MANUAL FOR STORAGE AND INSTALLATION OF REFRACTORY CONCRETES

Morgan Advanced Materials

THERMAL CERAMICS

INDEX

1. INTRODUCTION

Thermal Ceramics manufactures many hydraulic-setting refractory concretes, dense and insulating types, which are installed by casting, vibrating, slap trowelling or gunning to meet a great variety of industrial needs.

Each of these products is a mixture of high quality raw materials which are carefully selected, blended and packed.

One policy of Thermal Ceramics which is strictly applied to the production of these concretes is that no aggregate made from refractory materials recovered from the demolition of old used furnace linings is included in any formulation.

Thermal Ceramics specialists continuously monitor these concretes during their manufacture as well as the properties of the finished products in order to be certain that they are of uniform, excellent quality.

Our product development programme is permanently on-going to ensure Thermal Ceramics continues to deliver improved and new formulated products. When necessary, concretes are designed to meet individual customer requirements or specifications.

These instructions and recommendations are offered as a guide in order to obtain the maximum benefits from these fine products.

Thermal Ceramics Refractory Engineers are always available for consultation should this guide not be sufficient for a specific application, while Thermal Ceramics Field Engineers are available on request to provide complete site assistance.

Classification of concretes

Thermal Cermics classifies its concretes according to their density after oven drying at 105°C, as determined on cast specimens.

Concrete type	*Density after oven drying at 105°C*
Very Light Weight	less than 720 kg/m^3
Light Weight	720 ÷ 1200 kg/m^3
Medium Weight	1200 ÷ 1840 kg/m^3
Dense	more than 1840 kg/m^3

1.1 STORAGE

Each Thermal Ceramics concrete is packed in a multi-ply paper bag which include a polythene film. Bags are usually packed on pallets and covered with water-proof shrink film wrapping.

To maintain the material in peak condition it is essential to store it in a cool, dry, ventilated warehouse, kept off from the floor and away from the walls.

Moistening the dry material can affect the concrete strength and cause it to start setting prematurely in the bags. Material affected in this way must be discarded.

If the concrete is stored in the open air it should be placed on a ventilated platform, off the ground and covered with strong tarpaulins to avoid water or ground moisture coming in contact with any of the bags of material. It is advisable to retain the original shrink-film around the pallet as long as possible for extra protection.

In cold conditions it is recommended the material to be stored in a frost-free environment to ensure that the mixing water does not freeze when added to the dry material. Should such storage not be possible, the bags of the dry material should be moved to a warmer area having a temperature not lower than 15°C for a period at least of 48 hours, prior to adding the water.

In hot climates it is recommended the bags of dry material to be stored in areas kept dry and as cool as possible by available means; certainly bags should not be exposed to direct sunlight for any length of time.

Due to the ageing process of the binders used in their formulations, the shelf life of hydraulic-setting concretes is limited. As a general rule if such concretes are stored in a cool, dry, ventilated condition a shelf life of at least 6 months can be expected.

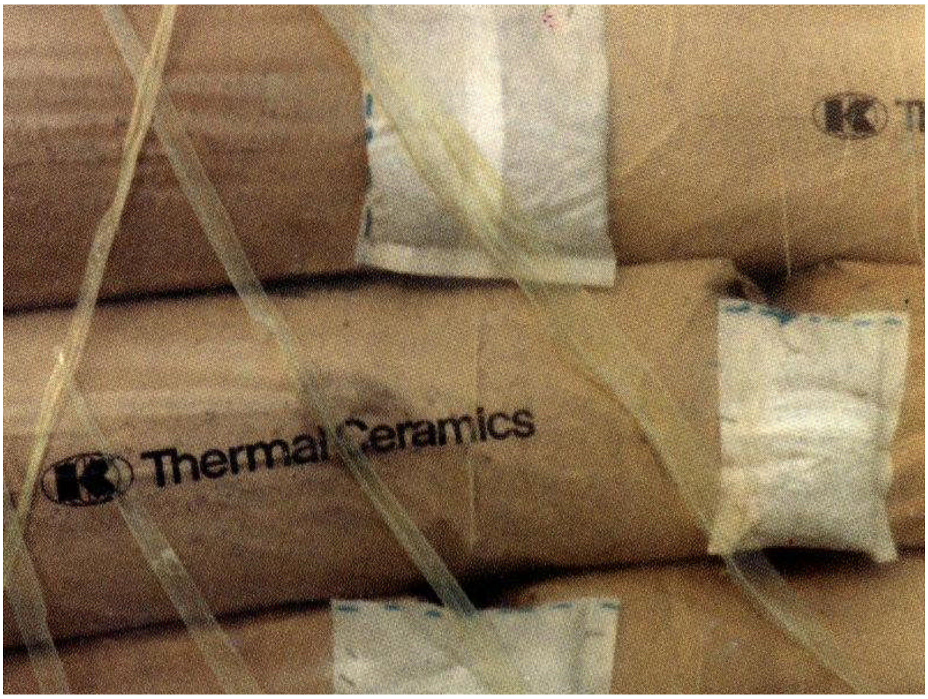
If, when the concrete is required to be installed, it has been at stock more than 6 months and appears in good condition, that is dry, without any obvious lumps or signs of pre-setting, some material should be mixed and its physical properties tested. If it is known that the material will be held at stock for a prolonged period, it is recommended that arrangements are made for the material to be tested every three months after the initial 6 months test.

The Cold Compressive Strength of a material after mixing with the recommended quantity of water and oven dried at 105°C, coupled with its bulk density is sufficient to decide if the material is useable.

Should there be any doubt whatever, the advice of a Thermal Ceramics Refractory Expert should be sought.

Thermal Ceramics can provide on request small bags of special de-hydrating agent placed under the shrink film on the pallet, in order to extend the shelf life from 6 months up to 12 months, provided the concrete is stored under the recommended conditions – cool, dry and well ventilated.

1. Typical pallet.



2. Double shrink-film with moisture protection.

1.2 PLANNING AND PRECAUTIONS

Before beginning installation, it is recommended to plan the operation. First it should be confirmed that all materials and necessary equipment are available or will be at the time demanded.

Ambient temperature

During the placement and curing of the concrete, the surrounding environment shall be at a temperature between 10°C and 32°C. If necessary suitable action must be taken to maintain this status. This also applies to areas with which the concrete comes in contact such as furnace shell or existing refractory lining.

Water

The water to be added to the dry concrete shall be at a temperature between 10°C and 25°C. Only clean, potable water with low acidity, free from salt, sugar and other foreign matter is recommended. Should the quality of available water be uncertain it should be analysed.

Thermal Ceramics recommend that the water used should comply with the following specification:

pH	6.5 ÷ 8.35
Ca^{2+}	< 300 ppm
Mg^{2+}	< 300 ppm
K^+ & Na^+	< 150 ppm
Cl^-	< 200 ppm
Fe^{3+}	< 300 ppm
SO_4^{2-}	< 200 ppm
Residue after evaporation at 180°C	< 1500 ppm

If water does not comply with the above limits, demineralized water should be used.

Equipment for storing and handling the water must be clean, so preventing possibly contaminating material from being introduced.

For further information ask to Thermal Ceramics Refractory Specialists.

Personnel, Tools and Equipment

It Should be that sufficient men and equipment are available on site to complete the job in the allowed time, including the time required for curing and drying, and that enough shuttering in available to allow the planned rate of installation.

The mixers to be used must be clean and free from such as Portland cement, to avoid quicker setting times and reduced strengths.

The equipment and tools such as the mixers, buckets, wheelbarrows, throwels and vibrators etc., shall be maintained clean.

The mixer and surrounding areas shall be dry, clean and free from loose mill scale, rust, grease, oil, dirt and other similar foreign matter.

1.3 ANCHORS

Furnace linings are supported by various types of anchorage. Anchors are welded or bolted to the shell and are used singly or in combination, to optimise their individual characteristics.

There is a wide range of flexible and fixed anchors as well as supports suitable for all kinds of positions, temperatures and process conditions.

The choice of type and quality of the anchors and supports, as well as the pitch and the pattern are determined at the design stage. Taken into consideration is lining thickness, position, service conditions and method of installation.

The maximum allowable temperature for metallic anchor depends on a number of factors such as type of atmosphere in the furnace and the section of the anchor itself. In normal oxidizing atmospheres without Sulphur, the following temperatures should be regarded as maximum on the "hot" tip of the anchor:

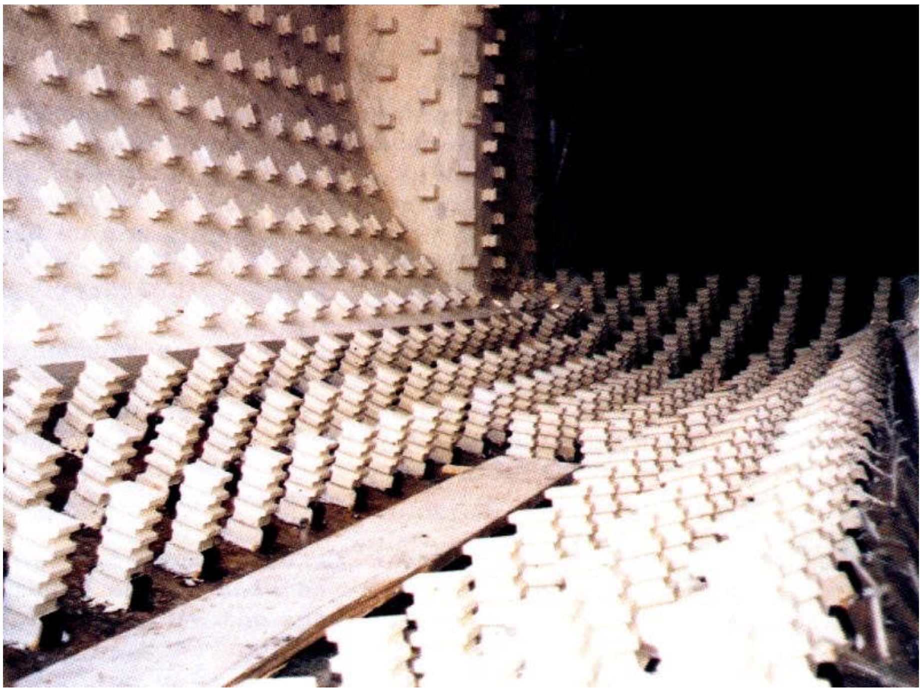
Steel or Alloy	**Temperature**
Carbon steel	590°C
18% Cr – 8% Ni (304 s/s)	870°C
25% Cr – 20% Ni (310 s/s)	1100°C
Special Alloys	
20% Cr – 32% Ni (e.g. Alloy 800)	1100°C
23% Cr – 60% Ni (e.g. Inconel 601)	1200°C

When the fuel used contains more than 0,5% in weight of sulphur, carbon steel anchors must be avoided.

