FINAL TECHNICAL REPORT
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Project Title: **UTILIZATION OF ILLINOIS FLY ASH IN MANUFACTURING OF CERAMIC TILES**

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ABSTRACT

The overall objective of the project is to utilize fly ash, produced by burning Illinois coal, which is currently being landfilled, as a major raw ingredient to manufacture value-added ceramic tiles and to commercialize the technology.

In the course of this project, the process was developed that allows utilization of fly ash with moderately high carbon content in manufacturing ceramic tiles. The processing method was developed that leads to oxidizing residual carbon from the ash and removal of a potential source of the tile warping, surface defects, and loss of strength. The mix proportions were finalized, and the prospective manufacturing process by dry pressing and fast firing was identified. The results indicated that the requirements for floor and outdoor applications were achievable in the fly ash-based system. The results also confirmed the initial premise that fly ash can be utilized as the major raw ingredient in manufacturing of ceramic tiles. This formed the basis for a successful experimental run on the actual mass-production industrial-type equipment. The technical and economic feasibility study for a commercial-scale plant based on this technology gives an estimate of the capital and operation costs involved, as well as the market prospective of commercialization of the technology. It was proposed that an extended experimental run should be conducted using the industrial equipment intended for the prospective commercial plant.

EXECUTIVE SUMMARY

The solid product of combustion of pulverized coal in power plants is called fly ash. It is fine particulate material that is electrostatically precipitated or mechanically collected from the stack.

Annually, the state of Illinois produces over 5% of the 60 million tons of fly ash generated in the U.S. Approximately 20% of this fly ash is utilized by the cement and concrete industry and the rest is landfilled. Any non-concrete utilization of the currently disposed fly ash would not only be environmentally sound and cost effective, but will also create a stable year-round demand.

The overall objective of this project is to utilize fly ash generated by the burning of Illinois coal as the major raw ingredient for manufacturing value-added ceramic tiles for wall, floor, and outdoor applications. Considering the size of the tile industry, a considerable fraction of the fly ash produced in Illinois can be utilized to prepare ceramic tiles. As raw materials constitute to the major cost in running a tile plant, replacement of costly raw materials by fly ash is attractive to tile manufacturers.

The project focused on manufacturing tiles out of fly ash at a commercial tile plant located in the State of Illinois, and fly ash-based tiles are manufactured with characteristics similar to those of conventional tiles. The parameters investigated were selected based upon important factors for the commercial manufacturing of fly ash-based tiles. Development of such information is essential for commercialization of this technology.

In *dry pressing*, approximately 5% water is added based upon the weight of dry solid. The floor, wall, and outdoor tiles produced in this method mostly have a flat surface, and the production rate for this method may be very high. In *wet pressing*, the amount of water used is relatively high (approximately 25%), and the resulting material has the consistency of putty. This procedure has the advantage of reasonably high production rates, and simple designs on the tile surface are adequately reproduced. In the *slip casting* method, a self-supporting shape, called a cast, is produced from a specially formulated slip (thinned mixture of clay and other solids with water). Intricate designs can be adequately reproduced using this processing method. However, a number of parameters play an important role in successful slip casting, which is even more complex in the presence of the multicomponent nature of fly ash.

Sintering of the green tile body takes place at 1000°–1200°, and solid bonds between particles are formed. The tile body is glazed at 950°–1000°C, which is lower than the sintering temperature. A glaze is a glassy material formed by melting of specially designed mixes on the surface of a ceramic body, and staying adhered upon cooling. Glazing improves the surface durability and adds different aesthetic values to tiles. In order to achieve a defect-free surface, it is important that the thermal expansion of the

glaze be equal to or slightly more than that of the ceramic body. Among other properties, breaking strength and water absorption are the most important properties to determine the quality and applications of ceramic tiles.

This phase of the research was designed to refine the technology that has been proven to be achievable in a commercial tile manufacturing plant. Processing methods and parameters that are relevant to commercialization of this technology, such as the pressing methods, temperature profiles, glaze composition, were emphasized in this present program, including presentation at technical meetings.

All processing methods mentioned above were investigated in this program, including variations of wet pressing. Dry pressing, being the technology of choice for the future commercialization, was paid special attention. It was tested at the pilot facility closely simulating the industrial tile production environment.

The results of this study demonstrate that high proportions of fly ash (over 50%) can be used in successful commercial manufacturing of ceramic tiles using wet pressing, slip casting, and dry pressing methods. The causes of a few problems relevant to processing and appearance have been identified, and remedial measures developed. The test results indicate that characteristics of fly ash-based tiles are superior to those required for wall tile applications and comparable to those required for floor and outdoor applications. Several fly ash tile bodies have also passed the standard specifications used in the tile industry, indicating potential for floor and outdoor applications.

There are reasons to believe that the processing method developed in this project for a specific Illinois fly ash has general applicability to other Class F fly ashes. However, variations of characteristics of ashes from different sources may necessitate some specific adjustments due to the shifts in those characteristics.

As an integral part of this project, an economic and technical feasibility study was conducted. It was shown that a green field tile plant in the central part of the U.S. has satisfactory prospects of capturing the appropriate share of the market place. The capital and operating costs were estimated and included in the study.

OBJECTIVES

The overall goal of this research is to utilize Illinois Class F fly ash in the commercial manufacture of value-added ceramic tiles for wall, floor, and outdoor applications. Fly ash can be used as the major alternative raw material for the ceramic tile industry for several reasons. Fly ash is a valuable raw material with some characteristics that are otherwise costly to produce.

- The fine powder form of fly ashes makes them usable in the as-produced form without any further size reduction.
- The composition of fly ash is such that it can be used as a major raw ingredient for making wall and floor tiles.
- Such utilization is environmentally sound, preserves our resources, creates a year-round demand for fly ash, and benefits the economy of the State.

In 1990, approximately 100 ceramic tile-manufacturing plants in the United States produced about 510 million square feet of tiles and the quantity is expected to rise in the near future. Because of the high cost of raw materials, U.S. manufacturers are less competitive than their foreign counterparts. Therefore, utilization of fly ash, now being landfilled, to make ceramic tiles is very attractive. The objectives were to manufacture tiles using any of three processing methods: slip casting, wet pressing, and dry pressing.

In order to accomplish this objective, both a technical and economic feasibility needed to be established and the factors associated with commercial manufacturing evaluated. In the first phase of the project, a technical feasibility study was conducted that included the proof of the concept, composition formulation, process development, characterization of products, and optimization of composition to meet the primary requirements for commercial tiles.

As a necessary step for the economic study, the process had to be scaled up from laboratory to manufacturing plant scale. The parameters and data that are necessary to commercialize this technology were obtained during the experimental work at the pilot tile plant. Another important set of parameters was produced by a marketing study as a part of general economic evaluation.

During the project period, ceramic tiles with satisfactory characteristics similar to commercial wall and floor tiles were produced in the laboratory and in a small scale commercial art tile manufacturing plant.

INTRODUCTION AND BACKGROUND

The fine particulate material that is electrostatically precipitated or mechanically collected from the stack gases of power plants burning pulverized coal is called fly ash. In fly ash, the rounded particles with a wide distribution in size are predominantly glassy while the angular particles are predominantly comprised of four crystalline solids: quartz, mullite, magnetite, and hematite. When the combined amount of the oxides of silicon, aluminum, and iron in fly ash is 70% or above (by mass), it is described in ASTM Standard Specification C 618 as a Class F ash. When this amount is between 50 and 70%, the ash is called a Class C ash. Power plants in Illinois burning Illinois coal primarily produce Class F ash. The glassy content in fly ash is generally higher than 70%. Depending upon the burning conditions, fly ash also contains varying amounts of hollow spherical particles, called cenospheres.

The chemical characteristics of fly ash are such that it can be used as a major raw ingredient to manufacture wall and floor tiles in an energy- and cost-efficient manner. The objective of this project is to study the feasibility of this concept, and ultimately manufacture tiles in a commercial tile plant.

The presence of clay in a tile raw mix provides the strength necessary for handling the green tile body. In many cases, clay addition levels of approximately 30% by mass are sufficient to impart adequate green strength. The addition levels of clay and other ingredients should be minimal in order to maximize the fly ash utilization, while retaining the characteristics that are similar to those of commercially available tiles. Other ingredients, such as wollastonite, nepheline-syenite, talc, are also necessary to control processing parameters, such as rheology, shrinkage, surface texture, thermal expansion, etc.

Ceramic Tiles. Ceramic tiles, used on floors, walls, and patios, both indoor and outdoor, are common construction materials and are used in residential households and commercial facilities of all sizes. The properties of commercial tiles are specified in the American National Standard Specifications for Ceramic Tiles (ANSI A137.1), published by the Tile Council of America (TCA). According to ANSI A137.1, tiles can be glazed or unglazed, and the performance requirements vary depending upon the application.

Dry pressing. In dry pressing, the mass contains approximately 5% water (based upon the weight of solid). The relatively dry mix of all the raw ingredients and water is then pressed between metallic platens to form the green tile body. Because of the dryness of this mix, the floor and wall tiles produced in this method always have a flat surface, and are called field tile. The production rate for this method is very high. The formed green body is then fired and glazed.

Wet Pressing. In wet pressing, the amount of water used is approximately 22 to 28%, and the resulting material has the consistency of putty. This procedure has the advantage of reasonably high production rates while designs with moderate intricacy can be adequately reproduced. As a result, both field and surface raised (with surface design) tiles can be produced using this method. The raw ingredients are first mixed with water, and the mix is extruded to obtain an air-free mass. The mix is then ram-pressed between two platens (flat plates or rolling cylinders) in which porous and stronger gypsum molds are embedded. Following pressing, compressed air through the porous molds is used to release the tiles. These tiles are then air-dried, fired, and glazed.

Slip Casting. *A*n aqueous slurry containing fine clay particles in suspension is traditionally known as slip. In this procedure, a self-supporting shape, called a cast, is produced from a specially formulated slip. The parameters important to successful slip casting are slurry rheology during mold filling; casting rate; density, yield strength, and viscosity of slip; flow rheology on draining; mold release; and shrinkage, green strength, and plasticity of the cast.

The amount of water used in slips for casting tiles is approximately 40% or higher by mass of solids. In order to achieve a stable suspension, additives such as a deflocculant, shrinkage-compensating compound, barium carbonate to capture sulfur, whitening agent, etc. are commonly used. The time of addition, the kinds and amounts of ingredients used, and the mixing time and temperature are critical in obtaining a slip with the characteristics appropriate for slip casting. The slip is then poured into a permeable gypsum mold to partially remove the water. Upon stripping from the molds, the casts are air-dried, fired, and glazed.

Sintering. Sintering is a process of consolidation of particles under the temperatures below the melting point (1000–1200°C) and caused, therefore, mostly by solid-state reactions. Sintering during firing forms solid bonds between particles. Such bonding reduces the surface energy by reducing the free surface. In this process, the grain boundaries are partially eliminated through grain growth and the pore volume is reduced, leading to a compact mass. The temperature necessary to induce such bonding depends upon the characteristics of the material and the particle size distribution.

Many theories describing various stages and transport phenomena have been proposed to describe the sintering phenomenon. Solid-state sintering takes place between particles of single or multiple phases, where homogenization takes place during the sintering of mixed phases that form a single-phase product. However, in many cases sintering takes place in the presence of liquid, especially when many phases are present, and is known as liquid-phase sintering.

As fly ash is a multi-oxide material, the densification is achieved through liquid-phase sintering. Formation of liquid in the sintering process primarily comes from the glass-forming oxides present in the fly ash. The glass-forming oxides commonly found in fly ashes are silica and alumina, depending on the coordination number and bond strength. The presence of alkali in fly ash is beneficial in reducing the processing temperature, as alkali silicates tend to form glass quite readily. Generally, alkaline oxides are known as "network modifiers." Cations with valency higher than alkali and alkaline earths may also contribute to the network structure and are referred to as "intermediates." Often, fly ash contains one or more intermediates. The role these various cations play, however, depends upon the valence, coordination number, and bond strength.

