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UNITED NATIONS INDUSTRIAL DEVELOPMENT ORGANIZATION
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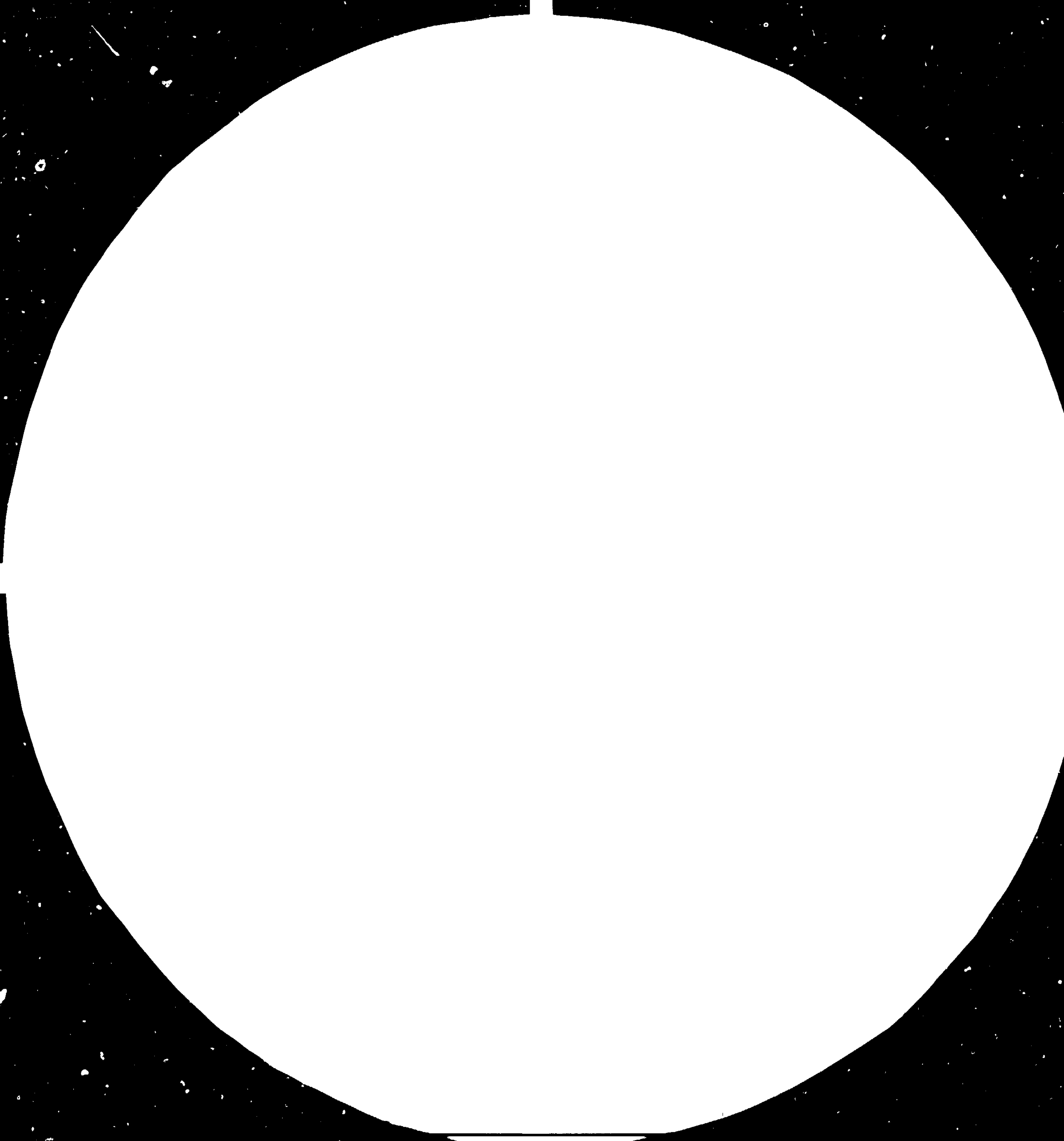

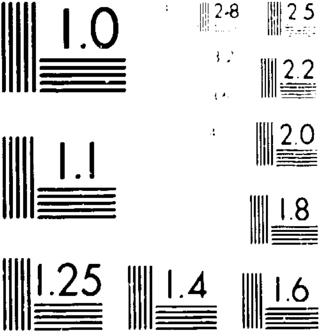
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by: Milan Nový +/

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+/ Research Institute for Ceramics, Refractories and Non-metallic Raw Materials, Pilsen, Czechoslovakia

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1. INTRODUCTION

Limited energy sources evoked the need to pay attention to the energy management in the consumption of energy all over the world. Energy conservation is therefore very actual programme for all countries in all branches of industrial production.

It is in the field of silicate industry where the solution of energy saving problems is the most important and urgent due to its relatively high specific energy consumption. Detailed knowledge of technical and operational conditions of heat consuming unit forms the base for measures tending to the energy savings.

For obtaining of the necessary technical data of a thermal unit operation the mobile diagnostic unit (MDU) of the Research Institute for Ceramics, Refractories and Non-metallic Raw Materials at Pilsen is used by the team of specialists. This unit is the main implement of the objective determination. It enables to find out directly, under the working conditions all the outside and inside circumstances and conditions which influence the optimal energy consumption in a technological plant. Every type of a heat consuming unit requires the application of the modified measurement set by using suitable measuring and recording techniques. The sets of values obtained under common working conditions being completed with the basic information of technological parameters of the production unit and fuel consumed are then objectively evaluated in energy conservation study. This study agrees with the user of a heat consuming unit as an indispensable basis for his further technical, operational and organizatio - nal measures and steps to reach advisable energy savings, production intensification, improvement in the quality of the products and reducing the rejects occurence.

2. TYPES OF MEASUREMENTS EXECUTED

The diagnostic measurements executed with the use of MDU by the team of specialists can be focused to two main fields : either to minimize the energy consumption or to optimize the thermal technological process. It is a mat - ter of course that both these fields are closely connec - ted. Due to this connection it is recommended to make both energy and technological measurements and surveys coincidentally to be able to prepare to the user an objec- tive and complex statement and to draft all suitable and recommendable adjustments and changes which are to be realized for its perfect and effective service. The MDU is used most frequently for testings of all types of kilns and driers, but boilers, gas producers and heat exchan - gers are tested as well.

The basic information for minimalization of energy consumption of a thermal unit is the heat balance of tes- ted equipment. Heat balance includes all items entering the tested unit and all items leaving the unit in the form of heat energy. Graphically is the heat balance expressed by Senkey's diagram(Fig. 1). To find out the heat balance of the unit all the qualitative as well as quantitative values of applied energies and all kinds of thermal losses are measured. Very important index showing the operation economy of the heat consuming unit is specific consumption of heat energy. It expresses the amount of heat energy necessary for firing 1 kg of ware or the amount of heat energy necessary for evaporation 1 kg of water (in drier).

For optimalization of the thermal technological process the knowledge of firing (drying) curve and temperature distribution in profile of the kiln (drier) is essential (fig.2).

Whatever the aim of the testing is i.e. energy conservation or thermal technological process optimalization the activities performed include following three stages:

- statement of the operation conditions of thermal unit, performance of objective tests and functional measurements
- evaluation of performed tests and measurements
- working out proposals for technical, energetic and, if need be, operation-organizational arrangements or recomandation on heat balance on reconstruction purposes