In general the length of the metallic anchors is such that the anchor tip is 12,5 - 25 mm from the hot face and the anchor thickness shall be adequate for the actual application.

Anchors welded to the furnace casing must be securely attached without any weld undercut. It is recommended that the strength of some welds is tested prior the installation of the concrete.

Any anchor, properly welded, shall be capable of withstanding being bent 15 degrees from the as-welded position in the direction of greatest resistance and back without evidence of weld failure.



CO Boiler refractory anchoring

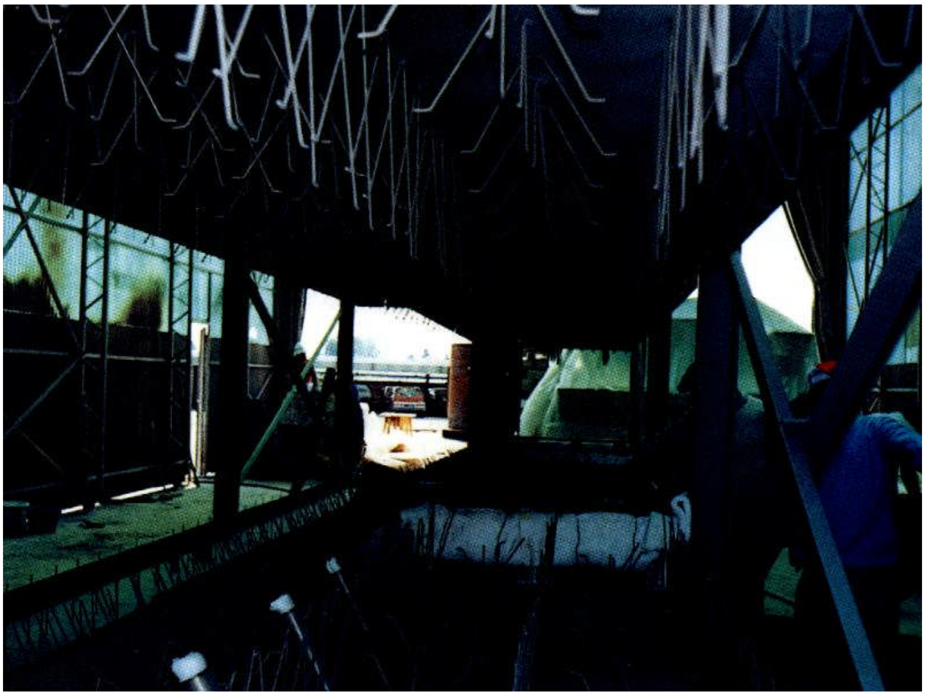
CO Boiler refractory and stainless steel anchoring

It is recommended that the anchors are wrapped with tape or coated with a bituminous paint in order to accommodate the thermal expansion of the anchors when the lining is heated. This helps to avoid the risk of cracking the lining at the position of the metal anchor while contributing to the reduction of heat load on the anchor. It is possible to obtain metallic anchors having a factory applied soft plastic cap on the tips.

Ceramic anchors are used where the concrete needs support completely through the working surface or where the temperature requirements exceed the safe working temperature of metallic anchors.

The tip of ceramic anchors are designed to be exposed to the interior if the furnace and their hot face should be 2 mm back from the hot face of the refractory lining.

Ceramic anchors shall be at least as resistant to heat as the refractory lining they support and shall be firmly secured in a metal anchor fixed to the casing before the installation of the lining begins.



Stainless steel anchor system for insulating concrete lining

1.4 SHUTTERING

For all types of concrete, shuttering shall be constructed from a non-absorbent, strong, water proof material; most usually selected are metal plate or wood. In all cases the shuttering structure must be sufficiently strong not to flex under the load of the concrete.

All joints in the shuttering shall be water-tight to avoid the escape of water possibly carrying with it fine cement-rich material.

Shuttering preparation

The problem of leakage becomes more noticeable in casting Very Light Weight Castables which need relatively very large quantities of water. Should leakage occur on no account should the viscosity of the concrete be increased by reducing the content of water. Apart from modifying the physical properties of the concrete the increase of density will result in shortage of material. Such a problem must be solved by modifying the shuttering.

Shuttering shall be oiled or suitably treated to facilitate easy stripping.

There are numerous types of mould release agents and that chosen should permit the shuttering to be stripped easily without any reaction with the castable surface.

2.1 MIXING

It is strongly recommended to use a paddle mixer.

While for insulating concretes the paddle mixer is preferred, it is essential for dense concretes in that it allows the material to be mixed properly and evenly with a much lower water content than for example with the barrel type concrete mixer.

The moisture content is critical for dense concretes where maximum strength with optimum density is required. Insulating concretes by nature are weaker than dense concretes and therefore it is important that they are mixed properly too, with the correct amount of water.

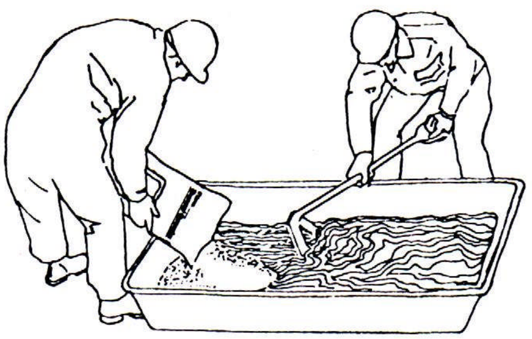
Too much water will reduce density and strength, too little will decrease the yield (with possible undesired shortage of material on site).

Because of the possibility of segregation of the various components of the concrete within the bag during shipment from factory to site, it is essential that only complete bags of concrete are mixed with the required water. Should for any reason this be absolutely impossible, the entire content of a bag must be mixed thoroughly before taking and using the required quantity.

Paddle mixer

For large projects, mostly those abroad, where long transportation and possibly warehousing times prior to installation are anticipated, Thermal Ceramics are prepared to supply several types of their concretes as two separate components. Packed in one group of bags is the inert material such as aggregates whilst in another group of bags or drums is the binder.

The quantities of each are so arranged that a complete number of bags of inert material is mixed with a complete number of bags or drums of binder without the need for weighing on site.
The re-composition must be made strictly in accordance with Thermal Ceramics specifications by skilled labour under close supervision if the required physical properties are to be obtained. The dry mixing can be made by hand or by means of a paddle mixer (for at least 2 minutes). In case of hand-mixing, the whole recomposed dry concrete mix should be turned at least 6 times in a clean container or on a clean surface.



The quality of water to be added to the dry mix shall be as previously described in section 1.2.

The quantity of water to be added must be as given in Thermal Ceramics data sheets in order to obtain the indicated physical properties.
To mix the concrete, it is recommended to add first 80-90% of the amount of water specified by Thermal Ceramics, then, while mixing gradually, add the remaining water a little at a time until the desired consistency is achieved.
Although acceptable methods are available to determine the right consistency and a few expert supervisors have the experience to do so by visual appearance, the following good practice is suggested (unless instructions have been provided by Thermal Ceramics for the concretes for a particular application:

- for insulating castables, water additions should be those indicated in latest Thermal Ceramics data sheets;
- for dense castables, use the minimum amount of water needed to install the material, which does not exceed the one indicated in the Thermal Ceramics data sheets. The best way to gauge the amount of water for dense castables is the “ball-in-hand” test, described later.

The mixing time is normally around 3 minutes and should be controlled: a too long mixing of a light weight insulating concrete changes the properties of the material, as most insulating aggregates are either soft or compressible and may become broken down by extended mixing. Only batches of size that can be installed within 20 minutes from the adding of water should be mixed. In some hot conditions it might be better to have smaller batches of concrete that can be installed within 10 minutes. In no circumstances must concretes be remixed after they have stiffened or started to set.

Ball-in-hand" test:
Add sufficient water to allow the castable to hold together in a ball when "bounced" in the palm of the hand.

Too dry: the ball will break up into a crumbly mass.

Too wet: it will slump through the fingers.

This "bouncing" in the hand should impart a slight glistening to the surface of the ball of concrete but there should be no appreciable transfer of water and cement to the palm.

