



# CARBON REGENERATION KILN





**100 kg/h Diesel fired carbon regeneration kiln c/w carbon holding hopper**



**3D Model of the 100 kg/h diesel fired carbon regeneration kiln c/w carbon holding hopper**

## CARBON REGENERATION PROCESS

Activated carbon adsorbs neutral species. These species can be of organic and inorganic nature. The presence of these species on the internal surface and in the pores of the activated carbon will reduce the ability of activated carbon to adsorb desirable species, in this case gold (as the calcium gold cyanide ion pair). The organic species are removed from the carbon using thermal regeneration to restore the original porous structure and activity of the carbon, causing as little damage as possible to the carbon itself.

The generally accepted conditions for thermal regeneration are in the temperature range of 650 - 750°C for a period of 10 to 30 minutes in a non-oxidising atmosphere. Steam is the most economical inert atmosphere to blanket the carbon and prevents the oxidation of the carbon at higher temperatures. This inert atmosphere is created in the first, or drying, stage of regeneration when the moisture in the carbon is driven out of the porous structure of the carbon as steam. The steam generated atmosphere has a slight positive pressure, preventing oxygen ingress.

All Kemix kilns are custom designed to meet application requirements with specific regard to the mode of heating, voltage, frequency and throughput. Selection of the method of heating include electrical elements, light oil, heavy oil or gas burners.

The kiln components comprise a base frame, heating cabinet, heat source, dewatering feed screw arrangement complete with variable throughput drive, discharge hopper, main and back-up drive units, retort tube, support rollers and a fully integrated control panel.

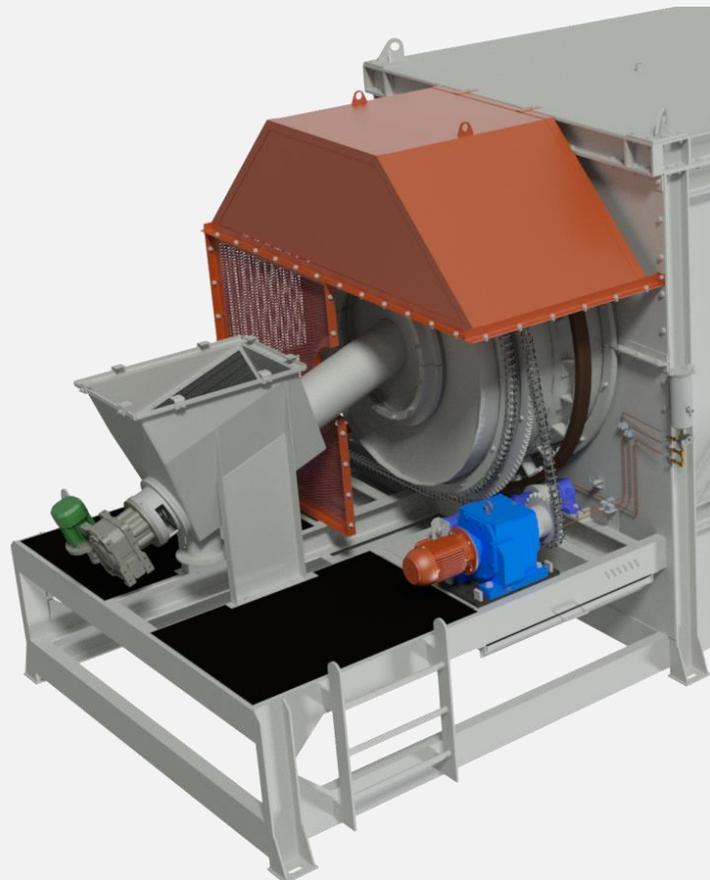
The retort tube is manufactured from specialised alloys capable of withstanding the high temperatures associated with thermal regeneration.

The design of the retort tube with consideration to peripheral speed ensures proper carbon bed turnover enhancing the complete thermal regeneration.

