Ceramitec papers

Novem lectures

14-17 October 1997

1 New kilns for fine ceramics

Mr. Arthur Reymer
TNO

New Kiln for Ceramic Tiles

Reymer
TNO Ceramic Technology

1

Design of a 'green' kiln

- low fluoride emission (< 5 mg/m^3)
- equal energy consumption or better
- same quality tiles or better
- cost of new kiln < old kiln + scrubber
- application also to sanitary ware, etc.

2

Solution to fluoride problem

- No need for scrubber
  - investment cost
  - space
  - waste
  - energy, labour
- Kiln itself can do the job

3

TNO Toolbox

- MATADOR roller kiln model
- Predicts or calculates:
  - heat transfer, temperature field of tiles
  - burners: type, location, power
  - gas flow, chicanes
  - energy consumption

4

TNO Toolbox

- Fluoride model
- Predicts
  - fluor
  - emission and absorption of fluoride in kiln
  - emission level for a given kiln design

5

TNO Toolbox

- Measurement in production kiln
  - specialized measuring instruments
- Lab analyses and experiments
  - specialized test equipment
- Modelling, simulation

6

Results

- New kiln design is ready
  - prototype will be engineered by SACMI
  - expected HF Emission 0-3 mg/m^3
- Toolbox available for industrial application
  - scan of fluoride situation
  - improvements in existing kilns and processing
- Scrubber not necessary

7

TNO Strenghts

- Basic and advanced ceramic technology
- CFD modelling, proces control, etc.
- Multidisciplinary team
- Fast, world-wide services

8

Key Benefits

- New 'green' low fluoride roller kiln
- TNO toolbox available
  - see also CERAPRO®
- Control your emission and avoid cost

9

TNO

Ceramic & Glass Research
Eindhoven

10

2 Soft mud forming process

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SOFT MUD BRICKMAKING:

The origin of Soft Mud Brick Making goes back to the Roman Age, when bricks were made by hand in individual moulds.

During the past century, different machines were developed to produce brick mechanically, such as Extruders for soft and stiff columns, or presses for stiff or soft mud systems.

Soft mud machines were built in Holland, where the clays are of silty nature and unsuitable for the extrusion process.

Soft mud brick, which closely resemble truly hand-made brick, soon became fashionable in other countries, where facing bricks are produced.

In Holland, the silty clays require virtually no clay preparation and can be processed as dug. Normally clay suppliers dump lorry loads into a receiving Box Feeder at the works, and a circular Screen Feeder reduces the clay lumps into small sausages. These are passed to a Soft Mud Mixer where the mixing water is added, and the material is prepared for brickmaking: normally at a moisture content of approximately 28%, depending on the type of raw material.

In other countries, more elaborate clay preparation systems have to be applied, due to the plastic or hard nature of the raw material; and often sand has to be added to create a similar material mix which is equivalent to the Dutch clays as dug

In order to obtain interesting fired colours, body fuels are added, which create reducing conditions during firing and provide irregular, antique looking colour shades.

To take full advantage of the soft mud brick feature, De Boer BV have developed a variety of brickmaking systems which are now applied world-wide.

Standard smooth sanded soft mud bricks can be produced fully automatically at different production rates, ranging up to 40,000 bricks per hour. With this machine, the prepared clay is fed into the Press Tower, which fills the empty moulds by means of a Press Block action. The moulds represent a mould chain which creates a positive location at each working position i.e., where the moulds are filled with clay, or where the pressed bricks are positively demoulded and safely placed onto the drying boards. The De Boer demoulding system pushes the bottom mould plate downwards and ejects the brick, which prevents any form of sticking of the sloppy raw material within the moulds, and contributes greatly to the high production efficiency factor which can be obtained with the De Boer machines.

After brick ejection, the moulds are washed, dried and sanded ready for the next cycle.

The machines can be operated at various cycles ranging from a practical 15-33 cycles per minute, depending on raw material and brick dimensions.

The width of the mould chain, i.e., number of bricks per drying board, can be chosen to suit existing handling systems, or with new plant to suit a practical handling rate; which is in the order of 25-30 cycles per minute.

Simulated hand-made bricks can be produced with the same machine, fitted with a hand-formatic attachment, without losing production capacity

In this event, small clay dots are pushed through moveable dies of pre-selected dimensions and shapes on to a walking beam system, where sand is added to create the hand-made brick textures.

The prepared clots are then thrown mechanically into the sanded, empty, moulds, which are positioned accurately by the mould chain system, and this simulates the original hand-made brick action. When the moulds are passed under the press-tower, the press block action will ensure that all moulds are completely filled, and that all bricks are of square shape.

The most individual looking simulated hand-made brickcs are produced with throwing belts, where oversized, sanded clay clots are thrown into the empty moulds by the belt drive action.

The brick texture can be influenced by the shape and size of the clot, and the amount of texturing sand which surrounds the clot.

A special waste removal system was developed to remove the surplus clay from the top of the moulds, and a wiper belt is applied to provide a smooth finish on the bed face of the brick. Frogs or trade-marks are applied to the bottom plate of the moulds in accordance with customers requirements.

In order to maintain a constant clay mixture, it is recommended that a secondary soft mud mixer is installed which unites the virgin day with the returned waste. The clay clots are in fact over twice the size of the produced brick volume which results in a large quantity of recycled clay, which contains the texturing sand.

The throwing belts can be installed above the De Boer Mould Chain, and combined with Press Tower, which provides a dual purpose machine which can produce smooth sanded bricks and individual looking simulated hand-made brick.

Alternatively, the throwing system can be installd above a loose mould circuit, which is applied when several raw materials are used which have different drying and firing shrinkages.

Water-struck brick are produced with the standard De Boer Press Tower Machine, which normally produces smooth sanded bricks. For the production of water struck brick, a special electrical programme is applied which prevents sand application onto the walls of the brick moulds. However; sand is applied to the bottom mould plate, to prevent sticking of the raw material, and ensure trouble-free brick ejection.

These bricks are produced at the norma l pressed brick rate without reduction, in production rate.

As a considerable amount of moulding sand drops off during the drying cycle, it is recommended to apply chamber dryers. where easy access is guaranteed to remove the sand at regular intervals from the drying chambers.

Fully automatic Setting Machines, Tunnel Kilns and De-Hacking Machines are successfully used with modern Soft Mud Brick plants to provide a fully automated Brickmaking Plant.

3 Modelling and optimisation of dryers

Mr. Albert Dalhuijsen
TNO

Modelling and optimisation of dryers

NOVEM - 14 October 1997

Albert Dalhuijsen
Han Velthuis
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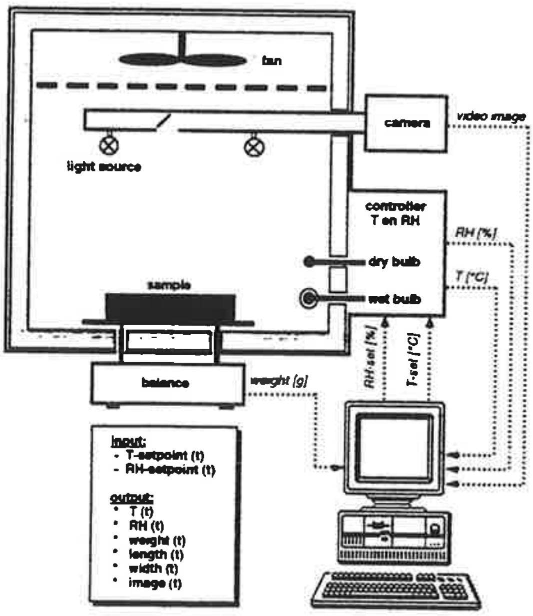
Ceramics drying

- **Energy intensive !!**
  - softmud bricks: 20 - 30 % water, drying times 15-70 hours
- **"Waste heat" from kiln is used in dryer**
  - of course !
  - but be careful: total system is often sub-optimal !
- **Optimize, but how ?**

Know why
Know how => **computer model**

TNO dryer optimization method

- **Objective: what is to be achieved ?**
- **Analysis**
  Current situation, available data ...
  Product drying behaviour, maximum drying rate
  "Ideal" drying-rate curve
- **Reference**
  Measuring program + Interpretation: balances, possible 'faults'
  Reference simulation
- **Optimization**
  Matching possibilities system/product
  Critical parameters, optimized drying curves, recommendations
- **Implementation**



Computer simulation

- **dryer model = dryer + product + installation + controls**
- **simulation of practise (full scale)**
- **all relevant physical mechanisms are modelled**
  - mass balances, thermal balances
  - all as a function of time (drying cycle)
- **chamber dryers and tunnel dryers**
- **validated in laboratory and in practise**

Example from practise: chamber dryer

- **Situation:** 1 kiln, 10 drying chambers, drying time = 44 hours
- **Goal:** double production (extra kiln+10 drying chambers)
- **Approach:** labdryer: dryingtime = 14 hrs
  measurements in practise, simulation DrySim
  Constraints: max. drying rate, temp. fans, etc.
- **Result:** controller 'repaired'
  drying time 22 hours, saving 9 chambers !
  specific electricity + gas reduced
  extra gas reduction if kiln air is less of higher temp.

4 Profits of Process integration

Mr. Aarnout van Duuren
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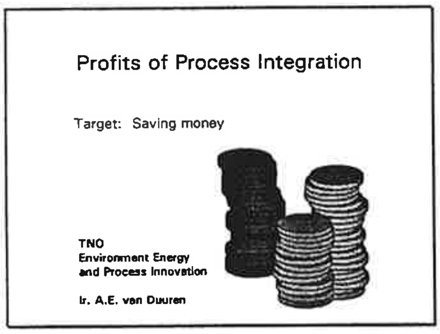
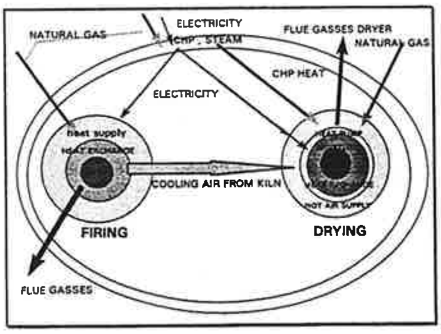
Dia 1



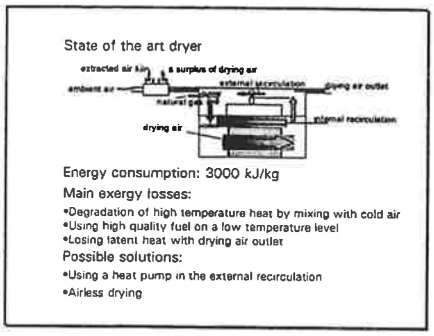
Since 1991 Aarnout van Duuren has been employed as a research scientist in the Energy and Base Materials Division at the TNO Institute of Environmental Sciences, Energy Research and Process Innovation. He works on several subjects for the ceramic industry, like optimization of tunnel and roller kilns, new dryer and kiln designs, measurements, energy and mass balances, introduction of combined heat and power, heat pumps, and last but not least process integration.

The full analysis of the ceramic production process can be illustrated by means of an onion model. The individual processes like drying and firing, can be found in the core of your production process Which process flows are important for your company? How much heating or cooling do the several flows need? At what temperatures is heat available or required? Process integration means that flows in ceramic production processes are interconnected with each other. This is done in such a way that local heat surpluses (cooling demand) are optimally used at places with energy demand (heating demand). In this way, an integrated network is formed in which process flows mutually exchange heat. The first step (first shell) considers passive heat exchange When the temperature difference between two process flows is large enough, a heat exchanger can diminish a net heat demand. If the temperature difference is too small, heat pumps can be used (second shell of the drying process). In this way, the available residual heat is optimally utilized in your factory. Once the potential of heat pumps has been fully utilized, the remaining energy demand can be further worked out (last shell). In this stage, options, such as combined heat and power systems, come into consideration.

Dia 2

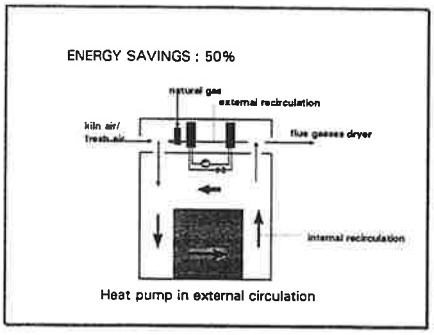


Dia 3



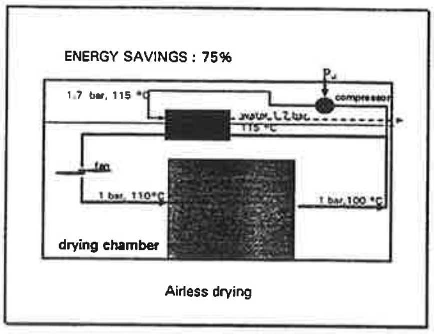
A state of the art dryer has a minimal energy consumption of 3000 kJ per kg of evaporated water. Several TNO tools TNO, like Pinch-technology and Exergy Analysis, show that this dryer has few major exergy (=Quality of energy) losses, like the three mentioned on the slide. In the ceramic industry the extracted air of the tunnel kiln is usually mixed with ambient air before it is applied for drying purposes. When, for example, in the drying chamber a burner is needed to adjust the temperature, a lot of energy is wasted. It also takes a lot of energy, i.e. 2500 kJ/kg to evaporate the water out of the green bodies. This energy input can be recovered by condensing the moisture content of the drying air in the exhaust or external recirculation.

Dia 4



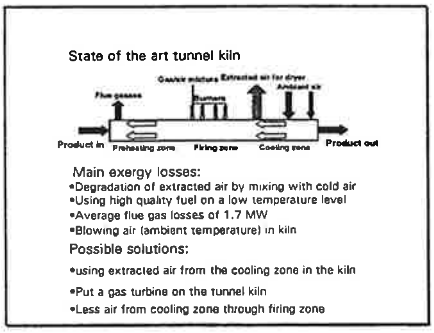
One of the possible solutions is a heat pump in the external circulation. A part of the internal air recirculation is extracted. This extracted air passes through the evaporator of the heat pump in the external recirculation. This stream is partly condensed. After the evaporator the cool condensed air, with a relative humidity of 100%, enters into the condensor where it is heated by the heat which is recovered from the evaporator. This heated air, which is most suitable for continuing the drying process, is used.
The energy consumption is now 1500 kJ/kg, that is to say, an energy saving of 50%.
Green bodies facing the same process conditions as in traditional drying is one of the great benefits of this application.

Dia 5



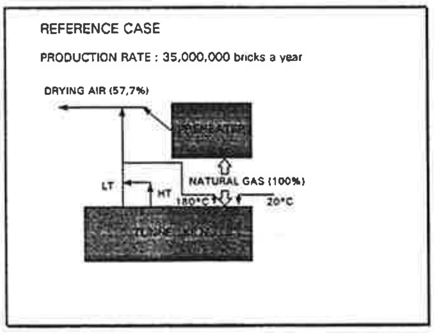
Another possible solution is steam drying. Steam drying is executed by means of superheated steam, under pressure or slightly above atmospheric pressure (Airless drying). This steam can be condensed or recompressed by MVR (Mechanical Vapour Recompression). A part of the steam needs to be condensed. A great advantage of this approach is that the green bodies vapour is used as a tool of the heat pump. This saves the investments costs of an evaporator. The energy consumption is now 750 kJ/kg, an energy saving of 75%.
Future research will throw light on the influence of new process conditions on product quality.

Dia 6



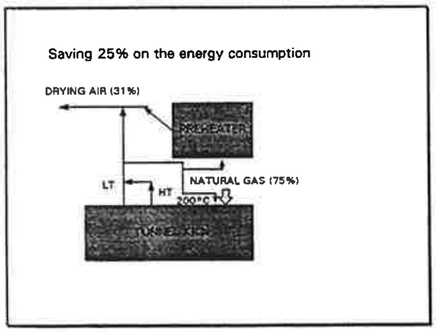
Several TNO tools TNO, like Pinch-technology, Exergy Analysis and the tunnel kiln simulation model Q-KILN, show that the tunnel kiln has a few major exergy (=Quality of energy) losses like the four mentioned on the slide. The most important message is that the extracted air of the kiln has to be used as much as possible in the kiln. One of the major sources of energy losses of several tunnel kilns are the flue gasses. However, there are new condensing heat exchangers on the market with a good performance.

Dia 7



As one of the several references a brickfactory (which is only a few years old) is shown with a production rate of 35 million bricks per year. Together with the Technical Centre for the Ceramic Industry TNO has carried out measurements in order to make an energy and mass balance. This project was financed by the Netherlands agency for energy and the environment.
The drying chambers receive too much drying air from the kiln and the preheater, i.e. 57.7% of the total input energy of the kiln and the preheater.
The dryer does not need any burners.

Dia 8



The amount of drying air can be strongly reduced by using the extracted air of the kiln instead of a seperate gasburner for the preheater. Then the preheaterburner is not needed any more, which results in a saving of 16% natural gas.
When the burners are running with secundary combustion air of 200°C (realising from the low temperature extraction point) instead of ambient air there is a 9 % saving.
More saving options at this factory are:

- improvement of the flow and temperature distribution around the brick setting by other setting patterns and flow inlet and outlet points of the tunnel kiln (10-20% energy saving is possible)
- Speed control of fans based on frequency modulation (10-20% energy saving is possible)

5 Energy efficient exhausting

Mr. Cyp Wagenaar
Mesys

MESYS BV

MACHINERY
TRANSPORT SYSTEMS
INDUSTRIAL SERVICE
SPECIAL CONSTRUCTIONS

Energie-efficient exhausting

by mr. C.G.J. Wagenaar **Mesys BV**

- Several exhausting techniques
- All coming down to the same point, trying to eliminate the dust with:
    - * as little as possible air usage
    - * --,,-- --,,-- energy usage
    - * --,,-- --,,-- maintenance
    - * --,,-- --,,-- exploitation costs
    - * but keeping a healthy climate for the employees.

- Every cubic meter air costs money, when you using a lot of air because of large suction hoods etc., then automatically your pipingsytem grows in diameter, your filter will be larger because of more air to be filtered and you need a bigger ventilator to maintain good under pressure with adequate volume on every suction point.

- There is no difference between the filter types when talking about consumed air. The different filter types influence your filtering quality (more or less emission), your running costs, your maintenance costs.

- There are some basic values you keep in mind:
  Within tubes you need a velocity of 20 mtr./sec airspeed to have good dust transport. When you go faster it will result in tube erosion, slower speed means dust settling within your transport tubes.

- First rule, try to buy ore develop an installation with as less as possible dust creating points. This means for example avoid rubbing stones over steel plates belts and chains.

  Even when you tried to design a dust free installation, there will be some points left who will create dust. For the best of your employees it is necessary to take away this dust with the dangerous alpha quarts fraction. Every dust creating point needs his own solution. This is specialists work, and has to be done with a capable company. But for example I will talk about a few types of suction hoods.

MESYS BV

MACHINERY
TRANSPORT SYSTEMS
INDUSTRIAL SERVICE
SPECIAL CONSTRUCTIONS

Important rules:

- * airspeed on hood-entry should be 10 mtr./sec.
- * place the hood as close as you can to the dust creating point.
- * construct in a way that will reduce speed in the hood, so heavier parts remain an fall down, just the dangerous dust be taken away.
- * the more you close off the place, the less air you need to make it dust free.
- * always talk to the machine operators, when you install something that will obstruct them in their work they will remove it and you're back to zero.

- Always ask for guarantee measurements, there are a lot suppliers who selling just "steel" and not a dust extraction system.

- To be clear:

YOU BUY A CLEANED WORKING PLACE FOR YOUR EMPLOYEES (SEE THE LAW OF YOUR COUNTRY) AND AN EMISSION RATE ACCORDING TO YOUR COUNTRIES LAW. WHEN POSSIBLE WITH LOW ENERGY USAGE.

How a supplier will design your installation is not that important, just check on above mentioned items.

Wet filtering:
- cheap filtering medium (your own process water is good enough)
- constant air volume
- only one ventilator motor, less energy usage
- very easy maintenance (can be made automatically)
- dust comes wet out off the filter
- air comes with a high humidity out off the filter
- low operational costs

Dry filtering
- with same volume a more expensive filter
- dropping air volume when filtering material pollutes
- pressed air usage by cleaning filter material
- Yearly costs of exchanging the filter material
- Can not handle wet or sticky-dust
- Can not handle air with a few sparks in it (sand dryer)
- high operational costs
- dust comes dry out off the filter

Which type you use depends on what you want with the claimed dust and with the cleaned air.

Thank you for your attention.

Cyp G.J. Wagenaar, Mesys BV

6 Mikrowellentrocknung in der Keramik

Mr. Hans Segerer
Riedhammer

Schnelle Fertigung in der Keramik

So lautete das Thema des Silicatkeramik-Workshops anläßlich der Werkstoffwoche '96 Stuttgart. Experten aus den verschiedenen Prozeßbereichen von der Aufbereitung bis zum Brennen gaben einen äußerst interessanten Überblick über die Entwicklung der vergangenen 30 Jahre und einen Ausblick in die Zukunft. Die dort gehaltenen Vorträge werden im Rahmen einer Serie in loser Reihenfolge veröffentlicht.[1]

Rapid Manufacturing Processes for Ceramics

This was the theme of the traditional ceramics workshop at the Werkstoffwoche '96 in Stuttgart. Experts on the different manufacturing stages from preparation to firing presented an extremely interesting survey of the developments of the past 30 years and discussed prospects for the future. In random order we are publishing the papers held at this workshop with, where appropriate, a short summary of the contents in English.[1]

Durchbruch bei der Mikrowellentrocknung

H. Segerer, Nürnberg*

Kurzfassung

Die Trockenanlagen, die mit Mikrowellen (MW) arbeiten, sind in letzter Zeit industriell in vielen Branchen (so vor allem in der Nahrungsmittelindustrie) stark forciert worden. Dies wurde begünstigt durch die Entwicklung einer kontinuierlichen, stufenlosen Leistungsregelung anstelle der üblichen getakteten Impuls-Regelung der Magnetrons. Der Verfasser erklärt zunächst das Wesen der Mikrowellen, die zuerst in Radaranlagen verwendet wurden. Dann wird das Wesen der MW-Erwärmung beschrieben, bevor auf die damit arbeitenden Trockenanlagen behandelt werden.

1 Geschichte

Schon vor nahezu dreißig Jahren wurde in Frankreich ein 2,45 GHz-MW-Trockner für Porzellanflachgeschirr gebaut [1]. Der Gedanke, aufgrund ihrer faszinierenden Eigenschaften Mikrowellenenergie so wie in anderen industriellen Erwärmungsanlagen auch für das keramische Trocknen einzusetzen, ist also nicht neu. Hohe Kosten für die Mikrowellenkomponenten, unzureichende Lebensdauerwerte der Magnetrons, Regelungsprobleme und applikationstechnische Schwierigkeiten hatten aber bisher eine breite Anwendung dieses Prinzips nicht zugelassen. Durch den industriellen Einsatz der Mikrowellentechnik in anderen Bereichen – wie etwa in der Nahrungsmittelindustrie – sind die Sender dank Weiterentwicklung und Großserienfertigung mittlerweile preisgünstig verfügbar. Darüber hinaus weisen sie je nach Betriebsweise eine Lebenserwartung von mehreren Jahren auf. Möglich wurde diese Steigerung durch die Entwicklung einer kontinuierlichen, stufenlosen Leistungsregelung anstelle der üblichen, getakteten Impuls-Regelung der Magnetrons.

MW-Sender mit dieser weichen, schonenden Regelung setzt *Riedhammer* mit Erfolg in Trocknungsanlagen ein – in exklusiver Zusammenarbeit mit der Schweizer Firma *MIPRO*. Dank dieser Verbindung zweier Spezialisten für thermische Verfahrenstechnik in der Keramik und für MW-Technik ist es nunmehr möglich, die physikalischen Vorzüge der 2,45 GHz-Technik in wirtschaftlich sehr günstiger Weise in der industriellen Fertigung zu nützen. Im folgenden Bericht soll versucht werden, Eigenschaften, Vorzüge und Anwendungsmöglichkeiten der MW-Erwärmung bei der keramischen Trocknung aufzuzeigen.