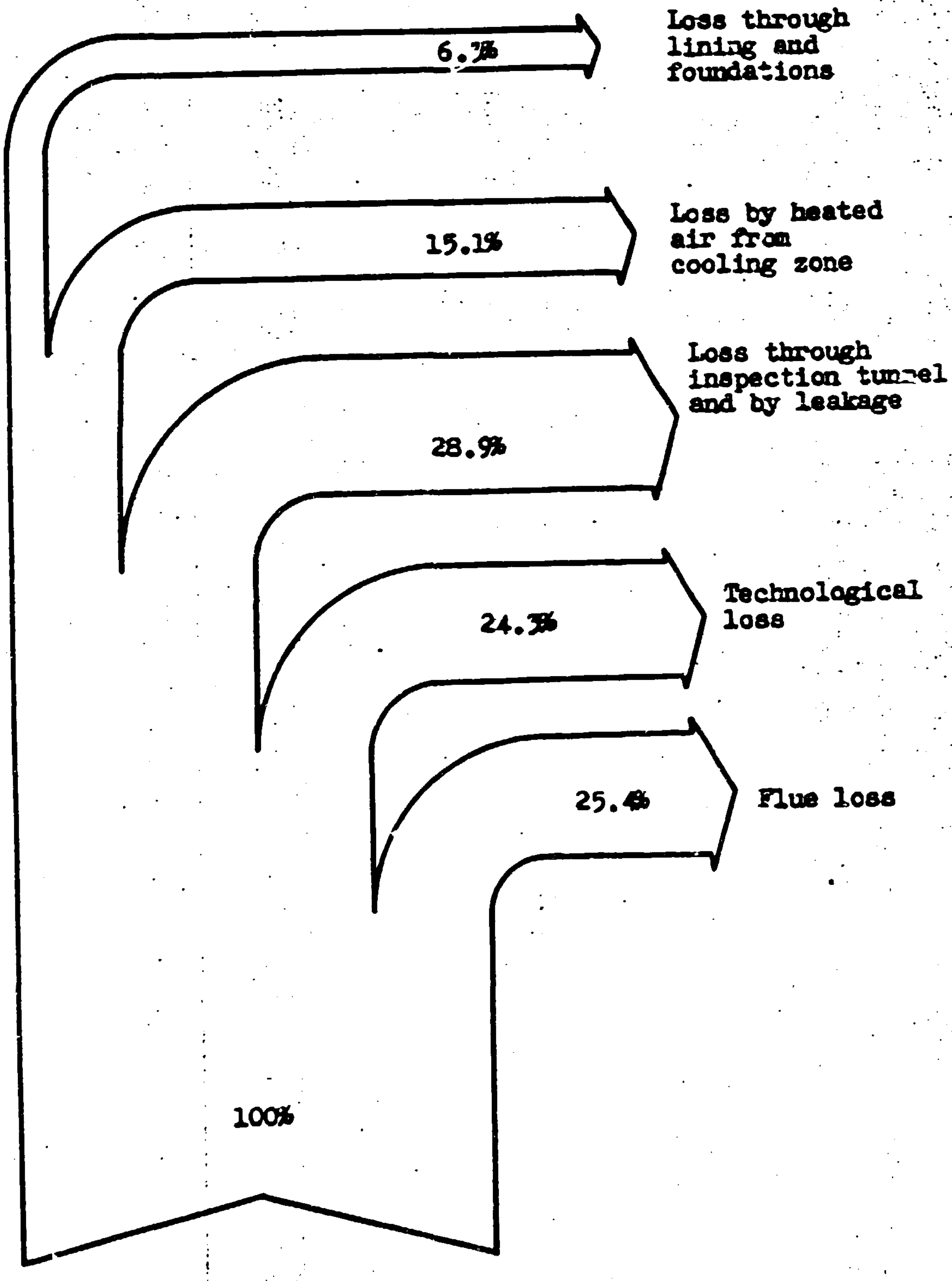


Fig. 1 Senkey's diagram

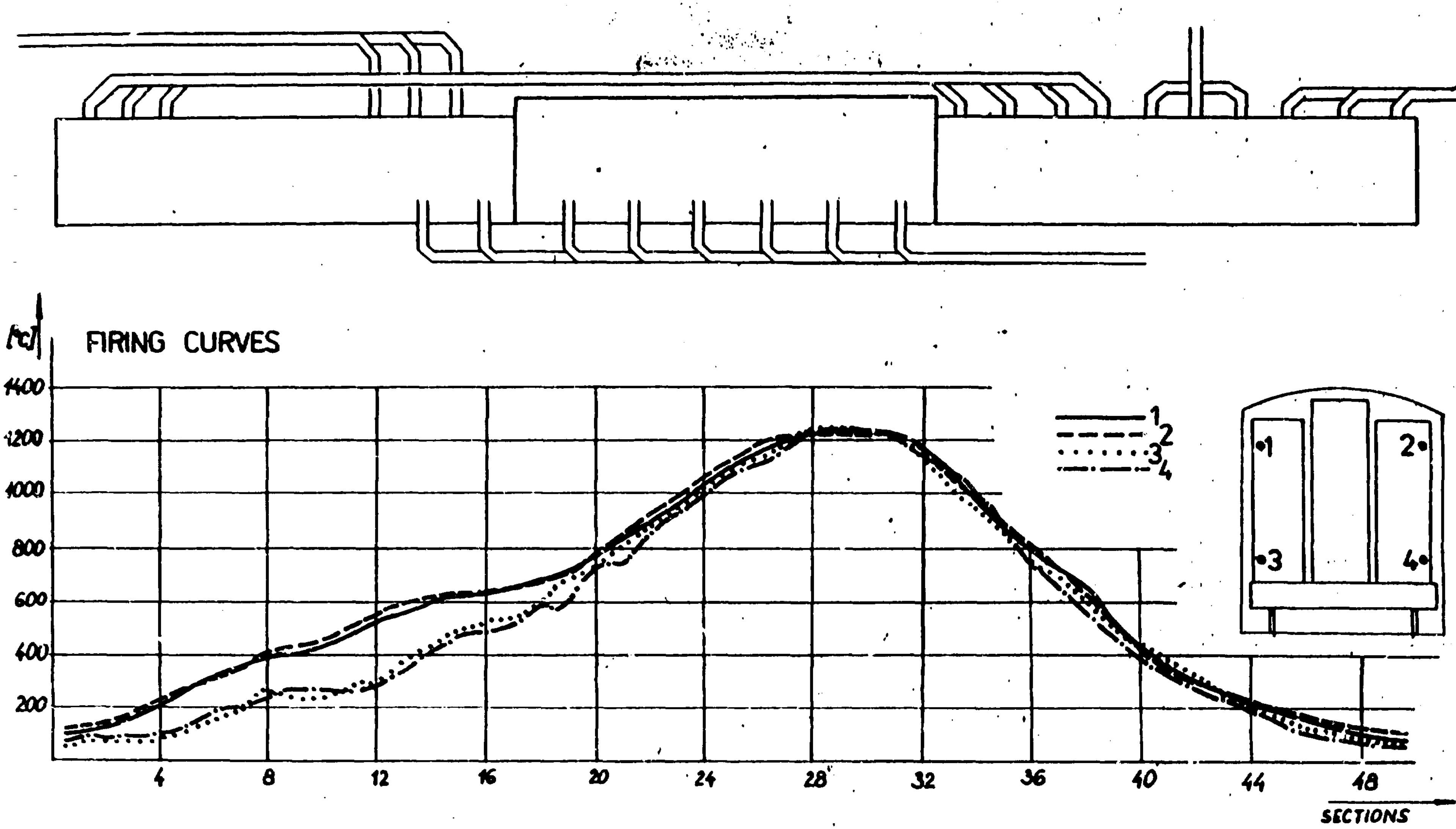


Fig. 2 Firing curves of a tunnel kiln

Put into practice the arrangements may lead to one (or more) of four main contributions:

- energy conservation
- quality improvement and reject decreasing of product manufactured through the improvement of heat technological conditions
- output increase of the heat unit
- substitution of high grade fuel by low grade one

3. MEASURING EQUIPMENT OF THE MOBILE DIAGNOSTIC UNIT

Measuring instruments for the mobile measuring laboratory were selected with regard to the possibility to perform power measurements i.e. for determination of heat balances and for ascertainment of technological conditions in thermal processing of ceramic materials.

The instrumental equipment of the MDU contains also devices for checking and calibrating the instruments and for minor repairs.

The measurements are extensive and heterogenous. The most important equipment available and its application is as follows:

A. Temperature Measurements

In measuring the temperatures most frequently measurements of atmosphere temperature and of surface temperature are required.

For the atmosphere measurement orthodox sensors are applied:

for the range up to

- 600°C resistance Pt thermometers
  mercury thermometers
  Cu-Ko thermocouples
- 1200°C Ni-NiCr thermocouples
- 1400°C Pt-PtRh10 thermocouples
- 1600°C PtRh6-PtRh30 thermocouples

Besides standard thermocouples Ni-NiCr with protective ceramic tubes so called jacketted thermocouples are used to a considerable extent. The advantage of these thermocouples is a considerably shorter time constant in comparison to orthodox wells. Jacketted thermocouples are also flexible and measurements can be taken even in spaces with difficult access. For example when temperature distribution in profile of the kiln is measured these thermocouples are successfully used. These thermocouples are delivered in length up to 5m and even longer (on request). The possibilities of application are considerable. For example the firing curves in the multi channel kilns can be measured by means of these thermocouples (fig. 3). By inserting the thermocouple into the

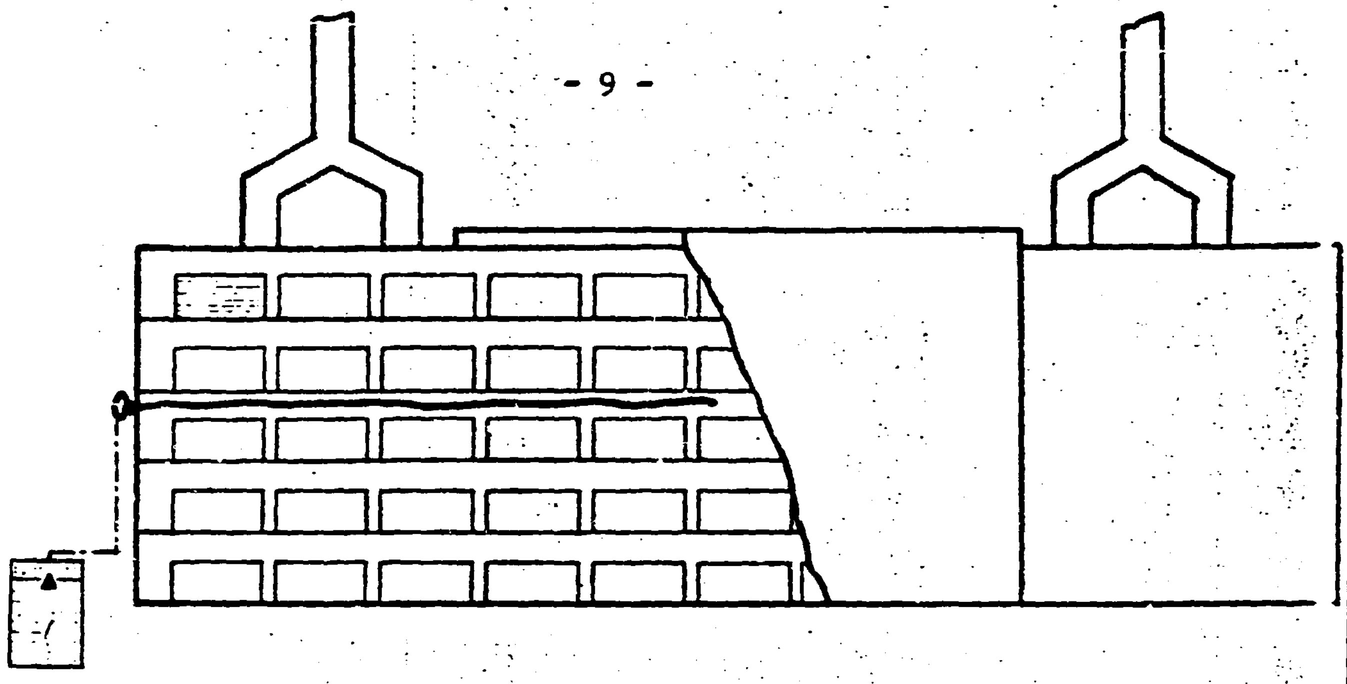


Fig.3 Measuring of firing curves of multi channel kiln

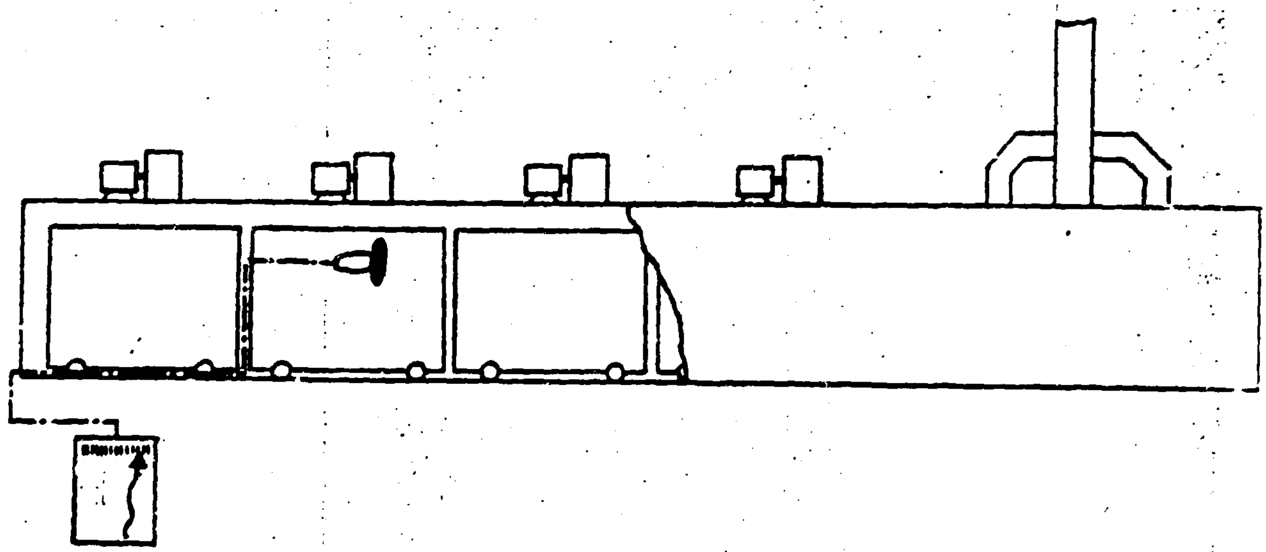


Fig. 4 Measuring car in channel drier

kiln and its gradual withdrawing firing curve of the channel is obtained within a few minutes. The measurement by the usual method would take some tenths of hours.

