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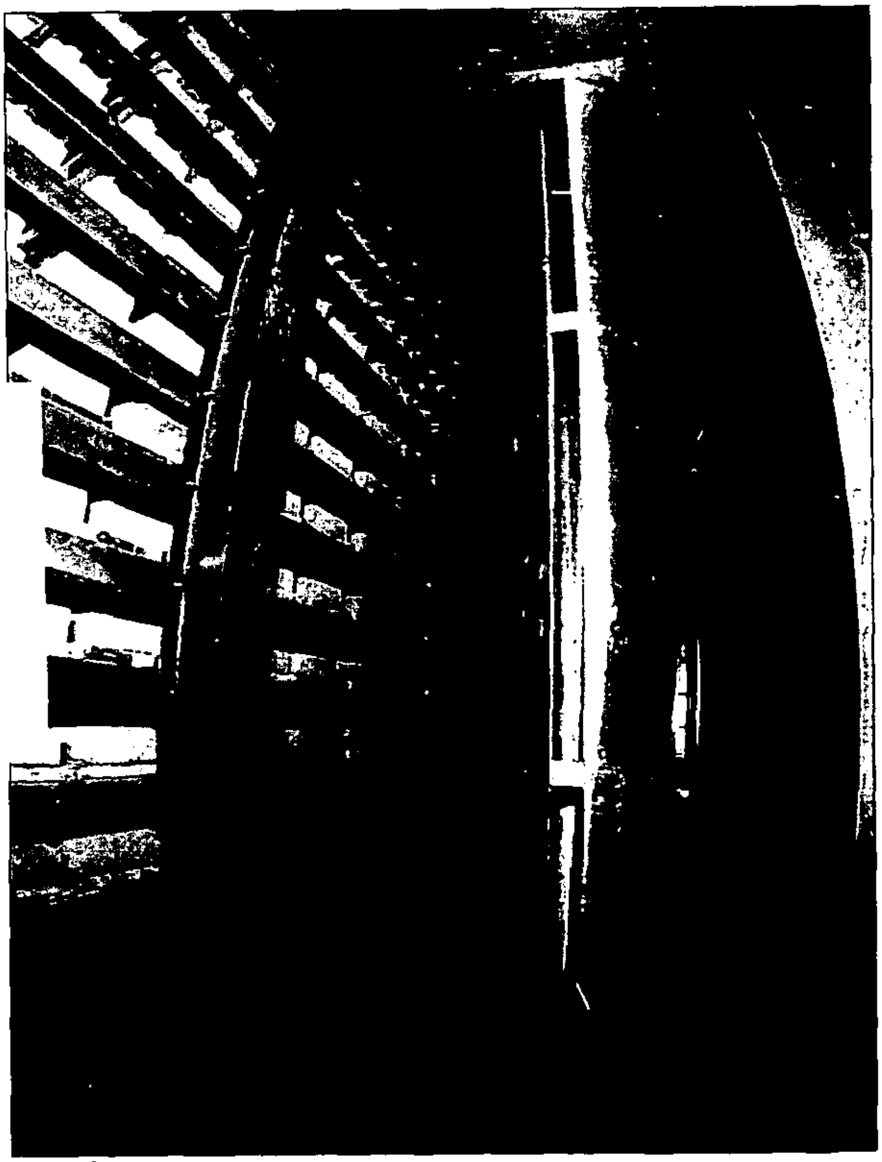
CERAMICS

Drying Technology for Today's Manufacturer

New drying techniques and equipment boost production levels and increase accuracy



Brick drying system.

By: Andrew Hall, Technical Director, Ceramic Drying Systems Ltd., Stoke-on-Trent, England

Today's modern dryers bear little resemblance to their predecessors, which were installed at a time when little emphasis was placed on analyzing performance in terms of operating costs, yields and drying periods. Until recently, the drying system was regarded as that part of the manufacturing process that occurs between the preparation/forming equipment and the kiln.

The industry is more aware of the costs involved in the drying process, particularly in view of developments in firing technology resulting in a breed of high-efficiency kilns.

It may be useful to describe the aspects of a typical modern dryer installation, drawing comparisons where applicable to previous methods. Broadly speaking, these recent developments apply equally to drying systems for the heavy clay industry, whether they be continuous or batch dryers.

The description of any drying system falls into three areas: structures, selection of equipment and control systems.

