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# PRODUCTION OF STRUCTURAL CERAMICS

SI/MOT/74/807

MONTSERRAT, BRITISH WEST INDIES

**Technical report: Techno-economic feasibility study for a structural ceramics production plant**

Prepared for the Government of Montserrat
by the United Nations Industrial Development Organization,
executing agency for the United Nations Development Programme

**Based on the work of G. Morales, ceramics engineer**

United Nations Industrial Development Organization
Vienna

id.77-8313

## Explanatory notes

References to "tons" are to metric tons, unless otherwise specified.

References to "gallons" are to United States gallons; one United States gallon equals 3.785 litres.

The monetary unit in Montserrat is the Eastern Caribbean dollar ($EC). During the period covered by the report, the value of the $EC in relation to the United States dollar was $US 1 = $EC 2.70.

CARIRI refers to the Caribbean Industrial Research Institute, in Trinidad.

A full stop (.) is used to indicate decimals.

A comma (,) is used to distinguish thousands and millions.

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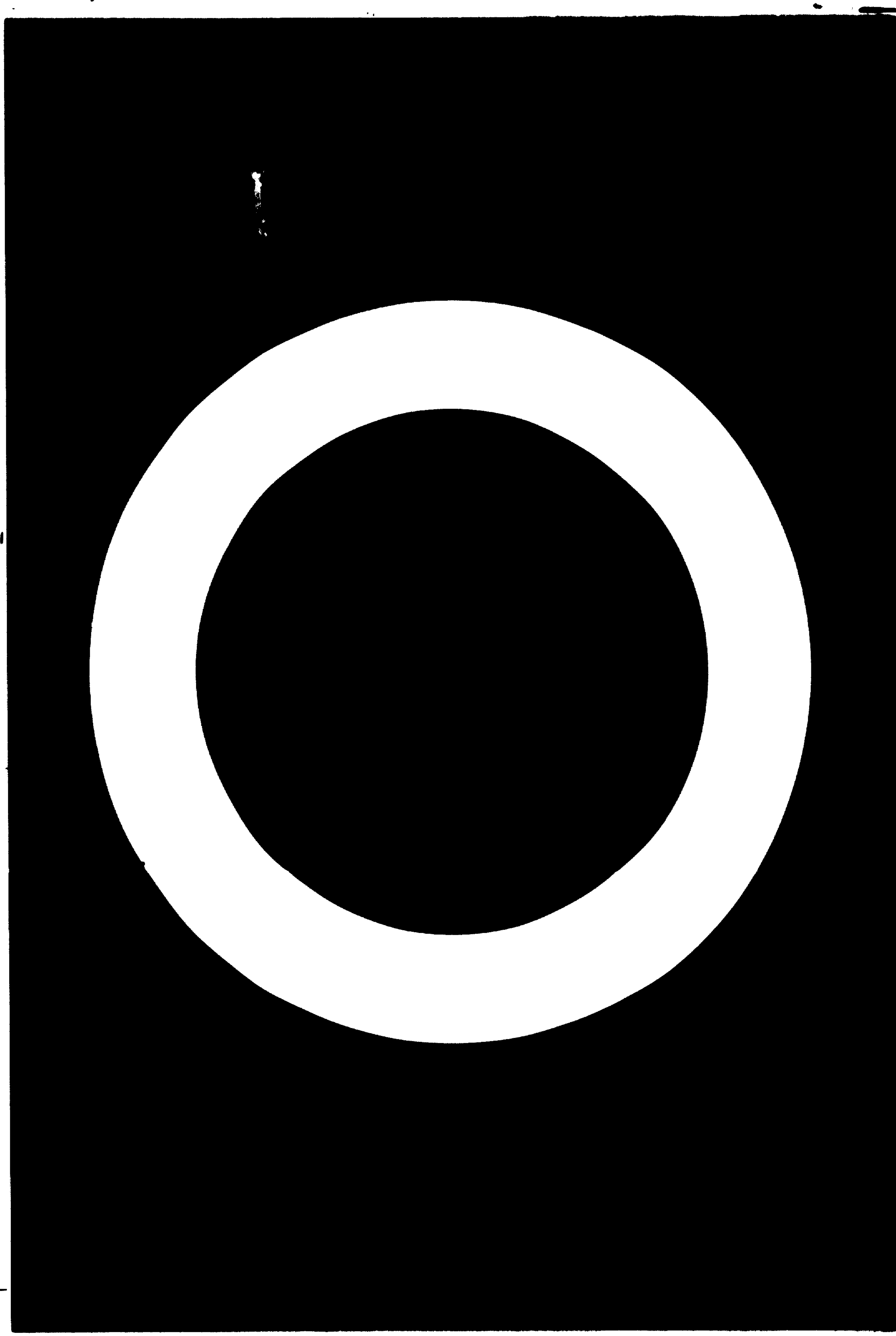
## ABSTRACT

The present report summarizes the mission of an expert sent by the United Nations Industrial Development Organization (UNIDO) to Montserrat, British West Indies, for the four months March-June 1977 to investigate the feasibility of establishing a ceramic building materials industry there. The mission was Phase III of the three-phase project "Production of Structural Ceramics" (SI/MOT/74/007). At the time the report was prepared, the quality of the clay deposit that was to supply the raw material had not been completely clarified, and the questions that had been raised in a preliminary report remained unanswered because the results of the industrial tests were not yet known. Unless the results of these tests are completely successful, the implementation of this project would not be justified.

Pending the outcome of the trials, the feasibility study was prepared on the basis of a local demand for 1,500,000 bricks per year. This demand was based on the housing policies of the Government of Montserrat and was expected to be maintained for the next ten years. On the basis of this projected production volume, the proved reserves of raw materials could be mined to support such production for more than 20 years.

The plant site selected is in the Windy Hill area, adjacent to the clay deposit, thus minimizing the transport of raw materials. From the technical point of view, the alternative selected is based on the lowest level of mechanization, a natural drying system and an intermittent down-draught oil-fired kiln. The total investment would be about $EC 454,780, production costs about $EC 237,725 yearly, and the annual profit before taxes about $EC 64,675, based on a price of $EC 210 per 1,000 solid bricks. The projected pl[illegible]t would employ about 14 workers.

The production of perforated bricks or hollow blocks would permit savings in fuel and raw materials. There are possible export markets in adjacent islands that might permit increased production volume and lower unit cost.



CONTENTS



Figures

## INTRODUCTION

The industrial sector of Montserrat is still limited to light, small-scale industries, so its Government is promoting industrial development so as to increase employment and for import substitution. No manufacture of structural clay products has yet been established. In the course of a search for basic material for the production of pottery,[1/] the idea of producing ceramic building materials emerged. A three-phase project "Production of Structural Ceramics" (SI/MOT/74/807), was formulated to assist the Government of Montserrat in establishing such an industrial operation. During Phase I, an expert in the testing and evaluation of clays established the existence of suitable deposits of raw materials on the island and prepared the terms of reference for the testing of the clays (Phase II), bearing in mind the envisaged end-products, such as bricks, blocks and tiles.

The clay samples that were collected were sent to Jamaica for testing and analysis. On the basis of this research, UNIDO sponsored an extensive exploration to confirm the suitability of a clay deposit in the Windy Hill area. The report on these tests, which were carried out by the Caribbean Industrial Research Institute (CARIRI) in Trinidad, indicated that these clays could be used to produce bricks and hollow blocks, provided that a non-plastic material were added in a suitable proportion.[2/]

Based on this conclusion, UNIDO found it appropriate to proceed with Phase III of the project and assist the Government in preparing a feasibility study for a structural ceramics production plant. An expert in the manufacture of structural ceramics was assigned to the project for four months (March-June 1977). The job description for this mission was as follows:

> To analyse the results and conclusions of phases I and II of the project, and on these results to base his recommendations as to the production lines possible from a technological point of view
>
> To study the market for clay-based building materials on Montserrat and in potential neighbouring markets and to prepare, on this basis, as well as raw material considerations, a proposal for the composition and volume of the production of the projected plant, including non-structural products such as hand-thrown wares

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1/ DP/ID/SER.A/15.

2/ M. Phillips, Montserrat Structural Ceramics, E-MSC-75-49-1 (Trinidad, CARIRI, 1976).

To select the part of the deposit to be mined, as well as the site for the production plant

To describe the relevant production technology with detailed equipment specifications, bearing in mind the possible pre-treatment of the clay and to establish the range and cost of locally available fuels for a kiln of the type and size envisaged

To prepare a techno-economic feasibility study for the proposed production plant, including the specifications for the required equipment

To assist in planning any required follow-up assistance, including assistance in the commissioning and running-in of the plant

# I. FEASIBILITY STUDY

## The market

The building materials industry plays a basic role in the development of any country. Its activity is very important in the accumulation of fixed capital.

In Montserrat this industry mostly uses cement blocks and wood. For the production of the first, cement must be imported, the price of which has risen considerably in recent years owing to the high costs of fuel all over the world. The wood is also imported, either from Guyana or Belize, and its price is likewise high owing to transport costs. These high costs of materials are reflected directly in the high price of housing.

Low-income families are the first to suffer under these circumstances; their hopes of having houses of their own seem ever more distant. However, a real deficit in building material is not apparent in the building activities of Montserrat. At this writing there was a decrease in the statistical figures; furthermore, the fact that every family seems to own its own lodgings makes it difficult to forecast demand.

## Demographic considerations

The population of Montserrat was estimated at 13,290 in 1975, with a very low rate of increase (negative in some cases) owing to emigration. However, this phenomenon has been changing in the last few years, owing to restrictions established by countries that formerly received immigrants. The present annual of rate of population growth is estimated at about 2.5%. Using this rate as a base, and considering that the foreign restrictions on immigration will be maintained, the population estimates for the 1975-1980 period appear as follows:

| Year | Population |
|---|---|
| 1975 | 13 290 |
| 1976 | 13 622 |
| 1977 | 13 962 |
| 1978 | 14 312 |
| 1979 | 14 670 |
| 1980 | 15 037 |

It is almost impossible to indicate exactly the number of existing houses through analysis of the statistical figures available. Furthermore, the number of persons in the normal nuclear family is far from clear. The present study has arbitrarily adopted five persons as the average family size. On this basis the estimated demand for building materials referring to solid brick (24 x 12 x 6 cm) has been calculated considering:

The present accumulated deficit
The demand resulting from the increase in population
The construction of houses by summer residents
The possibility of exports to St. Kitts and Nevis

The accumulated housing deficit. Referring to census information, it is estimated that, for the decade 1970-1980, a total of 120 houses per year would be required in order to satisfy the demand resulting from the increase in the number of families and normal replacement of existing housing. The Government's housing policy is directed towards providing low-cost housing requirements, resorting to self-help methods. An average of 80 units per year has been the proposed aim in this category.

