USER GUIDE TO CORDIERITE-MULLITE KILN FURNITURE

CONTENTS

1. INTRODUCTION

"Kiln furniture" refers to a wide range of refractory products used to support and protect products during high-temperature processes. Used traditionally in the firing of tableware, sanitaryware and heavy-clay products, it is employed extensively throughout the ceramics industry and beyond, into applications such as powder metallurgy, glass, composites, and even bread & pizza ovens.

Cordierite and Mullite are ceramic minerals formed at high temperature by the reaction of silica, alumina and magnesia. Cordierite has a low thermal expansion, which minimises the risk of thermal-shock during rapid heating and cooling. Mullite has good strength at high temperatures, which imparts resistance to bending and breaking under load. Cordierite-Mullite refractories are formulated to optimise the balance of these properties to suit different heat-treatment applications.

Most Cordierite-Mullite kiln furniture is stable at temperatures of up to 1350^{o}C (2460^{o}F), although practically its load-bearing capability (and therefore its useful life) starts to become diminished beyond 1300^{o}C (2370^{o}F). At higher temperatures, IPS can supply materials such as Silicon Carbide or Alumina, which are more suitable.

Kiln furniture ("KF") is often described as either "primary" or "secondary". Primary KF is the group of products that forms the superstructure of the kiln or the kiln cars. Generally, primary KF remains in position in the kiln or on the car throughout its life. Batts, props and kiln lining systems are examples of this type of kiln furniture. Secondary KF refers to the refractories that are used to directly support products during the firing / sintering process. Each is designed to be used with a limited range of products, and is usually removed from the kiln or furnace at the end of the process. This range of KF includes items such as plate setters, cranks and sanitaryware supports.

This User Guide is intended to support you in getting the best from your kiln furniture by helping you to understand the properties and some of the typical problems encountered in each of the main product groups, and by making recommendations on the best way to use kiln furniture to maximise performance, prevent premature failure and improve longevity.

2. CHOOSING THE BEST PRODUCTS FOR YOUR APPLICATION

IPS Ceramics sells tens of thousands of different shapes and sizes of kiln furniture items into a wide range of applications, and selecting exactly the right option for your process can be quite challenging. Performance of identical products can vary significantly between ostensibly similar processes, and even the conditions in different areas of the same kiln can vary sufficiently that kiln furniture can last longer at the bottom than the top of a kiln car, for example.

The extreme stresses placed on kiln furniture in normal use means that it's impossible to build-in complete resistance to every failure mode, and so choosing the most suitable product usually involves the best compromise of the most desirable properties:

- Resistance to bending
- Resistance to thermal-shock
- Strength
- Dimensional accuracy
- Cost

IPS's products have been developed and refined over many decades, and we have a range of materials and processes that are tailored to suit different requirements. The factors affecting these choices as they apply to each product range are covered in the following sections of this guide. However, for any product it is necessary to establish:

- Type of kiln or furnace
- Maximum temperature of the kiln
- Cycle time (heating, dwell & cooling)
- Atmosphere (oxidising, reducing, glaze volatiles, etc.)
- Weight and distribution of products in the kiln
- Handling methods, stability of the load, etc.

With this information, IPS Ceramics can offer you the best advice about the most appropriate products for your application. It's worth bearing in mind that the type of system you've been using for several years was probably the best available several years ago, and continuous improvement in design and materials means that a different method might be better for you now.

The following table can be used as a general guide to IPS's standard materials.

Material	Application	Max Usage Temp (°C)
STD	Standard KF	1320
FFR	Fast-Fire KF; Biscuit Setters	1300
HTR	Higher-Temperature Batts	1350
TUS	Extruded Tubes	1300
TEN	Extruded Batts for Fast-Fire Applications	1280
CSM	Cast KF	1300
NUK	Cast U & H Cassettes	1300
GEA	Crucibles	1150
LTS	LT Secondary KF	1250
GZR	LT Glaze-Resistant Secondary KF	1250

3. RECEIVING AND STORING YOUR PRODUCTS

All crates and pallets include a delivery label with information that allows traceability to the manufacturing process. This is particularly useful when investigating problems and we recommend that these labels (or copies / photos of them) should be retained for the life of the products.