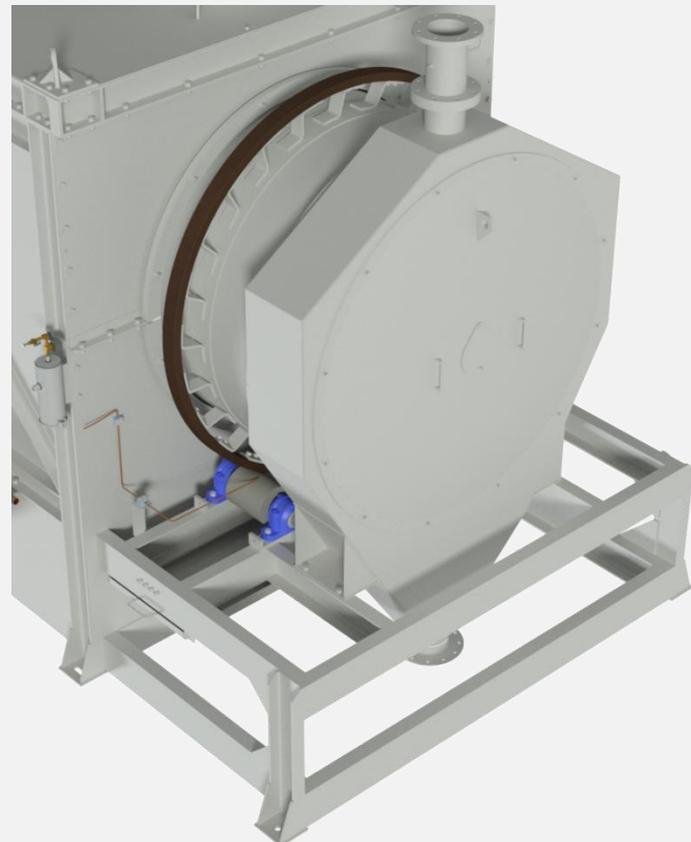
All Kemix kilns have an automatic start-up and shut-down sequence which reduces operator input. Speed variation of the screw feeder facilitates greater flexibility and complete plant integration.

### Structure and Casing

The framework is fabricated from a number of rolled mild steel sections which are welded together to form a robust and stable structure.



**Carbon regeneration kiln feed end**



**Carbon regeneration kiln discharge end**

The design allows for the mounting of the dewatering screw feeder charge section, drive arrangements, roller supports, heating section, cooling section and discharge hopper on the robust frame.

The casing which forms the heating section is made up of mild steel plates welded to the channel section steelwork. The roof of the casing is made from plate work sections, which are removable to allow access to the retort tube.

The kiln is inclined to the required angle on the kiln support structure. The kiln structure is a one-piece unit, therefore, the screw feeder, feed hopper and discharge hopper are inclined with the kiln.

### Dewatering Screw Feeder

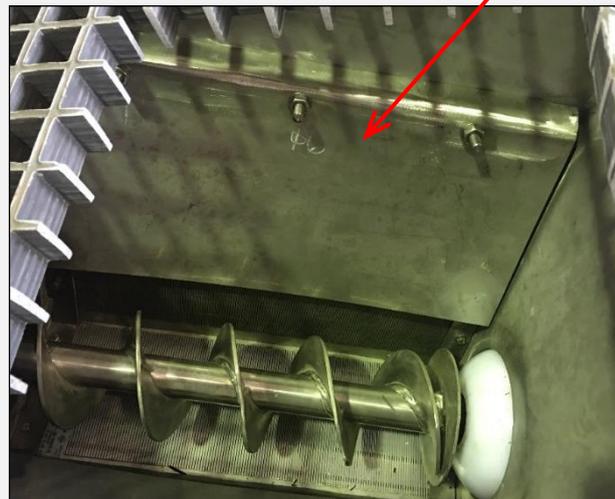
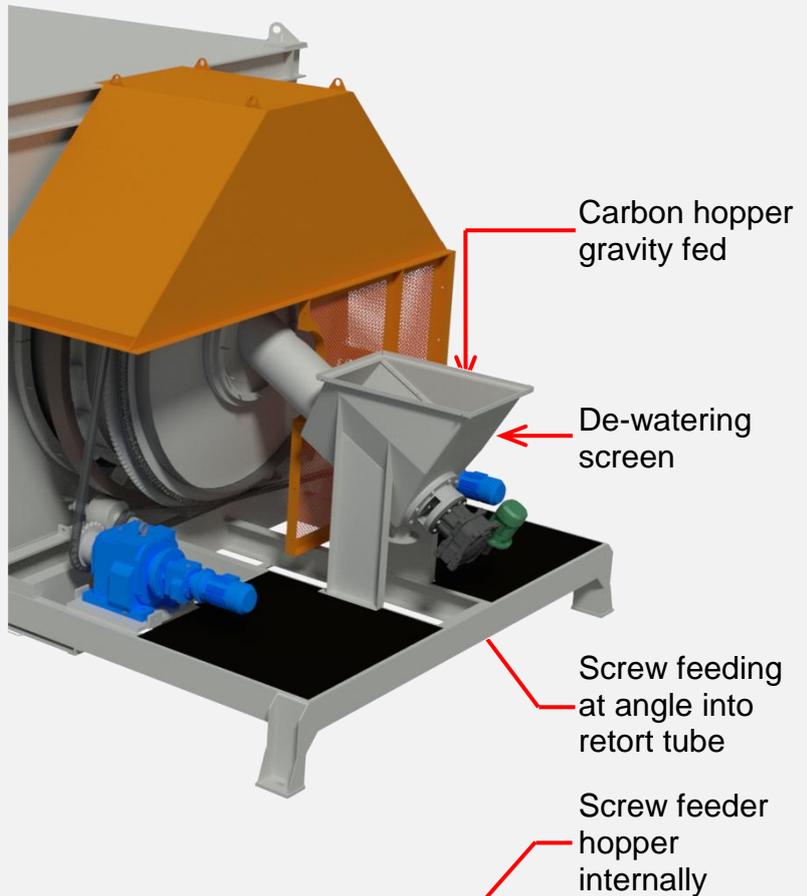
Wet carbon is fed by gravity from the feed hopper into the hopper of the screw feeder, where it is fed directly into the kiln retort tube. The dewatering screw feeder is a robust unit and mounts directly onto the kiln structure at the charge end. The feeder casing and screw auger are manufactured from stainless steel.

