Understanding The Small-Scale Clay Products Enterprise

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PREFACE

This paper is one of a series published by Volunteers in Technical Assistance to provide an introduction to specific state-of-the-art technologies of interest to people in developing countries. The papers are intended to be used as guidelines to help people choose technologies that are suitable to their situations. They are not intended to provide construction or implementation details. People are urged to contact VITA or a similar organization for further information and technical assistance if they find that a particular technology seems to meet their needs.

The papers in the series were written, reviewed, and illustrated almost entirely by VITA Volunteer technical experts on a purely voluntary basis. Some 500 volunteers were involved in the production of the first 100 titles issued, contributing approximately 5,000 hours of their time. VITA staff included Leslie Gottschalk and Maria Giannuzzi as editors, Julie Berman handling typesetting and layout, and Margaret Crouch as project manager.

Miska Petersham, the author of this VITA Technical Paper and a second one, "Understanding Clay Recognition and Processing," has worked in the field of ceramics for many years. He is also a designer in glass and wood and a wood carver, and has considerable experience in these fields in developing countries. Reviewers Daniel Rhodes and Gerald Rowan are also experts in clay and ceramics. Daniel Rhodes is a professor emeritus at Alfred University, New York, in ceramics. He is the author of four books on ceramics, and has experience with pottery design, glazes, kilns, molds, clay refining, etc. Gerald Rowan is the chairman of the art department at Northampton Community College, Pennsylvania. He has a wide knowledge of ceramics, clay, brick making, kiln building, glazes, owner made equipment, etc.

VITA is a private, nonprofit organization that supports people working on technical problems in developing countries. VITA offers information and assistance aimed at helping individuals and groups to select and implement technologies appropriate to their situations. VITA maintains an international Inquiry Service, a specialized documentation center, and a computerized roster of volunteer technical consultants; manages long-term field projects; and publishes a variety of technical manuals and papers.

I. INTRODUCTION

People discovered bow to use clay over 20,000 years ago. The basic principles of shaping, drying, and firing clay are still the same today as they were then. The only significant changes since the discovery of clay have been the identification of additional clay materials and improvements in the methods of making clay products.

Every age has left behind objects made of clay. Before the introduction of plastics and sheet tin, most containers for food--whether in solid or liquid form--were made of clay or glass. Clay was also used for architectural decoration as well as structural material, for it was plentiful and long lasting.

Although the introduction of new materials and techniques has reduced the use of clay in many areas, clay still plays an important role. It is a versatile material that can be used at all levels of technology. It is common in most parts of the world, and it is possible to collect and use it for some types of products without large capital outlays. Yet, in many developing countries, it is an underutilized resource.

APPLICATIONS OF CLAY

Ceramics is the general term for manmade products shaped from any natural clay material and transformed into a permanent hard state by heat. The term includes:

* Pottery and porcelain consisting of such articles as porcelain dolls, dinnerware, sanitary ware (toilets, sinks, etc.), cookware, and flowerpots. Pottery is defined as ceramic ware, especially earthenware and stoneware, which refers primarily to container forms (e.g., pots, vessels) often made from low-fired red clay. This definition, however, varies greatly from place to place. Hollowware and giftware are terms used when referring to dinnerware and decorative items such as ashtrays and small sculptures.

* Structural and industrial ceramics consisting of a wide range of articles used in building and industry. Bricks, tiles, and sewer pipes are some examples of structural ceramic products. Sparkplugs, insulators, furnace linings, etc., are some industrial ceramics.

ORIGIN AND COMPOSITION OF CLAY

The weathering of igneous rock (rock of volcanic origin) over long stretches of geological time causes the formation of clay minerals. This rock is usually feldspathic (i.e., it contains mostly feldspar) in temperate areas and on large continental land masses, whereas in tropic volcanic areas where little or no feldspar exists, it is usually basaltic (i.e., it contains mostly basalt). The different geographic locations, source materials, and climatic (weathering) conditions produce different combinations of clay minerals and different kinds of impurities which result in the different working characteristics of the clays.