Increasing population demand. The analysis of the population estimates for the decade 1970-1980 given above show an average of an increase of 350 individuals per year; it is estimated that this increase will continue during the near future. Assuming an average nuclear family of five persons, the above increase assumes a future demand of about 70 units, if each family is to live in a separate house.

Summer residents' houses. The Statistical Digest: 1976 of Montserrat shows a certain number of houses built specially by summer residents who usually spend about six months a year there. An average of 15 such houses per year was built during the period 1970-1975, an average that has experienced some fluctuations, linked undoubtedly to economic conditions in the home countries of these temporary residents.

Possibilities for exports. The high transport costs for building materials would be a disadvantage to exports, owing to weight and risks of damage in transit. However, exports should not be disregarded absolutely, as Montserrat's location with respect to Antigua, Guadeloupe and St. Kitts places it in a privileged position. St. Kitts not included in the Multi-island Project (DP/CAR/73/007) with its approximately 40,000 inhabitants, should be considered as a potential market for the output of this bricks, but it has not been included in this study since an official reply to request for information has not been received.

Assuming that the total Government programme will be achieved and that only a 5% population increase and the demands of the summer residents would have to be considered, there would still be an unsatisfied demand of 120 houses per year.

If the low-income category were given priority as to housing requirements, the average number of solid bricks (24 x 12 x 6 cm) per house would reach a total of approximately 12,000 units, which would bring the unsatisfied demand to approximately 1,440,000 solid bricks annually.

## Plant size and location

### Size

The market study reveals an annual unsatisfied demand for approximately 1,440,000 solid bricks, necessitating a production of about 20 tons/day. A lesser demand with this level of mechanization is hardly conceivable, so the productive capacity of the plant has been calculated accordingly. If good-quality clay bricks were produced, that is, ones with excellent characteristics and a probably lower price, they could well replace the cement blocks that are now produced.

### Plant location

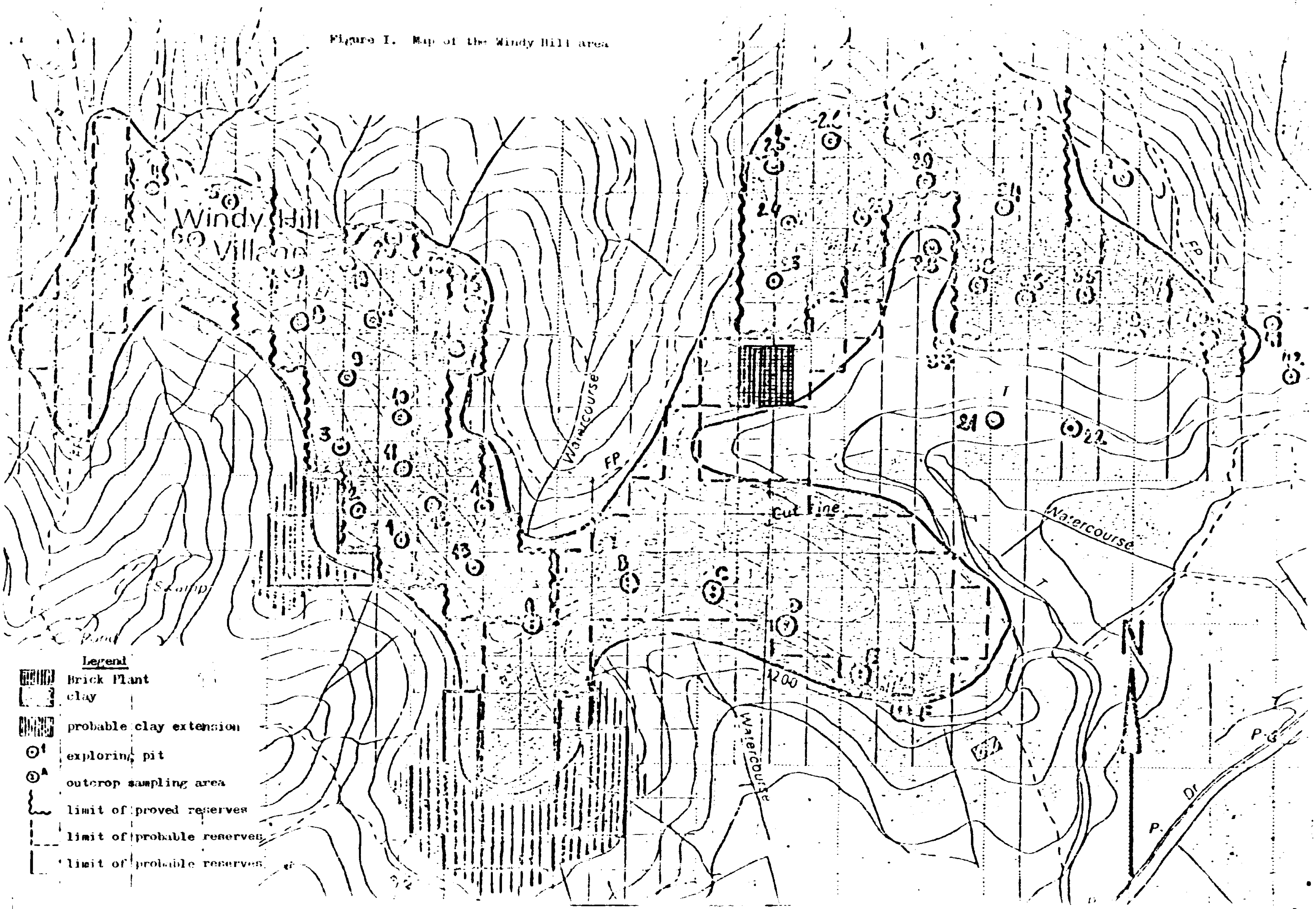
The location of the brickworks has been determined by the basic restrictions imposed by the raw material and the market. As a complement to the appropriate operation, the question of infrastructure should be considered. The short distances in Montserrat have been the decisive factor in the selection of the Windy Hill area as location for the production plant (see figure I).

## Project engineering

### Product analysis

Ceramic materials have been used for building since remotest antiquity. Their continued use has resulted from their many properties that are not easily replaceable by any other product.

Figure I. Map of the Windy Hill area



Articles suoh as solid bricks, hollow blocks and tiles are the result of the proper combination of clay and water, to which sand is sometimes added. Solid bricks are mostly used in house building but also in sewerage and other lesser construotions. The various manufaoturing processes yield a wide variety of products with different qualities that permit their use in a wide range of building activities.

Properties of ceramic building materials

Essentially, a good building produot should have certain minimum requirements to ensure that its use will be safe and that it will have an attractive appearance. Most important among these qualities are size, oolour, compressive strength and porosity. These qualities may be determined by testing against internationally recognized standards.

Manufacturing process

Brick manufacturing processes are dependant on the technologies and grades of mechanization employed. They range from the ancient hand methods to full automation, where the product is handled only at the end of the process during the selection of the finished product. Regardless of the technology employed, there are six basic operations, each of which may be performed in various ways: mining, preparation, moulding, drying, firing and selection.

Mining. The methods of mining the raw materials (primarily olay and sand) depend on the nature of the deposits as well as on the productive capacity of the plant. The clay is normally extracted from open pits, after the removal of the surface layer. It is then stored and aged under cover. The clay sometimes acquires certain characteristics that improve its workability during this stage. It is at times convenient to add non-clay minerals such as sand to give the material the desired properties.

Preparation. This operation should be carried out in such a way that a sufficiently homogeneous mixture is obtained. First, the undesirable oomponents such as stones and roots should be removed. Second, the clay is crushed and ground. When the plasticity of the clay is too high, its properties may be modified by adding low-plastic clay or grained sand, according to the technological evaluations. Whatever the mixture, it should be made homogeneous so as to obtain good workability for the moulding of the end products.

Moulding. This is the process of forming or shaping the paste by extrusion through a die or mouthpiece according to size and shape specifications of the ware end-product. The amount of mixing water used depends on the complexity of the shape of the product and the nature of the clay employed. The paste emerges as a ribbon and is then cut to the required dimensions with the wires of the cutting chariot.

Drying. Once the article has been shaped, the water should be removed as completely as possible before firing. The drying process occurs in two main stages: first, the constant-rate period during which the water loss is superficial and shrinkage occurs, and second, the falling-rate period during which the water evaporates within the body and little or no shrinkage occurs.

The most common methods of drying are the natural and the artificial; they depend on three characteristics of the ambient air: temperature, relative humidity, and velocity. The optimal combination of these three factors makes it possible to obtain the article without cracks. It is important to remember that the drying shrinkage of nearly all clay products is practically at an end when about one third to one half to the water has evaporated.

Firing. There are different kinds and varieties of kilns for firing ceramic products. They may be classified as intermittent, up-draught, horizontal-draught, down-draught, continuous kilns with fixed setting and moveable fire, and continuous kilns with moveable settings and fixed fires.

The most important purpose of firing ceramic bodies is to obtain a hard and resistant product. The following are the stages in the firing of ceramic materials: smoking, pre-heating, full-firing, soaking and cooling.

The smoking or drying stage is the period in which the articles are heated to a temperature of about 300°C, at which time the whole of the water should have been evaporated.

Pre-heating includes some decomposition. During this period the clay is partially decomposed and its combined water liberated. The stage normally covers the temperature range of 300°-800°C.

The full-firing includes the cycle within the temperature range from 800°C to the maximum temperature attained, the temperature rising as rapidly as possible without serious risk of damage to the article.

The soaking period is that during whioh the maximum temperature of heating is maintained so that the desired reactions and other changes are completed or are continued to a degree at which the articles obtain the desired properties. In this stage the temperature in the kiln does not rise rapidly; on the contrary, it should usually be maintained as constant as possible to permit the process to be controlled satisfactorily and readily. This stage includes the temperature at which the firing of the articles is finished. This temperature is specific to each product and even to each clay.

Cooling is the period during which the fired artioles are reduoed in temperature from the maximum to a point at whioh their removal from the kiln is safe and convenient. This stage is performed according to the burning cycle of each clay and product so as to avoid oraoking and other damage.

Inspection and seleotion. This is the last phase in the production line of the ceramic structural materials and is related to such qualities of the products as size, colour and resistance.

