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ASSISTANCE TO THE RESEARCH AND DEVELOPMENT
CENTRE FOR LIGHT BUILDING MATERIALS

DP/CPR/85/088/11-02

CHINA

Technical report: Quality control practices of the local
ceramic wall-tile industry

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

Based on the work of Mr. Friedrich A. von Metzsch,
expert in quality control of ceramic wall tiles

Backstopping officer: H. Yalçindag, Chemical Industries Branch

United Nations Industrial Development Organization

Vienna

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Explanatory notes

Besides the common abbreviations, symbols and terms, the following have been used in this report:

- | | |
|---------------|--|
| CICETE | China International Centre for Economic and Technical Exchanges, Ministry of Foreign Economic Relations and Trade |
| CNBM | China National New Building Materials Corporation |
| HDRI | Hangzhou Design and Development Institute for New Building Materials |
| SABMI | State Administration of Building Materials Industry |

ABSTRACT

Within the context of the project "Assistance to the Research and Development Centre for Light Building Materials" (DP/CPR/85/088), an expert in quality control was fielded on 13 September 1988 for the period of one month. The purpose of his mission was to assist the staff of the Hangzhou Design and Development Institute for New Building Materials (HDRI) in carrying out studies on the current quality-control practices of the local ceramic wall-tile industry.

Because the expert could not visit a wall-tile factory during his mission, an appraisal of existing quality-control practices could only be made through discussions. During a series of lectures, the expert tried to convey to the staff of the Institute and other participants an overview of modern wall-tile production, including quality control. In discussions on the topics of the lectures, a number of questions arising from actual design work could be answered or clarified. Because of the interest expressed, the expert also lectured on modern manufacturing techniques for floor tiles, split tiles and sanitary ware.

The report also contains recommendations for the improvement of HDRI's efficiency.

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INTRODUCTION

Within the context of the project "Assistance to the Research and Development Centre for Light Building Materials" (DP/CPR/85/088), an expert in quality control was fielded on 13 September 1988 for the period of one month. The purpose of his mission was to assist the staff of the Hangzhou Design and Development Institute for New Building Materials (HDRI) in carrying out studies on the current quality-control practices of the local ceramic wall-tile industry.

The scope of HDRI

The Hangzhou Design and Development Institute for New Building Materials (HDRI) reports to the China National New Building Materials Corporation (CNNBMC). However, HDRI can be regarded as independent since it has its own income from customers consulting it. Customers are manufacturers of building materials. Advice is sought by manufacturers who wish to install a new production line. In the event of joint ventures with foreign companies, the Government recommends to consult HDRI, which receives 2 per cent of the volume of contracted supplies.

HDRI is specialized in glass, cement and plastics for building purposes. Ceramics is the newest branch of HDRI and should be strengthened since the ceramic centre at Xi'an cannot cope with all demands in that field.

The staff of HDRI comprises young graduates and engineers, most of whom work on a particular project such as a wall-tile factory, a split-tile factory, a sanitary-ware factory or a production line for ceramic fritts.

HDRI is acting as a consultant for the whole territory of China and is an "A-level" institute, i.e. its statements overrule statements of "B-level" institutes such as the Bureaux for Industrial and Commercial Management in the provinces.

It is not the task of HDRI to issue certificates for finished products, but in the case of dissent between manufacturer and customer or end-user, HDRI acts as an arbitrator.

The head of HDRI is the managing director, Yu Ji Zhang. Mao Wen-jie, a staff member of HDRI, is the national project director of UNIDO project DP/CPR/85/088. A list of persons met during the mission is given in annex I.