Most clay is made up of several clay minerals, which are similar but have different working characteristics. Although one cannot see with the naked eye what clay minerals are present and in what proportion, experienced ceramists usually can guess the workability of clays by observing their handling and firing properties. Determining precisely what minerals are actually present requires expensive, careful, and elaborate laboratory analysis--but even this is subject to error.

Kaolin ([A1.sub.2.O.sub.3]/[2SiO.sub.2]/[2H.sub.2.O]) is the most common clay mineral, but pure kaolin deposits are a rare find. These deposits, when found, often have commercial value because their use in industry is not limited to ceramics. Pure kaolin is white, non-plastic, and highly refractory (refractory clays are ones that resist heat and do not melt when they are subjected to high firing temperatures). It is called a primary clay, because it is clay found where it was formed.

Most clays are predominantly kaolin mixed with other clay minerals and impurities such as iron, manganese, mica, silica, and rock fragments. The different mixes and proportions affect the working properties of clays, causing them to vary in their behavior. Some clays are suitable for one kind of product only, others have broader uses, and still others are totally unusable. The only sure way to determine the workability of a particular clay is to make the desired product on a trial basis and analyze the results. This kind of practical test is much more satisfactory for most operations than the more complicated laboratory testing, which should be undertaken only after a clay or blend is deemed usable.

Red clays are most commonly found in deposits on or near the surface of the earth. They are called secondary clays because they have been eroded and carried from their primary source by frost, rain, or water bodies, to become huge sedimentary deposits at the bottom of lakes and seas. As they are borne along, these clays come into contact with other natural substances, such as sand, calcium, and iron compounds. Red clays contain various impurities, which lower the clays' resistance to heat, making them suitable only for earthenware. Earthenware clay is usually dark red, very plastic, and fires at a relatively low temperature.

Many clays fall between kaolin (the purest clay) and red clay (the least pure clay) in their working properties, and each clay must be tested individually to determine its usefulness. Some general differences exist between clays found in temperate regions and those found in tropical volcanic regions. These differences are the result of changes in the proportions of clay minerals and impurities. The principal differences between the two clays are outlined in Table 1, generally indicating the extent to which clay deposits must be examined for suitablility.

Table 1. Reliability of Temperate Clays Versus Tropical Volcanic Clays

Distance Degree Quality Consis- Type of Origin of Clay of of tency Clay
Clay Traveled Weathering Clay Mix of Clay

Temperate From feld- Long Slow
Well- Relatively spathic rock weathered
mixed the same in many deposits Tropical From basal- Short Fast Poorly Many
Volcanic tic rock to weathered
mixed variations none
even in one deposit

Although all deposits should be checked carefully for consistency and content, this holds true especially for clays found in the tropics. Tropical clays can be used to make some kinds of clay products, but they are often more difficult to use and require much more skill and care.

II. BASIC TECHNOLOGY AND THEORY

ACQUIRING YOUR CLAY

If you paln to produce large quantities of clay objects, you should be sure that there is a sufficient reserve of clay of the same quality to last a minimum of 10 years. The clay should be of sufficiently high quality to produce the desired product. When purchasing clay, costs may vary from a few cents to 20 or 30 cents per pound. You should consider 10 to 15 cents a maximum. In an area where producers must gather and process their own clay, all associated costs must be taken into account.

PROCESSING CLAY

Clay can be processed either at a plant designed for one clay manufacturer or at a processing plant that serves several manufacturing operations. Clay is mined and its impurities removed; it is then ground if necessary, bagged, and stored in moist plastic form or as dry powder called clay flour. Removal of transported impurities from the clay is done either in the clay's wet or dry state, depending on the original material, amount needed, costs, and use. The dried, refined clay is then mixed with other clays or additives, such as feldspar, to produce the desired clay body (a clay body is the prepared material from which any ceramic article is made).

As in all industries, the ceramic industry has developed its own clay terminology over the years. In the sections that follow, some of the most common terms relating to various clay processes are defined. Almost all of these processes may be done by hand, by simple foot-powered machines, or by complex mechanically powered machines. Generally, both the cost and the quality of the clay product go up as the sophistication in technology increases. In the case of large-scale mass production of one item, the cost per item generally decreases, given that the demand for the item is high.