IPS CERAMICS

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CUSTOMER:	COBCRAFT MANUFACTURING LIMITED, BARKERS ROAD, OHOKA RANGIORA, NEW ZEALAND.		
O/NUMBER: (CUSTOMER)	ROB DUGGAN	Order Number (IPS)	577644
ITEM NO. PRODUCT CODE & DESCRIPTION		QUANTITY	QC CODE
FULL DISC 479 X 19MM - DOB		60	1336 BOX 1
		DATE:	29/05/2012

Be safe. Handle crates / pallets carefully using a fork-lift device, and ensure you have the correct tools and personal protective equipment for removing strapping and opening the crates. Beware of sharp nails and strap-banding under tension, which can spring when cut.

Products can be brittle and easily damaged or broken by impact, so must be handled carefully during unpacking and subsequent transportation. Always observe Manual Handling Operations Regulations when lifting large items such as batts.

Check that the quantity and description of the products are in accordance with labels and delivery notes and check carefully inspect the crates for any transport damage. Report any discrepancies or damage **as soon as possible** after delivery.

When first received, products can be wet due to processing (cutting, drilling or surface-grinding), or because of wet conditions during transportation. Wet products will be damaged if exposed to temperatures in excess of 110°C (230°F), as any absorbed water will create uneven rates of heating across the product which can then cause cracking. In severe cases, a rapid build-up of steam can result in fracturing or explosive fragmentation. **It is therefore essential that all products are dried before use**, and that they are stored in dry conditions if not used immediately.

Batts are best dried and stored by stacking together vertically on edge and ideally resting on two strips of soft wood. It is **not** good practice to store batts stacked flat as this increases the risk of breakage

Under certain conditions, allowing products to remain damp for long periods can lead to the formation of moss on the surface. This is not detrimental to the performance of the products, and can be removed using a fungicide, but in any case it will disappear completely after the first firing. However, in order to avoid this, products should be dried as soon as possible after receipt.

If wet products are allowed to freeze, there is a risk of frost-damage due to the volume expansion as water turns to ice, so KF should be kept at temperatures higher than 5°C (41°F). Dry products will not be adversely affected by freezing temperatures.

4. PRIMARY KILN FURNITURE

4.1. OVERVIEW

Primary KF is by far the largest group of products supplied by IPS Ceramics, and forms the superstructure of the kiln or the kiln cars. This can include the following components:

4.1.1. BATTS

From small, thin tiles up to large slabs several hundreds of millimetres long, batts are the main component in primary KF systems, and are used mainly as shelves to support products during firing. Batts are also often used as covers / guards, and as tiles in kiln lining systems.

Batts fall into three distinct types:

Plain Batts – These are usually basic, pressed shapes, occasionally incorporating surface features or small holes for the location of other components in an assembly (eg. Props). The simple design of a plain batt means it is usually least-prone to failure.

Extruded Batts – These are designed to reduce thermal-mass while maintaining a good strength: weight ratio. They are commonly used for sanitaryware kiln cars. It's usually recommended that extruded batts are supported by Silicon Carbide beams rather than props at the corner.

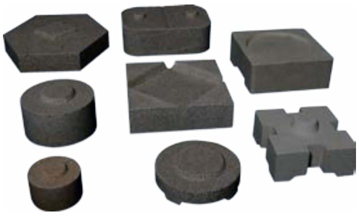
Perforated Batts – Sometimes referred to as Multihole batts, these are pressed or cast with several holes to reduce weight or allow air circulation through the batt. Depending on the number and size of holes, these can be considerably weaker than other batts, so they're not usually recommended where strength is a requirement.