SUMMARY OF RECOMMENDATIONS

To HDRI

1. The staff of HDRI should not limit their work to theoretical studies, but also carry out tests, particularly on raw materials, with the equipment available in the HDRI laboratory, with the aim of gaining practical experience and thus winning the respect of their counterparts in the factories.
2. The laboratory equipment for the testing of raw materials for ceramic production is incomplete and the items recommended by the expert should be purchased.
3. At a later stage, HDRI should also acquire equipment enabling it to perform all tests on finished tiles and sanitary ware according to European standards.
4. As the kind of product to be made determines the choice of equipment, officers advising customers on the design of a production line should have a collection of typical products at their disposal, to facilitate discussions and clarify customers' product targets.
5. HDRI should contact wall-tile manufacturers outside China to obtain samples of their products and to start a collection of all imported wall tiles, preferably displayed in a separate room, where the design could be discussed with local factory managers. This would also enable HDRI to anticipate trends of the tile market in China, assuming that designs, at present considered luxury, will constitute part of future local demand.
6. To get a better idea of trends in the world market, HDRI staff should visit international fairs and exhibitions.
7. With respect to standards, HDRI should keep strictly to International Organization for Standardization (ISO) standards.
8. A new model, developed by HDRI, which permits to carry out differential thermoanalysis (DTA) and thermal expansion simultaneously, has export potential. Its reliability should be verified in a test, whereby a standard kaolin would also be analysed by two European laboratories using traditional equipment and the results compared.

To UNIDO

9. To increase the competence of HDRI staff in advising local ceramic manufacturers they should visit ceramic factories outside the country and get training in practical quality control, laboratory methods and statistical evaluation of results.
10. Subject to the availability of funds, UNIDO should purchase the recommended laboratory equipment for ceramic raw material testing.

ACTIVITIES AND FINDINGS

Performance of the duties of the job description

According to the job description, the expert was expected to guide the national counterparts in evaluating the technology of the local wall-tile industry, appraise the techniques of quality control applied in the industry with regard to raw materials, body and quality testing of the finished products, and to assess the pressing and glazing technology used in wall-tile manufacture. Since it was not possible to visit a wall-tile factory during the mission, the expert could do such evaluation only by discussion.

Following a request by the counterpart, the expert was also required to deliver audiovisual-supported lectures covering recent technological trends and to discuss some particular problems. Consequently, the expert tried, during 10 lectures, to convey a complete picture of a modern wall-tile production, including quality control.

Because of the interest expressed, he also gave in addition a three-hour lecture on the manufacture of split tiles and a two-hour lecture on the manufacture of sanitary ware. The topics of all lectures are given in a separate section of this chapter.

Visit to a sanitary-ware factory

A visit to the Shang Yu factory for sanitary ware was arranged for 24 September 1988. The factory was built at an expense of 25 million yuan and is equipped with local machinery. Its planned output is 360,000 pieces per year of more than 10 different items. The equipment seems to work well. Whether the quality of the slip meets the requirements for a satisfactory casting could not be verified within the short time of the visit, but it seems that glaze and body harmonize, because no glaze faults could be detected. However, there is a lot of damage by cracks after firing and the firing curve needs to be improved, in particular shock cooling. At present, the journey through the tunnel kiln takes 30 hours (which is short) and the firing temperature was supposed to be Seger cone 7 (which would be low). The temperature control indicated, instead, a maximum temperature of 1,250-1,280 °C.

The breakdown of production cost shows 15 per cent for raw materials, 40 per cent for coal gas, and the remaining 45 per cent for personnel and depreciation. The expert pointed out that there are better methods to save energy than to lower the firing temperature (see annex II, question 16).

Raw materials

China has extensive deposits of ceramic raw materials, in particular talc, nephelin syenite and pyrophyllite. Each province of China has its Geological Survey Department which can give all necessary information.

On the occasion of his visit to the Shang Yu sanitary-ware factory, the expert saw a rocky pyrophyllite of obvious good quality. It may be of interest to export such raw material to Europe, especially as some of the deposits are not far from a sea port.

Lectures

The expert delivered 12 lectures of 2-3 hours each, covering the following basic chapters of ceramic manufacture:

1. Introduction: Market situation for wall and floor tiles in the Federal Republic of Germany;
Trends of decoration and colour.
2. Raw materials for ceramic production and their chemical composition:
Principles for developing a recipe for a body composition;
Examples for body compositions;
Criteria of quality of raw materials.
3. Body preparation: Various grinding procedures, wet and dry;
Spray drying.
4. Shaping (pressing, extruding, casting):
Efficiency of modern presses;
Comparison of mechanical and hydraulic presses;
Dies and pistons.
5. Principles of the drying and firing processes:
Different types of dryers;
Different types of tunnel kilns, pin kilns and roller kilns;
Comparison of biscuit/glost firing and single firing of wall tiles.
6. Glazing, preparation of glazes, examples of glazes:
Fritt production;
Adaption of the glaze to the body, quality range of glazes.
7. Decoration: Different kinds of decoration;
Technical means;
Sieve printing.
8. Sorting of wall tiles:
Usual faults of finished tiles;
Recognition of faults;
Packing, labelling, identification of article by number.
9. Quality control: Quality control of finished products, statistical evaluation;
Quality control of raw materials, intermediates and slips;
Necessary equipment of a quality control laboratory;
European standards for testing methods.
10. Manufacture of split tiles:
Particulars of the extrusion press;
Particulars of glazing and firing;
Economical survey, consumption figures for manufacture;
Market situation in the Federal Republic of Germany;
End users of split tiles.