Glazes and engobes. Generally, glazing is performed by refiring the sintered tile bodies at relatively lower temperatures. Glazing improves the surface durability and adds different aesthetic values to tiles. While wall tiles are almost always glazed, floor tiles and pavers are sometimes unglazed.

A glaze is a transparent glassy material designed to melt on the surface of a ceramic body, and to stay adhered upon cooling. It is important that the thermal expansion of the glaze must be equal to or slightly more than that of the ceramic body. Various glaze defects, such as crawling (due to improper wetting), crazing (due to a higher coefficient of thermal expansion of the glaze), shivering (due to a lower coefficient of thermal expansion of the glaze), pitting (due to the presence of volatiles in the body), etc. may occur.

Engobes play the same role as glazes, both functionally and aesthetically. Unlike glazes, engobes are opaque and mask the natural color of the tile body, thereby expanding the decorative possibilities.

Properties of Tiles. According to ANSI A137.1, tiles (glazed or unglazed), depending upon application, need to meet three acceptance categories:

- facial and structural defects
- dimensional characteristics
- destructive tests.

Of these three categories, destructive testing is directly associated with the properties of tile materials. Among the six characteristics (water absorption, breaking strength, abrasive hardness, bond strength, crazing, and thermal shock) included in the third criterion, the first four are related to the characteristics of the tile body and the last four are to the glaze on it. Therefore, it is obvious that tile bodies, regardless of their application, need to satisfy the water absorption and breaking strength (reflects tensile property) requirements. The floor tiles are required to have lower water absorption and higher breaking strength than wall tiles.

Porosity of the tile body, as measured by water absorption, is determined by a degree of sintering achieved during firing. Depending on the water absorption, tiles are subdivided into four categories (Table 1).

Table 1. Classification of tile bodies

	Water absorption, %
Non-vitreous	>7.0
Semi-vitreous	3.0-7.0
Vitreous	0.5-3.0
Impervious	<0.5

The breaking strength also depends on the sintering characteristics, especially upon the number and size of defects (such as pores, grain boundaries, etc.) within the load-bearing area. Therefore, the strength can be increased if the size and number of defects in the sintered body are reduced. This can be achieved by increasing the density of the sintered product. An increase in bulk density also reduces water absorption. However, excessive densification may increase shrinkage and warpage of the product to an undesirable level.

Table 2 summarizes the physical characteristics of various types of tiles as specified by ANSI A137.1.

Table 2. Standard physical characteristics of ceramic tiles.

		Water absorption, % (max.)	Breaking strength, lbs (min.)
Unglazed	Mosaic tile	0.5 (porcelain) 3.0 (clay)	250
	Quarry tile	5.0	250
	Paver tile	0.5 (porcelain) 5.0 (clay)	250
Glazed	Wall tile	20.0	90
	Mosaic tile	0.5 (porcelain) 3.0 (clay)	250
	Quarry tile	5.0	250
	Paver tile	0.5 (porcelain) 7.0 (clay)	250

EXPERIMENTAL PROCEDURES

The objectives of the project were accomplished through experimental work in several directions:

- Analysis of the recently procured fly ash oxide and phase compositions and particle size distribution.
- Laboratory evaluation of the conditions for pre-processing of fly ash for pressing.
- Performing pre-processing of fly ash under variety of conditions.
- Study of glaze and engobe applications.
- Firing of wet-pressed tiles at five different temperature regimes
- Water absorption of the wet-pressed tiles fired at four regimes
- Investigation of the causes of thickening of wet clay-fly ash mixes.
- Preparations for the experimental production of dry pressing of tiles at the pilot facility.
- Development of engobe and glaze formulas.

Ash Characterization. Fly ash obtained from the Vermillion plant was sampled and analyzed for chemical composition and fineness. The ash chemical composition is shown in Table 3.

Table 3. Chemical composition of fly ash

Analyte	Wt %
SiO_2	46.90
Al_2O_3	22.12
Fe_2O_3	15.49
CaO	5.09
MgO	2.52
SO_3	0.41
Na_2O	0.26
K_2O	0.53
TiO_2	0.09
P_2O_5	0.05
Mn_2O_3	0.09
SrO	0.05
L.O.I. (950°C)	7.31

Fineness of fly ash was characterized by the particle size analysis. The analysis was performed by Malvern laser diffractometer. The results are shown on Figure 1.

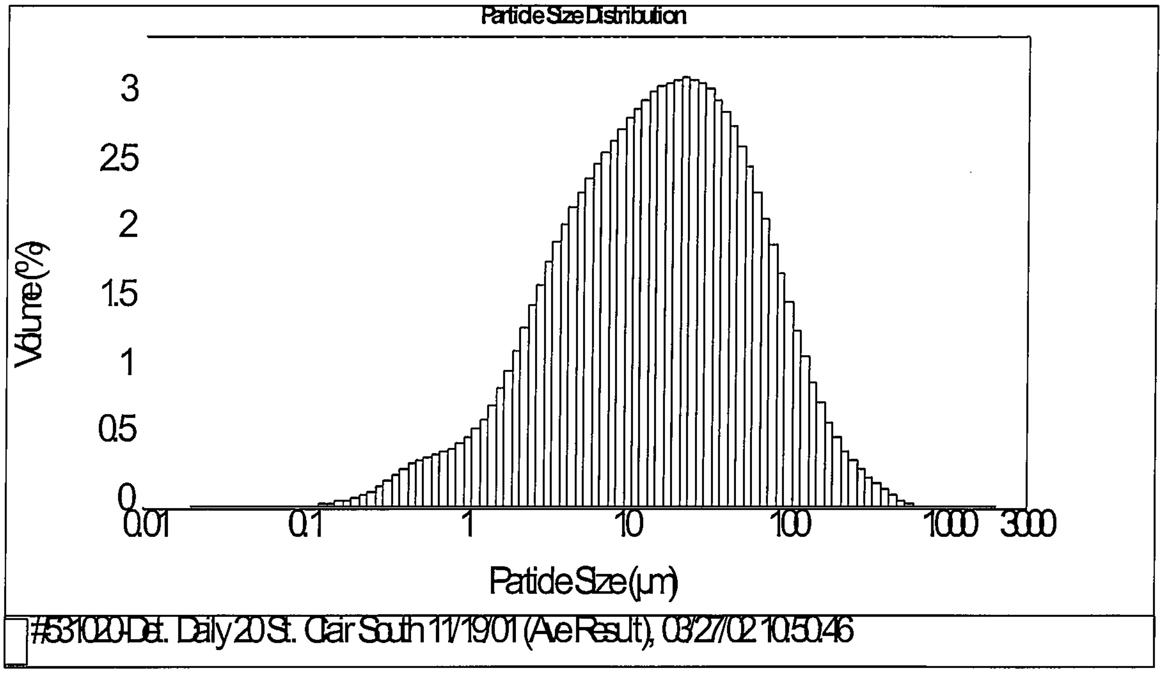

Fig. 1. Particle size distribution of fly ash

Preparation of laboratory samples. For manufacturing and evaluation of the fast-fired tiles bodies, the tiles were made of the following mixture of Vermillion fly ash, clay, and wollastonite.

At a laboratory scale, a few different mixing techniques have been used, such as mortar and pestle, a Hobart mixer, and the jar ball mill with rubber stoppers as a mixing device. At the commercial plant, mixes were prepared in a Mueller mixer. Firing of the tiles was done in a Lindberg electric muffle furnace.

In a separate study, 0, 4, 8, 12, and 16% water was added to five test batches of the standard mix. Samples were fired after 1, 7, and 21-day curing. It was found that the mix chemically absorbed on average 0.52% water and this amount did not change measurably over the curing period of up to 21 days. This is an important indicator that has to be taken into account when mixes for dry pressing are prepared. The optimum percent of free water in those mixes is to be in the range of 4 to 7%.

Pilot tile production. The project was brought to conclusion by the pilot production of tiles at the TCA research center in Anderson, SC. The facility has two pieces of the core tile-making equipment, namely a hydraulic press and a roller kiln. The press by WELKO (Italy) is a commercial model with maximum load of 650 tonnes. The kiln by Studio Uno (Italy) is a shortened version of a commercial kiln. The mix was prepared at M.E.

Tile Co. and shipped to the TCA location. During the tests water was added to the mix followed by mixing in an Eirich blender.

RESULTS AND DISCUSSION

Mix Stiffening. In the previous stages of the tests with slip casting and plastic forming, it was observed that curing of the clay/fly ash mixes led to stiffening of the mix.

Several complications were also encountered in the wet pressing method. The plasticity of the extruded mix was rapidly lost. Therefore, tiles needed to be pressed from the extruded mass immediately after mixing and extruding. Such time constraints impose manufacturing difficulties. Also, upon firing, wet-pressed tile bodies developed slight roughness due to the formation of fine whiskers on their surface, particularly at the curvatures.

In normal dry pressing operations, approximately 5 to 7% of water is usually added, and the tiles are pressed at least a day after water is added. Because of the hydration characteristics, a portion of the added water is apparently consumed by the hydrates leaving the amount that may not be adequate to achieve appropriate compaction. This aspect was investigated by performing thermogravimetric analysis (TGA), and formation of ettringite (calcium hydrosulfoaluminate) was tentatively identified as the most probable water-consuming reaction.

In order to determine the nature of this phenomenon, fly ash obtained from the Vermillion plant was tested in mixes of the composition corresponding to the mixes tested for producing tiles.

First, for this purpose, the standard mix was prepared of the following composition (percent by weight):

51% fly ash (Vermillion)
45% clay
4% wollastonite
10% water (dry basis)

The mix was prepared in a Muller mixer and was then stored in a sealed container. It was found that the optimum time for this process was seven days. At the seventh day the mass was remixed in a Muller mixer and the optimum of 15% more water was added. This yielded a body that could be extruded, wet-pressed, and have a reasonable shelf life before it becomes too hard to press.

The sample of the mix was also submitted for the analysis by differential scanning calorimeter (DSC). The unused material was placed in a sealed vessel and tested again at the 7 and 28-day ages.

The results of the DSC analysis give a strong indication that stiffening of the mixes coincided with formation of ettringite (calcium sulfoaluminate). If this reaction actually takes place, it not only removes free water from the system but also causes quasi-cementitious setting effect.

Carbon removal. High carbon content is potentially the most important factor that may have an adverse effect on the process implementation. Whereas carbon is easily burned out on the tile surface, its particles can be entrapped inside the tile body and cause a wide range of defects during sintering. In extreme cases it results in swelling and delamination. Blistering, or formation of swollen patches on the tile surface, was an issue for firing both in wet and in dry pressing methods.

Carbon contained in fly ash may become the largest obstacle to its use because of these potential detrimental effects. Therefore, the major effort was aimed at the development of practically feasible measures to remove the carbon particles from fly ash or to alleviate its effects.

First, the attempt was made to preheat fly ash in order to remove carbon and volatiles before mixing with other ingredients, and sinter in a fast firing schedule. Fly ash was heated at 20°C per minute to 800, 900, 1,000, 1,100, and 1,200°C, respectively. However, above 800°C, fly ash started to sinter, and at 1,000°C it formed a fairly hard mass. Since such agglomerated mass would require additional grinding, it was obvious that the processing temperatures need to be maintained at or below 800°C.

The fly ash heat-treated at 800°C for 5, 10, and 15 minutes was mixed in proportions of 51% and 61% by mass with clay and wollastonite, with 5% water added, to form discs 5.7 cm (2.24 in.) in diameter and over 6 mm (0.25 in.) thick under 17 MPa (2,500 psi) pressure. The formed bodies were then oven-dried at 105°C for 30 minutes in order to remove free water, and heated to 1200°C in about 50 minutes. After it reached the peak temperature, the furnace was allowed to cool down to below 500°C, and the specimens were removed. These specimens did not show any surface deformation. Tile bodies were made with fly ash that was. None of these mixes exhibited any surface deformation.