2 Die Mikrowellen und ihre Einwirkungen auf die Materie

Mikrowellen sind, wie Schall und Licht, elektromagnetische Schwingungen. Ihre Wellenlängen liegen zwischen 1 mm und 1 m, die Frequenzen dementsprechend zwischen 300 Mhz und 300 GHz. Sie sind damit kurzwelliger als etwa Schall- oder Rundfunk/TV-Wellen, aber langwelliger als Licht und Infrarot oder gar als UV- und Röntgenstrahlen (Bild 1). Mit diesen Wellenlängen ist es nicht möglich, den physikalischen Aufbau von Atomen oder Molekülen zu verändern, wie dies durch kurzwellige Strahlen unterhalb des Nanometerbereichs geschehen kann. Dagegen ist es ihnen möglich, unsymmetrische Moleküle wie Wasser oder frei bewegliche Ionen wie elektrische Dipole auszurichten – und das mit jedem Richtungswechsel des Feldes. Im hochfrequenten elektrischen Wechselfeld wird also durch Polarisationsschwingungen intermolekulare Reibungswärme erzeugt. Man spricht bei diesem Absorbieren von Mikrowellenstrahlung und deren Umwandlung in Wärme auch von dielektrischer Erwärmung.

Die erste bekanntgewordene technische Anwendung von Mikrowellen war die Entwicklung des Radars im Zweiten Weltkrieg. Dabei hat man es sich zunutze gemacht, daß Mikrowellen von metallischen Werkstoffen reflektiert werden, d.h. mittels Erfassung von Intensität und Laufzeit des zurückkehrenden Strahlungsanteiles können reflektierende Körper in einer mikrowellentransparenten Umgebung geortet werden.

Breakthrough in Microwave Drying

Microwave drying units have, in the last few years, successfully pushed their way into a number of industrial fields (especially in the foodstuffs industry). This was made possible through the development of a continuous, infinitely adjustable output control instead of the normal on/off impulse control of the magnetron. The author at first explains the nature of microwaves, which were first used in radar systems. The nature of microwave heat generation is then described prior to a discussion of their use in functioning drying units.

*Dr. Hans Segerer, Riedhammer GmbH, Klingenhofstraße 72, D-90411 Nürnberg. Vortrag auf dem Silicatkeramik-Workshop, Stuttgart, Mai 1996.

Technologie Forum

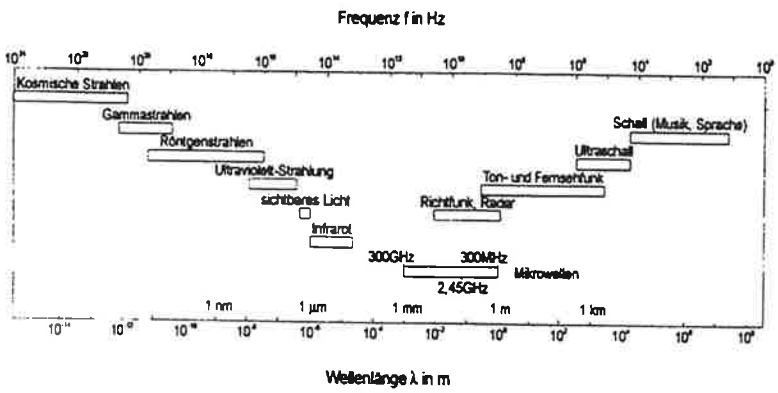


Bild 1
Frequenzspektrum elektromagnetischer Schwingungen (nach [2])

Absorbierend, reflektierend oder transparent: das sind die grundsätzlichen Eigenschaften, mit denen ein Körper auf Mikrowellenbestrahlung reagieren kann.

- *Absorbierend* verhält sich ein Material, das wie Wasser in der Lage ist, Mikrowellenenergie aufzunehmen und in Wärme umzusetzen. Wie weit dabei die Strahlung in das Innere eindringt, ist werkstoffspezifisch und hängt vom jeweiligen „Absorptionsgrad" (dielektrischer Verlustwert) ab. Bei Wasser beträgt die Eindringtiefe (definiert als Maß für den Abbau der Volumenleistungsdichte auf 37 % des Anfangswerts an der Oberfläche) je nach Temperatur etwa 1...6 cm (RT bzw. 100°C), bei nassen keramischen Massen 2...5 cm (bei 2,45 GHz). Besteht ein Werkstoff aus mehreren Komponenten, von denen mindestens eine gut absorbiert, so kann auch dieser gut erwärmt werden (z.B. zahlreiche Nahrungsmittel, frisches Holz, nasse keramische Massen).
- *Reflektierende* Werkstoffe wie Metalle oder Graphit lassen idealerweise keine Strahlung eindringen und werfen die auf der Oberfläche ankommenden Wellen unverändert in den Raum zurück. Sie absorbieren keine Energie und bleiben im Mikrowellenfeld kalt.
- *Transparente* Körper lassen die Strahlen ungehindert durch sich hindurchgehen, wie Licht durch Glas. Auch sie absorbieren idealerweise keine Energie und bleiben im Mikrowellenfeld kalt. Solche Werkstoffe sind unter anderen Luft und Flüssigkeiten wie Benzin oder Tetrachlorkohlenstoff, Kunststoffe wie Polyäthylen, PTFE od[er] Polystyrol, Quarzglas und zahlreiche wasserfreie kera[-]mische Massen.

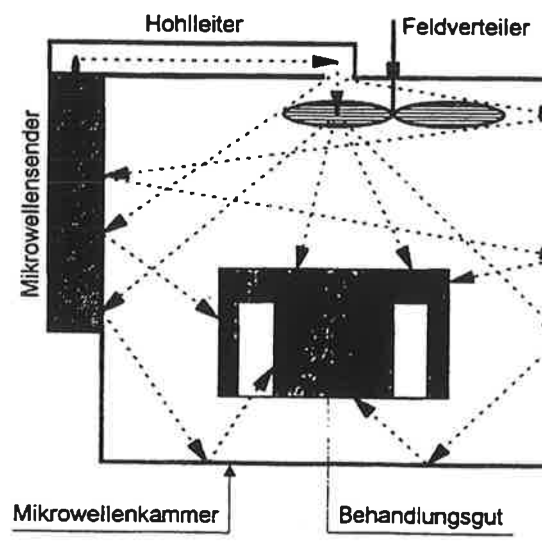


Bild 2
Schema einer MW-Erwärmungsanlage

Diese Eigenschaften sind häufig stark temperaturabhängi[g]. So kann es vorkommen, daß ein Werkstoff bei Raumtempe[-]ratur als nahezu transparent erscheint, während er sich b[ei] Temperaturen oberhalb von 1000°C zum guten Absorbe[r] entwickelt. Derartige Erscheinungen sind beispielhaft fü[r] Aluminiumoxide, Siliciumoxid, Glaskeramik und bestimm[-]te Bornitride [3]. Darüberhinaus gelten die beschriebene[n] Verhaltensweisen eines Werkstoffs immer nur für ein MW[-]Feld einer bestimmten Wellenlänge bzw. Frequenz: Eine trok[-]kene Porzellanmasse kann sich bei der heute verfügbaren un[d] hier betrachteten Frequenz von 2,45 Ghz nahezu ideal trans[-]parent verhalten, während sie sich bei etwa 30 Ghz in Minu[-]tenschnelle auf Sintertemperatur erhitzen läßt.

Zusammenfassend lassen sich damit folgende charakteristi[-]sche Eigenschaften von Mikrowellen nennen:

- Mikrowellenergie dringt in das Materialinnere ein
  → Homogene Wärmeerzeugung im Scherbeninneren
- Mikrowellenenergie koppelt direkt im Trockengut ein
  → Schnelle Erwärmung des Materials

3 MW-Erwärmung

Ein vereinfachtes Schema einer MW-Erwärmungskamme[r] zeigt Bild 2. Von der Antenne eines MW-Senders, dessen physikalische Wirkungsweise die Frequenz der abgestrahlten Energie bestimmt, wird diese über einen Hohlleiter in den Applikationsraum eingespeist und über einen Feldverteiler vergleichmäßigt. Die Aufgabe des Hohlleiters besteht in einer möglichst verlustfreien Übertragung und (aufgrund seiner geometrischen Gestaltung) in der weitestgehenden Vermeidung eines Leistungsrückflußes aus der Kammer auf die Senderantenne. Der Feldverteiler übernimmt mit seiner Gestaltung und einer gleichförmigen Drehbewegung die Homogenisierung des Feldes im Applikationsraum. Hohlleiter, Feldverteiler und Kammerwände bestehen aus Edelstahl, also aus einem Material mit nahezu ideal hohem Reflexionsvermögen. Unterlagen für das Behandlungsgut sind üblicherweise transparent. Damit ist sichergestellt, daß die eingespeiste Energie vollständig dem zu erwärmenden Material zugutekommt. Durch das Ausbreitungsverhalten der Mikrowellen und deren ständige Reflexion in alle Richtungen wird das Behandlungsgut von allen Seiten gleichmäßig beaufschlagt – bei richtiger Kammerauslegung auch unabhängig von Zahl und Lage der Einkoppelungsstellen. Das Gut selbst nimmt diese Energie nicht wie bei den konventionellen Verfahren über seine Oberfläche auf, sondern über sein Volumen: Mehr Masse nimmt mehr Energie auf, weniger Masse nimmt weniger Energie auf. Das Gut wird damit gleichmäßig von innen heraus erwärmt.

- Mikrowellenenergie erwärmt gleichmäßig unterschiedlichste Artikelbereiche
  → dickwandige Teile
  → unterschiedliche Wandstärken
  → hintergriffige Teile
  → kombinierte Kern- und Hohlgußbereiche.

4 Die MW-Trocknung

In einer MW-Kammer entsprechend dem zuvor beschriebenen Schema wurde folgender Versuch durchgeführt (Bild 3): In der Kammer (Luftvolumen ca. 0,3 m³) mit vier stufenlos regelbaren Sendern (im Leistungsbereich 5...100 %) befand sich ein 15 kg schwerer Porzellanhubel mit 15 cm Durchmesser und einer Anfangsfeuchte von 20 %, aufgehängt an einer elektronischen Waage. Mithilfe eines Thermoelements wurde die Temperatur im Hubel erfaßt und damit die MW-Leistung so geregelt, daß an der Meßstelle innerhalb von 30 min die Hubeltemperatur von Raumtemperatur auf 60°C erhöht und diese Temperatur dann bis Versuchsende konstant gehalten wurde. Die Versuchsdauer betrug 16 h, die Endfeuchte des Hubels ca. 5 %. Das Luftvolumen war abgeschlossen und wurde nicht ausgetauscht. Die Lufttemperatur lag während des Versuchs bei 30...40°C.

Der Temperaturausgleich zwischen oberflächennahen Hubelbereichen und dem Kern war nach weniger als einer Stunde erreicht, der Bedarf an elektrischer Energie lag bei unter 2 kWh pro kg ausgetriebenem Wasser. Die Trocknungszeit hatte etwa 40 % von der Zeit betragen, die erforderlich gewesen war, um in einem zweiten Versuch einen entsprechenden Hubel mit 60°C warmer Luft auf 5 % Restfeuchte zu trocknen. Bei Versuchsende war die Hubelfeuchte um etwa 15 % reduziert, d.h. um ca. 2,2 kg. Beim Öffnen der Kammertür tropfte das ausgetriebene Wasser von der Kammerdecke, rann an den Seitenwänden nach unten und stand größtenteils auf dem Kammerboden. Auf der Hubeloberfläche standen Wassertropfen wie Schweißperlen. Das Trocknen hatte in einer völlig gesättigten Luftatmosphäre stattgefunden – ohne jede Wasserdampf-Partialdruckdifferenz, die beim konventionellen Trocknen unabdingbar ist.

Sichtbar geworden sind damit unterschiedliche Wassertransportmechanismen bei Warmluft- bzw. Mikrowellentrocknung (Bild 4). Beim Trocknen mit Warmluft erfolgt ein ständiger Austausch von Wärme an das Trockengut (Temperaturgefälle im Gut von innen nach außen) und gleichzeitig eine Feuchtigkeitsabgabe $m'(\Delta p_{H2O})$ an die nicht gesättigte, umströmende Luft aufgrund der Wasserdampf-Partialdruckdifferenz zwischen feuchter Gutoberfläche und der Luft – zumindest dann, wenn die Luft nicht mit künstlicher Auffeuchtung zu Beginn eines komplizierten Trocknungsvorgangs möglichst ohne Trocknungseffekte nur zur Guterwärmung verwendet wird. Bei der MW-Erwärmung in gesättigter Luft fehlt als treibendes Potential die Wasserdampf-Partialdruckdifferenz völlig. Als treibende Kraft wirkt bei dieser Erwärmung von innen heraus das Temperaturgefälle zwischen Scherbeninnerem und Oberfläche: der Wärmestrom, der nach außen gerichtet ist. Dieser Wärmestrom verursacht gleichgerichtet einen Wassertransport $m'(\Delta T)$. In der Literatur existiert für dieses Phänomen der Begriff „Thermoosmose" [4].

Einen derartigen Thermoosmose-Effekt muß man natürlich auch im Falle der Warmluft-Trocknung bei dem nach innen gerichteten Wärmestrom annehmen. Hier wirkt dieser Effekt der Trocknung entgegen – er bedingt einen nach innen gerichteten Feuchtetransport, d.h. beim Warmluft-Trocknen wird die Trocknungsgeschwindigkeit durch die Wärmezufuhr von außen verringert. Damit gilt für die Wassertransportvorgänge im Scherben bei

- Warmluft- und/oder Strahlungstrocknung:
  $m' = m'(\Delta p_{H2O}) - m'(\Delta T)$
- Mikrowellentrocknung mit Luftaustausch:
  $m' = m'(\Delta p_{H2O}) + m'(\Delta T)$

Die MW-Energie bewirkt einen gleichgerichteten Wärme- und Wassertransport, die Trocknungsgeschwindigkeit wird deshalb erheblich höher.

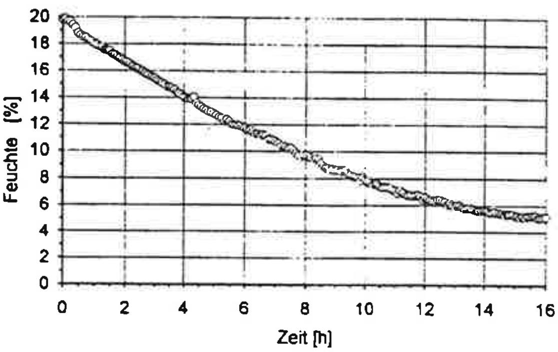


Bild 3
MW-Trocknung eines Porzellanhubels

5 MW-Trocknungsanlagen

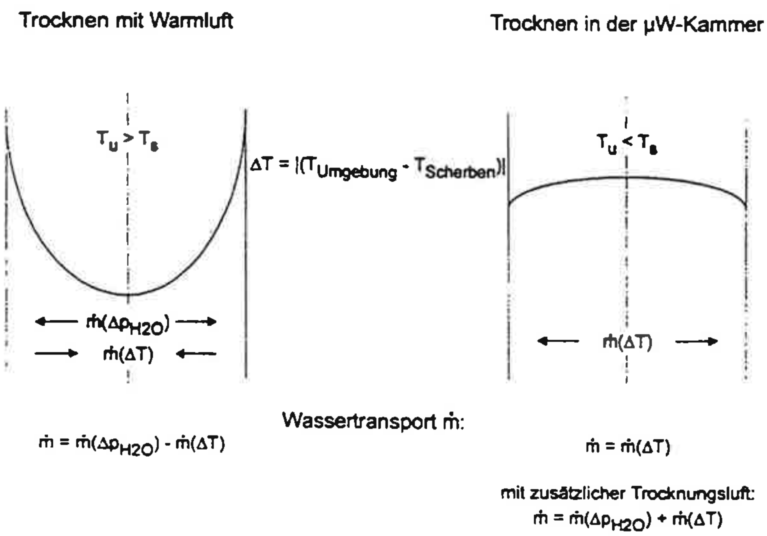
Die dargestellten Möglichkeiten sind bereits in verschiedenen Ausführungen realisiert und im Industrieeinsatz erprobt [5]. Konzipiert und gebaut werden diese Anlagen immer entsprechend den spezifischen Verhältnissen des Kunden und nach Versuchen mit seinen Materialien in den Versuchsanlagen.

MW-Anlagen werden eingesetzt in der Geschirr-, Sanitär- und Technischen Keramik und sind geeignet zum Lederhart- und Weißtrocknen, zum Antrocknen der Gießmasse, zum Gipsformenrücktrocknen und zum Trocknen von neuen Gipsformen [6], aber auch für Entbinderungs- und Aushärtprozesse. Ausgeführt werden sie als Kammer-, Durchlauf- oder als Durchlaufkammeranlagen. Durch ihre Modulbauweise ermöglichen sie eine genaue Anpassung an die jeweiligen Verhältnisse – jetzt und auch später bei eventuellen Kapazitätsänderungen durch Hinzufügen oder Wegnehmen einzelner Segmente. Die vorzugsweise eingesetzten Durchlaufanlagen bieten dank ihrer geringen Abmessungen und wegen des durch sie häufig realisierbaren Wegfalls von Zwischenpuffern und Transportwegen günstige Voraussetzungen für einen weiteren Automatisierungsausbau in diesem Fertigungsabschnitt.

Der schematische Aufbau einer Durchlaufanlage ist in Bild 5 dargestellt. Er entspricht im wesentlichen den Anlagen, die mittlerweile mehr als 40-fach im Einsatz sind und mit denen ein großer deutscher Porzellanhersteller einen erheblichen Teil seiner Lederhart- und Weißtrocknung durchführt.

Eine beispielhafte Ausführung aus dem Flachgeschirrbereich zeigt Bild 6: Zwei spiegelbildlich gleiche Anlagen bestehen

Bild 4
Wassertransport im Scherben bei Warmluft- und bei MW-Trocknung



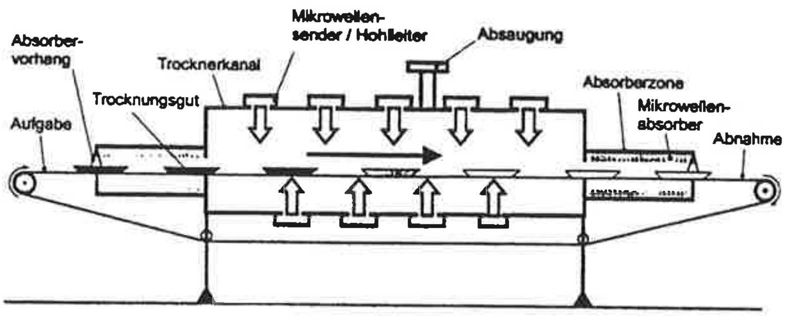


Bild 5
Schema eines MW-Durchlauftrockners

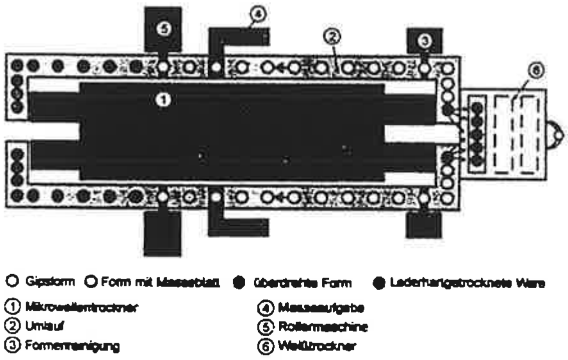


Bild 6
MW-Durchlauftrockner in der Porzellan-Flachgeschirrfertigung

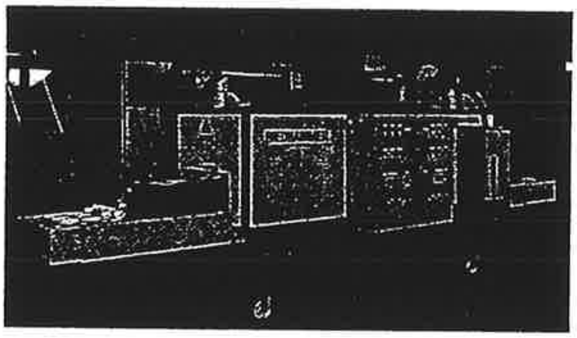


Bild 7
MW-Anlage für Trocknungsversuche

jeweils aus MW-Lederharttrockner, vorgeschalteter plastischer Flachgeschirr-Formgebung und anschließender Übergabestation zur Weißtrocknung. Jede Anlagenhälfte ermöglicht auf engstem Raum die Fertigung von 80 bis 150 Stück/h sehr komplizierter Artikel bei Durchmessern bis 370 mm, wobei gegenüber der konventionellen Trocknung die Bruchquote deutlich gesenkt werden konnte und gleichzeitig die Anzahl der benötigten Gipsformen entsprechend der Trockenzeitverkürzung verringert wurde. Die Trockner verfügen über eine Kanallänge von 10 m, über einen nutzbaren Kanalquerschnitt von 500·250mm (B·H), über 20 leistungsregelbare 1 kW-MW-Sender und über eine Saugzug-Lüftung mit 1000 m³/h. Der MW-Kanal besteht aus 2 und 3 m langen, hochfrequenzdichtverschweißten Edelstahlsegmenten, die mittels speziell ausgebildeter Flansche miteinander verschraubt sind. An Ein- und Auslauf befindet sich jeweils eine MW-Absorberzone, die dafür sorgt, daß die zulässigen Werte für MW-Streustrahlung sicher eingehalten werden.

Nach VDE bzw. IEC 27 dürfen dies maximal 50 W/m² b 5 mW/cm² sein, gemessen in 5 cm Abstand an jeder zugä lichen Stelle der Anlage. Ein entsprechendes Meßgerät z regelmäßigen Kontrollieren der Anlage gehört zum Lief umfang. (Zum Vergleich: Der zulässige Maximalwert li damit noch etwas unter der Strahlungsdichte, die ein Mob funktelefon mit einer Antennenleistung von 2 W bei kug förmiger Abstrahlung in 5 cm Abstand von der Antenne v ursacht.)

Einen weiteren Trockner nach dem gleichen Schema ze Bild 7. Es handelt sich hierbei um eine Durchlaufanlage r 3 m Kanallänge und einem nutzbaren Querschnitt v 500·250 mm. Sie verfügt über 12 regelbare MW-Sender s wie eine regelbare Atmosphärenbefeuchtung. Diese Anla wurde speziell für Versuche beim Kunden entwickelt. D herausragenden Punkte sind:

- Kontinuierliche, stufenlose Leistungsregelung → W che, materialgerechte Erwärmung → Hohe Magnetro lebensdauer (15 000h)
- Praxisgerechte Hohlleitertechnik → Gleichmäßige Fel verteilung → Kostengünstige Ausführung
- Industrieerprobte Anlagenausführung → Über 40 Troc nungsanlagen in der Porzellanindustrie → Zahlreic weitere Anlagen in anderen Branchen

6 Zusammenfassung

Der MW-Einsatz in der keramischen Trocknungstechnik biet zahlreiche Vorzüge gegenüber der konventionellen Praxi Das gilt in besonderem Maße in all jenen Fällen, in den heute vorsichtig und langsam getrocknet werden muß. MV Trocknungsanlagen

- verringern die Trocknungszeit
- erhöhen die Artikelqualität
- reduzieren den Ausschuß
- verbessern den Fertigungsablauf.

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7 Fast firing

Mr. Mori
Mori

MORI SpA - Via Sallustio, 81 – 41 100 Modena, ITALY Tel. 059/335152 - Fax 059/827647

Fast firing and specifically fast firing in Monker kiln.