11. Manufacture of sanitary ware:

General scope of market in comparison to wall tiles;
Particulars of the manufacturing process;
Consumption figures for manufacture.

12. General recommendations for the work of HDRI in the field of:

Market analysis;
Consultancy;
Data for raw materials.

Specific problems

Prior to his fielding, the expert received a list of questions, most of which were covered during his lectures. The remaining ones were answered separately, as well as questions from the auditorium after the lectures. All questions, together with the expert's reply, are listed in annex II.

Since most of the staff of HDRI have a good background in machine building and designing, but to a lesser extent in material science and ceramic processes, the expert made every effort to give them a better understanding of ceramics. Because he felt that all officers should have the possibility of consulting a textbook, he left the best standard textbook for ceramics, Industrial Ceramics by Singer and Singer, at HDRI. The expert also left all audiovisual aids (slide and transparencies) of his lectures at HDRI.

Standards

An explanation of the technical properties required to meet product standards was the subject of several lectures. For intermediates such as bodies or glazes no standards exist, except factory standards. A complete set of European standards (BSS) for testing finished tiles was handed over to HDRI.

CONCLUSIONS AND RECOMMENDATIONS

After having twice visited the premises of HDRI, and following several discussions and personal contacts, the expert arrived at the following conclusions and recommendations.

The staff of HDRI should not limit their work to theoretical studies, but also practise on the equipment of the HDRI laboratory, in particular the testing of raw materials. The investigation of raw materials by grinding, shaping (pressing or casting) and firing in a laboratory kiln gives a lot of experience in properties of raw materials and the manufacturing of ceramics. Such work would not only be valuable because of the results obtained in such tests, but would also help HDRI staff to gain the respect of their counterparts in the factories.

In a second step, laboratory tests of finished products according to standards could be carried out. This again would enable HDRI to gain insight into problems of quality control and specific difficulties in obtaining satisfactory quality. These investigations should first be done in a large number, without specific requests from customers, solely with the aim of gaining experience in testing and in comparing results.

For raw material investigation, the laboratory equipment of HDRI is not complete or not suitable, and the missing items should be purchased. The necessary equipment for raw-material testing for ceramic production is listed in annex III.

At a later time, HDRI should also acquire equipment enabling it to perform all tests on finished tiles and sanitary ware according to European standards (EN) which are regarded to be the best and most up-to-date in the world.

As HDRI not only advises on technical process design but also on product design, a market survey should be made. Technical process designing and product designing are interlinked. No reasonable layout for a ceramic production line can be designed without having sufficient knowledge about the product to be made, the size and shape of the product, its surface quality and technical properties such as strength, water absorption, or colour influence the choice of equipment.

Consequently, it would seem necessary for HDRI to have a collection of typical products. This would be helpful in discussions with customers to clarify their product targets. The respective samples should always be with the officer responsible for designing a given production line.

To anticipate trends of the tile market in China, it would be beneficial for HDRI to have a collection of all imported wall tiles used in hotels and other new buildings. It is likely that tiles, now seen only in public buildings, will be in demand by the next generation, and that all decorations, at present regarded as luxury, will one day be part of an extended market.

HDRI should contact the export managers of wall-tile manufacturers, explaining them that, being the leading consultant for the building industry of whole China, it is going to promote internationally accepted standards of shape, size and decoration for the domestic market within its extended building programme. It would be an advantage for the manufacturer if his most popular products could be displayed in the show room of HDRI. It should be possible to allocate one room of the large HDRI building for such an exhibition, where the design of wall tiles could be discussed with the factory management.

To get a better idea of trends in the world market, staff of HDRI should visit international fairs and exhibitions such as BAU in Munich and INTERCERAM in Bologna.

