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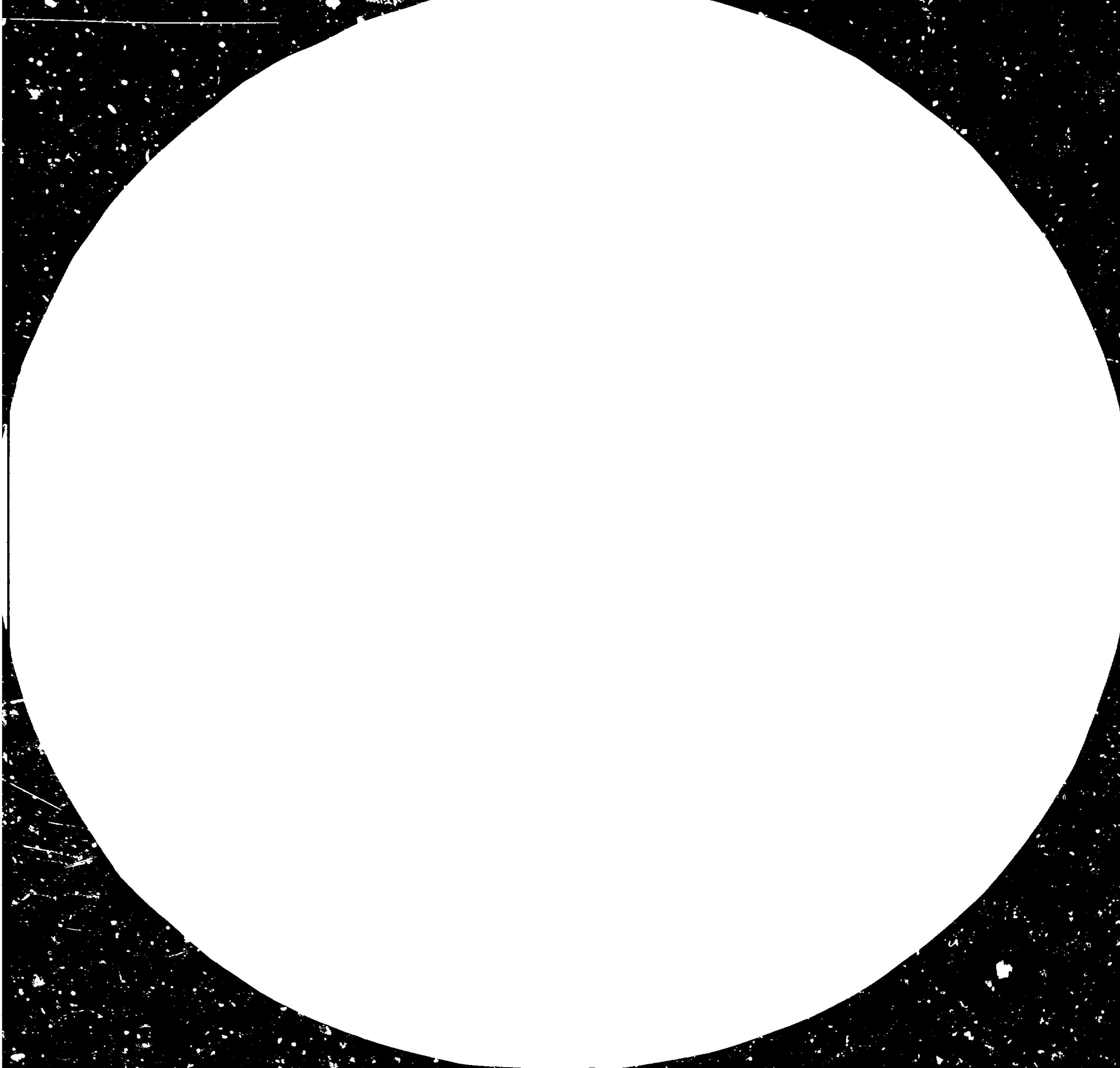

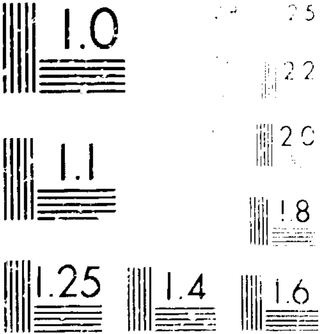
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GLASS INDUSTRY

DP/MLW/80/004

MALAWI

Technical report: The manufacture of clay-based fine ceramic products in Malawi, feasibility and appraisals

Prepared for the Government of Malawi
by the United Nations Industrial Development Organization,
acting as executing agency for the United Nations Development Programme

Based on the work of Ian Knizek, expert in market
research and preparation of
feasibility studies

United Nations Industrial Development Organization
Vienna

V.82-30922

Explanatory notes

Mention of firm names and commercial products does not imply the endorsement of the United Nations Industrial Development Organization (UNIDO).

The monetary unit in Malawi is the kwacha (K). During the period covered by the report, the value of the kwacha in relation to the United States dollar was $US 1 = K 1.07.

ABSTRACT

Within the framework of the United Nations Development Programme (UNDP) project "Glass industry" (DP/MLW/80/004) an expert was sent by the United Nations Industrial Development Organization (UNIDO), acting as executing agency for UNDP, to Malawi to investigate the possibility and make appraisals for the manufacture of clay-based fine ceramic products in Malawi. The mission was carried out from 14 June to 31 July 1982. The following are the main conclusions and recommendations:

1. Malawi offers a relatively small market for earthenware, wall tiles and sanitary ware.

2. There are large reserves of clay near Linthipe, suitable mostly for earthenware.

3. On the basis of import figures it seems feasible that 136,000 pieces of earthenware, 20,000 m^2 of wall tiles and 6,600 pieces of sanitary ware could be manufactured and sold in Malawi.

4. A combined small-scale operation comprising the manufacture of all three of the above products under one roof seems to offer a better chance of success than separate manufactures.

5. The outlook for the combined operation would be better if it could be incorporated within the glass-making operation that is being planned.

6. In view of the small market for earthenware it is recommended that alternate approaches to its manufacture be considered. Saucers and flatware could be pressed from glass, or dinnerware could be manufactured at the artisanal level.

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INTRODUCTION

The report "Glass Manufacture in Malawi (DP/MLW/80/004)" of March 1981 recommended that the possibility of manufacturing in Malawi clay-based goods, such as wall tiles, bathroom wall fittings, sanitary ware, domestic/commercial flatware and hollow-ware, as well as low-voltage insulators, be investigated once more.

Following the request from the Government of Malawi UNIDO sent Ian Krizek, expert in market research and preparation of feasibility studies, to Malawi to investigate the possibility and make appraisals for the manufacture of clay-based fine ceramic products in Malawi. The mission was carried out from 14 June to 31 July 1982.