Mori produces fast tunnel and roller kilns, for the fast firing of heavy clay, which is to say bricks, roof tiles, tiles etc. which are suitable for some specific firing, But Mori believes that the ultimate firing kiln machine is the Monker kiln. In fact we consider as fast firing the fast firing in the Monker kiln. This joins a very fast firing, between two and six hours, at a very high quality. Compared to tunnel kilns we assume that our kiln has no limitations in firing cycle but the composition of body, while on the other hand our kiln can transport all kind of materials with optimum quality of the product. Therefore we consider as fast firing the fast firing in quality and quality in the Monker kiln.

This assumption is confirmed by the results on the kilns in production, which are presently firing rooftiles, pipes and flower pots, results which **are relevant on technological and technical point of view and related to plant and work organisation.**
Let consider for a moment how a Monker kiln is made. We can take for this purpose the picture coming from the computer aided design in three dimensions, used by Mori to develop and study the different Monker kilns.

Monker kiln is the perfect and ultimate mixing of car kiln and roller kiln; where a very thin and resistant tray plays the role of an extremely light car running on rollers only on the side, and so doing allowing the maximum internal width to the useful load on the silicon carbide bars which constitute the tray, while having on the motion on roller the fastest and most continuous firing conditions.

So we have:
Higher frost resistance: this is due to the very fast firing. This very fast firing of three- four hours maximum, creates inside the fired body a prevalence of closed porosity compared to open porosity. This, as you can understand, allows less water entering inside the body when the roof tile is exposed to rain or snow and this gives the higher frost resistance which increases when diminishes the quantity of water that can enter the tile.

Higher mechanical resistance: The slightly higher temperature which compensates the fastest cycle gives also its contribution to have higher mechanical resistance.
Higher mechanical resistance is generated by the distribution of closed porosity inside the fired body. We can find, because of the fast firing, less closed porosity of larger dimensions than close porosity of little dimension but with equal surface. You can easily see how this can bring to higher mechanical strength as you can test easily by making many little holes on a sheet of paper and two big holes onto an equal surface on another piece of paper, the latter will be much more resistant than the former.

The third technology condition that was verified is **the minimum consumption per gross kilogram** passing inside the kiln: this is a direct consequence of the single layer configuration of the piece on the tray. Already in 1957 Mr. M. Korach[1] developed a well known theory according to which consumption is proportional to $s+s_2/l_2$, where "s" is how much the load is tall and "l" how much the load is large. As a consequence we have the minimum consumption since the single layer is the firing condition with the minimum "s".

Best geometrical characteristics are also obtained by single layer firing.

Suitability of 95% of presently used raw materials for fast firing in Monker: as consequence of geometrical possibility to work on single layer Monker best characteristics are also obtained by the single layer firing has the possibility, proved by our laboratory. to utilise the 95% of raw materials presently used. This does not mean that even more tremendous reduction of firing time and consequently increase of production could be obtained in future by elaborating even better raw materials for the purpose of fast firing. This is possible and we are not considering that we have reached a final objective of fast firing.

Another technical characteristic is that Monker fast. firing does not allow the fluorine to come out from the body, allowing the kiln to be a **non fluorine polluting kiln** without the need of cleaner or of an absorber joint with consequent money saving.
The minor quantity of refractory cassettes needed is dramatical and it brings to a minor cost of investments on refractory materials.

Another reduction in costs is coming from the reduction of space required for the plant for plant for same quantity of production obtained. Since it is not needed a space for the car and the tray can be stocked in a simpler way, we have additional savings in money coming from the space not required.

A final advantage is coming from the possibility to produce with the kiln all the time required by the presence of workers in charge of running the kiln, according to the company needs and to have perfect quality of the material immediately since the first roof tile is coming again out of the kiln after an intermittent stop or operating.

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[1] M. Korach, Theorie du Four Tunnel et cuisson rapide "Sandwich". H, 1957

8 Waste heat Recovery

Mr. Graham Small
Ceram Research

The Potential for Waste Heat Recovery

The Potential

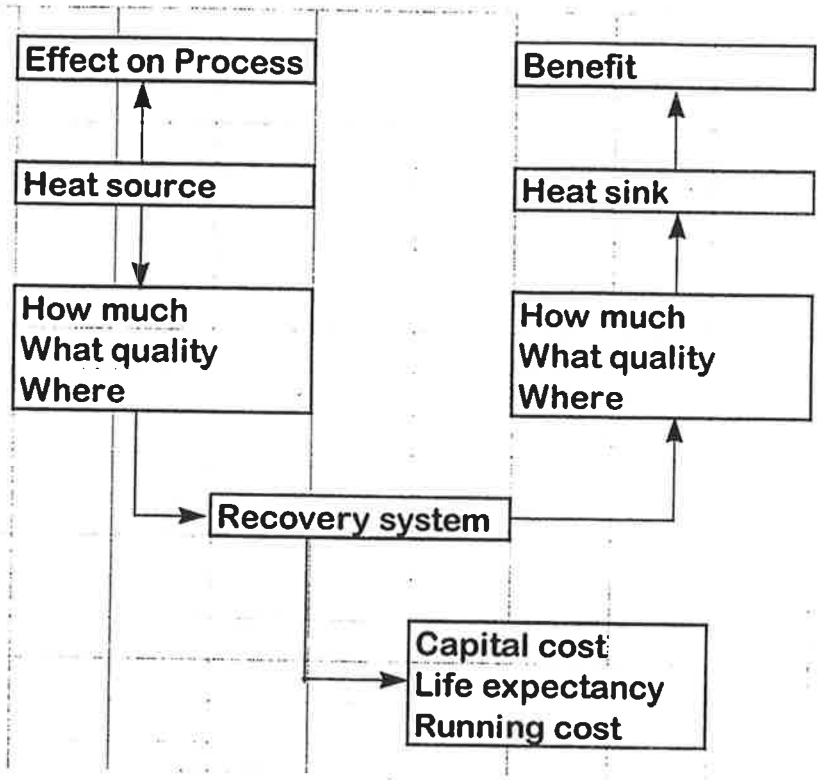
Annual Firing Energy Consumption	Flue Gasses (TJ) Available	Recovered	Cooling Air (TJ Available	Recovered
Whiteware 5,570	2,001	33	1,376	812
Heavy Clay 17,430	6,856	400	4,289	4,000
Refractories	1,336	40	891	557

Examples

- Tunnel kiln
- Cooling air to dryers
- Preheat combustion air
- Heat exchangers
- Heat pump drying
- Recirculation

Forthcoming Case Studies

- Preheating combustion air
- Heat exchanges in flues
- Raising steam with waste heat
- Heat pumps
- Preheating clay or other feed stocks
- Export heat for space heating
- CHP


Effect on Process
Heat source
How much
What quality
Where
Recovery system
Capital cost
Life expectancy
Running cost
Benefit
Heat sink
How much
What quality
Where

9 Energy Potential Scan

Mr. Marcel Engels
TNO

EPS

The Energy Potential Scan

energy- and cost-savings
tailor-made

EPS   EMS

FG

EPS

THE USED ABBREVIATIONS:

- ECA: Energy Consumption Analysis
- EAT: Energy ActionTeam
- PIO: Process Input Output
- EPS: Energy Potential Scan
- EMS: Energy Management Scan

FG

EPS

CONSUMPTION ANALYSIS
EFFICIENCY SCANS
MANAGEMENT SCAN

THE EPS-APPROACH:

1. THE ENERGY CONSUMPTION ANALYSIS

2. THE ENERGY SCANS:

- THE EFFICIENCY SCANS
  - √ PRODUCTION
  - √ UTILITIES
  - √ FACILITIES
- THE MANAGEMENT SCAN
  - √ ORGANIZATION
  - √ INFORMATION

3. THE REPORT/ IMPLEMENTATION-PLAN

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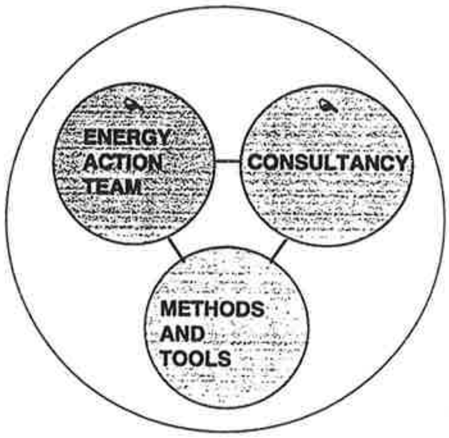
EPS

CONSUMPTION ANALYSIS
EFFICIENCY SCANS
MANAGEMENT SCAN

THREE RELATED ELEMENTS OF THE EPS-APPROACH

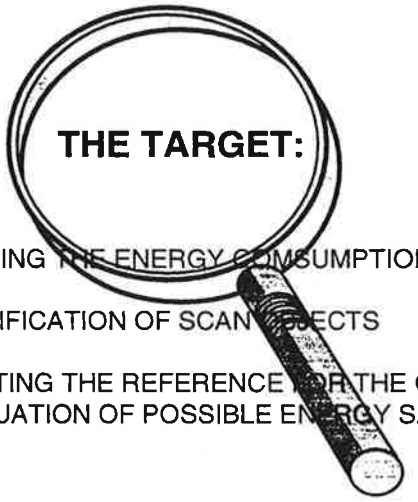


FG

EPS

THE ENERGY CONSUMPTION ANALYSIS:

CONSUMPTIE ANALYSE
EFFICIENCY SCANS
MANAGEMENT SCAN



THE TARGET:

- KNOWING THE ENERGY COMSUMPTION PATTERNS
- IDENTIFICATION OF SCAN OBJECTS
- CREATING THE REFERENCE FOR THE QUANTITATIVE EVALUATION OF POSSIBLE ENERGY SAVINGS

FG

EPS

CONSUMPTION ANALYSIS
EFFICIENCY SCANS
MANAGEMENT SCAN

THE PHASES OF THE ECA:

1. INITIAL ORIENTATION
(ORGANIZATION/PRODUCTION)

2. DEFINING THE ADEQUATE STRUCTURE OF DATA
(WHICH CLUSTERS)

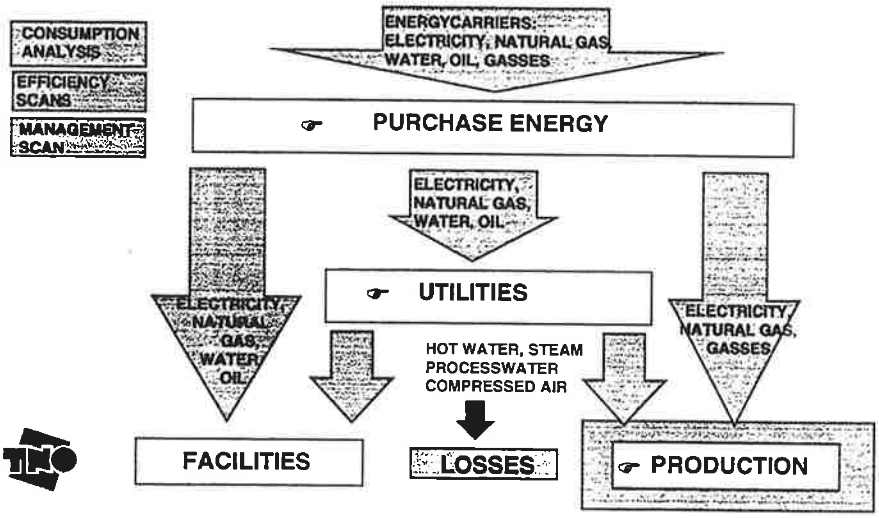
3. COLLECTING ENERGY-CONSUMPTION FIGURES

- **KNOWN**
- **MEASURED**
- **ESTIMATIONS**

FG

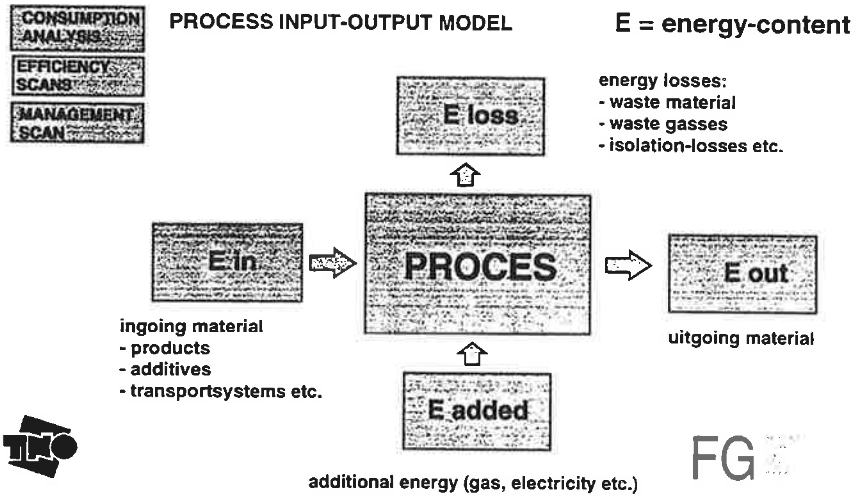
EPS

THE ENERGY CONSUMPTION ANALYSIS:



EPS

THE STRUCTURE OF THE EFFICIENCY SCANS



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EPS

THE PERFORMANCE OF THE EFFICIENCY SCANS:

CONSUMPTION ANALYSIS
EFFICIENCY SCANS
MANAGEMENT SCAN

- DISCUSSION OF THE RESULTS OF THE ECA WITH THE ENERGY ACTION TEAM
- DEFINITION OF THE PROCESSING STEPS TO SCAN
- EVALUATION WHICH OPTIONS FOR SAVINGS
- CLASSIFICATION OF THE OPTIONS FOR SAVINGS REGARDING:
    - % SAVINGS
    - TECHNICAL REALIZATION
    - TIME OF PAY-BACK

⇩

METHOD TO CLASSIFY OPTIONS FOR SAVINGS

FG

EPS

CLASSIFICATION-METHOD OPTIONS FOR SAVINGS:

CONSUMPTION ANALYSIS
EFFICIENCY SCANS
MANAGEMENT SCAN

CLASS :

CURRENT TECHNOLOGY ⇨ NEW TECHNOLOGY

	A	B	C
0 - 1 JR. (index "1")	A1	B1	C1
1 - 3 JR. (index "2")	A2	B2	C2
> 3 JR. (index "3")	A3	B3	C3

⇩

rentability
(pay-back time)

probability of realisation with current technology

A = realisable 90%
B = realisable 50%
C = realisable 25%

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CLASSIFICATION METHOD:

CONSUMPTION ANALYSIS
EFFICIENCY SCANS
MANAGEMENT SCAN

EXAMPLE:

A1 "GOOD HOUSEKEEPING"

↘

B2 LOWERING OF FIRING TEMPERATURE

↘

C3 "FACTORY 2010"

FG

EPS

THE ENERGY MANAGEMENT SCAN:

CONSUMPTION ANALYSIS
EFFICIENCY SCANS
MANAGEMENT SCAN

DEFINING THE POSSIBILITIES FOR AN ENERGY MANAGEMENT SYSTEM

FG

EPS

THE ENERGY MANAGEMENT SCAN:

CONSUMPTION ANALYSIS
EFFICIENCY SCANS
MANAGEMENT SCAN

Defining the possibilities of :
- organization and energy control
- retrieving information

Approach :
- using the ECA results
- visitting the production site, evaluation of data acquisition
- interviews with energy-users and supervisors

Result:
- preparing the implementation of energy management, tailor-made for the organization

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EPS

AND AT LAST:

CONSUMPTION ANALYSIS
EFFICIENCY SCANS
MANAGEMENT SCAN

↓

POSSIBILITIES FOR ENERGY SAVINGS AND ENERGY MANAGEMENT:

IMPLEMENTATION PLAN

↓

SUPPORTING THE IMPLEMENTATION

FG

10 Acoustic Measurement of Temperature and Moist

Mr. Theo Nohlmans
Novem

Acoustic Measurement of Temperature and Moist

'ACTEMP' and 'ACMOIST'

Innovation Handling 1997
Eindhoven, the Netherlands

1

Goal of the presentation

- An unusual temperature and moist measuring principle
- Indication of possibilities
- Accuracy of the system
- System architecture
- Price indications
- Installation, maintenance and support

2

Acoustic measurement principle

- Speed of sound and the gas temperature
- $c(T) = Sqrt\ (20.06\ T)$
- Real-time temperature measurement
- The mean temperature over a line
- Line versus point measurement
- A grid of measuring-lines
- Calculate the temperature distribution
- Take adequate actions for your process

3

Temperature Measurement 'ACTEMP' Properties for the customer

- Every possible temperature range
- Real-time temperature information
- Spatial temperature distributions
- Max. 128 Units are coupled in a network
- System is connected to e.g. a PC
- Accuracy less than 0.1 Kelvin possible

4

Moist Measurement 'ACMOIST' Properties for the customer

- Absolute humidity is measured
- Relative humidity over the full scale from 0% to 100% RH
- Temperature range from -15° to 200° C
- Accuracy e.g. 0.1% RH at 20°C
- Units coupled to a network and PC

5

Matching your needs
main advantages

- unique temperature and moist measurement
- high measuring ranges and accuracy
- system architecture flexible
- data logging central and stand alone
- price-performance reasonable
- increase your process and product quality

6

Some practical Applications
Measure your

- temperature of rotating equipment
- temperature distribution in an oven
- temperature in an air duct

- humidity in a greenhouse
- drying process of bricks at e.g. 140°C
- drying process of parboiled rice

7

Innovation Handling
Our strong points

- Main activity
  developing new ideas to products
- Situated at Eindhoven University of Technology
- Cooperation with industrial suppliers
- Professional installation and support from the suppliers in your application area

8

The Next Step

- ACTEMP and ACMOIST are your partners in *temperature* and *moist* measurement
- take our leaflets
- make us a partner in your problem

- Innovation Handling makes things clever
- Call (++31) 40 243 34 63

9

11 Water and re-use of water

Mr. Han Vugts
Verheijen

Water and re-use of water

Presented by Han M. Vugts
Auxill Separation & Filtration Techniques
In association with Verheijen BV

1

Water
from
abundance
to
scarce resource

2

Do you realize
what the actual costs of water is TODAY?

3

Analyses proces 'cooling'

use of water: protection of saw
cooling
transport of 'dirt'

quality: pump & spray nozzle protection;
temperature;
transport medium

quantity involved: > 2 - 5 m^3/hour

4

Analyses proces 'jet cutting'

use of water: protection of pumps & nozzles;
transport of cutting medium;
transport of 'dirt'

quality: clean water down to 5 μ; temperature;
transport medium

quantity involved: > 1 - 5 m^3/hour

5

The economical and environmental impact of
re-using water usually pays back the investment in proper filtration

6

Costs involved:

- actual water price/m^3
- pumping capacity kW/hr/m^3
- wear & tear/maintenance on pumps, filters & associated equipment
  - labor / spare parts / production down time

7

Costs involved:

- costs of 'filters' and cleaning filters
- disposel costs of
  - used water (bod / cod / suspended solids)
- filter media

8

In order to reduce costs

and operate according to
environmental legislation
analysing your needs is
the first step

9

Analyse

- what is the use of water
- what 'quality' is neccessary for this use
- what methods are available to maintain this 'quality'

10

Common methods of 'filtering' a.o.:

- sedimentation bassins
- sand filters
- physical / chemical processes
- hydro cyclones
- back flush filters

11

Analyse

- the advantages & disadvantages of the selected methods:
  - labor involved
  - energy consumption involved
  - output of the selected method
  - quality of water obtained
  - the neccessity of this quality
  - consider the total costs;
    now & 5 years from now

12

Major use in ceramic industry

Cleaning
cooling of saws
water jet cutting

13

Analyses proces 'cleaning'

use of water: transport of 'dirt'

quality required:

transport medium
no bothering
sediments on
cleaned objects

quantity involved: > 10 m^3/day

14

Analyses proces 'cooling'

use of water: protection of saw
cooling
transport of 'dirt'

quality: pump & spray nozzle
protection;
temperature;
transport medium

quantity involved: > 2-5 m^3/hour

15

12 Economy of masonry in Northern Europe

Mr. Michael Nieuwenhuys
KNB

MN/KK/97.2637

C E R A M I T E C 1 9 9 7
NOVEM LECTURE THURSDAY 16 OCTOBER 1997

"Economy of Masonry in Northern Europe"
Dipl.Arch.Michael Nieuwenhuys
Royal Association of Dutch Clay Brick Manufacturers (KNB)

SUMMARY.

Introduction.
The message about economically advantegeous masonry could be very simple: do it the Dutch way with a cavity wall consisting of inner walls from large calcium silicate thin layer elements, thermal insulation like mineral wool and a cavity for moisture protection, and finally a outer leaf of small facing bricks.
This construction of 350 mm performs a U-value of 0,25.
The average price for this construction for one-family houses is about DM. 175 per m2 in total, which is very competitive.

However, this will not be **the ultimate solution** for the economy of building. Just the problem of skilled workmanship to execute this building method is an obstacle for immediate introduction on a large and traditinal market like the European building market.
A vision is needed to combine both technical developments and commercial interests of the European masonry industry, whereas there is a competition going on between the "massive wall" and the "cavity wall" with a laughing third party and only loosers in the end.

Sustainable economy.
The economy in the building market is commercially based on building prices under construction, whereas for the users the overall life-cycle costs during lifetime are decisive. Facing bricks compared to a rendered wall cost DM. 308.00 per m2 against DM. 235.00, but after 10 years maintenance the facing brick wall has the same price. After 50 years lifetime the total costs are estimated DM.229.00 per year and m2 against DM. 260.00 for rendered walls.

Dead end for traditional massive and cavity wall.
Both technical principles for the massive and **the cavity wall** seem to have reached there limits, mainly because of the extreme thermal insulation requirements. To meet future U-values of 5.0, these constructions get large dimensions of over 400 mm thickness with problems related to sound protection and stability.

Integrated masonry construction of clay elements and bricks.
A solution presented could be a combined construction of highly insulating inner walls of large low-tolerance elements like used for massive rendered constructions, a thermal insulation with or without a cavity depending on the climatic conditions in the region, and finally a outer leaf of clay facing units in high strength and thin layer masonry, resulting in a 350-400 mm construction.

