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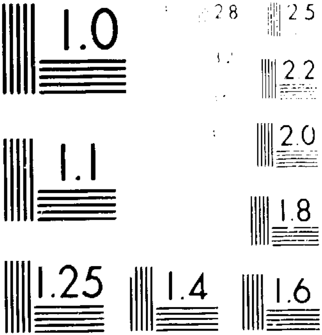
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ENERGY MANAGEMENT IN A CERAMIC PLANT

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Contents:

I N T R O D U C T I O N

The present situation in energy and the relating prognosis generally tend to an increased endeavour in fuel and energy economization first of all in the thermal equipment in view of their consumption of energy. This process complies fully with the principle that energy economization can be started at once but the development and construction of new sources is considerably demanding from the point of view of capacity and costs and requiring a lot of time.

It is a matter of course that large industrial units are in the focus of attention in these efforts particularly because the thermal processes taking place in them are of high and very high temperature ranges and the energy consumption of such equipment represents very high portion of the total consumption of the entire enterprises. Modifications and improvements in the processes of the existing units can only have a character of local racionalization measures but they are limited by the existing production technology as well as by the type of equipment, year of its commissioning and production conditions of the respective thermal equipment. Nevertheless, though we cannot undervalue the importance of the local racionalization measures, such steps alone cannot solve the present problems existing between the energy requirements and sources.

The problem of the world energy and its effects it has on the industrial development in various countries has reached a stage which requires already a higher form of solution, i.e. an overall system of controlling the energy consumption focused to individual industrial branches and to relating national plans of obtaining and consuming energy and fuels. In contrary to the form of local racionalization actions such a system represents a global solving of all energy problems beginning from the development and technology to thermal processes, analysis of contemporary situation up to the elaboration of a complex programme to reach an optimal condition. Logically, the main principles of the complex control system are essentially common for all industrial branches. Despite that, however, its application in a particular branch will possess peculiarities that will have to be fully respected and solved in details.

Ceramic industry, being of a high importance in many countries, is one of the industrial branches in which the energy and fuels consumption plays and important role. It produces a large assortment of ceramic lining materials used in architectonic designs of buildings, stoneware and brickware products for building industry as well as sanitary and artistic ceramics within the range of china and stoneware. Refractory and insulation materials are manufactured for boilers, industrial kilns, furnaces and driers to cater for the needs of metallurgical, chemical, energy producing and engineering industries. Porcelain insulators of all types are used in electrical industry and in the power distribution system. The ceramic industry, nowadays, constitutes a wide range of industrial activity being closely connected with a series of other industrial branches.

The energy demands in the ceramics stems up from the technological process the principal stage of it being the thermal processes - drying and firing through which only the ceramic products can get the required final properties and appearance. The energy consumption is high not only due to the considerably large quantity of masses and products being processed but first of all due to long time - consuming firing processes.

Hence, the implementation of the complex energy consumption control system in the ceramic industry is not only fully justified in view of achieving substantial savings but it enables, at the same time, to solve this problem in the entire production range beginning from the development of non-traditional raw materials up to the optimation of thermal processes in new types of kiln and furnace units.

1. ENERGY CONSUMPTION

Fuels and energy creating basic sources of production and conditions of economic development of every country have lately become the crucial world problem in the industrial as well as in the political sphere. Energy consumption has spiralled by 6 per cent yearly in the world average and, at the same time, the conditions for obtaining raw materials, fuels and energy worsened abruptly and particularly their prices rose steeply in the world markets during the first half of 70'. This trend has prevailed even in the 80' in fact and no signs can be noted towards any substantial improvement in the foreseeable future.

Both the chief factors - increased fuel and energy consumption by ever more vividly developing industries and their constantly spiralling prices - ever more distinctly affect the economics of various countries. It may not be even unexpected that this negative phenomena could adversely affect further development of a planned structure of industry or even endanger existence itself of some branches.

The influence of the energy penetrates also into the strategy of the world markets, manufacture of high energy consuming products is intentionally curbed and their import from abroad is promoted.

1.1 World energy sources and consumption

Energy sources, their transformation and consumption can be, when simplified a little, classified into two circuits - the primary and the secondary ones which can be distinguished by the basic form of energy and by the level of control, too.

By the primary energy could be understood that one being immediately obtained from the natural sources such as from coal, crude oil, natural gas, uranium ore, water etc. By reducing it to a common unit the primary energy represents thus all energy sources in such a state before they are transformed into secondary energy, i.e. electric power, city gas, briquetes, petrol (or gasoline) fuel oil, heavy fuel oil etc. These types of energy named also high grade energy or consumption energy are of the form of energy suitable for direct use in industrial consuming units. Nowadays, the production of the secondary energy is an important industrial branch and its share in the total industrial production grows ever higher.

The world consumption of the primary energy sources grows rapidly, a lot of world energy sources get exhausted step by step and there is a risk of limiting the industrialization process both in industrially developed and in developing countries.

The world total reserves and the time for their exhaustion can be quoted as follows:

black coal

Total reserves are approximated to about 620.10^9 tons and when compared with the yearly mining the reserves will be exhausted in 250 years.

brown coal

The assessed world reserves amount to about 230.10^9 tons; The mining conditions keep deteriorating however the yearly mining proper increases by about 3 per cent a year. Exhaustion of brown coal reserves may be expected after about 150 years.

Crude oil

It is the most widely used energy source nowadays and its consumption is considerably increased by its use in petro-chemical industry. The crude oil expected workable reserves may be assessed to 80.10^9 tons, the yearly production to 3.10^9 tons. The amount of 40.10^9 tons have been produced during the entire period of its production so far. Supposing that its consumption will not be further increased due to the world oil crisis and that some reserve could be expected to remain in the total reserve the crude oil reserves may be foreseen to be exhausted within about 30 years.

natural gas

It is quite a considerably often used energy source nowadays and may find its use even in the chemical industry. The world reserves are assessed to amount over 100.10^{12} cubic metres and they may be exhausted within about 70 years.

nuclear energy

Evidently, the electric power generation in the future will be chiefly based on nuclear fission. It begins to take more share in the total energy generation.

Depending upon the type of reactor the nuclear (fossil) fuel consumption amounts from 20 to 40 tons per year. The workable reserves of uranium and thorium may be assessed to 3 to 5 million tons while the envisaged total output of reactors in the year 2000 amounts to about 1500 GW, i.e. about 3000 reactors of 500 MW each. Ther consumption being 100.10^{3} tons should exhaust the reserves within 40 years when taking into consideration that about 70 years will be required before all the reactors are in full swing.

water energy

The electric power obtained from hydroelectric power stations in the world takes about 2,5 per cent share only while in some countries, such as in Norway it amounts to as much as 99 per cent. Out of the total potential on suitable rivers amounting to 2300 GW mere 10 to 15 per cent are utilized for the time being. Despite the fact that the exploitation of water energy grows up its growing share in the world scale in the future is not expected.

Besides the aforesaid energy sources new ways and transformations are tried to be found, so called energy sources of the future. First of all there are the controlled thermonuclear syntheses, magnetohydrodynamic transformations, utilization of geothermal energy, energy of the wind, the sun and of the oceans.

When we sum up the knowledge in the world-wide energy cum fuel reserves we may deduce some conclusions being decisive for the devel-oment in various countries because the changes in fuel sources and the spiralling of the world prices influence the present situation in energy policy of every country. Hence, the requirement for rationalization of all types of energy has entered the focus point of interest.

1.2 Growth of consumption

The world energy consumption expressed in million tons of specific fuel is shown in the following fig. No. 1.

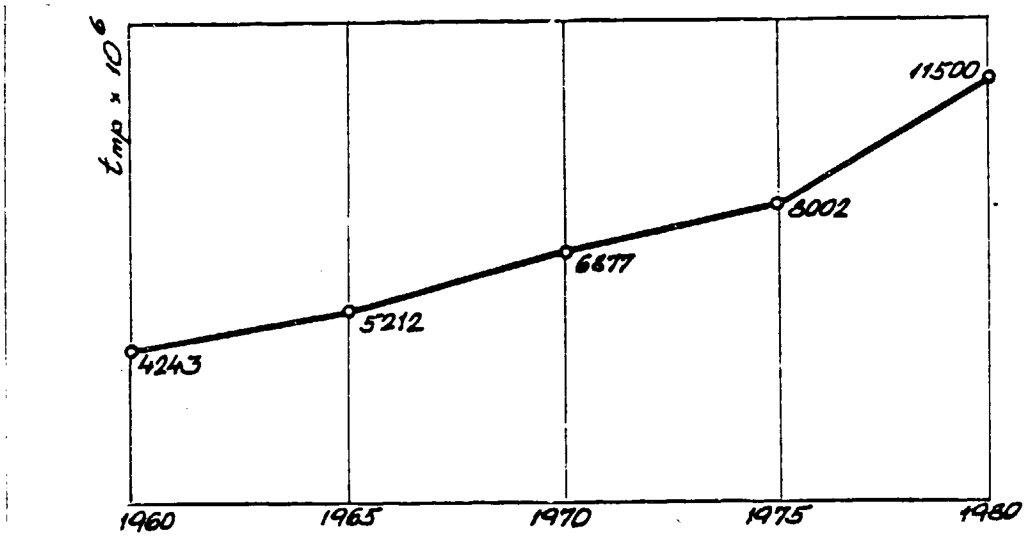


Fig. 1

When taking into consideration further development of this consumption supposing that the growth shown above will keep its pace we would arrive at literally terrifying energy consumption. Hence, certain balance in the energy consumption will have to be reached in the future years and any further growth of industries may be possible only on the basis of new fuel and energy sources.