The expert ascertained that a market amounting to K 110,000 per year did exist as of 1975. In view of its relatively small size the expert suggested that the manufacture of pottery in Malawi would be more justifiable economically if a multi-purpose plant manufacturing wall tiles, sanitary ware and pottery were established.

The interest in the manufacture of clay-based goods was aroused again with the discovery of a clay at Linthipe, 30 km from Lilongwe, and of clay-bearing sand deposits at Mchinji in 1978 and the idea to beneficiate it to produce glass-quality sand and develop a glass-making industry. The sand contained 1 to 2 per cent alumina so that the anticipated yield of 4 per cent was possible, since about 4,500 tons per year were to be beneficiated.1/* This would mean about 180 tons of clay per year, which could be used in the manufacture of certain clay-based products.

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*For the notes see page [illegible] below

CONCLUSIONS AND RECOMMENDATIONS

1. Malawi offers a relatively small market for earthenware, wall tiles and sanitary ware.

2. There are large reserves of clay near Linthipe having a buff firing colour and adequate working and firing properties.

3. The Linthipe clay is suitable for the manufacture of earthenware-type bodies but its fired colour might be a drawback for its use for dinnerware bodies.

4. Whether the Linthipe clay is suitable for the manufacture of sanitary ware cannot be decided without extensive tests.

5. Not enough evidence is available to decide whether enough clay can be gained from the Mchinji sand and whether it is of adequate quality.

6. On the basis of import figures it seems feasible that 136,000 pieces of earthenware, 20,000 m^2 of wall tiles and 6,600 pieces of sanitary ware could be manufactured and sold in Malawi.

7. A combined small-scale operation comprising the manufacture of all three of the above products under one roof seems to offer a better chance of success than separate manufactures.

8. At the level of manufacture compatible with the estimated market the envisaged combined operation is of questionable profitability.

9. Nevertheless the project is sensitive to increases in the scale of operation and improved revenue.

10. The outlook for the combined operation as envisaged in annexes III, IV and V would be better if it could be incorporated within the glass-making operation that is being planned.

11. In view of the small market for earthenware alternate approaches to its manufacture should be considered.

12. Saucers and flatware could, for instance, be pressed from glass and their sale might widen the range of products manufactured by the proposed glass works and increase its sales.

13. Another approach would be the manufacture of dinnerware at the artisanal level for which it might be possible to secure financing through the Small Enterprise Development Organisation of Malawi at Blantyre.

14. It is recommended that both of the above approaches be further pursued.

FINDINGS

A. Approaches

Markets

Since a detailed market study was not possible because of the time limit, official import statistics supplemented by interviews of leading importers or retailers were used as the basis for this report.

Earthenware

The available market is small (see annex I, table 1). The amount of pottery imported in 1981 is less than half of that which could be jiggered by a team of two on a hand jigger. Such an amount is hardly compatible with an industrial manufacture even at a labour-intensive level of technology. And it is difficult to imagine that the total yearly revenue associated with it could support an adequate administration and competent technical management.

The considerable variation in the import figures might be due to sporadic purchases of dinnerware by hotels. For this reason, the import figures can hardly be used for extrapolating the trend for future demands.

Hotel or institution dinnerware must, however, be excluded when considering a possible market in the country.

Wall tiles

In the case of wall tiles, in annex I, table 2, the figure for 1981 indicates an import of only 32,000 m^2 while 100,000 m^2 per year are normally considered barely adequate for an industrial production utilizing labour-intensive technology.

Furthermore, the comparatively high imports in 1979 and 1981 are probably due to the building of the capital city. So for instance, the construction of the Reserve Bank building in 1979-80, for which imported tiles were used for outside cladding, probably affected the import figures.[2/] Here again, on the basis of the available import figures the trend for future demands cannot be extrapolated.

The import figures shown in table 2 are supposed to include those of floor tiles. After consulting several builders, the expert concluded that these products are little used in the country so that their impact on the official import figures is believed to be slight.

Sanitary ware

The import figures for sanitary ware are similar to those for wall tiles. Here, too, caution should be exercised in using these figures to estimate future markets. The import figure for 1981 of 6,600 pieces seems more in line with the figures for 1975, 1976 and 1977 than with those for 1978, 1979 and 1980. In estimating the size of the market one should bear in mind that the import figure for 1981 represents less than one half of the output of a competent caster.

Raw materials

Linthipe clay

The clay deposits of Linthipe have now been quite well explored and tested by the Malawi Geological Survey at Zomba. So far two main clay bodies have been isolated, of which the so-called area 5 appears to be more promising because its clay contains less iron oxide. The total clay bearing area is reported to be approximately 1.5 km^2. It is said to be covered with a stratum 1.5 m thick, which will give a potential reserve of over 1.25 million tons.

The raw clay is dark grey when moist and feels as ball clay does except for its grittiness. Particle size analyses shown in annex II indicate that the content of 100 µm particles varies from about 5 to 24 per cent. Furthermore, the proportion of "clay particles", defined as anything smaller than 4 µm, ranges from about 45 to 63 per cent. The coarse particles have been identified as residue of the bedrock, generally plagioclastic feldspar nearest Labradorite. This is consistent with the results of the chemical analyses. The calcium oxide content decreases largely in the same proportion as that of particles under 4 µm increases. Apart from this and the rather high iron oxide content, the chemical compositions resemble those of an average ball clay. The clays are easily deflocculated through additions of sodium silicate. The few firing tests that have been run indicate a shrinkage of about 6 per cent at 1,150 °C and water absorption of about 8 per cent. There is no apparent cracking either in drying or in firing.

The fired colour is buff, of a rather unsightly hue. These results indicate that the Linthipe clay could be used in compounding earthenware bodies, i.e. such exhibiting water absorption of around 8 to 15 per cent.

Clay from the Mchinji sand

So far the clay from the Mchinji sand has not been tested in a more or less pure state. A sample obtained from the crude Dambo sand, reportedly by dry sieving through a 300 mesh (though 100 mesh seems more likely) contained only about 4 per cent of particles under 4 um. Few sedimentation tests that could be made by the experts showed the sand sediments out of the suspension with some difficulty because of their fineness. Therefore, if the sample that has been examined is representative of the material that will ultimately become available once the sand beneficiating operation gets started, the eventual sand-derived clay cannot be considered a viable raw material for the manufacture of clay-based products. It might be advisable to delay decision on the subject until samples of clay obtained by liquid beneficiation under industrial conditions become available.

The manufacture of most fine ceramic products requires, apart from clays, variable amounts of 200-mesh silica. It is envisaged that the minus 120-mesh sand, which will be discarded in the beneficiation operation and of which the crude sand contains about 30 per cent, could be used for the purpose.

Sizing the operations

Earthenware

In trying to size the operations several limiting factors have to be considered. The first is the appeal Malawi dinnerware might have for prospective buyers. Investigation of the retail market shows that the ware against which the Malawi-made dinnerware will be expected to compete is mostly white earthenware. Due to the charactertistics of the available clays the Malawi-made earthenware will not be white but of buff colour, which will automatically diminish its sales appeal for a buyer used to white dinnerware.