4.1.2. PROPS

Props are used to support batts in kiln car structures. They are either pressed or extruded, varying in size and shape according to the required strength and stability, and can incorporate features such as shelves to accommodate variable-height placing systems.

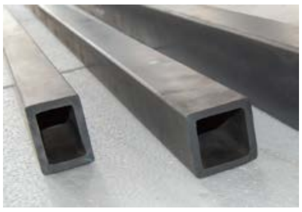
4.1.3. FITTINGS

Including Collars, Caps and Splicers, fittings are intermediate pieces that are sometimes used to connect batts, props and beams.



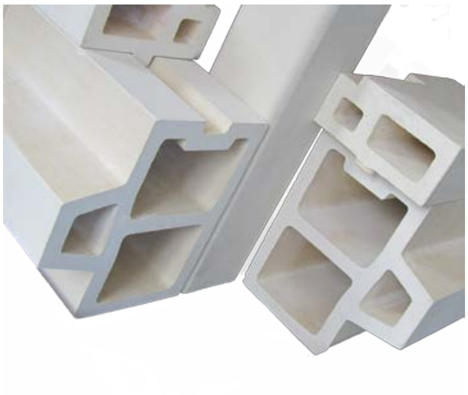
4.1.4. BEAMS

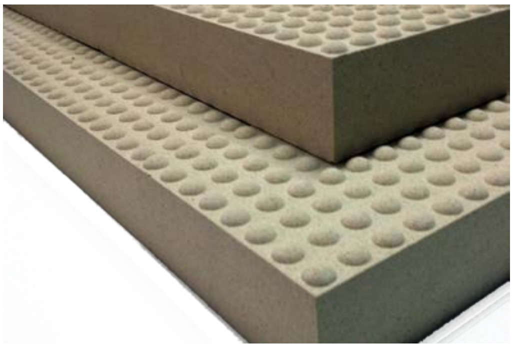
Typically made in Silicon Carbide material, Beams are used in conjunction with props and fittings to provide the best possible support for large batts carrying heavy loads.



4.1.5. KILN CAR BASE SYSTEMS

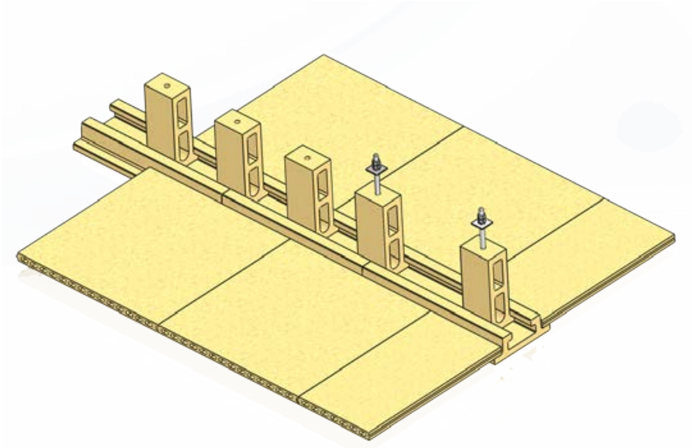
IPS Ceramics offer two types of kiln car base: Extruded / cast perimeter blocks, which are extremely robust, and Dry-Lock Bricks, which are a harder-wearing alternative to the conventional Lightweight Insulating Firebrick.





4.1.6. ROOF-HANGER SYSTEMS

These use a combination of specially-designed cranks and plain batts to form kiln ceilings or to enclose ceramic fibre linings in intermittent kilns.



4.2. CHOOSING THE RIGHT SYSTEM

The appropriate system for your application will depend on a range of factors, most importantly the temperature, load and the need for stability. The type and thickness of batt is the most important decision, and IPS Ceramics can recommend the optimum size and design to allow safe support of products while minimising thermal-mass in your kiln.