When we compare the par capita growth of consumption as shown in fig. 2

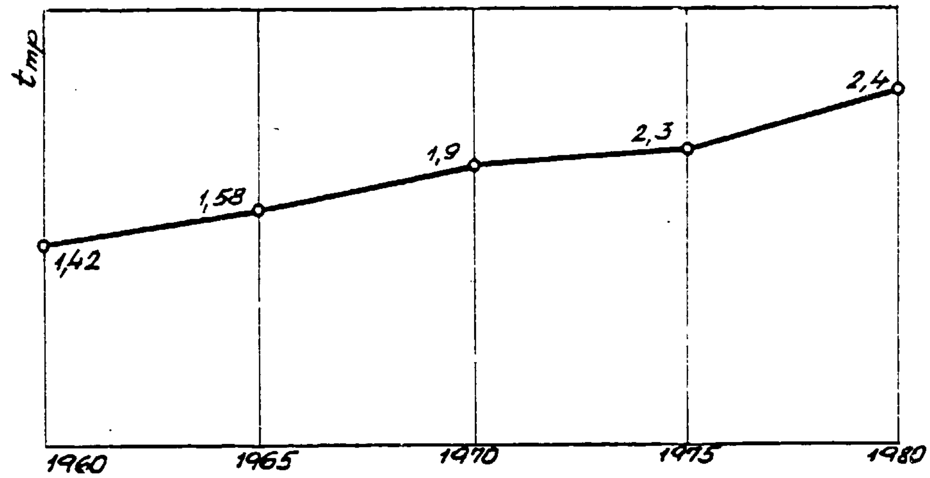


Fig.2

we obtain similar growth of consumption. It is a matter of course that the values differ considerably in the industrially developed countries (as much as 3.5 times more) against the developing and the least developed countries.

Hand in hand with changes in the energy consumption the structure of the individual primary energy sources has changed graduallyy too. These changes have taken place chiefly due to the growing efficiency in the exploitation of new energy sources.

It ensues from the chart shown in fig. 3 , that, due to the changes, the first places are taken gradually by liquid and gaseous fuels primarily owing to their high calorific value, easy transportation and efficient utilization in combustion processes.

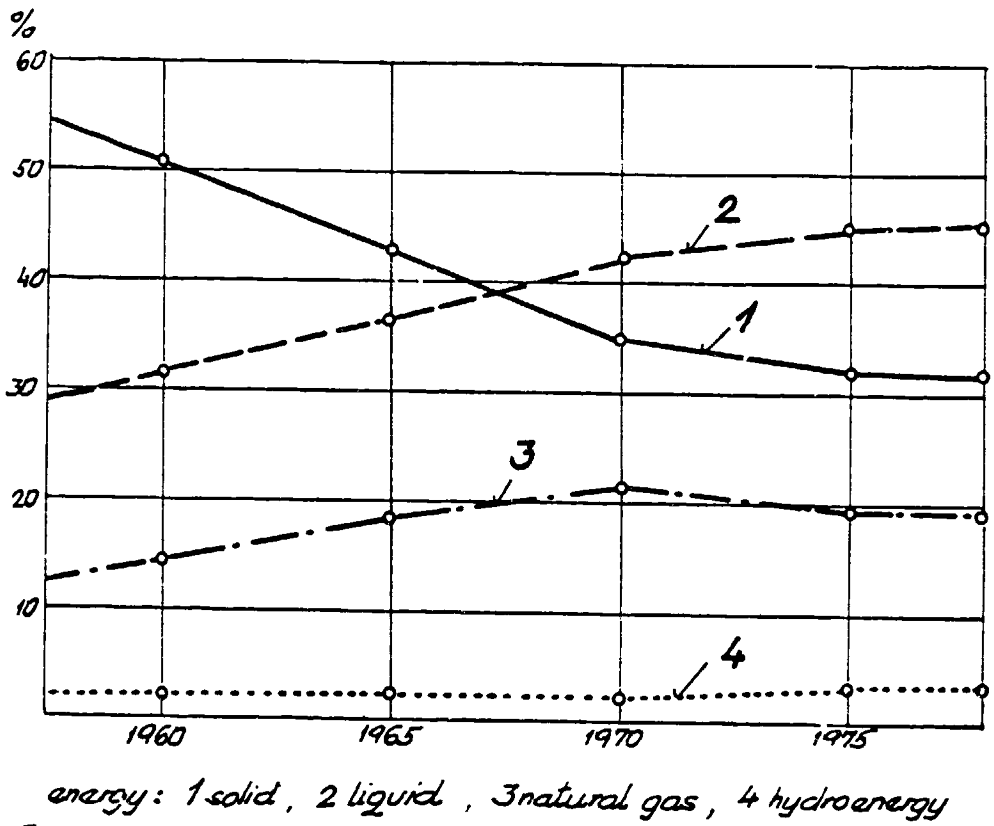
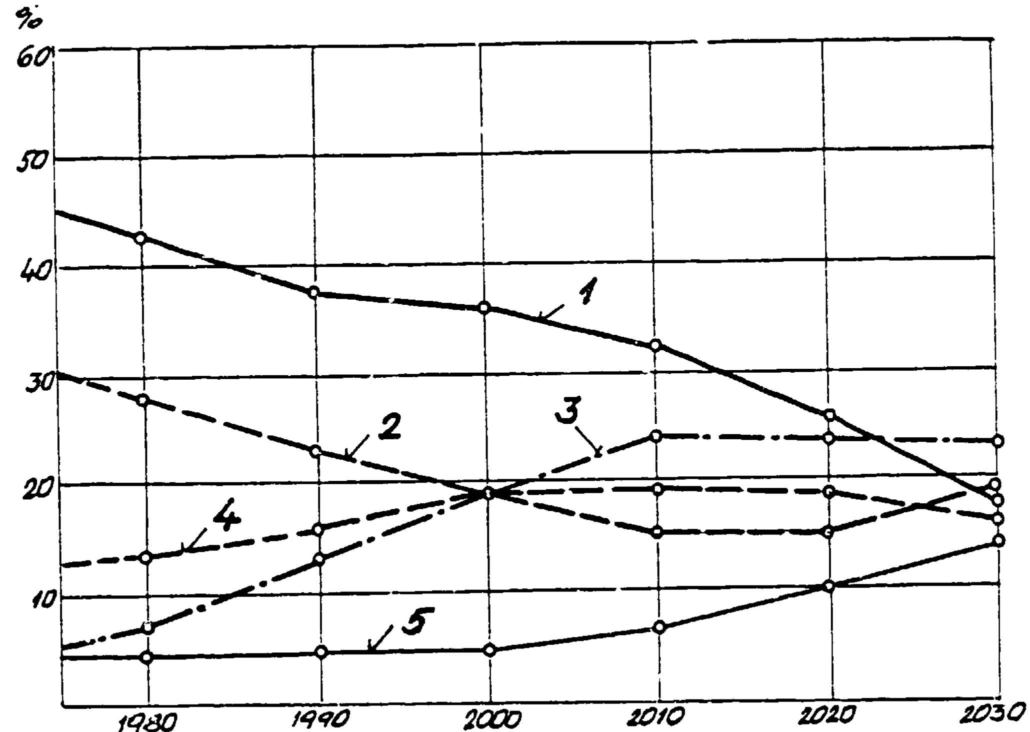


Fig.3

When we derive similarly the outlooks of the energy consumption structure in the future years fig. No. 4 we may find out that the present about 40 per cent share of liquid fuels will get lower gradually and the other components of energy sources will generally come down, too, except for the nuclear, water and other types of energy. When the year 1980 is compared with the year 2030 the total world consumption should be lowered from the original 100 per cent down to about 88 per cent in the year 2030.

When we evaluate now the past and the present situation as well as the prospects in the world consumption of fuels and energy the main conclusions for the energy policy may be deduced in which quite unquestionably the principal requirement for the implemenatation of the rationalization in all forms of energy will prevail in all industrial branches. The prospective industrialization programmes will have to be adapted to this situation.



1 liquid fuel, 2 solid fuel, 3 nuclear energy, 4 gas fuel
Fig.4 5 hydroenergy a. others.

1.3 Consumption in the individual branches

in various countries depends on the degree of industrial development and on the energy sources structure. Dispite a considerable difference an example taken from an industrially developed country will clearly demonstrate the distribution of the primary energy sources consumption among the individual areas of the national economy. It gives a clear picture mainly about the losses incurring in the energy transformation process and the share taken by the industry and building enterprises.

The structure of primary sources shown in fig. No. 5 in 100 per cent consisting of imported as well as country's own natural sources get smaller chiefly by the losses during the mining process, heat generation and electric power generation. They grow smaller to mere 2/3 of the original value. They are of the consumable (secondary) energy type which can be utilized directly.

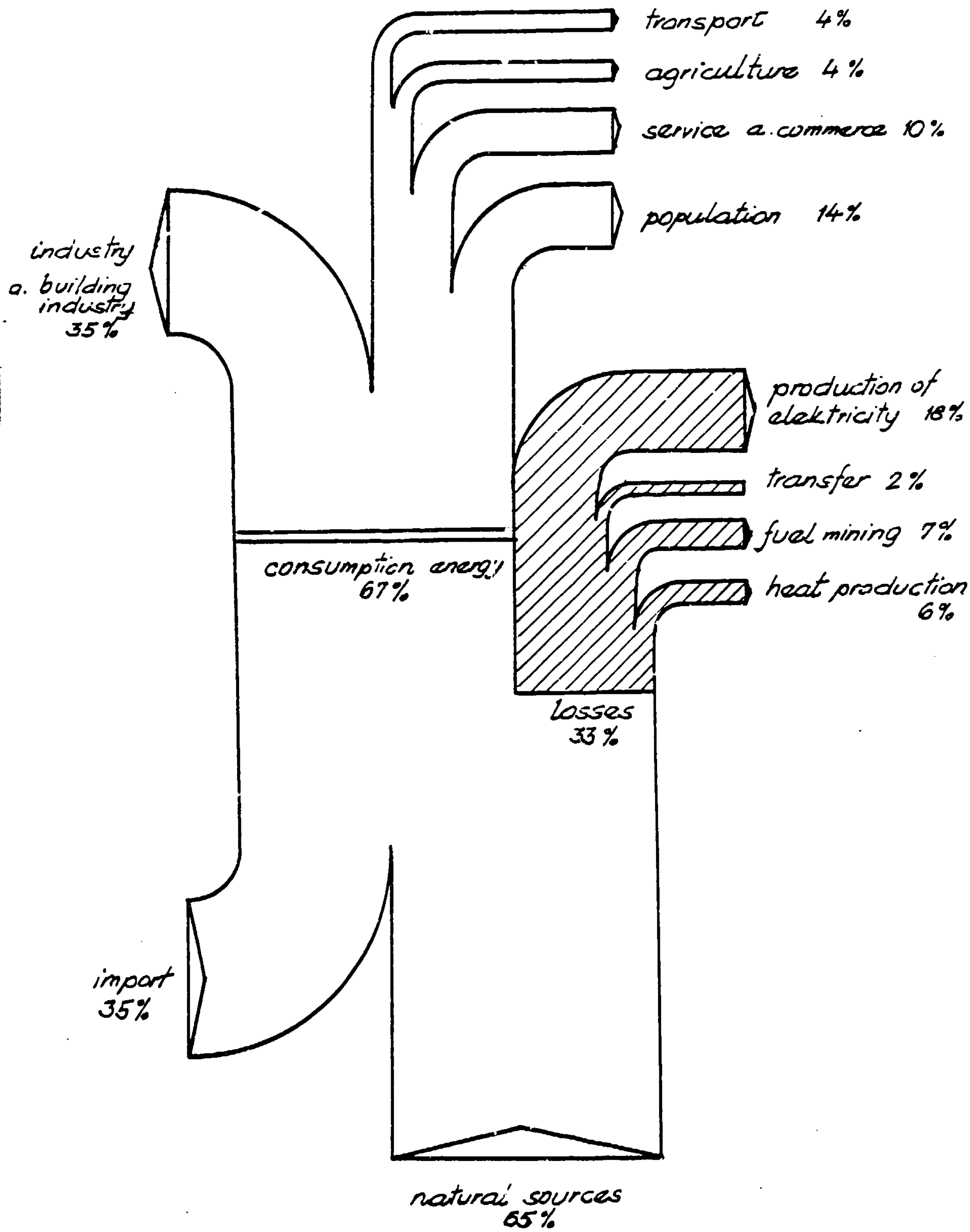

transport 4%
agriculture 4%
service a. commerce 10%
population 14%
industry a. building industry 35%
production of elektricity 18%
transfer 2%
fuel mining 7%
heat production 6%
consumption energy 67%
losses 33%
import 35%
natural sources 65%