3.1 CASTING

During the castable installation, the furnace casing and the castable lining temperatures shall be maintained between 10 and 32°C.
The concrete shall be installed immediately after it has been mixed.
The material must be poured in such a way as to minimize possible segregation.
It should be poured slowly into position, taking care that every undercut or profile be completely filled and that no air pockets are allowed to form.
For insulating castables, rodding or tamping is usually sufficient to remove voids and consolidate the material without excessive compaction. If a vibrator is needed, then a light poker should be used in order to move the castable rather than to compact it. Tamping of insulating concretes - especially those Thermal Ceramics " Light Weight " and "Very Light Weight " grades containing relatively weak aggregates and/or soft aggregate such as vermiculite - must be sufficient to correctly move the castable into place, but not excessively so in order to prevent disintegration of aggregate and compaction of vermiculite which would result in increased density (with possible undesired shortage of material at site).
For dense castables the use of a vibrator is more important and the effect of vibration during installation is beneficial in that it effectively reduces the amount of entrapped air thus achieving the optimum density.

Vibration should cease when no air can be seen coming from the mix, generally vibration should not exceed 2-3 minutes. Too long vibration can cause segregation of the mix (should there be an accumulation of water on the surface during vibration it is an indication that the mix is too wet and less water should be added to the next batch).
All movements of the vibrator within the concrete should be slow and deliberate allowing the material to flow and fully fill the space made by the vibrator as it is moved.

Care should be taken to move the vibrator around the concrete within the shuttering so that it is all fully consolidated. Special care must be provided at the corners of the shuttering and around anchors.
The vibrator should not be employed once the castable has started to stiffen and set.

Once the application has started it should proceed without any interruption until the entire section of the lining has been completed.
If an unavoidable interruption does occur, the 'wet' edge of the lining shall be cut back at right angle to the surface for the full thickness of the lining (or of the layer being placed, in case of multi-layers linings). All material ahead of the cut shall be removed and discarded.
The time between the pouring of consecutive batches must be such that the setting of the first batch has not begun.

For large surfaces it may be necessary to divide them into smaller and more manageable sections.
When the material is cast in horizontal position, the individual sections should preferably be around 1 m x 1 m in dimensions but not larger than 1.5 m x 1.5 m.

Each batch from the mixer shall be installed so that the full thickness of the lining is produced, rather than the building up of the thickness in layers.
When the concrete is cast in a vertical position, the shuttering employed shall be at least of 0.5 m high and 1.5 m long.
The concrete shall be cast evenly along the length of the shuttering and consolidated in order to obtain the required homogeneous lining.

Where multi-layer linings are installed, the surface of the first layer must be treated in order to prevent the absorption of water from the subsequent layer.
Under no circumstances should another layer be added before the previous one has been completed.

The surface shall be levelled off simply with a screed or a wood float and not be trowelled to a smooth finish.

In case of circular stacks and ducts it is sometimes found more convenient to install the lining with the stack or duct in the horizontal position on the ground. The lining is cast in "horizontal" sections and completed circumferentially in stages by partially rotating the stack or duct.

For diameters less than 1.5 m the recommended number of steps is 4 (90 degrees each) although under some conditions this might need to be reduced to 3 but this must be considered minimum.
For larger diameters more steps will be necessary.
Thermal Ceramics insulating concretes may be installed in this manner by reducing the amount of mixing water normally specified in order to make the wet mix more viscous. The resulting lining might show an increase in density of up to 5% but this is outweighed by the advantage of easier installation.

Allowance

While estimating the quantity of concrete required for an application by casting, a site allowance must be forecast. An allowance of 5% usually is sufficient to cover damaged bags, spillage, material left in bags and mixer etc. In difficult or remote areas the allowance should be increased to 10% or more depending upon actual conditions to be encountered.

3.2 SLAP TROWELLING

It should be understood that some engineering companies accept trowelling for contouring only while trowelled linings are not generally permitted.
However, there are instances where concretes may only be installed by trowelling; for example very thin linings or difficult positions where it is impractical to attempt installation by casting or gunning.

Trowelling is the installing of small quantities of concrete (mixed to a stiff consistency) which are picked up on a trowel and 'thrown' against a surface to be lined. (This is usually accomplished with an upward sweeping motion of the arm and a flick of the wrist which imparts sufficient velocity to the wet mass of material for it to stick where it is placed and consolidates into a monolithic coating with the material previously and subsequently placed). By this method it is possible to penetrate wire mesh or lath which forms the anchoring system for the lining.

The water addition in this type of application must be the minimum required to develop the stiff consistency. Water content can be varied as the job progresses to suit the requirements of the individual craftsman making the lining. Extra water should not be added to a mix if it becomes stiff. This 're-tempering' causes reduction in strength and thus a mix should be discarded if it becomes too stiff. This is probably an indication that too large batches are being mixed, therefore it is recommended that smaller batches be used.
Using this technique, an installation best proceeds from bottom to top, or from left to right, or from bottom left to top right. Manageable amounts of concrete should be placed near the point of installation so that the craftsman making the lining may work efficiently.

Less desirable than slap trowelling is a 'pushing' approach. Concrete is picked up on the bottom of a trowel and pushed through anchoring so that it sticks to the surface and consolidates with previously "pushed' material. 'Pushing' may be a necessity with anchoring containing small openings.

Concrete should not be applied in thin multiple layers as it will peel and spall during curing and upon exposure to heat. A single thickness layer is preferred.

The surface should be trimmed with the trowel edge or with the edge of a board to produce the correct lining thickness. The preferred finishing technique is as little as possible with the minimum action of a trowel bottom. Water should not be added to the surface. After the surface has been levelled it may be rubbed with a damp cloth to provide a textured surface.
Excessive working of the surface pulls water, fines and the cement binder to the surface which can cause cracking and spalling during curing and upon exposure to the ambient conditions. It will almost certainly cause spelling upon exposure to elevated temperature.

Insulating and Finishing Cements

Thermal Ceramics' range of Insulating and Finishing Cements are generally applied by trowelling.
The insulating cements JM 500, JM 460 are ideal for insulating irregular surfaces where it would be impractical to apply block or for pipe insulation.
Finishing cement JM 375 (hydraulic setting) is used to give the lining a hard, smooth surface which can be painted or weather-proofed.

Instructions and recommendations to be followed for trowelling these products are similar to those previously described in this section.
It is recommended that these further instructions be followed for correct procedure of installation.
The amount of water used to obtain the required stiff consistency resulting in high sticky properties shall be in accordance with Thermal Ceramics data sheets.
It is recommended for best results to mix by hand in a small container in small quantities rather than large.
After mixing, finishing cement should be used immediately while insulating cements should be allowed to stand for some 30 minutes to permit a slight pre-set developing the sticky nature of the cement.

Although both insulating and finishing cements may be applied using the different techniques previously described, Thermal Ceramics suggest they be installed by throwing small handfuls of wet mix against the surface to be lined, imparting sufficient velocity to the wet material that it sticks where it is placed and it consolidates into a monolithic coating with the material previously and subsequently placed.
For insulating cements the finishing technique again is "as little as possible" as described in this section. For finishing cement it is recommended to finish the surface with the action of the trowel bottom in order to have a smooth surface, ready for the painting or water-proofing procedure.

Thermal Ceramics specialists are always at your disposal for further information and advice.

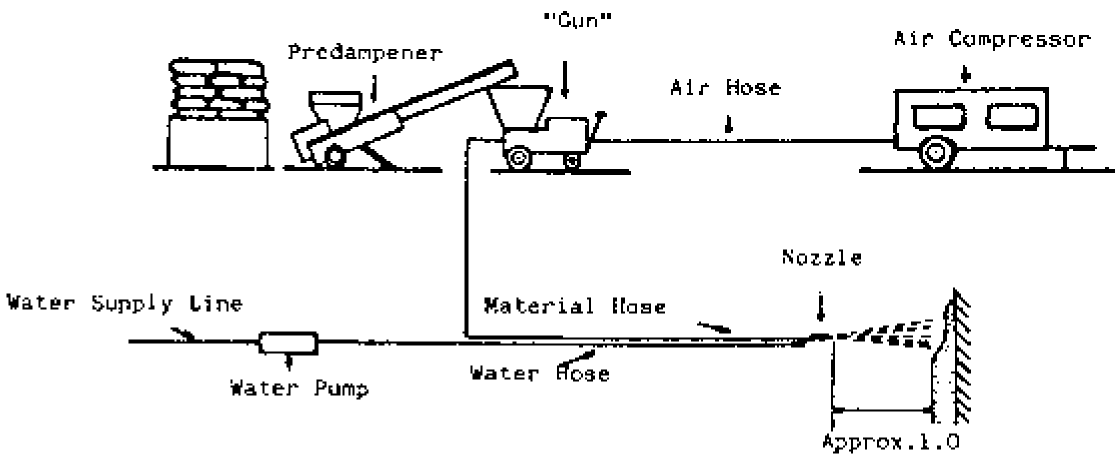
3.3 GUNNING

Thermal Ceramics generally prefer the casting method of installing refractory concrete rather than the gunning method because more accurate control over mixing and installation is possible, thereby producing thermo-physical properties closer to those given in published literature.

Thermal Ceramics appreciates however that the gunning method of installation is faster and therefore offers a number of materials suitably formulated for the application by gunning.

Where Thermal Ceramics materials are gunned it is recommended that the dry gunning principle is employed with the concrete being pre-damped.

In this process the pre-damped concrete is pneumatically conveyed to the installation area using especially developed equipment and finally projected onto the surface to be lined through a nozzle which includes a water injection system.