Selection of the system

Whatever system is selected for any given ceramics plant, all of the operations that have been mentioned must be oonsidered. In the present case, bearing in mind the rather small planned capacity, the most appropriate technical alternative would be that with the lowest level of mechanization that would nevertheless produce wares of good quality that meet standard speoifications. With a planned capacity of 20 tons/day, the following techniocal process has been selected:

Mining. Considering the amount of raw materials required to have the rated production of the plant, which is very small (about 10 $m^3$/day), the raw material may be extracted by means of a power shovel fitted with a front-end loader and/or a bulldozer operating for a few days a month. As this equipment would be used for only limited periods, the co-operation of the Public Works Department with the brickworks would be advisable. This would diminish the investment appreciably.

From the practical point of view, the extraction should begin in the area of bore holes 1 to 20 from the north end, to the south and south-east (see figure I). This area, which is only part of the proved reserves (104,300 $m^3$), can be mined for more than 20 years. The extraotion of the raw materials in this manner would require the provision of a storage area sufficiently large for about two months' production. To do so would be well worthwhile, since storage has a maturing effect on the clay, improving its workability.

Preparation. The quality of the end-products is related to the degree of preparation of the raw materials. Its main objective is to reach the degree of homogeneity and uniformity of the clay and sand which is appropriate to the mechanization level in the plant. That, in turn, usually depends, to a large extent, on the plant capacity. As the demand is very small, the required mechanization to satisfy it should be of the lowest possible order so as to avoid overpricing to compensate for unduly high investment costs.

Considering the points mentioned and the characteristics of the body mixture and shape of article, the following equipment would be recommended.

Box feeder. This is a rectangular box with a conveyor belt as its mobile bottom, which receives the raw material from the storage or directly from the pit and delivers the required amount of material to the next machine. The principal advantages of its use are the following: overloads in the production line are prevented; irregularities in the mix proportion are avoided; higher efficiency and lower power consumption are achieved; and continuous production is obtained.

Roller mill. This machine consists of two rollers, 1.0 to 1.5 mm apart, rotating at different speeds. A fine material is ensured in all cases. The advantages of its employment are good preparation of the mixed raw material and reduction of the particle size.

Mixer machine. This machine is an horizontal trough in whose interior there is a double shaft fitted with blades arranged in such a way that the material is swept along while it is revolving and being cut. Water is added simultaneously to produce a uniform plastic mass. Its advantages are uniformity of the plastic mass and control of the amount of water in it.

Moulding. As already noted, moulding is that part of the process in which products of different shapes are obtained by applying pressure. The shaping pressure is related to the water content and the shape of the products. The selection of the moulding pressure depends on factors such as the price of the equipment, the scale of production and the complexity and requirement for accuracy of the shape of the product.

The commonest methods of moulding are: the soft plastic process, the extrusion process, the stiff plastic process and the dry and semi-dry process. For the present study, the extrusion process has been selected because it can turn out products of high quality and different shapes with a moisture content between 12% and 18%. The equipment required would be:

The auger machine. This machine is composed of three parts. The first is a pug mill through which the material is introduced. It consists of one or two rotating shafts moving in a trough. The shafts push the material to the end of this trough, forcing it through a small opening into the second part, the vacuum chamber, the clay itself acting as a seal. Within the vacuum chamber the ribbon is cut up by revolving knives that fall through this chamber on to the third part, an auger that consolidates it and finally extrudes it through a nozzle or die, thus giving shape to the product. Its advantages are removal of air bubbles from the plastic mass, a great increase in the workability of the clay, possibility of producing high-quality ware in various shapes and increased density and strength of the green, dry and fired wares.

The cutting chariot. This machine works together with the preceding one, cutting the mass into pieces of the required dimensions. Its operating speed depends on the velocity with which the prepared body is extruded. A wire grid then cuts it into bricks or hollow blocks, which are pushed along to the end of the chariot. Its advantages are uniformity in the dimensions of the products and the cutting of products into different shapes.

The raw materials are moved from one machine to next by means of belt conveyors.

Drying. It has already been noted that there are various drying systems. The selection of the most suitable one depends on several factors, such as production scale, the various shapes of the products and operation costs. One of these systems is the natural drying process. It requires much labour, but the capital investment is low and fuel consumption is negligible. This system is feasible only in tropical regions with appropriate conditions, but fundamentally only in small-scale production where the clay is not very sensitive to drying. Since all of these conditions prevail in Montserrat, the natural drying system has been selected.

The method consists basically in placing the green ware in properly designed sheds, where it is left until its water content has evaporated into the air. The optimal operation conditions for the system should be determined on the site, based on the laboratory results.

Design of the sheds. There is a wide variety of designs for sheds used in the protection of the green ware from rain, direct sunlight, air currents and so forth. However, the saw-tooth roof system over a rectangular unit of 6.0 x 5.0 m held up by pillars is the most advisable and has proved effective in other regions.

The pillars are of reinforced concrete, 0.15 x 0.15 x 3.50 m and are connected by rafters. The roof should be of galvanized sheeting, complete with gutters and accessories. The floor should be leveled, compacted and have a suitable drainage system. The required area for this drying shed is 850 $m^2$. Details are shown in figure II.

Wooden frames for green ware. Once the ware has been out, it should be placed in wooden frames made in such a way as to facilitate the circulation of the lower layers of air with a high moisture content at the same time allowing a reasonable handling of the ware by means of a hand trolley. The size of the frames should be 1.10 m long by 0.60 m wide and 0.25 m high. The details are shown in figure III. The required number of frames is approximately 600 units.

Hand trucks. The handling of the ware is done manually by means of a hand truck provided with a jack in such a way that the frame can be lifted and loaded up to a capacity of 450-500 kg. With these two elements (the wooden frame and the hand truck) it is possible to perform a closed circuit in the transport of the ware, as well as in the working performance. This closed circuit is as follows:

First phase: Transportation of green ware on the wooden frames to the drying shed.

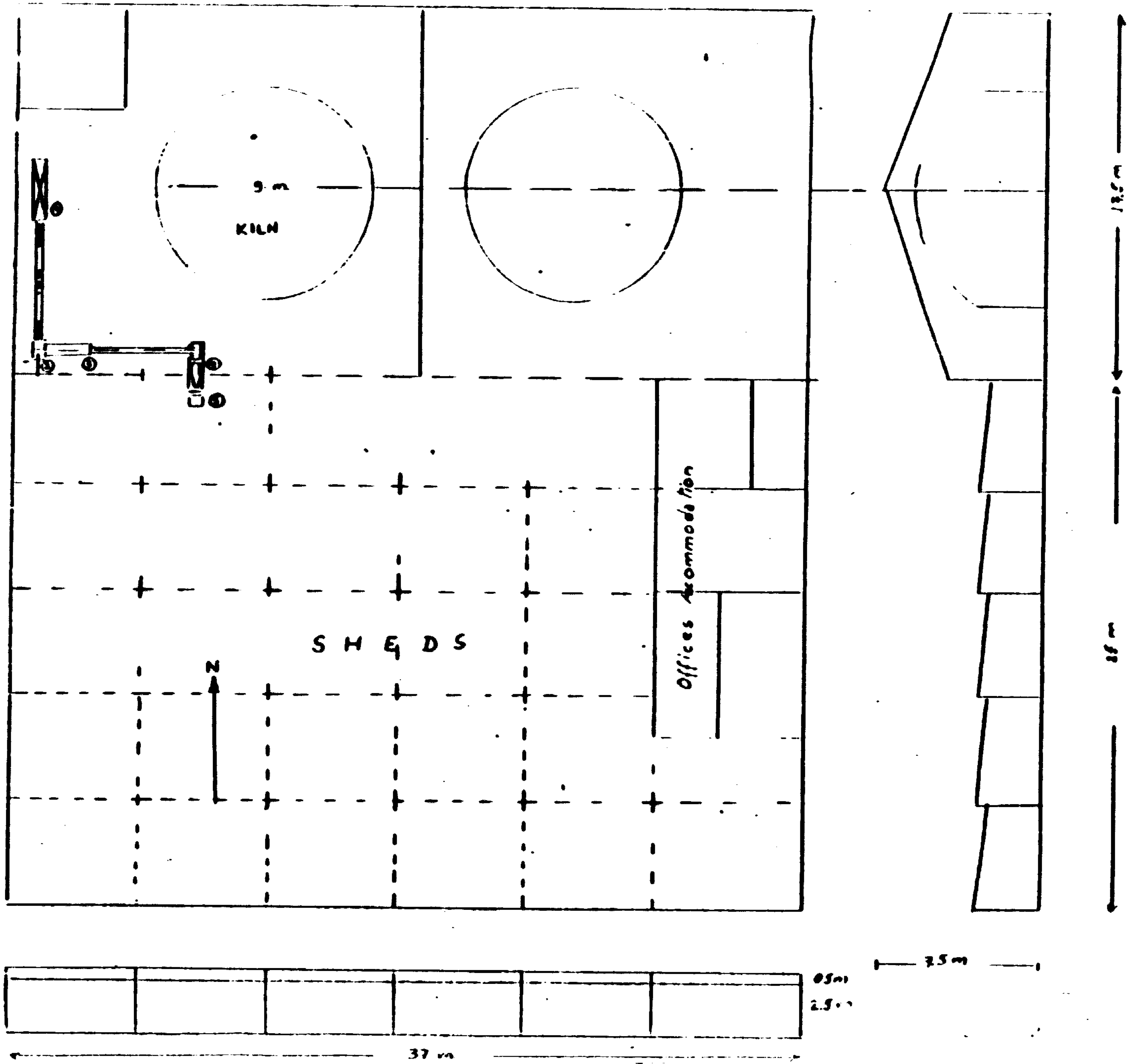
Second phase: Transportation of the frames with the dry ware to the kiln.

Third phase: Collection of the emptied frames at the kiln and transportation back to the starting point.

Two or three of these hand trucks would be required. Their details are shown in figure IV.