With respect to standards - an area in which HDRI is looking for assistance - it is recommended to keep strictly to ISO standards. English and American books sometimes use units which are only known in the former British Empire. While the United States of America is very experienced in steel construction, its standards for building in concrete are less strict. The highest standards for concrete are found in central Europe, and the DIN standards are more up-to-date than the ASTM.

HDRI has developed a handy, new model for the simultaneous performance of differential thermo analysis (DTA) and thermal expansion (dilatometer). It would be interesting to compare the results obtained with that new model with the results obtained with traditional equipment in Europe. It is therefore proposed to carry out a ring test on a standard kaolin involving two other laboratories. The expert could arrange this with two laboratories in the Federal Republic of Germany. If such a test is satisfactory, the HDRI equipment may become an article for world-wide export.

The staff of HDRI need further training to gain competence in advising ceramic manufacturers in China. They should visit some factories and get practice in quality control, laboratory methods and statistical evaluation of results. The expert will try to assist in finding training places, which would be easier if a tuition fee were offered, at least for the first two weeks until the trainee was able to perform his work without permanent assistance.

UNIDO should agree to a request by HDRI - provided that funds are available - to furnish its laboratory with equipment for the investigation of ceramic raw materials. The best evaluation of a clay and any clay mixture for suitability is to fire a pressed or moulded sample in a gradient kiln. All parameters which are relevant for a factory can be studied on such a sample.

Annex I

PERSONS MET DURING THE MISSION

MAO Wen-jie, National Project Director
YU Ji Zhang, Managing Director of HDRI
ZHOU Xiaoming, CICETE, Beijing
LU Peiyu, Deputy Director of HDRI, supervisor of project DP/CPR/85/088
LI Tao Ping, SABMI, Beijing
XU Gao Feng, HDRI
ZHEN Rong Li, HDRI
GAO Jing De, HDRI
LI Weying, CICETE, Beijing
WANG Jianhiao, SABMI, Beijing

STEPHENS Kenneth, SIDFA, UNIDO, Beijing
ZHOU Youlan, UNIDO, Beijing

WANG Hai Xu was assigned to the expert as interpreter.

Annex II

ANSWERS TO QUESTIONS AND COMMENTS ON SPECIFIC TOPICS a/

A. Raw material and body preparation

1. Which is the best equipment for dry grinding?

This depends on the material to be ground.

The well known ring mills (Newman, Esser or Pfeiffer) are still very popular for grinding with simultaneous drying.

A recent development is the centrifugal disk mill.

2. Compare the energy consumption for body preparation, dry and wet.*

(Dry = dry grinding and mixing; wet = ball-mill grinding and spray drier.)

	<u>Dry</u>	<u>Wet</u>
Electric energy (kWh/t)	70	45
x 3.6 = (MJ/t)	252	162
Heat (MJ/t)	<u>670</u>	<u>1,900</u>
Total	922	2,062

Savings of energy by dry grinding: 1,140 MJ/t.

3. What are the advantages of rubber-lined ball mills?

Compared with hard-lined ball mills (SILEX or equal), rubber-lined ball mills are 60 per cent more expensive, but the lifetime of the lining is at least double.

Rubber-lined ball mills have a 10-20 per cent higher volume, but this is necessary to compensate the expected longer grinding times. Rubber-lined ball mills are mainly used for paints and such material where the abrasion of ceramic lining is regarded as a contamination.

B. Dry pressing

4. What is the output of modern wall-tile presses?

For wall and floor tiles a 600 t hydraulic press is suitable. Pressures higher than 600 t are not recommendable.

Such a press does, theoretically, 30 strokes per minute, but in practice the number of strokes is 22-23 per minute.

a/ Questions or topics that were part of a list submitted to the expert before he was fielded are marked by an asterisk (*). All others were raised by the participants in the lectures.

For a tile size of 15 x 15 cm, a 6-hole die is used, and for a tile size of 20 x 20 cm, a 4-hole die is used. Consequently, the output is 3-3.5 m²/min.

5. Which advantage have heatable pistons (punchers)?

Heatable pistons avoid sticking of the body to the piston.

Heatable pistons are not always necessary. However, the additional expenditure is reasonable, particularly when at the time of ordering a press it is not certain which kind of body will have to be pressed. Sticking of the body causes bad quality and loss of capacity due to time required for cleaning.