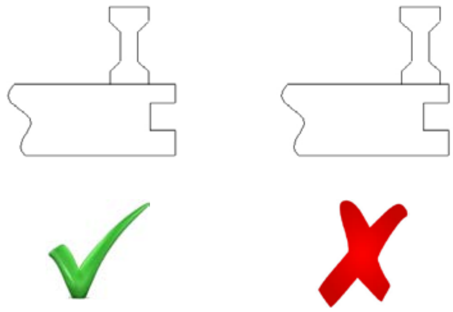
4.3. GUIDELINES FOR ASSEMBLY AND USE OF PRIMARY KF

4.3.1. INITIAL ASSEMBLY

The kiln car base is the foundation upon which the rest of the structure relies, and failure of batts (particularly cracked corners) can often be attributed to inadequate support due to uneven bases. It is therefore important that the base is completely level, and that any parts of the base that will directly support the rest of the structure are constructed using appropriate materials. Large cross-section props or heavy firebrick piers built up from the metalwork are considered the best solutions. Structures supported by inadequate materials such as Lightweight Insulating Firebrick should be avoided, as these will sink over time, resulting in an uneven base.

The same principle applies when building up a kiln car, ie. Each level relies on the components immediately below, and so it’s essential to ensure that all supporting props are perpendicular and decks are level. Ceramic fibre paper or wad-clay should be used to level batts and props.

Props used to support each deck must be aligned directly above the supports below in order to transfer as much of the weight of the kiln furniture as possible down into the base. Props that are out of alignment will apply bending stresses to the batts, leading to cracks and shortening their life. This also applies to overhanging areas of kiln car base seals; props should be positioned so that they are not directly above these.

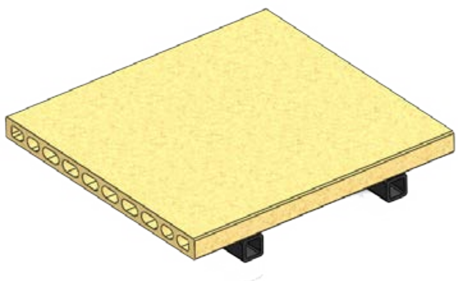


4.3.2. DATE-MARKING

When batts are first put into service, it is recommended that components should be marked with the date using a high-temperature pencil. This will allow you to monitor the performance and longevity of products, and can be especially useful when making a complaint about premature failure.

4.3.3. EXTRUDED BATTS

Except where the kiln temperature and load are low, it is not recommended that extruded batts are used with props in a conventional three-point or four-point support. The safest way to employ this type of batt is to support them on Silicon Carbide Beams, which should be aligned perpendicular to the cores of the batt. It is recommended that extruded batts are supported by just two beams. Where loading is fairly uniform, the beams should ideally be placed approximately $^2/_9$ of the length



of the batt from each end. Where loading is localised on part of the batt, IPS can give advice on the best beam positions

4.3.4. CARE & MAINTENANCE

If used at temperatures above 1000°C (1830°F), any batt will eventually bend, and the rate of bending will increase with higher temperatures and loads. The longevity of batts can be extended significantly by turning batts over before they become more than 2mm bent.

Thermal-shock is a common cause of sudden failure (cracking) in batts. This occurs when the temperature varies significantly across a batt, and is usually caused by rapid cooling. For fast-fire processes, materials with better thermal-shock resistance are normally used, but in applications where rates of heating and cooling are not extreme, this type of failure can be the result of opening kiln doors or removing cars at too high a temperature, or placing hot kiln cars in a cold area. It is recommended that kiln cars are cooled slowly until below 200°C (392°F).

Care should be taken to avoid impacts against the edges of batts, for example when placing and emptying products in setters. Cracks can propagate from small chips on the edges of batts.

Upper decks of kiln cars should be accessed using steps / platforms. Operators must not climb directly onto kiln cars.

4.3.5. BATT WASH

Where products are placed directly onto batts, alumina wash can be used to help reduce sticking to surfaces. If this is applied too thickly it can flake-off and cause contamination, so batts should be coated as thinly as possible, using successive thin layers to maintain protection.