Structures

Traditionally, dryers were constructed from brick or block walls with roofs formed either from concrete or, occasionally, rigid insulation panels. At the other end of the spectrum, there are dryers in operation built from far less durable materials, such as timber or sheet material. Doors, whether they be hinged, lift-off or sliding, quite often were a constant source of leaks.

While some of the original forms of construction, e.g., brick or concrete, have fared well over the years, the general trend at the present is for modern dryers to be formed from a skeleton steel frame clad with insulated metal panels, the outer surface of which can be painted or clad with lightweight corrugated panels for aesthetic reasons.

This type of structure requires no special foundations apart from a fairly level floor and can be built quickly by only a small quantity of erectors. Furthermore, it offers high levels of insulation and the panels are easily replaced or repaired in case of accidental damage.

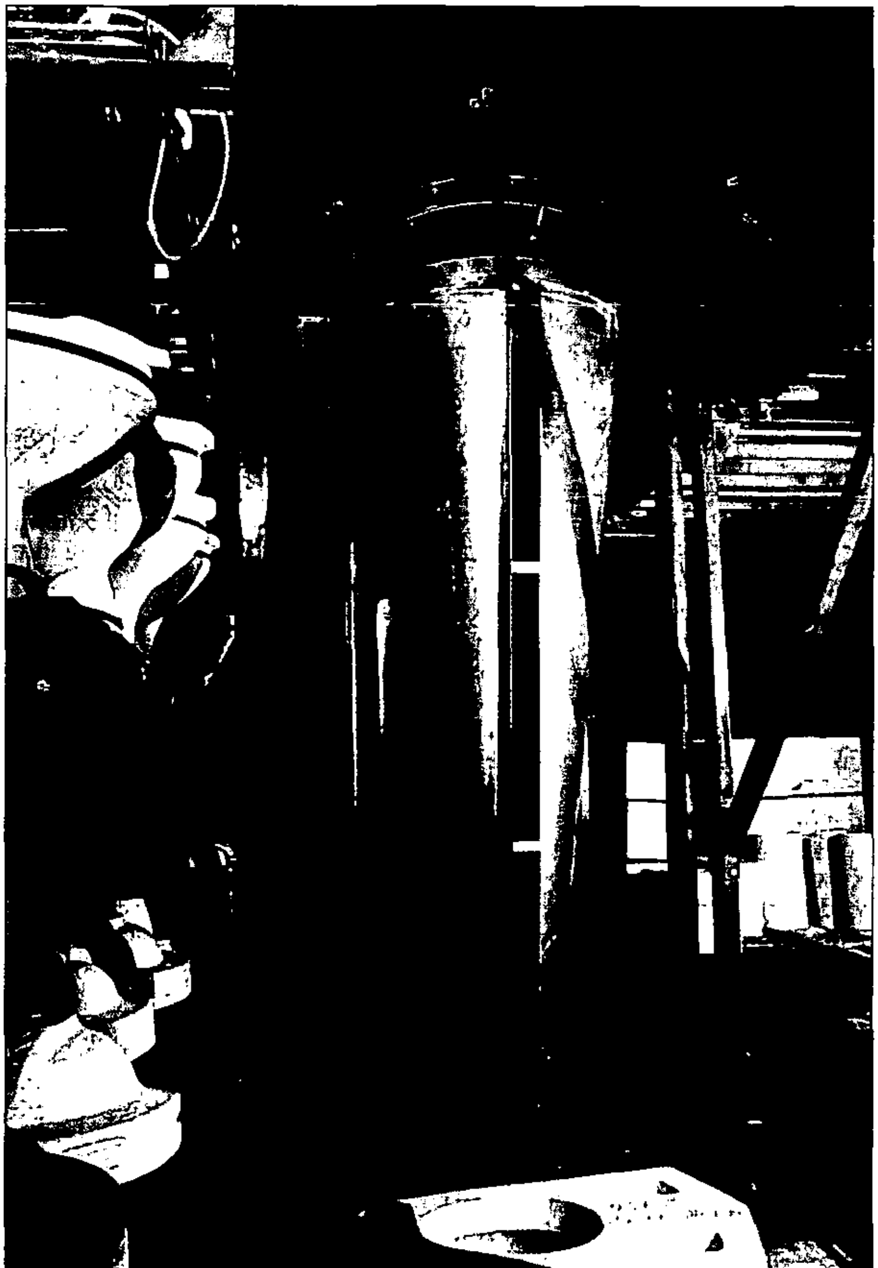
One useful advantage of this type of modular construction is that subsequent relocation of the dryer is made easier when it becomes necessary to reorganize factory layouts in later years. Provided that the internal surfaces are adequately treated against humidity and, in certain cases, corrosive elements in the dryer, there is no reason to doubt that this type of structure will equally withstand the test of time.