For the measuring proper and for recording of indications through the resistance and thermocouple sensors the equipment of mobile laboratory is provided by compensation recorders. These recorders have a large precision (error max. 0.5%) and writing width 250 mm. A great advantage of these recorders is the possibility of a prompt exchange of measuring range modules and of arbitrary combinations of two different range modules. One recorder has 12 inputs, so it can record information from 12 measuring points simultaneously.

Besides temperature indications the recorders are provided by standard ranges in mV. These ranges enable a series of further measurements. For example simultaneous temperature measurements and temperature differences with increased sensitivity can be performed. This measuring method can be applied when the heating rate of a setting is followed.

For measuring the surface temperature the mobile laboratory is equipped with thermoelectric contact thermometers. For higher temperatures three fully radiating pyrometers with mutually overlaping ranges are applied. They enable to take measurements and temperature recording if need be within the temperature range 150 - 2000 °C.

B. Gas flow measurements

The MDU is equipped with orthodox mechanicel anemometers and with mechanical-electrical anemometers for measuring the flows in driers and the sucking of fans. The anemometers can be connected to a specially adjusted recorder which enables to conduct a long-term investigation of flow conditions. These anemometers can be applied also in measuring cars in channel driers (fig. 4). The mobile laboratory is also equipped with several types of Pitot's tubes for gas flow measurements in tubing. Pitot's tubes can be applied also for mea - suring the flow of the generator gas

C. Pressure measurements

The most frequent task during operation tests is the measurement of low pressures both in pneumatic equipment and in the ascertainment of draught condi - tions, For this purpose precisious liquid micromano - meters are applied. These devices have changable measuring ranges. In case the record of pressure is needed the indication annubar ballance with the basic range ± 50 Pa can be applied. For measuring higher pressures the equipmentcontains series of precise manometers.

D. Dew point measurements

The knowledge of the dew point in the drying equipment is of a great importance. Together with temperature and flow velocity it gives the basic information about drying process. For dew point measurements the transportable sets are applied. The equipment consists of three probes and one plotting recorder. Every probe has a temperature resistance sensor (temperature of dry thermometer) and a dew point sensor (temperature of wet thermometer). The sensor of the dew point is based on the tension compensation of vapour produced by the LiCl electrolyte and vapour of the ambient. The stabilized temperature equilibrium corresponds to the temperature of the dew point. This set in connection with mechanical-electrical anemometers represents the equipment by which the basic parameters of the drying process - the temperature, the dew point and the flow velocity of the drying medium - can be measured and recorded.

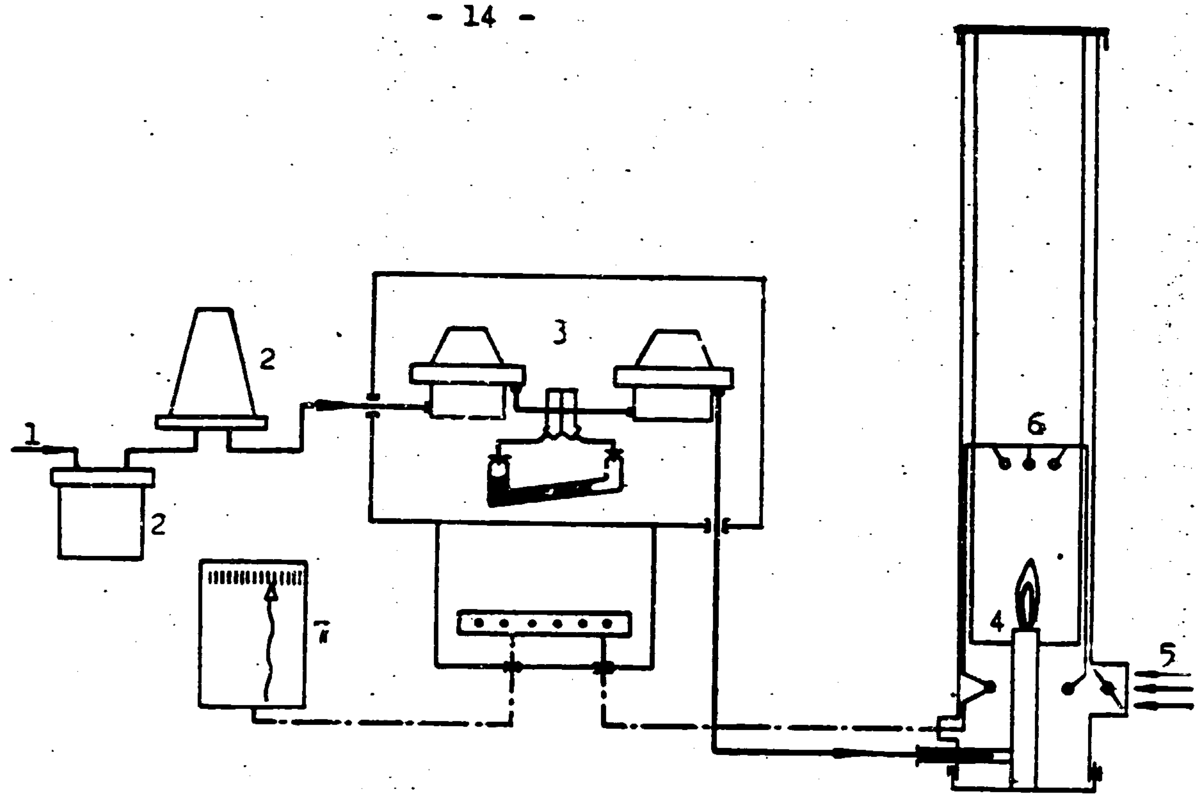
E. Measuring the properties of combustion gases- - analysis of combustion products

For ascertainment of heating gases composition the mobile diagnostic unit was equipped by an Orsatchromatograph. With regard to the difficult transportation of this instrument the application of the Wobbe's number- - meter proved to be more practicable. This instrument determines the Wobbe's number (the ratio of the heating value and the second root of the gas density) by measuring the temperature rise of a constant quantity of the air flowing through the combusted gas (fig.5). The output signal is the voltage of the thermobattery which is registered by the recorder directly in values of the Wobbe's number. The measurement precision rea - ches 5 - 10 % with regard to the applied calibration. The precise calibration is carried out by means of calibration gas mix delivered by the producer of Wobbe's number meter. The instrument can be adjusted for mea - suring the Wobbe's number of the generator gas, natural gas and town gas.

The Wobbe's number meter was successfully applied in measuring tunnel kilns in the plant where the causes of fluctuating firing temperature had to be ascertained.

For checking the firing process the mobile labo - ratory is equipped by transportable analyzers and by instruments installed in the van. The instrument Infralyt is applied for the determination of the CO and CO_2 content. The selective absorption of the infrared ra - diation by the measured gas is utilized for the determination of the content of the component looked for. For measuring the oxygen content the instrument Permolyt was used working on the increased permeability of oxygen with regard to other gases.

The instrument for the determination of CO_2 and O_2 contents consists of cleaning and drying filters, swit-



1 .... Tested gas
2 ....Filters
3 .... Pressure regulation
4 .... Burner
5 .... Air flow
6 .... Thermobattery
7 .... Recorder

Fig. 5 Wobbe's number meter

cher of measuring points, analyzers and plotting recorders. The operation of recorders and switcher is synchronized. Consequently measurements can be taken in 3 points at a time. The extraction of combusted products is conducted by pumps through extraction probes from a corrundum material.

Analyzers are used in checking combustion conditions and for inspecting the function of burners. Also the ascertainment of the air sucked in by leakages of kilns is important. It is applied especially in tunnel kilns where the tightness of sand grooves can be checked. The measurement of the kiln atmosphere in the preheating zone shows the economy of kiln operation and potential reasons of great temperature differences in kiln profile.

Gas analyzers can be successfully applied in non direct determination of fuel consumption of thermal unit. It is calculated from maximal portion of CO_2 in combustion gases possible, real portion of CO_2 measured by analyzers and flow of combustion gases.

4. HEAT BALANCE OF THERMAL UNIT - PROCESS OF MEASUREMENTS

Besides the tests and measurements proper the statement of the operating conditions of thermal unit must be done and recorded during the whole time of testing. Working order of equipment and all circumstances with signifieant influence upon the operation of the thermal unit must be find out. It is for example the type of regulation, working order of tubing, fans, regulators, operating thermocouples and recorders etc.

It is a matter of course that all the measurements and tests must be done in the course of stabilized state of the thermal unit operation (i.e. for instance the uniform advance of the kiln cars, no intervations with the unit etc.). Adjustment of all regulating elements must be recorded to specify the measuring conditions.

The values to be measured during the measurements and tests are as follows:

A. Testing of a kiln

- heat input
- heat losses:
  - flue loss
  - by conduction of brickwork
  - heat accumulated in kiln car
  - heat accumulated in ware
  - by conduction of foundations
  - technological loss

- heat from cooling zone draught for other purposes

- the production of the kiln

- combustion gases analyses

- pressure of the kiln atmosphere

- stack draught

heat input

- is calculated from amount of fuel consumed and its calorific value:

$$P = \dot{M} \cdot H \ / kW /$$

$\dot{M}$ .... amount of fuel /kg/s/

H .... calorific value / kJ/kg /

Indirectly can be the heat input calculated from combustion gases analyses and the amount of combustion gases. Very often are both these methods used paralelly to reach better precision of the measurement.