The pre-damping of the concrete is preferably carried out in a special pre-dampener. If this is not available, a paddle mixer might be used and placed immediately next to the gunning machine. The water required to pre-damp both dense and insulating concretes ie approximately 1/5 of the total water specified in Thermal Ceramics catalogues. The remaining water is added, as a fine spray, at the nozzle in such quantity to achieve the correct gunning consistency (usually this is the maximum addition that can be tolerated without the refractory slumping).
The pre-damped material must be mixed until it is homogeneous with no lumps and used within 20 minutes of mixing.
Pre-damping reduces the presence of dust at the nozzle with improved visibility for the operator permitting better control of the necessary water addition and easier adjustment of the lining thickness. In addition pre-damped material more readily accepts further water at the nozzle improving gunnability and resulting in minimum segregation and rebound losses.

The ultimate success of gunning application depends to a great extent on the skill of the operator and the correct use of equipment and material.
The gunning machine requires a constant supply of water and air, the respective necessary pressures of which depending on such factors, as the distance between the gunning machine and the nozzle, the nozzle-size, the elevation above the ground level of the surface to be lined and always the type of concrete being gunned.
It is essential that there be a direct communication between the nozzle operator and the gun-machine operator. The use of two-way telephone system is recommended where they are out of direct vision.

Once gunning has started, the application of the lining shall be continuous until the unit or section is completed.
Any break in gunning must be timed to coincide with the completion of a section. When an interruption is expected to extend longer than 10-15 minutes, the area not gunned to the full thickness must be cut out and removed.

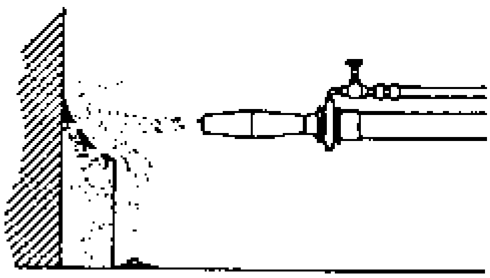
At no stage shall additional material be placed over previously applied material to build up the required thickness.

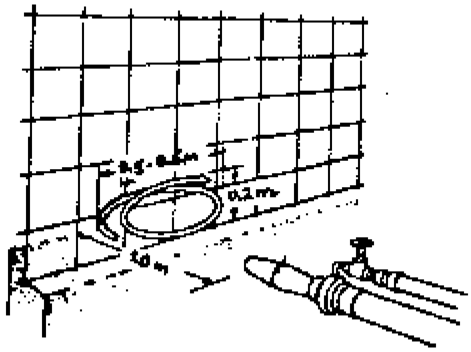
Where multi-layer linings are installed, the first layer must be suitably treated to prevent absorption of water from the subsequent layer.
The edges of 'unfinished' sections of concrete shall be cut back at right angle to the backing surface. All material ahead of the cut shall be removed and discarded.

The work shall always proceed along the wet edge of the band just finished and reach full linings thickness as quickly as possible before proceeding to another section.

The work area is generally divided into sections approximately 2 m x 2 m wide.
Thickness control is accomplished by profile boards of a depth equal to the lining thickness: alternate sections are installed and, when set, the profile boards are removed and the alternate sections gunned.

An alternative method for thickness control, which is necessary for spherical surfaces, for example, is to provide pins of about 2 mm diameter welded to the casing with 600 mm spacing and of a length equal to the lining thickness.





The gunning nozzle should be held at approximately 90 degrees to the receiving surface and maintained at a distance of approx. 1 m from the surface.

The nozzle shall be moved in a small circular motion that reduces the rebound loss and the risk of laminations and gives an equal material structure.

It is important that the material be gradually built up to the full thickness over a small area at a time.

Progress should be made from bottom to top when gunning concrete on vertical walls, this prevents rebound material dropping down and sticking to the unlined shell and to the anchors below.

Care must be taken to ensure that no rebound material be trapped in the stream of new material because voids and weak areas will result.

A normal gunned surface finish will be pitted to the extent of a variation between peaks and troughs of 3-10 mm, largely dependent upon the maximum aggregate size used in the mix.

For some applications this finish is acceptable, and the lining thickness is taken to the mid-point between peaks and troughs.

For many other applications it is easier and even faster to gun slightly over thickness and trim back to the desired precise thickness.

This is particularly important where a given distance between lining surfaces and process tubes must be respected, or wherever precision of thickness is imperative.

Where trimming is required, the surface shall be scraped with a trowel or a steel float or, better, with a special nailed brush as soon as possible after completion of the gunning.
A trowelled smooth surface finish must be avoided.

In all gunning operations some of the material rebounds from the work area and falls down; this material must be removed and discarded.

The amount of this lost material depends on many factors especially in the initial part of the installation whilst being gunned against the steel surface.
For a thin lining, the rebound loss is higher than for a thicker lining installed in similar conditions; overhead gunning will cause a higher rebound loss than gunning onto a vertical wall.

Allowance

While estimating the quantity of concrete required at site for an application by gunning, an allowance must be forecast as the sum of site allowance, material allowance and job difficulty allowance. Thermal Ceramics gunnable concretes require a material allowance of approx.10%.
Site allowance is usually 5% for domestic jobs, but for difficult or remote areas it must be increased to 10% (possibly even more.)
Job difficulty allowance depends on several factors such as the skill of the operator, the position of the surface (e.g. roof or vertical wall), the anchors spacing and type, the thickness of the lining, the environmental conditions. Although tables exist giving difficulty factors for a variety of cases, as a practical guide the following factors may be considered:
- vertical walls 10-15%
- roofs 30-40%

The sums of the 3 allowances give the following total gunning allowances:

	Material allowance	Site allowance	Difficulty allowance	Total allowance
Domestic projects				
- Vertical walls	10%	5%	10-15%	25-30%
- Roofs	10%	5%	30-40%	45-55%
Difficult / remote areas				
- Vertical walls	10%	10-15%	10-15%	30-40%
- Roofs	10%	10-15%	30-40%	50-65%

All engineering companies have their own standards for total gunning allowances, which generally lie in the above intervals, but the best – for equipment and operators - installation companies are able to stay close to the lower limits or even better.

Consult Thermal Ceramics specialist for selection of materials, estimate of allowances and further advice if in any doubt.

4.1 CURING

When water is added to concretes that contain high-alumina + lime cement, hydration occurs accompanied by the generation of heat.

The amount of heat generated is sufficient to release some moisture as steam thus preventing full hydration from taking place.

To compensate for this moisture loss and allow complete hydration to develop the optimum strength of the cement, a curing process is necessary. This consists in keeping the lining surface sufficiently damp and cool by spraying, with clean fresh water at frequent intervals or by covering it with wet sacks which must be maintained wet. In some cases with ducts, small vessels, etc. an alternative method is by air-proof closing of the equipment to keep all the moisture inside.

The curing process should start immediately after initial setting when the lining surface has set hard enough to permit impinging spray water from washing out the surface cement, and shall proceed for at least 24 hours.
Forms and shuttering may remain in place.

During curing operation, the refractory lining temperature shall be maintained between 10 and 32°C.

In cold temperature conditions the rate of evaporation is generally low, therefore the wet curing operation may not be necessary; however the lining temperature must be maintained above 10°C and under no circumstances must the material be allowed to freeze during setting and curing or until the lining has been dried to stable conditions.

In hot temperature conditions the rate of evaporation is generally high, then the wet curing operation is of the greatest importance.
The lining must be kept damp and cool within the first 24 hours. When the lining installation is carried out in open air, the surface shall be protected by shading from direct sunlight until the curing operation has been completed.

Refractory lined equipment shall not be moved, on site, until the curing operation has been completed and shall not be packed and transported until air drying operation has been carried out.

The steel casing stiffening shall be such that flextures and distortions are prevented in order to avoid damage of the lining.

4.2 AIR DRYING AND VENTILATION

When the curing process is complete, the concrete lining must be air dried at an ambient air temperature at least over 10°C for as long as possible (but not less than 24 hours) in order to obtain stable conditions prior to initial heating.
This operation allows the reduction of the amount of free water in the concrete which might otherwise cause undesired chemical reactions between the lining surface and the atmosphere. This is likely to happen if the lining, after the curing, is permitted to remain for a time in a damp, humid ambient air without any drying.

In general this phenomenon, known as "cathionic hydrolisis", take place more readily with insulating concretes which are based on porous aggregates that absorb high percentages of mixing water. This effect is more likely to be evident on installations made in cold weather and in cold countries where, in general, the air is humid and the rate of evaporation is low. Closed ambient, such a condition that exist in complete box type furnaces with no ventilation, are more likely to facilitate this undesired phenomenon.

The ideal recommendation is therefore to fully dry the concrete lining immediately after the curing has been completed. Where this is not possible, the concrete lining shall not be allowed to remain in a closed humid environment. It is recommended to ensure sufficient air ventilation either by leaving the lining in a well dry-ventilated area or, preferably, by providing a forced ventilation on the whole surface with an adequate fan or, even better, by a hot air blower.

In the Petrochemical Industry recent furnace construction trends, favour reducing installation time at site by using steel casing modules lined in the shop of the steel casing supplier (or not far away from such shop).

In such cases, it is recommended to air dry and ventilate the concrete lining before the module is packed for transportation and to ensure that packaging is adequate to protect it from the ingress of water.

Completed cured and dried concrete linings must not be left in such a way that they may be exposed to rain and its damaging effects on properties.

Thermal Ceramics specialists are at your disposal for further information and advice.

5.1 INSTALLATION IN COLD ENVIRONMENT

Neither dense or insulating concretes shall be installed when ambient temperature is below 10°C.
In cold weather, the minimum temperature of 10°C must be maintained by
artificial heating of the water, the concrete and its surrounding area (including the furnace shell) until the installed material has been cured and dried.