An important point, quite often overlooked in recent installations, is the need to incorporate sufficient areas of explosion relief in the structure whenever direct firing systems are employed. Basically, the explosion relief area should be sized to the ratio of 1 ft^2 of material to every 1.5-20.0 ft^3 of dryer volume; ejected above internal dryer pressures of 1 psi; and have a density no greater than 1 lb/ft^3. In addition, the panels should be designed to carry the weight of anyone inadvertently treading on them and ideally they should be insulated to conserve energy.

The final item regarding dryer structures relates to the selection of suitable doors. The choice of door design, either hinged, lift-off or vertical lift, is usually determined by the process and space available. It is obvious, but often overlooked, that care should be taken to ensure that adequate door seals are provided. The seals not only conserve energy, but retain humidity, which is an essential feature when sensitive loads are being dried.

Fans

It is widely accepted that an intermittent air supply to the ware is de-



Sanitaryware plaster mold drying.

sirable and, in many cases, essential to reduce the risk of skin hardening/cracking and distortion. During the air supply period, the vapor barrier surrounding the clay item is disturbed to allow surface moisture to be removed. The following still period, before the next air impingement, allows moisture redistribution to take place within the article to provide further surface moisture. The cycle is then repeated.

Many of the earlier drying systems were fitted with fans to provide either an intermittent, cross flow or vertical air movement depending upon the nature of the ware. In the majority of cases, these fans were of the axial flow design sometimes used in conjunction with traversing cones to provide the intermittent air supply.

In order to satisfy production demands, it became more important to minimize drying times, which invariably led to an increase of drying temperatures. These higher temperatures, coupled with the prevalent humidity conditions in the dryers, often led to premature equipment failure.

Despite certain claims made by motor and equipment suppliers concerning the temperature capabilities of their products, it is advantageous to ensure that moving parts such as motors and drives are external to the dryer.

When drying temperatures in excess of 60°C are used, it is preferable to provide roof-mounted units using purpose built centrifugal fans, which ensure that all transmission parts are readily accessible from the dryer roofs, i.e., in ambient air. This arrangement ensures longevity and simplifies maintenance.

Humidity control

Air needs to be introduced into dryers in order to absorb moisture, and subsequently is ejected from the dryers. If running costs are to be minimized, it is essential that the amount of air introduced is controlled. With a typical dryer temperature of 80°C and an ambient of ≈20°C, then every cubic meter of air introduced requires an additional heating load in excess of 1000 K/cal.

In the past, fresh air inlet dampers and exhaust systems had two settings, open or closed, and quite often it was left to the discretion of the operator to carry out the necessary adjustments (if any) by manual means.

Ideally, these dampers should remain closed at the start of the cycle to allow the product to be raised to its drying temperature as quickly as is safely possible under relatively high humidity conditions. Thereafter, internal humidities should be controlled (normally between 50-60% rh) by regulation of the relevant dampers. Relative humidity levels above this band may result in retarded drying, while low relative humidities, apart from wasting fuel, may cause product damage.

For the drying of sensitive products, some form of humidity input may be necessary during the initial phase of the drying process as temperatures are raised. An excellent method of achieving this involves the use of small packaged steam boilers. These will provide modulating control of humidity input at relatively low capital and maintenance costs.

At present, the primary weak point of any humidity dryer lies in the provision of a relative humidity sensing device capable of withstanding the harsh environment of a typical dryer. Hair element hygrometers have proven to be fairly reliable in low-temperature applications, e.g., the drying of plaster molds in the whiteware industry. But even so they need to be recalibrated at fairly regular intervals and the elements need frequent cleaning or replacing if their reliability is to be maintained.

Various makes of electronic sensing probes are now available. These have been found to provide good service.

Fresh air inlet and exhaust systems must be adequately sized since the evaporation rates are not constant throughout the drying cycle. Experience indicates that ≈50% of the total water quantity may be removed during ≈25% of the total drying period.