Small portion of heat input forms also the heat entering the unit by the specific heat of fuel.

flue loss

- is calculated from amount of combustion gases, temperature and specific heat of these gases:

$$P_1 = \dot{V} \cdot t \cdot c \ / \ kW /$$

$\dot{V}$ .... amount of comb. gases / m^3/s /

t .... temperature of comb. gases / K /

c .... specific heat of comb. gases / kJ/m^3K /

Flue loss is different for different types of kilns. For example the flue loss of a muffled kiln is generally higher than that of a kiln with opened fire.

loss by heat conduction of brickwork

- can be calculated from kiln atmosphere temperature, heat conductivity of brickwork and ambient temperature:

$$P_2 = k \cdot \Delta t \cdot S \quad / \text{kW} /$$

k .... heat-transfer coefficient / $kJ/s \cdot K \cdot m^2$ /

Δt .... temperature difference / K /

S .... brickwork area / m^2 /

It can be determined from surface temperature of brickwork and heat-transfer coefficient too.

loss by heat accumulated in kiln car

- to ascertain this loss the average temperature of the kiln car lining and average temperature of iron boggie must be determined from several measurements. Loss by accumulated heat is than calculated from average temperature and specific heat of material:

$$P_3 = \dot{M} \cdot t \cdot c \quad / \text{kW} /$$

$\dot{M}$ .... mass flow / kg/s /

t .... average temperature of material / K /

c .... specific heat of material / $kJ/kg \cdot K$ /

loss by heat accumulated in ware

- process is similar to that for heat accumulated in the kiln car.

loss by heat conduction of foundations

- this loss is very difficult to ascertain due to complicated conditions of heat conduction. The item of heat conduction of foundations in heat balance is usually lower than 5 - 10 % of thermal unit heat input. Therefore this loss is usually comprehend in so called undeterminable losses, as well as loss by leakage and loss through inspection tunnel. All these losses form in ordinary cases about 15 % of thermal unit heat input.

technological loss

- comprehends all losses for physical and chemical transformations in the material of ware.

heat from cooling zone draught for other purposes

- is calculated from the amount of heated air multiplicated by its temperature and specific heat:

$$P_4 = \dot{V} \cdot t \cdot c \quad / \text{kW} /$$

$\dot{V}$ .... amount of heated air $/ m^3/s /$

t .... temperature of air / K /

c .... specific heat of heated air $/ kJ/m^3K /$

Though this heat is usually used in technological process (for example for drying or preheating of ware), from heat balance-point of view it presents heat loss.

production of the kiln

- knowledge of production is necessary for calculation of the specific consumption of the kiln. This impor -

tant index enables to compare various types of kilns or various kilns of the same type mutually from operation economy-point of view.

combustion gases analyse

- is done usually through the sight holes of the kiln or by measuring kiln car and shows the economy of combustion (fig.6). From the portion of CO_2 in combustion products is determined the air excess coefficient which expresses the excess of air for burning and thus the economy of burning. As mentioned above from the portion of CO_2 in combustion gases at stack draught and the amount of combustion gases can be indirectly calculated fuel consumption of the kiln.

pressure of the kiln atmosphere

- is measured through the sight holes of the kiln to investigate its distribution along the kiln. It has the influence upon thermal losses through inspection tunnel and by leakage.

steck draught

- has direct influence upon regulation possibilities of the kiln from pressure distribution-point of view.

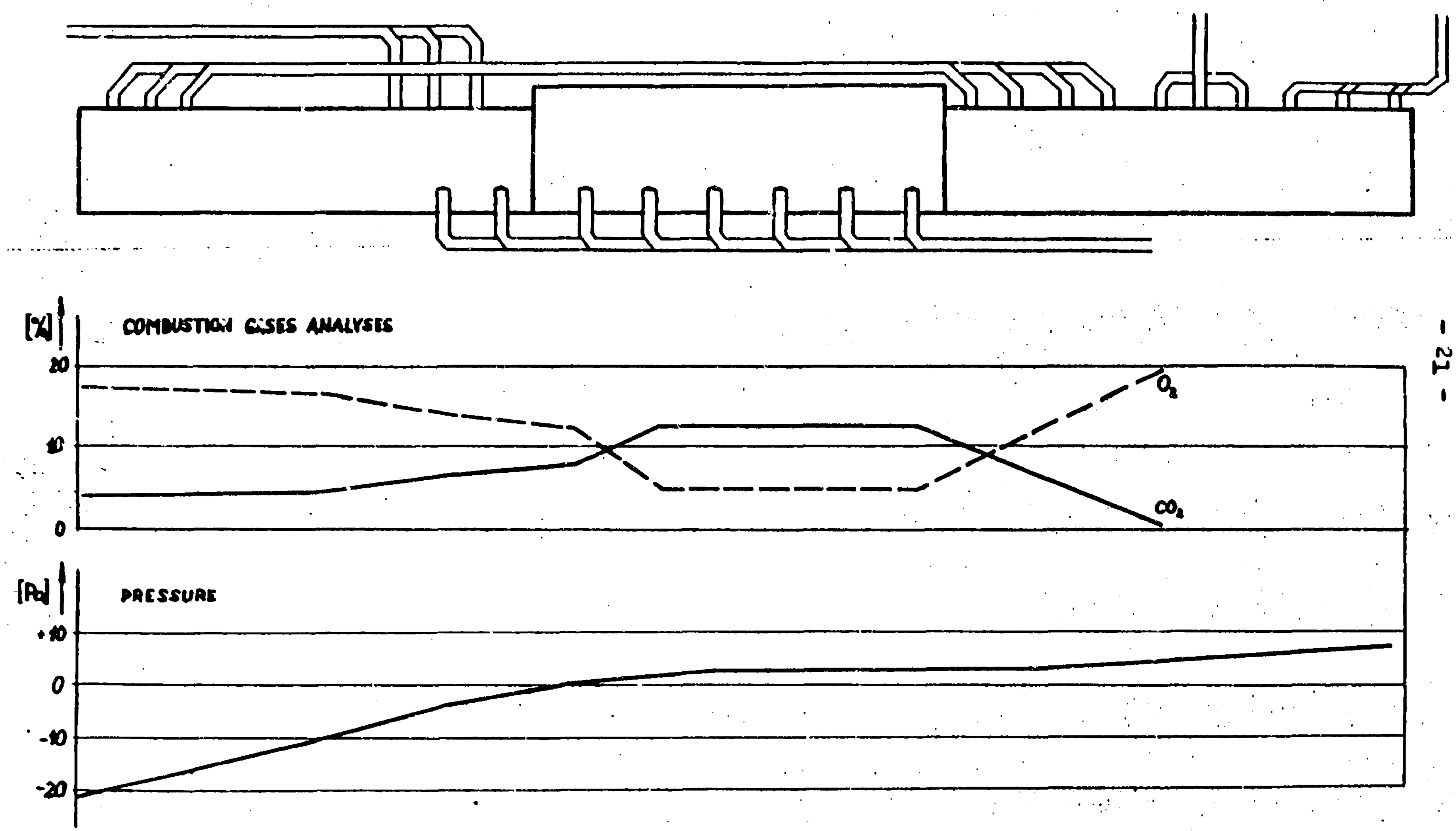


Fig. 6 Combustion gases analyses and pressure of the kiln atmosphere

B. Testing of a drier

- heat input
- heat losses: - by efficiency of heat exchanger
  - flue loss
  - heat accumulated in dryed material
  - heat accumulated in residual water
  - by exhausted air from drier
  - heat conduction of walls and foundations
- production of the drier
- combustion gases analyses
- relative moisture content of exhausted air
- relative moisture content of dryed material

5. OPTIMALIZATION OF THERMAL TECHNOLOGICAL PROCESS

For optimalization of thermal technological process the basic information is the course of thermal treatment of manufactured material. For a kiln it is represented by firing curve and by distribution of temperature in kiln profile. For a drier the most important information is the course of temperature, course of the dew point and flow velocity.

In the same way as by determination of the heat balance the statement of the operating conditions of thermal unit and recording of adjustment of all regulating elements is done.

A. Firing curve and temperature distribution of tunnel kiln

For investigation of firing curve the measuring kiln car is used (fig.7). The lining of measuring kiln car is drilled through and thermocouples are pushed through the holes. If need be, the probe for combustion gases analyses can be pushed through the holes together with thermocouples. Positions of measuring points are selected so as they give the sufficient information about temperature distribotion in profile of the kiln. For this purpose the jacketted thermocouples are successfully used. Cold junctions of thermocouples are connected by compensating lead-wire with recorder through the

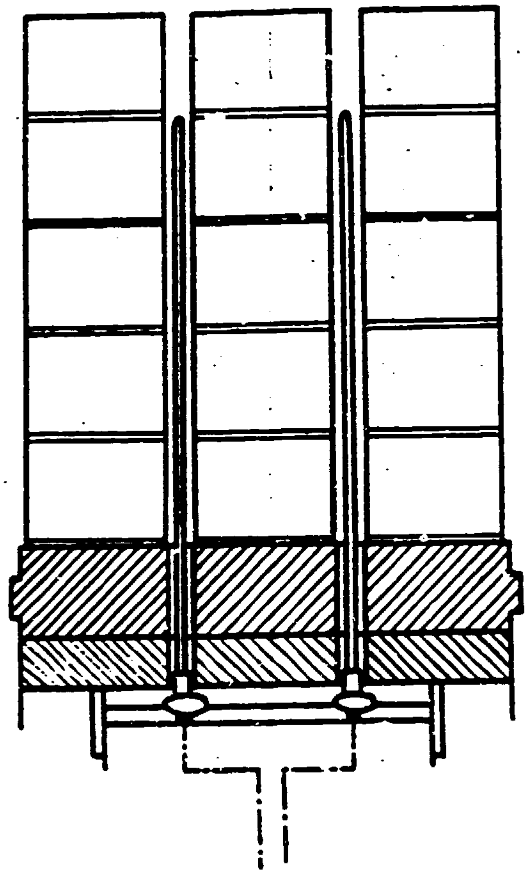


Fig. 7 Measuring kiln car

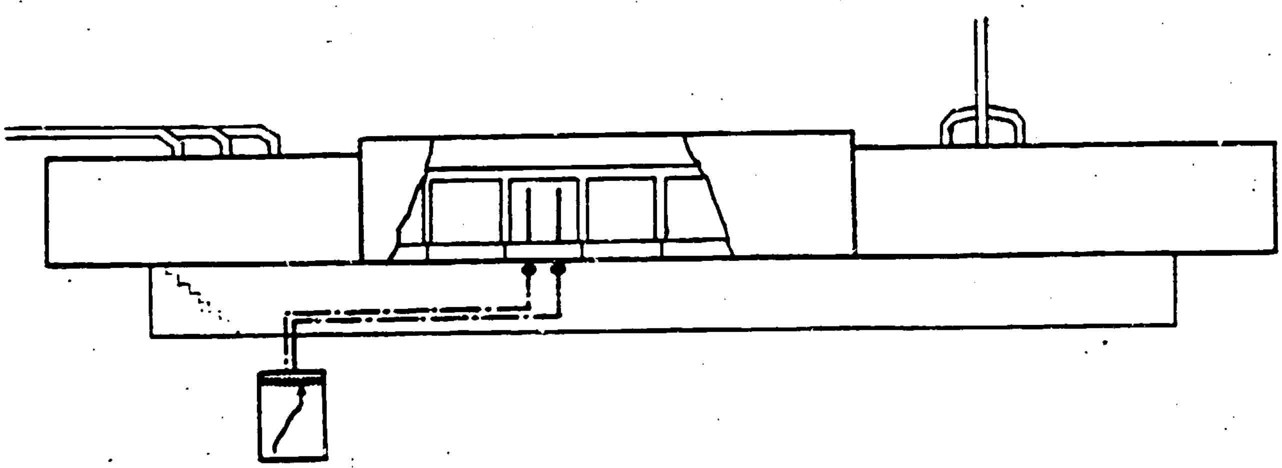
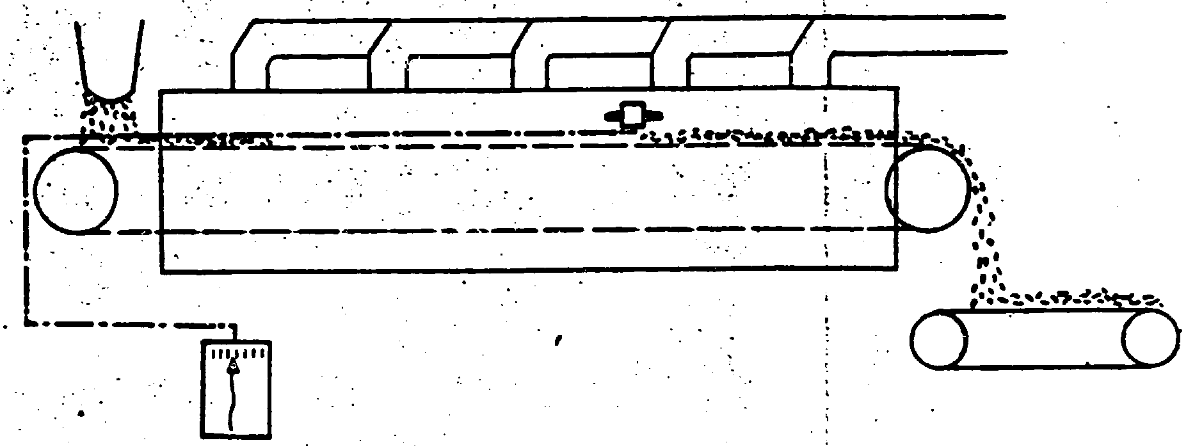


Fig. 8 Measuring of firing curves

inspection tunnel of the kiln (fig.8). This way the temperature in all measuring points is recorded continually.(fig.2). Besides the firing curve the pressure of the kiln atmosphere and combustion gases analyses are done as well (fig.6). On the base of measured values are proposals leading to the optimalization of thermal technological process worked out.