The feeder is equipped with a variable speed drive unit capable of feeding at the required throughput. Coupled with the slow speed gearbox, the inclined screw feeder arrangement and an enlarged screw pitch assists in reducing the possibility of water entering the retort tube. Water entering a retort tube contributes to 90% of premature retort tube failure.

The Kemix screw feeder has a unique dewatering arrangement installed in the feed screw housing incorporating an over flow which drains of excess water when the level inside the screw feeder housing reaches critical levels due to blinded screens.

The Kemix screw feeder also makes use of candle filters, for ease of cleaning and replacement. This design does not require any major components to be dismantled to service or clean the candle filters.

The screw feeder flight and casing are designed to utilize the carbon and act as a lining medium between the screw and the casing, this design ensures that the outer casing does not wear. The only wearing part in the feed screw is the screw itself.



Screw feeding open drain

A custom designed bearing support, reinforces the back of the screw. This enables the screw to penetrate directly into the retort tube and allows mechanical expansion at different temperatures.

The screw feeder is also equipped with an open drain assembly, this enables the operator to visually identify if the wedge wire screen is blinded or blocked.

Electrical interlocks are incorporated into the control design, to prevent the screw feeder from transferring carbon into the retort tube until a pre-set temperature or if the rotation of the tube stops.

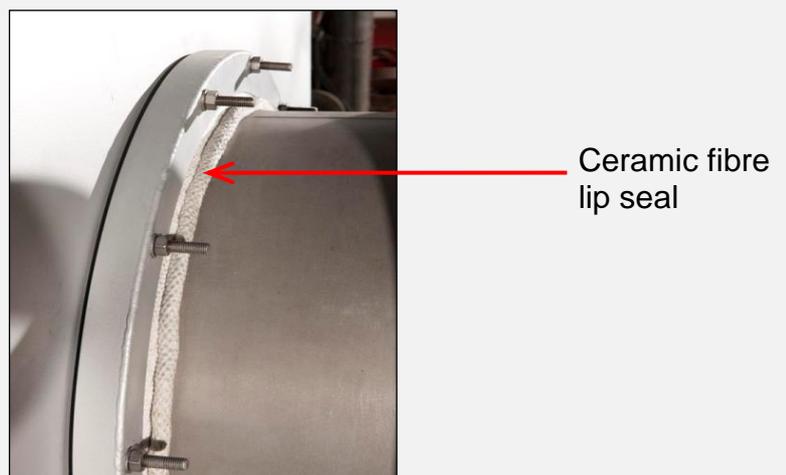
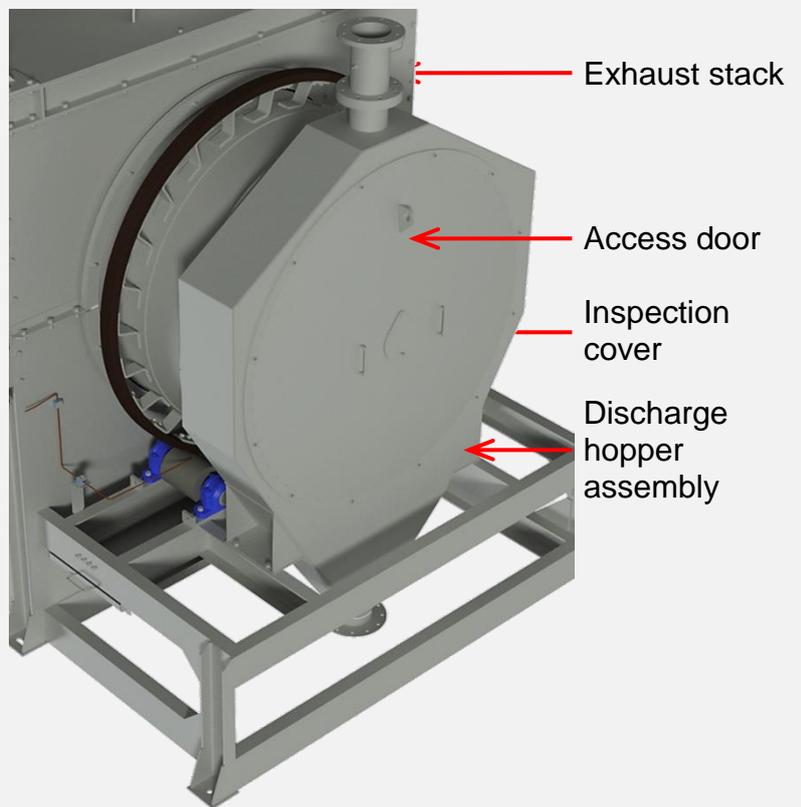
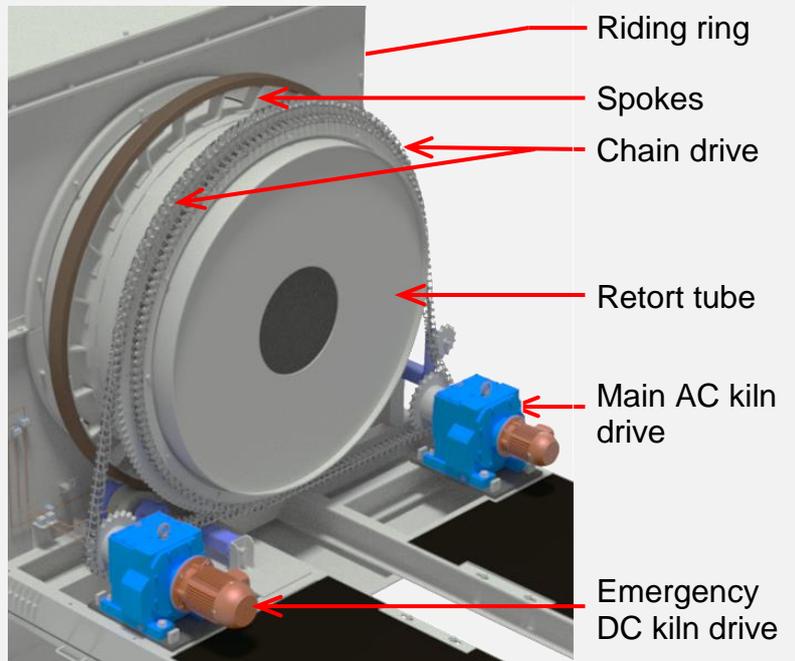
**Advantages of using the Kemix screw feeder arrangement:**