Firing. The selection of an adequate firing kiln depends on the productive capacity of the plant, the type of products and the available fuel. Continuous kilns can be employed economically only in large-scale production and are thus totally inappropriate for this project. The intermittent kiln is the most appropriate, because of its flexibility in firing different types of wares; its firing curve and internal conditions are easily modified. One of these is a modern type of round, down-draught kiln; namely the Temco kiln, whose average thermal efficiency permits a fuel saving of 35% to 50%. Its operation is as follows:

Figure 11. General layout of the proposed brickworks




Key:
1 Box feeder
2 Roller
3 Mixer machine
4 Auger machine
5 Cutting chariot

Figure III. Diagram of drying frames

WOODEN FRAME

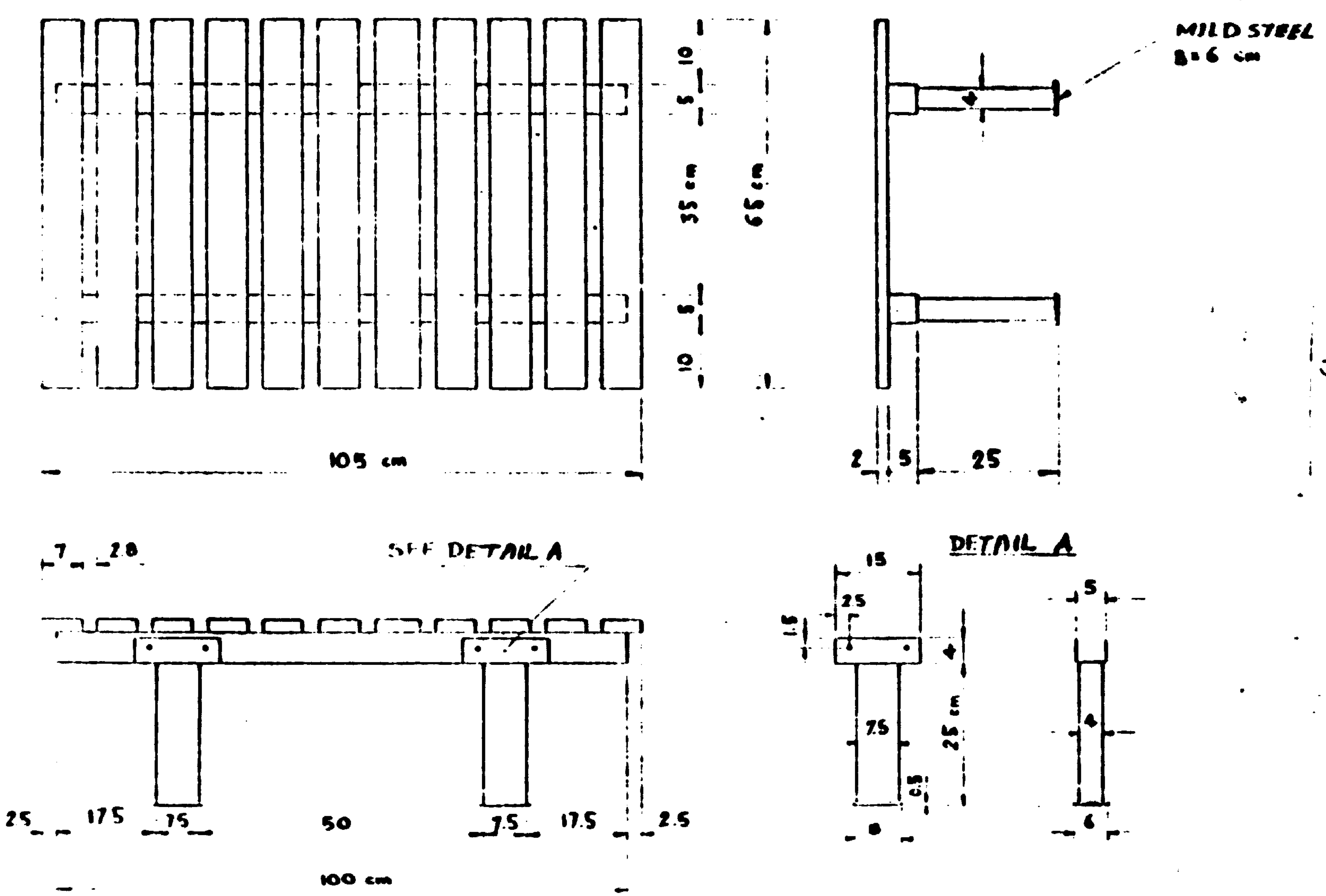
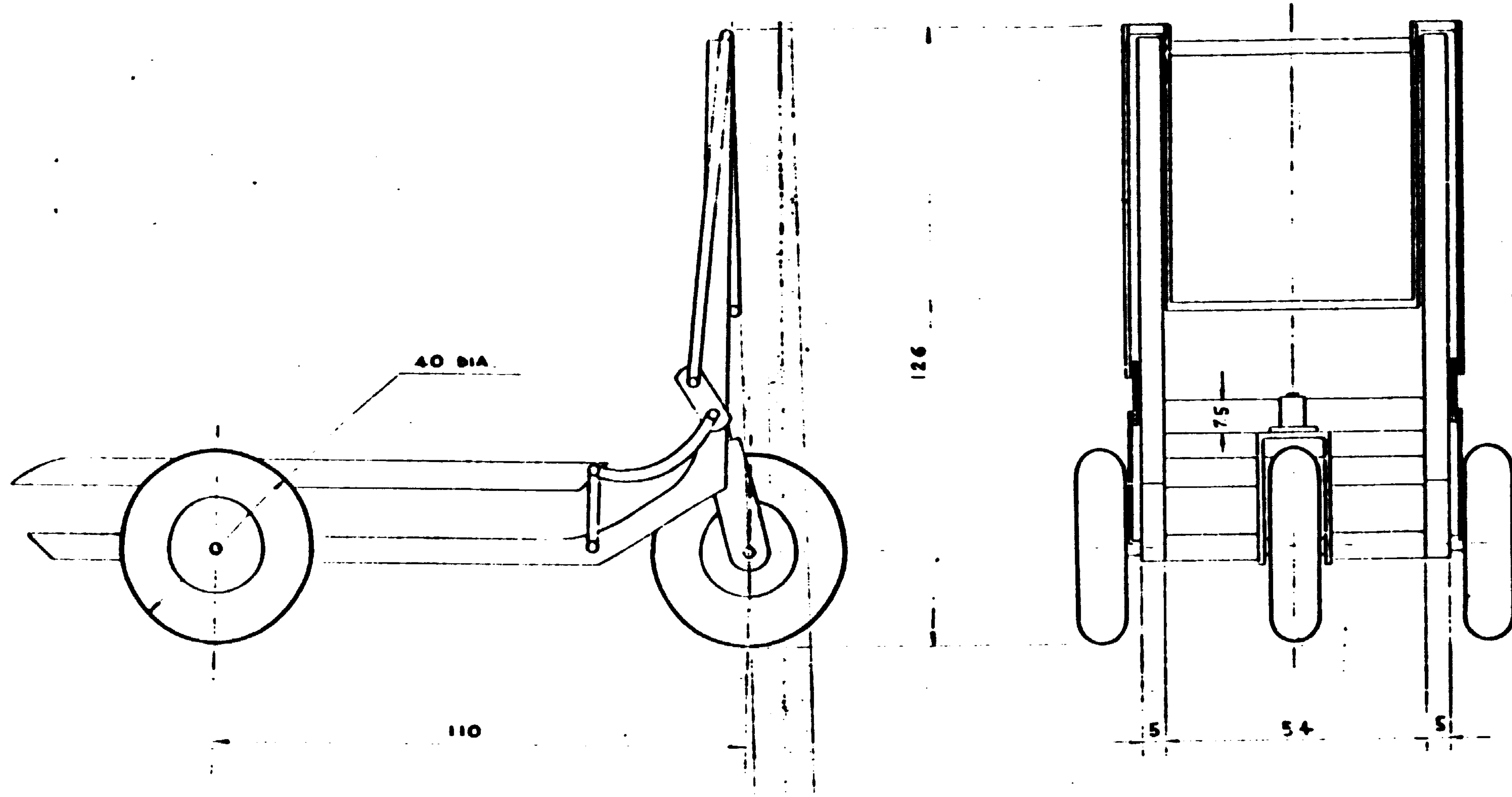


Figure IV. Side and bottom views of hand truck for transporting materials



The wares in the kiln are arranged manually in such a way that the hot gases flow through the setting, so that a well-fired product is obtained. The hot gasses rise from the firemouths, past the bag-wall, up to the crown, then down through the goods to the floor offtakes and by way of the under-floor flue system to the stack. Once the firing cycle has been completed, the products are removed from the kiln manually, then transported to the inspection and storage depot. Under these circumstances, it is considered that the installation of one Temco kiln unit of 9 m (28-foot) diameter would suffice for the brickworks envisaged here. Such a kiln is diagrammed in figure V.

Selection. As the products are basically solid bricks and hollow blocks, selection is done by a visual inspection. In this selection, the size, colour and texture should be considered. Quality control, even though an important part of the production process, should be flexible at the beginning. This is also true of the tests for concerning size and strength according to the standards specifications used. The flow sheet of the process is shown in figure VI.

Building and machinery distribution

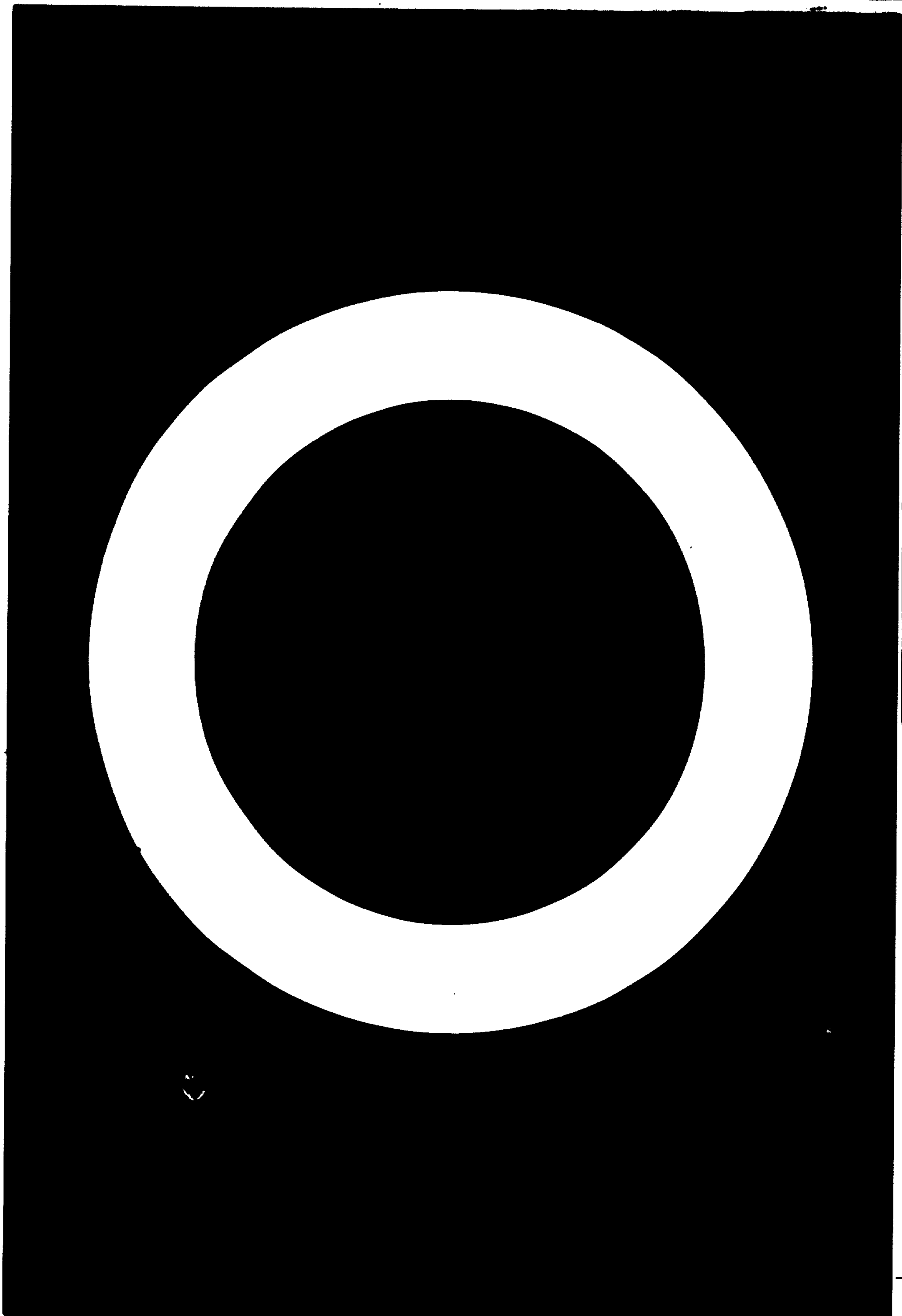
The total area required for the establishment of the brickworks is about 1,600 $m^2$ in order to obtain a rational distribution of buildings and equipment so as to maintain an efficient sequence of operation for the various activities in the plant. Figure II shows a general distribution of the different equipment and its location.