Dipl.arch. Michael Nieuwenhuys

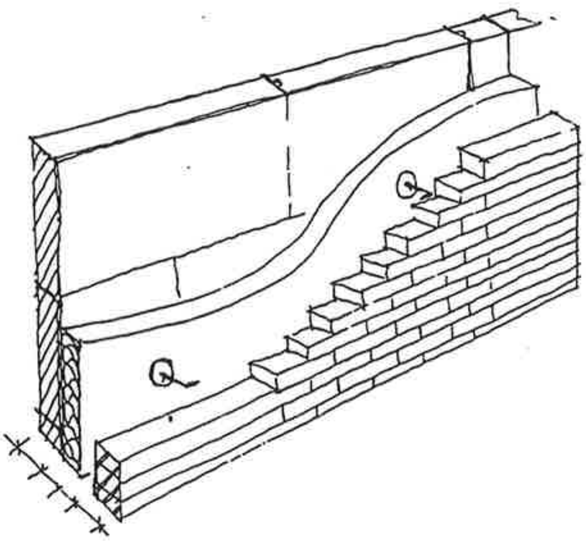
Royal association of Dutch clay brick manufacturers

'Economy of masonry in Northern Europe'

1

Low cost masonry: DM 175/M²

- calcium silicate inner wall
- cavity with mineral wool
- facing clay brick outer leaf



2

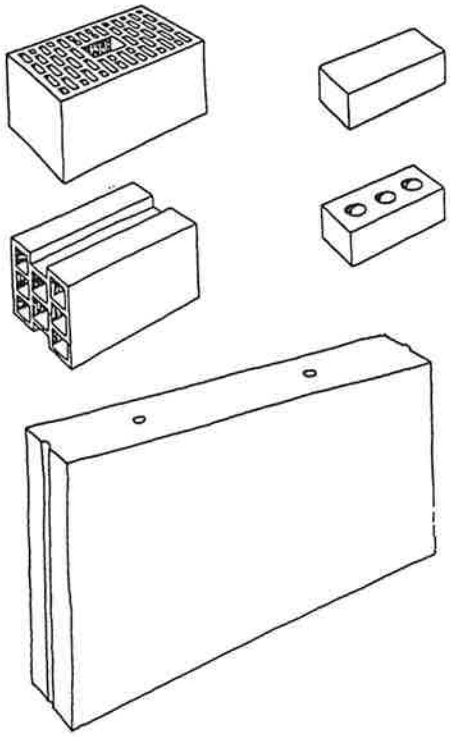
Economy - sustainability:

Building prices + life-cycle costs

Costs in DM per M²	**Rendered wall**	**Facing bricks**
construction	235	308
+ 10 years	865	865
after 50 years life time	13.000	11.500
per year	260	230

3

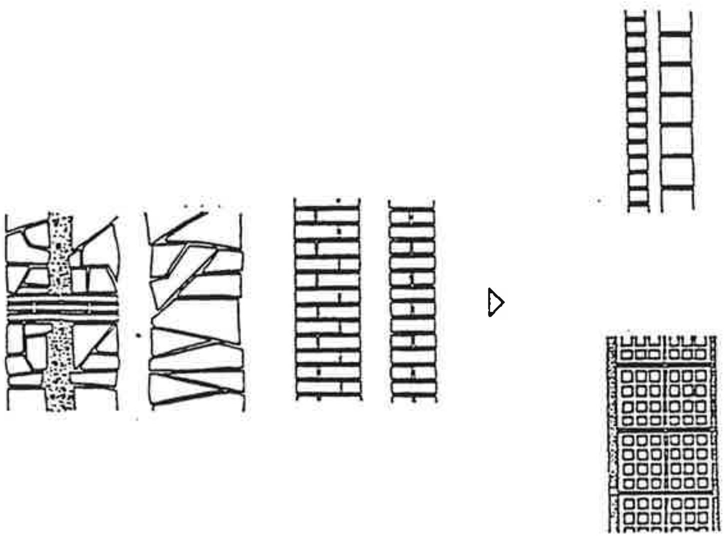
THE EUROPEAN MASONRY MARKET



A DIVIDED EUROPE

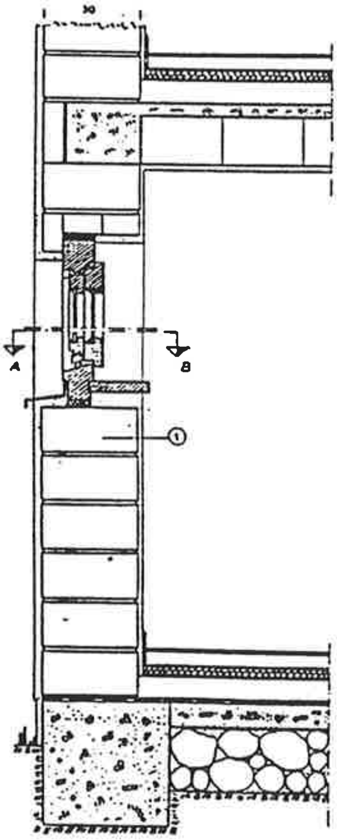
MASSIVE AGAINST CAVITY WALL

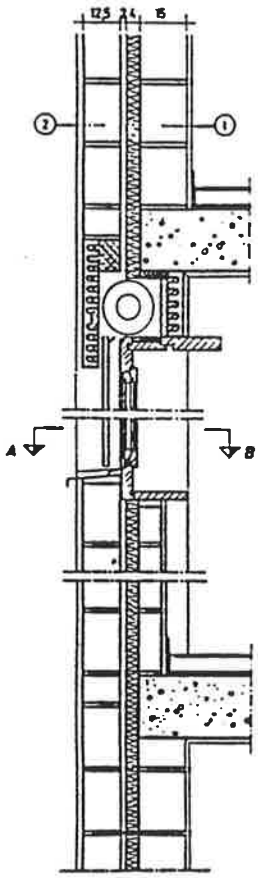
ACHIEVING THE BEST POSSIBLE U-VALUE



THE MASSIVE RENDERED WALL

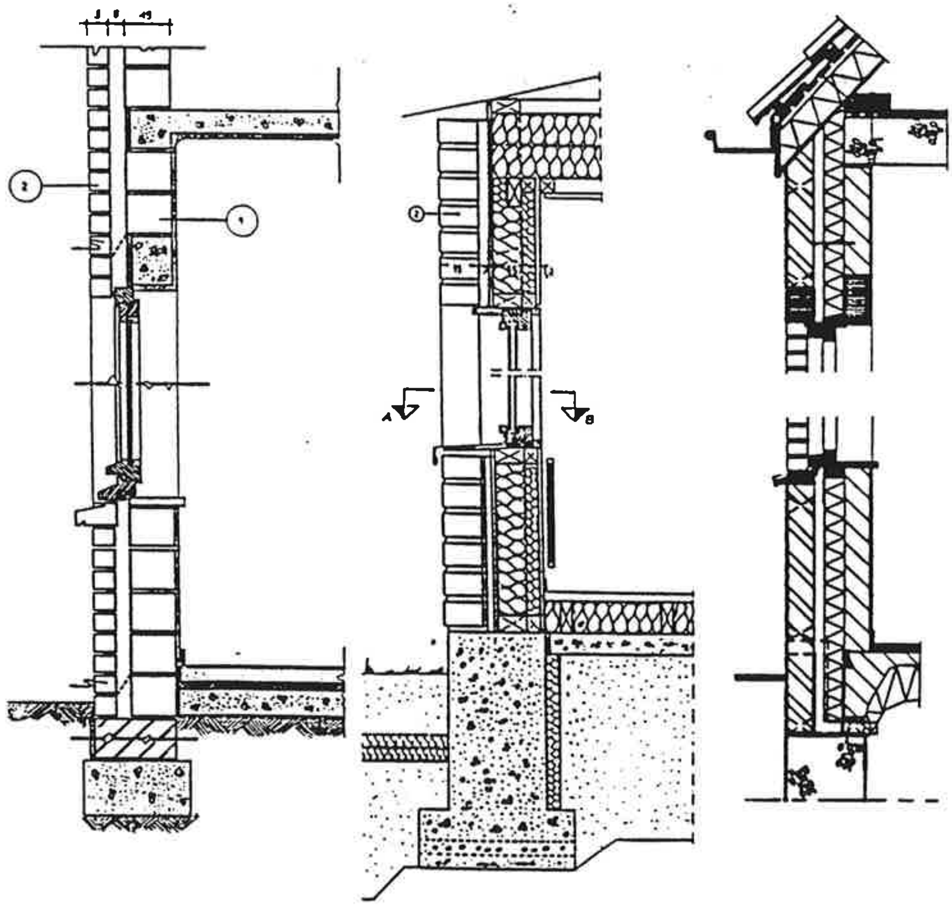
IN SOUTHERN EUROPE





THE CAVITY FACING WALL

IN NORTHERN EUROPE



Threats for masonry:

Higher thermal requirement
U-value down to 0,2

- massive wall 500 mm wide

- low-weight masonry brigs down sound protection

- cavity of more than 150 mm brigs down stability

Non-economic / competitive solution

Changes for masonry:

Technical developments in production (factory) and application (building site)

- large & low-tolerance thin layer elements with high thermal performance

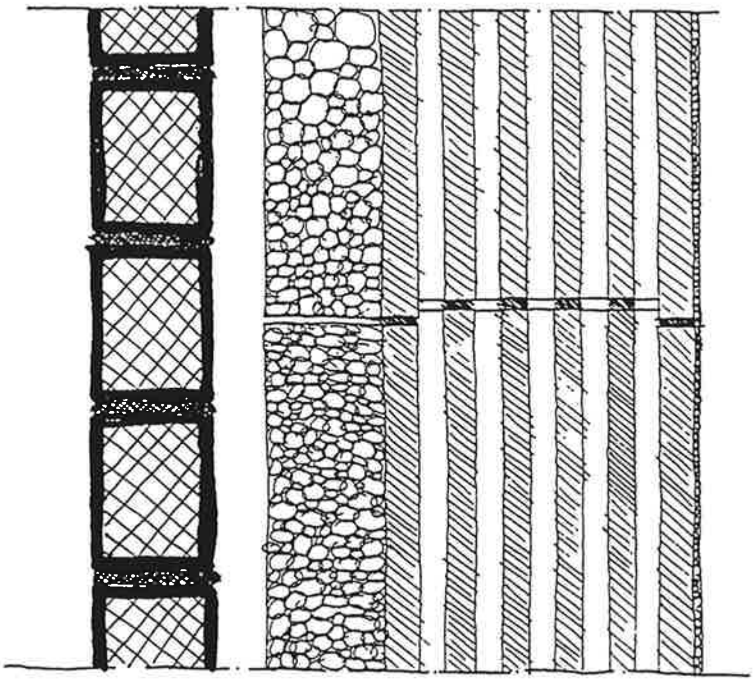
- cellular ceramics as insulation

- mechanized facing brick masonry by a mortar pump with high strenght performance

New economic / competitive solution

UNIFY THE BEST THAT ALL OF EUROPE'S

MASONRY INDUSTRY CAN OFFER



10

New vision on future masonry

For an economic
sustainable
high performance wall

- thickness of 350 - 400 mm
- u-value of 0,2 - 0,25
- low maintenance

13 Introduction of Cerapro®

Mr. Marcel Engels
TNO

CERAPRO®
Ceramic Process Control

The future in ceramic processing is here - CERAPRO®

If you are looking for possibilities to reduce manufacturing cost and raising product quality, reducing energy consumption and lowering emissions, then CERAPRO® offers you the solution. The CERAPRO® concept is a toolbox which allows you as manager to control your production process. CERAPRO® offers your employees custom-made know how to realise their targets.

CERAPRO®
Integral Knowledge Based Ceramic Process Control

The CERAPRO® concept
The application of new technology in combination with advanced statistical approach and automation is an inevitable route for better manufacturing and total process control. The developments on the international ceramics market and the legal demands in energy and environmental management, forces manufacturers of ceramics to produce in a flexible, low cost way, with minimum energy consumption and environmentally friendly. This means that existing technology has to be used as efficiently as possible and that new technologies are gradually being implemented (e.g. fast firing, pressure casting).

The traditional approach of process control is usually inadequate to deal with all the issues related to ceramic processing and, at the same time, to be a basis for the introduction of new technology. Integral process control from raw material to end product is rare.

At the other hand, process control, quality control, energy monitoring and environmental control have a basic common data set. This invites to an efficient approach, which is precisely the CERAPRO® approach, as developed by the Forschungsinstitut für Anorganische Werkstoffe-Glas/Keramik and the TNO Institute of Applied Physics.

The first step in this approach is to activate the existing knowledge within your production-organisation for this purpose. We achieve this by means of an intensive interaction of our specialists with your experts. This creates the basis to structure and save your company knowledge! The result of this first step is a practical process control, custom designed for your organisation.

TNO adds to CERAPRO® even more value. Once the correct set of process parameters has been chosen, correctly measured and statistically or model-based evaluated, our software handles this information clear and concisely. However, an operator or production manager wants more. He wants the domain knowledge and know-how around each process step and equipment easily at hand, which includes validated, reliable, company knowledge as well as public-domain know-how. He wants to retrieve knowledge on defects in material or product (defect diagnosis).
He wants to have standards, regulations, etc. under his fingers.

That's why TNO will build into CERAPRO® the **Navigator**, providing an operator with all the information he needs to complete his tasks. Of course, all this is updated regularly and remotely through datacommunication. Even a videoconferencing link with a TNO or FGK expert can be realised.

Thus, CERAPRO®, conceptualised by FGK and TNO, is a development directed towards the future, but in many ways combining existing technology and know-how. Unique is TNO's capability to use their process models like Drysim and Firesim for advanced model-based control. New technologies will be used wherever necessary. For instance, new sensors may reduce labour cost if they can measure on-line process parameters (instead of hand collection). Thus, CERAPRO® is directed towards

- lowering of manufacturing cost
- increase in product quality (substantial lowering of scrap)
- total process control
- energy saving
- environmental control.

CERAPRO® will always be tailored to specific plant or company needs and know-how. Any CERAPRO® license is therefore company held. The system is open and allows for company-specific know-how and information to be seamlessly combined with TNO and FGK or other third party or public domain know-how. Important is the direct involvement of production personnel and, thus, the transfer of knowledge and know-how leading to a structural improvement of your ceramic manufacturing process. This requires a strong and open partnership.

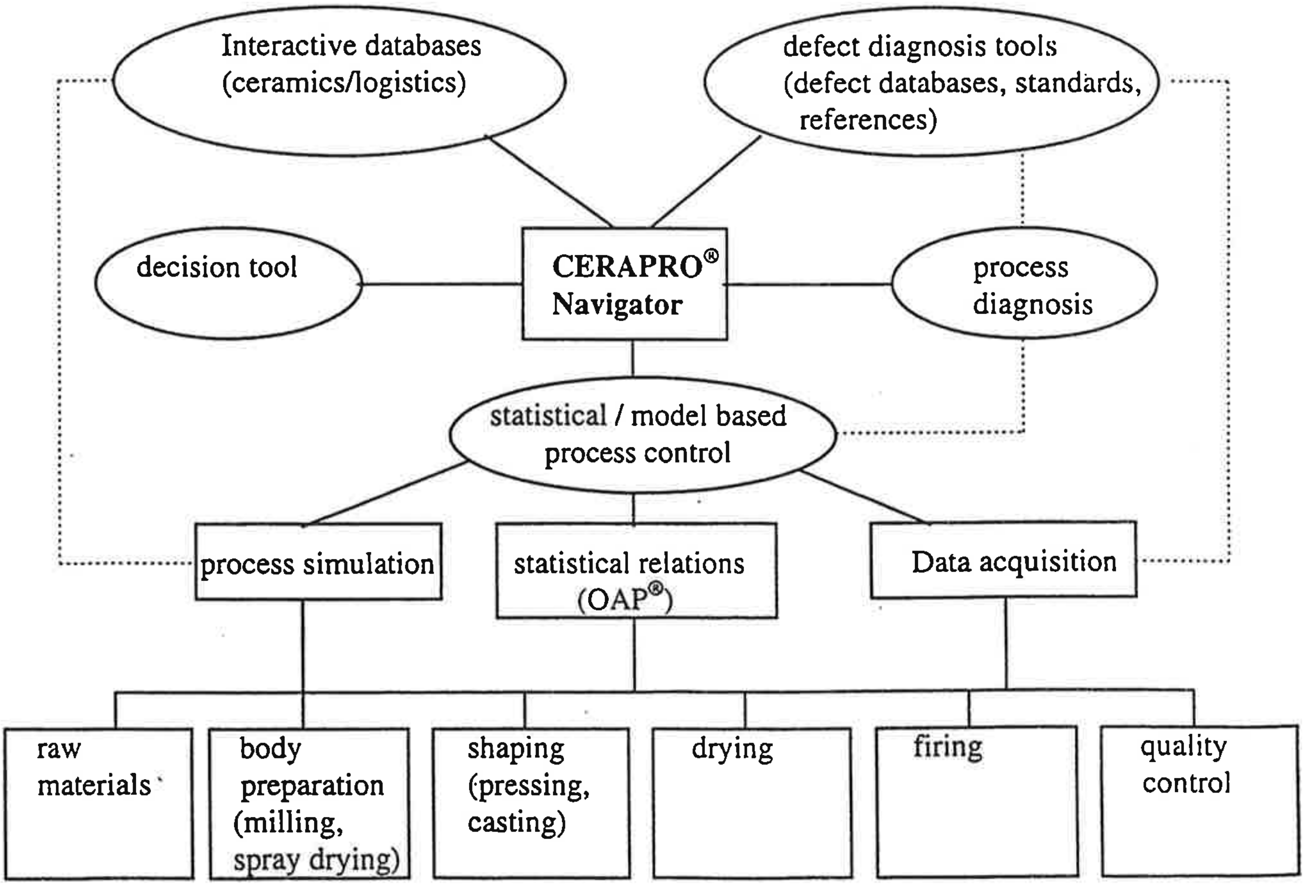
The CERAPRO® concept consists at this moment of three elements:

1. The basis is to streamline the present situation of process control and monitoring. This is performed by a strong interaction between our specialists and your experts, and leads to immediate improvements and profit. TNO/FGK use several existing tools and techniques to realise optimal process control, such as OAP® , the statistical definition of functional relations between the processing parameters. This phase renders
    - which parameters and parametersets to use and how to measure them
    - how to standardise measuring and reporting techniques
    - how to save energy and how to manage it
    - how to rationalise waste water control

2. The additional use of new techniques and tools with the aim of integrated monitoring and control
    - by using statistical process control
    - by using model-based control
    - by using state of the art control automatisation
    - by applying sensors and new measuring and inspection techniques
    - by combining these techniques to a basic control system

3. The heart of the concept: the CERAPRO® Navigator. Installation of a central monitoring and control system, combined with ceramic software, TNO's unique process models, intelligent interactive databases and defect diagnosis. The *CERAPRO® Navigator* combines process control with state of the art information and knowledge management. CERAPRO® Navigator allows for unprecedented ceramic processing standards.

The Navigator takes care of all process control methods (statistical, model-based, etc) and analyses and presents key figures or raw data, as the operator demands. In addition the Navigator provides access to interactive databases and defect diagnosis tools (glaze defects, pressing defects, etc). The system is self learning, in the sense that new data and information continuously expands the know-how base. The Navigator combines routine process control and monitoring with knowledge management. Small smart programmes for e.g. raw material calculations or glaze calculation are incorporated. Company specific data and logistical support are a basic part of the system. TNO's special simulation tools for drying, firing are available for on-line model-based control or off-line process simulation in "What if" cases. Modern hard- and software make this possible, without the need to invent new software technology.



What makes this concept unique is the combination of our in-house experts in all the necessary disciplines, who besides being specialists in their field also have field experience in production situations.
To guarantee the best possible solution for your company, we have the possibility to form a "best team", to create an unprecedented level of added value for each individual customer.

If you are interested in CERAPRO® approach, please contact:

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14 Microwave-assisted firing

Mrs. Ruth Wroe
EA Technology

Microwave-assisted Firing

Ruth Wroe

EA Technology Limited

Group Manager - Materials Processing

Microwave-assisted firing is concerned with combining microwave energy, together with more conventional energy sources, for example, radiant gas or electric heating, in order to process ceramic materials, and components to the high temperatures required for calcination and sintering.

Microwave-assisted firing offers significant economic benefits in the manufacture of high temperature ceramic powders and components. The development of microwave-assisted firing has achieved the goal of temperature control throughout the firing cycle, which, combined with reduced energy costs and significantly increased throughput, results in microwave-assisted firing being an economically attractive process.

The presentation will briefly describe the process, and concentrate on results from the trials which have been undertaken in the last 3 years, including those on the recently commissioned 15 metre tunnel kiln, which capable of producing 15 tonnes of product per day. The trials have covered the entire range of ceramic products, including heavy clay, tableware, sanitaryware, refractories, industrial ceramics and powder calcination.

Conventional Processing of Materials

- In the processing industries most heat is transferred by either convection, conduction or radiant energy mechanisms to the products surface(s), where it is then conducted through the material.
- The materials being covered today can be considered to the thermal insulating.
- This can therefore often lead to long process times, inefficient energy transfer & a temperature-property depencence.

Increasing Throughput

- Processing faster, more effectively and with greater flexibility, is a common goal of the process industries.
- However, with components there is a minimum thermal input required to make the component / material 'fit for purpose'.
- Attemps to increase the troughput rates in thermally insulating materials often fail
  - insufficient heat is inputted in the shorter time period
  - the ΔT through the component exceeds the maximum resulting in excessive thermal stressing

What are Microwaves?

- Microwaves form part of the 'electromagnetic spectrum' -which also includes: visible light, radio waves, infra red, x-rays and ultra-violet.
- Microwaves have more energy than radio waves but less than infra red, visible or ultraviolet light.
- Microwaves can be considered as high energy radio waves - their uses include communication and domestic and industrial heating.
- Microwaves used for heating operate at 915MHz or 2450MHz (FM radio 80-110 MHz).

3

Microwave Heating

- Microwave energy is a volumetric heating source, i.e. the microwaves heat trough interacting with the material of interest.
- Microwave energy offers a potentially novel solution to the problems caused by conduction-based heat transfer within an insulating body, by depositing the energy direcly within the component.

4

Microwave Firing of Ceramics

- Discovered in the 1980's that use you could sinter ceramic materials using microwave energy.
- Resulted in extensive research world-wide, predominantly
  - USA e.g. North-Western and Penn State Universities, LANL, ORNL
  - UK e.g. Nottingham and Staffordshire Universities, EA Technology.

5

Single Energy Source Limitation

- It became very apparent that the main problem with a single energy source, either conventional or microwave in the processing of materials is one of

PROCESS CONTROL

6

Process Control

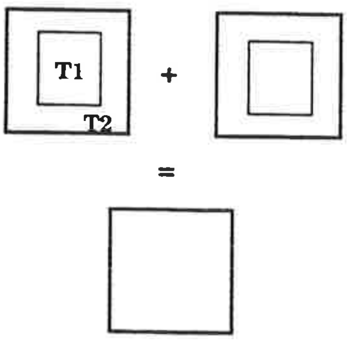
- For effective processing direct control is required over both the product and the environment in which it is being processed.
- Basis of Mirocwave-assisted Firing.

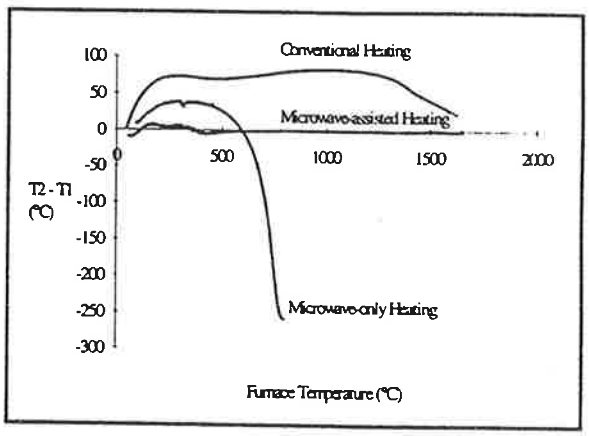
- Combine radiant / convective heating (gas or electric) with a volumetric energy source (microwave) at the same time, in the same furnance*.

- * For furance read also system, e.g. fluidised bed reactor, rotary calciner etc.

7

Microwave-assisted Firing





The key to process control is to combine conventional heating methods with microwave energy in the same furnace and on at the same time

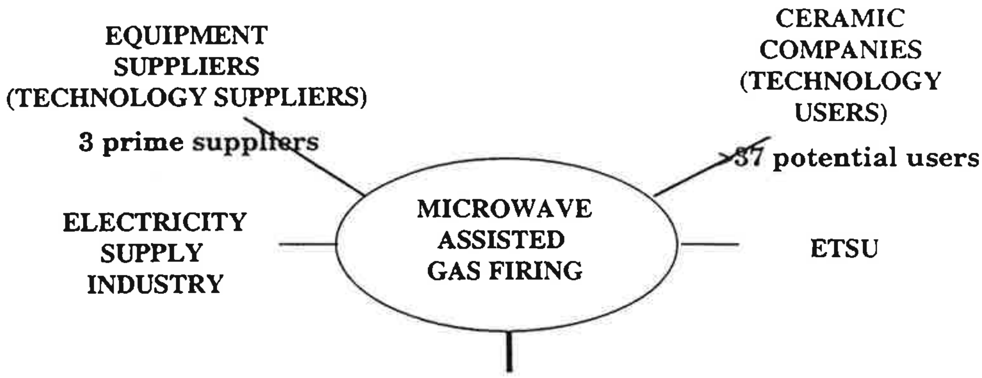
8

MAGF Project

- Commenced November 1993.
- Objectives were to design, build, install and commission 3 MAGF furnaces.
- Prior to extensive testing on customers products.