- No pre drying of carbon required.
- No additional steam required.
- **No water entering the retort tube through the screw feeder causing premature retort failures.**
- Shorter down time to replace the screw flight, wedge wire panel and other sub assembly parts.
- Minimal maintenance required on wedge wire panels.
- Screw feeder is fully fabricated from stainless steel.
- Use of mechanical reduction to optimize power efficiency and low rpm on screw flight
- Low operating cost.

**Retort Tube**

The retort tube of the kiln is manufactured from 321 stainless steel. The length of the tube is sufficient to accommodate the heating zone, cooling zone, charge section, drive arrangement, support rollers and discharge hopper.

Fitted inside the retort tube at the feed end is a stainless steel end plate which allows the feeding portion of the screw feeder to protrude into the tube and prevent carbon feedback into the feed section.



The retort tube is a one-piece unit and is supported by two forged steel riding rings, located at the feed and discharge ends of the kiln, either side of the heating zone.

The solid support rings are bolted to stainless steel spokes which are welded to the outer wall of the wrapper plates. The "Z" shaped flexible spokes allow for expansion of the retort tube.

EN9 steel rollers, supported by roller bearings in plummer blocks, carry the retort tube via the riding rings. The tube is fixed at the feed end between two thrust rollers, mounted either side of the front riding ring on the kiln support structure.

The support rollers at the discharge end have a face width greater than the calculated expansion which allows free movement of the tube along its length.

The riding rings, plate wheels, chains and steel rollers are enclosed within expanded metal guards.

A removable inspection cover is provided in the rear wall of the discharge hopper which allows for inspection and deposit removal inside the retort.

Fitted to the sides of the kiln at the discharge and feed ends are automatic drip feed lubricators filled with oil, which drip lubricates the chains, support rollers and riding rings. The bearings and thrust rollers are provided with greasing points mounted outside the guards. The main kiln drive, emergency DC drive and chain tensioners are mounted on the kiln structure.

### **Discharge Hopper**

Located at the discharge end of the kiln is a stainless steel hopper mounted on the main frame. The expansion of the retort tube during operation is accommodated in this hopper. Mounted on top of the hopper is a discharge duct, for the release of steam/volatile gases, etc., from the interior of the retort tube. An exhaust stack would be connected to the discharge duct during installation.

A large access door is mounted in the rear wall of the discharge hopper which allows access to the retort tube for maintenance and cleaning of the inside of the tube.