It was demonstrated that residual carbon could be removed from fly ash prior to mixing with other ingredients. Despite the promising results of using preheated fly ash, it was apparent that in a large-scale commercial production this approach was impractical. More realistic would be the one-step thermal treatment combining carbon removal by oxidation with sintering. The temperature profile of such process was developed and finalized in a series of trial tests in a laboratory electric furnace and in commercial-size batch furnaces at M.E. Tile Co.

Further laboratory experiments was performed in order to define the heat treatment conditions for the tiles made by dry pressing method, using heating in an electric furnace to

1,200°C within 30 minutes or more. This established the temperature profile necessary for fast firing of fly ash-based tiles.

In order to define the range of heating rate where bloating becomes an issue, the tile bodies were made with a fly ash unusually high in carbon content (approximately 20%) and fired at heating rates of 5, 10, 15, and 20°C per minute. No bloating was observed in any of the dry-pressed tile bodies. However, under the same heating rate, wet-pressed tile bodies bloated and cracked at the heating rate above 10°C per minute. The most likely explanation is the effect of free water on the body porosity and, therefore, permeability.

Based upon this observation, a mix with 51% of untreated fly ash was used in dry pressing under the same conditions. The sintered tile bodies had no surface deformation. However, when a piece of a wet-pressed tile made with 61% fly ash mix was fired under the same conditions, it underwent uneven volume changes (bloating). It indicated that porosity and compactness of formed tile body may be a contributing factor to this phenomenon. Subsequently, a few different untreated fly ashes with LOI ranging from 3 to 20% were mixed with other ingredients and fired (after water removal at 105°C) at a rate of as high as 40°C/minute to 1,200°C. In this fast firing, none of the tile bodies showed any surface deformation. This suggests that fast firing rapidly sinters the surface and makes it virtually impervious to air. As a result, the carbon particles encapsulated inside the specimen are not oxidized and do not generate any internal pressure to cause bloating.

During firing, oxidation of the present carbon begins at a temperature below 750^0C. Sometimes sintering began prior to complete oxidation of the carbon. The residual carbon does not seem to have an effect on the strength. The solution to this carbon problem was holding the tile in the furnace at 750^0C for 12 minutes. Air has been passed through the furnace in the attempt to shorten the amount of time needed to get the carbon to an acceptable level.

Upon fast firing of tile bodies containing over 51% fly ash, bloating was not observed. Based upon this observation and the past experience, we anticipated that bloating occurs only over a certain range of heating rate. At slow firing rate, carbon burns out while the piece being fired remains porous. When heated very rapidly, the surface gets sintered quickly and prevents air from going in, which entraps the interior carbon particles. The absence of bloating at heating rates from 20 to 40°C per minute indicates the high end of the rate spectrum.

In order to optimize the firing process, several tile bodies were fired in a laboratory furnace using different firing schedules. A 12-minute soak at 750°C was found to be adequate for an approximately 10 mm thick and 60 mm diameter tile bodies that were formed under a pressure of 25 MPa and fired at 1,200°C with a heating rate of 30°C per minute. In order to measure the strength characteristics of the fast fired tile bodies, 150 mm diameter tile bodies are being made and fired at the conditions found to be adequate to burn the interior carbon particles in smaller tile bodies.

However, although fly ash tile bodies were fast-fired in a laboratory furnace without encountering any bloating, carbon particles near the core of the tile bodies remained unburned, which might compromise other characteristics of the tile bodies. The black core of carbon-rich material may be undesirable from the standpoint of the tile appearance.

In order to minimize or eliminate dark core near the center of fast-fired tile bodies, several tile bodies were fired in a laboratory furnace using a 30°C/minute heating rate from 250°C to 1,200°C. The soaking time at 750°C was varied between 12 and 18 minutes to avoid dark core. The time required to reach the final temperature is about 45 minutes (including the 12-minute hold at 750°C). Several tile bodies were made with thickness of approximately 9 mm, which is about 1 to 2 mm more than regular ceramic tiles. This thickness was chosen to identify the conditions at which dark core does not form in thicker tile bodies. Also, in a few firings, air was supplied into the furnace for rapid burn off of the carbon. Using the conditions that have been established lately, a few tile bodies have been prepared with virtually no dark core.

The tile bodies were tested for breaking strength. Based upon the specification ASTM C'648 (Standard Test Method for Breaking Strength of Ceramic Tile), a setup for specimen support and force applicator were devised and fabricated. Tile bodies with thickness of approximately 8 mm were made and fired under the conditions established for the thicker tiles. These tile bodies were then tested for breaking strength.

Tile testing. The tiles produced in these tests were subjected to the strength test according to the ASTM procedure and based on a three-point support and a single point loading. The results are presented in Table 4.

Table 4. Test results of tile samples

Sample No.	Sample mass, g	Firing time, min.	Breaking load, lbs	Visible carbon
1	350	12	341.0	Abundant
2	350	15	345.7	Minimal
3	300	15	224.6	Minimal
4	300	18	295.3	None
5	350	18	317.8	None

The strength of four out of five tested specimens was higher than 250 lbs required by specification ANSI 137.1 for floor tiles.

After the key process parameters were widely studied at the laboratory scale, the experiments were transferred to the small commercial scale production facility at M.E.

Tile Co. Green tiles were produced by wet ram pressing, roller pressing, and slip casting. The tiles were fired in electric kilns with programmable controllers.

When tiles and other ceramic bodies are fired in an industrial kiln, the firing temperature is usually measured by standard cones (or rather slightly asymmetrical pyramids) made from calibrated and numbered ceramic mixes and placed in the furnace close to the heat-treated bodies. The behavior of cones, from initial deformation to full collapse, characterizes the actual temperature within the kiln charge. Therefore, in the following description, the firing temperatures are expressed by the cone numbers and (in parentheses) in degrees Celsius. Most standard-mix tiles were fired at Cones 03 (1086°C), 01 (1117°C), 3 (1152°C), and 5 (1184°C). The products were tested for strength and water absorption. Tiles fired at 1184°C were used for investigation of glaze and engobe applications.

All tiles passed the breaking strength requirements of the national standard. The following Table 5 summarizes the results of water absorption tests (average for batches of 8) as a function of the firing temperature.

Table 5. Water absorption of tiles

Sample No.	Firing temperature, °C	Water absorption, %
1	1086	11.3
2	1117	11.1
3	1152	10.6
4	1175	7.7
5	1184	6.6

While slight reduction in water absorption with progressive firing temperatures is obvious, a substantial decrease in water absorption occurred between 1152 and 1175°C, and continued to the final firing temperature of 1184°C. Tiles fired at 1184°C were used for investigation of glaze and engobe applications.

To determine the effect of moisture on the pore structure, the tiles were pressed and fired from the mixes with the different water content. Experimental firings were also conducted with mixes containing fluxes (nepheline-syenite, talc) to optimize the firing temperature and reduce water absorption. The results helped to finalize the mix composition intended for the pilot tests at the TCA facility.

TCA tests. The next step in the program was manufacturing dry-pressed tile bodies at the Tile Council of America (TCA). Because of the experimental nature of the test run, the press and the kiln were operated in a batch mode. The press was loaded manually. The green tiles were oven dried and loaded into the kiln. Individual tiles were pressed and fired under varying conditions in order to define the optimum conditions. Efficient carbon removal was the main criterion of the process optimization.

The principal equipment used during the tests is described in the previous section. Process parameters varied in the course of testing in the following ranges:

Tile size: 300x300 mm (12"x12")
Thickness: 7.1 mm to 8.7 mm ($^{9}/_{32}$" to $^{11}/_{32}$")
Moisture: 7 to 7.7%
Pressure: 190 to 220 kg/cm^{2h}
Firing time: 60 to 100 minutes
Pre-heating temperature: 660 to 740°C
Firing temperature: 1143°C
Pre-heating time: 24 to 50 min.

After the tiles were manufactured standard tests were performed at the TCA technical department to verify their compliance with the standard specification ANSI A137.1 (Tables 6, 7).

Table 6 ASTM C373 tile water absorption

Sample No.	Water absorption, %
1	12.9
2	17.6
3	15.8
4	16.0
5	11.5
6	17.6
7	11.2
8	13.5
Average	14.5

All tiles met the standard requirements for wall tiles. It should be noted that the firing temperature was below that established during the tests at M.E. Tile Co.

Table 7. ASTM C648 breaking strength

Sample No.	Breaking strength, lbs
1	207
2	287
3	283
4	259
5	225
6	255
7	281
8	243
9	255
10	215
Average	251

Discussion. In the course of this project, the processing method was developed that allows to utilize Illinois coal fly ash with moderately high carbon content in manufacturing ceramic tiles. The temperature profile of firing was developed that leads to oxidizing residual carbon from the ash and removal of a potential source of the tile warping, surface defects, and loss of strength. The mix proportions were finalized, and the prospective manufacturing process by dry pressing and fast firing was identified. The results indicated that the requirements for floor and outdoor applications were achievable in the fly ash-based system. The results formed the basis for a successful experimental run on the actual mass-production industrial-type equipment.

The marketing and economic feasibility study based upon this concept confirmed. that considering the size of the tile industry, a reasonable fraction of the fly ash produced in Illinois can be utilized to prepare ceramic tiles. Pursuing this technology is also important from the tile manufacturer's viewpoint, as raw materials contribute to a major cost of running a tile plant. Replacement of costly raw materials by less expensive fly ash would not only be attractive to tile manufacturers, but also it would make the U.S. tile industry more competitive against the foreign imports.

The next step in the development of the proposed technology would be producing a batch of tiles on the prototype equipment suggested for the prospective commercial plant. Such test would provide all information necessary for the actual plant design and engineering.

CONCLUSIONS AND RECOMMENDATIONS

1. The results produced in this program confirm that fly ash-based tiles can be successfully made using over 50% fly ash.
2. The temperature profile of thermal treatment was developed providing optimum conditions for carbon removal.
3. Dry pressing was determined as the method for pilot production.
4. Glazes and engobes were optimized in pilot firings.
5. The results obtained in the bench-top experiments and small batch commercial production were further confirmed by the experimental run on the mass production commercial equipment.
6. The marketing and cost analysis indicates that it would be economically feasible to construct a full-scale tile plant based on the technology developed in this project.
7. The commercial tile plant engineering should be preceded by a full-scale test on the actual industrial equipment, which would include slip preparation and drying, continuous pressing, and continuous firing in a roller kiln.

DISCLAIMER STATEMENT

expressed herein necessarily state or reflect those of the Illinois Department of Commerce and Community Affairs, Office of Coal Development and Marketing, or the Illinois Clean Coal Institute.

Notice to Journalists and Publishers: If you borrow information from any part of this report, you must include a statement about the State of Illinois' support of the project.

APPENDIX

ECONOMIC FEASIBILITY STUDY

Appendix A. MARKETING SURVEY

Appendix B. GENERAL DESCRIPTION AND COST ESTIMATE

Attachment B-1. Equipment costs

Attachment B-2. Power requirements

THE DIMENSIONS OF THE U.S. MARKET: PRESENT AND FUTURE

* The U.S. tile market has grown quickly in the past five years, from 149 million square meters in 1997 to 212 m.s.m. in 2000 (Table 1).

* The year 2001 has been the first year with no growth since 1991 (Table 2).

* Imports have caused most of the growth in U.S. tile consumption (Tables 1 and 2).

* In recent years shipments by U.S. manufacturers have declined (Table 1).

* For the next three years a slow increase in consumption is expected, led by U.S. manufacturers opening two new factories (Dal Tile and Crossville, both for the production of porcelain tiles). (Table 2)

* Italy controls the largest share of the U.S. tile market ahead of the U.S. (Table 3).