9

PROJECT STRUCTURE



EA TECHNOLOGY
IPR, MARKETING OF CONCEPT, DESIGN, ENGINEERING MATERIALS KNOW-HOW, THEORY, PROJECT MANAGEMENT, TECHNOLOGY TRANSFER
11 full-time personnel

A VEHICLE BOTH FOR PROCESS DEVELOPMENT AND TECHNOLOGY TRANSFER

10

Furnace #1

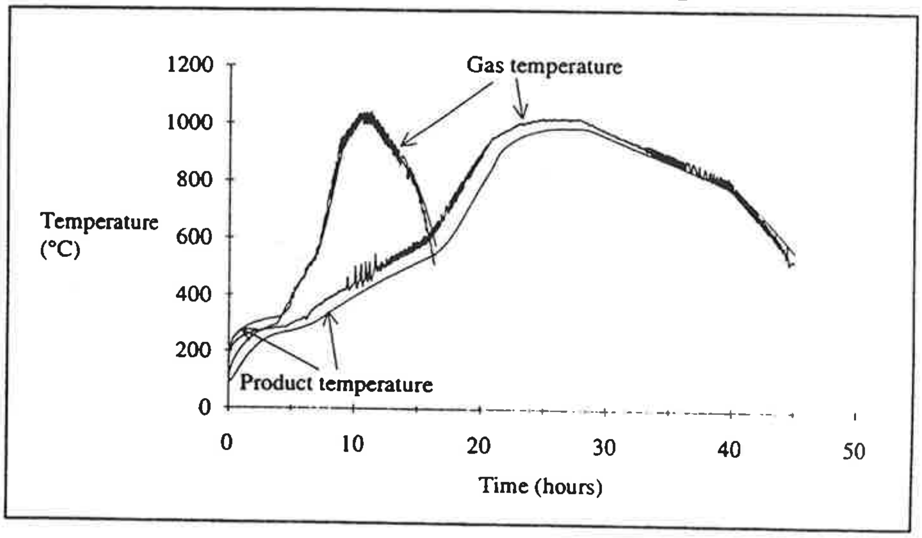
Proof of concept

- Specification - 10kg product to 1650°C, firing with gas only or microwave-assistance.
- Microwave energy supplied by 2 x 2.45GHz magnetrons, 30kWe available from the gas.
- Operating since April 1994.

11

Furnace #1 Results

Time Temperature Data for the Conventional & Microwave-assisted Firings



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Furnace #1 Results contd.

- Time Savings
  - From 46 to 16 hours
- Energy Saving
  - 61%
- Energy Cost Savings
  - 20% (4.5:1)

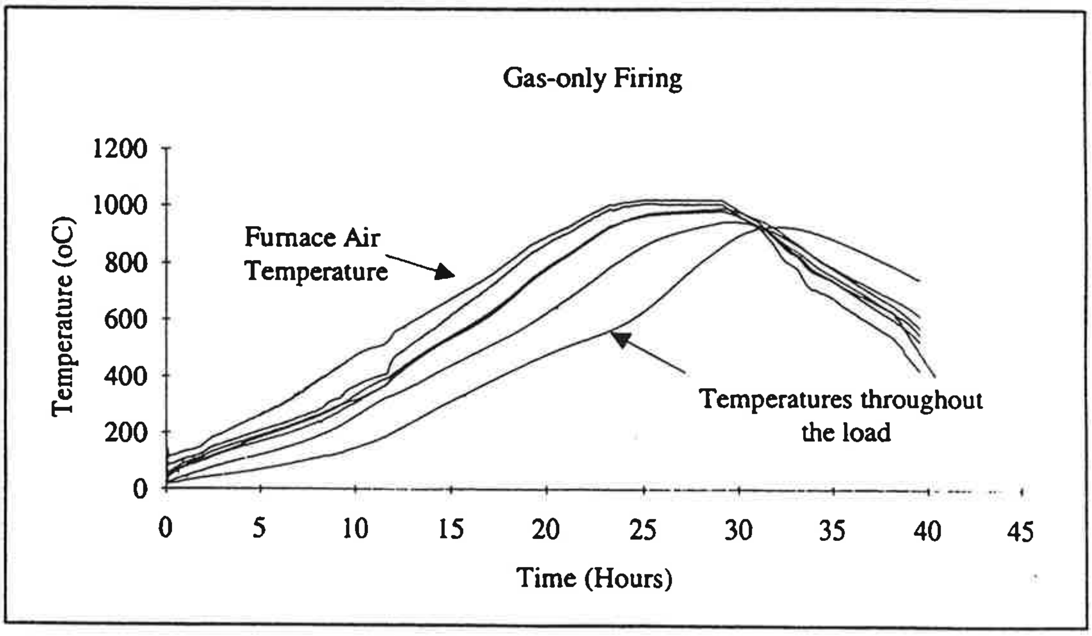
13

Furnace #2

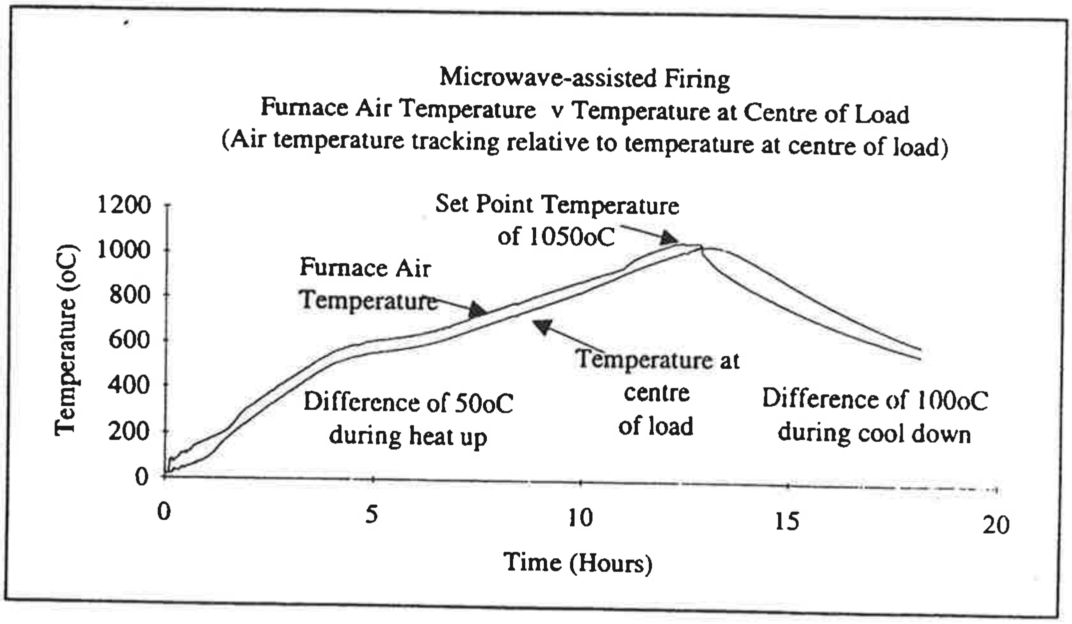
Prototype batch furnace

- Specification - 1 tonne product to 1610°C, firing with gas only or microwave-assistance.
- 540 kWe available from the gas.
- Microwave energy supplied by 2 x 896 MHz magnetrons, 85 kWe in total.
- Operating since September 1995.
- On average 3-7 tonnes of product per week.

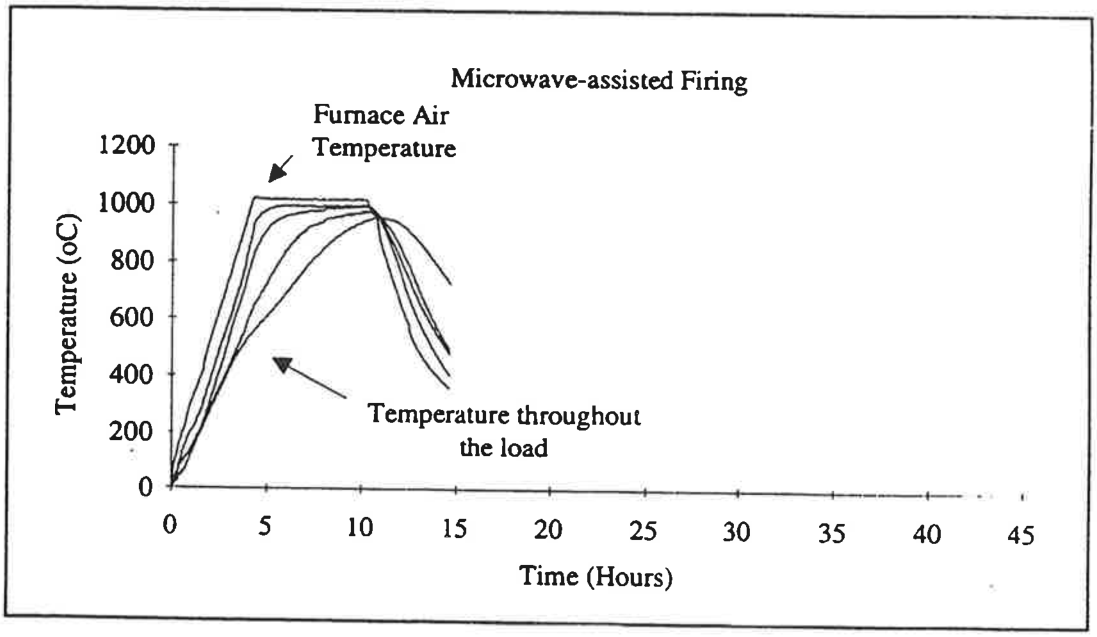
Furnace #2 Results



Furnace #2 Results contd



Furnace #2 Results contd



Furnance #2 Results contd.

- Time Savings
  - From 46 to 16 hours
- Energy Savings
  - 63%
- Energy Cost Savings
  - 18% (4.5:1)

18

Furnance #3 Results

Prototype tunnel

15 metres long - 3 metres wide - 2 metres high

1600°C temperature capability

Installation commenced March 1996

Commissioned July - Nov. 1996

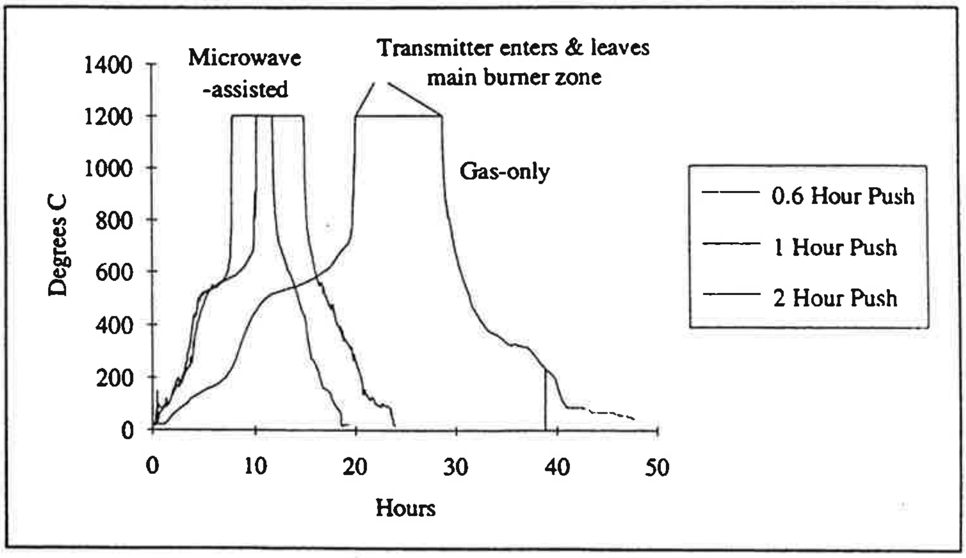
57 tonne product per week using MAGF

19 tonnes per week using gas only

First truly efficient, flexible ceramic tunnel kiln.

19

Furnace 3 Results contd



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Furnace 3 Results Contd.

- Throughput increase with microwave-assistence
  - From 19 - 38 - 57 tonnes per week
  - (125 - 250 - 375 kg/hour)
- Eenergy Savings
  - 43 - 57%
- Energy Cost Savings
  - 19 - 25% (4.5:1)

Products successfully fired

- Heavy clay (bricks and pipes)
- Tableware
- Sanitaryware
- Refractories
- Tiles
- Industrial ceramics
- Advanced ceramics

Demonstrated benefits of microwave-assisted firing include:

- shorter process times - increased troughput
- capital & energy savings
- fluorine emission reduction
- floor space
- FLEXIBILITY
- stronger, harder and more reproducible materials

15 Investment policy in ceramics industry

Hügli Pollock Read
Mr. Rom Bult

Investment policy in the building ceramics industry

the future need for energy-efficient technology

Developments

- from a local, family-owned, traditional to
  an international operating modern process industry
- less companies, more production per facility
- more competition with other materials/systems

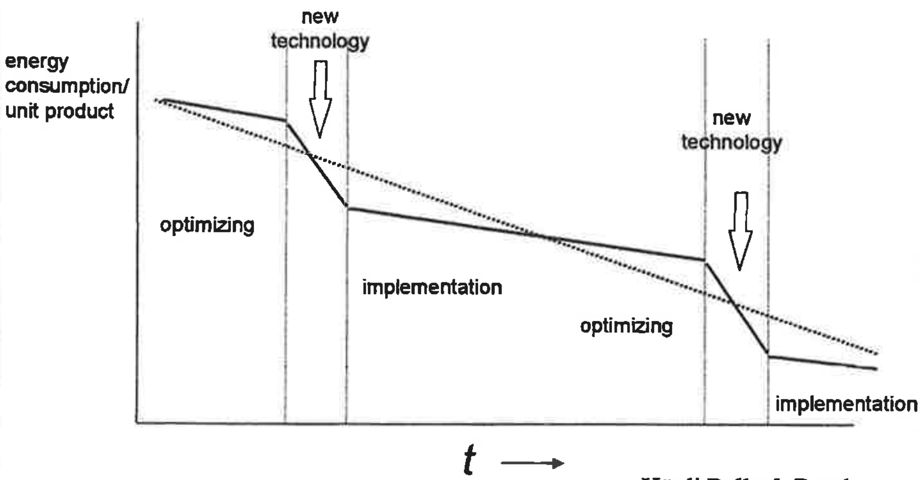
Hügli Pollock Read

Investments in energy-efficiency

- available technology (optimizing):
  - factory oriented, local
  - operational, criteria and decisions
  - short term (cost)orientation
- new technology:
  - company oriented, international
  - strategic
  - long term orientation

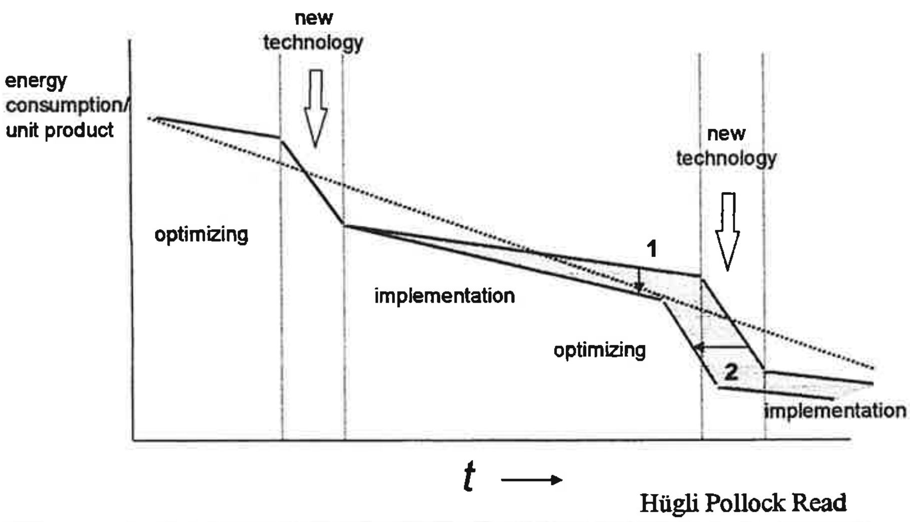
Hügli Pollock Read

Energy efficiency: autonomous development



Hügli Pollock Read

Effects of governmental support programmes on E-efficiency



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Future

- Further upscaling up to (international) company level
- More product differentiation
- Increased competition with other building materials and -systems
- Strategic items 'ceramic industry 2020':
  - Raw materials
  - Energy
  - Flexibility

Hügli Pollock Read

Statement

- Development of new technologies should be initiated by the international ceramic industry itself and not by research centres

Hügli Pollock Read

Statement

- An increasing demand for differentiated products requires production flexibility rather than better logistic flexibility in the future ceramic factory

Hügli Pollock Read

Statement

- Optimizing available technologies will not leed to the necessary substantial improvement of energy efficiency

Hügli Pollock Read

Statement

- National support programmes primarily support optimizing available technologies; Technology innovation calls for an international approach

Hügli Pollock Read

16 Airless drying

Mr. Graham Bird
CDS/Heat-Win

ABSTRACT

In the manufacture of ceramic products the moist clay, usually with a small proportion of other minerals added to it, is either cast, moulded or extruded to form products which must then be dried prior to kiln firing.

When they are dried the products shrink by up to around 10% dimensionally and 27% by volume, which causes cracking, warping or other damage to occur if they are not dried evenly. To prevent such damage by conventional hot air drying, a long and slow process with tight control of the air's velocity, temperature and relative humidity is employed.

During the warm-up phase of the patented airless drying process, the air initially contained in the dryer is expelled and replaced by atmospheric pressure superheated steam generated from some of the product's moisture.

Recirculating this superheated steam through the product settings then results in much faster drying with minimised product damage and with reduced energy input and capital employed, while most of the energy input can be recovered for re-use, either within the dryer or elsewhere.

THE DRYING OF CERAMIC PRODUCTS

Prior to drying, ceramic products comprise around 15 to 20% by weight of moisture and, because the specific gravity of dry clay is around 2.7, approximately 30 to 40% moisture by volume.

During the first phase of drying, the products cease to be plastic and shrink by up to around 10% dimensionally and 27% by volume as moisture separating the clay particles is removed until they come into contract with each other. During the second phase, known as the falling rate period, drying is completed without further shrinkage by removal of the moisture remaining in the interstices between the clay particles.

Figure 1 schematically illustrates the drying process, with each 'X' representing a clay particle, the large 'O's representing the moisture in a moist and still plastic product and the small 'o's the moisture remaining within a fully shrunken, first partly and then almost dried product.

The clay particles 'X' are in practice asymmetric and randomly distributed and, once shrinking is complete, are in direct interlocking contact with each other.

A COMPARISON OF CONVENTIONAL WITH AIRLESS DRYING

During the shrinking phase of conventional drying, the moist product cannot be heated to above the partially recirculated air's saturation temperature, typically around 60°C, and at that temperature both the moisture's surface tension and its viscosity are still relatively high. In consequence, unless the product's surface moisture is removed slowly, giving time for its core moisture to migrate outwards and enable uniform shrinkage to occur, warping or cracking results.

During the shrinking phase of airless drying, the entire product is rapidly and safely heated to 100°C by recirculation of the increasingly high RH air initially contained in the dryer without significant evaporation occurring and without further air being added, while heating the product to 100°C results in the moisture's surface tension becoming virtually nil and its viscosity being substantially diminished.

The 100°C moisture is then able much more easily to migrate outwards from the product's core and rapid evaporation and shrinking can take place without the product warping or cracking. At the same time, the steam generated by the moistures evaporation quickly displaces and replaces the dryers remaining initially contained air.

Once the shrinking phase is complete, the surface of the moisture retreats to below the products surface, enabling the outer layer of clay to come bone dry and porous and the temperature of the dry clay to rise to up to the dryers recirculation temperature.

With conventional drying. The temperature of the moisture remaining inside the product is typically at around 60°C, ie below its 100°C boiling point temperature, and it will not evaporate unless air is at above 60°C, but with a saturation temperature below 60°C is present at its surface. Safe evaporation of the core moisture is therefore a slow process achieved partly by fresh air penetrating the already dry outer layer of clay and partly by outwards diffusion of water vapour through the humid air already present in the outer layer.

In practice, because the high RH and above 60°C air present in a conventional dryer cannot absorb much additional moisture before becoming saturated, a substantially greater weight of humid air than of moisture still be removed must be recirculated through the product settings to complete the drying process, while the controlled addition of ambient air and corresponding removal of humid air transports the evaporated moisture out of the dryer.

By contrast, because with airless drying the core moisture is at 100°C No air is needed to transport it out of the product once it has been evaporated by heat transfer into it of thermal energy from the dryers typically around 130 to 150°C recirculating superheated steam atmosphere. In consequence, as the remaining core moisture is evaporated it simply becomes steam and emerges from the product through its already dry and porous outer layer.

Care still needs to be taken to avoid too rapid heating and the creation of an internal pressure sufficient to cause, for example, blistering of a products smooth outer surface. However, because there is no need as in a conventional dryer for a substantial volume of ambient air to enter the dryer and transport the evaporated moisture away from the product, sage falling rate moisture removal is much more rapid with airless drying.

Figure 2 compares conventional with airless drying processes.

To warm up the dryer and expel the air initially contained in it, that air is recirculated over an indirect heater, through the product setting and back to the heater. This heats the air and the dryers internal components to above 100°C, while the surface temperature and later the body temperature of the moist product rise safely to 100°C.

During this carefully controlled, no dwell warm-up phase:

1. The saturation temperature of the air rises automatically towards 100°C but only reaches that temperature after all product surfaces have attained 100°C. This prevents damaging condensation on them.

2. Steam generated by the evaporation of some of the surface moisture displaces and replaces the air initially contained in the dryer through a vent until, once all product surfaces are at 100°C and the recirculation temperature is above 100°C and the recirculation temperature is above 100°C, that recirculation comprises virtually pure, dry superheated steam.

The product is then quickly and safely dried by recirculating the superheated steam over the heater and through the setting, while the moisture removed is recovered as dimineralised water by condensing the additional steam then generated and vented.

The vented steams energy is also recovered in the condenser and re-used, for example to heat air for use in a conventional dryer or for space heating, or to heat process water. Alternatively, if the vented steam is first compressed to raise its saturation temperature and then condensed in a heater battery located in the airless dryer so that the recirculation passes through it, its latent energy can be re-used to heat the dryer itself.

An airless dryers indirect heater emits an around 250°C flue gas containing approximately 20% of the input energy. This energy can also be used in a conventional dryer or for space or water heating.

Figure 3 schematically illustrates the above process

THE ADVANTAGES OF AIRLESS DRYING

The R&D data extracted from the development and feed back from customers who are now using the technology in their factories confirms the following advantages to the ceramic industry of airless compared with conventional drying:

Energy costs are reduced by between 23 and 85%.
Safe drying times are reduced by 50 to 80%.
The cost of dryers per unit of output is reduced by 13 to 35%.
The floor space needed per unit of output is correspondingly reduced.
The value of work in progress is substantially reduced..
The evaporated moisture is recovered as demineralised water, and emissions are reduced making the process environmentally friendly.