4.3.6. GLAZE ATTACK

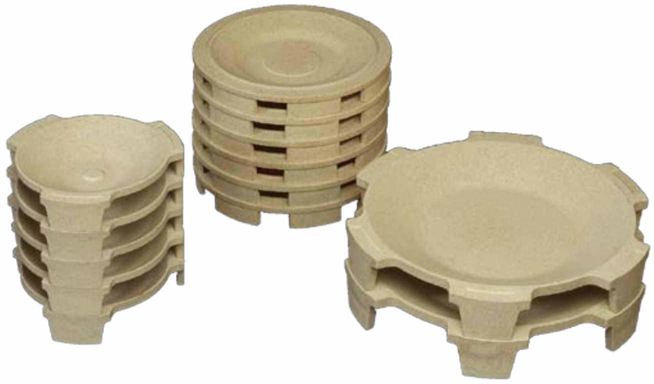
Where kiln atmospheres contain glaze volatiles, these can attack the surface of kiln furniture and cause the surface to peel. This isn't usually detrimental to the performance of the kiln car, but pieces of refractory

can contaminate ware, so loose pieces should be removed and surfaces vacuumed wherever possible.

5. BISCUIT SETTERS

5.1. OVERVIEW

Biscuit setters are used to directly support tableware items (plates, cups, etc.) during their initial "biscuit firing". They are designed to help the items to retain their shape during vitrification, the softening of clay ware at peak firing temperatures. Setters can range from small rings to maintain the roundness of the rim of a cup or bowl, up to profile setters, which fully-support the shape of a plate.



5.2. GUIDELINES FOR USE OF BISCUIT SETTERS

Profile setters are normally used in stacks ("bungs") to maximise kiln fill, and can be supplied either with or without integral legs. Legless or "plain" profiles have spacers cemented to the lower surface to allow them to be stacked.

Each type offers advantages over the other; legged setters can be used "straight from the box", but become useless if any of the legs are broken. Plain setters need to be assembled before use, but can usually be repaired if legs become broken or detached in service. Spacer legs can be attached using a refractory air-setting cement.

5.2.1. PROCEDURE FOR MIXING REFRACTORY CEMENT

Option 1: Cement is supplied as dry powder & liquid additive. The dry powder can be stored indefinitely under dry condition while the sealed additive can only be stored for 1 year. Once mixed, it will become hard within a few hours, so it is recommended that no more is mixed than can be used within two hours. For general use, a mix of 430g of additive to 1000g of powder is recommended. The cement should be well mixed, left to stand for fifteen minutes, then remixed. Initially it may appear too dry, but the consistency will change to a smooth paste after standing. The consistency of the cement can be adjusted if required by varying the amount of additive used. A skin will slowly form on the surface of any exposed cement. This skin can be stirred in to the cement without any adverse effect.

Option 2: Sealed mixed cement can be supplied and can be stored for 3 months. Once exposed in the air, it will become hard within a few hours, so it is recommended that no more is taken out than can be used within two hours.

5.2.2. PROCEDURE FOR ATTACHING SPACER LEGS

The type and position of spacer legs depends on the application, eg. The height of the spacer is kept to a minimum to maximise kiln-fill, but this can sometimes result in cooling problems and thermal-shock cracking. IPS Ceramics will be happy to recommend the best configuration, and this is often indicated on the product drawing for new setters, but as a general rule, the gap between spacers should be no greater than 1½ times the length of the spacer.

Ensure that the surfaces to be joined are dry and free from dirt / dust, and place the setter to be dotted working-face down on a small turntable, so that the spacers will be on the underside of the setter when in use. Dip the edge of the leg to be attached into the cement, then lightly press onto the surface of the setter. Remove any excess cement from the join, then repeat for all legs.