The buff colour of the body could be covered with a white opaque glaze, except that earthenware chips easily thus revealing the body colour below, which contrasts sharply with the white glaze. Covering a dark body colour with a white opaque glaze can be done in case of vitreous ware with its inherently much better resistance to impact.

The manufacture of vitrified dinnerware, however, cannot be recommended at this stage because the compounding of vitreous bodies is infinitely more critical and so is its firing. Furthermore, feldspar, which is required for it at the time being, would have to be imported at considerable cost. White nephenyl sienite occurs in the country but plans for its exploitation and beneficiation have so far not progressed beyond the experimental stage.

The manufacture of vitreous products requires the availability of an entirely uniform flux. Nothing is known as yet about the firing characteristics of the clay, above all its firing range, nor is it known how the clay will react to additions of fluxes. Also if vitrified dinnerware were covered with white opaque glazes, it would have to be on-glaze decorated, which would complicate matters.

Buff-coloured earthenware, on the other hand, covered with a transparent glaze can be easily under-glaze decorated and made attractive by spray-stencilling.

It is recommended, however, that once the manufacture of earthenware has been brought under control and the firing and fluxing characteristics of the clay cleared up, experiments with the possible manufacture of vitreous dinnerware should be initiated.

Under the conditions outlined above it is unrealistic to expect that Malawi-made earthenware would be able to capture more than 50 per cent of the market extrapolated to 1987, as shown in annex I, table 1, namely 136,000 pieces per year. And even that amount seems quite high since it comes close to 80 per cent of the total pottery imports in 1980 and very near to that imported in 1981.

The tentative output put forward above will be made up of 34,000 place-settings composed of one cup and saucer, one 18-cm side dish, a 23-cm soup dish and one 25-cm main dish. Hollow-ware, as for example teapots, may be disregarded at present since the ratio is only 1 at the most per 10 place-settings.

<u>Wall tiles</u>

The situation is much more favourable for wall tiles. Here the buff firing colour of the clay is not a drawback. The buyer has become used by now to dark-coloured bodies, which can be easily hidden by the very opaque zirconium glazes now available. The body itself is of the high water absorption earthenware type for which the Linthipe clay appears to be quite suitable.

The sizing of the operation if based on imports causes certain problems, related to bouts of building activity. It was pointed out to the expert that the period of large-scale official building for Lilongwe was just about over.[3] It was considered advisable to disregard the excessively high import figures for 1979 and 1981 and concentrate on the more steady ones for 1978 and 1980. The 1980 figure extrapolated to 1987 gave a tentative market of somewhat over 30,000 m^2 per year. Two thirds of this potential market could be captured by a local industry. This would be close to 20,000 m^2 per year or approximately 900,000 tiles measuring 15 cm x 14 cm. In addition to the traditional wall tiles there might be a potential market for akin products, in the manufacture of which more or less the same technology is used. Such products would include floor tiles and glazed cladding materials. Floor tiles appear to be little used in Malawi, the standard flooring material being terrazo made with imported white cement. The lowest cost for this type of floors is about K 20 per m^2 excluding overheads, profits and supervision. Contractors' prices are reported to be twice as high.

With floor tiles the trend world-wide has during the past decades been generally away from the vitrified type of materials and towards the so-called "quarry tiles", i.e. porous tiles covered by mat, non-slipping glazes and often decorated. This is the product that could be developed and marketed in Malawi.

Tiles for outside claddings also offer possibilities. The only examples of such cladding are the buildings of the Reserve Bank and the Commercial Bank at Lilongwe for which close to 90,000 tiles were imported from the Federal Republic of Germany between 1979 and 1981. These tiles were 24 cm x 12 cm x 1 cm. If similar tiles could be manufactured in Malawi - using a technology similar to that for wall tiles and therefore more or less the same equipment - their size should be somewhat smaller, namely 21.5 cm x 6.15 cm to conform with the brick size used in Malawi.

Since the above products do not have a ready market at this time, the possible demand for them cannot be estimated. It is recommended, however, that as soon as the manufacture of wall tiles in Malawi gets under way samples of floor and cladding tiles be prepared and offered to the trade.

Sanitary ware

With sanitary ware, too, the high-import years of 1978, 1979 and 1980 must be disregarded. Extrapolation to 1987 gives a figure of 9,352 pieces of assorted sanitary ware (wash-basin, WC bowl and tank). Estimating that about 70 per cent of imports could be substituted by locally manufactured ware gives a tentative market of 6,600 pieces per year.

Sanitary ware could be manufactured in Malawi. In general the sanitary-ware technology is not so complex since it involves slip-casting in plaster moulds. With properly designed models and adequate moulds - cast from case, moulds acquired abroad - the manual casting operation should be relatively simple.

Satisfactory casting, however, depends on the slip having the correct rheological characteristics, which must be kept constant all the time. Otherwise losses mount and the profitability of the operation is endangered. Large-scale sanitary ware manufacturers throughout the world have been known to go to considerable length to achieve optimum casting properties and their continuity. It became customary to employ up to five different clays on the well-proven principle that variations in the properties of individual clays are likely to cancel themselves out.[4/]

The availability of a single clay only may make the achievement of proper and constant casting characteristics problematic. In fact, nothing is known at the time of writing about deflocculability of the Linthipe clay except that it reacts favourably to additions of electrolytes, such as sodium silicate.

The vitrification characteristics of the Linthipe clay, and particularly its reaction to additions of fluxes is another problem.

A combined operation

At this point it is necessary to make a preliminary calculation of the approximate sales revenue on the basis of the outputs arrived at in the preceding sections using wholesale prices secured in individual interviews with importers:

	Anticipated output (Pieces)	Approximate wholesale price (Kwachas)	Total yearly revenue (Kwachas)
Earthenware	136 000	1.00	136 000
Wall tiles	900 000	0.35	315 000
Sanitary ware	6 600	50.00	330 000

It is evident even at this level of accuracy that none of the above operations by itself could support a decent administration and technical management and still produce an adequate return on the investment. Therefore the possibility of a combined operation involving the manufacture of all three of the above products under one roof would make sense economically. Not only would they benefit from the same administration and technical management but some of the manufacturing equipment as well as the control laboratory facilities could also be shared.

On the basis of the above a pre-feasibility study was prepared (annex III).

F. Technology

When the technological process was devised to enable the pre-feasibility study to be prepared the available raw materials and their characteristics were, naturally, taken into account. The only exception was feldspar, which will have to be imported in the form of a 200-mesh product.

Slip house and body preparation

The equipment and the processes used here will be as far as possible common to all the three products, the manufacture of which is being considered. Annex III shows to which extent this will be possible.

The weighed clay is elevated by means of a skip-hoist, blunged and then screened through a 120-mesh vibrating screen. The silica is wet-ground in a ball mill. Both these materials will be blended together in a mixing ark. Feldspar, if required, is added at this point. The prepared slurry is pumped into a storage ark and fed as required to the filter press for dehydration. From here on the body preparation processes diverge.