B. Drying curve of a drier

For investigation of drying conditions the probe for measurements of the dew point is send together with dryed material through the drier (fig.9). This probe consists of temperature resistance sensor and of dew point sensor. It is connected by cable with plotting recorder. This recorder is provided with three inputs so that it can record information of three probes simultaneously. Drying curve (fig.9) shows the drying conditions along the drier.



DRYING CURVES

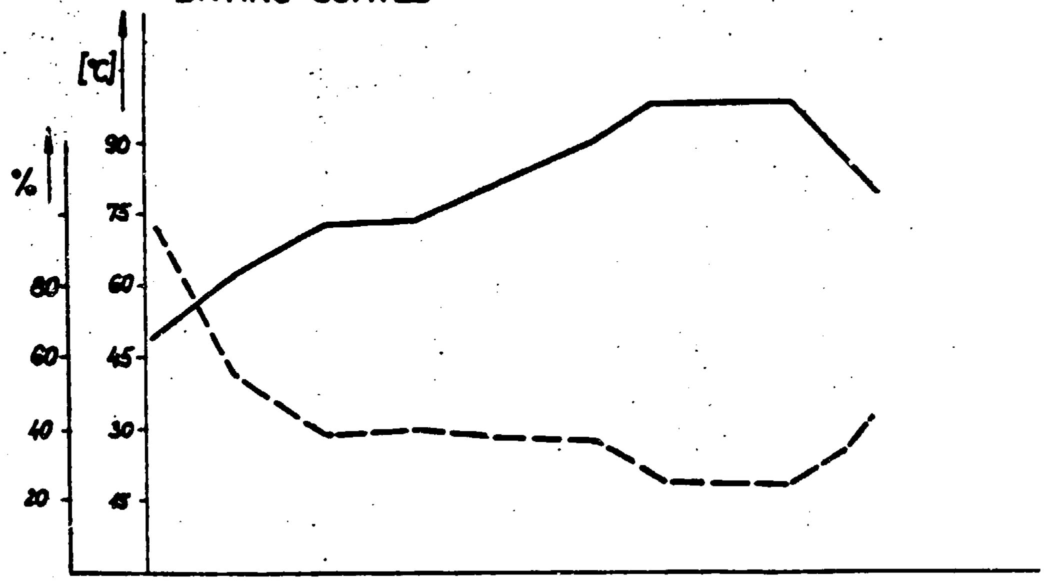


Fig. 9 Drying curves of a drier

6. OTHER UNITS TESTED

Kilns and driers are the most frequently tested heat consuming units in silicate production plants. But besides the MDU is used for testings of boilers, heat exchangersand gas producers. The testing in these cases includes statement of operating conditions and heat balance of the unit with special attention payed to the operation efficiency.

A. Boilers

- the most important values measured during the testing of boilers are as follows:

- fuel consumption
- quantity, temperature and pressure of the steam produced
- temperature and quantity of filling water
- temperature, quantity and composition of combustion gases
- temperature and quantity of combustion air
- analyses of fuel samples
- analyses of ash samples

B. Gas producers

-testing of gas producers includes following main measurements:

- fuel consumption
- qualities of fuel - analyses of fuel samples
- quantity, temperature and pressure of gas produced
- composition of gas produced
- quantity of air for burning
- quantity and temperature of steam for saturation
- analyses of ash samples

The measured values and results of testings are evaluated in energy conservation studies.

7. PRACTICAL EXAMPLES OF THERMAL UNITS TESTED

A. Semimuffled tunnel kiln for firing ceramic mosaic tiles

Target of measurement:

- to appreciate the economy and quality of the firing process and to investigate the reasons of increased breaking of support plates for firing mosaics.

Basic technical parameters of the plant

Fired product....... glazed mosaics 4x4 cm and 4x8 cm
Fuel................ town gas 14 445 kJ/Nm^3
Output in mosaics... 505 kg/h
Output including
firing furniture.... 1923 kg/h
Firing temperature.. 1050 °C
Number of cars
in the kiln......... 27
Mass of the setting
on the car.......... 427.4 kg

Method of measurement

Target of measurement comprehended both the economical and technological points of view. Therefore heat balance as well as firing curve were measured. With regard to the maximal temperature below 1200 °C the jacketted thermocouples Ni - NiCr were used. Samples of combustion products for analyses were taken through the sight holes of the kiln.

Results of the testing

Heat balance of the kiln

	Item	Heat quantity	
		/kW/	/ %/
Heat input	By gas combustion	1212	100
Heat losses	Flue loss	339	27.97
	By heated air from the cooling zone	11	0.91
	By heat accumulated in ware, kiln furniture and kiln car	107	8.83
	Technological loss	295	24.34
	Losses through kiln lining and foundations	202	16.67
	Losses through inspection tunnel and leakage	258	21.28

Specific consumption

- related to final product 8487 kJ/kg
- related to final product + auxiliary materials 2325 kJ/kg

Graphically is the heat balance shown at fig.10

The increased loss by accumulated heat is caused by considerably high temperature of material leaving the kiln. This loss can be reduced by the proper setting of control elements for the cooling zone.