When the installation is made in the open, it may be necessary to externally lag the unit being lined and also provide adequate heaters to maintain temperatures at a satisfactory level.

It is recommended that the concretes be stored in conditions that they be frost free and moved into a warmer area with a minimum temperature of 15°C for at least 48 hours before installation.

The mixing water temperature shall be in excess of 10°C and it is recommended that it be heated, if possible. to 20-25°C, while never exceeding 30°C.

The temperatures of the dry mix and water shall be controlled in such a way to always obtain at all times a temperature of the wet mix above 10°C.

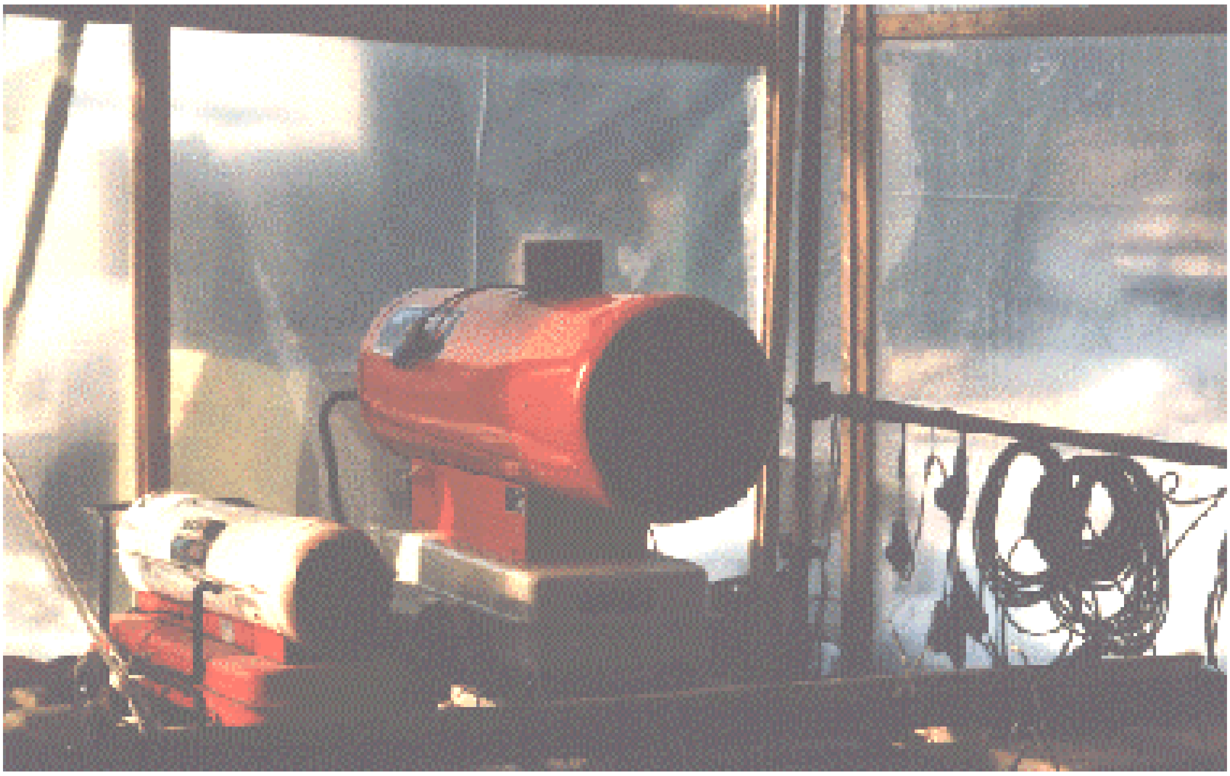
In gunning applications, the higher the material temperature, the better the gunnability and the lower the amount of rebound loss are.
The recommended water temperature is between 20 and 30°C.

During the application and curing, the concrete lining temperature must be maintained above 10°C and under no circumstances must the material be allowed to freeze.

When the curing operation has been completed, the lining shall be air dried at an ambient temperature above 10°C for as long as possible to obtain stable conditions of the refractory material.

The air drying operation is of the greatest importance when lightweight insulating concretes are installed, due to the high percentage of mixing water that they require.

The freezing effects on refractory concretes after curing depend totally on the content of free water.
If the refractory concrete has fully dried, freezing has no appreciable effect.



10. Equipment to maintain the material above10°C

5.2 INSTALLATION IN HOT ENVIRONMENT

The concretes must be stored in a cool and dry ventilated warehouse, avoiding direct exposure to the sun. If the temperature of the dry mix is high, it should be kept in a cool place before use, its temperature being maintained below 32°C.

Cool fresh water shall be used for mixing. If necessary, chilled water must be used, but under no circumstances must it be below 5°C.

The water and the dry mix temperatures should be controlled in such a way to always obtain a temperature of the wet mix below 25°C.

If the steel casing is exposed to sunlight, it is recommended that it be cooled down, during installation, setting and curing so that its temperature be below 32°C.
This can be done by shading from direct sunlight and/or by spraying with water the outside of the steel casing.

Because high temperature concretes tend to stiffen quickly, rodding or tamping soon restores the material to a normal consistency.

The addition of excess of water to restore consistency must be avoided and if necessary smaller batches of concrete should be mixed and installed.

If the material is installed by gunning, the same precautions should be taken as in casting.

A cool place should be selected. The mixer, the dry mix and the mixing water should not be allowed to be exposed to sunlight. During the curing operation, as with a cast lining, the refractory lining temperature must be maintained below 32°C.

The lining must be kept damp and cool within the first 24 hours; this is particularly important for the concretes with a high evolution of heat of hydration, as they are particularly vulnerable to cracking and explosive spalling if they are not correctly cured.

Where none of the above is possible, the installation should be carried out at night.

For a correct curing procedure, see section 4.1.

6.1 JOINTS

Refractories expand when heated.

Expansion joints are used to allow thermal expansion in refractory concrete linings where they are considered necessary by the engineer responsible for the design of the unit in order to protect the lining and the shell against forces which might be caused by unrelieved thermal expansion.

The expansion joints are generally placed with regular spacing, not greater than 1.5 m, in horizontal and vertical directions.

The expansion joints between adjacent panels, when panel constructions are used, should be packed with ceramic fiber having an adequate service temperature limit, such as Thermal Ceramics blankets (Cerablanket, Cerachem Blanket and Cerachrome Blanket) or felts (Cerafelt).

Separation joints and separation cuts (or score lines) are used to distribute the shrinkage of the lining uniformly and to prevent the formation of random cracks.

They should have a regular spacing of no more than 1.5 m in horizontal and vertical directions.

The separation joints are formed naturally while installing the lining part by part and are generally recommended for large surfaces or for panel constructions where a lining able to absorb mechanical stresses is necessary.

The separation cuts are manually made by scoring the concrete surface before its setting and shall be approx. 1.5 mm wide and 25 mm deep.
The surface cuts are always required with "facings" of dense type concretes: they are not strictly required - but still recommended - with "Medium Weight" and lighter facing materials.
The cuts should not be made by grinding after the installation when the concrete has already set.

6.2 HEATING-UP

Before being placed in service, all refractory concrete linings shall be thoroughly heat-dried.

Unfired concretes have a very low permeability hence the contained water has to be removed slowly. This to prevent high pressures being built up within the refractory structure which might lead to explosive spalling and damages to the lining.

The heating-up procedure must be carried out to well defined time/temperature curves.

These will depend on the amount and type of refractory concrete involved and the total thickness of the lining; in general, the thicker the lining the longer it will take to dry out and fire.

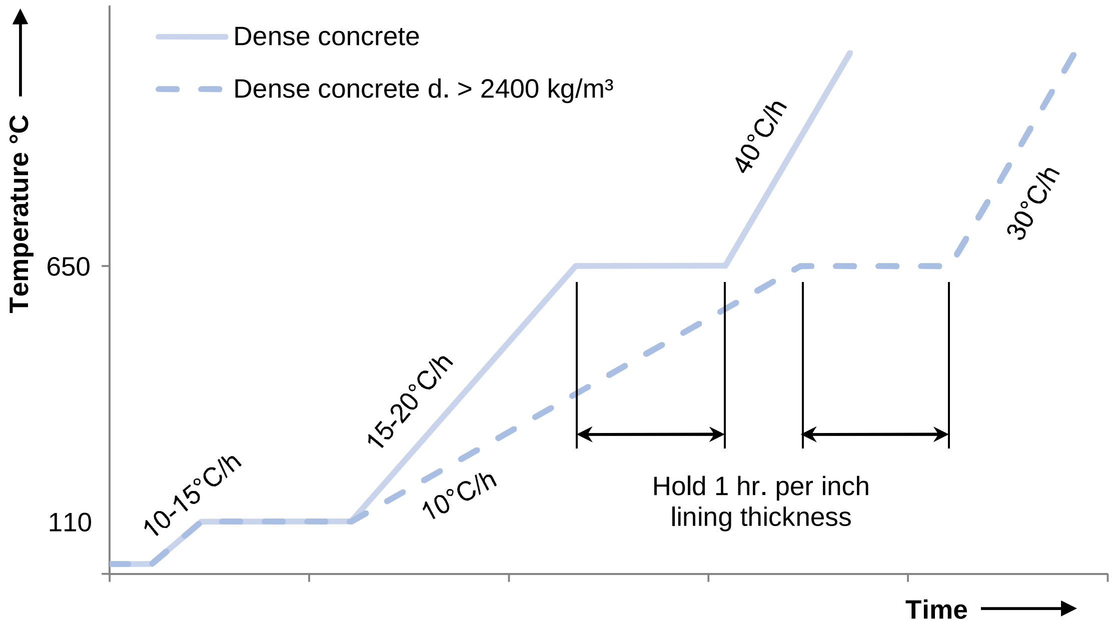
Once the planned heating-up has commenced, it should not be stopped or interrupted. In case of unavoidable interruption the lining must be kept warm.