Earthenware

The filter cakes are fed into a pug mill and 10-cm-diameter slugs are extruded, hand-cut and delivered to the jigger.

Wall tiles

The filter cakes are cut into smaller pieces, loaded on pallets and dried in racks. The dry cakes are ground in a pan grinder, screened and delivered to the press.

Sanitary ware

The filter cakes are weighed and dispersed in a blunger under simultaneous additions of electrolytes to prepare the casting slip. The slip is then transferred to the storage ark where final adjustments are made. From here the slip is hosed directly to the caster's bench by gravity.

Filter pressing of the body prior to its deflocculation is very convenient because of the elimination of most of the soluble salts, which might, and usually do, interfere with deflocculation.

Shaping

Earthenware

Hand-operated jigger is used here. The jiggerers operate in a team. While one prepares the bat the other one turns out the finished plate.

The plaster moulds with the wet product are loaded on wooden pallets and dried in racks. After reaching the leather-hard consistency the flatware is fettled, sponged, bunged five high and left to attain the bone-dry stage in racks. Handle is hand-stuck on cups. Handles are slip-cast in plaster moulds. The casting slip is prepared by the jiggerers themselves by deflocculation of scrap.

Wall tiles

Tiles are pressed in a hand-operated friction press. This type of press is gravity-fed by means of box feeder operated by the pressman. The feeder itself is fed from a hopper, which is manually filled by a second operator.

The pressed tiles are stacked up to five high on wooden boards for drying. The off-bearing of the pressed tiles and their loading and transport to drying racks is accomplished by a third operator, who may also assist in fettling the product if necessary.

Bisque-firing

An electric kiln is used. Electricity is cheaper in Malawi than fossil fuel, which must be imported.

Earthenware

Flatware is bunged up five high and set on fireclay bats. Cups are paired and put one on top of the other, up-ended so that the rims are in contact. Gum is used to stick them together during the bisque fire.

Wall tiles

The tiles are loaded on flat setters either singly or bunged up, depending on the body.

Decorating

Earthenware

Earthenware is underglaze decorated by colour banding by hand or by stencilling by aerographing. If desired, wall tiles can be stencilled after the glaze coating has been applied. The decor and the glaze are then matured together in the glost fire.

Glazing

For the preparation of glaze slips a ball mill is provided. A vibratory screen and a ferrofilter are auxiliary equipment. Earthenware and wall tile glazes are compounded from imported frits, which are zirconium-silicate opacified and coloured by means of imported glaze stains as desired.

Earthenware is glazed by dipping, wall tiles by waterfall application. Sanitary ware is glazed in the raw state by means of a spray-gun in a spray booth.

Glost firing

Flatware is set in refractory three-columned racks on pins up to ten cm high. Cups are set directly on refractory slabs after the glaze has been removed from the foot.

Wall tiles are set on flat refractory setters holding two tiles each. The individual setters as superposed one o top of the other.

Sanitary ware is set on sanded refractory setters. Firing schedules are expected to be 24 hours from cold to cold.

Efficiency of the operations

The envisaged operations are not likely to be very efficient. If the equipment has to be shared between difference processes, there will usually be a considerable loss of time. Facilities have to be cleaned to avoid contamination. Also the small scale of operations does not permit efficient use of some equipment, e.g. the extruder and the friction press. The smallest size that has been specified for the extruder is not likely to produce faultless and uncovered slugs.

The small scale of operations also means that workers will have to be frequently shifted from one operation to another. They will have to be "polyvalent", so to say, which means that a lot of the benefits of worker's specialization are unlikely to be secured.

C. Pre-feasibility study

Location

As far as fine ceramic products are concerned, it is no longer true that manufacturing plants should be located near the source of raw materials. The generally preferred location is near the consumption and distribution centres. Lilongwe and Blantyre would be appropriate. While the latter might at present have an advantage, the former being the capital is in the long run preferred for the seat of the industry.

Investment cost

Investment cost is given in annex III. Civil work is calculated on the basis of a quotation by Roberts Construction Limited. Equipment, given in schedules 6 and 6A, is based on recent quotation and estimates. Other expenses are shown in schedules 8 and 9, which indicate the sources.

Operating cost

The manufacturing expenses have been calculated in more detail than is customary for a pre-feasibility study. In most cases the costs are based on up-to-date quotations. The figures as quoted are supported by the schedules that accompany the pre-feasibility study. Energy cost has been calculated on the basis of the installed capacity and current rates. Actual charges may be perhaps 25 per cent lower.

On the whole the operating cost has been calculated conservatively so that certain small-scale economies are viable. So for instance the freight on some of the less expensive commodities, such as feldspar, increase their cost inordinately. A nearer source of supply might be considered.

Sales revenue

Sales revenue has been calculated on the assumption that the sales prices should be at best equal to the prevailing cost at port of entry plus import duty. The figures for sanitary ware and floor tiles have been supplied by a prominent importer and are reportedly based on quite recent imports.5/

As far as earthenware is concerned, on the basis of the information obtained from importers the expert concluded that successive mark-ups by importers, wholesalers and retailers would increase the landed cost plus import duty by 70 per cent.6/ Using this figure the average retail price of K 1.70 was taken as a basis of computation.

Feasibility

The return on capital is only a mediocre 7.1 per cent and the repayment period of 8.3 years is rather long. The figures indicate that even a drastic reduction in the operating cost would not be able to raise the return on capital above 10 per cent.

Sensitivity

Before the final conclusions are made it is necessary to determine the performance of the operation under conditions of increased output and sales revenue. In annex IV it was assumed that output and revenue could be doubled, which is not likely.

Since the capacity of the equipment has not been efficiently utilized under conditions given in annex III, it is probable that the investment in equipment would have to be increased only by 50 per cent to attain the increased production target. No increment is required for civil engineering since sufficient space has been provided in the original proposal.

As regards operating cost it is assumed that, except for labour, technical management, administration and ground rent, all the expenses listed in annex III will increase in direct proportion with that of output.

Since the labour force has not been used efficiently under conditions given in annex III, it is likely that only a 50 per cent increase of manpower could double the production. The technical management and administration could certainly deal with the increased output. Under those conditions the rate of return would raise to 16.8 per cent and the repayment period would decrease to four and a half years. There also appears to be sufficient margin should any of the presuppositions fall short of expectation.

Annex V shows the effect of an increase of output and sales revenue of only 10 per cent. Here it was assumed that direct expenses making up the operating cost would increase in the same proportion, and that technical management, administration and ground rent would remain the same. Since under conditions given in annex III both manufacturing equipment and manpower were under-utilized, it was assumed that they would be able to meet the increased output.

Annex V shows that in those conditions the rate of return raises to 8.6 per cent and the repayment period decreases to 7.4 years. That is still not satisfactory but the sensitivity of the project to increased output and sales revenue is clearly shown.