A slender loss is also included among losses, namely

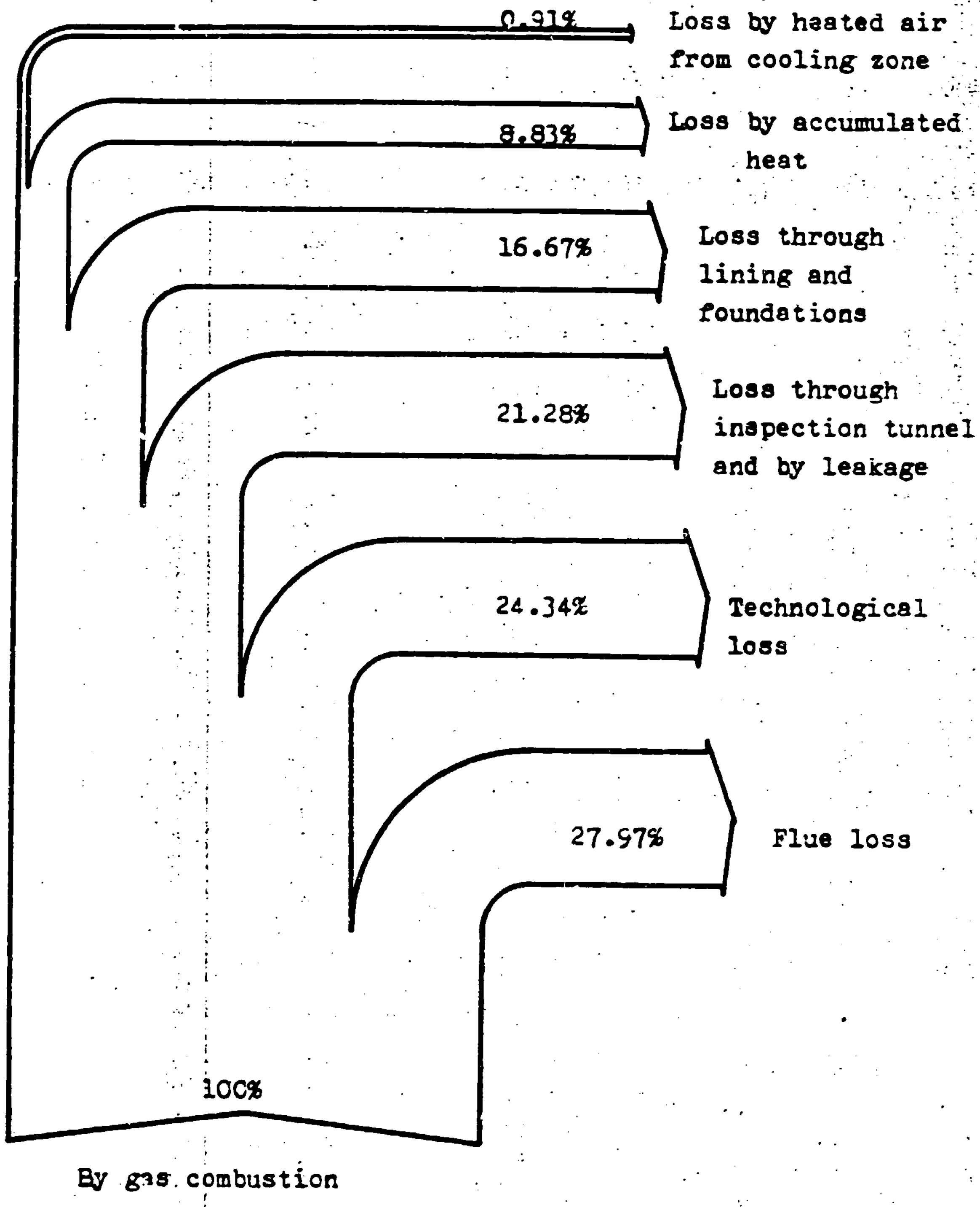


Fig. 10 Senkey's diagram

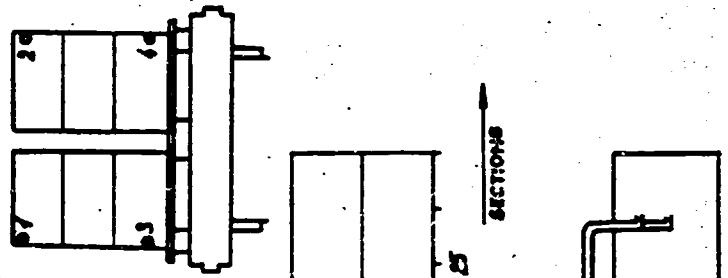
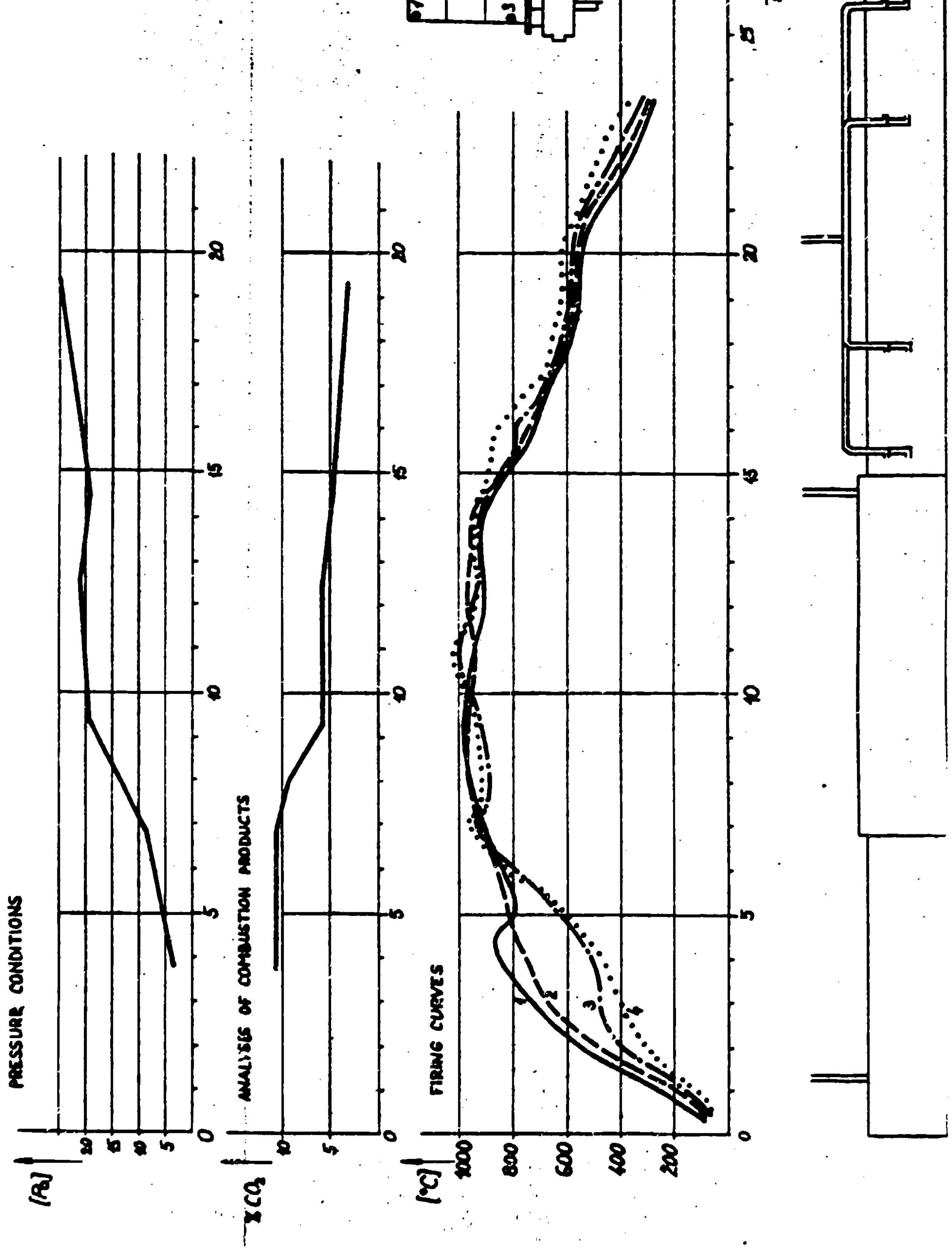
the loss by the air from the cooling zone (0.91%). This air is permanently discharged cut of the kiln to the atmosphere above the roof of the factory building. The amount of this air and the ensuing heat loss is reduced to an extremely low value due to the closed direct exhaust and the limitation of indirect cooling.

The cooling is performed mostly by the air from the kiln exit air lock. This air is heated in the cooling zone and blasted into the firing zone. Such method of operation considerably improves the economy of operation but high pressure of kiln atmosphere increases the temperature in the inspection tunnel. This fact is documented by the specific consumption. The specific consumption related to all heated material above the platform of the car amounts to 2325 kJ/kg and is unusually low.

Course and quality of firing

The measuring results of firing curves (fig.11) show that a rapid heating is realized in the preheating zone. The extreme velocity is in the upper parts of the setting. The average increase of temperature is 241 °C/h. This high heating rate causes here the breaking of support plates. The difference between the temperature of the lower and the upper part of the setting is also considerable and amounts to 280 °C in the 3rd section. This temperature difference is lowered in the 7th section by the first ignited burner. In the area of semimuffles the temperature of

Fig. 11 Firing curves, pressure of the kiln atmosphere and combustion gases analyses

the lower part of setting is permanently lower than un - der the arch of the kiln. Equalizing and on the contrary an increase of temperatures in the lower part of the setting takes place in the area of radial burners in the firing zone. The lower parts and the centre of the setting show the worst firing results due to unsufficient thermal treatment.

Pressure conditions

The kiln runs in a considerable overpressure starting from the 8th section. The pressure in the lower part of the kiln in the firing zone amounts almost to 20 Pa. In the upper part of the kiln is the overpressure even higher. In the direction to the cooling zone the pressure still increases due to the pressure produced by the exit air lock. These overpressures are very high. The overpressure in the zone of maximum temperatures should not exceed 10 Pa in the low part of the kiln. High overpressure causes the penetration of the kiln atmosphere to the inspection tunnel through the gaps between cars and sand seals. It brings about overheating of bogies and reduction of the life time of cars and bearings of wheels.

Proposals of arrangements

The accomplished testing and general evaluation reveal that the short preheating zone is an imperfection in the design of the kiln. This failure brings about operation complications with intense heating and breaking of support plates as well as unequal firing in the cross--section of the kiln.

To reduce the plates breaking it is necessary to lower the heating rate in the upper parts of the settings in the first four sections of the kiln. This operating order can be implemented by the following measures:

A. The exhaustion of combustion products needs to be concentrated into the exhausts of the first two sections of the kiln. Some exhausts immediately behind the kiln entrance are nowadays closed and consequently the ware in this part of the kiln is unsufficiently heated.

B. To improve heating immediately behind the kiln entrance the present kiln entrance overpressure air lock requires to be converted to the underpressure air lock by reversing the air discharge and the sucking of the fan. This provision will reduce the present cooling effect of the entrance air lock and simultaneously the combustion products will be drawn into the entrance part of the kiln. The closing effect of the entrance air lock will not be affected. The air discharge of the fan can be attached to the chimney of the kiln.

C. The existing permanent overpressure of the kiln atmosphere is not acceptable. The overpressure should be lowered by the adjustment of th3 cooling /opening direct exhausts by reducing the power of the kiln exit air lock/.

D. To improve the firing uniformity it is necessary to increase the quantity and possibly the velocity of combustion products delivered to the lower part of the kiln cross-section. Simultaneously only the inlet holes in the lower part of semimuffles should be kept opened. In this way the outlet velocity of combustion products will be increased and a greater amount of combustion products will reach the central part of the car and central gap in the setting.

Expected contributions

The contributions in this case will be mostly in the reduction of operation costs. Especially the item of support plates reproduction should be considerably reduced. Improved firing conditions should be reflected in higher quality and salability of products.

7.B. Tunnel kiln with opened fire for firing stoneware pipes

Target of measurement:

- to investigate the reasons for increased breaking of fired pipes.

Basic technical parameters:

Fired product..............stoneware pipes ⌀ 20 cm and ⌀ 60 cm
Fuel.......................heavy heating oil
Output.....................35 028 t/year
Firing temperature.........1280 °C
Number of kiln cars
in the kiln................33

Method of measurement

With regard to the aim of measurement for investigation of firing curve was used measuring kiln car with thermocouples Pt - PtRh.

Results of measurement

Firing curve is shown at fig.12. To the 6th section was the temperature in kiln profile satisfactorily distributed. From the 6th section the temperature difference between lower and upper part of profile increased and in 10th section it reached 250 °C. In the 12th section began the reduction of temperature difference between lower and upper part of profile. In 16th and 17th sections was realized rapid heating of lower part of setting (up to 280 °C/h).

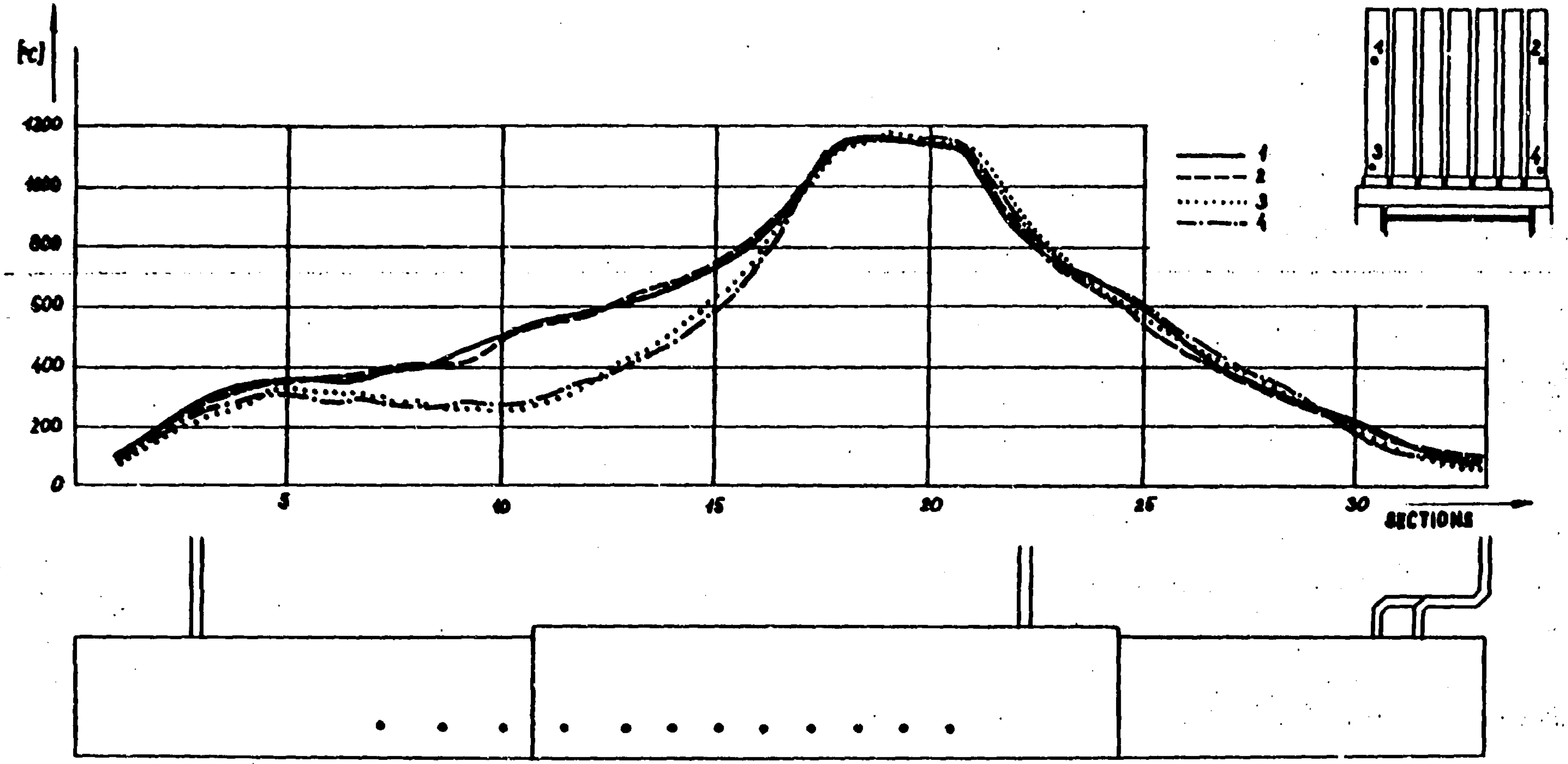


Fig.12 Firing curve of tunnel kiln for firing stonevare pipes

The rest of the firing curves didn't show any extreme conditions. The breaking of pipes came in the part of the kiln with the most rapid heating which caused extreme tension in material.