Fig.5

When this energy is further classified almost half of it is consumed by the population, transport, agriculture and in a non-productive sphere while the other half of the consumable energy remains for the industry and building enterprises.

When the distribution of the primary sources is further simplified then 1/3 is consumed in covering the losses by transforming it into the consumable forms of energy, the second third is consumed by industry and the last third is consumed by the remaining sphere of the national economy.

The values shown hereinbefore represent approximately the energy conditions prevailing in the industrially developed countries and they are comparable with the Czechoslovak conditions to some extent.

1.4 Energy consumption in the ceramic industry

According to the basic classification of industry the ceramic industry, due to its character, may be put under the branch of building industry. When compared with the other industrial branches the share of energy consumption in the building industry is relatively low and amounts to about 10 per cent (see fig. No. 6).

The ceramic industry within the framework of the building industry, besides the cement, lime and brickmaking branches, is one of the principal energy consumers. Its share in the energy consumption within the building industry represents about 17 per cent (see fig. No. 7). The Czechoslovak ceramic industry energy consumption e.g. amounts to about 500,000 tons of specific fuel in all its factories. When compared with the primary sources it is mere 0.5 per cent, however, but its value equals to 1.5 per cent of the consumable form of energy reserved for industry.

When we make an analysis of the energy distribution into 3 principal types the consumption in the ceramic industry is as follows:

fuels	about 80 per cent
heat	15 per cent
electric power	5 per cent

When the cost of the consumed energy is furthermore compared with the market prices of the ceramic products the proportion of the energy cost in average represents about 25 to 30 per cent of the total cost of a product. Hence, from the strategical point of view the ceramic products do not belong among advantegeous export articles within the scope of the energy sources consumption.

The aforesaid data have enabled us to get an idea about the classification of energy consumption within the individual branches of the national economy as well as about the share taken by the ceramic industry in this consumption.

The ceramic production can be classified into the following main products:

in raw materials:	kaolin
	shales
	sands
in products:	wall tiles
	floor tiles
	stoneware
	refractories

When it is further classified into the heavy ceramics and fine ceramics we may add

brickware
fine ceramics
sanitary ceramics
electroceramics

The difference in technology of the applied raw materials and thermal processes predestines also the difference in energy

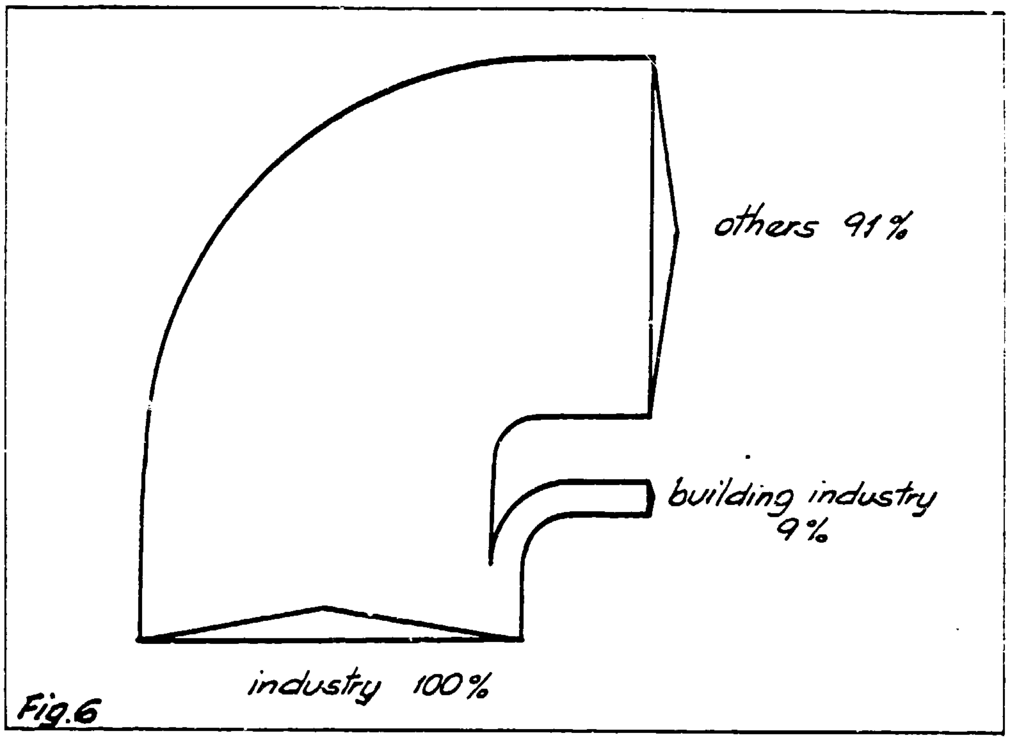

others 91%
building industry 9%
industry 100%

Fig.6

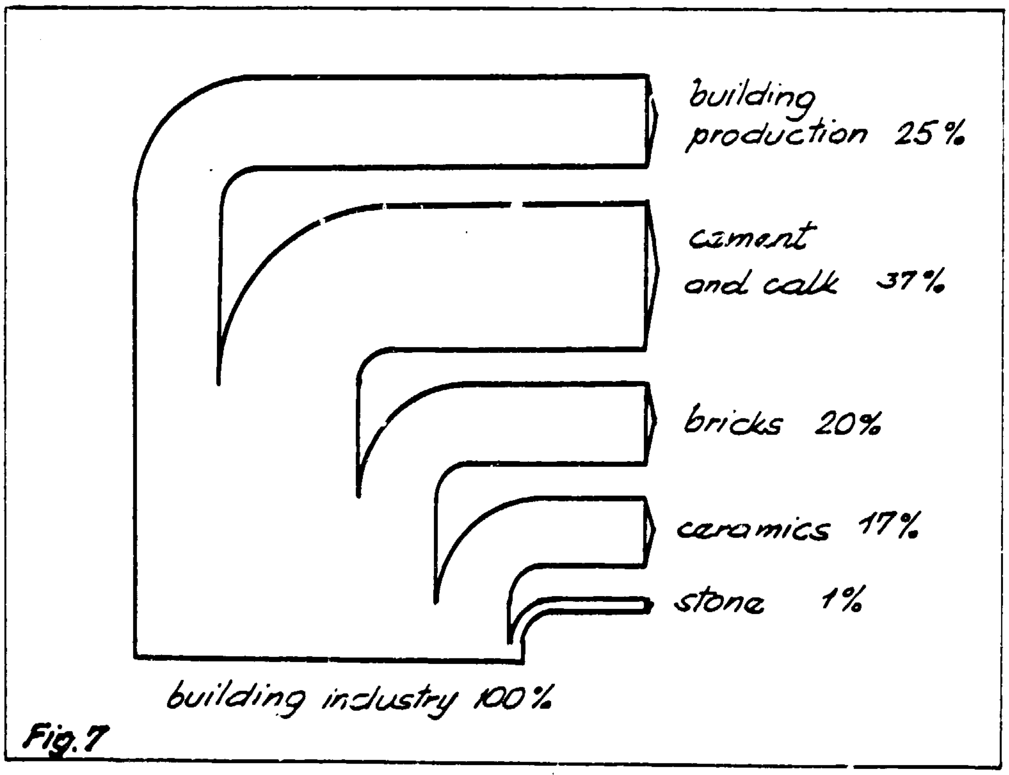

building production 25%
cement and calk 37%
bricks 20%
ceramics 17%
stone 1%
building industry 100%

Fig.7

consumption in the manufacture of various types of products. For easier judgement of their mutual difference in energy demands the value of specific heat expressing the energy consumption per kg of products is the most suitable way.

The specific heat values are shown in the following tables i.e. for drying, firing and for the total energy consumption:

drying: the average value for all groups of products is 150 to 300 kcal/kg

firing:	wall tiles (double fired)	1400 - 2300 kcal/kg
	" " (single fired)	850 - 1000 kcal/kg
	floor tiles (semidense)	1400 - 2100 kcal/kg
	mozaic	1700 - 1900 kcal/kg
	brickware	400 - 700 kcal/kg
	refractories	650 - 1200 kcal/kg
	stoneware tubes	600 - 900 kcal/kg
	stoneware	900 - 1200 kcal/kg
	insulators	3000 - 6000 kcal/kg
	sanitary ware	2800 - 3000 kcal/kg

Total energy consumption in the production process:

wall tiles	3400 kcal/kg
floor tiles	2260 kcal/kg
stoneware	1700 kcal/kg
refractories	1085 kcal/kg

According to the formula

$$1 \text{ kcal} = 1.43 \cdot 10^{-7} \text{ tons of specific fuel}$$

we may calculate, if need be, the amount of energy required for the manufacture of a certain quantity of products.

It also ensues from the aforesaid specific heat consumption that the products can be classified according to the energy demands as follows:

electrical insulator
sanitary ware
wall tiles
floor tiles
stoneware
refractories
brickware

When, finally, we take into consideration that the energy consumption in the production process proper amounts up to 80 - 85 per cent and the other remaining 18 per cent for non--production purposes then the summed up figure enables us to get an overall idea not only about the energy consumption in the ceramic industry itself but also about its overall social position within an industrially developed country.