* U.S. manufacturers control and market in the U.S. most of Mexican tile production. In this way they control over one third of U.S. tile market. (Table 4)

TABLE 1: U.S. CERAMIC TILE CONSUMPTION IN THE PAST FIVE YEARS
(million square meter)

Year	U.S. Shipments	Imports	Exports	U.S. Apparent Consumption (*)
2001	55.8	159.5	3.5	211.7
2000	60.2	155.2	3.3	212.1
1999	59.1	138.8	3.3	194.5
1998	59.2	114.7	3.9	170.0
1997	57.5	95.3	3.9	148.9
....	....	....	....	....
1994	54.8	66.2	1.0	120.0

Source: Estimates D. Grosser and Associates, Ltd. and data U.S. Dept. of Commerce.

(*) Apparent consumption = US Production + Imports - Exports

TABLE 2: U.S. TILE CONSUMPTION, 1990-2001, and PROJECTIONS 2002-2004 (MILLION SQUARE METERS)

YEAR	U.S. SHIPMENTS	IMPORTS	EXPORTS	U.S. APPARENT CONSUMPTION	YEARLY % INCREASE IN CONSUMPTION
2004	65	176.5	3.9	237.6	2.3%
2003	65	171	3.7	232.3	5.0%
2002	60	165	3.7	221.3	4.5%
2001	55.8	159.5	3.5	211.8	-0.1%
2000	60.2	155.2	3.3	212.1	9.0%
1999	59.1	138.8	3.3	194.6	14.5%
1998	59.2	114.7	3.9	170	14.2%
1997	57.5	95.3	3.9	148.9	12.6%
1996	53.8	81.6	3.2	132.2	9.0%
1995	52.6	71.8	3.1	121.3	1.1%
1994	54.8	66.2	1	120	8.5%
1993	52.1	59.6	1.1	110.6	15.9%
1992	46.1	50.3	1	95.4	9.9%
1991	44	43.8	1	86.8	-3.3%
1990	47.3	43.3	0.8	89.8	

Source U.S. Dept of Commerce and Estimates D. Grosser and Associates, Ltd.

Table 3: U.S. Consumption of Ceramic Tile, by Country of Origin (2000 and 2001)

Country of Origin	YEAR 2000		YEAR 2001	
	Million sq. mt.	Percentage	Million sq. mt.	Percentage
Italy	58.9	27.8%	57.0	26.9%
USA	56.9	26.8%	52.2	24.7%
Spain	31.6	14.9%	31.8	15.0%
Mexico	26.1	12.3%	26.7	12.6%
Other Imports	38.6	18.2%	44.1	20.8%
Total	212.1	100.0%	211.7	100.0%

Source: Estimates D. Grosser and Associates, Ltd. and data U.S. Dept. of Commerce.

TABLE 4:U.S. CONSUMPTION OF CERAMIC TILE (2001) BY PROVENANCE (million square meter)

PROVENANCE	MILLION SQ. MT.	%	%
U.S. shipments to the local market	52.2	24.7%	37.3%
Mexico	26.7	12.6%	
Italy	57	26.9%	62.7%
Spain	31.8	15.0%	
Brazil	15.6	7.4%	
Venezuela	3.6	1.7%	
Turkey	5.7	2.7%	
Other	19.1	9.0%	
TOTAL CONSUMPTION	211.7	100.0%	100,0%

Source: Estimates by D. Grosser and Associates, Ltd. based on data of U.S. Dept of Commerce.

CERAMIC TILE CONSUMPTION BY GEOGRAPHICAL AREA

* There is no precise data of U.S. tile consumption by state or by region.

* Estimates of consumption can be made by assuming a correlation between the number of distributors, retailers and contractors in a state, and tile consumption.

* The higher percentage of distributors in California and other states, reflects the fact that coastal states are those with largest imports (most distributors are also importers).

* The percentage of retailers and contractors in a state reflects the fact that there is a demand for tile and for tile installation. The limitation of this method is that it is nit known how many tiles are installed in average by contractors in a state, or how many are sold in average by dealers.

* Based on these assumptions, California and Florida are the states with highest tile consumption. Other important areas for tile consumption are Texas, New York, New Jersey, the Midwest and New England. (Table 5)

TABLE 5: TILE DISTRIBUTORS, AND TILE CONTRACTORS AND DEALERS, BY STATE OR REGION, 2000

	DISTRIBUTORS		CONTRACTORS & DEALERS	
STATE OR REGION	Number	%	Number	%
California	296	16.4%	2283	11.9%
Florida	235	13.0%	2231	11.7%
Texas	154	8.5%	1404	7.3%
New York	159	8.8%	877	4.6%
Pennsylvania, New Jersey	111	6.1%	1401	7.3%
Massachusetts, Connecticut, Rhode Island, Maine, Vermont, New Hampshire	65	3.6%	1120	5.8%
Illinois, Michigan, Ohio Wisconsin, Indiana	189	10.4%	2512	13.1%
Other	600	33.2%	7323	38.2%
TOTAL	1809	100.0%	19151	100.0%

Source: Table generated by D.Grosser and Associates, Ltd.

U.S. TILE PRODUCTIONS OF CERAMIC TILE

* Tile production and shipments by U.S. manufacturers have lagged in recent years. The reason for this is due to the closing of old and unprofitable plants. Average "ex factory" price of U.S. manufactured tiles is over $14 per square meter (Table 6). This is about 50% higher than average prices F.O.B. Italy, and almost three times average prices F.O.B. Mexico, Turkey or Brazil (Table 11). It must be noted, however, that the average landed price of most imports is 30-35% higher than F.O.B. prices, because of shipping costs, duties, insurance etc. Mexico is part of N.A.F.T.A. and duty rates are below 8%, and will drop to zero in 2008.

* The number one U.S. tile manufacturer is Dal Tile, recently taken over by Mohawk Industries, which is the second largest U.S. carpet manufacturer (Table 7). Dal Tile owns nine factories (Table 8), and is building a state-of-the-art porcelain tile plant in Muskagee (OK.)

* Florida Tile is the second largest U.S. tile manufacturer. It (as well as some other tile manufacturers) has not grown in recent years. One reason for this is insufficient investments in plant and equipment. Without proper technology a company cannot offer new products. As Italian manufacturers have shown, updated technology is the key to offer better products and maintain and increase market share.

* One growing manufacturer is Crossville. This company produces only porcelain tile, and is in the process of building another plant. Crossville has shown that in order to operate a successful ceramic tile plant, it is crucial to produce and sell high quality, high end niche products.

* Laufen is controlled by Roca of Spain. American Marazzi is held by Marazzi of Italy. A Mexican group own Interceramic. American Florim is controlled by Florim of Italy. Porcelanite is owned by a Mexican group.

TABLE 6: PRODUCTION, SHIPMENTS AND SALES OF CERAMIC TILES IN THE USA, 1995-2001

	PRODUCTION	SHIPMENTS		
YEAR	Million sq.mt.	Million sq.mt.	$ Million	Average Dollar price per Sq. Mt.
2001	56.4	55.8	830	14.87
2000	61.9	60.2	857	14.24
1999	58.1	59.1	843	14.26
1998	55.3	58.8	837	14.23
1997	58	59	834	14.14
1996	53.3	53.8	799	14.85
1995	53.7	52.6	728	13.84

Source: Tables by D. Grosser & Associates, Ltd. , based on data from US Dept. Of Commerce

TABLE 7: MAIN U.S. TILE MANUFACTURERS, 2000

Manufacturer	Location of factories	$ Sales Estimates in U.S.
Dal Tile (taken over by Mohawk in 2001)	TX-Mex	1000
Florida Tile	FL-GA-KY	200
Laufen Int'l	OH-TX-BRAS-SP	170
American Marazzi - Monarch	TX-AL-IT-SP	170
Interceramic	TX-MEX	125
American Florim Inc.- Tilecera	TN-IT	80
Crossville	TN	50
Summitville	OH	45
Porcelanite	NC-MEX	30-35
Tileworks	IA	30
Huntington Tile Group	TX	20

Source: Estimates by D. Grosser and Associates, Ltd.

TABLE 8: DAL TILE FACTORIES AND TYPE OF PRODUCTION

Conroe, TX	Glazed Floor Tiles
Dallas, TX	Glazed Wall Tiles
El Paso, TX	Glazed Wall Tiles
Fayette, AL	Quarry Tiles (unglazed)
Gettysbourg, PA	Mosaic Tiles (glazed and unglazed)
Jackson, TN	Mosaic (glazed)
Lewisport, KY	Quarry Tiles (unglazed)
Monterrey, Messico	Glazed Floor Tiles, Glazed Wall Tiles, Glazed Mosaic
Olean, NY	Mosaic (unglazed)

Source: Dal Tile Yearly Report

U.S. IMPORTS OF CERAMIC TILE

* In 2001 imports of ceramic tile were approximately 2% lower than in 2000 (Table 9).

* Italy controls 36% of imports followed by Spain (20%), Mexico (17%), and Brazil (10%) (Table 10).

* Brazil, Turkey, Venezuela and Mexico sell at prices that are approximately half of Italian manufacturers' prices (Table 11). Still, Italy controls the largest share of the market, due to its image, technology, design, and established distribution channels.

* In recent years the fastest growing countries (percentage increases) have been Brazil and Turkey (Tables 9 and 10).

* Most imported tiles are glazed (Table 12).

* Italy dominates the market segment of porcelain tiles (Tables 12 and 13).

TABLE 9: U.S. TILE IMPORTS IN THE YEARS 2000 AND 2001, BY COUNTRY (Dollars and square meters)

COUNTRY	MILLION SQUARE METER			MILLION DOLLARS		
	2000	2001	% CHANGE 2001/2000	2000	2001	% CHANGE 2001/2000
ITALY	58.9	57	-3.2%	556.4	545.7	-1.9%
SPAIN	31.6	31.8	0.6%	204.6	198.7	-2.9%
MEXICO	26.1	26.7	2.3%	141.2	141.5	0.2%
BRAZIL	14.7	15.6	6.1%	66.9	68.9	3.0%
TURKEY	4	5.7	42.5%	20.8	23.1	11.1%
VENEZUELA	3.1	3.6	16.1%	16.5	18.2	10.3%
OTHER	16.8	19.1	13.7%	111.3	113.4	1.9%
TOTAL	155.2	159.5	2.8%	1117.7	1109.5	-0.7%

TABLE 10: U.S. IMPORTS OF CERAMIC TILE BY COUNTRY, 1997-2001 (MILLION SQ. MT.)

Country	2001	% 2001	2000	% 2000	1999	1998	1997
Italy	57.0	36%	58.9	38%	49.2	41.5	32.5
Spain	31.8	20%	31.6	20%	28.3	24.4	19.0
Mexico	26.7	17%	26.1	17%	27.0	23.3	23.0
Brazil	15.6	10%	14.7	9%	10.4	7.2	6.1
Other	28.4	18%	23.9	15%	24.0	18.2	14.7
Total	159.5	100%	155.2	100%	138.8	114.7	95.3

Source: Estimates D. Grosser and Associates, Ltd, and U.S. Dept. of Commerce.

TABLE 11: U.S. TILE IMPORTS IN THE YEARS 2001, BY COUNTRY , AND AVERAGE F.O.B. PRICES

COUNTRY	$ MILLION	% DOLLAR	MILLION S.M.	% S.M.	Average F.O.B. Price per square meter (In dollars)
ITALY	545.7	49.2%	57	35.7%	9.57
SPAIN	198.7	17.9%	31.8	19.9%	6.25
MEXICO	141.5	12.8%	26.7	16.7%	5.30
BRAZIL	68.9	6.2%	15.6	9.8%	4.42
VENEZUELA	18.2	1.6%	3.6	2.3%	5.06
TURKEY	23.1	2.1%	5.7	3.6%	4.05
OTHER	113.4	10.2%	19.1	12.0%	5.94
TOTAL	1109.5	100.0%	159.5	100.0%	6.96

TABLE 12: U.S. IMPORTS OF CERAMIC TILE BY COUNTRY, BY TYPE OF TILE - 2000 (Million sq. mt.)