Clay Preparation

Clay bodies are a mixture of one or more natural clays plus such other materials as feldspar, silica, etc. Clay bodies are prepared in a liquid state for slip casting; in a semi-solid state for plastic forming, and in an almost dry state for dry pressing.

Clay-Forming Techniques

Potters shape clay in a number of ways. Some popular shaping methods are described below.

* Throwing is the act of turning a lump of semi-solid clay on a potter's wheel. The clay is "thrown" (shaped) on the wheel while the wheel turns.

* Jiggering is a highly mechanical method of making tableware. In this process, a lump of semi-solid clay is placed on a convex plaster bat and turned while a template is held against it. As the plaster bat turns, the clay is squeezed into shape.

* Extrusion involves pressing out a lump of semi-solid clay through a forming die.

* Pressing involves pressing a lump of semi-solid clay into a mold.

* Slip casting involves making slip (liquid clay) and pouring it into a dry plaster mold. The plaster absorbs water, forming a skin of drier clay on the mold surface. When the liquid is poured off, this skin is left, taking the same shape as the mold. The clay body is mixed with water to make slip but this ordinary slip is almost impossible to use due to excessive shrinkage. To make it work better, one or more deflocculants (water softeners) such as sodium silicate are added in very small amounts. This decreases the water necessary to make the slip liquid and therefore reduces the shrinkage, which allows it to be cast. Many clays are not suitable for casting due to difficulty in achieving deflocculation. Only a practical test of the casting properties will tell.

* Plastic forming: Before semi-solid (plastic) clay can be formed by whatever method, it should be mixed (kneaded) to obtain an even consistency and eliminate trapped air. This can be done by hand, by foot, or by machine. In most new plants, a mix muller to crush and mix and a vacuum pug mill to de-air and prepare clay are used.

* Dry pressing requires extremely high pressures and a carefully-controlled moisture content. Because of the need for expensive equipment, dry pressing is best suited for large-scale production.

III. ESTABLISHING A CLAY ENTERPRISE: VARIATIONS AND ALTERNATIVES

This section discusses the basic resources required to establish various kinds of small-scale ceramic plants. Before we proceed with this discussion, it is important to note the following:

Opening and maintaining a small-scale ceramic plant is a complex, demanding operation that requires a full-time commitment. People should consider embarking on such a venture only if they are sufficiently trained to make high-quality ceramic products, and are capable of designing and building the basic ceramic equipment necessary for making ceramic goods. The traditional apprenticeship for a ceramist is seven years.

A common error is the notion that anyone can set up a ceramic business and be successful at it after only a few weeks of training. Given that ceramic technology is relatively simple, setting up a ceramic business looks deceptively easy. Sound advice must be sought from a qualified ceramic expert in order to succeed in the ceramic industry. The expert must have broad experience in ceramic technology, design, and marketing, and must have the time to study the local cultural and economic conditions before giving advice.

Generally speaking, small-scale ceramic production progresses from relatively simple technology to more complex technology as demand, markets, and expenses increase.

A SMALL-SCALE BRICK MANUFACTURING PLANT

Unsophisticated brick manufacturing can be done in a small plant operated by one or more workers. Setup costs are very low, but a nearby clay source and cheap or free fuel are necessary. Fuel can be wood scraps, coconut husks, or similar material in abundance. Total costs range from about $1,000 for basic equipment to $10,000 for some good-quality, imported equipment.

The bricks can be formed in simple wood molds on the ground with no elaborate processing equipment required. For a more sophisticated operation, simple hand-operated (lever-type) pressing machines are available. This improves both appearance and quality.

In most cases of small-scale brick manufacture no proper kiln is used. An open setting called a clamp makes use of the brick that is to be fired. By leaving open channels through the clamp, a path for the heat is provided. After firing, all or part of the clamp is dismantled. Often the walls containing the fire mouths are left up and all other parts rebuilt after each firing. It is rare at this level that a regular pottery kiln is used since it is needlessly expensive and holds a minimum of bricks.

