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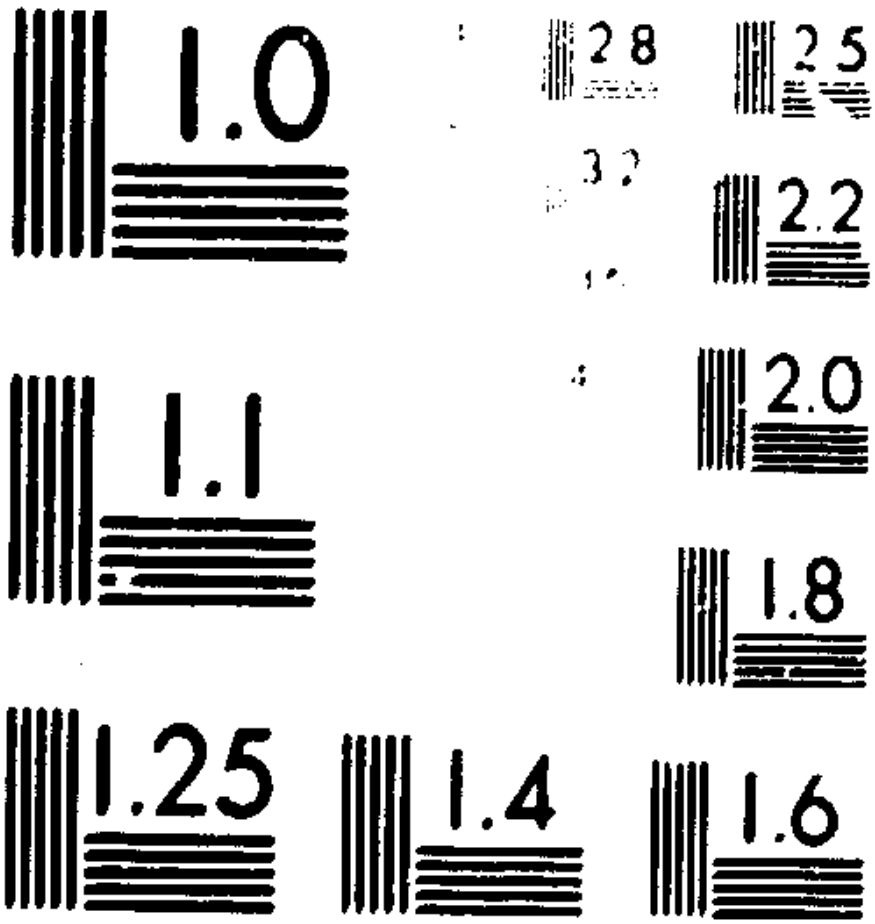

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SANITARY WARE MANUFACTURE

Technical-economic Information on Firing Process

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1. ABSTRACT

This paper deals with the explanation of specific questions on the manufacture of sanitary ware given by the Government of Mozambique. Consequently, it does not analyze all problems related to the manufacture of 2,500 tons capacity per year.

Two firing processes based on natural gas or electrically heated tunnel kilns are analyzed from the points of view of the equipment price and production costs. Advantages as well as disadvantages of both the processings are compared.

Two lay-outs of sanitary ware technology based on natural gas or electrically heated tunnel kilns are enclosed as the basis for a feasibility study preparation. Parameters of both the types of tunnel kilns are attached, too.

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3. CONCLUSIONS AND RECOMMENDATIONS

3.1. Gas heated tunnel kilns are more advantageous than electrically heated ones in the sanitary ware manufacture due to:

- larger cross-section of the kiln channel which necessitates higher capacity and more favourable loading of products on kiln cars,
- lower costs in firing products,
- shorter firing cycle and consequently higher capacity,
- waste heat can be utilized for other operations, such as drying plaster moulds and products.

3.2. The single firing process compared with the double firing technology offers good quality products and reduces investment as well as production costs.

3.3. Direct fired kilns in comparison with indirect fired ones show the following advantages:

- higher capacity,
- shorter firing cycle,
- lower investment costs,
- lower heat consumption,
- better temperature control and regulations of the firing process,
- lower amount of waste heat.

3.4. Provided that the used natural gas is sufficiently pure, a direct fired tunnel kiln heated by natural gas will be the best firing equipment for the sanitary ware manufacture.

To establish the sanitary ware manufacture in Mozambique, the following activities are recommended:

3.5. To apply to the UNDP office in Maputo and to UNIDO Vienna for high level consultations to analyze all factors related to the sanitary ware manufacture in detail.

3.6. To carry out the technological tests of the raw materials concerned.

3.7. To analyze the quality of the anticipated natural gas from the point of view of its purity.

3.8. To conduct a comprehensive feasibility study before establishing any industrial venture and decide which type of kiln is to be applied.

4. INTRODUCTION

This paper deals with the explanation of specific questions given by the Government of Mozambique. It, therefore, does not analyze all problems related to the firing process and other technological phases in the sanitary ware manufacture. All data given in this paper relate to the 2,500 tons annual production of sanitary ware the structure of which corresponds to that being current in European countries.