A small inspection cover plate is fitted to the access door which permits the operator to visually monitor the progress of carbon along the tube.

A stainless steel discharge pipe is fitted to the bottom of the hopper, allowing carbon to be discharged directly into the quench tank below.

### **Seals**

Sealing of the retort tube at the face of the charge section, discharge hopper and furnace casing is achieved using 50 mm square ceramic fibre seals. This eliminates unnecessary heat loss and provides a positive pressure within the tube. The seal housings are adjustable to compensate for wear on the seals.

### **Thrust Rollers**

The thrust rollers are mounted on the main frame and are located on either side of the feed-end riding ring on the centreline of the tube at a height which allows them full contact surface with the sides of the riding. The distance between the inner surfaces of the thrust rollers is approximately 5mm greater than the width of the feed-end tyre.

### **Support Rollers**

Riding rings are mounted concentrically to the kiln tube and on rollers mounted directly to the main frame. The expansion in tube length at operating temperature is accommodated by the longer discharge end rollers. Both the feed end and the discharge end rollers are mounted parallel and equidistant to the centreline of the tube. The accuracy of this alignment is important, both from the point of view of tyre / roller wear and steering.

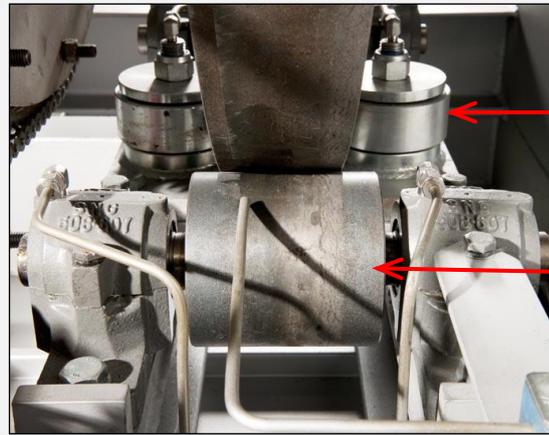
### **Steering**

In order to achieve a continuous positive flow of material through the inside of the tube, the entire furnace is set at an inclination to the horizontal, the feed-end being higher than the discharge-end. As the rollers are attached to the main frame, they too will be inclined to the horizontal at the same angle and in full contact with the riding rings attached at right angles to the tube.

This inclination to the horizontal, whilst relatively small, creates a horizontal component of the vertical loads and must be countered.

The ideal running condition is achieved when the feed end riding ring runs continuously between the upper and lower thrust rollers without making contact. However, due to variations in load, and/or lubrication conditions, this is not always achievable on a continuous basis. The thrust rollers will handle periodic contact.

In order to preserve the life of both the riding rings and the rollers, the contact surfaces between them should be continuously and adequately lubricated.



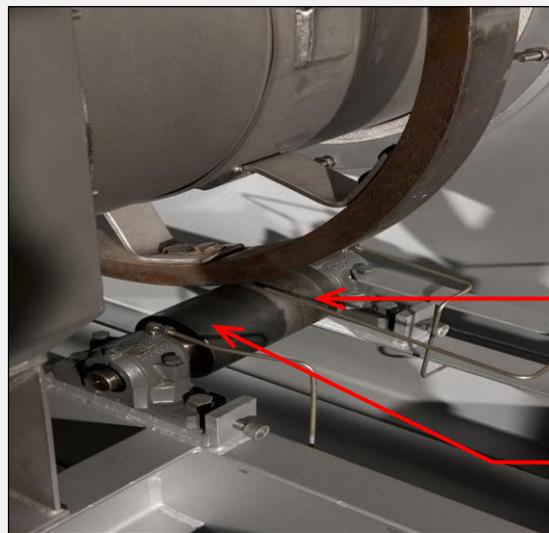
Thrust roller  
Charge end support roller

### Chains and Riding Rings Lubrication System

Lubrication of the chains and riding rings is automatic. Solenoids mounted on the base of cylindrical oil tanks are operated via the shutdown temperature controller to automatically start and stop the oil feed during operation. This prevents unwanted oil flow onto the chains and riding rings during shutdown periods.

Oil drip rates are adjusted via valves mounted on the underside of the oil tanks.

Sight glasses allow the oil level in the cylindrical tanks to be monitored. Periodic topping up is all that is required when necessary.