Burners

Most dryers tend to be direct fired using a gaseous fuel, producing efficiencies in the order of 90-95%. The selection of the burner type is important if high efficiencies are to be realized. Ideally, they should have a high turn down ratio and be fully modulating to satisfy the varying demands of the system. Combustion air should be provided by a small combustion air fan, or else excess amounts of fresh air may be wasted.

In a dryer complex of several drying chambers, it is more common to see one burner per dryer rather than one burner with a complicated ductwork system distributing the heat to the dryers, as was generally the case in industry. This arrangement provides closer control of conditions, as well as greater flexibility in case of burner failure.

In regard to heat input, it is possible for waste heat to be accepted in some dryers in the industry. This is the heat normally supplied from the kiln. However, it is important to be aware of some precautions.

First, in achieving greater firing efficiencies, is good quality waste heat available? Low-volume, high-temperature supply is of greater benefit than high-volume, low-temperature supply, since the useful heat contribution is based upon the temperature difference between the waste heat supply and the ultimate exhaust temperature from the dryer.

Second, how convenient is the waste heat source? If long duct runs are envisaged, then good quality insulation is necessary to minimize mains losses, adding considerably to the capital expense.

Third, depending on the nature of the product being dried, it may only be possible to introduce waste heat during the latter stages of drying, or the desirable humidity levels required at the critical first part of the drying process will be destroyed.

Fourth, from an energy standpoint,

Shuttle drying system for sanitaryware.

would it be possible to improve the efficiency of the kiln rather than justify the use of the heat available?

Control system

Twenty years ago, industry relied heavily on the skills of the operator to control drying conditions by manually opening heat input dampers or adjusting burners. Considering the crude equipment in use, no one can argue that the operator's skill and experience were not valuable assets to the company.

Gradually more technological advances were made relating particularly to temperature control. The mechanical cam controller became widely used. Temperature ramps and dwells had to be carefully cut from a disk of metal or plastic, which revolved in the instrument, and an actuating arm followed the profile transmitting signals to the burner to regulate heat input.

Although crude by design, and preventing instant changes to the desired conditions, the system ensured that the dryer was supervised 24 hr/day.

There currently is a wide choice of microprocessor-based instruments on the market which provide accurate control of conditions. These instruments can be linked to a central supervisory station. By this method, an entire bank of drying chambers can be monitored and their operational status changed at the push of a button by an authorized person located remotely from the actual plant. In addition, the plant supervisor is instantly made aware of any equipment malfunction with all relevant events being logged for future reference.

The systems are designed to be user-friendly and normally require the input of passwords to allow various levels of entry into the equipment for security reasons.

Research is currently being carried out in other areas, e.g., microwave drying. However, the development work carried out to date indicates that it will be some time before it becomes widespread in the ceramic industry.

Drying by dehumidification

There is one innovation that has achieved some success, particularly when employed for the drying of large blocks of clay or more delicate special shapes. The innovation is drying by dehumidification techniques using heat pumps.

The main components of this system include a well-insulated and vapor-sealed chamber, an air circulation system and a heat pump. The heat pump, similar to a mechanical refrigerator, is a thermodynamic machine comprising a compressor, condenser expansion valve and an evaporator.

The moisture-laden air in the chamber, absorbed from the product being dried, is drawn over the evaporator coil by a fan. The evaporator coil, maintained at a temperature around freezing point, rapidly reduces the air temperature to its dew point, and the water vapor condenses and is collected in the unit.

The refrigerant leaves the evaporator coil as a gas containing the latent heat absorbed and, after passing through the compressor, enters the condenser coil at a high temperature and pressure. Having left the evaporator coil, the air passes over the condensor coil rapidly regaining the latent heat. The refrigerant leaves the condensor coil in liquid form, and the cycle is repeated.

Upon leaving the condensor, the air passes over the unit's electrical components, cooling the components and gaining additional heat. Finally, the air passes through a heating coil before re-entering the chamber in a drier condition and at a marginally higher temperature than when it entered the unit. The process is continued until the products are dried to the desired degree.

Several of these systems are in use and provide excellent yields and low running costs. Invariably, their best application is for drying those items which have a relatively high resale value and normally require a gentle approach to drying. □

New Emphasis on Drying

A look at drying technology reveals new, cost-effective methods for tackling age-old problems

By: John T. Jones, Editor

Ceramic manufacturers have used a variety of methods to dry their wares over the years. The hot sunny day method (probably the first) is still used today in many parts of the world. Air drying works if a factory is located in an area with a dry climate. Such natural methods usually do not satisfy the needs of the modern, impatient industrialist who must make product economically at high production rates.