TYPE OF TILE	Italy	Mexico	Spain	Other	Total	%Total
Mosaics	0.2	0.7	0.1	1.1	2.0	1.32%
Glazed tiles	51.2	23.4	31.3	36.5	142.5	91.80%
Unglazed tiles (Porcelain, Terracotta, Saltillo, etc.)	7.5	2.0	0.2	0.9	10.7	6.89%
TOTAL	58.9	26.1	31.6	38.6	155.2	100.00%

Source: Estimates D. Grosser and Associates, Ltd. and data US Dept. of Commerce

TABLE 13: U.S. IMPORTS OF UNGLAZED PORCELAIN TILE, IN THE YEAR 2000 (million sq. mt.)

Country	PORCELAIN TILE IMPORTS	%
Italy	7.2	89%
Spain	0.2	2%
Other countries	0.7	9%
Total Imports	8.2	100%

Source: Estimates by D.Grosser and Associates, Ltd

MAJOR FOREIGN SUPPLIERS

* Foreign suppliers are well organized to sell tiles in the U.S. Italian, Spanish, Brazilian, Turkish companies own factories, warehouses, showrooms and distribution centers in the U.S.

* The Italian Marazzi has had a factory in Texas for 20 years. Florim took over Tilecera about three years ago. Other Italian companies with substantial sales are Imola, Atlas-Concorde, Iris, Graniti-Fiandre, Del Conca, Emilceramica, Ricchetti. Over 100 Italian companies export to the U.S.

* From Spain, well established companies are Roca (owner of Laufen), Azuvi, Azulev, Diago, Gayafores, Gres de Nules, Grespania, Porcelanosa, Saloni, Zirconio. Over 60 Spanish companies export to the U.S.

* From Brazil, Portobello and Eliane are the major players. Together they account for one third of imports of tile from Brazil.

*In Mexico, Dal Tile has a subsidiary that supplies about 40% of the company's total capacity. Interceramic and Porcelanite have taken over old U.S. manufacturing plants in order to establish themselves in the market.

THE DISTRIBUTION OF CERAMIC TILE IN THE U.S.

* Tile distribution has developed alongside the increase in tile consumption. In 1975 the main channel of distribution was the one from U.S. manufacturers to local tile installers and contractors (Table 14).

* In the 1980s the number of tile importers and retailers increased substantially, in order to serve the remodeling segment of the market.

* In the mid ‘80s foreign manufacturers opened a new channel of distribution by selling to U.S. manufacturers who had established networks of independent showrooms (Table 15).

* In the ‘90s local and foreign manufacturers began selling to Home Centers. Today Home centers, mainly Home Depot and Lowe’s, control about 16% (and perhaps more) of the U.S. tile market at retail level. In recent years Home Centers have been the main “motor” of sales expansion in the tile business.

* The latest trends are the entry of floor covering distributors into the distribution of ceramic tile (this has been successful only to a limited number of distributors, such as Hoboken in the East, Longust in the West, etc.), and carpet manufacturers such as Shaw and Mohawk. Carpet manufacturers sell directly to retail stores, buying mainly from low cost foreign suppliers, but also from local manufacturers.

TABLE 14: THE DEVELOPMENT OF CHANNELS OF DISTRIBUTION IN THE CERAMIC TILE BUSINESS (MILLION SQUARE METERS AND PERCENTAGES)

YEAR	U.S. TILE CONSUMPTION	% IMPORTS	% ITALIAN TILE	MAIN SUPPLYING COUNTRIES	MAIN TYPES OF TILE	NEW CHANNELS OF DISTRIBUTION
1975	29.6	26,5%	4,6%	USA, JAPAN	quarry tile, glazed wall, mosaic unglazed, double fired glazed floor	Manufacturers to tile contractors.
1980	46.8	46,8%	17,0%	USA, ITALY, JAPAN	Double fired glazed floor, single fired glazed floor, glazed wall	Importers to tile retailers.
1985	79.0	58,0%	21,9%	USA, ITALY	Single fired glazed floor, glazed wall	Foreign manufacturers to local manufacturers.
1990	92.4	53,5%	22,7%	USA, ITALY, MEXICO, SPAIN	Single fired glazed floor, glazed wall, porcelain unglazed	Manufacturers to home centers
1995	112.8	59,1%	20,9%	USA, ITALY, MEXICO, SPAIN	Single fired glazed floor, Porcelain unglazed	Manufacturers to floor covering distributors
2000	2121	73,2%	26,8%	USA, ITALY, MEXICO, SPAIN, BRAZIL, TURKEY INDONESIA	Single fired glazed floor, porcelain unglazed, porcelain glazed	Tile Manufacturers to floor covering manufacturers to floor covering retailers

Source: D. Grosser and Associates, Ltd.

TABLE 15: WHOLESALE DISTRIBUTION OUTLETS OF MAIN AMERICAN TILE MANUFACTURERS

MANUFACTURER	OUTLETS	TERRITORY
Dal Tile (USA)	230	National
Florida Tile (USA)	35	National
Laufen (Spain)	23	Morena Tile (7 in CA and NV), Sacramento Tile (6 in CA), Laufen (10 in AZ, CA, FL, NC, NV, OK, GA)
Interceramic (Mexico)	18	Ceramic Tile International (TX, GA. OK, AZ, NV,NM)
American Marazzi (Italy)	17	Monarch (AL, AZ, MO, NV, RI, TN), and American Marazzi (8 in Texas)
Olympia (Canada)	17	Kate Lo (5 in MN) Alpha Tile (8 in FL) Dobkin (1 a NY) , Thompson Tile (3 in WA and OR)
Summitville USA)	12	CA, FL, VA, IL, MD, NC, OH
Florim (Italy)	10	Impo Glaztile (8 in CA, IL, NE and NJ), Tilecera (2 in OH, NV)

Source: D. Grosser and Associates, Ltd.

TYPES OF TILES SOLD

* Most tiles sold in the U.S. market are glazed. Glazed floor tiles are more popular than glazed wall tiles. Most glazed floor tiles are imported. Most glazed wall tiles are Made in the U.S.A (Table 16).

* Glazed tiles are the fastest growing and competitive segment of the market.

* Mosaic tiles have been declining, while unglazed tile, especially porcelain tiles, in recent years have kept their share. Porcelain tile is considered the most profitable segment of the market.

* The preferred tile size for floor tile is 13"x13" (33x33cm). For wall tile, according to one source, the preferred size is 8"x10" (20x25cm). (Table 17).

* The residential segment of the market accounts for about three quarters of tile consumption (Table 18).

* Architects and designers specify tile most often for residential projects (Table 19).

* Porcelain tile is perhaps the most interesting segment of the tile market. Italian manufacturers have a 60% share of the market (Table 20). Crossville Ceramics is the only U.S. exclusive manufacturer of this product. Florim began producing porcelain tile at the beginning of 2001.

TABLE 16: THE U.S. TILE MARKET, BY TYPE OF TILE
(million square meters and percentages)

TYPE OF TILE	1985		1999		2001		2004	
Glazed floor tiles	13	15%	63	30%	136	57%	167	59%
Glazed wall tiles	52	61%	119	57%	70	30%	80	28%
Unglazed floor tiles	11	13%	21	10%	24	10%	30	10%
Mosaic	9	11%	7	3%	7	3%	7	3%
Total	85	100%	210	100%	238	100%	284	100%

Source: Estimates by D.Grosser and Associates, Ltd. and Tile Council of America

TABLE 17: THE U.S. TILE MARKET, BY SIZE OF TILE
(Replies by U.S. distributors, in percentages)

SIZE OF TILE	%
30x30cm (12'x12')	45%
33x33cm (13'x13')	26%
20x25 cm(8'x10')	11%
40x40cm (16x16')	7%
Other	11%
Total	100%

Source: Survey by National Floor Trends Magazine (2001)

TABLE 18: THE U.S. TILE MARKET, BY END USE, BY REGION (RESIDENTIAL AND COMMERCIAL)
(Replies by U.S. distributors, in percentages)

END USE	N. East	N. Central	S. East	S.W. Central	Rockies	Pacific	Total
Residential	76	71	62	77	91	79	**73**
Commercial	24	29	38	23	9	21	**27**
Total	100	100	100	100	100	100	**100**

Source: Survey by National Floor Trends Magazine (2001)

TABLE 19: THE U.S. TILE MARKET, BY TYPE OF PROJECT
(Replies by U.S. architects and designers, in percentages)

Type of Project	1991 (Designers)	2001(Architects and Designers)
Residential	70	71
Offices	43	44
Restaurants	24	24
Hospitals/Medical	16	22
Retail	11	22
Swimming Pools	13	17
Banks/Financial	10	15
Hotels	10	13
Shopping Centers	6	9
Schools	4	29
Factories	4	14
Other	4	20

Source: Surveys by STD Magazine (2001) and ID Magazine (1991).

TABLE 20: U.S. CONSUMPTION OF UNGLAZED PORCELAIN TILE, IN THE YEAR 2000 (MILLION SQUARE METERS)		
Country of Origin	Porcelain tile	%
Italy	7.2	60.9%
U.S.	3.7	31.3%
Spain	0.2	1.6%
Other Countries	0.7	6.3%
TOTAL	11.9	100.0%

Source: Estimates by D.Grosser and Associates, Ltd

ECONOMIC FEASIBILITY STUDY

This study has been undertaken for the purposes of estimating the capital and operating costs of a tile production facility based on the technology developed in this project. The annual capacity is assumed 2 million square meters which is considered the most economical for a plant with one production line.

1. Production capacity

The productive capacity of the plant in question will be the following:

- 5.174 m^2/day, at the kiln, of glazed floor tiles by single firing
  - Base size: 300 x 300 x 7.6 mm
  - Max. size: 400 x 400 x 8 mm
  - Average weight of the finished product: 18 Kg/m^2
  - Max. firing temperature: 1,100°C

Work organization:	
Working Shifts:	8h
Working weeks/year:	50
Working days/year:	350 (firing)

Section	**days / week**	**shifts / day**
raw materials and weighing	6	3
body slip preparation	6	3
glaze preparation	6	3
spray drying and powder storage	6	3
pressing and drying	6	3
glazing	6	3
firing	7	3
selection	6	3

- **Production storage:** 28 h
- **Fuel:**

  Methane gas – Inf. Calorific power: 8,300 kcal/Nm^3

- **Voltage** (tolerance ± 5%)
  and frequency (tolerance ± 1%)

2. <u>Acreage required</u>

Smaller section	sq. meters	2,688	acres [US survey]	0.664
Larger section	sq. meters	9,408	acres [US survey]	2.325
Total	sq. meters	12,096	acres [US servey]	2.989

3. Price Summary

Position	Description	Price USD
Technological Line		
1	Raw Materials and Weighing Section	$149,667.70
2	Body Slip Preparation Section	$745,472.00
3	Spray Drying nad Powder Storage Section	$795,522.00
4	Glaze Preparation Section	$284,911.90
5	Pressing and Drying Section	$1,397,214.00
6	Glazing Section	$424,005.40
7	Cars Movement Section	$524,951.70
8	Firing Section	$1,025,606.40
9	Selection and Palletisation Section	$359,804.90
	Total Price of Section	**$5,707,156.00**
Machinery		$0.00
10	Auxiliary Plants	$140,595.00
	Total Price of Section	**$140,595.00**
Machinery and Spare Parts		
11	Spare Parts	$175,520.80
	Total Price of Section	**$175,520.80**
Delivery FOB in Containers w/ Packing		
12	Charges for Loading on Truck w/ Suitable Packing	$240,877.00
	Total Price of Section	**$240,877.00**
Supervision to Erection and Start-Up		
14	Supervision to Erection and Start-Up	$284,193.00
	Total Price of Section	**$284,193.00**
	General Total Price	**$6,548,341.80**