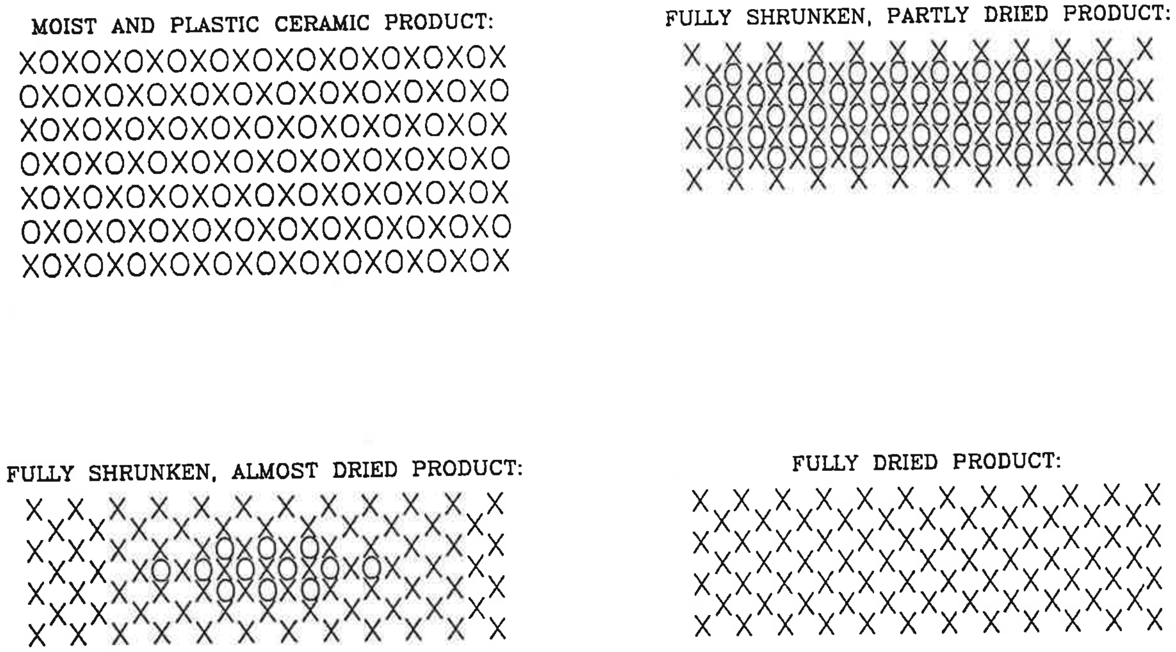


FIGURE 1 – Schematic of a Ceramic Product Drying Process

CERAMIC DRYING SYSTEMS LIMITED

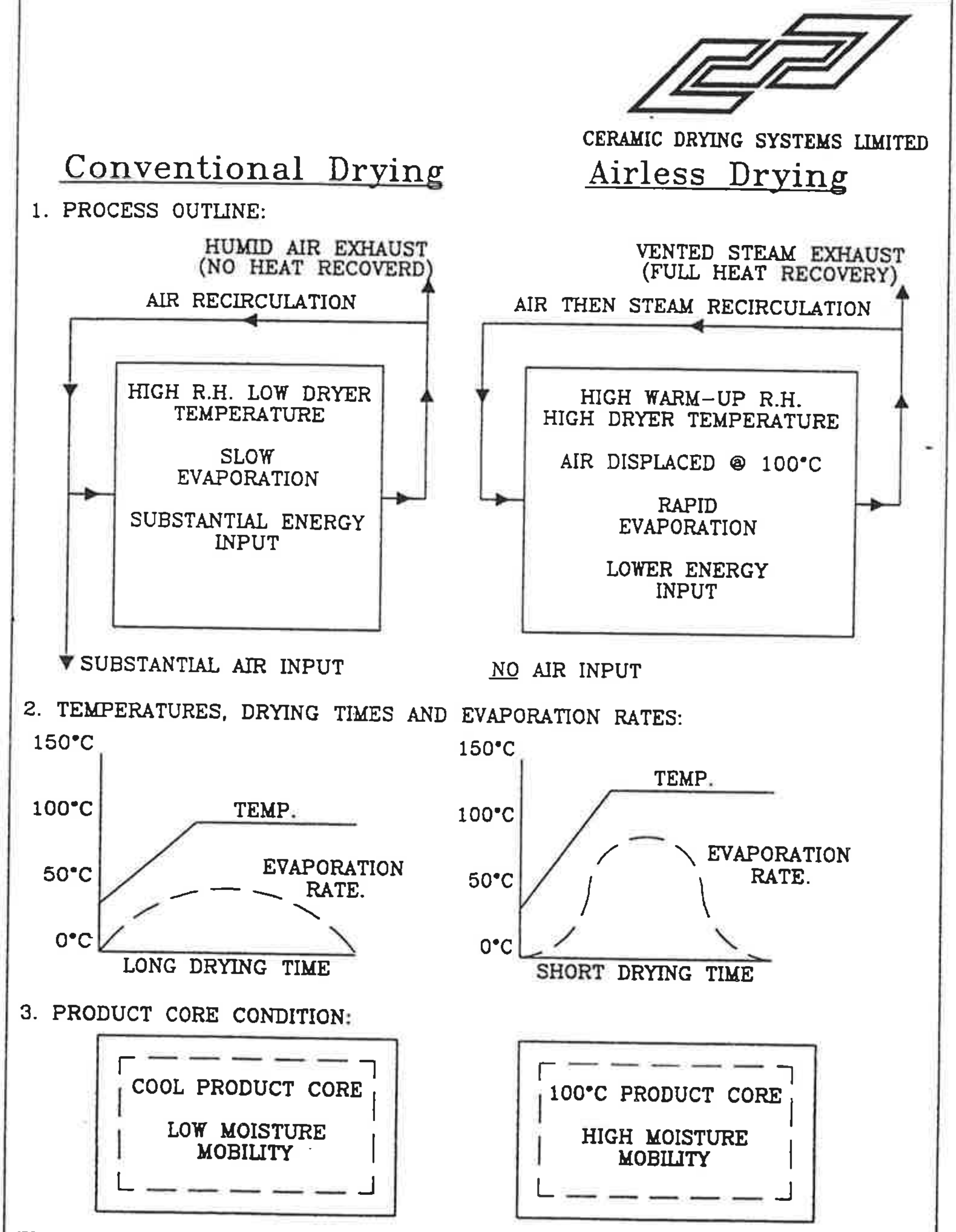


FIGURE 2 – A Comparison of Conventional with Airless Drying of Ceramics

Improving dryer energy efficiency

Dryer energy efficiency can be improved by recovering heat from the vented steam.
Methods which can be used include:

- condensing the steam to supply hot water or generate a supply of hor air for space heating;
- using Mechanical Vapour Recompression (MVR) to recover the latent heat for re-use in the airless dryer (or for other uses).

A schematic of the airless drying process is shown in Fig 3

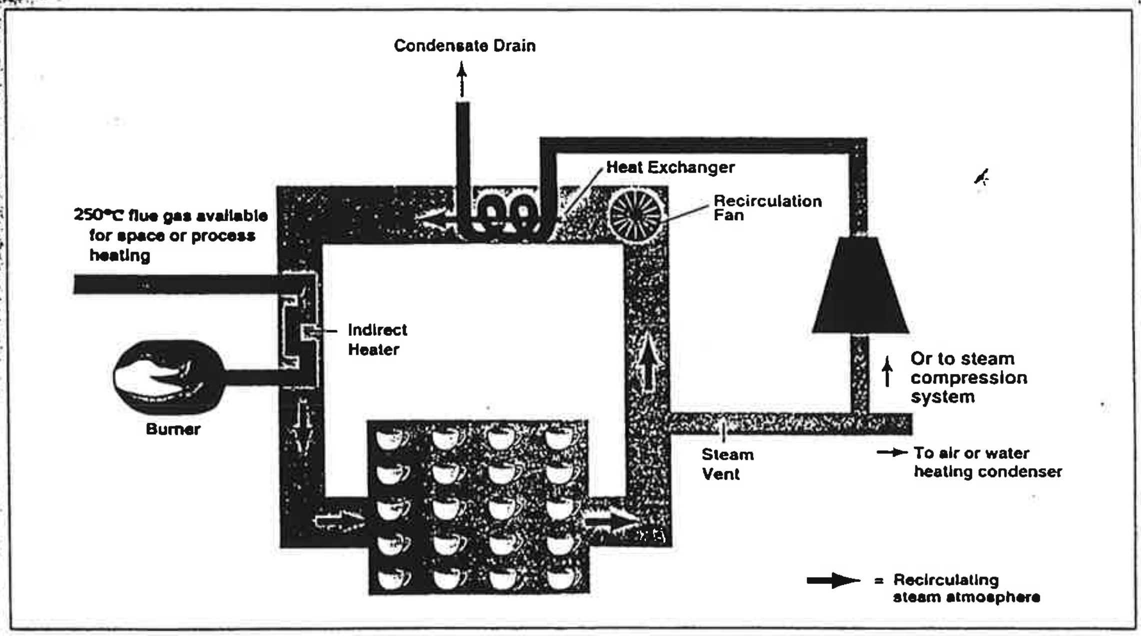
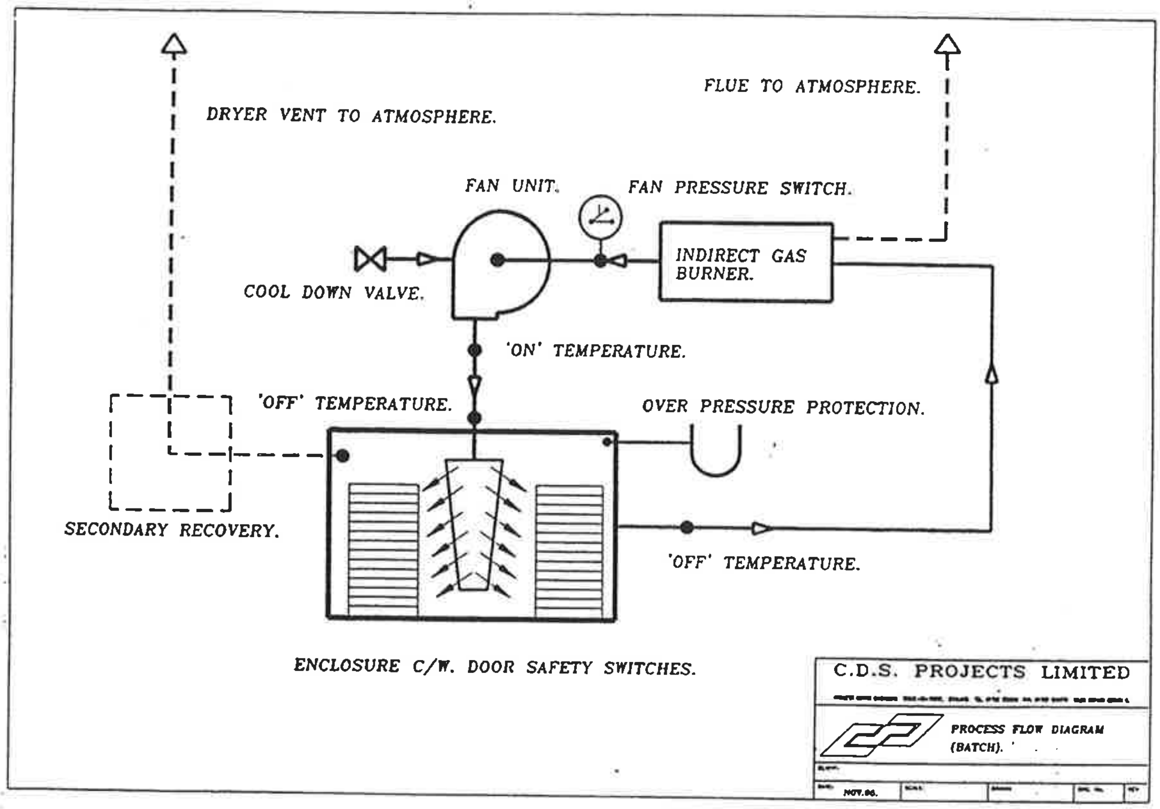


Fig 3 Schematic of airless drying process


DRYER VENT TO ATMOSPHERE.
FLUE TO ATMOSPHERE.
FAN UNIT.
FAN PRESSURE SWITCH.
INDIRECT GAS BURNER.
COOL DOWN VALVE.
'ON' TEMPERATURE.
'OFF' TEMPERATURE.
OVER PRESSURE PROTECTION.
SECONDARY RECOVERY.
'OFF' TEMPERATURE.
ENCLOSURE C/W. DOOR SAFETY SWITCHES.
C.D.S. PROJECTS LIMITED
PROCESS FLOW DIAGRAM
(BATCH).
NOV.96.

17 Leichtaufbauten für den Normalbrand und den Schnellbrand von grobkeramischen Erzeugnissen in Tunnelöfen

Mr. Hesse
Burton

Burton- Leichtaufbauten für den Normalbrand und den Schnellbrand von grobkeramischen Erzeugnissen in Tunnelöfen

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Kurzbeschreibung:

Der Schnellbrand keramischer Erzeugnisse wird in der Fachliteratur oft definiert als die maximale Annäherung der tatsächlichen Brennzeit an die theoretische Sinterzeit des jeweiligen Rohstoffes.Dies erfordert eine optimale Energiezufuhr an jedem Punkt der Oberfläche des zu brennenden keramischen Produktes.
In der Praxis wird dies erreicht durch die Verringerung der Besatzhöhen bis hin zum Einlagenbrand sowie durch eine Auflockerung des Besatzes, um eine optimale Umströmung des Produktes durch die Heizgase zu erreichen.
Gleichzeitig dürfen aber bei der Einführung der Schnellbrandtechnologie andere wichtige Parameter nicht außer acht gelassen werden. Dies betrifft insbesondere die Stabilität und Lebensdauer der Tunnelofenwagensysteme, die einen direkten Einfluß auf die Instandhaltungskosten haben.Ebenfalls von großer Wichtigkeit sind die Montagefreundlichkeit sowie die Zuverlässigkeit der TOW- Systeme im technologischen Prozess.
Diese Forderungen gelten aber auch im gleichen Maße für den Normalbrand, wobei hier allerdings i.d.R. robustere Systeme mit größerer mechanischer Stabilität zum Einsatz kommen.
Die Fa. Burton hat für verschiedene Anwendungsfälle sowohl für den Normalbrand als auch für den Schnellbrand Wagensysteme entwickelt, die bereits erfolgreich im Einsatz sind, und die für die jeweiligen konkreten Einsatzbedingungen des Anwenders als „maßgeschneiderte" Lösungen konstruiert wurden.
Im Vortrag werden einige dieser Lösungen vorgestellt und beschrieben.
Dies sind im Einzelnen:

- eine TOW- Systemlösung für den Brand von Hintermauerziegeln
- ein System für den Brand von Klinkerriemchen
- ein System für den Zweilagenbrand von Dachziegeln
- eine Lösung für den Einlagenbrand von Dachziegeln
- ein System für den Dachziegelbrand in Monokassetten

Mit diesen Wagensystemen ließen sich beim Anwender erhebliche Gewichtsreduzierungen des Feuerfestmaterials im Vergleich zu den bisherigen Standardlösungen erreichen, was in der Konsequenz zu Energieeinsparungen beim Anwender führt.

18 Process Control

Mr. Alan Amison
Alan Amison Associates

Process Control
by
Alan Amison

Alan Amison Associates Ltd
for the
UK Energy Efficiency Best Practice Programme

Alan Amison Associates recently produced a Good Practice Guide for the Energy Efficiency Best Practice Programme describing Energy Efficient Operation of Kilns in the Ceramic Industries. This identifies the importance of kiln monitoring and process control in maximising efficiency and minimising costs and environmental pollution.

The most important factors in the efficient opera6tion of kilns are product yields and quality. The greatest inefficiency of all being to fire a product which cannot be sold.

On a day to day basis it is possible to ensure high yield, good quality and maximum efficiency by setting up combustion systems correctly, optimising the control of the kiln temperature, atmosphere and pressure and by routine monitoring and maintenance.

For these goals to be achieved it is essential that the equipment supplier provides facilities required to make monitoring, analysis and subsequent adjustment of the kiln as simple as possible.

This requires firstly that the supplier is made aware of the facilities that are necessary and secondly that the ceramic manufacturer appreciates that the equipment will offer financial benefits, even though some additional capital cost may be incurred. Such cost can usually be easily justified even when equipment is fitted as a modification to existing plant but is more cost effective when included in new kiln specifications.

Rarely does the standard equipment specification allow the type of product specific analysis, kiln adjustment, and control necessary for optimum performance in all operating conditions.

It is known that the kiln temperature profile has an important effect on environmental pollution so it is important facilities exist which will allow the profile to be optimised for environmental performance for existing products. Optimisation of the profile by adjustments to kiln temperatures and atmosphere, as recipes are modified, should also be possible. This is very much a subject of future work at Alan Amison Associates supported by the Energy Efficiency Best Practice Programme.

The equipment necessary to set up and maintain optimum control, with respect to productivity, efficiency and environmental impact, as product changes, will be discussed.

19 Manufacturing of ceramic blades by power injection moulding

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ECN

SEPTEMBER 1997 ECN-RX--97-056

MANUFACTURING OF CERAMIC CUTTING BLADES BY PIM

ZBIGNIEW S. RAK, PhD
GERRIT SNIJDERS

THIS PAPER WILL BE PRESENTED ON THE 1ST EUROPEAN SYMPOSIUM ON METAL INJECTION MOULDING, PIM-97, DURING THE MUNICH TRADE FAIR, HELD IN MUNICH, GERMANY, OCTOBER 2-6, 1997

This paper will be presented on the 1st European Symposium on Metal Injection Moulding, PIM-97, during the Munich Trade Fair, held in Munich, Germany, October 2-6, 1997.

Abstract

Ceramic cutting blades of differing size and thickness varying between 0.15-0.60 mm are manufactured by powder injection moulding (PIM) using a feedstock based on the yttria partially stabilised zirconia (TZ-3YS) powder and polyacetal-based system. The injection process ensures a high production efficiency, and is followed by a short catalytic debinding process (1-3 h) at the temperatures of 105-115 °C. The sintered blades are machined to the final thickness, and if necessary, undergo an additional heat treatment in reducing conditions to improve the mechanical properties of the product. The influence of the manufacturing procedure on the quality of the final product is discussed. A comparison of the degree of densification, micro-structure and mechanical properties of ceramic knives manufactured by PIM, uniaxial pressing and tape casting is reviewed.

CONTENTS

1. INTRODUCTION

Tranformation toughened zirconia-based ceramics, known as "ceramic steel", but with significantly greater hardness, wear and corrosion resistance than steel, are now on the market for use in increasingly wide applications. These include ceramic blades used as scissors, knives for cutting plastic and metal foils, video and recorder tapes and surgical scalpels [1-4]. The advantage in the use of zirconias in such consumer products like knives and scissors is that they can retain their sharpness and resistance to a wide range of acids and bases. Such tools have been reported to perform better than traditional steel cutting blades due to higher cutting speed limits, un-interrupted cutting and longer life [5].
A new generation of high-performance ceramic cutting tools exhibiting improved properties through microstructural engineering have been made thanks to advances in ceramic processing technology. In the1980's rapid advances in zirconia powder technology resulted in development of tetragonal zirconia polycrystal (TZP) powders, very useful for ceramic blade applications. The powder is a key point in the successful fabrication of ceramic blades. The majority of TZP powders are made by wet chemistry and co-precipitation. The TZP powder is characterised by a fine grain structure, with a precise level of Y_2O_3, to ensure that the metastable tetragonal phase is retained. Low processing temperatures (1400-1450 °C) are used to produce TZP ceramics. The TZP powder provides ceramics of high strength and toughness due to the optimal zirconia particle size and distribution and, as a result of microcracking the amount of metastable tetragonal zirconia phase which can be transformed within the movement of the cracks. The TZP can be made with strengths of around 1000 MPa. The grain size of the sintered product is generally 0.3 μm or less, the material is hard and can be precision ground and polished to within 0.1 μm [5].

The ceramic blades for cutting applications are generally have been made by pressing and sintering, however, recently a number of other shaping techniques used successfully for this purpose, such as isostatic pressing, tape casting followed by lamination and injection moulding. The latter technique looks especially very promising in comparison to the others as it can greatly improve the economic side of the manufacturing process due to very high efficiency, near-net shaping and lowering the cost-intensive finishing of sintered components to a minimum. The production of ceramic knives and scissors originated in Japan. However a lot of interest in this production has recently been observed in Europe as well as in the East Asiatic countries. The Ceramic Group in ECN started the developement of powder injection moulding techniques, in low pressure injection moulding (LPIM) from water based systems and high pressure injection moulding (HPIM) using thermoplastic binders in the late 80's. The HPIM technique was adopted to the production of ceramic blades almost 4 years ago. The technology is continuously advancing.
Other shaping techniques such as uniaxial pressing and tape casting/lamination were tested and the properties of manufactured blades were compared to the products made by the standard manufacturing technique using HPIM and polyacetal based binder systems developed at ECN. The economic aspects of each technology are evaluated. A small production run of ceramic knives, a few thousand per year, is now carried out at ECN. The goal of this paper is to illustrate some critical aspects of manufacturing ceramic blades by PIM and gives a comparison of the mechanical properties of ceramic blades made by different shaping techniques.

2. INJECTION MOULDING OF CERAMIC BLADES

The injection-moulding process consists of various steps, such as compounding, preparation of granulate, injection moulding, debinding, sintering, machining and quality control (Figure 1). The most critical decision which should be taken before the preparation of a feedstock for the injection process is the selection of the ceramic powder and binder system. The introductory work carried out at ECN a few years ago proved that the best, from the sinterability and machinability point of view, is the zirconia powder TZ-3YS (Tosoh) [6]. This powder when used for the production of ceramic blades is characterised by a specific surface area of approximately 6 m^2/g and a mean particle size, $d_{50} = 0.40$ µm (Figure 2). The powder has a narrow particle size distribution [6]. With respect to PIM, this type of powder does not give dense packing of particles in the shaped body [7].

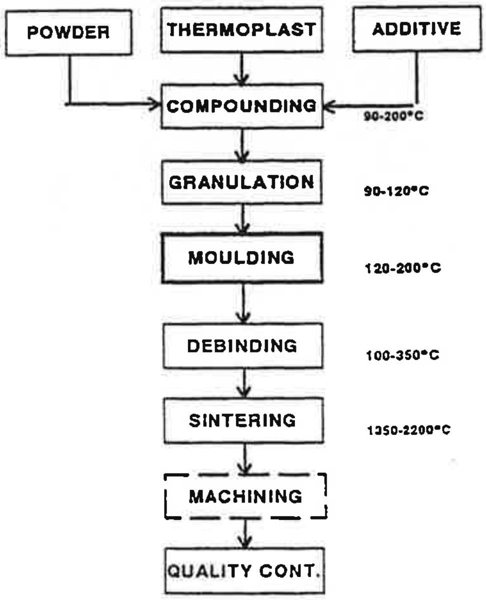


Figure 1 *The HPIM process flow chart.*

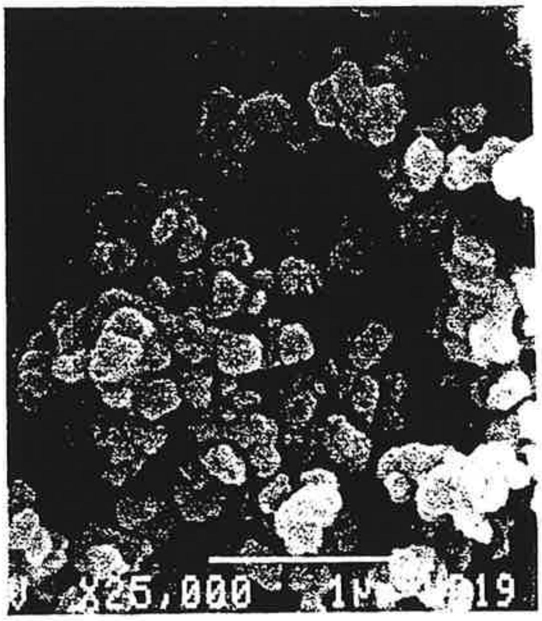


Figure 2 *The morphology of zirconia powder, TZ-3YS grade of Tosoh.*

Organic binder systems are usually added to the ceramic powder to obtain a mouldable mixture with the appropriate viscosity. The binder system constists in general of a major binder, a minor binder, a plasticizer/lubricant and a surfactant for particle wetting. As the major binder, polyacetal polymer, POM - polyoxymethylene (DuPont) was selected. The polyacetal polymer is widely used in the plastics industry and has a property which is a tremendous advantage in PIM; it degradates very easily in an acidic environment. The melting point of the polyacetal polymer used was quite high, above 175°C. The minor binder used was one of the Hoechst waxes with the task of lowering the temperature of the binder system (m.p. 141°C) and regulating the rheological properties of the mixture. As an internal/external lubricant, plasticizer and surfactant one of Montana waxes (m.p. 80°C) was used. The binder system composition consisted of 80-85 wt.% of the polymer POM and of the 10-15 wt% of the mixture of waxes. The optimisation of the binder system to achieve a high vol.% of solid material with good flowability and lowest possible binder content is the crux of the entire process. Thus the binder system displays a high company-specific know-how. The starting raw material composition for the plastization process consisted of 40-45 vol.% zirconia powder and 55-60 vol.% of the polyacetal binder system. Mixing of the ceramic powder and binder system was done in a Z-blade mixer with the temperature between 180-200°C. As-received mixtures were granulated to grain sizes below 2-3 mm in a jaw crusher (Figure 3). The feedstock was used as received in the injection moulding process.