6. Which green bending strength is considered to be the minimum?

	After pressing	After drying
	N/mm ²	
Wall tiles	0.5 - 0.75	0.9 - 1.0
Floor tiles	0.7 - 0.80	1.2 - 1.5

C. Glazes

7. Utilization of additives to reduce the water content of glazes.*

Normally additives for glazes do not reduce the water content of the glazing slurry. They are used to get the right viscosity. The optimal viscosity of a glaze depends on the process of application:

(a) For spraying a low viscosity is needed; for waterfall it depends on the desired thickness of glaze on the tile;

(b) For screen printing a high-viscous paste is needed. A list of additives is contained in lecture No. 6.

8. Which glaze fixing agents are usual additives for multi-colour screen printing?

There are many. Most of them are additives, such as e.g. (carboxy)methylcelluloses.

9. Current research on glazes and utilization of rare earths for glazes.*

Glazes are developed in the factory that uses them. Factories do their own research to get a certain colour or a certain effect to meet the demand of the market.

Rare earths are not used as oxides in glazes but are a component of stains to achieve a certain colour. They are very expensive. They are necessary only if a customer asks for a particular colour, e.g. pink.

10. Theoretical and practical aspects of binding between ceramic body (biscuit) and glazes.*

Most important is a "harmonious" thermal expansion. The thermal expansion of a glaze must be the same or a little bit lower than that of the biscuit. This can be measured by a dilatometer or a Steger apparatus.

D. Firing

11. Can you give a technical and economical comparison of different kiln types?

For large, unglazed and glazed tiles, the roller kiln has proven to be the best. For small tiles and non-rectangular shapes, the pin-type kiln is suitable, but that kiln has a high energy consumption.

The multi-channel kiln has a high consumption of refractories (saggar trays).

Traditional tunnel kilns are the best for sanitary ware, split tiles, form pieces of all kind, unglazed tiles and biscuit fired in pills.

The choice of the kiln depends on the product.

12. Automatic control of the firing process.*

Control of firing process means control of the kiln only, and control of the temperatures of a given firing curve as established by the production manager in accordance to the product specification. The temperatures of the burners are automatically regulated by the control system.

There is no reliable self-regulating system adapting the firing curve to the product or the loading of the kiln cars.

13. Which temperature differences are expected in a roller kiln in the cross section from left to right?

Some suppliers guarantee for their production lines a constant temperature of less than ± 5 °C over the cross section of the kiln, regardless of the type of fuel used (gas or diesel oil).

14. New technology of single firing for wall tiles and economic analysis.*

There is at least one company in the Federal Republic of Germany firing the whole wall-tile programme of 4 million m² by the single-firing process. Compared with biscuit and glost firing, only 57 per cent of energy is needed for drying and firing of single-fired wall tiles.

E. Sanitary ware

15. Which is the optimal density of casting slip?

The casting slip must have a density of 1.75-1.80 g/cm³. With lower densities the energy consumption for drying increases considerably, as well as the drying time.

Such density cannot be obtained from the ball mill. Dry parts of the composition or filtercakes have to be added.

16. Low-temperature firing of sanitary ware.*

Such process is not in use in the Federal Republic of Germany, because with a firing temperature below 1,230 °C, it is not possible to meet the demand of European standards for less than 0.75 per cent water absorption.

Energy can be saved by other means, for instance by increasing the load of the kiln cars, reducing excess air in the kiln, or working out a firing curve for faster firing.

17. Complete set of machines for the production of sanitary ware.*

The expert prepared a complete list of equipment. However, successful sanitary ware production requires more than good machines, know-how, a good organization and discipline. Most important are the moulds, starting with the master mould.

Master moulds of new designs can be purchased. That is the easiest way to obtain a competitive design within a short time.

18. Casting under pressure.*

The casting of sanitary ware under pressure was developed to save man-hours. The method has not yet stood the test of long-term application. Its influence on quality is not yet sufficiently known and there is no reduction of cost expected, except in man-hours.

19. Can sanitary ware be fired in an open-fire kiln with diesel oil?

Yes, if the sulphur content of the diesel oil is less than 0.75 per cent.