For more sophisticated brick manufacturing, the costs rise with increases in plant productivity and in the quality and quantity of equipment. The primary task here is to analyze the market, so that production capacity can be consistent with demand for the product. Only after analyzing the market can any determination of feasibility be made. This paper does not attempt to provide estimates on the cost of operating a sophisticated brick manufacturing plant; to do so would be meaningless, since all aspects of this type of operation are subject to local variation. A SMALL-SCALE FLOOR OR ROOF TILE MANUFACTURING PLANT

For a very simple, unsophisticated operation, the cost (excluding building costs) should be about $15,000. There are so many variables involved that this cost is at best an approximation for average conditions. It is possible to hand-make tile of all kinds at much lower cost, but these are not as readily accepted on the market as more sophisticated tiles. An exception is those areas where the hand tradition is already well established and in these cases the conditions of manufacture will already be well established.

Basic equipment items and their costs are given in Table 2.

Table 2. Estimated Equipment Costs for a Small-Scale Floor or Roof Tile Manufacturing Plant

Equipment Costs Type of (Dollars)() *Equipment Local Imported*

Press and dies 1,000 to 10,000

Mix muller 500 to
3,000

Jaw crusher 800 to
3,000

Pug mill 1,000 to 10,000

Ball mill 500 to
5,000

Kiln 1,000 to 10,000

Miscellaneous small equipment 1,000 to 5,000

Transportation (truck) 5,000 to 15,000

Costs will vary, depending on quality of equipment and where it is purchased.

Note: Processing equipment can often be built locally at considerably less cost than that for imported equipment.

A SMALL HOLLOWWARE PLANT

The type of hollowware product is the key to setup costs. Fine ceramics (e.g., china and porcelain) require highly refined kaolin, feldspar, and silica, which are expensive. These materials may be purchased locally, if available, or abroad, in their refined state; or they may be purchased in their unrefined state and refined at the factory. The setup costs will vary from operation to operation, depending on the local set of conditions each operation encounters. For example, the need to import materials could drive up the costs.

If ceramic materials are available locally, and do not require extensive processing, or if less than top-quality ware is the desired product, the setup costs can vary from $25,000 to $100,000, depending on the type and quantity of products produced, and whether the equipment is made locally or imported.

A small hollowware plant employing 10 to 15 people would have to secure a large market for its products to warrant the excessive setup costs of refining and processing ceramic materials. Imported processing equipment alone could cost over $100,000.

Plants already in existence in the Orient and some other areas have been set up for much less, but it must be remembered that the tradition, necessary skills, and market acceptance have been there for generations. In order to set up in an area without this background, very different conditions may apply. The costs are considerably higher since there are many more difficulties to overcome.

For large-scale production of clay products such as dinnerware and giftware, the setup costs can range from $100,000 to over $1 million. Investments of that magnitude call for a careful analysis of potential markets.

Specialty ceramics such as sparkplugs, insulators, or chemical porcelain require a small- to medium-sized, highly sophisticated operation, as well as a reliable source of high-quality kaolin, feldspar, and silica. The setup costs are therefore relatively high.

IV. COMPARING CERAMIC TECHNOLOGIES

ADVANCEMENTS IN CERAMICS

Simple ceramic technology was developed long ago by families and guilds who would jealously guard from the public any new advancements they had made in the field. For this reason, the field of ceramics was slow to change. Only within the past 30 to 40 years have new ceramic discoveries been made available to the public. The public now has access to books and courses providing them with a more open learning environment. Despite the knowledge that has been gained thus far, many aspects of ceramics are still not completely understood. Only through continuing research can we broaden our understanding of the field to make better ceramic products. New findings spurred by research into high heat-resistant materials continue to become available.

SIMPLE VERSUS ADVANCED TECHNOLOGIES

The advantages of the basic ceramic technologies over more advanced technologies are that:

* ceramists with only minimal skills can produce pottery, brick, or tile easily because of the simplicity of the technologies;

* entrepreneurs need to invest only a small amount of capital;

* ceramists can produce ceramic articles from local clays and sell them on the domestic market.

The only disadvantage of the basic technologies is that they produce low- to medium-quality products rather than top-quality products. In order to improve significantly the quality of ceramic products, entrepreneurs would need to invest in more sophisticated equipment, as well as hire more highly trained workers. To do so, however, would increase both the initial and the operating costs.