If cooling-down cannot be avoided, it must be done slowly and subsequent reheating must be carried out in accordance with the original heating-up procedure.

The following rules are valid in general for the first heating-up of a concrete lining:
- there should be a continuous flow of air through the furnace to remove the moisture;
- until the lining has passed the 650°C stage (see below), flame impingement should be avoided;
- all temperature fluctuations should be kept to absolute minimum.

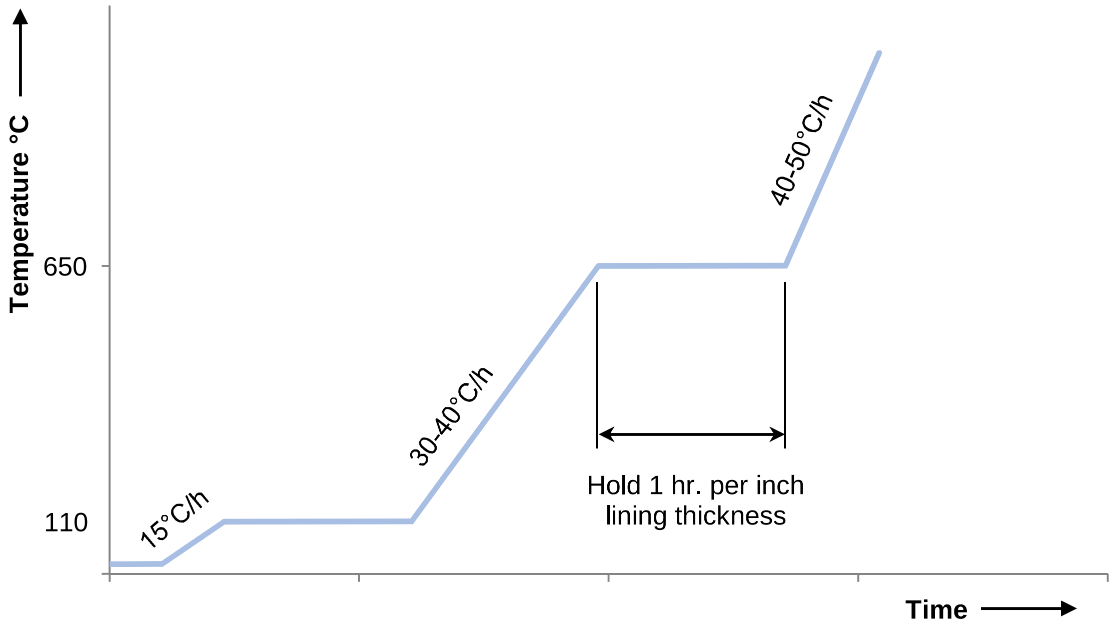
Dense Concretes

Linings of regular dense concretes must be evenly heated-up with a temperature increase not more than 10-15°C per hour up to 110°C and be maintained at 110°C for 18-24 hours, or longer, depending upon lining thickness, but at least until all steaming has stopped.
As a guide, it is suggested that the temperature be evenly raised to 650°C at a rate not more than 15-20°C/h (10°C/h for concretes with dried density above 2400 kg./m^3). The temperature should then be maintained for at least 1 hour per 25 mm of thickness of the lining, to allow equalisation through the lining. After this hold, the temperature can be raised to the working temperature at 40°C/h (30°C/h for concretes with dried density above 2400 kg./m^3).



Insulating Concretes

Linings of insulating concretes must be evenly heated-up with a temperature increase not over 15°C/h up to 110°C and be maintained at 110°C for 18-24 hours, or longer, depending upon lining thickness, but at least until all steaming has stopped.
As a guide, it is suggested that the temperature be evenly raised to 650°C, at rate not more than 30-40°C/h.
The temperature should then be maintained for at least 1 hour per 25 mm of thickness of the lining, to allow equalisation through the lining. After this hold, the temperature can be raised up to the working temperature at 40-50°C/h.
For more information or special projects, contact your Thermal Ceramics Refractory Specialist.



7.1 INSPECTION

After it is installed, the lining must be inspected to confirm that it conforms to the design requirements and to ensure that it can withstand the conditions under which the unit will operate.
The lining should be inspected only by experienced engineers. Inspection must be visual and audio (by using a test hammer) and is carried out after both normal air drying and firing dry-out

Visual inspection
Visual inspection should reveal if cracks or local concentration of cracks have formed. If cracks are found a decision becomes necessary to decide whether they are such that they are likely to adversely affect the normal operation of the unit.
Repairs should be made to areas containing cracks each wider than 1.5 mm as well as complete areas having random cracks up to about 1.5 mm width but which are within 300 mm of each other.
Irrespective of this width, repairs should be made to areas, where cracks criss-cross forming "blocks" that are likely to fall off with time/temperature.
Linings in general tend to move more on heat up and as a result tend to develop more cracks on cooling. It is therefore strongly recommended that, if at all possible, an inspection be made after cooling.
Visual inspection is required to further ensure that the lining finish is satisfactory and that its dimensions are correct.
The sizes and positions of the expansion joints must be inspected and confirmed correct. This inspection should also reveal if expansion joints have become infiltrated in any way with foreign matter. Such matter might resist the normal movement of the lining therefore it is necessary that any joint so affected be cleaned out and repacked with the correct material.

Sound inspection (Hammer Test)

This type of inspection is generally referred to as a Hammer test. It involves the practice of striking the lining over its entire area with a ball point machinist hammer having a recommended weight of 450 grams. The lining is struck according to various but specified grid patterns. For example a roof might be struck at 600 mm intervals while side walls and floors at 900 mm intervals.

Hammer testing will indicate whether or not lining is homogeneous. An experienced ear will determine, in more detail, faults which might cause a lining to collapse such as voids and delaminations etc.

When struck with a test hammer, the sounds emitted are more clearly distinguishable in fired linings rather than in those only naturally air dried; therefore, after dry-out, faults are more easily located.

For multi-layer linings, the hammer test should be conducted on each layer: after the curing of the back-up layer(s).
If sounding indicates the presence of an abnormality in an area greater than 150 mm x 150 mm, this area must be repaired. Also all soft or dry fill areas that reduce the effective lining thickness by more than 1/4 of the original thickness or if more than 13 mm deep.
If the area of defects -i.e. voids, "dry fill", cracks wider than 1.5 mm, or any defect in designated critical surfaces - is found to be more than 25% of the total lining surface, it is usual that the entire lining is replaced.
The Inspector or the Owner's Engineer will make the decision on replacement.

7.2 REPAIRS

If inspection reveals defective areas as previously defined greater than 150 mm x 150 mm, the full thickness of the defective concrete layer must be removed for 8 minimum area that includes 3-4 anchors.

Care must be taken in the removal of the faulty material that the surrounding sound lining is not damaged and neither, if it is present, the back-up lining.

The removal of the refractory concrete should progress at a small angle to the shell and the periphery of any repair be located nid-way, between anchors.

The area being repaired should be cleaned of all loose concrete and debris and the adjacent sound material thoroughly wetted before any new concrete is installed.

Only the same concrete as originally employed should be used for replacement and wherever possible, particularly in large areas, the same installation method as was originally used.

Where repair to only a random crack is necessary the full thickness of lining should be removed for an area same 120-150 mm each side of the crack and parallel to it.
It is recommended that if possible some auxiliary anchors should be installed along the area being repaired, in order to have a new longitudinal and transversal anchor pitch of about 200 mm.
The new concrete should be cast using forms made of boards propped and fixed again the sound concrete surface.

When areas after drying out are found to have a soft surface the defective material need to be removed and replaced only if it is considered that sufficient material will become disengaged to adversely affect the normal operation of the unit.

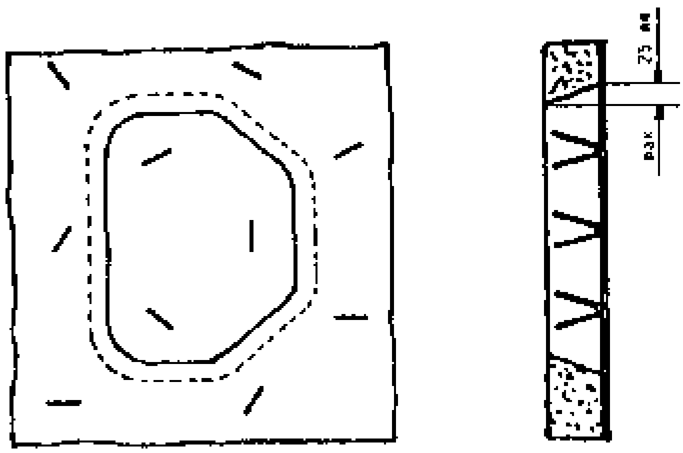
If replacement is considered necessary the removal shall be accomplished by scraping the soft concrete until sound material is encountered.

The removed lining thickness may be less than the limits defined in section 7.1. If it exceeds these limits the defective area shall be reinstalled entirely unless it is confirmed that the reduced lining thickness will meet the designed insulating properties satisfactorily .