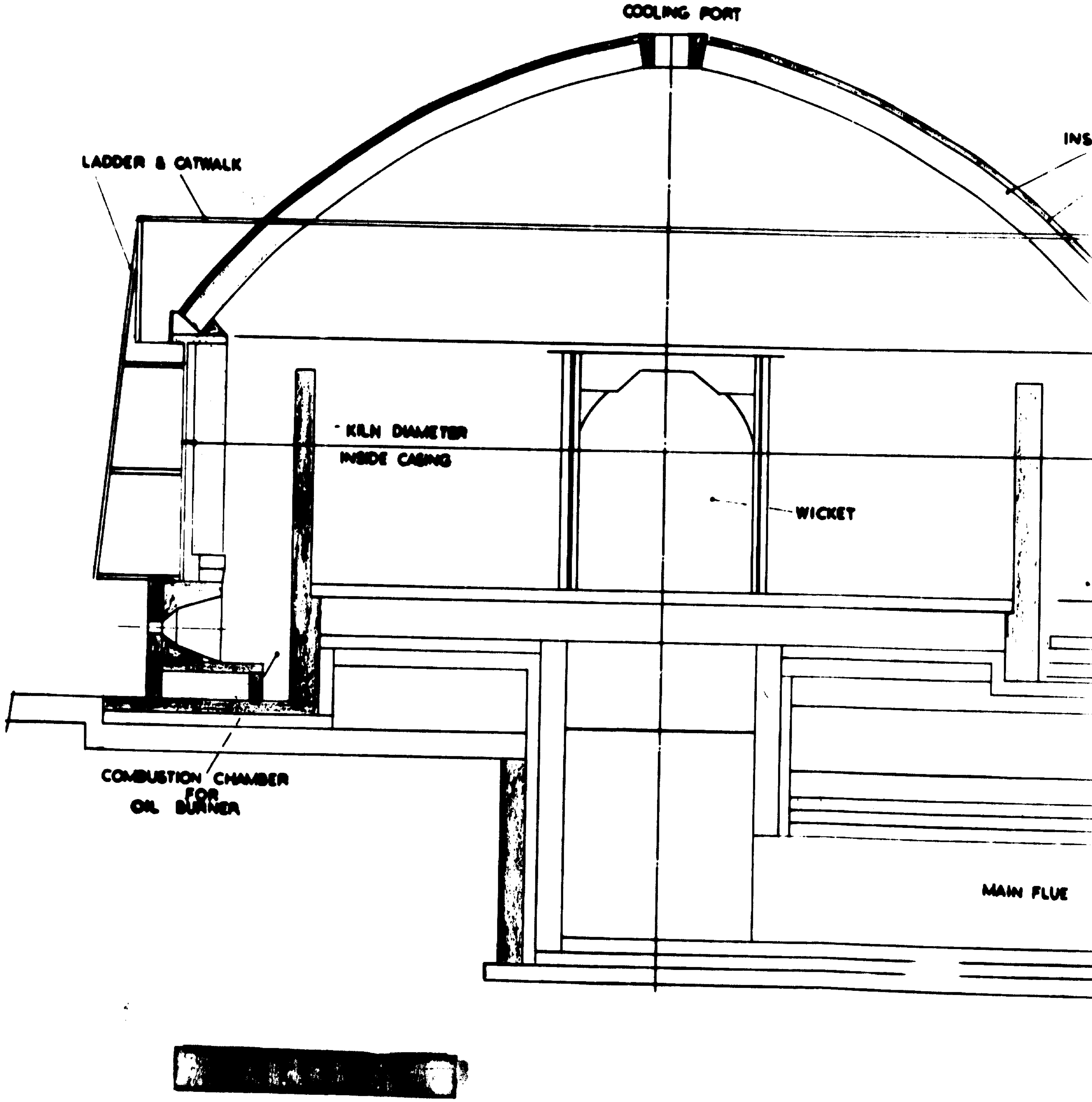
Buildings. The buildings are laid out in such a way that the handling of the ware is reduced to a minimum. This layout is divided into four basic areas: equipment (kiln), drying area, raw materials storage and offices. The general distribution is shown in figure II. The areas are approximately those shown below.

Equipment (kiln). This section should have an area of about 650 $m^2$ including 300 $m^2$ for a future extension of the plant. Initially, 350 $m^2$ should be roofed, and the floor should be of concrete. A structural engineer should be responsible for the designing.

Drying area. Assuming that the drying of the green ware will take about 10 days, the required area for this section is approximately 850 $m^2$.

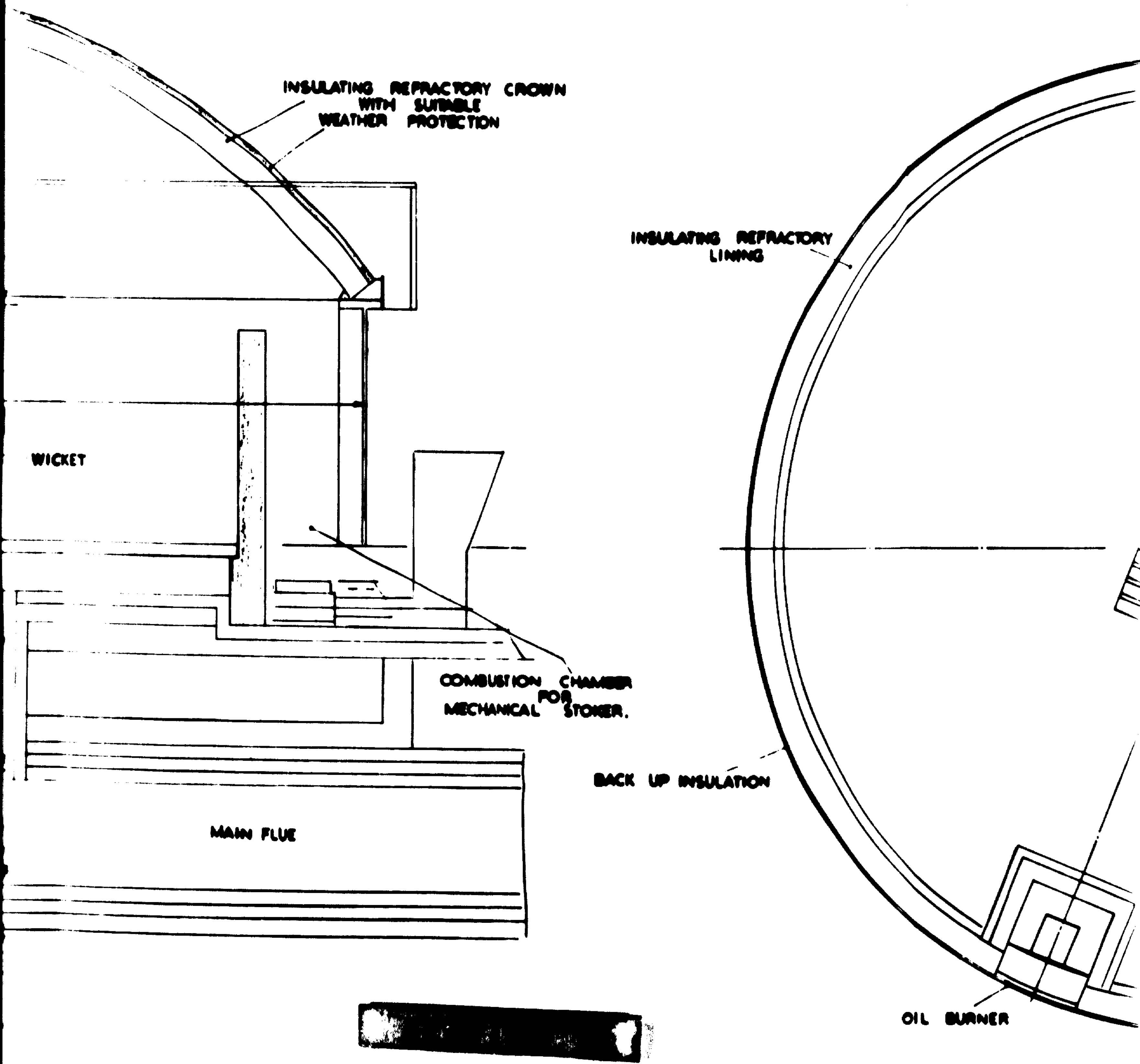
Raw materials storage. On the basis of the extraction method suggested, a storage area of about 130 $m^2$ will be required.