Due to the structure of final products, single firing process is taken into account.Double firing proces needed in case of larger products can be avoided in these conditions since there is a neglegible quantity of such products in the sanitary ware manufacture. The single firing process costs less and the quality of the single fired sanitary ware was practically confirmed in the production, too.

Direct fired tunnel kilns heated by natural gas and electrically heated tunnel kilns are submitted to the presented analysis. The former have one layer, the width of the kiln channel ca 1.65 m and the height 0.9 m. Having the cross-section with these dimensions, the kiln space is utilized to the maximum. The firing cycle of properly loaded ware fluctuates within the interval of 18 - 25 hours in case of the single firing process. With regard to the course of the firing curve, the optimum kiln length will be ca 100 m.

Tunnel kilns heated by electric current are used less frequently in the sanitary ware manufacture. From the technical point of view, their operation is interesting,

however, due to the production and investment costs, gas heated tunnel kilns are far more frequent. The electrically heated tunnel kilns are noted for the smaller width of the kiln channel (ca 0.8 - 1.2 m) and consequently for the lower specific capacity. In case of the proposed capacity of 2,500 tons net, it will be necessary to take into account two electrically heated tunnel kilns ca 90 m long, the firing process of which takes 30 hours.

5. SANITARY WARE FIRING PROCESS

5.1. Direct Fired Tunnel Kiln Heated by Natural Gas

Exclusively, the single firing process at the temperatures of 1250 - 1280°C is considered for firing sanitary ware in a direct fired tunnel kiln. Natural gas as fuel does not cause any difficulties when firing products with coloured glaze under the oxidizing atmosphere. The single firing process, if compared with the double one, reduces the costs in the material handling and in the glost firing process.

The direct fired tunnel kilns compared with the indirect fired ones with the same cross-section have economic and technical advantages which are shown in Table 1.

Generally, direct fired tunnel kilns transfer heat to products by means of radiation-convection combination. In order to intensify the firing process, burners with higher exit velocity of the combustion products can be built in. The use of these burners increases the influence of heat convection and contributes to the compensation of temperatures in all heights of the kiln channel in the preheating zone. It shortens the firing cycle and reduces the amount of rejects; the time total of the single firing process can be reduced to the interval of 18 - 25 hours.

In addition to the above mentioned, burners built in the kiln walls and leading to the grate make possible to widen the kiln channel to 1.2 - 1.8 m.

Using such an equipment increases the capacity of kilns as much as possible. The control of the direct fired kilns is easy and the waste heat from the kiln cooling zone can be utilized for drying products and plaster moulds.

Main parameters of a direct fired tunnel kiln heated by natural gas are given in Table 2.

5.2. Electrically Heated Tunnel Kiln

Exclusively, the single firing process at firing temperatures of 1250 - 1280°C is taken into consideration for firing the sanitary ware in a tunnel kiln heated by electric current.

The electrically heated tunnel kilns have similar way of heat conveying as those direct fired by natural gas have. In the temperature interval over 800°C, the heat is transferred from the heating units by means of radiation. To facilitate the heat transfer to the products in the temperature interval under 800°C, the equipment for powered air circulation running lengthwise and crosswise in the kiln channel is attached. This air circulation insecures the heat transfer by means of convection the share of which depends on the air flow velocity. The air circulation also reduces temperature differences in the channel.

Due to the prevailing heat transfer by means of radiation, the electrically heated tunnel kilns are noted for the reduced width of the kiln channel as well as the firing cycle is longer than that running in the gas heated tunnel kilns since the heat transfer cannot be intensified as it is in case of the gas heated kilns.

The application of the electrically heated tunnel kilns in the sanitary ware manufacture shows the following advantages:

- clean environment suitable for coloured glazes,
- exact and fine temperature regulation with uniform distribution according to the requirement of firing technology,
- reduced heat consumption owing to the eliminated waste gas losses.

On the contrary, main disadvantages are:

- small width of the kiln channel
- longer firing cycle
- low capacity of a kiln unit
- usually considerable costs in the firing process
- no waste heat from the cooling zone utilizable for drying processes.

According to the operation experience, the optimum kiln channel width is between 1.0 - 1.2 m which is the sufficient dimension for loading a current sanitary ware set. The firing cycle varies about 30 - 35 hours in the dependence on the heat transfer.

Main parameters of an electrically heated tunnel kiln are given in Table 3.

Due to the low capacity of the electrically heated tunnel kilns there would have to be installed two kiln units in a plant manufacturing 2,500 tons annually. See enclosed lay-outs.

5.3. Average Specific Heat Consumption

5.3.1. Natural Gas Heated Tunnel Kiln - Direct Fired

The specific heat consumption depends on the kiln technical conception and on the ratio between weight of the charged products and that of the kiln furniture. This ratio being 1:2 - 2.33, the specific heat consumption per kg of the fired ware amounts to 10.47 MJ $\pm$ 10% (i.e. 2.91 kW $\pm$ 10%).

5.3.2. Electrically Heated Tunnel Kiln

Similarly to the gas heated kilns, the specific heat consumption depends on the fired products - kiln furniture weight ratio and the kiln conception. This ratio being 1:2, the specific heat consumption per kg of the fired ware is 2.23 kW (i.e. 8.01 MJ).