Proposals of arrangements

A. To lower the output of burners in the part of rapid heating and to raise the output of burners in the previous part of the kiln.

B. To raise the stack draught which would bring the uniformity of heating in the part from 16th to 18th section. To eliminate the decline of temperature in the firing zone by raised output of burners.

C. If the previous arrangements were not sufficient, to install auxiliary burners in preheating sections of the kiln for better uniformity of preheating.

Contributions

The first two arrangements proved to be sufficient for reject decreasing from 19 % to less than 4 % and quality improvement of products due-to better firing conditions.

7.C. Tunnel kiln with opened fire for biscuit firing of wall tiles

Target of testing

To appreciate the firing conditions and operation economy for the purpose of output increasing and production modernization.

Basic technical parameters

Fired product...............biscuit firing of wall tiles

Fuel.........................generator gas

Output......................1.192.000 m^2/year

Firing temperature..........1240 °C

Number of cars
in the kiln.................68

Quantity of tiles
on the car..................184 m^2

Method of measurement

To comply with the target of testing the firing curve as well as the heat balance of the kiln was measured. Due to the firing temperature over 1200 °C the thermocouples Pt - PtRh were used.

Results of testing

Heat balance of the kiln

	Item	Heat quantity /kW/	Heat quantity /%/
Heat input	By gas combustion	2433	100
Heat losses	Flue loss	644	26.47
	By heated air from the cooling zone	815	33.50
	By heat accumulated in ware and kiln car	72	2.96
	Loss through kiln lining	196	8.08
	Other losses (technological, through foundations, inspection tunnel and by leakage)	706	29.02

Specific consumption: 6563 kJ/kg of product

Senkey's diagram is shown at fig.13.

Course and quality of firing

Firing curve presents fig.14. Firing curve displays several imperfections. First of all it is a great temperature difference between lower and upper part of the setting. Maximal temperature difference amounts to 340 °C . It is caused by uneven flow of combustion products in profile

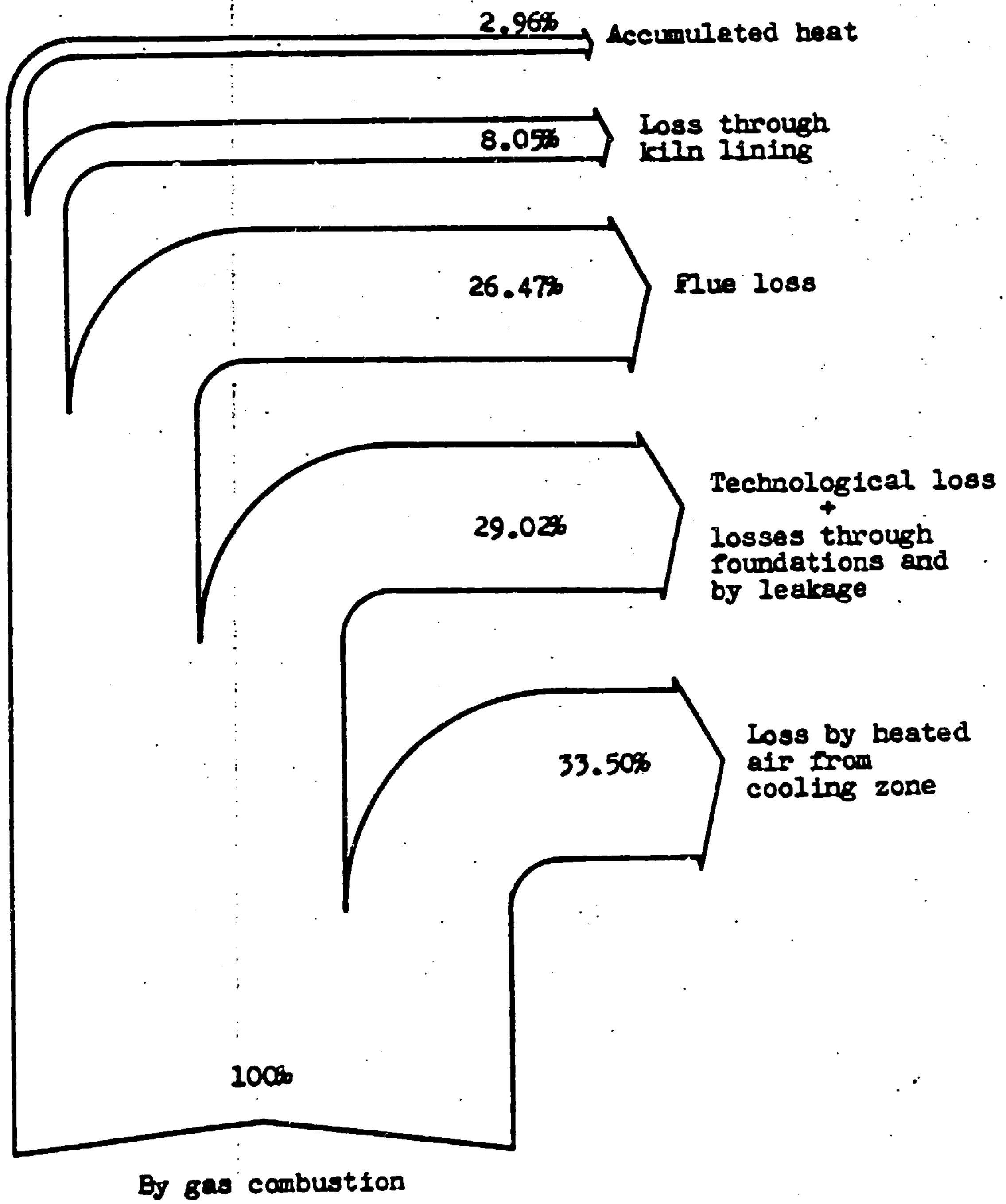


Fig.13 Senkey's diagram

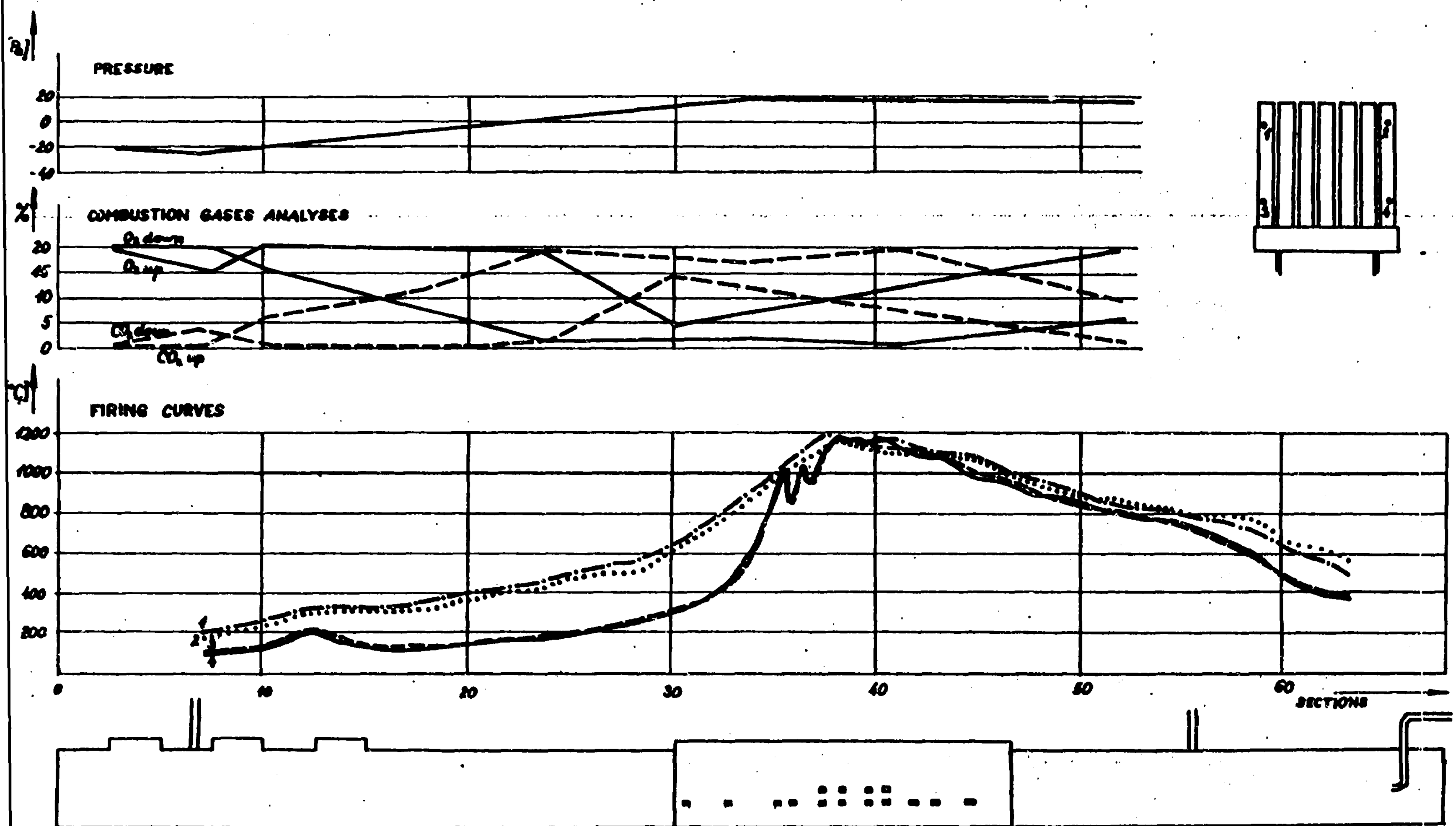


Fig. 14 Firing curves of tunnel kiln for firing wall tiles

of the kiln at the first 25 sections. It is confirmed also by combustion gases analyses (fig.14). The concentration of CO_2 is considerably higher in the upper part of the kiln profile. This unfavourable state is caused by higher density of the setting compared to the project (45 and 36 columns) and by imperfection of the kiln design. Preheating zone from 13th to 30th section has no temperature equalization. In the part from 33rd to 38th section comes rapid heating of setting in lower part of the kiln profile (up to 175 °C/h). This is the most critical part of firing curve. The decline of temperature in the cooling zone is too slow in the part to the temperature 750 °C (19 °C/h). In the following part of cooling zone which is critical from reject point of view is the decline fof temperature on the contrary considerably higher.