COOLING PORT
LADDER & CATWALK
KILN DIAMETER
INSIDE CASING
WICKET
COMBUSTION CHAMBER
FOR
OIL BURNER
MAIN FLUE

Figure V. Coal- or oil-fired Temco kiln



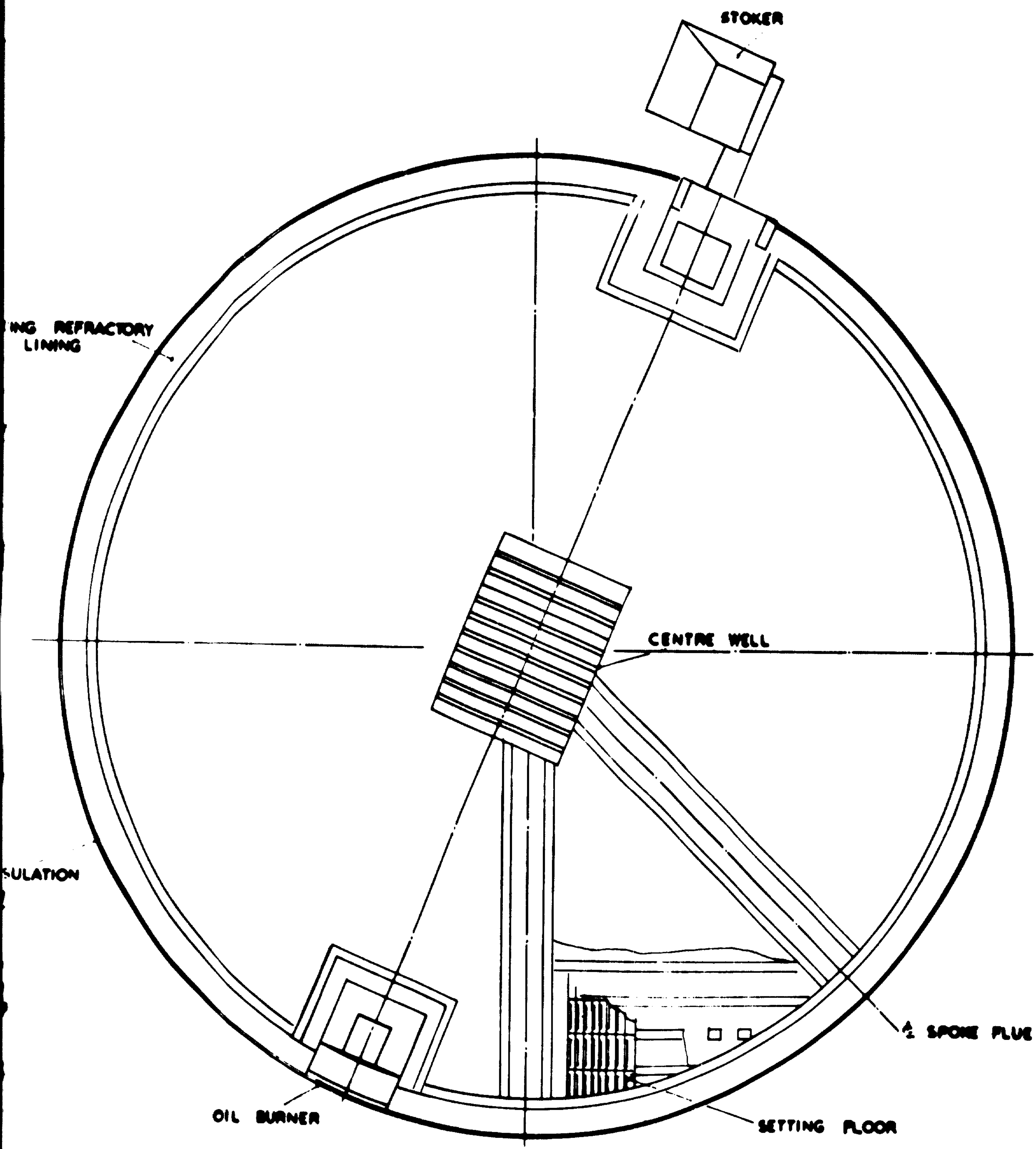

STOKER
ING REFRACTORY LINING
CENTRE WELL
SULATION
½ SPOKE FLUE
OIL BURNER
SETTING FLOOR

FIGURE 3

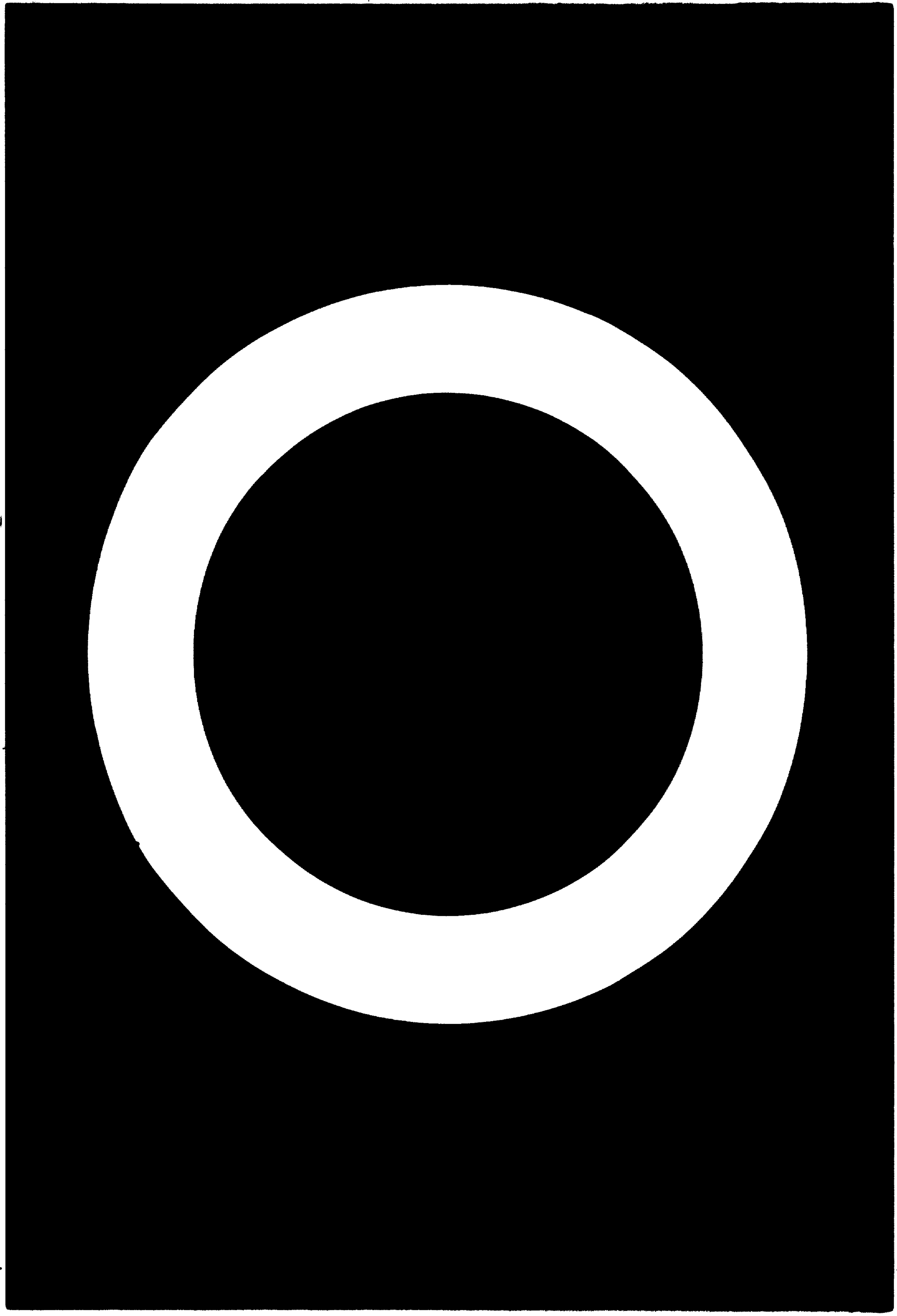
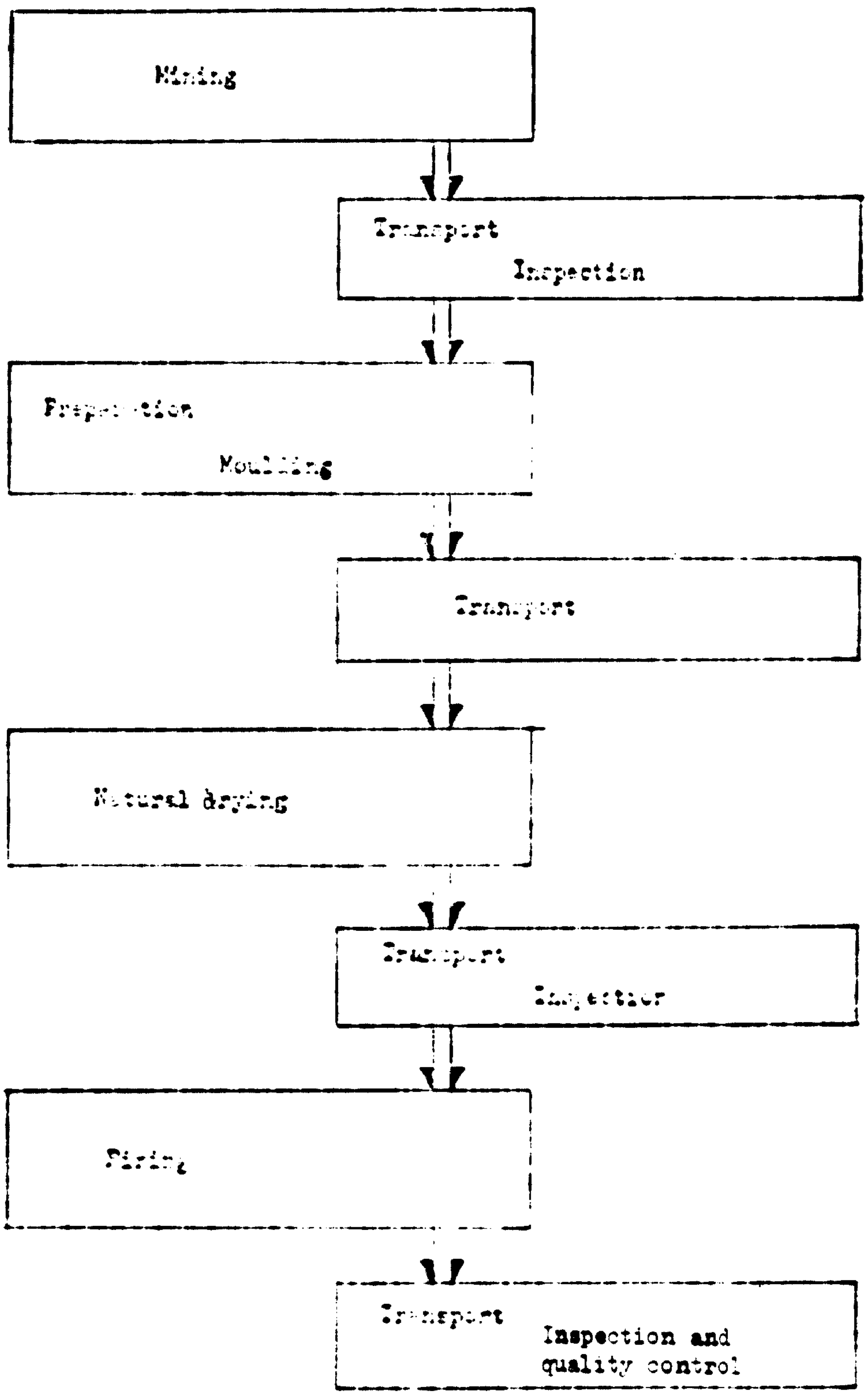


**Figure VI. Flow sheet of the brickmaking process**



Offices. In addition, an area of about 130 $m^2$ for office accommodation would be necessary.