Place another setter on top of the first and repeat, ensuring that the legs are placed in-line with those on the setter below. Continue to a height of no more than six setters, then remove five and transfer to a pallet or stillage. The bottom setter is left in place as a reference for the next five. Fill the pallet to a maximum of 10 – 12 setters high.

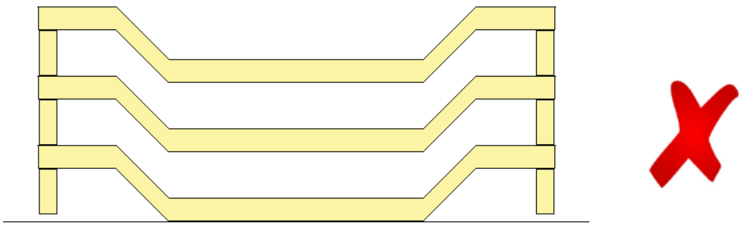
The cement does not become permanent until after its first fire, and so handling of newly cemented products should be minimized and care should be taken when handling the setters prior to first use. Fresh joints that fail during handling **must** be cleaned off and remade.

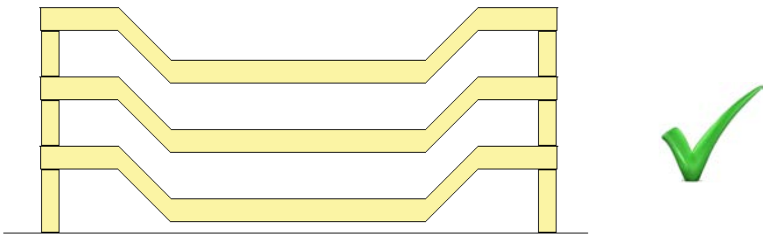
It is recommended that products are dried for at least four hours at 60°C. The cement will dry in lower temperatures, but the time will need to be extended (Three days at 20°C). After drying, the joint will be resistant to moisture in the air. If required, dried joints can be parted by immersing in boiling water. On firing above 500°C the cement becomes completely resistant to water. Optimum strength is achieved on firing above 1100°C.

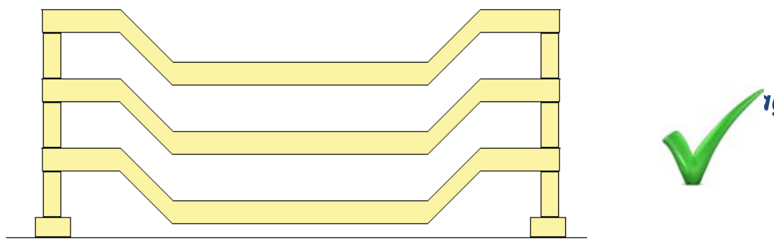
5.2.3. STACKING PROFILES IN USE

It is recommended that spacers are placed onto the underside of the setter rim. When stacked, spacers should be in-line throughout the stack to ensure that the load is transferred evenly downwards, and the bottom setter should not be in contact with the kiln deck, as this will increase the risk of distortion and thermal-shock cracking.

If the depth of the setter is greater than the spacer height, the bottom setter should be lifted using a ring, base setter or taller dots.







5.2.4. PLACEMENT OF WARE

Products must be placed centrally onto / into the ring / setter to ensure the best roundness / flatness are achieved during firing.

5.2.5. SETTER WASH

Alumina wash can be used to help prevent ware from sticking to the face of the setter. If this is applied too thickly it can flake-off, creating an uneven surface. The setter face should therefore be coated as thinly as possible, recoating as necessary to maintain protection. As successive coats are applied, the cumulative effect of slight variations in the wash thickness in different areas can eventually change the shape of the setter face, so take care to ensure an even coating. Spraying is recommended to achieve the best result.

6. GLOST CRANKS

6.1. OVERVIEW

Glost Cranks are usually used to support glazed tableware during firing. Their objective is to maximise the number of products that can be placed in the kiln. Glost cranks are normally suitable only for “foot wiped” ware; products that are glazed all over are usually supported in a Pin Crank System.