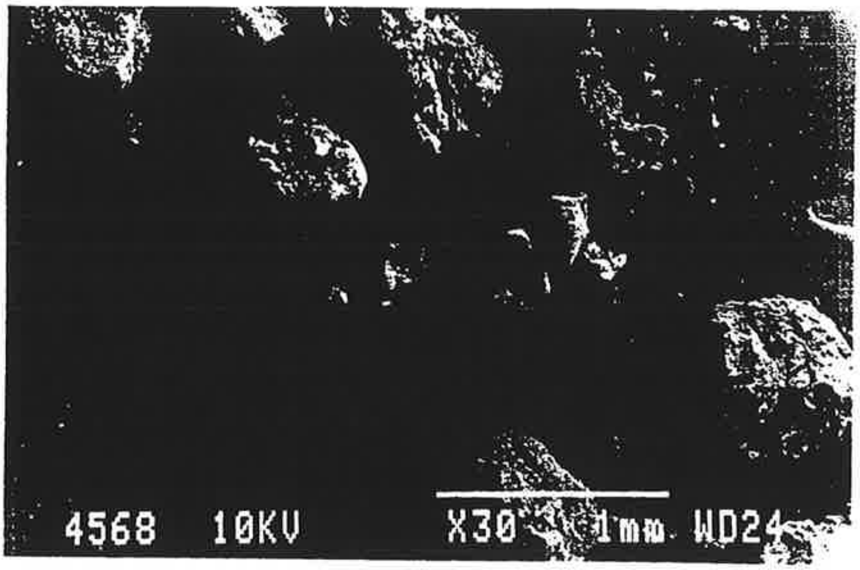


Figure 3 *The granulate for PIM process.*

The injection moulding machine used for the manufacture of the ceramic blades was a microprocessor controlled Battenfeld machine, model BA 350/125 CD plus, with Unilog 4000 closed loop control. A multiple cavity mould, with 2 or 4 cavities, was used. This mould was made as a "mother" mould with a number of exchangeable inserts which allowed for flexible production of ceramic blades of different sizes and thickness and with low tool fabrication costs.

The standard blades in the green stage have dimensions 56.5 x 32.2 x 1.25 mm^3, with 3 holding holes. Blades other types and sizes are also produced, depending on the requirements of the customer. The maximum injection moulding pressure was between 80.0 - 120.0 MPa, the temperature of the injection nozzle heater ranged from 175 to 185°C, and the temperature of the mould was within the range 140-150 °C due to the high specific heat value of the polyacetal polymer, nearly 20,000 J/kg.C at the temperatures between 125-150°C [8]. The productivity of these types of blades is between 800-1000 green blades/8 h.

3. THE BINDER REMOVAL PROCESS

Debinding of the green part is done using the unzipping reaction displayed by polyacetals in the presence of an acid. By exposing the moulded part to a nitrogen atmosphere containing about 1 % nitric acid, the polyacetal depolymerizes and releases the gaseous monomer formaldehyde according to the reaction:

$$--CH_2--O--CH_2--O--CH_2--OH + H^+ \rightarrow CH_2O \quad (1)$$

The polymer is gradually attacked from the outside in at a temperature lower than the melting point of the waxes, usually 105-115°C. The waxes are not attacked and ensure a reasonable strength of the debinded product. The debinding process was performed in a debinding oven, VT 6060/MU/2 (Heraeus Instruments Vacutherm). The time of debinding depends strongly on the grain size of the ceramic powder and the wall thickness of the product (see Figure 4). The debinding time for thin products like ceramic blades is short, and is usually between 1-3 hours.

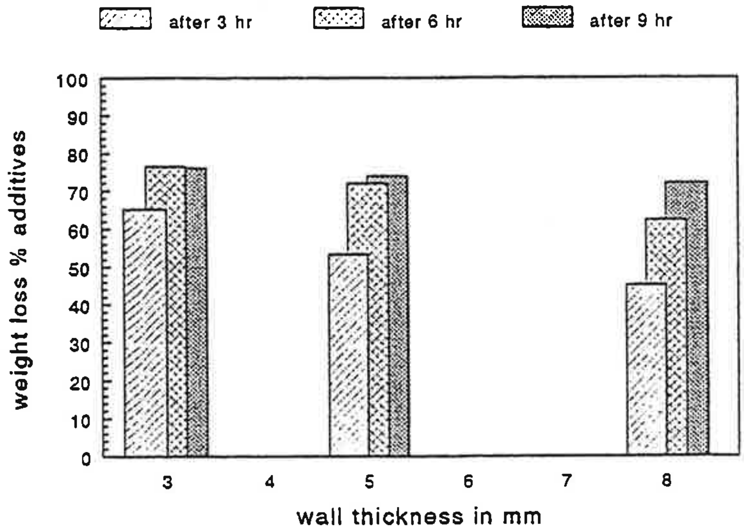


Figure 4 *Dependence of weight loss of polyacetal polymer during the catalytic debinding at 115°C vs. the wall thickness.*

The process is limited by the diffusion of aldehyde molecules to the surface of the product which can be easy calculated [7]. The reaction is diffusion limited towards the end of the debinding process if the mean free path, λ, is much larger than the pore radius, r, which results in a permeation limitation. The mean free path, λ, can be determined by using the equation:

$$\lambda = 1/(\sqrt{2} \,.\, \pi \,.\, M \,.\, \sigma^2) \quad (2)$$

where: M = gas density in molecules per unit volume,
σ = the molecular diameter.

In the case of formaldehyde, σ is taken as twice the C--H bonding length, thus $\sigma = 2.18.10^{-4}$ μm.

M can be calculated using the equation:

$$M = n \cdot N_A \qquad (3)$$

where: n = the number of moles in one unit of volume,
N_A = the Avogadro number = 6.10^{23} molecules/mol.

The latter can be calculated using the Boyle-Gay Lussac gas law for 1 μm^3:

$$N = p/(R.T) \qquad (4)$$

where: p = 10^{-7} $N/\mu m^2$ (= 1 bar)
R = $8.314.10^6$ $N.\mu m/(mol.K)$
T = 388 K (115°C)

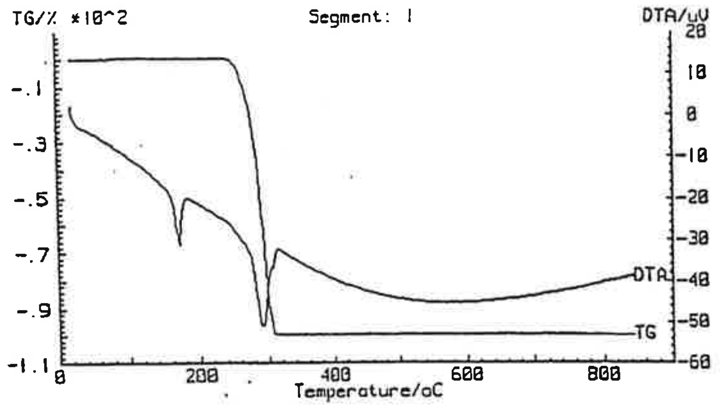
And this becomes : n = $3.1 \cdot 10^{-17}$ $mol/\mu m^3$.
M = $1.86.10^7$ $molecules/\mu m^3$
λ = 0.254 µm.

The pore radius can be estimated by using the equation [7]:

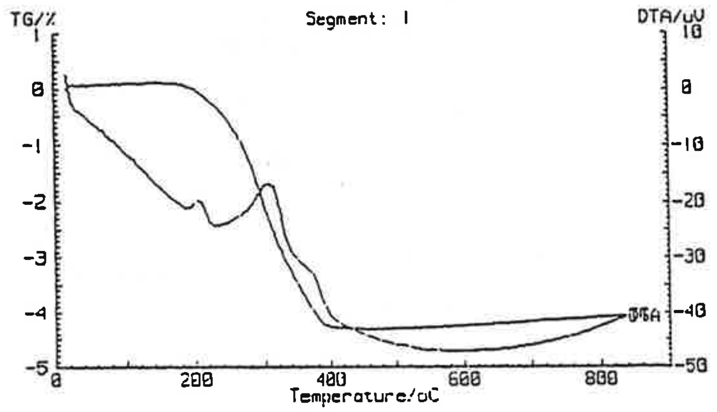
$$r = 0.306 \cdot \varepsilon \cdot d_{50} \qquad (5)$$

where: ε = the fractional porosity of the debinded PIM compact,
d_{50} = the particle diameter below which 50% of the powder is located.

For a typical TZ-3YS zirconia powder compact: $\varepsilon = 0.45$ and $d_{50} = 0.3$ µm.
Thus: $r = 0.413$ µm.
The performed calculation proved that in the zirconia compacts, it is possible to have a diffusion limitation as the mean free path of formaldehyde gas, λ, is much larger than the estimated medium pore radius, r, in the compact.
The measured debinding time for the zirconia compacts was always longer than that theoretically calculated [6]. After the debinding process all the polyacetal polymer was removed from the product. The remaining waxes burn out of the product at temperatures of 400°C during the sintering step (Figure 5).



A.



B.

Figure 5 *DTA and TG curves of polyacetal polymer (A) and the zirconia sample, after the debinding step (B). No residual POM compounds were found. The exothermic peaks present on graph B at 205, 305 and 370°C are typical for the pyrolysis process of the waxes.*

4. HEAT TREATMENT/CHARACTERISATION

After the removal of the binder, the blades were sintered at 1450°C for 3 h in air. Some blades were additionally heat treated in a GPS furnace in a graphite bed under a pressure of 25 bar of argon at 1500°C for 3 h. Other samples were densified in a HIP furnace under a pressure of 1500 bar at 1420°C for 1 h.
Small quantities of ceramic blades were manufactured by the uniaxial pressing (UP)[1] and tape casting/lamination processes (TC/L)[2]. All blades made by different shaping techniques were sintered at 1450°C for 3 h. After sintering (and additional heat treatment) the samples underwent machining and polishing operations and the procedure for shaping the cutting edge. The thickness of machined samples varied from 0.15 mm to 0.60 mm (Figure 6).

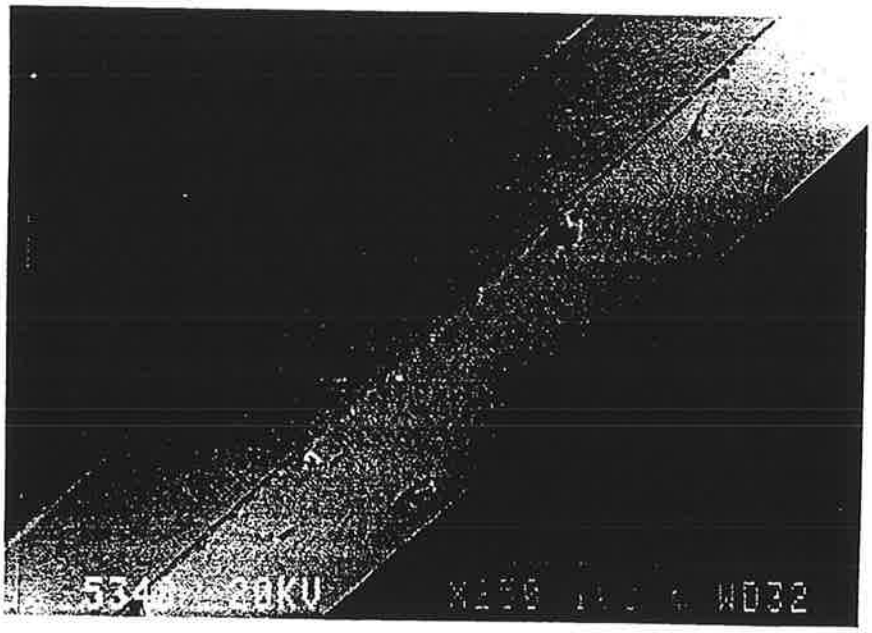


Figure 6 *The cutting edge of zirconia blade made by PIM, 0,15 mm in thickness.*

Densified materials were characterised according to their density, microstructure (SEM), phase identification (XRD), strength in bending at room temperature by 4-point bending test (4-PBT), span 40/20 mm or ring-on ring (ROR), span 20/10 mm, hardness on the cutting edge, Vickers hardness (Hv), load 19.62 N and toughness (K_{Ic}) by the Chevron notch test (CNT) or indentation method (IM), load 98 N. The Weibull modulus was calculated from 10 measurements. The density, K_{Ic} and Hv values are reported as an average value from 3 measurements.

[1] Zirconia powder TZ-3YB under a pressure of 1500 bar.
[2] TZ-3YS powder, acrylic binder system of Rohm & Haas.

5. MICROSTRUCTURE AND MECHANICAL PROPERTIES

Full densification of zirconia sintered blades were obtained using UP and PIM shaping techniques. A slightly lower densification degree was measured for the ceramic blades manufactured by the tape casting/lamination technique and for the samples additionally heat treated in the GPS furnace. In the first case, the tape casting process was still far from the final optimisation, and in the latter case, the lower density of so called "black knives" was attributed to an increase of the amount of monoclinic zirconia and the presence of amorphous intermediate phases from the system ZrO_2-ZrC on the surface of the sample [1]. Ceramic blades sintered under reducing conditions become totally black, in the HIP furnace grey black. The highest density was measured on the HIP-ed zirconia samples, 6.10 g/cm^3, due to the best densification of the product and the presence of the cubic zirconia in the sample (Table 1). The typical microstructure of sintered PIM blades is showed in Fig. 7.

Table 1 *Density and phase composition of zirconia blades made by different shaping techniques.*

Shaping technique	Heat treatment	Density, g/cm^3 (%)	Phase composition
PIM	Sintering in air	6.04 (99.8)	t,m-ZrO_2[3] (90/10)
PIM	Sintering + GPS	5.97 (98.7)	t-ZrO_2, ZrC - surface t,m-ZrO_2 - bulk mater.
PIM	Sintering + HIP	6.10 (100.0)	t,c,m-ZrO_2[4]
UP	Sintering in air	6.05 (100.0)	t,m-ZrO_2
UP	Sintering + HIP	6.10 (100.0)	t,c,m-ZrO_2
TC/L	Sintering in air	6.00 (99.2)	t,m-ZrO_2

The mechanical properties of structural ceramics are very important to their application. The difference in the mechanical properties of the blades manufactured by different shaping techniques were significant, especially the bending strength. The highest strength was measured for the samples made by UP, the lowest for samples made by the tape casting/lamination process (Table 2).

Table 2 *Mechanical properties of zirconia ceramics made by different shaping techniques.*

Manufacturing process	σ[5], 4-PBT, MPa	σ, ROR, MPa	Weibull modulus	K_{Ic}, MPa.m$^{1/2}$	HV, GPa
PIM	480 ± 45	587 ± 98	10.6	4.7 (CNT)	12.5
PIM + GPS	456 ± 25	663 ± 53	15.7	5.6 (CNT)	18.3
PIM + HIP	449 ± 35	-	13.2	5.6 (CNT)	13.2
UP	940 ± 70	-	13.7	4.8 (CNT)	12.6
UP + HIP	1437 ± 136	-	-	5.1 (CNT)	13.5
TC/L	-	483 ± 64	5.0	4.8 (IM)	12.5

[3] t-tetragonal, m-monoclinic form of zirconia
[4] c-cubic form of zirconia
[5] σ-bending strength

An additional increase in strength was observed for the samples additionally HIP-ed, which is understandable due to their superior degree of densification. The HIP treatment did not give such good results in the case of bars made by PIM. The measurements of bending strength made on the as-injected bars were quite low and can be attributed to detected circular flaws within the bars originating from the injection process [1]. The toughness of all samples differently shaped but with similar heat treatment was basically the same. An increase in toughness, nearly 20%, was observed for the samples additionally treated in GPS or HIP furnaces. The Weibull modulus calculated for the blades made by UP was slightly higher than those made by PIM. The additional heat treatment also had positive influence on this parameter. The Vicker hardness was in general not related to the shaping technique, but dramatically influences by additional heat treatments.

VH values in the range of 13.2-13.5 GPa were measured for HIP-ed samples, and increased as high as 18.3 GPa for the samples additionally treated in a GPS furnace under reducing conditions. This phenomenon was explained by a formation of a thin layer, between 10 and 20 μm, of ZrC compounds (hardness 26-28 GPa) on the surface of the blades [1]. Products obtained in this way had properties of typical functionally graded ceramics, as the hardness diminished from the surface to the inner part of the material as a function of the ZrC content . The thickness of the ZrC layer was strongly dependent on the temperature and time of treatment. A similar effect was observed by L. Chin in the case of Al_2O_3-ZrC functionally graded composites used as cutting tool material [9]. A practical conclusions of these observation is that the ceramic blades must firstly be machined to the right thickness before being subjected to an additional heat treatment in a GPS furnace, to avoid removal of the hard, beneficial ZrC layer. Once the ZrC is formed the cutting edge should only be polished gently.

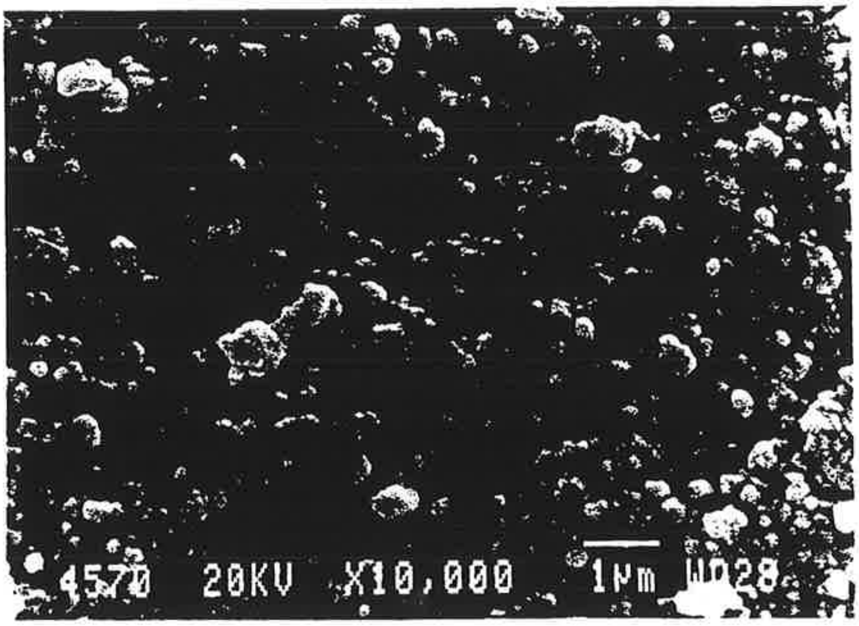


Figure 7 *SEM micrograph of the fracture surface the ceramic blade made by PIM.*

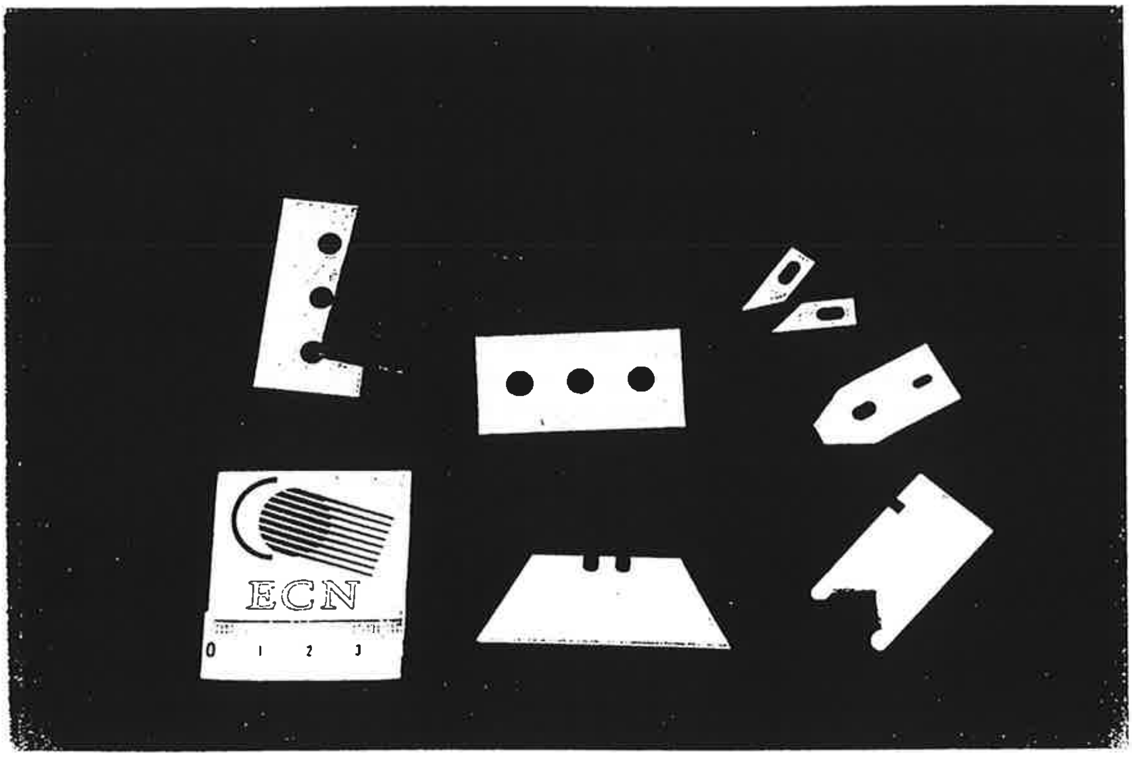


Figure 8 *The ceramic blades manufactured by PIM method at ECN.*

6. REPRODUCIBILITY

The shape and dimensions of the ECN ceramic blades manufactured by PIM (Figure 8) varied from 0.15 to 0.6 mm in thickness and from 10 to 60 mm in width/length. The dimensional tolerance measured on the thickness on the sintered knives (size 45 x 22 x 0.4 mm^3) were held within ± 0.2%, and on the width/length within ± 0.4%. These dimensional tolerances were similar for all sizes of knives manufactured. We noticed that the dimensional variation increases with the magnitude of the dimension. Larger dimensions exhibit larger scatter.

In practice a small variation in size of blade does not have a significant influence on the finished product due to the final machining and polishing operations. The most important factors are full densification of the material, small size of the zirconia grains as well as the small size of defects inside the sintered body. Most important is the machining and polishing process. The service life of the ceramic knife is not only dependent on the mechanical properties of the material, but also very much on the quality of the machining operation. So thin products, such as the 0.1 mm thick blades, can be produced by PIM followed by a suitable machining method. The presented observations are very much in agreement with those results presented by the Scandinavian research group [10].