Pressure conditions (fig.14)

Though the stack draught is adjusted at maximal value the overpressure of the kiln atmosphere is too high. It causes the increased loss of heat to the inspection tunnel and the loss by leakage.

Proposals of arrangements

As all the difficulties are mostly caused by imperfections of the kiln design the recommendations refer mostly to the reconstruction of the kiln focused to the better regulation of preheating and cooling zones.

A. To improve the pressure conditions by increasing of the stack draught (installation of the fan).

B. To renovate the closing elements of the kiln

C. To renovate the recirculation in preheating zone

D. To repair and renovate the brickwork of the cooling zone

E. To extend the cooling zone to the 43rd section of the kiln

F. To increase the output of fans at the exit air lock

Contributions expected

Better uniformity of firing and possibility of output increasing.

Reject decreasing.

Energy conservation due to reduced losses.

7.D. Belt driers for washed kaolin

Target of measurement

To asses the quality and economy of drying process and to determine the specific heat consumption.

Basic technical parameters of the equipment

Type of drier...........conveyor drier with forced circulation

Dryingmedium............air

Heating the air.........oil-fired heat exchanger

Output of drier.........5.13 t/h /10% output humidity/

Inlet humidity..........28%

Outlet humidity.........10%

Guaranteed specific consumption............max. 4180 kJ/kg of evaporated water

Parameters of heat exchanger

Fuel...........oil S 39776 kJ/kg

Heat input.....2585 kW

Heat power output...2020 kW

Quantity of heated air...5.83 Nm^3/s

Method of measurement

The installed operation meter was applied for determination of consumption. Drying curve was measured by the dew point sensor.

Results of testing

Heat balance of driers

		Heat quantity /kW/	/%/
Heat input	By burning oil	4481	100.00
Useful heat output	For evaporation of water	2726	60.83
Heat losses	Flue loss	717	16.00
	By exhausted air from driers	751	16.76
	By accumulated heat	43	0.96
	Heat radiation	244	5.45

Specific consumption: 4338 kJ/kg of evaporated water

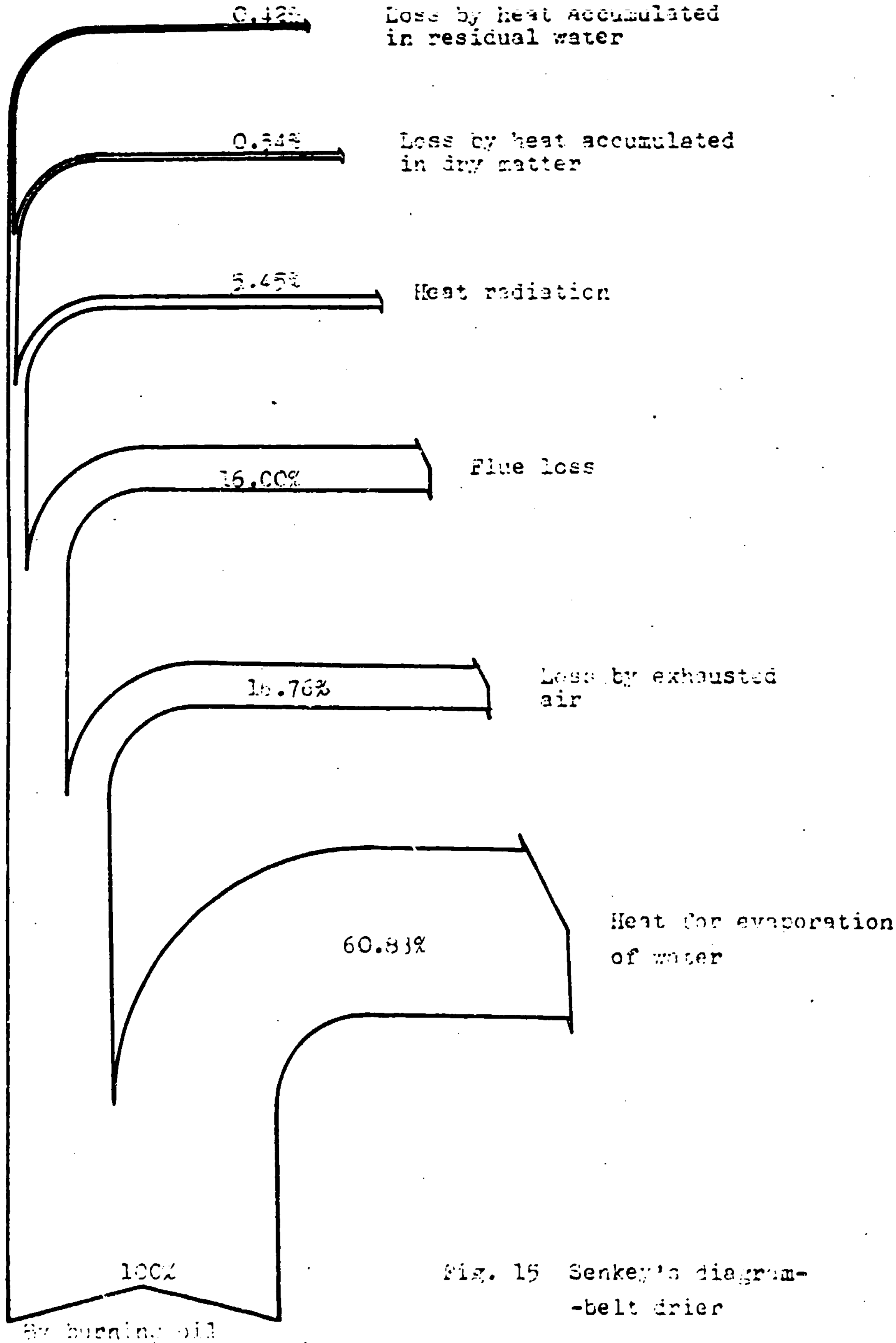


Fig. 15 Senkey's diagram--belt drier

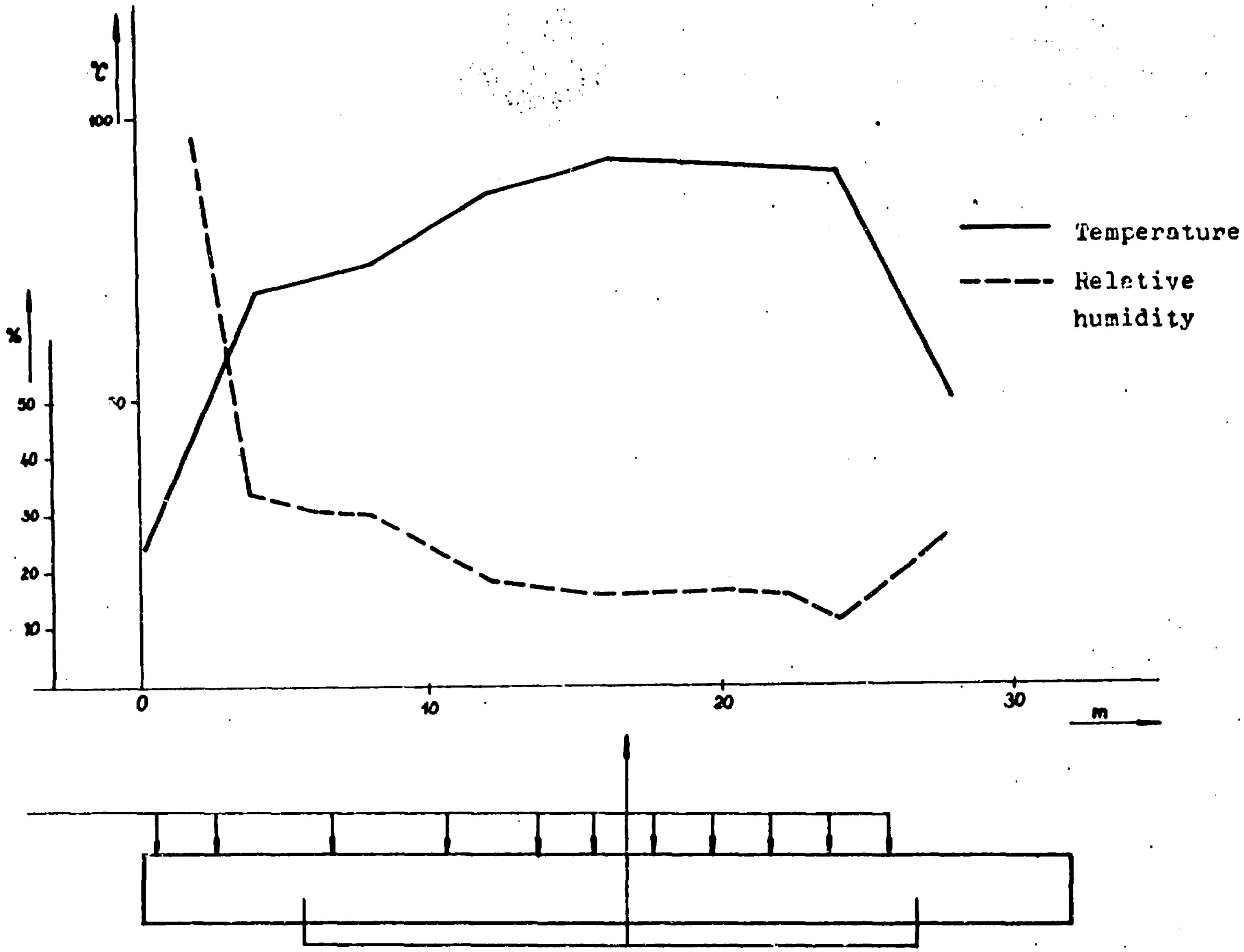


Fig. 16 Drying curve of belt drier

8. FINAL NOTE

The attention of Czechoslovak Ceramic Works and Research Institute for Ceramics, Refractories and Non-metallic Raw Materials at Pilsen is traditionally payed to the field of energy savings. The programmed energy savings are therefore reached in recent years in Czechoslovak ceramic industries. It is so thanks to the fact that the energy consumption control from energy management-point of view leads from the centre down to the plants.

Special basis for whole Czechoslovak ceramic industry is Research Institute for Ceramics, Refractories and Non-metallic Raw Materials, which in cooperation with the Head-quarters of Czechoslovak Ceramic Works and power-supply directors at plants performs diagnostic measurements of all heat consuming units. With regard to the importance of this activity about one houndred engineers are joined and they pay. This activity pay both from society and business-point of view because energy costs form more than 50 % of all costs in ceramic industries.

Annex 1

List of Figures

Figure No.