5.4. Comparison of Investment Costs

The investment costs are given in estimated relation between the price of one gas heated tunnel kiln and the price of two electrically heated ones because of the lack of concrete price data of electric kiln attachment delivered. This estimate is based on average prices requested by the noted suppliers. Consequently, if one gas heated tunnel kiln costs 100, two electrically heated tunnel kilns are estimated to cost 150 - 170.

5.5. Comparison of Production Costs

As production costs cannot be calculated without getting acquainted with concrete supplier offers, the local salaries and wages, prices of raw materials and fuels and other local conditions, only comparison of the differences of cost in the operation of both the types of kilns is submitted.

5.5.1. Fuel Costs

With regard to the consumption of 8.01 MJ per kg of fired products (i.e. 2.23 kW) in case of the electrically heated tunnel kilns, the annual consumption of electric current amounts to 6,244 MWh. In case of the gas heated tunnel kilns, annual consumption of 873,500 Nm^3 is a consequent of 10.47 MJ spent on firing 1 kg products (average calorific value of natural gas 33.56 MJ per Nm^3 is anticipated; Nm^3 = cubic meter under standard physical conditions). Consequently, energy cost equality in both the cases will set in if 1 kWh of electric current is approximately 7 times cheaper than 1 Nm^3 of natural gas.

5.5.2. Annual Depreciation

With regard to the higher price of two electrically heated tunnel kilns 1.7 times, the annual depreciation will also be higher in case of the same method of depreciation.

5.5.3. Wages

With regard to the double amount of kilns and kiln cars in case of the electrically heated tunnel kilns, the double

amount of kiln operators and car charging, discharging and repairing personnel can be supposed. However, the actual number of the mentioned staff depends on the number of hours per shift and per week in a given country and on the technical level of delivered equipment.

5.5.4. Waste heat from Gas Heated Tunnel Kilns

can be utilized for drying processes. Consequently, extra costs must be spent on drying in case of the electrically heated tunnel kilns.

6. FINAL NOTE

The submitted paper deals with 2,500 tons annual production of sanitary ware from the point of view of two available energy resources in Mozambique, i. e. natural gas or electric power.

The given data are performed in relative values of the mutual comparison of both the possible firing ways since the exact production costs and investment expenditures can be calculated only if supplier offers and all local economic conditions are studied on the spot.

Lay-outs of both the alternatives are enclosed that the preparation of a feasibility study may be started.

The UNIDO-Czechoslovakia Joint Programme for International Co-operation in the Field of Ceramics, Building Materials and Non-metallic Minerals Based Industries in Pilsen conducts extensive studies in the field of ceramics and can willingly offer any technical assistance either by means of an exploratory mission or preparation of technology or raw material testing. Market and feasibility studies necessary for any steps in the investment decision or for the efficient development of the ceramic industry can be conducted by its specialists. The UNIDO-Czechoslovakia Joint Programme can also assist in energy conservation programming and mediate an induvidual training of Mozambique's specialists in the Czechoslovak Ceramic Works. The former is important from the point of view of production cost and energy savings,

the latter will help to increase the professional level of the ceramic technicians as the prerequisite of the establishing and expanding of the ceramic industry in Mozambique.

Table 1 - Direct and Indirect Fired Kilns
- Comparison of Main Parameters

Parameter	Direct Fired Kiln	Indirect Fired Kiln
Capacity	100%	ca 70 - 80%
Firing Cycle	100%	ca 140%
Investment Costs	100%	ca 135%
Heat Consumption	100%	ca 140 - 165%
Temperature Control	good	worse
Regulation of Firing	good	worse

Table 2 - Main Parameters of a Gas Heated Tunnel Kiln for Sanitary Ware Manufacture

Parameter	Unit	Value
Net Kiln Capacity per Year	ton	2,500
Gross Kiln Capacity per Year	ton	2,800
Firing Cycle	hour	25
Kiln Channel Width	mm	1,650
Grate Height	mm	300
Charging Height	mm	650
Kiln Channel Cross Section	sq.m	1.17
Kiln Length	m.	100
Operating Time per Year	day	350
Operating Time per Year	hour	8,400
Charged Products to Kiln Furniture Ratio		1 : 2.33
Waste Heat Quantity Utilizable for Other Processes	MJ/hour	ca 879.06
Total Number of Kiln Cars	pcs	110

Table 3 - Main Parameters of an Electrically Heated Tunnel Kiln for Sanitary Ware Manufacture

Parameter	Unit	Value
Net Kiln Capacity per Year	ton	1,250
Gross Kiln Capacity per Year	ton	1,400
Firing Cycle	hour	35
Kiln Channel Width	mm	1,200
Grate Height	mm	300
Charging Height	mm	650
Kiln Channel Cross Section	sq.m	0.9
Kiln Length	m	90
Operating Time per Year	day	350
Operating Time per Year	hour	8,400
Charged Products to Kiln Furniture Ratio		1 : 2
Number Total of Kiln Cars	pcs	90