V. CHOOSING THE TECHNOLOGY

Choosing the size, location, and type of ceramic industry requires careful consideration of all the facts. There is no universal formula. Each case must be considered on its own since there are so many factors to consider.

Even for a very small operation, some kind of feasibility study by a qualified person should be undertaken. That the person chosen to perform the study be qualified is important, for getting bad advice from a nonexpert can cost more in the long run than getting sound advice from an expert at the very start.

FACTORS TO CONSIDER IN CHOOSING THE TECHNOLOGY

Ceramic Equipment: Domestic Versus Imported

Proper clay machinery is one of the keys to a successful operation. For example, a simple ball mill capable of handling 100-pound batches of clay can be built in-country if a good machine shop is available. This type of mill is unsophisticated, however, and has a relatively short life of about five years. On the other hand, it costs about $500 to $1,000 and can be repaired locally. The other extreme is to buy from the United States or Europe a sophisticated mill, which does essentially the same job as a simple ball mill. Sophisticated ball mills last considerably longer and require less maintenance, but spare parts are available from abroad only, and initial costs are much greater.

Suppliers of ceramic equipment are located in industrialized nations, and most of their equipment is built to order. Because these suppliers have very small inventories, if any, it may take them as long as one to two years to fill orders for new equipment, but there are few central clearing houses. The best source of information for used equipment is any large ceramic supply house in any of the industrialized countries.

Equipment manufactured in the United States, Britain, and Europe is well made, sophisticated, and expensive. India produces ceramic equipment that is sturdy, less sophisticated, and much cheaper, but shipping and actual arrival of the correct piece of equipment can be the source of many headaches.

Except for fire brick and setter slabs, which must be imported, most equipment can be built locally if a qualified machine shop is available.

In selecting equipment, careful consideration should be given to energy requirements; the availability of present and future energy sources; and current and future energy costs.

Clays: Domestic Versus Imported

Refined clays can sometimes be imported at reasonable costs, but in most instances the following reasons rule against imports:

* Reliance on an imported source could cause ceramic production to come to a halt if, for any reason, that source became unavailable.

* Costs to import are usaully somewhat higher e.g., shipping costs are higher).

* Importation of clays impedes the selling of local materials.

* Importation of clays drains money out of the country.

* Importation of refined clays takes business away from local clay-processing industries.

Answering Important Business Questions

Anyone interested in earning a living from ceramic manufacturing--be it a small-scale, medium-scale, or large-scale operation--should know the answers to the seven sets of basic business questions provided in this section. Groups of questions are divided into the following categories: market survey, fuel source, clay source, labor, equipment requirements, product design, and business location.

Market Survey

1. What clay products are currently in use?
2. In what volume?
3. What is made locally? What is imported?
4. What percent of the market does the local product represent?
5. What part of the market can you realistically fill?
6. If a new product is considered, what is the expected demand?
7. Is this a guess? result of a survey? general consensus? other?
   Fuel Source
8. Type desired? (Usually gas, oil, wood, or sawdust; electricity is expensive as is the equipment required to produce it. Fuel source and type of clay affect temperature ranges required to produce objects, which in turn greatly affects cost.)
9. Availability?
10. Cost?
11. Estimate of amount to be used?
12. Transportation (If wood or sawdust)?
    Clay Source
13. Availability in proper amount? (10-year supply minimum)
14. Cost to collect and process? (Under 15 cents per pound to use)
15. Quality? (Knowledge of test results and pilot products tried)
16. What imports are necessary? (Should not be more than 20 percent)
17. What to import? cost? availability?
    Labor
18. Trained locally? how? where? cost?
19. Trained overseas? availability? cost?
20. Wage pattern, skilled and semi-skilled?
21. Relative productivity?
22. Trainability? (i.e., conversion of nomadic tribesman to factory worker)
23. Cultural consideration (i.e., low-class or caste occupation, sexual bias, etc.)
24. Training allowances? (Usually six months to one year for general production personnel; and two to six years for foremen, technicians, and designers)
    Equipment Requirements
25. Locally built? (Possible with competent machine shop)

