100,0	100,0
Vitrification point °C	1250	1120
Total shrinkage at vitrification point, %	13,4	12,2

The above examples demostrate the possibilities and the technologist`s responsibility in composing new ceramic bodies at which he can take quite a distinct share in the energy conservation.

IV. THERMAL UNITS

In the process of processing, refining and industrial application of non-metallic raw materials there are many cases when they are to be dried or fired. In the following part briefly mentioned are some examples of a choice of suitable thermal unit and optimization of thermal processes.

The contemporary situation in the technical development of thermal equipmnet for the field of non-metallic raw materials can be characterized by

- a considerably increased capacities of thermal equipment while using substantially higher thermal inputs,
- making the heating systems more perfect with perfect fuel combustion, automated regulation and with feedback control system and temperature registration,
- improved transfer of heat into the material to be heated,
- light structures of the equipment while using high quality insulation materials,
- a development of entirely different systems of the thermal equipment to be used universally within a certain range of thermal processes and designed to quite a fair technical standard.

It may seem, therefore, that mastering of the thermal processes can be achieved unambiguously by the existing technical standard and assortment of the thermal equipment.

The present world energy situation has brought a new strong impuls into the thermal equipment designing. It is the minimizing of specific heat consumption in the existing technology which predominates even at the account of more demanding structures of thermal equipment and investment costs.

This new trend has completely changed the general opinion on the existing technical standards of thermal equipment and has forced both the manufacturers and the technologists to revise the present laboratory tests leading them thus towards new research to determine limits of thermal conditions and to verify all the heat transfer methods.

The optimalization of all the three ways of heat transfer, i.e. conduction, radiation and convection, was the common denominator for different granulometric conditions of raw materials, different sizes and shapes of pre-processed materials and for their different movement in the thermal field.

These researches resulted in entirely new views on the optimal solution of thermal processes. They ensue from new dressing technologies into small particle sizes of clays and other earthen materials prior to their heat treatment and their movement in the hot field at maximum heat transfer by convection.

Firing of refractory shales are a classical example of this development. It reflects both the development of firing kilns and optimal reevaluation in compliance with the new requirements for minimizing the energy consumption.

Shaft kilns represent the classical technology of such firing process as well as kiln. Their development has resulted in certain improvements derived from various types of burners and automated firing process but the principle of heat transfer proper could not have been changed in transferring the heat into an immovable mass of material whereby the convection of heat transfer has not enabled to make more use of the heat.

Rotary kilns show some betterment in this respect. The material in these kilns proceeds gradually in a slow rolling motion through the individual zones of the kiln whereby a partial utilization of all the ways of heat transfer is made. The use of rotary kilns for these purposes was motivated first of all due to the high production capacities of these rotary kilns but mostly to the detriment of the uniform quality and regardless the fly-losses.

The use of tunnel kilns for the firing of preprocessed extruded shapes means a mere improvement in quality on the account of increased energy demands.

An entirely new progressive method of firing these relatively fine-grained materials appears to be the quick firing process during which the particles are hovering and moving for a very short time in a fluid layer being exposed to an intensive heat transfer in all its ways. The basic research results confirm not only the optimality of this type of firing but also the absolute minimizing the energy requirements while all the combustible components of the raw material being so processed are completely utilized.

Consequently, it is obvious that the development of the thermal systems in the processing of non-metallic raw materials is far from being finished and that the contemporary thermal units of equipment derived and improved from the conventional ones are yet to undergo considerable changes.

V. NON-CONVENTIONAL SOURCES OF ENERGY CONSERVATION

Non-metallic raw materials may take a significant share in energy conservation either by using them alone or as fillers they may substitute part of crude oil products used in the production of large variety of products in the form of various polymers or, to the contrary, they may be subjected to the effects of a non-conventional energy to be dried, fired or even melted.

1. Kaolins and limestones when suitably ground and dressed constitute an excellent raw material for filling purposes into organic polymers such as polyethylene, polypropylene, polyurethane, etc. These non-metallic raw materials may substitute as much as 50 to 60 per cent of scarce polymers produced from crude oil in the petrochemical industries,

   By using suitably dressed non-metallic raw materials as fillers not only crude oil can be saved but the utility value of the products is improved and the assortment of packing materials in food industry is made broader, new coatings are being developed in rubber industries and in cable production, new types of paper are made having special properties, metallic components can be substituted by plastics in car industry and in other branches of the engineering industry. For instance when 1 metric ton of plastics is used in the engineering industry instead of metals the power savings in working when compared with metal working amount to 3 000 or 4 000 kWhrs.

2. Application of microwave power sources in the technology of drying, firing and melting of non-metallic raw materials and products will bring revolutionary changes yet in this century. Practical use of microwaves is really versatile and advantageous for the drying of non-metallic raw materials and products, for quicker solidification of concrete, for vitrification processes, firing, melting as well as for blasting of rocks.

It is necessary to use a suitable form of a microwave energy for a particular purpose. Practically, one of the two following ways may come into question:

a) use of a large-space applicator of non-reforming character using low temperatures for drying,
b) use of cavity reformers operating with high temperatures for sintering, firing and melting.

The principle of high-frequency heating has been already known for a number of years but all its possibilities have not been utilized so far. The world energy crisis will thus expedite the application of microwave energy sources for a wide practical use as early as in eighties of this century.

3. Broader application of <u>liquefying agents</u> in the field of non-metallic raw materials, ceramics and refractories enables to use less water in the bodies while their workability remains unchanged. It reduces thus the requirements for thermal input necessary for its evaporation and for drying the semiproducts.