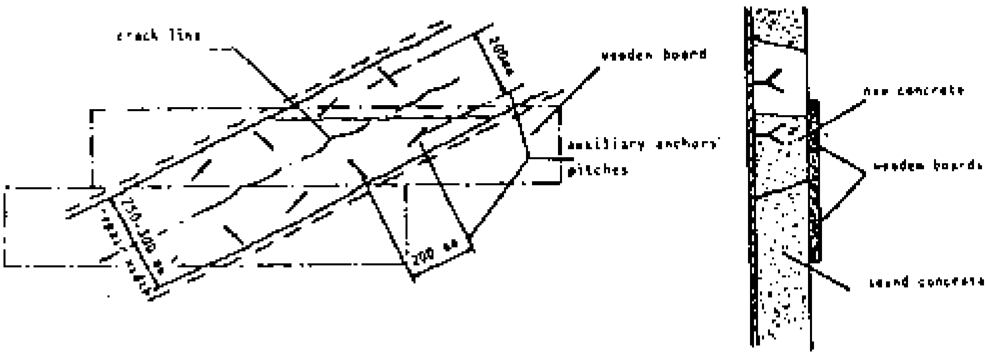
The Inspector or the Owner's Engineer, however, might reject this demonstration and request the repair of that affected area of the lining.
Curing, air drying and dry-out procedures for repaired areas are the same described in the sections 4.1, 4.2, 6.2.

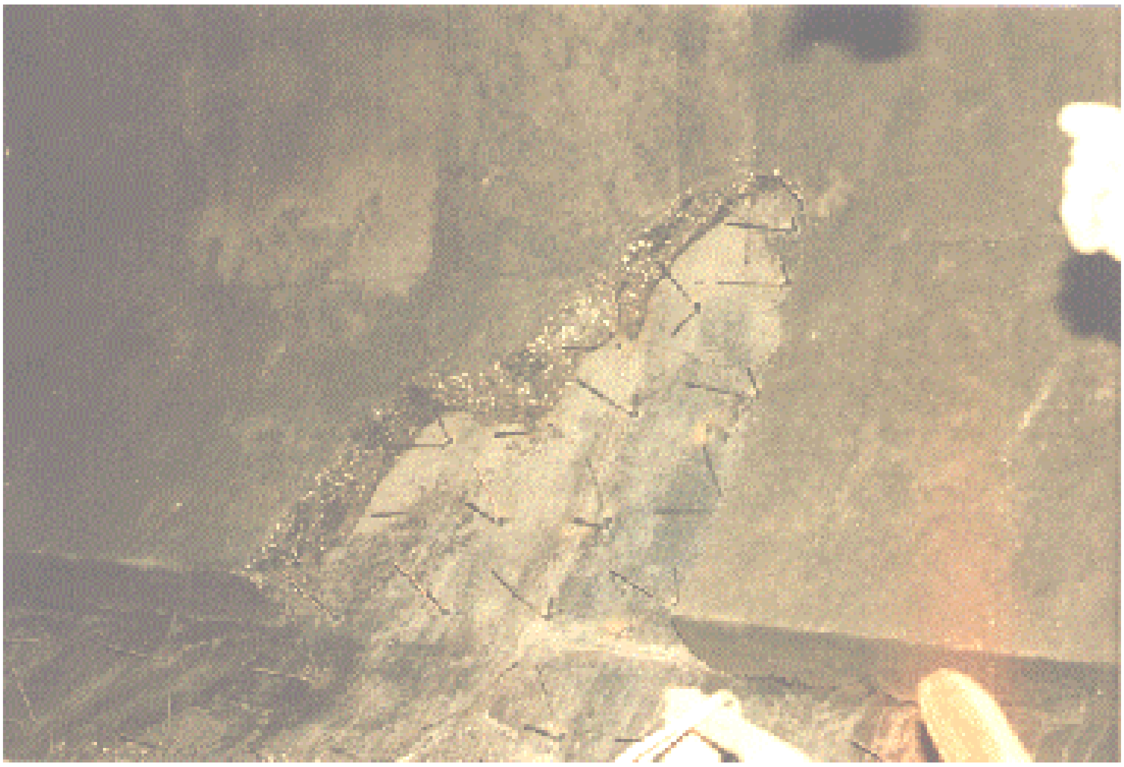
For small repairs (less than 3 m2), accelerated procedures if required may be discussed with Thermal Ceramics Refractory Specialists.

Repair of Single Layer Insulating Lining



Repair of Random Cracks In Insulating Lining




11. Detective area removed to be repaired

8.1 SAMPLING AND TESTING

For quality testing of consignments of refractory concretes, sampling involves the selection of relatively small quantities of materials which must be considered to be representative of the total consignment and from which test-pieces may be prepared under closely controlled laboratory conditions
(PRE-INSTALLATION TESTS).
In addition, it is often the case with refractory concretes that laboratory testing is required of test-pieces which are prepared on the site of an installation. This is done in order to gain some appreciation of the quality of linings which may be installed under site conditions very different from those encountered in a laboratory and which are sometimes far from ideal
(AS INSTALLED TESTS).
After the installation, visual and audio (hammer testing) inspections are the common non-destructive tests of a lining (AFTER INSTALLATION TESTS).
The amount of sampling and the extent of testing must of necessity be a compromise between customer and supplier.
The total quantity of concrete involved in a particular project and the time that is available for physically testing samples, reporting results, review and the granting (or otherwise) of approval are important considerations in deciding the maximum amount of testing that can be accommodated, both by the testing laboratory involved and by the rate of installation desired. It is essential therefore that the properties to be tested and the number of tests required be agreed at the time the concrete materials are ordered.
The test methods used are those accepted by all countries such as ASTM, DIN, AFNOR and JIS. Sometimes Thermal Ceramics will propose an in house test method usually based on ASTM which they have developed for a specific purpose usually for the saving of time.
Thermal Ceramics' normal policy is to hold themselves ready for discussion with their clients in order to agree a mutually accepted plan.

12. Moulds for test specimens

8.2 PRE-INSTALLATION TESTS

Thermal Ceramics operates a Corporate Quality/Assurance Policy, part of which dictates that all products made at their plants be tested, approved and released for shipment only on the authority of the Quality Control Supervisor for the particular plant at which the product is made.

The very first stage of quality control concerns the suitability of the raw materials that need to be employed. The properties required of all raw materials are covered by a stringent Thermal Ceramics Purchase Specification which is imposed on all suppliers. In spite of this, all incoming materials are tested on arrival at the plant before being accepted for concrete production.

The blending of the raw materials is computer monitored which eliminates the risk of quality failure at a later stage due to initial incorrect blending.

Thereafter each shift of production is routinely controlled by the laboratory for sieve analysis, water/mix ratio, cold compressive strength and permanent linear change. Period tests are carried out at various intervals on chemical analysis, thermal conductivity, thermal shocks resistance, abrasion resistance and when applicable resistance to effects of CO dissociation.

For large projects, pre delivery testing may be performed in Thermal Ceramic's laboratories in the presence of a customer's inspector or his nominated representative on samples selected at random from materials awaiting shipment.

By utilising such a procedure the entire process of sampling, specimen preparation, testing and acceptance can be achieved under the most ideal conditions.

Should a project call for a particular requirement, customer's engineers are invited to liaise with Thermal Ceramics specialists in the initial stages of the contract in order to arrive at a mutually acceptable sampling plan and testing procedures for the required materials prior to shipment.

As mentioned in the section on STORAGE, after a period of time in storage a concrete - initially proven satisfactory before leaving the plant - must be re-qualified before use.
For this it is usually sufficient to compare the cold crushing strength (after drying test piece at 105°C) against the bulk density of the particular concrete.

Such a procedure is particularly recommended if the installation is to be made in a difficult or remote area where lengthy transportation and/or warehousing times are involved and certainly where quality of storage facilities are lower than recommended.

Panel test - Gunning application

A particular example of pre installation testing is the gunned panel test which is usually employed to qualify the compatibility of gun operators along with their equipment for a particular concrete.
With gunned applications, panel tests are imperative and are made prior to the actual lining placement. Each operator should gun at least one panel of each concrete to be installed. The test panel must always be produced with the same gun equipment that will be used under site conditions.
The size of the panel shall be 900 mm x 900 mm minimum and having a depth, the same as the lining to be installed.
The test panels are gunned in the vertical position with the nozzle of the gun equipment held approx. 1 m from the panel surface. The panel should be produced in accordance with the gunning procedure as
in section 3.3.
The panel should be cured for 24 hrs., then dried at 105°C for a further 24 hrs.
The integrity of the panel is checked by hammer test (Sect. 7.1) and its density established. A sound panel having density within acceptable limits will serve to qualify the operator and his equipment.
At the discretion of the customer or his representative the panel may be cut into 4 pieces for internal examinations for inclusions and lamination.

8.3 AS INSTALLED TESTS

Test pieces prepared on site are often of accepted standard dimensions, but specimens are sometimes preferred by some engineering companies or plant owners. The object of this type of test piece is to be able to sample a monolithic lining in order to assess its quality without the need of core drilling or cutting the complete lining. The process employed is, in effect, the production of test pieces in the same manner, as close as possible as the lining installation proper.
Generally agreement is reached by the interested parties of a project that test pieces be fabricated from batched material which has been prepared for installation. Sample test pieces are taken at times corresponding to installation of various sections of the lining and marked accordingly (if preferred, the sampling may be based on shifts worked).

Thermal Ceramics suggest the following sampling method at site:

- Application by casting

One sample per section of the lining (or per shift) for each quality of concrete being installed is taken during actual installation.