Labour requirements and activities

The details of the personnel required for the projected plant in the various jobs and their functions would be as listed below:

Management and administration. These responsibilities should be undertaken by one person, who should have the following functions: legal representation of the company, planning and direction of factory operations and promotion and sale of the products.

Supervision. This activity should also be undertaken by one person, who would have the following responsibilities: supervision of the workers, checking on the maintenance of the plant equipment, supervising the preparation of the raw materials and reporting to the management on the operation of the plant.

Raw materials supply. As suggested earlier, the mining of the raw materials should be done with the co-operation of the Public Works Department. Transportation (about 300 m) should be by means of a truck or hopper on rails, unloading directly into the box feeder. The cost of two or three such hoppers and 300 m of rails would be about $US 5,000. The cost of the raw material would be about $US 1/$m^3$ (approximately $US 4,700/year) if excavated free of charge by the Public Works Department. This system would require three or four workers. Their main activities would be the transportation and storage of a reasonable stock of raw materials.

Extrusion and cutting of the products. The operation and control of the equipment mentioned should be undertaken by one worker with the following responsibilities: operating the extruder and cutting-chariot, changing the dies of the extruder and replacing the wires of the cutting chariot.

Loading and transport of the green wares to the drying sheds. This work should be undertaken by three workers in accordance with the closed circuit described in the section Drying.

Loading and unloading the kiln. This task should be undertaken by the workers responsible for the firing.

Firing the kiln. The most appropriate fuel for heating the kiln would be fuel oil fed to automatic burners. The firing should be performed by skilled workers. During the firing cycle, the kiln works continuously, so three kiln operators would be needed (one in each shift), with the following duties:

loading the kiln, heating it according to the firing cycle, control and maintenance of the burners, control of the draught by means of a damper and unloading the product from the kiln.

Equipment specifications

The equipment for the brickworks should be selected carefully, with due regard for quality, technical evaluation, characteristics and costs. Unfortunately, no tenders had been received when this report was being prepared. Consequently, machinery for a brickworks of the proposed capacity, utilizing a body composition of 75% clay and 25% sand, was selected from the only catalogue available (that of a manufacturer in Italy). The detailed costs of setting up a brickworks with this equipment are present in the annex to this report.

## II. CONCLUSIONS AND RECOMMENDATIONS

### Conclusions

Raw material quality

These conclusions must be considered as tentative, since the quality of the clay that would be the raw material for the projected brickworks has not yet been determined completely, for the following reasons:

In its analysis of the material, the final report of CARIRI,[3/] expresses serious doubts about the feasibility of its use in the production of ceramic building materials. Furthermore, some preliminary tests conducted at the Craft Centre in Montserrat, based on the recommendations of CARIRI, have not helped to clarify these doubts. A second series of tests was programmed prior to the performance of industrial trial runs, but their results were not known at the time the present report was prepared. Consequently, the present feasibility study has been prepared on the assumption that the findings of these tests, which are being carried out in Trinidad, will be positive.

Market

A survey of the local market has revealed a demand for about 1,500,000 solid bricks yearly, with the expectation of some exports to the adjacent islands of Nevis and St. Kitts. In accordance with the housing policy of the Government, this demand should be maintained for the next ten years.

Raw material reserves

Considering the projected capacity of the brickworks, the proved reserves of clay (104,300 $m^3$) could be mined to support production for more than 20 years.

The plant

Based on the minor scale of production, the establishment of a single brickworks, with the least possible mechanization, has been proposed. The natural drying system has been selected, considering the scale of production and the operating costs, as well as the tropical climatic conditions that prevail. The Windy Hill area, adjacent to the clay deposit, has been selected as the plant site, so as to minimize raw materials transport costs.

The total annual production costs of the plant would be about $EC 237,275; plant revenues have been estimated on the basis of the price of $EC 210 per 1,000 solid bricks (24 x 12 x 6 cm). The annual profit of the operation at 100%

3/ M. Phillips, Montserrat Structural Ceramics, E-MSW-73-33-1 (Trinidad, CARIRI, 1975).

capacity would be about $EC 64,675 before taxes. The project would employ 14 direct workers and stimulate construction activities.

Comment

Owing to the small local demand for its product, the profitability of the projected brickworks would not be great. However, the matter should be considered from a socio-economic point of view, since the project would not only provide employment for a number of people but also stimulate building activities and provide suitable housing for a number of families. Furthermore, the marginal profitability of the venture might be improved if its rate of production were increased sufficiently to capture, or at least to penetrate, the export market in the adjacent islands. Such an increase in volume would help to reduce the unit price of the product.

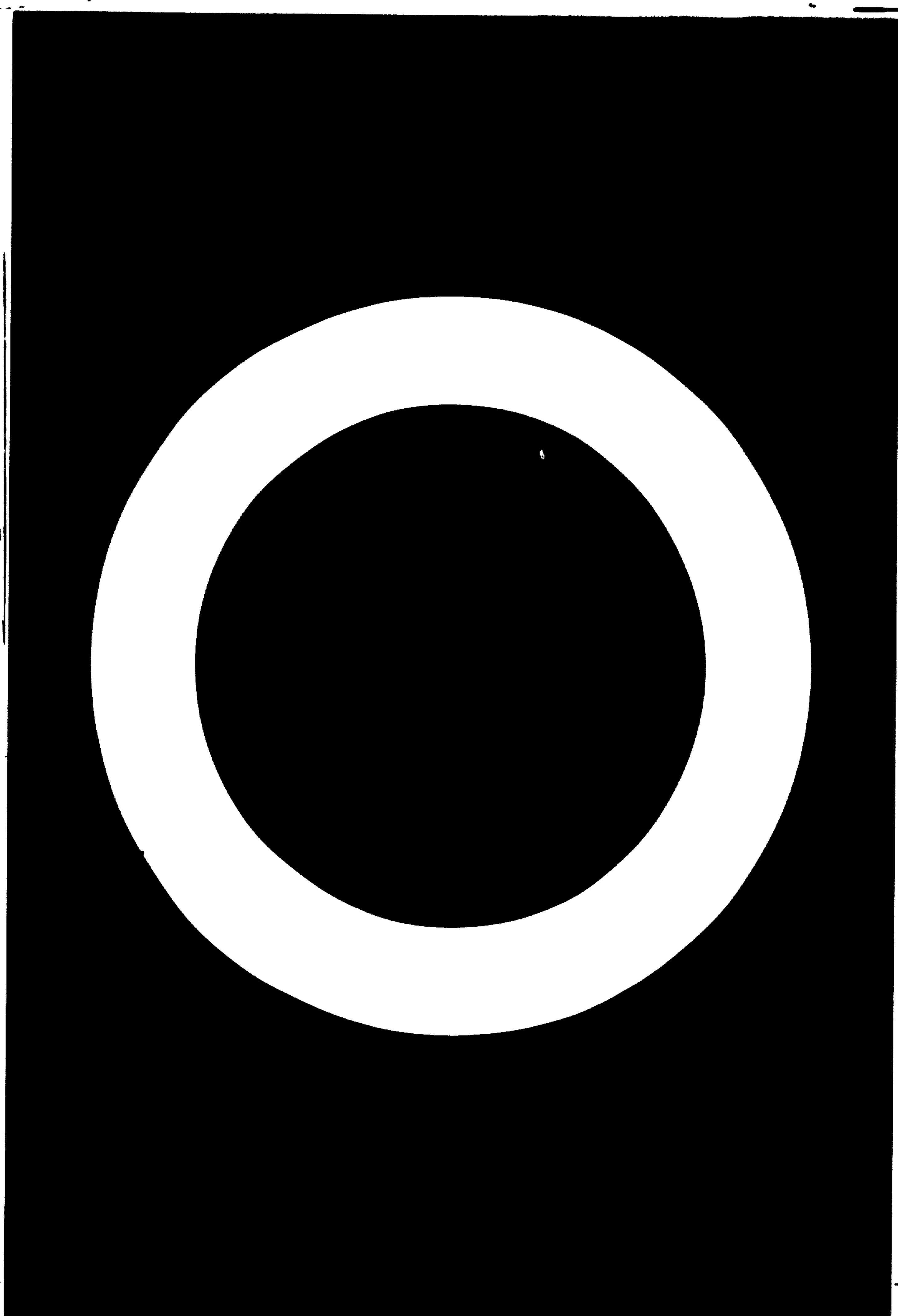
## Recommendations

The implementation of this project would be justified only if the results of the industrial trial runs being carried out in co-operation with CARIRI in Trinidad are completely successful.

A ceramics adviser should be responsible for the selection of the needed equipment, checking out the tenders of prospective suppliers as regards technical evaluation of quality, costs and characteristics.

Any implementation of this project should include technical assistance from UNIDO and some training abroad (possibly in Trinidad) for the manager of the brickworks.

If the results of the trials prove to be negative, some alternative solutions may be considered. First, the establishment of a plant in Antigua, based on the successful surveys performed by another UNIDO expert (DP/CAR/73/001) could be considered from a regional point of view. Second, taking into account the same expert's survey in Antigua (Report No. 6, Antigua 26/5/1977) and considering the presence of lateritic clay in the Windy Hill deposit, it might be appropriate to study the possibility of manufacturing lime-stabilized laterite blocks from it.