Though the ceramic industry in the majority of countries (except for Italy) does not belong among the main industrial branches from the point of view of an entire country it yet represents an energy consumer for which there are all good reasons for the implementation of energy rationalization system within the full scope of the manufacturing process.

1.5 Relation to the primary energy sources

The natural energy sources are more and more, along with the growth of industrialization, often transformed into such forms which can be utilized in industry more efficiently, i.e. such as industrial gases, liquid fuels, electric power etc.

The transformation of energy proper takes place in power stations, petrochemical plants, in gas generators and it is eccompanied with considerable losses of primary energy. As it is shown for instance in fig. No. 5 this loss amounts to 33 per cent of primary sources. It may be found out, through a more detail study, that for one thermal unit in the form of electric power it is needed 3.58 of the unit in the form of brown coal in the mine, for the unit of city gas 1.61 of similar unit. Therefore, it is impossible to judge the industry only in view of the consumption forms of energy, the impact on the primary sources should be also considered while chosing the types of fuels. Some firing processes can take place in electrical resistance kilns as well as in kilns fired by a city gas or by a natural gas. A correct choice of fuels is not only a question of a suitable fuel system for a particular technology but due attention is to be paid to the effects on the primary sources as well as to the question of economy because cost relations of high grade fuels are high and tend to grow even more.

2. ENERGY CONSUMPTION CONTROL

As it has been already mentioned the world energy situation calls for an efficient solution that will extend the life of energy sources in the future, enable the development of new types of energy and ensure further development of industrialization in various countries.

The problem of energy may be classified into three areas

- natural energy sources
- energy producing industry
- consumption areas

Ensuring the energy sources either from country's own deposits or by importing them it is the subject of activity of a government control and planning authorities and it is a part of an entire energy policy of each country. The capacities and construction of the energy producing industry securing the generation of consumption types of energy are the principal part of the national economy control and planning both from the capacity and development point of view.

The entire consumption area of fuels and energy can be divided between the industry and the other sections (transport, agriculture, population etc.) approximately in similar shares.

The consumption of energy by other sections is given by the living standard and after it reaches an optimum stage it does not change substantially anymore.

The industry keeps a foremost position in the energy consumption. The present energy consumption is derived from its capacities, technical level of the equipment and its control proper; the prospective one then from its further development, rationalization and application of the scientific and research results in the entire production cycle.

Therefore, the industrial sphere is the main field of activity that should reach an optimum stage in the energy consumption through the complex control system of energy consumption whereby the entire all-country balance in energy should be improved or, to enable further expansion of the industry, by energy economization, as the case may be.

2.1 The principle of consumption control

The complex control system of fuel and energy consumption in the industry aims at reaching optimation of production capacities and thermal processes under the condition of minimum energy consumption. Each industrial branch is of a different nature given by the technological process. Therefore, the consumption control system can be most properly applied within the individual industrial branches so that it sould act effectively and completely. Despite that the principle of this system is common for all the branches.

Establishment of a team organization is the basis of an energy consumption control system (fig. No.8). Such a team organization should ensure all the research and technical activity in the principal areas aimed at the energy consuming equipment and should elaborate finally a complex rationalization programme based on the research results, analyses of the consuming equipment and on the optimation considerations.

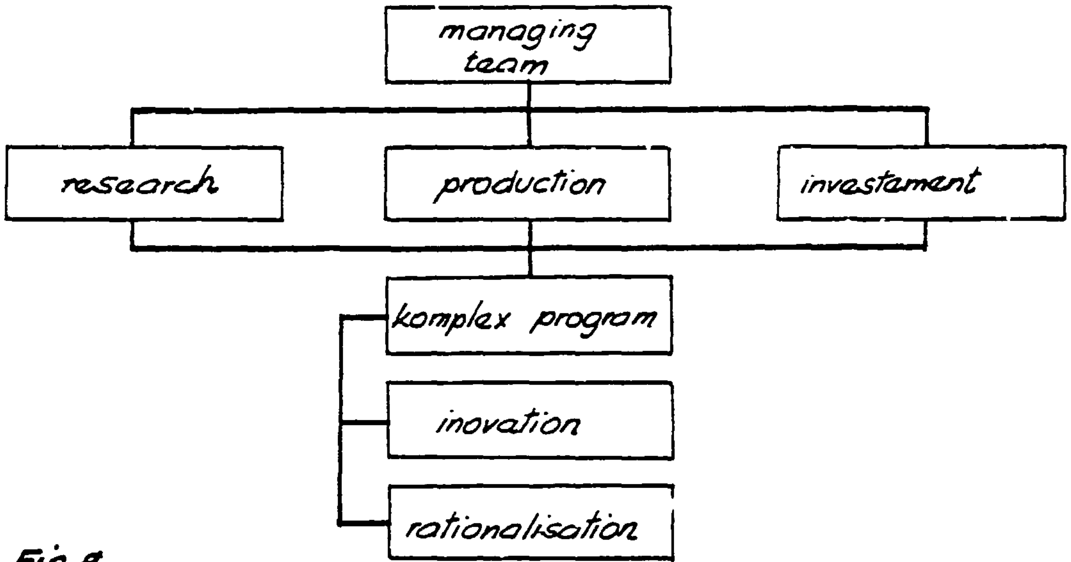


Fig.8

2.2 Managing team

It consists of organization workers and specialists shown hereinafter (fig. No. 9). The main activity of the specialized groups is first of all to elaborate a programme of research and diagnostic work in the individual areas, gathering of the results and processing all the summarized materials and giving proposals for solution.

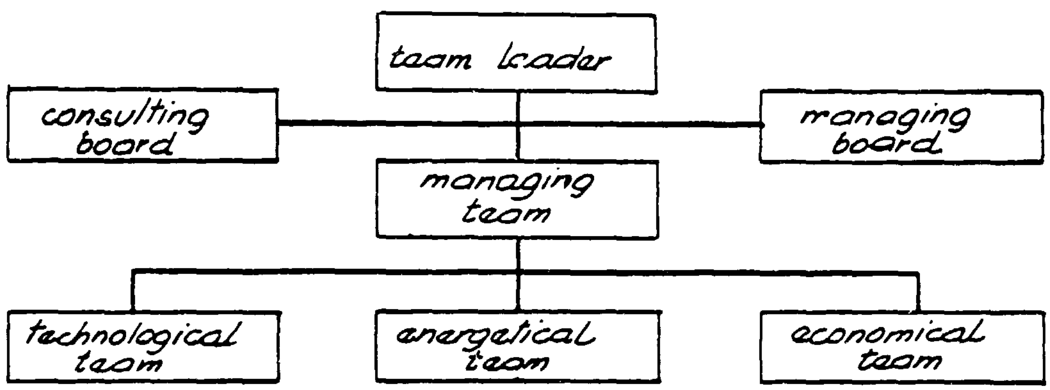


Fig.9

The results of the individual sectional works should be compiled into the proposals for solution, consulted in the oonsulting board and submitted to the managing board. The managing board then takes into consideration the results obtained from the technological, energy and economical teams, summarizes the appropriate proposal and takes a decision on incorporating the proposal into the complex programme including the determination of time and extent.

2.3 Research area

Research and development form a very important area which, when aimed at reducing the energy consumption, plays a vital role in the development of a particular branch. The programmes of the tasks specified by the managing team and solved by the research are classified into two parts - the technological and thermal ones cover the following principal problems (fig. No. 10):

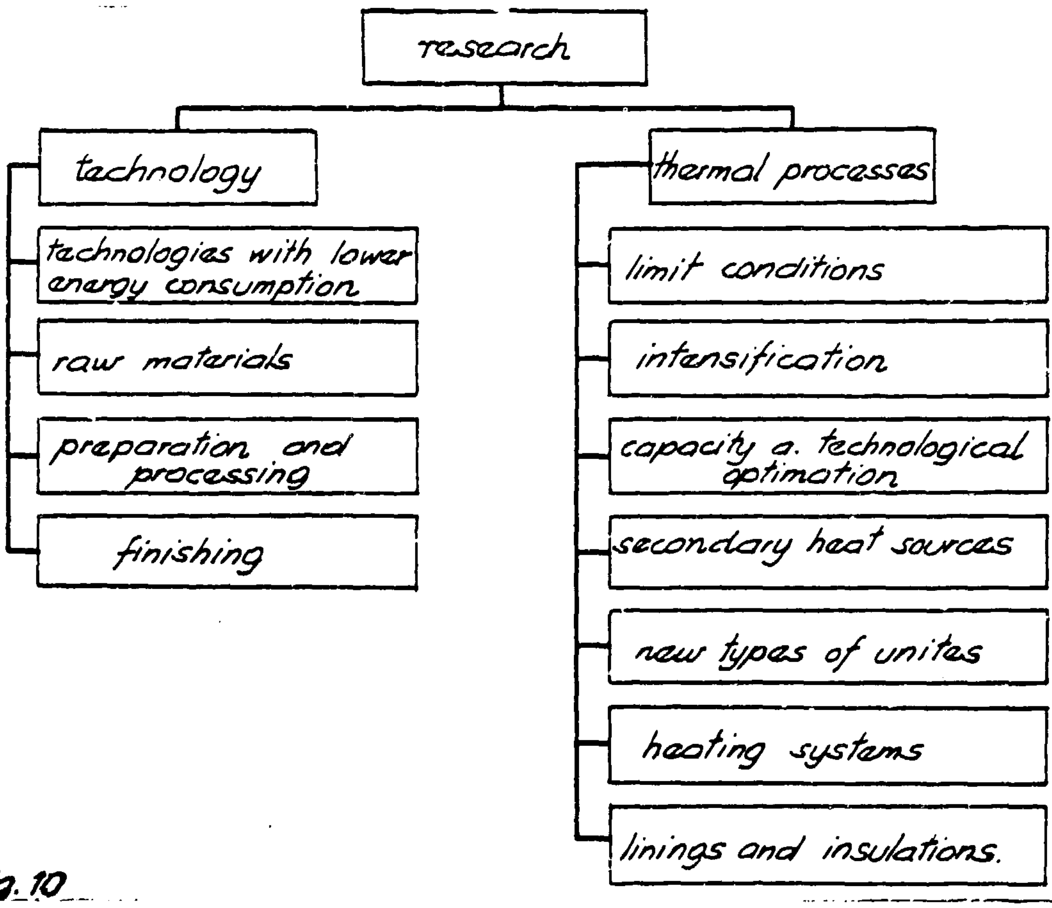


Fig. 10

The research tasks may be, as partial ones, aimed at the solution of some contemporary problem in the production to reach more effective production by means of a reconstruction, changes in technology or by an optimation of the process. Mostly, however, they are aimed at a future innovation programme through which more distinct energy effects should be achieved.