Position	Qty.	Item Description	Unit Price EURO	Total EURO	Unit Price USD	Total USD
RAW MATERIALS AND WEIGHING SECTION						
1.1	1	Mechanical Pay-Loader, Diesel Operating Bucket Capacity: 1.7 m3 - Cod. 640077	Customer's Supply	Customer's Supply	Customer's Supply	Customer's Supply
1.2	1	Weighing Box of 20,000 KG, Complete with Loading Cells and Hopper - Cod. 540035	€ 49,530.000	€ 49,530.000	$45,072.30	$45,072.30
1.3	1	Conveyor Belt of 600 x 2,000 mm, Fixed-Inclined Type - Cod. 470003	€ 3,880.000	€ 3,880.000	$3,530.80	$3,530.80
1.4	1	Conveyor Belt of 600 x 32,000 mm, Fixed-Inclined Type - Cod. 475032	€ 13,900.000	€ 13,900.000	$12,649.00	$12,649.00
1.5	1	Conveyor Belt of 600 x 3,000 mm, Fixed-inclined Type - Cod. 475003	€ 4,140.000	€ 4,140.000	$3,767.40	$3,767.40
1.6	1	Conveyor Belt of 600 x 10,000 mm, Fixed-Inclined Type - Cod. 475010	€ 6,310.000	€ 6,310.000	$5,742.10	$5,742.10
1.7	1	Conveyor Belt of 600 x 5,000 mm, Fixed Type - Cod. 470005	€ 4,470.000	€ 4,470.000	$4,067.70	$4,067.70
1.8	1	Conveyor Belt of 600 x 9,000 mm, Fixed-Reversible Type - Cod. 480009	€ 6,200.000	€ 6,200.000	$5,642.00	$5,642.00
1.9	1	Conveyor Belt of 600 x 15,000 mm, Movable-Reversible Type - Cod. 485015	€ 11,380.000	€ 11,380.000	$10,355.80	$10,355.80
1.10	7	Safety Measures According to CE Rules for Conveyor Belt - Cod. 470700	€ 480.000	€ 3,360.000	$436.80	$3,057.60
1.11	1	Mill Loading' Electric Driving Board, with Logic - Cod. 930138	€ 19,000.000	€ 19,000.000	$17,290.00	$17,290.00
1.12	1	Set of Electric Connections Between Driving Board and Single Users - Cod. 930139	€ 8,460.000	€ 8,460.000	$7,698.60	$7,698.60
		Total Section EURO & USD		**€ 127,750.000**		**$116,252.50**

BODY SLIP PREPARATION SECTION						
2.1	1	Control Equipment for Mill Recovery Water Load -Cod. 340036	€ 3,160.000	€ 3,160.000	$2,875.60	$2,875.60
2.2	3	Ball Mill of 40,000 L. - Cod. 170625	€ 111,600.000	€ 334,800.000	$101,556.00	$304,668.00
2.3	3	Set of Connection Cables between the Board of Mill with 40,000 L. Capacity and Single Utilizations - Cod. 170965	€ 680.000	€ 2,040.000	$618.80	$1,856.40
2.4	3	Italian Rubber Lining for Mill of 40,000 L - Cod. 170678	€ 39,680.000	€ 119,040.000	$36,108.80	$108,326.40
2.5	3	Grinding Media in Alumina 90 Balls (26000 Kg) for Mill of 40,000 L. w/ Rubber Lining	€ 70,940.000	€ 212,820.000	$64,555.40	$193,666.20
2.6	6	Cement Tank of 60 m3 - Cod. 990060	Customer's Supply	Customer's Supply	Customer's Supply	Customer's Supply
2.7	6	Blade Stirrer - Cod. 210265	€ 10,100.000	€ 60,600.000	$9,191.00	$55,146.00
2.8	2	Pneumatic Memrane Pump of 3" - Cod. 550102	€ 1,920.000	€ 3,840.000	$1,747.20	$3,494.40
2.9	1	Electric Driving Board for 'Body Slip Tank Accessories' - Cod. 930156	€ 13,500.000	€ 13,500.000	$12,285.00	$12,285.00
2.10	1	Set of Electric Connections Between Driving Board and Single Users - Cod. 930157	€ 7,360.000	€ 7,360.000	$6,697.60	$6,697.60
2.11	1	Set of Painted Metallic Carpentry for Support and Instection, Gangways ... - Cod. 920A01	€ 50,760.000	€ 50,760.000	$46,191.60	$46,191.60
2.12	1	Body Slip Distribution Net (Pipings -	€ 11,280.000	€ 11,280.000	$10,264.80	$10,264.80
		Total Section EURO & USD		**€ 320,980.000**		**$292,091.80**
SPRAY DRYING AND POWDER STORAGE SECTION						
3.1	3	Vibrating Sieve D 1,200 mm, w/ 3 Seperation Stages, 2 Nets, and 2 Magnetic Separators - Cod. 600160	€ 8,590.000	€ 25,770.000	$7,816.90	$23,450.70
3.2	1	Electric Driving Board for 'Spray Dryer Feeding Tank' - Cod. 930214	€ 4,300.000	€ 4,300.000	$3,913.00	$3,913.00
3.3	1	Set of Electric Connections between Driving Board and Single Users - Cod. 930215	€ 370.000	€ 370.000	$336.70	$336.70

3.4	1	Control Equipment for Spray-Dryer Body-Slip Tank - Cod. 340060	€ 620.000	€ 620.000	$564.20	$564.20
3.5	2	Cement Tank of 50 m3 - Cod. 990060	Customer's Supply	Customer's Supply	Customer's Supply	Customer's Supply
3.6	2	Blade Stirrer - Cod. 210260	€ 9,760.000	€ 19,520.000	$8,881.60	$17,763.20
3.7	1	Pneumatic Membrane Pump of 3" - Cod. 550102	€ 1,920.000	€ 1,920.000	$1,747.20	$1,747.20
3.8	1	Spray-Dryer 'As 5000' Type, Gas Operating, w/ 2 Pumps of 9 m3/h - Cod. 180500	€ 349,370.000	€ 349,370.000	$317,926.70	$317,926.70
3.9	1	Metallic Carpentry for "As 5000" Spray-Dryer Support and Inspection - Cod. 183325	€ 38,680.000	€ 38,680.000	$35,198.80	$35,198.80
3.10	1	Dry Scrubber for 'As 5000' Spray-Dryer (Powder Content ,20mg/Nm3) - Cod. 184860	€ 95,800.000	€ 95,800.000	$87,178.00	$87,178.00
3.11	1	Chimney for Spray-Dryer - Cod. 920105	€ 2,960.000	€ 2,960.000	$2,693.60	$2,693.60
3.12	1	Set of Electric Connections between the Board of 'As 5000' Spray-Dryer w/ Scrubber and Single Utilizations - Cod. 180886	€ 11,130.000	€ 11,130.000	$10,128.30	$10,128.30
3.13	1	Body Slip Basket Filter - Cod. 600635	€ 4,580.000	€ 4,580.000	$4,167.80	$4,167.80
3.14	1	Vibrating Screener 800 x 1,500 mm - Cod. 600066	€ 8,740.000	€ 8,740.000	$7,953.40	$7,953.40
3.15	1	Conveyor Belt of 500 x 12,000 mm, Fixed Type - Cod. 490012	€ 6,090.000	€ 6,090.000	$5,541.90	$5,541.90
3.16	1	Conveyor Belt of 500 x 8,000 mm, Fixed Type - Cod. 490008	€ 5,040.000	€ 5,040.000	$4,586.40	$4,586.40
3.17	1	Conveyor Belt of 500 x 4,000 mm, Fixed Type - Cod. 490004	€ 3,930.000	€ 3,930.000	$3,576.30	$3,576.30
3.18	1	Plastic or Steel Bucket Elevator h=20 - Cod. 290220	€ 22,220.000	€ 22,220.000	$20,220.20	$20,220.20
3.19	1	Conveyor Belt of 500 x 7,000 mm, Movable-Reversible Type - Cod. 505007	€ 7,610.000	€ 7,610.000	$6,925.10	$6,925.10
3.20	1	Electric Driving Board for 'Bin Loading' w/ Logic - Cod. 930228	€ 16,020.000	€ 16,020.000	$14,578.20	$14,578.20
3.21	1	Set of Electric Connections between Driving Board and Single Users - Cod. 930229	€ 6,650.000	€ 6,650.000	$6,051.50	$6,051.50

3.22	5	Metallic Bin of 120 m3 - Cod. 920595	€ 29,870.000	€ 149,350.000	$27,181.70	$135,908.50
3.23	5	Propeller Level Indicator - Cod. 380080	€ 180.000	€ 900.000	$163.80	$819.00
3.24	5	Max. Propeller Level Indicator - Cod. 380100	€ 200.000	€ 1,000.000	$182.00	$910.00
3.25	5	Wolf Mouth' Extractor, Electropneumatically Driven - Cod. 310360	€ 1,220.000	€ 6,100.000	$1,110.20	$5,551.00
3.26	1	Conveyor Belt of 500 x 14,000 mm, Fixed Type - Cod. 490014	€ 6,600.000	€ 6,600.000	$6,006.00	$6,006.00
3.27	1	Plastic or Steel Bucket Elevator h=9m - Cod. 290209	€ 14,720.000	€ 14,720.000	$13,395.20	$13,395.20
3.28	1	Vibrating Sieve D 1,200 mm, w/ Net - Cod. 600165	€ 6,850.000	€ 6,850.000	$6,233.50	$6,233.50
3.29	1	Conveyor Belt of 500 x 6,000 mm, Fixed Type - Cod. 490006	€ 4,540.000	€ 4,540.000	$4,131.40	$4,131.40
3.30	1	Conveyor Belt of 500 x 5,000 mm, Fixed-Reversible Type - Cod. 500005	€ 4,620.000	€ 4,620.000	$4,204.20	$4,204.20
3.31	1	Electric Driving Board for 'Bin Unloading/Press Feeding' w/ Logic - Cod. 930248	€ 15,520.000	€ 15,520.000	$14,123.20	$14,123.20
3.32	7	Safety Measures According to CE Rules for Conveyor Belt - Cod. 470700	€ 480.000	€ 3,360.000	$436.80	$3,057.60
3.33	1	Set of Electric Connections between Driving Board and Single Users - Cod. 930249	€ 5,820.000	€ 5,820.000	$5,296.20	$5,296.20
3.34	1	Setr of Painted Metallic Carpentry for Support and Inspection, Gangways ... - Cod. 920A01	€ 23,970.000	€ 23,970.000	$21,812.70	$21,812.70
		Total Section EURO & USD		**€ 718,970.000**		**$654,262.70**
GLAZE PREPARATION SECTION					**$0.00**	**$0.00**
4.1	3	Metallic Container of 1/3 m3 for Transport and Collection of Glazes - Cod. 920220	€ 3,340.000	€ 10,020.000	$3,039.40	$9,118.20
4.2	1	Chain Electric Hoist, w/ Electric Car, Capacity 2000 Kg - Cod. 530032	€ 4,230.000	€ 4,230.000	$3,849.30	$3,849.30
4.3	1	Control Equipment for Mill Water Load - Cod. 340055	€ 1,800.000	€ 1,800.000	$1,638.00	$1,638.00