Technical partnership and co-operation

It seems that there will still be a need for technical assistance from an established manufacturer, even if consultants are retained as suggested. The technical assistance may range from a simple procurement of case moulds to full-fledged co-operation in matters of formulation, production and quality controls, procurement and training of personnel. Technical assistance of the kind envisioned must either be paid for in the form of a royalty or by means of a lump sum. A much better form of technical co-operation are technical partnership arrangements under which an established manufacturer is offered a part of the equity in exchange for a specified co-operation and assistance. It does not have to be a European organization to provide the services that are desired. Some African countries possess ceramic industries which might have already acquired experience under African conditions and which would perhaps be interested in technical co-operation.

Alternate approaches to the manufacture of dinnerware

The manufacture of earthenware as envisaged here will probably be more of a problem than anything else. In accordance with the available market the planned output is very small. But it will still required the services of a foreign technician. It cannot be expected that a technician versed in the manufacture of wall tiles and sanitary ware will also possess the expertise and experience for earthenware. The manufacture of earthenware also requires specialized equipment, which is not likely to be fully utilized.

This being the situation it might be wise to consider alternate approaches to dinnerware:

(a) Cups, saucers and general flatware could undoubtedly be pressed from glass within the glass-making project now under consideration;

(b) A possibly different segment of consumers could be satisfied by dinnerware produced on an artisanal level. Financing for an operation of this kind at Blantyre could probably be secured from the Small Enterprise Development Organization of Malawi.

It is recommended that both approaches be pursued.

Conclusion

At the proposed level of output the operation as envisaged under "Sizing the Operations" and in annex III does not constitute an attractive proposition. The results obtained with an increased production and sales revenue, however, offer some prospects.

The prospects for the project could be further improved if it could be incorporated with the glass-making project sharing with it its administration and marketing. It must be reiterated here that unless the suitability of the Linthipe clay for sanitary ware slip is proven there cannot be much of a project.

Notes

1/ A.T. Mndala, "A provisional estimation of reserve and quality of glass sands in parts of Samphale 2, Sankhani 2, and Tsumba 2 Dambos, Mchinji District", Report ATM/4, Geological Survey of Malawi, Zomba, June 1980.

2/ Between 1980 and 1981 the W C. French Ltd. (Malawi) imported for the building of The Reserve and Commercial Banks close to 90,000 20 cm x 10 cm tiles weighing approximately 60 tons. (Personal communication from A.L.C. Bristeir, Managing Director).

3/ Personal communication from A.V. Roper, Manager, The Roberts Construction Co. Ltd. (Malawi).

4/ The following is a good example of the complexity of sanitary ware slip formulations:

	Percentage
Spartan pegmatite	30.3
Silica sand	14.0
Peerless china clay	11.0
27 china clay	9.7
B - 2 Badry black clay	8.5
B - 3 Badry black clay	8.5
C. and C. ball clay	13.0
Martin 5 ball clay	5.0
	100.0

Source: Kilgore Ceramics Corporation, Kilgore, Texas, United States of America.

5/ Personal communication from P. Eraclides, Branch Manager, Shire Limited, P.O. Box 340, Lilongwe.

6/ Personal communication, Phiri, Assistant Merchandise Manager, Hardware and General Supplies Ltd.

Annex I

IMPORTS OF POTTERY, FLOOR AND WALL TILES AND SANITARY WARE

Table 1. Imports of pottery[a]

Year	Amount (tons)	Value (thousands of kwachas)	Number of pieces[b]	Price per piece (kwachas)
1975	59	123	163 889	0.75
1976	58	109	161 111	0.68
1977	80	153	222 222	0.69
1978	73	182	202 778	0.90
1979	89	193	247 222	0.78
1980	62	149	172 222	0.87
1981[c]	48	181	133 333	1.36
1987[d]	98		272 222	

Source: Annual Statement of External Trade 1979, National Statistical Office, May 1981, and personal information.

a/ Malawi Custom Classification 69.110000.

b/ Calculated on the basis of average piece weight of 360 g.

c/ Extrapolated from official 11 months figures.

d/ Extrapolated from the trend line.

Table 2. Imports of floor and wall tiles[a/]

Year	Amount (tons)	Value (thousands of kwachas)	Area (m^2)[b/]	Number of pieces[c/]	Price per piece (kwachas)
1977	100.775	52.027	8 398	369 512	0.14
1978	227.100	116.749	18 925	832 700	0.14
1979	330.910	126.664	27 576	1 213 344	0.10
1980	229.108	193.598	19 092	840 048	0.23
1981[d/]	384.348	292.143	32 029	1 409 276	0.21
1987[e/]	614.160		51 180	2 251 920	

Source: Annual Statement of External Trade, National Statistical Office, May 1981 and personal information.

a/ Malawi Custom Classification 69.070000.

b/ Re-calculated on the basis of 12 kg/m^2.

c/ Re-calculated on the basis of 44 wall tiles (15 cm x 15 cm) per m^2.

d/ Extrapolated from official statistic for 11 months.

e/ Extrapolated from the trend line.

Table 3. Imports of sanitary ware[a/]

Year	Amount (tons)	Value (thousands of kwachas)	Number of pieces[b/]	Price per piece (kwachas)
1975	164	234	9 840	23.78
1976	84	85	5 040	16.86
1977	107	145	6 420	22.58
1978	258	330	15 460	21.35
1979	463	543	27 780	19.55
1980	263	251	15 760	15.93
1981[c/]	101	240	6 060	39.60
1987[d/]	155		9 373	

Source: Annual Statement of External Trade, National Statistical Office, Zomba.

a/ Malawi Custom Classification 69.100000.

b/ Calculated on the basis of 50 kg per set of wash-basin, WC and tank.

c/ Extrapolated from statistical data for 11 months.

d/ Extrapolated from the 1975-1981 trend line.

Annex II

ANALYSIS OF LINTHIPE CLAY[a]

(Percentage)

Type	Particle size (µm)							Chemical composition[a]						
	<10[illegible]	<63	<30	<15	<8	<4	<2	SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	K_2O	Na_2O
[illegible]	[illegible]	[illegible]	56.6	[illegible]	49.8	44.7	39.7	42.6	30.9	2.4	3.1	0.7	0.4	1.6
[illegible]	[illegible]	[illegible]	61.8	57.8	53.3	48.1	43.8	47.3	31.6	3.1	1.9	0.7	0.3	1.5
[illegible]	[illegible]	[illegible]	60.6	57.7	51.5	49.6	14.1	44.8	31.1	2.9	[illegible]	0.5	0.3	1.3
[illegible]	[illegible]	70.9	66.0	60.4	56.3	51.3	46.0							
[illegible]	[illegible]	[illegible]	61.8	[illegible]	[illegible]	52.0	47.7	44.9	31.5	3.0	[illegible]	0.6	0.6	1.4
[illegible]	[illegible]	77.1	[illegible]	71.1	67.1	62.6	58.8	44.5	32.3	3.7	1.0	0.5	0.3	0.4
[illegible]	[illegible]	79.1	75.5	[illegible]	67.5	[illegible]	58.6	42.5	33.5	3.9	0.5	0.3	0.2	0.4

Source: Malawi Geological Survey.

a/ Loss on ignition and TiO_2 not available at the time of writing.