2.4 Production area

The energy consumption control in the production sphere is first of all focussed to a complex diagnostics of the present condition to a detail determination of production conditions and corresponding energy consumption. The specialized teams then work out the initial documents based on the data having been so found out i.e. types of energy, specific consumption and the existing energy standards for each unit. They serve as a basis for the elaboration of a plan and materialization of all types of rationalization actions. For the scheme of the activities see fig. No. 11:

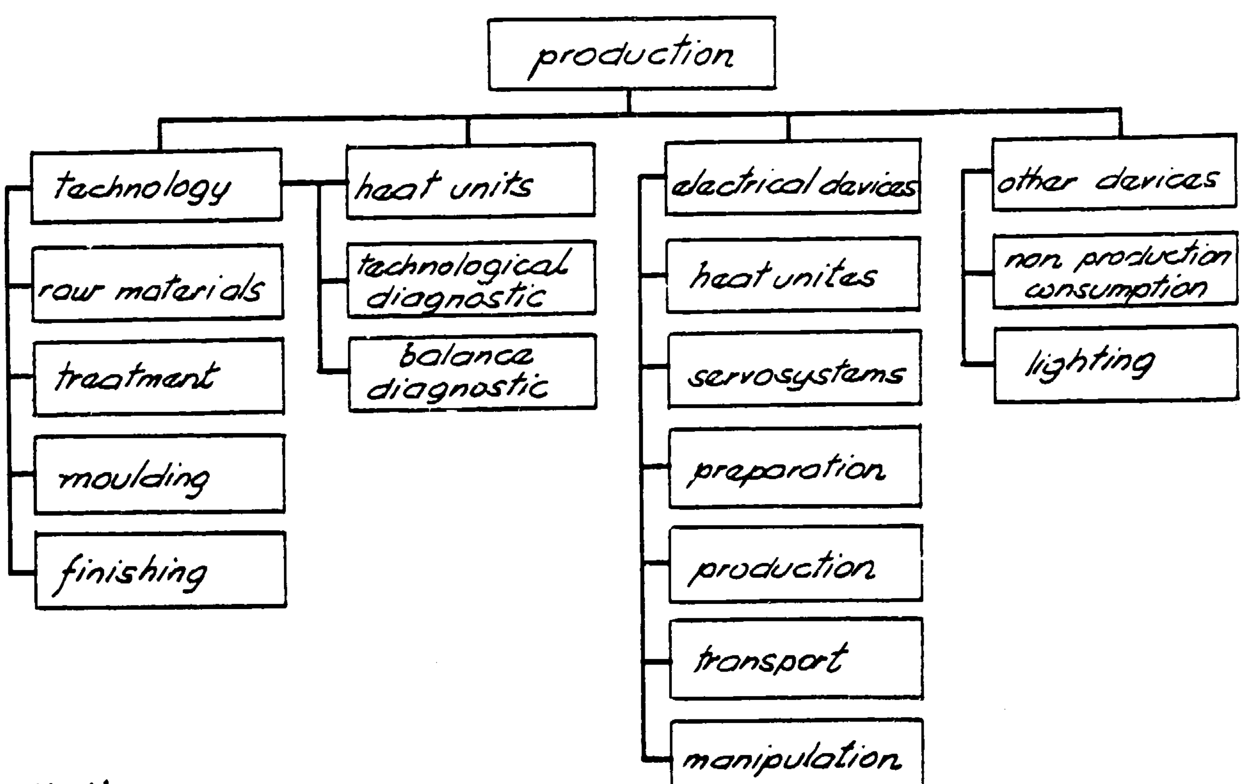


Fig. 11

2.5 Investment area

Plans of the investment development in every branch are derived from the needs of inner market as well as from the export possibility. They secure an innovation programme both for individual pieces of production equipment and by a construction of new workshops or factories. The activity of the energy consumption managing team has a double form in the investment stage. Knowing the existing condition of the production equipment and the results of the research and development the managing team is capable of passing a judgement on any intended investment from the energy requirements point of view whether the energy consumption will comply with the intentions determined by the complex rationalization programme. It is also possible to judge the progressivity of every new technological process in comparison with the existing degree of the world technics.
The scheme of the activities within the investment area is shown in fig. No. 12:

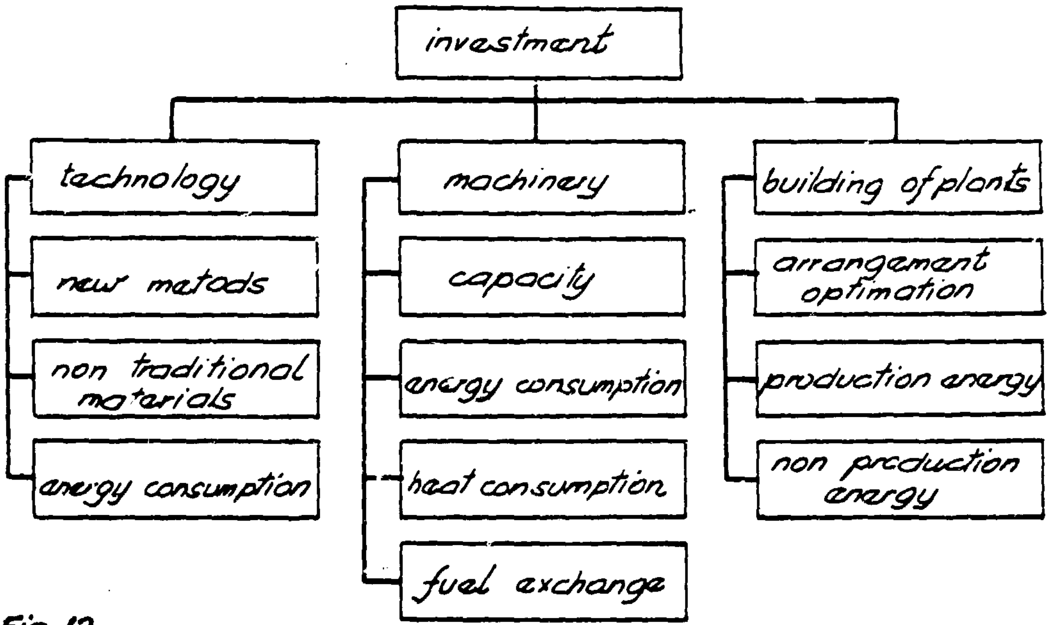


Fig. 12

2.6 Complex rationalization programme

Research, technical and production basic documents from the foregoing stages are coming to the managing team where they are processed carefully.

The diagnostics of the production sphere of a branch enables to get an overall picture of the existing state and how the energy consumption is distributed factory wise, production lines wise down to the individual machines and equipment wise. It also gives data on capacities and technology.

The research and development render the basic information of the present development in the world. The research and development activity in its tasks is to solve new technologies and thermal units applicable in the innovation actions or in the construction of new production lines and plants.

Investment plans and intentions enable to judge further expansion of a branch from the point of view of new technology, sales and, first of all, of the required energy sources and their efficient exploitation.

The managing team elaborates all alternatives of the technical and economical solutions based on these extensive bases and evaluates them economically. The result of it are completely realistic ways of modernization that should secure lower demands for energy. Several solutions on different levels are made for a certain problem.The following alternatives e.g. are elaborated to reduce energy consumption in the firing process of bricks in a tunnel kiln: change in the raw material composition, change in the positioning of bricks on th tunnels cars, optimation of the thermal curve and of the heating system, intensification of the heating, even reconstruction of the unit if necessary, utilization of waste heat and even replacement by a completely new equipment as the case may be. It is a matter of course that several ways may be materialized simultaneously. It is upon the economists and the managing team to decide the time schedule and extent of the whole rationalization action.

The individual stages of these actions may be classified into

optimation of 1st grade
optimation of 2nd grade
and innovation

The optimation of the 1st grade covers all technological and thermal changes in the existing state that, according to the diagnosis results, contribute to achieving an optimum process without any substantial modifications.

The optimation of the 2nd grade covers new technology of lower energy demands, reconstruction of heating systems, utilization of waste heat, intensification of processes etc.

The innovation represents the highest grade and is connected with the implementation of new technologies, change in fuel types, construction of new equipment etc.

Final complex rationalization programme for fuels and energy within a specified branch represents than a set of individual actions being documented technically in details, supported economically and compiled into an accurate time schedule of materialization. It results then in a conclusive programme of progressive reduction of fuel and energy consumption which begins after the diagnosis of the existing conditions and their optimation and ends by the innovation actions. The character of this principle of consumption control is a general one and when worked out for the conditions prevailing in a certain branch it may incur specific changes. Nevertheless, it is the only way how to solve progressive reduction of energy consumption in the industry completely starting from the present conditions up to realistic prospects.

3. APPLICATION IN THE CERAMIC INDUSTRY

The application of the control system of energy consumption in the ceramic industry in compliance with the main principles mentioned in the foregoing chapter may only be introduced when the existing peculiarities of the technological processes of this branch are respected. The system requires certain modifications in research and production; the sphere of investments is identical with the general chart shown in fig. 11.

This modification may then be used as guiding one for all the branches of ceramics where all the technological processes are very similar consisting of the raw material composure, their dressing, preparation and processing, forming by pressing, casting etc., drying, firing and finishing. Under these conditions, when the common principles are duly taken into consideration, the chart of management may be modified in the sphere of research and production in the ceramic industry according to figs. 13 and 14.