F. Split tiles

20. Which is the best body preparation for split tiles?

The body preparation for split tiles, as for all tiles, depends on the product.

If a brick-like, rough surface is wanted, no fine grinding is needed. Such rough surfaces are welcome for the use on floors, but not for walls. To get a smooth surface for wall tiles, one has to prepare a fine-grain body, which is achieved by ball mills and dry grinding.

G. Fritts

21. Main factors to be considered in the fritt-making process.*

The expert described the equipment of a production line for fritts and gave consumption figures. He warned that the manufacture fritts in too many small units would require further investments.

The most popular rotating kilns have a batch size of 500 kg. How many rotary kilns are necessary depends not so much on the total planned output but on the number of fritts to be produced.

The planning of a fritt-production line in China for 5,000 t/year is recommended. This corresponds to about 5 million m²/year of wall tiles only.

The production of stains and colour oxides is not recommended until such time when the required quantity of one colour stain will reach about 100 t/year.

H. Standards

22. How to meet the standards?

The expert left with HDRI a complete set of European standards (in English) for the testing of tiles and dealt with existing standards for finished products in many of his lectures. However, it has to be pointed out that the most important standard is always the factory standard. In most cases the factory standard means higher quality than that required by a given national standard; but even if it is lower, it will be accepted by customers if the standard is made known and customers can rely on compliance with it.

Therefore continuous quality control in the factory and reports on technical parameters are essential. It is a well-known fact that quality standards differ from factory to factory. That is the reason why most customers, when ordering, ask not only for the company but for the factory where the tiles have been manufactured.

Quality control is a responsibility of the management; the laboratory is only executing the required tests and controls.

Quality certificates, based on controls executed only every three or five years, are of limited significance.

I. Modern technologies

23. Can you tell us more about modern technology?

The expert pointed out that in his lecture he had covered all recent developments, including such which are not yet described in books. In fact, 80 per cent of recent innovations in Europe were aimed at reducing man-hours. They comprise transport and handling of tiles by robots, and glazing of sanitary ware by robots. The introduction of such technologies in Chinese factories would increase production costs considerably instead of decreasing them.

Another area where progress has been made is energy conservation, and this had been mentioned by the expert in connection with dry body preparation and the single-firing of wall tiles.

Production by automatic lines has increased awareness of the importance of quality control. It has been realized that quality control should have started much earlier with the traditional production lines.

Modern presses with a capacity over 3 m²/minute were not available 12 years ago. Mosaic tiles can now be fired within 30 minutes. Such modern technologies, which may be unknown in China, require considerable know-how which cannot simply be purchased together with modern machinery.

The development of techniques for the decoration of tiles took 10-15 years. The expert felt that decorated tiles are not considered important for the domestic market, although he noticed that in all hotels where he was staying decorated wall tiles had been used. Therefore, there would seem to be a domestic market for such products, and, moreover, the industry cannot be successful on the export market without having a decorative programme.

The expert explained that, while a good deal of new technologies were discussed in technical papers and magazines, he was of the opinion that it was better to inform the audience about proven technologies and not about unproven ideas.

K. Market

24. World status of production of ceramic wall and floor tiles and sanitary ware; trends for further development; situation of these products on international markets.*

In general, it is important to know the market situation before planning for a product and establishing a new production line. But tiles are not sold like coal or sulphuric acid. Tiles are always ordered from a catalogue according to size and a specific surface. The demand differs from place to place, particularly with regard to size and surface. The price of 15 x 15 cm white wall tiles, which the expert was told to be the only tiles of interest in the country, is extremely low on the world market. The production of plain white wall tiles is, on the other hand, most difficult. The tile distributors at Singapore, which is a distribution centre for South-East Asia, are looking more for trade-marked tiles, i.e. catalogued tiles, including specification of decoration and technical data.

The decorated wall tiles used in Chinese hotels must have been imported since Chinese factories offer only white tiles. Chinese factories should, therefore, come to their own designs. It is recommended to adapt well-known Chinese designs of dinner ware or other china ware to wall tiles.