Annex III

PRE-FEASIBILITY STUDY

Combined operation

1. Market and demand

   See Findings, Markets.

2. Supply of material inputs

   See Findings, Raw Materials.

3. Location

   See Findings, Pre-feasibility Study.

4. Project engineering

	Pieces
Earthenware operation, Schedule 1	136,000
Wall tile operation, Schedule 2	900,000
Sanitary ware operation, Schedule 3	6,600

5. Processes

   See Findings, Technology.

6. Manpower and management

Foreign supervisors	3
Skilled staff[a]	18
Unskilled labour	13

7. Project scheduling

Total implementation time	18 months

8. Financial analysis

Investment cost	Kwachas
Land and site preparation[b], Schedule 4	39,536
Civil engineering, Schedule 5	392,000
Machinery ready erected, Schedules 6 and 6A	570,036

Locally purchased equipment, Schedule 7	60,000
Consultants and engineering expenses, Schedule 8	265,650
Overhead expenses during planning and construction period, Schedule 9	61,820
	1,389,042
Contingency	138,904
	1,527,946
Working capital[b]	156,380
	1,684,326

9. Commercial profitability

Sales revenue	Kwachas
136,000 pieces of assorted earthenware at K 1.10 per piece	149,600
900,000 15 cm x 15 cm wall tiles at K 0.35 per piece	315,000
6,600 pieces of assorted sanitary ware at K 60.50 per piece	399,300
	863,900

Operating cost	
Clay and silica, Schedules 10-13	7,654
Feldspar (imported), Schedule 14	11,054
Plaster (imported), Schedule 15	8,000
Amortization of case moulds, Schedule 16	430
Glaze, stains and colours, Schedules 17 and 17A	77,726
Power	85,000
Manpower, Schedules 18, 18A	10,725
Spare parts and supplies, Schedule 19	25,200
Water, Schedule 20	828
Technical management, Schedule 21	114,200
Refractories, Schedules 22, 23 and 24	7,309
Flushing hardware for 2,200 tank	33,000
Cartons and packaging, Schedule 25	15,220
Administration, Schedule 26	58,700

Sales tax, 10 per cent	86,390
Annual ground rent	1,482
	542,918
Depreciation, Schedules 5, 6A and 6B	82,600
Total	625,518

<u>Profitability calculations</u>

Sales revenue	863,900
Operating cost	-625,518
Gross profit before tax c/	238,382
50 per cent corporate tax	-119,191
Net profit	119,191

$$\text{Rate of return} = \frac{119}{1,684} \times 100 = 7.07 \text{ per cent}$$

$$\text{Repayment period} = \frac{1,684}{119 + 83} = 8.3 \text{ years}$$

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a/ It is assumed that they will become skilled after their training period.

b/ Three-month operating expenses.

c/ Fifty per cent corporate tax is levied on all profits but rebates may be negotiated.

Schedule 1. Earthenware operation

<u>Production schedules</u>

	Pieces	
	Per day	Per year
Net output	453	136,000
To jigger	604	181,333
To bisque-fire	533	160,000
To glost-fire	479	143,158

Schedule 2. Wall tile operation

Production schedules

	Pieces	
	Per day	Per year
Net output	3,000	900,000
To press	3,750	1,125,000
To bisque-fire	3,529	1,058,824
To glost-fire	3,333	1,000,000

Schedule 3. Sanitary ware operation

Production schedules

	Pieces	
	Per day	Per year
Net output	22	6,600
To cast	25	7,333
To fire	23	6,948

Schedule 4. Land and site preparation[a/]

	Kwachas
Development charge per hectare	19,768
Total charge	39,536

a/ No site preparation required, only development charge.

Schedule 5. Civil engineering

2,000 m^2 industrial building

	Kwachas
4 metres high at K 170/m^2	340,000
Septic tanks for 40 people	1,600
Sedimentation tank	17,000
1,000 m^2 of concrete floors at K 22/m^2	22,000
570 m wire-mesh fence at K 20/m	11,400
	392,000
Depreciation at 5%/year	19,600

Schedule 6. Machinery ready erected

List of imported equipment		Operation[a]
1	travelling scale and hopper, 1,000-kg capacity	C
1	skip-hoist, 1 m^3 bucket	C
1	agitator for clay dispersing	C
1	water metre, dial model	C
1	ball mill, Ø 1.1 m x 0.9 with lining and balls	C
2	vibrating screen, 2,000 l/h	C
1	drive and propeller for mixing ark	C
1	agitator for storage ark	C
1	agitatory for cake blunger	S
1	agitator for slip storage	S
1	filter press, 0.6 x 0.6 m cakes	C
1	hydraulic pump for filter press	C
3	slip-transfer pumps, compressed air operated	C
1	dry pan grinder (for filtercakes)	T
1	dry vibrating screen (for filtercakes)	T
1	air compressor 10 m^3/h	C
1	vacuum extruder (pug mill - maximum slug diameter 10 cm)	E
2	jigger and jolley machines with head cups	E
1	friction hand-operated press	T
2	2-cavity dies for 15 cm x 15 cm tiles	T
1	weighing scale for plaster, 50 kg capacity	E,S
1	plaster mixer, 7.5 cm propeller, variable speed	E,S
150	machined cast-iron back-up rings (for plaster moulds)	E
2	pattern maker's lathe and turntable	E
6	semi-line skids, 60 x 120	C
2	lifters for skids	C
	Slip lines and hose for casters	S
2	spray-pots with guns hose and fittings	E,S
3	metres roller conveyor, 30 cm	S
1	ball mill Ø 50 cm x 60 cm with lining and balls	C
1	separator, 50 cm Ø	C
1	ferrofilter with rectifier AC/DC	C
1	spray booth	S
2	decorating spray guns with hose and fittings	E
4	banding whirler (hand operated)	E
1	electric shuttle kiln, 7.5 m^3 capacity	C
	miscellaneous equipment (plastic buckets, tubs etc.)	C
	laboratory equipment	C
1	balance, platform model 10 kg capacity	C
1	balance, 2 kg capacity	C
1	stirrer, variable speed (for colours)	E
1	4-jar ball mill, 4 l each	E

a/ C Combined operation
E Earthenware
S Sanitary ware
T Wall tiles

Schedule 6A. Machinery ready erected

	Kwachas
Total landed cost of equipment	441,550
Import duty (13%)	57,402
	498,952
Installation (10%)	49,895
Total cost of installed equipment	548,847
Electric installation 2% of K 1,059,447	21,189
	570,036
Locally acquired equipment	60,000
Depreciation on equipment	630,000
10%/year	63,000