There are three distinct types of crank:

T & Y-Cranks – As the name suggests, these are T or Y-shaped setters that support the foot of a plate at three points, giving the best ware-to-KF weight ratio and maximum airflow around products. They are available with integral legs, or with separate spacers that are usually cemented on to form the legs.

Total Foot Supports (TFS) – These are effectively a small batt that gives full support to the foot of a plate during firing, minimising distortion. As with T-Cranks, they are available with or without integral legs.

Skeleton Cranks – These are cast items that resemble TFS cranks, but with much of the area removed. They have the low-weight advantage of a T-Crank while offering good support around the foot of the plate. Skeleton cranks are available only without legs, with a range of props to allow stacking.

6.2. GUIDELINES FOR USE OF GLOST CRANKS

6.2.1. HANDLING AND STACKING

T-Cranks and Skeleton Cranks in particular are very fragile and prone to breakage if they are not handled carefully. This can cause problems in automatic handling systems, particularly in high stacks where small individual height deviations can lead to larger errors.

Cranks should not be stacked to a height that leads to instability and the risk of falling over. As a general rule, stacks of more than 20 cranks are not recommended, although this figure can be higher or lower depending on factors such as the flatness of the placing surface and the amount of movement in the process.

6.2.2. USE OF PINS

For some applications, and particularly in T-Cranks (which often have slots for this purpose), ceramic pins are used to lift the ware from the surface. This can reduce plucking of the foot and prolong the life of the crank.

6.2.3. GLAZE ATTACK

Where kiln atmospheres contain glaze volatiles, these can attack the surface of kiln furniture and cause the surface to peel. This isn't usually detrimental to the performance of the cranks, but pieces of refractory can contaminate ware, so loose pieces should be removed wherever possible. If glaze attack is a particular problem, then materials with an increased resistance to attack are available.

7. PIN CRANK SYSTEM

7.1. OVERVIEW

The Pin Crank system offers a method of supporting tableware during glost firing, which gives the very best refractory-to-ware ratio by fitting the maximum number of plates into the available firing space. It comprises three main components: Bases & Covers, Uprights and Pins. These are interchangeable to give a very wide range of options.

7.2. GUIDELINES FOR ASSEMBLY AND USE OF THE PIN CRANK SYSTEM

7.2.1. ASSEMBLING CRANKS

The location of uprights into bases and covers is designed to give good stability, but if the fit is too tight, they can become stuck together, which leads to breakage. For this reason, some flexibility is required, which can lead to "scratching" of the ware at the point of contact with pins if there is too much movement. In order to minimise this, wax can be used in the base holes to keep the crank rigid prior to firing.

In order not to exacerbate this problem, it is strongly recommended that cranks are not stacked on top of each other.

7.2.2. PINS

While the main body of the crank (bases, covers and uprights) can survive hundreds of cycles, pins are designed to be used only once, as the corner in contact with the ware is damaged after use.

During transit, dust can develop in bags of pins, and it is recommended that pins are coarse-sieved before use to prevent this dust finding its way into the process.

8. COMPLAINTS PROCEDURE

In the event that you are dissatisfied with the quality or performance of products, or any aspect of administration or service, IPS Ceramics operate a formal Customer Complaints procedure to thoroughly investigate the causes and to establish solutions and remedies.

“Failure in Service” complaints are often difficult to conclude, but we have the best chance of success if there is as much information as possible early in the investigation. Wherever practical, we will visit to study the failure in-situ, but it might not always be possible to organise this immediately. Detailed information, picture and samples can help to investigate the problem remotely:

- Process conditions (temperature, cycle time, weight of products, etc.)
- Details of failure (type, quantity, time in service / number of cycles completed)
- Batch details (stamps on products and / or delivery label information)
- Sample of failed product for testing (Samples of products that are working ok can also be useful for comparison)
- Photographs of the failed products indicating the nature and quantity involved
- Any other information that might be relevant