Discharge end support roller  
Provision length on support roll for tube expansion

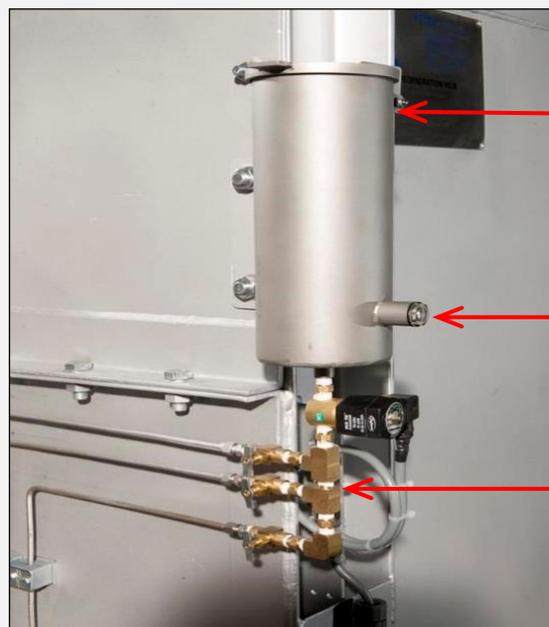
### Bearings

The support and thrust bearings are manually serviced via grease nipples mounted on easily accessible greasing stations on the side of the kiln.

### Kiln Main Drive

When operating under normal conditions, the retort tube is driven by an AC motor, close coupled to a reduction gearbox with a keyed shaft arrangement.

Mounted on the output shaft of the gearbox is a free-wheel clutch fitted with chain sprocket. The driving of the tube is carried out using a simplex chain from the driving sprocket to a plate wheel mounted on the tube.



Lubrication header tank  
Oil sight glass, oil level indication  
Valve to set oil drip rate

A frequency inverter is installed in the electrical control panel to provide the required rotational speed of the retort tube.

### Emergency Drive

An emergency DC drive system is incorporated to protect the heated retort tube from distortion when the main power supply is interrupted. Changeover from main supply to emergency supply and vice versa is automatic and instantaneous. The speed is fixed.

The battery supply will drive the tube for a minimum period of four hours to allow the tube to cool to a safe temperature. As the emergency drive system is dependent on power from the batteries for its function, it is important to remember that for the emergency backup system to function properly, the batteries need to be kept charged.

Should a rotation fail or main fail situation occurs, the kiln will automatically switch over to the emergency drive. It will continue to run on the emergency drive until:

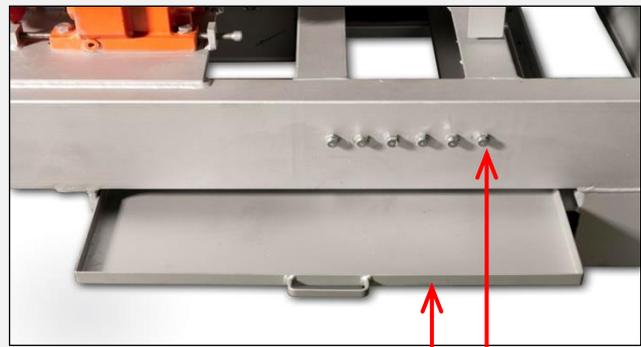
- i. The alarm is reset and the fault is cleared.
- ii. The kiln temperature has dropped below the level set on the DC shutdown controller.
- iii. Low battery voltage is detected.
- iv. The mains are restored in case of a power failure.

### Rotation Check

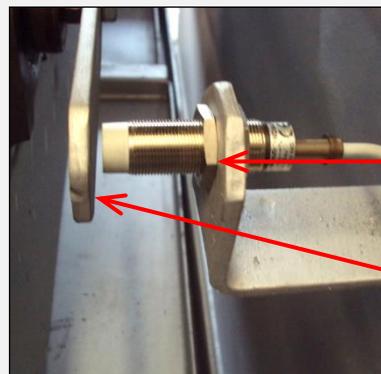
Continuous checking of the tube rotation is achieved with a proximity detector, which supplies a reset pulse to the pulse relay card mounted in the control panel. If no pulse is received the timer relay energises after a pre-set period and initiates the alarm system, which:

- i. Sounds an audible "rotation fail" alarm.
- ii. Switches off the power to the main drive motor.
- iii. Switches off the power to the heating system.
- iv. Switches off the screw conveyor motor.
- v. Switches on the auxiliary drive motor.

The rotation check will operate exactly the same way, whether the failure is electrical or mechanical.



Grease nipples for bearings



Drip tray

Rotation proximity

Rotating plate mounted on support roll

Lubrication header tank



Laser proximity sensor

Laser proximity protective cover



The following rotation check devices are available:

- i. Inductive proximity sensor
- ii. Laser proximity sensor

### **Alarm system back-up**

The 24V DC alarm system is designed to control the changeover from main to emergency drive and shut down the kiln to keep the retort tube rotating until it is sufficiently cool to stop.

### **Insulation**

The roof, side and end walls are lined with various grades of ceramic fibre blanket, limiting heat losses to a minimum and significantly reducing the overall weight of the kiln. The blanket is attached to the casing with heat-resistant, high chromium steel studs, stud-welded to the inner wall and held in place with Twist-lock washers.