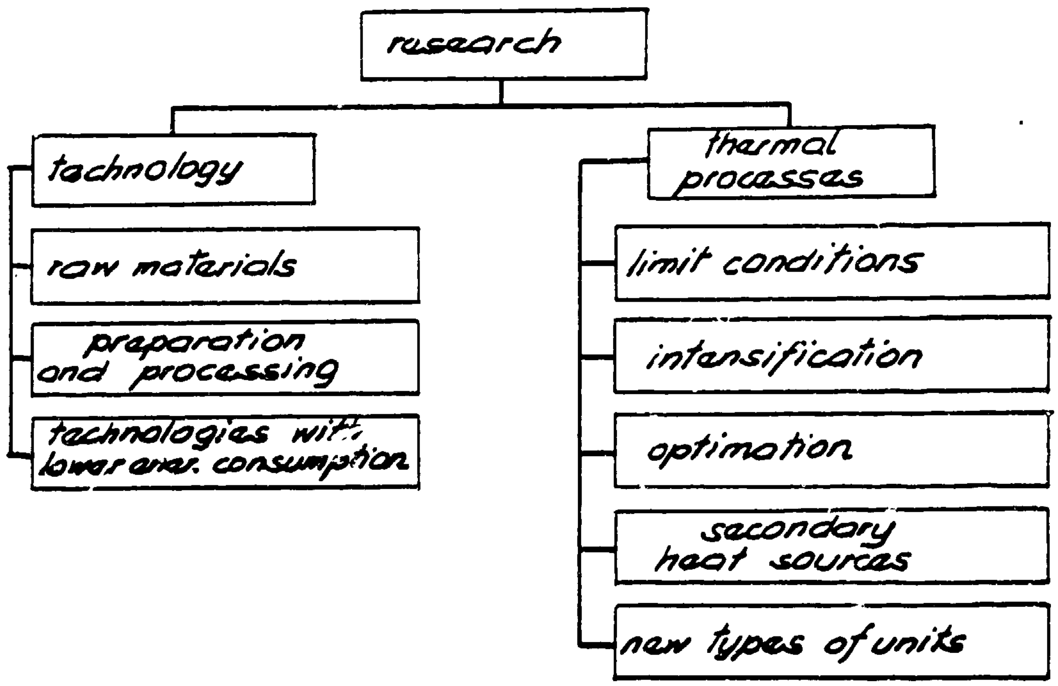


Fig. 13

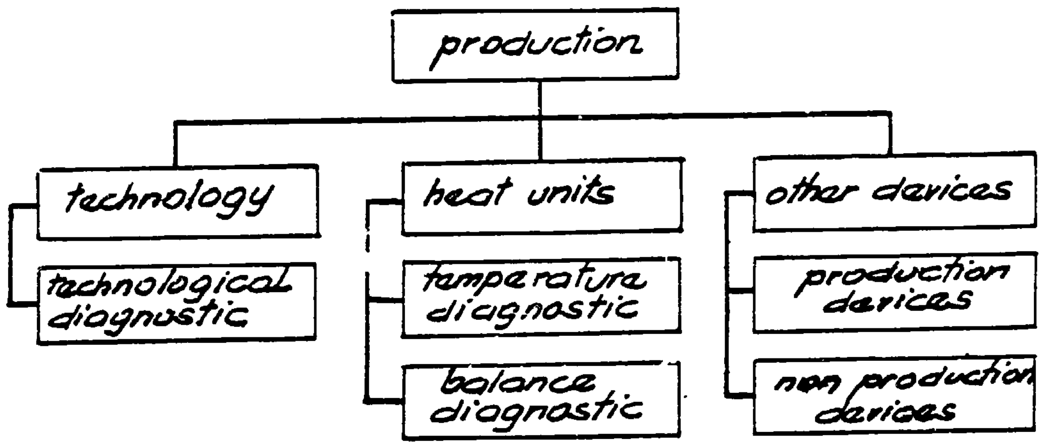


Fig. 14

3.1 Main directions of activity

The basic documents entering the managing team from the production sphere give a summarized picture of the contemporary fuels and energy consumption starting from individual units up to whole plants.
The research then submits proposals for new solutions in raw materials, technology, thermal processes and equipment.

According to figs. 13 and 14 both the groups of activities have common field of interests that may be summed up, from the technical point of view, into the main directions of activity as follows:

technology

- non-traditional raw materials
- new methods of preparation of bodies
- technology with lower energy consumption
- diagnostics

thermal processes

- limit conditions
- intensification
- optimation

thermal equipment

- diagnostics
- heating systems and linings
- new types of units

secondary sources of heat

- minimizing of waste heat
- use in other units

other consuming devices

- for production
- non-production

climatic conditions

3.2 Technology

The properties of input materials and applied raw materials in many industrial branches are so constant that no significant effect could be achieved in the energy demand for various products by modifying the composition of raw materials or their preparation process. However, possible use of non-traditional raw materials for new body composition may be found in the ceramic industry to enable a reduction in maximum processing temperature or cut down the firing time. It is also possible to combine the firing process of body and glaze of the tiling materials into an one-fire process by suitable composition of the body and glaze having formerly been fired in two separate firing processes. The classical building materials fired under high energy consumption can be fully replaced by the newly developed refractory concretes and plastic unshaped masses which need not be fired for the use in the construction of furnace and kiln linings.

Possible modifications in technology aimed at minimizing the energy consumption can be done practically at every ceramic product. Within the extent of this material, however, only several typical possibilities of solution can be pointed out.

Tiling ceramic materials

Reducing the firing temperatures, cutting down the firing time and transition from a double-firing to one-firing way of production belong to the possible forms of energy conservation.

Wall tiles

The development of the firing temperatures and the firing cycle from the time point of view in the technology of the double-fired wall tiles having been existing so far are shown in table No 1.

Table No. 1

	bisque firing		glaze firing	
	Temp. °C	Time (hrs.)	Temp. °C	Time (hrs.)
After the World war II	1280-1300	60-120	1120-1160	24-48
beginning of 60'	1230-1250	24- 68	1100-1120	3-24
at present	1050-1080	1- 48	1020-1040	1-24
prospects by 2000 y.	1000-1020	0.5	900- 960	0.5

Similar to the majority of ceramic materials the wall tile bisque is based on the combination of traditional materials

- kaolinite, silica and feldspar. Generally, however, these materials require relatively high firing temperature.

Both from the energy and technological point of view, the transfer towards a non-traditional lime-siliceous body with a lime or marlstone is interesting for which the firing temperature can be by 200° C lower. Energy can also be saved by replacing fired kaolin with a non-fired one.
For the raw material composition and the effect on the firing temperature may clearly be seen in table No.2.

Table No. 2

Raw material %	Kaolinitic body	Lime-siliceous body	
		with lime	with marlstone
Clay A	20	15-20	10-15
Clay B	20	15-20	10-15
washed kaolin	10 - 15	0-10	0-10
raw kaolin	-	30-40	30-40
fired kaolin	38 - 43	-	-
marl	-	-	30
lime	-	15	-
fired breakage	6 - 8	6 - 8	6 - 8
firing temperature °C	1260	1050 - 1080	1050 - 1080

Hence, by utilization of the non-traditional raw material in case of wall tiles the energy can be reduced by 8 - 12 % owing to the reduced temperature as well as to practically half of time required for the firing stages.

Glazes, too, like bodies, are undergoing a development. Non-transparent zirconium glaze made on the basis of feldspars and used in kaolinitic bodies was fired at 1120° C. The lime-siliceous wall tile body needs a development of a new glaze based on sodium-calcareous feldspars for which the firing temperature reaches 960 - 1040° C. Zirconium glaze belongs among the well-proved glazes at which $ZrSiO_4$ oxide has been introduced into the frit body the basis of which are the sodium feldspars. The glaze gets molten as early as at the temperature of 960° C.

The development of glazes, however, has not yet been completed and further reduction in the firing temperatures may be expected to as low as 900° C.

Floor tiles

Semidense glazed and unglazed floor tiles are quite a widely used type. Classical technology is based on using a raw and washed kaolin and clays of low meltability. The firing temperature at a usual body moves in the vicinity of 1250° C.

These floor tiles are the products at which the firing temperature can be reduced by using non-metallic raw materials with a melting effect. The use of phonolite (table No. 3) is an example enabling the reduction of the temperature down to 1100° C achieving thus about 10 - 15 % savings in energy consumption.

Table No. 3

Composition in %	Usual body	Body with phonolite
Clay A	35	40
Raw kaolin	10	30
Washed kaolin	25	-
Phonolite	-	30
Feldspar	30	-
Firing temperature °C	1250	1100

The implementation of one-fired method of firing of glazed floor tiles of this type is of an extraordinary significance in the energy conservation. The combination of firing the body and glaze has been enabled by further modification of the phonolite body while choosing a suitable glaze.

Single-layer firing in a conveyor line takes place after the drying and glaze-firing at the temperature of 1050° C the time-cycle being one hour only. While considering that the double-firing method needs the thermal energy of about 1400 - 1950 kcal/kg this value at the one-firing method is reduced to mere 900 - 1100 kcal/kg. The savings in energy represent thus as much as 40 % of the original energy consumption.

Stoneware

Low-heat kaolinitic clays containing about 4 per cent alkalis are a suitable raw material for the manufacture of stoneware products. Depending on the required plasticity they are used either directly or with the addition of grog (silica sand, fired shale etc.).

Fluxes again are used to reduce energy demands that leads towards technological changes. Suitable finely ground fluxes to be used in stoneware are e.g. marlstone, phonolites, tuffs and tuffites, perlite, dolomite etc. In case of stoneware used for tiling purposes the firing temperatures can so be reduced by about 100° C whereby 8 % energy saving can be achieved.

The composition of bodies for the manufacture of stoneware tubes is shown in table No. 4 and the effect of adding marlstone and phonolite on the reduction in firing temperature may be noted.

Table No. 4

	Body		
	current one	with marlstone	with phonolite
Clay A	47	31	32
Clay B	47	31	31
marlstone	-	32	-
phonolite	-	-	31
stoneware breakage	6	6	6
Firing temperature °C	1250	1160	1080

China

The efforts to achieve energy savings in the manufacture of china, as against other groups of ceramic products, encounters certain tradition in quality, well established technology and rather stable raw material basis.

The products having been made so far are represented by a feldspar china which can be classified according to the firing temperature into soft one (1320 - 1380° C) and hard china (1380 - 1460° C).

It is indispensable in the technology to make separate bisque firing and separate glaze firing inclusive of the reducing atmosphere within the range of 900 - 1200° C.

It may not be insisted that there are no ways of modifying the china body composition which may result in energy consumption. In case of the soft type of china with about 15 % of clay content a clay with higher proportion of alkalis may be used but the savings in energy will not be quite distinct. In case of the hard type of china there is a possibility of replacing a part of feldspar with nepheline-syenite whereby the energy saving will thus amount to about 10 per cent.