4.4	2	Ball Mill of 5,500 l., Reinforced Type (30Kw) - Cod. 170220	€ 28,330.000	€ 56,660.000	$25,780.30	$51,560.60
4.5	2	Set of Connection Cables between the Board of Mill w/ 5,500 l. Capacity and Single Utilizations - Cod. 170930	€ 340.000	€ 680.000	$309.40	$618.80
4.6	2	Lining in Alumina 90 for Mill of 5,500 L., Cod. 170225	€ 8,120.000	€ 16,240.000	$7,389.20	$14,778.40
4.7	2	Grinding Media in Alumina 90 Balls (5,200 Kg) for Mill of 5,500 L. - Cod. 170230	€ 14,460.000	€ 28,920.000	$13,158.60	$26,317.20
4.8	1	Ball Mill of 2,150 L., Reinforced Type, Complete w/ Revolution Counter and Electric Board - Cod. 440167	€ 22,360.000	€ 22,360.000	$20,347.60	$20,347.60
4.9	1	Set of Connection Cables bewteen the Board of Mill w/ 2,150 l. Capacity and Single Utilizations - Cod. 440168	€ 250.000	€ 250.000	$227.50	$227.50
4.10	1	Lining in Alumina 90 for Mill of 2,150 L. - Cod. 440170	€ 4,010.000	€ 4,010.000	$3,649.10	$3,649.10
4.11	1	Grinding Media in Alumina 90 Balls (2,200 Kg) for Mill of 2,150 L. - Cod. 440175	€ 6,320.000	€ 6,320.000	$5,751.20	$5,751.20
4.12	1	Ball Mill of 500 L., Reinforced Type, Complete w/ Revolution Counter and Electric Board - Cod. 440057	€ 10,700.000	€ 10,700.000	$9,737.00	$9,737.00
4.13	1	Inside Lining in Alumina 90 Bricks for Mill of 500 L. - Cod. 440060	€ 3,330.000	€ 3,330.000	$3,030.30	$3,030.30
4.14	1	Grinding Media in Alumina 90 Balls (450 Kg) for Mill of 500 L. - Cod. 40065	€ 1,330.000	€ 1,330.000	$1,210.30	$1,210.30
4.15	2	Vibrating Sieve D=900, w/ Pump, 1 Net, 1 Magnetic Separator and Car - Cod. 600139	€ 8,600.000	€ 17,200.000	$7,826.00	$15,652.00
4.16	6	Stainless Steel Tank of 4 m3 - Cod. 920849	€ 4,960.000	€ 29,760.000	$4,513.60	$27,081.60
4.17	6	Blade Stirrer in Stainless Steel - Cod. 210225	€ 3,500.000	€ 21,000.000	$3,185.00	$19,110.00
4.18	1	Electric Driving Board for 'Glaze Tank Accessories' - Cod. 930272	€ 14,710.000	€ 14,710.000	$13,386.10	$13,386.10

4.19	1	Set of Electric Connections between Driving Board and Single Users - Cod. 930273	€ 3,590.000	€ 3,590.000	$3,266.90	$3,266.90
4.20	1	Set of Painted Metallic Carpentry for Support and Inspection, Gangways ... - Cod. 920A01	€ 47,940.000	€ 47,940.000	$43,625.40	$43,625.40
4.21	1	Glaze Distribution Net (Pipings - ValvesConnections - Various Fittings) - Cod. 970001	€ 12,040.000	€ 12,040.000	$10,956.40	$10,956.40
		Total Section EURO & USD		**€ 204,260.000**		**$185,876.60**
PRESSING AND DRYING SECTION						
5.1	2	Metallic Hopper of 2 m3 for Magnum Press - Cod. 920620	€ 3,160.000	€ 6,320.000	$2,875.60	$5,751.20
5.2	2	Propeller Level Indicator - Cod. 380080	€ 180.000	€ 360.000	$163.80	$327.60
5.3	2	Motorized Powder Distributor - Cod. 125166	€ 6,440.000	€ 12,880.000	$5,860.40	$11,720.80
5.4	2	Press Car Feeding, w/ 'Wolf Mouth' Hopper, Grid-Holder Car and Self-Level-Ling Grid (Max. size of 400x400mm) - Cod. 125090	€ 3,050.000	€ 6,100.000	$2,775.50	$5,551.00
5.5	2	Magnum 2105 SL ED' Press - Cod. 125233	€ 369,010.000	€ 738,020.000	$335,799.10	$671,598.20
5.6	2	Press Fitting for 'Syncro' Demoulding - Cod. 125837	€ 11,850.000	€ 23,700.000	$10,783.50	$21,567.00
5.7	2	Lower and Upper Plug Magnetic Fastening Device - Cod. 125587	€ 4,830.000	€ 9,660.000	$4,395.30	$8,790.60
5.8	2	Magnetic Upper Plate for Upper Plugs Fastening - Cod. 125595	€ 9,280.000	€ 18,560.000	$8,444.80	$16,889.60
5.9	2	Set of Connection Cables bewteen Power Board and Press - Cod. 125760	€ 2,850.000	€ 5,700.000	$2,593.50	$5,187.00
5.10	1	Whelled Device for Filtering Press Oil - Cod. 125765	€ 5,980.000	€ 5,980.000	$5,441.80	$5,441.80
5.11	1	Electric and Oleodynamic Car for Die Change - Cod. 125772	€ 23,460.000	€ 23,460.000	$21,348.60	$21,348.60
5.12	2	Self-Leveling Honey Comb Grid - Cod. 125098	€ 3,050.000	€ 6,100.000	$2,775.50	$5,551.00

5.13	1	Refrigeration Plant of 110,000 Kcal/h for Magnum Press - Cod. 580383	€ 37,540.000	€ 37,540.000	$34,161.40	$34,161.40
5.14	2	3 Cavity Die 400x400 mm w/ Entering Punches, w/ Isostatic Upper Plugs - Cod. 111720	€ 28,820.000	€ 57,640.000	$26,226.20	$52,452.40
5.15	1	Back Face Copy for Size 300 x 300 mm - Cod. 133310	€ 1,010.000	€ 1,010.000	$919.10	$919.10
5.16	1	Back Face Copy for Size 400 x 400 mm - Cod. 133340	€ 1,320.000	€ 1,320.000	$1,201.20	$1,201.20
5.17	1	Front Face Copy for Size 300 x 300 mm - Cod. 133810	€ 340.000	€ 340.000	$309.40	$309.40
5.18	1	Front Face Copy for Size 400 x 400 mm - Cod. 133840	€ 470.000	€ 470.000	$427.70	$427.70
5.19	1	Station for Plugs Control - Cod. 111900	€ 1,500.000	€ 1,500.000	$1,365.00	$1,365.00
5.20	2	Roller Conveyor, for Mahnum Press and Vertical Dryer - Cod. 135255	€ 33,650.000	€ 67,300.000	$30,621.50	$61,243.00
5.21	2	Safety Measures According to CE Rules for Roller Conveyor - Cod. 135700	€ 1,830.000	€ 3,660.000	$1,665.30	$3,330.60
5.22	2	Vertical Dryer w/ Roller Mangles, Type VDL7/1350 XL, Gas Operating (Mangle 1350 x 1570 mm) - Cod. 140580	€ 238,310.000	€ 476,620.000	$216,862.10	$433,724.20
5.23	2	Set of Protections for Vertical Dryer - Cod. 140630	€ 5,950.000	€ 11,900.000	$5,414.50	$10,829.00
5.24	2	Set of Materials for Insulation of Fans for Vertical Dryers - Cod. 140640	€ 8,920.000	€ 17,840.000	$8,117.20	$16,234.40
5.25	2	Chimney for Vertical Dryer - Cod. 920120	€ 710.000	€ 1,420.000	$646.10	$1,292.20
		Total Section EURO & USD		**€ 803,510.000**		**$731,194.10**

GLAZING SECTION

6.1	2	Automatic Glazing Line for Single-Firing Cod. 610001	€ 168,500.000	€ 337,000.000	$153,335.00	$306,670.00
6.2	1	Equipment for Belt Welding - Cod. 610950	€ 600.000	€ 600.000	$546.00	$546.00

6.3	6	Stainless Steel Fixing Booth 'AirlessType' - Cod. 610093	€ 1,330.000	€ 7,980.000	$1,210.30	$7,261.80
6.4	2	Airless' Pump for Fixing Booth (3 or 4 booths) - Cod. 610097	€ 6,180.000	€ 12,360.000	$5,623.80	$11,247.60
6.5	6	Automatic Decorating Machine, Complete w/ Board (Suitable up to 400 x 400 mm) - Cod. 610310	€ 20,380.000	€ 122,280.000	$18,545.80	$111,274.80
6.6	6	Vertical Compenser of 30 Pieces, w/ Rongues, Complete w/ Board - Cod. 310310	€ 4,620.000	€ 27,720.000	$4,204.20	$25,225.20
6.7	6	Pump for Glaze Feeding - Cod. 610113	€ 3,000.000	€ 18,000.000	$2,730.00	$16,380.00
		Total Section EURO & USD		**€ 204,610.000**		**$186,195.10**
CARS MOVEMENT SECTION						
7.1	2	Roller Cars Loading Machine, 2 Columns Type, w/ Telescopic Arm (w/ 2 belts) - Speedy Type and Inverter Controlled - Cod. 081101	€ 46,560.000	€ 93,120.000	$42,369.60	$84,739.20
7.2	1	Roller Cars Unloading Machine, 2 Columns Type, w/ Telescopic Arm (w/ 2 belts) - Speedy Type and Inverter Cintrolled - Cod. 081191	€ 43,500.000	€ 43,500.000	$39,585.00	$39,585.00
7.3	3	Set of Protections for Cars Loading or Unloading Machine - Cod. 081940	€ 8,110.000	€ 24,330.000	$7,380.10	$22,140.30
7.4	45	Roller Container Car w/ 45 Floors (1830 x 1510 mm), Demounted Type - Cod. 095260	€ 3,770.000	€ 169,650.000	$3,430.70	$154,381.50
7.5	1	Commissionsing Template and Starlock Gun - Cod. 095400	€ 3,720.000	€ 3,720.000	$3,385.20	$3,385.20
7.6	1	Device for Cars Changing w/ Translator - Cod. 100130	€ 26,520.000	€ 26,520.000	$24,133.20	$24,133.20
7.7	1	Double Device for Cars Changing w/ Translator - Cod. 100135	€ 34,100.000	€ 34,100.000	$31,031.00	$31,031.00
7.8	2	Single Automatic Transfer Car w/ Programmable Logic - Cod. 105024	€ 42,980.000	€ 85,960.000	$39,111.80	$78,223.60

7.9	60	(m) Festoon Cable Electric Feeding - Cod. 105070	€ 93.000	€ 5,580.000	$84.63	$5,077.80
7.10	1	Cars Automatic Movement Plant - Cod. 100001	€ 33,290.000	€ 33,290.000	$30,293.90	$30,293.90
7.11	1	Set of Rails for Container Cars - Cod. 920075	€ 33,220.000	€ 33,220.000	$30,230.20	$30,230.20
7.12	1	Set of Rails for Translators/Transfer Cars - Cod. 920077	€ 23,880.000	€ 23,880.000	$21,730.80	$21,730.80
		Total Section EURO & USD		**€ 299,743.000**		**$272,766.13**
FIRING SECTION						
8.1	1	Connection between Machine and 1 Channel Kiln Loading Group (w/ 2 belts) - Cod. 085033	€ 14,160.000	€ 14,160.000	$12,885.60	$12,885.60
8.2	1	1 Channel Kiln Loading Group (w/ 2 belts) - Speedy Type and Inverter Controlled - Cod. 085240	€ 28,340.000	€ 28,340.000	$25,789.40	$25,789.40
8.3	1	Security Rope for Connections and 1 Channel Kiln Loading/Unloading Group - Cod. 085680	€ 1,740.000	€ 1,740.000	$1,583.40	$1,583.40
8.4	1	F1-NH 1 Channel Kiln .2500 x 872mm, 1 m Refractory Rollers - Cod. 074086M	€ 797,610.000	€ 797,610.000	$725,825.10	$725,825.10
8.5	100	Equipment for "Flame Detection Installation" on Kiln Burner - Cod. 115A04	€ 76.000	€ 7,600.000	$69.16	$6,916.00
8.6	1	Supervisory Microprocessor Unit for F1-NH Kiln - Cod. 115027	€ 19,680.000	€ 19,680.000	$17,908.80	$17,908.80
8.7	1	Set of Reserve Fans, w/ Accessories, Roller Kiln - Cod. 115A03	€ 66,110.000	€ 66,110.000	$60,160.10	$60,160.10
8.8	1	Sound Proof Cabin for Kiln Fans - Cod. 115350	€ 23,800.000	€ 23,800.000	$21,658.00	$21,658.00
8.9	1	Set of Chimneys (n.3) for F1NH Kiln - Cod. 920173	€ 3,950.000	€ 3,950.000	$3,594.50	$3,594.50
8.10	1	Set of Electric Connections Among Single Channel Kiln Board and Single Utilizations - Cod. 115600	€ 16,280.000	€ 16,280.000	$14,814.80	$14,814.80
8.11	1	Generating Group of 33 KVA - Cod. 115060	€ 14,450.000	€ 14,450.000	$13,149.50	$13,149.50
8.12	1	Telecamera w/ Monitor - Cod. 115150	€ 1,470.000	€ 1,470.000	$1,337.70	$1,337.70