7. CONCLUSIONS

1. The production of ceramic blades by a powder injection moulding technique is feasible, with a significant cost reduction in comparison to other shaping techniques.

2. The polyacetal-based binder system used ensures a good quality, stiff green product, easy to debind defect free and with very good process economics in comparison to other commercial binder systems [11].

3. The mechanical properties of the products manufactured by PIM are lower in comparison to the material made by unaxial pressing, however this does not significantly influence the service life of the final product.

4. The machining and polishing operations are very important for the good quality and high dimensional tolerances of the final product.

5. Additional heat treatments can improve significantly the hardness (GPS in reducing conditions) or mechanical strength of the product (HIP).

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20 Reduction of Fluor and Sulphur

Mr. Jan Denissen
TNO

SAFE
Sulphur And Fluoride Emission

Jan A.M. Denissen

TNO Institute of Applied Physics
Department of Ceramic Technology

1

SAFE
Sulphur And Fluoride Emission

- What is our state-of-the-art?
- What do we plan in the future?
- Why will we be successful?

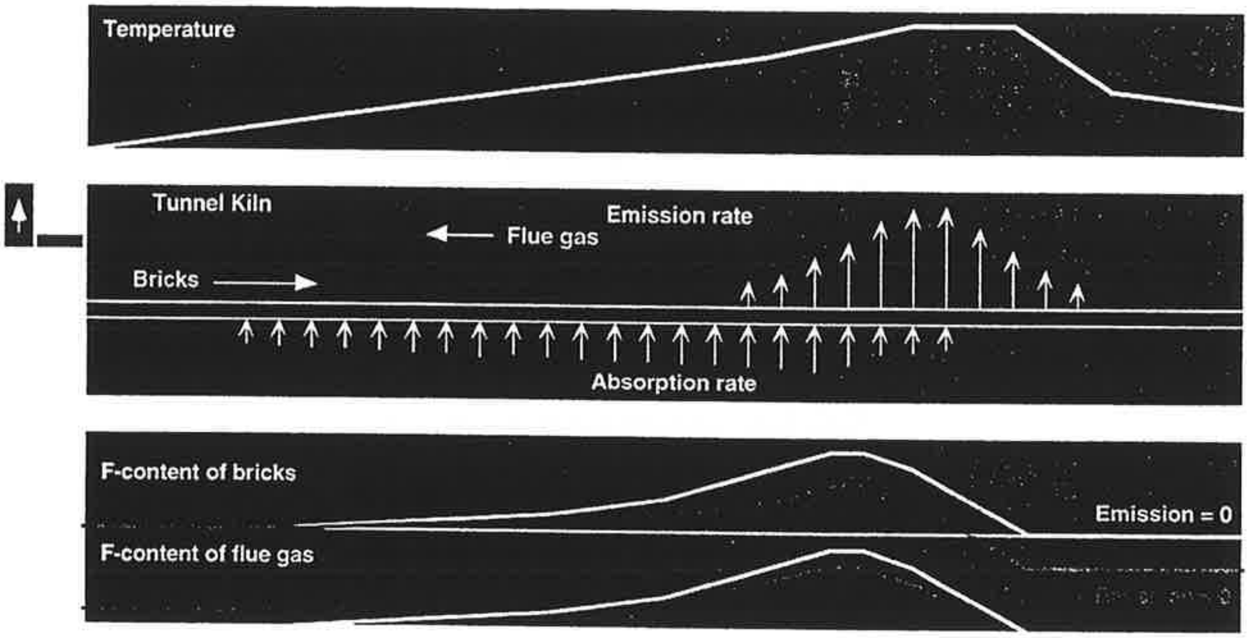
2

What is our state-of-the-art?

- EC project on fluoride emission is finished
- Mechanism of fluoride emission is known
- Several options for fluoride emission rediction are available

3

What is our state-of-the-art?



What is our state-of-the-art?

- Plants with a fluoride emission below 50 mg/m³ have a fair change of getting below the limit of 5 or 10 mg/m³ at low costs
- Fluoride emissions above 50 mg /m³ will probably need larger investments
- Depending on the situation some very low cost options may lead to a large emission reduction

What do we plan in the future?

- Investigation of the sulphur emission process in the same way as fluoride was approached
- Modelling of S and F emission to predict influence of other modes of operation
- Application of project results in European ceramic industry

6

Why will we be successful?

- Know-how and infrasctructure is available
- Modelling of F emission from roller kiln for tiles was successful in a previous project
- Fluoride emission process and Sulphur emission process are very alike

7

21 Utilisation of waste materials

Mr. André de Vries
TNO

UTILISATION OF WASTE MATERIALS

André H. de Vries, TNO Institute of Applied Physics,
Department of Ceramic Technology at Eindhoven The Netherlands

A Solution for the problem of waste materials.

To reduce the problem of waste materials dumping, it is imperative that waste materials should be utilized in an environmentally safe manner either as a raw material for other products or for some other beneficial purposes. While such large quantities of waste materials get accumulated facing very serious problems of safe disposal, the building material industry is on the verge of diversification and it could be possible with the help of the industry to sensibly put to use such waste products into very useful, interesting and cost effective items. The idea of "No Waste" that is accepted and followed in developed countries can be transferred to our situation. However, although there are industrially feasible methods that have been developed and practiced abroad effectively, it is not sensible to exactly imitate those technologies. For example, fly ash is a "Scarce Material" in the Netherlands to the extend they import from other countries. However, the quality of the fly ash differs mainly concerning residual carbon and other fluxes and hence it becomes very difficult to follow same processes for utilization. Hence the situation calls for a definite way of our own thinking to prove the possibilities of an integrated approach for the fly ash and clay based building materials.

TNO is the Netherlands Organization for Applied Scientific Research. TNO's primary tasks are to support industry, the authorities and other groups of the community in technological innovation, and to assist clients in solving problems.

This lecture describes some of the work that has been carried out by the TNO - TPD Ceramic Department. Work that has been carried on the utilization waste materials as alternate for the use of raw materials for building products.

UTILISATION OF CHROME-CONTAINING SLUDGES

Clay based building ceramics have been considered to be the most suited link in the disposal of solid waste materials. The major advantage in the bulk utilization possibilities is due to the large out put in such processes and also the large production practices. Coconut pith has been one of the agricultural waste products, based on which the ' light weight bricks' were developed. Another very significant solid waste is tannery sludge, a waste material produced in India to the tune of 1.50.000 tones containing 5000 tons of Cr coming from over 2500 tanneries out of which about 1200 tanneries are in the State of Tamil Nadu alone. At the moment, they are gathered in the premises of the tanneries itself or used as land fills. The major factor which demands their safe disposal is the presence of chromium mostly as leachable Cr (VI). This implies extensive land and water pollution and threat to living beings in nearby areas. Sinlilar problems exist in many other developing countries where tannery industry exists. How ever, this is one sector which earns extensive foreign exchange to the countries producing leather. Earlier attempts to utilize the sludge as fuel, land fill etc. were not successful due mainly to he leaching of Cr (VI) and any method to utilize sludge in large quantities should primarily aim at reducing the Cr (VI) to nonleachable Cr (1 1 1). Scattered attempts in Italy to make bricks by firing sludge clay mixtures also were unsuccessful because of the conversion of all forms of chromium to Cr (VI) due to oxidation during firing
The problem was primarily taken up by the Department of Traditional Ceramics

(TNO-E) of the TNO Institute of Applied Physics (TNO TPD) The Netherlands and at the building materials group of the Regional Research Laboratory in Trivandrum (RRL-T), (India), jointly with Central Leather Research Institute, Madras, India. Sludge Contain 50-60% organic matter along with salts of sodium and calcium. The chromium content varies from 1.5 to 6.5% as chromium oxide depending on the source. Dried sludge is very hard and cannot be easily ground. Clay-sludge mixtures were made based on calculations of plasticity, shrinkage and fired strength. An extensive method of homogenization of the clay-sludge mixtures was devised wherein the sand present in the clay acted as a grinding medium for sludge. The mixtures were extruded and formed to bricks, dried and subjected to a patented process for oxidative firing and reductive cooling where, the bricks got fired and gained strength and also the chromium got converted to non leachable chromium (III) during reductive cooling. The bricks are black in color and are called TANSLU© bricks. The organic part of the sludge acted as internal fuel. In view of the magnitude of the Indian brick production (approx. 40.000 - 45.000 mln pieces in 1992) processing yearly 90 - 1000 million tons of clay, the application of 150.000 of chrome sludge must be considered as well feasible. For the leather industry the safe processing of chrome sludge's in brick making is a great relief which fits nicely in an integral approach to the solution of its environmental problems.

NEW-BUILDING PRODUCTS OUT OF FLY ASH

The process developed at RRL (T) together with the with the TNO Institute of Applied Research (TNO-TPD), The Netherlands is similar to the adopted in the conventional tile and bricks industry Fly ash is mixed with less than 10% plastic clay and a few additives and pressed tiles or bricks. These shapes are fired in the range 950 - 1000 °C where strong bricks/tiles having brick red color are obtained .More than 85% of fly ash is used in the process. The process is based on formation of low melting flux at the firing temperatures which partly react with the fly ash and form a high temperature reactive glass binder phase for fly ash The flux is controlled to provide just adequate strength and toughness to the fly ash fired product. The unburn carbon is used as fuel. A variety of colors can be made by changing the initial composition. By subjecting to oxidative firing and reduction cooling (OFRC) process, a range of fired colors from brick red to black can also be obtained. the process of flux bonding is patented in India.

COLD BONDED BUILDING MATERIALS OUT OF FLY ASH

TNO has developed a new lightweight building material. The material has been called "KERATON " on the basis of its properties ("ceramic concrete"). The project has resulted in several innovations:

- The material is completely new among building materials,
- Strength is obtained by low-temperature ("cold") hardening,
- Microwaves are employed for the processing.

The material can be produced in a variety of building blocks, depending on local markets and regulations. KERATON consists of cheap and ubiquitous raw materials like aluminosilicates, silica and alkalic components, often as fly-ash and other waste materials. These materials are mixed and a bonding agent is added. Mixed raw material is casted in moulds. The moulds are processed in a microwave oven for about 4 minutes. After cooling and de-moulding the building blocks are ready for transport to the building site. KERATON can be applied as a light-weight material in the house-building industry and utility building, such as stables, barns, garages, etc.

Utilisation of waste materials

André H. de Vries
TNO Institute of Applied Physics
Department of Ceramic Technology

CONTENTS

- Introduction
- TNO Organisation
- TNO Projects in the past
- Utilisation techniques
- Development of new products
- The Chrome Sludge project
- The Fly Ash project
- Our vision

TNO Organisation

The Netherlands organisation for applied scientific research

TNO aims at increasing competitiveness of industries and assists governments with formulation of policy and implementation through:

- Strategic research
- Applied research and development
- Consultancy

TNO Projects in the past

- **Sludges**
  - Harbor, Sewer and Industrial sludges
- **Fly ash**
  - From coal fired power stations
- **Miscellaneous**
  - Waste from industries (coatings, metals)
  - Waste from households
  - Agricultural waste
  - Waste glass

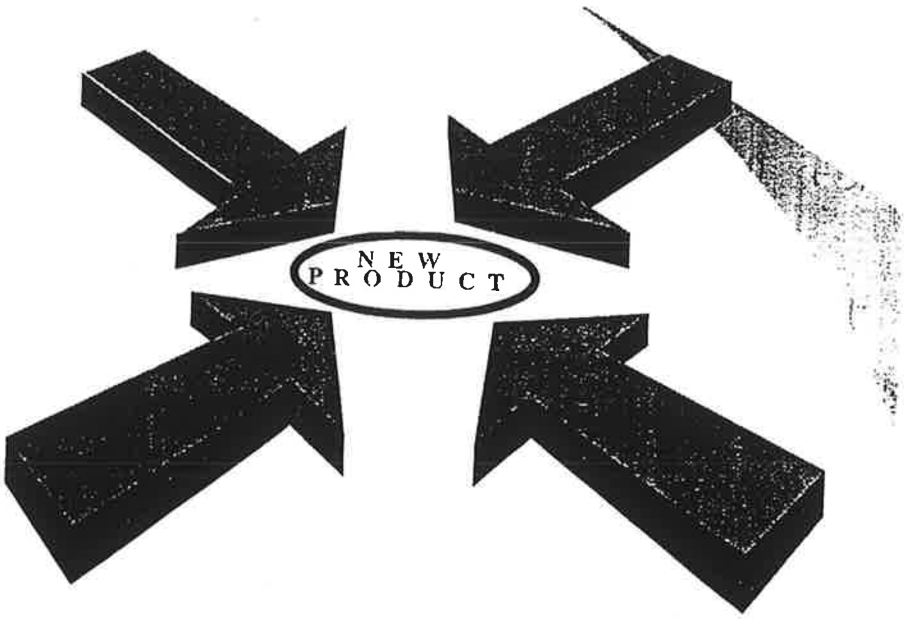
4

Utilisation techniques

- Ceramic immobilisation
- Calcination
- Melting
- Cold bonding
- Modification of the clay body

5

Development of a new product



6

Statements

- The building materials industry is not keen on utilisation of waste materials
- Building materials are not a rubbish-dump
- The producer is responsible for his products
- Environmental care is accepted by the society
- Environmental friendly production can be a selling point
- Government must prescribe the utalisation of waste materials

The Chrome Sludge Project

Safe utalisation of chrome containing sludges in bricks

India produces yearly 150.000 ton Chrome containing waste in the leather industry.

Project objective: to find a safe technology for waste disposal in bricks under Indian working conditions.

Results: A new technology (patented) to use this hazardous waste in Indian bricks.

The Fly Ash project

Fly ash utilisation in India

India produces yearly 40 million tons of fly ash in coal fired power stations.

Project objective: to find a technology to use a high amount of fly ash in building materials for Indian working conditions.

Results: A new technology (patented) to use up to 90% of fly ash in Indian bricks.

Our Vision

- **Make product not worse by waste materials**

- **Develop 'new' products out of waste materials**

- **Develop new products with a team of several disciplines**

22 Heat Pumps

Mrs. Gerdi Breembroek
Heat Pump Centre

Saving energy with Heat Pumps in the ceramics industry

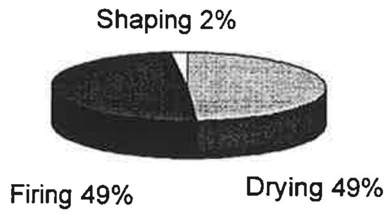
Gerdi Breembroek and Onno Kleefkens
IEA Heat pump Centre / Novem
The Netherlands

Contents

- Energy requirements in Ceramics industry
- Process integration
- Heat pumps - in drying processes
- Application in Dutch ceramics industry
  Subsidized by Novem
- Problems and benefits
- Conclusions

Energy consumption in ceramics industry

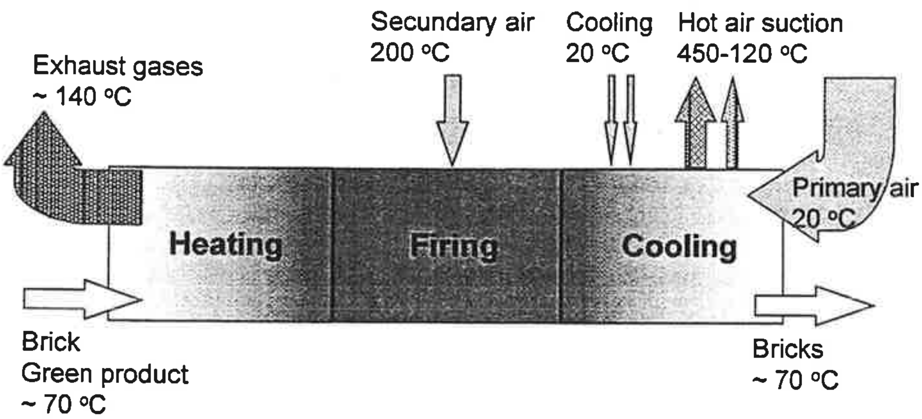
3100 MJ/ton



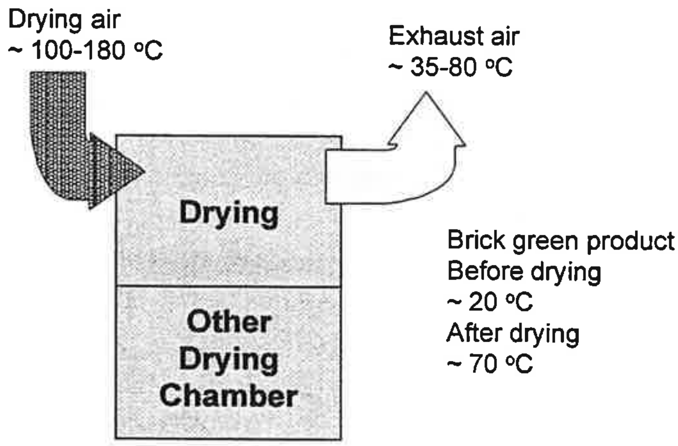
waste heat
firing
for drying

- **Drying**
  Temperature 40 °C - 95 °C
  Mostly charges in chambers
- **Firing**
  Temperatures up to 1200 °C
  Heating, firing and cooling zone
  Continuous operation

Kiln heat, general case



Drying flows, general case



Process integration

- **Pinch studies ceramics process:**

  (heat demand and heat surplus at all process temperature levels)

  Kiln has heat surplus below 600 °C (mostly below 200 °C)

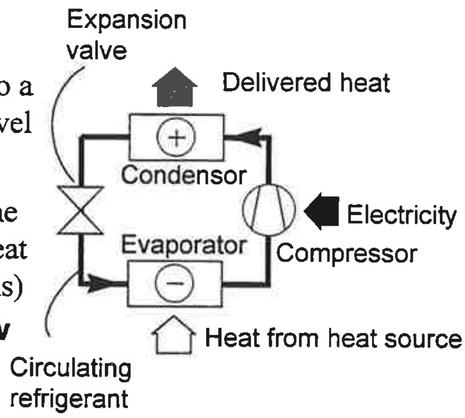
  Dryers have heat demand above 60 °C; surplus below 60 °C

- **Towards a better energy efficiency**

  1. Optimize the individual processes (Kiln burning air)
  2. Optimize heat exchange
  3. Investigate possibilities for heat pump application

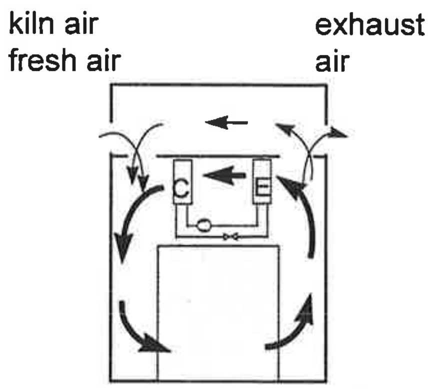
Heat Pumps

- **Heat "Reuse"**
  brings waste heat (sensible and latent) to a higher temperature level
- **Drive energy**
  only 0.3 - 0.1 times the total useful emitted heat (industrial applications)
- **High efficiency at low temperature lifts**



Heat pump for drying in ceramics industry

- **Decreased amount of waste kiln hot air**
- **Heat pump enables re-use of latent heat,**
- **as well as air dehumidification!**
- **Many applications in drying processes (lumber, tea, flower bulbs)**



Application

- **HUWA brick factory**
- **Building in progress**
- Subsidized by Novem - demonstration project energy efficiency in the ceramics industry

- Heat Pump in external recirculation drying air
- Partial dehumidification
- Careful embedding in drying and firing scheme (Hot air surplusses)

Benefits and challenges

- Simple pay back period installation
  (80 % investment is for heat pumps):
  4.6 years (no subsidies)
- Net annual energy savings heat pumps
  (100 million bricks)
  1.06 million mn^3 natural gas equivalents
- Heat pump operation temperature:
  Finding suitable equipment is hard

Conclusions

- **Energy savings through**

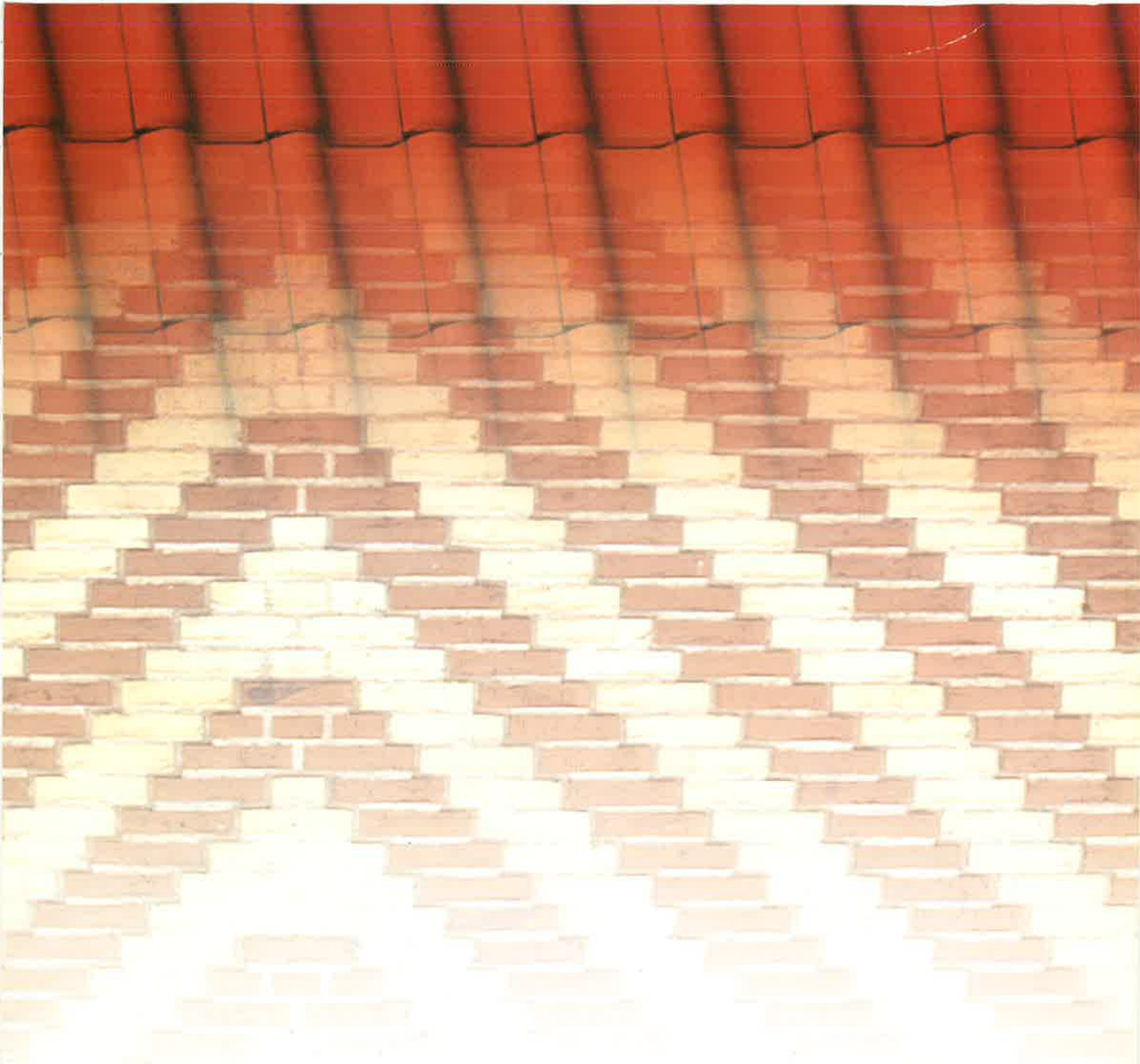
  Process changes to avoid waste heat

  Exchange heat

  Application of heat pumps
- **Heat pumps for drying process**

  Pay back period 4.6 years

  Annual energy savings 1.06 million mn^3 natural gas
- **Heat pumps for this temperature range no standard product**



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