Refractories

Fired shaped bricks made on the basis of refractory clays and fired shales are the typical products. Specific heat consumption in the drying and firing processes amounts to 750 - 1350 kcal/kg depending on the type of products. Possible reduction in this value by technological way is rather insignificant. Any use of raw materials with lower sintering temperature would result in deteriorating the refractory properties. Certain possibility may be seen in partial replacement of fired shales by the unfired ones.

The present stage of development, however, offers a possibility of complete removal of fired refractory clay and replace it by unshaped, unfired refractory masses - plastic ramming masses and refractory concretes. Both the groups enable to make monolitic or prefabricated linings while these masses get their final properties during the period of putting the kiln into operation.

Ramming masses with chemical or chemical cum ceramic bond are of the form of moist plastic mass, refractory concretes on the basis of aluminate cements are supplied as dry mixtures.

By producing these refractory masses the so far supplied fired refractory clays and other fired types of materials are practically completely replaced.

Brickware

There exists practically no possibility to reduce energy consumption in the technology of the brickware manufacture. The raw materials of the individual plants are given by the nature of the clays being used as well as by the grog added in the form of sand, clinker, ashes, coal etc. The raw materials are usually optimized to achieve the required properties. The only possibility lays in reducing the moisture in the body but the result is insignificant.

As aforesaid, in the majority of ceramic products there exist considerable chances to reach energy conservation through changes in the traditional composition of bodies or in the technology of the firing process. It goes without saying that these changes must be completely verified by research and the respective production conditions adjusted accordingly before implementing them into the production process.

3.3 Thermal processes

The foregoing chapter has shown the bases and possibilities of technological changes in the composition of raw materials for the ceramic products aiming at the reduction in energy consumption. The indispensable research in this direction must result in an optimum raw material composition while achieving the lowest possible firing temperature and respecting the raw material localities, accessibility, efficiency of winning and an overall economy. It is a unconditional for the technological research to accomplish a product of the required properties. In this stage the time curve of the temperatures during the firing is not decisive but only the height of the firing temperature and its dwell are important.

Limit conditions of the firing

The temperature curve in heating, firing and cooling processes in many a thermal unit being in operation has been derived from long-years production experience that suited both the type of unit and the quality of the fired goods. These so called technological thermal curves of the firing process, however, do not correspond any longer to the most cases of technology that enable to make products of the required quality. Structural changes accompanied with the forming of internal stress in the ceramic body proper take place in the heating and cooling zones of the firing process.

They depend first of all on the speed of heating and cooling, hence, on the time changes in temperature. The knowledge of the maximum conditions of the heating and cooling, i.e. of the limit temperature curves is of utmost significance to enable an intensification of the process,i.e. of shortening of its time. Such a process can be shortened and applied in old thermal units such as in tunnel kilns by accelerating the cars passage and by modifying the heating system as well as in case of new kilns having already been constructed in compliance with a new temperature curve.

Limit temperature curve means maximum rise in temperature during the heating and cooling processes without affecting adversely the quality of the product being so fired. This curve should be determined first in a laboratory with the use of a product of optimum raw material composition. Such a product should be exposed to an intensive heating in the kiln space under the condition of heat transfer from all sides. The time consuming tests result then in a limit firing curve set for the particular material.

The experience we have had so far has shown that there is quite a considerable difference between the limit curves and the so called experience-proven technological curves chiefly in the time stages of the heating and cooling processes. Hence, the limit curves establish an important document for the following intensification of the thermal processes.

Intensification of the firing process

The determined limit curves have shown the limit values for a quick time course of the firing process at a multi-lateral heat transfer. Such a way of thermal process, however, can only be applied in new types of kilns with a single-layer arrangement of products in the firing zone. Older types of firing kilns for instance the high-capacity tunnel kilns have the material loaded very much densely on the tunnel cars that does not allow to achieve temperature changes given by the limit. The considerable thickness of columns of the wall tiles or floor tiles to be fired causes shading of the inner parts of the load, their slower rise in temperature whereby also difference in temperatures along the cross section of the kiln.

While speaking of intensification it may evoke erroneous opinion that it will result in high consumption of energy. However, the time factor must not be forgotten - it changes. For instance, to achieve a rise in temperature of goods under the former technology the thermal input required is Q_1 for the period of T_1, for the intensified process it is Q_2 for the period of T_2. The product of input and time is decisive for the consumption of energy since T_2 is lower than T_1 in case of the intensified process the higher thermal input can thus be applied for a shorter period. And now three basic cases of solution may happen. At first the intensification would be performed at a higher consumption of energy where $Q_2 \cdot T_2$ would be higher than $Q_1 \cdot T_1$. This case, however, is undesirable from the energy point of view. The intensification in the second case would be take place at an identical energy consumption , i.e. $Q_1 \cdot T_1$ will be equal to $Q_2 \cdot T_2$. From this the input can be derived: $Q_2 = Q_1 \cdot \frac{T_1}{T_2}$. And finally, energy consumption in the third case should fall ($Q_2 \cdot T_2 \quad Q_1 \cdot T_1$) and the process could yet be intensified.

The first and second examples are uninteresting for us because they do not result in energy saving but even opposite - in its rise. Therefore only such intensification may be interesting at which the energy consumption is lower in its individual stages, the heating will take place at a higher thermal input but for a shorter time.

The aforesaid consideration is fully applicable for the intensification of the processes in the existing kilns but it also is decisive for the construction of new kilns.

What level of intensification is to be determined - it is the question of judging the conditions existing in a particular kiln, i.e. by a reserve the heating system has, by the improvement of loading to obtain better heat transfer into the material etc. By due judgement of all factors the optimum conditions can be achieved for the intensified heating and the respective saving of heat can be derived.

Optimation of the firing process

The intensified firing process within a shorter time and with a higher input e.g. in tunnel kilns does not entail any longitudinal changes, just an accelerated movement of cars will suffice.

The first condition is to explore the feasibility of an increased thermal input, That may be arranged for either by an existing reserve in the input of the burners or replacing them for those of higher input or by changing a fuel for a higher grade one. Mostly, however, the input can be arranged for without any substantial modifications.

The second condition is an improvement of the function of burners. The existing types of burners ensure the transfer of heat into the material mostly by radiation into the lateral layers, another transfer is by heat conduction through mutual contact of the loaded products. The intensification, however, needs more perfect heat transfer which can only be ensured by convection of heat within the kiln space. This can only be enabled by burners with high outlet velocity of combustion products which, by flowing round the products, transfer their heat substantially faster and more uniformly.

The third condition is a suitable loading of the products in the kiln space or on the cars. The densified loading done so far does not allow a good circulation of combustion products in the kiln space, couses excessive firing of the marginal products and, to the contrary, imperfect firing of faces being shaded.

Hence, the intensification needs to arrange for such a loading so as there should be formed systematically distributed gaps to allow proper flow of the combustion products. It goes without saying that by looser loading the weight per 1 sq.m. of the kiln or car area is thus reduced. That cannot influence the total production capacity of the unit because the whole firing cycle has been thus shortened.

Similarly, as we speak about accelerating the firing process the cooling process can also be shortened and intensified. It ensues from the experience in limit curves that ceramic materials can be cooled down much faster than it has been done so far.

When we sum up the aforesaid conditions for the intensified firing and when we specify the attainable values and when we judge them mutually we obtain the determinating factors for an optimum thermal process. The difficult work does not rest in the materialization part proper so much as first of all in the research part in which the limit conditions of the firing process, intensification conditions and, finally, the optimum of the given thermal process should be derived.

The system of energy managment enables to a full extent to solve the intensification of thermal processes that results not only in significant savings of energy but also a modernization of the thermal equipment without extensive modifications.

3.4 Thermal equipment

The technical level of thermal equipment plays the most important role in the system of the energy conservation management in the ceramic production branch. The ceramic kilns and driers cannot be all of peak level in all countries since it depends on the level of industrial development and on the intensity of modernization the equipment is. There are everywhere kilns and driers of different year of construction, hence, kilns may be modern, medium technical standard and even kilns absolete. From the energy conservation point of view the latter two types are in the focus point of interest because, under the present conditions, they do not work economically any longer and they have to be modernized to some certain extent. Only a detail diagnosis of their operation may give an answer up to what extent they do not operate economically and how they can be usefully modernized.

Diagnostics of the thermal equipment

A detail analysis of the present condition of all pieces of thermal equipment and specification of energy demands for their operation form an essential input part of further activity within the energy consumption management system.

In order to make an expert measurement of a thermal equipment a set of measuring instruments and a team of trained specialists in the field of measuring and thermal equipment are required. A mobile unit outfitted with the necessary instruments, data collecting centre and evaluating computer that can be moved in the vicinity of the equipment to be measured is an optimum arrangement. By direct connection between the sensors at the measured points and the instruments of the mobile unit the measured values can be watched centrally and their evaluation can be done quickly. The Diagnostic Mobile Unit of the Ceramic Research Institute at Pilsen is a suitable type for this purpose. Its service activity in the enterprices within the Czechoslovak Ceramic Works has already brought about results in the energy conservation.

From the point of view of energy management centre the activity of such a diagnostic unit must first of all be aimed at specifying the energy balance of an equipment, i.e. to find out the input as well as the output energy. A technological diagnostics is also important - it verifies the temperature time curves of the entire technological process.

While specifying the energy balance by a measurement e.g. in case of a kiln the following basic data are to be found out:

thermal input - it is derived from the consumption of fuel and its calorific value

thermal losses - in a chimney be draughting the combustion products into open air
- by accumulated heat in the goods and into the lining
- by leakage through the kiln walls into the open air
- by leakage into the kiln foundations
- technological for physical and chemical transformations of material
- by cooling air in the cooling zone of the cycle

auxiliary values - stechiometry of combustion
- pressure conditions inside the kiln
- regulation of the drought conditions
- kiln performance in terms of kg of material per hour.

When the time curve of the temperatures of the whole cycle is to be verified for the control of the firing technological curve a suitably positioned thermocouples are used inside the chamber furnace or in the goods loaded on the car of the tunnel kiln. The thermocouples are connected by means of a compensation lead with the registration instrument and the whole time curve of the temperatures is thus recorded. It serves for the derivation of the thermal difference between the individual measuring points as well as the deviations of the measured curve from the prescribed one.

After some time of operation every thermal equipment is "detuned" to certain extent i.e. it does not operate under optimum conditions. It is caused mainly by some irregularities in the operation, imperfect operators, etc. It is the first task of the diagnostic unit and team to recrify these discrepancies. It means that the initial measurement of the kiln or drier may be considered as controlling one its purpose being to detect and rectify all shortcomings hempering the optimum operation.