## Annex

### COST CALCULATIONS FOR THE PROPOSED BRICKWORKS IN MONTSERRAT

#### Equipment

| Units | Machinery | Type | Capacity (hourly) | Horsepower requirement |
|---|---|---|---|---|
| 1 | Box feeder | ID | | |
| 6m | Belt conveyor | | | |
| 1 | Motor | | | 2 |
| 1 | Motor | | | 2 |
| 1 | Roller mill | 2LR | 2 $m^3$ | |
| 1 | Motor | | | 15 |
| 1 | Mixing machine | ID/1 | | |
| 1 | Motor | | | 4 |
| 5m | Belt conveyor | | | |
| 1 | Motor | | | 2 |
| 1 | Auger machine | 10TR | 2-3 tons | |
| 1 | Motor | | | 30 |
| 1 | Cutting chariot | 3T | 1 000 bricks | |
| | Drying system | | | |
| 600 | Wooden frames | | | |
| 2-3 | Hand trolley | ICAM | 400 kg (each) | |
| | Firing and Control equipment | | | |
| | Round, down-draught Temco kiln | | | |
| | Automatic oil burners | | | |
| | Ancillary equipment (filters, pump, thermometers, manometers, motor, tank) | | | |
| | Intsrumentation (galvanometer thermocouples etc.) | | | |

Economic evaluation

Investment partioulars

Fixed actives

Equipment[a/]

| Units | Machinery | f.o.b. ($US) | c.i.f. ($EC) | |
|---|---|---|---|---|
| | Preparation | | | |
| 1 | Box feeder | | | |
| 1 | Motor | 3 200 | 9 920 | |
| 6m | Belt conveyor | | | |
| 1 | Motor | 1 400 | 4 340 | |
| 1 | Roller mill | 5 200 | 16 150 | |
| 1 | Motor | | | |
| 1 | Mixing machine | | | |
| 1 | Motor | 4 500 | 13 970 | |
| 5m | Belt conveyor | | | |
| 1 | Motor | 1 200 | 3 730 | |
| 1 | Auger machine | | | |
| 1 | Motor | 13 000 | 40 360 | |
| 1 | Cutting chariot | 1 500 | 4 660 | |
| 6 | Dies | 1 200 | 3 370 | |
| | Spare parts (15%) | 4 700 | 14 590 | 111 450 |
| | Drying system | | | |
| 600 | Wooden frames | | 6 000 | |
| 3 | Hand trolleys | 1 500 | 4 590 | 10 590 |
| | Firing and control equipment | | | |
| | Temco kiln | 20 000 | 62 100 | |
| | Automatic oil burners | | | |
| | Ancillary equipment (filters, pump, thermometer, manometers, motor, tank) | | | |
| | Instrumentation (galvanometer, thermocouples etc.) | 8 000 | 24 840 | 86 940 |
| | | | | 208 980 |

a/ The c.i.f. price of the equipment has been estimated at 15% over the f.o.b. price.

| | | |
|---|---|---|
| **Buildings** | $EC | |
| 850 $m^2$ Drying shed | 85 000 | |
| 350 $m^2$ Equipment kiln shed | 56 000 | |
| Equipment foundations | 2 000 | |
| 270 $m^2$ Concrete floor (10 cm thick) | | |
| Equipment (kiln) | 5 000 | |
| 130 $m^2$ Office accommodations | 25 000 | |
| 850 $m^2$ Compacted drying area | 5 000 | 178 000 |
| **Land** | | |
| 15 Hectares, including the mine and other areas | 15 000 | 15 000 |
| **Furniture** | | |
| 2 Desks | 2 000 | |
| 1 Typewriter | 1 000 | |
| 1 Adding machine | 1 000 | 4 000 |
| **Services** | | |
| Electrical installation | 4 000 | |
| Fuel-oil tank | 5 000 | |
| Hydraulic installation | 2 000 | |
| Workshop tools | 4 000 | 15 000 |
| Total fixed actives | | 420 980 |
| **Deferred charges** | | |
| *Initial investment for operating* | | |
| One month's operational costs in direct and indirect labour, services, and maintenance | 16 900 | 16 900 |
| *Working capital* | | |
| One month's operational costs in direct and indirect labour services and maintenance | 16 900 | 16 900 |
| *Summary of investments* | | |
| Fixed actives | 420 980 | |
| Deferred charges | 16 900 | |
| Working capital | 16 900 | |
| Total investment | 454 780 | |

| | $EC | |
|---|---|---|
| **Annual production costs** | | |
| **Direct labour** | | |
| 4 Skilled workers | 15 600 | |
| 7 Unskilled workers | 18 200 | 33 800 |
| **Indirect labour** | | |
| 1 Manager | 10 000 | |
| 1 Supervisor | 6 000 | |
| 1 Typist | 4 200 | 20 200 |
| **Raw materials** (appendix I) | 750 | 750 |
| **Services** | | |
| Electricity (400 kWh x 250 days x $EC 0.04) | 4 000 | |
| Fuel (appendix II) | 134 900 | |
| Water | 200 | |
| Telephone | 600 | 139 700 |
| **Depreciation** (appendix III) | 25 225 | 25 225 |
| **Maintenance** | | |
| 5% Over the c.i.f. value of the equipment | 5 580 | 5 580 |
| **Insurance premium** | | |
| 1% Over the c.i.f. value of the equipment | 1 150 | 1 150 |
| **Unforeseen** | | |
| 5% Over the above costs | 11 320 | 11 320 |
| Total annual production costs | | 237 725 |

## Income and profits

The income and profits estimates are based on a price of $EC 210 per thousand solid bricks. This price has been selected because the cement block unit commonly used in Montserrat, equivalent to three solid bricks, has a price of $EC 0.65 on the local market. On the other hand, taking into account the process and the kiln selected, full production would be reached very rapidly during the first year. Therefore, the production would be about 80% the first year, and from then on 100% of capacity. The gross profits estimated would be as follows:

| Item | First year | Years 2 to 10 | Years 10 to 20 |
|---|---|---|---|
| Production (1 000) | 1 152 | 1 440 | 1 440 |
| Depreciation ($EC) | 25 225 | 25 225 | 11 285 |
| Total production costs ($EC) | 237 725 | 237 725 | 223 785 |
| Income ($EC) | 241 920 | 302 400 | 302 400 |
| Profits ($EC) | 4 195 | 64 675 | 78 615 |

As noted, these calculations are based on the production of solid bricks. The production of perforated bricks or hollow blocks should permit economies of fuel and raw material.

## Appendix I

### RAW MATERIALS: ESTIMATIONS OF VOLUME AND COSTS

On the basis of the production of solid bricks at capacity production, the total output of the projected brickworks would be 1,440,000 units per year. (The production of perforated bricks or hollow blocks would permit a smaller consumption of raw materials.) Assuming a body composition of 75% clay and 25% sand and a unit weight per solid brick of 4.2 kg, the amount of raw materials required would be as follows:

1,440,000 bricks of 4.2 kg each = 6,050 tons

| Item | Clay (75%) | | Sand (25%) |
|---|---|---|---|
| Required amounts | 4 050 tons | | 1 510 tons |
| With allowance for damage (8%) | 5 000 tons | | 1 630 tons |
| Mining efficiency of 75% (25% wastage) | 6 670 | | 2 180 |
| Bulk density: 1.8 tons/m$^3$ | 3 700 m$^3$ | | |
| 2.2 tons/m$^3$ | | | 990 m$^3$ |
| For 20 years | 74 000 m$^3$ | + | 19 800 m$^3$ = 93 800 m$^3$ |

The costs of these raw materials have been estimated on the basis of the price of the land ($EC 15,000) divided by the number of cubic metres to be extracted over twenty years. Thus,

$$\frac{\$EC\ 15\ 000}{93\ 800} = \$EC\ 0.16/m^3$$

The annual consumption of raw materials (clay and sand) would be 4,690 m$^3$. The annual cost would thus be,

$$4\ 690\ m^3 \times \$EC\ 0.16 = \$EC\ 750$$

## Appendix II

### FUEL CONSUMPTION AND COST

The usual fuels for firing heavy olay wares in intermittent kilns are ooal, liquefied petroleum gas (LPG) and fuel oil. Considering that in Montserrat any of these would have to be imported, the selection should be justified by the analysis of some of the most important oharaoteristios, suoh as moisture oontent, calorific value and availability. It would thus appear that heavy fuel oil is the most appropriate, since its oalorific value, on a weight basis, is notably higher than that of coal. The properties of heavy fuel oil are:

| | |
|---|---|
| Maximum viscosity: Redwood I at 100°F (37.8°C) (sec.) | 950 |
| Net calorific value (Kcal/kg) | 9,750 |
| Speoific gravity at 60°F (15,6°C) (g km³) | 0.95 |
| Minimum handling temperature °F | 80°F (17.6°C) |

If the coal consumption of a round down-draught kiln for firing one thousand solid bricks is known, the fuel oil required would be as follows:

| | |
|---|---|
| Coal consumption | 500 kg |
| Calorific value of coal | 6 500 Koal/kg |
| Calorific value of fuel oil | 9 750 Koal/kg |
| Fuel oil consumption | $\frac{500 \times 6\ 500}{9\ 750} \cong 335$ kg |
| Specific gravity of fuel oil | 0.95 |
| Volume of fuel oil | $\frac{335}{0.95}$ = 352 litres = 93 gallons |

Annual production: 1,400,000 solid brioks

Annual fuel consumption: 93 x 1,440 = 133,920 gallons

The price of fuel oil has been estimated taking into aooount that its value is about 73% of that of diesel oil. At this writing, the price of the diesel oil used in the power station was $EC 1.63 per imperial gallon (about $EC 1.38 per US gallon). Based on the above the annual cost of fuel oil is 133,920 x 1.38 x 0.73 = $EC 134,900. As has been noted the production of perforated brick or hollow blocks would permit fuel economies.

## Appendix III

### DEPRECIATION SUMMARY

| Actives | Equipment value ($EC) | Residual value (10%) | Estimated life (years) | Depreciation ($EC) |
|---|---|---|---|---|
| **Equipment** | | | | |
| Moulding and cutting machine | 111 470 | 11 147 | 10 | 10 030 |
| Drying system | 10 590 | 1 060 | 10 | 950 |
| Firing system: | | | | |
| Kiln | 62 100 | 6 210 | 20 | 2 790 |
| Instrumentation | 24 840 | 2 480 | 10 | 2 240 |
| **Buildings** | | | | |
| Sheds etc. | 153 000 | 15 300 | 20 | 6 880 |
| Office accommodations | 25 000 | 2 500 | 20 | 1 120 |
| **Furniture** | | | | |
| Desks, typewriter etc. | 4 000 | 400 | 10 | 360 |
| **Services** | | | | |
| Electrical installation | 4 000 | 400 | 20 | 180 |
| Fuel oil tank | 5 000 | 500 | 20 | 225 |
| Hydraulic installation | 2 000 | 200 | 20 | 90 |
| Workshop tools | 4 000 | 400 | 10 | 360 |
| Total | | | | 25 225 |

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