Each sample shall comprise three 50 mm + 0.4 mm (or 2" + 1/64) cubes which are cast in approved metal or plastic moulds, the required quantity of concrete being taken from the material which is being installed. The cubes are cured, carefully coded and marked and the codes indicated on drawings of the lining. Also recorded should be the type of concrete installed in that particular position.

- Application by gunning

One sample per section of lining (or per shift) for each quality of concrete being employed is taken during installation. Each sample of concrete consists of three specimens 114x114x64 mm + 1.0 mm (or 4"-1/2x4"-1/2x2"-1/2 + 1/32).

The concrete required for the tests is obtained from a panel 600x600x75 mm which is gunned by each gun operator working the particular lining section (or shift). The concrete is gunned into a test box (from 25 mm timber or 3 mm thick metal plate) which is rigidly mounted in a vertical position with the gun nozzle held approx. 1 m from the sample box (see section 3.3). The panel is produced slightly over 75 mm and finally carefully trimmed back. A section approx. 300 mm square is cut for the full depth from the middle of the test panel before the concrete finally sets, it is cured in a plastic bag coded and recorded for future use. Should testing be required specimens shall be cut out with a diamond saw, dried at 105°C and tested.

Thermal Ceramics consider this preparation of panel acceptable believing the panel to be sufficiently representative of the actual lining. However, preparation of specimens by successive diamond saw cutting may introduce micro cracks and stresses in the specimens being cut. The strength comparison of such specimens cut to 50 mm, with that of cubes cast in the same concrete should allow for an additional variation of say 10% to accommodate possible weaknesses introduced by sawing.
Properties to be tested on cast or gunned specimens depend on many factors such as type of equipment, type of lining, service conditions. Another factor which might be introduced depends on whether the concrete has been delivered already dry-mixed in bags or with the inert (aggregate) material separated from the binder agent for dry re-composition at site.
Unless other testing is agreed with a customer for a particular project,
Thermal Ceramics suggests the following testing of specimens from site:

- Ready blended concretes
Cubes of a sample will be oven dried at 105°C and tested for bulk density and cold compressive strength.

- Concretes delivered separated - unblended
As with ready blended, but with double sampling for what is considered critical areas of the lining, 3 sample cubes will be tested after drying at 105°C while the twin sample of 3 cubes will be kept as reserve.
Should the density and cold compressive strength of first sample not to be acceptable, the reserve 3 cubes will be oven dried at 105°C and comparison tests made or tested in accordance with customers' demands (after 5 hours at 815°C for example).

Acceptance Criteria might be the same although tolerances night be increased; this would be a matter for agreement between interested parties.

8.4 AFTER INSTALLATION TESTS

If all the instructions described in this manual have been respected, after Installation Testing need to be limited only to Visual Inspection and Hammer Testing as described in the section of Lining Inspection.

However, should it be required to resolve questions concerning installed quality, core samples might be taken from the in-place lining and tested for cold compressive strength after oven drying at 105°C. In such a case, 50 to 75 mm diameter core samples shall be taken, and then diamond saw cut to a length/diameter ratio of approx. 1. Compression tests shall be made as described. The strength comparison of core cylinders to 50 mm cubes should allow for an additional tolerance (usually 10%) in acceptance criteria.

9.1 MANUFACTURING OF PRE-CAST SHAPES

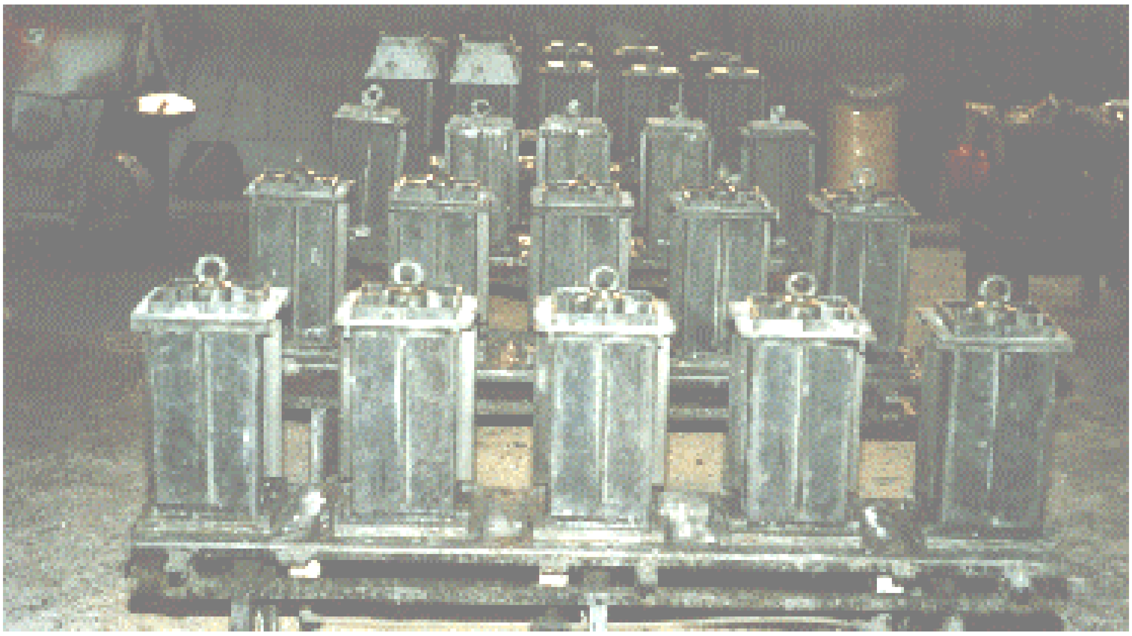
A variety of pieces - such as burner blocks, peephole and support blocks, baffles, dampers, etc. are often pre-cast in formworks in the shop using a vibrating table instead of an immersion poker.

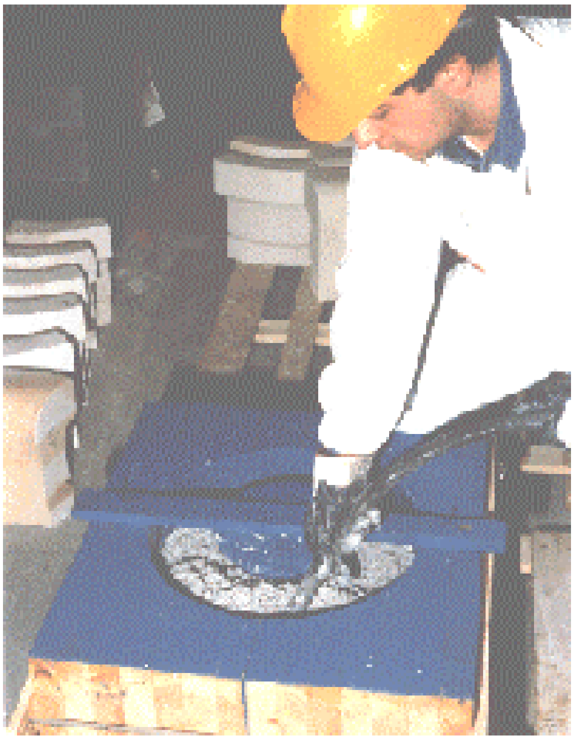
Metal moulds are preferred, but wooden moulds with special coating on the internal surfaces may be used. Moulds shall be designed to allow easy casting and stripping of the pieces and shall be sufficiently strong to withstand vibration cycles. Care must be taken that the moulds are securely clamped to obtain the maximum amount of vibration.
In the design stage of moulded shapes, special attention must be provided to be sure that pieces can be manufactured by casting: this means that the shape shall be such that it is possible to remove it from the mould, possibly modifying the design of the shape if the problem cannot be solved with the design of the mould.

For large series, lost burnable moulds - or cores - may be foreseen; the material can be cast and cured in the moulds, then drying and firing of material and moulds together can be made. In such a case, a cheap method to produce the moulds - for instance, in polystyrene - must be available.

Mixing, casting, curing, drying and heating instructions for shop moulded pieces are the same as already described. However, for economic reasons, it is advisable that the shop be adequately equipped with paddle mixers, batteries of vibrating tables, a curing room, drier and furnace of sufficient capacity.
The shop must be clean, having a proper potable water supply and exhaust system. The shop should be maintained at a convenient temperature and provided with storage facilities for the moulds. Skilled labour is imperative.
After the stripping of one cast piece the mould must be carefully cleaned, oiled and prepared for the next casting. All Thermal Ceramics castables normally permit manufacturing of two pieces per day using the one mould (excluding the night shift).
This must be kept in mind when deciding the number of moulds to be provided to meet contractual delivery schedules, not forgetting the time for curing, drying and - if required - firing the pieces, plus a reasonable allowance for any production losses.
In some cases with Dense Concretes mainly when the quantity of pieces combined with a short delivery time results in a larger number of moulds that would greatly affect the total cost of the pieces it may be convenient to select one of the Thermal Ceramics Vibrated Concretes which allow high frequency stripping, thus limiting the number of formworks. All Thermal Ceramics Dense Vibrated Concretes require less than 6% mixing water: in spite of this low quantity, the drying and firing operations of the pieces require special care to avoid cracks and explosive spalling, unless the Quick-Heating types of concretes have been chosen.
Even more important than for normal casting, skilled operators are imperative for manufacturing of vibrated pieces.

For best results Thermal Ceramics Specialists should be contacted at the beginning of every shop operation of moulded pieces manufactured with Thermal Ceramics Concretes and in some cases the visit of the Thermal Ceramics Specialist to the shop may be beneficial.


13. Manufacturing of moulded pieces in shop


14. Casting in the mould by vibrating needle