In the raw material dressing section such a classical example of spray drier process of washed kaolin drying may be mentioned, the ratio of dry substance and water being 60 : 40 is usually indicated as a fundamental criterion of economically advantageous application of the spray drier in ceramic industry. When suitable liquefying agents are applied the content of dry substance in a slip can be increased to 66 per cent while the slip consistence remains unchanged. In such a case the thermal energy saved is equivalent to 6 per cent of water. In case of a spray drier of the capacity of 2 000 kg of evaporated water per hour the heat saving amounts to about 120 000 kcal/hr while the spray drier output is higher at the same time.

When refractories are manufactured by plastic process the body moisture content ranges from 14 to 18 per cent. By using properly chosen liquefying agents the body workability remains same while its moisture content can be reduced as low as 10 to 12 per cent. It results in expediting and often even in higher quality of the entire drying process.

4. Solar energy

The problem of utilization of solar energy nowadays in the world is concentrated to the direct heat transfer by radiation into accumulating areas and media as well as into the field of thermocouples to get electric energy sources. The present scientific experience proves the practicability of solar energy utilization and its advantages within the worldwide energy balance.

The extent to which it has been utilized so far, however, is influenced considerably by several factors. First of all it is the high investment cost of establishing such a system, the heat so developed is rather limited and the capacity of such installations is very low from the energy point of view. Climatic conditions are the decisive factor having yet a distinct limiting impact on the two above mentioned ones.

Under these conditions keeping in mind the considerably high energy losses the today`s thermal processes are suffering in the industry as well as their imperfect utilization sometimes even due to labour incapabilities the utilization of solar energy may seem utopistic which can never play a significant role in the world energy balance.

This opinion, however, cannot be accepted. The present methods, systems and possibilities of utilizing this energy are to be considered as a mere initial stage of an entirely new energy system which cannot be neglected solely from the point of view of the present huge energy requirements. It is to be viewed under the nowadays conditions as a supplementary energy source the significance of which will rise while the systems of utilization, cost reducing of investments and widening the fields of its use will take place at the same time.

It is therefore fundamental to study the local conditions of solar energy incidence, to optimize its collection and to aim its development towards its combination with other natural energy sources for the improvement of the living condition of inhabitants of our planet as well as for its industrial exploitation.

There are many countries where the conditions for this field of science and technology are favourable and which can be and will have to be utilized earlier or later.

5. Non-fired products

Refractory building materials and insulations are indispensable for making linings of thermal equipment in whith the technological processes mostly take place under high temperatures. Steel, cement, glass and other similar industrial products cannot be made without refractories.

Until recently so called "classical building method" predominated in the linings technique. They were made of fired shapes based on refractory clays, magnesite, chromemagnesite, alumina and high-alumina bodies. They are produced by a standard technological process starting from the raw material preparation, mixing, pressing, drying as far as to firing at temperatures being higher than those maximum ones under which they are to be applied. Their production represents large energy consumption and reasons are always at hand to insist on their processing in all the usual stages in which the product gains its final thermal and technical properties. Under these conditions heavy refractory shapes are still manufactured nowadays for the first layers of linings and light-weight ones for the transition layers and final insulation layers to prevent excessive heat losses into ambient atmosphere.

The processes of heat flow in linings indicate rather the marginal conditions for the properties these materials should have but in no way they could stress their necessity in the whole volume of a refractory shape in view of the wellknown linear heat flow in linings. They neither specify unanbiguously that the properties must be necessarily gained through the firing process.

The developments in the field of linings are influenced by the endeavour towards industrialization and expediting the construction of kilns and furnaces as well as by an unpleasant necessity of the considerably broad variety of shapes needed for a classical structure. Therefore, it aims to the field of non-fired bodies which can be made of refractory concrete based on a hydraulic binders, ramming masses in plastic state chemically prebonded and with ceramic binders and masses to be applied by guniting. These masses made either monolitically in the furnace structures straightforward or in the form of dried up prefabs or gunited layers have found gradually a considerable application chiefly due to their versatility in use, mobile storage possibility as well as for the increased life of linings and enhanced furnace and kiln capacities. The contemporary world production share of these non-shaped refractory masses has risen to one third of total production.

Their contribution may be felt not only in the aforesaid advantages but from the energy point of view their application has completely removed the necessity of energy consumption being indispesable for the firing of the classical shaped materials. The firing of the monolitic or prefabricated linings made of shapeless building materials takes place directly as late as during the drying or heating cycles when the kilns are re-commissioned and to such temperatures only which exist in the particular thermal zone.

VI. FINAL NOTE

The presented paper has pointed out some examples when the branch of non-metallic raw materials may take a reasonable share in solving the world energy crisis and contribute to energy conservation. Due to the limited time it was impossible to deal in detail with all examples but, nevertheless, it pinpointed some of a series of possibilities which every technologist, designer, design engineer and expert must keep in mind nowadays if he wants to achieve minimum energy demands in the processing of non-metallic raw materials.

Because of the fact that energy becomes a limiting factor in further development of the mankind the problem of energy conservation must be given an utmost attention in any undertaking.

VII. REFERENCES

Colomban P., Badot J.C., Le Chauffage par microondes methode de cuisson des ceramiques en 1990!, Industrie Ceramique 725, A/79, P 101 - 107

Engelthaler Z., Ceramic Glazes, CKZ Prague 1975

Engelthaler Z., Technology, UNESCO Scientific Seminar Geochim, Damascus, 1979

Kuna L., Linings for Industrial Furnaces, SNTL Bratislava 1969

Kuna L., Insulations of Heat and Cold in Industry, SNTL Bratislava, 1965