### **Electric Kiln Heating Medium**

The layout and positioning of elements in a Kiln is the most critical criteria to be reviewed during design and construction phase. This part of the kiln will determine the operating cost as well as the down time required to replace or maintain these elements.

The following points need to be taken in consideration with position and selection of elements:

- Access to elements to replace and maintain.
- Dust accumulation on elements.
- Mechanical parts to be removed to gain access to elements (retort).
- Electrical connection points.
- The accumulated heat from the element into the electrical connection point.
- Heat Transfer coefficient to the carbon bed.
- Watts loading per element.
- The philosophy of electrical current control.

Kemix has developed the use of the SIC element which is controlled by using phase angle controllers which enables the delivery of the required heat at a given time without any delays.

The SIC elements offers the following advantages against other types of elements:

### **Advantages of Kemix SIC elements above any other Element Type:**

- Less elements required to produce the same KW of heat.
- The elements offer a cold connection point on both sides of the elements, which lead to no heat losses outside the insulation area and has no hot electrical connections.
- Specified heat radiation surface which enable direct heating onto the carbon bed positioned on the lower side of the retort tube.
- Elements extend through the sidewall which enables replacement from the side of the kiln, instead of from the top or even from the inside of the cabinet.
- Elements are positioned below the retort tube in close proximity to the carbon bed, which reduces heat losses due to the direct heat radiation in to the carbon bed.
- Elements are raised from the floor, which prevents the accumulation of dust and spillage on the bottom of the floor from affecting the elements.
- Elements do not deform or short out and burn off.
- Estimated life cycle of an element set is 5-7 Years.
- Maintenance is simplified because elements can be replaced while the furnace is hot. This reduces downtime Element replacement takes 5-10 min and only requires one person to perform the task.
- In some applications the use of metallic elements (including candle elements) creates a risk of short circuit / tracking due to conductive dust (including carbon regen & vanadium furnaces). SIC perform better in this environment.
- Maximum element temperature capability exceeds those of metallic heating elements.

- Element support is simplified (only uses one or two ceramic supports compared to many hangers needed for metallic strip elements)
- Higher power density is possible
- High efficiency due to increased emissivity
- Can be installed across long distances (in excess of 3m in special cases) due to high mechanical strength



**Ceramic fibre blanket**

### **Kemix SIC Elements**



**Clamping arrangement on SIC elements  
(no bus bar connection required)**



**Kemix SIC elements installed on bottom of the retort, operation at temperature**



**Cold connections on bus bars when the kiln is in operation**



**Installation of SIC element from outside of kiln with no mechanical access required, only electrical isolation required**

## Strip and candle element disadvantages:

### Strip elements

- Strip elements have a design Watt loading of 2 - 3 W/cm<sup>2</sup> which requires many elements to provide the KW heat required. (Photo 1)
- Elements are positioned on the bottom of the retort and on the side which requires the retort to be removed to gain access to replace the units. (Photo 1&3)
- Temperature on the connection points of the elements is approximately 170Deg C, which results in cable and bus bar fatigue. (Photos 6-8)
- Dust settling within and on top of elements which insulate the strip and cause elements to burn off.
- High Operating cost on replacing elements. (Life expectancy on elements is between 1-2 years on a set)

### Candle Elements

- The watt loading per element is similar to the strip elements due to the same material of construction which results in much more elements required to provide the necessary KW heat required.
- The roof will be fully fitted with elements supported from the top hanging down on both sides of the retort. Due to the elements being positioned on the side of the retort which has no direct heating into the carbon bed. Heat transfer efficiency into carbon is less than SIC elements.
- The elements will start to stretch under their own weight at operating temperatures, and cause premature failures.
- The temperature on the connection points of the elements is approximately 170Deg C, which results in cable and bus bar fatigue.
- Dust settling within the ceramic discs causes elements to burn off.
- High operating cost on replacing elements (life expectancy on elements is between 1-2 years on a set)
- Removal or replacement of elements after being in operation becomes difficult due to the bending and distortion of the elements.



**New strip elements installed on the bottom of the kiln cabinet – if a retort failure occurs all elements would require replacement**



**Strip elements starting to fail after 2 months in operation – distortion of the steel elements can be seen**



**The cabinet roof must be removed to access elements – estimated down time for inspection and replacement of distorted elements is 20hrs**



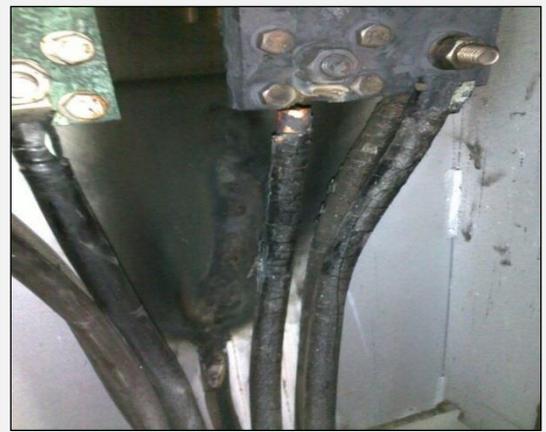
**New replaced strip elements – actual down time to complete repairs 52 hours**