Schedule 6B. Kiln space requirement: combined operation

		Cubic metres/year
Earthenware operation		624
Wall tile operation		1,029
Sanitary ware operation		394
Total		2,047
Number of firings per year	300	
Kiln space required	6.8 m^3	

Schedule 6C. Kiln space requirement: earthenware operation

	Per day	Per year
	Bisque firing	
Pieces to be bisque-fired	533	160,000
Volume of pieces per m^3	685	
Kiln space required, m^3	0.78	234
	Glost firing	
Pieces to be glost-fired	479	143,158
Pieces per m^3 of kiln space	367	
Kiln space required, m^3	1.31	390
Total kiln space required, m^3	2.09	624

Schedule 6D. Kiln space requirement: wall tiles operation

	Per day	Per year
	Bisque firing	
Pieces to be bisque-fired	3,529	1,058,824
Kiln space per 1,000 tiles, m^3	0.50	
Kiln space required, m^3	1.76	
	Glost firing	
Pieces to be glost-fired	3,333	1,000,000
Kiln space per 1,000 tiles, m^3	0.50	
Kiln space required, m^3	1.67	500
Total kiln space required, m^3	3.43	1,029

Schedule 6E. Kiln space requirement: sanitary ware operation

	Per day	Per year
Pieces to be fired	23	6,948
Kiln space requirement per piece, m^3	0.0567	
Total kiln space required, m^3	1.30	394

Schedule 7. Locally purchased equipment: combined operation

1 Sheet iron tank (Ø 2.1 x 1.8 m)
1 Steel platform over ball mill
1 Concrete tank (Ø 3 m x 2 m)
1 Concrete tank (Ø 4 m x 2 m)
1 Sheet iron tank (Ø 2 m x 1.8 m)
1 Sheet iron tank (Ø 2.2 m x 1.7 m)
1 Miscellaneous parts and tools
1 Benches, racks and pallet
1 Silo for plaster, 1 m^3 capacity

Total cost K 60,000

Schedule 8. Consultants and engineering expenses: combined operation

	Kwachas
Consultants' fees	
90 days at K 2,000	180,000
1 Expatriate technician for 1 year	
Base salary	20,000
Fare	10,000
Housing	9,600
Medical service	1,500
Schooling	1,300
	42,400

	Kwachas
1 Ceramic engineer (6 mon-hs)	
Base salary	10,000
Air ticket	6,000
Housing	4,800
Medical service	750
Schooling	1,300
	22,850
1 Engineer, junior, 12 months	4,200
Clay testing	10,000
Workers' salaries during the training period	
15 workmen during 4 months	1,200
Materials used in training	5,000
	265,650

Schedule 9. Overhead expenses during planning and construction period: combined operation

	Kwachas
1 General manager, 18 months	22,500
1 Accountant, 18 months	15,000
1 Secretary, 18 months	7,200
1 Store keeper, 1 year	2,160
1 Time keeper and payroll clerk	2,160
Office supplies	1,800
Office rent, 50 m^2, 12 months	6,000
Travel expenses	5,000
Total	61,820

Schedule 10. Clay and silica: combined operati-

	Kilograms	
Total clay demand	Per day	Per year
Earthenware (Schedule 11)	229	68,800
Wall tiles (Schedule 12)	1,240	371,250
Sanitary ware (Schedule 13)	538	161,592
Total	2,007	601,642

Total silica requirement	Kilograms Per day	Kilograms Per year
Earthenware	69	20,640
Wall tiles	372	111,375
Sanitary ware	86	25,708
	527	157,723

Total domestic raw materials	759,365 kg
Cost per ton in Lilongwe	K 10.79
Total cost	K 7,654

Schedule 11. Clay and silica: earthenware operation

Raw material requirement

Body composition[a/]

Linthipe clay 70 per cent
Silica 30 per cent

	Kilograms Per day	Kilograms Per year
Total body requirement 0.43 kg per piece x 160,000	229	68,800
Netto raw material requirement		
Linthipe clay	160	48,160
Silica	69	20.640
Gross raw materials requirement		
Linthipe clay	229	68,800
Silica	69	20,640
Total gross raw materials requirement	298	89,440

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a/ Conjectural.

Schedule 12. Clay and silica: wall tile operation

Raw material requirement and cost

Body composition[a/]

Linthipe clay		70%
Ground silica		30%
		100%
	Per day	**Per year**
Number of tiles to be pressed (as per schedule)	3,750	1,125,000
Body required per tile, 0.33 kg		
Total weight of body (kg)	1,240	371,250
Assumed moisture content of clay		15%
Residue on 325 mesh		15%
Total loss		30%
Gross clay requirement (kg)	1,240	371,250
Silica requirement (kg)	372	111,375
Total weight of raw materials (kg)	1,612	482,625

a/ The above body composition is entirely conjectural. The proportion of silica is not known at this point, nor whether feldspar will be required. It is assumed that the silica fines originating in the glass sand washing operation will be used here and that its cost will be the same as that of the Linthipe clay.

Schedule 13. Clay and silica: sanitary ware operation

Raw material requirement

Body composition[a/]

Linthipe clay		60%
Silica		20%
Feldspar		20%
	Kilograms	
	Per day	**Per year**
Total slip requirement	428	128,539

	Kilograms	
	Per day	Per year
Net raw material consumption		
Linthipe clay	257	77,123
Silica	86	25,708
Feldspar	85	25,708
Gross raw material requirement		
Linthipe clay at 70% recovery	367	110,176
Silica	86	25,708
Feldspar	85	25,708
Total raw materials requirement	538	161,592

a/ The above body composition is entirely conjectural since the required proportions of feldspar and silica respectively are not known at this point and must be determined experimentally.

Schedule 14. Feldspar: sanitary ware operation

Cost of imported feldspar	Kilograms
Total weight of body per year	128,538
Weight of required feldspar (conjectural proportion of feldspar in body of 20 per cent)	25,708
Cost of feldspar CIF Lilongwe	Kwachas
Cost FOB European port	0.08
Freight to Lilongwe	0.30
Landed cost	0.38
Import duty (13%)	0.05
Total cost per ton	0.43
Total cost of feldspar per year	11.054

Schedule 15. Plaster: combined operation

Plaster requirement and cost

Earthenware

Average life of plaster mould (number of castings)		45 pieces
Net output of pottery per year		136,000
Number of plaster moulds required per year	$\frac{136,000}{45}$	3,022

	Kilograms
Average plaster requirement per mould	2.8
Total requirement of plaster per year	8,462
Requirement of case moulds	
0.07 kg per working mould x 3,022	212
Total plaster requirement per year	8,674

Sanitary ware

Average life of working mould (number of castings)	60
Number of pieces to cast per year $\frac{7,333}{60} = 123$	
(Schedule 14)	7,333
Number of moulds required per year	123
Requirement of plaster per working mould (kg)	78
Requirement of plaster per year (kg)	9,594