The drying problem is not confined to the conventional ceramic industry. Solvents and binders must be removed from injection molded ceramics, tapes and other products using such technology. Such binder systems may include expensive solvents that need to be reclaimed and recycled.

Drying cycles may be designed to incorporate the evaporative characteristics of the individual solvents and binders in the system. For example, the weight loss with time might be held constant by controlling the temperature for each phase of the cycle. Low molecular weight solvents and plasticizers that evaporate early in the drying cycle would be subjected to relatively low temperatures. Higher molecular resins would be subjected to higher temperatures as the cycle proceeds.

Water removal

In most ceramics, water is the carrier that makes processing economically feasible. Removing the water is complicated by several factors. First, the removal of water from the ceramic occurs only at the surface. How rapidly the water can be removed is governed by the rate at which the interior water moves to the surface. The water moves to the surface by seeping or wicking through interconnecting pores. Second, the rate of water removal from the surface must not exceed the water supply rate from the interior of the ceramic. If it does, case hardening may occur in which the surface shrinkage exceeds the shrinkage of the interior of the ceramic. This results in cracking of the ceramic, which may be considered one of the long-standing difficulties in making ceramics.

The individual particles which make up the as-formed ceramic are separated by water (or other materials in some technical ceramics). Shrinkage occurs until the particles touch. The more water, the more shrinkage. When shrinkage stops, the ware is not dry, but the ware can now be dried at higher temperatures and lower humidity until it is bone dry. If thicker sections of a piece dry more slowly than thinner sections, cracking may occur. If this is a problem, special care must be taken to dry the thinner sections at lower rates matching that of the thicker sections.

Drying curve

Fig. 1 shows the typical drying curve for ceramics. Starting from right to left (higher to lower moisture content), the evaporation rate is not moisture dependent (A-B). The surface acts as a free water surface. This is the constant rate period. The first falling rate period (B-C) often shows a linear dependence between drying rate and moisture content. The

Fig. 1: Typical drying curve for ceramics.

evaporation rate can still be influenced by the convective air moving over the surface, but while water is moving from the interior of the ceramic, the surface is not a free water surface. Point B is designated the first critical moisture content, and point C, the second critical moisture content.

The rate of evaporation from the surface is diffusion dependent below point C. Water cannot be removed from the surface faster than water moves through the ceramic. This is the second falling rate period (which is not always distinguishable) and shows a curvilinear relationship between drying rate and moisture content. Diffusion of the water slows as the diffusion paths become longer.

The traditional ceramic dryer has humidity and temperature control. The dew point of the air must be high enough to prevent condensation of moisture on the ceramic. Adequate circulation is required because the high humidity air needed in the early stages of drying has limited moisture holding ability and must not become completely saturated such that the dew point is reached. Air flow in traditional dryers is supplied by fans through ducts (with motor-controlled dampers) and monitored by humidity, temperature and pressure detectors. Heat is supplied by gas, electric elements or waste heat from kiln operations.

A tremendous amount of energy is used in drying to supply the latent heat of evaporation of water. This heat is difficult to recover from convective air drying systems. Ceram Research, Heat-Win, Airflow and E A Technology are collaborating on a £600,000 project to develop airless drying technology. Using atmospheric pressure superheated steam at temperatures above 100°C, rather than air, yields higher heat and mass transfer coefficients. The intake of cold air common to conventional dryers is eliminated, and the late latent heat in the steam is easily recovered.

Radio frequency and microwave drying, especially combined with vacuum or forced air drying, are finding increased usage in the ceramic industry. Advantages include:

- Energy input decreases as the water content of the ceramic decreases;
- Large thermal gradients are avoided;
- Energy into the product is consistent and measurable;
- Processing time is reduced along with the space required for drying.

In England, electric companies such as Midland and Eastern help ceramic manufacturing clients set up these drying techniques in their factories. Microwave drying under vacuum reduces the in-mold drying time of lamp bases at one British factory from up to 20 hr to ≈15 min. Similar results are being reported for other factories.

Heat pumps, electric convection ovens and infrared techniques are being improved to reduce energy cost and processing time in the ceramic industry. □