In this stage no changes or modifications are made in the equipment construction but only its burners and fans are adjusted, the draught of the combustion products is tuned up and other regulation devices set up. That all can be reliably performed at the time of reading it on the measuring instruments.

By control measurement and simultaneous adjustment we can get a document of the economy of the equipment being measured summed up practically into single value -

specific heat consumption

related in kcal per kg of heat treated product. By that we also will know how the individual types of energy loss are distributed and the complete control of all temperatures.

The values having so been obtained they will show the energy cum technical condition of the equipment and will thus enable to compare it with other similar preces of equipment and to classify so its overall economy.

The optimation measurement and adjustment of the equipment are not the single activity of the measuring team. Similar measurements have to be carried out when new technological processes are implemented, after the equipment has been reconstructed and even at new kilns and driers within the framework of verification of the guaranteed parameters.

The measuring team, on the basis of its expert knowledge, works out also the main principles for the first two degrees of modernization, i.e. operation modifications of the equipment and reconstruction. The overall judgement of these suggestions, however, falls under the competence of the management team.

Modernization of the thermal equipment

At the time of the industrial development when the cost of energy was not such an important item in the whole economical balance the thermal equipment was constructed first of all to ensure the technological process, high durability and simplicity while the heat losses were an item of a low importance. Producer gas was mostly used as fuel, the linings were heavy the reason for which was given that it was indispensable for maintaing a stability at high temperatures.

The problem of ensuring energy sources has caused a distinct change in the conception that may be characterized by two principles:

- automation of the thermal process and
- minimizing the heat losses.

This technical philosophy is the only correct way of further development. First of all, it eliminates the human factor from the management of often considerably complicated thermal processes and ensures an optimum operation of the equipment. Minimizing of the heat losses is indispensable even on the account of higher investment and maintenance costs because, in case the world energy crisis would grow deeper, the industrial activity in various branches will have to be reduced. Under these circumstances then only such equipment with the lowest energy consumption will be left in operation for the longest time.

While speaking about modernization of kilns, it is necessary to speak separately about electric resistance kilns, chamber and tunnel kilns.

A partial switchover to electric resistance kilns up to 1200° C temperature was the accompanying phenomena in the modernization of kilns in ceramics.

The heat radiation method required a single-layer arrangement of products so that it has progressively developed up to the present types of firing kilns for tiling materials.

The substantially reduced energy consumption was a considerable advantage of the electric kilns because there are no chimney losses and the losses due to heat leakage to open air and through accumulation are at minimum level. The regulation system of the individual zones also is simple and perfect.

The development of chamber kilns was not so significant. They can be used for some products only (refractory shaped bricks, insulator) and most of these kilns have only survived from the past. For the above mentioned special cases there is a switchover to combined car - chamber kilns having minimized weight of lining and new types of burners.

Gas heated tunnel kilns having been the most widely used high capacity kilns so far have noted the highest degree of modernization. City gas and natural gas are the fuels today that enable tu use an automatic heating system. In the new types of high-speed burners the air - gas ratio is controlled automatically and as for the output the burners are regulated by control sensors with a feedback. All the automatic and regulation are centralised. New types of burners enable better heat transfer inside the kiln and remove former muffling. The lining of these kilns and cars is made of high quality and insulating materials which minimise the heat losses. The methods of regaining a part of the waste heat from the combustion products and from the cooling air have also been considerably improved. Kilns are designed to the conditions of an optimum heating and to the specified output. Hence, the development of kilns has passed an extensive research and expecially the latest types show extraordinarily low specific heat consumption.

The majority of old kilns is not in such a condition lest their economy could be improved by any degree of modernization. One of the main possibilities is to replace the producer gas by city gas or natural gas and by reconstruction of the heating system i.e. of burners, gas and air distribution systems. Thereby, conditions are created for the application of a regulation system controlled by the measurement of temperatures at the same time. Another possibility is an improvement in the insulation properties of the lining by using an additional insulation layer. A part of heat can be obtained from the outgoing combustion products by using a heat exchanger. Accumulation losses in chamber kilns can be reduced by applying an additional lining made of ceramic fibre products to its heat side. Similarly, the weight of cars lining can be reduced, too.

There exist a number of partial modifications of the equipment which can more or less contribute to the improvement of energy conservation. Several innovation degrees can be worked out for every case. It is a matter of course that it will require different amount of expenses and different effects. All such alternatives must be well based on proper documentation and they should be evaluated technically and economically so that the managing team should have available reliable decision-making documents of the energy consumption.

3.5 Utilization of waste heat

Heat coming out from the combustion products, cooling air or air from the driers constitutes important so called secondary sources of heat that were not made use of till recently. Many kilns were built in times when the opinion regarding the utilization of waste heat was not influenced by endeavour to its obtaining but, to the contrary, negatively by constructing additional equipment, increase in expenditures etc. The present situation in energy, however, requires a maximum utilization of these sources.

The heat from the cooling zone of kilns is being utilized to greater extent nowadays. The medium is a clean or little impurified dry air of 100 - 200° C temperature being suitable for direct utilization in drying of a body or of pressings. Furthermore, it may also be used for heating of workshops either directly or by using a heat exchanger in case the air is not clean.

Drying of goods in the ceramic industry is an integral part of the heat treatment of practically all types of the products. When the heat of the cooling air is not used in the kiln directly as a heated primary air for burners or in the preheating zone, it is most suitable to use it for drying as a secondary source in combination with the regulated source. Driers and kilns are usually so situated that it mostly enables a direct connection of the two units without any substantial losses by transportation. The heat of the cooling system of a kiln represents usually 10 to 30 per cent of the rated input. An input of the current tunnel kilns for the firing of e.g. wall tile bisque ranges usually from 0.9 to 1.7 mil. kcal/hr. When 50 per cent of heat from the cooling zone is utilized we may gain as much as 250.000 kcal/hr of thermal output.

Combustion products from the ceramic kilns are a source of waste heat being less utilized. Their temperature is comparatively high but their chemical composition is not suitable to be utilized directly, i.e. an icreased proportion of carbon dioxide (CO_2), carbon oxide (CO) and sulphur oxide (SO_3). While cooling the combustion products below their dew point weak acids are formed which cause a corrosion of the metal equipment. For this reason the thermal energy of the combustion products by air offers a certain possibility of their use in burners as combustion air. The effect, however, is insignificant. Installation of a heat exchanger in the exhaust of the combustion products is another possibility as far as the exhaust fan has high enough reserve in its output.

The fact that the combustion products can be cooled down to the temperatures above the dew point only at the cost of high investments reduces the number of cases of utilization to those only where it will be advantageous from the economy point of view.

Driers of ceramic bodies and products are the third significant source of the waste heat. The temperature of the outgoing air ranges usually between 50 and 160° C temperature and the loss by this air mostly amounts to 20 - 50 per cent of the drier output. Direct utilization of this air is out of question mostly due to a high content of impurities and increased relative humidity.

A little more favourable situation is in such cases where the amount of impurities contained in the air is negligible. For the temperature zones and a certain quantity of waste heat, heat exchangers based on closed thermal tubes, rotary exchangers or some classical types are suitable.

Apart from the aforesaid secondary sources of heat there exist a series of other sources in the ceramic industry being specific for various types of production. Therefore it is essential to focus attention in this sphere to revealing all possibilities of utilization of wate heat and to materialize them everywhere where it is advantageous. In the sphere of utilization of waste heat it is imperative for the technicians and economists of the managing team to assess these cases and incorporate them progressively into the complex rationalization programme.

3.6 Climatic conditions

New projects of thermal equipment are designed on the basis of detail specified main parameters determined according to the detail technological analyses, optimation considerations and investment studies.

These data cover also values specifying the climatic conditions, first of all the temperature, humidity and atmospheric air pressure and their changes during a day as well as in the course of the whole year. In the conditions of minimum changes the calculations of the equipment include their average values. It is fully acceptable e.g. under European conditions where the thermal equipment is operated in enclosed indoor areas where the ambient temperatures change very little. However, even these relatively small changes e.g. in the temperature of outside air play a more significant role in case of drying equipment. This equipment has to be oufitted with an automatic control for the optimation of their operation during the summer and winter seasons.

The difference of climatic conditions is more distinctly noted at equipment installed in the developing countries of Asia, Africa and Latine America where the daytime temperatures are high and their difference during the day is quite considerable. In these cases it is necessary to take these climatic conditions into consideration as early as in the project design of the kilns and driers and to determine their regulation within the respective limit values.

The optimation of the thermal equipment operation deserves in this sphere, too, a sensitive attitude towards the solution in the interest of rationalization in fuels consumption.

3.7. Other consuming units

Thermal inputs of kilns and driers are not the sole sphere of the energy consumption. Each of these pieces of equipment is outfitted with a number of electric motors to drive fans, cars movement, door lifting, rollers movement, operation of the measurement and regulation instrumentation. Their energy consumption is also significant and cannot be neglected in the overall balance. Therefore, the energy consumption is expressed separately in two items - fuels and electric power.

The possibility of optimation and economization in the sphere of electric consumers is rather small. Most of the electric driving motors are designed in compliance with the actual requirements and it is then only a question up to what extent they are suitably timely switched on to prevent losses in their idling.

The present level of technical knowledge in this sphere has already enabled an application of a number of control and regulation elements resulting in really optimum timely utilization and, thereby, minimizing the energy consumption.

Nevertheless, it is indispensable to examine all the electric devices necessary for the operation of the thermal equipment so that even the electric power consumption should be minimized in this sphere.

4. COMPLEX RATIONALIZATION PROGRAMME

It ensures from the data mentioned in the main trends that the extent of the activities to manage the entire sphere of energy consumption rationalization the establishment of the managing team is indispensable. It must also cover the follow-up activities of other groups of research workers, technicians and production workers. Under these conditions only the outlined survey of all possibilities leading towards energy conservation may be achieved, evaluate them and elaborate the complete rationalization programme. This programme must be worked out in details down to individual actions showing the extent, time schedule and economical results. The summerized data should specify the total costs in connection with the materialization along with the gradually gained amount of fuels and energy.

The above mentioned management system may provoke thoughts of considerable financial means spent on its implementation. However, it is to be taken into consideration that similar activity is carried out nowadays in the local plant conditions without any relation to the problems within a whole branch. It is, therefore, a sole way how to solve a progressive reduction in energy consumption in the industry under present conditions to a full extent and up to a realistic prospect.

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