Cost of plaster	Kwachas
Price FOB European port (per kg)	0.088
Freight to Lilongwe	0.300
	0.388
Duty 13%	0.050
Total (per kg)	0.438

Total plaster requirement and cost

Earthenware	8,674 kg
Sanitary ware	9,594 kg
Total	18,268 kg
Total cost of plaster per year	K 8,000

Schedule 16. Amortization of case moulds

Cost of 3 case moulds	
(Lavatory, bowl, tank)	K 21,000
Average life of case moulds	6,000 casts
Number of working moulds per year	125
Annual amortization of case moulds	K 430

Schedule 17. Glaze: combined operation

<u>Glaze requirement for earthenware</u>

Glaze requirement per piece	0.1 kg
Total yearly output	136,000 pieces
Total glaze requirement per year (136,000 x 0.1)	13,600 kg

Cost of glaze	Kwachas
Ex-factory price	0.75
Freight	0.30
	1.05
Import duty of 13%	0.14
Cost of glaze CIF Lilongwe	1.19
Total cost of glaze per year	16,184

<u>Glaze requirement for wall tiles</u>

Number of 15 cm x 15 cm tiles to be glazed per year	1,000,000
Glaze requirement per tile	0.023 kg
Total glaze requirement per year	23,000 kg

Cost of glaze	Kwachas
Ex-factory price (per kg)	1.00
Freight	0.30
Total landed cost	1.30
Import duty of 13%	0.17
Total cost	1.47
Total cost of glaze per year	33,810

<u>Glaze requirement for sanitary ware</u>

Number of pieces of sanitary ware to be glazed per year (Schedule 3)	6,948
Consumption glaze per piece	1.1 kg
Requirement of glaze per year	7,643 kg
Cost of glaze per kg	K 0.75
Total cost of glaze per year	K 5,732

Schedule 17A. Stains and colours: combined operation

Requirement and cost of stains and colours

	Kwachas
600 kg/year of underglaze, on-glaze and glaze stain at K 25	15,000
400 kg of glaze stains for sanitary ware at K 15/kg	6,400
Total cost of stains per year	21,400

Total cost of glazes and stains

Glazes for earthenware	16,184
Glazes for wall tiles	33,810
Glazes for sanitary ware	5,732
Stains and colours	21,400
Total cost per year	77,126

Schedule 18. Manpower: combined operation

	Man-hours	Kwachas
Earthenware operation	18,000	2,250
Sanitary ware operation	12,000	1,500
Wall tiles operation	27,000	3,375
Services (Supervision mechanics, guards), Schedule 18A	16,800	3,600
Total	73,800	10,725

$$\frac{57{,}000 \text{ man-hours per year}}{2{,}400} = 24$$

Plus services	7
Total labour force	31 men

Schedule 18A. Cost of services

	Days/year	Daily pay (kwachas)	Total cost/year (kwachas)
1 Foreman	300	4	1,200
1 Fitter	300	2	600
1 Electrician	300	2	600
4 Guards	1,200	1	1,200
			3,600

Schedule 19. Cost of spare parts and supplies

	Kwachas
Installed and wired equipment	570,036
Locally acquired equipment	60,000
	630,036
Cost per year (4%)	25,200

<u>Industrial use</u>

2.214 tons of clays x 4 m^3 per ton per day	8.856 m^3

<u>Personal use</u>

40 people x 25 l per day	1.000 m^3
	9.856 m^3/day
Total water consumption per year (300 days)	2.956 m^3
Cost per m^3	K 0.28
Total cost of water	K 828

Schedule 21. Technical management: combined operation

	Kwachas
2 Technical supervisors	30,000
1 Ceramic engineer	20,000
Fares from and to home country	27,000
Housing	28,800
Medical service	4,500
Schooling	3,900
Total	114,200

Schedule 22. Refractories: earthenware operation

1. Firing racks

$\frac{685 \text{ pieces} \times 6.8 \ m^3 \text{ (kiln space)}}{10 \text{ pieces per rack}}$	466 racks
Average life of rack	100 firings
Number of firings per year	35

$\frac{466 \text{ racks}}{3}$ = 155 racks required per year

<u>Cost of racks</u>	Kwachas
Average cost per rack	5.00
Freight	1.70
Import duty of 13%	.87
	7.57
Total cost of racks	1,173

2. Slabs

140 slabs, 34 cm x 60 cm, per firing	
Life of slab	100 firings
Number of firings per year	7
Slabs required per year	10
	Kwachas
Cost of slabs	10.00
Freight	3.00
	13.00
Import duty 13%	1.70
	14.70
Total cost of slabs per year	147

Schedule 23. Refractories: wall tile operation

Flat setters 34 cm x 16 cm x 2 cm; weight, 1 kg	
Total of setters per firing	4,500
Life of setters	400 firings
Cost of setters	Kwacha
Replacement of setters per year	2,250
FOB cost of setters	2,000
Freight	300
	2,300
Import duty of 13%	300
	2,600
Total cost of setters per year	5,850

Schedule 24. Refractories: sanitary ware operation

	Kwachas
Cost of setters per piece	0.02[a]
Total cost of setters per year	139
(6,948 pieces to be fired)	

a/ Estimated on the basis of experience.

Schedule 25. Cost of cartons and packaging

	Kwachas
Earthenwares	
136,000 pieces at K 0.04	5,440
Wall tiles	
900,000 wall tiles at K 0.005	4,500
Sanitary ware	
6,600 pieces per year at K 0.80	5,280
Total cost of packaging	15,220

Schedule 26. Administrative expenses: combined operation

	Kwachas
Salaries	
1 General Manager	15,000
1 Sales Manager	10,000
1 Accountant	10,000
2 Secretaries	7,200
4 Clerks	9,000
	51,200
Stationery and office supplies	2,500
Travel expenses	5,000
Total	58,700

Annex IV

COMMERCIAL PROFITABILITY AT DOUBLED OUTPUT

AND REVENUE

	Thousands of kwachas
Investment cost	2,101
Commercial profitability	
Sales revenue	1,728
Operating cost	- 906
Depreciation	- 114
Operating profit	708
50% corporate tax	354
	354

Rate of return = $\frac{354}{2,101}$ x 100 = 16.8%

Repayment period = $\frac{2,101}{354 + 114}$ = 4.5 years

Annex V

EFFECT OF 10 PER CENT INCREASE OF OUTPUT AND SALES REVENUE ON PROFIT

	Thousands of kwachas
Investment cost	1,684
Commercial profitability	
Sales revenue	950
Operating cost	- 580
Depreciation	- 83
Gross profit before taxes	287
50% corporate tax	143
Net profit	144

Rate of return = $\frac{144}{1,684} \times 100 = 8.6\%$

Repayment period = $\frac{1,684}{144 + 83} = 7.4$ years