26. Imported?
27. What country? (In the United States, Britain, Europe, and India, cost and quality vary)
28. Size and type needed? (Generally requires expert help)
    Product Design
29. Design quality? (For successful market penetration, designs--especially giftware and hollowware--must be unique and of high quality)
30. Design source? In house or outside designer?
31. Cost?
32. Availability?
    Business Location
33. Retail sales potential?
34. Transportation of raw materials (clay is heavy, and a large quantity is needed; it must also be stored for processing and use) versus transportation of finished product?
35. Availability of labor?
36. Zoning?
37. Access to shipping imports or exports?
38. Fuel source?
39. Pollution of environment?

CERAMIC ORGANIZATIONS

American Ceramic Society Bulletin American Ceramic Society 65 Ceramic Drive Columbus, Ohio 43214 USA

British Ceramic Research Association Queens Road Penkhull Stoke-on-Trent, ST4 7LQ UNITED KINGDOM

Ceramic Industry and Brick and Clay Record Cahners Publishing Company, Inc. 1350 E. Touhy Avenue Box 5080 Des Plains, Illinois 60018 USA Publishes Ceramic Industry magazine

Indian Ceramic Society Central Glass and Ceramic Research Institute Calcultta 700032 INDIA

Indonesia Ceramic Research Institute J1. Jend. Achmad Yani 392 Bandung, West Java INDONESIA

CERAMIC SUPPLIERS AND MANUFACTURERS

GENERAL AND USED EQUIPMENT

Bonnot Company Chambers Brothers Division 805 Lake Street Kent, Ohio 44240 USA

British Ceramic Plant and Machinery Manufacturer's Association Box 87 Weybridge, Surrey, KT13 9JS, UK

Denver Equipment Division Joy Manufacturing Company Box 340 Colorado Springs, Colorado 80903 USA

Globe Trading Company (used equipment) 1801 Atwater Ave. Detroit, Michigan 48207 USA

International Clay Machinery of Delaware, Inc. Box 211 Wellsville, Ohio 43968 USA

Mohr Machinery Company, Inc. (used equipment) Box 1148 Dearborn, Michigan 48121 USA

Netzsch, Inc. Sub. Gebrueder Netzsch 119 Pickering Way Exton, Pennsylvania 19341-1393 USA

SACMI Via Statale Selica 17-A 40026 Imola, ITALY

Takasago Industry Company, Ltd. Dachi-cho Toki-city, Gifu-pref, JAPAN 09-54

A. J. Wahl, Inc. 8961 Central Avenue Brockton, New York 14716 USA

BALL MILLS AND MIX MULLERS

Paul O. Abbe, Inc. 400 Center Avenue Little Falls, New Jersey 07424 USA

American Clay Machinery Corporation 1716 Dillion Place, NE Canton, Ohio 44705 USA

Clearfield Machine Company Box 992A Clearfield, Pennsylvania 16830 USA

National Engineering Company Simpson Mix-Muller Division 20 N. Wacker Drive, Suite 2060 Chicago, Illinois 60606 USA

DECORATING MACHINERY

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Haendle, Karl & Soehne Postfach 1251 D-713 Muehlacker, WEST GERMANY

KILNS

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Bickley Furnaces, Inc. Box 6069 Philadelphia, Pennsylvania 19114 USA

Harrop Industries, Inc. 3470 E. Fifth Avenue Columbus, Ohio 43219 USA

Heimsoth Keramische Ofen Schuetzenallee 41 3200 Hildesheim, WEST GERMANY

DRYERS

Anhydro, Inc. 165 John L. Dietsch Square Attleboro Falls, Massachusetts 02763 USA

TILE PRESSES/BRICK AND TILE MACHINERY

Abex Corporation Dension Division 1220 Dublin Road Columbus, Ohio 43216 USA

AC Compacting Presses, Inc. Box 1766 New Brunswick, New Jersey 08902 USA

Cincinnati, Inc. Box 11111 Cincinnati, Ohio 45211 USA

J.C. Steele & Sons, Inc. Box 951 710 S. Mulberry Street Statesville, North Carolina 28677 USA

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