The expert provided the following consumption and production figures for the Federal Republic of Germany:

	<u>Consumption in 1980</u>			
	<u>Million m²</u>	<u>Percentage</u>		
		<u>Total</u>	<u>Used for wall covering</u>	<u>Used for floors</u>
Wall tiles	63	59	54	5
Stoneware tiles (glazed and unglazed) including mosaic	23			
Split tiles (glazed and unglazed)	18	41	6	35
Clay tiles	3			
		<u>100</u>	<u>60</u>	<u>40</u>

Production in 1987

	<u>Million m²</u>
Dry-pressed, glazed tiles (wall and floor)	34.4
Dry-pressed, unglazed tiles	7.7
Split tiles, glazed	14.1
Split tiles, unglazed	7.7

The average price of imported tiles (wall and floor) in 1987 was DM 14.07 m². The average selling price of tiles made in the Federal Republic of Germany in 1987 was DM 21.29 m².

Annex III

RECOMMENDED EQUIPMENT FOR RAW MATERIAL INVESTIGATIONS

The equipment recommended below is either not available at HDRI or the existing equipment is not suitable.

	<u>Price in US dollars</u>
1. Simon Muller kiln (for loss on ignition)	400
2. Two sets Andreasen sedimentation equipment with pipettes and 20 evaporation dishes (Brand, Wertheim)	200
3. Automotive agate mortar with pestel (Retsch)	1,000
4. Boron carbide mortar with pestel (ESK)	450
5. Rotor beating mill (Retsch)	900
6. Stereo microscope (binocular) 1:20/1:40	900
7. Camera (Polaroid) for this microscope	300
8. Fibre-glass lamp, Intralux 5000 (Volpi)	1,400
9. Hydraulic press for 20 t, hand-operated, with gauge (Enerpak) Dies, 5 x 5 and 5 x 12 cm, to be made locally	3,000
10. Gradient kiln with nine temperature zones and spare heating elements (Kilns and Furnaces)	5,800
11. Bending-strength tester 401 (Netzsch-Gerätebau)	5,800
12. Vernier caliper, 200 mm	20
13. Five CEC-colour-cards	30
14. Mohs hardness set Equipment for measuring water absorption under vacuum: vacuum chamber to be made locally (for small parts a large desiccater will suffice)	20
15. Vacuum pump with digital vacuum meter and all connecting tubes, one wash bottle and safety valves (brand)	1,100

Price in US dollars

16. Platform balance 0.01-999.00 g (or more) (Sartorius) (A local one would be acceptable, but as Sartorius balances are regarded as the best in the world, it is felt that HDRI should have one.)	2,000
17. Differential dilatometer with plotter 402 EP for green curve and thermal expansion of fired ceramics (Netzsch- Gerätebau)	10,000
18. Calculator Canon F 73 for compiling of statistical data	<u>50</u>
Total	33,370

Annex IV

MODEL DATA SHEET FOR CLAYS AND BODIES

Loss on ignition %

Particle size

Wet sieving residue on sieve 0.125 mm (120 BSS mesh) %

Wet sieving residue on sieve 0.063 mm (240 BSS mesh) %

Andreasen sedimentation analysis:
(after shaking for 2 hours with
0.9 g/l $\text{Na}_4\text{P}_2\text{O}_7 \cdot 10\text{H}_2\text{O}$)

30-63 μ	%
15-30 μ	%
8-15 μ	%
4-8 μ	%
2-4 μ	%
1-2 μ	%
below 1 μ	%

Casting properties

Viscosity of a slip of 1.8 g/cm³ density
Lowest viscosity with addition of g/l standard sodium silicate

Special physical properties

DTA-curve

TG-curve

Raw ("green") curve in dilatometer

Thermal expansion curve of fired clay in dilatometer

Moisture expansion of fired clay in dilatometer

Annex V

MODEL DATA SHEETS FOR OTHER CERAMIC RAW MATERIALS

These data sheets must cover information given below.

Feldspar

Loss on ignition (LoI)

Softening/melting temperature ("firing intervall")
(to be evaluated in heating microscope or gradient kiln)

Properties in a mixture with standard clay

Full chemical analysis

Dry sieve analysis (if feldspar is supplied ground)

Calcium rocks

Loss on ignition (LoI)

Chemical analysis on CaO and MgO
(further analysis only if there is a large difference to 100%)

Dry sieve analysis (if calcite or dolomite are supplied ground)

Silica sand

Loss on ignition (LoI)

Analysis of acid-soluble compounds

Sieve analysis

Chemical analysis of iron contents (if desired)