8.13	1	Channel Kiln Unloading Group (Fixed belt type) - Speedy Type and Inverter Controlled - Cod. 085278	€ 27,260.000	€ 27,260.000	$24,806.60	$24,806.60
8.14	1	Security Rope for Connection and 1 Channel Kiln Loading/Unloading Group - Cod. 085680	€ 1,740.000	€ 1,740.000	$1,583.40	$1,583.40
8.15	1	Connection w/ Squaring Devise between 1 Channel Kiln Unloading and Machine, Dunting Control Included (w/ 2 belts) - Cod. 085181	€ 22,000.000	€ 22,000.000	$20,020.00	$20,020.00
8.16	1	Emergency Stacker Band Type, w/ Connection - Cod. 085209	€ 10,390.000	€ 10,390.000	$9,454.90	$9,454.90
8.17	1	Transport and Connection Line - Cod. 610A01	€ 11,750.000	€ 11,750.000	$10,692.50	$10,692.50
8.18	1	Suction Machine for Bisque Loading in Containers - Cod. 565440M	€ 45,510.000	€ 45,510.000	$41,414.10	$41,414.10
8.19	20	Metallic Container - Cod. 565380	€ 660.000	€ 13,200.000	$600.60	$12,012.00
		Total Section EURO & USD		**€ 1,106,976.000**		**$1,007,348.16**

SELECTION AND PALLETISATION SECTION

9.1	1	Suction Machine for Bisque or Glaze Unloading from Containers - Cod. 565446M	€ 55,790.000	€ 55,790.000	$50,768.90	$50,768.90
9.2	1	Equipment w/ 2-Row Selection Bench and Reconveyance from 2 to 1 Row - Cod. 420105	€ 28,760.000	€ 28,760.000	$26,171.60	$26,171.60
9.3	1	Automatic Selection Line w/ 7 Exits, w/ Packing Machine and On Line Selection Bench - Cod. 420101	€ 244,760.000	€ 244,760.000	$222,731.60	$222,731.60
9.4	1	Safety Measures and Sound Proofing According to CE Rules - Cod. 420288	€ 12,010.000	€ 12,010.000	$10,929.10	$10,929.10
9.5	1	Flatness and Guage Control System (w/o physical contact) - Cod. 420110	€ 47,040.000	€ 47,040.000	$42,806.40	$42,806.40
9.6	1	Box Collection and Transport Belt - Cod. 420550	€ 7,030.000	€ 7,030.000	$6,397.30	$6,397.30
		Total Section EURO & USD		**€ 395,390.000**		**$359,804.90**

AUXILIARY PLANTS

10.1	1	Sleeve Filter of 8,500 m3/h Complete w/ Motor, Fan and Board - Cod. 955320	€ 22,640.000	€ 22,640.000	$20,602.40	$20,602.40
10.2	1	Sleeve Filter of 21,500 m3/h Complete w/ Motor, Fan and Board - Cod. 955350	€ 41,480.000	€ 41,480.000	$37,746.80	$37,746.80
10.3	1	Sleeve Filter of 17,000 m3/h Complete w/ Motor, Fan and Board - Cod. 955340	€ 31,160.000	€ 31,160.000	$28,355.60	$28,355.60
10.4	1	Set of Sheet Pipings, Supports, Connections, Hoods, Flexible Pipes, Chimneys - Cod. 955500	€ 59,220.000	€ 59,220.000	$53,890.20	$53,890.20
		Total Section EURO & USD		**€ 154,500.000**		**$140,595.00**

Position No.	Qty.	Part Description	KW Installed Power In Plant
		RAW MATERIALS AND WEIGHING SECTION	
1.2	1	Weighing Box of 20,000 KG - Cod. 540035	1.50
1.3	1	Conveyor Belt Fixed Type - Cod. 470003	0.74
1.4	1	Conveyor Belt Fixed and Inclined Type - Cod. 475032	4.00
1.5	1	Conveyor Belt Fixed and Inclined Type - Cod. 475003	1.10
1.6	1	Conveyor Belt Fixed and Inclined Type - Cod. 475010	1.50
1.7	1	Conveyor Belt Fixed Type - Cod. 470005	0.70
1.8	1	Conveyor Belt Fixed and Reversible Type - Cod. 480009	0.74
1.9	1	Conveyor Belt Movable and Reversible Type - Cod. 485015	1.84
		Total Section Unit Installed Power in KW	**12.16**
		BODY SLIP PREPARATION SECTION	
2.2	3	MS 40 000 Rotating Ball Mill - Cod. 170625	110.00
2.7	6	Slow Blade Stirrer - Cod. 210265	15.00
		Total Section Unit Installed Power in KW	**125.00**
		SPRAY DRYING AND POWDER STORAGE SECTION	
3.1	3	Circular Vibrating Sieve, Diameter 1.200mm w/ 3 Seperation Stages, 2 Nets, 2 Magnetic Separators - Cod. 600160	1.50
3.6	2	Slow Blade Stirrer - Cod. 210260	11.20
3.8	1	Spray-Sprayer, AS 5000 Type - Cod. 180500	126.00
3.10	1	Dry Scrubber for Smokes Coming from the Spray-Dryer AS 5000 - Cod. 184860	37.00
3.14	1	Single-Net Vibrating Screen for Spray-Dried Powders, complete w/ car - Cod. 600066	0.90
3.15	1	Conveyor Belt Fixed Type - Cod. 490012	1.50
3.16	1	Conveyor Belt Fixed Type - Cod. 490008	1.10
3.17	1	Conveyor Belt Fixed Type - Cod. 490004	0.74
3.18	1	Bucket Elevator for spray-dried powder - Cod. 290220	5.50
3.19	1	Conveyor Belt Movable and Reversible Type - Cod. 505007	1.10
3.26	1	Conveyor Belt Fixed Type - Cod. 490014	1.50
3.27	1	Bucket Elevator for spray-dried powder - Cod. 290209	4.00
3.28	1	Circular Vibrating Sieve, Diameter 1.200mm, w/ 1 Net	0.60
3.29	1	Conveyor Belt Fixed Type - Cod. 490006	1.10
3.30	1	Conveyor Belt Fixed and Reversible Type - Cod. 500005	0.74
		Total Section Unit Installed Power in KW	**184.48**
		GLAZE PREPARATION SECTION	

4.2	1	Chain Electric Hoist, w/ Electric Transfer Car, Articulated for Curvilinear Runs - Cod. 530032	2.00
4.4	2	MS 5500 Rotating Ball Mill extra-powered - Cod. 170220	30.00
4.8	1	Rotating Ball Mill of 2,150 L. Reinforced Type - Cod. 440167	11.00
4.9	1	Set of Connection Electric Cables between the Board of the Mill w/ 2,150 L Capacity and the Various Users - Cod. 440168	8.00
4.12	1	Rotating Ball Mill of 500 L., Reinforced Type - Cod. 440057	3.00
4.15	2	Wheeled Unit Equipped w/ a Circular Vibrating Sieve, Diameter 900mm, w/ 1 Net, 1 Magnetic Separator and Membrane Pump - Cod. 600139	0.73
4.17	6	Slow Blade Stirrer - Cod. 210225	2.20
		Total Section Unit Installed Power in KW	**56.93**
		PRESSING AND DRYING SECTION	
5.5	2	"Magnum 2105XL E.S." Hydraulic Press - Cod. 125233	148.00
5.7	2	Device for the Magnetic Anchorage of Die Lower and Upper Plugs, to be Installed on the Magnum Press (Electromagnetic Board for XL Presses) - Cod. 125587	1.00
5.10	1	Filtering Set for the Press Oil Mounted on Wall 0- Cod. 125765	0.73
5.13	1	Plant for the Refrigeration and Recirculation of Press Cooling Water (Suitable for No.2 Magnum 2105 Press) - Cod. 580383	37.50
5.20	2	Roller Conveying Table, for the tile collection and connection between the press and the vertical mangle dryer - Cod. 135255	3.00
5.22	2	Hot Air Automatic Fast Mangle Dryer for Tiles, Synchronized w/ the Press Production, Vertical Type VDL7/1350XL - Cod. 140580	65.00
		Total Section Unit Installed Power in KW	**255.23**
GLAZING SECTION			
6.1	2	Automatic Glazing Line for Single-Firing - Cod. 610001	53.64
6.3	6	"Airless" Stainless Steel Fixing Booth for Glue - Cod. 610093	0.74
6.5	6	Silk-Screen Automatic Decorating Machine (Suitable up to Size 400 x 400mm) - Cod. 610114	0.37
6.6	6	Vertical Compenser w/ Tongues of 30 Pieces (max. size 450 x 450mm) - Cod. 610310	0.37
		Total Section Unit Installed Power in KW	**55.12**
		CAR MOVEMENT SECTION	

7.1	2	Automatic Machine for the Tile Loading into Roller Container Cars (type w/ 2 columns, suitable up to size 400x400mm) - Speedy Type and Inverter Controlled - Cod. 081101	6.00
7.2	1	Automatic Machine for the Tile Unloading from the Roller Container Cars (type w/ 2 columns, suitable up to size 400x400mm) - Speedy Type and Inverter Controlled - Cod. 081191	6.00
7.6	1	Device for Car Change w/ Automatic Translator - Cod. 100130	2.50
7.7	1	Double Device for Car Change w/ Automatic Translater - Cod. 100135	2.90
7.8	2	Single Automatic Transfer Car, Equipped w/ Programmable Logic - Cod. 105024	4.20
7.10	1	Plant for the Automatic Movement of the Container Cars - Cod. 100001	3.30
		Total Section Unit Installed Power in KW	**24.90**
FIRING SECTION			
8.1	1	Connection between the Machine and Automatic Loading Group of the Single-Channel Kiln - Cod. 085033	1.24
8.2	1	Mechanization Group for the Automatic Loading of tTiles into the Single-Channel Roller Kiln (speedy type and inverter controlled) - Cod. 085240	1.75
8.4	1	Roller Kiln 'F1-NH' Type, Single Channel - Cod. 074086M	114.00
8.13	1	Mechanization Group for the Automatic Unloading of Tiles from the Single Channel Roller Kiln (speedy typr and inverter controlled) - Cod. 085278	1.50
8.15	1	Connection between the Single-Channel Automatic Kiln Unloading Group and the Machine - Cod. 085181	2.50
8.16	1	Automatic Emergency Stacker, w/ belt to be connected to the belt squaring device or directly to the kiln unloading group, complete with a connection belt section w/ inverter, of 2 m. abt. - Cod. 085209	1.00
		Total Section Unit Installed Power in KW	**121.99**
SELECTION AND PALLETISATION SECTION			
9.2	1	Equipment Selection Line w/ Bench on 2 Rows and Conveyance from 2 to 1 Row - Cod. 420105	1.50
9.3	1	Automatic Selection Line w/ 7 Stackers, Packing Machine and Selection Bench on Line - Cod. 420101	12.00
9.6	1	Conveyor Belt for collection and transfer of the tile boxes - Cod. 420550	1.10
		Total Section Unit Installed Power in KW	**14.60**
AUXILIARY PLANTS			
10.1	1	Dust Removing Plant w/ Bag Filter, for spray drying and storage department - Cod. 955320	16.00

10.2	1	Dust Removing Plant w/ Bag Filter, for pressing and drying department - Cod. 955350	31.00
10.3	1	Dust Removing Plant w/ Bag Filter, for glazing and tile brushing department - Cod. 955340	23.00
		Total Section Unit Installed Power in KW	**70.00**