**Electrical connection onto bus bars – the discolouring of the bus bar can be seen**



**Bus bar fatigue as a result of excessive heat from the element connection**



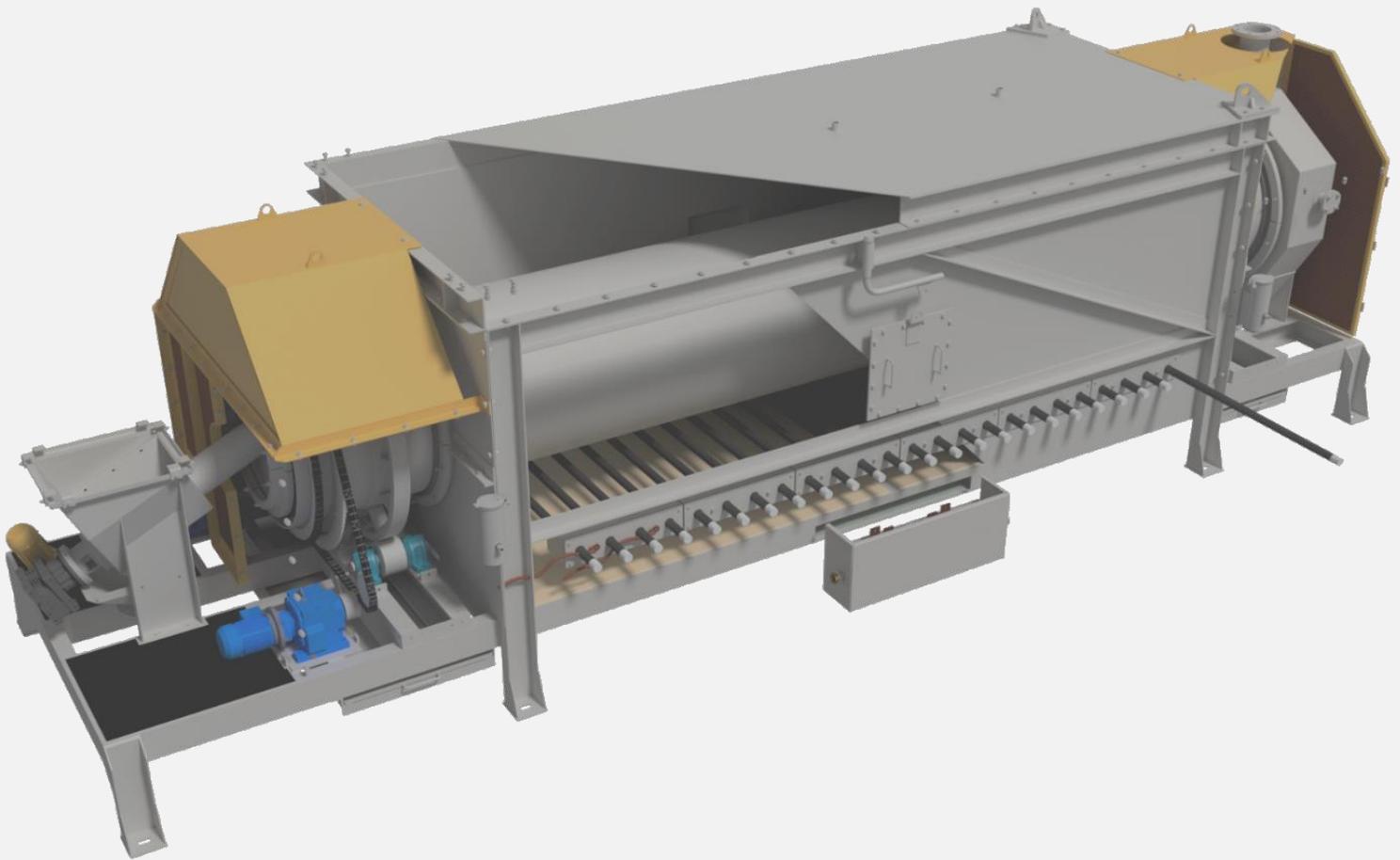
**Cable insulation which has begun to melt as a result of excessive heat from element lead out from the cabinet**



**Strip element burned off – major risk that could cause electrical short circuit**



**Candle element burn off and distortion**



**Electric fired carbon regeneration kiln c/w Kemix SIC elements**



**1700 kg/h Diesel fired carbon regeneration kiln**



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